He considered that they were connected with the disturbances which have taken place in comparatively recent times along the eastern coast of the Morea. The sulphur, which usually occurs in small globular masses in gypseous beds, was found in these Solfataras in a crystalline form, and in connexion with the fissures from which the heated gas issues. There was therefore a marked difference in the manner of its occurrence, both in Italy and in Greece. In Greece the sulphur-deposit in nodules is found on the west of the principal chain of mountains, and the crystalline sulphur on the east. In Italy the crystalline sulphur is limited to the vicinity of Vesuvius, and the nodules are abundant both in Sicily and on the east coast of the mainland.

3. *On the ORIGIN of CLAY-IRONSTONE.* By J. LUCAS, Esq., F.G.S., of the Geological Survey of England.

A. 1. CLAY-IRONSTONE* is an impure carbonate of iron, containing generally from 30 to 33 per cent. of metallic iron mingled with varying proportions of clay, oxide of manganese, lime, and magnesia.

2. When the principal foreign matter in this mineral is of a bituminous or combustible nature the variety thus formed is called "Black band"†. This combustible matter often amounts to 25 or 30 per cent.

3. Sometimes lime so far predominates in Clay-ironstone as to give it the general appearance of a compact limestone, when the presence of iron may be detected by the great weight of the mass, and by the decomposition of the exterior, which turns a dark brown to the depth of a quarter of an inch or more on oxidation.

4. Through the intermediate forms it passes into a pure limestone. Such limestone bands are characterized by being densely compact, very hard, dark-coloured, and by being devoid of organic remains.

B. 1. The foregoing varieties occur throughout the vast thickness of delta-deposits whose remains now constitute the Carboniferous formations. They lie in beds varying in thickness from a fraction of an inch to about 2 feet.

2. When the top of a bed is exposed it is often found to be traversed by a series of cracks, which present the general appearance of a net of very unequal and irregular mesh. These cracks are filled with sediment like that in which the bed of Clay-ironstone lies.

3. Very frequently the beds of all varieties are so irregular as to appear in clean section like a layer of flattened nodules. These irregular layers are always very thin.

4. A glance over the copious details contained in Jukes's "Me-

* Miller's 'Elements of Chemistry,' pt. ii. p. 575, ed. 1864; 'Elements of Geology,' p. 492, 6th ed.; Student's Elements, p. 385; Bristow's 'Glossary of Mineralogy,' p. 87; 'Manual of Geology,' Jukes, p. 356, ed. 1862.

† Miller's 'Elements,' pt. ii. p. 575, ed. 1864; 'Glossary of Mineralogy,' Bristow, p. 44.

moir on the South Staffordshire Coal-field," will show that bands of Clay-ironstone alternate with the same sediments and in the same way as the coals themselves do.

5. Sometimes beds of ironstone rest actually upon beds of coal, as is shown in the following section * :—

No. 1.

	ft.	in.
Black shale	0	2
Clunch	0	10
Batt... ..	0	5
Ironstone	0	2
Coal	1	2
Clunch	3	0
Clunch and Ironstone	4	0
	9	9

"Clunch is a tough clay, breaking into blocks, sometimes rather sandy, generally grey or yellowish"—a description which applies to many seat earths.

"Batt† is a highly carbonaceous shale, commonly very compact and splitting into the finest laminae, almost invariably black, and often interstratified in layers with the coal"—an impure coal in fact. Both Batt and Clunch appear from these descriptions to be old terrestrial surfaces.

6. That calcareous Clay-ironstone has been formed upon a terrestrial surface is shown by the following section from Millstone-grit shales in Nidderdale, Yorkshire.

No. 2.

	ft.	in.
Black shale.....	0	1
Nodular limestone	0	5
Coal.....	0	4
Seat earth	1	10
Grit and shale,		

In the South-Staffordshire coal-field, after the splitting up of the thick coal, fifteen bands of Clay-ironstone occur between the top and bottom coals or limiting horizons, thus pointing to a succession of terrestrial surfaces.

C. 1. On the whole, by comparison with the beds of shale and sandstone, the occurrence of bands of Clay-ironstone, and of ferruginous limestone, in the carboniferous formations above the base of the Millstone-grit is a very exceptional thing.

2. The beds of Clay-ironstone are especially characteristic of those great deltas, though from what follows it will appear that there is no reason *primâ facie* why they should not be found in other deltoid formations as well.

We have thus a general view of the varieties, chemical composition, and mode of occurrence of Clay-ironstones.

* Memoir on South Staffordshire Coal-field, p. 53, 2nd edit. † Ibid. p. 16.

Reverting to A. 1, we find the beds so thin, and with so high a percentage of iron, that it appears next to impossible that beds containing it should be thrown down in layers in the midst of sediments almost, and in some cases quite free from it, when we take into consideration the fact that carbonate of iron, which is the salt contained in most ferruginous springs, is rarely present in them in a larger quantity than 1 grain per pint*. Of course I am aware that thick deposits are formed in the open air at the mouths of such springs; but even if carbonate of iron exists in so high a proportion anywhere in estuarine waters, the deposition of it in very thin beds containing 30 to 40 per cent. of metallic iron, appears far less probable than that it should be generally distributed through a greater thickness of mud in less quantity.

For the formation of beds containing a percentage of iron certainly insignificant when compared with that of Clay-ironstones, Prof. Ramsay supposes an inland basin to have been necessary; how much more, then, is it necessary that a bed containing 30 per cent. of iron should have been formed in circumscribed waters?

Again, concerning the varieties of Clay-ironstone which contain a great excess of lime, and of the densely compact thin limestone bands which occur in the millstone-grit series, there can be no doubt that these beds have had a similar origin; for carbonate of lime can rarely be precipitated at the bottom of the sea by chemical action alone†.

The formation of all varieties of Clay-ironstone lying in beds is rendered intelligible by the supposition that they were formed in peaty or non-peaty lagoons on the alluvial flats of the deltas of the Carboniferous formations, according to the predominance or absence of carbonaceous matter in the ironstone. Drained by evaporation and percolation after the subsidence of floods, the stagnant pools occupying these hollows would afford just the circumstances most favourable for the deposition of iron from ferruginous, and lime from calcareous waters, and from the chemical action described by Mr. Hunt. I believe the cracks so often seen in beds of Clay-ironstone to have been formed under these circumstances by the sun when the stagnant pools dried up, as they exactly resemble those formed in the substance of ordinary clay under similar circumstances. The next layer of mud transported into the bed filled them up, so that when seen now they are found to be filled with shale, very often not in the least ferruginous, and quite soft.

This view explains the occurrence of layers of nodules equally well if the surface of the lagoon presented slight undulations, or even in some cases ripple-marks.

It explains also why the beds of Clay-ironstone never run to a greater thickness than about 2 feet, as the lagoons would be necessarily very shallow, in fact nothing but slight hollows in the alluvial flats, sometimes containing a film or bed of peat, sometimes

* Miller's 'Elements of Chemistry,' pt. ii. p. 614, ed. 1864.

† Student's Elements, p. 38.

not, and subject to be overflowed now and then, and to have vegetable matter left in them. The reason why the sediments in which these beds occur are not ferruginous or calcareous to the same extent becomes then equally plain, because the bed of Clay-ironstone formed would sometimes be sufficient to fill the hollow, or a slight subsidence might carry that terrestrial horizon down.

Sometimes these horizons appear to have been spreads of warp, as in the following section copied from the Explanation of Quarter-sheet 93 S.W. In it the black shale is coloured by carbonaceous matter, and in fact is an impure drift coal, and therefore marks a succession of terrestrial surfaces.

No. 3.

	ft.	in.
Ironstone (impure)	0	1
Black shale.....	0	9
Ironstone	0	0 $\frac{1}{2}$
Black shale.....	0	2
Ironstone	0	1
Black shale.....	0	8
Ironstone	0	1 $\frac{1}{2}$
Black shale.....	0	1
Ironstone, Top Balls.....	0	2 $\frac{1}{2}$
Black shale.....	0	6
Ironstone, Middle Balls	0	2
Black shale.....	0	11
Ironstone, Low Measures.....	0	1 $\frac{1}{2}$
Black shale.....	1	0

The above section rests upon the terrestrial surface of the Black-Bed Coal.

I can imagine nothing more convincing as to the terrestrial origin of these beds than the above section. By "terrestrial" I mean a surface exposed to the air, but subject to be covered by floods.

The process described by Mr. Hunt might then come into play; in fact I cannot see that it could avoid doing so. Carbonic acid formed in the lagoons from decomposing vegetable matter, meeting with protoxide of iron in solution, would unite with it and form a carbonate of iron; and this, with the mud in the lagoon, would form a clay-ironstone.

I may remark that it cannot be shown that the chemical agents have not formed beds of clay-ironstone when discharged into open waters, that it cannot be proved that they ever did so under those circumstances, and that the above sections do prove that clay-ironstone beds have been formed on terrestrial surfaces.

If the action were possible in open waters, why are the beds not more generally diffused? and why are they so compact and local amongst the beds in which they lie? Surely the red marls of Prof. Ramsay's inland seas should contain them; but they do not.

The above supposition will explain all the varieties of Clay-ironstone lying in beds, of course not those formed by segregation from a state of general dispersion through the sediment in which they lie as concretions. Such concretions may, however, be made

to strengthen the present case, as where the iron was obviously discharged into open waters it was *generally* distributed, and not in local beds.

I believe, then, that every bed of Clay-ironstone marks a terrestrial horizon as much as every coal-bed does, or as every bed of sediment which bears the print of raindrops.

Since the above paper was written I have had the opportunity of witnessing, on a small scale, the operation which I suppose to have taken place on a large one. Between Redcar and Saltburn the shore is guarded by a line of cliffs formed of red Boulder-clay; and between the foot of these and low-water mark there is a broad extent of smooth sand. Several small streams cut through the clay, and at certain times, not being strong enough to cut out a channel through newly laid sand, they sink through it, leaving a film of red mud (peroxide of iron), together with various vegetables brought down by them, and considerable quantities of sea-weed. Some of this mud I took up in a bottle. In a few days, being closely corked, it turned to a dark blue black, and effervesced with nitric acid. Here, then, we have an absolute case of the formation of carbonate of iron under the circumstances named in this paper.

A paper by Mr. James Geikie has also lately come into my hands, in which the following passages occur. "The numerous coal-seams point to a recurrence of a land surface, and the gas-coals and *ironstones* to the former existence of numerous *wide lakes and lagoons*. Gas-coals are not unfrequently found to pass into common coals, or into black shales, and sometimes into Black-Band ironstones. And this arises from the mode in which these seams were accumulated. Gas-coal has certainly been deposited in water. It contains *fresh-water* or *brackish-water fossils*, and may be traced, as just stated, until it is found to pass into a black argillaceous shale. If we conceive of a more or less wide expanse of fresh water surrounded by broad stretches of densely wooded flat grounds, we shall have the conditions under which the common coals, gas-coals, and ironstones of the limestone series were most probably formed. Over the bed of the lake would gather a slimy vegetable mud, which in some places might be highly impregnated with ferruginous matter. Here and there this slime or black vegetable mud would pass into a dark clay or silt at points where streams entered the lake; while all along the shores, wherever the water shallowed, luxuriant growths of marsh-plants would cluster upon the muddy bottom. Beyond this thick marshy growth, again, there would be the drier land covered with enormous trees and a dense undergrowth of ferns. The plants that grew upon the land would give rise to common coal, the marshy vegetation to splint coal, and the dark vegetable silt to gas-coal, oil-shale, and black-band ironstone; and all these seams would anastomose or pass into each other at certain points. And thus the same mineral seam may be alternately a common, splint, or gas-coal, an oil-shale, or a black-band ironstone, according as the physical conditions varied at the time of its formation. With

regard to Clay-ironstones, I think they are often due to subsequent changes in the strata: the carbonate of iron having been originally more or less diffused through the silt beds, or shales, has segregated in time, so as to form irregular balls or bands." (I have above made a reservation in the case of concretionary balls.) "But the extreme regularity of many of the bands would lead one to infer that these at least were due rather to deposition than to segregation" *.

In the Cleveland district the Oolitic ironstones can sometimes be traced to their natural limits. Their structure changes from an oolitic one to a dense compact Clay-ironstone, first in a number of thin beds, which diminish in number till the whole disappears. Thus a bed of inferior ironstone, known as the "top bed," in some places 30 feet thick, is at one place represented by thirty distinct bands of Clay-ironstone in a thickness of 8 feet, whereas a little further north one single bed, 10 inches thick, of a compact Clay-ironstone, is the sole representative of the 30 feet of loose oolitic ironstone further south. A little further north still there is nothing whatever to represent this bed. These bands appear to me to point to littoral conditions, and to be explained as in the paper.

Note.—An abstract of the above paper, with much additional matter, was published in 'Iron,' April 26, 1873.

DISCUSSION.

Prof. AXSTED thought that the explanation offered by the author, though satisfactory for instances of limited thickness and confined area, was not equally applicable to the far larger deposits, such as those in America, extending over hundreds of square miles, and many times as thick as those described. The beds had by some been considered due to segregation subsequently to deposition; but this view also seemed hardly such as could be generally accepted. The deposits of ironstone varied much in character, sometimes consisting of layers of distinct nodules, sometimes of continuous bands. The origin of these two classes appeared to him to have been different; and in some of the Coal-deposits the ironstone bands were present on a more extended scale than seemed consistent with the author's theory.

Prof. RAMSAY thought that the paper exhibited considerable ingenuity, and that the examples given by the author were intended by him to be equally applicable to large areas. The estuarine character of much of the Coal-deposits was an acknowledged fact; and the theory proposed by the author was quite in accordance with such a state of things. He did not agree with him that ironstone was never deposited in marine strata, as it occurred in the Yoredale beds and in some Liassic beds. As to the deposits of ironstone in fresh water, he referred to those still taking place in some of the Swedish lakes.

* 'On the Geological Position and Features of the Coal- and Ironstone-bearing Strata of the West of Scotland,' by James Geikie, F.R.S.E., p. 14.

Mr. FORBES, whilst admitting that in many instances Clay-iron-stones had been deposited in circumscribed waters or shallow lakes, as is the case with the lake iron-ores in Sweden now actually in process of formation, pointed out that some of the largest Clay-iron-stone deposits in England—those of the Yoredale series—contained marine fossils in abundance. On chemical grounds it is not clear in what state of combination the author imagines the iron to have been held in solution previously to being, according to him, converted into carbonate of iron, by meeting with the carbonic acid formed in the lagoons from decomposing vegetable matter; and further, the mere fact that the Saltburn mud effervesced with nitric acid after having been bottled for some days, must not be regarded as necessarily proving the formation of carbonate of iron in it.

Mr. CHARLESWORTH called attention to the nodules of ironstone which were found in the coprolite diggings in Suffolk, as to the origin of which little was known. The banding in the interior of these nodules was posterior to their formation, as was evinced by its following the contours of the exterior, and even of lithodomous borings in them.

4. *Note in vindication of LEPTOPHLEUM RHOMBICUM and LEPIDODENDRON GASPIANUM.* By Principal DAWSON, LL.D., F.R.S., F.G.S.

[Abridged.]

THE author forwarded to the Society photographs illustrating his species *Leptophleum rhombicum* and *Lepidodendron gaspianum*, with the view of showing that they are specifically and generically distinct, and also distinct from the plant identified with them by Mr. Carruthers*, and from *Lepidodendron nothum* of Unger†, to which species Mr. Carruthers referred the whole series of specimens, both from Australia and Eastern North America.

Dr. Dawson states that, though he has not seen Unger's specimens, he has carefully studied that author's figures and descriptions of *Lepidodendron nothum*; and in the original description of *L. gaspianum*‡ he indicated that it is allied to *L. nothum*, although he regarded it as specifically distinct. He considers that *L. nothum* is not at all near to his *Leptophleum rhombicum*, and that a comparison of Unger's figure or Mr. Carruthers's figure of Mr. Daintree's plant with the photographs of *L. rhombicum* will show that there is not even a generic connexion between them.

To show the want of identity between *Leptophleum rhombicum* and *Lepidodendron gaspianum*, Dr. Dawson sums up their characters as follows :—

* Quart. Journ. Geol. Soc. vol. xxviii. pp. 351–353.

† Denkschr. Akad. Wiss. Wien, math.-naturw. Cl. vol. xi. (1856) p. 175.

‡ Quart. Journ. Geol. Soc. vol. xv. p. 483.