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OBSERVATIONS

ON

BITUMINOUS SUBSTANCES,

WITH

A DESCRIPTION

OF THE

VARIETIES OF THE ELASTIC BITUMEN.

By CHARLES HATCHETT, Esq.
F. R. S. LOND. AND EDINB. F. L. S. ETC.

Read in the Linnæan Society May 2, June 6, and July 4, 1797.

IX. *Obſervations on Bituminous Subſtances, with a Deſcription of the Varieties of the Elaſtic Bitumen. By Charles Hatchett, Eſq. F. R. S. Lond. and Edinb. F. L. S. &c.*

Read May 2, June 6, and July 4, 1797.

§ 1.

IT is now generally believed that the bituminous ſubſtances are not of mineral origin, but that they have been formed from certain principles of ſubſtances belonging to the organized kingdoms of Nature, which, after the loſs of animal and vegetable life, have ſuffered conſiderable changes by long contact and union with mineral bodies.

Theſe changes have been however ſo conſiderable, that the bitumens can no longer be referred to their firſt origin, and they are therefore regarded by general conſent as forming part of the preſent mineral ſyſtem.

The bituminous ſubſtances are:

Naptha,
Petroleum,
Mineral Tar,
Mineral Pitch,
Aſphaltum,

Jet,
Pit Coal,
Bituminous Wood,
Turf,
Peat, and

thoſe combinations of the oxides of certain metals with bitumen called Bituminous Ores*.

Thoſe who are acquainted with the nature of theſe ſubſtances will immediately perceive, that they may be formed into two diviſions: the firſt of which conſiſts of ſimple ſpecies, or unadulterated bitumens: and the ſecond is compoſed of bitumen mixed or combined with the earths, vegetable matter, and metallic oxides; ſo that theſe appear to merit the name of compound ſpecies.

I ſhall now firſt conſider how the ſimple ſpecies are connected with each other.

§ 2.

IT has been the opinion of ſome eminent Naturaliſts and Chemiſts, that naptha is an ethereal oil produced from the more compact and ſolid bitumens by a ſort of natural diſtillation. This however appears to be an hypotheſis founded upon analogy, and ſupported only by a few local facts which may often be queſtioned. But many facts and obſervations concur to prove that the contrary moſt frequently happens, and that the compact bitumens are often, if not always, formed from naptha and petroleum by inſpiſſation. I will not however now inſiſt upon the proofs of this, as the varie-

* As I intend only here to notice the modifications of naptha and petroleum, I have not mentioned amber and the honey-ſtone.

ics

ties of the elaſtic bitumen, which I ſhall ſoon deſcribe, will be ſufficient for the purpoſe*.

NAPTHA.

NAPTHA is a ſubſtance well known to Mineralogiſts as a light, thin, often colourleſs oil, highly odoriferous and inflammable, which is ſometimes found on the ſurface of the waters of ſprings, and at other times iſſuing from certain ſtrata.

When expoſed to the air, it becomes at firſt yellow, afterwards brown, and in the like proportion it thickens, and paſſes into

PETROL OR PETROLEUM.

THIS has a greaſy feel, is thicker than the preceding ſubſtance, is tranſparent or ſemitranſparent, and of a reddiſh or blackiſh brown colour. By air it becomes like tar, and then is called

MOUNTAIN OR MINERAL TAR, BITUMEN PETROLEUM TARDE FLUENS.

THIS ſubſtance is viſcid, and of a reddiſh or blackiſh brown or black. When burned, it emits a diſagreeable bituminous ſmell, and by expoſure to the air it paſſes into

* Bergman was of opinion, that the liquid bitumens were often, if not always, formed from thoſe which are ſolid, by the means of ſubterraneous heat; and expreſſes himſelf thus: "Cæterum ad fidem pronum eſt, napthan, petroleum, bituminoſoſque liquores, quibus abundat Aſia, plures harum materierum exhibens non tantùm ſcaturigines, ſed rivulos quoque, quibus etiam, parcius licet diſtributis, Auſtralis Europa non caret; probabile, inquam, eſt, has pinguedines liquidas variis antea terris inhæſiſſe exſiccatas, et mediante calore ſubterraneo, ſi non ſemper, ſæpe tamen fluiditatem recuperâſſe. Novimus ignem ſe alto haud raro agere, quamvis in ſuperficie vix obſcura ejuſdem indicia inveſtigare liceat: novimus præterea e ſicco aluminari ſchiſto petroleum extorqueri juſto caloris gradu, cui arte exponitur.—*Bergman de Productis Vulcaniis Opuſcula*, tom. iii. p. 238.

MOUNTAIN OR MINERAL PITCH—BITUMEN MALTHA.

THE mineral pitch much reſembles common pitch, and, when heated, emits a ſtrong unpleaſant odour, like the former ſubſtance. When the weather is cold, it may be broken, and then exhibits, internally, a glaſſy luſtre; but when warm, it is ſoftened, and poſſeſſes ſome tenacity. It is however ſuſceptible of a ſuperior degree of induration, and then becomes

ASPHALTUM—BITUMEN ASPHALTUM—PETROLEUM INDURATUM.

THIS is a light, brittle ſubſtance, of a browniſh black, or black. When broken, it ſhews a conchoidal fracture with a glaſſy luſtre. It has little of the bituminous odour, unleſs it is rubbed or heated. It eaſily melts, is very inflammable, and, when pure, burns without leaving any aſhes.

In this manner, naptha, by inſpiſſation, paſſes ſucceſſively through different ſtates until it becomes aſphaltum, which appears to be the ultimate degree of induration which the pure bitumens derived from naptha can receive.

I have at this time ſpecimens before me which prove theſe gradations; and I have ſeen a remarkable inſtance in a bitumen brought from the Iſland of Trinidad, which exhibits mineral tar paſſing into mineral pitch, and laſtly into aſphaltum *.

§ 3.

* The progreſſive changes of naptha into petroleum, mineral tar, mineral pitch, and aſphaltum, appear to be cauſed by the gradual diſſipation of part of the hydrogen of the bitumen, and the conſequent development or diſengagement of carbon. Hence, I am inclined to believe, ariſe the changes of colour, the degrees of inſpiſſation, and the increaſed proportion of carbon found in thoſe ſubſtances by chemical analyſis.

I would

§ 3.

THE diviſion which comprehends the ſimple bituminous ſubſtances derived from naptha, may therefore be conſidered as terminating in aſphaltum; but Nature appears to have glided on by an uninterrupted chain which connects the ſimple bitumens with thoſe which we have called compound; and this effect is produced by the gradual increaſe of the carbonic principle, and the introduction of extraneous matter, the different quantity of which, together with the greater or leſs degree of mixture or of chemical union, occaſion conſiderable changes in theſe ſubſtances, ſo that they are gradually removed from thoſe characters which diſtinguiſh the pure bitumens.

To form an accurate table of theſe gradations, it would be neceſſary to have comparative analyſes of the different bituminous ſubſtances, and alſo to contraſt the analyſes with the properties of theſe bodies. But at preſent theſe analyſes, for the greater part, are wanting; and although at ſome future time I intend to attempt a ſeries of ſuch experiments, I muſt now content myſelf with the obſervations and facts which I have been able to collect *. From theſe I am of opinion, that the moſt immediate gradation from aſphaltum (which is the laſt of the ſimple bitumens) into thoſe which are compound, takes place in the ſubſtance called

I would be underſtood however to mean that the carbon is only relatively increaſed, in reſpect to the other ingredients, in a given quantity of theſe bitumens, and that it predominates in proportion to the diſſipation of a certain portion of the hydrogen, which was originally neceſſary to the forming of the bitumen in conjunction with the carbon.

* This paper was written and read before I had ſeen the ingenious experiments which the celebrated Mr. Kirwan has publiſhed, in the laſt edition of his Elements of Mineralogy.—Vide vol. ii. p. 514.

JET.

JET.

JET is a ſubſtance well known to be of a full black, ſometimes however inclining to brown. It is conſiderably harder and leſs brittle than aſphaltum. It breaks with a conchoidal fracture, and the internal luſtre is glaſſy. It has no odour except when heated, and it then reſembles aſphaltum. It melts in a ſtrong heat, and, when burned, leaves an earthy reſiduum.

Wallerius conſidered jet as aſphaltum which had become indurated by time, and Mr. Fourcroy is of the ſame opinion *. Others again have arranged it with the varieties of coal †. I am inclined however to believe, that it is neither aſphaltum nor coal, but an intermediate ſubſtance which may be regarded as the firſt gradation from the ſimple bitumens into thoſe which are compound. The matter of aſphaltum undoubtedly enters into it in a large proportion, and has conſequently ſtamped ſeveral of its characters upon it; but the increaſe of carbon, and of the extraneous or earthy matter which is intimately mixed or rather combined with it, has had ſo much influence, that the characters of coal are alſo in ſome meaſure apparent, and are rendered the more ſtriking by the ſimilarity of certain local circumſtances which attend theſe two ſubſtances. The characters of coal are however by no means fully eſtabliſhed in jet, but from this we paſs immediately to another, in which theſe characters cannot be queſtioned.

This is the ſubſtance called

CANNEL COAL,

which is of a full black, of a ſmooth, ſolid, even texture; it breaks in any direction, and the tranſverſe fracture is conchoidal. It

* *Elémens d'Hiſt. Nat. et de Chimie*, tom. iii. p. 456.

† *Widenmann's Handbuch der Mineralogie*, p. 628.

burns

burns well, and is ſo compact that it is often employed, like jet, to be formed into trinkets.

The great reſemblance which cannel coal has to jet in many of its properties, induces me to regard it as the next gradation of the compound bituminous ſubſtances, and as the leading variety of coal from which the others follow according to the degree of their bituminous character.

The limits of this paper will not allow me to enter into a circumſtantial account of all the other varieties of pit-coal; neither is it neceſſary, after the gradations of aſphaltum to jet, and of jet to coal, have been noticed. I ſhall not therefore deſcribe the varieties of coal known by divers names in different countries, and even in different provinces, ſuch as thoſe called in England caking coal, rock coal, ſplent coal, &c. &c.; but ſhall only obſerve, that the pit-coals in general appear to be compoſed of bitumen intimately mixed, or rather combined, with various proportions of carbon and earthy matter; and according to the intimacy of the union, and the exceſs of one or other of the ingredients, ſo the compound poſſeſſes more or leſs the characters of perfect coal, or, by various ſhades, paſſes into certain earthy or ſtony ſubſtances, which, although impregnated with bitumen, do not merit the appellation of coal, and theſe alſo at length gradually loſe the bituminous character *.

It is likewiſe worthy of notice, that the quantity of earthy matter does not appear to be the principal cauſe why pit-coals do not burn with the rapidity which is to be perceived in ſome other earthy ſubſtances impregnated with bitumen. For we may conclude, that

* From Mr. Kirwan's experiments it appears that carbon is a conſtituent principle of coal, and that the preſence of it is a principal cauſe of thoſe modifications which produce the ſpecies. It even ſeems chiefly to form the Kilkenny coal.—*Kirwan's Elements of Mineralogy*, vol. ii. p. 521.

the

the ſlow combuſtion of coal proceeds from the joint effects produced partly by the relative proportions of the bituminous, carbonaceous, and earthy ingredients, and partly by the more or leſs perfect degree of mixture which connects them together, and which degree of mixture, I believe, in many caſes, nearly approaches to chemical union, if not actually ſo: when, therefore, the degree of mixture is ſo perfect as that every particle of bitumen is connected with much carbon or earthy matter, it is not ſurpriſing that the rapid combuſtible property of the former ſhould be checked in a conſiderable degree; and, by a parity of reaſoning, when the mixture is groſs and imperfect, ſo that it conſiſts of a ſtony or earthy ſubſtance, which has ſimply imbibed bitumen, it is natural to expect that the bitumen (although leſs abundant than in coal) ſhould enter readily into combuſtion, which is vehement in proportion to the ſhortneſs of its duration; and this we find to be the caſe in many earthy ſubſtances, and looſe ſand-ſtones which are ſimply impregnated with bitumen.—To return, however, to the varieties of coal, I muſt obſerve, that, from the cauſes above-mentioned, the different characters and properties of coal appear to me to be produced. That in this manner, perfect pit-coal paſſes into ſchiſtoſe or ſlaty coal, and this again, by certain gradations, paſſes into the varieties of combuſtible or bituminous ſchiſtus, which alſo, by the gradual decreaſe of the bituminous ingredient, become at length confounded with the varieties of the common or argillaceous ſchiſtus.

We have a remarkable example of this in the gradations of bituminous ſchiſtus into argillaceous ſchiſtus, which are to be obſerved at Kimmeridge, on the coaſt of Dorſetſhire, where a peculiar bituminous ſchiſtus is found, which is uſed as fuel by the inhabitants, and is improperly called Kimmeridge coal.

By the ſeries of gradations which have been noticed in the foregoing

going pages, the ſimple bituminous ſubſtances appear to paſs into thoſe which are compound; and theſe alſo, by declining ſhades, at laſt paſs into ſubſtances appertaining to the claſs of earths and ſtones.

In the compound bituminous ſubſtances the prevalent earthy ingredient is for the greater part generally, if not always, argillaceous; and although certain calcareous grits (ſuch as the Portland ſtone*) as well as limeſtones and marbles are found impregnated with bitumen, yet I know not of any inſtance in which this happens to the degree requiſite to form a combuſtible ſubſtance.

This curſory view of the ſimple bitumens, and of their combinations, would be ſufficient as an introduction to the principal ſubject of this paper; but, to complete the ſeries, I ſhall make ſome obſervations on the vegetable ſubſtances which contain bitumen, and ſhall afterwards mention the mixtures of bitumen with metallic oxides.

§ 4.

WHEN we conſider the facts which apparently prove that vegetables have contributed principally to the formation of bitumen, we have every reaſon to expect that mixtures of vegetable matter with bitumen ſhould frequently occur. But by the mixture of bitumen with the parts of vegetables, we underſtand the remains and parts of vegetables mixed and connected with the bitumen which they themſelves have produced.

This ſeems to be the nature of the ſubſtance called

* The Portland ſtone, when recently broken in the quarries, emits a ſtrong bituminous odour, like the bituminous limeſtone or ſtink-ſtone. It is alſo full of extraneous foſſils, or at leaſt the veſtiges of them.

BITUMINOUS WOOD, as well as of TURF and PEAT.

BITUMINOUS or foſſil wood is found in many places; but in reſpect to that which is found at Bovey, near Exeter, and which is therefore called Bovey coal, there are ſome peculiarities which deſerve to be mentioned. The Bovey coal is a dark brown, light, brittle ſubſtance, which in texture and other external properties much reſembles wood which has been half charred. It is not found as ſcattered logs or trunks, but forms regular ſtrata.

The pits are on a heath which is flat and ſandy; the ſtratum of ſand is however but thin, after which a pale browniſh grey clay is found mixed with quartz pebbles. This prevails to about ſix feet, at which depth the firſt ſtratum of the coal commences. The quality of this is however much inferior to that of the ſubſequent ſtrata, which in all amount to ſeventeen, producing a depth of nearly ſeventy-four feet from the ſurface. Between each ſtratum of coal is a ſtratum of clay. The direction of the ſtrata is from eaſt to weſt, and the inclination or dip is from north to ſouth. The inferior ſtrata are thought to afford the beſt coal, and the coal is more ſolid and of a better quality towards the ſouth. The thickeſt ſtratum of coal is from ſix to eight feet *.

The Bovey coal burns readily with a flame like half charred wood: it does not crackle, and, if but moderately burned, forms charcoal; or if completely burned, it leaves a ſmall quantity of white aſhes exactly ſimilar to thoſe of wood. The ſmell of it when burning alſo reſembles that of wood, with a faint diſagreeable odour. It is certainly very remarkable that this ſubſtance ſhould form regular ſtrata, although it poſſeſſes the texture and moſt of the

* In the winter, twelve men can raiſe about 120 tons of this coal in a week, the whole of which is employed in a neighbouring Pottery.

properties

properties of wood; and that theſe ſtrata do not exhibit any of thoſe irregularities on their ſurfaces, which might be expected, on the ſuppoſition that they were formed by the roots, trunks, and branches of trees long buried in the earth. It is alſo difficult to imagine wood to have been tranſported and depoſited in this place at ſeventeen different periods, and yet it muſt be allowed that theſe ſtrata have been formed by ſucceſſive operations. I muſt confeſs, that after having twice viſited and examined the ſpot expreſsly for the purpoſe, I ſtill find myſelf utterly unable to offer any opinion upon the ſubject.

The characters of bitumen are but little apparent in the Bovey coal, and the ſuperior ſtrata even appear to have loſt a portion of their combuſtible principle, while the inferior ſtrata poſſeſs it. The lower parts alſo of theſe ſtrata are more compact and more combuſtible than thoſe parts which are immediately upon them *.

Another remarkable ſort of foſſil wood, which much reſembles the Bovey coal, and in like manner is arranged among the bituminous woods, is that found in Iceland, which is called by the inhabitants *Surturbrand*. This is rather harder than the Bovey coal, but in every other reſpect is the ſame. It alſo forms ſtrata many feet in thickneſs; but it is very extraordinary that theſe ſtrata appear to be formed of trunks of trees, which, in their tranſverſe

* At about 100 yards to the weſt of the pits, is a bog of conſiderable extent, where peat is cut, and decayed roots and trunks of trees are found, which do not, however, in the leaſt approach to the nature of the Bovey coal. Whether this bog has been in any manner connected with the formation of the above-mentioned ſubſtance, I do not pretend to determine.

A yellowiſh brown compact ſubſtance, which in colour and fracture reſembles ferruginous clay, is alſo found occaſionally with the Bovey coal: it is brittle, and is highly inflammable; it melts like a bitumen, and emits a ſmoke which in ſmell reſembles amber. This ſubſtance is but rarely found.

ſection, exhibit the concentric circles of their annual growth, with this difference, that the trunks have been ſo compreſſed as to be nearly flat, ſo that the circles appear like parallel lines connected at their extremities by a ſhort curve.

I did not obſerve ſuch an appearance at Bovey; but this would depend upon the poſition of the trunks of the trees, in reſpect to the ſection of the ſtrata.

Chaptal *, Troil †, Bergman ‡, and many others, have been of opinion that the ſurturbrand is wood which has been charred by the heat of the lava. But I cannot diſcern why it ſhould be ſuppoſed that it has been acted upon by fire, any more than that the Bovey coal has been ſubjected to the effects of the ſame agent. The qualities of the two ſubſtances are the ſame; and as (from Archbiſhop Troil's and Profeſſor Bergman's account) the ſurturbrand is ſtratified, I think we may venture to pronounce that the circumſtances

* *Elements of Chemiſtry*, vol. iii. p. 199.

† *Von Troil's Letters*, p. 43.

‡ Quid de ligno foſſili Iſlandiæ ſentiendum ſit, gnaro in loco natali contemplatori decidendum relinquimus. Interea, ut cum Vulcani operationibus nexum credamus, plures ſuadent rationes, quamvis huc uſque modum ignoremus, quo ſitum texturamque adquiſiverunt hæc ſtrata. Scilicet truncis arborum perquam craſſis conſtant, qualis in Iſlandiâ nullibi reperiuntur, et ne quidem hoc tempore creſcere poſſe videntur. Hi ſitu horizontali in ſtratis multorum pedum craſſitiei congeſti ſunt et petroleo plus minus penetrati, non jam molli, ſed optimè indurato, a quo tam nigrorem, quam flammæ ſub deflagratione qualitatem mutuantur. Sed quod in primis attentionem meretur, eſt truncorum in lamellas planas compreſſio.

Ponamus truncum arboris cujuſdam tranſverſim ſectum, hinc, uti notum eſt, figura oritur in orbem rediens circiter circularis, quæ omnia monſtrat annotina incrementa, extimo propemodum parallela. Fingamus jam talem ſectionem in tenuem laminam compreſſam, et veram habebimus ligni foſſilis, de quo heic agitur, ideam; nam in magnis hujus materiæ fruſtis, tranſverſim ſectis, quemlibet annotinorum orbium viſu perſequi licet, ita plerumque coactum, ut duas lineas fere parallelas exhibeat, quarum extrema brevi

ſtances under which they are found, are alſo ſimilar*. The whole, therefore, of the opinion in favour of fire, appears to reſt on the volcanic nature of Iceland; but it ſurely would be going too far were we to aſcribe to fire all the phænomena which are obſerved in volcanic countries.

Bovey coal, like the ſurturbrand, reſembles half-charred wood; and I will allow, and indeed am diſpoſed to believe, that it is in a ſtate nearly ſimilar; but from this it does not follow that fire has been the cauſe.

Carbon is known to be one of the grand principles of vegetables, and alſo as that which is the moſt fixed, excepting the ſmall portion of the earths contained in them. As a fixed principle, carbon appears to form, in great meaſure, the vegetable fibre; and after a certain degree of combuſtion, (by which the other principles have been diſſipated,) it remains, and the particles of it keep the ſame arrangement which they poſſeſſed when the vegetable was complete. If, however, the combuſtion has been carried on with the

brevi flexura ſunt adunata.—Quæ autem immanis requiritur vis, ut truncus cylindricus ita complanetur? Nonne antea particularum nexus putredinis quodam gradu fuerit relaxatus? Certe, niſi compages quodammodo mutatur, quodlibet pondus incumbens huic effectui erit impar. Cæterùm idem obſervatur phænomenon in omni ſchiſto argillaceo.

Orthoceratitæ, quæ in ſtrato calcareo conicam figuram perfectè ſervant, in ſchiſto planum fere triangulare compreſſione efficiunt. Idem valet de piſcibus, conchis, inſectiſque petrefactis. Cauſa adhuc latet, ſed in utroque caſu ſine dubio eadem eſt, et digna quæ exploretur. Obſervatu quoque dignum eſt, quod idem reperiatur effectus, quamvis ſtratum calcareum ſub ſchiſto collocatum ſit et majori ideo pondere comprimente onuſtum.——*Bergman de Productis Vulcaniis Opuſcula*, tom. iii. p. 239.

* "It is found (the ſurturbrand) in many parts of Iceland, generally in the mountains, in horizontal beds; ſometimes more than one is to be met with, as in the mountain of Lack in Bardeſtrand, where four ſtrata of ſurturbrand are found alternately with different kinds of ſtone."—*Troil's Letters*, p. 42.

free acceſs of air, the carbon enters into combination with oxygen and caloric, and forms carbonic acid.

We have many examples in which carbon is formed or rather liberated from thoſe ſubſtances with which it was combined in vegetables; and theſe are now explained as effects ſimilar to thoſe of combuſtion, although fire has not been the cauſe. In both caſes the carbon has been freed from the more volatile principles; and under circumſtances not favourable to the union of carbon with oxygen, the former muſt neceſſarily remain more or leſs undiminiſhed.

During the combuſtion of vegetable matter, the more volatile principles contained in the vegetable fibre (which with carbon alſo form the reſinous and other ſimilar ſubſtances) appear to be firſt ſeparated; and in proportion to this ſeparation, the other more fixed ſubſtance, which we call carbon, is developed.

Thus, by the progreſs of combuſtion, wood becomes brown, and afterwards black; ſo that the ſtate of the wood ſhews the degree of combuſtion to which it has been ſubjected, or, in other words, how far the ſeparation of the other principles from carbon has been effected.

Combuſtion is therefore a ſpecies of analyſis by which the principles of vegetables are ſeparated, according to their affinities, and according to their degree of volatility. By this operation hydrogen and azote (if it be preſent in the vegetable) are firſt diſengaged and form new combinations, while the carbon is the laſt which is acted upon; ſo that unleſs a ſufficient quantity of oxygen be preſent, it remains fixed and unchanged.

But the ſame ſeparation of the vegetable principles happens whenever vegetables in the full poſſeſſion of their juices are expoſed to circumſtances which favour the putrid fermentation.—As in

combuſtion,

combuſtion, ſo by the progreſs of putrefaction does the vegetable loſe its colour, become brown, and afterwards black; at the ſame time a gas is diſcharged, which is compoſed of hydrogen, azote, and carbonic acid.

When combuſtion is long continued with the free acceſs of air, the whole of the carbon is diſſipated in the ſtate of carbonic acid; but in the proceſs of putrefaction a conſiderable portion of carbon commonly remains even long after the putrid fermentation has ceaſed. Although, therefore, it is as readily developed by putrefaction as by combuſtion, it is not, however, when liberated from the other principles, ſo ſpeedily diſſipated by the former as by the latter proceſs.

According to the degree of combuſtion within certain limits the carbon is more or leſs apparent, and the like prevails according to the degree of putrefaction; ſo that whenever the cauſes which have promoted this ſpecies of fermentation have ceaſed, the vegetable ſubſtance will remain with more or leſs of its firſt principles, and with more or leſs viſible carbonic matter, according to the degree of putrefaction which has prevailed, and the vegetable ſubſtance will conſequently have the appearance and properties of wood which has been charred more or leſs.

To this cauſe, therefore, I am inclined to attribute the formation and appearance of the Bovey coal and ſurturbrand; and I believe that the portion of oily and bituminous matter, which I have obtained from them by diſtillation, is nothing more than the remainder of the vegetable oils and juices which have been partly modified by mineral agents*.

The

* "Coal not only forms the reſiduum of all vegetable ſubſtances that have undergone a ſlow and ſmothered combuſtion, that is, to which the free acceſs of air has been prevented,

The characters of bitumen are much more apparent in turf and peat, than in the greater part of the foſſil woods. Turf is well known to be compoſed of the parts of vegetables, ſuch as ſmall roots, twigs, &c. mixed with a portion of petroleum; and peat is the ſame, excepting that it generally contains more of earthy matter, or that the vegetables have undergone a more complete decompoſition.

The boggy nature of the places in which they are found, proves that a certain degree of maceration is neceſſary to form the bituminous matter which they contain; and I have already noticed, that every fact appears to demonſtrate, that the bitumen is a product of thoſe vegetables, the remains of which conſtitute the other ingredient of turf and peat.

The different proportion of vegetable matter, of bitumen, and of earth, together with the different ſtate of the bitumen, as well as the degree of perfection reſpecting the formation of it from the vegetable principles, contribute to alter the properties and characters of the compound, and thus produce varieties. It is believed that theſe ſubſtances have been materially concerned in the formation of pit-coal, and ſome eminent mineralogiſts maintain that there is an uninterrupted ſeries which connects the varieties of turf and peat with thoſe of coal*.

§ 6.

vented, but alſo of all putrid vegetable and animal bodies: hence it is found in vegetable and animal manures that have undergone putrefaction, and is the true baſis of their ameliorating powers; if the water that paſſes through a putrefying dunghill be examined, it will be found of a brown colour, and if ſubjected to evaporation, the principal part of the reſiduum will be found to conſiſt of coal. All ſoils ſteeped in water communicate the ſame colour to it in proportion to their fertility; and this water being evaporated, leaves alſo a coal, as Meſſrs. Haſſenfraz and Foureroy atteſt."—*Kirwan on Manures*, p. 154, Vol. v. of *The Tranſactions of the Royal Iriſh Academy.*

* Man findet in der natur einen ununterbrochenen übergang von dem raſen und papiertorf

§ 5.

LITTLE need be ſaid concerning thoſe mixtures of bitumen with metals or their oxides which are ſometimes called the bituminous ores of mercury, copper and iron, for they ſhould rather be arranged with the adulterated or impure bitumens. Few of them contain the metallic ingredient in a proportion ſufficient to cauſe the compound to be worked as an ore; and the only exception with which I am acquainted, is the ſubſtance found at Idria, in Carniola, compoſed of mercury mixed with bituminous matter, a quintal of which, according to Mr. de Born, affords from fifteen to twenty pounds of mercury *.

§ 6.

FROM the preceding obſervations it will appear, that although I have firſt mentioned naptha in order that I might be better underſtood in reſpect to the degree of connection prevailing between the bituminous ſubſtances, yet, to have followed them from their origin and the period of their formation, I ſhould rather have begun with thoſe ſubſtances which moſt clearly point out how much the vegetable kingdom has contributed to the production of them, with the probable occaſional concurrence of animal ſubſtances.

That the latter have contributed in ſome meaſure to the forming of bitumen, we can only infer from the veſtiges and exuviæ of animals, which ſo commonly accompany bituminous ſubſtances;

papiertorf durch den moor oder ſumpftorf in den pechtorf, und von dieſem in die braun ſchiefer und pechkohle.—*Widenmann*, p. 630.

* *Catalogue de la Collection des Foſſiles de Mlle. de Raab*, tom. ii. p. 294, 348, & 400.

but no doubt can be entertained in reſpect to vegetables, for it appears that bitumen is formed from them by long maceration, and by other proceſſes at preſent unknown to us:

That when certain portions of vegetable matter remain undecompoſed, and are mixed with the petroleum thus produced, the varieties of turf and peat are formed:

That wood in general contributes to the production of bitumen; but does not ſeem to retain it, after the formation of it, in ſo conſiderable a proportion as the foregoing ſubſtances:

That the bituminous matter thus formed, and occaſionally ſeparated, is in different ſtates according to the degree of inſpiſſation:

And laſtly, with various proportions of carbonic and earthy matter, it forms jet, coal, and bituminous ſchiſtus; and with metallic ſubſtances it produces thoſe compounds called bituminous ores.

§ 7.

ABOUT the year 1786 a new ſpecies of bitumen was diſcovered near Caſtleton, in Derbyſhire, which much reſembles, in elaſticity and colour, the ſubſtance known by the name of cahout-chou, or Indian rubber.

Mr. de Born was, I believe, the firſt who mentioned it*; but as he appears to have known only one variety of this ſingular ſubſtance, I am induced to hope that a deſcription of many other varieties, which have ſince been found, will not be unacceptable to this Society.

The elaſtic bitumen, which reſembles the cahout-chou, was firſt diſcovered in the cavities of a vein in the lead-mine called Odin, which is near the baſe of Mamtor, to the north of Caſtleton. The

* *Catalogue de la Collection de Mlle. de Raab*, tom. ii. p. 77.

ore

ore of this mine (which is ſuppoſed to be one of the moſt ancient in England) is galena, accompanied by fluor, calcareous and heavy ſpars, quartz, blende, calamine, ſelenite, aſphaltum, and the elaſtic bitumen, although the latter is now rarely found*. Another ſpecies of the elaſtic bitumen has within about three years been found in a neighbouring rivulet; but I ſhall not at preſent notice it, as I intend firſt to deſcribe the varieties of that which was firſt diſcovered, and which reſembles the cahout-chou. In order to do this with more perſpicuity, I ſhall deſcribe the ſpecimens belonging to my collection, according to the mode in which I have arranged them.

SPECIES THE FIRST.

A, No. 1.

ELASTIC bitumen of a yellowiſh brown colour, part of which is almoſt liquid like petroleum, and adheres to the fingers; the other part is of a darker colour, of a mammillary form, does not adhere to the fingers, and is ſoft and elaſtic. This is on a grey bituminous limeſtone, with white calcareous ſpar in the figure of hexaedral pyramids, forming that which is called the dog-tooth ſpar.

A, No. 2.

Bitumen of a yellowiſh brown, partly liquid, and partly elaſtic, which, however, adheres to the fingers; on pale grey limeſtone, with cryſtals of white fluor ſpar, blende, and galena.—On another part of the limeſtone are ſome globules of bitumen of a reddiſh brown, perfectly hard and brittle.

* I am indebted to the ingenious Mr. White Watſon, of Bakewell, for much information reſpecting the local circumſtances which attend this bitumen.

A, No. 3.

Dark brown bitumen of a ſtalactitical form, hard, but in ſome degree elaſtic.

A, No. 4.

Bitumen of a reddiſh brown, in the form of globules, ſome of which are elaſtic, and others hard: on browniſh-grey limeſtone, accompanied by cryſtallized white fluor, dogtooth calcareous ſpar, and pyrites in ſmall cryſtals, ſome of which are on the ſurface of the globules of bitumen.

A, No. 5.

The ſame of a darker brown, of a ſtalactitical form, hard and brittle; on pale brown calcareous ſpar, impregnated with bitumen.

A, No. 6.

Bitumen of a dark reddiſh brown, very hard; on pale brown ſparry ſtink-ſtone, with grey limeſtone, in which are ſome coralloides.

A, No. 7.

Bitumen of a dark yellowiſh brown, elaſtic, but very ſoft, ſo that it adheres to the fingers.

A, No. 8.

The ſame thinly ſpread over grey ſparry ſtink-ſtone.

A, No. 9.

Bitumen of a browniſh olive colour, which becomes reddiſh brown by the air, but when oppoſed to the light it appears ſemi-

tranſparent,

tranſparent, and of a yellowiſh brown inclining to orange. It is ſoft, very elaſtic, and (when recently cut) adheres to the fingers.

A, No. 10.

The ſame of a darker brown, and harder in a ſmall degree. The ſpecific gravity of this ſpecimen is 0,9053; water being eſtimated at 10,000 at temp. 60°.

A, No. 11.

Bitumen of a dark brown, harder than the former. This exactly reſembles the cahout-chou in the degree of elaſticity, and in the property which it poſſeſſes of removing the traces of black-lead.

A, No. 12.

The ſame, but rather harder.

A, No. 13.

The ſame of a blackiſh brown, which is ſlightly elaſtic when the weather is warm, but is brittle when cold.

A, No. 14.

The ſame of a blackiſh brown, nearly black, which ſcarcely poſſeſſes any elaſticity; it breaks, and reſembles aſphaltum in luſtre, colour and fracture.

A, No. 15.

The ſame of a reddiſh brown, perfectly hard and brittle. The characters of aſphaltum are complete in this ſpecimen.

The ſpecific gravity is 10,233.

The other ſpecies of elaſtic bitumen, which I ſhall diſtinguiſh by the

the letter B, has been found during the laſt three years in a rivulet which runs at the baſe of Mamtor, from Weſt to Eaſt, at a ſmall diſtance from Odin mine.—The varieties of it, in my poſſeſſion, are as follow:——

SPECIES THE SECOND.

B, No. 1.

ELASTIC bitumen, which, recently cut, exactly reſembles fine cloſe cork in colour and texture, but, by the air, in a few days it becomes of a pale reddiſh brown.—This forms a thin coat, which completely covers a maſs of elaſtic bitumen, which is ſoft, and of a browniſh olive colour, like A, No. 9.

B, No. 2.

The ſame, excepting that the coat or cruſt is much thicker.

B, No. 3.

The ſame, but the coating is thicker than that of No. 2, and the browniſh olive-coloured bitumen much leſs in quantity.

B, No. 4.

The ſame, excepting that the greater part of the maſs reſembles cork, ſo that only a very ſmall nucleus of the brown bitumen remains*.

B, No. 5.

The ſame, excepting that the bitumen, which is coated, is in the ſtate of aſphaltum.

The ſpecific gravity of this ſpecimen is 0,9881.

* One of the ſpecimens in my poſſeſſion, ſimilar to B, No. 4. weighs between 13 and 14 pounds.

B, No. 6.

B, No. 6.

Elaſtic bitumen, the whole maſs of which reſembles fine cork.—The ſpecific gravity is 0,9748.

B, No. 7.

The ſame, but friable, and apparently paſſing by decompoſition into an ochraceous coloured powder.

THE varieties of the firſt ſpecies of the elaſtic bitumen, or that which is like the cahout-chou, evidently appear to be formed from a naptha or petroleum, which, like that which produces the other ſimple bituminous ſubſtances formerly mentioned, is ſuſceptible of various degrees of inſpiſſation.

All the varieties of the firſt ſpecies, from No. 1, to No. 15, may be regarded as thus formed, for in theſe we can trace all the modifications comprehended between petroleum and aſphaltum; with this difference, that the intermediate modifications of this ſpecies have the remarkable property of elaſticity, which is the moſt complete in the variety which occupies the middle place between petroleum and aſphaltum.

The ſecond ſpecies B, or that which reſembles cork, appears ſo different from that marked A, that it is not at firſt eaſy to conceive how they are connected, or at leaſt the difficulty muſt appear great to thoſe who have only ſeen ſpecimens of each ſpecies complete in their reſpective characters. But, from an attentive examination of many ſpecimens, and particularly of thoſe which I have deſcribed, I am convinced that the varieties of the ſpecies B are only modifications of the ſpecies A, produced probably by long maceration in the water of the rivulet in which this ſpecies is found, to the effects of which we may, with ſome appearance of reaſon, add the

viciſſitudes

viciſſitudes of the ſeaſons, of air, and of the weather in general, as well as thoſe of reiterated moiſture and dryneſs occaſioned by the riſe and fall of the water of the rivulet; and what ſeems to corroborate this opinion is, that the ſubſtance, like cork, incruſts the ſpecies A, and appears to be only a change which has penetrated deeper into the ſubſtance of it in proportion to the duration of the cauſes which I have mentioned, ſo that at length the original ſubſtance no longer remains in its primitive ſtate. I do not believe, however, that this change ariſes from any alteration in the conſtituent principles, but merely from a partial and minute diſunion or diſintegration of the particles of the original ſubſtance, as both ſpecies melt into one which is perfectly ſimilar. I muſt alſo add, that the ſpecies A burns eaſily, and with rapidity; but the ſpecies B burns with ſome difficulty, and crackles as if it had imbibed a quantity of water.

I have remarked, when the different varieties of the elaſtic bitumen were melted, that they completely loſt the elaſtic property, and a quantity of air or gas appeared to be diſengaged, particularly from the ſpecies B. I alſo obſerved, that the ſubſtances which remained after this operation, correſponded, in reſpect to conſiſtence, with thoſe which had been employed, as the following Table will ſhew :——

A, No. 7 and 8. ...	produced a thick liquid petroleum, not apparently different from that which is commonly known.
A, No. 9.	produced a thicker petroleum, approaching to mineral tar.
A, No. 11 and 12.	produced mineral tar.
B, No. 6.	produced the ſame, approaching to mineral pitch.
A, No. 13.	produced mineral pitch.
A, No. 14 and 15.	did not ſuffer any change, but remained as at firſt, with all the characters of aſphaltum.

From what I have related, I ſuſpect that the elaſtic property is occaſioned by the interpoſition of very minute portions of air or ſome other elaſtic fluid between the parts of the bitumen, and that this takes place by reaſon of ſome unknown cauſe at the time of formation; but when theſe bitumens are melted, the elaſtic fluid is liberated, and the maſs loſes that fine ſpongy texture which I ſuſpect to have been the cauſe of the elaſtic property *.

Derbyſhire is well known as a country which exhibits, in the moſt ſtriking manner, the remarkable changes which our globe has ſuffered. In every part of it, the moſt indiſputable evidences appear of ſome great and extraordinary revolution; and there is not any place where extraneous foſſils, ſuch as the remains and impreſſions of vegetables and animals, are more abundant.

Bitumen, in other countries, is moſt commonly found where theſe preſent themſelves; and, in like manner, there are few countries which abound ſo much with bitumen as Derbyſhire.

Whoever has examined the limeſtone rocks about Matlock, and moſt other places in this county, muſt be convinced of the truth of this aſſertion.

The limeſtone and calcareous ſpars alſo, where the elaſtic bitumen is found, are, for the greater part, in the ſame ſtate; ſo that no doubt can be entertained but that this bitumen has had the ſame origin as thoſe which are more generally known; and it would

* The elaſtic bitumen, A, No. 9. when digeſted in ſulphuric ether in a temperature of about 55°, is partly diſſolved. The ſolution is yelloviſh brown when oppoſed to the light; but when otherwiſe viewed, is like the bitumen, that is, of a browniſh olive colour. By ſpontaneous evaporation, the etheric ſolution leaves a yelloviſh brown bitumen, which is totally devoid of elaſticity. The undiſſolved portion (like the cahout-chou under ſimilar circumſtances) is ſoftened, and is much increaſed in bulk.

The ſpecies B, No. 6. cut into very thin ſlices, communicates a yellow tinge to ſulphuric ether; in other reſpects it is but little affected.

undoubtedly have been confounded with them, had it not been diſcovered when paſſing from the liquid to the ſolid ſtate.

The elementary principles of bitumen are, hydrogen, carbon, ſometimes azote, and probably ſome oxygen, which, by its action on the other principles, tends to form the concrete bitumens, nd alſo produces that portion of acid obtained by chemical operations. Theſe ſame principles, hydrogen and carbon, conſtitute the vegetable oils and reſins; and the ſame, with ſome azote, form the oils and greaſe of animals. Now it is known that very ſmall changes in the reſpective proportions of theſe ingredients, and in the circumſtances which attend the combination of them, will cauſe conſiderable variations in the nature of the products; and in like manner, it appears very probable, that when the organized bodies in their recent ſtate, and in the full poſſeſſion of the above-mentioned principles, have been buried in a ſituation where theſe principles have been long elaborated under certain favourable circumſtances, and ſubjected to the action of mineral bodies; I ſay that it appears highly probable, that a new combination, which we call bitumen, may be formed, which, although different in ſome reſpects from the vegetable and animal products, ſtill, however, retains many characters of thoſe ſubſtances from the principles of which it has been formed.

HAMMERSMITH,
April 26, 1797.