respects the same, he was evidently inclined to class the whole of these genera under one generic denomination, despite their marked and manifold external differences. In his Sil. Suppl. p. 95, he says: "It will remain a question for further consideration whether we are justified in retaining the three generic denominations of *Nucleospira*, *Retzia*, and *Meristina*, for shells possessing the same simple loop." It is therefore in agreement with the principles of classification adopted by Davidson that I now place the species which Sowerby named *læviuscula* under the genus *Bifida*, of which *Bifida lepida* is the type.

P.S.—Davidson's Sil. Suppl. was issued in two portions in the Annual volumes of the Palæontographical Society for 1882 and 1883. After writing the above article I have found in the Index accompanying the latter portion of the Suppl. that Davidson ultimately had the same doubts as myself as to the true generic position of *læviuscula*. In the Index referred to—Sil. Suppl. p. 233—Davidson puts a note of interrogation to the generic name of *Athyris* as applied to *læviuscula*, and he adds concerning *Athyris*,—"It is not certain whether we possess any true British Silurian species of the genus."

NOTICES OF MEMOIRS.

Abstracts of Papers read before Section C. at British Association Meeting, Cardiff, August, 1891.

I.—Discovery of the Olenellus-zone in the North-west Highlands. By Sir Archibald Geikie, F.R.S., Director-General of the Geological Survey.

Ever since the Geological Survey began the detailed investigation of the structure of the North-west Highlands of Scotland the attention of its officers has been continuously given to the detection of any fossil evidence that would more clearly fix the geological horizons of the various sedimentary formations which overlie the Lewisian gneiss. A large collection of organic remains has been made from the Durness Limestone, but it has not yet yielded materials for a satisfactory stratigraphical correlation. The study of this collection, however, has confirmed and extended Salter's original sagacious inference that the fauna of the Durness Limestone shows a marked North American facies, though, according to our present terminology, we place this fauna in the Cambrian rather than in the Silurian system. Below the Durness Limestone lies the dolomitic and calcareous shaly group known as the 'Fucoid beds,' which, though crowded with worm-castings, has hitherto proved singularly devoid of other recognizable organic remains. In following this group southwards through the Dundonnell Forest, in the west of Ross-shire, my colleague, Mr. John Horne, found that, a few feet below where its upper limit is marked by the persistent band of 'Serpulite grit,' it includes a zone of blue or almost black shales, During a recent visit to him on his ground, when he pointed out to

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me this remarkable zone, I was struck with the singularly unaltered character of these shales, and agreed with him that, if fossils were to be looked for anywhere among those ancient rocks, they should be found here, and that the fossil collector, Mr. Arthur Macconochie, should be directed to search the locality with great care. The following week this exhaustive search was undertaken, and Mr. Macconochie was soon rewarded by the discovery of a number of fragmentary fossils, among which Mr. B. N. Peach, who was also stationed in the district, recognized what appeared to him to be undoubtedly portions of *Olenellus*. The importance of this discovery being obvious, the search was prosecuted vigorously, until the fossiliferous band could not be followed further without quarrying operations, which in that remote and sparsely inhabited region could not be at that time undertaken. The specimens were at once forwarded to me, and were placed in the hands of Messrs. Sharman and Newton, Palæontologists of the Geological Survey, who confirmed the reference to *Olenellus*. More recently Mr. Peach and Mr. Horne, in a renewed examination of the ground, have found, in another thin seam of black shale interleaved in the 'Serpulite grit,' additional pieces of *Olenellus*, including a fine head-shield with eyes complete. There may be more than one species of this Trilobite in these Ross-shire shales. The specific determinations and descriptions will shortly be given by Mr. Peach.

The detection of *Olenellus* among the rocks of the North-west Highlands, and its association with the abundant *Salterella* of the 'Serpulite grit,' afford valuable materials for comparison with the oldest Palæozoic rocks of other regions, particularly of North America. The 'Fucoid beds' and 'Serpulite grit' which intervene between the quartzite below and the Durness Limestone above are now demonstrated to belong to the lowest part of the Cambrian system. The quartzites are shown to form the arenaceous base of that system, while the Durness Limestones may be Middle or Upper Cambrian. On the other hand, the Torridon Sandstone, which Murchison placed in the Cambrian series, can now be proved to be of still higher antiquity. The marked unconformability which intervenes between it and the overlying quartzite points to a long interval having elapsed between the deposition of the two discordant formations. The Torridon Sandstone must therefore be pre-Cambrian. Among the 8,000 or 10,000 feet of strata in this group of sandstones and conglomerates, there occur, especially towards the base and the top, bands of grey and dark shales, so little altered that they may be confidently expected somewhere to yield recognizable fossils. Already my colleagues have detected traces of annelids and some more obscure remains of other organisms in these strata. These, the oldest relics of life yet known, have excited a vivid desire in the Geological Survey to discover further and more determinable fossils associated with them in the same primeval resting-place. We shall spare no pains to bring to light all that can be recovered in the North-west Highlands of a pre-Cambrian fauna.

II.—A Comparison between the Rocks of South Pembrokeshire and those of North Devon. By Henry Hicks, M.D., F.R.S., Sec. Geol. Soc.

THE clear succession from the Silurian rocks to the Carboniferous to be observed in many sections in South Pembrokeshire offers, in the author's opinion, the key to the true interpretation of the succession in the rocks of North Devon, for there cannot be a doubt that the post-Carboniferous earth-movements which so powerfully affected and folded the beds in North Devon extended into and produced almost identical results in South Pembrokeshire. In the latter area, however, the succession remains clearer, and can be traced more continuously.

The base of the Silurian (Upper Silurian Survey) is exposed at many points, and the lower beds repose transgressively on the Ordovician, and even on some pre-Cambrian rocks. Near Johnston and Stoney Slade the conglomerate contains numerous pebbles of the Johnston and Great Hill granite as well as of other igneous masses which were formerly supposed to have been intrusive in these beds. From the Silurian to the Carboniferous beds there does not appear to be any marked break in the series; moreover, all these beds were folded together and suffered equally by the movements which affected the area. The axes of the folds strike from about W.N.W. to E.S.E. The movements, therefore, at this time were in a nearly opposite direction to those which affected the Ordovician and Cambrian rocks at the close of the Ordovician period. Within the broken anticlinal folds portions of the old land surfaces have been exposed in several places by denudation.

The succession exposed in this area and the effects produced by the earth-movements so nearly resemble those already described by the author as occurring in North Devon, that he is convinced that the beds must have been deposited contemporaneously in one continuous subsiding area, and that the differences recognizable are chiefly in the basal beds, which were deposited on an uneven land surface.

III.—On the Evidences of Glacial Action in Pembrokeshire, and the Direction of Ice-flow. By Henry Hicks, M.D., F.R.S., Sec. Geol. Soc.

THE occurrence of ice-scratched rocks and of northern erratics in North-west Pembrokeshire has already been mentioned by the author, but in this paper he brings forward additional evidence to show that, during the Glacial period, a great thickness of land-ice must have passed over Pembrokeshire.

The glacial striæ, which are so well preserved under the drift along the north-west coast, especially at Whitesand Bay, show that the ice travelled over that area mainly from a north-western direction. The presence of erratics from North Wales and from Ireland would tend to the conclusion that glaciers from these areas coalesced in St. George's Channel, and that the ice which overspread Pembrokeshire was derived from both these sources, as well, probably, as from a flow extending down the channel from more northern areas.

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Although there are in the district many northern erratics, notably a large boulder of granite and another of picrite, which the author found on Porthlisky farm, two miles south-west of St. David's, yet by far the majority are of local origin, and can be traced back to the parent rocks. The great igneous masses which now form such conspicuous hills along the north coast yielded most of the boulders, many of very large size, which are so freely spread over the undulating land reaching to the coast of St. Bride's Bay. There are clear evidences to show that this bay was itself overspread by a great thickness of drift from these hills. The intervening pre-glacial valleys were also filled by this drift, and the plains and rising grounds up to heights of between 300 and 400 feet still retain evidences of its former presence, and many perched blocks. Excellent sections of unstratified drift, containing large ice-scratched boulders, are exposed in Whitesand Bay, and a thickness of several feet of an irregularly stratified sand was, some time since, exposed under the Boulder-clay on the east side of the bay. Chalk flints have been found at heights of over 300 feet, having probably been brought from Ireland. The picrite boulder already referred to has been shown by Prof. Bonney to resemble masses of that rock exposed in Carnarvonshire and Anglesea, and the granite boulder, which before it was broken must have been over 7 feet in length and 3 to 4 feet in thickness, is identical with a porphyritic granite exposed in Anglesea, but not found anywhere in Pembrokeshire. The evidences, therefore, which go to prove that Pembrokeshire was buried under an ice-sheet that must have spread southwards into the Bristol Channel, are, the presence of many northern erratics, both as perched blocks and in drifts at heights above 300 feet, ice-scratched, smoothed and polished rock surfaces, and, in places, much crushing and bending of some of the strata; also great dispersions of boulders from igneous rocks on the north coast in a south-west direction, and some well-marked examples of 'crag and tail.'

IV.—Notes upon *Colobodus*, a Genus of Mesozoic Fossil Fishes.

By Montagu Browne, F.Z.S., F.G.S.

COLOBODUS appears to have been first constituted a genus in the year 1837 by Louis Agassiz (see 'Poissons Fossiles,' Tome II., iie partie, p. 237), who gave this name to some *Lepidotus*-like teeth (*Colobodus hogardi*) from the Muschelkalk, which he described thus:—"Par leur taille elles tiennent le milieu entre les Microdon et les Sphærodus. De formes arrondies et cylindracées vers la base, les dents ont leur couronne renflée en forme de massue, et sur le milieu de la couronne s'élève encore un petit mammelon tronqué, ce qui a valu à ce genre son nom de *Colobodus*."

Since that time teeth of a similar generic character have been described or figured by various authors, *e.g.*, Count Münster (assuming *Asterodon* to be identical), Plieninger, Giebel, Gervais, Meyer, Chop, E. E. Schmid, Alberti, Eck, Winkler, Gürich, W. Dames, and A. S. Woodward. The typical teeth, however—*i.e.* those upon which the 'nipple,' or apical tubercle, is present—must be sought amongst the various species of *Colobodus* and *Lepidotus* (of Plieninger, 1847); whilst intermediate forms, or those from which the 'nipple' has been partly or entirely removed by wearing or by *post-mortem* abrasion, must be sought amongst those described under the various species of *Lepidotus, Sphærodus, Gyrodus*, '*Tetragonolepis*' (of Winkler, and of Agassiz in part), *Tholodus* and *Thelodus, Eupleurodus, Sargodon* (not cutting teeth), and even amongst teeth variously attributed to *Saurichthys* and to 'Saurians,' whilst the chisel-shaped, or pre-maxillary, teeth are probably those attributed to *Sargodon tomicus*.

Fragments of the head and trunk and scales of *Colobodus* have been described or figured by H. B. Geinitz, Meyer and Plieninger, Giebel, Meyer, Quenstedt, Eck, Kner, H. Kunisch, W. Dames, J. von Rohon, and A. S. Woodward, and must be sought amongst the various species ascribed to *Gyrolepis* and *Amblypterus, Lepidotus, Heterolepidotus, Eugnathus, Pleurolepis, Dactylolepis*, and also amongst various Ganoid scales ('Ganoidschuppen' and 'Fischschuppen').

Up to the present neither the teeth nor the scales of *Colobodus* have been recognized as such in Britain by any authors, or, above the Muschelkalk and Lettenkohle, abroad: its occurrence and recognition, therefore, in the Rhætic of Britain is interesting, and the author exhibits typical and transitional teeth which he found and recognized in the Rhætic 'bone-beds' of Wachet and Aust Cliff; worn and abraded teeth ('*Sargodon tomicus*' and '*Sphærodus*') from thence and from Leicestershire; and what are probably the larger cutting teeth from Aust and Leicestershire; also fine characteristic scales and (? head-)bones showing vermiculated sculpture from Aust. All may, for the present, be referred to *Colobodus maximus* (Quenstedt).

Finally, should *Colobodus* prove to be identical with *Lepidotus*, a fusion of *Heterolepidotus* and *Eugnathus* will give *Colobodus* a more extended upward range than has hitherto been supposed.

V.—The Ammonite Zones of Dorset and Somerset. By S. S. Buckman, F.G.S., Hon. Memb. Yorks Phil. Soc.

THE lower part of the *Murchisonæ*-zone is often intimately connected with the upper part of the *Opalinum*-zone; but, a little higher, there is an horizon characterized by numerous specimens of *Ludwigia Murchisonæ*. The fauna of this horizon corresponds to the *Murchisonæ*-zone of Oppel, and to the Brauner Jura β of Quenstedt. Above the *Murchisonæ*-zone a considerable break in the sequence of strata is frequently met with. In the neighbourhood of Bradford Abbas, however, is found, superior to the *Murchisonæ*-zone, an horizon marked by a very peculiar fauna, in which *Lioceras concavum* and species of the genus *Sonninia* predominate. Taken in a general sense the fauna of this zone (*Concavum*-zone) does not agree with that of Quenstedt's Brauner Jura β or γ, nor with that of the *Sowerbyi*-zone, as illustrated by Waagen, Douville, etc. Further,

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the *Sonniniæ* of the *Concavum*-zone are, biologically, of an earlier type than those of the *Sowerbyi*-zone.

Continental authors find a marked stratigraphical and palæontological break between the *Murchisonæ*- and *Sowerbyi*-zones; and they wish to draw, at this point, a dividing line between Lias and Oolite, or between Toarcian and Bajocian. It is suggested that the absence of the *Concavum*-zone is the cause of this break; and, in former papers to the Geological Society, the author, in supporting the Continental plan, regarded the *Concavum*-zone as Toarcian.

In the Bradford Abbas district there is a break above the *Concavum*-zone. So far as is known at present, Dundry is the only locality showing a complete sequence; but some years ago a quarry—Coombe, near Sherborne—was open, and it yielded a large series of Ammonites indicating a fauna agreeing with the *Sowerbyi*-zone as illustrated by Continental authors. This quarry has been closed for years; and nothing is known as to how the strata are situated with regard to the *Concavum*-zone below, or with superior horizons. It is richer than Dundry, and is, practically speaking, unique among Inferior-Oolite exposures. It is the only locality in England which yields this particular fauna. So far as is known, the true *Sowerbyi*-zone is absent from all quarries in Dorset and Somerset, with the exception of Coombe and Dundry; and, therefore, the majority of exposures in the district fully support the Continental geologists in their contention as regards a dividing line.

Waagen places a zone of *Am. Sauzei* above the *Sowerbyi*-zone; and an horizon with this species and with a particular fauna is shown in 'the marl with green grains' at Frogden quarry, near Sherborne.

Above this is the zone of *Am. Humphriesianus*, in which the fauna *Stephanoceras* and *Sphæroceras* predominate. This is the equivalent of the *Coronaten-schichten* of Quenstedt's Brauner Jura δ. The upper part of the Brauner Jura δ is the Bifurcaten-schichten; and this corresponds with the *Cadomensis*-beds of Frogden—an horizon which, containing a fauna distinct from the *Humphriesianus*-zone, may therefore be known as the *Cadomensis*-zone.

The strata above this horizon have usually been called the '*Parkinsoni*-zone.' There are several objections to this name; and the strata are capable of more subdivision.

The bed at Halfway House which yields the large *Parkinsoniæ* is superior to the *Cadomensis*-zone. It may be called the *Truellii*-zone. At the top of the limestone of the Broad-Windsor district *Stephan. zigzag* and species of *Morphoceras* are found; and this is a still higher horizon (*Zigzag*-zone). Just below the Fullers' Earth of this same district, in the Fullers' Earth itself of Eype, but in the upper white limestones (about 25 feet thick) of the Bradford-Abbas district, are found *Oppelia fusca* and other species indicating a still higher horizon. It is suggested that the white limestone of the Bradford-Abbas district is contemporaneous with the so-called 'Fullers' Earth clay' of Eype. This horizon may be called the zone of *Oppelia fusca*; and whether this zone belongs to the Inferior Oolite or to the Fullers' Earth depends on whether the observer be regarding the limestones of the Bradford-Abbas district or the clay of Eype cliff.

Several Continental geologists, however, commence the Bathonian with the *Cadomensis*-zone. To this idea the presence of *Parkinsoniæ* and other facts gives considerable support.

VI.—On the Continuity of the Kellaways Beds over extended areas near Bedford, and on the Extension of the Fullers' Earth Works at Woburn. By A. C. Cameron. [Communicated by permission of the Director-General of the Geological Survey.]

IN this paper further evidence is submitted from different parts of the country of the continuity over extended areas of the Kellaways Rock above the Lower Oxford Clay. Several fine excavations, the result of railway enterprise, have afforded sections of these beds in places where their presence was only inferred before. More than the usual thickness is indicated by records recently obtained from deep sinkings and borings in the Midland districts, especially the Bletchley boring of 1886–7.

The extraordinary concretionary stones noticed in Wiltshire by Smith as characterizing this formation, and quarried away years ago at Kellaways for road-stone, jut out in the Valley of the Churn, near Cirencester, and stand about in clusters in the Valley of the Ouse at Bedford like gigantic fungi. The plane of separation of the Upper Oxford and the Kellaways in Bedfordshire is formed by a shelly calcareous band in contact with a shelly cap to the concretionary stones. Where this plane is a broken one there is no development of concreted rock, and the lowest sediment of Upper Oxford clay is loamy, passing down into Kellaways sand. Above the calcareous band there is sometimes an indurated seam of sandy marl, breaking into conical forms; the product, apparently, of stalactitic infiltration. Pits are opened at the outcrop of the Kellaways (a persistent stratum in the Ouse Valley) and are carried down through the Lower Oxford (selenite clay), Cornbrash and Cornbrash clay to Great Oolite limestone, which is quarried for lime-burning; the 'lam earth,' the loamy portion of the Kellaways, being mixed in the mill with the Lower Oxford, which is dug for brickmaking. Excellent sections, showing the above series, are to be seen.

Observations on the extensions of the Fullers' Earth Works at Woburn Sands, with some description of the beds, are given, and the mining industry now springing up is commented on.

VII.—The Mastodon and Mammoth in Ontario, Canada. By Prof. J. Hoyes Panton, M.A., F.G.S.

THE writer in this paper gives a complete description of the remains of a Mastodon discovered (1890) in a marl bed near Highgate in the Province of Ontario, Canada, and also the remains of a Mammoth found under similar conditions near Shelburne in the same Province (1889).

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Both specimens were discovered by John Jelly, Esq., of Shelburne. The following measurements are given for comparison:—

	Jumbo.	Newburg Mastodon.[1]	Highgate Mastodon.
Longest rib	44 inches	$54\frac{3}{4}$	$55\frac{1}{2}$
Humerus	36 ,,	39	40
Radius	— ,,	29	34
Femur	42 ,,	39	$47\frac{1}{2}$
Tibia	— ,,	28	29
Tusk	— ,,	104	92 not complete.
Third spinous process	15 ,,	$23\frac{1}{2}$	$23\frac{3}{4}$

The bones obtained of the Mammoth are not so numerous, the chief being thirty-one ribs, one 50 inches in length and 11 in circumference; several vertebræ, some $14\frac{1}{2}$ inches across; a massive tusk $12\frac{2}{3}$ feet with a portion broken off; and a tooth weighing $16\frac{3}{4}$ lbs. The writer also refers to remains of Proboscoidea found at other points in Ontario, viz. St. Catherine's Dunville, Goat Island, Niagara Falls, and Kimbal, near the western side of the Province.

VIII.—The Cause of Monoclinal Flexure. By A. J. Jukes-Browne, F.G.S.

Folds of the ordinary arch and trough type are generally ascribed to the influence of lateral pressure; but it is not easy to see how a monoclinal flexure which appears in section as a flexure connecting two horizontal bars of strata can have been produced by direct lateral pressure exerted at the ends of the bars.

The author suggests that monoclinal flexuring is a structure impressed upon a horizontal series of uncompressed strata by the displacement of a subjacent mass of faulted and flexured rocks, the lateral compression of the deep-seated mass resulting in the vertical uplift of certain portions of the 'cover.' If a series of stratified rocks rests in a horizontal position on a mass of ancient rock, which has been compressed, indurated, flexured, and faulted before the deposition of the upper series, it is supposed that the lower series of rocks would give way under lateral pressure along the pre-existing faults, and that the blocks which lie between upward diverging faults would be forced to move upwards, carrying with them those tracts of the 'cover' which rest on them. It is evident that these tracts would be divided from those resting on blocks defined by downward diverging faults by faults or monoclinal flexures, the production of a fracture or a flexure depending partly on the thickness and pliability of the strata forming the cover, and partly on the amount of local uplift. It is conceivable that the displacement might take place partly by faulting and partly by flexuring, and that what was a fault near the plane of unconformity might pass upward into a flexure.

The writer desires criticism on the above suggestion, especially from those who will have a chance of seeing the grand monoclinal flexures of the Colorado region during the excursion of the approaching International Geological Congress.

[1] The Newburg Mastodon is one of the finest ever discovered in America. The bones are in a most excellent state of preservation, and sufficient have been obtained to enable the skeleton to be set up.

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IX.—The Origin of Petroleum. By O. C. D. Ross.

IN the course of introductory remarks the author contends that, owing to the mystery surrounding the origin of petroleum, and to the paucity of indications where to seek for it, practical men in this country distrust the permanence of the supply, and hesitate to adopt it for many useful purposes; while the object of this paper is to suggest a way of resolving the mystery which is calculated to dissipate that distrust. The theories suggested by Reichenbach, Berthelot, Mendelejeff, Virlet, Verneuil, Peckham, and others, which are briefly described, make no attempt to account for the exceeding variety in its chemical composition, in its specific gravity, its boiling-points, etc., and are all founded on some hypothetical process which differs from any with which we are acquainted; but modern geologists are agreed that (as a rule) the records of the earth's history should be read in accordance with those laws of Nature which continue in force at the present day. *E.g.*, the decomposition of fish would not now produce paraffin oil; hence we can hardly believe it possible thousands, or millions, of years ago, so long as it can be shown that any of the ordinary processes of Nature are calculated to produce it. The chief characteristics of petroleum strata are enumerated as: I. The existence of adjoining beds of limestone, gypsum, etc.; II. Volcanic action in close proximity; III. The presence of salt water in the wells; IV. The great extent of the production of oil, indicating subterranean receptacles of vast dimensions.

I. The close and invariable proximity of limestone to the wells has been noticed by all writers, but they have been most impressed by its being 'fossiliferous,' or shell limestone, and have drawn the erroneous inference that the animal matter once contained in those shells originated petroleum, but no fish oil ever contained *paraffin.* On the other hand, the fossil shells are carbonate of lime, and, as such, capable of producing petroleum under circumstances such as many limestone beds have been subjected to. All limestone rocks were formed under water, and are mainly composed of calcareous shells, corals, encrinites, and foraminifera, the latter similar to the foraminifera of 'Atlantic ooze' and of English chalk beds. Everywhere, under the microscope, its organic origin is conspicuous. Limestone is the most widely diffused of all rocks, and contains 12 per cent. of carbon. Petroleum consists largely of carbon, and there is a far larger accumulation of carbon in the limestone rocks of the United Kingdom than in all the Coal-measures the world contains. A range of limestone rock 100 miles in length, by 10 miles in width, and 1000 yards in depth, would contain 743,000 million tons of carbon, or sufficient to provide carbon for 875,000 million tons of petroleum. Deposits of bituminous shale have also limestone close at hand; *e.g.* coral-rag underlies the Kimmeridge clay, which is more or less saturated throughout with petroleum, and it also underlies the famous Black-shale of Kentucky, which is extraordinarily rich in oil.

II. The evidence of volcanic action in close proximity to petroleum strata is next dealt with, and extracts in proof thereof are given from several writers. In illustration of volcanic action on carbonate of lime, a sulphur mine in Spain, within a short distance of an extinct volcano (with which the author is well acquainted), is mentioned. That petroleum is not far off is indicated by a perpetual gas flame in a neighbouring chapel and other symptoms; and, these circumstances having attracted his attention, he observed that Dr. Christoph Bishop records in his writings that he had produced sulphur in his own laboratory by passing hot volcanic gases through chalk, which fact further led the author to remark that, in addition to sulphur, *ethylene*, and all its homologues (C_nH_{2n}), which are the oils predominating at Baku, would be produced by treating—

2, 3, 4, 5......equiv. of limestone (carbonate of lime) with
2, 3, 4, 5......equiv. of sulphurous acid (SO^2) and
4, 6, 8, 10......equiv. of sulphuretted hydrogen (H^2S);

and that *marsh gas* and its homologues, which are the oils predominating in Pennsylvania, would be produced by treating—

1, 2, 3, 4, 5......equiv. of carbonate of lime, with
1, 2, 3, 4, 5......equiv. of sulphurous acid, and
3, 5, 7, 9, 11......equiv. of sulphuretted hydrogen.

Thus, we find that

Carbonate of lime	$2Ca^2CO^3$	yield	$2(Ca^2SO^4.H^2O)$ (gypsum)
Sulphurous acid	$2SO^2$		$4S$ (sulphur)
and sulphuretted hydrogen	$4H^2S$		C^2H^4, which is *ethylene*,

and

Carbonate of lime	Ca^2CO^3	yield	$Ca^2SO^4.H^2O$ (gypsum)
Sulphurous acid	SO^2		$3S$ (sulphur)
and sulphuretted hydrogen	$3H^2S$		CH^4, which is *marsh gas*.

These and all their homologues would be produced in nature by the action of volcanic gases on limestone.

But much the most abundant of the volcanic gases appear (at any rate at the surface) as steam, and petroleum appears to have been more usually produced without sulphurous acid and with part of the sulphuretted hydrogen H^2S replaced by H^2O (steam), or H^2O^2 (peroxide of hydrogen), which is the product that results from the combination of sulphuretted hydrogen and sulphurous acid ($H^2S+SO^2=H^2O^2+2S$). Thus

Ca^2CO^3	yield	$Ca^2SO^4.H^2O$ (gypsum)
H^2S		and
$2H^2O$		CH^4, *marsh gas*

and

$2Ca^2CO^3$	yield	$2Ca^2SO^4.H^2O$ (gypsum)
$2H^2S$		and
$2H^2O^2$		C^2H^4, or *ethylene*.

Four tables are given at the end of the paper, showing the formulæ for the homologues of ethylene and marsh gas resulting from the increase in regular gradation of the same constituents.

It is explained that these effects must have occurred, not at periods of acute volcanic eruptions, but in conditions which may be and have been observed at the present time wherever there are active solfataras, or fumaroles, at work. Descriptions of the action of solfataras by the late Sir Richard Burton and a British Consul in

Iceland are quoted, also a paragraph from Lyell's "Principles of Geology," in which he says that the mud-volcanoes at Girgenti, in the Tertiary limestone formation, "are known to have been casting out water, mixed with mud and *bitumen*, with the same activity for the last fifteen centuries." Probably at all these solfataras, if the gases traverse limestone, fresh deposits of oil-bearing strata are accumulating; and how much may there not have been produced during fifteen centuries!

Gypsum may also be an indication of oil-bearing strata, for the substitution in limestone of sulphuric for carbonic acid can only be accounted for by the action of these sulphurous gases. The abundance of gypsum in the United Kingdom indicates that large volumes of petroleum are probably stored in places where it has never yet been sought for. Gypsum is found extensively in the petroleum districts of the United States, and it underlies the rock-salt beds of Middlesboro' (N.E. Yorkshire), where, on being pierced, it has given passage to oil-gas, which issues abundantly mixed with brine, and under great pressure from a great depth.

III. and IV.—Besides the space occupied by 'natural gas,' 17,000 million gallons of petroleum have been raised in America since 1860, and that quantity must have occupied 100,000,000 cubic yards; a space equel to a subterranean cavern 100 yards wide by twenty feet high and eighty-two miles in length, and it is suggested that beds of 'porous sandstone' could hardly find room for so much; while vast receptacles may exist, carved by water out of former beds of rock-salt adjoining the limestone.

This would account for the brine; and the increase to the molecular volume of the gases consequent thereon, would in part account for the pressure. It is further suggested that when no such open spaces were available, the hydro-carbon vapours were absorbed into and condensed in contiguous clays and shales, and perhaps also in beds of coal, only partially consolidated at the time. There is an extensive *bituminous limestone* formation in Persia, containing 20 per cent. of bitumen; and the theory elaborated in the paper would account for bitumen and oil having been found in Canada and Tennessee imbedded in limestone, which fact Mr. Peckham (in his article on Petroleum in the 'Encyclopædia Brit.,' 9th edition) thought was a corroboration of his belief that some petroleums are a "product of the decomposition of animal remains."

Above all, this theory accounts for the many varieties in the chemical composition of paraffin oils, in accordance with ordinary operations of Nature during successive geological periods.

X.—The Geology of Petroleum and Natural Gas. By W. Topley, F.R.S., Assoc. Inst. C.E.

THE object of this paper is to give a summary of some of the more important facts as to the geological conditions under which petroleum and natural gas are found in various parts of the world, noting the geological ages of the rocks in which they occur, and the influence of geological structure in determining this occurrence.

Few cases are known in which petroleum occurs in rocks older than the Silurian, and none where the amount is of any importance.

Petroleum occurs, but not in large quantity, in a trachyte-breccia at Taranaki, New Zealand. In N.W. Hungary it is found in a trachytic tuff of Miocene age. These, however, are exceptional cases; not only is petroleum not found in volcanic rocks, but in the great majority of cases it is far removed from any known indications of true volcanic action.

The great stores of petroleum and gas in Pennsylvania and New York are in sandstone beds of the Devonian and Lower Carboniferous rocks. Of late years great quantities of gas and oil have been obtained, chiefly in Ohio and Indiana, from the Trenton Limestone (Ordovician).

The oil- and gas-fields of Pennsylvania and New York have a very simple geological structure. The rocks lie comparatively undisturbed, being only gently folded into a series of anticlinals and synclinals parallel with, and along the N.W. side of, the main axes of the Alleghanies. These folds have themselves a gentle inclination towards the S.W. In the Alleghanies, and to the S.E. of the range, where the rocks are greatly disturbed, neither oil nor gas is found. Some of the larger gas wells are on or near the summits of anticlinals, but many are not so placed. In the Trenton Limestone fields of Ohio and Indiana the productive areas are mainly over anticlinals, gas occurring at the crown of the arch, oil on the slopes.

The essential conditions for a largely productive field of gas or oil are—a porous reservoir (generally sandstone or limestone) in which the hydrocarbons can be stored, and an impervious cover of shale retaining them in the reservoir. It is also believed that they only occur where, in or under the porous reservoir, there have been accumulations of fossil remains, the original decomposition of which yielded the hydrocarbons. In the case of the sandstones the original source was probably the fossiliferous shales which underlie them; in the case of the Trenton Limestone the source was probably the fossiliferous limestone itself. The limestone is only productive under certain circumstances; in its normal condition it is a compact rock, and then it contains neither gas nor oil. But over large areas the limestone has been dolomitized, and so transformed into a cavernous and porous rock in which gas and oil are stored. The enormous quantities of gas and oil given out from beds of limestone and sandstone can be fully accounted for when their porous nature, thickness, and extent are taken into consideration. Some of these rocks can contain from $\frac{1}{10}$th to $\frac{1}{8}$th of their bulk of oil.

The high pressure under which gas and oil flow from deep borings can in most cases be fully explained by artesian pressure.

In Kansas gas occurs mainly in the Lower Coal-measures. In Kentucky and Tennessee oil is found in the Ohio shales (Upper Devonian), in Colorado in shales of Cretaceous age. In California it is found in Tertiary strata, mostly much disturbed.

In Canada the chief source, in Ontario, is in Devonian rocks, along a well-marked anticlinal; but gas and oil also occur in the

Trenton Limestone. In the North-West Territories there seem to be great stores of oil in Devonian rocks. Gas and oil now found in Cretaceous strata of the prairies and Athabasca may have been derived from underlying Devonian rocks; but in the Rocky Mountains, at Crow's Nest Pass, oil is probably native to the Cretaceous beds.

In Mexico, the West Indies, and parts of South America, Tertiary strata seem to be the chief source of oil. The age of the petroleum-bearing unfossiliferous sands, etc., of the Argentine Republic (province of Jujuy) is not certainly known; they have been referred by different writers to various ages from Silurian to Tertiary; they are probably sub-Cretaceous. In Europe and Asia the petroleum-bearing beds are of Secondary or Tertiary age, the Palæozoic rocks yielding only an insignificant supply.

In North-west Germany we find petroleum in the Keuper Beds, and more or less in other strata up to and including the Gault. As we pass to the south and south-east from this district we find, as a general rule, that oil occurs in newer strata. The various productive horizons of different districts are as follows:—

North-west Germany	Keuper to Gault.
Rhone Valley, Savoy	Jurassic.
Pyrenees, Spain	Neocomian and Cretaceous.
Elsass	Oligocene.
Bavaria	Lower Tertiary (Flysch).
Italy	Eocene.
Galicia, North-east Hungary	Neocomian to Miocene.
Poland, Roumania, Caucasus	Miocene.

The important districts of Baku occur on plains over anticlinals of Miocene beds. The petroleum-bearing sands are interstratified with impervious clays, separating the strata into distinct productive horizons.

In Algeria oil occurs in Lower Tertiary beds. The Egyptian petroleum comes from Miocene strata.

Petroleum seems to be unknown in peninsular India; but it occurs in many places along the flanks of the Himalayan range, and also in Lower Burma, generally in Lower Tertiary strata. In Upper Burma and Japan the oil-bearing rocks are probably Newer Tertiary. In all these areas the beds are greatly disturbed, and the same is the case with the great Carpathian field; but it frequently happens that the most productive regions are along anticlinal lines.

In New Zealand oil occurs in Cretaceous and Tertiary strata.

Petroleum and gas almost universally occur associated with brine. This may come wholly or partly from the decomposition of the animal matter which has produced the hydrocarbons, together with the remains of the sea-water originally present in the rocks. But the frequent occurrence of rock-salt in the neighbourhood of petroleum-bearing districts is worthy of note.

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Summary.—The main points to be considered in respect of the geological conditions under which petroleum and gas occur seem to be as follows:—

1. They occur in rocks of all geological ages, from Silurian upwards. The most productive areas are Palæozoic in North America, Miocene in the Caucasus.
2. There is no relation to volcanic action.
3. The most productive areas for oil in great quantity are where the strata are comparatively undisturbed. Oil, but in less abundance, frequently occurs when the strata are highly disturbed and contorted, but gas is rarely so found.
4. The main requisites for a productive oil- or gas-field are a porous reservoir (sandstone or limestone) and an impervious cover.
5. Both in comparatively undisturbed and in highly disturbed areas, an anticlinal structure often favours the accumulation of oil and gas in the domes of the arches.
6. Brine is an almost universal accompaniment of oil and gas.

XI.—Vulcanicity in Lower Devonian Rocks. The Prawle Problem. By W. A. E. Ussher, F.G.S. [Communicated by permission of the Director-General of the Geological Survey.]

In the area extending south from the Middle Devonian volcanic series of Ashprington to the Prawle there appears to be no proof of the occurrence of strata older than Lower Devonian. There is no adequate reason for assuming that Lower Devonian rocks as old as the Gedinnian occur on the surface, and there is no certainty that the lowest beds are older than the Lower Coblenzian.

The occurrence of local volcanic action in Lower Devonian time is proved by a series of diabases and tuffs near Dartmouth, in the Kingswear Promontory, near Stoke Fleming, and in the line of country west from Torcross.

In association with the northern chloritic band (running from the mouth of the valley on the north of Hull Sands on the east to Hope on the west) we find volcanic materials identical in character with varieties of volcanic rocks associated with the Devonian slates in the line of country west from Torcross; and here and there in the line of country west from Torcross the volcanic rocks assume a more or less pronounced chloritic aspect. The junction of the slates on the north with the northern chloritic band is a strictly normal one, the chloritic rocks being almost invariably separated from the slates by brown volcanic materials which are everywhere succeeded by the same type of Devonian slate, and in the Southpool Creek and many other sections are found to pass insensibly into the chloritic type. In the Southpool Creek section a hard bluish diabase (? aphanite) occurs in the chloritic band. In the southern chloritic districts of the Prawle the volcanic rocks may still be here and there detected by texture or colour. Volcanic rocks occur in the mica schists of the Start coast, and can be detected even when only a few inches in thickness. At Spirit-of-the-Ocean Cove chloritic rock with much calcspar occurs in association with tuffs and a grey rock with incipient foliation, presenting a slightly gneissoid appearance, and apparently a much sheared diabase. The association of the chloritic rocks with the mica schists is of as intimate a nature as that of the volcanic materials with the unaltered slates to the north. From these facts it seems evident that the chloritic series is nothing more than a Devonian volcanic group, of which the Torcross, Stoke Fleming, Dartmouth, and Kingswear coast tuffs and diabases were either sporadic offshoots or evidences of more or less contemporaneous local vulcanicity.

The more evident crinkling of the mica schists in contact with the chloritic group seems to be due to their comparative softness and greater fissility during the crumpling and contraction to which both were subjected.

The comparative suddenness of the transition from unaltered to more or less highly altered rocks may be explained by the lessening of strain (in receding from the harder masses of ancient rocks, against which the beds were jammed), being coincident with the thinning out of the volcanic materials northward, and furthermore favoured by the soft character of the grey slates with limonitic interfilmings which everywhere bound the northern chloritic band on the north. It is not the author's present purpose to enter more particularly into the stratigraphy of this interesting region, which is not yet thoroughly worked out. It only remains to acknowledge the prior claim of Mr. Somervail to the suggestion of the identity of the Devonian diabases with the chloritic rocks.[1]

XII.—Note on Boulders at Darley, near Matlock, Derbyshire.

By Herbert Bolton.

During the excavation for a small lake close to the Midland Railway Station at Darley, near Matlock, a cluster of fifteen boulders were exposed, the size of several being sufficient to justify an examination. The boulders lay in a bed of Boulder-clay which had a thickness of nine feet.

The upper part of the clay was of a strong yellow colour and very stiff. Below, the colour varied from yellow to brown and red, and pockets of sand were common.

Only two boulders were rounded, the rest being sub-angular, on their upper half, and fairly angular on the lower.

All the boulders consist of gritstone identical in character with the Chatsworth grit of the adjoining hills.

No striations occur in the boulders, but this may be due to the original surface having crumbled away.

A series of parallel and shallow grooves occur on the side of the largest boulders, and a deep hollow has been scooped out of its southern face.

The major axis of the undisturbed boulder was approximately north and south, the general direction of the cluster being 8° west of north. The blocks were arranged in the order of their weight

[1] The views above expressed are those to which the author himself has been led, but they have not yet been fully considered and adopted by the Geological Survey.

in a north to south direction. The clay was found to rest upon a deposit of the nature of river gravel.

The writer is of opinion that the clay is redistributed Boulder-clay from the adjoining heights, and that the boulders were brought down at the same time from the line of outcrop of the grit.

He is led to this conclusion by the local character of the boulders, the almost total absence of foreigners, and the character of the clay.

The red and brown colour of the latter at its base seems to show that oxidation of the contained iron has proceeded for a longer time than in the case of the uppermost clay. This would be expected if the clay was redistributed, for the basement mass of clay must have been the superficial clay of the heights. The enclosed sand would also indicate the complete disintegration of boulders of grit-stone, etc., whilst the clay was in its primary position.

The amount of disintegration which has taken place since redistribution is marked by the crumbling surface of the large boulders.

The general direction of the boulders may be explained by noticing that the river flows from north to south.

REVIEWS.

I.—Pineal Fontanelle of Placoderm and Catfish. By Bashford Dean, A.M., Ph.D. Nineteenth Report of the Commissioners of Fisheries of the State of New York, pp. 307–363, pls. i.–xiv. (Albany, 1891.)

Dr. Dean, as assistant to Prof. Newberry, of Columbia College, New York, has had the privilege of studying the fine skulls of *Dinichthys* described by the Professor. He has directed attention more especially to the pineal region of the cranial shield, and now attempts to show, from a study of the pineal foramen in the Siluroids, that the well-known foramen in *Dinichthys* and its allies must have been the seat of a median eye. The aperture is remarkably minute, and after a detailed description of the surrounding bone, Dr. Dean remarks that this foramen "becomes naturally the pinhole of the camera to produce an inverted image upon the retina, a condition almost unparalleled for primitive simplicity, obviating as it does a diaphragm (iris), as well as the specialized humours, aqueous, crystalline, and vitreous. Moreover, it will at once be seen to do away as well with all devices for accommodation, since the focal distance would be practically the same for a point at any given distance." The author's numerous dissections of the soft parts of the Siluroid head afford material for a valuable series of notes and figures; and it seems to be demonstrated that the pineal eye exists in a very degenerate condition. At the same time, we fail to recognize in the new memoir any additional evidence in favour of the supposed genetic connexion between the Coccostean fishes and modern Siluroids. Dr. Dean's researches merely result in the plausible explanation of a feature in the cranial roof of *Dinichthys*, by reference to a nearly analogous structure in an existing type of fish.

A. S. W.