XV. *Observations on the Change of some of the proximate Principles of Vegetables into Bitumen; with analytical Experiments on a peculiar Substance which is found with the Bovey Coal.* *By* Charles Hatchett, *Esq. F. R. S.*

Read June 14, 1804.

§ I.

One of the most instructive and important parts of geology, is the study of the spontaneous alterations by which bodies formerly appertaining to the organized kingdoms of nature have, after the loss of the vital principle, become gradually converted into fossil substances.

In some cases, this conversion has been so complete, as to destroy all traces of previous organic arrangement; but, in others, the original texture and form have been more or less preserved, although the substances retaining this texture, and exhibiting these forms, are often decidedly of a mineral nature. Some, however, of these extraneous fossils (as they are called) retain part of their original substance or principles, whilst others can only be regarded as casts or impressions.

From the animal kingdom we may select, as examples, the fossil ivory, which retains its cartilage;* the bones in the Gibraltar rock, consisting of little more than the earthy part or

* I have also found the cartilage perfect, in the teeth of the mammoth.

phosphate of lime; the shells forming the lumachella of Bleyberg, which still possess the lustre and iridescence of their original nacre; and the shells found at Hordwell in Hampshire, and in Picardy, which are chiefly porcellaneous, but more or less calcined; also the fossil echini and others, so commonly found in the limestone, chalk, and calcareous grit of this island, which, although they retain their original figure, are intirely, or at least externally, formed of calcareous spar, incrusting a nucleus of flint or chalcedony. And if, in addition to these, we may be allowed to regard the more recent limestone and chalk strata as having been principally or partly formed from the detritus of animal exuviæ, we shall possess a complete series of gradations, commencing with animal substances analogous in properties to those which are recent, and terminating in bodies decidedly mineral, in which all vestiges of organization have been completely destroyed.

The vegetable kingdom has likewise produced many instances not less remarkable; and it is worthy of notice, that animal petrifactions are commonly of a calcareous nature, while, on the contrary, the vegetable petrifactions are generally siliceous;*

It is not, however, my intention here to enter into a minute discussion concerning the formation of these extraneous fossils; I shall therefore proceed to consider other equally or perhaps more important changes, which organized bodies, especially vegetables, appear to have suffered, (after the extinction of the principle of life,) by being long buried in earthy strata, and by being thus exposed to the effects of mineral agents.

* Pyrites, ochraceous iron ore, and fahlertz, are also occasionally found in the forms of vegetable bodies.

§ II.

The principal object I have in view, is to adduce some additional proofs, that the bituminous substances are derived from the organized kingdoms of nature, and especially from vegetable bodies; for, although many circumstances seem to lead to the opinion, that the animal kingdom has in some measure contributed to the partial formation of bitumen, yet the proofs are by no means so numerous, nor so positive, as those which indicate the vegetable kingdom to have been the grand source from which the bitumens have been derived. But this opinion, (founded upon very strong presumptive evidence,) although generally adopted, is however questioned by some persons; and I shall therefore bring forward a few additional facts, which will, I flatter myself, contribute to demonstrate, that bitumen has been, and is actually and immediately formed, from the resin, and perhaps from some of the other juices of vegetables.

The chemical characters of the pure or unmixed bitumens, such as naptha, petroleum, mineral tar, and asphaltum, are, in certain respects, so different from those of the resins and other inspissated juices of recent vegetables, that, had the former never occurred but in a separate and unmixed state, no positive inference could have been drawn from their properties, in proof of their vegetable origin. Fortunately, however, they have been more frequently found under circumstances which have strongly indicated the source from whence they have been derived; and much information has been acquired from observations made

on the varieties of turf, bituminous wood, and pit coal, on the nature of their surrounding strata, on the vestiges of animal and vegetable bodies which accompany them, and on various other local facts; all of which tend considerably to elucidate the history of their formation, and to throw light upon this interesting part of geology.

Some instances have already been mentioned, which show that fossil animal substances form a series, commencing with such as are scarcely different from those which are recent, and terminating in productions which have totally lost all traces of organization.

Similar instances are afforded by the vegetable kingdom; but, without entering into a minute detail of every gradation, I shall only cite three examples in this island, namely,

1. The submarine forest at Sutton, on the coast of Lincolnshire, the timber of which has not suffered any very apparent change in its vegetable characters.*

2. The strata of bituminous wood (called Bovey Coal) found at Bovey, in Devon; which exhibits a series of gradations, from the most perfect ligneous texture, to a substance nearly approaching the characters of pit coal, and, on that account, distinguished by the name of Stone Coal.

3. And lastly, the varieties of pit coal, so abundant in many parts of this country, in which almost every appearance of vegetable origin has been destroyed.

The three examples abovementioned, appear to form the extremities and centre of the series; but as, from some local

* Account of a submarine Forest on the East Coast of England, by Dr. CORREA de SERRA. Phil. Trans. for 1799, p. 145.

circumstances, the process of carbonization, and formation of bitumen, has not taken place in the first instance, and as these effects have proceeded to the ultimate degree in the last, it seems most proper that we should seek for information, and for positive evidence, in the second example, which appears to be the mean point, exhibiting effects of natural operations, by which bitumen and coal have been imperfectly and partially formed, without the absolute obliteration of the original vegetable characters; and, although I have selected the Bovey coal as an example, because it is found in this country, we must recollect that similar substances, or strata of bituminous wood, are found in many parts of our globe; so that the example which has been more immediately chosen, is neither rare nor partial.*

The nature, however, of the various kinds of bituminous wood, may in some respects be different; but this I have not as yet had the means of ascertaining; I shall therefore only state the facts resulting from experiments made on Bovey coal, and more especially on a peculiar bituminous substance with which it is accompanied. But, before I enter into these particulars, it will be proper to mention a very remarkable schistus, with which I was, some months since, favoured by the Right Hon. Sir JOSEPH BANKS.

* Strata of bituminous wood are found in various parts of France, in the vicinity of Cologne, in Hesse, Bohemia, Saxony, Italy, and especially in Iceland, where it is known under the name of Surturbrand.

§ III.

This schistus was found by Sir JOSEPH, in the course of his tour through Iceland, near Reykum, one of the great spouting hot springs, distant about twenty-four English miles from Hafnifiord; but circumstances did not permit him to ascertain the extent of the stratum.

The singularity of this substance is, that a great part of it consists of leaves, which are evidently those of the alder, interposed between the different lamellæ. I do not mean mere impressions of leaves, such as are frequently found in many of the slates, but the real substance, in an apparently half charred state, retaining distinctly the form of the leaves, and the arrangement of the fibres.

The schistus is light, brittle, of easy exfoliation, in the transverse fracture earthy, and of a pale brown colour; but, when longitudinally divided, the whole surface constantly presents a series of the leaves which have been mentioned, uniformly spread, and commonly of a light gray on the upper surface, and of a dark brown on the other; the fibres on the light gray surface being generally of a blackish-brown, which is also the colour assumed by the schistus when reduced to powder.

The leaves appeared to be in the state of charcoal, by being extremely brittle, by the blackish brown colour, by deflagrating with nitre, by the manner of burning, and by forming carbonic acid. I was, however, soon convinced that the substance of these leaves was not complete charcoal, but might more properly be regarded as vegetable matter in an incipient state of carbonization, which, although possessed of many of the

apparent properties of charcoal, still retained a small portion of some of the other principles of the original vegetable.

My suspicion was excited, partly by the odour produced during combustion, which rather more resembled that of wood than that of charcoal, and partly by the brown solution formed by digesting the powder of the unburned schistus in boiling distilled water; for, by various tests I ascertained, that the substance thus dissolved was not of a mineral nature. In order, however, fully to satisfy myself in this respect, I digested 250 grains of the pulverized schistus with six ounces of water.

The liquor was, as before, of a dark brown colour.

It had but little flavour.

Prussiate of potash, muriate of barytes, and solution of isinglass, did not produce any effect; nitrate of silver formed a very faint cloud; sulphate of iron was slowly precipitated, of a dark brownish colour; and muriate of tin produced a white precipitate.

A portion of the solution, by long exposure to the air, was partially decomposed; and a quantity of a brown substance was deposited, which could not again be dissolved in water.

Another portion was also evaporated to dryness, and afforded a similar brown substance, which was only partially soluble in water; and the residuum, in both of the above cases, was found to be insoluble in alcohol, and in ether.

When burned, it emitted smoke, with the odour of vegetable matter.

250 grains of the schistus, afforded about three grains of the above substance; and, when the properties of the aqueous solution are considered, such as its partial decomposition, and the deposit which it yielded by exposure to air, and by evapora-

tion; the insolubility of this deposit when again digested with water, alcohol, or ether; the smoke and odour which it yielded when burned; and the precipitates formed by the addition of sulphate of iron and muriate of tin to its solution; when these properties, I say, are considered, there seems much reason to conclude, that the substance dissolved by water was vegetable extract, which had apparently suffered some degree of modification, but not sufficient to annul the more prominent characteristic properties of that substance.

The powder of the schistus, which had been employed in the preceding experiment, was afterwards digested in alcohol during two days; and a pale yellow tincture was thus formed, which, by evaporation, left about one grain of a yellow transparent substance, possessing the properties of resin.

It appears, therefore, that a substance very analogous to vegetable extract, and a small portion of resin, remain inherent in the leaves of this remarkable schistus.

As solution of isinglass did not produce any effect, there was reason to conclude, that the aqueous solution above-mentioned did not contain any tannin; but, as the tannin might be combined with the alumina of the schistus, I digested a portion of it in muriatic acid, which, after filtration, was evaporated almost to dryness, leaving, however, the acid in a slight excess. This was diluted with water; and afforded a blue precipitate with prussiate of potash, a yellowish precipitate with ammonia, and a white precipitate with muriate of tin, but not any with solution of isinglass. The tannin which might have been contained in the recent vegetable, appears therefore to have been dissipated or decomposed, with the greater part of the other vegetable principles, excepting the woody fibre reduced to the state of an imperfect

coal, and the small portions of extract and resin which have been mentioned.

Previous to having made the analysis, I had an idea, that this schistus might be a lamellated incrustation, formed by the tufa of the hot springs; but, according to Mr. KLAPROTH's analysis,* the tufa of Geyser is composed of,

Silica - -	98
Alumina - -	1.50
Iron - -	.50
	100.

It is therefore very different from the schistus, the component ingredients of which were ascertained by the following analysis.

ANALYSIS OF THE SCHISTUS FROM ICELAND.†

A. 250 grains, by distillation, yielded water, which, in the latter part of the process, became slightly acid and turbid, = 42.50 grains.

B. The heat was gradually increased, until the bulb of the retort was completely red-hot. During the increase of the heat, a thick brown oily bitumen came over, which weighed 7.50 grains; it was attended with a copious production of hydrogen, carbonated hydrogen, and carbonic acid, the whole of which may be estimated at 23.75 grains.

C. The residuum was black, like charcoal, and weighed 176.25 grains; but, being exposed to a strong red heat in a crucible of platina, it burned with a faint lambent flame, and was at length reduced to a pale brown earthy powder, which weighed 122 grains; so that 54.25 grains were consumed.

* *Beiträge; Zweiter band*, p. 109.

† The remaining specimens are now in the British Museum, and in the collection of the Right Honourable CHARLES GREVILLE.

D. The 122 grains were mixed with 240 of pure potash; and, as some particles of charcoal remained, 50 grains of nitre were added, and the whole was strongly heated, during half an hour, in a silver crucible. The mass was then dissolved in distilled water, and, muriatic acid being added to excess, the liquor was evaporated to dryness, and was again digested with muriatic acid much diluted; a quantity of pure silica then remained, which, after having been exposed to a red heat, weighed 98 grains.

E. The liquor from which the silica had been separated, was evaporated nearly to dryness, and added to boiling lixivium of potash; after the boiling had been continued for about one hour, the liquor was filtrated, and a quantity of oxide of iron was collected, which amounted to 6 grains.

F. Solution of muriate of ammonia was added to the preceding filtrated liquor; and, the whole being then heated, a copious precipitate of alumina was obtained, which, after having been made red-hot, weighed 15 grains.

Carbonate of soda caused the preceding liquor (after the separation of alumina) to become slightly turbid, but not any precipitate could be collected.

By this analysis, 250 grains of the schistus afforded,

		Grains.
Water	A.	42.50
Thick brown oily bitumen	B.	7.50
Mixed gas (by computation)	B.	23.75
Charcoal (by computation)	C.	54.25
Silica	D.	98
Oxide of iron	E.	6
Alumina	F.	15
		247.

But the water and vegetable matter must be regarded as extraneous; and, if they are deducted, the real composition of the schistus is nearly as follows.

Silica - - - -	82.30
Alumina - - -	12.61
Oxide of iron - - -	5
	99.91.

It evidently, therefore, belongs to the family of argillaceous schistus, although the proportion of silica is more considerable than has been found in those hitherto subjected to chemical analysis.

This schistus has not been noticed by von TROIL, nor by any of those who have written concerning Iceland; for the slate which was sent to Professor BERGMANN by the former, and which is mentioned by the latter in one of his letters, is there expressly stated to be the common aluminous slate containing impressions.*

§ IV.

From the experiments which have been related, we find that the leaves contained in the Iceland schistus, although they are apparently reduced almost to the state of charcoal, nevertheless retain some part of their original proximate principles, namely, extract and resin. This, of itself, is undoubtedly a remarkable

* Letters on Iceland, by UNO von TROIL, p. 355.

Mr. FAUJAS ST. FOND has however described a schistus nearly similar, which is found near Roche-Seauve, in the Vivarais. The stratum extends about two leagues; and the only difference is, that, according to Mr. ST. FOND, the schistus at Roche-Seauve is of the nature of marle, or, as he terms it, argillo-calcareous, whereas this of Iceland is undoubtedly argillaceous. From Mr. ST. FOND's account, it does not appear that the vegetable leaves contained in the schistus of Roche-Seauve have been chemically examined. *Essai de Geologie,* par B. FAUJAS ST. FOND, Tome I. pp. 128 and 134.

fact; but, if it were unsupported by any other, the only inference would be, that the schistus was most probably of very recent formation, and had been produced under peculiar circumstances.

I was desirous, therefore, to discover some similar cases, which might serve as additional corroborative proofs of the gradual alterations by which vegetable bodies become changed, so as at length to be regarded as forming part of the mineral kingdom; and, from the reasons which have been stated in the commencement of this Paper, as well as from a certain similarity in the external characters of the substance composing the leaves above-mentioned with those of the Bovey coal, I was induced to make this last also a subject of chemical inquiry.

In the Philosophical Transactions for the year 1760,* some remarks on the Bovey coal, and an account of the strata, are stated, in a letter from the Rev. Dr. MILLES to the Earl of MACCLESFIELD. The object, indeed, of the author, was to establish that this and similar substances are not of vegetable, but of mineral origin; and, to prove this, he adduces a great number of cases, most of which, however, in the present state of natural history and of chemistry, must be regarded as proving the contrary; whilst others, mentioned by him, such as the Kimmeridge or Kimendge coal, are nothing more than bituminous slates, and of course are of a very different nature.

Dr. MILLES's account of the varieties of the Bovey coal, and of the state of the pits at that time, appears to be very accurate; and, for the present state, or at least such as it was in 1796, I shall beg leave to refer to a Paper of mine, published in the fourth volume of the Transactions of the Linnean Society;†

* Vol. LI. p. 534. † Observations on bituminous Substances, p. 138. See also PARKINSON's Organic Remains of a former World, Vol. I. p. 126.

for, as this is more immediately a chemical investigation, I wish to avoid, as much as possible, entering into any minute detail of geological circumstances.

It may however be proper to observe, that the Bovey coal is found in strata, corresponding in almost every particular with those of the surturbrand in Iceland, described by von TROIL,* and by Professor BERGMANN.† The different strata of both these substances are likewise similar, being composed of wood or trunks of trees, which have completely lost their cylindrical form, and are perfectly flattened, as if they had been subjected to an immense degree of pressure.‡

* Von TROIL's Letters, p. 42.

† *Opuscula* BERGMANNI, Tom. III. *De Productis Volcaniis*, p. 239.

‡ BERGMANN, in the dissertation above quoted, accurately describes this appearance of the surturbrand, and then says, "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. Ceterùm idem observatur phænomenon "*in omni schisto argillaceo.*" This is certainly a very curious fact; and the learned Professor, with his usual acuteness, rejects the idea that mere weight can have been the cause. As a farther proof also, he afterwards observes, "Orthoceratitæ, quæ *in strato "calcareo conicam figuram perfectè servant*, in schisto *planum fere triangulare com-"pressione efficiunt.* Idem valet de piscibus, conchis, insectisque petrefactis." And again, "Observatu quoque dignum est, quod *idem reperiatur effectus, quamvis "stratum calcareum sub schisto collocatum sit, et majori ideo pondere comprimente "onustum.*" *De Productis Volcaniis*, p. 240. It is evident, therefore, that weight alone has not produced this effect; and BERGMANN's idea, that the solidity of the vegetable bodies may have undergone some previous change, in the manner of incipient putrefaction, by moisture, and by becoming heated in the mass, must be allowed to be very probable. But bodies such as shells could not be thus affected; and therefore they must have been exposed to some mechanical effect, peculiar to argillaceous strata; which effect, however, from the circumstances which have been adduced, evidently could not have resulted from the mere pressure of the superincumbent strata. To me, therefore, it seems not very improbable that, together with a certain change in the

The Bovey coal is commonly of a chocolate-brown, and sometimes almost black. The quality and texture of it are various in different strata; from some of these, it is obtained in the form of straight flat pieces, three or four feet in length, resembling boards, and is therefore called Board Coal. Others have an oblique, wavy, and undulating texture, and, as Dr. MILLES observes, have a strong resemblance to the roots of trees, from which, most probably, this sort has in a great measure been formed.

Some kinds also appear to be more or less intermixed with earth; but that which produces the most powerful and lasting fire, is called stone coal; it is black, with a glossy fracture; has little or none of the vegetable texture; is more solid and compact than the others, being almost as heavy as some of the pit coals, the nature of which it seems very nearly to approach.

For chemical examination, I selected some of the coal which had a wavy texture, and rather a glossy fracture; the quality of this sort being apparently intermediate between the others, as it retains completely the marks of its vegetable origin, while, at the same time, it possesses every perfect character of this species of coal.

solidity of vegetable bodies, produced in the manner imagined by BERGMANN, and, together with some degree of superincumbent pressure, a real and powerful mechanical action has been exerted, by the contraction of the argillaceous strata, in consequence of desiccation; this, I believe, has not hitherto been much considered, but I am inclined, from many circumstances, to attribute to it a very great degree of power.

A. 200 grains of the Bovey coal, by distillation, yielded,	Grains.
1. Water, which soon came over acid, and afterwards turbid, by the mixture of some bitumen - -	60
2. Thick brown oily bitumen - - - - -	21
3. Charcoal - - - - - - -	90
4. Mixed gas, consisting of hydrogen, carbonated hydrogen, and carbonic acid, estimated at	29
	200.

The charcoal, in appearance, perfectly resembled that which is made from recent vegetables. By incineration, about 4 grains of yellowish ashes were left, which consisted of alumina, iron, and silica, derived most probably from some small portion of the clay strata which accompany the Bovey coal. But it is very remarkable, that neither the ashes obtained from the charcoal of the Bovey coal, nor those obtained from the leaves of the Iceland schistus, afforded the smallest trace of alkali.*

B. 200 grains of the Bovey coal, reduced to powder, were digested in boiling distilled water, which was afterwards filtrated, and examined; but I could not discover any signs of extract, or of any other substance.

C. 200 grains were next digested with six ounces of alcohol, in a very low degree of heat, during five days. A yellowish-brown tincture was thus formed, which, by evaporation, afforded a deep brown substance, possessing all the properties of resin, being insoluble in water, but soluble in alcohol, and in ether; it

* This, as far as relates to the Bovey coal, has been also noticed by Dr. Milles. Phil. Trans. Vol. LI. p. 553. But wood, however long submerged, is not deprived of alkali, unless it has more or less been converted into coal; for I have, since the reading of this Paper, made some experiments on the wood of the submerged forest at Sutton, on the coast of Lincolnshire, and have found it to contain potash.

also speedily melted, when placed on a red-hot iron, burned with much flame, and emitted a fragrant odour, totally unlike the very unpleasant smell produced by burning the coal itself, or by burning any of the common bituminous substances. The quantity, however, which could be extracted from 200 grains of the coal, by alcohol, was but small, as it did not exceed 3 grains. But this small quantity was sufficient to prove, that although the Bovey coal does not contain any vegetable extract, like the schistus formerly mentioned, yet the whole of the proximate principles of the original vegetable have not been entirely changed; as a small portion of true resin, not converted into bitumen, still remains inherent in the coal, although the bituminous part is by much the most prevalent, and causes the fetid odour which attends the combustion of this substance.

Upon a comparison of the general external characters of the Bovey coal, with those of the substance which forms the leaves contained in the Iceland schistus, a very great resemblance will be observed; and this is farther confirmed, by the similarity of the products obtained from each of them in the preceding experiments, with the single exception, that the leaves contain some vegetable extract, which I could not discover in the Bovey coal. They agree however in every other respect; as they both consist of woody fibre in a state of semicarbonization, impregnated with bitumen, and a small portion of resin, perfectly similar to that which is contained in many recent vegetable bodies; and thus it seems, that as the woody fibre, in these cases, still retains some part of its vegetable characters, and is but partially and imperfectly converted into coal, so, in like manner, some of the other vegetable principles have only suffered a partial change. Undoubtedly, there is every reason to believe

that, next to the woody fibre, resin is the substance which, in vegetables passing to the fossil state, most powerfully resists any alteration; and that, when this is at length effected, it is more immediately the substance from which bitumen is produced. The instances which have been mentioned corroborate this opinion; for the vegetable extract in one of them, and more especially the resin which was discovered in both, must be regarded as part of those principles of the original vegetables which have remained, after some other portions of the same have been modified into bitumen.

The smallness of the quantity of resin obtained in both the preceding cases, by no means invalidates the proof of the above opinion; but, as an additional confirmation of it, I shall now give an account of a very singular substance, which is found with the Bovey coal.

§ V.

Dr. MILLES, in his remarks on the Bovey coal, (which I have several times had occasion to notice in the course of this Paper,) states, that "amongst the clay, but adhering to the coal, are "found lumps of a bright yellow *loam*, extremely light, and so "saturated with petroleum, that they burn like sealing wax, "emitting a very agreeable and aromatic scent."*

This substance, I also observed, when I visited the Bovey coal-pits, in 1794 and 1796. At that time, however, it was scarce, and I could only procure one small specimen, which is now in the British Museum; but, from a cursory examination of it, I was convinced that it was a peculiar bituminous substance, and not loam impregnated with petroleum, as Dr. MILLES had supposed. I could not then conveniently make a regular analysis

* Phil. Trans. Vol. LI. p. 536.

of it, and therefore contented myself with briefly describing it, in a note annexed to my Paper on bituminous Substances.*

Lately, however, my friend JOHN SHELDON, Esq. of Exeter, F. R. S. obligingly sent me several pieces of it, together with specimens of the different kinds of Bovey coal which have been mentioned; and thus I was enabled fully to ascertain its real nature and properties.

DESCRIPTION OF THE BITUMEN FROM BOVEY.

It accompanies the Bovey coal, in the manner already described, and is found in masses of a moderate size.

The colour is pale brownish ochraceous yellow.

The fracture is imperfectly conchoidal.

It appears earthy externally, but, when broken, exhibits a slight degree of vitreous lustre.

The fragments are irregularly angular, and completely opaque at the edges.

It is extremely brittle.

It does not apparently become softened, when held for some time in the hand, but emits a faint resinous odour.

The specific gravity, at temperature 65° of FAHRENHEIT, is 1,135.

Some specimens have dark spots, slightly approaching in colour and lustre to asphaltum; and small portions of the Bovey coal are commonly interspersed in the larger masses of this bitumen.

When placed on a heated iron, it immediately melts, smokes much, burns with a bright flame, and yields a very fragrant odour, like some of the sweet-scented resins, but which at last becomes slightly tainted with that of asphaltum.

* Transactions of the LINNEAN Society, Vol. IV. p. 139.

The melted mass, when cold, is black, very brittle, and breaks with a glossy fracture.

EXPERIMENTS.

A. 100 grains of this bitumen, when distilled until the bulb of the retort became red-hot, afforded, Grains.

1. Water slightly acid - - - - 3
2. Thick brown oily bitumen, very similar to that which was obtained from the Bovey coal, but possessing slightly the odour of vegetable tar - - 45
3. Light spongy coal - - - - 23
4. Mixed gas, composed of hydrogen, carbonated hydrogen, and carbonic acid, (by computation,) - 29.

The coal yielded about three grains and a half of ashes, which consisted of alumina, iron, and silica, with a trace of lime.

B. The bitumen was not affected by being long digested in boiling distilled water.

C. By digesting 100 grains in lixivium of pure potash, a brown solution was formed; this was saturated with muriatic acid, and a brown resinous precipitate was obtained, which weighed 21 grains.

D. A portion was digested in nitric acid: at first, much nitrous gas was evolved, and, after the digestion had been continued for nearly 48 hours, a part was dissolved, and formed an orange-coloured solution, which did not yield any precipitate, when saturated by the alkalis, or by lime; the colour only became more deep, and, by evaporation, a yellow viscid substance was obtained, which was soluble in water. The above nitric solution possessed every property of those nitric solutions of resinous substances which I have mentioned in a former Paper.*

* Phil. Trans. for 1804, p. 198.

E. The benzoic and succinic acids were not obtained from this substance, by any of the methods usually employed.

F. Alcohol almost immediately began to act upon this bitumen; and, being added at different times, gradually dissolved a considerable part of it. The solution was reddish-brown, and had a resinous odour; by the addition of water it became milky, and, by evaporation, afforded a dark brown substance, which had every property of resin, whilst the residuum left by the alcohol possessed those properties which characterize asphaltum.

The following analysis was then made, to discover the proportions of the component ingredients.

ANALYSIS OF THE BITUMEN FROM BOVEY.

A. 100 grains, reduced to a fine powder, were digested during 48 hours with six ounces of alcohol, the vessel being placed in sand moderately warmed. A deep reddish-brown tincture was thus obtained; and the operation was again twice repeated, with other portions of the same menstruum, until it ceased to act upon the residuum.

The whole of the spirituous solution (which had been cautiously decanted) was then subjected to a very gradual distillation in an alembic, and yielded a brown fragrant resin, which weighed 55 grains.

B. The residuum, which could not be dissolved by alcohol, was digested in boiling distilled water, but this did not act upon it; the whole was therefore collected on a filter, was gradually dried, without heat, by mere exposure to the air, and then weighed 44 grains.

These 44 grains consisted of a light, porous, pale-brown substance, which, being melted, formed a black, shining, brittle mass. It burned with the odour of asphaltum, but rather less

disagreeable, owing most probably to a small portion of the resin, which had not been completely extracted by the alcohol. It was insoluble in water, and in alcohol, but was readily dissolved by heated fat oils; and in every other particular was found to possess the properties of asphaltum.

The 44 grains of asphaltum, when burned, left a residuum, which weighed 3 grains, and consisted of alumina, silica, and iron.

By this analysis it appears, that the bitumen which accompanies the Bovey coal, is a peculiar and hitherto unknown substance, which is partly in the state of vegetable resin, and partly in that of the bitumen called Asphaltum, the resin being in the largest proportion, as 100 grains of the abovementioned substance afforded, - Resin - 55

	Asphaltum -	41
	Earthy residuum	3
		99.

Thus we have an instance of a substance being found under circumstances which constitute a fossil, although the characters of it appertain partly to the vegetable, and partly to the mineral kingdom.

§ VI.

The powerful action which alcohol exerts on most of the resins, may justly be regarded as forming a marked distinction between those substances and the bitumens. But, as some of the bitumens are acted upon by alcohol, in a slight degree, I was desirous to ascertain whether a small portion of resin was contained in any of these; or, if that was not the case, I wished to determine the nature of the substance which could be separated, although very sparingly, by this menstruum. I therefore made the following comparative experiments, on the soft brown

elastic bitumen from Derbyshire; on the genuine asphaltum; on very pure cannel coal; and on the common pit coal.

100 grains of each were digested with three ounces of alcohol, in matrasses placed in warm sand, during five days, some alcohol being occasionally added, to supply the loss caused by evaporation. After the abovementioned period had elapsed, the liquid contained in each matrass was poured into separate vessels.

I. The alcohol which had been digested on the elastic bitumen was not tinged, nor, when spontaneously evaporated, did it leave any film or stain on the glass.

II. From asphaltum, the alcohol had extracted a yellow tincture, which, in some situations, appeared of a pale olive colour, and, being spontaneously evaporated, a thick brown liquid was deposited, in small drops, on the glass; these drops did not become hard after two months, and possessed the odour, and every other property, of petroleum. The asphaltum had lost in weight about one grain and a half.

III. The cannel coal had communicated a pale yellow tint to the alcohol, which, in the manner above described, was ascertained to be caused by petroleum; but, from the smallness of the quantity, the weight could not be determined.

IV. The alcohol which had been digested on pit coal, had not assumed any colour; but, by spontaneous evaporation,* it left a film on the glass, which, by its odour, was also found to be petroleum.

By these experiments we find, that the action of alcohol on the bitumens is very slight; and that the small portion which

* Spontaneous evaporation, by exposure to the air, was employed in these experiments, for reasons which must be sufficiently obvious.

may thus be extracted from some of them, is petroleum. In these, the process of bituminization (if I may be allowed to employ such a term) appears to have been completed, whilst in the Bovey coal, and especially in the substance which accompanies it, nature seems to have performed only the half of her work, and, from some unknown cause, to have stopped in the middle of her operations. But, by this circumstance, much light is thrown on the history of bituminous substances; and the opinion, that they owe their origin to the organized kingdoms of nature, especially to that of vegetables, which hitherto has been supported only by presumptive proofs, seems now, in a great measure, to be confirmed, although the causes which operate these changes on vegetable bodies are as yet undiscovered.

Many facts indicate, that time alone does not reduce animal or vegetable bodies to the state of fossils. In this country, there are numerous examples of large quantities of timber, (even whole forests,) which have been submerged prior to any tradition, and which nevertheless completely retain their ligneous characters.* Other local causes and agents must therefore have been required, to form the varieties of coal and other bituminous substances. In some instances, (as in the formation of Bovey coal,) these causes seem to have acted partially and imperfectly, whilst, in the formation of the greater part of the pit coals, their operation has been extensive and complete.

In the pit coals, the mineral characters predominate, and the principal vestige of their real origin seems to be bitumen; for the presence of carbon in the state of oxide, cannot alone be considered as decisive.

* Phil. Trans. for January, 1671. Phil. Trans. Vol. XIX. p. 526. Ibid. Vol. XXII. p. 980. Ibid. Vol. XXIII. p. 1073. Ibid. Vol. XXVII. p. 298. Ibid. for 1799, p. 145.

Bitumen, therefore, with the exuviæ and impressions so commonly found in the accompanying strata, must be more immediately regarded as the proofs, in favour of the origin of pit coal from organized bodies; and, considering the general facts which have been long observed, together with those lately adduced respecting the Bovey coal, and the substance which is found with it, we seem now to have almost unquestionable evidence, that bitumen has essentially been produced by the modification of some of the proximate principles of vegetables, and especially resin.

Modern chemistry had comparatively made but a small progress, when the illustrious BERGMANN published his Dissertation entitled *Producta Ignis subterranei chemice considerata;* for, at that time, the extent and power of chemical action, in the humid way, were very imperfectly understood. In that part, however, of the above work, where he speaks of the fossil wood of Iceland, called Surturbrand, he evidently appears doubtful how far volcanic fire may have acted upon it; although he conceives that, in the formation of it, there has been some connection with volcanic operations. His words are, "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 hucusque "modum ignoremus, quo situm texturamque adquisiverunt "hæc strata." It certainly was very natural that BERGMANN should entertain this opinion, in respect to the surturbrand; and it is remarkable, that the leaves contained in the schistus lately described, are of the same nature, and are found in the same country. The leaves also described by Mr. ST. FOND, are likewise found in a country which, according to him, was formerly volcanic. Were these substances, therefore, never found

but in countries which either actually are or were volcanic, we should be almost compelled to believe, with the Swedish Professor, that the operations of subterraneous fires have been concerned in the formation of these bodies, or rather in the conversion of them into their present state.

But similar substances are found in countries where not the smallest vestige of volcanic effects can be discovered, and Devonshire most undoubtedly is such; yet, nevertheless, the Bovey coal is there found similar to the surturbrand, in most of the external, and (from experiments which I made some years ago, I believe I may say) chemical properties; to which must be added, that both these substances perfectly resemble each other, by forming regular strata.*

Moreover, the half charred appearance of Bovey coal, and of surturbrand, cannot be adduced as any proof, that the original vegetable bodies have been exposed to the partial effects of subterraneous fire; for, at this time, we know that the oxidizement of substances is performed, at least as frequently, and as effectually, by the humid as by the dry way. It would therefore be superfluous here, to enter into an elaborate discussion, to prove that coal and bitumen, with much greater probability, have been formed without the intervention of fire; and I am the less inclined to say more upon this subject, as I have already published some considerations on it in a former Paper.†

Before I conclude, I must beg leave to observe, that as the substance which is found with the Bovey coal is, in every respect, so totally different from any of the bitumens hitherto

* Trans. of the LINNEAN Society, Vol. IV. p. 138. Von TROIL's Letters, p. 42. *Opuscula* BERGMANNI, Tom. III. p. 239.

† Trans. of the LINNEAN Society, Vol. IV. pp. 141, &c.

discovered, it seems proper that it should receive some specific name; and, as it has been proved to consist partly of a resin and partly of a bituminous substance, I am induced to call it *Retinasphaltum*,* a name by which a full definition of its nature is conveyed.

I have lately seen, in No. 85 of the *Journal des Mines*, p. 77, an account of a peculiar combustible fossil, found near Helbra, in the county of Mansfield, and described by Mr. VOIGHT, in his *Versuch einer Geschichte der Steinkohle, der Braunkohle*, &c. p. 188. This substance is of an ash-coloured gray, passing to grayish-white; it is found in a bed of bituminous vegetable earth, which has apparently been produced by the decomposition of fossil wood. The purest specimens are in the form of nodules; the fracture is earthy; it is opaque; soft; brittle; and is very light. When applied to the flame of a candle, it burns and melts like sealing-wax, at the same time diffusing an odour which is not disagreeable. This substance appears to accord in so many properties with the retinasphaltum of Bovey, that I cannot but suspect it to be of a similar nature, and I have little doubt that, by a chemical examination, it will be found to consist partly of resin and partly of bitumen.

* From ῥητίνη, resin; and ἄσφαλτος, bitumen.