THE

NATURAL HISTORY

OF THE

MINERAL KINGDOM.

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MINERAL KINGDOM.

IN THREE PARTS.

PART I.

Of the Natural Hiſtory of the Strata of Coal, and of the Concomitant Strata.

PART II.

Of the Natural Hiſtory of Mineral Veins, and other Beds and Repoſitories of the precious and uſeful Metals.

PART III.

Of the Natural Hiſtory of the Prevailing Strata, and of the principal and moſt intereſting Phænomena upon and within the ſurface of our Globe.

By JOHN WILLIAMS, Mineral Surveyor, F. S. S. A.

IN TWO VOLUMES.

VOL. I.

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1789.

DEDICATION.

TO

ROBERT BAIRD

OF

NEWBYTH

ESQ.

SIR,

I BEG leave to preſent to you my Hiſtory of the Mineral Kingdom, a work which is intended to facilitate the reſearches of thoſe who are employed in exploring thoſe dark regions of nature, which contain treaſures for the comfort of the public at large, and the emolument of each individual to whom they belong.

You,

You, Sir, are interefted in the fuccefs of every fcheme which tends to promote this great defign ; and, therefore, with the greater freedom I venture to infcribe to you the refult of my enquiries.

The undertaking is difficult, the fubject is dark, and the road has been explored by few. It will be allowed that my intention is good, in endeavouring to affift gentlemen to obtain poffeffion of thofe treafures of nature, and in the beft and eafieft manner to draw them from their fubterraneous abode.

I cannot venture to fay how far I have fucceeded in the execution of my defign. My intention is not fo much to propofe or eftablifh new theories, as to elucidate the fubject, by conclufions drawn from fact and experience; and every one muft allow thefe are our fureft guides in fcience and in art. I pretend not to inftruct the philofopher, but he may be amufed, by having fuch operations of nature delineated to him as he never had an opportunity in perfon perſon to inveſtigate. May I hope that my labours will prove uſeful to landed gentlemen, in directing their future proceedings in Mineralogy? From your connection with the ſubject, and your enlarged views concerning it, you are juſtly ſenſible of its advantages to ſociety. I requeſt you will take it under your protection, and allow me, with the greateſt reſpect, to ſubſcribe myſelf,

SIR,

Your much obliged and

Moſt obedient humble ſervant,

JOHN WILLIAMS.

GILMERTON,
September 1789.

PREFACE.

GREAT BRITAIN has long ago been called a fortunate iſland, and it muſt be acknowledged, that the appellation is as proper to Britain as to any other iſland or country in the world. The ſoil of this iſland is adapted to produce excellent grain and fruits. Her downs and verdant hills are covered with ſtore of the beſt of ſheep, which yield excellent fleeces for our manufactures, as well as food for our tables. Numerous herds of beeves are fed upon her mountains and in her meadows, and her ſeas and rivers abound in the moſt delicious fiſh. The climate of this iſland is mild and healthy; her mountains breathe the pureſt air, and abound in the ſweeteſt ſprings, and her valleys are waſhed and fertilized by pure and limpid ſtreams.

This fortunate iſland is placed almoſt in the center of the habitable world, with free and ready egreſs to the Mediterranean, the Baltic, the Eaſt and Weſt Indies, and all other ſeas to the ſouth and north;—the moſt convenient ſituation for extenſive commerce, which is greatly facilitated by the

the ſafety and prodigious extent of her ſea coaſts, the depth and numbers of her rivers, and the depth and numbers of her bays and ſinuſes all round the iſland.—Her foreſts produce the hardieſt oaks for ſhip-building, and her ſea-ports the beſt and hardieſt ſailors, who are in a manner bred upon the water; and no iſland in the world ever yet arrived at ſuch commercial eminence, and, in conſequence, at ſuch a height of power, wealth, and grandeur.

But it is not all the external productions of this iſland put together, favoured as ſhe is by the goodneſs of her ſoil and ſituation, and aſſiſted by the excellence of her conſtitution, and the utmoſt exertion of the genius of her ſons, that ever was, or ever will be able to raiſe her to ſuch a height of power and wealth, or to ſuch commercial and political conſequence in the world. The ſoil of ſome other countries is as good as that of Britain. The iſland of Sicily produces as excellent grain and better fruits, and ſome parts of Spain as good, if not better fleeces. But Britain has other valuable ſources of commerce and wealth. The materials of many of the various and extenſive

tenſive manufactures of the iſland, are derived from the bowels of the earth, from her plentiful mines and coal-works.

This is the ſource of the materials of our moſt numerous and extenſive manufactures, and of the utenſils of them all; and it is our manufactures that fill and extend the channels of commerce, and bring home our wealth from afar.

This iſland is a nurſery of arts, as well as of manufactures and commerce.

It is a curious and entertaining amuſement to reflect upon the connection and dependence of the arts upon one another, and upon the improvements and advances of ſociety in a poliſhed commercial country. A man of genius and of judgment, equal to the taſk, with a ſtock of information and ſcope of thought like Raynal, who would write a book to ſhew us the progreſs and improvements of the uſeful arts, the æra of remarkable diſcoveries and their effects, and the influence which the improvements of the uſeful arts has upon the commercial and political ſtate of the nation, and of the world in general, would deſerve the thanks of his country for the

extenſive

extenſive information, uſeful inſtruction, and national entertainment which his book would afford.

Perhaps it would then appear, that the great quantity and variety of metal which this iſland produces has more influence upon the commerce, wealth, and power of the nation than we are accuſtomed to imagine at preſent. But as I have neither abilities nor materials for ſuch enquiries, I will leave them to be inveſtigated by ſuch as are equal to the taſk. This much, however, appears very obvious to me, that great numbers are profitably employed in our mines, and in conveying the metals out of the nation; that the value of theſe metals, whether raw or manufactured, is all clear gain to the nation; that ſtill greater numbers are employed to work upon the metals for all uſeful and ornamental commodities, and for all utenſils, trades, and arts. What is done without the metals? Look into the kitchens and buffets of the great and wealthy: what profuſion! And yet all for uſe. When we paſs thro' Cheapſide in London, one might imagine that all the metal of the world was furbiſhed bifhed up and arranged there for his infpection; and yet it is in fome proportion equally plentiful every where. The utility of the metals is analogous to their abundance. The mathematical inftrument maker does but little without them, and much is ufed by the blackfmith, whitefmith, copperfmith, pewterer, tin-plate worker, coachmaker, cabinet-maker, clockmaker, filverfmith, engraver, printer, &c. The quantities ufed by the various forts of founders, and the plumbers, are immenfe. But if you would wifh to have a full and comprehenfive view of the profufion and great utility of the metals, ftep into the work-fhops and ware-houfes of Birmingham: How many thoufands are there at work! What amazing quantities of wrought goods are ftored there ready for exportation and home confumption! There you will fee them bufied in making all that is worn of metal by the lady and her maid, the clown and the beau, the horfe and his rider, both for ornament and real ufe; and their ware-houfes contain enough for half the world, which muft pafs through the channels of commerce. In fhort, the plenty ty and variety of our own metals, and the plenty and excellent quality of our coals, enables us to manufacture and export more and greater variety of metallic goods than any other nation whatever.

From this imperfect ſketch of the profuſion and extenſive uſe of our metals, I would infer the great importance of the Britiſh mines to the commerce, wealth, and grandeur of the nation; and I would likewiſe infer the importance of improvements in the natural hiſtory of the mineral kingdom in ſuch a country, eſpecially at this period.

Mineralogy is now become a faſhionable ſtudy in moſt countries of Europe, and many uſeful and entertaining diſcourſes have been made of late years. But the preſent vogue and reputation of this branch of knowledge is nothing in compariſion of its great utility. There cannot be a more intereſting ſtudy for a Briton; for while we have extenſive mines and collieries, and while the production of them can be obtained at a moderate expence, we ſhall be conſiderable as a manufacturing and a commercial people.

It

It is a particular loſs to the increaſe of knowledge in the natural hiſtory of the mineral kingdom, that this branch of ſcience is neglected in our public ſchools. Mineralogy is taught in the Univerſities abroad. I believe, that what may be called foſſilogy, or the arrangement and deſcription of mineral foſſils, is taught in ſome of our public ſchools; but their inſtructions are founded upon ſmall detached ſamples, the collections of the cabinet, which leave the country gentleman and the young miner as much in the dark as before, with reſpect to the knowledge of nature and of real mineral appearances, which are the true ſources of uſeful knowledge in theſe matters; and this ſpecies of knowledge is of great importance. No country in the world depends ſo much upon the productions of the mineral kingdom, for the means of comfortable accommodation, wealth, and power, as the iſland of Britain.

Coal is now become of ſuch immenſe conſequence to our cities and populous counties, to our forges and other manufactures, that it was impoſſible for us to have arrived at ſuch commercial eminence, and it is as much impoſſible for us to ſupport our preſent flouriſhing ſtate of ſociety without it; and we are equally indebted to the other parts of the mineral kingdom for many of the ſtaple commodities, which are ſo widely diffuſed in the numerous channels of our extenſive commerce.

When we conſider that many thouſands, I may ſay millions, of induſtrious hands are employed one way or other about the produce of the mineral kingdom in this iſland, we are convinced of the importance of the increaſe of knowledge in Mineralogy, and of the advantage that would accrue to the nation from the inſtitution of a claſs for teaching this ſcience at our public ſchools.

It may be ſaid, that the neceſſary aids for ſuch an inſtitution are wanting in this iſland;—there has not yet appeared any genuine natural hiſtory of the mineral kingdom, founded on ſuch ſound principles of philoſophy, as would enable a teacher to lay the foundation of, and to complete a continued courſe of inſtructions in the ſcience of mineralogy. There are not, that I know of, many valuable books upon the

the ſubject in our language, excepting ſuch as treat of chemiſtry or metallurgy, and ſuch as arrange and deſcribe foſſil bodies, as they are found in the cabinets of the curious,—almoſt all the reſt is nothing but wild theory and ſyſtem, built upon fanciful notions and opinions, the fruits of the cloſet, which have no foundation in the truth of facts, as they appear in natural hiſtory; and therefore ſuch books can be of no uſe but to amuſe, to multiply diverſity of opinions, and to increaſe ignorance of the real knowledge of nature.

It is this conſideration which induces me to give to the public a work the fruit of more than forty years experience and obſervation, to which great opportunities and a mind ardent in reſearches of this nature prompted me. How I have executed my plan, the Public ſhall judge: But I flatter myſelf, from the great number of facts I have aſcertained, and from the many diſcoveries I have made, that my obſervations may be productive of real uſe to mankind, by exciting the purſuit of, and giving a proper direction to the ſtudy of this ſcience, with more pleaſure, eaſe, and proficiency than hitherto. The knowledge of truth in every branch of ſcience is pleaſant and profitable; and it is generally acknowledged, that natural hiſtory is the moſt pleaſant and profitable of all human ſtudies and reſearches; and of all the parts of natural hiſtory, the mineral kingdom is the moſt magnificent and auguſt, provided that we ſtudy nature herſelf. There is a noble air of grandeur and magnificence in the ſections of lofty piles of ſtrata, in huge rugged rocks, and hanging precipices, in profound caverns, and high and extenſive cliffs of the ſea, not to be found in other objects around us.—Theſe ſcenes aſtoniſh and captivate the mind at firſt ſight; and the better we are acquainted with them, the more we are enraptured with the view of the wonderful and endleſs variety which we diſcover in theſe ſcenes of nature; and habitual application to theſe reſearches aſſimilate the mind by degrees to the greatneſs of the ſubject. Diſcoveries of truth and attainments of knowledge in theſe reſearches have the happieſt effect on the human mind. In purſuing theſe ſtudies ſucceſsfully, the

mind

mind is elevated, the underſtanding is enlarged and filled with great ideas, and all the powers of the ſoul are exalted and pleaſed at being able to comprehend ſomewhat of theſe great works of God. In ſhort, I conclude that there are no human ſtudies ſo amuſing, ſo entertaining, and delightful as theſe, when the ſtudent delights in the ſequeſtered ſcenes of nature. There is ſuch a dignity and variety in every part of this ſubject, that it is impoſſible for a perſon of any genius and taſte to be cloyed with theſe purſuits. Who can poſſibly weary of endleſs change, and all either aſtoniſhingly great, or fantaſtically groteſque, or beautifully regular; and I know well, that the more we improve in the knowledge of theſe natural ſcenes, the more we delight in them; and therefore, without being a prophet, I will venture to predict, that whenever young gentlemen of genius and attention take pleaſure in theſe reſearches, it may be then proclaimed, that the darkneſs is paſt, and that the glorious light of ſcience is riſing upon the mineral horizon. Great and rapid progreſs will then be made in this branch of

natural

natural knowledge, and the mineral kingdom will ſoon be underſtood as well as the animal and vegetable kingdoms. But the importance of theſe ſtudies ſhould be preferred to the pleaſure of them in this mining, manufacturing, and commercial country, where it may be ſuppoſed there are but few landed eſtates that do not contain ſome mine or mineral foſſil or other, which may contribute to the public good, and to private emolument; and, therefore, I wiſh to excite a lively ſenſe of the importance of increaſing mineral knowledge.

In ſuch a country as this, young gentlemen of landed property ſhould be initiated in the principles of Mineralogy, and ſuch youth as aim at profeſſional abilities in mineral lines of buſineſs, ſhould have it in their power to lay an early foundation of knowledge in this branch of natural hiſtory, which is the beſt way to arrive at eminence in the ſtations they are intended to fill.

I have, in the following ſheets, contributed a ſmall moiety towards the acquiſition of knowledge in mineral ſcience.

I have treated pretty fully of the natural hiſtory of the ſtrata of Coal, and of ſuch other ſtrata as are found to accompany coal; I have treated fully and diſtinctly of the appearances, indications, and ſymptoms of coal; and I have been very careful to diſtinguiſh the real and certain appearances from ſuch as are either falſe or doubtful. In this part of my ſubject I have taken due pains to inveſtigate and explain every thing that I thought would throw light upon and communicate uſeful information relating to a ſubject of ſo much importance to ſociety; and I am perſuaded that my treatiſe upon coal will be of uſe to landed gentlemen, towards facilitating the progreſs of youth in the knowledge of this branch of natural hiſtory, and as an index for the young coal-maſter.

The ſecond ſubject treated of in this work is the Natural Hiſtory of Mineral Veins, and of the other beds and repoſitories of the precious and uſeful metals. I did not at firſt intend to publiſh my treatiſe concerning metallic mines at this time, becauſe, it is not completed; but when

when the firſt part of my work was put in the preſs, I reflected that this ſecond part contains a number of particulars which may be uſeful to landed gentlemen and young miners; and as it is very uncertain whether I ſhall proceed any farther in theſe mineral eſſays than the two volumes now publiſhed, I thought it was better to offer this in its preſent imperfect ſtate than to ſuppreſs it altogether.

The hiſtory and deſcription of mineral veins is perhaps more full and explicit than can be found any where elſe. The precepts upon ſhoading and huſhing are the reſult of much practice: The obſervations and inſtructions concerning the appearances and ſymptoms of mines will give ſatisfaction, and be a ſure guide to all ſuch as have occaſion to conſult them; and the local examples of the appearances of ſome valuable mines may, in the courſe of time, be of great uſe to ſociety.

Such hiſtorical facts have always been conſidered as valuable communications. In ſhort, all that is advanced in this imperfect

perfect fragment is the fruit of my own obſervation and experience; and, therefore, it ſhould be of ſome value, ſuch productions being generally uſeful to ſociety.

Theſe two eſſays upon coal and the metallic mines compoſe the firſt volume.

In the ſecond volume I proceed to take a view of the prevailing ſtrata of Great Britain, and of many intereſting phænomena of the ſuperficies of our globe.

The philoſophy or natural hiſtory of the ſuperficies of the globe is an intereſting ſubject to all mankind in a ſocial ſtate.

Many of the neceſſaries, and moſt of the conveniencies of life are found either upon or a little within the ſurface of the globe, being the productions of the mineral kingdom; and we are obliged to many of the ſtrata for the plenty and excellence of our food. Lime is of great uſe to meliorate the ſoil, and to ſtimulate or excite vegetation, and the gradual weathering and decompoſition of the ſuperficies of many other ſtrata, reſtore and increaſe the ſoil, which may be in part exhauſted or carried away by rains and currents; and if we look upon our houſes, and within them, we may ſoon perceive how much we are indebted to the mineral kingdom.

The moſt remarkable phænomena which preſent themſelves to us upon the ſurface, and as far as we penetrate within the ſurface of the globe, are remarked and explained in this third part under ſeveral heads.

1ſt, I have taken a view of the prevailing rocks and ſtrata of this iſland, to ſee which of them are ſtratified, and which of them are not. On this head I have examined the appearance, colours, quality, thickneſs, regularity, bearing, ſlope, and courſe of the ſeveral claſſes of ſtrata: I have collected a great number of intereſting facts and local examples; and I have been at great pains to ſelect, and to examine particularly ſuch ſtrata as are moſt uſeful to ſociety.

2d, I have treated of the ſtratification of the ſuperficies of our globe by the agency of water. In this diſquiſition the enlightened and candid naturaliſt will find a conſiderable number of abſtruſe, but intereſting phænomena above ground and below,

low, raiſed from obſcurity, and treated of and explained upon rational principles, in a clear, convincing, and ſatisfactory manner.

3d, I have examined part of the modern ſyſtem of Count Buffon and others upon this ſubject, to ſee how they correſpond with the real ſtructure of the ſuperficies of the globe, and other phenomena of nature; and what I have advanced under this head will bear the ſevereſt ſcrutiny by every teſt.

4th, I have treated of the natural hiſtory of mountains, and of their glens and excavations, which is a ſublime and difficult ſubject. In this part the height and figure of the mountains, the profundity, direction, and extent of their excavations, the exterior and interior ſtructure, with all the moſt remarkable phænomena of mountains, and other irregularities of the ſurface of the globe, are fully accounted for and explained to a demonſtration, upon the principles of the agency of water, and of the prodigious height and force of the diluvian tides; and the clear light which is thrown upon this great ſubject, will

will convince every candid naturalift of the truth of my propofitions.

5th, I have examined the nature, or quality, the fize, figure, and other phænomena of the larger grains and fragments which are found in the compofition of our rocks and ftrata, and thefe enquiries naturally lead us into profound and interefting difquifitions relating to the univerfal deluge, —to the prefent and the antediluvian earth.

This profound and awful fubject is naturally myfterious and obfcure, but it has been involved in infinitely greater obfcurity and confufion by the theories and fyftems of all ages, as the fubject never has been well underftood;—out of which obfcurity and confufion I have endeavoured to raife it, and to explain and illuftrate the doctrine of the deluge upon rational principles, agreeable to the laws and phænomena of nature.

6th, I have made a few obfervations concerning feveral other fubjects relating to the mineral kingdom, among which there will be found an interefting treatife of Volcanoes.

I beg leave in this place to obſerve, that in all this work I aim at being uſeful to ſociety, eſpecially within the limits of my own country,---my native iſland; but in the tract upon volcanoes my genius and imagination ſoars above the height of the Britiſh mountains, and takes a view of all mankind upon the whole face of the globe, and eſpecially where they now are, or may hereafter be plagued with the dreadful calamity of volcanoes; and to be the inſtrument of ſaving many lives from ſudden deſtruction,—to mitigate the miſeries and abridge common loſſes in volcanic countries; and if my rules and inſtructions for that purpoſe are thoroughly conſidered and followed, I am perſuaded that what I have written will produce happy effects. The tract upon volcanoes is founded upon experimental ſcience and real knowledge of natural hiſtory; and, therefore, I hope, that in time very happy conſequences will reſult from my eſſay upon this ſubject; in compoſing which, the whole powers of my ſoul were animated and exerted in fervent deſires of doing good.

The

The diſſertations concerning the balance of the waters of the ocean, and the accumulated mountains of ice and frozen ſnow, which mutually and reciprocally depend upon and illuſtrate one another; concerning the peopling of America by land from the north-eaſt of Aſia, and its being ſtocked with land animals from Armenia, in an early age, before the mountains of frozen ſnow were greatly accumulated;—concerning the peſtilential effects of humid vapours ariſing from the ſlime of new formed lands, from marſhes and extenſive woods in warm countries, and how to mitigate theſe diſmal calamities, and to baniſh theſe undermining enemies of the human race;—concerning the deepening and improving the beds and bars of the navigable and other rivers of the world, and the draining and improving of marſhes, new formed, and wood-lands, with the great and glorious conſequences of ſuch works, for the health, longevity, general happineſs, and proſperity of all nations; are humbly ſubmitted to the examination and cenſure of ſuch candid and benevolent philoſophers as make advances in uſe-

ful

ful improvements, and the profperity and happinefs of mankind the ultimate end of the exertion of their talents. In thefe differtations they will find many valuable hints, which they can improve, and a great deal of matter of vaft importance and confequence to the health and welfare of the world, very ill put together, and in an uncouth drefs, but which they may arrange, improve, and clothe in better language.

Since writing the above, and all I propofed to advance at prefent in the following effays, I have perufed a New Theory of the Earth, by James Hutton, M. D. F. R. S. Edinburgh, concerning which I beg leave to make a few remarks in this place.

Dr Hutton is a naturalift of eminent abilities, whofe knowledge in feveral branches of mineralogy does honour to his country, as fome of his obfervations in the treatife under review clearly evince. The propofitions he ftates, with the conclufions he draws from them, to confirm his hypothefis in the theory of the earth, fhall be the fubject of the following obfervations.

The Doctor's general ſyſtem in his theory of the earth may be compriſed in theſe four propoſitions.

1*ſt*, That all our rocks and ſtrata have been formed by ſubſidence under the waters of a former ocean, from the decay of, and waſte of a former earth, carried down to the ſea by land-floods.

2*d*, That theſe ſubmarine rocks and ſtrata were heated to the degree of fuſion by ſubterraneous fire, while immerſed under the waters of the ocean, by which heat and fuſion, the lax and porous ſediment was conſolidated, perfectly cemented, and all the pores and cavities filled up by the melted matter, while the whole maſs was in a ſtate of fuſion.

3*d*, That the rocks and ſtrata, ſo formed and conſolidated under the waters of the ocean, were afterwards inflated and forced up from under water by the expanſive power of the ſubterraneous fire, to the height of our habitable earth, and of the loftieſt mountains upon the ſurface of the globe.

4*th*, That theſe operations of nature, viz. the decay and waſte of the old land, the

the forming and consolidation of new land under the waters of the ocean, and the change of the strata now forming under water to future dry land, is a progressive work of nature, which always did, and always will go on in a perpetual succession, forming world after world.

I. The first of these propositions has been fully answered and refuted before it was written, at least before it was published, in my examination of the system of Count Buffon in his Theory of the Earth, which will be found in the second Volume of my Essays upon the Mineral Kingdoms, concerning which, I will venture to say, and the candid intelligent naturalist will say with me, that I have not left the Doctor so much as a particle of earthy matter to form one of his future worlds, for a single particle would save the whole succession. I have now effectually cut off all his supplies, and appropriated them to a better use; and I hope it will be acknowledged, that I have made a good use of them. There is little or no difference between Count Buffon and Dr Hutton in this part of their ſeveral theories; and therefore, what I have advanced concerning Buffon's, is equally applicable to the Doctor's.

I have, in my examination of Count Buffon's Theory, frankly acknowledged the truth of almoſt all that the Count and the Doctor advance about the weathering, decompoſition, and waſte of the ſuperficies of many of our rocks and ſtrata, and of our mountains and cavernous ſhores.

The ſpoils of the mountains are carried down by land-floods to the valleys and to the borders of the ocean. So far we go together; but here we muſt part, as I poſitively deny that any ſtrata are formed under the waters of the ocean. I have, in that part of my eſſays, made it evident to a demonſtration, that the ſea purges itſelf by the tides of all the earthy matter carried down by the floods, which earthy matter is thrown back upon the ſhores, in the bays and creeks, and at the mouths of great rivers, where, by degrees, it enlarges the bounds of the dry land in exact proportion to the quantity carried down by the floods.

It

In that part of my eſſays, I have clearly demonſtrated, that the earthy matter waſhed off the face of our mountains and rocks has no manner of tendency to the real waſte and deſtruction of the preſent earth; ſo far from it, that, on the contrary, the habitable parts of the earth are gradually, but really and effectually renovated, enlarged, and improved thereby. I have proved, that many lakes, marſhes, and frightful gulphs among the mountains and in the plains, have been filled up in the courſe of the rivers of the world, which are now rich, beautiful and habitable countries; that many millions of acres of new land have been made in the valleys and plains, at the mouths of the rivers in the bays, creeks, and ſhores of the ocean; and that very many and extenſive portions of this new land are now the fat valleys by the rivers, which are the ſcenes of population, wealth, and ſocial happineſs. It is upon this deſcription of land that the higheſt number of the great commercial cities of the world are ſeated, ſuch as, for inſtance, London, Amſterdam, Alexandria, and many of the cities of China, &c. which have

have long been the ſeats of learning and the arts, of commerce, wealth, and glory.

Whoever will take the trouble to peruſe my eſſays, will be convinced and ſatisfied that the Deltas, Belgias, and Carſes, and other deſcriptions of new land, formed and forming in all parts of the world, fully and perfectly correſpond with the quantity of matter waſhed off the mountains and rocks, and they will there ſee it clearly proved that all this is a real, a great, a ſubſtantial, and a durable improvement of the preſent earth. Man cannot live upon the ſummits, nor high up the ſides of lofty mountains; but the froſts and thaws, and other changes of the air and weather, decompoſe part of the ſuperficies of the mountains, which is carried down by the floods to the valleys and to the margin of the ſea, where new land is gradually increaſed, which enlarges the bounds of the earth in convenient ſituations for increaſed population, and for all the improvements which are neceſſary for increaſing human and ſocial felicity; and are not the ſpoils of the mountains much better diſpoſed of in this way, than if ſpread out at random

through

through the bounds of the ocean, to form imaginary worlds in the craniums of our modern philoſophers?

But this uſe which the wiſe and benevolent providence of God makes of the ſediment of rivers in the ordinary courſe of things, is not a well fancied hypotheſis, propoſed for the amuſement or confuſion of the inquiſitive mind of man; but it is a real and viſible fact, which may be viewed, examined, and thoroughly inveſtigated by the man of leiſure and abilities; and I am perſuaded, that if Dr Hutton will read my papers upon this ſubject, he will be convinced of the errors of his hypotheſis.

Now, it being clearly demonſtrated, that no ſtrata are formed in the bed, or under the waters of the ocean, all our author's inveſtigations and reaſoning upon that ſubject of courſe fall to the ground; and I have in my eſſays made it evident to a demonſtration, that if, for argument's ſake, we allow the particles of matter carried down by the rivers to be ſpread out over the bounds of the ocean, and to ſubſide in it, we ſhould, in that event, have no coal, no limeſtone, freeſtone, nor any other uſeful foſſil body. We ſhould have no ſuch thing as ſtrata, nor bed, nor diviſion of any kind whatſoever, but all would be one uniform ſolid maſs of ſediment, compounded of all things. It is in vain to ſay it would be otherwiſe. The known and acknowledged laws of nature forbid it; and all the experience we have of ſediment proves the fact, that all would be a blended indiſtinguiſhable maſs, as I have fully ſhewn in my eſſays, to which I refer for clearing up the point under conſideration. If we can ſuppoſe any order or diſtinction in ſediment, it muſt agree with the laws of gravitation; of courſe the heavieſt particles would ſubſide, and take poſſeſſion of the loweſt place, from which they would not be diſlodged by the lighteſt. But we need not deſcend to particulars. Stratification muſt be performed by a ſhallow ſpread and flow of water; but we cannot allow of ſtratification, nor of any diſtinction of ſtrata of different qualities under the bed or waters of the ocean, without a miracle for each; and we need not have recourſe to miracles, when the phænomena of of nature can be as well and better explained upon rational and mechanical principles, agreeable to the known laws and visible operations of nature. But I will not insist upon this topic here. I have already confuted this part of the Buffonian theory, and the Huttonian differs but little from it.

II. The second thing proposed to our consideration in Dr Hutton's Theory is, the consolidation of our rocks and strata, while still under the waters of the ocean, by the heat and fusion of subterraneous fire. Our author's doctrine of subterraneous fire, and its effects in the consolidation of the strata, by means of fusion beneath the waters of the ocean, is a singular hypothesis; but it is not altogether new.—Woodward and others have advanced the notions of central and subterraneous fires; and they also pretended to account for many of the phænomena of nature from the operations or effects of these imaginary fires; but I do not know that any of them before our author gave these fires the office of melting the earthy mass, in

order

order to cement and consolidate our strata; though Ray conjectures, that mountains might be forced up by earthquakes, and by the flatus of volcanic fire; but none, that I know of, before the Doctor, have given this imaginary central fire the office of melting the oozy bed of the ocean, in order to reduce it by fusion into solid rocks and strata.

Our author's abilities as a naturalist, and his chemical knowledge, enable him to produce and reason upon many seeming facts to support and illustrate his hypothesis; but, unluckily for this proposition, we see in little the very same natural effects produced before our eyes without the application of visible fire, though not without the influence and effects of the elementary atmospherical fire. There is no room to doubt, that natural chemistry is more powerful, extensive, and various than the artificial. It is difficult to limit the powers and effects of variously combined mineral liquors, in dissolving part of various fossil bodies in their natural situations, in the bowels of the earth. One thing we are sure of, that various terrene

matters

matters are in a diſſolved or fluid ſtate, mixed with the waters which percollate the pores and cranies of our rocks and ſtrata. As an undeniable proof of this, we ſee numerous foſſil bodies of various qualities and degrees of hardneſs formed and forming before our eyes, which are as well conſolidated and cemented as if they had been fuſed by fire upon our author's plan of cementation; and theſe, not in ſmall and inconſiderable cryſtallizations and ſtallactites, but we ſee conſiderably large concretions formed by a gradual accretion of matter depoſited by water. In ſome places, we ſee caverns of various degrees of extent and magnitude, ſome of which are almoſt, and others altogether filled up by a ſmall flow of water, depoſiting particles of ſtony matter; and the bodies ſo formed are afterwards conſolidated, in the courſe of no very long time, to degrees of ſtrength and induration equal to any of our rocks and ſtrata. Mines recently worked are in many places ſo quickly choaked up by the formation of various concretions, that we are often obliged to demoliſh them, to prevent their ſtopping up the paſſage altogether.

I have ſeen ſubterraneous mines or galleries, which were worked by my direction, ſo filled up and choaked; and I can ſhew ſome others, which, if neglected for ten or a dozen of years, would be choaked up ſo effectually, and the contents would be ſo conſolidated, that it would require an expence to open them up again, almoſt if not fully equal to the firſt. The hiſtory or natural philoſophy of ſtony concretions is already explained in the 2d Vol. of my Eſſays, and need not be repeated here.

We find in many places various kinds of ſpar, of fluor, and of agate, formed and forming by water, depoſiting particles of different qualities. Some of the bodies ſo formed are homogeneous, and ſome compounded. Some of theſe concretions aſſume a fine ſmooth uniform texture; others exhibit, when broken, a cubic and a tabulated ſtructure; and others again have a coarſe and homely grain in the inſide. In ſome places, the quality of theſe concretions is calcareous, in others ſiliceous,

ceous, and in many places ferruginous; and we frequently find them containing a mixture of particles of different qualities. Many of theſe acquire degrees of ſtrength and hardneſs equal to any of our rocks and ſtrata; and therefore we may infer, that the cementing quality is either contained in the maſs of matter depoſited by the water, or that it is imparted by the influence of the atmoſphere. I am much inclined to believe it is the laſt, and, I am perſuaded, that the elementary fire of our atmoſphere inſpiſſates a great many fluid ſubſtances in all the three kingdoms of nature; and by penetrating their maſſes, and being detained and lodged there, brings them gradually to various degrees of ſolidity, ſtrength, and hardneſs. Now it is very obſervable, that the cementing matter which fills up the pores and interſtices of our rocks and ſtrata,—which connects their ſeveral parts, and promotes their ſolidity, ſtrength, and induration, has the very ſame appearance, and is of the very ſame quality, as the various foſſil concretions we are ſpeaking of; but both the ſtony concretions and the cementing

ting quality of the ſtrata contain a greater variety and mixture of ſtony matter than we can eaſily enumerate or deſcribe.

From theſe obſervations we may ſafely infer, that theſe various ſubſtances of different qualities are now in a diſſolved fluid ſtate, mixed with water. The various concretions formed by water, iſſuing into places acceſſible to the external air, juſtifies the inference, and proves the truth of it; and that our rocks and ſtrata are cemented and conſolidated by ſimilar ſubſtances, is evident to our ſenſes; but whether the cementing matter was contained in, and blended with the general compoſition when the ſtrata were firſt formed, or was afterwards inſinuated by the percollation of water, through the pores and cranies of the ſtrata, I will not now enquire. Some ſmall veins and maſſes of theſe ſubſtances, found pure in our rocks and ſtrata, ſeem to favour the ſuppoſition of the ſtrata being cemented by the inſinuation of particles, and the extraordinary induration of ſome of our external rocks countenances the ſame idea; and I have no doubt, that the elementary fire has a great ſhare in producing every degree of ſolidity and induration.

Much of the cementing matter of our rocks has more of the appearance of a jelly, which is hardened by degrees from an aqueous ſolution, than of being produced by the fuſion of fire.

Theſe obſervations and facts make it evident to a demonſtration, that fuſion by fire is not neceſſary for the cementing and induration of our rocks and ſtrata. We have abundance of examples in little of a contrary proceſs; and, in truth, the component parts of ſome of our ſtrata, the inflammable quality of others, and every ſituation and phænomena of the ſtrata in general, proves, that they have not been affected by fire. We ſee evident marks of water in the diſpoſition, ſtructure, and form, and in all the exterior and interior phænomena of the ſtrata; but we ſee no real mark or character of fire, excepting in volcanoes, which are accidental, local, and very limited, have every character of being accidental, and only produce diſorder and confuſion; and, moreover, the origin and natural hiſtory of volcanoes is pretty

pretty well known, and is inveſtigated and explained in the 2d Vol. of my Eſſays.

The philoſopher or naturaliſt, who can deliberately embrace the idea of our real ſtrata being cemented and conſolidated by fuſion by fire, either under or out of the waters of the ocean, muſt have his mind ſtrangely warped by attachment to ſyſtem. Such a heat as would melt and bring the whole ſolid globe to a ſtate of fuſion, muſt neceſſarily heat the whole waters of the ocean up to boiling, and the boiling heat of the waters muſt continue for many ages. I ſuppoſe, that a ſolid globe of the magnitude and denſity of our earth, heated to a ſtate of fuſion, would require many thouſand years to cool again to the temperature of our earth and water; of conſequence, the waters would be kept in a boiling ſtate the moſt of the time: What then would become of all the finny and teſtaceous tribes of the ocean?

Neither any of them, nor any of their ſpermatic powers and virtues could poſſibly live in ſuch a heat; of courſe, they muſt be all created anew after each of theſe worlds is cooled. The terreſtrial tribes

tribes muſt be in as bad a ſituation as thoſe of the watery element. This appears to be an aukward hypotheſis. With reſpect to the ſolid part of the globe itſelf, ſuch a ſubterraneous heat as would effectually penetrate the whole maſs, ſo as to bring every part to a ſtate of fuſion, inſtead of leaving diſtinct and regular ſtrata of various qualities, thickneſs, and other characters, ſeparated from one another, as we find them, the whole ſolid globe muſt be run together into one ſolid ſlag, which might exhibit many cracks and fractures after cooling; but they would all be the cracks and fractures of an immenſe maſs of glaſs or ſlag. There could be no horizontal diviſions, nor marks of ſtrata of any kind, nor could we have any coal, nor any uſeful ſtone or foſſil whatſoever.—Such is the nature of this extraordinary hypotheſis?

We have the moſt early traditions of our globe ſuffering a great cataſtrophe and change by water, which is recorded by Moſes, and by many other eminent ancient philoſophers; and Count Buffon, Dr Hutton, and many other modern naturaliſts, ſee fee and acknowledge the marks of water in all parts of the fuperficies of the globe: but fuch is their bias to the fyf- tem of fire, that they attempt to con- vert all the rocks and ftrata of the globe into fo many lavas of different colours and ftructures; and in order to countenance and affift their favourite agent, with all the powers of a heated unguarded imagina- tion, one goes up to the fource of all fire, in order to have the folid parts of our globe melted down in the fun; another goes down to the fubterraneous regions, and blows up his fire there to a fufficient degree of heat to melt all the fuperincum- bent rocks and ftrata to the degree of fu- fion, even when immerfed under the wa- ters of the ocean, which is, I think, a new method of fufing earthy matter by fire.— Others again are content to honour this agent with the formation of fome few of our ftrata, fuch as the bafaltes, and a few others of nearly a fimilar appearance; but after all that they have advanced, or can advance to countenance this hypothefis, it is certain that none of the rocks and ftrata, which are a part of the folid fuper-

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ficies of our globe, exhibit any of the real marks and characters of being formed by fire.

The quality, component parts, interior ſtructure, and appearance of our rocks and ſtrata, are very diſtinguiſhable from ſlags or lava. Dr Hutton acknowledges this in the 66th page of his Theory of the Earth, where he ſays, that " a fuſible ſubſtance, ' or mineral compoſition in a fluid ſtate, ' is emitted from thoſe places of the earth, ' at which ſubterraneous fire and expan- ' ſive force are manifeſted in thoſe erup- ' tive operations. In examining theſe ' emitted bodies, men of ſcience find a ' character for ſuch productions in gene- ' ralizing the ſubſtance, and underſtand ' the natural conſtitution of thoſe bodies. ' It is in this manner that ſuch a perſon ' finding a piece of lava in any plac of ' the earth, ſays with certainty, Here is a ' ſtone which had congealed from a melted ' ſtate." This paſſage is abundantly di- ſtinct, and I will ſay farther, that it is ge- nerally very eaſy for every unprejudiced naturaliſt to diſtinguiſh a real ſtone from a piece of ſlag or lava. The baſaltes is a real ſtone, which all modern philoſophers have ſet down as belonging to the claſs of lavas ; but I have made it evident in my eſſays, that the baſaltes is a real ſtone, the component parts of which I have pointed out ; and I have made it appear, that there are in ſeveral places many and extenſive ſtrata of this ſtone, which are diſpoſed in their ſtations among other ſtrata of different characters and qualities, which are placed above and below the ſeveral ſtrata of baſaltes, and theſe ſtrata of baſaltes ſpread out as wide, and ſtretch as far every way as the other different ſtrata among which they are ranged ; and therefore, no man, who underſtands the real ſtructure of the ſuperficies of our globe, will pretend to ſay that baſaltes is a lava, unleſs he ſays that all the other ſtrata which accompany baſaltes are alſo lava. Where ſtrata of baſaltine rocks are blended promiſcuouſly among ſtrata of different rocks, it is neceſſary either to call them all ſtrata of lava or ſtrata of ſtone. Dr Hutton indeed talks in his Theory of inſerting a lava, viz. baſaltes, among other ſtrata of different qualities ; but I would aſk the Doctor how he is to lift

up

up the ſuperincumbent ſtrata to a ſufficient and equal height from the ſtrata below them, for many miles extent every way, and to keep them aſunder, until ſuch a quantity of melted lava is poured in as will fill up all the extenſive empty ſpace to form the new inſerted ſtratum. I am ſpeaking of regular and extended ſtrata, which belongs to the natural hiſtory of baſaltes, and I can ſhew Dr Hutton a conſiderable number of ſtrata of baſaltes, blended ſtratum ſuper ſtratum, among other various ſtrata of different characters and qualities, among which are a conſiderable number of ſtrata of pit coal; and ſome of theſe coals are in immediate contact with ſtrata of baſaltes, as the immediate roof and pavement of the coals; and I can ſhew him all theſe ſeveral ſtrata, with their concomitant ſtrata, in a ſtretch of many miles; and I can ſhew ſimilar phænomena in Weſt Lothian, in Ayrſhire, and in Fife, &c.; and, therefore, it is difficult to believe that baſaltes is lava, unleſs we alſo believe that ſeams of coal, and all their concomitant ſtrata,

ſtrata, likewiſe are lava, which ſounds very like an abſurdity.

It appears to me rational, and even neceſſary to ſuppoſe, that if the ſtrata were conſolidated and cemented by the heat and fuſion of ſubterraneous fire, all the ſtrata, which have a tendency to, and may eaſily be hardened by fire, would be found in an indurated ſtate; but this in fact is not the caſe,---ſo far from it, that it is well known to every perſon who takes the leaſt notice of theſe things, that we find in all countries great numbers of tilly and argillaceous ſtrata, ſo very ſoft, that they differ little from a mere ſediment, from which the water has been preſſed out, and which decompoſes and falls to a mere ſediment or clay, almoſt immediately upon being expoſed to the external air: And it is remarkable, that theſe ſoft argillaceous ſtrata are commonly ſituated immediately above and below very hard ſtrata of indurated ſtone, upon which the external air has no ſudden viſible effect. How ſhall we account for this fact upon this hypotheſis? It cannot be pretended, that theſe ſoft ſtrata contain any marks or cha-

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racters of being consolidated by the heat and fusion of fire; for they are not consolidated nor cemented at all, but only compressed by the superincumbent weight of strata; nor can it be pretended, that they are not capable of being hardened by fire. In fact, we know the contrary by experience, as they are every day hardened in our open fires, and in proper kilns, for various purposes, and to various degrees of solidity and induration. If subterraneous fire had produced the solidity of our rocks, these soft substances would have been indurated, as well as their concomitant strata. But these soft strata are a proof, that our rocks are cemented by a terrene, sparry, and siliceous fluid, which is, by degrees, inspissated and hardened by the pressing out or evaporation of superfluous moisture; and they also prove, that these argillaceous strata can only be consolidated and cemented by fire, which has not been applied to them. We can only select a few facts which oppose this system. The instances to be found in the book of nature are endless.

III. The third propoſition which we are to conſider in our author's Theory of the Earth, viz. That the rocks and ſtrata, which were formed and conſolidated beneath the waters of the ocean by ſubterraneous fire, were afterwards inflated and forced up from under water, by the expanſive force of the ſame ſubterraneous fire, to the height of our habitable earth, and of all the mountains upon the face of the globe, is an hypotheſis as ſingular and extraordinary as the conſolidation of ſtrata beneath the waters of the ocean by the heat and fuſion of fire. Moſt of the operations and effects of ſubterraneous fire, that we have any knowledge of, are outrageouſly violent and deſtructive, and only produce diſorder and ruin. If the bed of the ocean was really to be forced up by ſubterraneous fire to the height of our mountains, we might expect to find as great confuſion and diſorder, and marks of the ruins of a world, among Dr Hutton's mountains as among Dr Burnet's; but I have ſhewed, in my Natural Hiſtory of Mountains, that the ſtrata of our real mountains are as regular as in any of the plains.

plains. In truth, I have not ſeen ſuch regularity of the ſtrata any where elſe as among the highland mountains of Lochaber, which are the higheſt in Britain.—The local examples, which I have pointed out there, will evince the truth of this aſſertion to any who wiſh to aſcertain the fact.

Our author lays great ſtreſs upon the phænomena of mineral veins, and of the ores and other ſubſtances found in them, to ſupport and confirm his fiery ſyſtem; but, in truth, every appearance of mineral veins, and of their contents, point to water with a diſtinct and legible index, as the chief agent in their formation, &c. which ſubject I have inveſtigated and explained in my Natural Hiſtory of the Mineral Kingdom.

Upon the ſuppoſition of our author's Theory of Mineral Veins being true, all our veins ſhould be wide above, and narrower below, which is not found true in experience, very many of them being exceeding ſtrait and narrow for many fathoms next the ſurface, which are very wide further down; and if this Theory

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was true, every ſubſtance found in theſe veins ſhould be the hardeſt in all the bowels of the earth, becauſe the force and violence of the ſubterraneous fire would have a much freer paſſage through theſe open fiſſures, than through ſolid unbroken ſtrata of ſeveral thouſand miles of thickneſs; but this, in truth, is not the caſe, the inſide of many of our mineral veins being exceeding ſoft and argillaceous.— Again, upon the ſuppoſition of the contents of our mineral veins being formed by metallic ſteams, forced up from below by the influence of ſubterraneous fire, our mineral ores ſhould be all pure and unmixed with earthy or ſtony matter, which is not ſo; and moreover, upon this hypotheſis, no metallic or mineral ore would be found out of the cavities of mineral veins; but neither is this the caſe; on the contrary, every mineraliſt knows very well, that gold, ſilver, copper, tin, lead, iron, &c. are commonly found, in a diſperſed ſtate, in large and ſmaller grains, flowers and maſſes, throughout the body of many of our rocks and ſtrata, intimately mingled with their compoſition as one of the component

ponent parts of ſuch rocks and ſtrata.— Gold is generally found in grains of various ſizes, mixed in the compoſition of many rocks and ſtrata, and the origin of gold-duſt is from the decompoſition of the ſuperficies of theſe rocks, which is waſhed down by the floods, and depoſited in the beds of rivers. Iron is blended in great quantity in the compoſition of moſt of our rocks, and ſo abundantly in ſome of them, as to be worth ſmelting out for uſe; and, moreover, we have in many places great numbers of whole ſtrata of iron ſtone ſo rich as to be equal, if not to exceed, the beſt of our iron ores in the produce of the furnace. In working downwards, many of our mineral veins are cut out, and fail at various depths, by a different ſtratum coming in below, which the vein does not penetrate. The rich vein of lead at Llangunog, in Montgomeryſhire, which was five yards wide of ſolid ore, was cut off below in this manner:

A bed of ſchiſtus came in at a certain depth below, which cut out both the ore and the vein ſo entirely, that no veſtige of either entered the ſchiſtus, or could ever after be found. Extenſive trials were made on all hands to no purpoſe, as neither vein nor ore ever appeared. Theſe circumſtances do not agree with the idea of our ores being formed by mineral ſteams, forced up by ſubterraneous fires; and, therefore, we muſt acknowledge, that the ſubſtances of which our ores have been formed were poured into our veins by water from above, as well as the various ſpars and all the contents of mineral veins.—There is a curious and ſurpriſing mixture of many different ſubſtances in ſeveral mineral veins. In ſome of them, we find lead, copper, ſilver, and ſeveral other metallic and ſemi-metallic ores; and, in the ſame vein, we find calcareous and ſiliceous ſpar, with a variety of other ſtones and mineral matters of various colours, qualities, and degrees of hardneſs; and we frequently find many of theſe, and ſometimes all of them, blended together in the concavity of the ſame vein. Every phænomenon of theſe different ores and different ſtones proves to ocular demonſtration, that all the different ſubſtances in the compoſition were poured in from above, and mixed together

together while in a humid or fluid ſtate, and that they were afterwards conſolidated together into ſuch compound maſſes as we find them.

IV. The fourth propoſition offered to our conſideration, in our author's Theory of the Earth, is alſo pretty ſingular, which is, that theſe operations of nature, viz. the decay and waſte of the old land, the forming and conſolidation of new land under the waters of the ocean, and the change of the ſtrata now forming under water into future dry land, is a progreſſive work of nature, which always did, and always will go on, forming world after world in perpetual ſucceſſion.

This hypotheſis agrees pretty nearly with Count Buffon's, only that the Count brings about his ſucceſſive changes by a watery proceſs, without the agency of fire, after having the original matter of the whole globe once thoroughly vitrified in the ſun. Both the Count and our author ſtrenuouſly inſiſt upon the waſte of the ſuperficies of the mountains, and of the rocky ſhores of the ocean, by the force of the tides and ſtorms,

ſtorms, as an infallible proof of the gradual deſtruction of the exiſting dry land, and they both infer from hence the ſucceſſive changes of habitable worlds as a neceſſary conſequence. I have in my Eſſays fully inveſtigated and explained theſe matters. I have pointed out the utmoſt extent of the waſte of the mountains; and I have acknowledged, that the weight of mighty waves, propelled by the tides and ſtormy winds, have powerful effects in undermining and waſting the rocky ſhores; but then I have made it evident, that this waſte and deſtruction only advance to a certain length and degree, where it ſtops; and I have drawn the line, and pointed out the depredations of the waves with ſome exactneſs; and have made it evident to our ſenſes, that hitherto they come, but no farther.

In ſome places, the ſands are interpoſed to defend the rocks, and the very ſlow diminution of the ſands by attrition is abundantly made up by freſh ſupplies furniſhed by the rivers. In other places, the rocks are covered by a ſhelly incruſtation, the work of ſmall teſtaceous tribes, which perfectly defends theſe rocks againſt any

injury

injury from the waves. We may ſuppoſe, that all or moſt of our maritime coaſts were at firſt expoſed to the ravages of the ocean. At preſent, the greateſt part is defended by the ſands and teſtaceous incruſtations; and it is rational to ſuppoſe, that, in the courſe of time, all the ſhores of the ocean will be perfectly defended by theſe means. With reſpect to the real encroachments which the ſea has hitherto made, or may hereafter make, upon the land, I think we may ſafely conclude, that a million of acres of new land have been made from the ſediment of the rivers for every ſingle acre of the rocky ſhores that has been waſted by the waves of the ſea.

This is no ſuppoſition; it is a fact abundantly evident to our ſenſes; and it is a ſort of retrograde operation towards the ſucceſſive change of worlds contended for by our philoſophers.

Dr Hutton inveſtigates a conſiderable number of foſſil bodies, and explains their phænomena to countenance his own hypotheſis. It would extend this Preface to too great length, were I to examine what he has advanced upon them all.

At

At present, I will only take notice of the teſtaceous tribes of the ocean. He tells us, that theſe exuviæ, being found in the body and compoſition of our rocks and ſtrata, is a clear proof, that thoſe ſtrata were formed by water, which is ſo far true. I alſo aſſert, that theſe exuviæ, and all the other remains of plants and animals found in the body and compoſition of our ſtrata, is a deciſive proof that the ſtrata were formed by the agency of water; at the ſame time, I poſitively deny, that our ſtrata were formed beneath the waters of the ocean. The natural hiſtory of the formation of our ſtrata is fully explained in the ſecond Volume of my Eſſays upon rational and mechanical principles, to which I refer for ſatisfaction on this topic. In my opinion, our author's philoſophy is not more exceptionable in any part of his Theory than in treating of marine teſtaceous animals, as he makes theſe in effect to be very extenſive creators of matter, which is exalting them much too high in our ſyſtem of things. The Doctor ſays, that one fourth part of the ſolid bulk of our globe is compoſed of limeſtone, marble,

and

and other calcareous matter, which I think is giving it too great a proportion. My general obſervations have been pretty extenſive; and, as far as I can judge, all our limeſtones, marbles, chalk-ſtone, and clay-marl, which is ſoft limeſtone, and all other calcareous foſſil ſubſtances, may amount to about a ſeventh or eighth part of the ſolid bulk of the ſuperficies of the globe, which is a great deal indeed. Now our author aſſerts, in plain terms, and in ſeveral parts of his Theory, that this immenſe bulk of ſolid calcareous foſſil matter was all of it produced from the remains of the teſtaceous tribes of the ocean. In my opinion, the propoſition may be reverſed; and we may with more truth aſſert, that the calcareous matter produced them, than that they produced it. Snail-ſhells are found in great numbers near old ſtone and lime walls; yet we never imagine, that theſe walls were produced by ſnails. It is almoſt evident to our ſenſes, that theſe animals find the calcareous matter in a fluid ſtate mixed in the waters of the ocean and the land, which they collect and uſe to make ſhells, coral, &c. To ſay that they

they produce this matter, is much the ſame as to ſay that they create it. Matter is only changed from one form of exiſtence to another in the reproduction and growth of animal and vegetable bodies, but they really produce no part of matter that did not exiſt before in another form. I grant, that the exuviæ of teſtaceous animals are found in great abundance in many of our limeſtones and marbles, but not in all of them. There are very extenſive rocks and ſtrata of the mountain-limeſtones, and marbles of various colours, texture, and degrees of hardneſs, in which not the leaſt particle of ſhell or coral is to be found.

Theſe ſhells are alſo found in ſeveral other ſtrata beſides the calcareous, all which only proves, that theſe marine exuviæ were blended in the maſs of chaotic matter when theſe ſeveral ſtrata were formed; but to ſay that theſe animals can produce any particle of matter, is not good philoſophy. We know, that calcareous matter certainly exiſts in a diſſolved fluid ſtate, mixed in abundance with the waters of the ocean, which is ſeparated from the water in conſiderable quantity, in the common

mon procefs of making falt of fea brine. How the teftaceous tribes make ufe of it in making fhells and corals, is too nice a procefs for my inveftigation. Shells and corals could not exift, as we find them in the body of the rocks and ftrata, upon the fuppofition of thefe rocks being confolidated by the heat and fufion of fire, becaufe a fmaller degree of heat than is fufficient to bring our rocks to a ftate of fufion, would calcine all the fhells and corals, with the limeftones to boot; and when once they are calcined, they are no more fhells, &c. but quick lime, to which they would fall with the leaft humidity; and the whole bowels of the earth, as far as we penetrate, is full of humidity.

In fhort, few of our author's conclufions are defenfible, and no wonder, when he warps and ftrains every thing to fupport an unaccountable fyftem, viz. the eternity of the world; which ftrange notion is the fartheft of all from being defenfible. All parts of nature, the minute as well as the grand and magnificent, proclaim aloud, and point out in legible characters the infinite power and fkill of the all-wiſe and benevolent Creator and Preſerver of the univerſe. The Supreme Being hath highly favoured us with an exalted ſtation, and hath given us the image of his own attributes. We daily enjoy the fruits of his care and benevolence, and we feel the effects of his goodneſs, whether we advert to and acknowledge it or not. The impreſſions of divinity are legibly ſtamped on all the works of God; and when we clearly behold the characters of ineffable wiſdom in the great plan of creation,---of infinite ſkill and intelligence in the contrivance, diſpoſition, and fine fabric of all the parts of nature,---of almighty power in producing all things and upholding them,---and of exuberant and unbounded goodneſs in communicating good to all animated nature, we then have exalted ideas of the Supreme Being; and if we reflect upon our own diſtinguiſhed rank and ſituation in the ſcale of beings, and of our privileges and powers of acquiring knowledge and promoting mutual and ſocial happineſs, our hearts will exult in the diſplay of the glory of the Creator in his works; and if we believe that the

Creator

Creator and Governor of the world protects and cares for us, our hearts will overflow with grateful love of the Deity; we ſhall then rejoice in his works and in his goodneſs.

But ſceptical notions have a pernicious influence in damping the ſacred fire in our hearts, in cooling the ardour of our ſpirits, and in blotting out the native impreſſions of the Deity ſtamped on our hearts. The wild and unnatural notion of the eternity of the world leads firſt to ſcepticiſm, and at laſt to downright infidelity and atheiſm. If once we entertain a firm perſuaſion that the world is eternal, and can go on of itſelf in the reproduction and progreſſive viciſſitude of things, we may then ſuppoſe that there is no uſe for the interpoſition of a governing power; and becauſe we do not ſee the Supreme Being with our bodily eyes, we depoſe the almighty Creator and Governor of the univerſe from his office, and inſtead of divine providence, we commit the care of all things to blind chance. Like a mob, who think they can do well enough with-

out

out legal reſtraints, depoſe and ſlay their Magiſtrates. But this is rebellion againſt lawful authority, which muſt ſoon end in anarchy, confuſion, and miſery, and ſo does our intellectual rebellion. How degrading is infidelity! how miſerable muſt a thinking man be in diſtreſs, who does not believe that there is at the head of the creation, a good, intelligent, and powerful being, who cares for his welfare through all the ſtages of exiſtence!

That Dr Hutton aims at eſtabliſhing the belief of the eternity of the world, is evident from the whole drift of his ſyſtem, and from his own words, for he concludes his ſingular theory with theſe ſingular expreſſions: "Having, in the natural hiſtory 'of the earth, ſeen a ſucceſſion of worlds, 'we may from this conclude, that there 'is a ſyſtem in nature, in like manner 'as, from ſeeing the revolutions of the 'planets, it is concluded, that there is a 'ſyſtem by which they are intended to 'continue thoſe revolutions. But if the 'ſucceſſion of worlds is eſtabliſhed in the 'ſyſtem of nature, it is in vain to look 'for any thing higher in the origin of the 'earth.

'earth. The refult, therefore, of our pre-'fent enquiry is, that we find no veftige 'of a beginning,---no profpect of an 'end."

Thus, our modern philofophers labour hard to confirm their favourite fcepticifm, &c. by all poffible means; or, in other words, they labour hard to rob us of our beft inheritance, both here and hereafter, ---to fap the foundations of our belief in revelation, and of the fuperintending care and love, and of the over-ruling providence of the all-benevolent, all-powerful God, our Saviour, who cares for us, and upholds us through all the ftages of our exiftence,---and like actual robbers, thefe philofophers give as nothing in exchange for our natural inheritance. If they fay that we are poor miftaken ignorants, and that they wifh to convince us of our error,---this is worfe than nothing. If we err in charity, let us live and die in this error. It is more happy to live in a full perfuafion,---in a feeling fenfe of the love of God and man, while here, and in the confident hope of eternal felicity hereafter, than to fuppofe that there is no fuch

thing,

thing,---that thefe divine faculties and propenfities of our fouls which make us capable of loving God and man,---of admiring God in his works, and of ranging thro' his creation with fublime delight,---fhall perifh for ever, and fink into the horrible gulph of *non-entity*.---Let us turn our eyes from the horrid abyfs, and ftretch out our hands, and cry, Save, Lord, or we perifh!

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Singular Obſervations.

PART I.

The Natural Hiſtory of the Strata of Coal, and of the concomitant Strata.

A SEAM or bed of coal is a real ſtratum, which is found to be fully as regular as any of thoſe other concomitant ſtrata found in the coal field, lying above and below the coal, or indeed of any other of the various ſtrata which compoſe the ſuperficies of our globe.

There are in many coal countries, and in many coal fields, a conſiderable number of ſtrata or beds of coal, of various qualities and thickneſs, placed *ſtratum ſuper ſtratum*, with a great variety of other ſtrata interpoſed between them; and ſometimes *different* ſtrata or ſeams of coal are ſo near to one another, that two, three, or more of them are cut through and worked in one pit. Every ſtratum of coal has ſome degree of declivity or ſlope, and a longitudinal bearing, and it ſtretches as far every way as the other ſtrata which accompany it; and therefore it muſt be concluded, that coal is not an adventitious recent production, but that every ſtratum of it bears its proportion in compoſing the ſuperficies of the globe, and that the ſtrata of coal are coeval with the other ſtrata which accompany them.

As there is nothing ſo effectual as local examples to enable us to form proper ideas in enquiries of this nature, let us go to the rocky ſhores of the ocean, or to ſome river which has cut deep into the rock, and chuſe out a fair and lofty ſection of the ſtrata; but care ſhould be taken to chuſe a proper ſection: Now a ſection that is cut in a line parallel to the bearing of the ſtrata, is not a proper one, nor ſhould the ſtrata be too thick, as very thick ſtrata of ſtone are apt to be broken tranſverſely from the beds of the ſtrata, and it is not eaſy to diſtinguiſh the real beds or ſtratification of the rock from the tranſverſe cutters. I have frequently ſeen very thick beds of ſtone broken tranſverſely into ſuch equal and parallel diviſions, that it required a good deal of attention to diſtinguiſh the real beds of the ſtrata from theſe tranſverſe cutters.

The beſt ſection for aſſiſting our ideas, to form proper notions of the diſpoſition of the ſtrata, is one cut in a line nearly parallel to the declivity of the ſtrata, that is in a line nearly from dip to

riſe,

rise, and where the strata are mostly thin, or of middling thickness, and the divisions of the several beds perfectly distinct. In such a section the several strata of various thickness and qualities are seen lying one above another, in as regular order as the leaves of a book, or a stack of planks.

If the strata decline a little with an easy slope, the section is the better adapted for this examination, as in that case the one edge of each stratum will dip down gradually out of our sight, and the other edge will be seen to rise up quite to the grass roots; and this order, in the disposition of the strata, is the most convenient imaginable for society, as it favours the discovery of working of coals, quarries, &c.

We find, that strata of coal do not always continue so good and regular so near the surface of the ground as some others of a harder texture. Limestone, whinstone, basaltes, and many other hard rocks, continue firm and good quite up to the superficies of the strata; whereas, on the contrary, many of the softer and weaker strata crack and crumble, or dissolve, near the surface, and the superficies of such strata decompose, and fall into sandy particles, which are mixed with the soil, or carried down the stream.

Many coals are not more goodly to look to near the surface than a heap of soot, and many

beds

beds of fine free-ſtone decompoſe, and exhibit nothing but a layer of ſand immediately below the upper ſoil: Nevertheleſs, further down, under proper cover, the ſeams of coal, and other ſoft ſtrata which accompany them, acquire ſtrength and conſiſtence, and preſerve their thickneſs and their ſtation one above another as regularly as other harder ſtrata.

A fair and regular ſection of the ſtrata, if it be a lofty one, is a magnificent and a pleaſing ſight. If we look up to the ſummit of a magnificent pile of ſtrata, we perceive that they keep the ſame diſtance from one another above as they do below. Let us fix (for example) upon any two diſtinct layers, or ſtrata, at ſeveral yards diſtance from one another, and ſtretch a horizontal line below, from the baſe of the one to the baſe of the other; we will ſuppoſe that the line meaſures a hundred feet: Now, if the ſame length of line is ſtretched horizontally up at the ſurface, we will find that it ſpans them above as well as below, and that they are nearly the ſame diſtance from one another. The upper edge of every individual ſtratum in the ſection is called by Scotch colliers the *crop* of it; and if it appears to the day, it is called the *out-burſt* of the ſtratum. In England, they ſay it *baſſets out*. Now, as the diſtance betwixt the two different ſtrata is a hundred feet at the ſurface, and the

ſame

ſame below, it will be found, that the ſtrata of this ſection keep the ſame line of bearing, and the ſame declivity or ſlope for half a mile, or any given diſtance; and in that caſe the two layers or ſtrata fixed on will continue at the ſame diſtance from one another all the way, ſo long and ſo far upon the line of bearing, as the ſtrata preſerve the ſame degree of declivity. If they turn flatter, or nearer to the horizontal poſition, then the crops of them will be found at a greater diſtance; but if they are elevated to a greater degree of ſlope, or nearer the vertical poſition, in that caſe, they will be found nearer to one another, in proportion to the greater or leſſer degree of ſlope.

From this obſervation it appears, that the ſame claſs or range of ſtrata always run parallel to one another. What I mean by a range or claſs of ſtrata, is any number of ſtrata that lie contiguous to, and accompany one another, and that are diſpoſed one above another in the ſame place; as for inſtance the number of ſeams of coal and the other ſtrata which accompany them in the ſame coal field. Theſe are all diſpoſed one above another in regular order, as I have ſhown in the ſection under review, and they all run parallel to one another to any diſtance; for if one of them ſuffer any interruption, diſturbance or change, they generally all ſuffer the ſame, and when they

have

have got over ſuch trouble or interruption, they all floor regularly again, ſo that the parallelifm of the ſame range of ſtrata is always preſerved.

Every ſtratum in a whole range, or claſs, or coal field, is ſpread out to a vaſt extent in an inclining plane, we may ſuppoſe of a mile, or of ſeveral miles ſquare, like an inclining field, or face of a country. A dead level line, drawn through this inclining plane, is called the bearing of the ſtrata, and another line, drawn right acroſs the dead level or bearing, is called the declivity of the ſtrata, or the dip and riſe of the ſtrata. We generally can ſee but a very little way from the riſe to the dip, or along the line of declivity of the ſtrata, becauſe the ſtrata ſoon dip down out of our ſight, and generally a great number of other ſtrata come on above them; but, on the contrary, we can ſometimes trace the ſame individual ſtratum or number of ſtrata along the ſurface, or dead level line, for ſeveral miles; and therefore we may properly call this the longitudinal line of bearing.

It very frequently happens that the ſtrata ſtretch or ſpread as far upon the latitudinal line of declivity as they do upon the longitudinal line of bearing; but then we cannot ſee them ſo far. We often ſee the ſuperficies of the ſtrata in different places upon the line of bearing burſting out, and appearing to the day, in rivers, rivulets,

rocks,

rocks, ſcars, &c.; and we frequently work quarries, and eſpecially coals, to a conſiderable length upon the ſtretch of this line; whereas the ſtrata upon the ſtretch of the line of declivity are ſoon concealed out of our ſight. From theſe obſervations it appears, that every individual ſtratum in the whole ſection keeps its ſtation where you ſee it placed, and that it ſpreads as wide and ſtretches as far as any of thoſe which are placed above and below it, which perhaps may be for ſeveral miles every way. Now a ſeam of coal being a regular ſtratum, it muſt follow of conſequence, that when the crop or outburſt of a ſeam is once diſcovered, it will ſpread as wide every way as any of the other ſtrata which are found to accompany it.

The ſtratum which is placed immediately above the ſeam of coal, is properly called the *roof* of the coal, and the ſtratum which is placed immediately below a ſeam of coal, is properly called the *pavement* of the coal. Now theſe three, that is, the ſtratum of coal, and its roof and pavement, with the other concomitant ſtrata lying above and below them, always preſerve their ſtations and paralleliſm, that is, they are all ſtretched out and ſpread one above another upon the ſame inclining plane, and they have the ſame line of bearing and the ſame line of declivity.

When

When a young naturaliſt has viewed a few regular ſections of the ſtrata, and has conſidered a little the ſtretch or ſpreading out of the regular ſtrata, as deſcribed above; when he afterwards deſcends into a coal-work, and is ſhewn the ſections of the ſeams of coal, and other ſtrata cut through in ſinking the pit; when he examines the ſeam of coal which they are then working, and finds it preſerve an equal thickneſs between roof and pavement, perhaps for ſeveral hundred yards from the pit bottom; when he has ſeen the whole coal wall, that is the unwrought coal, and all the boards or rooms in which the colliers are working, with a prodigious number of coal pillars left for ſupporting the roof, and finds the coal every where of nearly the ſame thickneſs, and preſerving nearly the ſame declivity or ſlope, the firſt thing that ſtrikes his imagination, next to the novelty of the whole ſcene, is the extreme regularity of the ſtratum of coal ſo deep down, and to ſuch an extent below ground; and he will perhaps imagine it a very eaſy matter to purſue and work out a ſeam of coal to any extent, even through the whole length of the iſland; but experience does not find it ſo eaſy a taſk as a ſanguine theoriſt may be apt at firſt to imagine.—Experience meets with numberleſs rubs and interruptions in working coal, many of which occaſion great trouble and expence, and ſome of

them

them prove the loſs of the coal altogether, either by its being cut off, or rendered unfit for working with profit.

An accurate knowledge of the ſtrata in a coal field is indiſpenſably neceſſary to a coal-maſter; and to obtain this knowledge, he ſhould himſelf enter the pits, mines, and levels ſunk and drove in the coal field. In theſe he will ſee a great number of the different ſtrata of ſtone, and of the other coal metals, thick and thin, hard and ſoft. An accurate coal-maſter will make himſelf well acquainted with the quality, colour, and thickneſs of each of theſe, and how far each of them is above or below ſuch and ſuch a ſeam of coal. He will carefully conſider the order of the different ſtrata, as they lie *ſtratum ſuper ſtratum* with reſpect to one another, by which means, when he ſees any one of them, he knows what others are to be found next to it, both above and below. Now this knowledge is often of ſingular uſe to him; as for inſtance, when the coal is thrown either up or down by one of thoſe ſlips, which I am by and by to deſcribe. In that caſe, the coal appears to be loſt. Well, what is he do in this difficulty? The coal is of too much conſequence to be given up. What method then is to be adopted in order to recover it? That he cannot properly reſolve upon, until he knows firſt how far it is thrown out of its regular courſe, up or down. But how is he to know how far the coal is thrown off its former level? The readieſt way to be maſter of this intereſting point, is to pierce the ſtone, or rather ſtrata, which faces the workmen, where the coal is cut off and loſt; and if he knows it with certainty, he is encouraged, as in that caſe he knows pretty nearly how far the coal is thrown off its ordinary level, either up or down; and he can then judge which is the moſt proper method to recover it with leaſt expence of time and money. The coal is ſometimes thrown a great way out of its former courſe by great dykes and ſlips, which frequently make it neceſſary to ſearch for it upon the other ſide of ſuch *troubles;* and many accidents happen which make it ſometimes neceſſary to ſhift the former ſtation altogether, and to ſink new pits, &c.; in which caſes, an acquaintance with the hiſtory of the ſtrata which accompany the coal becomes abſolutely neceſſary, and the want of it makes many to grope in the dark, and often to commit blunders at a great deal of unneceſſary expence and loſs of time, and ſometimes to miſcarry altogether, when they might have ſucceeded better had they but known what they were about, and been maſter of the hiſtory of the ſtrata which accompany their coals.

Some of the ſtrata which lie near the coal are frequently ſeen cropping out in rivulets and other

places

places, where the ſuperficies of the ſtrata appear, and an expert coal-maſter knows what uſe to make of ſuch diſcoveries. He will be very careful to inveſtigate all he ſees from time to time, until the place, and diſpoſition, and other phenomena of all the ſtrata in the coal field are become familiar to him.

I ſhall now give a hiſtory and deſcription of ſuch breaks and interruptions of the regularity of the ſtrata as are commonly met with in working coals.

The ſlips, dykes, gaſhes, and other accidents which are met with in working coals, are all of them in general, and not improperly, called *troubles* by Scots colliers.

I. The *ſlip*, properly ſo called by the Engliſh colliers, but improperly called a *dyke* by moſt of the Scots colliers, is the moſt frequent accident or interrupption which we meet with in working coals. In a ſlip the ſtrata are all cut or broke aſunder, frequently in a ſtraight line, though ſometimes in a curved line, and thoſe upon the one ſide of the breach or ſection are ſlipt down a conſiderable number of feet, perhaps many fathoms below the edges of the ſame ſtrata upon the other ſide of it. In ſome coal fields, the metals or ſtrata are thrown up by one ſlip as much as they were thrown down by another, and in other fields all the ſlips which we meet in work-

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ing away the coal towards one point of the compaſs are up ſlips, which in courſe would be all down if you were working towards the oppoſite point.

There is no coal-work of any conſiderable extent without ſlips. In pointing out a ſlip to a young ſtudent in this branch of natural hiſtory, it will be proper for his conductor to ſhew him the coal wall in perfection, as near the ſlip as he can, where he will find the coal nearly of the ſame thickneſs as in other parts of the work; and by ſhifting the candle ſlowly forward along the coal wall a few yards, he will ſee the ſlip. If it be a down ſlip, he will ſee the coal beginning to be cut off firſt above near the roof, and ſo downwards, by degrees, to the pavement, not always in a perpendicular, but generally in a ſloping line, though ſome ſlips ſtand much nearer the perpendicular than others. When, in a down ſlip, the coal is cut off in this manner, you will meet with ſtone or other metals * inſtead of it, firſt near the roof; and the ſtone continues to meet the workmen in the face, or in the place where the coal ſhould be with a ſlope downwards, until at laſt, down at the pavement, the whole ſtratum

* When I uſe the word *metals*, in treating of coal, I mean ſuch ſtrata of different colours and qualities as are commonly found accompanying ſeams of coal.

ſtratum of coal is cut off, and no more of it remains in ſight. To a perſon of no experience in theſe matters, the coal in this inſtance appears to be cut off altogether, nor would he know what was to be done in order to find it again; but an experienced coal-maſter has pretty good rules by which he can recover it. As the coal in this down ſlip began firſt to be cut off at the roof, and ſo gradually downwards, until it was entirely cut off at the pavement; your conductor, with the point of a pick, can open up a little of the viſe or fiſſure in the pavement, and in that fiſſure you will perceive ſome veſtigia of the coal remaining. Sometimes an inch or two, or more, of the coal is ſeen going down in the fiſſure, but frequently nothing is found in the ſection or fiſſure, but a blackiſh ſoft ſticking of clay, perhaps not above half an inch thick. I have ſeen the joint ſo very cloſe, that there was hardly room to thruſt the blade of a knife betwixt the two hard ſides of the fiſſure, nevertheleſs the ſection or fiſſure continued to be diſtinctly ſeen with two ſmooth ſides. It will then be proper to ſhew our young learner where the ſlip has been pierced by a mine; and when he has gone through the mine to the other ſide, he will ſee that from thence the ſame trouble becomes an up ſlip. Above, upon the other ſide, the coal began firſt to be cut off at the roof, but, on the contrary, it begins

begins here to be firſt loſt below at the pavement, and the ſtone comes in inſtead of it gradually upwards, until all the coal is entirely cut off at the roof. You will find the coal flooring as regularly down, upon the low ſide of the ſlip, as it was above on the other ſide of it, before it was cut off; and if the mine has been made in the viſe or fiſſure of the ſlip, you will ſee ſome dark veſtige of the coal all the way through, from the place where the coal was cut off, upon the one ſide of the ſlip, until it floors regularly again, at full thickneſs, upon the other ſide of it. At leaſt, you will perceive a ſection or fiſſure cutting all the ſtrata in a ſlanting direction from where the coal is loſt above, until it is found again below.

When we firſt meet with one of theſe troubles, we do not immediately know what to make of it, or how far it has thrown the coal up or down, unleſs we have pierced it before in ſome other part of the field, as they differ widely in magnitude, or in the number of feet, or of fathoms, they throw the coal off its ordinary floor or level; and they alſo differ widely in the confuſion they make in the metals, and in the line of bearing; but they all agree in this one circumſtance, that there is always a cut or fiſſure in the ſtrata, though not always in a ſtraight line; and that the ſection of the ſtrata upon one ſide of the fiſ-

fure

fure is always thrown or funk down below the fection or edges of the fame ftrata, on the other fide of the fiffure.

Slips in the coals and coal metals are either parallel, direct, or oblique:

1*ft*, By *parallel flips*, I mean fuch as cut the ftrata in a line parallel to the dead level line or bearing of the ftrata; and the bearing in Great Britain, and other places in the fame parallels of latitude, is nearly from north-eaft to fouth-weft, excepting fmall fpots or places where they have been partially warped or twifted out of the true line of direction by accidental caufes, fuch as a different dip or declivity of the ftrata, which is occafioned by the waving and wheeling of the ftrata, &c. to be explained hereafter.

The effect of the parallel flip is this: When you are working a coal towards the dip, or pufhing a mine towards the dip, in order to gain a greater breaft of coal, you ftrike one of thefe flips, which meets you in the face as you pufh downwards, cuts off the coal, and throws it many feet or many fathoms up. Some of thefe flips throw the coal quite up to the furface, though you have fixty, eighty, or more fathoms of cover where it is cut off. The coal has generally the fame, or nearly the fame declivity or dip upon both fides of one of thefe parallel flips, and likewife the fame bearing; and, therefore, when the coal

coal is only thrown up a few feet, or a few fathoms, the interruption is eafily overcome, by running a mine or level right acrofs the ftrata, from the one fide of the flip, until you cut the coal upon the other fide of it. But when it happens to be a great flip, you have either a long mine to drive, in order to level the water upon the other fide of the flip, and bring it to the adit or engine, or elfe you muft remove the engine to a proper ftation, to gain as great a field of coal upon the other fide of the flip, as it is able to drain. It will be eafily conceived, that in this inftance, what is an up flip from one fide, is a down flip from the other; that is, when you are working with your face to the dip, and meet an up flip, if you were working upon the other fide of it, and working with your face to the rife of the coal, it would be a down flip.

Thefe parallel flips are frequently the occafion of our having fuch fine and regular fections of the ftrata as we often meet with upon the banks of rivers, cliffs of rocks, and the fhores of the ocean. One of thefe flips, or perpendicular fiffures, cutting the ftrata in a line, and that part of the range of ftrata which was without the fiffure, or towards the crop of it, being undermined by water, or otherwife broken off, a regular fection of the ftrata, from the top to the bottom of the rock, on the fide which ftood firm, is exhibited to view.

2*d*,

2*d*, The *oblique ſlips* are ſuch as cut the ſtrata in a diagonal direction acroſs the ſlope. Theſe ſlips differ but little from the former in deſcription, only they throw the coal up or down in the ſame oblique direction, and they throw it to one ſide, out of the line of bearing, in proportion to the obliquity of the line of the fiſſure or ſlip to the line of bearing of the ſtrata, and the number of feet or fathoms the coal is thrown up or down off its former level.

3*d*, The third ſpecies of ſlips, which I call *direct*, are ſuch as cut the ſtrata right acroſs, nearly in a line from crop to dip. When you are carrying forward a breaſt of coal, which dips towards the north, and are working along the dead level line or bearing of the coal, with your face towards the weſt, and meet one of theſe direct or rectangular ſlips, if it be a down ſlip, the coal is thrown ſo far to the left hand out of the former line of bearing; but, on the contrary, if it be an up ſlip, the coal is thrown to the right hand, in proportion to the number of fathoms it is thrown off its former level, and to the quick or ſlow riſe and declivity of the ſtrata. In this caſe, when it is a down ſlip, a mine or level drift muſt be turned off to the left hand; but if an up ſlip, it muſt be turned off to the right from the loweſt or level room, and carried in the viſe or fiſſure of the ſlip, in order to level the coal, and winn it properly upon the other ſide of the trouble. It may be proper to obſerve here, that you cannot depend with abſolute certainty upon ſuch mine or level for diſcovering the coal upon the other ſide of this trouble, until you firſt know that the ſlip is a ſingle ſlip, for many large ſlips have ſeveral branches. In a ſingle ſlip, which only throws the coal once up or down, you are ſure to find the coal with a mine, as pointed out above, by keeping a good hold of the firm metals in the farther ſide of the mine, where the coal is to be found, that is, by cutting the edges of the ſolid ſtrata in the farther ſide of the viſe, or ſoftneſs contained in the fiſſure of the ſlip. But if the ſlip conſiſts of ſeveral branches, or, in other words, if there are two or three, or more ſlips near one another, which often happens before the coal is got clear of that trouble, and floors again as before, it requires farther attention. We ſometimes meet with a range of troubles or ſlips, parallel to, and ſo near one another, that we muſt try to get beyond them all before the coal ſhall floor regularly. In that caſe, the mine or drift mentioned before is not ſufficient. This mine is ſuppoſed to be driven in the viſe of the ſlip, and the whole breadth or wideneſs of the mine is not above three feet; whereas the whole trouble, including the bundle of parallel ſlips, may be twenty, forty, or even a hundred feet broad, or

more;

more; and, therefore, a croſs mine through all the branches muſt be cut before the coal can be found and levelled by ſuch a mine. When a parallel ſlip, an oblique ſlip, and one that cuts aright acroſs the ſtrata, meet at certain angles or points, they often produce a triangular piece of coal, of leſs or greater dimenſions, in proportion to the diſtance theſe different ſlips happen to be from one another. Sometimes the ſides of theſe guſſets of coal are nearly of equal, and ſometimes of very unequal lengths. When a great number of theſe different ſorts of ſlips happen to cut and interſect a field of coal in all directions, they often make ſad havock in it. A proper plan of the fiſſures and diſturbances in ſuch a field would much reſemble a large ſheet of ice, broken and fallen in, where pieces and fragments are to be ſeen of all ſhapes and dimenſions, the edges of the fragments being elevated and depreſſed, or ſlipt by one another in all directions and in all degrees.

Theſe ſlips, as well as all other troubles and interruptions met with in working coals, are generally looked upon only as real evils incident to the practice of colliery; and it muſt be confeſſed that they are ſo, and that they often prove exceeding troubleſome and expenſive; and moreover, they certainly are the moſt frequent interruption of the regularity of the ſtrata; but it is perhaps

perhaps the only coal trouble by which we reap any benefit. Contrary to what is generally imagined, a very obvious advantage to coal-mining arises from these slips. They are often a general good when they prove a partial evil.—By throwing the strata of coal up and down this way and that, they are spread wider over the face of a country; and the slips throw more of them up, so near the surface of the ground as to be within our reach, than we could otherwise possibly get at, were the strata to keep the same uniform stretch, bearing, and declivity invariably, without any interruption or breach of regularity.—A parallel slip especially gives us the same field of coal over and over again, as often as it is thrown down by a slip of that sort.—One parallel slip, if it throws the coal sixty or eighty fathoms down, or as much as you can reach with your level, or engine, gives you the same field of coal twice over in any given length upon the longitudinal line of bearing. Three parallel slips, in like manner, give the same field exactly three times over, and so on to any number, provided that there is a sufficient distance betwixt each slip, from crop to dip, to give an ample breast of coal; and the other sorts of slips have in some degree the same effect of keeping the coals floating near the surface, within our reach, which makes the slips a public good, when in fact they often prove a private evil.

When

When a great ſlip has many branches, or when there are many ſlips running parrallel, and near to one another, they often prove very troubleſome and expenſive. I have ſeen ſome of theſe very wide, and the metals betwixt each of the branches, being generally imperfect and tender, and dipping confuſedly every way, make it difficult to get over them.

Sometimes the coal ſeems to floor regularly between the diviſions of theſe great ſlips, but the compartments are ſo ſmall, that although the coal ſhould be found at full thickneſs, yet it is cut off again when we have advanced a few feet, or at moſt a few yards forwards in it. The coal is ſometimes found pretty good between the grains of theſe troubles, and pretty regular, with the proper dip and riſe; but it is much oftner found imperfect, ſoft, and uſeleſs.

When the coal is thrown forty or fifty fathoms off its former level, by a ſlip compoſed of ſeveral parallel diviſions, which cut acroſs the ſtrata, it often alters the declivity, ſo that the coal ſhall lie much flatter upon the one ſide than the other of this trouble; in which caſe it is very difficult to calculate exactly how much the coal is thrown off the former level, and how far it is thrown to the right or left out of the former line of bearing. Where the ſuperficies of the ſtrata are ſeen in rivulets, glens, and other places, where the

the ſurface of the earth is broken, ſome imperfect notices may be obtained, if we are maſter of the hiſtory of the ſtrata of the field; but if the ſurface is unbroken, and the ſtrata covered with clay or ſand, &c. the moſt ſkilful are in the dark until they have made trials by boring, or otherwiſe.

The facility with which boring is now performed by men of ſkill in that branch of buſineſs, with a good apparatus, is of great conſequence to ſet us right in ſuch difficulties, and in doubtful caſes, at a moderate expence. Before boring was brought to ſuch perfection, and became common, many expenſive blunders were committed; and ſo there are ſtill when that wiſe precaution is neglected. It is no uncommon incident in the hiſtory of collieries to hear of ſinking expenſive pits, and ſometimes of erecting ſteam engines, where they had no coal to work when they got down, becauſe they unfortunately happened to place their pits between two ſlips which were pretty cloſe to one another, and ran parallel to one another. The metals, or different ſtrata which they cut through in ſinking ſuch pits, perhaps might appear to lie fair, and to dip and riſe regularly; but when they come to drive mines in the coal, in order to open it up for working in form, they find, when it is too late, that they have no coal of any conſequence to work upon. They are ſoon cut off by troubles on each hand, and all their expence and time is loſt, which might have been prevented had they duly examined their field by boring.

I have already hinted, that ſome of the great ſlips have many parallel branches, between which branches, or parallel ſlips, the metals are imperfect, and in the greateſt confuſion and diſorder; there are other great ſlips that throw the coal forty, ſixty, or eighty fathoms up or down at once, that is, at one ſlip without any parallel branches in that place. When theſe are known, they are generally more eaſily conquered than ſuch as are compoſed of many branches, becauſe the metals are generally good and regular immediately upon the other ſide of the ſingle ſlips; whereas the confuſion and trouble continues, and is often very wide and difficult to get over, where many ſlips run near to one another. The ſingle ſlips, or ſteps, for they are known by both names, are of various degrees of magnitude, from ſixty or eighty fathoms, or more, down to a few feet, and even a few inches. When theſe ſlips are ſmall ones, they are called *hitches* by Scots colliers; and it frequently happens that ſuch a ſmall hitch only cuts off a part of the coal, and that the other part of the thickneſs of the ſeam continues ſtill in ſight. In this caſe, the worſt conſequence generally is, that the coal is ſhaken,

tender

tender and foul, and continues ſo until you are quite clear of ſuch trouble. If one of theſe ſmall ſlips or hitches ſhould not throw the coal above three or four inches off its ordinary level, yet, nevertheleſs, it will very ſenſibly affect the coal ſeam, and all the metals about it, as this trifling ſlip cuts through them all; and they are always in a leſs or greater degree ſoft, tender, and brittle upon both ſides of the fiſſure; for which cauſe the colliers are generally obliged to contract their boards, or rooms, much narrower when they paſs through one of theſe hitches, in order to ſave the roof until they are quite clear of it. Theſe ſmaller ſlips are very frequent near the ſuperficies of the ſtrata, and much more ſo in ſome fields than in others. But the ſmall hitches found at the ſurface ſeldom go far down; whereas the larger ſlips continue from the ſurface down, as deep as we ſink, and cut through every individual ſtratum in their courſe.

There is yet one material remark to be made concerning ſlips, namely, that every one of them are not always equal in every part of the work; that is, all ſlips do not always throw the coal and concomitant ſtrata an equal number of feet, or fathoms, off its former level in all parts of the ſame work. Some of them are very conſiderable ſlips near the ſuperficies, or crop of the ſtrata, and throw the coal, &c. a great many fathoms

off

off its former regular floor, or bed, which prove but ſmall ones further down, towards the dip; and, on the contrary, ſome are great ſlips to the dip, and ſmall ones near the crop. I have ſeen many of theſe that threw the coal ſeveral fathoms up or down near the crop, which grew leſs and leſs as we wrought down towards the dip, until they at laſt dwindled away to nothing, and were no more ſeen: And I have ſeen very conſiderable ſlips pretty far down towards the dip, which grew leſs and leſs as we advanced upwards, and at laſt dwindled away, and were no more ſeen, before they reached the crop.

I believe it may be obſerved, in general, that the ſlips which vary ſo much between the crop and dip of the coal, are commonly ſuch as cut acroſs the ſtrata, either in a right or a diagonal direction. The parallel ſlips, I am perſuaded, are generally more regular, that is, they continue to a greater length, along the bearing of the ſtrata, to be a ſlip of ſo many fathoms as we found them at any given point.

It is exceedingly difficult to explain all the phœnomena of every particular ſlip which we meet with in working coal, becauſe they all differ from one another in ſome manner or degree.

All the ſlips found in the coal metals are mineral veins, and of that ſpecies of veins which are called by naturaliſts *perpendicular fiſſures*, and by miners, *rake veins;* and as theſe veins are ſofter or harder, wider or cloſſer between the ſides, ſo are the ſlips *. Some of the ſlips are very wide betwixt the two ſides of the fiſſure, and the cavity often contains heterogeneous or adventitious matter, frequently ſuch as inclines to be ſoft and argillaceous; and the ſides of ſuch wide ſlips are generally ſoft, looſe, and dangerous, as they cannot be mined either along or acroſs the ſlip without ſecuring the mine with timber. Other ſlips are hard and cloſe, at leaſt in ſome places upon the longitudinal line of them; and though the ſtrata may be thrown a great many fathoms off the ordinary level by them, yet the two ſides of the vein, or fiſſure of the ſlip, will be found in ſome places perfectly cloſe together, though the fiſſure or joint will always be diſcernible to a ſkilful eye.

Again, ſome of the ſlips contain ſeveral ſpecies of heterogeneous matter, between the ſides of the fiſſure, of a harder nature; ſuch as pyrites, ſeveral kinds of ſpar and cryſtallizations, and ſometimes lead ore, &c. I have frequently ſeen pyrites and large ribs of ſpar in ſeveral ſlips, and more than once a little lead ore in the collieries of Scotland; but Coalcleugh, in the north of England, is the moſt

* I have explained this ſubject more fully in Part II. where I treat of the natural hiſtory of Mineral Veins, to which I refer the reader.

moſt remarkable place for producing a great quantity of lead in the coal metals, of any I have yet heard of. There the lead cut off the coal, or threw it off its regular bed, as other ſlips do which contain no lead. The coal was found upon the other ſide of the ſlip, and wrought as uſual, according to my information, and the lead was wrought with eminent ſucceſs.

There are a great variety of leſſer *troubles*, or diſturbances of the regularity of the ſtrata, ſuch as *hitches*, *ſkews*, *backs*, &c. which are more local, and in general only affect one particular ſpot. Theſe are not eaſily deſcribed, as no two of them are alike, and they are ſeldom of much continuance.

A *hitch* is a ſmall ſlip, which only throws part of the thickneſs of the coal off its former level, and the other part of it always remains in ſight, ſo that the coal is never quite loſt with a hitch.

Skews and *backs* are only local joints of an irregular curved figure, which often reſemble hitches when we firſt meet with them, but they only ſtrike out a little way, and turn in again; that is, ſome of them deſcribe a ſegment of a circle of leſſer or greater dimenſions, and others of them only prove a diſcontinued joint, which only affects a ſmall part of the coal, and the coal roof, &c, but ſeldom extends to any great diſtance.

It

It may be proper to repeat here, for the ſake of memory, that there are two circumſtances peculiar to all ſlips and hitches. Firſt, there is in every one of them a real ſection, or fiſſure, right acroſs the beds of the ſtrata; and ſecondly, the beds of this ſection, or cut, is ſlipt down ſo that the ſeams of coal, and other particular ſtrata, floor lower down upon the one ſide of the fiſſure, or ſection. If the ſtrata lie in a horizontal poſition, the fiſſure of the ſlip will be nearly perpendicular; but if the ſtrata hang with any conſiderable degree of declivity, the fiſſure of the ſlip will be found in a ſlanting direction; as all theſe ſections generally cut tranſverſely, or right acroſs the bed of the ſtrata, or nearly ſo. I obſerved before, that every ſlip of the coal metals has a viſe, or veſtigia, which points out to a ſkilful eye which way the metals are thrown out of their former courſe, or level; and this viſe is generally ſome imperfect remains of the coal; a ſoft ſooty-like ſubſtance, or elſe ſome ſpecies of clay contained in the joint betwixt the two ſides of the fiſſure of the ſlip. In an up ſlip, the coal begins firſt to be cut off at the pavement, and ſo upwards, by degrees, until all the coal is loſt, in which caſe the viſe leads up into the roof; and on the contrary, when it is a down ſlip, the coal is firſt loſt at the roof, and ſo downwards, by degrees, or in a ſlanting direction, until the coal is quite

quite loſt at the pavement; in which caſe the viſe ſtrikes down into the pavement; and this makes the viſe of ſingular uſe to ſatisfy us which way the coal is thrown off its former level; and it is a guide to lead us the right way to find it again. Sometimes the roof preſſes down upon the coal, and cuts off much of its thickneſs, without any ſlip or hitch. This, in ſome places, will be of ſeveral fathoms extent, and in others no broader than the bottom of a pot. In ſome places, without any apparent cauſe, the coal turns foul, and mixed with ſtone or clay, ſo as to be good for little or nothing, for a leſs or greater extent.

II. The ſecond great interruption of the regularity of the ſtrata, and trouble met with in working coal, is a *dyke*. Dykes are very commonly found in many coal-works, and they are of various kinds, ſuch as, *1ſt*, Dykes of baſaltes, or other hard ſtone, which are commonly called *whin dykes*: *2d*, Dykes of imperfect ſtone: *3d*, Dykes of clay; in ſome of which the clay is chiefly of a homogeneous quality, and in others it is compounded or mixt with gingle, gravel, &c.: *4th*, Dykes of gingle and of gravel, without any mixture of clay: And *5th*, Dykes of ſand.

I ſuppoſe that this ſpecies of coal-trouble was firſt called *dyke* from the reſemblance of ſome of the

the leſſer hard ones to a ſtone wall, or ſtone dyke, ſome of them being no thicker than a common garden wall; however, theſe dykes vary greatly in thickneſs as well as in quality, and the matter of which they are compoſed. They vary in thickneſs from two or three inches up, to a great many fathoms; in ſome inſtances, too many fathoms to be croſs cut, or pierced through with a mine; in which caſe, they are obliged to abandon the preſent pits, and to ſearch for the coal upon the other ſide. But theſe prodigious unconquerable dykes are not frequently met with.

A dyke, in the natural hiſtory of the ſuperficies of the globe, may be called a crack, fiſſure, or chaſm in the ſtrata; the concavity of which chaſm is filled up commonly with foreign heterogeneous matter, which appears to have been carried there by water, and poured in when the ſubſtance of which the dyke is compoſed was in a fluid ſtate.

Some dykes of *whin*, and of other ſtones, are ſo hard that every inch of them in driving a mine muſt be blaſted with powder. Beſides theſe dykes of compact and indurated rock, there are others which are compoſed of ſofter and more imperfect ſtone, ſometimes reſembling fragments of the neighbouring ſtrata packed into the cavity betwixt the ſides of the chaſm, and others are compoſed of an indigeſted maſs of imperfect

ſtony

ſtony matter. There are ſome of the hard ſtone dykes found pretty dry, even at a conſiderable depth below ground, and others are full of open cracks and cutters, and ſome of them have a longitudinal fiſſure in the middle of the dyke; theſe often let down a conſiderable quantity of water. The dykes compoſed of fragments of imperfect ſtrata, reſembling ſome of the coal metals, are ſeldom very dry.

The *clay dykes*, both the homogeneous and the compounded, are generally very dry; but on the contrary, the gingle, gravel, and ſandy dykes always, at conſiderable depths, produce a great quantity of water, and eſpecially below level, in flat and plain ſituations. At the ſame time, it may be of uſe to remark, that if one of theſe gingle or gravel dykes, or any others compoſed of open looſe materials, happen to croſs a glen, or dingle, or to point towards any low river, it may happen to drain the coal, and render the field dry, and *comeatable* as low down as that river or valley.

Dykes do not throw the coal ſeams and other ſtrata off their former levels like the ſlips; but on the contrary, when a dyke is pierced through with a mine, the coal is commonly found upon the ſame level as where it was loſt upon the other ſide. There are indeed ſome dykes which throw the coal, &c. a little off the former level, and

theſe

theſe I will, for diſtinction's ſake, call *ſlip dykes*. Theſe ſlip dykes differ nothing in appearance, or in any point of deſcription from the others which leave the coal upon the ſame level, but that they throw it leſs or more off the ſame level.

Dykes appear variouſly when you ſtrike them firſt. Sometimes the coal continues good and clean, until it is entirely cut off by a wall of ſtone, that meets the collier full in the face. At other times, that is, in other dykes, they meet with foul coal ſeveral feet, and in ſome places even ſeveral fathoms before they touch the dyke. The foul coal upon the face of a dyke is plentifully mixed with ſand, and other particles of ſtony matter, which renders it unfit for uſe. This is commonly called in ſome places burnt coal, the quantity of which upon the face of the dyke varies greatly in different places. Upon ſome dykes there will not be above two or three feet of bad coal, and upon others there will be two or three fathoms, or more. I have ſeen above four fathoms upon both ſides between the clean coal and the ſtone dyke. There is no viſe or joint in the dyke to lead them through it to the coal upon the other ſide, as in the ſlip; on the contrary, a ſolid body of ſtone meets them in the face, which exhibits no manner of veſtige or leader whatever to point out which way the coal is gone, and therefore they are obliged to drive a

mine

mine through a dyke at all adventures, without being able ſo much as to gueſs at the thickneſs of it, until they find the coal upon the other ſide. However, when they have once pierced a dyke by driving a mine through it, they have then a near gueſs what it will be when they meet with it in another part of the field.

Some of the ſtone dykes are ſo hard, as I hinted before, that a mine in them can only be made with the help of gun-powder, and others, on the contrary, are ſo ſoft, and the ſtone they cut through ſo tender and rotten, that every foot of the mine muſt be lined or ſupported with timber. Thin dykes, which do not ſpoil the coal much, are commonly eaſy to be got over, but it is generally a work of much time and expence to pierce through ſome of the greater dykes; and, as I obſerved before, ſome few of them are ſo very thick that they prove an inſurmountable barrier, ſo as to oblige them to ſearch for the coal upon the other ſide.

The clay dykes are generally pretty eaſily pierced, but the mines driven in the clay are not always ſo eaſily ſecured. It is often exceedingly difficult to drive a mine through ſome of the gingle, gravel, and ſand dykes, and eſpecially at conſiderable depth below level, as they then contain a great deal of water, which diſturbs and retards the progreſs of the miners.

III. A *gall* or *gaſh* is very frequently met with in coal-works. A gaſh is a crack or chaſm in the coal, and in the concomitant ſtrata above and below the coal. Theſe galls or gaſhes vary greatly from one another in magnitude, and in their miſchievous effects. Some of them prove only to be a ſmall chaſm or crack, which does little more harm than to entender and ſpoil a ſmall quantity of the coal upon both ſides of the gaſh. Theſe are ſoon got over, the coal being always found upon the ſame, or nearly upon the ſame level on both ſides of the trouble; but, on the contrary, many of the wider gaſhes prove very troubleſome and expenſive. The chaſms or fiſſures between the ſides of the larger gaſhes are generally filled with ſand, gravel, clay, and other looſe matter, which will run down upon the workmen, and choke up the mine they are puſhing through, if they neglect to ſecure every inch of it with timber as they advance; for if it once begins to run, it may prove difficult to ſtop it, and it may bring ſuch a preſs or weight upon the mine, that they may not be able to ſecure it afterwards; and, therefore, the beſt way is to take it in time, and to ſecure it with timber, ſtep by ſtep, as they advance, and to ſet their timber ſtrong and cloſe, in proportion as they ſee that circumſtances require it.

In

In ſome coal fields they meet with gaſhes ſo wide (filled with ſand, clay, and other looſe matter) that the colliers call them ſand dykes.—Theſe are often very wet and difficult to croſs, and ſometimes altogether impracticable.

Theſe gaſhes, and the dykes deſcribed above, are ſo like to one another in many inſtances of approach, that ſome of them are hardly diſtinguiſhable, are to be inveſtigated upon the ſame theory in many reſpects, and ſeem to me to have originated from the ſame natural cauſe, *viz.* a crack or ſection, in a line acroſs the ſtrata, ſuch as we ſee in miniature in brick-makers clay, ſpread out, and left too long in the ſun; and theſe chaſms being afterwards filled up with heterogeneous matter poured in from the ſurface; and this foreign matter ſo poured in is the real dyke, which ſeparates the edges of the coal, and other ſtrata, from top to bottom, where they are broken aſunder by ſuch chaſm or fiſſure; ſo that the only material difference which I can find between a dyke and a gaſh is, that the foreign matter which fills up the chaſm of the dyke is in ſome indurated, in others only dried to different degrees, whereas it always continues looſe and generally very wet in the gaſhes.

In ſome coal fields ſeveral dykes run parallel to one another. Sometimes they are found to be two or three hundred fathoms aſunder, and often

often much fewer, the field of coal being divided by them into ſo many compartments, and each of the compartments between the ſeveral dykes and gaſhes, are ſubject to be diſturbed and ſubdivided by ſlips, ſhakes, *&c.*

IV. Another formidable, and often a very dangerous interruption to their progreſs under ground in working coals, is a *ſhake* in the metals or ſtrata which affects the ſeams of coal, and all the other ſtrata above and below the coal. The ſhakes alſo vary conſiderably from one another, both in kind and degree. In ſome ſhakes, the coal and the other ſtrata are only ſhaken, cracked, and broken to pieces, ſpoiled and made ſoft, tender, and uſeleſs, but remain at or pretty near their former thickneſs and poſition. Theſe are commonly pretty eaſily got the better of, being ſeldom of great extent. The worſt and moſt dangerous ſhakes are of two ſorts, which, for diſtinction ſake, I will call the *waving* and the *twiſted.*

In the *waving ſhake*, the ſtrata are not entirely broken and ſeparated by a fiſſure or chaſm, as in the ſlips and gaſhes, &c. but only ſhaken, cracked, and thrown into great confuſion. When the coal enters into one of the waving ſhakes, it is ſeldom or never altogether loſt, but it is always rendered uſeleſs,—commonly very ſoft, tender,

and

and ſhattery,—ſometimes thicker, ſometimes thinner,—generally waving up and down, yet preſerving nearly the ſame ſtretch, bearing, and declivity. Some of theſe ſhakes do not continue long before the coal comes in, and floors again in its uſual regularity and perfection; in other places they prove very wide and extenſive, even up to ſeveral hundred yards, ſo as to make it neceſſary to look for the coal quite beyond them, and to open up the works of new.

Some ſhakes only cruſh and ſpoil the coal, make it tender and bad, but do not alter the thickneſs, nor the bearing and declivity of it; and it generally happens that this ſort of ſhake only continues a few fathoms; in which caſe, the common method is to drive two or more narrow mines through it, until they come into good and firm coal upon the other ſide, and then to winn or open out the works of new.

The *twiſted ſhake* is often more dangerous in its conſequences than the *waving*, being ſometimes (I do not ſay always) occaſioned by a total interruption of the courſe or bearing of the coal metals, where the coal and all the other ſtrata of the coal-field are entirely cut off by another range of ſtrata, which are altogether foreign to the coal. This happens at the extremity of the coal country, both in the longitudinal line of bearing, and upon both ſides where other ſtrata commence

entirely

entirely of a different quality from the coal metals. But this is not always the caſe. There are frequently twiſted ſhakes to be ſeen in the middle of the coal-field. It is very difficult to deſcribe a twiſted ſhake, as it exhibits the utmoſt confuſion imaginable in all the extremes, from the regularity of the ſtrata. The ſtrata or metals, in ſome parts of a twiſted ſhake, appear waved and diſtorted ſeveral ways,—bent round to various ſegments of a circle,—dipping this way and that in confuſion and diſorder; fragments of the coal and other ſtrata appear in neſts here and there, without continuity, or any other veſtige by which to trace out the coal; ſo that when a large ſhake of this ſort is met with in the middle of a coal-field, the beſt expedient is to look for the coal upon the other ſide of it, where the metals are found to floor, and ſtretch again fair and regular.

But all the twiſted ſhakes are not ſo formidable. They are found in all degrees like other coal troubles; ſome of the ſmaller ſort can be got the better of without much expence of time or money, and without quitting the preſent pits, and ſome of them only continue a few feet.

I ſhall here point out a few of the many places in the Lothians, where the lovers of mineral knowledge may behold the ſuperficies of the ſtrata laid

laid bare for their inſpection; where they may ſee ſtrata of coal, and its concomitant ſtrata, both above and below, and likewiſe ſtrata of ball-iron ſtone, which is now become an article of much value and conſequence in Scotland.

The vertical or edge ſeams of Gilmerton and Loanhead are the neareſt coals to Edinburgh, of any that have been yet diſcovered and wrought.

The ſuperficies of ſeveral of theſe ſeams of coal, and of their concomitant ſtrata, are to be ſeen when the tide is out, within flood mark, between Edinburgh and Muſſelburgh, near Duddingſton fire-engine; and there is a pretty good ſection of them to be ſeen in the high road (upon the left hand) from Edinburgh to Dalkeith, betwixt the parks of Drum and Edmondſtone *. But the beſt ſections of theſe coals, and of the ſtrata which accompany them, are to be found and ſeen in the levels and croſs-cut mines in the coal-works of Gilmerton.

The rivers North and South Eſk, in Mid-Lothian, cut through a remarkably rich coal-field. Theſe two rivers join in one before they reach Muſſelburgh, where the united Eſk falls into the tide. Though the two Eſks are but ſmall rivers, yet

* Since writing the above, theſe ſections are concealed by a ſtone wall, and the ground is levelled and planted.

yet they have in many places ſcooped out or worn very deep channels; and there are many fine ſections of the ſtrata of coal metals to be ſeen upon their banks in the deep ravines.

There are good and regular horizontal ſtrata of the coal metals, and of poſt freeſtone, to be ſeen in the bed, and upon the banks of the river Eſk in ſeveral places, below the junction of the two branches of it, particularly near the corn-mills of Cowpits colliery, where ſome pretty good ſections are to be ſeen in quarries upon both ſides of the river, dipping towards the north and north-weſt, with an eaſy ſlope.

There are ſeveral ſections of the flat or horizontal coal metals, a little way above the ford of the North Eſk upon the Newbattle road from Edinburgh, and likewiſe below the ford near the iron mills.

The bed or channel of this river is remarkably deep about Roſlin and Hawthornden, where abundance of high and romantic rocks appear upon both ſides; but theſe rocks will not afford much inſtruction in this ſcience, becauſe they are chiefly compoſed of thick ſtrata of poſt free-ſtone, running parallel to the bed and courſe of the river, which cauſes a dull uniformity in the appearance of theſe rocks; I mean with reſpect to ſtratification; but as the rocky banks of a

ſmall

ſmall river, they are abundantly magnificent and curious.

Between Roſlin and Auchindinny bridge, there are ſeveral fine and lofty ſections of the ſtrata of coal metals upon both ſides of the river, among which there are ſeveral thick beds of red and white poſt ſtone, with a variety of ſuch other ſtrata as commonly attend coal; and there are a conſiderable number of coal ſeams both above and below theſe ſections, many of which have been, and continue to be wrought. The ſections of the ſtrata in this part of the river lie flat or horizontal, and in ſome places theſe flat-lying ſtrata dip a little towards the ſouth-eaſt, and in other places towards the north-eaſt. This diverſity and oppoſition of dip or declivity is occaſioned by the waving of the ſtrata up and down, which is a very common incident where the ſtrata lie very flat, or nearly level with the horizon. There is to be ſeen in a quarry about a quarter of a mile above Roſlin, and alſo near Auchindinny, upon the north ſide of the river, a regular continuous ſeam of coal, only about one or one and a half inch thick, with very ſtrong thick beds of poſt ſtone above it; and I know that there are ſeveral thick ſeams of coal both above and below this thin one, ſome of which are now working.

There are alſo a variety of ſtrata lying in various poſitions between Auchindinny and Penny-

 cuick.

cuick. About two hundred yards above Auchindinny bridge, in the bed of the river, we ſee the vertical and the horizontal ſtrata in the ſame place, the edge metals occupying the north, and the flat ones the ſouth ſide of the bed of the river. This ſpot deſerves the examination of the curious, as it determines the place and manner of their coming in contact in this part of the country.

Some of the foundations of the cotton mill at Pennycuick, and of the water courſes, are cut pretty deep in horizontal coal metals, where they have cut through one regular ſeam or ſtratum of coal, about twelve or fourteen inches thick, which is to be ſeen betwixt the eaſt end of the higheſt building and the bed of the river.

There are a variety of inſtructive particulars relating to this ſubject in the lands of Pennycuick, between the village of Pennycuick and the lands of Newhall: And there are various ſections of the flat, and likewiſe of the edge-coal metals in the river, and in the rivulets in the lands of Newhall and Carlops. The horizontal coal ſtrata lie ſo very flat in this place, and eſpecially in the farm of Carlops, that the coal ſeams frequently wave up and down, which occaſions ſeveral gently ſwelling ridges and troughs, or elevations and depreſſions, of the horizontal ſtretch of the coal and the other ſtrata. This incident is known

with

with certainty, as ſome of the flat coals have been worked in that farm, where the ſtrata were found thus waving up and down.

It is remarkable, that both the edge and the flat coals, with their ſeveral concomitant ſtrata, preſerve their paralleliſm, and the true line of bearing from the ſea, until they reach the lands of Carlops, and there the true line of bearing of the coal metals ends, and they turn away almoſt in a right angle towards the ſouth-eaſt, inſtead of the ſouth-weſt direction, which was the former line of bearing from the ſea to this place.

The edge-coal, and all its concomitant ſtrata, appear, and really are in the utmoſt diſorder and confuſion imaginable, when they arrive at the extremity of the true line of bearing in the lands of Carlops, and they are dwindled away almoſt to nothing, the thickeſt of the ſeams of coal being hardly ſo many inches as they ſhould be feet thick.

This diſorder and diminution is occaſioned by this being the out-ſkirts of the coal-field; and this confuſion of the ſtrata is to be ſeen diſtinctly in the banks of the river below the bridge of Carlops.

There are abundance of horizontal ſtrata to be ſeen in the bed of the river South Eſk, upon the eaſt and ſouth ſide of the town of Dalkeith, betwixt the Duke of Buccleugh's and the Marquis

of

of Lothian's parks. Thefe ftrata flope with various degrees of declivity towards the north-weft, and in fome places they dip towards the north, and in other places towards the weft.

There is alfo a variety of horizontal ftrata, and confiderable fections of them upon both fides of this river, between Newbattle and Dalhoufie; and about a quarter of a mile below Dalhoufie bridge, there are fome irregular difcontinuous imperfect feams of coal. The difcontinuity of fome irregular beds of coal is an incident which is frequently met with.

Many rocks and ftrata are to be feen in the main branch of the river between Dalhoufie and Temple, all of them lying in a horizontal pofition, with various degrees of declivity.

The neighbourhood of Temple is one of the happieft walks imaginable for the ftudent of the ftrata of coal. He will there meet with various fections of feams of coal, and of their concomitant ftrata, appearing fair and regular. It is but rarely that we meet with a more complete and regular fection of the ftrata of coal than the one to be feen clofe by the Temple mill, and not much above a hundred yards below the church. This is a fair and clean horizontal fection, cut nearly perpendicular, and pretty high, in which there are at leaft four different feams of coal diftinctly feen dipping a very little towards the

N.

N. N. E. The ſtrata in the neighbourhood of Temple lie remarkably flat. About a mile above Temple church, the ſouth branch of the river runs upon the face of a hard ſtratum of rock for more than a hundred yards in our ſight, as upon a ſmooth pavement, and we ſee it running upon the face of the ſame ſtone below the church. There are ſeveral ſeams of coal to be ſeen in this branch of the river above Temple church, dipping moſtly north, though ſometimes the declivity changes, and the ſtrata are found to dip towards the N. W. and alſo towards the N. E. This variety of declivity is commonly met with among horizontal ſtrata, eſpecially thoſe of the coal metals. It is occaſioned by the waving and wheeling of the horizontal ſtrata.

The north branch of this river is well worth the inſpection of the curious.

About a hundred yards above the bridge, two pretty thick ſeams of coal appear, and there are various ſections of the coals and coal metals to be ſeen in ſeveral places for more than two miles up the river, ſome of which have been and are now working.

The Saliſbury Craigs, near Edinburgh, are well worth the examination of the mineral ſtudent. The thick bed of rock at Saliſbury Craigs, which was quarried ſome time ago, is a ſtratum of baſaltes, which is eaſily known by examining the

the quality of the ſtone; and the fact may be further evinced by tracing the ſtratum to the ſouth ſide of Arthur's Seat, where the ſame individual bed of ſtone will be found regularly formed into columnar baſaltes; the columns are diſtinct, and of conſiderable length and magnitude. When the examiner has made himſelf maſter of the ſtretch, bearing, and declivity of this particular ſtratum, he may then proceed to inveſtigate the reſt of the ſtrata of Arthur's Seat, which is not an eaſy taſk for a beginner, the whole hill being chiefly compoſed of different irregular thick ſtrata of baſaltine rocks, which vary in thickneſs conſiderably in different places; a circumſtance common to baſaltes; and, therefore, on account of the difficulty of inveſtigation, I would not adviſe the mineral ſtudent to begin a ſurvey of the ſtrata of this mountain, until he is pretty well advanced in the knowledge of the natural hiſtory of ſtrata in general.

When he comes to examine theſe rocks, he will obſerve, that the whole hill is not entirely compoſed of baſaltes. There are alſo thin ſtrata of various ſpecies to be found among thoſe rocks. For inſtance, ſeveral beds of free-ſtone have been quarried deep down upon the ſouth ſide of Saliſbury Craigs; and there are regular thin ſtrata of ſeveral kinds to be ſeen immediately above

and

and below the thick ſtratum of rock which is properly called Saliſbury Craigs.

There is a pretty good ſection of various thin ſtrata upon the ſouth ſide of the Water of Leith, immediately below the mills, and there are a great number of thin ſtrata to be ſeen in the bed of the river, all the way down below the Mineral Well. Theſe ſtrata appear pretty fair and regular, dipping with an eaſy ſlope towards the N. W. or W. N. W.; but the circumſtance which is beſt worth the inſpection of the ſtudent in this place, is a couple of whin dykes which cut the ſtrata aſunder. Theſe two dykes are to be ſeen in the bed of the river, one of them near the Mineral Well, and the other a little higher up. They run quite acroſs the river, almoſt at right angles; and theſe dykes, or ridges of ſtone, are the more remarkable, that theſe ſort of troubles, or interruptions of the regularity of the ſtrata, are but ſeldom met with in the Lothians, though common enough in other places.

But although whin dykes are not ſo commonly found in the Lothian coalleries as they are in ſome other coal-fields, yet the Lothians are not exempted from them. A large whin dyke paſſes through the coals, &c. a little below Niddry, where it croſſes almoſt at right angles to the bearing of the ſtrata. Another, ſtill larger, is is to be ſeen emerging out of the ſea at Cockenzie, where it forms the north ſide of the little harbour, and then runs end-ways through the country.—And, in like manner, ſeveral other very large whin dykes are to be ſeen as you go farther to the N. E. along the ſhore, ſome of which form conſiderable ridges of rock as they paſs through the country, which appear in many places high above the ſurface of the ground; and all of them are diſtinctly ſeen to cut through the coal metals in a line nearly right acroſs the bearing of the ſtrata.

It may not be improper, however, to remark, that there is one circumſtance appertaining to the two whin dykes in the Water of Leith, that is not common to every one of the kind, which is, that each of theſe two is both a dyke and a ſlip; that is, the ſtrata, which are cut aſunder by the dyke, are not here found upon the ſame level on both ſides of the dyke, which happens in moſt (though not in all) others of the ſame kind. Theſe dykes, which throw the ſtrata off the ordinary level, may properly enough be called ſlip-dykes.

There are a great variety of ſtrata further up in the river Leith, about Slateford, Collington, Currie, and ſtill farther up, and ſome pretty good ſections.

There

There are various ſections of the ſtrata to be ſeen upon the banks and in the bed of the river Almond, particularly all the way between the ſea and Cramond bridge, and farther up, all the way till within three or four miles from Calder.

There are good ſections of the ſtrata in the branch of that river which runs upon the ſouth ſide of Calder, above the bridge, and eſpecially above the houſe of Calderhall, and ſtill farther up towards the moors. About half a mile below the ſouth bridge of Calder, there croſſes the river a thick ſtratum of coarſe limeſtone, which contains ſome lead ore in grains and flowers, blended in the compoſition of the ſtone; but it does not appear in ſuch quantity as to be worth working.

A conſiderable variety of ſtrata are to be ſeen in the north branches of the river Almond, above Calder, and among them ſeveral coals, ſome of which have been worked; and there are ſome pretty good ſections of coals, and their concomitant ſtrata, in the branch of that river called Breich.

There is a fine ſection of two ſeams of coal, and of the ſtrata accompanying them, to be ſeen in the free-ſtone quarry upon the eaſt ſide of the river near Cranſton.

The county of Fife is a fertile field for the amuſement and inſtruction of ſuch as wiſh to improve in the knowledge of the natural hiſtory of the coal country, as almoſt all the rivulets in the county exhibit ſections of ſeams of coal and their concomitant ſtrata.

There are many ſections of the coal metals to be ſeen upon both ſides of the Forth, above and below Inchkeith.

The river Clyde, and its numerous branches on both ſides, cut and interſect an extenſive coal country, where a variety of fine ſections are to be ſeen; and there are magnificent ſections and romantic ſcenes in the channel of that river, between Hamilton and Carſtairs.

Almoſt the whole county of Ayr abounds in coal, and it alſo abounds in ſcenes proper for the amuſement of the mineral ſtudent. All the rivers, and almoſt all the rivulets of that country, exhibit fine ſections of the ſtrata, and particularly the river Ayr and its ſeveral branches.

I have now pointed out a ſufficient number of local examples of ſections, and of regular ſtrata, and the places where they are to be found in the Lothians, &c. When once a ſpirit of enquiry about theſe matters is excited among young gentlemen, they will then be forward to look

out

out for more, and they will eaſily find as many as they can wiſh for.

The coal fields, or coal countries, are not the only places where we meet with regular ſtrata. There are, beſides the coal-fields, numberleſs fine and regular ſections of them to be found in the rivers, and eſpecially upon the ſhores of the ocean, all round the iſland of Britain, and particularly round the Highlands and north of Scotland; and of all places in the Highlands and north of Scotland, Caithneſs is the moſt remarkable. The ſea coaſt of Caithneſs is ſingular for magnificent, extenſive and lofty ſections of remarkably thin and uncommonly regular ſtrata; and though the ſtrata upon the ſhores in ſome parts of Galloway, particularly in the ſtewartry of Kircudbright, are regular and lofty, yet they are not generally ſo thin as thoſe of Caithneſs.

In both theſe places, eſpecially upon the ſouth-eaſt coaſt of Caithneſs, and in the pariſh of Colvend in Galloway, the ſtudent has an opportunity of viewing and contemplating regular ſtrata for miles in length, where he will not only ſee beds of ſtone, which exhibit a great variety as to thickneſs, colour, and other external appearances, lying *ſtratum ſuper ſtratum*, as he advances along ſhore, with various degrees of ſlope or declivity; but he will alſo have an opportunity of viewing and of inveſtigating a great many of the troubles,

breaks,

breaks, and irregularities of the ſtrata, ſuch as dykes, ſlips, ſhakes, &c.

These extenſive and lofty ſections, or cliffs, may be called the anatomy of ſome parts of the mineral kingdom, where the ſtudent can ſee ſome parts of his ſubject diſſected and laid open for his examination.

Among a great variety of other particulars to be ſeen in the two diſtricts under review, are a great number of caves or caverns of different magnitude and length. Some of theſe caves are exceeding wide and high, others of them are of middling and of leſſer dimenſions. Again, ſome of them are only a large and ſpacious cavern, at and near the mouth, but are of no longitudinal extent, that is, do not puſh far in, and others of them puſh a great way in under the land. It is a remarkable fact, which, in my opinion, deſerves to be noted, that each of theſe caves or caverns is a real mineral vein, and the moſt of them, if not all, are real ſlips in the ſtrata, ſuch as were deſcribed above in the coal metals. The moſt of theſe are what is called by miners *rake veins*,—by naturaliſts, perpendicular mineral fiſſures; and it is a fact which I have ſeen, and deſerves farther to be noted, that a conſiderable number of theſe veins in both places, but moſt at Colvend, contain copper ore, which may in time become valuable.

Many

Many of the caves upon the ſea ſhores of Caithneſs, are the common lying-in hoſpitals for the ſeals, where they go to bring forth their young, and to ſuckle them until they are fit to ſwim, and many of them, both young and old, are taken in theſe caves by the country people, who ſurprize them at night with lights, and knock them on the head, and ſometimes theſe people are hurt by the ſeals, who make a deſperate reſiſtance, and many of them eſcape by mere force.

The cliffs, in many parts of the Weſt Highlands and Iſles, reſemble very much the ſhores of Caithneſs and Galloway, and almoſt every conſiderable rivulet in ſeveral parts of the Highlands has cut through many regular and curious ſections of the ſtrata, and many of the Highland rocky mountains exhibit ſome prodigious cliffs or ſections of immenſe height and magnitude. In the Highlands of Scotland the mineral ſtudent will meet with abundance and variety of amuſement and inſtruction, that can hardly be met with any where elſe.

Though the examples of ſtratification I have here pointed out, may be deemed a digreſſion, when treating of the natural hiſtory of coal, I, however, think theſe a piece of neceſſary information to a mineral ſtudent.

When young gentlemen defcend into the rivers and glens, and other places in the coal country, or elfewhere, to improve themfelves in the knowledge of the ftrata, and come to examine various fections, it may be proper for me to drop a few hints about the different forts of fections of the ftrata, and how they are to diftinguifh one fection from another. There appear to be three different forts of fections of the ftrata: 1ft, *The level or parallel fection;*—2d, *The right-angled fection;—and* 3d, *The oblique, or diagonal fection.*

1ft, The level fection is one that runs in a line parallel to the bearing of the ftrata. When we are viewing one of thefe parallel fections, we fee the edges of the feveral ftrata lying flat or level before us; and when we face fuch a fection at right angles, fo as the right and left hand are equally near the face of the rock, the declivity then is in a right line from the eye acrofs the ftrata, and the dip is in a right line either down towards the foot, or away from the eye; and if the ftrata lie very flat, it may fometimes be difficult to know which way the ftrata decline in fuch a fection, as perhaps no fenfible flope appears any way.

2d, The right-angled fection is one that is cut in a line right acrofs the bearing of the ftrata, and parallel to the declivity, or in other words, this fection is in a right line from crop to dip.

When

When we face one of theſe ſections, ſo as to bring the right and left hand equally near to it, then a line drawn ſtraight forward from the eye is a dead level line, which runs parallel to the bearing of the ſtrata. This right-angled ſection is more entertaining and inſtructive than the former, for in this we not only ſee the various kinds of ſtrata diſpoſed in a regular order, *ſtratum ſuper ſtratum*, for our examination, but we alſo ſee the degree of ſlope or declivity of the ſeveral ſtrata.

In this ſection we ſee the one ſide or edge of each ſtratum dipping downwards quite out of our ſight, and the other ſide or edge riſing up quite to the day, or to the clay or other cover, if the ſuperficies of the ſtrata happen to be covered in that place.

3*d*, The oblique, or diagonal ſection, is more difficult to be deſcribed or explained with preciſion than either of the former two, becauſe it may be ſo various, or may run in ſo many diagonal directions or collateral lines acroſs the bearing and declivity; and, therefore, I ſhall only in general obſerve, that ſome of theſe ſections may approach pretty near to the parallel or horizontal ſection, and yet have a ſmall degree of ſlope or obliquity, and others may approach pretty near to the right angled ſection, and yet not be quite parallel to the declivity, or be in a right line from crop to dip, though near it.

It

It is to be ſuppoſed, that there are a greater number of theſe oblique or collateral ſections than there are of the parallel or right angled, becauſe all thoſe that are cut in any poſſible acute or obtuſe angle or line between the other two, muſt come under this denomination or deſcription.

With reſpect to the firſt, that is the *parallel ſection*, it may be impracticable to determine the degree of ſlope or declivity of the ſtrata, even with an inſtrument, becauſe you only ſee the edges of the ſeveral beds of ſtone, or others, facing you in level or parallel lines. If it be a fair, regular, and uniform ſection, perhaps the beſt rule then for judging of the degree of declivity, eſpecially if the ſlope is right away from the eye, is to conſider the poſition of the face of the ſection. If it ſtands nearly perpendicular, we may generally conclude that the poſition of the ſtrata is nearly horizontal. If the face of the ſection leans back with a conſiderable ſlope, and the foot of the rock advances forward towards your foot, you may then conclude that the ſtrata decline away from you with a conſiderable or proportionable degree of ſlope, as the ſeveral tranſverſe fiſſures which occaſion ſuch regular ſections, are generally cut acroſs at right angles to the bed of the ſtrata. If the declivity lean forward towards the eye, you will then ſee the edges

edges of the ſtrata hang down towards you, and then you can judge of the degree of ſlope. When the ſlope is down towards you, ſuch ſections generally overhang a little.

With reſpect to the ſecond, that is a *right-angled ſection*, you can take the degree of the declivity of the ſtrata in it at once, as a line ſtretched from crop to dip along the face of any individual ſtratum in the ſection, will be exactly parallel to the ſlope or declivity of the ſtrata.

But it cannot ſo eaſily be determined what is the degree of ſlope, or declivity of the third, or *diagonal ſection*, becauſe the ſection itſelf is cut in a collateral line, and it cannot be determined at once without examination how far this line is upon one ſide or other of the line of bearing, or upon one ſide or other of the line of declivity, which two lines, that is the bearing and declivity, form a right-angle.

All that I have yet advanced on this ſubject, relates only to what may be called regularly diſpoſed ſtrata, and to ſuch accidents as locally diſturb and break through that regularity.

But it may be proper to enquire whether or not all the rocks which compoſe the ſuperficies of our globe are regularly ſtratified, or if there are certain ſpecies, claſſes, or arrangements of rocks which are always found ſtratified, and others that are not.

With refpect to ftratification, the materials which compofe the fuperficies of the globe, may be divided into three claffes: *1ft*, Such as are always, or at leaft generally found regularly ftratified; *2d*, Such as are partly and imperfectly ftratified; and *3d*, Such as are feldom found ftratified at all.

Of the firft fort are all the coal metals, moft of the argillaceous ftrata, the generality of limeftones, and many of the indurated mountain rocks of feveral fpecies.

Of the fecond fort are many of the mountain limeftones, which are extremely irregular, both as to the thicknefs of the ftratum, and as to the continuity of it in the line of bearing; and many of the bafaltine rocks fo frequently met with in the Lothians, Fife, and other parts of Scotland, are likewife very irregular in thicknefs and in continuity upon the line of bearing. Both of thefe are fo irregular in this refpect, that fometimes they fwell out to an enormous thicknefs, and a little way forward, upon the longitudinal line of bearing, they are found dwindled away to almoft nothing, and two or three hundred yards farther forward, ftill upon the fame line, the fame individual ftratum will fwell out again to various degrees of thicknefs. Many of the mountain limeftones exhibit the fame irregularity.

Of

Of the third ſort are many mountains of granite in the Highlands of Scotland, and many other places. It is no uncommon thing to ſee granite rocks ſo perfectly free from any marks of ſtratification, that there is no difference between a ſmall ſolid maſs of that ſtone and a mountain, except only in magnitude, the whole mountain being one prodigious maſs of ſolid ſtone, without any diviſion of ſtrata.

There are alſo ſome other rocks beſides the granite mountains which have very little appearance of ſtratification. Such, for inſtance, are ſome little hills of mountain limeſtome, which we meet with in the Highlands and other places, and likewiſe little hills of baſaltes, which we ſee forming little iſlands in the frith of Forth, in many parts of the Lothians, Fife, and other parts of Scotland.

Many of the rocks which may be called regularly ſtratified, have in ſome places very great imperfections in the ſtrata.

Some of theſe are imperfect in point of continuity, and ſuch either fail entirely, and are loſt in the longitudinal line of bearing, or elſe turn thinner or worſe in quality in the ſame line.

Others are found to reſemble a wedge, and ſuch a ſtratum will be found pretty thick at the ſurface, but as it goes down towards the dip, it

wears

wears thinner and thinner until it comes to an edge, when it ſoon ends in nothing.

Some again are found of a good thickneſs below, which wear thin as we come upwards, and at laſt come to a thin edge, and end in nothing before they come up to the ſurface.

Some particular ſtrata are found irregular, wear thicker and thinner, and are ſometimes entirely loſt in advancing upon the longitudinal line of bearing, as well as in going down upon the line of declivity.

Again, there are ſome ſtrata ſo imperfect, that they reſemble a double wedge, that is, ſuch ſtrata are found irregular, and fail in continuity both ways, and do not ſtretch ſo far as the regular ſtrata which accompany them. Theſe are found to be thick in the middle, and to wear thinner and thinner, and end in nothing, as we advance both ways upon the line of bearing.—There are many other inſtances of imperfect ſtratification too tedious to be inveſtigated here.

I ſhall now enquire whether a ſtratum of coal found but thin at the crop or ſurface of the ground, will grow to be a thick ſeam farther down towards the dip?

A ſeam of coal is found fully as thick in the ſuperficies of the ſtrata as it is farther down. When once a ſeam of coal is diſcovered at or

near

near the ſurface of the ground, if it appears when diſcovered, or is afterwards by trials brought fairly between regular roof and pavement, it may be taken for granted that it is then at its full thickneſs, and would not increaſe, though you ſhould ſink twenty fathoms in it.

There are particular inſtances of coals being thicker below than above, and alſo of their being thicker above than below; but, in general, they are at full thickneſs when found between roof and pavement.

In a conſiderable coal-field, there are a great number and variety of ſeams of coal cut through in bringing up levels, in driving croſs-cut mines, and in ſinking pits. Some of theſe ſeams of coal are of very conſiderable thickneſs, and others of them are very thin, perhaps not above two or three inches. And again, many of them are of all the medium thickneſſes between the two extremes of the thickeſt and the thinneſt.

Now all theſe various ſeams are generally found to be very near the ſame thickneſs above as they are below, when once they are found between ſolid and regular roof and pavement; and this is neceſſary in the nature of things, becauſe then the ſeam of coal is a regular ſtratum among regular ſtrata, which are diſpoſed above and below it, and, therefore, it ſhould, and in fact it does keep its ſtation full as regularly as any of thoſe

found

found placed above and below it, both in the longitudinal line of bearing, and from crop to dip in the line of declivity.

In ſhort, when a ſeam, whether it be thin or thick, is once found fairly bedded betwixt regular roof and pavement, and is perfectly clean and free from hitches, or any other troubles, it is then at its full thickneſs.

Perhaps theſe aſſertions may ſeem to intimate, that all ſeams of coal are invariably regular in thickneſs, both in the line of bearing, and likewiſe in the line of declivity; but I would not wiſh what I have ſaid to be underſtood in that light. True it is, that in common experience we find a ſeam of coal pretty regular and uniform in thickneſs when we have it fairly betwixt roof and pavement, and this in general will hold good, and may be conſidered in practice as a fixed principle; nevertheleſs, there are ſome circumſtances and accidents which alter the caſe, and occaſion the ſeam to vary conſiderably in thickneſs.

However, the maxim will hold good in general, notwithſtanding theſe accidents. A ſeam of coal is frequently found thicker upon one ſide of a ſlip than the other, and likewiſe upon one ſide than the other of a great dyke. The ſame may be obſerved of ſome of the great ſhakes and gaſhes. The ſame individual ſeam of coal feldom preferves invariably the fame uniform thicknefs to the extent of four or five miles forward upon the line of bearing, though it may pretty nearly within a more limited field of only a mile or two. Great variations in the dip and rife of a coal frequently affect the thicknefs of the feam, and fuch changes in the degree of dip or declivity often occur as we advance upon the line of bearing, and when a feam of coal falls fuddenly from higher to much lower ground, the thicknefs of the feam is frequently altered.

Some coals are much more regular and uniform in thicknefs than others. I have feen many feams continue perfectly regular and equal in thicknefs for a confiderable extent every way, and I have feen other feams fo exceedingly variable, that you could not depend upon finding the coal equally thick for twenty yards together in any part of the field, and in fome feams you cannot find ten yards of it of equal thicknefs.

The common accidents which we meet with in working coals, fuch as dykes, flips, gafhes, fhakes, &c. frequently occafion their varying in thicknefs.

Sometimes the roof falls down for a certain fpace below its ordinary level, and preffes the coal, or fqueezes it much thinner, efpecially in the middle of that fpace. Thefe accidents of the roof

roof preſſing down nearer the pavement than it ſhould be, and ſqueezing the coal below its ordinary thickneſs, are of leſs and greater dimenſions. Some of them are not above two or three feet in diameter. Theſe leſſer ones are like a wart or ſmall protuberance on the under ſide of the ſtratum, which is the immediate roof of the coal; and this protuberance ſinks down into the upper ſide of the ſeam of coal like the bottom of a great pot. Theſe protuberances are called by Scotch colliers a *bonnet caſe*, and a *pot arſe*.

But all theſe accidents are not of ſuch ſmall dimenſions as the bonnet caſe. Some of them are not only two or three feet, but two or three yards diameter, and ſometimes even up to thirty or forty yards, and more. I obſerved that the ſmall ones thruſt down ſuddenly into the upper ſide of the bed of coal like the bottom of a great pit; but, on the contrary, the large ones generally preſs down gradually with a gentle ſwell.

Theſe troubles ſometimes ſqueeze out one third, and at other times one half or more of the thickneſs of the coal. They are frequently of a roundiſh figure, and they ſqueeze out the coal thinneſt in the middle of the trouble, which riſes gradually higher as it extends from the center, until the roof comes to its ordinary level, and the coal comes to its ordinary thickneſs at the outſkirts.

But

But the principal and greateſt of all the cauſes of the variation of the thickneſs of the coal happens when the ſeam approaches the extremity of the coal country, where foreign ſtrata commence of a quite different quality from the coal metals. The coal metals, and eſpecially the coal ſeams, always wear thinner and thinner as they approach the outſkirts of the coal country, as it may be called, that is the out boundaries of the coals and coal metals. In this caſe, I have ſeen ſeams of five or ſix feet thick dwindled to ſo many inches, and even to leſs than ſo many inches at the extremity, where the coal metals ended entirely, and other different claſſes of ſtrata commenced.

The vulgar error of the *craw coal*, as it is called in Scotland, frequently proves a dangerous error, and, therefore, I will explain the matter in order to give a caveat againſt the pernicious conſequences of that notion.

What is meant by the craw coal, is the crop coal, or upmoſt ſeam of coal in the field, which is always ſuppoſed to be a thin one.

The notion of the craw coal originated from the falſe ſuppoſition, that in all places where coal is found, a thin ſeam is upmoſt, and that when once a thin ſeam is found, you are ſure to find a thick feam at a moderate depth below the thin one, or craw coal. This, it is acknowledged, may fometimes happen, and indeed it frequently does happen. We know it by experience, and therefore it cannot be denied; at the fame time nothing can be more abfurd than to affert that it always happens fo. That notion is the child of ignorance and fraud. The ignorant imagine the affertion to be true, becaufe it founds like fomething they wifh to be true. It feems to give them a clew to lead them at once through depths of knowledge which they have not yet explored, and they either cannot or will not take the trouble to examine the truth of the pofition, and the crafty make ufe of the notion to lead the unwary to throw away expence upon a bad fubject.

By obfervation and real experience, we know that nothing in the world can be more promifcuous and uncertain than the way we find the thick and thin feams of coal blended through one another in a coal-field; and this fact of their being promifcuoufly blended together we know with abfolute certainty, by cutting through a great number and variety of them in fome extenfive coal-fields, where we as often find a thick feam upmoft as a thin one, and we as often find a thin feam below as above a thick one.

The truth is, we can form no true notion of their difpofition and order until we have either

cut

cut through them, or have ſome other opportunity of ſeeing how they are diſpoſed one above another; and yet the notion of the craw coal ſtill prevails in many parts of Scotland; for I have often heard thoſe who were making trials for coal ſay, with a tone of aſſurance, that they were now certain of coming to a good ſeam a few fathoms deeper, this being an infallible ſymptom of a thicker and better ſeam being near.

But a man of real knowledge and extenſive obſervation, will frankly declare that he knows nothing about the matter until experience comes in for his guide. Ignorance and conceit, which are near of kin, and often go hand in hand, ſometimes favour us with many raſh and unphiloſophical aſſertions which experience and obſervation diſprove.

In great coal-fields, which contain a great number of ſeams, we find that the thick and thin ſeams are mingled with ſo much uncertainty, that we never pretend to know which of them are above, or which are below, until we have ſeen them all, and then we know their order and ſtations very well.

I have frequently ſeen three or four (and ſometimes more) thin ſeams of coal placed next to one another, neither of which were any thing near thick enough to work; and I have often ſeen good workable ſeams of ſufficient thickneſs lying next to one another, without any thin coals intervening betwixt them; and I have as often, perhaps oftener, feen the thick and thin and middling feams blended promifcuoufly. Indeed they are always fo blended, that we know of no order or natural ftation, nor of any thing elfe relating to them, but what we come to know by experience, after we have once feen all or moft of all the feams in the coal-field.

Further, it is not only the feams of coal that are thus promifcuoufly blended together in the coal field; the various and different coal metals are alfo mingled together, and with as much uncertainty, as to any rule or order of their ftations, as the feams of coal.

There are in moft coal-fields a multitude and furprizing variety of different kinds of ftrata accompanying and lying between the feveral feams of coal; and of this vaft multitude, and variety in quality, thicknefs, and colour, we find the hard and foft, thick and thin, the black and white, blue and gray, red and yellow, and all the varieties of quality, thicknefs, and colour fo promifcuoufly blended together, that when we are finking pits, or driving mines through any of them, the moft experienced do not know what is to come next, until they have fomehow or other acquired that knowledge by former obfervation, that is, by

feeing

feeing the order and difpofition of thofe ftrata fomewhere before.

We have in our coal-pits and crofs-cut mines, and in the rivers and rivulets which have cut and wafhed the fuperficies of the ftrata in our coal-fields, abundant ocular demonftration of the truth of the pofition that the coals and coal metals are promifcuoufly blended together, without any certain order to be depended upon as a rule or indication in practice; and moreover, the great variety of ftrata of different qualities and colours, hard and foft, thick and thin, which are found to be the immediate roof of the feveral feams of coal, even in the fame field, is another convincing proof of the truth of the pofition, in aid of ocular demonftration, if it needed any aid.

Though there fhould be twenty feams of coal in the fame field, it is twenty to one but they fhall be found to have twenty different roofs, that is, that ftratum, which is the immediate roof of one feam of coal, fhall differ from the immediate roof of another feam in quality, colour, and thicknefs, in fo much that perhaps no two out of the twenty fhall be exactly alike.

The feveral roofs of coal may, in point of hardnefs, be divided into three different claffes. There is fuch a variety of thefe in point of quality, colour, and thicknefs, that it would be exceedingly difficult to arrange them properly with reſpect to all theſe varieties.

I will take a curſory view of ſome of them in point of hardneſs, and will juſt touch at their ſeveral qualities and colours, and in doing this, I will, 1*ſt*, examine ſuch as may be called very hard ;—2*d*, Such as may be called good and firm coal roofs of middling hardneſs ;—3*d*, Such as may be called ſoft roofs, but in reſpect to the exact thickneſs of the ſtratum, with the colour, quality, and degree of hardneſs, the variety is almoſt endleſs.

I. Among thoſe which may be called very hard roofs are,

1*ſt*, Strata of baſaltes, commonly called whinſtone. Strata of baſaltine rocks are very common in many coal-fields in Scotland. There are ſeveral thick beds of this ſtone betwixt the different ſeams of coal at Borrowſtounneſs, and one of them is the immediate roof of a ſeam of coal in that ground ; and there is a thin ſeam of coal below a bed of beautiful columnar baſaltes at Hillhouſe limequarry, a mile ſouth of Linlithgow. In the Bathgate hills, ſouth of Linlithgow, there are ſeveral ſtrata of coal and ſeveral ſtrata of baſaltes blended together, *ſtratum ſuper ſtratum.*

Theſe inſtances may ſuffice as a proof that ſtrata of baſaltes are ſometimes the immediate roof

roof and pavement of ſtrata of coal. The ſeveral ſtrata of baſaltine rocks are always very hard, often very thick, and generally of a black or blackiſh grey colour. But it is proper for me to remark here, that the baſaltine rocks are only known to be ſuch by a very few naturaliſts. They commonly go by the general name of whin-rocks in moſt parts of Scotland and the north of England. I think it goes by the name of *cockle* among Corniſh miners, and it is called *ſkurdy* in the north of Scotland.

Among the few gentlemen who are acquainted with baſaltes, the moſt of them imagine that the rock ſhould always be found formed into priſmatical figures or angular columns; but this is ſuppoſing too much, for the truth is, that this rock is only found formed into columnar or other regular figures in ſuch places where the rock was originally expoſed to the influence of the external air.

As a proof of this aſſertion, the thick ſtratum of rock near Edinburgh, called Saliſbury Craigs, is only formed into regular columns upon the ſouth ſide of Arthur's Seat, where it was originally expoſed to the atmoſpherical influence.

Another proof of the above aſſertion will be found in the ſtratum of baſaltes, which is formed into ſmall and beautiful columns at Hillhouſe lime-quarry near Linlithgow, as the ſame individual

vidual ſtratum will be found not formed at all in ſeveral places at a ſmall diſtance from that quarry.

The baſaltine rock is to be judged of and denominated from its quality and colour and component parts, and not only from the figure it ſometimes aſſumes, which is merely accidental, ariſing from ſituation more than from the quality of the ſtone. This rock is very common in the coal countries; and in many other parts of Scotland, and it is frequently found formed into glebous, ſpherical, and other figures, as well as the columnar; but always where it now is, and we have good reaſon to ſuppoſe that it always was expoſed to the external air.

Wherever we trace a ſtratum of baſaltes under the cover of other incumbent rocks, it is not then formed into any regular figure. Wherever we cut through it in ſinking coal-pits, we do not find it regularly formed. Wherever the face of a regularly formed baſaltine rock is quarried away until it goes under other incumbent rocks, we ſoon loſe the angular figures, and an uniform face of a rock comes in without the leaſt appearance of a priſmatical glebous, or any other regular figure.

2d, Lime-ſtone may be reckoned among the very hard roofs of coal. Strata of lime-ſtone of various thickneſs, quality, and colour are very

common

common in coal-fields. Sometimes the ſtratum of lime is the immediate roof of the coal, and ſometimes there is a thin argillaceous ſtratum or following clod a foot thick, leſs or more, found betwixt the ſtratum of lime and the ſtratum of coal.

There are ſeveral beds of lime-ſtone in the coal-field of Gilmerton, near Edinburgh, and ſome of them are very good, and of conſiderable thickneſs.

At Blackburn, in Weſt Lothian, a ſtratum of lime-ſtone, of ſix or ſeven feet thick, is the immediate roof of a good ſeam of fat caking coal, which ſeam is alſo about five or ſix feet thick.

At Carlops, and at Spittlehaugh in Tweedale, they have a ſeam of coal immediately below their lime quarries, which they work out to burn the ſtone.

I have ſeen lime immediately above coal in a great many places; but theſe are ſufficient inſtances in point, as the fact is commonly known.

3d, Some of the poſt free-ſtones prove very hard roofs of coal. What is commonly called poſt ſtone, is a thick and ſolid ſtratum of free-ſtone, out of which blocks or pillars of any ſize and figure may be cut out by a ſkilful quarrier. Thick ſtrata of poſt ſtone are frequently found to be the immediate roof of ſeams of coal, without the intervention of a following clod, or any ſtratum whatever between them, and ſometimes with a following clod, or a thin argillaceous ſtratum betwixt the coal and the main roof of poſt ſtone; and the poſt roof is frequently rendered very hard, by being interſected with foul ribs, or mixed throughout with ferruginous matter, of a ſpecies of iron or pyrites.

4th, Thinner ſtrata of freeſtone are commonly found in moſt of coal-fields to be the immediate roof of coal; and ſome of theſe, as well as the poſt ſtones, are rendered very hard by admixtures of ferruginous or ſulphureous matter.

5th, What is called a *dogger band* by Scotch colliers, is very frequently found to be the immediate roof of coal, and theſe are very hard.

Some call ſtrata of iron-ſtone dogger bands, and the ball iron-ſtone they call doggers, and they alſo call maſſes of the pyrites doggers in many of the Scotch collieries; but beſides the ſtrata of iron-ſtone, there is alſo another ſpecies of coal roof frequently met with, which is called a dogger band. This dogger band is an imperfect ſtone, compoſed of ſeveral heterogeneous mixtures, among which pyrites bears a conſiderable proportion, which ſo effectually binds and connects the whole together, that it is ſometimes very difficult to break through it. This ſpecies of dogger band is ſometimes much

thicker

thicker than the ſtrata of iron-ſtone, though not always. Both the ſorts are well known to be very hard, and to be frequently found immediately above the coal.

6th, There are in many coal-fields ſeveral ſtrata of whin-ſtone, properly ſo called, which is not baſaltes. Some of theſe are of conſiderable thickneſs, and others not above two or three feet thick; and they are of various colours, ſuch as black, a blackiſh and lighter grey, brown, red, &c. Theſe ſtrata of whin-ſtone are always very hard, and they are frequently the immediate roof of coal.

II. There are a great many good and ſubſtantial roofs of coal, which yet are kindly to work, and only of middling hardneſs. Among theſe I will reckon,

1ſt, Poſt-ſtone of a kindly quality, which is not impregnated with ferruginous matter, or any other heterogeneous mixture which hardens the ſtone too much, and makes it croſs and difficult to be cut.

2d, Regular ſtrata of free-ſtone of various colours, textures, and degrees of thickneſs; but none of which are ſo thick as to deſerve to be called poſt-ſtone.

The thinner ſtrata of ſand-ſtone, that is of free-ſtone, are perhaps the moſt numerous of all ſtones in moſt of coal-fields, and they are ſo frequently found to be the immediate roof of coal, that it would be ſuperfluous to ſay any more about them; only it may be noted, that ſome of theſe regular ſtrata of clean and pure ſand-ſtones, are not above three or four feet thick, and others not above three or four inches; and they are commonly found of all degrees of the medium thickneſs between theſe two extremes; and theſe thin and middling ſtrata of free-ſtone make good coal roofs eaſily cut through in ſinking; and they are eaſily quarried, and make excellent rubble ſtones for building, and ſome of the thickeſt of them produce good cutting ſtones for ribbets, &c. though I do not think they deſerve to be called poſt-ſtone until they exceed three or four feet thick.

3d, Grey bands, or grey coloured free-ſtone bands, are likewiſe commonly found to be the immediate roof of many ſeams of coal, and theſe may be reckoned among thoſe of middling hardneſs. Theſe grey bands, or grey thin ſtrata of imperfect free-ſtone, are very numerous in all coal-fields, and there are generally a great number of them arranged together in the ſame place, lying immediately above one another; and they are frequently found of all degrees of thickneſs, from one inch up to twenty inches, though the moſt common thickneſs is from two to ſix inches. Theſe thin grey ſtrata are called by Scotch colliers

liers *grey fekes* as well as grey bands. They are often found moderately hard, and of a ftrong texture, fo as frequently to make good flags and covers for fewers. When there is a confiderable number of thefe together, they commonly make a very good and fafe coal roof, as they generally have a confiderable degree of ftrength and cohefion, efpecially when the ingredients in the compofition of the ftone, which give it the blackifh or grey caft, partake of the nature of the coal; but when the black admixture partakes of the blaes, or black tilly argillaceous matter, then the grey bands are more weak and fragile.

4th, Hard, ftrong, and well ftratified blaes may be reckoned among the coal roofs of moderate ftrength and hardnefs. Strata of blaes, or bleas, are very common and exceeding numerous in coal countries. They are always black, or of a bluifh black or a black grey colour, and there is nothing more commonly the immediate roof of coal. There is in moft coal-fields a great variety of blaes, efpecially in refpect of ftrength and hardnefs; but in this divifion of middling coal roofs, I only point at fuch as are pretty ftrong and hard. Some of the ftrong and hard blaes are perfectly black, or of a greyifh black, and fome of thefe ftrata of different fhades of the black colour, are pretty thick, and others are pretty thin. I fay pretty thick, for it is not

common

common to find ſtrata of good and ſtrong blaes much above a foot and a half thick; but they are commonly found of all degrees of thickneſs, from about a foot and a half down to two or three inches and leſs; and the moſt common medium of the ſtrata of the beſt blae roofs is from one foot down to three or four inches thick.

Some of this ſort of blaes is ſo ſtrong as to make a very good and a very ſafe coal roof, but it is rare to find any of it ſo hard as not to be eaſily cut through in ſinking. All blaes ſeem to have a conſiderable quantity of a black argillaceous matter in the compoſition of the ſtone, and theſe ſtrong blaes appear to contain a conſiderable quantity of ſand, and they frequently contain a conſiderable portion of an inflammable oil, and ſometimes they partake of the real coal itſelf in ſuch quantity as to be ſometimes viſibly ſeen.

In ſome places the thinneſt of theſe ſtrata are found to be the immediate coal roof, and in other places the thickeſt; and again, in other different places, thoſe of all the degrees of medium thickneſs.

There is as great a variety in the quantity of theſe blaes found together immediately above different coals as there is in the thickneſs of the particular ſtrata. In ſome pits we do not find above five or ſix inches of blaes immediately upon the

the coal; in other pits, we find five or fix fathoms upon the coal, and in fome particular places even much more than five or fix fathoms, and it is very common to find the blae roofs of all the medium thickneffes.

5th, Whitifh and afh-coloured argillaceous ftrata, of middling ftrength and thicknefs, are in many places found to be the immediate roof of coal.

Some of thefe light coloured argillaceous coal roofs are pretty thick, others of them are thin and of middling thicknefs, like all the other coal roofs of pretty equal ftrength and hardnefs. I have feen fome of thefe up to two feet thick, and I have feen others of them not above two inches thick, and they are commonly found of every medium thicknefs between thefe two. There are a great many coal roofs of this colour, and much of the fame quality, which are very tender, fragile, and dangerous. At the fame time, many of them prove very good roofs, owing either to fome particular ingredient in the compofition, or to a more perfect contexture and formation of the ftrata.

6th, Streaked coal roofs of middling ftrength and hardnefs. Thefe ftreaked roofs are of two forts. *Firft*, Such as are compofed chiefly of fand, with a very fmall mixture of clay and blaes; and *fecond*, Such as are compofed chiefly of clay or blaes, with a very fmall mixture of fand.—

Some

Some of theſe exhibit larger, and others ſmaller ſtreaks or ribs. I have frequently ſeen ſome of theſe ſtones ſo finely ſtreaked as to reſemble the moſt beautiful ſtriped cotton ſtuffs.

The ſtrips or ſtreaks lie all of them exactly parallel to one another, and exactly parallel to the bed of the ſtone, and the ſtrips always ſpread out the whole breadth of the ſtratum. The colour of theſe ſtrips is various in different ſtrata. I have ſeen ſome of the ſtrips nearly black and white, others white and red, and yellow and red. In ſome ſtrata the ſtrips appear of a lighter and a darker grey colour. In ſhort, theſe ſtrips in different ſtrata appear of various colours, and of various ſhades of thoſe colours.

Some of the finely ſtriped ſtones exhibit ſtreaks leſs than a quarter of an inch. It is very common to ſee ſtrips about a quarter, and between that and three quarters of an inch; but in theſe finely ſtratified and finely ſtriped ſtones, it is not common to find ſtreaks of a full inch thick, without ſome different ſhade in one ſide or other of the ſtrip. The ſtratification of theſe ſtriped ſtones is generally as perfect and regular as can be imagined.

The ſecond ſort of theſe ſtriped coal roofs, that is, ſuch as are chiefly compoſed of blaes, with a leſs mixture of ſand, differ but little from the firſt in appearance; only the colours are not always ſo bright, nor the ſtrips ſo fine, nor is the roof quite ſo hard as the ſand-ſtone ſtriped roof.

III. Soft coal roofs, of which there are a very great number and variety, with reſpect to quality, colour, and thickneſs. I will point out a few of them, and I ſhall begin with ſuch as are of a black, a bluiſh black, and a black grey colour. Of theſe ſome are regularly ſtratified, others are imperfectly ſtratified, and ſome of them not ſtratified at all. All theſe ſoft black and blackiſh coal roofs are by the Scotch colliers, and thoſe of the north of England, called by the general name of *blae*, or till.

1ſt, I will firſt take notice of ſuch as are regularly ſtratified. Some of the ſtratified blae roofs are formed of pretty thick ſtrata, others of them are formed of thin ſtrata, and many of ſtrata of middling thickneſs. There are arrangements or claſſes of regularly ſtratified blaes found as the immediate roof of different coals of a great variety of thickneſs, from three or four inches up to a good many fathoms; but of the particular thickneſs of each ſtratum of thoſe I call regularly ſtratified, I have ſeldom ſeen any one of them much above a foot and a half, or at moſt two feet thick; but I have frequently ſeen great numbers of them not above two or three inches, and ſome of them not much above one inch thick, even where there was in all a confiderable thicknefs of blaes, confifting of a great number of ftrata, thick and thin, arranged together. Some of thefe tender roofs of regularly ftratified blaes have an oily appearance upon the outfide, and through all the fiffures and joints of the ftrata, that is, they appear fmooth and gloffy, and are very flippery to the touch. Others of them have nothing of this; but whether oily or not, thefe foft blaes make but a bad or indifferent roof at beft, as they are always tender, weak, and fragile.

2d, The fecond fort of foft coal roof which I am to mention is blaes, which is only ftratified in part, or imperfectly ftratified. This fort of roof is in every refpect the fame in quality and colour as the laft, the only diftinguifhable difference between them being in the different degrees of ftratification. This fort appears clumfily ftratified, and the ftrata or beds of it are not perfect, but unequal and lumpifh, which makes it a bad and dangerous roof, as the inequality and various joints of the ftrata occafion their falling down in large maffes or lumps when the coal is wafted from under it. Some of thefe irregular ftrata of blaes appear in thick, and others in thin and middling beds; and fome of thefe, as well as the laft mentioned, have a greafy or oily fmoothnefs, and they are called by Scots colliers *creefhy blaes*, that is, greafy blaes. This oily fmoothnefs makes

thefe

these irregular strata particularly troublesome and dangerous in a coal roof, as these being full of joints and natural divisions, which run in all directions, the oil runs through all the joints, and occasions this sort of blaes to slip and fall out so soon as the coal is worked away from under it.

Some of these glossy greasy blaes have such a quantity of the natural oil as to make them flame a little in the fire, and there is in some places a considerable quantity of the hard stratified blaes mentioned above, which will not only flame in a fire, but some of it will actually burn when fire is set to it, though it will not consume. There is a species of pretty hard stratified blaes at Pitfirran in Fifeshire, which burns so well, that if a small fire is once kindled at one corner of a hillock, it will burn throughout; but it is no less in bulk after than before it was burnt, nor does it produce any ashes. This blae is of a pretty good black colour before it is burnt, but the fire turns it to a pale red, in which it is so far from consuming, that it acquires a considerable degree of hardness in the fire, which makes it pretty good stuff for roads. It is remarkably good for horse and foot paths, but not so proper for such roads as are constantly occupied by heavy wheel carriages. It appears pretty evident, that this blae contains a portion of natural oil in the

composition

compofition of the ftone, as it burns, but does not confume at all; for if it partook of the coal matter in fuch quantity as to make it inflammable, part of the coal would be feen, and moreover, part of the blae would confume, and produce fome afhes, which actually is the cafe when a blae has fuch a quantity of coal in its compofition as to make it in any degree inflammable; which circumftance I have frequently feen, that is, I have frequently feen a fmall mixture of coal in fome blaes, and thofe blaes, when burnt, produce lefs or more afhes; but this fort will not burn itfelf, like the Pitfirran blaes, but requires a continual application of fire.

3d, Soft blaes, which are not ftratified at all, that is, there is no more than one ftratum or bed of this blae in the fame place, without the intervention of other ftrata above and below it. This fpecies of blaes is as commonly found to be the immediate roof of coal as any thing elfe I know, and the beds of it are found of various degrees of thicknefs, from two or three inches up to two or three fathoms; but whether the ftratum of it be found thick or thin, the whole ftratum is always one uniform mafs, without any divifions into feveral ftrata. But it fhould be remarked, that all thefe unftratified beds of foft blaes are not equally of one uniform mafs throughout the whole ftratum. Some of thefe foft blaes

are

are found divided into ſmall angular maſſes in the ſtratum, and other beds of it are divided into larger angular maſſes or glebes; but whether theſe ſoft blaes are found glebous or uniform throughout the whole ſtratum, they always prove a bad and troubleſome coal roof.

Theſe black argillaceous ſtrata of the coal-field are by many called beds of till. The uniform ſort are called *dauk*, and the glebous ſort are called blaes, or *lipey blaes*, by Scotch colliers. Both the uniform and the glebous ſoft blaes frequently contain a quantity more or leſs of ball iron-ſtone, or glebous iron-ſtone, though ſome of it contains none at all. The regular continuous ſtrata of iron-ſtone are commonly found in ſtratified ſoft blaes.

There is a variety of ſoft coal roofs of a grey colour, and of theſe ſome are regularly ſtratified, and ſome are not.

4th, Of regularly ſtratified ſoft grey coal roofs there are ſeveral ſorts. The firſt of theſe which I will take notice of is the ſoft grey bands or grey fekes, which have a conſiderable quantity of ſand in the compoſition of the ſtrata.

Many of theſe ſoft grey bands are as regularly ſtratified as any coal metals whatever.

Numbers of them are found in very thin ſtrata, and others of middling thickneſs; but whether

thick

thick or thin, they are fo weak and tender as to make a very bad and troublefome coal roof. Many of thefe grey bands look pretty well at firft, but they foon fail and come down when undermined and expofed to the influence of the air; and I fuppofe that this is owing partly to there being too great a quantity of clay in the compofition of the ftone, and partly to the want of a fufficient quantity of natural cement to connect the feveral particles of the ftone together and promote induration.

5th, Soft grey regular ftrata, or grey bands of an argillaceous kind, and of thefe there is likewife a great variety, efpecially as to colour and thicknefs. Some of thefe are of a dark and others of a lighter grey, and fome of them exhibit pretty thick, and others middling and thin ftrata.—Thefe foft grey argillaceous ftrata are very numerous in moft coal-fields, and they are frequently found to be the immediate roof of the coal; and thefe, as well as the black kinds, are found in all quantities or degrees of thicknefs above different coals from a few inches up to feveral fathoms; but whether there is much or little of it together, and whether thefe ftrata are thick or thin, this fort is generally found to be a weak and fragile roof.

6th, Soft grey argillaceous bands, imperfectly ftratified. Thefe differ little or nothing from the

the laſt in quality or colour, the only diſtinguiſhable difference being in the different degrees of ſtratification. Many of the laſt mentioned ſort are as finely ſtratified as can be imagined, that is, the ſtrata of them are generally thin and of middling thickneſs, and perfectly regular, finely ſpread out, and every part of each ſtratum equally thick; but on the contrary, this ſort, though it has the appearance of ſtrata, yet the ſtratification is but clumſy and irregular, that is, the ſeveral beds are unequal and divided by many irregular joints into unequal misſhapen maſſes, which makes this ſort a bad and troubleſome coal roof, as the maſſes ſeparate at the joints, and fall down when the coal is waſted from under it.

7th, Soft grey argillaceous beds of metal or coal roofs not ſtratified at all, and this, as well as the black ſort deſcribed above in the third diviſion of ſoft roofs, is of two kinds or varieties, viz. firſt, ſuch as is found broken or formed in the ſtratum into glebes or maſſes; and ſecond, ſuch as is found in one uniform maſs throughout the whole bed, without any diviſion into maſſes or ſtrata. I need not repeat that theſe grey ſoft roofs are of all degrees of thickneſs, from a few inches up to a great many fathoms, as well as the black. There is but very little difference between them in any reſpect, excepting the colour.

But

But it may be proper to obſerve here, that ball or glebous iron-ſtone is frequently found in this as well as in the black unſtratified blaes, and that both in the glebous and uniform beds, and that ſtrata of iron-ſtone are alſo found in the ſtratified ſoft grey blaes.

8*th*, White and aſh coloured ſoft argillaceous coal roofs, and of theſe there is as great a variety as of any other whatever. Of this ſort of roof ſome are regularly ſtratified, ſome imperfectly, and others not at all. Of the whitiſh argillaceous roofs, ſome are a compound of a gritty ſand and clay, others appear to be chiefly compoſed of pure clay, and ſome of a loamy clay.

I will begin with ſuch as are regularly ſtratified and mixt with ſand, and of this ſort ſome ſtrata are mixt with ſharp and gritty ſand, and ſome with ſofter ſand. What I have ſaid above with reſpect to the variety of thickneſs of the ſeveral ſtrata, and of the ſeveral parcels or arrangements of thoſe ſtrata into general beds of various thickneſs, may be ſaid of the white as well as of the black and grey argillaceous coal roofs; and, therefore, I need not repeat what has been ſo often ſaid above about the regularity and various thickneſs of the ſtrata, and of the accumulating arrangements or parcels of ſtrata. I have ſeen many of this ſort of gritty or ſandy clay roof very ſoft, weak, and fragile.

9*th*,

9th, The next whitiſh argillaceous ſoft roof I ſhall take notice of, is ſuch as we find regularly ſtratified, and of a homogeneous quality, or not mixt with ſand. Some of theſe are very finely and perfectly ſtratified, and they are found of different degrees of hardneſs. However, in general, the moſt of them prove but a weak and tender coal roof. What has been ſo often repeated about the different thickneſs of the ſeveral ſtrata, and of the different general thickneſs of the ſeveral roofs, is perfectly applicable here, and therefore I refer to what is ſaid above, to ſave a multitude of unneceſſary words, as the principal difference between theſe and the black and grey argillaceous coal roofs, is in the colour, in which reſpect they differ widely, as ſome of theſe under immediate conſideration are pretty white, others of an aſhen white, and ſome of a yellowiſh white colour. I ſhall obſerve here, that this ſort is not all equally well ſtratified. There are ſome of theſe as well as of the above found in irregular ſtrata, and with all the other imperfections and varieties mentioned before.

10th, White and aſh coloured argillaceous coal roofs not ſtratified at all, and of this ſort there is a very great variety. Sometimes we find very thick beds of white and whitiſh argillaceous matter in the coal-fields, and ſome of theſe, as well as of the black ſoft roofs, riſe in glebes and maſſes of different ſizes, and others are uniform and homogeneous throughout the whole bed, however thick it may be; and theſe, as well as the black, are found of every degree of thickneſs, from two or three inches up to ſeveral fathoms. Some of theſe beds of white argillaceous marl-like matter are found to be a ſandy or loamy clay, and others of them are of a pure homogeneous clay, which does not feel gritty between the fingers nor in the mouth. I have frequently taken ſome of theſe fine white clay roofs to waſh my hands, and found it anſwer nearly as well as ſoap. The ſhades and varieties of colour in this ſort are as numerous as in the laſt mentioned. All the clay roofs of a homogeneous uniform ſtructure, are called *dauk* by Scots colliers, whatever be the colour of them.

The general ſpecies and the ſeveral varieties pointed at, and deſcribed above, may be conſidered as a pretty full ſelection of the moſt common roofs of coal; but it muſt only be conſidered as a ſelection, and as a very brief and imperfect account of ſome of them. The different ſtrata of the coal metals found every where in different coal-fields, are ſo numerous, and there are ſo many varieties of them, that it would take a large volume to enumerate and deſcribe them all; but I can only pretend to give a general

neral hiſtory of ſome of them; and therefore I ſhall only further obſerve here, that what I have ſaid above about the coal roof is equally applicable to the pavement of the coal, as in fact we find as great a variety of different ſtrata below different ſeams of coal as we do above them.

Having taken a view of the various ſtrata which accompany coal, I would now proceed to point out the ſtrata of the mountain rocks, that is, ſuch other ſtrata as are not commonly found to accompany coal, in order to diſtinguiſh them from the coal metals; but my obſervations upon this branch of my ſubject have extended to ſuch a length, that I have thought it proper to allot to them a diſtinct portion of my work.—(See part III.)

All the works of God are wonderfully magnificent, numerous, and diverſified. There are a thouſand diſcoveries to be made in all parts of the creation, and a thouſand improvements to be made of thoſe diſcoveries. The great maſters of nature, who have looked into the animal and vegetable kingdoms with a keen and comprehenſive eye, have produced ſuch diſcoveries and improvements as are at once an infinite benefit to ſociety, and an honour to human nature. The mineral kingdom is a very fruitful field, but all parts of it have not yet been ſuitably cultivated. I can only be reckoned a common labourer in this

this field, but I am refolved to deferve the praife of being a faithful labourer in it.

Fanciful fyftem builders, and fome learned philofophers, but of fmall knowledge in thefe matters, have made a coil about deep and extenfive ftrata which compofe the fuperficies of our globe, and fome of them have propofed various fchemes, and tried many experiments for obtaining fuch fections, with a view as they fuppofed to countenance and confirm their feveral fyftems.

I am informed from good authority, that M. de Maupertuis propofed finking a fhaft of enormous depth in Iceland, in order to determine the ftructure and matter of the globe at fuch a depth below the upper furface; but why in Iceland more than in France, England, or Germany, which abound with materials, and men of fkill, I am at a lofs to know, unlefs he fuppofes that every individual ftratum forms a zone, or rather a fhell, which ftretches quite round, and envelopes the whole globe, like one of the coats of an onion; and that in confequence of the figure of the earth, thefe furrounding ftrata are all of them much thinner in the neighbourhood of the poles than they would be found nearer the equatorial regions; but however plaufible this theory may be, it is not true. There is in fact no fuch general and extenfive ftretch of any individual ftratum, nor

nor of any claſs of ſtrata. The various claſſes or kinds of ſtrata which are found in different countries and diſtricts, are arranged together in greater or leſſer patches upon the face of the globe, which ſhall be clearly demonſtrated by a ſufficient number of examples, and well authenticated facts, confirmed and illuſtrated by examples, are more to be depended upon than general theories founded upon ſuppoſitions which do not exiſt. I will ſave theſe gentlemen the trouble and expence of ſinking their ſhaft, and will give them a ſection of four times the depth which they can ſink; and indeed it is neceſſary for me, or ſome other in my line, to relieve them from this embarraſſment, as the revenue of an empire would not be ſufficient to ſink a ſhaft to the depth M. de Maupertuis propoſed, which I think was half a mile, or near three thouſand feet.

Coal maſters and mineral engineers will ſoon (perhaps too ſoon) find it a difficult matter to go down one half of that depth below the ſurface of the ground in a plain country.— It is indeed practicable to draw up coals and other mineral foſſils from greater depths in a champain country, by means of ſeveral ſhafts ſunk in ſtages, one below another, with a proper landing at the head of each ſhaft; but it will not be found an eaſy matter to draw up the

water

water from ſuch great depths, unleſs ſome new kind of machinery ſhall be diſcovered, more convenient and ſuitable for the purpoſe than any we have at preſent.

The fire or ſteam engine, which is ſo very uſeful and neceſſary to ſubterraneous operations, is indeed very powerful; but ſuch a multiplicity and enormous length of ſpears or pump-rods as would reach down to the depth of four or five hundred fathoms, or even to the depth of three hundred fathoms, would become a dead weight upon an engine, and every way difficult, expenſive, and troubleſome.

Many of our colleries in Britain are already very deep, and in a few years hence theſe colleries will require to be yet much deeper, otherwiſe the proprietors and others, as well as many of our great towns and manufactories, will ſuſtain a very ſenſible loſs, and, therefore, from tnis conſideration, it is to be wiſhed that mineral engineers would ſtudy the philoſophy of engine ſpears, and communicate to the public the reſult of their enquiries and experiments.

Fir timber is light, and of a regular grain and reed, but it is of a lax texture, and comparatively weak, and ſo far it is unfit for a very long ſpear or pump-rod. It may hereafter be very material to know what timber will anſwer beſt for this purpoſe, purpofe, when it becomes neceffary to fink our coal-pits to a much greater depth.

With refpect to a grand fection which our philofophers want for afcertaining the nature, quality, form, and difpofition of the ftrata at a great depth, I will give them one ready made, not only of three thoufand, but even of fix thoufand feet. This grand fection of the ftrata is cut through the coal metals at Gilmerton, near Edinburgh, and the fame ftrata are cut through at Loanhead, about two miles fouth-weft from Gilmerton. This pofition requires to be explained, as it may appear myfterious to many how fuch a prodigious fection of the ftrata happens to be made in thefe places; and in order to this explanation it is neceffary to premife, that the ftrata at Gilmerton, &c. as has already been taken notice of, hang or decline with a flope near about the angle of forty-five from the horizon. This flope varies greatly in different parts of the field. In fome places the feams of coal and other ftrata incline with a flope of above fifty degrees from the horizontal pofition. In other places not above twenty-five, and even as low as twenty; however, upon a medium, I reckon that the flope or declivity of the ftrata at Gilmerton is about the angle forty-five. The dip or declivity of the ftrata in this diftrict is towards the fouth-eaft, and both at Gilmerton and Loanhead there is a

confiderable

confiderable flope and fall of the furface of the ground towards the fame point of the compafs; and they have in both places availed themfelves of this figure of the furface to bring up a level or adit from the low grounds, in order to drain their coals of the water to the depth of thefe levels. Thefe level mines are driven up in a right line acrofs the bearing of the ftrata; that is, fuppofing the longitudinal bearing of the ftrata trends to the fouth-weft, the level mines are cut at right angles, with the bearing and point to the north-weft. This level mine is cut in this direction acrofs the ftrata for a mile, or about fix thoufand feet, by which there is made the grandeft and moft extenfive fection of the ftrata, perhaps, that is to be found in any country. There are indeed in many countries much longer adits or level mines cut from the valleys up to the mountains and higher grounds, for the purpofe of draining the water from mining fields; but it rarely, or perhaps never happens, that they pierce and cut through fuch a multiplicity and variety of ftrata in thefe long adits as they have really cut at Gilmerton. In many places the ftrata lie pretty flat, and in various degrees of flope from the horizontal pofition. In thefe they may drive or cut forward a confiderable number of feet or fathoms with little or no change of ftrata; whereas in perforating the ground with a level mine at

Gilmerton

Gilmerton, they have a continual change of ſtrata on account of their great declivity. The number and variety actually cut through in this field is ſo immenſe, that it would fill a large book to enumerate and deſcribe them all. They are all what is commonly called coal-metals, that is, ſuch ſtrata as are generally found to accompany beds of pit coal; and there are above ſixty beds or ſtrata of coal, thick and thin, cut through at Gilmerton in this noble ſection, among which, about twenty of them are workable, and have been worked at Gilmerton, and the neighbouring coal-fields.—The reſt are thin, though regular ſtrata of coal, generally from between two feet to about three or four inches thick, and ſome of them, though regular ſtrata, not above one or two inches. The other ſtrata of different qualities, which have been cut through in this great ſection, are in general ſuch as have been pointed out above as the ordinary roof or pavement of coal. Such as, for inſtance, of the hard ſtones, they have cut thro' whin-ſtone, lime-ſtone, iron-ſtone, thick beds of poſt free-ſtone, middling and thinner beds of free-ſtone, dogger-bands, that is, hard beds of ſtone blended with a great quantity of pyrites and other mineral particles, which cement this ſtone into a hard,. ſtubborn, obdurate maſs, not eaſily broken or worked through; and they have cut through a confiderable variety of thefe feveral fpecies of hard ftones. They have likewife cut through a great variety of other ftones not quite fo hard as the few juft named, fuch as, for inftance, poft free-ftone of various fhades of white, of yellowifh white, and of greyifh white colours, of middling hardnefs, and kindly to work; alfo regular ftrata of free-ftone of various textures, colours, and degrees of thicknefs, none of which, however, are fo thick as to be called poft-ftone. Grey-bands are innumerable, which are thin bedded ftrata of a compound ftone; of thefe there is almoft an infinite variety, as to colour, quality, and thicknefs. Of ftratified blaes, or argillaceous coal-tills, there is alfo a prodigious variety, in refpect to colour, thicknefs of ftrata, and degrees of ftrength and hardnefs. The fofter coal metals, as they are called, that is, the argillaceous ftrata cut through at Gilmerton, are fo very numerous and various, that it would require a volume to defcribe them all; and as a confiderable number of them have been defcribed before in the hiftory of coal roofs, it will be needlefs to give a repetition of them. In fhort, the ftrata cut through in this great fection contain fuch an amazing number and variety, that they may be confidered as a very complete affemblage and example of the ftrata which accompany coal,

excepting

excepting regularly figured basaltes, of which there is none at Gilmerton, though they have cut through several beds of whin of various colours, which approach the quality of that stone.

This vast section and immense variety of strata have not only been cut through in a horizontal direction, by driving level mines through them at various depths below the surface of the earth, but they have also been repeatedly cut through in a perpendicular direction by a very great number of pits, or shafts, of various depths; and although it would be impossible to cut through them all in one particular shaft, yet they have been all frequently cut through by a very great number of different shafts of various depths. Each of these different shafts have cut through a certain number of the strata of this great section in different parts of the field; but if all these shafts which have really cut through different strata were placed one above another in a perpendicular line, it would be a shaft of about nine thousand feet in depth, which happens of course from the greatness of the declivity of the strata; and all the strata in this great section are cut through as effectually and as distinctly by the number of shafts in different places, as if they were cut through by one perpendicular shaft to the whole depth.

The facts here asserted, relating to this great section, are well known to a number of gentlemen of knowledge and ſkill in theſe matters, ſo that it is impoſſible for me to impoſe upon the public without being detected.

To know with ſuch a degree of certainty what is to be found nine or ten thouſand feet below the ſurface of the ground in any country, is an article in natural hiſtory worth attaining. There are but few, if any other, parts of the world which can produce ſo deep and extenſive ſections of the ſtrata which compoſe the ſuperficies of our globe. It is true, indeed, we have traced out much deeper and more extenſive ſections of the ſtrata in the rivers, glens, and precipices in the Highlands of Scotland, as will be ſhown and explained in the ſecond volume of this work; but theſe ſections were cut by the operations of nature; thoſe at Gilmerton, &c. are the effects of art and induſtry.

I ſhall now return to my purſuit of the hiſtory of the coal metals. It has been obſerved, that the general courſe or bearing of the ſtrata in this iſland is nearly from north-eaſt to ſouth-weſt; but this is ſo far from being a particular rule that may always be depended on, eſpecially with reſpect to the coal metals, that we can never preſume to know which way they trend, nor which way they dip, until we ſee ſome of them. Thoſe ſtrata which decline from the horizon with a conſiderable degree of ſlope, are

generally

generally found to be more true and conſtant to the line of bearing, than ſuch as lie much nearer the horizontal poſition; the reaſon or cauſe is obvious. When ſtrata lie very flat, or nearly parallel with the horizon, they frequently vary from the ordinary line of bearing, by waving and wheeling. We ſometimes find them waving up and down like a high ſea in a calm, after the wind which raiſed the waves is abated. But this is too brief. We muſt take more pains to explain this point. It has been laid down as a rule, that the bearing of the ſtrata in general is nearly in a line from north-eaſt to ſouth-weſt, though this general rule is not without ſome local exceptions. We ſhall endeavour to point out and explain the real cauſe of theſe exceptions, in order to which, let us ſuppoſe, that the coal metals or ſtrata in any field lie pretty flat, or nearly parallel to the horizon; that the ſtrata in that field trend in general towards the ſouth-weſt; and that the general dip or declivity of the ſtrata in that field is towards the ſouth-eaſt, and the riſe towards the north-weſt, which is in a right line acroſs the bearing. Now, ſo long as thoſe ſtrata continue to have exactly the ſame degree of ſlope, they will alſo continue to have exactly the ſame line of bearing; but where the ſtrata are very flat, this perfect regularity ſeldom ſtretches a great way in any line, becauſe the

ſtrata

ſtrata which are nearly flat in any particular place, are very often found to fall perfectly flat a little way forward upon the line of bearing, we may ſuppoſe at the diſtance of half a mile; and when they fall quite parallel to the horizon, they very often fall over the horizontal poſition line, and ſo acquire for ſome ſpace a different dip or line of declivity than they had before, and very probably they alſo trend in a different line from the former for the ſame ſpace or diſtance. Let us, for the further explication of this ſubject, ſuppoſe, that the ſtrata are perfectly flat and level with the horizon at any fixed point, as, for inſtance, in a particular inclosure of ſo many acres, which is bounded by its own fences, and that when you advance forward out of this incloſure into the next, with your face towards the ſouth-weſt, the ſtrata then begin by degrees to fall from their level horizontal poſition, and to dip towards the ſouth-weſt. In this caſe the line of declivity is towards the ſouth-weſt, which was the line of bearing before the ſtrata fell quite flat. Now when, and while the line of declivity is towards the ſouth-weſt, the bearing of courſe muſt be in a line from north-weſt to ſouth-eaſt, as the line of bearing and the line of declivity always croſs each other at right angles. In theſe caſes of the ſtrata flattening, and of their dipping towards another point, it conſtantly happens that this change

change of dip is only local, and continues but for a limited ſpace or diſtance, though the precise diſtance cannot be determined by us, until we come to know it by obſervation or experience. But we may ſuppoſe that they continue to dip towards the ſouth-weſt, with an eaſy ſlope, for about a quarter of a mile, and when the ſtrata arrive at that point, they generally fall perfectly flat again, and continue ſo for a limited ſpace, without any ſenſible dip any way, and at the far ſide of that ſpace the ſtrata begin to riſe gradually towards the ſouth-weſt, with an eaſy acclivity, and then the line of declivity is towards the north-eaſt.

At preſent they riſe towards the ſouth-weſt. A little farther forward in that line the ſtrata arrive at the height of that acclivity, flatten upon the height for a limited ſpace, and ſtill farther forward they gradually begin to dip again towards the ſouth-weſt, and ſo on perhaps for many times over again; and this is what I call the waving of the ſtrata; and in fact the ſtrata in this caſe reſemble, upon a large ſcale, the waves of the ocean in a calm day after a ſtorm.

When the ſtrata fall quite flat, or perfectly parallel to the horizon, between theſe great waves, of conſequence they muſt then ſpread over a much greater extent of country than before, while they dipped towards the ſouth-eaſt; and as the

the true line of declivity is ſuppoſed to be towards the ſouth-eaſt when the ſtrata fall quite flat, then they muſt ſtretch away and ſpread out far towards the north-weſt, a great way beyond the former line or limits of the ſurperficies of the ſtrata; and this I call the wheeling of the ſtrata; and in fact, when in this poſition, they frequently do ſtretch far beyond the former limits of the ſuperficies or crop of the ſtrata, and fetch a great compaſs over an extent of country, ſometimes of miles north-weſt of the former crop or outburſt. When the horizontal ſtrata, from dipping a little towards the ſouth-eaſt, fall quite flat, they ſometimes do not ſtop there, but fall over, that is, the north-weſt ſide of that claſs or range of ſtrata fall quite over the horizontal level, and dip for ſome diſtance towards the north-weſt, which occaſions the ſtrata to ſtretch ſtill farther towards that point, than if they only fell quite flat or parallel to the horizon. The truth is, when once the ſtrata come to a horizontal flatneſs, they are often found, while they continue near that poſition, to lean and dip this way and that, without the leaſt regard to the true line of bearing or declivity.

While the ſtrata continue in this horizontal poſition, they are ſometimes found equally flat, that is, to continue upon a level plane for a conſiderable extent of ground; but more frequently they

they are only found to be flat in general with reſpect to their ſpreading over an extenſive country; but with reſpect to different particular ſpots or compartments of that country, they are found to lean this way and that at much uncertainty; ſometimes forming ridges and troughs, and ſometimes a baſon; and theſe various changes of dip and riſe in the horizontal coal metals, are ſometimes upon a large ſcale, and ſometimes upon a ſmall one. What I mean by a baſon in the horizontal ſtrata is, when any extent of them of leſs or greater dimenſions fall loweſt in the middle, and riſe gradually towards the outſkirts, all round, in the form of a piece of low hollow ground in a meadow, which contains a lake of ſtagnant water in a rainy ſeaſon; and to form this baſon in flat ſeams of coal, it muſt be underſtood that the ſtrata dip inward all round towards a common center, and of courſe there muſt be an acclivity or riſe of the ſtrata from that center quite round towards the outſkirts of that baſon. It cannot be ſuppoſed that theſe baſons dip regularly towards the center in a perfect circular form; however, I have ſeen ſome of them ſo near it, that the eye could not determine at once, without examining circumſtances, which was the ſhorteſt or which the longeſt diameter of the circle. Theſe baſons, as well as all the other various poſitions of the ſtrata, are found upon various ſcales. Some of them are not a quarter of a mile in diameter before the ſeam of coal and other ſtrata ſtretch away in a different poſition, and ſome of them are much more than a mile in diameter; and it generally happens, that in theſe large baſons the dip and riſe of the coal are ſo little and gradual as hardly to be perceived in ſome parts.

When theſe various local declinations of the flat-lying ſtrata happen to be upon a large ſcale, it makes ſmooth work in carrying on a colliery in any of them, becauſe you advance a great way before you come to any ſenſible change of the dip and riſe that will any way affect and diſturb the plan of working; but on the contrary, when the waving and wheeling of the ſtrata is upon a ſmall ſcale, the different ſudden changes of the dip and riſe are frequently very troubleſome and expenſive. As, for inſtance, the narrower or ſmaller a trough is, it generally happens that the coal and other ſtrata dip down the more precipitately, in proportion to the ſmall dimenſions of the trough, and of conſequence it is more difficult to work down a ſudden precipitate ſlope than a gradual eaſy ſlope, and eſpecially if there is much water in the mine. The ſame difficulty occurs when we meet with high and narrow ridges between troughs. We may aſcend up the neareſt ſide of one of theſe thefe ridges, and work away over the top or highest part of it very well; but when we begin to defcend down the far fide of it, we immediately find water, and perhaps cannot proceed until we go back to the loweft place, and bring up a level mine under the pavement of the coal, quite through the ridge, in order to level the coal upon the other fide of it. Some of the Scots colliers call this a *ridge*, others of them call it a *hirft*, and fome of them call it a *fow's-back;* but all the hollow parts in the coal are called troughs by them, whether they are troughs or bafons, &c. The coal is fometimes found thinner than ordinary upon the top of a fow's-back or a narrow ridge, but when the waving of the ftrata is fo gradual as to make the dip and rife of the coal fcarcely perceptible, the thicknefs of the coal is but feldom affected, either by the ridges or the troughs.

I obferved above, that thefe ridges and troughs fometimes refemble long and large waves of the fea; but it may be proper for me farther to obferve, that thefe ridges are in fome places upon fo large a fcale, that the waves of water are not fuited to convey an adequate idea of the fpacious dimenfions of the troughs, and of the ample extent and magnitude of the ridges. Every body muft have feen long and low mountains or ridges of rifing ground running parallel to one another, with

with valleys of moderate extent or breadth interpofed between them. In fome places, the waving of the ftrata is upon fo large a fcale as to refemble thefe parallel ridges and valleys which diverfify the face of the country.

Let it not be imagined that all this buftle about the waving and wheeling, and other various declinations of the coal metals, is the work of fancy, an imaginary fcheme to amufe fuch as are ignorant of thefe matters. It is a fact well known to all who are acquainted with the natural hiftory of the ftrata, and the fact is obvious to the obfervation of fuch as look into thefe matters, and it might be proved by a number of local inftances. The horizontal coals which are worked in Mid-Lothian in Scotland, all round Dalkeith, are found to wave confiderably in feveral places, particularly when they go fouth towards the parifhes of Carington and Temple, and farther weft, in the parifh of Linton in Tweedale; fome of thofe coals have been worked in the lands of Carlops, through feveral troughs and over feveral ridges.

The coal which has been moftly worked out in the farm of Carlops, fo far as they could reach it with adits or levels, is all of it found in the waving order, that is, in ridges and troughs, and the variation of the dip and rife there generally confifts of gentle eafy fwelling waves, and I know that the coal is whole and unwrought in the bot-

tom

tom of ſome of the troughs there, becauſe they could not drain it with their levels; and, moreover, it is known to ſeveral coal-maſters, that the ſplenty coal and others, which are wrought to the ſouth-weſt of Dalkeith, acroſs under the rivers North and South Eſk, aſcend the north ſide of the hill or riſing ground to the ſouth of Dalkeith,—croſs the height of that hill by Blackſide, &c. and then deſcend quite down the ſouth ſide of the hill, and croſs the valley by Oxenford and Cranſton, and are actually ſeen and wrought upon the ſouth ſide of the valley and river at Cranſton, ſo that here they are found to wave, or to riſe and fall, upon a large ſcale, as the extent of the ground now mentioned is about five miles in a line from Laſſwade, which is ſituated a little weſtward of Dalkeith, to the fartheſt place where theſe coals have been worked upon the ſouth ſide of the river at Cranſton; and in this line the ſplent coal, &c. has been worked, and is now working by John Clerk, Eſq; of Eldin,—by the Marquis of Lothian in ſeveral places ſouth of Dalkeith,—by Sir John Dalrymple at Blackſide, and alſo upon both ſides of the river at Cranſton. I could produce a great many more inſtances in point, but theſe are ſufficient to ſhow the fact, and to confirm the doctrine of the waving of the ſtrata.

From

From this investigation of the subject, that is, from the result of these enquiries about the waving and wheeling of the horizontal strata of coal, it is obvious at first glance that this variation of the strata from the common lines of bearing and declivity, is so far from deserving to be reckoned in general among the ordinary troubles and irregularities of the strata, that in fact, instead of being a nuisance, they are in general a great benefit to society. Their falling very flat, and sometimes falling quite over the horizontal level, and dipping the contrary way, and their waving up and down, as described, spreads abroad the same individual stratum, or a number of strata of coal, over a much greater extent of country than if they preserved invariably the same degree of declivity, and the same line of bearing, as they are found to have before they fell quite parallel to the horizon. Their falling sometimes quite flat, and their declining this way and that, in the variety of positions described, keeps the coals floating near the surface, within our reach, over an extensive country, by which means we can, at a moderate expence, work ten times more of them; in some instances, perhaps, we can work twenty times more of them than if they dipped down towards the center with an uniform and invariable slope or declivity; for if the line of declivity was invariable,

invariable, however eaſy and gradual the ſlope might be, they would too ſoon dip down quite out of our reach. But matters are much better diſpoſed for our good, as by means of the parallel ſlips deſcribed above, which throw the ſame coals many times up again nearer the ſurface, which gives us the ſame ſeams of coal many times over again; and, by means of this waving and floating of the coals near the ſurface, we have a much greater fund of them in our power than we could have by any uniformity of the ſtrata. There is an inſtance of this at Pitfirran in Fife, where the coals dip towards various points of the compaſs, and in conſequence, I believe, that they have already worked out ten times more coals there, than they could have done with one uniform line of bearing and declivity.

Here we have an opportunity of admiring the wiſdom and benevolent deſigns of providence, in making the irregularities of the ſtrata, which may be thought by ſome to be the blemiſhes of nature, yet theſe are made to turn out for the convenience and emolument of ſociety. But I mean to ſhow in another place, that the breaks and irregularities of the ſtrata are not blemiſhes of nature, but that they are all of them the neceſſary and unavoidable reſult and effects of natural and neceſſary cauſes.

Before

Before I leave this topick, I ſhould obſerve, that although the coals and coal metals are found ſometimes to fall from different degrees of declivity to a horizontal flatneſs, and while they continue near that poſition, that they wave and wheel, and vary the ſlope and bearing, and ſo float and ſpread near the ſurface over an extent of country, yet it muſt not be underſtood that they always continue in this waving poſition. In ſome coal fields they do continue in the horizontal waving poſition over an extent of country of ſeveral miles every way, but in other places they do not ſpread ſo wide before they fall back towards the firſt and regular line of bearing, and again acquire a regular ſtretch, bearing, and declivity; and when the ſtrata are thus reduced to a more uniform bearing and declivity, there is no ſuch thing as determining the degree of ſlope they may fall to. I have ſeen ſome coals acquire a horizontal and a waving poſition, and afterwards, farther towards the ſouth-weſt or towards the north-eaſt, I have ſeen the declivity again fall ſo ſteep as the angle forty-five, and in ſome particular inſtances I have ſeen them ſtill nigher the vertical poſition. There are alſo ſome inſtances of their not recovering the former regular bearing and declivity, but continue to wave and wheel to the extremity of the limits of the coal field, eſpecially towards the ſouth-weſt. We have

have an inſtance of this in the horizontal coal metals of Mid-Lothian, which never recover a regular, uniform, and continued line of bearing and declivity, after they once begin to wave, until they arrive at the extreme boundary of the coal metals towards the ſouth-weſt, and I could produce other inſtances if neceſſary.

There is yet another circumſtance relating to the ſtrata of coal, which I ſhould note in this place. I have made it evidently appear, that the ſtrata of coal, and their concomitants, ſometimes vary from the true line of bearing conſiderably, by falling to the horizontal poſition, and by waving and wheeling, &c.; but in this caſe, however, the true line of bearing ceaſes to be the dead level line, as any change in the degree, or in the line of declivity, changes the dead level line; yet it generally happens, nevertheleſs, that there really is coal ſtill in the true line of bearing all the way to the extreme boundary of the coal field, although that line ceaſes to be the dead level line, and, therefore, we cannot determine, without experience, at what depth it is to be found. We reckon the true line of bearing, or what may be called the bearing of the ſtrata, in general through the Iſland of Britain, to be nearly from north-eaſt to ſouth-weſt. When this line is loſt in any particular place in a coal field by the flattening and waving of the ſtrata, it enlarges the coal field in breadth, but it does not follow that the coals are loſt in any part of the line.

I believe that there are many who imagine that the coals below reſemble the figure of the ſurface of the ground above, and that they are affected by it; and I apprehend that my obſervations about the various changes of declivity in horizontal ſtrata, and the inſtances adduced in proof of that variety, may be conſtrued by ſome as a confirmation of that opinion. If the notion were true, that the diſpoſition of the ſtrata below ground reſembles the figure of the ſurface above, I apprehend that the obſervation might be ſo improved as to be of great utility in practice. Upon this ſuppoſition, when we ſee an uniformly regular ſurface, we might expect that the ſubterranean geography would alſo be regular. When we ſee a wavy country, which gently ſwells into broad ridges, and ſinks into hollow valleys, we might then expect that the ſtrata would likewiſe wave up and down; and when we meet with a rugged broken ſurface, we ſhould be led to expect as much irregularity below ground as above.

This hypotheſis may appear to ſome at firſt ſight at leaſt plauſible, and there may be inſtances found where the dip and riſe of the ſtrata appear to confirm the hypotheſis; but theſe inſtances are ſo few, and there is ſo much of chance in them, that

that whoever ſhall depend upon always finding this correſpondence, will be frequently diſappointed, becauſe ſuch an inſtance is a mere chance, and, therefore, in ſuch caſes we ſhall always find it wiſeſt and beſt to ſuſpend our judgment until we can bring obſervation and experience in aid. Theſe will infallibly lead us the neareſt way to the truth. Opinion and ill-grounded notions will generally lead us aſtray.

I have frequently ſeen great irregularity and diſorder beneath a regular unbroken level ſurface; and, on the contrary, I have ſeen the ſtrata remarkably plain and regular underneath a rugged unequal broken ſurface. In ſome few places, we ſee the ſtrata for a little way dip and riſe as the ſurface of the ground does; but this in general is all chance, and of ſhort continuance. It is no rule upon which we can depend, for we ſhall as often, and much oftener, find them dipping into the hill, againſt the riſe of the ſurface of the ground, and acroſs it in a right and in a diagonal direction, and to all points, without regard to the figure or quality of the ſurface.

I have in ſome places ſeen low hills in coal countries which ſwelled to a round or oval figure, with an eaſy riſe or aſcent upon all ſides, in which the ſtrata appeared to dip and riſe almoſt all round, nearly with the ſame ſlope as the ſurface of the ground; and, on the contrary, in other little

little hills of the ſame figure, I have ſeen the ſtrata dipping into the hill upon all ſides, ſo that each ſtratum on ſuch little hill formed the figure of a baſon, and all the ſtrata in the hill formed a neſt or pile of baſons within one another; but theſe are uncommon inſtances, ſeldom to be met with, and only to be ſeen in a very few places, where circumſtances favour the diſcovery, and which are never to be regarded as a rule.

The declivity of the coal metals is ſo variable, both in reſpect to the degree of ſlope, and to the point towards which they dip, that we have no ſure rule which will guide us every where to judge of it but obſervation and experience, for we find them as often dipping againſt the ſlope of the ground as with it. Sometimes we find the ſtrata in a coal country running parallel to the ſide of a hill, or ridge of ground, and we as often find them croſſing ſuch a hill in a right and in a diagonal line.

The coals, lime-ſtones, and other ſtrata run almoſt right acroſs the Bathgate hills in Weſt-Lothian, and almoſt right acroſs the high and low grounds contiguous to thoſe hills upon both ſides; and although the coals and other ſtrata climb quite over the high ground to the ſouth of Dalkeith, and acroſs the low grounds at Cranſton, as I pointed out above, yet this has

more

more relation to the waving of the ſtrata than to the waving of the ſurface of the ground.

As a proof of this aſſertion, the ſtrata, as I already hinted, run nearly right acroſs the Bathgate hills, and of the valleys and high grounds upon both ſides, from the ſouth ſide of the Forth until they croſs the river Breich, ſouth-weſt of Mid-Calder; yet it is to be obſerved, that the ſtrata of coal, lime-ſtone, and others in thoſe high and low grounds, decline ſometimes towards the weſt, and ſometimes towards the eaſt, which muſt be owing to the waving of the ſtrata, but then they do not wave with the ſurface of the ground. The ridges and valleys here run nearly eaſt and weſt, but the bearing of the ſtrata is nearly north and ſouth; and whether the ſtrata dip to the weſt or to the eaſt, the ſame line of bearing towards the ſouth is ſtill continued, and of conſequence the difference of dip or declivity of the ſtrata muſt be occaſioned by their waving up and down, without any regard to the figure of the ſtrata.

In all my obſervations, which have been pretty extenſive, I never yet found that the external figure of the ſurface governed the poſition or the bearing and declivity of the ſtrata below, and, therefore, I infer, that wherever the coal and other ſtrata below are found to dip and riſe as the ſurface of the ground does above, it is merely accidental and by chance, without the leaſt relation

tion or reſpect to any rule or regular law of nature. And even in the inſtance above-mentioned to the ſouth of Dalkeith, where the ſtrata paſs under the valleys, and climb over the high grounds, yet even there they are far from dipping and riſing every where with the ſurface of the ground; on the contrary, the riſe and declivity of the ſtrata are found to be different from the ſlope of the ſurface in ſeveral places within the diſtance above-mentioned, which muſt be owing to the waving of the ſtrata, and to the various degrees of declivity in different places.

I have dwelt the longer upon this part of my ſubject, and have taken pains thoroughly to ſearch it out, with a view to obviate the miſtaken notion which many entertain of the coal ſtrata preſerving one continued line of bearing invariably, and to ſet people on their guard againſt the conſequences of ſuch a miſtaken notion.

From all the obſervations which I have made in the courſe of my ſolitary perambulations, and from my long experience, I may ſafely draw this general concluſion, and lay it down as a rule, namely, that we can place no dependance upon the bearing and declivity of the ſtrata, at any conſiderable diſtance out of our ſight and knowledge of them, and more eſpecially the horizontal ſtrata, becauſe they are ſo often thrown out of the courſe of both, by waving and wheeling, and by dykes,

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ſlips, &c. which ought to make people more cautious than they often are in launching out expences in ſinking for coal at hazard, from a confident perſuaſion of its running invariably upon one line of bearing through the whole length of a country. Experience will often in this caſe puniſh them for their temerity when they find that they are wrong.

I have frequently ſeen, in a great number of places, the horizontal ſtrata varying the line of bearing by their falling flat, and then dipping towards various points different from the former line of declivity, and by theſe means ſpreading abroad over a great extent of country, quite out of the former line of bearing, which I have proved to be a great benefit to the community in general, as by this means the coals are kept floating near enough to the ſurface to be worked, ſometimes for ſeveral miles every way; from which I infer, that if they are thus liable to be diverted out of the former line of bearing, we ought not to riſk too much upon an uncertainty. There are more chances of the coals being turned off the line of bearing than of their continuing in it at any conſiderable diſtance; and as there are means of aſcertaining the point, we ſhould be well aſſured of coal before we launch into expenſive trials for it.

With refpect to fuch ftrata of coal as have a great degree of flope, it may be obferved of them in general, that they are more regular in the lines of bearing and declivity than the horizontal ftrata. When the line of declivity of a feam of coal, with its concomitant ftrata, approach the angle forty-five, or a few degrees above or below that angle, the ftrata are found to be much more regular in their declivity and bearing than when they are very flat; however, even thefe are not fo regular as not to vary, and fometimes confiderably.

In fome coal countries we find claffes or arrangements of coal feams, with their concomitant ftrata, dipping down with fo much precipitation as to be denominated edge-feams; and fometimes, in the fame neighbourhood, we fhall have another clafs of coals, &c. lying very flat, and both of thefe running parallel to one another. We have an inftance of this in the edge-coal feams of Gilmerton, &c. near Edinburgh, and of the flat coals to the fouth of them.

The edge feams, as I obferved before, are in general much more regular in the bearing and declivity of the ftrata than fuch as are very flat, notwithftanding we find neither of them fo regular as not to meet with great variations. In tracing the courfe of edge-feams backward and forward upon the line of bearing, I have frequently feen them vary confiderably in the degree of de-

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clivity, ſo as in ſome places to become nearly and even altogether as flat as ſome of the horizontal coals, which in Scotland are denominated flat-broad coals; and, in other places, I have ſeen them turned up quite on edge, or into a vertical poſition. There is an inſtance of both theſe variations to be ſeen in the edge-coals and coal metals to the ſouth of Edinburgh. This arrangement of coals, with their concomitant ſtrata, trend away from the ſouth ſide of the Forth by Duddingſtone, Niddry, Edmondſtone, Gilmerton, Loanhead, and other places. There are more than ſixty ſeams of theſe edge-coals, thick and thin, and in ſome places in their courſe there are more than twenty ſeams of them workable.

This claſs of coal-ſeams, with their concomitant ſtrata, dip towards the ſouth-eaſt, and riſe towards the north-weſt, and of conſequence the bearing or dead level line, which is the ſame as the line of bearing, is towards the ſouth-weſt. I am pretty well acquainted with theſe coals and their concomitant ſtrata, from the ſea at Duddingſtone, for about ſixteen miles ſouth-weſt upon the line of bearing, where they terminate and go no farther in that line, but turn away in a right angle towards the ſouth-eaſt. I have ſeen theſe coals in many places upon this line of bearing, which is about ſixteen miles long, and in general they are very regular in the lines of declivity and bearing. Thefe coals are called edge-feams, becaufe they dip precipitately with a very great flope. The general degree of the declivity of thefe coals is about the angle forty-five from the horizon. In fome places they ftand higher, that is, more upright, and in other places fome lower; but I think that the medium dip is about forty-five, or at moft forty-feven degrees.

There are but few places in Scotland where a clafs of coals and coal metals can be traced fo far as thefe in a ftraight line, which naturally infers, that thefe coals ftretch away up the country very regularly in the true line of bearing, and confequently that the declivity of thefe coals is likewife very regular, as in fact the mutual regularity of thefe two lines, when applied to feams of coal, depend upon one another. But notwithftanding the remarkable regularity of the bearing and declivity of thefe coals in general for fo long a ftretch, there are by the way in fome places confiderable deviations from both. At a place called the Bank, betwixt Edmonftone and Niddry, about two miles fouth-weft from the fea thefe ftrata are found perfectly in a vertical pofition. In proof of this, coal-pits of confiderable depth have been funk in a feam of coal from top to bottom without going out of the coal the whole depth, either into the roof, which is upon one fide, nor into the pavement, which is upon the other fide

of

of the ſeam of coal; and this is the cleareſt proof imaginable of their being in a vertical poſition, as theſe pits are ſunk by a plumb line perfectly perpendicular.

I hinted before, that the ſuperficies of a conſiderable number of theſe ſtrata are cut in the ſide of the high road from Edinburgh to Dalkeith, near Edmondſtone, where they likewiſe appear to ſtand in a vertical poſition; and this place is about half a mile ſouth-weſt from the Bank. At Gilmerton, which is more than a mile ſouth-weſt of the Bank, the greateſt number of the edge-ſeams decline much about the angle forty-five, though ſome of the ſouthmoſt of the coals are higher, but then ſome of the northmoſt of them are lower, and therefore I reckon the angle forty-five to be the medium dip in that ground.— Some of theſe coals are pretty near to one another, and others of them are farther aſunder; but the northmoſt of all the ſeams which have been worked is much farther off than any of the reſt, that is, there is a much greater diſtance betwixt this ſeam and the next workable coal to the ſouth of it, than there is betwixt any other two ſeams in the whole field; and, as they ſtill flatten by degrees, the farther north we advance, this coal, which is called the North-green ſeam, is conſiderably flatter than the reſt, eſpecially towards the north-eaſt end of the coal field, which is about a mile long upon the bearing of the coal. In the fouth-weft end of this field, the North-green feam ftands as much on edge as the reft of the coals. About the middle of the field it is fomewhat flatter than any of them, and in the north-eaft end it is confiderably flatter, and, of confequence, the feam ftretches farther out towards the north-weft. In one place near the north-eaft end of that field, this coal firft falls quite flat, and afterwards falls quite over, fo as to dip towards the north-weft, which is diametrically oppofite to the real true dip or line of declivity, which is towards the fouth-eaft; and the North-green feam continues in this north-weft declivity a confiderable way over the ordinary line of the crop of this coal.

This tongue of the North-green feam is about half a mile broad, but it ftretches away towards the north-weft more than half a mile over the ordinary line of bearing. The coal and other ftrata in this place fall over in a kind of trough, fo that the middle of the tongue is by far the deepeft part of it; and it rifes and crops out upon both fides, that is, towards the fouth-weft and towards the north-eaft, fo that there is a dip or declivity from both thefe fides towards the middle of the trough, and the middle of the trough dips away towards the north-weft.

Perhaps

Perhaps I may not be perfectly underſtood in pointing out theſe different dips; but as Gilmerton is near Edinburgh, young gentlemen can go out and inveſtigate circumſtances upon the ſpot, which is very practicable, as a fine lime-quarry lies below this coal, and the quarry is wrought upon both ſides of the tongue; and as the quarry dips and riſes juſt as the coal does, the various declivities mentioned will be eaſily traced out.

Gilmerton lime-quarry is worked under ground by leaving pillars to ſupport the incumbent weight of the rock above; theſe ſubterranean lime-works are ſingular and extenſive, and their magnificent appearance ſtrikes the imagination with a pleaſing awe and aſtoniſhment.

Slips in edge-ſeams throw them more to one ſide than up and down. There is a large ſlip about the middle of the coal-field at Gilmerton, which throws the coal upon the weſt ſide of the ſlip, about one hundred and ſixty yards farther ſouth than they are upon the eaſt ſide of it. At firſt ſight, this may appear as a deviation from the true line of bearing, but I reckon very little upon ſuch a ſlip, becauſe another ſlip may throw the coals as far to the north as this has thrown them to the ſouth.

Theſe variations in the lines of the bearing and declivity of the edge-ſeams are ſufficient to ſhew, that there is perhaps no ſuch thing as a long

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ſtretch of the ſtrata of coal any way in a ſtraight line, without ſome deviations in the lines of declivity and bearing, and yet theſe run in as ſtraight a line as any that can be pointed out in the country; and, moreover, what I obſerved above, will generally hold true in all coals, viz. that the greater the ſlope or declivity of the coals and coal metals, the truer and more regular they will be found, both in the line of declivity and in the line of bearing; but, in general, ſo much the worſe for the community, becauſe the coals dip down ſo ſuddenly out of our reach, that we can work but a ſmall quantity of them in compariſon of the flat broad coals, and eſpecially in compariſon of ſuch flat coals as in ſome places wave and wheel over a great extent of country.

There are yet other deviations from the true line of the bearing of edge metals, and ſuch as have a conſiderable degree of ſlope, beſides the two inſtances now mentioned. I have frequently ſeen them bend like an elbow, and then run in another direction from the former line of bearing. As thus, ſuppoſing the line of bearing to be ſouth-weſt as you advance along this line, you come to a place where the ſtrata bend backward and turn away to the weſt, and ſometimes towards the north-weſt. But the ſtrata in theſe deviations do not always bend backwards. They ſometimes turn the contrary way, and from a

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ſouth-weſt direction come to point towards the ſouth, and even towards the ſouth-eaſt. Theſe bendings in the line of bearing of the edge coals are exceedingly various. Sometimes they only bend a little either towards the weſt or towards the ſouth, with an angle ſo obtuſe, that it is ſcarcely diſcernible at firſt ſight, and ſometimes they take a quicker and more ſenſible turn; and again, they are not all alike in reſpect to the manner of turning. In ſome of them the ſtrata come about with a gentle, eaſy bend or ſweep, and in others they turn ſhorter, either with an obtuſe or a right angle, and after theſe turns, the ſtrata bear away towards the new point which they have gained by the turn ſometimes to a conſiderable diſtance; but it is not common for them to ſtretch very far upon this new tack before they turn again and come into their former line. When theſe traverſes in the line of the bearing of the ſtrata are ſhort, that is, when there is but a ſhort diſtance between the ſeveral angles or turnings, it would be exceeding difficult to work a ſeam of coal in ſuch ground.

I have ſeen upon the ſea-ſhores, and in other places where the ſtrata were laid bare, ſome of theſe traverſes or angles ſo near to one another, that it would be impracticable to work coal in them, the ſtrata in that caſe being too much diſtorted and broken by being ſo often turned and

twiſted

twiſted to and fro; but when there is a conſiderable diſtance between each turn or angle, the ſtrata are generally as perfect between the turns as in any other place, and in that caſe coals may be wrought very well. The edge-ſeams of Gilmerton and Loanhead, &c. have ſome of theſe bendings in the line of bearing, and that both backward and forward, that is, in ſome places they bend a little backward, or towards the weſt, and in other places they bend a little forward, ſo as to point more towards the ſouth than before; but there is no turn in theſe ſtrata between Duddingſtone and Carlops ſo conſiderable as to come any thing near a right angle.

A great deal may be ſaid hereafter for the information of the public about the inferior and the ſuperior, or the nether and upper ſtrata of coal.

It may perhaps in time be found, that the inferior coals have a greater degree of ſlope, and are more regular in the line of bearing than the ſuperior coals; and, on the contrary, that the ſuperior ſtrata of coals are generally more flat and horizontal than the inferior; and that they more frequently wave up and down, and float near the ſurface over the face of the coal countries.

But as this part of the natural hiſtory of the ſtrata of coal leads into abſtruſe diſquiſitions, and as the thought is but new to me, having had as yet

yet neither time nor opportunities of inveſtigating circumſtances with a view to aſcertain the fact, I muſt at preſent drop the point, and leave it to be examined by others.

All that I can ſay to it juſt now is, that there are claſſes or arrangements of edge coals, with their concomitant ſtrata, at Gilmerton, &c. to the ſouth of Edinburgh, and there are a number of flat ſeams of coal, with their concomitant ſtrata, lying to the ſouth of the edge-ſeams, and running parallel to them all the way from the ſea-ſhore near Muſſelburgh, as far up the country as the edge-ſeams ſtretch in the line of bearing, which is, as I hinted before, about ſixteen miles.

I have in ſeveral places ſeen the point of contact, or rather the line of contact, where the ſouth ſide of the edge metals join to the north ſide of the flat metals or ſtrata; and, in other places, where I have ſeen them join, both the edge and the flat ſtrata appear in full perfection; that is, they are both of them firm and good, without any confuſion or diſorder, and the flat metals are immediately flat, and the edge metals are immediately on edge, where they come in contact with one another. It is generally ſuppoſed by thoſe who underſtand theſe matters in the Lothians, that the edge-ſeams do ſtretch way under the flat coals, and alſo under the valley at Dalkeith, and that they riſe up again about five or ſix miles to the south-east of Gilmerton, &c. where they begin to dip down precipitately towards the south-east.

It must be confessed that this hypothesis is very plausible, but to me it is very doubtful, and, therefore, I will leave it as a doubt, although I have very good reasons to suspect that the edge seams do not rise again from under the flat coal towards the south-east. I have been hitherto very careful not to admit or introduce any thing into the natural history of the coal, but what I was certain of being truth from my own observation and experience, and I am resolved to keep strictly by the same rule for the future.—Whatever faults, whatever imperfections may be found in these papers, and perhaps there will be plenty of both, yet I am resolved that there shall be none in point of truth. I will not introduce hypothetical conjectures as matters of fact.

The next question relating to the history of coal, which falls naturally to be examined, is the extent of coal fields or coal countries.

Many are of opinion that the strata of coal keep their course in general in the line of bearing quite through the island, and perhaps round the globe.

I have heard coal-masters of great knowledge, and who were, moreover, men of sound judgment,

ment, aſſert, that the coals and coal metals ſtretch away in under the mountains, and emerge again upon the other ſide, and keep their courſe, or trend in general to a certain point; and this was once my own opinion,—but it was my opinion when I had not ſo much knowledge and experience as I have now acquired; for I am now fully perſuaded of the contrary, and my perſuaſion is founded upon the cleareſt conviction—from a full demonſtration of the truth; and this conviction I obtained by many obſervations—by frequently examining the ſame claſs of circumſtances in many and in diſtant places, all of which agree and amount to a full proof in point.

In refutation of an opinion ſo generally received, I reckon that nothing ſhort of a clear demonſtration of matter of fact is ſufficient, as one man's opinion is as good as another's; and therefore, in order to decide this point, I will recapitulate and examine ſome of thoſe circumſtances.

I obſerved above, that I was formerly of opinion that the coals, and their concomitant ſtrata, did puſh their way under the mountains, and emerged again upon the other ſide. But as I have been long and much in the practice of viewing and examining all circumſtances in my power, relating to the ſtrata which form the ſuperficies of our globe, I was reſolved thoroughly to inveſtigate this point. In order to which, I carefully examined ſeveral places in diſtant parts of the country where the coal metals end, and thoſe of the mountain rocks begin, in expectation of ſeeing the coals and coal metals thrown down, and the other claſſes of different ſtrata riding above them; but I never could obſerve any ſymptoms of this being the caſe in any one place I examined; on the contrary, I every where ſaw the cleareſt demonſtration of the coal and coal metals being upmoſt, and of the other different ſtrata puſhing in below them. I have in ſeveral places ſeen the coal metals, where they approached the ſide of a hill, or any other place where different foreign ſtrata commenced, diſcover great irregularity; and when they came in contact with the foreign ſtrata, the coals and coal metals were evidently thrown up, and in the higheſt degree of confuſion and imperfection imaginable, ſo that the coal appeared to be no better than droſs or ſoot, and the hardeſt ſtones among the concomitant ſtrata no better than rubbiſh or ſand; whereas, on the contrary, the new or foreign claſs of ſtrata emerged from under this confuſed imperfect maſs in full perfection of quality and regularity of ſtrata. In ſome places where the ſeams of coal and their concomitant ſtrata approached the outſkirts or extremity of the coal country, I have ſeen the coal ſeams firſt begin to grow thin and troubled, even at a conſiderable diſtance,

and

and then, as they advanced nearer the extremity, grow more and more troubled and diſtorted, and at laſt, when they arrived at the extremity, the coal ſeams of ſeveral feet thick were ſqueezed and dwindled away to hardly as many inches, and the coals, with their concomitant ſtrata, forced round, quite out of their natural courſe, ſo as to croſs the true line of bearing at right angles, but in the higheſt confuſion imaginable, and entirely uſeleſs; whereas, on the contrary, thoſe different ſtrata, which commenced inſtead of the coal metals, were perfectly regular and good, and trending away in the true line of bearing to the point the coal metals trended to before they were thrown out of the ground, and loſt their courſe.

Now, it is impoſſible to have a clearer proof of the extremity of the outbounds of a coal field than what I have pointed out. I have ſeen this change commence in low ſituations, at ſeveral miles diſtance from any mountains or hills, in the true and real line of bearing, both of the coal metals and of other different ſtrata; and I have ſeen ſtill lower ground farther forward in the ſame line, after the new ſtrata commenced, than where the change took place; and in this lower ground the new range of ſtrata appeared in a great many places, keeping the ſame regular courſe or line of bearing which the coals and coal metals had loſt.

As local examples are moſt convincing and demonſtrative in ſuch diſquiſitions as theſe, I will give an eminent inſtance of this not far from Edinburgh, which may be examined by mineral ſtudents, and when they have thoroughly inveſtigated it, they will find it a clear and ſatisfactory proof of what I have advanced upon this point.

I have already mentioned and deſcribed the edge coals to the ſouth of Edinburgh, and ſhewed, that the north-eaſt end of this claſs of coals, with their concomitant ſtrata, appear firſt in our ſight upon the ſea-ſhore at Eaſter Duddingſtone, and that they trend away from thence towards the ſouth-weſt by Gilmerton and other places for about ſixteen miles, and there is not perhaps one quarter of a mile of the whole ſixteen where theſe coals have not either been wrought, or elſe are to be ſeen croſſing the rivulets which run down from the Pentland hills right acroſs the ſuperficies of theſe ſtrata.

Many of theſe ſeams of coal are either now working or have been wrought at Duddingſtone, Niddry, the Bank, Edmondſtone, Drum, Gilmerton, Melvill-Moor, Loanhead, Dryden, Greenlaw, Cooking-Parks, Pennycuik, and Newhall. All theſe places are ſet down in the order of their ſituation as we advance from Duddingſtone towards the ſouth-weſt; and Newhall, which is the

laſt

laſt mentioned, is at leaſt ſixteen miles from Duddingſtone. The lands of Newhall are about two miles long upon the line of bearing, that is, from north-eaſt to ſouth-weſt. The edge coals are ſeen in perfection about the middle of thoſe lands, only, that the greateſt number of the ſeams are thinner here than farther eaſt; and at the place or manſion-houſe of Newhall, which is a little farther ſouth-weſt than the middle of the ground, ſome of the edge ſeams have been wrought, but they were found there much troubled and in conſiderable diſorder; and leſs than half a mile farther ſouth-weſt than the place or manſion-houſe of Newhall, theſe coals arrive at the utmoſt boundary or extremity of the coal field in the line of bearing. The bridge of Carlops over the North Eſk, is about half a mile weſtward from the houſe of Newhall. About a hundred yards, or a little more below this bridge, the river begins to run acroſs the ſuperficies of theſe coals and their concomitants in a diagonal direction. The lands of Newhall are upon the north, and the lands of Carlops upon the ſouth ſide of the river where it runs acroſs the coals.— The banks of the river in that place are very high, and the ſtrata of coals and coal metals are ſeen diſtinctly from both ſides, and likewiſe in the bed of the river. The north bank of the river upon

upon the Newhall fide is much higher than the fouth or Carlops fide; and in this north fide we fee many of the feams of coal and their concomitant ftrata, but we fee them in fuch diforder and confufion as is not eafy to be defcribed.

In fome parts of that north bank of the river, the ftrongeft poft-ftone and the foft coal metals are twifted and blended together into a perfect chaos, and in other parts of the bank where fomething like ftrata is to be feen, both the coals and their concomitant ftrata have been fo fqueezed, twifted, and degenerated as to be rendered entirely ufelefs. About eight or ten miles farther north-eaft, fome of thefe feams of coal are up to fix, feven, or eight feet thick, and one of them, called the great feam, is in fome places about fourteen feet thick; but where thefe capital feams of fine coal crofs the Efk betwixt Newhall and Carlops, there is not any of them regularly up to one foot thick; the moft of them are only four or five inches, and fome of them much lefs: all thefe coal feams, with their concomitant ftrata, are fqueezed and diftorted into the greateft confufion and diforder, and they are fqueezed together into much lefs room in the line acrofs the ftrata, and, moreover, they are turned from the fouth-weft to a foutherly direction. About a quarter of a mile farther forward, towards the fouth, they com-

plete

plete the turn to a right angle, that is, the courſe is changed from a ſouth-weſt to a ſouth-eaſt line of bearing.

The river Eſk iſſues out from among the Pentland hills, immediately at the bridge of Carlops; and it is remarkable, that the rocky baſe of the ſouth ſide of thoſe hills comes down cloſe to the river ſide, immediately below the bridge, and continues cloſe to it for about three hundred yards farther down; and in that very place the ſouth-weſt line of the edge metals, which is the true line of bearing, glances in a ſlanting direction againſt the ſide of the baſe of the hills.

Now, if the coals really immerged and paſſed away under the mountains, we ſhould certainly loſe ſight of the edge ſeams in this place; but the fact is, that we do not loſe ſight of them: On the contrary, we evidently ſee them riſing up and cropping out, inſtead of being immerſed under the hills; and, moreover, we evidently ſee that the outburſts or crops of them are ſqueezed and diſtorted, and thrown into endleſs confuſion, where they come in contact with the baſe of the hills; and we alſo ſee the crops of them turn away towards the ſouth and ſouth-eaſt, in a right angle to the former line of bearing; and all this is as evident as ocular demonſtration can make it.

I have already obſerved, that there are horizontal coals, with their concomitant ſtrata, immediately upon the ſouth ſide of the edge coals; and that theſe flat coals run parallel to the edge coals all the way from the ſhore of the Forth, as far to the ſouth-weſt as this claſs of ſtrata are found to ſtretch. Some of theſe flat coals are found in the lands of Carlops in their proper ſituation, parallel to the edge coals; however, they go no farther in the line of bearing; but theſe, as well as the edge coals, are alſo found to crop out towards the ſouth-weſt, or former line of bearing, and the crops of them likewiſe turn away gradually to the ſouthward, with a gentle ſweep round, until they at laſt gain a ſouth-eaſt direction; but it is obſervable, that theſe flat coals are not thrown into ſuch confuſion and diſorder at the turn and extremity of the field as the edge coals, becauſe they are at ſome diſtance from the root of the Pentland hills, which comes in contact with the edge metals, and diſturbs and throws them up, and out of their true courſe, a little before they arrive at the extreme boundary of the coal field.

Now, the fact of the flat metals turning from a ſouth-weſt to a ſouth-eaſt direction, is evident to ocular demonſtration two different ways.

Firſt, the crops of the flat coals, and of the lime-ſtones which accompany them, are ſeen and wrought in ſeveral places upon the turn, and after they have gained a ſouth-eaſt direction;—and, ſecondly,

ſecondly, Other rocks of quite a different quality are ſeen in a great number of places in lower ground in the former or ſouth-weſt line of bearing, viz. in the river Line, and ſeveral other places round the village of Linton, and in a great number of places, over a large extent of country to the ſouth and weſt of Linton.

I have traced the crops or outward extremity of theſe coals, and their concomitant ſtrata, more than fifteen miles from Carlops, upon the ſouth-eaſt bearing, and ſee evidently that they do not immerge under cover, and ſtretch away again any where towards the ſouth; on the contrary, they are ſeen to crop out in the farm of Carlops, and likewiſe in the lands of Magbiehill, to the ſouth of Carlops. They are alſo ſeen to crop out upon the ſouth ſide of the Wheem, which is ſtill farther eaſt; and, afterwards, they crop out over a great extent of pretty high moory ground, betwixt the Wheem and the foot of the Moorfoot hills, to the ſouth of Arniſton, where I do not know the names of particular places.

Now, in all this extent of country, ſtrata and rocks, of a quite different quality from the coal metals, are every where ſeen immediately upon the outſide of the crops, or outburſt of the coal metals; and, moreover, as a farther proof that they do not any where ſtretch away towards the ſouth-weſt, the river Line runs nearly

nearly parallel to them, and in much lower ground; and this river washes the superficies of the strata all the way from the Pentland hills, down until it falls into the Tweed, and afterwards the Tweed washes them clean to Peebles; and in all that distance, which is near twenty miles, nothing but strata of the mountain rocks appear, which are entirely of a different quality from the coal metals; and all the rivulets and broken places of the surface, all along upon the south and west side of the extremity of the coals, discover the same sort of strata as are seen in the rivers Line and Tweed. Thus far I have seen the trending and outburst of the coal strata; and thus far I can answer for the truth of my observations.

To the south and south-west of Arniston, the flat coal metals approach the north-west side of the Lammer or Moorfoot hills, and there they turn first to an easterly, and then, by degrees, to a north-east direction; and they afterwards continue to crop out to the south-east, and to trend towards the north-east, until they immerge into the Forth, to the west of North Berwick. There are a few miles of this course from the skirts of the Moorfoot hills, south of Arniston, to Blackshiels, which I have not seen; but from many circumstances too tedious to be explained, I am confident that the flat coals crop out to the south-

east

eaſt in that ſhort extent, as well as all the reſt of the extremity of this coal field; all round the moſt of which, I have not only ſeen, but have minutely examined all circumſtances in it relating to the extent, bearing, and declivity of the ſtrata of coals and coal metals.

From what I have advanced upon this head, I think myſelf fully authorized to make the two following inferences or concluſions, which are naturally ſuggeſted as the reſult of theſe reſearches and obſervations, viz. Firſt, it evidently appears, even to ocular demonſtration, that the coals and coal metals do not immerge under the high mountains, ſtretch away through beneath them, and riſe again upon the other ſide of them;—and, ſecondly, it alſo appears evident to ocular demonſtration, that coal fields or coal countries are but patches of limited, though different dimenſions; ſo that the extent every way of the coals, and their concomitant ſtrata, wherever found, may very aptly be called the coal field, as different fields of corn or graſs are of different dimenſions, but ſtill they all have their limits.

The Mid-Lothian coal field is nearly a ſquare of about fifteen miles over every way, though it is not an exact ſquare. The frith of Forth is the boundary of the north end of this ſquare. The weſt ſide of it trends away from the ſhore of the Forth near Duddingſtone, towards the ſouth-weſt,

weſt, in a line almoſt parallel with the Pentland hills; but this line, by ſlow degrees, approaches nearer to the ſouth-eaſt ſide of thoſe hills as it advances weſtward, until at laſt it comes in contact with the baſe of the hill at the bridge of Carlops; and this line, from the ſea-ſhore to the bridge of Carlops, is about ſixteen miles long, and there that line and that ſide of the coal field ends.

From Carlops, the coals and the coal metals trend away in a ſouth-eaſt direction to the ſkirts of the Moorfoot hills, pretty nearly, though perhaps not exactly in a ſtraight line; and I ſuppoſe that the diſtance betwixt Carlops and the Moorfoot hills in that line, will be about fifteen or ſixteen miles.

From the point where the coal metals approach thoſe hills, they trend away in a north-eaſt direction, parallel to the line from Duddingſtone to Carlops; and this north-eaſt line continues until the coals and coal metals immerge into the Forth, a few miles weſt of North Berwick. I do not exactly know the length of this ſouth-eaſt ſide of the coal field, but I evidently ſee that it is ſomewhat longer than the north-weſt ſide, which runs parallel to it.

The public road to England from Edinburgh by Dalkeith and Blackſhiels, runs almoſt in a right angle acroſs this coal field. I think it is fifteen

teen miles from Edinburgh to Blackſhiells. The coal field commences upon that road about two miles ſouth of Edinburgh, and it ends near Blackſhiels. Coals have been wrought near that place upon the north ſide, and I have evidently ſeen the mountain rocks a little way ſouth of Blackſhiels; and, therefore, the ſouthern extremity is thereabouts, ſo that the line acroſs the coal field upon this road is about thirteen miles long. The line acroſs it, upon the road from Leith to Haddington, is likewiſe about thirteen miles, and a line drawn acroſs this coal field farther weſt, would come to be much about the ſame length, which ſhews, that this coal field is about ſixteen or eighteen miles long upon the line of bearing, and about twelve or thirteen miles broad in a line at right angles acroſs the bearing of the ſtrata; but it ſhould be remarked, that we cannot determine the real length of this coal field upon the line of bearing, becauſe the north-eaſt ends of the coals immerge into the ſouth ſide of the frith of Forth.

I have perhaps been a little tedious upon this head; but it is once for all. I know the extreme boundaries of other coal fields with as much certainty as this, but I will not meddle with them in the preſent inveſtigation; becauſe, I think it would only be travelling the ſame ground over again to no purpoſe, all the material circumſtances being ſimilar.

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The one I have pointed out is near Edinburgh, and, therefore, the truth of every circumſtance may, in future, be thoroughly inveſtigated by young gentlemen who engage in theſe ſtudies. And, moreover, the reſult of my enquiries about the Lothian coal fields eſtabliſhes two important points in the natural hiſtory of coal, viz. Firſt, that every coal field is of limited extent and dimenſions, and that the coals crop out to the ſurface of the ground, or at leaſt to the ſuperficies of the ſtrata, every where quite round the coal field; and, therefore, ſecondly, the coals do not ſtretch away under our high mountains, and emerge again upon the other ſide of them. The real extent of all other coal fields in the iſland may be traced out and determined as well as this of Mid-Lothian.

From Eaſter Duddingſtone to Carlops, the crop, or outburſt of the coals, trends towards the ſouth-weſt; but from Carlops to the foot of the Moorfoot hills, the outburſt, or crop of the coal, trends towards the ſouth-eaſt, at right angles to their former courſe. However, in this ſouth-eaſt line, from Carlops to the Moorfoot hills, other ſtrata, of quite different quality from the coal metals, emerge from under the outburſt, or crop of the coals and coal metals, and trend away towards the ſouth-weſt, in the exact line of bearing which the coals loſt at Carlops, which is the true line to which

which the ſtrata trend in general through this iſland; and it is to be obſerved, that the ſtrata of the mountain rocks are found immediately in full perfection of quality and regularity of ſtrata when they firſt appear from beneath, and immediately to the weſtward of the coal metals, and the line of bearing of thoſe foreign ſtrata is immediately perfect ſo ſoon as they are ſeen; from which circumſtance, in conjunction with many others, it evidently appears to me, that the coals and coal metals were among the laſt formed of the ſtrata which compoſe the ſuperficies of our globe, at leaſt in this part of the world; but I will not enter upon ſuch abſtruſe diſquiſitions here. It is my intention to keep as cloſe as I can to the inſtructive parts of the natural hiſtory of the coals and the coal metals.

I imagine that I have already been abundantly particular and explicit in proving that the coals and coal metals do not puſh their way through beneath the mountains, and emerge again upon the other ſide of them; and in proving that the coal fields are but limited patches, the extent and boundaries of which may generally be traced out and aſcertained, an inſtance of which I have given in the coal field of Mid-Lothian.

As all I have yet produced upon that head is of the nature of direct and poſitive proof, I will now beg leave farther to point out a few other circumſtances which immediately relate to the ſubject, and may be conſidered in the light of collateral proofs of the double point under conſideration.

With reſpect to the coals diving through beneath the mountains, and emerging again upon the other ſide, it is perhaps very rare, if ever, we find them upon the other ſide of a mountain, compoſed of ſtrata altogether different from the coal metals, in the true line of bearing; and if ſuch a thing ſhould happen, there is yet, beſides all that has been ſaid upon this head, another ſubſtantial objection to their being the ſame coals and coal metals. I never yet ſaw, and I am perſuaded that no other perſon has yet ſeen, the ſame claſs of coals and coal metals in any two fields, ſo diſtant from one another as upon the oppoſite ſides of great ranges of mountains. Such claſſes of coal ſeams, and their concomitant ſtrata, would be perfectly well known again by men of ſkill and experience, by their number, quality, thickneſs, poſition, or ſtations one above another, and by many other characters. In ſhort, they would be as well known by an obſerving coalmaſter, as a family of children and domeſtics would be known by the maſter of the houſe, if he accidentally ſaw them arranged at dinner in ſome diſtant

tant part from home; but the truth is, that we never ſee the very ſame coals, &c. in any two very diſtant coal fields, much leſs upon the oppoſite ſides of ranges of mountains.

But, in order to throw all the light I can upon this ſubject, and to place it in as clear a point of view as poſſible, it may be proper for me to diſtinguiſh the difference between a real range of mountains properly ſo called, through or under which the coals do not paſs, and ſuch leſſer hills as are frequently found diſperſed here and there, within the limits of the coal field or coal country.

A range of mountains, properly ſo called, are generally compoſed altogether of various mountain rocks, that is, of ſuch different rocks and ſtrata as ſeldom or never accompany coal, and among which no ſeams of coal are ever found; theſe mountains are generally of greater dimenſions in height, breadth, and length than ſuch leſſer hills as are ſometimes diſperſed through the coal country. What I call the leſſer hills, which are often found dropt here and there within the limits of a coal field or coal country, are generally compoſed of ſuch rocks and ſtrata as very frequently accompany coal; and ſometimes the coal ſeams ſtretch away in the line of bearing quite through theſe hills.

Such gentlemen, and even ſuch philoſophers and naturaliſts as are not proficients in this

ſilence,

ſcience, may be led to imagine, from the rugged craggy appearance of ſome of theſe leſſer hills, that they are compoſed of materials altogether foreign from coal; and as coal is frequently found upon both ſides of ſuch hills, they perhaps may be led to conclude, that the coals and their concomitants dive down and ſhoot away under the hills, and emerge again upon the other ſide; but this is one of thoſe haſty concluſions, when too much is taken for granted, before all circumſtances have been inveſtigated, which are but too numerous in matters relating to the mineral kingdom. If they would take the trouble thoroughly to inveſtigate circumſtances, they would generally find, that although theſe hills ſhould in ſome places exhibit externally a rugged and formidable appearance, they are nevertheleſs compoſed of ſuch rocks and ſtrata as are frequently found to accompany coal. Such, for inſtance, are many thick beds or ſtrata of baſaltes, commonly called whin rocks, which are frequently found in the coal fields of the Lothians, Fife, and other parts of Scotland. Now, theſe ſtrong beds of rock are not only found in the coal countries, or in the neighbourhood of coal fields; they are alſo frequently found both above and below ſeams of coal, and coal pits are frequently obliged

to

to be ſunk through them, as at Borrowſtounneſs, Bathgate, &c.

It is remarkable of the baſaltes, as well as of ſome other very hard and ſtrong rocks, that although they are found diſpoſed in beds or ſtrata, with other regular ſtrata above and below them, yet the baſaltes are often found very thick and very irregular in the thickneſs of each ſtratum. In one place, a ſtratum of this rock ſhall not be above two or three fathoms thick, and farther forward upon the line of bearing, it ſhall be found two or three times, perhaps in ſome places more than ſix times as thick. The baſaltes frequently ſwell greatly in thickneſs, and riſe up from a plain to a conſiderable mountain, as the beds of it advance in the true line of bearing.—The ſame phenomenon frequently happens to ſtrong beds of the mountain lime-ſtone. I have in many places ſeen the lime rocks ſwell out, and dwindle again from two or three fathoms to more than a hundred fathoms thick.

An inſtance of coal ſeams, and their concomitants, ſtretching through ſome rocky rugged hills, may be ſeen in the Bathgate hills, in Weſt Lothian. Theſe hills in ſome places are remarkably craggy and rugged, and of conſiderable height and extent; nevertheleſs, they are entirely compoſed of coal metals, and ſeveral ſeams of coal ſtretch quite through the whole breadth of thoſe hills,

hills, from ſide to ſide; and ſome of theſe ſeams have not only been wrought upon both ſides, but they have alſo been wrought up the ſides, and in ſeveral places upon the ſummit of thoſe hills.—There are in the ſtructure of theſe hills, beſides the ſeams of coal, ſtrata of free-ſtone, blaes, and other conſtant attendants of coal, ſeveral beds of lime-ſtone, of the coal metal ſpecies; and there are alſo ſeveral ſtrong beds of baſaltes, which in ſome places riſe up to a conſiderable height, and give ſeveral parts of theſe hills a rough and formidable appearance, and I know that ſeams of coal riſe up among the higheſt craggs of theſe hills.

I have already pointed at the columnar baſaltes to be ſeen in theſe hills, and, therefore, it is unneceſſary to ſay any thing farther upon that ſubject here.

In the inſtance of the Bathgate hills, and of many others that might be produced, we evidently ſee that the coals do not dive away under the mountains, and emerge again upon the other ſide. If they paſs through mountains at all, they ſtretch up to the ſummits of them, along with their concomitant ſtrata,—are a proportion of the conſtituent parts of the compoſition or conſtructure of ſuch mountains, and the ſuperficies or crops of the coal ſeams riſe up to the day, whereever they ſtretch into or through ſuch mountains.

With

With respect to the supposition of the coal seams stretching away in the line of bearing, I know not where or how far, it may be remarked, that there are but very few coals as yet discovered in Ireland, although the numerous seams found in Cumberland and those of Ayrshire point towards that island, as well as those of Lancashire and North Wales, and many of them are known to immerge into the ocean upon the British side, but they are not found to emerge again upon the Irish side of the water. If these British seams of coal continued in the line of bearing, as many confidently assert, they should emerge out of the ocean upon the other side, and appear again upon the Irish shores, there being neither mountains nor hills by the way in the line of bearing to conceal them from discovery. I have not heard of any coals being found in the Isle of Man, which is much nearer than Ireland. But I need not insist upon this topic. The matter of fact is abundantly evident, even to ocular demonstration; and whoever examines circumstances in all parts of the countries he is best acquainted with, will see abundance of instances in proof of what I have advanced upon the subject.

This history of the strata of coal has been tedious, but I think it may be singularly useful. The knowledge of truth in all cases must be use-

ful,

ful, and eſpecially when it is likewiſe the knowledge of nature.

From the tenor of the above diſſertation upon the diſpoſition, ſtretch, and bearing of the ſtrata of coal through a country, there is one very important leſſon that may be treaſured up by every perſon concerned, who is at pains to examine and inveſtigate the ſubject, namely, that it is not prudent, that it is often dangerous, to lay out large ſums of money in trials for coal at any conſiderable diſtance from the place where the coal is ſeen and known, upon the faith of the ſtrata continuing the ſame ſtretch and line of bearing invariably; and that before we begin upon an expenſive plan, we ſhould procure a perfect hiſtory of the concomitant ſtrata which are found above and below the coal; and if we fail to diſcover and to recognize them with ſufficient certainty, we have good reaſon to ſuſpect that the coal is thrown off its ordinary ſtretch and level, or out of its ordinary courſe or line of bearing, by ſome of the many accidents which I have deſcribed above. If they cannot find ſeveral of the particular ſtrata which accompany the coal in the field where it is ſeen and wrought, and in the ſame order, one above another, as in the former field, it is quite out of nature to expect to find the ſame coal without them; and even though they diſcover ſtrata which appear like them, it will

will not do, unlefs they be really the very fame. There is often a very near refemblance in the appearance and characters of particular ftrata in quite different fields, and fometimes in different places of the fame field; yet there is always fuch difference either in the particular ftratum itfelf, or in fome of thofe immediately above or below it, as will be readily diftinguifhed by a fkilful eye.

This leffon may be of fingular ufe to fuch gentlemen as are perfuaded that there is abundance of coal in their eftates, becaufe their lands are fituated in the line of bearing towards which the coals trend, which are now working at fome diftance, perhaps two or three miles off. The want of fufficient knowledge in thefe cafes, frequently occafions many blunders, much needlefs expence, and fubfequent vexation, when their fanguine, but ill-grounded hopes are fruftrated.— They fhould either fee the coal itfelf, or feveral of the known concomitant ftrata, before they make themfelves fure of a coal which is wrought in their neighbourhood at a confiderable diftance, and where no coal is near to juftify a prefumption of its being in the place defired; they fhould either fee the outburft or crop of fome coal, or at leaft, they fhould fee feveral of the known concomitants of a particular diftant coal, which points that way, before they proceed to expenfive trials, or indeed to any trials at all.

 Several

Several coal-maſters and other gentlemen who have paid ſome attention to this branch of natural hiſtory, are of opinion, not only that the coals ſtretch away under the mountains, and emerge again upon the other ſide, but alſo, that the ſeams of coal dive down to the center of the earth.— They ſee that all ſeams of coal have certain degrees of declivity, excepting only that in ſome places the coals and their concomitant ſtrata acquire a temporary flatneſs, or wave up and down with different dips for a ſhort ſpace; but they know very well at the ſame time, that theſe variations in the poſition of the ſtrata are only fleeting changeable incidents, and that in general they all decline leſs or more towards one particular point; and, therefore, from this true obſervation, they conclude, that all coals dip down to the center of the earth: But although I acknowledge the juſtice of the obſervation, that the ſtrata in general decline leſs or more in all coal fields towards ſome particular point, yet I cannot join with them in the inference. I am rather of the contrary opinion. I imagine that the coals and coal metals do not dive down to any very great depth; and I find myſelf obliged in this place to lay more ſtreſs upon my opinion than in any other part of this hiſtory, as I find it difficult to clear up the point to the conviction of every enquirer, by adducing obvious and ſatisfactory examples.

However,

However, I ſhall offer a few obſervations in ſupport of my opinion, after premiſing, that with reſpect to the center of the earth, two or three hundred fathoms, or two or three thouſand fathoms, are neither of them a great depth, in compariſon of the ſemi-diameter of the globe. It is but very rare that we ſink two hundred fathoms perpendicular into the ſurface of the earth, and two hundred fathoms, comparatively ſpeaking, is but a ſuperficial ſcratch, and, therefore, we are not enabled to form any judgment of this matter from the obſervations we can make below ground; and, as the queſtion is merely curious, I ſhall not be very anxious to defend my opinion by the obſervations which I have made above ground.

I obſerved before, when treating of the bearing and declivity of the ſtrata of coal, that ſome coal ſeams are known by real experience to crop out every way. I could produce many inſtances in point, but I incline to bring obſervations of this nature as near to Edinburgh as poſſible, where I hope that this branch of natural hiſtory will one day be publicly taught.

It has been remarked already, that the ſeams of coal, and their concomitant ſtrata, in the north-weſt ſide of the Mid Lothian coal field, dip towards the ſouth and ſouth-eaſt, and that the coals in the ſouth and ſouth-eaſt ſide of the ſame field dip to the oppoſite ſide of the compaſs, viz. to-

wards

wards the north and north-weſt. This fact is commonly known upon the north ſide of this coal field, and it is obvious upon the ſouth ſide of it, in the pariſh of Temple, and other places farther eaſt.

Now this does not look like the coals dipping down to the center of the earth. It rather looks like their declining a little way down from the ſurface of the earth to a ſufficient depth to be preſerved freſh and good, even in full perfection, until the exigencies of ſociety have occaſion for them, and that when they have declined down ſo far, they then become quite flat, and afterwards riſe again upon the oppoſite ſide of the coal field, with an oppoſite dip and riſe, and ſo form a great trough, reſembling a valley, which is one of the beſt ſimilitudes of the poſition of the ſeams of coal in a coal field as can be imagined.

Let us ſuppoſe, that the middle or loweſt part of the valley reſembles the deepeſt part of the trough of the coal. There are in ſome extenſive valleys ſeveral inequalities of ſurface, that is, little pieces of riſing ground, higher and lower places, which reſembles the waving of the ſtrata of coal up and down, and this way and that, when they turn flat or horizontal; however, when we have quite croſſed the valley, we always come to a ſenſible and a decided riſe or aſcent of the ground, which brings us out of the valley; and, from my own knowledge and obfervation, I am clearly convinced that this in general is the true defcription of the difpofition of the ftrata in every coal field, though perhaps it may not every where be an eafy tafk to inveftigate all circumftances, fo as to be enabled to prove the point to ocular demonftration.

Many more inftances in point, however, might be produced, befides the Mid Lothian coal field, but I will only mention one, which is likewife pretty near Edinburgh.

The range of coals and coal metals which are found upon the north fide of Dunfermline, and trend from thence by Halbeath, Sir John Henderfon's colliery, and farther eaft in Fife, decline at Halbeath, &c. towards the north or north-weft. There are a very great number of feams in the Fife coal field, which reach in length from Stirling to St Andrews, and I fuppofe that it is in fome places about ten miles in breadth. There is no better coal in any part of Scotland, either hard or foft, than in Fife. The fmithy coal of Balmule and Rofebank is the beft in Scotland as yet difcovered.

Now, all the feams in the fouth fide of this fine and extenfive field, dip with various degrees of flope towards the north or north-weft; and, as has been obferved of the Mid Lothian coal field, they wave up and down over a great extent of country, and at laſt they riſe again and crop out upon the north ſide of this coal field. If any ſhould doubt the truth of this aſſertion, let them examine circumſtances as I have done, and they will be thoroughly convinced. They may have an excellent opportunity of ſeeing this ſubject diſtinctly, and of clearing the point to their full ſatisfaction in the rivulet above the village of Dollar, and immediately below the magnificent ruins of Caſtle Campbell, where they will ſee the coal metals in the bed of the mill-lead, cropping out to the day, and dipping precipitately towards the ſouth, and the ſtrata of the mountain rock commencing and appearing immediately below the free-ſtone and other coal metals, and the very place where the different ranges of the coal metals and the mountain rocks come in contact, is there diſtinctly ſeen. Immediately above where the coal metals finally crop out, the rivulet emerges out of a deep, rocky, and impaſſable gulph below the old Caſtle, which place is every way a curious romantic ſcene.

The reſult of this inveſtigation refutes by inference another erroneous opinion concerning coal, which I have often heard aſſerted with great confidence, viz. that coal is inexhauſtible. That the fund of coal treaſured up in the ſuperficies of the globe, for the accommodation of ſociety, is very

very great, I readily acknowledge; but that it is inexhauſtible, in the proper ſenſe of the word, I deny.

Some portions of ſome particular ſeams of coal may be ſituated ſo deep below the ſurface of the ground, that it may be impracticable for man to work out all the coal in ſuch places, and of conſequence all the coal in ſuch particular ſpots never will be exhauſted; but ſuch a particular circumſtance, and ſuch a particular ſpot, does not imply that coals in general are inexhauſtible. I very well know, and when I come to explain the real origin of coal, I will make it appear, that the ſource of coal, or the matter of which it was formed, though copious, was limited in quantity, and, therefore, the quantity of coal is alſo limited, and the real ſource and origin of coal may juſtly be produced as a ſufficient reaſon why ſo many tracts of country, in many extenſive regions of the world, are abſolutely without any coal at all.

I have not the ſmalleſt doubt that the generality of the inhabitants of Great Britain believe that our coal mines are inexhauſtible, and the general conduct of the nation, ſo far as relates to this ſubject, ſeems to imply that the inexhauſtibility of our coals is univerſally held as an eſta-

bliſhed

blished fact. The conduct of the public says so in plain enough language. If it was not a generally received opinion, would the rage for transporting coals be allowed to go on without limitation or remorse? But it is full time that the public were undeceived in a matter which so nearly concerns the welfare of this flourishing island.

If our coals really are not inexhaustible, the rapid and lavish consumpt of them calls aloud for the attention of the Legislature, because the very existence of the metropolis depends upon the continued abundance of this precious fossil, and not only the metropolis, but also the existence of the other cities and great towns, and of the most fertile countries in the three kingdoms, depend upon the abundance of this valuable article; and, moreover, most of our valuable manufactures are in the same predicament, and, therefore, if our coal mines are not inexhaustible, it is high time to look into the real state of our collieries.

I feel in myself a strong reluctance against sounding the alarm to my country in a matter of so much importance. I am but an obscure individual, of very little consequence in the world, and I have not the least doubt that I shall be severely censured by many for my presumption, and therefore I proceed with sensible remorse; but it

is

is not guilty remorse; on the contrary, my heart tells me, that were I to temporize with my own feelings of reluctance, and to conceal a truth which so nearly concerns the welfare of the community, for fear of incurring censure, my silence would be unpardonable. I could wish that I did not find myself under the necessity of publishing a truth which perhaps may be disagreeable to many individuals; that there was the least foundation for supposing that I am mistaken; and that it could be made appear with any shew of truth, that our coal mines are inexhaustible; but, on the contrary, so far are our coal mines from being inexhaustible, that they are in many places already beginning to make quick advances towards being exhausted. I will not make use of much reasoning in support of this assertion. A few instances in point will be more convincing than a thousand arguments.

Mr Hume, in his History of England, and Mr Arnot, in his History of Edinburgh, place the first discovery of coal in this island about the middle of the thirteenth century, and it appears highly probable that they are right; Mr Whitaker places it much earlier in his History of Manchester, but his reasons or proofs are vague and unsatisfactory; and indeed such as are to be found in the present or former bed of every river, and in numbers of the gravelly tumuli in all the coal countries; and, therefore, I lay aside his pretended antiquity of this discovery.

As Mr Arnot has been at pains to trace out this subject, and to place it in a clear point of view, I will beg leave to quote a passage from his History of Edinburgh, concerning the first discovery and use of coal in Britain, before I proceed to give any hints of my own about the present state of our collieries.

" As the use of coal claims our attention, ' both by reason of its being the most valuable ' species of fewel hitherto discovered, and also ' an article of extensive and advantageous com- ' merce, we hope a short digression concerning ' its introduction will not be considered as im- ' pertinent. We enter upon it the more willingly, ' because we are fully persuaded that the use of ' coal was first known in the period we have de- ' scribed, and that the date of its origin may be ' brought within a very narrow compass."— " Necessity is said, not unaptly, to be the mother ' of invention. Had our remote ancestors known ' that a valuable inflammable substance was lod- ' ged under ground, the abundance of fewel ' which wood and turf afforded, would naturally ' prevent them from digging into the bowels of ' the earth for that which its surface so amply ' supplied them.

" Even

"Even when wood became very ſcarce at the
' diſtance of ſeveral centuries after the diſcovery
' of coal, the manner * of working it was ex-
' tremely rude, the progreſs and extent of the uſe
' of it ſlow and limited. The ſtatutes enacted by
' the Scottiſh Parliament, and the patents granted
' by the Kings, diſplay their ignorance in work-
' ing coal, ſet forth ſtrongly its decay, and guard
' anxiouſly its preſervation. In the beginning of
' the ſixteenth century, coal ſmoke † was deemed
' very pernicious, and even in the end of it,
' the uſe of coal in making ‡ of iron was
' hardly known in Scotland. If the progreſs in
' working of coal was ſlow, its firſt diſcovery was
' not very remote. Coal certainly was not diſ-
' covered in the middle of the twelfth; and it was
' as certainly known in the beginning of the
' thirteenth century. In the *Leges Burgorum*,
' which were enacted § about A. D. 1140, a par-
' ticular privilege is granted to thoſe who bring
' fewel into boroughs. Wood, turf, and peats
' are particularly mentioned, but with reſpect to
' coal there is a dead ſilence. But, in the year
' 1234,

* Mary Parl. 9. c. 84.

† Northumberland Houſehold Book, p. 21.

‡ Patent by James VI. *A. D.* 1594, in the Archives of the Earl of Balcarras.

§ Leg. Burg. c. 38.

' 1234, Henry III. of England * renews a charter ' which his father had given to the inhabitants of ' Newcaſtle, and in this renovated charter, he ' grants, upon their ſupplication to the perſons in ' whoſe favour the charter was conceived, licence ' to dig coals upon payment of L. 100 a-year, ' which is the earlieſt mention of coal in the ' iſland. By the end of the thirteenth century, ' the uſe of coal was ſo much advanced, that it ' was frequently brought by ſea carriage † from ' one port to another. But the firſt mention that ' is made of coal in any charter in Scotland is in ' a grant executed A. D. 1291, in favour of the ' Abbot and convent of Dunfermline ‡, of the ' privilege of digging coal in the lands of Pit- ' tencrieff, in the county of Fife.

" Æneas Sylvius, who afterwards aſſumed the ' Purple under the name of Pius II. viſited this ' iſland about the middle of the fifteenth century. ' He relates, " That he ſaw in Scotland § the " poor people, who in rags begged at the " churches, receive for alms pieces of black " ſtone with which they went away contented. " This

* Anderſon's Origin of Commerce, v. 1. p. 111.

† Statuta Gildæ, c. 44.

‡ Cartulary of Dunfermline, p. 80. Advocates Library.

§ Æneï Sylvii Opera, p. 443.

" This ſpecies of ſtone (ſays he), whether with
" ſulphur, or whatever inflammable ſubſtance it
" may be impregnated, they burn in place of
" wood, of which their country is deſtitute."

" And Boetius, in his Deſcription of Scotland,
' his native country, written in the beginning of
' the ſixteenth century, ſays, " There are black
" ſtones alſo digged out of the ground, which
" are very good for firing; and ſuch is their in-
" tolerable heat, that they reſolve and melt iron,
" and therefore are very profitable for ſmiths
" and ſuch artificers as deal with other metals *;
" neither are they found any where elſe (that
" I know of) but between the Tay and Tyne
" within the whole iſland."

" In China, it is probable that coal was diſco-
' vered long before it was known in the weſtern
' world.

" About the middle of the thirteenth century,
' a noble Venetian, in his Deſcription of China,
' obſerves, " That through the whole province
" of † Cathay, certain black ſtones are dug out
" of the mountains, which being put in the fire,
" burn like wood, and when kindled, they con-
" tinue burning a long time, in ſo much, that
" if

* Boetii Scotorum Regni Deſcriptio, p. 10.

† Marcus Paulus Venetus, Purchas's Pilgrim. v. 3. p. 28.

" If they are lighted in the evening, the fire will
" keep alive during the whole night. Many uſe
" theſe ſtones, although they have plenty of wood,
" the conſumption of fewel in ſtoves being very
" great."

" It is curious to obſerve the ſimilarity with
' which Marcus Paulus, Æneas Sylvius, and
' Boetius ſpeak of the ſame matter."

Upon the whole, we have little heſitation in fixing the diſcovery of coal to have been made between the middle of the twelfth and beginning of the thirteenth centuries.

Although it appears to be full 400 years ſince coal was firſt diſcovered in Britain, yet it is not above 200 years ſince it came into common uſe, and it is even leſs than 200 years ſince it came to be generally uſed in London.

Upon the firſt introduction of coal into London for common uſes, one or two ſhips was ſufficient for the whole coal trade; but from ſuch a ſmall beginning, they have gradually increaſed in number to ſeveral thouſand ſail of ſhipping in the coal trade, from the ports of Shields, Sunderland, and Blyth only, and ſome of them are of vaſt burdens, even up to a thouſand tons and more, and many of them make ſeveral voyages a-year, fully loaded with coals.

Such

Such a prodigious number of ſhips continually carrying coals from Newcaſtle, Sunderland, and Blyth, not only to the metropolis and the other cities and towns of England, but alſo to almoſt all parts of Europe and America, muſt drain away an immenſe quantity of coal from the neighbourhood of Newcaſtle. Dr Campbell, in his Political Survey, ſays, that in his time they conſumed 600,000 chaldrons of coals a-year in London alone; and, as the bounds of the metropolis is greatly increaſed, we may ſafely conclude that the conſumption of coals in London is alſo increaſed, at leaſt one third, if not fully doubled, ſince he wrote his Survey; and the conſumpt of London, though great, is nevertheleſs but inconſiderable in compariſon of what is carried from Newcaſtle and its neighbourhood round the coaſts of Britain, and to all other parts of the world.

The run of coals from Newcaſtle and Sunderland has been ſo very great for above fifty years paſt, that we need not be ſurpriſed if we were to find the coals conſiderably waſted in the neighbourhood of Newcaſtle, ſo as to be in danger of ſoon raiſing the price conſiderably to the metropolis, &c.; and in fact this is the caſe. The coals near the ſea in the neighbourhood of Newcaſtle are already waſted to a great extent, and to ſuch a depth, that they cannot conveniently and profita-

bly

bly go much deeper, without encreaſing the expence prodigiouſly; and, therefore, we may ſafely conclude, that a conſiderable riſe in the price muſt happen at no very diſtant period.

The price of coals is pretty high at Newcaſtle already, and I may venture to aſſert, that the price there would have been much higher, had not the coal trade from Scotland been a check upon them for a conſiderable time paſt, I believe I may ſay the moſt of the time ſince the Union.

Some of the coal pits of Newcaſtle are one hundred and twenty fathoms deep, and they have increaſed the powers of the fire engine ſo much, that it may be ſaid it draws a river from that vaſt depth; but they cannot increaſe theſe powers much farther, without a conſiderable increaſe of expences.

Theſe circumſtances clearly prove, that coals are ſo far waſted near water carriage in the neighbourhood of Newcaſtle, that they are become already very difficult and expenſive to winn; as a proof of this, they now work coals for ſea ſale near twenty miles up the country from Newcaſtle, which they bring down to the water upon waggon-ways, that is, roads compoſed of frames of timber, which are made and upheld at a vaſt expence.

It is not above thirty years ſince the Carron Company founded their great iron works in Scotland,

land, and yet they have already confumed an immenfe quantity of coal.

Several of the coal feams at Borrowftounnefs and Grange, in Scotland, are greatly wafted, and the works are pretty deep, and the coals are worked at confiderable expence with large fire engines in feveral other places upon the banks of the Forth. The cities of Edinburgh and Glafgow depend upon the fire engine for their fupply of coals, and yet they fhip away from Glafgow all the coals they can get any demand for, without any apprehenfion of the future.

At Whitehaven, which chiefly fupplies the city of Dublin, and many other parts of Ireland, with coals, they already work their coal at the enormous depth of more than a hundred and twenty fathoms; and, of confequence, great part of the coal eafily come at is exhaufted, and what remains muft be worked at great expence.

I will only point out another place where the coals are exhaufting rapidly, and the fcarcity and dearth of them, I fear, will foon be felt by many of the commercial cities and induftrious inhabitants of Britain. The ifland of Britain is famous in the earlieft records of antiquity for the tin mines of Cornwall. The tin and copper mines of Cornwall are to this hour of great confequence to the manufactures and commerce of Britain; but the tin mines efpecially have been worked ſo long, and, of conſequence, are now ſo deep, that very little of that valuable metal can be raiſed there now without the fire engine, but alas! they have no coals in Cornwall. All the coals neceſſary for working the fire engine, and for their ſmelting furnaces, are brought by ſea from South Wales. I do not pretend to be well informed either of the extent of the coal fields, or of the proportion of the coal already waſted in South Wales; but from ſuch information as I could get, it appears that the coals there are waſting rapidly; and what will become of the mines of Cornwall when they are exhauſted? I have been informed that the price of coals in South Wales is already ſo high, that ſeveral Corniſh mines are now ſtanding on that account, becauſe they cannot be carried on with profit while coal is ſo dear; and if coal riſes to a higher price in Wales, which very probably will happen in a few years, it will be equal to a prohibition from working moſt of the Corniſh mines. When this event happens, what will become of many of our valuable manufactures, upon which much of our lucrative commerce depends?

This is a mortifying view of the ſubject, but I am afraid it is too juſt a repreſentation, and yet, as far as I know, this intereſting ſubject has never been conſidered in this light, nor has any perſon, public or private, to the beſt of my knowledge, ever

ever taken the trouble to make a fair repreſentation of this matter to thoſe whoſe buſineſs it is to look into and to remedy ſuch evils. There is no reſtraint upon the unneceſſary conſumption of thoſe coals, nor of any other coals in the iſland, however many and important the manufactories may be which depend upon them.

The exportation of coal to foreign countries is now become a great trade, which has encreaſed rapidly within a few years paſt. No doubt this trade is beneficial to ſome individuals, and alſo to the revenue; at the ſame time, we ſhould reflect that this avidity for the pleaſure of preſent profit has a deadly ſting in the tail of it. We are now eagerly ſupplying other nations, and frequently our worſt enemies, with thoſe coals which the metropolis and our manufactories will one day ſtand in need of. And even now, the exportation trade has raiſed the price of coals ſo high as to be exceedingly inconvenient to many of our manufactories, and to many of the induſtrious poor, eſpecially in South Britain.

If this is the caſe at ſo early a period from the firſt beginning of the general uſe of coals in this iſland; if they are ſo much exhauſted, and raiſed to ſo high a price, in little more than two hundred years from the firſt beginning of the uſe of coals, and in leſs than one hundred years from the commencement of an extenſive conſumpt, what may

we

we ſuppoſe will be the price of them two hundred years hence?

The continual increaſe of the coal trade, and of the general uſe of coals, is ſo great, that I am perſuaded that the one half of all the coals that ever were conſumed in this iſland and exported from it, have been raiſed within the laſt eighty years, as there was, comparatively ſpeaking, but little coals uſed eighty years ago; and, if this is true, it ſhows us how rapidly our coals are waſting, for it is certain that our coal works in many places are deep, the coal waſtes extenſive, the machinery and whole apparatus of the works very coſtly, and the coals, in maritime places eſpecially, raiſed at a great expence; ſo great indeed, that ſome coal works are carried on with loſs.

The preſent rage for exporting coals to other nations may aptly be compared to a careleſs ſpendthrift, who waſtes all in his youth, and then heavily drags on a wretched life to miſerable old age, and leaves nothing for his heirs.

When our coal mines are exhauſted, the proſperity and glory of this flouriſhing and fortunate iſland is at an end. Our cities and great towns muſt then become ruinous heaps for want of fewel, and our mines and manufactories muſt fail from the ſame cauſe, and then conſequently our commerce muſt likewiſe fail. In ſhort, the commerce,

merce, wealth, importance, glory, and happineſs of Great Britain will decay and gradually dwindle away to nothing, in proportion as our coal and other mines fail; and the future inhabitants of this iſland muſt live, like its firſt inhabitants, by fiſhing and hunting.

My natural hiſtory of the ſtrata of coal may be diſputed by ſuch novices as are abſolutely ignorant of the ſubject, but it cannot be diſproved by ſuch proficients in the ſcience as will take the trouble to examine all circumſtances; but whether my hiſtory be diſputed or not, the general facts which I have ſtated relating to the ſubject of our collieries and of our coal trade are indiſputable. Theſe facts are eaſily inveſtigated. Accurate ſurveys can be made, and pretty near calculations of the coal to be had, and of the time it will laſt, when compared with what has been worked out of each coal field for a limited time paſt.

Now, if theſe facts ſhall, upon due examination, be found as I have repreſented them, I will leave it to diſintereſted well-wiſhers of their country to judge whether or not this ſubject deſerves and requires the attention of the public.

I am no judge of the lawfulneſs or propriety of reſtraining the ſubject from the uncontrouled uſe of his property in this land of freedom; but I clearly foreſee, and can form ſome judgment of the fatal conſequences to future ages of a too rapid

pid consumption of our coals, especially in the maritime parts of the country.

It is very well known to numbers of individuals, though perhaps not sufficiently well considered by the public in general, how much this nation is indebted to the mineral kingdom for the principal commodities which are conveyed round the globe in the numerous and extensive channels of our commerce.

The manufactories which prepare the materials and fabricate these commodities are exceedingly multiplied and various, and the number of hands employed about our mines, manufactories, and commerce is very great; and it is an established truth in politics, that numbers of people well employed are the riches of a nation, and it is especially so in this case, as all the materials from the mineral kingdom are our own. Our other mines produce the raw materials of our various hard manufactures, but some of those materials cannot be raised out of the mines, and none of them can be prepared and manufactured without coals.

I have no abilities for nice and extensive calculations, or what is called political arithmetic; however, if this subject was but duly attended to by the public, there are not wanting numbers who are capable of calculating, and of properly stating

ſtating the effects that a general riſe of the price of coals would have upon our manufactures and commerce.

There are ſome plain facts, however, which appear to me very evident, and muſt appear ſo to every other perſon who takes even but a curſory view of theſe matters: Such as, for inſtance, *1ſt*, The lower the price of coals is, the cheaper the crude materials from the mineral kingdom can be prepared, and the cheaper the commodities can be manufactured from them: *2d*, The cheaper our commodities can be manufactured, the better we are enabled to rival other nations in commerce: *3d*, While we have coals enough at a moderate price, our manufactures and commerce will continue to flouriſh, but it is impoſſible that they ſhould flouriſh any longer than our coals are plenty and reaſonable; becauſe, other nations have greatly the advantage of us when our coals are either exhauſted or too dear, as moſt of them have a much greater quantity of wood than we can boaſt of, or it would be our intereſt to have: *4th*, There are plenty of productive mines of all the Britiſh metals upon the continent of Europe, which they cannot now manufacture into ſuch a number, quantity, and variety of excellent commodities as we can, on account of the plenty and excellence of our coals; but when our coals fail, or are become too dear, then they can rival and exceed us on account of their extenſive woods.

Theſe facts are plain and ſelf-evident, and, therefore, they neither ſtand in need of proof nor illuſtration; but they certainly call for attention, and it would require extenſive knowledge, wiſdom, and ſkill to form ſuch regulations as will favour our own manufactures, and at the ſame time do juſtice to the Britiſh ſubjects and to the revenue.

I am really concerned for the metropolis and her younger ſiſters, when I conſider what a great proportion of the Newcaſtle coal is already waſted in ſo ſhort a period of time. The city of London, and the other cities and towns upon the eaſt and ſouth coaſts of England, ſeem to me to have a ſtrong claim, if not a natural right, along with our manufactories, to all the coals which the north of England can produce; and if proper care is not taken of their right in due time, they will too ſoon be deprived of it. There is indeed a pretty good fund of coal in Fife, and other places upon both ſides of the frith of Forth, which may be ſent to the metropolis, and to other places upon the eaſt and ſouth coaſts of England; but there are a number of manufactories upon the banks of the Forth, which would be ſoon hurt by an extenſive coal trade from thence, as ſuch a trade

trade would raiſe the price of coals there too high for ſuch manufactories; and, moreover, the north of Scotland depends upon the frith of Forth for a ſupply of coals, and they ſeem to have a natural right to all the coal that can be ſpared from thence.

The mines of Cornwall and our copper manufactories, and ſuch other manufactories in the weſt of England as uſe tin and copper, ſeem to me to lay claim to all the coals that can be ſpared from South Wales, as thoſe mines and thoſe manufactories are of the firſt conſequence to great numbers of Britiſh ſubjects, and to ſome important branches of our commerce and revenue.

The city of Dublin, and many other parts of Ireland, depend upon Great Britain for a neceſſary ſupply of coals, even for culinary uſes; and I hinted before, that the collieries of Whitehaven, from whence Dublin is chiefly ſupplied, are already very deep. However, there is a valuable and extenſive magazine of coal for Iriſh conſumption treaſured up in the county of Ayr; and it is well for Dublin, and other parts of Ireland, that there are ſuch magazines in Ayrſhire and the north-weſt of England; and what would become of Dublin, &c. were theſe coals to fail? In that event, it might be ſaid with propriety, that the Iriſh volunteers would blow a cold coal.—They little think of this when they begin to ſwagger, diſturb the peace, and neglect their proper occupations. They little think that Britain can ſtarve them, knock up many of their manufactories, and ruin their cities for want of fuel.

When theſe matters are taken into ſerious conſideration, and thoroughly examined, I preſume it will then be thought by all the impartial and diſintereſted, that the leſs coal is tranſported out of Britain, the better for the nation in general, and the better for the manufactories of Great Britain and Ireland; and if foreigners get any coals at all from us, they ſhould pay well for them by an increaſed duty.

Reſtraints impoſed upon any eſtabliſhed branch of our export trade, however ſalutary the tendency of them might be for the community in general, and of the national manufactories in particular, would, nevertheleſs, be interpreted by many as an infringement of the freedom of commerce, and of the liberty of the ſubject to diſpoſe of his own property to the beſt advantage.

Theſe matters are far above me; but they certainly merit the moſt ſerious conſideration.

Another great difficulty occurs to me. Any reſtraints impoſed upon the exportation of coal, would in ſome degree affect the revenue for ſome time at leaſt. This difficulty ſeems to ſtand as an inſurmountable barrier in the way of the future

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welfare of the people and manufactories of Britain with respect to cheap coals, and yet cheap coals is absolutely necessary for the welfare of both.

I am not politician enough to be able to suggest the proper remedy or succedaneum for all these difficulties; but I will beg leave to observe, that, in my humble opinion, the coals of Cape Breton, and other parts of the western world in our possession, may be brought to make good the deficiency which the revenue might suffer by diminishing the export of coals from Britain. I am not sufficiently well informed of the history of the coals of Cape Breton, &c. to be able to state the circumstances relating to them with any degree of precision; however, in general, it appears certain, that there is abundance of coal in that island, and that some of them were wrought by the French, and exported to their sugar islands.

Several navigators who had been at Louisbourg assured me, that the island abounds with coal to such a degree as to appear in the cliffs near the harbour; but as none of these were men of science in this branch of natural history, their account was vague and unsatisfactory. Raynal's account of these coals, in his History of the Settlement and Commerce of the West Indies, is not more satisfactory than that of the ship-masters I conversed with.

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In general, I learn from Raynal, that the coal lies in a horizontal poſition; that the French wrought it very near the ſurface without any hydraulic machinery, and even without any level mine or adit for draining off the water. It is probable that they began upon a ſtratum of coal in the face of one of the cliffs, and wrought it under cover, which is commonly done in Britain when coal is diſcovered in a cliff, or a ravine, and wrought upon a ſmall ſcale.

Raynal's account of this matter, or any other information I have yet procured, gives no grounds for apprehending that any conſiderable quantity has been wrought. Such a work as Raynal hints at could have produced but very little coal that was worth raiſing at all. It is very well known to men of ſkill and obſervation, that ſuch parts of every ſtratum of coal as are very near the ſurface of the ground, and as are naturally drained by the figure and diſpoſition of the ſurface, is ſeldom good for any thing; and it ſeems to ſay much in favour of the Cape Breton coal, that thoſe ſuperficial works produced ſuch as was worth the raiſing.

We are farther informed by Raynal, that a ſeam of coal was ſet on fire at Cape Breton, which burned with great fury. As this accident may ſeem very alarming to ſuch as have not thoroughly inveſtigated theſe matters, it may be pro-

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per to obſerve, that this conflagration cannot be of very dangerous conſequence to the coal. It will only conſume the ſtratum that is on fire in the horizontal direction, until the fire arrives at one of the natural bars which are ſo frequently found to interrupt the regular ſtretch and bearing of the ſtrata, known by the names of dykes, ſlips, &c. and there it will be ſtopped, for there the ſtratum of coal is partially cut off; and, therefore, the fuel of the conflagration muſt fail. It will only conſume the ſeam of coal towards the dip or declivity of the ſtrata to the water's edge, that is, ſo far down as the ſeam of coal is naturally laid dry by the cliffs and ravines, and other inequalities of the ſurface of the ground; and when it only burns down to the water, it is ſure to leave the beſt of the coal; for real experience aſſures us, that the deeper coals are wrought down under water, the better they always prove. But it is proper to obſerve, that while a coal is burning near the crop or ſurface, it is not prudent to open any works to the dip upon that ſeam until the fire is really extinguiſhed, becauſe the fire will communicate with the works below when it gets air, and deſtroy the whole. However, in caſes of neceſſity, the fire may be got under, and wholly extinguiſhed, by corking and ſtopping the mines and ſhafts, and other apertures and air vents, and the effect will be haſtened if a rivulet can be turn-ed into the burning cavities, and ſuch ſtoppages made as will confine the water to riſe within the excavations. But if the external air can be perfectly excluded, the fire will be extinguiſhed without any farther trouble.

As the iſland of Cape Breton is of conſiderable extent, and as there is a certainty of coal exiſting in the iſland, there is great probability that it may prove a valuable coal-field; and, moreover, there is but a narrow ſtraight between Cape Breton and Nova Scotia, and the latter is ſituated directly in the line of bearing of the ſtrata, and, therefore, it is probable that coals may be found in the maritime parts of Nova Scotia, where, it is ſaid, that they really have been ſeen; and it is alſo ſaid, that coals have been diſcovered in the iſland of Newfoundland; one or both of which places may turn out well, if properly tried: But ſuppoſing they ſhould not, Cape Breton is of ſuch conſiderable extent, that it promiſes a fund of coal equal to a very extenſive exportation, and to the demands of the new world, for a long period of time, there being no room to doubt the exiſtence of a number of ſeams; and it is highly probable, from what is related of them, that they are ſeams of a good thickneſs and quality.

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This ſubject, therefore, appears to be of ſuch importance as to merit an inquiry, whether or not it is proper for Government to encourage the working of thoſe coals upon a large ſcale? In my humble opinion, it cannot admit of a doubt that it would be highly proper, and in the event of this new trade proving ſucceſsful, it would ſoon become greatly beneficial to the mother country, by keeping down the price of coals at home, which would encourage her manufactures, and by drawing a revenue from the foreign coal trade.

It is not improbable that this ſcheme would meet with ſome oppoſition at firſt from the wealthy coal owners of Britain, as it might excite in them an apprehenſion of ſome abatement of their profits, as they now ſhip a conſiderable quantity of coal for the weſtern world; and, it muſt be confeſſed, that if the exiſtence and proſperity of the Britiſh empire was only to laſt for the ſhort ſpace of thirty or forty years, commenſurate to the time that a ſet of men may be fit for puſhing a lucrative branch of buſineſs ſucceſsfully, and that at the end of that period all was to ſink in oblivion when thoſe men die, it would be very proper to hear them.

Upon ſuch a ſuppoſition, it does not appear that any real good to Britain could be propoſed from opening American or Weſt India coals, becauſe there is at this time a conſiderable quantity

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of coal carried from Britain to the Weſt Indies and America; which branch of trade the American coal would interfere with and diminiſh. Self-intereſt acts upon the principles and views of preſent profit, and neither cares nor conſiders what will be the future conſequence to poſterity, provided it reaps the preſent advantage; but God forbid our Britiſh rulers ſhould at any time be ſo unconcerned about the preſent and future welfare of this commercial iſland, as to do or to leave undone what would hurt and injure the community in general, to gratify the avaricious views of a few wealthy individuals.

Upon this ſuppoſition of the coal of Cape Breton being opened, and proving as ſucceſsful as there is reaſon to hope and expect, the coaſts of the Weſt India iſlands and of the continent of America are ſo very extenſive, and the cities and towns upon the coaſts ſo numerous and conſiderable, that the trade for thoſe coals might be enlarged to ſuch an extent as in time to bring in a revenue to the Britiſh Treaſury, equal, if not ſuperior, to the receipts from the whole coal trade of Great Britain, without laying too heavy a duty, or any way oppreſſing the weſtern trade.

This event of itſelf is devoutly to be wiſhed by every diſintereſted Britiſh ſubject; but it is not this conſideration that lies neareſt my heart.

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It appears to me certain, as an infallible consequence of the nature of things, that the commercial wealth and glory of this induſtrious and happy iſland muſt dwindle away by degrees, in proportion as coals become ſcarce or riſe in price, and diſable us from keeping down the prices of our manufactures, at leaſt upon a par with our rivals; and, therefore, it is the ſaving of our own coals for our own uſe, and for the public good, that ſhould be our chief motive to open the Weſt India coal; and, moreover, it may not perhaps be improper to work out thoſe coals as ſoon as poſſible, while they are in our power, leſt we ſhould not have them to work in time to come, if we let ſlip the proper opportunity, which ſeems to be now in a time of peace, when we have leiſure to look after ſuch matters.

We ſee, that with the help of our rivals, thirteen of the American provinces are made independent, and it is probable that they will ſoon be formed into a great empire. Many of the inhabitants of the principal cities of America have burnt Britiſh coals for a conſiderable time paſt, which they found cheaper than wood, after the country began to be cleared near the ſea-coaſt, notwithſtanding that the purchaſe, duty, and freight of coals from Britain muſt raiſe the price of them prodigiouſly to the Americans. I do not know that there is much coal, if any, as yet discovered within the territories of the States of America; and, therefore, it is to be supposed, that as they gather strength, and feel more the want of coal, they will cast an evil eye upon Cape Breton, &c. and envy us the possession of an island in their neighbourhood, which seems to be a vast magazine of coals.

Fire wood will soon grow scarce and dear along the coasts of North America, and manufactories will soon be established there, which cannot be properly and effectually carried on without large supplies of coal; and, therefore, we must suppose that the very sense of their wants will alone be sufficient to make a conquest of Cape Breton for the sake of our coal. Such a conquest might be accomplished and secured before we in Britain could be well apprized of the preparations for it; but if we had flourishing and extensive collieries, and a brisk coal trade going on there, in conjunction with our fisheries, it would be more worth our while to keep the island in a more sufficient posture of defence than it is at present. In short, I am of opinion that the sooner those coals are worked the better.

The certain knowledge of a fund of coal lying there unwrought, may be the means of losing all our West India possessions on account of those coals. It is not only the Americans that stand in need of thofe coals. The French, &c. are alfo much in need of them; and why may not the French join the Americans to conquer the reft of our American poffeffions, when they find by experience that the coal is abfolutely neceffary for both parties? We know what they have done, when they had no other motives, in procuring independence to our colonies, than to weaken us, and to appropriate our American trade to themfelves; and why may they not do the fame again, when they have the additional motive of fecuring to themfelves our coal mines and fifheries, which are by far more precious to a manufacturing commercial people than gold mines?

If we could give the Americans a plentiful fupply of coals from Cape Breton, it is prefumed, that they would find this to be fo great a national convenience, that it would induce them to extend their trade with Great Britain in preference to all other countries.

As matters now ftand, no other nation can fupply them with this precious and neceffary commodity; and all people feel themfelves happy when their wants are fupplied. Our fupplying them with coal, muft, as a natural and neceffary confequence, turn the balance of trade to our fide. They will give the preference to our commodities for the fake of our coals, which no other nation can fupply them with; and, therefore, we

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can keep the balance in our favours so long as we keep all our present possessions, and make a good use of them.

It has been said that there are coals in Canada, which I cannot disprove; however, as far as Professor Kalm of Sweden had an opportunity of viewing the superficies of the strata in that country, there is not the least appearance of coal in Canada: And his account of the strata, which he saw in a journey from New York to Montreal, along the margin of some of the lakes and rivers, and along a considerable part of the river St Laurence, is sensible, judicious, and satisfactory; but Mr Kalm saw not the least symptom of coal among the strata which he viewed in Canada.

I am fully sensible that my information is not so perfect as the magnitude and importance of this subject deserves; but I, nevertheless, think it my duty to communicate such hints as are in my power; and however imperfect my hints are, I cannot help thinking that their great importance merits the attention of Government, and this attention will produce proper enquiries, which will enable them to investigate the truth of the facts which I have hinted at; and such enquiries will give them the knowledge of many circumstances relating to this subject, which at present are out of my reach.

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The farther I look into this fubject, the more interefting it appears. The exiftence of abundance of coal in the ifland of Newfoundland, is generally underftood to be an eftablifhed fact.—This is ftill a more interefting fituation for coals than Cape Breton, on account of its vicinity to the great fifhing bank. Cape Breton may be called the key of Canada, but Newfoundland is the afylum and defence of the cod fifhery; and the importance of this great nurfery for failors is of the firft confequence to a maritime and commercial nation, whofe natural and fureft defence is her naval force.

In the light which this fubject appears to me, it is to be wifhed that the coals of Newfoundland, as well as thofe of Cape Breton, were worked out by us.

An extenfive and fuccefsful coal trade at Newfoundland and Cape Breton, would produce fuch an increafe of commerce and revenue, as would make our poffeffions in the weft a great and conftant object of care and attention. Our coal fhips and other trading veffels would be continually traverfing the coafts of the iflands and continent of America. They would have fomething to do in every creek and harbour, north and fouth, which would give us perfect intelligence of what is going on in all the regions of the new world; and,

and, therefore, we could never be furprifed; and, as a confequence of the increafe of commerce, we fhould always have a greater naval force in the Weft Indies than prefent circumftances require.

The Americans have plenty of timber for fhip-building, and for charcoal to fmelt their own iron ores. They have plenty of good land fit for raif-ing hemp for cordage and fail cloth; and abun-dance of thefe articles in perfection will put it in their power to build fhips of war at a cheaper rate than we can do; and it is vain to imagine that they will not fome time or other avail them-felves of the advantages of their fituation, and of the natural productions of their country, and of the fertility of their foil; and it is as vain to ima-gine that they will not caft an evil eye upon our weftern coal mines and fifheries when they have fully fettled their form of government, and feel their own ftrength, and their want of our poffef-fions for the farther increafe of their manufac-tures, commerce, and wealth, and the farther aggrandizement of their power.

When Government is fully fatisfied of the va-lue and importance of the Weft India coals, of courfe it becomes a ferious queftion, what is the moft proper plan for opening and working thofe coals, for the intereft of the nation and of all con-cerned?

A few hints upon a ſubject of ſo much conſequence from a profeſſional man, cannot be thought unreaſonable.

In diſcuſſing this topic, we preſume to ſuggeſt, that, in the firſt place, it is neceſſary for Government to explore and diſcover theſe coals, and lay them bare for the inſpection of Britiſh coal maſters or companies, and with this view, the firſt thing to be done, is to employ a prudent man of abilities and ſkill in the theory and practice of the coal buſineſs; to ſurvey the Weſt India coals and coal fields; to make ſuch trials upon the coals already diſcovered, and thoſe he may diſcover, as may be neceſſary to aſcertain the thickneſs, quality, and ſituation of each ſtratum of coal that may be judged worth attention; and to make out a full and ſubſtantial report of all the material circumſtances relating to each coal, for the information and uſe of Government, and of ſuch gentlemen and companies as may wiſh to look into this intereſting ſubject.

As far as circumſtances can be inveſtigated, his report ſhould give a ſatisfactory account of the quality and thickneſs of each ſeam or ſtratum of coal; of the number of workable ſeams in each coal field; of the roof and pavement of each ſtratum of coal, and the other concomitant ſtrata ſituated above and below each coal, ſo far as they can be ſeen, and of the ſlope or inclination of the ſeveral coals from the horizontal poſition. He ſhould conſider the eaſe or difficulty of ſinking upon, and of winning and working each ſtratum of coal; what machinery will be neceſſary for that purpoſe; the diſtance from a good harbour or ſhipping place; the eaſe or difficulty of conveying the coals to the ſhore, and of ſhipping them; and the preſent condition and neceſſary improvements of the ſeveral deſcriptions of ſhipping places ſhould come under his conſideration. He ſhould calculate and report his eſtimate of the expence of opening and winning ſuch a ſeam or ſeams of coal in Britain to a proper depth, and upon a proper ſcale, to be ready to work with a ſufficient number of colliers, including the neceſſary machinery, and how much per ton is commonly paid the colliers in Britain for working ſuch ſeams of coal. Allowance muſt be made by thoſe hereafter to be concerned between the expence of ſuch works at home and in the Weſt Indies. In ſhort, he ſhould conſider and report every thing that is neceſſary and proper to be known for the information of all thoſe concerned, and the information ſhould be very complete and particular when the ſubject is ſo remote, and is of ſuch conſequence to the commerce, wealth, and power of the Britiſh empire.

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When this report is made and confidered by Government, fuitable encouragement fhould be offered to gentlemen and to companies of character, ftock, and abilities for fuch undertakings, to open and work fome of thofe coals. It might be prudent for Government to give fome aid at firft to the undertakers; but fuch works would not thrive if carried on at the public expence,—they muft be carried on by frugal and fkilful undertakers, if we would expect them to fucceed; and it will be neceffary for one at leaft, and a fkilful one, of thofe concerned, to be always upon the fpot.

The firft undertakers fhould be allowed a fufficiently extenfive coal-field, and every reafonable privilege and indulgence; but they fhould not have a monopoly. Other adventurers fhould have room to employ their fkill and capitals in this line of bufinefs in the weft as well as in Britain. Monopolies feldom do much good. The views of monopolifts are always too felfifh and confined to be of extenfive utility and public benefit.

Newfoundland, Cape Breton, and the peninfula of Nova Scotia are all in the true line of the bearing of the ftrata of coal, and others in the fame parallels of latitude in other countries.—The ftrata of Great Britain, and thofe in the fame parallels of latitude of other countries, trend from north-eaft to fouth-weft, or nearly ſo; and, from viewing the map, it appears, that Newfoundland, Cape Breton, and Nova Scotia are ſituated in this line of bearing; and, therefore, it is probable, that the ſame coals and coal metals ſtretch through theſe three different countries. There ſeems to be a certainty of plenty of coal in the two iſlands, and it is probable that the coal of Cape Breton ſtretches through the narrow ſtraight into the peninſula of Nova Scotia, which is but a ſhort diſtance.

The diſcovery of abundance of good coal in theſe three countries will give ample room for a number of undertakers: But ſuppoſing they were only found ſufficiently good and plentiful in one of the three countries, there will ſtill be room enough for a number of adventurers, and for a very extenſive coal trade. How many different collieries of great extent are wrought in the two counties of Northumberland and Durham in England? and moſt of the coals of thoſe counties are ſhipped off in the two ports of Shields and Sunderland. The populous ſea coaſt of North America is ſo extenſive, and the cities and ſea-ports upon that coaſt are ſo numerous and flouriſhing, that there is no room to doubt of a ſufficiently extenſive demand to excite the activity and exertions of a number of adventurers in the weſtern coal trade, beſides the demand of the Carribbee

Iſlands,

Iſlands, which of themſelves are ſufficient to create a briſk trade.

In the event of a briſk coal trade in the Weſt Indies, Halifax or Louiſbourg will ſoon become a famous mart, the ſtaple of a great and extenſive commerce, which will be created by the coal trade, and which will increaſe and flouriſh in proportion as the coal trade increaſes. Canada and Nova Scotia will ſhare with the mother country the benefits of the new commerce of the weſt. A new and powerful ſpring will be given to the agriculturiſts. Their rich and extenſive ſoils will receive the higheſt improvements, by ſupplying with proviſions the numerous ſhipping and increaſed population which this new commerce will ſoon create.

Commerce gives the means and neceſſary aid for improvements in agriculture; but agriculture itſelf is the foundation of the commerce and proſperity of all nations. Agriculture gives to commerce men, proviſions, and a great part of naval ſtores, and commerce ſupplies the means of improvements in agriculture. If Canada and Nova Scotia were favoured with theſe aids to improve their lands, the rich ſoils of thoſe countries might ſoon come to ſupply Great Britain with all her naval ſtores. The woods of Canada and Nova Scotia will ſupply maſts, yards, and tar, and their fertile ſoils will ſupply abundance of hemp, when

when they are enabled to advance the improvements of thofe foils. With refpect to iron, there is now a confiderable quantity made in Great Britain; and, to my certain knowledge, we have abundance of the raw materials for making any quantity that might at any time be defired. If a fmall encouragement was given for the making of iron at home, and fome difcouragement to the importation of foreign iron, our furnaces and blomaries would foon increafe to fuch a degree as to produce a fufficient quantity to anfwer all the demands of agriculture, manufactures, and fhipping; and this regulation would have a direct tendency to enrich the nation, by keeping the money at home in circulation which now goes abroad to enrich other nations, and by employing great numbers of our own people to work upon our own materials. Our own iron manufactories certainly merit the public attention.

The Britifh coal trade is well known to be an excellent nurfery of able and hardy feamen. Few naval fcenes in the world, if any, are more active and more conftant than the coal trade from Newcaftle and other parts of Britain; and it is where they are conftantly employed in rough and dangerous feas, like the coafts of Britain, which always require hard labour, that able and hardy feamen are bred; and thefe, on board our fhips

of

of war, under able commanders, are the glory and defence of the Britiſh dominions.

The coal trade of the weſt, when it is improved, and the other branches of trade which it will create or increaſe, will employ and breed many thouſands of good and hardy ſeamen: Our dominions in the weſtern world will then become active and flouriſhing upon the American ſeas like the coaſts of Great Britain, and our mercantile ſhipping will form a bridge of ready communication from the old world to the new.

But the harbours of Cape Breton and Newfoundland being frozen up during ſix months in the year may be conſidered as a great diſcouragement to this coal trade. The ſailors employed in it cannot afford to lie idle during the winter half of the year, when no other employment is to be had, nor can the ſhip-maſters afford to lay up their veſſels ſo long in this dead ſeaſon, when they cannot be employed at the fiſhing. The coal-works will require to be carried on conſtantly, to prevent the works, the materials, and machinery from falling to ruin. The colliers muſt be conſtantly employed, or paid for going idle, and habits of idleneſs will ſoon ſpoil them, and take away the power and inclination to work. If they work conſtantly for half a year without any conſumption of the coals, they will accumulate to ſuch a degree as to become troubleſome, or they will ſpoil and inlake upon hand; and, therefore, it will be neceſſary to ſhip off ſome coals in winter. When the winter is fairly ſet in, and the ſnow fallen, the weather is generally ſerene and pleaſant, though cold during the reſt of the winter in North America. We preſume that it may be practicable during this ſettled weather to ſhip off ſome coals from the outer edge of the ice. For this purpoſe I would adviſe that the coals be carried out upon the ice to the ſhipping in a ſort of boats or lighters, which may be drawn along the ice, fixed in a frame to move upon four wheels, or in the manner of a ſledge. A windlaſs upon the ſhore, and another on board the ſhip, would draw this vehicle to and fro with a line upon the ice very expeditiouſly, provided the diſtance is not too great for the line to reach; in that caſe it muſt be drawn along by men or cattle. If the ice ſhould happen to break at the outer edge near the end of winter, the boat-form of the carriage will ſecure it from ſinking. If a ſhip can get out loaded to the open ſea, ſhe will find no difficulty in ſailing ſouthward, where the ports are always open. In a country ſo cold as Cape Breton, &c. where the froſt is ſo intenſe, and of ſo long a continuance, it may be neceſſary to have ſubſtantial buildings raiſed over the coal-pits, and over the engines and other apparatus, where fires ſhould be kept burning during the ſe-

verity

verity of the weather. If ſuch precautions are neglected, all the machinery will ſoon be frozen up and rendered uſeleſs for a long time, or be in danger of breaking to pieces in a moment if employed. All the maſonry about the collieries muſt be done in ſummer, and care ſhould be taken to build none when froſt appears, and in ſuch a country it will be very neceſſary to build with hot lime, that is, with lime newly ſlaked from the burnt lime-ſhells, which ſhould be immediately mixed with ſand and uſed before it cools; and all that is ſlaked and mixed each day muſt be wrought up before night to prevent its being touched with froſt. Mortar once frozen will never take band. This caution ſhould be carefully obſerved in all buildings in thoſe countries, eſpecially in the garriſons and harbours.

But whatever may be the fate or the ſucceſs of the American coals, it will not leſſen the conſequence of our own, nor the neceſſity of looking into the real ſtate of our collieries, becauſe it is of the utmoſt importance to the metropolis, and our other trading cities and towns, that there ſhould be a certainty of the continuance of a plentiful ſupply of fuel at a moderate price. It is of the utmoſt importance to the proſperity of our manufactures that this fuel ſhould be cheap; the proſperity of our commerce immediately depends upon our manufactures; and both muſt dwindle and decay in proportion to the ſcarcity or the high price of our coals.

It is of great conſequence to our manufactories that coals ſhould be plenty and cheap near the ſite of ſuch as are already eſtabliſhed, and where new ones are to be ſet agoing; becauſe, in moſt inſtances, the crude materials will not admit of being carried to the coals, and, therefore, the coals muſt be carried to them; or, in other words, remote country places, at a great diſtance from the ſea, will not anſwer for the ſite of moſt of our manufactories, and, therefore, it would greatly injure them to have the price of coals raiſed too high in maritime ſituations, where ſuch manufactories are and ſhould be eſtabliſhed and carried on; and they will too ſoon be raiſed high, if ſome proper regulations are not made in time to prevent it.

I do not know that the nation is much enriched by the money our coals are ſold for in foreign countries, but I know that the increaſe and proſperity of our manufactures and commerce enriches the nation, becauſe our own productions are thereby uſed to the beſt advantage, and our own people are employed; and it is the number of people well employed that brings ſolid riches to all nations; and I apprehend that it is yet practicable to increaſe our manufactures conſiderably.

I know certainly that in many places our metallic mines are not worked to the extent to which they might be carried on with profit; but dear coals muſt throw a prodigious damp upon mining, becauſe the ſteam engine is now become neceſſary to mining at any conſiderable depth, which cannot be worked without cheap coals, nor can they afford to manufacture the crude productions of the mines if the coals are too dear.

There is much money ſent out of the nation for bar iron, and yet we have plenty of materials at home for making iron: And I can prove to ocular demonſtration that there is great abundance of the richeſt iron ores and iron ſtones to be had in Scotland eſpecially, which can be raiſed at very moderate expences, where coals are alſo abundant and reaſonable.

A greater number of blomaries would increaſe the number of uſeful manufactures, and the national advantages of the increaſe of uſeful manufactures is a ſubject which has been frequently explained; and, therefore, it would be idle and impertinent in me to proceed any farther, than barely to ſtate theſe brief hints relating to the connection and dependence of our manufactures upon coal. But I hope to be pardoned for ſaying a few words more about the neceſſity of encouraging manufactures with a view to employ a greater number of hands.

There are very loud and juſt complaints of a general diſſolution of manners, of thefts and robberies, and of emigrations to America. It deſerves ſome enquiry, whether or not there is any fault in the police of the country; any public error or neglect which operates as the cauſe of theſe evils? It too frequently happens that the great and wealthy men of the world know very little about the ſtate and circumſtances of the induſtrious poor, even upon their own eſtates. Some of them never ſaw their own eſtates, unleſs perchance they may have caſt their eye upon the plan for a moment! As I live in the induſtrious part of the community, and live by induſtry, I believe that there is often a want of employment. I know that great numbers here in Scotland are either forced to beg or emigrate for want of employment, even in the moſt improved ſtirring parts of the country, where moſt labouring work is to be had: I frequently ſee numbers every day ſeeking work which they cannot get; and when I reprove a ſturdy beggar for being idle, he tells me roundly, that he cannot get employment.

The idle of all ranks and denominations are generally more miſchievous than the buſy, and their example has a malignant epidemic influence in corrupting others, and the idle poor eſpecially; and ſuch as have waſted their fortunes, or never had any, become the moſt dangerous and the moſt deſtructive nuiſance to ſociety.

Now, if there is ſuch a general want of employment for numbers of the (would be) induſtrious poor in the Lowlands of Scotland, where improvements in agriculture, manufactures, and the uſeful arts are advancing rapidly, what muſt be the conſequence in the Highlands, which, for the moſt part, are not capable of ſuch improvements? The caſe of the poor Highlanders is deſperate indeed! Though not a Highlander myſelf, I have been nearly all over that country, where I have ſeen ſuch ſcenes of miſery and want as would ſoften the moſt obdurate heart, and draw a tear of compaſſion from the eye of the pitying beholder; and all for the want of employment!

I have ſeen near two hundred people, old and young, in one glen, where ten or a dozen were equal to all the real or poſſible buſineſs of the ſpot, which was not capable of improvement; how then were the reſt to live? how were they to procure food, where nothing could be done to earn it, or to raiſe it where none could grow? The Highlanders have been blamed for emigrating to America, and they are called lazy; but what can they do? All poor people in all poor countries are lazy, merely for want of the means

and

and the habits of induſtry. Give them profitable employment, and they will become induſtrious.

Thouſands of the Highlanders walk three or four, and ſome of them five or ſix hundred miles, going and returning, every harveſt, and work near two months in the Lowlands, and in England, to earn twenty or thirty ſhillings; which go to eke out the profligate luxury of his landlord in London or Edinburgh; and this they repeat every year: Is this a proof of their lazineſs! Their country in general is not capable of much improvement in agriculture, nor can it be the ſite of manufactories for want of food. Some little might be done at Fort William, and in ſome parts of Argyleſhire, in woolen manufactories for coarſe ſtuffs, and the woods might be profitably improved in Roſs and Inverneſs-ſhires; but all other improvements, excepting the fiſheries, would require but few hands. In the fiſheries only is there a proſpect of plenty for all as the reward of induſtry. The fiſheries will give preſent food to all of both ſexes, and of all ages, with the well founded hope of future profit.

But I am afraid that our ſchemes for the improvement of the fiſheries, will mar the proſperity of them, and ſquander away the public money upon unneceſſary projects. I do not ſee the neceſſity of beginning with building towns; but I ſee the neceſſity of beginning with building granaries

naries and ſtoring them. Build granaries in all the proper ſituations which the herring frequent, and where veſſels can lie ſafe, and go eaſily in and out, and ſtore theſe granaries well with ſalt and tree, and materials for nets and boats, and whatever elſe may be neceſſary for taking and curing fiſh. Give the people of the country a little aſſiſtance at firſt to prepare nets and boats, to be in readineſs by the time the herring make their appearance. Give them at each ſtation one or two experienced fiſhers from the north of Scotland, to learn them to make and bait their lines, and to take and cure cod, ling, &c. in the intervals of the herring fiſhery, and I will anſwer for it that the Highland Fiſhery will ſoon be improved to give plenty and happineſs to the Highlands, and to be the glory and wealth of the nation.

There are plenty of men in the Highlands, who are naturally hardy and addicted to the ſea. Teach theſe to take and cure all ſorts of fiſh in the beſt manner, and give them ſome aſſiſtance at firſt to ſet them a-going; that is, furniſh them upon account, and the beſt ſecurity they can give, with ſalt, caſks, and other neceſſaries, and they will thrive.

Of all the methods in the world of doing good to the induſtrious poor, there is none ſo effectual and beneficial as aiding their own exertions, and aſſiſting their efforts to ſupport themſelves;

felves; and if this is properly done in the Weft Highlands, the fisheries will be fuccefsful, and the Highland fifhers, and fuch as fupply them with neceffaries, will foon build towns for themfelves, without any public aid but the fruits of their own induftry; and it is very neceffary that it fhould be fo, becaufe all the public money that can be raifed will be found little enough to build and ftore a fufficient number of granaries, which will require an immenfe fum; and till this is done, the improvements of the fifhery is not begun, although twenty towns were built. If you begin with building towns, they will be peopled by knaves, idle fchemers, and whifky drinkers; not by fifhers, whofe towns are their veffels or temporary huts, which Highlanders can erect in two hours. The towns will fruftrate the hopes and good intentions of the public; the public money will be wafted, the fcheme ruined, and the fifheries left unimproved; which God forbid!

I fincerely wifh that men in power may be wifely directed to begin and proceed upon the beft plan to improve the fifheries, for the relief of that miferable country, and for the good of the community in general.

There cannot be a more humane and benevolent action than to relieve thoufands from extreme want and mifery, and give them plenty and happinefs; and, eventually, it muft entail everlafting fame,

fame, as it cannot fail of increafing the glory and wealth of the nation, but by proceeding upon a wrong plan.

A fuccefsful coal trade at Cape Breton, and fuccefsful fifheries at Newfoundland, and over all the extended coafts of the Highlands and Ifles of Scotland, would employ above a hundred thoufand hardy feamen, which would greatly increafe our ftrength and revenue. What a glorious profpect for a maritime and commercial people, whofe wealth and bulwark is the fea!

It appears to me a matter of importance that country gentlemen fhould be inftructed in the indications and external appearances of coal, and efpecially fuch gentlemen as have landed property in coal countries. I have no doubt that many fuch will be glad to have the true and moft infallible fymptoms of coal pointed out to them, and diftinguifhed from the falfe and doubtful.

Some of the gentlemen whofe eftates lie contiguous to certain coal-fields, will no doubt have coal in their own grounds, and others will be confident they have coals, whether it really is fo or not, for it frequently happens that thofe who are wrong, or ought to doubt, are neverthelefs the moft confident. I will, therefore, for the inftruction of all concerned, make fome enquiries about the appearances of coal, and I will carefully

fully endeavour to diſtinguiſh the true and in-fallible from the falſe and doubtful. It may be ſaid with truth, that coal itſelf, in ſome form or other, is the moſt infallible appearance of coal; but this is too general. I will point out a few of the particular appearances of it, ſeveral of which have already been taken notice of and deſcribed in this hiſtory.

In order to enter properly upon this branch of enquiry, let us go back and look to the various ſections of the ſtrata of coal, and their concomitant ſtrata, which I have already pointed out in the rivers and rivulets of Mid-Lothian, &c. and likewiſe to the various ſorts of ſtrata which I have ſhown to be the immediate roof and pavement of coal. We ſhould alſo go back and examine my hiſtory of the diſpoſition, bearing, and declivity of the ſtrata of coal, and their concomitants, where it evidently appears that the ſeams of coal, and ſuch ſtrata as accompany them, all crop out to the ſolid ſuperficies of the globe ſome where or other.

This foundation being laid, we can proceed upon pretty ſure principles in our ſearch for coal. It being once underſtood that the one ſide at leaſt, if not both ſides of every ſeam of coal, riſes up to the ſurface of the globe, and crops out ſomewhere, it is our buſineſs to go to ſuch places where the ſuperficies of the ſtrata have a chance

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of being difcovered; as, for inftance, to the rivers, rivulets, gullies, rocks, and ditches, in fome, or all of which, we may get a view of the prevailing ftrata of the country; and if they are of the clafs of coal metals, we are fo far encouraged to proceed.

But I will beg leave to repeat here an obfervation which I made before, viz. that there may be, and certainly are, feveral fpecies of the coal metals, or of fuch as exactly refemble thofe that accompany coal, in feveral places where no feams of coal are to be found. Such, for inftance, are feveral varieties of the white and of the red free-ftones, &c.; but, on the contrary, the black and bluifh blaes and foft coal tills, in which there are frequently found balls of ironftone, and the grey bands, or greyifh thin ftrata, of a flaggy ftone, in the compofition of which, and often between the beds, there is found a fmall quantity of the fubftance of coal; thefe are feldom or never feen but in a coal field or in a coal country.

In working free-ftone quarries in a coal country, there is often feen blackifh beds of a coal-like fubftance between the ftrata or beds of ftone, and there frequently appear fmall quantities of real coal in the heart of the ftone when broken. Thefe fymptoms are not found between the beds, nor upon breaking the free-ftone, in countries where there is no coal; and, therefore, where these symptoms are found, they are so many signs of the coal neighbourhood; but it is impossible from these alone to know how near or far off you are from a stratum of coal; and, therefore, it is necessary for us to proceed a little farther in our search.

I have laid it down as an established fact, that the seams or strata of coal rise up to the superficies of the globe as well as all other strata, only they do not always push up so boldly to the very surface of the ground as many hard stones and other indurated strata are found to do; but, on account of the tender and more friable texture of the coal, the superficies of the stratum is often mouldered down, and lies concealed under a thicker or thinner bed or cover of clay, gravel, sand, or earth: However, the superficies of the seam of coal is frequently discovered where the concealing substances which covered it are washed off the face of the strata by rivulets, or are cut through by ditches, &c. Where the cover which conceals the coal is washed off, or any way cut through, the stratum of coal is sometimes laid bare, so as to be seen distinctly, but more frequently you can only discern some more obscure and imperfect appearances of the outburst or crop of the coal, such as small bits or grains mixed with the soil. When you are searching a ravine, a rivulet, or gully, and difcover grains or fmall bits of coal in any part of the flope, fuch grains point out the feam of coal to be higher up than where you ftand. If you difcover a quantity of foft, black, foot-like matter, you fhould dig in it, becaufe it is very probable that you have found the crop of a feam of coal, as the fuperficies of fome coal feams are diffolved into a foft undiftinguifhable mafs, refembling black friable earth, in which fometimes there is not a grain of coal to be feen immediately at the furface; neverthelefs, if you dig down a little in it, you will foon difcover grains and bits of coal. When the furface cover of clay, fand, or earth is fo thin that the fuperficies of the ftrata are touched in cutting ditches, and by the plough, the outcropping of a feam of coal is in that cafe frequently difcovered by grains of coal of different fizes, or a quantity of black footy ftuff being thrown up by the fpade or the plough. Perhaps at firft this black matter will not look like coal; but if you examine it narrowly, and efpecially if you dig in it, you will foon find fmall bits of coal, though perhaps at firft no bigger than peafe. In digging down for trial upon a real or fuppofed outburft or crop of a feam of coal, it is neceffary to have fome knowledge of the declivity of the ftrata in that ground, both with refpect to the point of the compafs towards which they flope, and alfo of

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the degree of declivity, in order to know how to push the cut you are digging towards the dip, otherwise you may soon cut through and overshoot the appearance of coal, and find nothing below but clay or rock, or some other earthy or stony matter, without the least vestigia or appearance of coal.

It is very well known in experience, that the crop or outburst of some coals spread upon the surface, sometimes to a considerable distance from the real and solid crop of the coal where the seam is to be found betwixt roof and pavement, even upon level ground; and where there is less or more declivity, it then spreads still farther from the solid stratum.

I have frequently seen the vestigia or appearance of a thick seam of coal spread upon the surface, beneath the upper soil, twenty or thirty yards from the real seam, where the surface of the ground had a considerable declivity. The side of this vestige or appearance of coal next the solid seam, is sometimes as thick as the seam itself; but it gradually wears thinner and thinner as it recedes or spreads away farther from the seam; and it also grows worse and worse, or the more unlike coal the farther from the seam. The side of this vestige, next the solid stratum, chiefly consists of the debris or rubbish of coal broken small. A little farther from the seam, it

consists

confifts of very fmall grains of coal mixed with a black foot-like matter; and ftill farther, nothing appears but footy matter, refembling black friable earth or clay, efpecially if there is any clay either in the foil or under it; and, at the extremity of the veftige, I have feen it dwindled away to an inch or lefs, of a blackifh foft fubftance, like a thin ftratum of clay. Where the furface of the ground has the leaft declivity, the veftige or appearance of coal is fure to fpread downwards from the feam, be the flope of the ftrata which way it will; and the greater the declivity of the furface, the farther down we may expect to find the extremity of the veftige.

When a coal crops out upon level ground, we fhall not find the veftige of it fpread out fo far from the feam as upon a declivity; and as the veftige is not fpread out fo far, neither will it be found fo thin at the extremity upon a plane as upon a declivity. When a ftratum of coal crops out upon a plane or level field, there is one remark to be made concerning the veftige of it, which is different from the declivity. Upon a plane, the veftige of the coal always fpreads out in a right line forward from the acclivity or rife of the feam of coal.

But I muft be more explicit. Let us fuppofe then that the ftratum of coal declines or dips with an eafy flope towards the fouth-eaft; in that

cafe,

case, the rise or acclivity of the seam comes to be towards the north-west, and in that case the vestige of the coal will be found a little way from the solid seam farther forward towards the north-west; and, therefore, when a vestige of coal so inclining is found upon level ground, and you have cut through it, and found different soils below, you must then turn your face towards the south-east, and dig away in the vestige, keeping your cut down to the clay or rock, or whatever matter you find immediately below the vestige of the coal, and by following the vestige or appearance of coal towards the real dip of the seam, it will not be long before you will find the solid seam between roof and pavement.

This circumstance of the vestige or crop of the coal spreading forward in a line with the acclivity of the seam, makes the knowledge of the declivity of the strata in that place very necessary, as without it you do not know which way to push or advance forward with your trial for the coal, although you should find a vestige or lively appearance of it. But in finding some appearance of coal upon an inclining plane field, or in the side of a glen or dingle, or any other description of sloping ground, the case is quite different. To whatever point of the compass the dip and rise of the strata should happen to be, the vestige of the coal is sure to slide down the

slope

ſlope of the ground, and we are ſure to find it ſpread thin in proportion to the precipitance of the ſlope, and the diſtance from the ſolid crop of the ſeam of coal.

When gentlemen wiſh to know if there are appearances of coal in their eſtates, they ſhould, in the firſt place, make themſelves well acquainted with the appearances and characters of the various ſtrata which commonly accompany coal. The characters and appearances I have deſcribed above: And, ſecondly, they ſhould make themſelves acquainted with the various ſymptoms and indications of a ſeam of coal, which I have now under conſideration. When they have acquired theſe two branches of knowledge, their buſineſs is to walk up and down, and carefully to examine all the ravines, gullies, rivulets, ſcars, and ditches in their eſtates, with ſuch rocks and precipices and other places where the ſuperficies of the ſtrata may be ſeen.

I have ſaid above, and I know it to be truth, that there are few amuſements more pleaſant, entertaining, and agreeable, perhaps there are none that ſoothe, enlarge, and elevate the mind like reſearches of this kind. It is in theſe ſcenes that we diſcover what the ſolid ſuperficies of our globe is compoſed of, and how it is formed; and the variety which we behold, and the diſcoveries which we make, are a never-failing ſource

ſource of pleaſure and entertainment to an inquiſitive and intelligent mind; and it is in theſe broken ſcenes of nature that we have the greateſt chance of making mineral diſcoveries of various kinds, and particularly diſcoveries of coals and quarries.

Sometimes the crop and bearing of ſtrata of coal run parallel to one of theſe ravines or gullies for a conſiderable length of ground, and ſometimes they croſs the glen or dingle in a right or a diagonal direction. When a ſtratum of coal croſſes a glen in any angle whatever, there is a probability of diſcovering the crop of the ſeam or ſome indications of it, either in the bed of the rivulet or upon one ſide of it.

It is not uncommon, in ſome places in coal countries, to find the ſuperficies of the ſtrata waſhed clean by a river or rivulet *in ſtatu quo*, that is, to find the ſeam or ſtratum of coal in its proper regular poſition in the ſolid ſuperficies of the ſtrata, at full thickneſs and in perfect form betwixt roof and pavement, dipping towards the ſame point with the ordinary declivity of the ſtrata in that place; but it is more common to diſcover in ſuch places only ſome appearances of coal, which frequently require knowledge and acuteneſs to diſcern, with ſkill and judgment to make a proper uſe of the diſcovery.

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I have all along in this hiſtory inculcated the neceſſity of ſome proficiency in the natural hiſtory of the various ſtrata which compoſe the ſtructure of the ſuperficies of our globe, in order to qualify us for reſearches of this kind.

It is neceſſary for us in the preſent caſe to have ſome knowledge of the bearing and declivity of the ſtrata, in the place where any indications of coal are found, before we can form any judgment of the diſcovery, and know how to make a proper uſe of it.

When a ſeam of coal runs parallel to a glen or gully, and crops out any where within the banks upon one ſide or the other, there is a great chance of diſcovering ſome indications of the coal, perhaps in ſeveral places as you advance up or down the glen.

I have ſhown already, that the outburſt, or ſuperficial veſtigia of a ſtratum of coal, upon a ſlope, is always found to ſlide downwards, and that the longer and more precipitate the ſlope is, the farther down the veſtige will ſlide when the crop of the ſeam happens to be high up. I have alſo ſhown, that the extremity of the veſtige of a coal ſeam at the ſurface is ſometimes diſſolved into a ſoft ſooty ſubſtance, hardly diſtinguiſhable from a thin ſtratum of black clay or earth; however, the ſuperficies of all coal ſeams are not ſo liable to be diſſolved to that degree. The debris of ſome of the ſplent and cannel coals frequently remain in hard and ſharp maſſes of various ſizes, even when mixt with the ſoil, and removed at ſome diſtance from the ſolid crop of the ſeam; and ſome of the cherry coals, or roch coals, as they are called in Scotland, do not diſſolve upon the ſurface into an undiſtinguiſhable maſs like a friable clay; but, on the contrary, although the debris, or coal rubbiſh, at the ſurface ſhould be broken very ſmall, yet there will be found ſome ſharp angular grains and bits of coal, of the ſize of peaſe, nuts, and plumbs. In places where ſeams of coal crop out, ſome appearance of the coal will be ſeen by an obſerving ſkilful eye in ſuch glens as we have been ſpeaking of. Sometimes maſſes of ſplent or parrot, (*i. e.* cannel coal), larger than a man's fiſt, will be found upon the ſide or at the bottom of a ravine, which have ſlipt down by degrees from the crop of a ſeam of coal ſituated above, and ſometimes ſmaller bits like the thumb, or leſs; but when the ſeam happens to be a cherry coal, the debris or veſtige of the coal which has ſlipt down, is then a great deal ſmaller, very often like duſt, and part of it in ſmall diſtinguiſhable grains, though perhaps no bigger than peaſe.

From theſe enquiries it appears, that the veſtigia and appearances of the outburſt or crops of different

different ſeams of coal are of three ſorts; *1ſt*, Pretty large maſſes of hard coal, not ſo apt to diſſolve when expoſed to the influence of the external air: *2d*, Smaller maſſes and grains of cherry coal of a diced or cubic form, which is frequently mixt with a ſoot-like coal duſt: And, *3d*, Coal duſt, without any viſible grains and maſſes, ſometimes reſembling ſoot, and ſometimes hardly diſtinguiſhable from a blackiſh or dark brown friable earth. One or other of theſe veſtigia or appearances of coal are frequently to be found mixt with the upper ſoil upon the ſide or at the bottom of a glen or gully. Sometimes they are to be found appearing under the upper ſoil upon the face of the rock in ſome break or ſcar.

When any of theſe appearances are diſcovered within the banks of a ravine or glen, the firſt thing to be done is to go to a place where the ſuperficies of the ſtrata are to be ſeen in the ſame glen, and to examine the points of the compaſs towards which the ſtrata trend, and incline or dip; and when theſe points are aſcertained, you will be enabled to know whether the ſtrata run parallel to, or croſs the glen, where the appearance is found. If the bearing of the ſtrata is either parallel, or nearly parallel to the trending of the ſides of the glen, you can eaſily diſcover the

the ſeam of coal, by digging ſmall pits at a proper diſtance from one another, cutting through the veſtigia of coal, and in a line up the ſlope; and if the laſt of theſe, that is, the upmoſt, ſhould happen to have no veſtige of coal, it is very probable that you have overſhot the ſeam, and in that caſe you muſt go back to the next pitting in which the appearance of coal was found, and dig a croſs cut in a line upwards, and you cannot fail to cut the ſurface or crop of the ſeam of coal, if you dig to the face of the rock or ſolid ſtrata. If the bearing of the ſtrata croſſes the glen, either at right angles or in a diagonal direction, your digging then muſt be directed acroſs the courſe and bearing of the ſtrata; and perhaps in this caſe it may be more proper to dig a trench, in a line from the place where the veſtige of coal is found, than to make pittings; the trench to run acroſs the bearing of the ſtrata; but of this thoſe who are upon the ſpot muſt judge which method of trial is beſt, as circumſtances vary conſiderably in different places.

But it frequently happens that the ſuperficies of the ſtrata are not to be ſeen in ſeveral places, in many glens the face of the ſolids being often concealed under a deep or thick cover of gravel ſand or clay.

It is very common in a coal country to find banks or beds of ſmall gravel, and likewiſe beds

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of ſand and clay, mixt with ſmall maſſes of coal of various ſizes, which indeed is an indication of your being in a coal country; but ſuch bits of coal ſo found are no indication of a ſeam of coal in this place; nevertheleſs, a ſeam, or ſeams, of coal may be there, but the bits of coal lodged in the banks of ſand or clay are not the veſtigia of them, as theſe maſſes of coal were carried there when the reſt of the ſand or clay with which they are blended was lodged there by water; and, therefore, it is neceſſary, when you find ſmall maſſes and grains of coal, to be able to judge whether they are mixt with the natural ſoil, or in adventitious beds or banks of gravel, ſand, or clay. If amongſt adventitious matter, you need not dig, unleſs you have ſome other more certain indications of a ſeam of coal being near.

Of all the beds and banks of adventitious matter which are found above and conceal the ſuperficies of the ſolid ſtrata from our view, clay is the moſt common in coal countries; though it frequently happens that we have to dig through ſand or gravel in ſinking coal-pits, yet we more frequently ſink through clay; and of all the ſpecies of clay, a ſtrong, hard, and dry clay, mixt with leſs or more of ſand, gravel, or ſtones, is the moſt common in coal-fields. When this ſpecies of clay is blended with boulders and bullets,

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with ſome gravel and ſand, it is frequently very ſtrong and dry, and almoſt as hard as a rock.— In ſome places this ſpecies of compounded cover clay contains ſpecimens of all the ſtrata found in the neighbourhood; and when it is of this ſort, which may be called a general compoſition, it is frequently a very curious and a very confuſed maſs of indigeſted matter. Grains, maſſes, and fragments of every ſpecies, quality, and colour of the ſtrata to be found in that country, are promiſcuouſly blended in this heterogeneous ſpecies of clay.

I have in the third part of this work inveſtigated and explained the natural hiſtory of theſe compound clays, and of the beds and hillocks of ſand and gravel found in ſo many places upon the ſurface of the earth, and, therefore, I will not loſe time here in repeating what I have ſaid elſewhere.

There are in ſome places vaſt beds and banks of theſe compounded clays, which cover and effectually conceal the ſuperficies of the ſtrata for a conſiderable extent; ſometimes over the whole face of an extenſive neighbourhood, excepting where it happens to be cut through by a ſtrong current of water; but it is ſometimes ſo hard that the ſtrongeſt currents are not able to wear it through. I have in many places ſeen this ſpecies

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of clay from a yard up to thirty or forty yards deep, and more, above the rock or ſuperficies of the ſtrata; and, as I hinted above, it frequently contains ſpecimens of the coals, and of all other ſtrata found in the neighbourhood. I have often ſeen ſuch a quantity of larger and ſmaller maſſes of coal blended in this ſort of clay in ſome particular places, as might deceive many, and make them imagine that it was the veſtigia of the crop of a ſeam of coal. I know that many do imagine it, and I have no doubt that ſeveral will be induced, from the quantity and variety of bits of coal found in different places in this clay, to make ſome trial in it; and for ſuch as are not very well acquainted with this compoſition, perhaps it would be wrong to diſſuade them altogether from digging a little in it, becauſe it is in ſome inſtances pretty difficult to diſtinguiſh between the veſtige of the crop of a ſeam of coal, and a neſt of bits and grains of coal blended in the compound clay; eſpecially when we conſider and know that a real outburſt of the crop of a coal is frequently mixt with clay at the ſurface of the ground; and, therefore, when appearances are ſo doubtful that a gentleman cannot readily diſtinguiſh with certainty whether the maſſes and grains of coal which he beholds are the veſtigia of a ſeam or adventitious, it may be proper for him to dig a little. If the appearance of coal, upon

upon which he is going to make ſome little trial, is adventitious, and belonging to the compound clays, the ſymptoms will not alter much upon digging in it, there being ſometimes a great depth of this clay above the ſuperficies of the ſolid ſtrata, and, therefore, he will not find any material change in digging. He will find no appearance of any diſcovery; there is nothing but the ſame compounded clay continuing with adventitious grains and maſſes of coal in it; which coal is part of the compoſition, and the whole maſs of the clay, as well as the coal, is adventitious.

I hinted before, that it is the character of ſome beds of this clay to be compounded of ſpecimens of all the neighbouring ſtrata; and in fact theſe ſpecimens, and the whole of this compoſition, was torn off the ſuperficies of the ſtrata by water, ſoon after they were formed, before induration was complete; and the matter ſo torn off was carried forward a little by the weight and force of thoſe high tides; and when the tides began to abate, and fall lower and weaker, theſe beds of clay were left as we find them when the weight and force of the water failed.

The numerous hillocks and extenſive beds of gravel which we behold in ſo many places upon the face of the earth, have the ſame origin.—Thoſe gravel beds and banks are alſo a compoſition of various ſpecies of ſuch ſtrata as were indurated,

durated, and they were likewiſe torn off the rocks, and after being rolled in the waters until all the aſperities and ſharp angles were worn off, the whole was lodged as we find it.

As ſeveral of theſe beds of compound clay contain ſpecimens of all the ſtrata of the neighbourhood, which is an evident fact, eaſily proved by comparing the ſpecimens with the ſtrata from which they were broken off; and as coal is a part of this compoſition, I give this as another ſymptom or indication of coal, which may be called an infallible one. I cannot, it is true, by ſeeing this ſymptom of coal, pretend to ſay there is a ſeam of coal within ſo many yards, nor within ſo many hundred yards: I have nevertheleſs no difficulty to aſſert that there is coal in the neighbourhood where this compounded clay appears with maſſes and grains of coal in the compoſition.

I have been thus explicit in pointing out the difference between ſmall maſſes of coal diſcovered in the compound clay, and the real veſtigia of the crop of a ſeam of coal, for the information of ſuch as cannot yet perfectly diſtinguiſh the one from the other.

After this explanation of the origin, appearance, and component parts of theſe beds of cover clay which ſo frequently conceal the ſuperficies of the ſtrata from our view, I hope that all gentlemen, even ſuch as are not adepts in this ſcience, will be able to diſtinguiſh between ſmall maſſes or bits of coal found in theſe beds of clay, and ſuch as belong to the real outburſt or crop of a ſeam of coal; and in caſes where they are not certain at firſt, and reſolve to dig, they will ſoon be able to diſtinguiſh between the veſtige of the crop of a ſeam, which is generally continued, and increaſes from the firſt diſcovery until we find the crop of the ſeam betwixt roof and pavement; whereas the bits found blended in the compound clay are generally detached from one another, are imbedded in a vaſt maſs of clay, without any continued ſtratum or veſtigia which might lead to a ſeam of coal; and, therefore, when gentlemen are ſatisfied that they are digging in a bed of this ſpecies of clay, it will be needleſs for them to proceed, there being no hopes of making any diſcovery in it.

There is one circumſtance yet to be remarked. The maſſes and bits found in the compound clay are generally hard, clear, and perfect; whereas the bits found in the veſtigia of the crop of a ſeam of coal have frequently a decayed imperfect appearance, ſometimes quite diſcompoſed or diſſolved into duſt, reſembling ſoot or black earth; and where there are ſmall maſſes of coal, they

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are generally tender and friable, and blended with different quantities of diſſolved coal duſt, excepting in the caſe of the ſeam of coal containing a ſtratum of hard parrot or of hard ſplent, as theſe ſometimes produce pretty large maſſes, which are found ſliden down the ſlope, or ſcattered about the ſurface, at a conſiderable diſtance from the crop of the ſeam of coal. Theſe larger maſſes frequently appear in conſiderable degrees of perfection, without any other veſtige of coal, at a diſtance from the ſeam, though other veſtigia may be found nearer to it. Maſſes of cannel and hard ſplent coals bear tumbling about, and they bear the external influence and changes of the air without injury as well as ſome ſtones; but all the cherry coals, roch coals, and ſome of the ſplents, diſcompoſe at the ſurface, and fall either to duſt or to ſmall grains, and it frequently happens that ſome parts of the ſame ſtratum of coal diſſolves to powder, and other parts of it fall down to ſmall debris, or to grains and bits of various ſizes; and theſe are found blended together either upon the furface of the ground or under the cover clay, or other matter.

I obſerved before that the veſtigia or appearance of coal is ſometimes ſo near the ſurface as to be diſcovered by the ſpade and by the plough; and I have frequently ſeen ſmall bits or grains of coal mixt with the mold caſt up by the mole,

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when the ſuperficies of the ſtrata happened to riſe to the ſurface of the ground; but when bits or grains of coal are caſt up by the plough or by the mole, it ſhould be conſidered and judged whether ſuch grains of coal are adventitious, or belong to the veſtige and crop of a ſeam.

Coal has been laid down in a vaſt number of places upon the face of the earth for burning lime and bricks, and for many other purpoſes, and a quantity of the ſmall debris of it will remain; and, moreover, where coal is burnt for common fuel, a quantity of the debris of it is carried out with the aſhes and ſpread over the fields. In theſe caſes, bits and grains of adventitious coal will appear after the plough, and in the mole hillocks, where no ſeam is to be found, which circumſtance ought to be well conſidered before gentlemen are too ſanguine in their expectations.

I have already adviſed gentlemen to examine well the glens and rivulets, and all other places where the ſuperficies of the ſtrata may be ſeen, which are likely places for diſcovering ſtrata of coal.

It generally happens in all coal fields or coal countries, that the ſuperficies or outburſt of a great number of ſeams of coal are to be ſeen in ſuch places, which I know for certain from my

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own obſervation and experience; but of all the places where coals are diſcovered, new made ditches are the moſt remarkable; however, it muſt be noted, that no mineral diſcoveries of any kind can be made in ditches, by forming roads, nor by any other ſuperficial methods of digging, where a thick bed of clay or a bed of gravel or ſand covers the ſuperficies of the ſtrata, but where the rock or ſtrata come up ſo high as to be found immediately below the upper ſoil, or under a very thin bed of ſurface clay, the veſtigia of coal are frequently thrown up by ditching. I have very often ſeen three or four, or half a dozen crops or veſtigia of ſeams of coal appearing in the ditches which were newly made to encloſe a field of ground.

I need not obſerve here that the ſymptoms or indications of coal appear in ditches by black ſtrokes acroſs the dyke or bank thrown up out of the ditch, which ſtrokes or ſtripes are ſometimes diſcernible at a conſiderable diſtance.

When ditches are cut acroſs the crop of a ſeam of coal, they throw up a quantity of black matter upon the top of the dyke, which generally appears obvious; but the veſtigia of coal ſo thrown up is not always diſtinguiſhable at firſt ſight from the veſtigia or crop of blaes, and all the black coal tills. The one is generally as black as the other to appearance, and, therefore, circumſtances muſt be well examined.

If a quantity of black argillaceous matter is dug through and thrown up, without any bits or grains of coal appearing in it upon examination, then it may be concluded that you have only cut through blaes or ſome ſpecies of black coal till; but if any bits or grains of coal are found, ſome trial ſhould be made by digging.

I hinted before, that the extremity of the veſtigia of a ſeam of coal is ſometimes no better in appearance than an inch or two of black clay or earth. When ſuch a faint and obſcure appearance is found in cutting ditches, it ſhould be narrowly inſpected, to ſee if any ſymptoms of coal can be found in it, ſuch as ſmall grains of coal, or if it be of a friable quality and appearance, like wet coal duſt. In this doubtful caſe you ſhould dig a little in it, following the veſtige towards the acclivity, if the ground is ſloping, but if it is a perfect plane, towards the ſtrongeſt ſide of the veſtige; and if a ſeam of coal crops out there, and if you are digging towards it, the veſtigia of the coal will encreaſe, and grow more and more like coal as you advance towards the ſeam, and grains of coal will appear, which will encourage you to go on with your trial.

But the veſtigia of coal diſcovered in cutting ditches are not always ſo obſcure. It is very common

mon for a quantity of coal to be thrown up with the ſpade, which may be ſeen in grains and ſmall maſſes upon the top of the dyke, eſpecially after a ſhower of rain; and it ſometimes happens that the crop of the coal is ſo near the ſurface of the ground, that they cut through the real ſuperficies of the ſeam in the ditch, and throw up the ſmall coal with the ſpade in great abundance.

When the veſtigia of a ſeam of coal is once diſcovered in a ditch, or in any other place or ſituation, it may be proper to make ſuch trials upon it, by pitting towards the dip, or by following the veſtigia with a trench, as will trace the ſeam under cover in ſolid metals, or until the proprietor is ſatisfied. No true judgment can be formed of the thickneſs and quality of a ſtratum of coal, until it is found under the cover of ſolid metals, that is, until you have it within the ſolid ſtrata, and between roof and pavement. When you have purſued the veſtige of a coal until you have it within the ſolid ſtrata, with a ſolid regular roof above the coal, and a ſolid and regular pavement below it, you can then judge of its thickneſs, as it ſeldom alters much in thickneſs when you go farther down in it, and you can ſometimes judge of its quality. When you have a regular roof and pavement, you can judge of ſome of the characteriſtic qualities of your coal; you can then ſee whether it is clean or foul coal,

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that is, whether the coal is pure, and free of heterogeneous matter, or if it is mixt and blended with pyrites, ſtone, or argillaceous matter; or if there are beds of ſtone, blaes, &c. running in the middle of the ſeam of coal, and ſo dividing it into two or more ſtrata: and ſometimes you can judge pretty near the crop or ſurface whether it will be a hard or ſoft coal, and if it will prove a good burning coal or not; though you cannot always judge of theſe laſt mentioned qualities ſo near the ſurface, as ſome coals, which appear ſoft, tender and uſeleſs, when but a few fathoms below the ſurface, improve wonderfully in ſtrength and quality at a greater depth, when under a great weight of ſuper-incumbent ſtrata. Some ſeams of coal appear and burn pretty well when firſt found between roof and pavement, and others are good for nothing ſo near the ſurface, and not fit for uſe until they are under many fathoms of ſolid cover. This is very well known in experience, and generally the deeper down the better.

Of all branches of buſineſs; of all the experiments that a man of ſenſibility can be employed in or attend to, there is perhaps none ſo amuſing, ſo engaging, and delightful, as a ſucceſsful trial upon the veſtigia or appearance of a ſeam of coal, or other mineral diſcoveries.

When you are attending the people who are digging down or forward upon the veſtige of the

coal,

coal, and that the indications are increafing and ftill growing better under your eye, the fpirit of curiofity and attention is awakened, and all the powers of expectation are elevated in pleafing hopes of fuccefs; and when your wifhes are crowned with fuccefs, when you have difcovered a good coal of fufficient thicknefs, and that all circumftances are favourable, the heart then triumphs in the accomplifhment of its wifhes with folid and fatisfactory joy. There is more rational delight, more fubftantial pleafure and happinefs, to be enjoyed in fuch fcenes as this,than in all the celebrated amufements which luxury invents and purfues.

I imagine and hope that I have been fo explicit in pointing out the appearances of coal upon the furface of the ground, and of the method of improving fuch appearances, that any gentleman who difcovers fuch appearances in his eftate, will be able, with his own fervants or labourers, to make fuch trials as will fatisfy him as to the exiftence of a feam of coal, and of what thicknefs it is; and it will enable him to guefs its quality, without fending for men of fkill in this firft experiment.

In my account of the external appearances and indications of coal, I have faid nothing about the Petroleum and Ochre, which are faid to iffue out from coal, about which a great coil is made by many who imagine that they underſtand theſe matters; and I have purpoſely avoided ſaying any thing about them as indications of coal, for a very good reaſon, viz. becauſe I would not wiſh to deceive. Theſe at beſt are but vague and uncertain ſymptoms of coal, and in moſt places where they abound, they are no ſymptoms at all.

The petroleum is an oily inflammable ſubſtance, found upon the ſurface of the earth, which in many places iſſues out of the rocks, from peat bogs, and from putrified vegetables, in a thouſand places where coal is not to be found; and ochre is compoſed of earthy ferruginous particles, carried by water from mineral bodies, and lodged or left by the water in various ſituations and quantities, and both of them frequently a hundred miles from coal. Why then ſhould we attend to, or have any thing to do with ſymptoms ſo very uncertain as theſe? Some ſpecies of petroleum may have a near relation to coal, and under certain circumſtances, for any thing I know to the contrary, coal may produce ſome little of it, but I am confident that it does not produce ochre. The petroleum is not only to be found upon the ſurface, but alſo it appears to me to be an univerſal oil, preſent in leſſer or greater quantity, and under ſome form or other, in all foſſile bodies, and ſo plentifully diffuſed in the atmoſphere, and

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through all the ſoils, as to be one of the chief principles and component parts of all plants. It is evidently combined with, or infuſed in ſeveral rocks and ſtrata, which compoſe the ſuperficies of the globe. Many of the coal blaes, and of the thin ſlate-formed argillaceous ſtrata of the coal metals, contain it in ſuch quantity as to produce a ſtrong flame when put in the fire; and ſome of them, when fire is applied to the ſide of a large parcel, will burn throughout of themſelves without the aſſiſtance of any other fuel; as, for inſtance, at Pitfirran in Fife, where ſeveral large heaps have been burnt, and where the whole maſs or heap grows red hot throughout; but the fire neither conſumes any of the quantity or bulk, nor does it produce any aſhes; and after the fire goes out of itſelf, the blaes aſſume a pale red colour, and are ſo much harder than before as to make good materials for private roads. Petroleum is likewiſe well known to be diffuſed in leſſer or greater quantities through the body of all lime-ſtone; and it is often found lodged in its cavities, ſometimes of the colour and conſiſtence of baſilicum ointment of the apothecaries, which I have ſeen at the Camp lime-quarries and at Dechmont lime-quarry, the one to the eaſt, and the other to the weſt of Mid-Calder in Scotland.

I have frequently ſeen thinly ſtratified lime-ſtone near a hundred miles from coal or coal metals, containing ſo great a quantity of this natural oil, as to produce a ſtrong flame when put in the fire, and the oil could be ſeen oozing out in the fire, though the ſtone was hard, and made a good produce of excellent lime when burnt for that purpoſe. I have alſo ſeen many black, ſhivery, and ſlate-formed or laminated ſtrata of the mountain ſchiſtus, that is, ſuch as are every way foreign from, and ſituated at a great diſtance from the coal metals, produce neverthelefs a ſtrong flame in the fire; and I have ſeen, very far from coal, beds of black hard ſtoney matter breaking or naturally ſeparating into ſmall angular maſſes, ſo plentifully impregnated with this oil as to emit a ſtrong flame when put in the fire.

Now, from all theſe obſervations and facts, and many more which might be produced, it is abundantly evident that this foſſile oil is univerſally diffuſed through all ſubſtances within the ſuperficies of our globe, and upon the ſurface of the earth, and is perhaps a conſtituent part in the compoſition of almoſt all bodies, though in widely different degrees, combinations, and forms.

I am aware that ſome will grant me that the petroleum or natural oil is found in many foſſile bodies, upon the face of the earth, yet, nevertheleſs, that coal is the chief repoſitory of it.

Many

Many gentlemen are of opinion, that the flowing of the petroleum is the principal, if not the ſole original cauſe, or the producer and nouriſher of coal; and theſe gentlemen argue thus, and ſay, "That the hypotheſis appears highly probable, 'as it is a well known fact that different coals 'are better and worſe in various degrees; ſome 'of them being very good, ſome indifferent good, 'and others worſe, very bad, and imperfect.— 'May we not ſuppoſe, ſay they, that all theſe have 'arrived at different degrees of maturity; that 'the worſt are yet far from being ripe; but that 'they will all come to perfection in the courſe 'of a very long time?"

This theory, which makes coal to be now a progreſſive work of nature, may appear to ſome plauſible; it is, however, very liable to weighty objections.

A ſeam of coal is an original ſtratum, which keeps its ſtation as regularly as any of thoſe placed above and below it. Of this truth I have ſhewn abundance of inſtances, to which I refer.

Now, if a ſeam of coal is an original ſtratum, the matter of it muſt have been collected, and the ſtratum of coal formed when the ſuperincumbent ſtrata and thoſe below it were formed. This is neceſſary in the nature of things, becauſe new ſtrata cannot now be inſerted among the original ſtrata.

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This account of the matter will not agree with the ſuppoſed progreſſive formation, and yet this is a well known fact, obvious to the moſt common obſervation; and, moreover, the impurities of bad coals, that is, the heterogeneous matter found blended in the different ſeams of bad coal, are real foſſile and mineral ſubſtances, ſuch as pyrites, iron-ſtone, free-ſtone, and ſeveral ſorts of argillaceous matter, which will keep their ſtations where they are; and, of conſequence, ſuch coals as contain theſe heterogeneous ſubſtances, muſt for ever remain as imperfect as they now are; and, therefore, we muſt give the coal a more ancient date in the annals of natural hiſtory; and we muſt alſo allow it another origin, or natural immediate cauſe, though the petroleum, for any thing I know, may in part be the remote origin of it.

Coal has very obvious and ſtriking appearances of being compoſed of vegetable ſubſtances. I have frequently ſeen evidently the grain and other characters of wood in ſeveral coals; and in ſome enquiries and diſquiſitions in another place, viz. in my natural hiſtory of the ſtrata and rocks in general which compoſe the ſtructure of the ſuperficies of our globe, I have made it evidently appear, even to a demonſtration, that the antediluvian timber was the original of coal.

It will appear highly probable, from what is ſaid in that hiſtory, that the greateſt part of the antediluvian earth was covered with a tall and luxuriant growth of timber, and it is eaſy to conceive that ſo many millions of acres of tall timber formed into coal, would produce a very great quantity of that valuable foſſile; and in this reſpect the effect and the cauſe exactly correſpond to one another; the quantity and variety of coals found within the ſuperficies of the earth, ſeems to tally with the immenſe quantity of timber which produced it. I am not the only perſon who has ſeen and obſerved the appearance and characters of timber in coal. Several other gentlemen who are converſant in theſe matters, have aſſured me, that they have not only frequently ſeen evident marks and indications of the grain of timber in coal, but that they have alſo ſeen conſiderable pieces of whole timber, which, though black as coal, yet not ſo diſſolved and altered as to loſe the original form and grain of a round piece of timber.

From every ſituation and circumſtance relating to the ſtrata of coal, and of the other ſeveral ſtrata which accompany coal, it is abundantly evident that they were all formed by the agency of water, as well as the reſt of the ſuperficies of our globe; which ſubject I have clearly explained in another place; and, therefore, it follows, by a natural and neceſſary inference, that the ſtrata

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of coal, and of all the coal field, were formed at the ſame time as the other ſuperficies of the globe, though this time comprehended the continuation of days, weeks, and months; and it appears to me that the ſtrata of coal and of the coal field were among the laſt that were formed; which circumſtance I hinted at before.

All the beds or ſeams of coal are equally well ſtratified with the other concomitant ſtrata of the coal field, and the ſtrata of coal are in every reſpect fully as regular as any other ſpecies of ſtrata found above or below the coal; which ſubject I have alſo explained above; and beſides theſe general characters of ſtratification which ſeams of coal have in common with the other ſtrata of the field, a great many ſeams of coal exhibit, moreover, ſuch internal marks and characters of ſtratification, as clearly point them out to the curſory obſerver to have been formed by the motion or flowing of water.

It is very common to ſee the conſtructure of many ſeams of coal compoſed throughout of a great number of thin and very regular layers or ſtrata of coal, which ſeams of coal in appearance, and in reality, are of a laminated ſtructure. Some of theſe laminated ſeams of coal are compoſed of a great number of thin ſtrata of nearly the ſame quality and texture, and other ſeams contain ſtrata or lamina of two or three different ſpecies

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of coal. And again, ſome of them contain a conſiderable number of ſpecies and varieties of coal in the ſame individual ſeam or ſtratum; and theſe ſeveral varieties of coal of different appearance, quality, and texture, are all diſpoſed in very regular ſtrata or laminæ, lying one above another in the ſame ſtratum of coal. We commonly find in one ſeam of coal a ſtratum of ſplent and a ſtratum of cherry coal, and ſometimes we find ſtrata of ſplent, cherry coal, roch coal, parrot, and of run ſplent in the ſame ſeam. There is a thick ſtratum of coal among the edge ſeams of Gilmerton, Loanhead, &c. in Mid-Lothian, called the Great Seam, which contains coals of ſeveral different qualities and varieties, ſuch as ſplent coal, roch coal, run ſplent coal, a ſtratum of fine parrot, or cannel coal, of excellent quality, and a ſtratum of coarſe parrot of inferior quality; and there are in the ſame great ſeam varieties of the roch coals and of the run ſplents; ſo that this individual ſtratum contains a conſiderable number and variety of coals of different appearance, quality, and texture; and this variety of coals is found in the great ſeam in all the different places where it has been worked, in a diſtance of ſeveral miles in length upon the bearing of the coal.

Having mentioned many different ſorts of coal, it may be proper to give a ſhort hiſtory of the ſeveral known ſpecies of coal in a regular ſeries.

There are at leaſt ſix different ſpecies of pit coal, ſuch as,

1ſt, Caking coal, of a fat bituminous or reſinous quality which melts in the fire, and then runs together into one maſs when thoroughly heated, and burns to a cinder with a thick fuliginous ſmoke; but, the beſt varieties of it produce very little aſhes.

This ſpecies of coal is commonly of a fine black clear colour, of conſiderable brightneſs when newly worked, and remarkably clean and pure, though not without exceptions, being in ſome places debaſed with clay, pyrites, and other foul admixtures.

There are ſeveral varieties of this ſpecies of coal. One of them is called cherry coal, which is of a cubical or diced ſtructure, the moſt tender and brittle of all coals, which generally breaks ſmall in working and carriage, but the ſmalleſt coal duſt of it cakes or runs together in the fire to a ſtrong and pretty hard cinder when it is thoroughly heated, and even before it is all quite red hot. Some varieties of theſe fat coals exhibit no regular form or ſtructure, but are run together in the ſtratum to a general confuſed maſs, with-

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out any appearance of laminæ or other determinate figures. Some of theſe are ſoft and eaſily worked, and produce moſtly ſmall coals, and others of them are more hard, ſtrong, and ſolid, and yield great coals in working; but none of theſe are quite ſo hard as ſome other ſpecies of coal.

Northumberland, and other parts of the north of England, are famous for producing abundance of this ſpecies of coal, great quantities of which are ſhipped at Newcaſtle and Sunderland, and it is commonly known by the name of Newcaſtle coal.

This ſpecies of coal is not quite ſo common in Scotland as the north of England. The greateſt quantity and beſt quality as yet diſcovered in Scotland, is at Balmule, near Dunfermline, in the county of Fife, where the ſeams or ſtrata of coal are of good thickneſs; and they will, in the courſe of time, become of great value, when this ſpecies of coal is all worked to a great depth in the north of England. There are ſeveral ſeams at Balmule of excellent quality, which ſtretch longitudinally through a conſiderable length of country, eſpecially towards the north-eaſt. There is alſo pretty good caking coal at Pitfirran, and other places in the neighbourhood of Dunfermline; and in other parts of Scotland,

land, but not in ſuch abundance as in the north of England.

2*d*, The ſecond ſpecies I ſhall take notice of is called rough, roch, or rock coal, which is a free coal of various degrees of ſtrength and hardneſs, commonly of a good black colour, though not ſo bright and gloſſy as the Newcaſtle coal.

Moſt of the varieties of this ſpecies burn to a good cinder, though they do not cake, run together, nor cohere in the fire ; but they frequently produce more aſhes than the Newcaſtle coal, though not all of them. Some of the varieties of the roch coals are as pure and as free of heterogeneous mixtures as any coal whatſoever ; and theſe pure roch coals produce very little aſhes, and are in fact the beſt of all coals for culinary uſes, making a ſtrong, clear, and open fire.

There are many varieties of the roch coals. Some of them are finely ſtratified, the ſeam of coal appearing to be compoſed of numbers of thin and regular ſtrata or beds, lying one above another, and ſtrongly cemented together, and broken tranſverſely into irregular ſquare maſſes of no determinate ſize or figure.

Some varieties of theſe coals approach to a cubical or diced form, which are called cherry coals, although they want the caking quality. Theſe

Theſe are generally ſoft, brittle, and eaſily worked, and break ſmall in working and carriage. Some of the roch coals are run together into a hard ſtrong maſs, which appears of a flat or horizontal texture, but without any diſtinct ſtrata or laminæ in the coal wall or ſtratum.

In ſhort, the form and texture of the varieties of the roch coals are ſo numerous, that it would be tedious to enumerate them all. Many of theſe coals are very hard and ſtrong, producing large maſſes or great coals in working, which ſtand carriage well. Such of theſe coals as do not burn to a good cinder are debaſed by a conſiderable proportion of ſome earthy matter, which cauſes them to produce a great quantity of aſhes, and this great proportion of aſhes prevents or ſpoils the cinders.

Great abundance of this ſpecies of coal is found in the counties of Edinburgh, Linlithgow, Fife, Stirling, Lanark, and other parts of Scotland, and likewiſe in Shropſhire and ſeveral other parts of England.

3d, Stone coal, or ſplent coal, which is of a laminated or ſlaty ſtructure, burning freely with a ſtrong flame and much ſmoke, and producing leſs or more aſhes in proportion to the purity or debaſed quality of the coal.

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This ſpecies of coal is remarkably hard and ſtrong, and difficult to break acroſs the bed of the ſtrata, excepting at the natural tranſverſe cutters, but it cleaves or ſplits eaſily into thin broad flags like boards, which kindle almoſt as readily and burn as freely as fir dales. No foſſile bodies of conſiderable bulk are more regularly ſtratified than ſplent coals. Some varieties of this ſpecies are very light and pure, from which a natural oil ſometimes oozes out in the fire, and theſe burn fiercely with much flame and ſmoke, but they produce very little aſhes. Some of theſe burn with ſuch a clear ſtrong flame as to give a light equal to that of a number of candles; and the country people in many places uſe no other light in the winter nights. Other varieties of it are more ſtony, hard, and ponderous, which produce much aſhes, and ſome of them are ſo foul as to leave a white ſlaty maſs in the fire, which will not burn down to aſhes.

One variety of this coal is by Scots colliers very properly called *run ſplent*. This variety is of a more clear and gloſſy black colour than moſt of this ſpecies, which is of a more duſky black than moſt of the other coals.

Many of the run ſplents exhibit a mixed texture, being partly laminated and partly uniform, like broken pitch, and ſome of them are laminat-

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ed throughout the whole ſtratum; but they all appear to be of a mixed quality, and the ſtrata or laminæ are ſo run and cemented together, that they will not ſplit aſunder ſo eaſily nor ſo completely as the perfect ſplents.

All the run ſplents are certainly of a mixed quality, ſome of them being compoſed of about half and half of the ſecond and third ſpecies, and ſome of them of the ſame proportions of the firſt and third; and, as a proof of this mixture, the laſt partakes of the caking quality of the firſt ſpecies in ſo conſiderable a degree as to run together in the fire, and to produce excellent cinders in burning, whereas the pure ſplents burn to aſhes.

All the run ſplents are amongſt the beſt coals in the world for culinary and all domeſtic uſes. The ſplent or ſtone coals are very common in the Lothians, Fife, Ayrſhire, and all the other coal countries of Scotland, and in ſome parts of England.

4th, Cannel coal, or parrot coal, which is of a good black colour, and of a fine, ſmooth, ſolid, uniform texture, conſiderably hard, and breaking in any direction. When this ſpecies of coal is clean and free of heterogeneous mixtures, it is pretty light, makes a chearful fire, with a ſtrong flame

flame and but little ſmoke; and it burns to a leſs or greater quantity of aſhes in proportion to the good or bad quality of the coal.

Some of the beſt varieties of this coal are ſo fine and ſolid as to be often turned and otherwiſe formed into many ſorts of utenſils and trinkets, which bear a good poliſh—but they are more beautiful than durable; however, the coal is ſo fine and clean as not in the leaſt to ſtain the hands nor the cloaths when made into toys.

This ſpecies of coal is very common in the county of Edinburgh, and in many other parts of Scotland and England.

5th, Culm, or blind coal, which is of a fine clear, gloſſy, black colour, and of a bright metallic appearance.

This is a very ſingular ſpecies of coal, which emits neither ſmoke nor flame in burning. It is not very eaſily kindled, but when thoroughly ignited, it burns a long time with a clear, ſtrong, glowing heat, like charcoal, being very durable, and without the leaſt ſmoke or flame from the beſt varieties of it; but it emits a ſtrong, diſagreeable, ſuffocating effluvia when burning.

This coal is very free and tender, and generally breaks ſmall in working and carriage; but it has nothing of the caking quality, nor does it burn to a cake or cinder, nor produce much aſhes.

It is very remarkable, that when a quantity of culm has been all on fire in a grate or furnace, and after every particle of it has been burning with a clear glowing heat, when the fire is either extinguiſhed or allowed to go out of itſelf, what little culm remains in the grate or furnace has no marks of fire on it. Even the ſurfaces of the ſmall bits which remain unconſumed, retain the ſame gloſſy black colour, the ſame texture and bright appearance as before, and partly of ſome other ſpecies of flaming coals.

6th, Jet, which is a peculiar ſpecies of coal, is of a fine bright black colour, remarkably clean and light, of a ſmooth and ſolid texture, and bearing an elegant poliſh; and, therefore, much uſed in making ſnuff-boxes and other trinkets.

Jet has a near reſemblance of the finer varieties of cannel coal, excepting that the cannel coal has an uniform texture, without any viſible grain, and breaks in any direction with equal eaſe; whereas jet has the apparent grain and ſtructure of wood, not readily breaking acroſs, but it cleaves eaſily lengthways like the ſplent coals.

Jet is found in England, and in other parts of the world, in detached ſeparate maſſes of various ſizes lodged in other ſtrata, and likeways in clay pits and in other loofe matter, lying above the fuperficies of the folid ftrata; but as I do not know of any regular ftrata of jet being as yet difcovered any where, it cannot properly be included in a natural hiftory of the ftrata of coal.

However, the natural hiftory of jet leads me to imagine that there are ftrata of it within the folid fuperficies of the globe, although they are not yet difcovered. Samples of all the other fpecies of coal are alfo found in detached maffes of various fizes, lodged in the ftrata of free-ftone and others, within the bounds of the coal fields or coal countries, and likeways in the beds and banks of clay, fand, and gravel; fometimes in fuch confiderable quantity as to deceive many, who are led to imagine, from the abundance of this loofe coal which they fee, that they have difcovered the crop or furface of a ftratum of coal; whereas it is only a great quantity of detached maffes and particles of coal blended in fuch clay, fand, and gravel as lies above the fuperficies of the folid ftrata. But it is a certain fact that thefe famples of coal which are fo found in detached maffes and particles lodged in the ftrata, and in the banks of clay, fand, and gravel in coal countries, are exactly of the fame fpecies, texture, and quality as the ftrata of coal which are found in the fame neighbourhood as this loofe coal; and, moreover, this loofe fcattered coal

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is only found in the neighbourhood of coal, or never far from the coal fields; which fact I have thoroughly investigated and explained above.

From this known truth in the natural history of coal, which many have, and every body may observe, I am led to imagine that there may be regular strata of jet as well as of the other fossile coals: Samples of all which are found in like situations and circumstances as the jet, and no doubt they have the same origin, which I have shewn above to be the superficies of the regular strata of coal.

This account of the several species of fossile coal which have been discovered hitherto, makes it evident, I might say to a demonstration, that coal is composed of vegetable substances, and that the antediluvian woods is the real origin of it.

The form, grain, and texture of timber has been so repeatedly seen and observed by naturalists, and by other men of judgment and skill, in such great quantities, and in so many places, that the position cannot be denied without rejecting the evidence of the phenomena of nature.

That wood is the origin of coal is so plain and evident a truth, that we can almost trace and point out the particular species of wood which composed

compoſed particular ſpecies of coal; ſuch as, for inſtance, we may ſuppoſe, that the long-grained reſinous pines and fir timber are the principal ingredients in the compoſition of our fine flaming ſplent coal, which, like the fir timber, will readily cleave from end to end, and will kindle almoſt as eaſily and burn as freely as the reſinous fir timber itſelf. The like comparative characters and ſimilitude might be found and pointed out between other kinds of wood and the other ſpecies of coal, which would be found to correſpond with remarkable exactneſs, after allowing for the various mixtures of ſeveral ſorts of wood in one ſtratum of coal, and for the great alteration the wood muſt ſuffer by being ſo long agitated in the waters of the deluge, and the great effects which compoſition and mineralization muſt neceſſarily have upon the appearance and properties of the ſeveral ſpecies of coal.

Some of our coals indeed are remarkably clean and pure for ſuch bulky foſſiles placed among numerous ſtrata of heterogeneous ſubſtances.— Theſe diſcover very little of foreign matter in the compoſition of the ſtratum; but, on the other hand, many of them are blended and mineralized with various proportions of ſtone, clay, pyrites, and other heterogeneous matter, which debaſes and ſpoils the coals to ſuch a degree that many ſeams are of an inferior quality, and ſome

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of them are rendered entirely ufelefs. But as this enquiry and inveftigation muft be conjectural, and would be merely curious, as it could convey no ufeful information, I will proceed no farther in it.

Coal tar, which has of late been extracted in fuch great quantity from this valuable foffile, is another proof that wood is the origin of coal.— The coal tar is fo nearly of the fame nature and quality as the foreign vegetable tar, that there feems to be no other difference between them than what muft neceffarily be communicated or acquired by the compounded mineralized ftate of the foffile coal: But I could wifh that this proof of the vegetable origin of coal had never been produced. The difcovery of coal tar will be of infinite detriment to the nation in the courfe of time.

The avidity for prefent profit will prompt many to confume the coal in making tar, which our cities, our populous countries, and our manufactories will foon want. Where iron works are carried on near the tar kilns, I would approve of making coal tar, becaufe, in that cafe, the cakes produced by the kilns are ufed in a valuable manufacture, which is a national benefit; but where the tar and iron works are not conjoined, at leaft in the neighbourhood, the coal tar is a pernicious manufacture.

Let

Let us now return to our enquiries about the petroleum and ochre. If all our coals were found in the concavities of mineral veins, and not in regular ſtrata, there would be ſome more reaſon to ſuppoſe that coal was produced by the continual flowing of the petroleum or of foſſile oil; but where it really is found in regular ſtrata, there is not the leaſt foundation for ſuch a ſuppoſition. It is not even poſſible in the nature of things. I have ſeen coal in the cavities of mineral veins at Caſtle Leod, in the highlands of Scotland. This extraordinary coal is lodged in common rake veins, or perpendicular mineral fiſſures in the mountain rocks, far from any ſtrata of coal, or of the coal metals. The veins at Caſtle Leod open into bellies or concavities of different lengths and capacity, and cloſe again, or check, by the ſides of the veins coming together; and they have every character and deſcription common to good rake veins, and the coal is lodged in the cavities of them, exactly in the ſame manner as lead, copper, &c. are found in ſuch veins in other places. I got ſome coal dug out of one of theſe veins, which I burnt in the houſe: The coal was very ſoft and tender, being very near the ſurface; but it was perfectly clean and bright—about one foot thick where I opened the ground, but it grew thinner towards the ends of the belly or concavity of the vein,

and

and it ſoon dwindled away to nothing, and twitched out entirely; and I ſaw it open again in ſeveral places in the bearing of the vein. This coal was exceedingly fat, ſo as to run together ſtrongly in the fire like the beſt of the Newcaſtle coal. I look upon this phenomenon in the natural hiſtory of the mineral kingdom as a great curioſity. I call it a phenomenon, becauſe it is an extraordinary appearance quite out of common experience. I did not know any thing about coal in ſuch a ſituation and circumſtances until I ſaw this. I had never heard nor imagined any ſuch thing until this offered itſelf to my conſideration. I was at all due pains to inveſtigate this phenomenon thoroughly, ſo as not to leave out any circumſtance which ſhould be conſidered, and ſo as not to be miſtaken in any point.

There are ſeveral mineral veins at Caſtle Leod running parallel to one another upon the north-eaſt ſide of a pretty high and rocky mountain; and there are ſome leſſer ſtrings branching out from the principal veins.

There is coal found in three or four of theſe veins, part of which had been wrought out of ſeveral bellies of thoſe veins, as far as they could go down for water, before I was there; and as I had no apparatus for drawing the water out of the old works, I was obliged to open new ground farther

farther forward upon the bearing of one of the veins, out of which coal had been wrought.—When I opened the ground the coal was only about one foot thick, and it only continued for a few yards in length at that thicknefs, before it began to dwindle away by degrees, and it was foon fqueezed out entirely at both ends of this little belly; however, I faw evidently, that fome of the bellies or concavities of the veins, out of which they had formerly dug fome coal, were wider than the one which I opened. Some of them were up to three or four feet wide between the fides of the veins; and the concavities, out of which they had dug coal, were alfo fomewhat longer than the one I opened. But they had chofen the beft places for their trials, which was not difficult, as the coal was to be feen in the veins at the furface of the ground. I faw coal in feveral places in the checks or twitches of thofe veins between the open bellies, not above one inch in thicknefs.

The circumftance of thefe coal veins opening into bellies, or concavities, between the fides, and twitching again by the two fides coming clofe together, is common to all mineral veins of this defcription, though the concavities of the veins at Caftle Leod are remarkably fhort; and the twitches, or clofe parts, are alfo fhort, thefe being a fpecies of piped rake veins; the character and

and defcription of which is, that they open and clofe again at fhort diftances in the line of bearing, and the pipes or concavities put down in the dip of the vein parallel to one another.

The coal at Caftle Leod will not pay for working, unlefs it was for fome very particular purpofe, and that other coal could not be had without an extravagant price; but it would be a noble experiment to put down to a great depth in one of thefe pipes or bellies of coal, in hopes of finding fome mineral ore. There is at leaft a probability that the coal may be cut out below, and fome one of the precious or ufeful metals come in inftead of it.

A change of the produce of mineral veins at different depths is not out of nature and experience. One of the richeft mines of Saxony was at firft next the furface an iron mine. At fome confiderable depth the iron was cut out below by copper. It was wrought a long time as a copper mine, but at a ftill greater depth the copper was cut out below by cobalt; and when they had wrought fome time longer and deeper down, the cobalt was laft of all cut out below by filver ore, and they have for a long time been working it as a rich filver mine. They have found a change of metallic ores in Germany, befides that in Saxony. I do not pretend to infer from thofe inftances of the German mines, that there is any certainty; but there is a probability that ſome valuable metallic ore would cut out the coal at a good depth in the Caſtle Leod veins.

I have ſeen a very ſmall quantity of coal in ſome other parts of the Highlands, in ſmall fiſſures of the rocks, ſince I ſaw the above; but none to be compared for quantity to that at Caſtle Leod.

I ſaw none above two or three inches thick in any other place, nor of any continuity to ſignify.

There is coal in the Iſle of Mull of a pretty good thickneſs. I have been told that it is above three feet thick; and from the imperfect deſcriptions which I could obtain, I ſuſpect it to be a vein of coal; but this I cannot poſitively aſſert, as I never was there, nor did I ever meet with a perſon that had been there who had ſcience enough to diſtinguiſh between a ſtratum of coal and a vein of coal, or that could diſtinguiſh a ſtratum from a vein of any ſort.

I was a good deal ſurprized when I firſt ſaw the coal veins at Caſtle Leod; however, upon weighing the matter, and examining all circumſtances, I was afterwards able to comprehend this phenomenon. I have in another place made it evident, that water was the agent in the formation of the ſtrata; that all the phenomena which we behold upon and within the ſuperficies of our globe were produced by water, and it was

water

water that brought and poured the ingredients of all the mineral ores into the cavities of the veins, while thofe ingredients were in a fluid ftate, and confequently it was water that carried and poured the fluid fubftance of the coal into the veins at Caftle Leod.

I have in its proper place fully inveftigated and explained thefe fubjects in a clear and fatisfactory manner, where I have demonftrated that it was water alfo that fpread out the fluid fubftance of the coal where it is found in regular ftrata: But I will not meddle with thofe difquifitions here, which I have fully difcuffed elfewhere.

I think that I have now made it abundantly evident that coal is not produced by the flux of petroleum, nor by any fictitious caufe; but that the ftrata of coal were formed by water at the fame period of time, and in the fame manner, as all other ftrata were formed; and that the origin and fource of the coal was the antediluvian timber; and, therefore, it is neceffary to give up that point. But it may be faid, that I cannot poffibly deny, with any fhadow of truth, that coal produces ochre, as we have, it may be faid, the evidence of our fenfes for the truth of the pofition; it being very common to fee coals quite red and covered all over with ochre; and upon breaking the maffes of coal, it is found lodged in all the interftices, fo as to make it internally red as well as upon the outfide; and it is pretty well known that coal lying dry, without any water about it, for a confiderable time before it is wrought, is the caufe of this ochry colour, and, therefore, it may appear to many that coal produces ochre, when it is found fo plentifully lodged through the whole mafs. But, however evident it may feem to many, I cannot grant the pofition, and therefore it is incumbent on me to refute it. Water is the common vehicle of all foffile particles below ground.

I have afferted above that the foffile oil is very widely diffufed, and I now affert that the fources of ferruginous particles or ochre, which are known to be iron pyrites, are perhaps as widely diffufed through all foffile bodies.

Iron is found in lefs or greater quantities almoft every where upon the face of the earth and under its furface; and it is commonly very plentiful, both in balls and ftrata, in the neighbourhood of coal, and it is very well known that the pyrites are very near, if not altogether as common. Both are frequently found the immediate roof of coal, and pyrites efpecially is fometimes found in various quantities, and commonly in flattifh glebes, mixed in the ftratum of coal itfelf.

Now, as thefe ferruginous fubftances are found imbedded in the feam of coal, and very frequently ly in the roof and pavement of it, no doubt corroding waters find it there, and lodge the minute particles of it in the interſtices of the coal ſeam, where it appears in an ochreous ruſt when the coal has been laid dry for ſome time.

That water percolates the pores and fiſſures of the ſtrata, and carries various particles along in its ſubterraneous motion, I explained elſewhere. While this ſubterraneous water is excluded from the effects of the external air, it continues to carry about the various foſſile particles which are mixed in it; but when it iſſues into the external air, or any how approaches it, the quantity of water immediately diminiſhes by evaporation; and, of conſequence, the foſſile particles are deſerted and lodged where the water left them. When a ſeam of coal is levelled with an adit, the water is carried off the coal by that drain. The air gets admittance into the works in great quantity through the pits and mines, and then a conſiderable portion of air penetrates the natural joints or cutters of the coal when it is laid dry, which evaporates the water that was in all the joints or interſtices of the ſeam when it was firſt drained, and the ochreous particles that were combined or mixed with the water are left behind in ſuch quantity as to colour the coal of a browniſh yellow red.

When

When water containing ferruginous particles iſſues out of an artificial adit, or at any natural vent, to the ſurface of the ground, part of the water is immediately diſſolved upon its coming in contact with the external air, and carried up in ſteam or vapour, and then the remaining part of the water is not ſufficiently abundant to carry along all the particles which were at firſt brought out in it; and, of conſequence, ſome is lodged ſediment, and ſome of it adheres to whatever it comes in contact with, and it continually accumulates, until it becomes a conſiderable body of ochre. The ſame happens in a leſſer degree in the interſtices of the ſeam of coal, and of ſeveral other foſſile bodies beſides coal. I have frequently ſeen free-ſtone and other ſtrata as red with ochre as ever I ſaw coal, and from the very ſame cauſe, viz. the ferruginous particles, firſt carried, then lodged, and afterwards deſerted by the water.

The water which ſurrounds the ſtrata, and penetrates all their pores and cranies, is plentifully impregnated with iron in a fluid form, or with ochreous particles; but when thoſe ſtrata are drained by an adit or otherwiſe, the greateſt part of the water runs off, and the remaining part is evaporated by the admitted air, and the ochreous particles are left behind, being deſerted by the

water

water which fuftained them, and they colour all the ftrata and every foffile body they adhere to. Take a mafs of cannel or of fplent coal, which is red with ochre, and break it where there is no natural joint or crack, and the heart or folid part of the mafs will be found as black as any other coal, and perfectly free from the leaft tinge of ochre, though the outfide and all the joints and interftices fhould be quite red with it.

I have perhaps faid too much about thefe vague and falfe fymptoms of coal. My apology for fo doing is this: I know that many are in danger of being deceived, and that many have been deceived by them. There is much money laid out imprudently in fearching for coal upon the fole footing of one or other of thefe fymptoms. I lately faw and examined a remarkable inftance of each kind.

In one of thefe places a number of long mines had been driven into the fides of the hills and glens, and deep pits had been funk in different places at great expence, upon the faith of the petroleum, becaufe a little of it (a thin film or pellicle) was feen to iffue out from fome beds of fchiftus of the mountain rock, and becaufe fome of thofe fhivers would flame a little in the fire.

This place is fituated in the mountains, at leaft thirty miles from coal or coal metals, but it

is

is not at all uncommon for the ſchiſtus, or ſuch platy and ſhivery rocks to be inflammable, from their being impregnated with the foſſile oil.—There is not in this place the leaſt ſymptom in nature of coal, nor of any ſtrata or ſpecies of rock that is found to accompany coal.

In the other inſtance which I hinted at, they had ſeen a little ochre, and therefore they certainly muſt have coal, for coal, ſaid they, produces ochre, and upon this aſſurance of ſucceſs they fell to work by ſinking and boring to a conſiderable depth, and at great expence. I viewed this place before they gave over working, and ſaw nothing round about them but grey indurated ſtrata of the whiny mountain rock,—nothing that had the leaſt affinity or reſemblance to any of the concomitants of coal. Upon examining the rubbiſh thrown out of their ſhaft, I found that about one third of it was iron ore, mixt with a conſiderable quantity of iron ſpar, which appeared to me likewiſe to contain iron. The myſtery of their deception is thus explained: The iron ore produced the ochre which they ſaw upon the ſurface, and the ochre led them to ſink their ſhaft upon a vein of iron ore.

Now theſe two recent inſtances are in point, and they are both eminent inſtances of being deceived by ſuch pretended vague appearances.

I have honeſtly and faithfully endeavoured to diſtinguiſh and point out the true and real appearances of coal, and to overlook or reject ſuch as are falſe or uncertain; and this I have done from the beſt of motives, viz. to enable ſuch as may be concerned to chuſe the one and to reject the other; and, therefore, if I have in any place been a little tedious or prolix, I hope to ſtand excuſed, as my intention is good.

END OF PART I.

PART II.

Of the Natural Hiſtory of Mineral Veins, and other beds and repoſitories of the precious and uſeful Metals.

IN this part we ſhall treat, *firſt*, of mineral veins, and of ſome of the other ſituations and circumſtances of the mineral ores: *Second*, of the moſt promiſing and certain appearances and indications of valuable mines; and, *third*, I will point out ſome few local examples of new mining fields, which deſerve to be explored.

There are at leaſt four diſtinct ſpecies of mineral veins, viz.

1ſt, The *rake vein*, or perpendicular mineral fiſſure.

2d, The *pipe vein.*

3d, The *flat* or *dilated vein;* and I will venture to add a

4th, Which I will call the *accumulated vein.*

And

And besides these four, which may be called capital veins, there are a great number and variety of inferior strings and branches accompanying the principal veins, and leading to and from them in all directions.

I will attempt to describe the principal veins in the order they are mentioned above, and some of the many branches which are found to accompany them.

1st, The rake vein, called by naturalists the perpendicular mineral fissure, is the most common and best known among practical miners. The rake vein in mining is the same species of perpendicular fissure as was described by the name of slip in the coal metals. They have both the same origin and natural cause, which will be explained in the third part of this work. They are both of them a longitudinal gash, rent, or opening in the rock and strata, commonly running in straight lines. This gash or fissure cuts all the strata and rock quite through from the surface, as far down towards the center as that vein dips, which is generally out of our reach, and as far forward in the line of bearing as that vein reaches. I say the rake vein is a longitudinal gash or fissure commonly in a straight line, which begins at the superficies of the strata, and cuts the rock and strata asunder, generally farther

down

down than we can reach. Sometimes this vein ſtands nearly perpendicular, but it commonly hangs with leſs or more ſlope, which ſlope is called by miners *hading*, or the *hade* of the vein. I ſaid that the rock is cut aſunder by this fiſſure, and the rock upon both ſides of the gaſh is called the ſides of the vein, and theſe ſides are called by miners the hanging ſide and the ledger ſide, and briefly the hanger and ledger. Some miners call them the hanging ſide and the hading ſide, and the longitudinal line which the fiſſure points to, is called the bearing of the vein.

Of theſe perpendicular fiſſures or rake veins, there are two ſpecies. The origin of one of theſe, as I hinted before, is a crack or rent and a ſlip of the ſtrata, and the other is a gaſh or chaſm in the rock without a ſlip; the ſides of the gaſh are ſeparated and opened aſunder; but the edges of the ſtrata upon both ſides of the fracture, continue oppoſite to one another, ſo that there is no ſlip. This diſtinction or different ſpecies of vein is not commonly known among miners or mine-maſters, as they are not accuſtomed to examine all the phenomena of the ſtrata. It is in the collieries that all theſe things are carefully examined and inveſtigated. The miner is careful to inveſtigate every circumſtance relating to his vein, but is very little concerned about the regularity or irregularity of the ſtrata; on the contrary, the collier

collier is chiefly concerned with the regular ſtrata, and he is only obliged to inveſtigate the veins when they occur to him as ſlips or gaſhes, in order to know how to get the better of them.

I will point out ſome diſtinguiſhing marks or characters of each, to enable the miner to know the one from the other when he is working them. The ſlip veins are ſeldom wider above than below, but are generally narrower, that is, the ſides of the fiſſures are cloſer together above at the ſuperficies of the ſtrata than farther down. The ſlip veins are very ſubject to checks or twitches, ſo called by miners, when the two ſides, or hanger and ledger, come cloſe together, and no cavity or open ſpace is left between them, ſo that there is no room for any material quantity of ore to be lodged in a twitch.

There are many of theſe checks in all this ſpecies of rake veins, which continue for ſeveral feet or for ſeveral fathoms, and the cavities or openings between the ſeveral twitches are wider or narrower, longer or ſhorter, at all poſſible uncertainty. The ſides of many of the veins are very cloſe together above at the ſuperficies of the ſtrata, which, nevertheleſs, open to conſiderable but very different degrees of wideneſs below, and theſe openings are called the bellies or cavities of the vein; and again, many of them are found regular and uniform, and carry a good rib of ore for

for a conſiderable length upon the bearing of the vein, and others may carry ſome ore and good enough mineral ſoil in ſmall quantity, and yet never open at all to do any good, ſo far as we try them. The gaſh veins, on the contrary, are always wide above, and grow narrower, or the ſides come cloſer together as we work down in them at ſome uncertain depths, and they often cloſe or check out below altogether. The gaſh vein is not ſo ſubject to twitches in the line of bearing as the ſlips, but it is frequently croſſed and interſected by whin dykes or bars of hard ſtone, which generally ſhoves it a little to one ſide, off the true line of bearing; and I believe it may be aſſerted of them, that they always carry moſt ore above pretty near the ſurface; whereas, on the contrary, the rake or ſlip veins are generally wideſt betwixt the ſides, and carry moſt ore below at a conſiderable depth from the ſurface.

There is a remarkabe mineral vein, of the ſpecies I call a *gaſh*, at Strontian in the Highlands of Scotland. All the rocks in the mining field at Strontian are a grey granite, which is called *moor-ſtone* by the Corniſh miners.

Several veins at Strontian were opened, firſt by the York Building Company, and a conſiderable quantity of lead ore was raiſed by them.

The

The principal vein at Strontian is perhaps the ſtrongeſt mineral vein as yet worked in any part of Britain, in which the York Building Company found a large body of exceeding good ore at firſt, putting up quite to the day, which they worked out open-caſt, that is, their works were cut up quite open to the day, like a large longitudinal trench or gulph, the vein being exceeding wide, and they did not mine it under cover at all. This open-caſt has been worked to a great length upon the bearing, and the old works now exhibit a horrid and frightful gulph of great length, and ſeveral fathoms wide.

This large vein or chaſm in the rock muſt have happened when the whole maſs was humid, before the rock was thoroughly indurated; I ſay rock, becauſe there is not here the leaſt appearance of regular ſtrata, nor of any ſtratification at all; the whole mountain being one prodigious maſs of grey granite, in which there has been at firſt a great many cracks or gaſhes beſides this vein, as may be ſeen by the other mineral veins and the great number of whin dykes ſeen in this mining field; which dykes croſs, interſect, and diſturb the mineral veins in many places, and are frequently ſeen upon the ſurface; theſe extenſive rocks being moſtly all bare, and waſhed clean by the heavy rains ſo frequent in that country.

Tradition ſays, that the York Building Company had a rich vein of ſolid lead ore here, at firſt of four or five feet wide, quite up at the ſurface of the ground, beſides ſeveral feet wide of ore, mixed with ſpar and vein-ſtone; and the appearance of the old man, that is, of the old works, ſeems to confirm the truth of the tradition, the old works being exceeding wide at the ſurface, and for many fathoms down; and I can ſee no reaſon for working ſo wide, had they not found the ore as wide, the ſtony parts of the vein where the ore is not ſo good being ſufficiently ſtrong and firm; and, moreover, we do not ſee any great quantities of waſte or rubbiſh, but ſuch as the waſhing and dreſſing of the ore has produced, which is a clear proof that they had ſome ore, ſolid or mixed, in all the wideneſs of the old works, which points it out to have been a very rich vein at firſt.

The lead ore of Strontian is of the ſpecies called *potters ore*. It is a fine rich ore of the kind, very free from any heterogeneous matter of a pernicious quality, but it is at preſent very much mixed with a fine white and pure ſpar or fluor, which eaſily ſeparates from the ore in the ordinary methods of waſhing, and what remains in the cleaned or dreſſed ore is found to ſerve as a flux, and rather furthers than retards the ſmelting of the ore.

When I was at Strontian a few years ago, they had ſome ore in ſeveral veins, part of which they worked occaſionally, now and then, and they had generally about three or four feet of pretty good ore in the ſoles of the works in the principal vein, flowered and mixed with a pure and friable ſpar or fluor.

Another famous vein of this ſpecies was worked at Llangunog in Wales, in the Duke of Powis's time, whoſe property it was. Llangunog was perhaps the richeſt vein of lead ore, for the time it laſted, of any yet diſcovered in this iſland. They had there a ſolid rib for a conſiderable time, five yards wide, of clean ore in the middle of the vein, which was poured out of the kebbles at the ſhaft head into the waggons, and carried directly to the ſmelting houſe, without being touched by the waſhers and dreſſers of ore, beſides ſeveral feet upon the ſides of the vein, which was mixed with ſpar and other ſtoney matter, and went through the hands of the waſhers.

This rich and noble vein was at once cut out below by a bed of black ſchiſtus or ſhiver, and that ſo entirely, that there was not the leaſt fiſſure or veſtige of the vein remaining, nor ever could be found afterwards, though diligent ſearch was made by the moſt ſkilful miners for ſeveral years, and at ſeveral times.

Now,

Now, I reckon it material for the intelligent mine-mafter to know the diftinguifhable difference between the gafh and the flip vein, to enable him to manage properly in the cafe of fuch accidents. When the flip vein is in a twitch, whether it be horizontal or perpendicular, the vein will open again when they fink down or drive forward through that twitch; but it never opened, nor no trace of the vein could ever be found at Llangunog, though diligently fought at a very great expence; and no wonder they did not find it, when in fact it was not to be found. The crack or gafh which broke afunder the harder rock above, did not enter into the bed of fhiver below, and, of confequence, there was no vein or fiffure in the fchiftus in that place. The caufe and natural hiftory of the flips and of the gafhes in the ftrata and rock, will be fully explained in the third part of this book.

I have felected Strontian and Llangunog as eminent inftances of the diftinction I made above between the gafh and the flip veins. I have feen a great many more, but I think thofe two fufficient to explain my meaning, and as a hint to the intelligent miner.

From what has been faid of the gafh, it appears, that this fpecies of mineral vein is eafily defcribed, it being an open fiffure in the rock, generally running in a ftraight line, often nearly perpendicular,

perpendicular, as that at Strontian, and always wider above than below, at a confiderable depth, if we go deep enough to know it.

The other fpecies of rake vein, which I call the flip, is not fo eafily defcribed, there being a very great variety of veins of that fpecies, and all of them fubject to great diverfity of accidents. I will point out and endeavour to defcribe fome of the great variety of the rake veins, or perpendicular mineral fiffures, which I call flips, and I will begin firft with the moft regular, and think I may fay the moft profitable of all mineral veins.

The vein which I call the moft regular, is one that runs in a ftraight line to a confiderable diftance upon the bearing, fets downwards near the perpendicular, at leaft it fets down to a confiderable depth, with an equal hade or flope, has room enough between the fides, which we will fuppofe fhould be at leaft between three and four feet, or good drift room, and a good regular vein continues fo open betwixt the hanger and ledger for a great way forward as we advance upon the line of bearing in it, and for a great depth as we fink or work down in it; or, in other words, the regular vein is equally wide betwixt fides to a confiderable diftance forward upon the bearing, and downwards. Some of thefe regular veins are quick and others dead, as they

they are called by miners. A quick vein, or a bearing vein, is one that carries ore, and a dead vein is one that only carries fome fort, or forts, of mineral foil, but no ore. Some of thefe regular rake veins bear a folid rib of ore, of one, two, or three feet wide, for a confiderable ftretch forwards and downwards, and fome of them bear two, three, or more thin ribs of ore, of various dimenfions, from half an inch to five or fix inches thick, with fpar or other mineral matter interpofed between them.

It is a pleafant and chearful fight to fee a great number of miners, one before another, in a ftraight line, working upon ftopes, or fteps, on a rib of folid ore, of two or three feet thick. I have feen feveral regular veins, or ribs, of folid lead ore in Wales, between three and four feet thick, and which continued at nearly the fame thicknefs for a confiderable time.

One of the moft regular and moft durable of thefe was a rib of fteel-grained lead ore at Darenfawr in Cardiganfhire. I faw at Darenfawr between twenty and thirty miners in a row, one before another, ftoping upon the low foles, about fifty fathoms down below the furface, befides as many, or more, who were fumping, driving, and roofing in other parts of the work upon the fame vein, and a great many more were at the fame time working upon a ftring which ftruck

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off with an acute angle from the principal vein; and, as the soles of the string were nearly upon a level with the soles of the vein, I could see the miners who were stoping out the ore in the string, by turning an acute-angled corner where the string came into the vein. This fine rib of ore was generally about three feet wide, both in the vein and string, though in some places it was not above two feet, and in others near four feet wide.

Steel-grained lead ore is generally rich in silver, and this at Darenfawr was remarkably so, the produce in silver being very great.

There are in many parts of Britain, &c. a great many regular veins which carry no ore at all where they are tried, and others of them carry a small rib, or ribs, but so insignificant as not to be worth working, though the ore gave five times the price; and again, others produce small detached bits here and there as we advance in them not worth working.

It is a very common thing to see dead veins, that is, such as bear no ore at all, continue very promising and regular for a great way, both in driving and sinking in them. I have seen more than fifty fathoms driven in some of these regular veins under great cover, that is, under perhaps twenty or more fathoms down from the surface, where the mineral veins were promising, and what we reckon likely to produce ore, and yet no ore was found, or none to ſignify, only ſo much perhaps as to ſhew the miners what ſort of ore they were to expect, and to tempt them to go on, when, nevertheleſs, they would continue perfectly regular, and the ſides about four or five feet aſunder all the way. I will ſpeak hereafter of the mineral ſoils, hard and ſoft, which fill up the ſpace between the ſides of the dead veins.

There are again many regular veins which are not ſo wide and roomy between the ſides as thoſe I have deſcribed above.

I have in the courſe of my perambulations ſeen great numbers of perfectly regular veins, not two feet wide, which, nevertheleſs, would continue fair and regular for a conſiderable length, which I could eaſily ſee when they were waſhed along the vein by a rivulet, and where the rocks were otherwiſe made bare.

Some of theſe regular thin or cloſe veins contain ore at the ſuperficies of the ſtrata, and others contain none at the ſurface. What they may carry farther down cannot be known without proper trials, and it is but ſeldom that proper trials are made in them, even although they carry ſome ore at the ſurface where they are diſcovered, the confined appearance they make being a great diſcouragement to the trying of them. I know very well that there is a kind of general

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averſion, both among ſkilful miners and others, to the trying of theſe ſtraight veins, even when they carry ſome ore at the ſurface; and I have ſeen a great number of ſuperficial trials in ſuch as carried ſome ore, but do not remember ever ſeeing a thorough trial made in any one of them. A little hole, five or ſix feet down, or a longitudinal ſlit, along the vein, perhaps not ſo deep, generally ends the trial. How far this may be right I will not poſitively determine; however, it may be proper for me to give my own obſervations upon a point of ſo much importance to the public, as theſe veins are very common to be found in all countries where the ſuperficies of the ſtrata are ſeen; and, in general I have obſerved that the greateſt number of ſuch veins as are roomy and capacious between the ſides at a good depth, that is, from ten to twenty fathoms down, are generally very ſtraight and cloſe at the ſuperficies of the ſtrata; and beſides ſuch as I have ſeen in mining fields, I have examined great numbers of them in deep glens or gulphs, cut or ſcooped by rivulets in mountainous places, and upon the ſhores of the ocean in many parts of Britain, particularly round Caithneſs and other parts of the north of Scotland, round a good deal of the coaſt, and ſeveral arms or inlets of the ſea in the Highlands of Scotland, and part of Galloway, in all of which places the

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rocky cliffs are generally very high and clean, washed by the dashing of the waves; and it is astonishing what a prodigious number of fine mineral veins are to be seen in many places upon those coasts, and many of them containing some ore and other good mineral symptoms, some of which I will point out hereafter. At present, let it suffice to observe, that the most of the veins which I have seen cut deep down by the water or otherwise, are narrow or close at the surface, and wider down below: At the same time it is also proper to observe, that it is very uncertain at what depth they begin to open. I have seen a great number of fine veins, with their sides perfectly close above, so as to appear at the superficies of the strata no wider than a common joint, the sides of the vein perhaps not an inch asunder, which, nevertheless, would gradually open downwards, until the cavity or body of the vein between the sides, at twenty or thirty fathoms down, would be six or eight feet wide, or more; and some of these veins which are close above and wide below, begin to open soon, that is, two or three fathoms below the surface; others do not begin to open until they are eight or ten fathoms down: and, again, I have seen some which continued so close and straight for a great way down, that they would not be a foot wide at twenty fathoms below the surface, which, neverthelefs, would open out to feveral feet wide at a greater depth.

Thefe remarks feem to favour ftraight or narrow veins, and, in my extenfive obfervations, I do not remember feeing many fuch as were clofe or narrow at the furface, which did not open below, if there was an opportunity of feeing them at a good depth.

There may be feveral reafons given for this fpecies of vein being narrow above and wide below; but thefe reafons will become obvious to the obferving miner and the intelligent naturalift, when they come to read and confider the natural hiftory of the phenomena of the ftrata in general, in the third part of this work, where I hope to make many circumftances evident, plain, and eafily underftood, which are now apparently very dark and puzzling.

I will now enter upon an exceeding difficult part of the tafk which I have undertaken, viz. to attempt a defcription of fuch rake veins as may very properly be called irregular; and here I can only pretend to point out fome few of the numberlefs irregularities and accidents met with in working fuch veins; but they are found to be fo Proteus-like, that it is almoft impoffible to defcribe minutely all their appearances, irregularities, and changes.

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In this part of the natural hiſtory of mineral veins, I will begin with ſuch as are very wide between the ſides, but have good and regular ſides, which the miners know where to find, though they are very far aſunder; I do not mean here ſuch wide veins as ſwell out ſuddenly into wide and irregular bellies, and ſoon contract again into much narrower compaſs; but I mean ſuch wide veins as continue wide for ſome conſiderable length and depth before they are very much contracted by twitches, &c. Of this variety of vein, as well as all others, there are ſome of them quick and others dead, or ſome carry ore and others produce none, ſo far as they are tried; and again ſome produce ore in ſome places in working forward, or down in them, and in other places they are quite dead, and produce no ore at all.

One of the greateſt points of difficulty in deſcribing wide veins, is how to convey a proper idea of the various articles or mineral ſoils, hard and ſoft, and of the various figures and conditions of the ores found in ſuch veins; for it would be a very eaſy matter to ſay that a vein is ſo many feet or yards wide; but the various phenomena of the inſide of theſe veins, and of the ſoils or mineral matters they contain, is not eaſily deſcribed or conceived, without ſeeing them in their various appearances.

I obſerved before, that the two ſides of a mineral vein are called by miners the hanger and ledger. Theſe ſides are always of the rock or ſtrata which compoſe the mountain or mining field, the vein being a crack, breach, or fiſſure in thoſe ſtrata, the ſides of which fiſſure are opened aſunder to a vaſt variety of degrees. What is called dead veins, that is, thoſe which do not bear ore at the ſurface, nor produce any upon ſuch trials as may be made in them, frequently contain between their ſides, in different places and in different veins, a vaſt variety of mineral ſtones and of ſofter mineral ſoils. The moſt common and the moſt promiſing of the mineral ſtones, as concomitants of ore, are the ſpars and veinſtones of different ſpecies. What I call veinſtone, is a compound mineral concretion, of various colours, appearances, and degrees of hardneſs, and not unfrequently of various colours in the ſame maſs, though white often prevails.—This compounded ſtoney concretion is called by miners a *rider*, perhaps from its riding the vein, or ſeparating it longitudinally into two or more diviſions. This mineral ſtone is hard and heavy, ſometimes compact and ſolid, but frequently cracked and cavernous, riſing in irregular and miſhapen maſſes, and generally exceeding hard, A rider frequently contains a variety of different ſubſtances or ſpecies, as well as different colours,

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in the ſame maſs, ſuch as ſpar, quartz, fragments of the rocks near the vein, ſometimes pyrites, and often ore in grains and flowers, and ſometimes different ores, as lead, copper, &c. in the ſame maſs, and all theſe ſtrongly coagulated or concreted together by a whitiſh or a browniſh white ſubſtance, reſembling quartz and agate, which ſeems to have enveloped the ſeveral articles in the compoſition when the whole was in a fluid ſtate. I call this vein-ſtone, as I think the term ſhould be the moſt intelligible to naturaliſts, it being always found in veins, upon the ſuperficies of them, and in fragments and maſſes lying about upon the face of the ground, which have ſliden or been forced off the ſuperficies of veins. But the vein-ſtone does not always contain ſo great a variety in its compoſition. It is often pretty white, and appears like a quartzy concretion of a porous, or rather a cavernous texture; and the inſide of the caverns, though ſmall, frequently contain a browniſh ferruginous ſoft ſoil, of a ſnuffy appearance; and ſometimes the inſide of theſe ſmall caverns are finely lined with great numbers of pointed or priſmatical cryſtals, generally exceeding beautiful, and ſparkling like diamonds. But all the vein-ſtones, or riders, are not white nor whitiſh. In many places they are of a brown or a reddiſh brown, and ſeveral other colours; but the whitiſh colour

colour moſt commonly prevails. Strong wide veins often contain a large rib of this vein-ſtone betwixt the ſides ſeveral feet thick; but in all degrees of thickneſs, from a few inches up to ſeveral feet, I have ſeen ſtrong bold veins carry ſuch a rib or body of this ſtone as to appear in a ridge above the ſurface of the ground a great way, the ſuperficies of the native rock being withered and waſted away from both ſides of it.

The next moſt common ſtone found in mineral veins is ſpar, of which there are ſeveral ſpecies, and theſe frequently tinged with ſeveral colours, and eſpecially in veins which contain leſs or more of copper or iron.

The mineral ſpars may be divided into the calcareous and vitreſcible, or, to ſpeak as a miner, there are three different and diſtinct ſpecies of mineral ſpar, viz. 1*ſt*, the *calcareous ſpar;* 2*d*, *cauk ſpar;* and 3*d*, the *quartzy ſpar*.

The calcareous ſpar found in lead mines is commonly, though not always, of a white and whitiſh colour, both the homogeneous and that which is mixed with ore and other mineral matter, unleſs it happens to be tinged or tarniſhed with ſoft ſoils, in which it is often found: I ſay it is commonly white, or of a bluiſh, a yellowiſh, a reddiſh, or a browniſh white colour, frequently of a looſe friable conſtitution, and generally of the ſame internal grain and texture as the ore

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it is mixed with, or which accompanies it in the ſame vein. Some of this ſpar is of a ſcaly and of a tabulated texture; ſome of it again is of a granulated texture, which appears uniform in the inſide, and much of it is of a cubical or diced ſtructure; ſome of larger, and others of ſmaller cubes, contiguous and ſlightly adhering to one another.

Cauk ſpar is not calcareous, nor is it generally of ſo pure a white as the calcareous ſpars. I have ſeen cauk ſpar of a dead white, but moſt commonly it is of a yellowiſh, a browniſh, or a reddiſh white, or of a fleſh colour: It is a dull ill looking ſpar, frequently riſing in glebes and irregular maſſes, and ſo exceeding heavy, that miners have always imagined that it contained metal; only they think that the proper flux for it is not yet diſcovered. No doubt this mineral body is replete with the vitriolic acid and other mineral matter, which the art of the chemiſt may extract; at the ſame time, I think it highly probable that it is not a metallic ore. This ſpar being ſo very ponderous makes it very difficult to ſeparate it from the metallic ores in dreſſing them.

Quartzy ſpar is generally of as pure a white colour as the calcareous, frequently more beautiful, and ſometimes not unlike it in appearance; but it is of quite a different quality, as it will

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not effervefce with aquafortis, nor burn into lime, which are properties of the calcareous fpar: On the contrary, inftead of calcining, it vitrifies to a glafs or flag in the fire. Some of this fpecies of fpar is found of a cubical and of a tabulated texture, refembling the ftructure of the common blue potter's ore; and I have feen much of it fine, fmooth, and uniform throughout, without any vifible grain or texture, and it is apt to fhoot into prifmatical cryftals, which are commonly found pure and pellucid, fo as almoft to vie with the diamond in luftre, and frequently fo hard as to cut glafs.

Moft of the mineral fpars are frequently found fhot into prifmatical, cubic hexagonals, or other figures. Thefe figured cryftals are generally tranfparent and very beautiful. It is a great curiofity to behold the infide of fome of the large cavities in which they are formed. Thefe open caverns are frequently met with in hard mineral veins, and they are generally called by miners lochs or loch-holes.

The miners know nothing of thefe cavernous vacuities until they ftrike into them as they advance in working, and they are of various dimenfions, from the bignefs of a nut up to room enough for more than three or four men to turn themfelves in them.

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The magnitude of theſe caverns is generally in ſome proportion to the capacity of the veins in which they are found, and the inſides of them frequently exhibit all the variety, beauty, and ſplendour of the moſt curious grotto work.

There is commonly a hard concreted ſtony cruſt, called *druſe*, adhering to the inſide of the cavity, out of which, as out of a root, an innumerable multitude of ſhort priſmatical cryſtals are ſhot, which ſparkle like a thouſand diamonds with the candle, or when brought up to the ſun. Between theſe cluſters of mock diamonds, and ſticking to them promiſcuouſly, there are often ore, pyrites, and ſpar ſhot alſo into priſmatical, cubic, and other figures; and beſides theſe cluſters of groteſque figures which grow out of one another, and are as it were piled upon one another, the whole inſide of the cavern is ſometimes moſt magnificently adorned with the moſt wildly groteſque figures, which grow upon, and branch out of one another, in a manner not to be deſcribed, and with all the gay and ſplendid colours of poliſhed gold, of the rainbow, and of the peacock's tail, and all theſe blended together, and the maſſes reflecting all the beauty of ſuch an aſſemblage of gaudy colours: But it may be remarked, that theſe caverns are never ſo magnificent and glorious but when there is leſs or more of yellow copper ore, or of the pyrites in them, as theſe ores are found to produce in hard veins the moſt beautiful colours in the world. An eminent inſtance in proof of this aſſertion is to be ſeen in the copper veins in the pariſh of Colvend in Galloway.

Theſe mineral loughs or caverns are the great ſource of materials for grotto work, and the ſpecimens collected from the mines are generally the moſt ſhowy dazzling articles in the whole arrangement of the ſplendid grotto.

Neither the calcareous nor the cauk ſpars will ſtrike fire with ſteel, unleſs there is a mixture of the pyrites in them; but the quartzy ſpar, on the contrary, gives fire plentifully. Pure quartz of a fine, ſmooth, uniform texture, breaking like glaſs, is often found in thoſe mines where the quartzy ſpar prevails, and it is frequently mixed with ore.

What I call pure quartz is a white, ſemi-tranſparent, hard and heavy ſtone, of a fine, ſmooth, uniform texture, and of conſiderable brightneſs, and not exhibiting any viſible grain.

Quartz does not riſe in blocks or large regular maſſes, neither in the mines nor any where elſe, it being full of cracks and flaws, ſo as to break into ſmall irregular maſſes, with various ſharp angles, and it is ſo hard as to waſte the tools more than any other ſtone. Where quartz and quartzy ſpar prevails, the veins are commonly ly very hard and difficult to work, and it is as difficult to ſeparate the ore from the quartz in dreſſing it, being ſo hard that it requires much labour to break the quartz mixt with ore ſmall enough, and ſo heavy, that it does not eaſily ſeparate. I will only give this ſpecimen of ſuch mineral ſtones as are moſt common and moſt generally known; there are a great many others found in different mines of various colours and textures too tedious to be deſcribed here juſt now.

The ſoft mineral ſoils are as various in quality and appearance as the hard. I will point out a few of them, in which I will make no choice or arrangement, but will give them as they occur to my memory. The *firſt* I will take notice of is a white or whitiſh mineral ſoil or clay, ſometimes fine, tenacious, and ſmooth, but often more friable and courſe to the touch, not unlike ſlaked lime mixt with ſmall ſand. This ſpecies of mineral ſoil is frequently a promiſing ſymptom of lead ore; but I will leave the diſcuſſion of this point until I come to examine the ſymptoms and appearances of mines or good mineral veins.

2d, Red fatty clay in veins, which indelibly ſtains the hands and clothes, is an indication of iron, concerning which I will ſay nothing juſt now, but that the better ſorts of iron ores are

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generally accompanied with red ſtaining ſoftneſs, by which they are eaſily diſtinguiſhed; at the ſame time it is proper to obſerve, that ſome lead and copper veins contain a conſiderable quantity of iron, and conſequently of a red, or a browniſh red ſoft ſoil, and eſpecially near the ſurface.

3d, Bluiſh and greeniſh mineral ſoils, light and friable, and alſo heavy and tenacious.—Theſe, and ſeveral others, will be treated of when we come to examine ſymptoms.

4th, Yellowiſh, aſh-coloured, and marbled ſoft ſoils, or mineral clays, which are frequently not to be diſtinguiſhed from ſurface clays of the ſame colours, but by the ſkilful miner.

5th, Black and blackiſh brown ſoft ſoils, commonly light and friable, though there are ſome of them more tough and weighty.

6th, The moſt remarkable and diſtinguiſhed of all the ſoft mineral ſoils, and frequently the moſt promiſing, is of a brown colour, and of a lax and friable texture, often reſembling rappee and other ſnuff in colour and appearance, being ſometimes blackiſh, but generally brown, in all the degrees and ſhades of that colour.

Having given this brief ſpecimen of the hard and ſoft ſoils which are moſt commonly found in mineral veins, I will now return to the hiſtory of the

the veins, and of the appearance theſe foils make in them.

It is very common to find a large body of rider in ſuch a ſtrong vein as the laſt mentioned in a rib, or ſtanding in the middle of the vein like a wall, with a ſpace between it and the ſides of the vein. This rib of rider or vein-ſtone ſo ſituated divides the vein in two, as there is a ſpace like a vein betwixt this rib and each of the real ſides of the vein.

This rib or body of vein-ſtone may be, and frequently is, found of various dimenſions, from five or ſix inches up to five or ſix feet thick. In ſtrong veins, like the one preſently under conſideration, it is not uncommon to find a body of vein-ſtone ſeveral feet thick. Sometimes this vein-ſtone is richly flowered, ſpotted, and veined with ore, and ſometimes there is little or no ore found in it; and it frequently happens that when it is mixed with ſome ore, it is found in ſuch ſmall ſpecks and threads, and the ſtone is ſo hard, that it is not worth ſeparating. This rib of rider in a ſtrong vein is not always found in the middle of the vein, but is frequently found nearer to one ſide than the other, and it is not uncommon to find it adhering ſtrongly to the ſide, and mixed with ore. When a rib or wall of rider is ſituated in the middle of a wide vein, there is ſometimes good ore found upon each ſide of it,

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and at other times upon one ſide only; and this ore is found either in a continued rib or diſcontinuous maſſes.

When the ore is found in ribs betwixt the vein-ſtone and the real ſides, theſe ribs of ore, as well as that of the ſtone, are of various dimenſions, from two or three inches up to two or three feet or more in thickneſs. In ſtrong wide veins, which have a rib of rider in the middle, it is not uncommon to have a rib of good ore upon each ſide of the rider, of one, two, or three feet thick, though it is not commonly found ſo thick upon each ſide; but it is common to have a rib of two or three feet thick, or more, upon one ſide of the vein-ſtone, and a thin rib upon the other.

Theſe continued regular ribs of ore which are found in wide veins, running parallel to the rib of rider, and betwixt it and the ſides of the vein, are ſometimes ſolid ore and ſometimes mixed with ſpar and other heterogeneous matter; and it often happens that ore, found thus betwixt a rider and the ſide or ſides of the vein, is partly ſolid and partly mixed.

Again, the ore found betwixt a rider and the ſides of a vein, is not always in regular continued ribs. It is ſometimes found in a diſcontinuous rib or ribs, that is, in large flat ſlabs or maſſes, which appear like a rib for two or three feet, perhaps

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for five or fix, every way, and then you come to the end of it, if you are working forward horizontally, or to the bottom of the mafs, if you are finking down in the vein; but then you are not long before you touch the edge of another cake of this difcontinued rib. Thefe cakes, or flat maffes of ore in the difcontinued rib, are of various fizes, fome being very large and others very fmall, and the diftance betwixt them is as various as the dimenfions of the maffes. In different veins, and in different parts of the fame vein, the maffes are fo near one another as fometimes almoft to touch, and at other times there will be a diftance of from a foot to five or fix feet between the maffes, and frequently more; but this diftance is exceedingly variable, even in the fame vein, and often at no great diftance.

It is proper for me to obferve here, that thefe difcontinuous ribs of ore are imbedded in one of the foft mineral foils mentioned above; that is to fay, all the maffes, or flabs of ore, are encompaffed with foft foil, and the fame foftnefs continues betwixt mafs and mafs; and it is further to be obferved, that although the rib is really difcontinued, and that there is lefs or more fpace betwixt the different maffes of ore, yet the feveral maffes are thinner and thinner towards the edge of the mafs, and do not break off at once when at full thicknefs. The difcontinuous, as well as the continued and regular ribs of ore, are of various dimenſions or thickneſs, from an inch up to two or three feet or more.

A diſcontinuous rib of ore may be, and often is, found every way as deſcribed above, in a vein, without any rib or continued body of rider. Again, the ore is frequently found betwixt the rider and the ſides of large roomy veins, in glebes and irregular maſſes of various ſizes and dimenſions, imbedded in, and ſurrounded with ſoftneſs. Some of theſe roundiſh maſſes are no bigger than eggs; others are ſo large as to produce ſeveral tons of ore out of the ſame maſs; and they are like ſtones in a brook, of all the intermediate ſizes.

Rider in a vein is not always found in a continued rib, no more than the ore. It is frequently found in a diſcontinuous rib; ſometimes in a vein that is more hard and cloſe; but generally amongſt ſoftneſs in a vein that is looſe and open; and moreover, rider is not only found in ribs of ſeveral dimenſions, and in ſeveral degrees of continuity, but it is alſo found in larger and ſmaller glebes, and irregular maſſes. Theſe glebes and irregular maſſes of rider or vein-ſtone in wide, ſoft, looſe veins, are found of all dimenſions, from the ſize of the fiſt, up to the ſize of a hogſhead, and much bigger. In ſome very wide looſe veins, irregular maſſes of rider will be found in one ſide

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of the vein, and irregular maſſes of ore in the other, and both the maſſes of rider, and thoſe of the ore, lying without any order among ſoft looſe mineral ſoil, and without the leaſt appearance of continuity: Sometimes the maſſes being pretty near and contiguous to one another, and ſometimes the miners have to work forward or downward ſeveral feet of the ſoft ſoil before they touch one of them.

Theſe large maſſes of rider are frequently ſo very hard, even among the exceſſive ſoftneſs of the looſe ſoil which ſurrounds them, that they cannot be broken to pieces with any tools and ſtrength of men without gun-powder. Theſe maſſes of vein-ſtone, found looſe and detached among ſoftneſs, are of all colours, as white, yellow, red, brown, black, green, and aſh-coloured, in all their ſhades and varieties, and frequently ſeveral of theſe colours are found blended together in the ſame maſs. Theſe maſſes of rider lodged in ſoftneſs in wide looſe veins, are ſometimes poor, ſometimes rich in ore, and they are frequently found to contain none at all. When they are poor in metal, they are then to be called riders mixt with ore; but when they are very rich in metal, they may be called maſſes of ore mixt with rider. It is not uncommon to find theſe riders mixt with ſeveral ſpecies of ore in the ſame maſs, as, for inſtance, lead, copper, iron,

 pyrites,

pyrites, &c. which mixture generally renders them all very uſeleſs, the riders being often ſo hard that it is not eaſy to break them ſmall enough for ſeparation, and the different ores ſo mixt and combined together, that clean ore can hardly be made out of any one of them.

Again, wide, ſoft, looſe veins ſometimes only produce larger and ſmaller maſſes of ore without any rider at all.

The dimenſions of theſe glebes and maſſes of ore in ſoft wide veins cannot be determined. It is common to find detached bits amongſt the ſoft ſoils as ſmall as peaſe, and even ſmaller, but generally ſo coated over as to be imperceptible, until they happen to be cruſhed or bruiſed between two hard bodies, when their bright metallic quality appears. Bits and maſſes are commonly found detached and ſurrounded with ſoftneſs as big as eggs and leſs, as big as the fiſt, the head, and ſo on, up to large unweildy maſſes, which cannot be ſtirred from the place where they are found, but muſt be wrought out piece-meal; and in ſome very wide ſoft veins, they ſometimes meet with maſſes ſo large as to produce a great many tons of lead out of one lump.

Theſe larger and ſmaller lumps of ore in ſome ſoft works are all pure and ſolid; in others, they are leſs or more mixt and blended with ſpar, rider, ſtone, and other heterogeneous bodies. In

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ſome ſoft veins, pure and mixed maſſes of different ſpecies of ore are found, ſuch as lead, copper, iron, &c.; and there are often found in the ſoftneſs maſſes of all ſizes of different kinds of ſtone, beſides ſpar and rider; and every ſubſtance found in the inſide of theſe ſoft looſe veins generally has the appearance of being corroded and waſted, the maſſes large, and ſmall, of ore, and others, being of no determined or regular ſhape, but having much the appearance of ſome degree of corroſion, and a partial waſting as they harden, they generally having a lax texture and appearance like ſlaked lime or ſnuff. I hinted before that the lax duſty ſoils are of various colours, though a ſnuffy colour or darker brown are the moſt common. Theſe ſoft lax ſoils are called *mother* by Scots miners, and where diſcovered in a vein, they are generally reckoned a good omen both of lead and copper. Some ſoft looſe veins, nevertheleſs, contain a great quantity of theſe ſoft ſoils without any ore, ſo far as they are tried, and there are often conſiderable trials made in it, the ſoil being reckoned ſo fruitful of ore, and ſo often to accompany it, which often proves a temptation or inducement to go on.

The phenomena of the inſide of theſe veins are ſo various, that it is almoſt impoſſible to go through every point of deſcription; and, therefore,

fore, I will now proceed to obferve, that all bold wide veins are not foft. There are many of them very hard. The hard wide veins are alfo various in their appearances and in their contents. Some of thefe bold veins have produced great bodies of lead ore. At Llangunog in Wales, they had fifteen feet wide of ore, befides feveral feet more which was mixt with fpar, rider, &c.; and from the reports of tradition, which are corroborated by circumftances, it appears they had ore of great width at Strontian, in the Highlands of Scotland, in the York Building Company's time, and ore of great width has been wrought in hard veins in feveral other parts of Britain. They had folid lead ore of fix feet wide at Wanlockhead in Scotland when Mr Telford had thofe works. I faw it afterwards four feet wide of fine folid ore in the fame vein. They have frequently had remarkably rich lead ore in feveral veins at Leadhills; and it is faid to be up to fourteen feet wide of folid ore at prefent in one of thofe veins; and four, five, or fix feet of folid ore in hard veins, and fometimes much more, has been no uncommon phenomena in feveral parts of England and Wales.

But the cavities, or rather the fpace betwixt the fides of bold hard veins, are not always filled up with pure and folid ore; it may rather be afferted that fuch a thing feldom happens. They

generally

generally contain, beſides the ore, a great quantity of rider, ſpar, and other hard matter.

Wide hard veins frequently carry a ſtrong body of hard rider of ſeveral feet, and ſometimes of ſeveral yards thick. In ſome places a rib of ore is found upon one ſide of this rider, and in others upon both ſides of it; and it is but too common that none at all is found, neither upon the one ſide nor the other.

Hard bold veins, containing no metal to begin with, are very diſcouraging for mineral trials, the ground being ſo very difficult to cut, that trials in them ſoon become very expenſive; but ſometimes this difficulty is in part removed by a thin ſtrake or ſeam of clay betwixt the rider and the ſide or ſides of the vein, which miners call a *ſticking*, and which helps them forward greatly, as they cut this out firſt the length of a pick helve, which frees the *hards*, and makes it eaſier wrought with gun-powder or otherwiſe.

It is almoſt as difficult to deſcribe the inſide of a hard vein as a ſoft one, as the riders, ſpars, and ores appear in ſuch a variety of conditions and mixtures in different veins.

I obſerved above that ſome hard veins carry a rib or body of rider, with a rib of ore upon one or both ſides of the rider. Theſe ribs of ore are of various dimenſions or thickneſs, from leſs than one inch up to three, four, or five feet;

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ſometimes theſe ribs of ore, running parallel to a rider in hard wide veins, are fine and ſolid, but they are more frequently found mixt and debaſed with ſpar and other heterogeneous matter. It is not uncommon to find no ore in one of theſe hard veins, but what is mixt and blended with a prodigious body of ſtrong rider of great width, which, at any rate, is very difficult to work; and, therefore, the ore muſt be in conſiderable quantity when ſo mixt to defray the expences of raiſing and dreſſing it.

Again, ſome wide hard veins have little or no rider in them, but contain a conſiderable body of ore mixt with ſpar of ſeveral feet thick.—Some of theſe wide veins of ore mixt with ſpar are pretty rich in ore, ſo as to be worth working with profit; others, though wide, are hardly worth working, and many of them are ſo poor in ore as to be worth nothing at all; and there are ſome wide bold veins which contain a great body of ſpar, as there are others of rider without any ore at all.

And again, there are ſome bold regular good like veins, containing a conſiderable quantity of ore, which is all ſpoilt and rendered uſeleſs by its being blended with a great body of cauk ſpar, from which it cannot be ſeparated with moderate expence; and ſome good veins of ore are ſpoilt and rendered uſeleſs by being mixt with a great

quantity

quantity of pyrites, or mundic, as it is called by Cornish miners. There is sometimes a rib of three or four feet or more of the pyrites found in a wide vein, with a considerable quantity of fine lead ore.

If the lead ore happens luckily to lie in a rib, or otherwise, in one side of the vein, it may be wrought with profit; but if they are blended together, it is ten to one that the lead is not worth working; the mundic or pyrites being so ponderous that they cannot be separated to advantage.

Wide sparry veins sometimes carry two or three or more ribs of ore, separated from one another by so many ribs of spar, which are not always worth working; for it too often happens that when ore is in this or any other way divided, it is rendered unprofitable; however, this depends upon the quality and goodness of the ore. If the ribs are each of them some inches thick of pure solid ore, they may work very well, but sometimes such divided ribs are not above one inch a-piece, and even less.

I have dwelt long upon what may be called regular veins, and yet I have not finished their history; a great deal more may be said about them, but that I may not be unprofitably tedious, I will remark here in general, that every word I have said about wide veins, hard and soft, might be repeated in giving the history of those which are in all

all degrees narrower. The ore, the ſpars and riders, and all the ſoft ſoils with and without ore, appear exactly in the ſame manner in the middling and leſſer veins as in the large and wide ones, only allowing for quantity. There is not ſo much room in the leſſer ones as in the greater; but they contain the ſame articles, and they are compounded and diſpoſed alike in each; and therefore I will refer to what I have ſaid about the large and wide veins, to ſerve for the hiſtory of the middle and ſmall veins.

I will now proceed to give ſome account of ſuch rake veins as may be called irregular; and theſe are, *1ſt*, Such as open ſuddenly into very wide bellies, and cloſe or check again as ſuddenly: *2d*, Waving veins, or ſuch as open and cloſe alternately at very ſhort diſtances, as you work forward horizontally in them; and, *3d*, Such rake veins as have a very great hade or ſlope, which is a ſufficient irregularity of itſelf, and beſides theſe, are apt to be very irregular in wideneſs. Theſe three are only varieties of the ſame vein; and, indeed, the varieties are ſo many, that it would be exceeding difficult to deſcribe them all.

Some hard veins come under the deſcription of theſe three; and it is not uncommon to ſee a pretty wide and rich belly of good ſolid ore, which does not continue for any conſiderable length, as

you

you work forward upon the bearing of the vein, but ſoon checks or twitches out by the ſides of the vein coming together as you advance horizontally. By " ſoon twitches out," I mean, that it fails at the end of a few fathoms, where the ſides of the vein come together, either ſuddenly, or more gradually; and the twitch, when the ſides of the vein come together, is either total or in part. Some of theſe twitches carry a ſmall rib of ſolid ore quite through, until the vein opens again, and produces another belly; and in other twitches, we have a rib of rider going quite thro' the twitch, and this rider is ſometimes mixed with ore, and at other times it is quite barren; and again, in many of theſe twitches we have neither ore nor rider, but in ſome of them the ſides of the vein are ſqueezed as cloſe together as a joint between two hewn ſtones, and in others there is nothing but a thin ſtrake or ſeam of clay, perhaps not an inch thick, or not above one or two inches at moſt. Miners call this thin ſeam of clay a *Sticking*. When there is either a thread or ſmall rib of ore, pure or mixed with ſpar or rider, or elſe a rib of barren rider leading through the twitch, or again, where there is a ſticking of clay, there is no difficulty in the caſe, except in point of labour and expence; an unexperienced miner may find his way through the twitch well enough; But where the ſides come perfectly cloſe, and are run or cemented together, which is often the caſe, it then requires the care and attention of an obſerving experienced miner to keep the vein with certainty as he drives through the twitch, and eſpecially if it proves a long one.

In general, the veins do not cloſe at once when one of theſe twitches are coming in, but the belly of ore begins from the wideſt part to wear gradually leſs and leſs, until at laſt the ſides of the vein are come pretty cloſe together, and the ore wears out to a point or thin edge, and is in ſome twitches ſqueezed out altogether, and in others to a ſmall thread or rib which goes through with them. Theſe twitches are of various lengths.

No miner, when his vein is checked or twitched out, can poſſibly tell how long it is to continue twitched, or, in other words, how many fathoms he has to drive through it before the vein opens again, unleſs he cut through the ſame twitch before, either higher up or lower down; and this uncertainty of the length or extent of twitches is one of the moſt puzzling dilemmas, or greateſt difficulties met with in the practice of mining. Some of theſe bars betwixt bellies, or wide places in a vein, will not continue above two or three fathoms before the vein begins to open again upon the other ſide; but others will continue for ten, twenty, thirty, or forty fathoms, and even up to ſixty, eighty, and a hundred fathoms,

or

or more; ſo that we are frequently in a ſad dilemma, when we have driven ten or fifteen fathoms in an unknown twitch, and it is very hard to determine whether we ſhould puſh forward or ſtop ſhort. When the miners have cut a drift through a twitch, the vein begins to open, and the ſides to part aſunder upon the other ſide. If they had a thin rib of ore to lead them through the twitch, it begins to grow thicker; but if they had none, they firſt touch the thin edge of it. Perhaps they firſt touch it at an inch thick, or even leſs; but as they advance forward, the ore increaſes gradually, and grows better and better, until they come to the beſt and wideſt part of the belly, as a fiſh's tail increaſes gradually from the point forward to the thickeſt part of the body.

Theſe bellies of ore are of indeterminate dimenſions both as to length and breadth or thickneſs; ſome of them are but a few fathoms long in all, others continue for a great many fathoms; ſome continue at full wideneſs where the ore is beſt for ſeveral fathoms, and others begin to dwindle or wear thinner almoſt as ſoon as you arrive at the beſt and thickeſt part of the belly, and again they vary as much in width or thickneſs as in length, as they are found in different veins, and ſometimes in different places in the ſame vein, from a few inches up to ſeveral yards wide. It ſometimes happens, that the miners meet with a falſe

appearance

appearance in driving through a twitch, that is, with a ſmall quantity of ore, which does not continue, neither as they advance, nor up and down; but they ſoon loſe it again, which proves a great diſappointment, as they naturally expect, in ſuch a caſe, that they have got hold of one edge of a belly of ore, and it proves a falſe belly, or only a ſmall neſt.

When one belly of ore proves pure and ſolid, it generally happens that all the bellies prove ſo in the ſame vein, and eſpecially in the contiguous parts of the mining field. The contents or produce of a vein frequently change greatly at a diſtance.

I have, as yet, in this vein only mentioned ſolid bellies of ore; but it muſt be obſerved, that where ore is found in this deſcription of vein, it is not always ſolid; on the contrary, it is oftener found mixt with ſpar and rider, than ſolid; and too often theſe bellies in this ſort of hard vein only contain ſpar or rider, without any ore, or ſo little that it is not worth working. It is in theſe veins that the open cavities ſpoken of above are moſt frequently met with, many of which are exceeding curious.

I hinted before, that the miners know nothing about theſe loughs or concavities, until they ſtrike their tool into one of them at once, nor do they know any thing about the dimenſions of them until

until they open them up; for they are, as I hinted, of all dimenſions, from the ſize of an egg and under, to the ſize of a ſmall houſe. Miners like well to meet with theſe concavities in hard veins, and eſpecially after driving a long time in a hard check or twitch, as one of theſe latch-holes proves the firſt and ſureſt indication of the veins beginning to open again, and of another belly of ore coming in. When this ſpecies or deſcription of hard veins are barren of ore, the ſpars and riders, &c. are found in bellies in them, in like manner as the ore is found in the bearing veins; and theſe barren hard ſoils begin and end in a narrow or thin edge at the extremities, and ſwell out gradually in the middle of the belly, exactly as the ore does, and the checks or twitches are the ſame in the barren as in the bearing veins. Sometimes a thin rib of the ſpar or rider they contain leads through the twitch, and ſometimes a thin ſticking of clay, or elſe the ſides of the vein are found ſqueezed cloſe together, as deſcribed before.

This ſpecies of big bellied veins are as often found ſoft as hard; but the ſoft bellies are much more difficult to deſcribe than the hard, and likewiſe more difficult to work.

The ſoft ſoils found in the bellies of this ſort of vein, are much the ſame as we deſcribed in the ſoft and wide regular vein; and the ore is found

in

in them much in the ſame manner, excepting that there is no regular ribs found in theſe bellies. The ore in theſe wide and ſpacious cavities or bellies of theſe ſoft veins, is generally found in glebes or irregular maſſes, frequently of a glebous, roundiſh, or oval figure, and of as various dimenſions as can be imagined, ſurrounded with, and buried in ſoft ſoil.

I obſerved of the hard veins of this deſcription, that the bellies of ore, or of ſpar or rider in them, ſwell out ſometimes to ſeveral yards wide in the middle of the belly; but ſome of the cavities or bellies of the ſoft ones prove a great deal wider. It is no uncommon thing in North Wales, and many other places, to find the ſoft openings in this ſort of vein ſwell out to an enormous wideneſs, ſo as ſometimes to make it difficult to find the real ſides of the vein, and ſometimes the real ſides are ſhaken and looſe, occaſioned by the ſoftneſs of the ſoil within the real ſides yielding to the preſſure of the ſides. Working theſe ſoft veins is the moſt difficult part of mining. There is no advancing a foot in theſe, without advancing ſquare timbers as far as they go, in form of a trance or paſſage in a houſe; each pair of which timbers are compoſed of two door-cheeks, or ſide-poſts, and of a lintel and ſole-tree.—The miners ſtand within this ſquare timber when

they

they work, and ſtill ſet more timber as they make room for it. This is expenſive, troubleſome, and dangerous, if they have not good ſkill in ſetting the timber, for the ſoil is generally quite ſoft and looſe; and being commonly mixt with leſſer and greater glebes and maſſes of ore and ſtone, the whole will frequently ruſh down with violence before their timber to a greater height than they incline. A ſkilful miner does all he can to prevent the ſoil from running or waſhing down before his timbers, by driving in polins or ſharp pointed ſtakes. He enters theſe above the lintel or head-tree, and without the ſide-poſts of his foremoſt pair, and with his mallet drives them forward, paſt the ſquare timbers, into the ſoftneſs; and if a maſs of ore, or any other hard ſubſtance, retards the point of one of his polins, he draws it out of the way with his pick; and when the end of his polin is freed, he drives again until it is far enough up; and when they are all driven as far up or forward as is wiſhed, he then works out room to ſet another pair within thoſe polins, and enters another courſe of polins, and ſo on; and whether they advance horizontally, ſink down, or riſe upwards in theſe ſoft places, they muſt do all with ſquare timbers, which is very troubleſome and expenſive; but it frequently happens that the ore is ſo plentiful

plentiful and good in theſe veins as abundantly to compenſate all this trouble and expence.

I hinted above that theſe ſpacious bellies in ſoft veins frequently contain glebes and maſſes of ore of various ſizes. Sometimes theſe glebes of ore are pretty large, and the concavity of the vein pretty full of them, intermixed with a leſſer quantity of ſoft friable mineral ſoil, and ſometimes there is leſs or more ſpace between moſt of the glebes; in which caſe the miners have a conſiderable quantity, and ſometimes a great quantity of the ſoft ſoil to work out, in proportion to the quantity of ore produced. In ſome parts of theſe veins they meet with very large and very ſmall glebes of ore, and with all the intermediate ſizes, exactly as they are found in the wide and ſoft regular veins deſcribed above, excepting that no regular ribs of ore are found in theſe irregular bellied veins; and it is not uncommon to find in the ſoft opening of one of theſe irregular veins a ſingle maſs of ore ſo large as to take a conſiderable time to work it out, and to prove a great treaſure to the proprietors.

Theſe enormous maſſes of ore are by ſome miners called bellies of ore; but properly ſpeaking, the belly is the ſudden dilatation or opening aſunder of the ſides of the vein to a great width, and when they contract or come together again as ſuddenly.

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The glebes of ore found in the ſoft bellies of theſe irregular veins are commonly ſolid and good, that is to ſay, pure and unmixed with ſpar and other heterogeneous matter; and ſuch pure and ſolid glebes coſt but little trouble and expence in dreſſing and preparing the ore for the furnace, and they generally yield a good produce in ſmelting. But they are not always ſo rich,—ſometimes ſpar, &c. is mixed with them, which makes it neceſſary to break the moſt of them down ſmall in waſhing and dreſſing the ore, and then the produce in ſmelting is ſeldom ſo good as when the maſſes are ſolid.

The glebes and maſſes of lead ore which are found immerſed among ſoft ſoils in the cavities of ſoft mineral veins, are of various colours and appearances. In many ſoft works, the glebes of ore are all coated over with a white ſubſtance, reſembling lime to look at; but this white ſcurf is a kind of native ceruſs or efflorescence, occaſioned by corroſion, or beginning decay of the outſide of the maſſes. Bits of lead ore lying a long time above, gather the ſame ſort of ſcurf, which undoubtedly is occaſioned by the moiſt and corroſive quality of the atmoſphere; and ſuch bits expoſed a long time to the influence of the external air, would, in the courſe of time, be altogether waſted away by it.

In ſome ſoft works there is great appearance that the maſſes of ore below ground are alſo corroded, and part of them waſted away, as ſome of them are found cavernous, as it were honey-comb'd, and of very irregular figures, and of as irregular ſharp angles, points, and edges, the cavernous and honey-comb'd places containing a blackiſh or a brown ferruginous powder; and the whole of the ſoft ſoil in which ſuch maſſes are immerſed, has generally a ferruginous appearance, and is of a lax and friable texture. Theſe ſeemingly corroded maſſes of ore are not white like thoſe mentioned above, but are generally of a brown or a blackiſh brown hue on the outſide.

Again, in ſome ſoft works the maſſes are outwardly of a dull, tarniſhed, leaden hue, though inwardly, when broken, of a bright, lively, blue colour.

The moſt beautiful maſſes of lead ore I ever beheld was a few years ago at Leadhills in Scotland. I was then riding through Leadhills in haſte, without the leaſt intention of ſtopping, when a ſingular appearance of a fine, bright, yellow colour at ſome diſtance attracted my notice. I went up to it, and by ſome little breaks in ſome of the maſſes, I ſaw it was a rich heap of fine lead ore, lying upon a ſhaft head, juſt as it had been drawn up out of the works, which ore I

viewed

viewed and examined a while with great pleaſure and admiration. The maſſes of ore were pretty large, few of them being leſs than one hundred pounds weight, and many of them much more; and the outſide of every one of theſe maſſes was of the brighteſt and moſt beautiful yellow colour I ever beheld, and the inſide of each of them was a bright blue, the common colour of lead ore. Upon nearer inſpection, I found this glorious colour to be a rich efflorеſcence upon moſt of the maſſes; this yellow efflorеſcence was near an inch deep, of a fibrous, columnar, or ſtriated texture, the columns ſhooting out regularly from the maſs all round it, and all of them diſpoſed perpendicularly, and parallel to one another. In ſhort, this was an exceedingly curious, and a moſt beautiful natural production.

Perhaps there ſeldom has been ſeen a richer bloom or flowers of lead. I was ſorry to find no perſon in ſight, and time would not allow of my turning back to the mining village, to enquire about the nature and appearance of the bed or ſoil in which this curious ore was found, though I know from the appearance of the maſſes, which were all whole and unbroken, that it muſt have been found in ſoftneſs.

I have ſeen the maſſes of ore in ſome ſoft works of a red colour. This happens when the clay or ſoft ſoil contains ſome iron, and there are ſeveral

rich

rich lead veins which hold a quantity of iron, both in a hard and soft state, and sometimes too much, so as to render the lead unprofitable.

It is not uncommon to see the masses of lead, when drawn out of soft works, of the same colour as the clay, or other soft soil, in which they were immersed in the vein; and as the colours of these are various, so must the colours of the masses likewise be; but I have given sufficient examples, and, therefore, I will drop this point of description.

The second sort of irregular rake vein I am to describe is what I call the *waving vein.* This is a rake vein or perpendicular fissure, which opens and closes at very short distances. This vein is very near a-kin to the last described, as it consists of bellies and twitches; but the twitches are so numerous and so near to one another, that there is not room nor distance enough between them for any of the bellies in this vein to open out to any considerable wideness; and of consequence this vein is never so rich and valuable as the last mentioned, there not being room enough in these small cavities or openings for any considerable quantities of ore.

As the concavities or bellies in this vein are small and of short continuance, so it generally happens that the twitches or grips between them are also short and of no great continuance; and as the

the ſmall openings and twitches are ſo frequent and near to one another, I call this the waving vein, as the ſmall bellies in this vein reſemble the hollows between the waves on a pool of water.

I have ſeen both lead and copper veins of this deſcription, but I have not yet ſeen any of them produce a great quantity of ore; and as the ſides of theſe veins are ſo diſtorted by being ſo frequently ſqueezed together by the numerous twitches, it generally happens that the maſſes of ore and other mineral ſoils found in them are tortuous, twiſted, and irregular.

The third irregular vein of the rake ſpecies is that which has a great hade or hang. It may be proper to obſerve, that the perpendicular figures or rake veins have a greater or leſſer hade or ſlope in proportion to the declivity of the ſtrata, as the mineral fiſſure, or vein, is a tranſverſe ſection cut at right angles to the lay or bed of the ſtrata; that is to ſay, when the ſtrata are perfectly flat or horizontal, then the mineral fiſſures we call rake veins are perpendicular; when the ſtrata decline one or two degrees from the horizontal flatneſs, then the vein will have a ſlope of one or two degrees from the perpendicular. Let us ſuppoſe, for example, that the ſtrata cut by a rake vein have a declivity to the ſouth of two degrees from the horizontal line; in that caſe, the vein which cuts

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theſe ſtrata will hade or ſlope as you ſink down in it two degrees from the perpendicular towards the north. If the ſtrata dip ſuddenly to the ſouth, and the declivity is ſo ſteep as to be near the angle of forty-five to the horizon, the hade or ſlope of the vein ſhall be upon the angle forty-five to the north, or near it, as theſe veins generally cut the rocks at right angles to the beds of the ſtrata, or nearly at right angles; and therefore whatever be the ſlope of the ſtrata one way, the hade or ſlope of the vein is as much from the perpendicular the other way: But then it is alſo neceſſary to obſerve, that this can only be ſaid of that rake vein which runs parallel to the bearing of the ſtrata. There are north and ſouth, and eaſt and weſt rake veins, or what is called ſo by miners, though they ſeldom anſwer exactly to theſe points. The one of theſe cut the rocks in a line parallel to the bearing of the ſtrata, and the other cuts right acroſs the ſtrata; ſo that theſe two veins interſect one another at right angles. Now the general bearing of the ſtrata in Great Britain, and in all countries under the ſame parallels of latitude, is nearly from north-eaſt to ſouth-weſt, conſequently the parallel veins, or thoſe which cut the rocks in a line parallel to the bearing of the ſtrata, muſt point towards the ſouth-weſt and north-eaſt, or thereby; and thoſe which cut acroſs the ſtrata, and interſect the parallel veins, muſt

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run or point from the north-weſt towards the ſouth-eaſt, or thereby, where the bearing and declivity of the ſtrata is not warped by any accidental cauſe, but is fair and regular, according to the general courſe and lay of the ſtrata in the iſland.

There are alſo other rake veins, beſides the parallel and rectangular ones, which cut the ſtrata in a diagonal line acroſs the ſlope or declivity. Theſe I call, for diſtinction ſake, *oblique veins*. Now where the beds of the ſtrata are nearly flat or level with the horizon, all theſe three veins may ſtand nearly perpendicular; but where the ſtrata have a great hang or declivity, the parallel and the oblique veins will likewiſe have a great hade or ſlope the contrary way, though the rectangular vein, or that which cuts the ſtrata in a right line acroſs the bearing, may be nearly upright, when the others have in courſe a great hade. The veins I call oblique cut the ſtrata in all directions acroſs the ſlope; of conſequence, they either come into or interſect the parallel and the right-angled veins in all directions. I ſhall have occaſion to examine the courſe of the oblique vein hereafter; and therefore I will drop that part of the hiſtory of it here, and will proceed to give ſome account of ſuch rake veins as have a great hade or ſlope.

I obſerved before, that the right-angled veins, that is, ſuch as cut the ſtrata right acroſs, or in a right

right line from crop to dip of the ſtrata, are generally more upright, or nearer the perpendicular poſition, than the parallel and oblique veins. I explained before, that theſe laſt mentioned veins are nearly upright only when the ſtrata they cut are near the horizontal poſition; but when the ſtrata hang conſiderably towards any point, the parallel and oblique veins have alſo a conſiderable hade or ſlope, nearly in proportion to the declivity of the ſtrata; and it is theſe two veins that come under the deſcription of ſuch rake veins as have a great hade or ſlope, and therefore deſerve to be called irregular veins. Theſe veins are generally very troubleſome to work, on account of their great hade, and of the irregularity of the hade, as theſe veins frequently vary the ſlope; and beſides the frequent variation of the ſlope or hade of theſe veins, which is of itſelf a ſufficient irregularity, the two ſides, or hanger and ledger of theſe veins, are alſo generally very irregular. The hanging or upper ſide of them ſometimes riſes up into a concavity, quite out of the regular flat courſe of it, and ſometimes again it falls down to a convexity, and if the rock, which is the ſubject matter of this ſide, happens to be any way lax or tender, then this hanging ſide comes to be very troubleſome, expenſive, and dangerous, and requires much timber to ſupport it, even where the vein may be called hard; and if the

the vein happens to be soft, it is still worse to support this hanging side. The ledger, or lower side of this vein, is also irregular, falling into concavities, and rising up to convexities.

The natural hade or slope of these veins makes them abundantly troublesome to work, and these additional irregularities of the sides make them still worse. The greatest and most peculiar difficulty in working these veins, is in getting the work out of them; but as I shall perhaps have occasion to mention them again in another part of this work, in order to enquire into the best methods of bringing out the work, I will dismiss them here, after observing, that these irregularities of the great degrees of slope, and of the convexities and concavities of the hanging and ledger sides, are over and above the irregularities met with in other rake veins, such as bellies, twitches, &c.

I have dwelt the longer upon the history of the rake vein or perpendicular fissure, because it is the most common and frequent of all veins, and almost the only one as yet wrought in Scotland. I should now proceed to the history of the pipe vein; but before I begin with it, I think it is proper for me to give a brief account of some of the strings, and other partial veins which branch out from the principal ones, as theſe properly be-long to, and accompany the rake veins.

A ſtring, in mining, is a diſcontinued vein or mineral fiſſure, which flies out in a right line, but with an acute angle from the principal continued vein; and when it has ſtretched in that line to an indeterminate, though no great diſtance, it then terminates in a point, and is ſqueezed out to no-thing by the two ſides coming cloſe together, co-aleſcing, and having no marks or veſtige of a vein; or in other words, it is really the one end of the crack or fiſſure, and further forward, the ſtratum or rock is whole and unbroken. The other end, as hinted already, joins the principal vein ſomewhere, and comes into one ſide or other of it in an acute angle, but does not croſs it; if it croſſes the vein, and is found quite through upon the other ſide, it is not a ſtring, but an oblique or diagonal vein. When a ſtring has really joined and is come into a vein, they are afterwards in that line no more two but one; the line of the ſtring, and the ſtring itſelf, being loſt in the vein, and the vein only continues the line of bearing. Theſe ſtrings flie out from the veins in all directions, though always diagonally; and they are ſometimes as rich, and I have ſeen them for a ſhort time even richer than the vein itſelf; but they at laſt ſqueeze out, and come to

nothing

nothing at a lefs or greater diftance. The reft of the hiftory and defcription of a ftring is the fame as that of a rake vein or veins as above, to which I refer, to prevent tedious and unprofitable repetition.

There is another fpecies of ftring which has no relation to, nor, perhaps, is not near any vein at all. This fpecies of ftring is, properly fpeaking, an imperfect difcontinued vein, which neither puts down to any confiderable depth, nor does it ftretch forward to any confiderable diftance upon the line of bearing either way ; neverthelefs it may, for a fhort time, look as well, and produce as good ore, and other mineral foils, as a real continuous vein.

The mining field in the ifland of Ifla, upon the weft coaft of Scotland, is remarkable for a great number of thefe ftrings, or imperfect difcontinuous mineral fiffures ; fome hundreds of which produced, and now contain, fome fmall quantity of good lead ore, and yet certainly come to nothing at the depth of a few feet, or a very few fathoms, and at no great diftance in the line of bearing ; and that not by a twitch and fuch a coalefcence of the fides of the vein as will open again further forward in the line of bearing, which is an accident common to all veins, but actually by the difcontinuance of the crack where the ftrata ſtrata appear as whole as a number of unbroken planks lying one above another.

As I have named the iſland of Iſla, it may not be unprofitable, and it may gratify the curious, to give a brief hiſtory of the mining field in that iſland.

The mining field in Iſla is wholly, or, at leaſt, chiefly comprehended, or included in a patch of limeſtone; I call the limeſtone of Iſla a *patch*, becauſe it covers but a ſmall part of the iſland. The lime field in Iſla is compact, or nearly as broad as long, and is ſomewhere about ten miles over every way; but perhaps the world does not contain a patch of ſtone of any kind which exhibits a greater number of mineral veins; and it is remarkable, that they almoſt all bear ſome good lead ore quite up to the day.

The lime rock in Iſla is moſtly bare, excepting tufts of graſs, and little ſpots of arable ground about half an acre leſs or more here and there. The ſuperficies of the lime rock being ſo generally ſeen, has given opportunity for diſcovering ſuch a vaſt number of mineral veins: Among theſe there are a great many north and ſouth, and a great many eaſt and weſt veins, or what are ſo called, which croſs and interſect one another nearly at right angles; and, moreover, there are alſo a great many oblique or diagonal veins, which croſs and interſect the others at all manner of a-

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cute and obtufe angles: And it is worthy of remark, that befides the mineral veins, there are alfo an innumerable multitude of whin-ftone dykes, of all fizes and dimenfions, which crofs and interfect one another, and which crofs and interfect the mineral veins in all manner of directions, fo that the whole patch of lime is curioufly cut and divided into an innumerable multitude of compartments, or angular pieces of all dimenfions and figures, only that none of them can be very large.

Some of the whin-dykes are not a foot thick, others are two, four, or fix feet thick, and again feveral of them are eight, ten, or twelve feet, and fome few a great deal thicker. Many of thefe dykes or ribs of ftone run parallel to one another, and crofs and interfect one another. Great numbers of thefe ribs of ftone rife up into ridges above the furface of the ground, the lime being weathered, decompofed, and wafhed away from both fides of them, and the whin being very hard, ftands the weather better than the fuperficies of the lime. I have ftood upon an eminence or rifing ground there, and feen fome fcores of thefe whin-dykes in my view, croffing and interfecting one another in all directions. The quality of thefe whin-dykes is generally a fpecies of that hard ftone which naturalifts call *bafalts*; but as I am to give the natural hiftory of the bafalts,

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and of the whin-dykes, in the third part of this work, I will ſay no more about them here, but juſt obſerve, that they are all mineral veins.

I am very ſenſible that the moſt of miners will ſtartle at this obſervation, and will be loth to own that they are mineral veins; however, I expect to make it abundantly evident, that they were originally the ſame ſort of fiſſure, though filled afterwards in whole or in part with matter foreign from what is called mineral matter. I ſaid *in whole or in part*; and as a proof of my being right, ore has been found upon one or both ſides of theſe ribs of ſtone; as an inſtance of this, Charles Freebairn, a late leaſſee of the mines of Iſla, had a rib of ſolid lead ore for ſome ſhort time about three feet, and for a longer time about two feet wide, running parallel to one of theſe ribs of ſtone in the ſame vein, and quite cloſe to it; and deeper down in the ſame vein, he had a conſiderable wideneſs of ſoft mineral ſoil, with ſome lead ore in it, upon the other ſide of the ſame rib of ſtone. I examined this vein myſelf, and inveſtigated the truth of the circumſtances, only I did not ſee the ore at its full wideneſs; but both the maſter and the miners aſſured me that they had it ſo wide ſome time before I was there; and, moreover, I ſaw both ore and mineral ſoil upon one ſide of ſome, and upon

both

both ſides of others, at the ſurface of the ground in other parts of this mining field.

I obſerved before that this mining field contains a great number of good north and ſouth veins, and likewiſe a great number of good eaſt and weſt veins, all of which cut and interſect one another nearly at right angles; that there are alſo a great number of diagonal veins which interſect the others at various acute angles, beſides prodigious multitudes of ſtrings and imperfect veins, numbers of which branch off from the principal veins, and others are quite detached from them; and it is a true, but ſurpriſing fact, that ſome hundreds of theſe veins, perfect and imperfect, have been tried, and ſome lead, leſs or more, found in them all.

The phenomenon of ſuch prodigious numbers of ſuperficial trials within ſo ſmall a compaſs of ground, not above ten miles over, ſtruck me with ſurpriſe, and, therefore, I made ſome enquiry about it, and I was informed, that ſome time ago a company of Glaſgow merchants took a leaſe of this mining field, and their method of working it was as ſingular as it was pernicious to the future welfare of the mines. Whether I was told that they had any practical miners there or not, I do not now remember; however that may be, their principal way of procuring ore was by employing and encouraging the peaſantry of the iſland to dig and raiſe the ore at ſo much per bing, which is a certain weight or meaſure; and in conſequence of ſome ore being ſeen at the ſurface in numbers of veins, the country people ſearched, dug, and rummaged the whole face of the mining field. They laid all the veins open to the day, like a trench or ditch, where they found any ore. In ſome places they did not go down above two or three feet in the veins and ſtrings, at moſt not above two or three fathoms, when they generally came to more water than they could caſt out with a diſh; and as they had no pump, windlaſs, nor other apparatus for drawing buckets, they could neither bring out the water nor the work to a greater depth conveniently than about two or three fathoms.

No doubt this imperfect method of ruſtic mining would produce a conſiderable quantity of good ore for the time; however, it had a moſt pernicious effect upon the mining field for the future, as they went down every where in ore as deep as they could for water; and as they cut up the veins along open to the day, they are now ſo many wet ditches, which receive all the ſurface water, which conceals the ore they left in the ſoles, and it is not eaſy getting down to examine it in a long ditch of water. However, ſeveral of them have been examined, and very good ore found in ſome of the veins, and ſmal-

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ler ribs of good ſolid lead ore, from three to ſix inches, have been ſeen in the ſoles of numbers of theſe ſuperficial old works.

I laboured very hard about three weeks in the iſland of Iſla, viewing and inveſtigating the mineral appearances, and declare I never ſaw, nor do I ever again expect to ſee, ſo many good and regular veins ſo near to one another, in many of which good ore has been found and wrought; and there is ore very well worth beginning upon in the ſoles of the ſuperficial works above deſcribed, in a conſiderable number of very fine promiſing veins.

There are ſeveral rivulets and rills of water in the neighbourhood of the mines, and good ſituations for reſervoirs, which, if properly made uſe of for water engines, the mines of Iſla might become very profitable, extenſive, and durable.

I beg leave to enter a caveat here againſt any ſuſpicions of partiality. I never ſaw, nor do I know any thing in the world about the proprietor of the mines of Iſla, and I ſolemnly declare that any hints of information conveyed in this hiſtory ſhall be abſolutely free, independent, and impartial, and ſuch as I think may be uſeful to poſterity.

I am fully convinced of the great value of the lead mines now under water in Cardiganſhire, and the ſouth-weſt corner of Montgomeryſhire, and, therefore, I ſhall hereafter give ſhort hints concerning them, merely to point out where a treaſure lies hid, which can be of no farther uſe to me than the pleaſure of endeavouring to make it uſeful to others, by communicating ſome hints of my knowledge of it, and the hints about the mines of Iſla, and all others, of whatever kind, ſhall proceed from the ſame principles.

I know very well that a great deal of the beſt lead in the iſland of Britian lies under water, and if I can give any uſeful hints about ſo valuable a ſubject, I ſhall in ſo far be an uſeful member of ſociety, which is an ambition I wiſh my mind to be poſſeſſed with.

I will now return from this digreſſion to proſecute my account of ſome of the ſmaller branches of the mineral veins, and the next I will take notice of is a *bar*.

A bar is a ſhort diſcontinuous vein, which runs between two parallel veins, either right acroſs, or in a diagonal direction, and joins them both together, that is, the one end of the bar comes into one of the veins, and the other end goes into the other vein; but it does not croſs either of them—it joins them together like the letter H.

A *ſkew* is an irregular diſcontinous mineral fiſſure, ſtriking out from the principal vein in an uncertain

uncertain direction, and which generally lies in a very ſlanting irregular poſition. Theſe imperfect mineral fiſſures ſeldom ſtretch out to any conſiderable diſtance from the principal veins.

A *back* is a mineral fiſſure, which often reſembles a ſegment of a circle. The back breaks off from the hanging ſide of a vein, ſtrikes out to a leſs or greater diſtance, fetches a ſweep, and comes back into the ſame vein again at a diſtance from where it ſets out.

All theſe inferior branches produce good ore in ſome mines. Ore is ſometimes found in ſo many ſhapes and ſituations accompanying good veins, that it would be too tedious to trace it through all its various appearances, if they could all be recollected; but as I think the enquiry of no farther conſequence in this place, I will drop it at preſent. Some part of it will be reſumed when I come to point out ſome other beds of the metallic ores beſides regular mineral veins.

The *ſecond* mineral vein I am to deſcribe is the *pipe*, and the deſcription of it will be very difficult, as the pipe at beſt is but an imperfect and irregular vein.

A pipe vein reſembles in many reſpects a huge irregular cavern, puſhing forward into the body of the earth in a ſlanting or ſloping direction; but many

many of them with very different degrees of ſlope, ſome of them having but a few degrees of ſlope from the horizontal flatneſs, and others declining precipitately, ſo as to be nearer the perpendicular poſition than the angle forty-five. In ſhort, they ſtand in all poſitions between the perpendicular and the horizontal. The pipe, as I hinted above, is like a huge irregular cavern, which puſhes forward in a ſloping direction, until it goes down out of our reach, but it is bounded by rock on all hands. The pipe in general does not cut the ſtrata like the rake vein, but it is an opening between them, ſo that if the lay or poſition of the ſtrata is nearly horizontal, ſo is the bearing of the pipe; but if the declivity of the ſtrata is precipitate, the pipe ſhoots down headlong almoſt like a ſhaft. Some pipes are very wide and high, others are very low and narrow, ſometimes not ſo large as a common mine or drift, and others again are of all the mean dimenſions.

Some pipe veins are hard and others are ſoft. The hard pipes contain all the variety of mineral matter which is commonly found in hard rake veins. Some of them are found quite full of ſolid ore, others are full of ore, mixed with ſpar, rider, &c. and ſome again are full of ſpar or rider without any ore at all. Large pipe veins full of ſolid ore are generally exceeding rich.— Theſe ſometimes open out on the right and left hand

hand to a great many fathoms wide, and it frequently happens that they riſe up into the roof and ſink down into the ſole at the ſame time, ſo that the pipe, which perhaps was not before much above a fathom high and a couple of fathoms wide, ſwells out ſuddenly into a prodigious belly, which in bearing pipes proves immenſely rich; but all the hard pipes are not of ſuch ſpacious dimenſions, nor do they all bulge out into ſuch large bellies.

I ſaw them working a pipe in Denbighſhire in Wales no wider than a good mining ſhaft or coal-pit. This pipe was almoſt round, and it put down in the rock with a ſlope between the angle forty-five and the perpendicular. It was quite full of good lead ore, about ſix feet diameter. I ſay diameter, becauſe the vein or pipe was of a tubular form, and quite full of ore.

Some of the largeſt loughs or open caverns deſcribed above are met with in hard pipe veins, concerning which I will ſay no more here, as they were fully deſcribed before.

Soft pipe veins are as frequently met with as the hard; that is ſuch as contain ſoft mineral ſoils within the tubulous concavity of the pipe. The ſoft mineral ſoils have been deſcribed above, and therefore I need ſay no more about them here. The ſoft pipes are found in various poſitions as well as the hard: Some put down with a quick,

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and others with an eaſy ſlope. The ore is found imbedded and buried among the mineral ſoils in the ſoft pipes, much in the ſame manner as in the wide and bellied ſoft rake veins, as deſcribed above, to which I refer to avoid repetition.

It ſhould be obſerved, that pipe veins do not always approach the tubular form. Several of them are much wider than they are high, and theſe flatter pipes frequently come to be very low between the roof and ſole, or upper and nether ſtratum, towards the ſkirts or extremities of the pipe upon the right and left hand. I will alſo obſerve, that all pipe veins do not continue betwixt two diſtinct beds of ſtone. Sometimes they burſt their way up through the ſtrata, and then they have a much greater ſlope than the ordinary declivity of the ſtrata where they are found.

I will further obſerve, that in ſome mining fields two or more pipe veins run parallel to one another, and ſometimes very near to one another. When two or more pipes run parallel to, and near one another, they are then generally flatter than a ſingle one, and approach ſomething near the figure and deſcription of the ſtreeks or flat veins, which are to come next under conſideration; and it ſometimes happens, that in ſome particular places the ſkirts or ſides of two parallel pipes approach ſo near to one another, as to come in contact; and in this caſe, when the ore is

wrought

wrought out of both, there will be a hole or communication made between them. This generally happens only when one of them flies out wider than ordinary into the ſide next the other.

The bearing of ſuch pipes as continue between the ſtrata is exactly the ſame as the declivity of the ſtrata; that is to ſay, the bearing of ſuch runs parallel to a line drawn acroſs the ſtrata from crop to dip; and it ſhould be underſtood, that pipes have no horizontal bearing whatever: Their bearing is in a declining or ſloping line, and is towards the ſame point of the compaſs as the declivity or dip of the ſtrata.

I obſerved before, that the ſlope of one of theſe pipe veins is the ſame as the declivity of the ſtrata in the mining field, and even in that part of the field where they are found; and as the declivity of the ſtrata is extremely various, and changes ſo often, the ſlope of theſe pipes muſt be as various in different places.

With reſpect to the other ſpecies of pipe veins which have burſt their way up through the ſtrata, it is more difficult to point out their bearing, as they generally dip down precipitately, and may be ſaid to have no bearing at all, as the one end dips down towards the center, and the other end points up towards the ſurface; and ſuch of them as do not ſtand ſo near the perpendicular, ſeldom or never run in any ſtrait line whatever, but wind

downwards

downwards in a ſloping and in an oblique direction.

Some parts of this ſort of pipe will ſometimes put down for a few fathoms as perpendicular as a coal pit or ſhaft, and not unlike a clumſy round or oval ſhaft, both as to figure and ſize, and then it will turn away to one ſide or other with leſs or more ſlope: It is uncertain which way it will ſlope until we ſee it in working; and theſe pipes frequently open and contract again as we go down in them, and ſometimes they will ſwell and belly out to an enormous wideneſs, and, lower down, they will contract again as narrow as ever.

This ſpecies of pipe veins are generally more irregular than thoſe which continue between the ſtrata; but they have this one advantage, that they are generally nearer the perpendicular poſition, and therefore it is eaſier to ſink ſhafts in them; however, they do not all put down ſo near the perpendicular poſition; ſeveral of them have a great ſlope: But whether they ſtand nearly upright, or hang with a greater ſlope, they are all irregular and winding leſs or more, and they all contract and dilate greatly in wideneſs as we go down in them.

The next bed of the metallic ore that comes under conſideration is the *ſtreek*, or *flat*, or *dilated vein*, which is the third in the order ſet down of thoſe I call *principal veins*. Neither this nor the

pipe

pipe can come under the denomination of mineral fiſſures, as in fact they are no fiſſures at all. The flat or dilated vein is a ſpace or opening between two ſtrata or beds of ſtone, the one of which lies above, and the other below this vein, in like manner as the roof and pavement of a ſtratum of coal are above and below that coal. When the ſtrata between which this vein is found lie nearly parallel to the horizon, the vein is likewiſe in the ſame horizontal poſition; and when the ſtrata vary from the horizontal poſition, the dilated vein varies likewiſe with the ſame degree of declivity; and this of neceſſary conſequence, as this vein does not burſt the ſtrata, but always continues between the ſame two beds of ſtone.

Theſe flat veins lie between the ſtrata in ſome reſpects, as ſeams of coal are found; at the ſame time I muſt obſerve, that there is no further reſemblance between them, than that they are both found between the ſtrata, and that they have exactly the ſame horizontal or declining poſition as the ſtrata of the place where they are found: in theſe reſpects they are to be inveſtigated upon the ſame theory as the ſtrata or ſeams of coal; and there is alſo this further reſemblance, that theſe veins are ſubject or apt to be interrupted, broken, and thrown up and down by dykes, ſlips, and other interruptions of the regular ſtretch or plane poſition of the ſtrata, in the ſame manner as in the ſeams of coal, with this difference only, *viz.* that in working coal theſe interruptions are generally real troubles, and getting over them is ſo much pure loſs of money and time; whereas, on the contrary, when they are met with in working a flat vein, they often prove a great advantage, as they are, in fact, other mineral veins of different denomination and deſcription; ſo that as often as theſe interruptions are met with in the flat vein, it is an adventitious increaſe of the reality, or, at leaſt, the chance of meeting with more treaſure in the ſame field. In other reſpects, the theory of the flat vein and the ſeam of coal are widely different: The ſeam of coal preſerves an equal thickneſs betwixt roof and pavement, and, in fact, is a ſtratum fully as regular as any of the ſtrata above and below it; whereas, on the contrary, the flat or dilated vein is only an opening or ſpace between the ſtrata, of very unequal depth or height, which ſpace is always filled with mineral matter. Sometimes theſe flat or ſtrata veins, as they might be called, open wide betwixt the roof and ſole, or lid and ſole, which openings contain a variety of mineral matter ſoft and hard, and generally with a leſſer or greater mixture of ore, and not unfrequently the whole ſpace is filled with good ſolid ore. The flat or ſtrata veins are frequently diſcovered by ſinking or working downwards in the rake veins; and when it ſo happens, it is reckoned a lucky accident, as they can turn off, and work away horizontally in it, with the ſame ſhaft, *&c.* if it be found rich enough. In ſome mining fields they actually do work in the perpendicular, and in the horizontal or flat veins at the ſame time, and with the ſame ſhafts, engine, or level, &c.

Theſe flat veins found between the ſtrata are diſcovered in ſome mining fields in ſeveral ſpecies of ſtone; but they are moſt frequently found in limeſtone lying either in a horizontal or declining poſition.

Some Engliſh miners call the flat veins *ſtreeks;* and when they have both a rake vein and one of theſe in the ſame field, they diſtinguiſh them by the appellations of *the vein*, and *the ſtreek*. By the word *ſtreek* they mean ſtretch, or a vein between the ſtrata which ſtretches or ſpreads in a horizontal poſition. But theſe veins are not all found in the horizontal poſition: I have ſeen great numbers of them in a declining poſition, which muſt neceſſarily be the caſe, as theſe veins are always found between the ſtrata, and are themſelves in reality imperfect ſtrata, and therefore they muſt of neceſſity have the ſame declivity as the ſtrata, which is found in all degrees between the vertical and the horizontal poſition.

I have ſeen a great many of theſe veins in argillaceous ſtrata of the mountain rocks, in which the

the vein itfelf is frequently nothing elfe but a foft argillaceous ftratum, often containing nodules or maffes of pyrites, fpar, quartz, and other ftones, which, upon breaking, are found to hold a lefs or greater quantity of lead ore; and fometimes thefe foftifh argillaceous veins contain nodules and maffes of good folid ore; notwithftanding, I believe thefe argillaceous ftrata veins feldom hold fo much ore as to be worth working, at leaft not near the furface. It is common in fome places to fee thefe argillaceous ftrata veins of various dimenfions, from a few inches up to feveral yards thick; however, when the clay is ftrong, and of a cohefive quality, I would not advife much trial to be made in them; but if it be lax, and of a friable texture, with fome ore, let them follow their own inclination.

I obferved before that the flat or ftrata veins are not cracks, fiffures, or gafhes in the ftrata like the rake veins, but, on the contrary, they are always found between the ftrata, and are themfelves imperfect ftrata, or at leaft each of them occupies the place of a ftratum, fo that there is a very wide difference in the theory of thefe two fpecies of veins, the rake vein being always a longitudinal fiffure, or break, acrofs the ftrata in fome line of direction, in which cafe the vein is the chafm or fpace between the fides of that longitudinal fracture; whereas, on the contrary, the

the ſtreeks or flat vein in this caſe is a ſpace between two layers of ſtone, which ſpace is generally filled with ſome mineral matter or other: But notwithſtanding this wide difference in the theory or natural hiſtory of theſe two ſpecies of veins, they frequently have a very ſtriking likeneſs and agreement in their internal contents, appearance, and accidents. The flat or ſtrata veins open and cloſe as well as the rake veins. Sometimes the ſtratum, which is the immediate roof or lid of this vein, comes down and joins cloſe to that below it, to that degree, that there is perhaps no ſpace left between them, and little or no veſtige of a vein left; and theſe twitches, or coming together of the roof and ſole of the vein, will continue to a leſs or greater diſtance, and the vein be entirely, or in part, ſqueezed out from betwixt the two layers of ſtone, as is found in the rake veins when they check, or their ſides cloſe together. Sometimes the ſtrata veins will continue of a moderate and pretty regular height between the roof and ſole for a conſiderable extent, and at other times the roof and ſole come together, and open again at ſhort diſtances.— Sometimes the ſpace, which we may call the concavity of the vein, is but low betwixt the roof and ſole, ſo that when the ore is worth working, part of the roof or rock above it muſt be worked away with the ore, to give the workmen room

room to advance ; and at other times they open wider or higher, fo as to give room enough for a good body of ore ; and, again, they fometimes open up to an enormous height, which may be called the bellies of thefe veins.

The ftreek or dilated veins are found both hard and foft : Some of the hard ftreeks contain a good body of folid ore, others produce ore mixed with fpar or vein-ftone, rich or poor ; and fome of them again are found to hold nothing but fpar and vein-ftone, without any ore at all. Leffer and greater bellies, with loch-holes, or open cavities, with other accidents and alterations, are found in thefe veins, which in many refpects refemble the rake veins.

In foft ftreeks the ore is fometimes found in large bellies, but more frequently in flattifh glebes or maffes, generally lying nearer the fole than the roof. The ore in thefe ftreeks often lies in large irregular cakes upon the floor or fole, and fometimes feveral layers of thefe cakes are found one above another, quite up to the roof of a wide vein, with foftnefs or foft mineral foil filling up the fpaces between the feveral flattifh maffes.

It fhould be obferved here, that when two or more checks or twitches in a ftreek or flat vein run in a parallel, and are at no great diftance from one another, the ftreek has then a near affinity

finity to one ſort of the pipe vein; and when the parallel twitches are near one another, and that the concavities of the veins riſe to a conſiderable height between the twitches, they go then under the denomination of pipes, and are worked as ſuch.

I obſerved above that the ſpecies of pipe which approaches in affinity to the ſtreek, lies between the ſtrata, and conſequently it has the ſame declivity as the ſtrata in like manner as the ſtreek, ſo that there is an original affinity between them; and when twitches run parallel in one of theſe ſtreeks, and the roof riſes up to a conſiderable cavity between the twitches, the name *pipe* is then impoſed by the miners.

The *fourth* and laſt capital vein I am to take notice of is the *accumulated vein.* The accumulated, concentrated, or conical vein is not eaſily deſcribed, ſo as to convey a diſtinct idea of it. Some of theſe veins approach to the form of vaſt irregular cones, and others of them have ſome reſemblance of inverted cones; but whatever is the form or deſcription of this mineral repoſitory, it generally contains a great deal of wealth in a ſmall compaſs of ground, the accumulated veins being often the richeſt of all mines.

Some of theſe veins reſemble many of the pipes, eſpecially

eſpecially in their dipping down from the ſurface, either in a perpendicular or a ſlanting direction, and in their being encompaſſed and circumſcribed on all ſides with rock; but they frequently differ from the pipes in the interior ſtructure.

The accumulated vein is often pretty narrow, or of ſmall diameter above, and very wide at a conſiderable depth down from the ſurface, and ſome of them open out to an enormous width as we ſink down in them; but the moſt remarkable diſtinction between the accumulated and the pipe vein, which lays moſt claim to our attention, is the radiated form of the accumulated or concentrated vein, from which a number of leſſer veins or mineral fiſſures diverge every way, and ſtretch ſome of them to a leſs, and others to a greater diſtance, from the main pipe or body of the vein, in which the one end of each of them concenters.

The main pipe or ſhaft of the accumulated vein reſembles the inſide of a glaſs-houſe, and the vaſt capacity of this vein is often ſtored with a rich body of metallic ore, frequently bedded with ſoft mineral ſoil; but the veins and branches which join this pipe, and diverge from it, commonly reſemble our rake veins or perpendicular mineral fiſſures.

When the ore is worked out of a large accumulated vein, it exhibits then a horrid frightful gulph,

gulph, ſome of which may be fifty or ſixty feet wide below, and they are often worked down to a great depth from the ſurface.

From ſome of theſe large pipes, a greater, and from others a leſſer number of nearly perpendicular fiſſures, or rake veins, meet and join in one common center, from which they ſpread out like radii to different diſtances from the main body of the ſhaft or cone; and theſe branches frequently contain rich bodies of ore, which being worked out, there remains a vaſt perpendicular arched concavity, as it were hanging upon pillars.

We ſee nothing in the practice of mining ſo awful and tremendous as the excavations of large accumulated veins which have proved rich in ore. The mining ſhaft or pit for drawing up the ore, and for deſcending down to the works, is frequently ſunk upon the vertex of the cone or perpendicular pipe; and when you deſcend fifty or ſixty fathoms down in one of theſe ſhafts, you are then ſwinging in the middle of an immenſe void ſpace, where you ſee on all ſides rugged, frightful, hanging rocks, which threaten to fall upon you and cruſh you to pieces.

The excavations of the perpendicular irregular pipe is of itſelf ſufficiently frightful; but when the hanging rocky ſides of the main pipe or cone are ſlitted up and opened, perhaps from top to bottom, in many places, in working the collateral diverging veins, the appearance of this horrible gulph is then frightful beyond defcrp-tion.

There is, as I hinted above, a variety of the accumulated vein, which refembles an irregular inverted cone, or the infide of a glafs-houfe turn-ed upfide down. Some of thefe inverted veins are found fo wide at the furface of the earth as to fhew at firft no appearance of a vein, as no-thing is feen but a prodigious neft or heap of ore huddled together, until they go down fome con-fiderable depth, and then they find that the ore is circumfcribed or encompaffed by rock on all fides; and though they continue confiderably wide for fome time, yet they grow narrower by degrees as we go down in them, until at laft they contract within the compafs of one of the erect pipe veins which was defcribed above.

I obferved before that fome of the pipes are very irregular at all depths,—fometimes ftanding nearly erect, and then turning to a flanting or a fpiral pofition; and with refpect to the capacity of this pipe, it is fometimes of middling widenefs, but it often contracts and dilates again to various dimenfions, and it fometimes opens out to an enormous widenefs far down as well as at the furface, when it may be called an accumulated vein.

When a rich pipe is very wide at the ſurface, it may with propriety be called an accumulated vein, as there is often found in it a great body of ore as it were accumulated in one heap, and ſometimes more treaſure is raiſed out of one of theſe in a few weeks than can be raiſed out of ſome mines in ſo many years, even when they are worked with profit, and the accumulated ore is generally raiſed with very little trouble and coſt, in compariſon of the expence of working other veins.

Many iron mines are found in this deſcription of vein, and lead and copper ores are frequently found and worked in both the ſorts of accumulated veins. A rich body of lead ore was found and worked in Yorkſhire a few years ago, in what I call the inverted conical vein.

I have now gone through the natural hiſtory and deſcription of the four capital mineral veins, viz. the Rake, the Pipe, the Flat or Streek, and the Accumulated Veins, which are the principal repoſitories of the greateſt quantities of the metallic and other mineral ores which are found within the ſurface of the earth.

It may be proper for me now to remark, that mineral veins are ſubject to ſeveral accidents which may be met with in the progreſs of working them; ſome of which are the more dangerous,

gerous, as they may occaſion the entire loſs of the vein, if not well underſtood; and, therefore, as it is poſſible that theſe troubles or accidents are not in general ſufficiently well known to all miners, they deſerve to be inveſtigated with attention.

I obſerved before, that the flat vein found between the ſtrata is frequently liable to be twitched or ſqueezed out by the roof and ſole coming together; however, when there is no more in the caſe than the roof and ſole coming together, they are always ſure that the vein will open again, and that they will find it again upon the ſame level when they have cut through that ſqueeze or twitch.

Theſe grips or twitches are generally pretty well underſtood by all miners who have been uſed to flat works; but there are other troubles or accidents incident to theſe veins, which are not ſo generally known, nor ſo eaſily inveſtigated; ſuch as dykes, ſlips, gaſhes or chaſms, the ſame as are met with in the coal and coal ſtrata, which have been deſcribed already; nevertheleſs it may be neceſſary to touch briefly at what has been ſaid about them. The flat ſtrata veins, as well as the ſeams of coal, are ſubject to be interrupted and cut aſunder in two by whin dykes; by dykes of ſofter ſtone; by dykes of imperfect indigeſted ſtone; by all ſorts of clay dykes, wet and dry, hard and ſoft, homogeneous and compound, or mixed with gingle, gravel, &c. They are alſo ſubject to be interrupted and cut aſunder by gaſhes or chaſms, which are generally filled with gingle, gravel, ſand, or looſe earthy matter; and all theſe dykes and gaſhes are wide or narrow, difficult or eaſy to get over, the ſame as in the coal and coal metals, which were particularly explained before. The ſtrata or flat vein, as well as the ſeam of coal, will be found nearly upon the ſame level upon both ſides of the dyke and of the gaſh.

Theſe veins are alſo liable to be interrupted and thrown off their level by ſlips. When a flat or ſtreek vein meets with a ſlip, it is thrown ſo many feet or ſo many fathoms up or down in the ſame manner as the ſtrata of coal, where this trouble was fully explained. There is one material circumſtance relating to this ſlip in the ſtreek vein, which I hinted at before, and will now repeat, *viz.* that a ſlip in the ſtrata is always a rake vein; a ſlip in the ſeam of coal, in any other ſtrata, and in the ſtreek vein, is one and the ſame thing in natural hiſtory; therefore, when a ſtreek vein is thrown up and down out of its ordinary courſe and level by one of the rake or ſlip veins, if the ſlip happens to be tolerably wide, and to contain more or leſs of ore, or of other promiſing mineral ſoil, there is in that caſe no danger; it may rather be thought a lucky accident. They

will

will follow the rake vein up or down whichever way it has thrown the ſtreek, until they meet with it again, and then they will work one or both of them as they prove or appear worth while: But, on the contrary, if the ſlip or rake vein happens to be in a cloſe twitch in that place, and that the two ſides of the fracture are cloſe and cemented together, in that caſe there is the more danger, as ſome of theſe ſlips which throw the ſtrata and flat veins a great many fathoms up or down, are ſo cloſe and imperceptible, that the flat vein may be loſt without the utmoſt attention. Exactly the ſame circumſtances will happen in this caſe in the flat vein as in the ſeam of coal. When the vein is cut off by the ſlip, and thrown off its former level, the miners meet firm ſtone in the face, inſtead of their vein, and when they touch this ſtone, if they are perfect in the hiſtory of the ſtrata above and below their vein, and recognize the ſtone which meets them in the face, they can then make a near gueſs how far the vein is thrown off its former level. If it is a down ſlip, the vein will be cut off firſt above; but, on the contrary, if it be an up ſlip, it will be cut off firſt below, and there will always be ſome ſmall veſtige, although it ſhould be no more than a cloſe joint, to ſhew which way the vein is gone; and if they are not well verſed in the hiſtory of the ſtrata or binds, ſo as to know how far the flat vein is thrown

thrown off its former level, it may be neceſſary to follow the cloſeſt viſe or veſtigia, to prevent the danger of loſing the ſtreek or flat vein. The ſtreek will ſtretch or ſpread out again upon the other ſide of a ſlip, much the ſame as it did before it was cut off by it, and as the ſeam of coal does. Theſe breaks and irregularities of the ſtrata are generally diſtreſſing troubles in the coal field; but they do not always prove ſo diſtreſſing in the mining field; very often they are quite the contrary.

I have ſeen ore upon one and upon both ſides of a whin dyke; and the gaſhes in the ſtrata, as I hinted before, often prove very rich and fruitful veins.

The ſlips, which are the moſt numerous of all the interruptions of the regularity of the ſtrata, are alſo the moſt frequent and the moſt durable mineral veins; ſo that there is always, at leaſt, the greater chance the more of theſe interruptions of regularity are found in a mining field; and for a very good reaſon, becauſe they are all mineral veins.

The rake veins or perpendicular fiſſures are frequently checked and interrupted by the ſides of the vein coming cloſe together, both in the longitudinal and perpendicular direction, and in theſe checks or twitches, the ſides of the fiſſures are often ſo cloſely preſſed together, that every

veſtige

veſtige of a mineral vein is ſometimes entirely ſqueezed out. However, as I obſerved before, experienced miners are ſo accuſtomed to theſe twitches, that they are ſeldom in danger of loſing the vein by them, excepting in the caſe of their continuing too long, there being always ſome dark imperfect veſtige of the courſe of the vein remaining, though ſometimes hardly perceptible, the two ſides being clapped as cloſe together as the joint between two hewn ſtones.

But the perpendicular fiſſures are ſubject to ſtart aſide to the right or left hand, which is ſometimes a more dangerous accident than the twitch, becauſe it is in general leſs known. When one of theſe perpendicular fiſſures ſtarts aſide, the miner meets ſolid ſtone in the face, and the vein is ſqueezed out as effectually as in the common twitch; and there is moreover this material difference between the two accidents, *viz.* When a vein is ſqueezed out by a twitch, there remains ſome veſtigia of the vein keeping the ſame perpendicular poſition and longitudinal bearing as the vein, before it came into the twitch; on the contrary, when a vein is cut off by a ſtart, or is thrown to one ſide, there remains not the leaſt joint or veſtige of the vein in the line of its former courſe, becauſe it is ſtarted or thrown into one ſide quite out of its former courſe or bearing, and therefore it is the more neceſſary in this caſe

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to examine carefully all circumſtances relating to this accident, as there are, I am perſuaded, many good and valuable veins entirely loſt by it.

A rake vein is thrown off its courſe to one ſide, either by a cloſe joint, or an open croſs vein.— When a vein is ſtarted, or thrown out of the line of bearing, into one ſide or other, it is proper to obſerve, that the vein in this caſe is always cut off by a ſmooth joint, which meets the miners full in the face, inſtead of the vein; and behind this joint, ſtraight forward in the line of bearing, there is not the leaſt appearance of the vein, becauſe it is thrown off its former courſe to one ſide.

There is one circumſtance relating to this back joint which deſerves to be particularly remarked, viz. If the vein is ſtarted into the right hand ſide, the ſmooth joint which cut it off meets the miner firſt on the left hand; and, on the contrary, if the vein is thrown into the left hand ſide, the joint meets the miner firſt on the right hand, and ſo paſſes on in a ſlanting or diagonal direction acroſs the forehead of the mine, or foremoſt working in the vein: That is to ſay, a perpendicular joint or cloſe fiſſure throws the vein to one ſide in the manner now deſcribed; but if it be a horizontal joint, it comes in acroſs the ſoles, and the vein is cut off horizontally, and loſt entirely in the former direction as they work downwards in it. The ſame rule is to be obſerved with reſpect to the horizontal ſtart, as the perpendicular, to know into which ſide the vein is thrown, ſlipped, or ſtarted. The horizontal ſtart or joint which cuts off the vein as they go down in it, does not cut it off in the true horizontal line, but leans or declines a little ſome way; and we may be certain that the vein is gone the ſame way as the joint declines. I believe it may be aſſerted, that the horizontal ſtart throws the vein generally into the hading or ledger ſide. It deſerves further to be noticed, that this ſtarting joint not only croſſes the whole breadth of the vein, where it is cut off, but alſo continues its courſe forward into the ſide, until it comes to the vein again, to which it infallibly leads, if properly followed; and when the vein is found again upon the other ſide of this ſtart or ſlip, it always reſumes the ſame poſition, and bears to the ſame point of the compaſs, as it did before it was loſt, or thrown aſide by the ſtart. It will frequently happen in this caſe, that the miners will cut thro' the ſmooth joint which is the veſtige of the ſtart; and for a while they may work forward into ſolid rock, in the line of the bearing of their vein, until they begin at laſt to ſuſpect they have loſt their vein. If there is a ſmall ſtring of ore, or a ſtrake of good mineral ſoil in the joint or viſe of the ſtart where it enters the ſide, there is not ſo much

danger

danger in this dilemma as if it was only a clofe joint, as in that cafe, when they are tired of working forward in clean rock, without the leaft appearance of recovering their vein there, they will come back to the appearance they left behind in the fide, which they will better examine, and it will lead them to their vein.

But if the veftige of the ftart is only a clofe joint, without any thread of ore, &c. and they continue their mine or drift forward through it, it is a hundred to one if ever they take any further notice of it, and fo the vein is for ever loft. I verily believe that many valuable rich veins are loft by this accident; for it is a certain fact, that thefe joints or veftigia of the ftart are often very clofe, and may be thought not worth noticing, which is my reafon for being fo particular on this point.

In the *2d* place, when a vein ftarts into the fide, off its former courfe, by the interpofition or interfection of another open vein, the courfe and bearing of which is acrofs the former vein, which is cut off and thrown afide, there is not much danger, as the miners will readily follow the interpofing or interfecting vein, whether it bears much ore or not. It muft have either ore or a quantity of mineral foil, if it be an open vein, that is, if it is a vein of any tolerable capacity or widenefs, and the miners will follow the foil without

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ore in ſearch of their loſt vein, eſpecially if it was rich. If the new vein which interſects the old one proves rich, in that caſe it is a lucky accident.

Having finiſhed the natural hiſtory of the mineral veins, it now remains for me to ſay ſomething about the other beds of the metallic ores, and the principal of theſe are two, viz. *1ſt*, Such as are found in the heart and body of the ſolid rock and ſtrata, blended and mixed with the ſubſtance and compoſition of the ſtone: And *2d*, Such as is found upon the face of the rock, which is called float ore. Gold is chiefly found in larger and ſmaller grains, blended with the compoſition of the rock; and this is the original cauſe of ſo much gold duſt and grains being found in the beds of rivers. The ſuperficies of moſt rocks weather and decompoſe, and the decompoſed parts are carried down by the currents, and lodged in the beds of rivers, and the grains and particles of gold being the moſt ponderous, there is proportionally leſs of it carried forward to the borders of the ocean than of the lighter ſand and gravel. It deſerves to be remarked, that gold found mixed in the body and compoſition of the ſolid rock differs in quality or condition from lead or copper, &c. found blended in the rock in the ſame manner. In whatever place or quantity gold is found,

found, it is always found pure and malleable; whereas the other metals are generally found mineralized, that is, mixed with fulphureous, arfenical, and other heterogeneous particles, which renders them brittle and impure.

Lead, copper, and other ores are alfo found in the compofition of the folid body of the rock in many places. I faw a ftupendous rock at a place called Cwmyftwith in Cardiganfhire, Wales, where fo much lead ore was found blended in the rocks as to be worth working and feparating from the rock.

The rocks at Cwmyftwith are of great height, and I faw the miners there fufpended in ropes blafting down the rocks with gun-powder, and a number of bufy hands breaking and knocking the compounded ftone and ore fmall, in order to get the ore feparated by wafhing and dreffing. I believe it always happens, that where ore is found blended in the compofition of the folid rock, any joints and fiffures found in fuch rocks generally contain fome ore. This was the cafe at Cwmyftwith. They had been working fome veins and ftrings long before I was there, and they were then going on with fome of them. But it was the working away the folid rock that ftruck my attention moft.

This part of the work was extenfive, and in feveral places they had cut down the rock, fo as to

have

have very good footing for ſtanding to work. It is ſo long ſince I ſaw this ſingular work, that I do not now remember certainly of what ſpecies or quality the rocks at Cwmyſtwith are; but I ſtill retain an imperfect idea that they are lime-ſtone.

One of the moſt remarkable rocks containing metallic ore in the compoſition of the ſtone, is the breccia or pudding-ſtone at Gourock, near Greenock in Scotland.

Both lead and copper are often found in lime-ſtone quarries in ſeveral countries, and I have ſeen very good lead and copper in lime-ſtone in ſeveral parts of Scotland; but I do not know how it happens that few of theſe fine appearances in lime-ſtone have ever turned to good account in this country as yet. The copper ore found at Currie in the Lothians, and at Kiſſern in the Highlands of Roſsſhire, is remarkably good in quality, and trials have been made, and copper raiſed in both places, but not in quantity ſufficient; and yet the copper at Kiſſern is of the beſt quality, perhaps, of any ore of that metal found in Britain; and very good lead ore has been diſcovered in lime-ſtone, and partly wrought, near Bathgate, and alſo near Calder and other parts of Scotland, but not with ſuch ſucceſs as to conſtitute durable mines, excepting at Bathgate, where they formerly had a rich lead mine, which yielded

yielded a conſiderable quantity of ſilver, and the mines of Iſla, which are in lime-ſtone, which I am confident would be both durable and lucrative, if they were carried on with ſkill and ſpirit. Whether the ore in lime-ſtone in other parts of Scotland is really not to be found in ſufficient quantity, or that the trials upon the ſeveral appearances have been made without ſufficient ſkill, or ſpirit, or perſeverance, I will not pretend to determine; though there is great room to ſuſpect that this is the caſe, when it is ſo well known that many laſting and profitable mines are found in lime-ſtone in other countries. Mineral ores are found blended in the compoſition of ſeveral other ſpecies of rock beſides lime-ſtone. The tin grains are found mixed in the compoſition of the granite ſtone in Cornwall; and I have ſeen lead ore mixed in the compoſition of the mountain rocks in the Highlands of Scotland and ſeveral other places.

There is a ſingular ſtratum of ſtone near Loſſy-mouth, in the ſhire of Moray, of about eight feet thick, which is compounded of ſeveral ſpecies of hard and fine ſtones of various beautiful colours. This ſtratum is a ſpecies of breccia, or pudding-ſtone, in the compoſition of which there is blended in ſome parts of it, about an eighth part of good blue lead ore, of the ſpecies called potter's-ore.

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This curious bed of ſtone lies in a horizontal poſition, and dips away towards the north, under the ſea, or Moray frith, with an eaſy ſlope, and the lead is found in larger and ſmaller grains and flowers blended through the whole body and compoſition of the ſtone, in the ſame manner as the ſmall maſſes of agate, white and coloured cryſtals, and other ſpecies of ſtone are found blended through the whole body of the ſtratum.

I cannot help being perſuaded that perfect metallic ores being found in the body and compoſition of regular ſtrata of lime-ſtone, and in other ſolid rocks, is not only an argument, but a clear deciſive proof, that the materials which formed the ſeveral ores, and their intermixed and concomitant ſpars, were poured into the veins and taken up into the compoſition of the ſtrata of ſtone when they were firſt formed; and although many fanciful notions of the ſubſequent formation of ſolid ores in the cavities of mineral veins may be advanced, it is impoſſible to give any good reaſon for ſeveral ſpecies of ore being found blended with rider, ſpar, and ſtone in the cavities of ſuch veins, and in the compoſition of the ſolid rocks which form the ſides of the veins; much leſs can good and perfect ore, found blended in the body and compoſition of various ſtrata, be rationally accounted for, without acknowledging that ſuch ore is coeval with the ſtrata, and

and veins in which it is found; and the float ore found in ſome mining fields is a farther proof of their being coeval.

Float ore is always found either ſpread out thin, or accumulated in hollow places upon the ſuperficies of the rock, frequently with a bed of clay above it, and ſometimes a conſiderable depth of gravel ſand or earth above the clay. Float ore is always water worn, like ſtones and gravel by the ſea-ſide or in a river. It is found like water worn bullets and gravel, of all ſizes. I have ſeen in Flintſhire rounded maſſes or lumps of it up to two or three hundred weight and more; and in the ſame float ſome of all ſizes, down to ſmall gravel, and part of it ſo ſmall as to go through the ſieve in waſhing, and it is always found mixed with water, round ſtones, and gravel of all ſizes.

Now, float ore, which is ſo called from its being always found floating upon the face or ſurface of the rock, is never diſcovered higher nor upon a level with the vein or veins of that field, but always in lower ground near them, and it is always of the ſame quality, ſpecies, and grain as the ore found in the veins above, which is a clear proof that it was torn off the ſuperficies of thoſe veins by water, and that it was agitated in the water until all the aſperities and ſharp angles were worn off, and until it ſettled in hollow or level places upon the ſurface of the rock, from whence the water could not eaſily lift and remove it again ; and the clay, gravel, earth, &c. were afterwards lodged above it by the future ſtreams and agitation of the water.

I am to make it evident hereafter, that the ſtrata, and all the phenomena of the ſtrata, and of the ſuperficies of the globe, were formed by the waters of the ocean raiſed to extraordinary high tides, and it appears to me very evident that all I have advanced about the metallic and mineral ores muſt have happened very early before the waters were ſettled in the preſent bed of the ocean ſo low as they are now found.

I am ſorry that the natural hiſtory of float ore, and the methods of diſcovering it, are not more generally known, as I am perſuaded it is to be found in many places which never have been ſearched, nor ever thought of. I have ſeen float ore in many places where no trials were ever made for mineral veins, or to know if the float was rich or not. But it may be proper for me to obſerve here, that there is a very material difference between float and ſhoad ore, although they are both found upon the ſurface of the rock. Shoad ore, ſo called by miners, is always found in looſe maſſes of all ſizes, either in or under the upper

ſoil,

ſoil, ſometimes upon the top, baſſet, or out-cropping of the vein, but more frequently a little to the lower ſide, where there is a declivity, and where the vein croſſes the ſlope.

Float ore differs from the ſhoad in that the former is water-worn, which the latter is not; and, moreover, the float ore is generally mixed with water-worn bullets and gravel, which the ſhoad never is, unleſs it happens to be waſhed off the ſuperficies of the vein by ſome rivulet or ſtream of water.

Shoad ore is a pretty ſure indication of a vein where it is found, or a little above, but you muſt judge of the diſtance above, by the greater or leſs acclivity of the ſlope. If the ſide of the hill is very ſteep, it may ſlide a great way down; but if there is but little declivity downwards from the vein, the ſhoad will be found proportionally at a leſs diſtance. The ſhoad ore is found of all ſizes, from very large maſſes down to the ſize of peaſe and ſmaller grains, and it is produced by the weathering or decompoſing of the ſides of the vein, ſo as to have the ore ſtanding higher than the ſuperficies of the rock, which in time ſlides off where the ground is ſloping. It is a common thing in ſome mining countries for the miners to go a-ſhoading, that is, to go a-ſearching for the ſhoad, when they will traverſe rivulets, gullies, ſcars, and other places where the ſurface of the ground

ground is broken, and in ſome places where the ſuperficies of the ſtrata riſe up to the graſs roots; they will even examine newly ploughed land and molehills, and not always without ſucceſs. From the hiſtory or deſcription of the float and ſhoad ore already given, I have no doubt that an intelligent perſon, though no miner, will be able to diſtinguiſh the one from the other; but in caſe either of them ſhould be found, it may be proper for me to point out the proper methods which ſhould be taken to diſcover the vein. Shoad ore is found in rough irregular glebes, or angular maſſes of all ſizes, frequently coated with white upon the outſide. When ſuch happen to be diſcovered upon a flat level piece of ground, a croſs trench ſhould be cut to the rock in the very place where it is found, thus | ; but if you find it upon a ſlope, or immediately at the foot of a ſlope, then you are to look for the vein at a leſs or greater diſtance above, in proportion to the ſlope or declivity of the ground. When ſhoad is found upon a ſlope, or at the foot of it, your firſt buſineſs is to look about you upon all hands, to ſee if you can diſcover any other ſymptoms of a vein, and if not, then you muſt judge from circumſtances what method you ſhould chuſe to diſcover the vein. If you find that the cover upon the ſuperficies of the rock is thin, and the diſtance from the place where the ſhoad was found to the higheſt

eſt part of the ſlope is but ſhort, you may begin a cut to the rock upon the ſpot where you found it, and puſh your trench right up the ſlope, keeping the ſurface of the rock until you diſcover the vein; but if you ſhould fail to diſcover the vein by cutting upwards in a right line, come down again to the foot of your trench, and there cut a little acroſs, in caſe the vein ſhould run in a right line up and down parallel to your cut, or in a diagonal direction, and you have been a little to one ſide at firſt ſetting out. If the cover upon the ſuperficies of the rock is thick, it will in that caſe be troubleſome and expenſive to cut a long trench, and therefore your beſt method is to ſink a ſmall ſhaft down through the cover until you come to the ſolids.

You muſt take particular notice of every thing you ſee in going down with this ſhaft, and if you find bits of ore, of ſpar, or of good whinſtone, it is to be ſuppoſed that you are ſtill below the vein; but if you can diſcover no mineral ſoil, nor any ſymptom of a vein, neither as you go down nor in the ſuperficies of the rock, you have perhaps overſhot the vein, and muſt come lower down, and ſink another ſhaft about half way between the firſt and the place where the ſhoad was found; on the contrary, if you find bits of ore, or lively mineral ſoil, in going down with the firſt ſhaft, in that caſe you are to ſink another ſtill further up in the line of the firſt, from the place

where

where the ſhoad was found, and if the ſymptoms continue ſtronger in the ſecond ſhaft, a third, a fourth, &c. muſt be ſunk, ſtill keeping the line. You may happen to hit the vein in one of theſe pittings; but there is a chance of twenty to one againſt it; nevertheleſs, if there is either a good ſhew of ore, or of other mineral ſoils above you, the ſymptoms will increaſe in quantity as you advance nearer the vein; and therefore it is your buſineſs to continue the pittings until you either touch or overſhoot the vein. When you find that you certainly are above all your ſymptoms, come back half way to the next ſhaft containing them; and if you find them again more plentiful and lively, then you ſhould drive a drift upwards, keeping or baſing the face of the rock in the ſole of the drift, until you cut the vein; but if you miſs the ſymptoms in this retrograde ſhaft, then you ſhould drive the mine, as juſt now directed, from the bottom of the laſt ſhaft which contained them. It ſhould be carefully noticed, if all the ſymptoms you once had continue or not as you advance upwards with the line of pittings. If ſome of them only continue, and you miſs others which you had below, there is a preſumption that you have overſhot one vein, and that there is ſtill another above you. In this caſe it is your buſineſs to advance upwards, as already directed, and to come down again to the laſt ſhaft

which

which contained all the ſymptoms, and drive a drift from it upwards, until you cut the vein which you have overſhot.

If the ſymptoms ſhould appear ſtronger, and more in quantity, in one ſide of your ſhafts than in the other, it is probable that the vein runs up and down the ſlope parallel to your line of pittings. In this caſe you ſhould go to the ſhaft which contains the moſt and beſt mineral matter, and drive acroſs upon the face of the firm rock into the moſt promiſing ſide; and if the ſymptoms increaſe as you advance, puſh forward your drift until you cut the vein. I have already obſerved, that if your proſpect is good, the mineral ſymptoms ſhould increaſe as you advance nearer the vein with your line of pittings. The ſame obſervation will hold in trenching, where the cover upon the face of the rock is thin enough to admit of adopting that method of trial, which is the ſimpleſt and ſureſt of any, where circumſtances favour it. If the ſymptoms increaſe as you advance with your trench, you are ſure that the vein is ſtill before you, and muſt perſevere while they continue; but if they appear ſtronger in one ſide of your trench than in the other, you ſhould cut leſs or more acroſs in the promiſing ſide, as circumſtances encourage you, keeping the forehead of your main trench open, in order to continue it, in caſe you do not ſucceed in cutting acroſs.

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With refpect to the float ore, I do not think it fafe to advife any method of trial for the vein it originally came from, until fuch vein is otherwife firft difcovered, it being very difficult to know how far the ore has been carried by the water before it was lodged in its prefent bed; and, therefore, I would advife a diligent fearch on all hands, efpecially towards the higher grounds, to fee if any other fymptoms of a vein can be difcovered before you proceed to expenfive trials for it. But notwithftanding this caution in proceeding to expenfive trials for the vein, it is highly proper to make trials upon the float ore itfelf, in order to difcover what quantity there is of it, that you may be able to judge whether or not it is worth purfuing.

In trying the float ore, it is proper for you to make a trench or cut in it quite down to the furface of the rock, and to pufh your trench forward the way that moft ore appears. It is likewife proper to pufh forward crofs cuts from your firft trench every way where any ore leads you, as there may be nefts and accumulated parcels of it lodged on either hand where not expected, and, therefore, it is proper to follow every fymptom, and to examine every probable fpot, efpecially flat or hollow places.

Float ore, and likewife fhoad ore, may at firft be turned up by the plough, and by the fpade in making

making ditches, canals, roads, &c. It may alſo be diſcovered in accidental or continued runs of water, and in any other places where the ſurface of the ground is broken.

Whatever way it may be diſcovered, it is proper to make trials upon it every way by trenching to the rock, and if the cover of clay, gravel, earth, or any other looſe rubbiſh which lies above the float ore, ſhould be in any place too thick for trenching, in that caſe you ſhould put down pittings upon it here and there, and if a quantity of ore is diſcovered worth working, you are then to judge whether you can raiſe it cheapeſt by throwing off the cover which lies above, ſo as to lay the whole ore bare, or by mining it under ground, and ſecuring it over-head with timber. Whatever method is choſen, as the ore lies upon the ſurface of the rock, it is to be obſerved that there is a chance of diſcovering a vein in trying and raiſing the float ore.

Where either float or ſhoad ore is found in a ſettle or ſmall flat ſpot, in the middle of a ſloping piece of ground, or near the bottom of a ſlope, there is a very good method of trial, beſides trenching and pitting, called *huſhing*, which is often practiſed with great ſucceſs; and where circumſtances are favourable, it is undoubtedly the moſt effectual, and at the ſame time the moſt frugal method of trial in the world for making mineral difcoveries; but it is neceffary that feveral favourable circumftances concur to make hufhing convenient. In the *firft* place, a flope of confiderable declivity is abfolutely neceffary; and, in the *fecond* place, it is neceffary that water can be collected into fome convenient place for making a dam-head or refervoir for the water, and the higher up fuch a head can be made the better; but the dam muft be fo fituated that you can make little collateral diagonal cuts acrofs the flope, on both fides, to lead or conduct the water from fmall rivulets or higher fprings, and alfo rain water, into the refervoir. If a little dingle, fettle, flat, or hollow place can be had for the fite of this refervoir, fo much the better, as the head can in that cafe be made with the lefs expence to hold much water; but where fuch a convenient fpot cannot be had, they are often made upon the inclining plane of the declivity, in the form of a crefcent. A large dam is always better than a fmall one if it can be had; and where the floping ground to be hufhed is of any confiderable length from the hufh-dam down to the bottom of the flope, the refervoir muft contain a confiderable quantity of water, otherwife its force will be fpent too foon before it proves effectual to carry down the great quantity of rubbifh which the water will raife in a long hufh-gutter; and, therefore,

fore, if your dam or reſervoir has not a level area for the water to ſpread upon a conſiderable ſuperficies, it is neceſſary that the head ſhould be the higher, in order to make up in depth what is wanting in the length and breadth of the piece of water. I will only hint in general that the head of this reſervoir and the ſluice muſt be wide in proportion to the quantity of water to be let out at once, and to the ſtrength of water neceſſary for ſcouring the huſh gutter.

From this huſh dam you draw a line right down the hill, unleſs there be ſome hillock or other obſtruction by the way, in which caſe you muſt draw your line in ſuch a direction as the water will run beſt in a trench or huſh gutter when made. When you have worked out the line of the huſh gutter all the way down to the bottom of the ſlope, then you muſt cut off the ſod or upper ſurface of the ground out of it, about two or three feet wide, and about a foot or a foot and a half deep, all the length, to make room for it to contain a ſmall run of water, and when the gutter is ſo prepared, you muſt let out but a ſmall quantity or run of water at firſt, in proportion to the capacity of the gutter, and when the water is let out the two or three firſt times, the men muſt be divided at proper diſtances from one another, with their tools in their hands, to help to looſen the earth for the

water

water to carry away, and to take out obſtructions which may ſtop the water and turn it out of the gutter. When the water is all run out, then ſtop up the ſluice again, and turn ſuch big ſtones out of the gutter as the water is not able to carry down, until the gutter is wider and deeper, and clear the gutter of all other obſtructions which the water cannot remove, until it has greater weight and force than there is room for in this ſtate of the huſh. Let the water be encreaſed every time it is let out, in proportion as the gutter wears deeper, to be capable of carrying more of it, and let the men continue to aſſiſt the water as long as the gutter is ſhallow, and it is ſafe ſtanding upon the edges of it, which it is not when the gutter is worn ſo deep as to contain a ſtrong huſh of water. By only removing the big ſtones and other obſtructions after every huſh, the frequent application of the water will wear down the gutter to a great depth, generally without any digging or farther trouble than lifting and cloſing the ſluice, and keeping the gutter in repair. When ſtones too large for turning out whole are diſcovered in the gutter while it is ſhallow, they muſt be blown in pieces with gun-powder; but when the gutter is worn deep enough to hold a ſtrong huſh or current of water, it will carry down an amazing quantity of ſtones and rubbiſh with ſuch incredible force

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and violence, that it is impoffible to defcribe or imagine without feeing it. The fteeper the declivity, and the longer the gutter is, the greater force it has. I have feen ftones of feveral tons weight, and as big as little huts, carried feveral hundred yards down a large hufh gutter; and the water and ftones of all fizes which the water carries down, wears at laft not only the furface cover, which lies above the rock, but it alfo wears down, by the friction of the ftones, a confiderable depth of the fuperficies of the rock itfelf, and, of confequence, it muft difcover and wafh clean all the veins, ufeful and curious ftones, &c. which crofs the line of that gutter in any direction, by which means valuable difcoveries are often made; and where water can be had, and can be properly ufed, hufhing is by far a more effectual method of trial than either trenching or pitting. When a hufh is worn pretty deep, where there is a weighty cover above the fuperficies of the rock, fometimes great ftones or other obftructions turn the water to wear the one fide of the gutter more than the other; and fometimes both fides wear, undermine, and fall in alternately, until the water is fpread fo wide in that part of the gutter that its force is loft. In thefe cafes it is neceffary to turn the big ftones to one or both fides, fo as to give the water room to run as near as poffible in a ftraight line, which

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is the only way to make it ſcour the bottom effectually.

But notwithſtanding all I have ſaid about turning out and removing ſtones in the gutter, it muſt only be underſtood that this is neceſſary and proper in two caſes, viz. to turn the big ſtones at firſt, when they are a real obſtruction before the gutter is big enough, and the ſtream of water ſtrong enough to carry them down; and to turn them aſide afterwards, to confine the water in the middle of the gutter. Excepting in theſe circumſtances, the more ſtones the water has to carry down the better; and therefore when the huſh is over, the men ſhould be employed to looſen the ſtones out of the clay, to blaſt ſuch of them as are too large into ſmaller pieces, all of which ſhould be left in the gutter for the next huſh to carry down, as the more ſtones come down with the water, the ſooner the clay and other rubbiſh will be torn up and waſhed off, and the ſuperficies of the rock bared and worn down. When there is a little flat, or an eaſy ſlope immediately below the ſluice, and that the form of the ground will otherwiſe allow of it, two, or even three huſh gutters may be made, and ſcoured with the ſame reſervoir, by turning the water off to one ſide at firſt, and giving it a different direction, by which means more diſcoveries may be made, not only of other veins, but alſo in other parts of the veins diſcovered in the

the firſt huſh gutter; as it very often happens that the ſame individual vein which proves barren in one place, produces good ore in another place at ſome diſtance in the line of bearing.

This method of diſcovering mines by the help of water, in the manner I have pointed out, muſt be very effectual where the figure of the ground, and other circumſtances, are convenient for this mode of trial; and I like it the better, as it may be ſaid to bare to the bone, and ſhew us every thing that is to be ſeen in that ſection of the hill.

I will now proceed to point out ſome of the other appearances and ſymptoms of mineral veins, beſides that of finding float and ſhoad ore upon the ſurface of the ground.

Mineral veins may be, and frequently are, diſcovered in all places where the ſuperficies of the ſtrata and rocks are to be ſeen, ſuch as upon the rocky ſhores of the ocean and of lakes, in rocky precipices, in the rocky banks, and beds of rivers and rivulets, in dingles or ravines, and ſcars, and in all other places where the ſolid ſuperficies of the ſtrata are either to be ſeen, or have ſo thin a cover that ſome of the mineral ſhoads are found mixed with the upper ſoil; but where there is a thick cover of clay, ſand, or other looſe matter, upon the ſurface of the rock, all mineral ſymptoms are then perfectly concealed from our view, until ſuch cover is cut through by ſome ditch or trench,

or

or waſhed away by ſome rivulet or current of water, &c.

As a perfect knowledge of the real ſymptoms of mines is of material conſequence, I will attempt a deſcription of the external appearances of mineral veins, and of the ſeveral ſorts of mineral foſſils, which, having ſlidden off the ſurface of veins, are indications of the veins being near the place where ſuch mineral ſubſtances are found; and if theſe points of inveſtigation are made clear and diſtinct, men of obſervation may and will make uſeful diſcoveries, when traverſing diſtricts either for pleaſure or buſineſs, where the ſuperficies of the ſtrata are to be ſeen. The remarks of the land-ſurveyor will then be more diſtinct and uſeful; and gentlemen, when ſearching for game through the mountains, may diſcover uſeful mines.

The rake vein, or perpendicular mineral fiſſure, being the moſt common in all countries, I will begin with it; and with reſpect to external appearances and ſymptoms, rake veins ſhould be divided into the *hard* and the *ſoft*, becauſe the indication and the contents of each are different, and will be eaſily diſtinguiſhed.

A rake vein is a gaſh or fiſſure which cuts the rocks and ſtrata aſunder in ſome certain line of direction; but as the ſpace between the ſides of a vein is commonly filled up with ſome mineral matter or other, it requires attention to diſtinguiſh the

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back or baſſet of the vein from the reſt of the circumjacent rocks.

Wherever the regularity of the ſtrata is broken and interrupted, or any breach or fracture appears in the rock, there is reaſon to ſuppoſe that it is occaſioned by a mineral vein; and therefore, when a conſiderable gaſh or crack is obſerved in the face of a rock, or cutting acroſs the ſtrata, it ſhould be taken notice of and examined. The fiſſure of a vein may be diſtinguiſhed from ſuch a recent crack as is occaſioned by the undermining of water, or by the gradual yielding of a precipice. The ſides of an accidental recent fiſſure are generally rough, unequal, and jagged, and the chaſm or ſpace between the ſides are generally empty, at leaſt of mineral matter; whereas the ſides of the mineral veins are more regular, and may be traced in pretty ſtraight lines, whether the vein ſtands nearly perpendicular or in a ſlanting poſition, and the ſpace between the ſides, whether the vein is narrow or wide, is always filled either in whole or in part with ore, or with ſuch other mineral foſſils, hard or ſoft, as accompany ore in the veins.

When a hard vein is diſcovered in the face of a precipice, in the bed of a river or rivulet, or in any other bare rock, if no ore is immediately found in it, the firſt thing that ſhould be attended to by an unſkilful perſon is, to find the true ſides of the vein, which ſometimes are eaſily diſtinguiſhed; but this cannot always be fo readily afcertained, becaufe falfe fides frequently appear in the middle of a bold hard vein, by the interpofition of a rider, or of other ftoney matter, which apparently divides the vein into feveral parts. When the true fides of a vein are found, upon the outfides of which the rock or ftrata will again appear regular, then the contents of the vein fhould be carefully examined. Some hard veins contain nothing between their fides but hard mineral fubftances, and others contain, befides, a thin ftratum or fticking of foft mineral foil, either near the middle or in one fide of the vein ; and fome wide veins contain more than one ftratum of clay, or other foft foil. The mineral fubftances commonly found in hard veins are vein-ftone, fpar, and fluor, with the metallic and femi-metallic ores.

Lead ore, expofed to the open air in the furface of a vein, feldom exhibits its native colour and brightnefs, but is found either coated or tarnifhed ; however, when ftruck with a pick or a hammer, it difcovers a vivid colour and fhining appearance. In very hard veins the lead ore next the furface, which is expofed to the air and weather, is generally tarnifhed of a dun or greyifh ftoney hue, without exhibiting to a curfory view the leaft indication of any thing metallic, until it is touched with a tool or a hard ftone, when its bright and fparkling texture will foon appear ; and therefore

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when a hard vein is difcovered, every fubftance found between the fides, of whatever colour or appearance, fhould be carefully examined with a tool, as the ore very often does not look like itfelf, but appears like any other fubftance found in the vein, when it is either coated or tarnifhed.

The mineral fubftances commonly found in hard veins, befides the metallic and femi-metallic ores, are the vein-ftones, fpars, and fluors. The fpars found in hard veins are of three diftinct fpecies, viz. calcareous fpar, cauk fpar, and quartzy fpar. The feveral forts of fpar are pretty eafily diftinguifhed from other common ftones, being commonly of a white, a brownifh, reddifh, or of a yellowifh white colour; and they have always a mineral appearance, and a particular ftructure, being either of a tiffilated, rhomboidal, fcaly, or of a tabulated form, in the infide of the maffes, efpecially the lead fpars. Some of the fpars which are found in mineral veins are femi-tranfparent and others opaque; and again, fome fpar is tinged or tarnifhed on the outfide of a black or brown colour; but when the particular maffes are broken, they will exhibit their native texture and colour in the infide.

The vein-ftone or rider has always a mifhapen, irregular, mineral appearance. The pureft and whiteft famples of this ftone have fome refemblance of a burr, and it is often equal to the burr in hardneſs; but this ſtone is ſeldom or never ſo uniform and regular in its texture as the burrs, being frequently compounded of different ſpecies of mineral matter, ſuch as the baſes of the ſtone itſelf, which is generally of a ſiliceous quality, with ſeveral ſorts of metallic ores, pyrites, ſpar, fluor, &c. blended in a hard, rugged, miſhapen, heavy ſtone, which has the ſtructure and appearance of a concrete, which is ſometimes ſolid, and ſometimes cavernous, and the cavities are frequently lined with druſe, or cluſters of tranſparent pointed cryſtals. When the vein-ſtone is compounded of different kinds of mineral matter, it often exhibits different colours in the ſame maſs; but when it is moſtly of one ſort of matter, it is generally of an uniform colour; but whatever be its colour, it has always a rugged appearance and form, and indeed looks like a vein-ſtone, and not like any other ſtone.

The fluor or flux ſtone reſembles ſome of the fineſt ſpecies of ſpar. The fluors have generally a fine gloſſy appearance, and they are of various beautiful colours, as white, blue, green, yellow, violet and brown, with various ſhades and tinges of theſe and other colours. They are always of a fine glaſs-like texture, and generally of a cubical, a rhomboidal, or of a laminated ſtructure, and ſome of it is of an irregular form; but whatever is the form or colour, fluor may be known

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and diſtinguiſhed by its weak and glaſſy conſtitution, and by its elegant appearance, being generally either diaphanous or ſemi-tranſparent.

When one or more of theſe hard mineral ſubſtances are found ſcattered upon the face of the ground, it may be preſumed that a hard mineral vein is not far off, as theſe may be called the ſhoads and indications of the vein. When theſe mineral foſſils are found in ſuch plenty as to attract the attention of the obſerver without ſeeing a vein, the figure of the ground muſt then be conſidered, in order to judge of the ſituation of the vein which theſe ſubſtances come from. If the ground is pretty level, the vein may be found by digging immediately under theſe ſhoads; but if there is a declivity, the vein undoubtedly is ſituated higher up; and therefore, if it is judged proper to ſearch for it, I have pointed out the proper method of trial above, when treating of the ſhoad ore. When any of theſe hard mineral ſubſtances are found in a river or in a rivulet, the vein ſhould be found either higher up croſſing the ſtream, or in one of the banks running parallel to the ſtream, becauſe all theſe ſubſtances tend downwards in the courſe of time, by the ſliding of the banks, the flow of water, and the gravity of theſe ſeveral bodies.

The preceding deſcription ſuppoſes a mixture of ſtoney matter in the hard veins, however there are

are hard quartzy veins in many countries, with and without ore, in which no ſtoney matter appears but the quartz itſelf. The ore in quartzy veins is either blended in the quartz or more ſolid; but whether ſolid or mixed, lead ore in quartzy veins is always bright and ſhining in the inſide when broken, though it is generally dull and tarniſhed upon the outſide when expoſed to the external air.

The quartz in theſe hard veins is generally pretty white, of a fine gloſſy texture, and remarkably hard and heavy; and when any caverns are found in theſe veins, they are filled with priſmatical cryſtallizations, which are ſo hard, fine, tranſparent, and pure, as ſometimes to emulate the diamond itſelf in beauty and goodneſs.—Quartzy veins are frequently very wide and ſtrong, with diſtinct ſides, which may be diſcerned with certainty by an experienced eye, accuſtomed to take notice of the external appearance of mineral veins. Many quartzy veins are ſo ſtrong and bold, as to riſe up in a ridge above the ſurface of the ground, or ſurrounding rocks, and be diſtinguiſhed and traced in the line of bearing a great way through the mountains. I have frequently traced ſuch veins for two or three miles in mountainous rocky countries; and it generally happens, that ſome ore of lead or copper is to be found in one place or other, and ſometimes in ſeveral

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places in the ſurface of ſuch veins; but by reaſon of their exceſſive hardneſs, it ſeldom happens that any trials are made in theſe hard quartzy veins, unleſs the ore is found at once at the ſurface in ſufficient quantity to be worth working. But if any ſuperficial trials ſhould be made in ſome of theſe hard veins, they are generally attempted by unſkilful workmen, who can make little or no progreſs in ſo hard a ſtone, which baffles all their efforts to ſink down or to drive forward in it, and of conſequence the work is given up, before any real and ſatisfactory trial is made upon the ore which appeared in it. For theſe reaſons, moſt of our very hard quartzy veins will remain entire, as a corps de reſerve in mining, which may be of great uſe to future generations, when our mines which are eaſily worked are either exhauſted, or too deep for draining out the water; as I have no manner of doubt that there are valuable treaſures in many of theſe veins lodged at different depths, in ſome near the ſurface, and in others further down; and in general we are aſſured from experience, that the further down the better for plenty of good ore.

There is yet one ſort of hard vein, the external appearance of which has not been deſcribed, and yet it is very material to be known, being frequently the moſt productive of all veins. The

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vein I mean is found in ſuch mountain rocks as exhibit nothing but *rachel*, or a looſe ſhattered broken rock at the ſurface, which falls into ſmall angular maſſes of irregular figures. It is very difficult to point out the exterior ſymptoms of this vein where it baſſets out, by reaſon of the looſe and broken ſtate of the rock at and near the ſurface of the ſtrata. Where the rocks are thus looſe and broken at the ſurface, and fallen to ſmall irregular maſſes, or mouldered down to rubbiſh, it requires great attention to inveſtigate the ſymptoms in ſuch ground, ſo as to find the baſſet or ſurface of the vein. In rocks that are thus broken down to rubbiſh at the ſurface, ſpar, vein-ſtone, and other ſymptoms, are ſometimes ſcattered about pretty wide, and the more ſo, if the ground is any thing inclining. This debris of the broken rachel, and of the mineral ſymptoms thus ſcattered looſe about the ſurface, is called by Corniſh miners the *broil*, or the *broil of the vein*.

When veins in ſuch rocks are not very wide at the ſurface, there is then no room for any conſiderable quantity of mineral ſoil, hard or ſoft, and therefore the mineral ſymptoms cannot be ſtrong; and when the rock is fallen to looſe rubbiſh, the mineral fiſſure and mineral ſymptoms are ſcattered in ſmall ſtrings among a number of vagrant

grant cutters, which are disjointed by the separation of the loofe and broken rock, in which condition, a vein that is not very wide above is often difficult to be difcovered, even by a fkilful eye, and no doubt many fuch veins are overlooked.

However, notwithftanding thefe caufes of obfcurity, there are always fome veftigia of the vein to be found, if carefully attended to; fome fmall maffes of fpar or vein-ftone, or fome other fymptoms of mineral foil fcattered among the broil or in the disjointed cutters; and where fuch are feen they fhould be attended to, and fome of the rachel or fhattered furface of the rock fhould be dug off, to fee how matters appear below in the folid rock, where the vein will appear diftinct between regular fides, and then its value can be in fome meafure judged of.

The top of almoft all the veins where they baffet out, in fome of the beft mining fields, are found in this defcription of rock at the furface; fuch, for inftance, as the great mining fields of Leadhills and Wanlockhead, in Scotland, where the debris of the loofe and disjointed furface of the ftrata is of confiderable depth, almoft every where upon thofe mountains, which fo conceals the baffet or top of the veins, that fome valuable rich veins are but lately difcovered; and, in general, the baffet of their richeft veins is not feen, but they are difcovered by cutting crofs mines or galleries, either for levels to drain the water, or for the purpofe of difcovery.

The foft mineral foils are as various in quality and appearance as the hard. I will make fome obfervations upon foft veins, and defcribe fome of the foft mineral foils; and the firft I will take notice of is a white mineral foil or clay, which is fometimes fine and fmooth, but often more friable and coarfe to the touch, not unlike flaked lime when mixed with fand. When this foil feels a little gritty, and there is tolerable room between the fides of the vein, a little of it fhould be dug out and well examined, by wafhing it in water, and by pounding it between two fmooth ftones, as this fpecies of mineral foil frequently contains fmall maffes and grains of lead ore, which is coated white, and fo of the fame colour as the clay; however, by wafhing and pounding, fome bright particles of the ore will appear, if any large grains are mixed in the foil; and if fmall maffes of lead ore are found at the furface, by digging in a vein containing this foft foil, a plentiful crop of it may be expected below.

Red fat clay in mineral veins, which indelibly ftains the hands and cloaths, indicates iron, of which I will fay nothing in this place, but that the better fpecies of iron ores are generally accompanied with red ftaining foft foil, by which they are eafily diftinguifhed; at the fame time, it

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is proper to obſerve, that ſome lead and copper veins contain a conſiderable quantity of iron, and conſequently of a red and a browniſh red ſtaining ſoil; and, therefore, circumſtances require to be examined with ſkill and care in the caſe of diſcovering ſoft ſoil in a vein of a reddiſh colour.

The next I ſhall take notice of is a bluiſh, a grey, a greeniſh, or a brown tough clay, or ſticking; and when theſe appear in ſmall quantity or in very thin ſeams between regular ſides, which are nearly cloſe together, that is, where the ſides of the vein are uniformly cloſe, with a thin vein or ſticking of tough clay between them, without any appearance of ore, I would not adviſe much trial to be made in ſuch veins, unleſs ſome more promiſing ſymptoms are diſcovered in ſome other places in them. But if the veins containing ſuch ſoils are moderately wide, and that leſs or more of ſpar or vein-ſtone, &c. appears with the clay, ſome little trial may be made in it; but I would not go far in ſuch trials without finding ſome ore.

It is proper to obſerve here, that mineral clays and ſoft ſoils in veins are found of all colours and appearances, which makes it almoſt impoſſible to deſcribe them all perfectly, ſo as to be able to diſtinguiſh them from other common clays and ſoft ſoils; and, therefore, it is neceſſary, in

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the firſt place, to be able to aſcertain with certainty that you have a vein, by ſeeing two ſides and a regular continuous fiſſure cutting through the rocks in ſome certain line of direction; and if you can diſtinctly ſee a fiſſure cutting through the ſtrata in a continued line, and can diſcern two ſides, and ſee the clay between the ſides, it is mineral ſoil, whatever the colour and other appearances of it may be.

But it is neceſſary for me, before I proceed any farther, to make another explanatory remark.

I juſt now obſerved, that it is neceſſary to know that we have a vein before we form any judgment of ſuch ſoft ſoils as appear like mineral ſoil; and the very ſame may be ſaid of the hard mineral foſſils, ſuch as ſpar, feldtſpat, vein-ſtone, &c. Theſe often appear where there is no good and regular mineral fiſſure or vein, and, therefore, whether the mineral foſſils diſcovered are ſoft or hard, their conſequence depends upon the mineral vein which they belong to. But the remark which I am going to make is this, viz. that it is not always eaſy to judge from the external appearance of a vein at the ſurface of the ground whether it is a good one or not, even where the ſuperficies of the rock is ſeen, which will evidently appear from what follows. I believe I obſerved before that thoſe rake veins or mineral fiſ-

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ſures which were cauſed by a fracture and a breach in a line, and by the fracture opening aſunder to a wide chaſm, without any ſlip or ſinking down of the ſtrata upon one ſide of the chaſm below the other ſide of it, are always wideſt above; and that thoſe veins which were cauſed or produced by a chaſm and a ſlipping down of the ſtrata upon one ſide of it, are generally narrow above and wideſt below.

I have ſo often ſeen very cloſe contracted veins at the ſurface open out below to various capacities, that there is no room to doubt the fact, which makes the firſt appearance of the ſlip veins in ſome ſituations very deceiving, and in ſome circumſtances not eaſily inveſtigated by the moſt ſkilful, ſo as to enable them to form a proper judgment. Where the rocks are hard, compact, and cloſe, or free from numberleſs cutters at the ſurface, a rake vein may be known, even where the ſides of it are pretty cloſe together; but, on the contrary, if the ſuperficies of the ſtrata is a rachel, or looſe and ſhattered, and full of cutters in all directions, the inveſtigation of a vein that is cloſe above becomes very difficult, ſometimes almoſt impracticable, without ſome trial. I have frequently ſeen rocks, that were ſolid and regular at the ſurface, cut by veins ſo narrow above, that the two ſides of the vein were cloſe together in two parallel lines, and ſo near to one another,

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that to an inexperienced eye, the narrow and hardly discernible fissure would appear to be no more than a common cutter; and yet I have very frequently seen these veins open out gradually as they went down, until they became some of the boldest and widest veins below; and I am persuaded, from what I have observed in my own experience, that many rich and valuable veins are overlooked and neglected, because they are narrow and confined above, and do not look promising at first sight; and, therefore, when one of those narrow veins is discovered, with some little ore in it, supposing it is no thicker than the blade of a knife, I would advise sinking some fathoms in it, as very probably it will open out below; and if it begins to open a little at a moderate depth, there is then the greatest reason to expect that the sides will dilate to a sufficient wideness when you are deep enough down in it. But if neither ore nor spar, &c. appears at first in a regular contracted vein, then the line of bearing, or the point to which the vein trends, should be taken with an instrument or compass, and two or three trenches cut to the rock across the vein, in order to discover it at a distance, where it does not appear at the surface; as it is always found in experience that veins appear and prove better in one place than another, at the surface of the ground as well as down below,

low, and often carry ore and other mineral ſoils in one place, when ſcarcely any ſymptoms of the vein appear in another place, even at no great diſtance.

Soft mineral veins, which contain ſoft ſoils at the ſurface, are eaſily diſcerned and known, provided that a ſufficient quantity of the vein is ſeen to enable the obſerver to determine at firſt ſight that it is really a mineral vein and mineral ſoil, and not a bed of common ſurface clay, for theſe ſoils are not always diſtinguiſhable by the colour or by any other external appearance; and in ſome places, where only a little ſoft ſoil is to be ſeen in a ſcar, or other ſmall break in the ſurface of the ground, neither the ſides of the vein, nor any other ſymptom of a vein, except the clay or ſoft ſoil, are to be ſeen without breaking ground to make ſome trial, and, therefore, circumſtances ſhould be examined.

If the ſuperficies of the rock is to be ſeen in other parts of the ground, not very far off, and that none of that clay or ſuppoſed mineral ſoil appears in thoſe places, there is the more reaſon to ſuppoſe that it is the ſurface or baſſet of a vein; however, the beſt way to make ſure work, is to dig in it to diſcover the ſides of the vein, if there be one, and to ſee if you can diſcover any ore or other promiſing mineral ſubſtance in it.

But I ſhould warn you here not to be too ſoon diſcouraged if you ſhould not find the ſides immediately, as ſome ſoft veins are very wide, and contain a great breadth of the ſoft ſoil at the ſurface; and ſuch wide veins deſerve the more attention, as they frequently prove very rich.

The ſoft mineral ſoils in veins are found of all colours and appearances, as white, black, and blackiſh, all the ſhades of grey, yellow, green, and marbled, &c.; but the moſt remarkable and diſtinguiſhed of all the ſoft mineral ſoils, and frequently the moſt promiſing, is of a looſe, light, and friable texture, often reſembling rappee, and other ſnuff, in colour and external appearance when dry, it being ſometimes blackiſh, but generally brown, in all the degrees and ſhades of that colour.

When veins are regularly open and roomy between the ſides, or open into irregular bellies and large cavities, containing conſiderable quantities of this browniſh friable mineral ſoil, it is generally looked upon by miners as a promiſing ſymptom. But it is proper to remark that the moſt promiſing ſymptoms in mining often prove fallacious and uncertain. The ſame mineral ſubſtances, or mineral ſoils, hard and ſoft, that accompany good ore in ſome places, will be found in good and regular veins in other places, and yet no ore diſcovered, or none to ſignify, by the

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moſt judicious trials, ſo that ore is the beſt, indeed the neceſſary ſymptom of a good mine.

Good ore may be, and often is, diſcovered by digging in a barren vein with promiſing ſymptoms; but if no ore was ever found in the field, I do not hold it wiſdom to proceed too far in trials without finding ſome of it. At the ſame time it muſt be acknowledged, that this ſoft mineral ſoil, which miners call *chun*, *ghurr*, or *mother*, is the moſt promiſing, and is often found in great quantities in the beſt mines of lead and copper. In ſome good mining fields, where the veins are wide and roomy, and produce plenty of ore, it is not uncommon to find great quantities of maſſes of ſolid ore of various ſizes lying looſe in this ſort of ſoft ſoil; and in ſome places where the concavities of the veins are exceeding wide, there will ſometimes be found a ſingle maſs of ſolid lead ore ſo large as to produce a great many tons of lead.

Where theſe ſoft ſoils, or the hard broil of ſpar, vein-ſtone, and other ſymptoms of a mineral vein, are in ſuch quantity, and of ſo good a quality, as to induce you to look into the vein, and you cannot readily diſcover the ſides to direct you to ſink a little in it with propriety, your beſt method in ſuch a caſe is to cut a trench upon the place down to the rock, in the form of a croſs, as directed above in the caſe of finding ſhoad ore upon level ground, which is the ſureſt method of finding the ſides and courſe of the vein; and when you have diſcovered theſe points, you will then be able to judge how you ſhould proceed.

It has been obſerved that mineral veins may be diſcovered in almoſt all places where the upper ſurface of the ground is ſo broken as to diſcover the ſuperficies of the ſtrata, ſuch as in the rocky mountains and cliffs, in the rocky banks and beds of rivers and rivulets, in ravines or gullies, and in all other places where the ſurface of the rock is to be ſeen.

Generally all the large caverns and ſmaller cavities upon the ſhores of the ocean are mineral veins. Theſe veins, and the mineral ſoils contained in them, are much ſofter than the rocks which are cut by the veins; and being continually expoſed to all the changes of the air and weather, and more eſpecially to the rage of a ſtormy ocean, whoſe mighty waves daſh againſt the ſhores with a force and fury that is almoſt irreſiſtible by the hardeſt rocks, the mineral ſoils are worn out of the veins.

When a vein points in any direction into the ſea, the continual beating of the waves againſt it wears the mineral ſoil out of it by degrees, and then it becomes an empty cavern. Theſe excavated cavernous veins are very numerous, almoſt

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all round the ſea coaſts of Scotland, many of which I have entered and examined with lights, and I have ſeen both lead and copper in numbers of them, many of which are very deſerving of attention.

Some celebrated writers of natural hiſtory have aſſerted that mines and mineral fiſſures are only to be found in mountains and hilly countries, and that there are none of them in the plains and valleys, which is an erroneous poſition, abſolutely falſe in fact and in experience. I have myſelf ſeen great numbers of veins upon the ſhores of the ocean, where the ocean was the boundary of extenſive plains. I have alſo frequently ſeen them in the beds of rivers, in places where the ſurface of the rock was waſhed; and I have often ſeen both lead and copper in them. I have ſeen very conſiderable mine-works carried on with ſucceſs ſo low as in the beds of rivers, which were turned into new channels for that purpoſe, in North Wales, and in other places, which rivers were but a little elevated above the level of the ſea. Theſe inſtances are ſufficient to prove the fact, and there is no arguing againſt obſervation and experience in ſuch caſes.

And, moreover, agreeable to ſacred philoſophy, in the inveſtigation of the phenomena of the ſtrata, there are the ſame natural reaſons for the exiſtence of veins, and even of their great numbers,

numbers, in the plains as in the mountains. I will juſt now defer the tracing out and explanation of theſe phenomena ; they will come in my way in ſome future enquiries in the third part of this work ; at preſent, I will only obſerve, that the poſition is dangerous as well as falſe, which is my reaſon for inſiſting upon this topick. If it is once received as an undoubted fact, that no mines nor mineral fiſſures are to be found in plains and valleys, farewell to any enquiries about ſymptoms or attention to them. Upon this ſuppoſition, if good ſhoad ore was found in a plain, the reaſoning mind would immediately ſuggeſt, that it was carried and dropt there by accident, and of courſe it would be overlooked, neglected, and forgotten.

Wherever the ſuperficies of the ſtrata are diſcovered in low plains, we ſee them as frequently cut by mineral fiſſures, as in the mountains ; and oftentimes the veins are more numerous in the plains than in many very hard and lofty mountains ; and as ore is ſeen in veins, and worked in ſuch low places, and as veins are ſeen as numerous in the rocky ſhores of the ocean, and running under the ſea, as in many other ſituations, there is no room to doubt that mineral fiſſures, containing all ſorts of mineral ores, exiſt in the low plains as well as in the hills and mountains ; only the ſituation is not ſo favourable for diſcove-

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ry, the ſuperficies of the ſtrata being frequently covered in the plains by earth, ſand, clay, and gravel.

But it may be obſerved here, that ſome plains are compoſed of ſtrata in which metals or mineral ores are ſeldom found; ſuch for inſtance are beds of chalk, of ſchiſtus, and of the coal metals. Metallic ores are but ſeldom found in any of theſe: I do not ſay never, as all the ſlips and dykes in the coal fields are really mineral veins; and I have ſeen ſome little lead and copper ore in ſome of them; and a valuable lead mine has been worked a long time at Coalcleugh in Northumberland, which, as I was told, is entirely in the coal metals, that is, in ſuch ſtrata as accompany coal: And moreover I was informed, that the lead vein at Coalcleugh actually cut off the ſtratum of coal, in the ſame manner as it is cut off by a common coal-dyke; and that the coal was found to floor and ſtretch upon the other ſide of the vein of lead, as regularly as before it was cut off by it. However, this is an uncommon inſtance. In general we know by experience, that free-ſtones, argillaceous tills, and the other concomitants of coal, are unfriendly to the metallic ores. I have not ſeen, nor heard of any metallic ores being found in chalk; and although I have ſeen ore, in ſmall diſcontinued quantities, in ſchiſtus, I never expect to ſee a plentiful and durable mine in it.

It

It may be objected to this, that the iron-ſtone ſo frequently found in thin ſtrata, and in nodules in coal fields, is a refutation of what I have advanced, as this iron is found in ſuch abundance among the coal metals in many places, as to become the foundation of increaſing manufactories in many places which employ thouſands of hands; but it muſt be remembered, that this is iron-ſtone, not iron ore. This ſtone, it is true, is found in great plenty in many coal works, and in the near neighbourhood of them; but it is as ſeldom found in the mineral fiſſures, that is, in the dykes, ſlips, gaſhes, in any conſiderable quantity, as any other of the metallic ores. This iron-ſtone is found in regular ſtrata and in nodules, which have been broken off from the ſuperficies of the ſtrata, rolled in water, and afterwards lodged in the argillaceous ſtrata of the coal fields; and as this ſpecies of iron-ſtone ſo frequently accompanies coal, and is always found in the ſame circumſtances of ſtrata and nodules or glebes, it muſt be reckoned as one of the coal metals, or concomitants of coal. Iron ore, properly ſo called, is found in mineral veins, in the ſame manner as lead and copper, &c.

The ſtrata which are generally the moſt productive of the metallic ores are limeſtones. Moſt ſpecies of whinſtones, or the indurated argillaceous mountain rocks, of which there are many varieties

rieties, appearing in thick, thin, and middling ſtrata, and ſome of theſe rocks are very hard, and others of middling hardneſs. Theſe mountain rocks are of various colours, though moſtly of ſome of the ſhades of grey. Many rich and valuable mines are found and worked in granite or moor-ſtone rocks: Such, for inſtance, are the lead mines of Strontian, in the Highlands of Scotland, and ſeveral mines in Cornwall, &c. Theſe three orders or claſſes of rocks and ſtrata are moſt commonly cut and interſected by mineral fiſſures, containing the greateſt quantities of the metallic and other mineral ores.

In many countries, ſuch as Derbyſhire in England, the iſland of Iſla in Scotland, &c. limeſtone is the moſt common repoſitory of the precious and uſeful metals. In other countries, the moſt productive veins are found in granite rocks, as at Strontian above mentioned, where many of the veins are remarkably ſtrong, bold, and roomy, in which exceeding good lead ore has been found in great quantities, and, in my opinion, few mining fields in Scotland promiſe better ſucceſs, if the beſt veins were properly explored with ſkill and perſeverance. But this valuable mining field has always been very unlucky. It was firſt opened by the York-Building Company, when the ore was exceeding good and plentiful; but in whoſe management, or rather miſmanagement, nothing

nothing could profper, and ever fince they failed, thefe mines have always been in the hands of fuch as either wanted fkill, attention, or prudent able management.

But of all the claffes of ftrata in which productive mineral veins abound, the indurated argillaceous mountain rocks are the moft numerous and extenfive. In Britain, all the rich and extenfive mines of Leadhills and Wanlockhead, the mines of Tyndrum in the Highlands, of Machrimore in Galloway, and many others in Scotland, are found in fome one or other of the fpecies of this rock. Many of the mines of North-Wales, almoft all the numerous, rich, and extenfive mines of Cardiganfhire, and moft of the other mines of South Wales, are in thefe ftrata, and fo likewife are great numbers of the mines of Yorkfhire, Weftmoreland, and many parts of the North and South of England.

I fhould in this place take fome notice of the indications and external appearances of pipes and ftreeks, that is, of the pipe and flat veins. As the pipe veins only pufh downwards in a flanting direction, like an irregular pit or fhaft, we are not to expect to find any longitudinal ftretch or courfe in the external appearances of this fort of vein. This vein only baffets, or appears at the furface in a confined fpot of only two or three feet, or of two or three yards diameter, and therefore we

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need not look for the indications at any confiderable diftance from that confined fpot, only when the baffet or outburft of the pipe is fituated upon a flope, or that the ground has been much ftirred by ploughing or otherwife, the mineral fymptoms, whether hard or foft, may be fcattered about much wider than the real diameter or compafs of the baffet of the vein, when it enters within the folid fuperficies of the ftrata. If the baffet of the pipe is fituated upon a flope, the mineral fymptoms will tend downwards, and therefore the baffet of the vein where it enters the folid ftrata muft be looked for higher up than where the fymptoms are found; but if the fite is upon level ground, the mouth of the pipe fhould be found about the center of the mineral fymptoms which appear, unlefs there is good reafon to fuppofe that the fhoads or indications have been all moved one way by fome natural or artificial caufe. The mineral fymptoms or foils of the pipe are the fame in quality as thofe of the rake, which have been defcribed.

The external fymptoms and baffet of the ftreek or flat dilated vein, has a longitudinal ftretch or bearing as well as the rake vein. I have before noted and defcribed this fpecies of mineral vein, as being fituated between the beds of particular ftrata, one particular ftratum of the rock being the roof or upper fide, and the next ftratum below being the fole or under fide of this fpecies of vein; and this vein doth not cut in any direction acrofs the ftrata, but, on the contrary, it ftretches horizontally between the ftrata, and therefore it has exactly the fame longitudinal bearing, and the fame fpread or ftretch every way, as the ftrata of the field in which the vein is found; and the flat vein is fubject to all the accidents and irregularities of thefe ftrata, fuch as being thrown up and down off the ordinary level, ftretch, and bearing of the ftrata, by flips and hitches, and of being partially cut off by dykes and gafhes, which were defcribed in the firft part of this work. But it may be obferved, that miners have one confolation in meeting with thefe interruptions of regularity, which colliers are not favoured with, viz. every one of thefe are mineral veins of another defcription. The parallel, direct, and oblique flips, which throw the ftrata and dilated vein up or down off its former ftretch and level, are each of them rake veins, and therefore, in meeting one of thefe in the courfe of working the dilated vein, a new chance of additional treafure prefents itfelf to them, without their being at any trouble or expence in looking for it. When a flip or rake vein is difcovered in the progrefs of working a flat vein, it very often happens, that the flip vein contains good ore immediately when firft touched, and in working this ore out of the flip vein, they come at the flat vein,

where

where it floors and ſpreads out again upon the other ſide of the ſlip, whether it was thrown up or down by it.

The theory of the ſlip will, I hope, be now ſo well underſtood by my readers, as to enable them readily to comprehend, that when a miner is working forward in a flat vein upon one ſide of a ſlip, with his face towards one perpendicular point of the compaſs, and meets a down ſlip, if he was working upon the other ſide, with his face towards the oppoſite point of the compaſs, it would from thence be an up ſlip. The ſtreek, flat, or dilated vein (for it is known among miners by all the three names) is frequently diſcovered by working downwards in the perpendicular mineral fiſſure, or ſlip vein. The flat vein appears in one or other of the ſides as they go down in the perpendicular vein, and ſometimes it contains ore immediately when diſcovered, and ſometimes none at all, or very little of it. When good ore of ſufficient workable thickneſs appears immediately, there is no difficulty or cauſe of dilemma in the way. In that caſe they work away horizontally in good ore in the flat vein; but in ſome mining fields, the flat veins are overlooked, when they only contain mineral ſoils without ore, or a ſmall quantity of ore where firſt diſcovered, which perhaps is not immediately worth working, becauſe the miners in ſome countries do not un-

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derſtand the dilated flat veins, and therefore are neither moved by curioſity nor hope to look into them. I have, in ſome mining fields, ſeen five or ſix inches of good lead ore overlooked and paſſed by in working downwards in rake veins, without making the leaſt trial upon the ore, particularly in the iſland of Iſla, where I could not engage proper attention to the flat veins, becauſe the miners knew nothing about them; and as my viſit there was but ſhort, I had no opportunity of making them underſtand this ſpecies of vein. However, in Derbyſhire and other parts of England, great attention is paid to all the ſtreek veins. Indeed, much of the treaſure of ſome mining fields, ſuch as Derbyſhire, is found in the ſtreek veins; of courſe there is no danger of their being overlooked, whether rich or poor, for they know very well by long experience, that this deſcription of vein is fully as ſubject to checks and twitches, and other interruptions of regularity, as the perpendicular veins. It is very common for the flat vein to be ſqueezed thin upon one ſide or other of the perpendicular vein; and, therefore, in a productive field, the flat vein ſhould always be tried ſome fathoms in from the ſlip vein, until they are paſt the influence of that ſqueeze or twitch.

It was obſerved that dilated veins are moſt commonly found in the lime-ſtone country, that is, where ſtrata of lime-ſtone are the prevailing rocks;

rocks ; however, they are not excluded from the hafle-whin and fome other claffes of ftrata.— Whenever perpendicular fiffures appear in the ftrata of lime-ftone, there is always a chance, almoft a certainty of meeting with ftreeks, if the perpendicular veins are worked to any confiderable depth. When the fuperficies of the rocks are bare and expofed to view, where a flat vein baffets out, the indications of the vein or the mineral foils, whether hard or foft, which belong to the baffet of the vein, advance forward along the furface of the ground, in the fame longitudinal line as the bearing of the ftrata ; and, therefore, when any part of the baffet or outburfting of a ftreek is difcovered, if the trending of the ftrata in that place is known, the proper method of trying the baffet of the vein in different places is eafy and fimple, as this vein always continues between the two particular ftrata which are at firft found immediately above and below the vein.

Where the baffet or fuperficies of a ftreek is difcovered, and you want to make fome trial to fee how it appears under cover, at fome confiderable depth or diftance from the furface of the earth, you are not to expect that this vein is to dip down precipitately like the perpendicular fiffure, unlefs the dip or declivity of the ftrata in that place is fo precipitate as to ftand near the

vertical

vertical poſition. In trying this vein you muſt conſider the diſpoſition of the ſtrata. If they are ſo flat as to approach the horizontal poſition, ſo will the vein ; and, on the contrary, if the ſtrata hang with ſo great a ſlope as to be near the vertical poſition, the vein will dip with juſt as great a degree of ſlope, and, likewiſe, in all degrees of medium ſlopes between the vertical and horizontal poſitions ; and, therefore, when the poſition of the ſtrata is known, you know exactly how to purſue a ſtreek under cover, even with unſkilful men ; and where there is not a conſiderable body of ore, or of other good ſoils, to be an infallible clue to lead them in a right direction.

I will now give ſome account of the appearance of the metallic ores, as they are found in the baſſet of the veins when firſt diſcovered at the ſurface, or lying looſe near them.

I have before deſcribed what is called ſhoad ore of lead. By ſhoad ore is meant lumps, maſſes, or grains of ore which have either ſlidden off from the baſſet of a vein, which is ſituated upon a declivity, or elſe lie looſe upon the back or baſſet of the vein, and that is carried down by a ſtream of water.

Having before treated of the ſhoad ore, I will only repeat here that the ſhoad of lead is always either coated or tarniſhed, unleſs it has been recently

cently broken and bruiſed by ſome accident, ſo as to diſcover its native colour and brightneſs. Shoad lead ore found in a dry ſituation, or any way blended with or buried in the ſoil, is generally coated over with a white cruſt, or ceruſs, reſembling lime, which perfectly conceals the bright blue colour of the ore until the maſs is broken; but ſhoad found in a rivulet, or in any run of water, is generally tarniſhed, of a dull greyiſh leaden hue, at firſt ſight no more goodly nor attracting to the eye than common pebbles found along with it in the rivulet.

Lead ore found in the baſſet or ſurface of a vein, either in hard or ſoft mineral ſoil, ſeldom exhibits any of its native colour and brightneſs, but is either tarniſhed or coated. Such maſſes and grains as are found in the ſoft ſoils in the baſſet of ſoft veins, are generally coated white, though they are alſo coated of a browniſh and of a yellow colour in ſome ſoft veins. In the baſſet of hard veins, the lead ore which is expoſed to the air and weather, is moſt commonly tarniſhed, of a dun or greyiſh ſtony hue, without exhibiting to a curſory view the leaſt indication of any thing metallic, until it is touched with a tool or a hard ſtone, when its fine texture and bright colour will appear; and, therefore, when a hard vein is diſcovered, every ſubſtance found between the ſides, of whatever apparent colour, ſhould

ſhould be carefully examined with a tool, as ore in ſuch a ſituation does not look like itſelf, but appears at firſt ſight like any other indifferent ſtony ſubſtance, when it is either coated or tarniſhed, but when broken, the colour and texture will appear, of whatever ſpecies it may be.

There are three principal ſpecies of lead ore, which are eaſily diſtinguiſhed from one another, viz. *cubical potter's ore*, the *fibrous*, or *longiſh-grained ores*, and the *granulated*, or *ſteel ore*, and of theſe three there are many varieties.

1ſt, What is commonly called *potter's ore*, on account of its being uſed for glazing earthen ware, is found in greateſt quantity of all the lead ores. Much of this ſpecies of ore is of a teſſelated, cubical, or diced ſtructure. Some of the varieties of this ſpecies of ore are compoſed of very ſmall cubes, others of middle-ſized, and ſome of pretty large cubes, even up to near an inch ſquare, the cubes appearing of a laminated texture, and ſlightly adhering together, ſo as to be eaſily broken to pieces with a ſmall blow, and when broken, the ore appears very bright and glittering, and of a fine metallic blue colour.

Many of the varieties of this ſpecies of ore appear of a laminated and of a ſcaly ſtructure, approaching to, but not of a regularly diced form; and of theſe ſome are compoſed of large broad ſcales. And again, ſome of theſe laminated or ſcaly ores have no appearance of a cubical form, but the maſſes of ore appear partly of a convolved ſtructure, the ſcales being irregularly diſpoſed and placed all manner of ways.

But it may be obſerved of the potter's ores, that in general a rich and plentiful vein produces ore of a regularly diced form, without much variety of ſtructure; but when the vein is confined or irregular, or any way diſturbed by checks, thick riders, or from any bending or warping of the vein, the ore which it produces is generally found of an irregular texture; and if the vein is much contracted and irregular, the ſmall quantity of ore which it yields will be found in miſhapen maſſes of a tortuous, imperfect, ſcaly texture. However, when the veins are freed from theſe accidental irregularities, and open into wide concavities, producing rich bodies of ore, the ore will then aſſume a regular form and texture.

All the potter's ores are extremely heavy, and they commonly yield a great produce of lead in ſmelting, but they ſeldom contain much ſilver.

2*d*, The fibrous lead ores. Theſe frequently exhibit a longiſh grain or ſtructure, ſometimes approaching a ſtriated form or texture, but not perfectly ſtriated, and very difficult to be deſcribed. I have ſeen ſome of the varieties of this ſpecies exceeding bright and beautiful, and more of a whitiſh blue, or a ſilver colour, than the bright potter's ores, and many of them are remarkably rich in ſilver.

3d, The ſteel ore, or ſteel grained lead ore, is of an uniform and granulated texture, ſome of the varieties of which are compoſed of fine grains, appearing in the inſide of the maſs like fine ſteel when newly broken; ſome like coarſer ſteel, and others appear like coarſe iron. Much of the ſteel grained lead ore is bright and ſparkling in the inſide of the maſſes, and of a fine blue or ſilver grey colour. Some of the varieties are of an iron grey, and others ſtill more dull in the inſide, and approach to a blackiſh grey.

The ſteel ores are moſtly very hard, the maſſes being frequently ſonorous in ſome mine works, and they are generally rich in ſilver.

There are rich and durable mines of this ſpecies of ore in Cardiganſhire in Wales, and many other parts of Britain. Many of the veins producing this ſort of ore in Cardiganſhire contain ſtrong, regular, and extenſive ribs of ſolid ore, ſome of which I have ſeen working to great advantage; but ſeveral of theſe rich and valuable mines are now under water.

Cardiganſhire is one of the moſt rich and extenſive mining fields in Britain.

A great many veins in the neighbourhood of Darenvaur, Cwmſymlog, Cumyſtwith, about the north and north-weſt corners of the country, and in many other places, have produced great quantities of the richeſt lead ore in the iſland, at leaſt the richeſt in ſilver. Many of theſe veins were opened and worked by the Romans, whoſe works were remarkable and ſingular, being all open caſt, like a great ditch or gulph. They cut open the vein longitudinally, and formed wide gulphs in the courſe or bearing of the veins. I ſaw one of theſe gulphs at Darenvaur, where the fine ſteel ore was very rich in ſilver, ſo large, deep, and long as to begin upon one ſide, and reach quite through the ſummit of a conſiderable mountain; and this vaſt trench was ſo deep and wide as to be about ſeventy fathoms down below the ſurface of the ground near the ſummit of the mountain; but they had worked none in the vein down in the level ground at the foot of the mountain, where I ſaw very rich modern works under level, upon a regular rib of ſteel ore, which was from a foot and a half to three feet wide in different parts of the vein, and remarkably rich in ſilver.

Great numbers of theſe veins have been worked in modern times, as deep as they could go, with ſuch level mines as were eaſily obtained to drain the water; but as Cardiganſhire is diſtant from the wealthy mining countries and mining companies, little or nothing to ſignify was done below level about forty years ago, when I was pretty well informed of the mineral hiſtory of

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that county; and I was lately told that very little has been done below ſince that period.

When theſe rich veins are opened again, and well explored, valuable treaſures will be found in moſt of the old ſoles below the levels, by which they were formerly worked, as well as new ground, in different places in the courſe or bearing of thoſe veins.

I have myſelf ſeen fine ribs of ſolid ore in that county from one to three feet thick and upwards, which are now lying under water; and I was then well informed of others which I did not ſee. Few of theſe rich mines can now be effectually opened without ſome powerful machinery for drawing out the water.

As moſt of Cardiganſhire is a hilly country, conſiſting rather of ridges of a moderate height, with narrow valleys between them, than of high mountains, rivulets and runs of water may be collected and led to proper places, and reſervoirs may be made for keeping quantities of rain water, for working powerful hydraulic machines in many places. In other ſituations, nothing would anſwer effectually excepting the ſteam engine; but there is as yet no pit coal diſcovered in that county, nor near it, and the expence of bringing coals by ſea, with the addition of duty and a long land carriage, cannot be ſupported by any common produce.

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The country to the northward, north-eaſt, and eaſtward of Darenvaur, abounds in peat bogs, and ſome veins bearing lead ore have been diſcovered, but not explored in the middle of ſome of theſe peat moſſes. Where good ore is found, and water cannot be had, or cannot be properly applied, ſteam engines may be worked with good peats well prepared. In preparing peats for the engine, the upper parts of the moſs muſt be cut off and thrown into the old peat pits, where it will vegetate again, and enſure the duration of the moſs; and nothing but the black heavy peat ſhould be prepared for uſe. This black moſs muſt be cut into ſmall peats, and the cutting ſhould begin early in the ſpring, in order to have the peats in good condition before the heavy rains come on, the dry weather of ſummer in that country being only in the months of March, April, May, and ſometimes June. The heavy black peat, which is of a cloſe and ſolid ſubſtance, cannot be thoroughly and perfectly dried in one year; but when two years old, and well prepared, well thatched, or kept under a ſhade, they make a ſtrong, clear, and durable fire, little inferior to good coals, and even better than ſuch as are but indifferent. Steam engines may be effectually worked with the black peat, without any material alteration in the conſtruction of the machine, excepting that the furnace may be a little wider than for pit coals. Meſſ.

Taylor

Taylor and Symington's new improved patent engine will anſwer beſt for ſuch mining countries as Cardiganſhire, becauſe it certainly can be work-ed with much leſs fuel than any other engine that has yet appeared.

Beſides the above-mentioned blue lead ores, there are other ſpecies of different colours, ſuch as white, yellow, green, brown, and a yellowiſh brown colour, &c. But theſe ſeveral ſpecies are ſcarce, and of little conſequence, as they are but ſeldom found in ſuch quantities as to conſtitute rich veins worth working, and therefore a particu-lar deſcription of them would be as uſeleſs as it is difficult.

Theſe ſeveral ſorts of lead ore can only be di-ſtinguiſhed from other mineral ſubſtances by a ſkilful eye, and even the moſt experienced are not always certain of them without proper trials.

Copper ores are found in Britain of almoſt all the colours on earth and ſhades in the rainbow, ſuch as black, red, brown, yellow, green, blue, grey, with all the mixtures, ſhades, and tinges of theſe colours, and the ores of copper aſſuming ſuch a great variety of colours and appearances makes many of them difficult to be known, as ſome of theſe ores reſemble at firſt ſight a great many other foſſil ſubſtances. However, all the copper ores are not ſo difficult to be known; many of

them

them have a bright metallic appearance in the inside of the masses; and it may be observed of most of these ores, that they have always a mineral appearance which will distinguish them; and when masses or shoads are found which are doubtful, there is a short and ready way of trying this metal, to know with certainty whether the doubtful mass contains any copper or not, viz. Put a little aquafortis with a feather upon the mineral mass; let it act upon it for a minute or less, and then touch the part with a knife, a key, or any other polished iron, and, if it is copper ore, a thin plate or scale of pure copper in its native colour will appear upon the iron. The aquafortis dissolves part of the copper out of the ore or stoney mass in which it is concealed; but when the iron comes in contact, it imbibes the acid, which leaves the copper behind upon the surface of the iron. But it should be remarked, that if the copper is mixed with, or contained in any species of gypsum, vitriolic pyrites, or other mineral substance, containing much of the vitriolic acid, the aquafortis will not act upon the copper so as to produce the real metal in this experiment. In this case, fire is necessary to prove the existence of copper in the doubtful samples.

There are a great many species and varieties of copper ore found and worked in this island, some of which I will describe in a plain and familiar

way,

way, ſo as to convey a diſtinct idea of the ſeveral ſorts when diſcovered. Some ſpecies of copper ore are of one uniform colour, and other ſpecies contain two or more colours in the ſame maſs of ore:

1ſt. Native copper, commonly called virgin copper, reſembles the real metal itſelf in colour and quality, as it may be either cut or hammered when firſt diſcovered or dug out of the earth.

2d. Grey copper ore is a common ſpecies found in Britain. Some of the grey ores are of a granulated texture, or ſteel-grained, tolerably bright in the inſide, conſiderably ponderous, and of a ſilver grey, a ſtone grey, or of an iron grey colour. But all the grey copper ores are not of a granulated ſtructure; ſome of them are ſmooth and uniform in the inſide, and when the ore is bright, it exhibits a gloſſy appearance, and this ſort is frequently called glaſs copper, or vitreous copper ore. Many varieties of the vitreous ores of this colour diſcover leſs or more of a yellow or of a brown mixture with grey, when you look attentively at the inſide of the maſſes; and again all the varieties of the grey ores are not of a bright metallic appearance, ſome of them being more dull and tarniſhed. This ſpecies commonly yields a good produce in ſmelting, and ſome of the varieties are often found to be rich in ſilver.

3*d*. Red copper ore. Some varieties of this ſpecies are of a clear bright red, and of a ſmooth uniform texture, called vitreous red copper ore; but the moſt common ſorts are of a darker red, approaching to a browniſh red colour.

The maſſes of this kind are ſometimes ſonorous, generally ponderous, and ſome of the varieties are more like the melted metal than any other ſpecies of mineralized copper ore. Some of the red copper ores are of a granulated, and others of a ſolid uniform texture. The varieties which are of the fineſt red colours are generally bright and gloſſy in the inſide; but ſome of thoſe which are of a browniſh red, have a more dull and ordinary appearance; however, moſt of the red ores yield a good produce in ſmelting.

4*th*. Yellow copper ore is the moſt common ſpecies found in Britain. There are a great many varieties of yellow copper ore, moſt of which are very bright and beautiful, of a gloſſy metallic appearance, and of the colour of poliſhed braſs. Some of the beſt of the yellow copper ores approach to a laminated texture, and are ſmooth and ſhining in the inſide. Some of the yellow copper ores are of a granulated or ſteel-grained texture, but moſt of the varieties are ſmooth and uniform in the inſide, without any determinate grain. Many of the yellow copper ores differ but little in appearance from ſome of the brighter pyrites; it requires a ſkilful eye to diſtinguiſh the one from the other, and ſometimes they cannot be diſtinguiſhed without aquafortis, or ſome other mode of trial. But although yellow copper ore is the moſt common and the moſt beautiful, yet in general it is not the richeſt. Moſt of the varieties are the pooreſt in the produce of the furnace; but what they want in quality is made up in quantity, there being more rich and plentiful mines of this ſpecies in Britain than of any other colour.

When yellow copper ore exhibits a tinge or efflореſcence of green, it may generally be known as ſuch by the young miner; but when it is of an unmixed yellow colour, it ſhould be tried with aquafortis or otherwiſe, before the landed gentleman builds too much upon its value.

5th. Copper ore of a mixed colour, containing two or more colours in the ſame maſs of ore. In ſome veins maſſes of copper ore are found of a pure unmixed green colour, and alſo of a blue colour. Some maſſes are purple, and others black, and of a liver brown colour, with little or no mixture of other colours in the reſpective maſſes; but it more commonly happens that ſeveral of theſe colours are blended with yellow, and may be diſtinctly ſeen in the ſame individual maſs of ore. Maſſes of copper ore, or of ſuppoſed copper ore, of a pure unmixed green, blue, purple

or

or liver brown colour, and of a ſmooth uniform texture, require to be tried with aquafortis, as well as the pyritical or marcaſtical yellow copper ores, before it is determined that they really are copper; becauſe very many ſtones and pyrites ſo nearly reſemble theſe in colour, texture, and the general appearance of the maſs, that ſometimes they cannot be certainly diſtinguiſhed without trial; however, the doubt is ſoon cleared up with a drop of aquafortis, and a key or knife, as directed above, excepting in the caſe of the maſs of ore being mixed with a gypſeous matter, or being ſaturated with the vitriolic acid, in which caſe the aquafortis will not diſſolve the copper ſo as to produce a thin plate of it upon the poliſhed iron; and therefore, when the maſs of ore has a ſtrong metallic or mineral appearance, and yields no copper with the aquafortis, it will be prudent to have it tried by a proper chemical proceſs.

The copper in many veins is compoſed of yellow and green; in other veins the ore is chiefly of the yellow and brown colours blended together. In ſome veins we find a mixture of yellow, brown, and green; in others a mixture of yellow, black, and brown; and in ſome veins there is a mixture of yellow, purple, and of all the glowing colours of the rainbow and peacock's tail. In ſhort, copper ores are found of all colours, and of all the ſhades and tinges of thoſe colours, and many of thoſe

thoſe colours are often mixed and blended in the ſame vein, and ſeveral of them even in the ſame individual maſs of ore, which makes a juſt and proper deſcription of ſome of the copper ores a difficult taſk.

Some of theſe mixed copper ores are of a granulated texture, or approach to a ſteel grain; but moſt of the varieties are ſolid, hard, and firm, and of an uniform texture. Some of theſe are dull and ſtony like, and many of them appear of various degrees of beauty and metallic brightneſs.

Copper ore is often decompoſed and diſſolved by corroding waters paſſing over it; and the particles thus diſſolved are often carried away by water, and lodged at different diſtances from the veins. This weathered or diſſolved copper is found in many places in the ſtate of an ochre or of a looſe powder.

This powder is commonly of a green or of a blue colour, and is called mountain green and mountain blue, ſome of which appear of a beautiful bright green and blue colour, and others are of a more dull and earthy appearance. Some of the ochreous copper ores are indurated, and others are more looſe and friable; however all theſe may ſoon be aſcertained with a little aquafortis. In this experiment, the friable ochreous and the powdery ſamples muſt be put into a

drinking

drinking glaſs, with ſome aquafortis, and after ſtanding about a minute, touch the liquid with a key or a knife, and a thin plate of real copper will appear on the iron, if the matter ſo tried contains that metal.

Copper found in the ſtate of an ochre or of a powder is commonly mixed with calcareous matter, and effervеſces in the aquafortis, in the ſame manner as lime-ſtone and other calcareous ſubſtances, and ſome copper ore found in veins likewiſe effervеſces with aquafortis; but the calcareous mixture does not hinder any of theſe ſamples to ſhew the copper upon the iron in the experiment with aquafortis.

The ſeveral ſorts of copper ore curſorily pointed at under theſe few heads, eſpecially the laſt article, might be ſub-divided into a number of diſtinct ſpecies and varieties; but as my whole aim is to point out ſuch deſcriptive marks and characters as ſhall make theſe ores known, and as may diſtinguiſh them from other foſſil bodies of nearly the ſame colours and appearance, I am no way concerned about a formal regular mode of claſſing them. I only wiſh to make them known.

The mineral veins which contain the various ſpecies of copper ore, are exactly of the ſame deſcription as the lead veins, and the various unmetallic mineral ſubſtances, hard and ſoft, contained

tained in thofe veins, are the fame which have been fully defcribed above, and, therefore, a farther repetition would be ufelefs. However, it may be obferved, that in foft veins containing chun and mineral clays, we need not look for copper in the white and whitifh friable clay defcribed above, which frequently contains particles, and fometimes fmall maffes of lead ore coated with cerufs. There feems to be a quantity of native cerufs mixed with this mineral foil, which perhaps has been produced by acid corroding waters diffolving part of the lead ore, which produces the native cerufs that is mixed with this clay, and which coats or covers all the fhoads, and all other maffes of lead ore that are covered with a white coat, efflorefcence, or ruft.

The veins which contain copper and lead ores, as I obferved above, are the fame, and the various mineral bodies which accompany both thefe ores are alfo very near the fame, and to fave unneceffary repetition, it is alfo proper to obferve, that the various kinds of copper ore are found in hard and foft veins, exactly in the fame manner as the various fpecies of lead ore; and, therefore, when a mineral vein is difcovered, in which no lead ore is found, it fhould be carefully examined for copper.

As all mineral fubftances in the baffet, outburft, or furface of a hard vein are fometimes fo

tarnifhed

tarnifhed and difcoloured as to conceal their native hue and appearance, I before advifed that the furface of every fubftance within the fides of a hard vein fhould be broken or fcratched with a pick, or other iron tool, and if no lead, or but a very fmall quantity, is found in it, it fhould then be carefully examined for copper. Copper ore in a hard vein may be either red, black, blue, green, yellow, grey, and brown, or of the various fhades and various mixtures of thefe colours.—Moft of the copper ores of the fimple colours, and of their fhades and varieties, have a mineral and metallic appearance, with various degrees of mixtures, fufficient to diftinguifh them from mere ftones or other mineral fubftances of the fame colour, efpecially in very hard veins. However, fome varieties of thefe ores may be fo dull and tarnifhed as not to be eafily diftinguifhed, in which cafe, aquafortis fhould be ufed, when foffils refembling any fort of copper ore are found in fuch a vein. It commonly happens, that fome little verdigreafe or a fine green ruft or efflorefcence, appears upon the face of copper ore expofed to the external air in the furface of veins, and likewife upon the outfide or furface of loofe maffes of copper ore, which have long been expofed upon the furface of the earth: However, if no verdigreafe or fuch fine green ruft fhould appear, the various colours and appearances of the

the copper ores have been fo particularly defcrib-ed as to point them out to an attentive obferver, independent of the verdigreafe, which, however, is always an indication of the prefence of copper in lefs or greater quantities.

Copper ore may be and often is found upon the furface of the earth in fhoads and floats, in the fame manner as lead ore, and, therefore, when vein-ftones, fpars, &c. are found fcattered upon the furface, they fhould be carefully examined, to fee if they contain any copper in fpecks or flowers, and the place fhould be well examined for lefs or greater famples of copper ore.

Maffes and fmall bits of copper ore which have fliden, or been any way forced off the baffet of a vein, and lie fcattered upon the furface of the ground, generally fhow fome little verdigreafe, and when they do not, the ore has much the fame appearance as defcribed above, only a little more dull and tarnifhed than famples of the fame ore newly broken, but the tarnifhing is only upon the outfide of the maffes; but however dull and tarnifhed fuch maffes and fmall bits of ore may appear, they have generally a mineral appearance and character, which diftinguifhes them to an obferving eye from common ftones; and, therefore, when fpar, vein-ftone, &c. are feen, every hard fubftance in fuch a place fhould be broken to fee how they appear in the infide.

When

When treating of lead ore, I directed how to ſearch for and trace out the veins, by means of ore and other mineral ſubſtances found upon the ſurface, to which I refer, as it need not be repeated here, all circumſtances being alike, reſpecting the ſhoads or appearances of copper and lead.

Copper ore is found in all the deſcriptions of ſoft mineral veins, in the ſame manner as lead ore, and the copper is accompanied in theſe veins by moſt of the ſoft mineral ſoils which accompany lead, excepting the white friable clay, which ſeems peculiar to lead. But of all the ſoft mineral ſoils found in veins, the blackiſh and all the ſhades of brown chun, or mother, is the moſt promiſing for copper. It has been noted before, that chun, which is alſo called ghurr, is a ſoft, lax, friable ſoil, found in the concavities of mineral veins, which generally has a duſty or ſnuffy appearance when the vein is dry.

When a vein is found, and opened a little, containing this ſort of ſoft ſoil, if no lead is found in it, then it ought to be carefully examined for copper. Let every hard ſubſtance found in the vein, whether it is mixed and buried in the ſoftneſs, or adhering to the ſides, from the ſize of a ſmall pea, and upwards, be broken, to ſee if any copper appears, which in ſuch veins is commonly ſo tarniſhed or covered over with the ſoft ſoil, in which it is buried, as to conceal its real colour and metallic appearance, which, however, will be diſcovered when either ſmall or great maſſes containing copper are broken. But if no maſſes of good copper are found, nor any ſpecks or threads of copper are diſcovered in breaking the hard ſubſtances of the vein, then let ſome of the chun be put in a glaſs with aquafortis, and after ſtanding a little, touch the liquid with clear iron, and if any copper appears, it may be concluded that it is a copper vein, and farther trials ſhould be made by ſinking down in it, even to a conſiderable depth, there being little doubt of finding much copper in ſuch a vein, if you go far enough down in it.

Beſides the ſeveral deſcriptions of mineral veins, copper ore is found in all other ſituations and circumſtances the ſame as lead; ſuch, for inſtance, as blended in the compoſition of the ſtrata of lime-ſtone and other rocks, in the ſame manner as lead ore, which has been deſcribed above, and need not be repeated here.

Copper mines have been worked for a long time in many parts of England, to the great emolument of the public, and of the ſeveral diſtricts where this metal is found; but mines of copper have not hitherto made any figure in Scotland. The trials for that metal have neither been numerous nor very ſucceſsful, perhaps for want of ſkill and perſeverance. But, however

that

that may be, as it is probable that more attention will be paid to that metal hereafter in this country, I will point out ſome places where I have ſeen copper ore, and appearances of good copper mines in Scotland, which communication may be uſeful to poſterity.

A great many mineral veins appear in the cliffs of the ſea, all round the coaſt of Caithneſs, in the north of Scotland, in ſome of which I have ſeen lead, and in others copper ore.

Many of thoſe veins are coved by the waves of the ſea waſhing out the ſofter mineral ſoils. There are ſeveral fine regular rake veins trending towards the north and ſouth, and others towards an eaſt and weſt direction, near the old ruinous caſtle of Olrick in Caithneſs, which interſect one another at right angles, in ſome of which I found pretty good copper ore.

The veins at Olrick are remarkably good and promiſing, and regularly open between the ſides, containing ſome copper ore even at the ſurface, with various other good mineral ſoils both hard and ſoft. I juſt touched the ſurface of two of the north and ſouth veins at Olrick, which could not be called a trial. One of the places was in the cliff of the ſea, about half way down from the ſummit, in a ſtrong bold vein, containing ſome copper ore; but as moſt of the mineral ſoils in this vein were hard, there was but very

very little done in it. The other vein was alfo feen in the cliff, but it was fearched for and found by a little trench upon the plain ground above, at fome diftance from the face of the cliff. This vein was found open and good, immediately below the upper foil, containing fpar and vein-ftone, and a blackifh brown chun, or foft mineral foil, with fome copper ore at the very furface; and if I remember well, there was not above a yard funk down in the vein, juft to fee how it appeared.

The copper was found in fmall maffes in the chun, and mixed or blended through all the vein-ftones and fpar. The copper ore at Olrick was moftly of a yellow and a brown colour, and frequently a mixture of yellow, brown, and green. It did not appear to be very rich in quality; but, perhaps, that is not ultimately againft it, for it may be remarked, that in Cornwall, and other places where they have the moft rich and durable copper mines, the ore is generally poor in quality, which defect is compenfated by the great quantity produced; and as far as I can judge from appearances, Olrick promifes to be a productive copper mine, when the beft veins fhall be opened and effectually explored.

The beft copper ore that I ever faw, and, perhaps, the beft that has been feen in Britain, is found at Kiffern in the Weft Highlands of Scot-

land.

land. This remarkably rich ore is of a reddiſh grey colour. It is uncommonly ponderous for copper ore, and the beſt maſſes of it are ſonorous, and ring like the melted metal. This fine ore is found in a rake vein or perpendicular mineral fiſſure, which croſſes a middle-ſized hill of fine limeſtone, within a mile of the ſea, or an inlet called Loch-Kiſſern, upon the weſt coaſt of Roſsſhire. There have been ſuperficial trials made at Kiſſern, (the name is ſounded Kiſhon), and ſome tons of copper raiſed at different periods. The ore is found there in neſts or ſmall openings in the vein, with ſhort intervals between them, but they have never yet ſunk to any depth in it. I am of opinion that Kiſſern deſerves to be explored more effectually by proper trials. There is the higheſt chance in its favour, not only of this vein and other perpendicular fiſſures opening wider and more regularly at proper depths, and producing good bodies of ore, but there is alſo a probability of diſcovering dilated veins as they work down in the rake veins.

Flat dilated veins are commonly found in all limeſtone mining fields, and they would probably be met with at Kiſſern, were the perpendicular veins worked deep enough to come at them. When I was at Kiſſern, I ſaw the baſſet of a flat vein there in the limeſtone meaſures, containing iron ore at the ſurface, a common circumſtance

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in other copper mines. The rake vein, out of which the copper was raiſed, opens and cloſes, or checks again, at ſhort intervals near the ſurface, and they have not gone far down in it. The ore was found in every ſmall opening of the vein, and the quantity found was always in proportion to the ſize and length of the open ſpace in the vein, and when theſe openings cloſed or checked as they worked forward horizontally in the vein, the copper was cut out and loſt, until they came to another opening, which was commonly at the end of two or three feet, or of two or three yards at moſt, when they were ſure to find more copper. A ſhaft put down in the vein where the beſt and moſt copper was found, to the depth of twenty or twenty-five fathoms, and a horizontal mine driven likewiſe in the vein from the bottom of the ſhaft, a conſiderable number of fathoms towards the height of the hill, might be productive of great diſcoveries; at any event, the copper which would be raiſed in going down and driving in the vein, would probably defray the expence of the operation. This may be done at a moderate expence, with a ſmall horſe-gin or whimſy, inſtead of a windlaſs, for drawing the water and work in ſinking.

Among the prodigious number of lead veins which are ſeen in the iſland of Iſla, there are ſome few regular good veins containing copper ore,

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upon which trials to a ſmall depth have been made, and ſeveral tons of pretty good copper ore were raiſed out of them. The copper of Iſla is moſtly of the yellow, brown, and green colours mixed together, and of a cloſe grain or texture; but moſt of the copper of Iſla is mixed with blue lead ore, which is a great detriment to the copper.

The Ochill Hills are famous for producing various kinds of good metallic and ſemi-metallic ores in ſeveral places, ſuch as ſilver, lead, cobalt, &c. and among the reſt copper ore has been found in ſeveral parts of thoſe mountains, ſome of which I have not ſeen; but I ſaw ſome very good regular perpendicular veins bearing copper ore, near the bridge of Allan, which have been worked, and a great deal of copper raiſed at different periods. The copper of this mining field is good in quality. I do not diſtinctly remember all the colours of it, but I recollect there was yellow, green, and grey ore produced; and the yellow copper ore there, which is of a laminated ſtructure, and a bright yellow colour, was the fineſt yellow copper I ever ſaw. From my own obſervations, joined with the information of ſenſible ſkilful miners, I am of opinion, that the copper mines at the Bridge of Allan were raſhly thrown up and ſtopped about twenty years ago, when they had good copper in ſeveral foreheads, and ſtill

better

better in ſome of their ſoles, as I thought in ſufficient quantity to be worked with profit. But there being no furnaces and other apparatus for preparing and ſmelting the metal in Scotland, is a great detriment to the ſucceſs of copper mines in this country.

The mining field at the Bridge of Allan promiſes a rich and plentiful produce of copper, if conducted with ſkill, ſpirit, and frugality.

There have been trials made, and grey, yellow, and greeniſh brown copper ores found at Curry, in the county of Edinburgh. The grey copper found at Curry was exceeding rich, of a bright grey colour, of a granulated texture, remarkably heavy, and very pure, and from its appearance I imagine it contained ſome ſilver. This fine ore was found in limeſtone, but I do not now remember whether the copper was found in a regular vein, or in neſts in the lime-rock. I alſo ſaw at Curry a great many ſmall vagrant ſtrings of copper ſcattered in the ſuperficies of the rock in ſeveral places, upon which they have been digging and making ſuperficial trials at different periods. I imagine that they have paid too much attention to thoſe vague appearances, becauſe they ſaw ſome little copper, and neglected ſome real mineral veins, becauſe they did not carry ore immediately at the ſurface.

There are appearances of other copper mines in ſeveral parts of Scotland, which I have not ſeen; and ſome that I have ſeen I do not ſo diſtinctly remember as to be able to give a juſt account of them.

In the pariſh of Colvend, in Galloway, there are great numbers of mineral veins, in which ſeveral ſpecies and varieties of copper ores have been found. Many of theſe veins appear in the rocky cliffs of the ſea, upon the north ſide of the Solway frith, which are high and precipitous. Several of the perpendicular veins containing copper in this field are ſo narrow and cloſe at the ſurface of the ground, upon the ſummit of the rocky cliffs, that they could hardly be known above for mineral fiſſures, if they were not ſeen to open gradually wider and wider as they cut the ſtrata aſunder down the face of the cliff; but notwithſtanding their being ſo very ſtrait and cloſe above, many of them open aſunder to three or four feet wide, and more, before they are half way down from the ſummit to the beach, and ſome of them are ſix or eight feet wide below at the beach. Some of theſe veins are coved a conſiderable way into the hill, by the continual agitation and beating of the waves which waſhes or gradually wears the mineral ſoil out of the veins. Many wonderful ſtories were related to me concerning one of theſe, called the

 Piper's

Piper's Cove, when I was in that country near thirty years ago, which raiſed my curioſity to examine it with lights. Before I entered the cove, I ſaw that it was a large ſtrong mineral vein, which engaged my attention to the internal parts of it as ſuch, and before I came out, I diſcovered copper ore in the vein.

This prompted me to take a view of the cliffs further along ſhore, to ſee if any more diſcoveries could be made; and the reſult of my ſearch was, that I found ſome copper in the cliffs along ſhore in more than twenty veins. In a year or two after the firſt diſcovery, a company tried ſeveral of thoſe veins, and ſome tons of copper were raiſed and ſold; but whether the company and their ſervants had not ſufficient ſkill in copper mines, or that they made ſome ſuperficial trials in too many places where a little copper appeared, but did not puſh far enough into the beſt veins with ſufficient ſpirit and perſeverance, or that the ore was found in too ſmall quantity to be worked with profit, or whatever was the cauſe, the work was thrown up, after making a great number of trifling ſuperficial trials, although ſome copper was found in moſt of them. From what I ſaw and know of the matter, as I ſometimes paſſed that way, my opinion is, that they tried too many places which deſerved no trial at all, and of conſequence, they ſoon found too much money out, and but little coming in, which difcouraged them; whereas, had they concerted and fteadily followed a proper plan, and pufhed their trials effectually in two or three of the moft promifing veins containing copper ore, it is highly probable that their fuccefs had been quite different, and that this had proved one of the greateft and beft copper mines in Europe. Moft of thefe veins are very clofe and ftrait above at the furface of the ground, but open gradually downwards, and feveral of them are wide and regular below, containing fome copper ore at or near the day, with very promifing mineral foils, both hard and foft, as brown chun, &c.

A great variety of copper ores appear in this extenfive mining field. The principal fpecies are the yellow, green, and brown. There are a great variety of mixtures of the yellow, green, and blue colours, fome of which are tinged with all the beauties of the rainbow and peacock's tail; but thefe gaudy ores are generally in hard poor veins, which do not promife much fuccefs, at leaft not near the furface. In the opener veins, containing foft mineral foils and kindly fpar, &c. the yellow ore mixed with green and brown colours are generally prevalent. There were ribs of folid ore in fome of thefe veins, when the trials were given up, in one or two of the beft veins

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the rib was up to four or five inches, or more, of a brownifh yellow copper, mixed with green; and I am perfuaded that the ore in fome of thofe veins would pay for working, as it now ftands, if managed with fpirit, fkill, and frugality; and as the veins are good, and trend into a range of mountains, which have a gradual rife or acclivity from the fhore, until they afcend to a great height, there is the greateft probability of fuccefs, by driving horizontal mines or galleries in the veins from the fhore, towards the mountains, in which veins there is middling good ore to begin upon, which would pay for the mine or gallery; and as moft or all of thefe veins open gradually downwards, it might be prudent to fink down below the level of the fea in one or more of the veins which produce the beft ore and other mineral foils.

In fhort, this is a noble mining field for an able, fkilful, prudent company to engage in, and I am perfuaded that fome time or other, when the beft veins fhall be properly opened and purfued, this will prove one of the beft and moft extenfive copper mining fields in Britain, if not in all Europe.

The next metallic ore I fhall take notice of is iron. In thefe curfory obfervations, concerning the metallic and mineral ores, I follow no fyftem of mineralogy, nor eftablifhed rule of precedence,

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but I rather have refpect to the extent and riches of our Britifh mines, and their importance to our manufactures and commerce, than to any other motive of choice and order. Our lead and copper mines have long been, and ftill are worked to great extent and advantage, and it is yet very practicable to increafe them. Our iron mines and iron furnaces have begun to make a figure of late years, and I hope they will increafe in fome proportion to their great national confequence.

Of all the mineral ores found in the fuperficies of the globe, iron is of the greateft importance for all the purpofes of fociety; and therefore, it fhould be reckoned the moft precious, as it is the moft ufeful of all metals. Iron is either neceffary or applicable to moft of the great and important ufes of metal. Its ferruginous quality is indeed againft it for feveral domeftic and ornamental purpofes; but where the great and neceffary ufes of metal are wanted, for ftrength, durability, fine edge and point, iron is, without comparifon, the moft ufeful and the moft valuable metal in the world; and like the other common bounties of nature, the general abundance of iron is equal to its great utility. However, the other metals have alfo their value and importance in various ornamental and ufeful purpofes of life, and they are of great confequence to our Britifh manufactures and commerce. Unlefs it is the

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firſt great expence which is requiſite for erecting iron works, I am at a loſs for the reaſon why we have ſo few blomaries in the iſland of Britain; and why we were ſo long, in Scotland eſpecially, before we began to extend this valuable manufacture of our own produce, which is of ſuch vaſt national importance.

It is ſaid that a million of good hard caſh is annually carried out of the nation for iron, which goes into the coffers of cold friends and commercial enemies. It ſhould be the fervent wiſh of all the real friends of our national proſperity, that the blomaries, or iron works of Britain, were ſo much increaſed as at leaſt to keep our dry caſh at home, and if we imported any iron at all, that it ſhould be in exchange for Britiſh manufactures; and I am perſuaded that the means of ſuch an increaſe is abundant.

Iron works in Scotland, for manufacturing the produce of the country, are but of very late eſtabliſhment; but to my certain knowledge, the foſſil means of numerous iron works in this country are abundant and good.

I will not pretend to reaſon upon the policy of national bounties to encourage the increaſe of theſe public works; but it appears to me abundantly evident, that bounties and premiums, wiſely diſpoſed of in this way, would prove a national

tional advantage, by employing a great additional number of hands in preparing and manufacturing the produce of our iron mines, and in keeping at home a million of caſh annually, which may be employed in carrying on thoſe iron works, by which means it would flow like vital nouriſhment in home circulation.

Our worthy young Premier has inveſtigated many important ſubjects reſpecting our national proſperity,—I wiſh he would look into this alſo.

Iron, in its crude foſſil ſtate, may be ranked in two ſorts, viz. iron ore and iron ſtone. Iron ore, properly ſo called, is found in all the ſeveral ſpecies of mineral veins deſcribed above, and alſo upon the ſurface of the earth, in a coagulated or concreted ſtate, which is called bog-ore, and iron-ſtone is found in thin but regular ſtrata in the coal fields and others, and in glebes and nodules of various ſizes, blended in argillaceous ſtrata likewiſe of the coal fields. Several ſpecies of iron-ſtone, ſuch as ruddle and ſlaty or ſhivery iron-ſtone or ore, are found in regular continuous ſtrata among the ſtrata of the mountain rocks, and it is found in indurated rocks in many places.

There are ſeveral ſpecies of iron ore, ſuch as, *1ſt, Blood-ſtone ; 2d, Kidney ore ; 3d, Grey iron*

ore ;

ore ; 4th, *Bog ore*, &c. and of each of theſe there are many varieties.

1ſt, The *hæmatites*, or *blood-ſtones*, are reckoned among the richeſt of the iron ores. They are either of a dark brown, a reddiſh brown, or of a grey colour, remarkably heavy, and generally of a radiated ſtructure. The reddiſh and brown ſorts are commonly of a ſmooth uniform texture; but the grey are frequently granulated, ſome of which are of a dark grey colour and dull appearance, and other varieties are of a light grey and of a bright metallic appearance.

The maſſes of theſe ſorts are ſtrongly marked, being of a ſtriated and radiated form and texture; the radii very diſtinct, and diverging every way from a common center, and they are generally mixed with a whitiſh or fleſh-coloured iron ſpar. Many varieties of the blood-ſtones are very hard, as well as the iron ſpar which accompanies them.

2d, *Kidney ore* is found in ſmall maſſes blended in a red, ſtaining, ſoft clay or earth, called *ſmit*, which is alſo an iron ore. The ſolid maſſes which are mixed in this red clay are remarkably heavy, and of a blackiſh brown, or dark grey colour; they are either roundiſh or kidney ſhaped, and of a cruſtated ſtructure, the ſmall maſſes being formed of concentric cruſts or folds like an onion, though in ſome varieties the ſmall maſ-

ſes

ſes of ore are of a more ſolid ſtructure, without the appearance of different folds or cruſts. The moſt profitable iron mines in Britain produce this ſpecies of ore.

2*d*, *Grey iron ore*, of which there are many varieties, moſt of them pretty hard and heavy, and ſometimes of a dull blue, but generally of various ſhades of an iron grey colour. Some varieties of the grey iron ores are of a granulated texture, and compoſed, ſome of coarſe grains, reſembling coarſe iron when broken, and others of finer grains, reſembling the ſteel-grained lead ores; and ſome of theſe are of a blackiſh or dark grey, and others of a bright grey colour, reſembling ſome of the granulated lead ores. Again, ſome varieties of the grey ores are of a cubical or diced ſtructure, and others are ſcaly, and theſe are compoſed of larger and ſmaller cubes, and of larger and ſmaller ſcales, in the ſame manner as the diced and ſcaly lead ores, which many of theſe reſemble, only that they are of a duller blue, or of an iron grey colour.

But I will not purſue this deſcription, which is not very neceſſary, the iron ores in general being pretty eaſily known and diſtinguiſhed from all others, by their being accompanied with leſs or more of a browniſh red, or of a brighter red ſoft ſoil, which indelibly ſtains the hands and cloaths, and therefore I will leave the deſcription imperſect, and will proceed to point out ſome of the many places in Scotland where I have ſeen appearances of good iron mines; and it was only for the ſake of communicating this local hiſtory, which may be of future uſe, that I ſaid any thing at all about iron.

I have formerly ſeen appearances of iron ore in ſeveral places round the coaſts, from the weſt ſide of St Andrews to Montroſe; but it is ſo long ago, that I can now give no diſtinct account of the matter.

About ſeven or eight miles north of Montroſe, in the neighbourhood of a fiſhing town, which I think is called John's-Haven, there are ſtrong appearances of plenty of good iron ore, particularly near Mr Carnegie of Charlton's lime works. The iron among theſe lime works appears at firſt ſight to be plenty and good, but my ſtay there was ſo ſhort that I had no time to examine it minutely. It is eaſily diſtinguiſhed by the ſtrong, red, ſtaining ſoftneſs which accompanies it. If this ore is found good, it is almoſt cloſe to the ſea.

There are appearances of iron ore between thoſe lime-works and Stonehaven, and between Stonehaven and Aberdeen, concerning which I can ſay nothing diſtinctly.

There are ſtrong appearances of iron upon the coaſt, about the Ord of Caithneſs, and in many

many places between the Ord and Wick, and to the northward of Wick.

The coaſt of Caithneſs is remarkable for pretty high rocky cliffs, in which great numbers of veins, or perpendicular mineral fiſſures appear, many of which contain iron ore. I remember obſerving ſome of theſe near the old ruinous caſtle of Girnigo, and between Girnigo and the caſtle of Ackergill. Theſe veins appeared to be bold and roomy, and to contain plenty of good iron ore, from the abundance of a bright red iron earth found in the ſurface of them; but I did not thoroughly examine circumſtances, having no proſpect then that iron ore would ſo ſoon become of conſequence in Scotland.

There is great abundance of bog ore over all the low country of Caithneſs. In many places it almoſt covers the whole face of the ground to a conſiderable depth. It is eaſily known and diſtinguiſhed by the friable conſtitution of its miſhapen maſſes; by its blackiſh and ruſty colour on the outſide, and by its blackiſh grey colour and granulated porous texture in the inſide. It is always found looſe upon the ſurface of the ground, in the ſame manner as float ore, without any connection with vein or ſtratum.

Iron ore has been wrought in the main iſland of Orkney, and ſhipped for uſe at Carron, concerning

cerning which I can ſay nothing farther, as I never ſaw it.

Good iron ore appears in the lime rocks of Kiſſern in Roſsſhire, where the rich copper mentioned above was found. I did not traverſe all the lime rocks at Kiſſern, but I ſaw fine iron there in two different places, and of two different ſpecies. The firſt which I obſerved is grey iron ore, contained in a perpendicular fiſſure or rake vein, which appears diſtinctly in the ſide of a ſmall rivulet near the road, upon the ſouth ſide of the field in which the copper was found. This vein, if I remember well, is between two and three feet wide at the ſurface, and full of good-like grey iron ore. In the ſecond place which I obſerved, the iron ſeems to be of the ſpecies called kidney ore, and it is contained in a flat or dilated vein in the lime-ſtone, and ſituated about a hundred yards or more weſtward from the copper vein. I ſaw not the leaſt trial upon either of theſe two, but they appear to be very good. The ſite of them and of the copper is about a mile from the ſea, or ſalt-water loch of Kiſſern.

I am perſuaded that ſeveral of the Weſtern Iſles abound in iron ore, ſome of which I have ſeen in Cannay, &c. which I had not time to examine.

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There appears plenty of good iron ore in ſeveral mineral veins in the ſouth ſide of the mining iſland of Iſla, part of which is found in the lime within the bounds of the lead mining field, and part to the ſouth of the field which abounds moſt in lead ore. There are many appearances of iron along the coaſt of Iſla, which I have only ſeen at a diſtance, but from what came under my eye, I am confident that Iſla is an eligible place to ſearch for a valuable iron mine, which would anſwer well for iron works upon the Clyde, in Ayrſhire, or in any part of the weſt coaſt.

A ſtrong appearance of a great quantity of iron is to be ſeen in the hills which are ſituated to the eaſtward of Girvan in Ayrſhire, which appearance of iron ſtretches away longitudinally towards the north-eaſt, as far as the pariſhes of New Cumnock and Muirkirk, which may be ſoon of great uſe to the new iron works lately erected at Muirkirk, and perhaps to others in the courſe of time, there being plenty of coal and coal-field iron-ſtone in the ſouth-eaſt parts of Ayrſhire.

Iron mines appear in manyplaces upon the ſea coaſt of Galloway, particularly in the pariſh of Colvend, both to the weſt and eaſt of the copper mining field above-mentioned, where many veins containing kidney ore and other ſpecies are to be found,

found, feveral of which I have feen, but not examined.

The north-weft fide of the Ochil hills abounds in iron, which I have feen in croffing thofe hills. It ftretches longitudinally, but of what quality I do not know; however, it deferves to be afcertained, the fite being convenient for the great quantities of excellent coal and iron-ftone of the coal-field found upon the banks of the Devan, a plentiful ftream, and in the moors to the fouth of the Devan.

The iron ore or iron-ftone at Noblehoufe is pretty well known, being opened a little a few years ago by the proprietor, Sir William Montgomery of Magbyhill. This is not a vein, but a ftratum of iron, which ftretches longitudinally a confiderable way towards the north-eaft and fouth-weft, through the lands of Magbyhill, La Mancha, and others. This ftratum of iron is of confiderable thicknefs, being above twenty feet acrofs the ftratum where it was opened at the furface near Noblehoufe. It is a flaty or fhivery iron ore, or iron ftone, of a reddifh brown colour, and fmooth uniform texture in the infide of the maffes when broken, and mixed with ftaining iron earth of the fame colour. When I faw this iron mine, I thought the ore fhould have been very rich, but was told that it only produced about twenty-five or thirty per cent.

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at moſt upon trial; however, as they only dug the ſurface of the ſtratum, which muſt be mixed with ſurface-earth carried down by rains into the iron ore for ages, I imagine it ſhould be richer if worked down to a proper depth. I am perſuaded that this will become of great value in the courſe of time, as the extenſive muirs to the north of it abound in coal and coal-field iron-ſtone, and the ſituation only ſixteen miles from Edinburgh, and convenient for the extenſive inland countries to the ſouth and weſt of it.

The beſt of all iron-ſtone, which is found in thin ſtrata, and alſo in detached glebes and nobules in the argillaceous ſtrata which accompany ſeams of coal, abounds in all parts of Scotland where any ſtrata of coal have been diſcovered. I call this iron-ſtone of the coal-field, becauſe it is always found in thoſe argillaceous ſtrata which attend coal, and which are very commonly the immediate roof of coal; and therefore, it is cuſtomary to rummage the coal waſtes for this ſort of iron-ſtone, from whence it is raiſed much cheaper than by digging it out of ſolid ground.

This ſpecies of iron-ſtone is found upon both ſides of the frith of Forth, from the eaſt of Fife and oppoſite, all the way up to Stirling, a length of more than fifty miles, and in a great many places it is found quite down to the ſhore, and within flood-mark. Upon the north ſide of

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the Forth, the coal-field, and of courfe the iron-ftone field is generally about eight miles broad from the fhore inland, and in length, as hinted before, above fifty miles. The iron-ftone in this extenfive coal-field is very plenty and very good, and it is all entire, excepting a very little, which the Carron Company have picked near the fhore, and a confiderable quantity which they have taken from Pitfirran.

The inland coals at a diftance from the fhore are remarkably good and plenty in feveral parts of Fife and Clackmannan fhires, and as there is appearance of iron ore in the Ochil hills, this country may, in the courfe of time, become the fite of extenfive and valuable iron works.

The iron-ftone upon the fouth fide of the Forth is found as abundant and as good as upon the north fide, with this addition, that in many places the coal and iron-ftone field upon the fouth fide is more than double the breadth of the other. The greateft part of this fouth field reaches from the banks of the Forth all the way to the fouth fide of Ayrfhire, which is more than fix times the breadth of that upon the Fife fide of the water.

The Mid-Lothian coal and iron-ftone field reaches from the fouth fhore of the Forth near twenty miles up the country towards the fouth-weft, and it is of pretty equal breadth, being every where about twelve or thirteen miles acroſs. The ſouth-eaſt ſide of this field conſiſts of a range of horizontal ſtrata, and the north-weſt ſide of vertical or greatly ſloping ſtrata, and both ranges abound in good coals and iron-ſtone. The flat, broad, or horizontal coals of this great field are of excellent quality, and remarkably plenty and cheap in the neighbourhoods of Ormiſton, Cranſton, Carington, and Temple, which diſtricts alſo abound in good iron-ſtone; and therefore, theſe are ſuppoſed to be good ſituations for iron works; and iron ore is found in abundance at Noblehouſe, and farther eaſt; and there is appearance of iron ore in the range of hills upon the ſouth ſide of this coal-field.

In the range of vertical and greatly ſloping ſtrata, in the north-weſt ſide of the Mid-Lothian coal-field, there are a great number of thick ſeams of excellent coal, and the ſtrata of iron-ſtone are innumerable, beſides a great quantity of nodules contained in thick beds of coal-till, and all apparently of excellent quality. The coals of this range, for eight or ten miles from the ſhore, ſell at a good price, being carried to Edinburgh; but farther up the country they are of ſmall value, and not worked at all, or none to ſignify; and, therefore, it is preſumed, that the neighbourhoods of Auchindinny, Pennycuick, and Newhall, would be eligible ſituations for iron

 works,

works, which can be ſupplied with excellent and cheap coals from the horizontal ſtrata upon the ſouth, and from the edge ſeams upon the north ſide of the river Eſk, and with abundance of iron-ſtone from both, part of which can be carted weſtward from the coal waſtes of Loanhead and Gilmerton; and there is abundance of iron ore for mixing with the ſtone at Noblehouſe, and farther eaſt, at a ſmall diſtance from theſe propoſed iron works.

It ſhould give real pleaſure to all the friends of our national proſperity to obſerve, that iron works have been lately erected at Cleugh, upon the banks of the river Clyde above Glaſgow, and at Muirkirk, which I heartily wiſh may ſucceed. Other proper inland ſituations in the counties of Lanark, Renfrew, and Ayr, where coals are plenty, excellent, and of ſmall value, and the iron-ſtone plenty and good, are ſo numerous, that I will not attempt to point them out. I wiſh that plenty of good iron ore were to be found contiguous to theſe ſituations. But I have already ſaid as much upon this ſubject as is conſiſtent with brevity, propriety, and truth.

THE END OF VOLUME I.

ERRATA in this VOLUME.

In the PREFACE.

Page 21. line 11. *after the word* and, *read* I hope to.
25. l. 19. *for* for, *read* if.

VOL. I.

P. 3. l. 15. *for* of working, *read* and working.
19. l. 4. *for* aright, *read* right.
24. l. 23. *for* are, *read* is.
28. l. 6. *for* is, *read* are.
39. l. 3. *for* ſtrata of ball, *read* ſtrata and ball.
146. l. 10. *read* compoſed altogether of the ſame ſtrata of coal metals.
186. l. 15. *read* ſufficient to ſtimulate them to.
191. l. 3. *for* unreaſonable, *read* unſeaſonable.
226. l. 26. *for* diſcompoſed, *read* decompoſed.
249. l. 1. *for* cake, *read* cokes.
299. l. 12. *for* they, *read* the ſoft ſoils.
309. l. 6. *for* latch holes, *read* loch holes.
311. l. 11. *for* waſhing, *read* ruſhing.
317. l. 16. *for* figures, *read* fiſſures.
361. l. 17. *for* round, *read* rounded.
364. l. 17. *this mark* | *ſhould be thus* +.
365. l. 18. *for* whinſtone, *read* veinſtone.
366. l. 16. *for* baſing, *read* baring.
371. l. 16. *for* worked, *read* marked.
395. l. 26. *for* ſacred, *read* ſound.
403. l. 8. *for* perpendicular, *read* particular.
427. and 428. *for* Olrick, *read* Old Wick.
441. l. 5. *for* 2d, *read* 3d.