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NEW SERIES. VOL. VIII.—No. 7.

THE CANADIAN NATURALIST

AND

Quarterly Journal of Science.

WITH THE

PROCEEDINGS OF THE NATURAL HISTORY SOCIETY OF MONTREAL:

B. J. HARRINGTON, B. A., PH. D.
J. FRASER TORRANCE, A. B., B. A. Sc. } EDITORS.

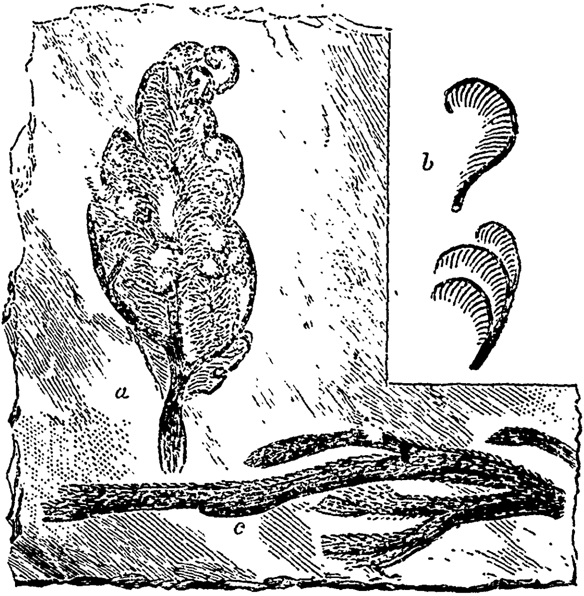
MONTREAL:
DAWSON BROTHERS, Nos. 159 AND 161 ST. JAMES STREET.

MITCHELL & WILSON, PRINTERS, 192 ST. PETER STREET.

Price Three Dollars per Volume, in Advance.

CONTENTS OF No. 7, Vol. VIII.

Published April 10th, 1878.



PTILOPHYTON THOMSONI.

(*a*) Impression of plant in vernation.

(*b*) Branches conjecturally restored.

(*c*) Branches of *Lycopodites Milleri.*

In this cut the parts of the fossil are given more coarsely and distinctly than in the original.

THE

CANADIAN NATURALIST

AND

Quarterly Journal of Science.

NOTES ON SOME SCOTTISH DEVONIAN PLANTS.

By J. W. Dawson, LL.D., F.R.S., Principal and Vice-Chancellor of McGill University, Montreal.

(Read before the Edinburgh Geological Society, 20th Dec. 1877, D. Milne Home, Esq., LL.D., President, in the chair.)

Since the publication of my Memoirs on Devonian Plants, in the Journal of the Geological Society of London and in the Reports of the Canadian Geological Survey, I have watched with some interest the progress of discovery in the Devonian Flora of Scotland, and desire now to make a few remarks on new and critical forms, and on opinions which have been expressed by workers in this field.

Previously to the appearance of my descriptions of Devonian plants from North America, Hugh Miller had described forms from the Devonian of Scotland, similar to those for which I proposed the generic name *Psilophyton*; and I referred to these in this connection in my earliest description of that genus.* He had also recognized what seemed to be plants allied to Lycopods and Conifers. Mr. Peach and Mr. Duncan had made additional discoveries of this kind, and Sir J. Hooker and Mr. Salter had described some of these remains. More recently Messrs. Peach, Carruthers and McNab have worked in this field, and in the present year † Messrs. Jack and Etheridge have summed up the facts and have added some that are new.

* Journal Geological Society, London, 1859.

† Ibid, 1877.

The first point to which I shall refer, and which will lead to the other matters to be discussed, is the relation of the characteristic *Lepidodendron* of the Devonian of Eastern America, *L. Gaspianum*, to *L. nothum* of Unger and of Salter. At the time when I described this species I had not access to Scottish specimens of *Lepidodendron* from the Devonian, but these had been well figured and described by Salter, and had been identified with *L. nothum* of Unger, a species evidently distinct from mine, as was also that figured and described by Salter, whether identical or not with Unger's species. In 1870 I had for the first time an opportunity to study Scottish specimens in the collection of Mr. Peach; and on the evidence thus afforded I stated confidently that these specimens represented a species distinct from *L. Gaspianum*; perhaps even generically so.* It differs from *L. Gaspianum* in its habit of growth by developing small lateral branches instead of bifurcating, and in its foliage by the absence or obsolete character of the leaf-bases and the closely placed and somewhat appressed leaves. If an appearance of swelling at the end of a lateral branch in one specimen indicates a strobile of fructification, then its fruit was not dissimilar from that of the Canadian species in its position and general form, though it may have differed in details. On these grounds I declined to identify the Scottish species with *L. Gaspianum*. The Lepidodendron from the Devonian of Belgium described and figured by Crepin,† has a better claim to such identification, and would seem to prove that this species existed in Europe as well as in America. I also saw in Mr. Peach's collection in 1870, some fragments which seemed to me distinct from Salter's species, and possibly belonging to *L. Gaspianum*.‡

In the earliest description of *Psilophyton* I recognized its probable generic affinity with Miller's 'dichotomous plants,' with Salter's 'rootlets,' and with Goeppert's *Haliserites Dechenianus*, and stated that I had "little doubt that materials exist in the Old Red Sandstone of Scotland for the reconstruction of at least one species of this genus." Since, however, Miller's plants had been referred to coniferous roots, and to fucoids, and Goeppert's *Haliserites* was a name applicable only to fucoids, and since the structure and fruit of my plants placed them near to Lycopods,

* Report on Devonian Plants of Canada, 1871.

† Observations sur quelques Plantes Fossiles des dépôts Devoniens.

‡ Proceedings Geological Society of London, March 1871.

I was under the necessity of giving them a special generic name, nor could I with certainty affirm their specific identity with any European species. The comparison of the Scottish specimens with woody rootlets, though incorrect, is in one respect creditable to the acumen of Salter, as in almost any state of preservation an experienced eye can readily perceive that branchlets of *Psilophyton* must have been woody rather than herbaceous, and their appearance is quite different from that of any true Algae.

The type of *Psilophyton* is my *P. princeps*, of which the whole of the parts and structures are well known, the entire plant being furnished in abundance and in situ in the rich plant-beds of Gaspé. A second species, *P. robustius*, has also afforded well characterized fructification. *P. elegans*, whose fruit appears as "oval scales," no doubt bore sac-like spore-cases resembling those of the other species, but in a different position, and perfectly flattened in the specimens procured. The only other Canadian species, *P. glabrum*, being somewhat different in appearance from the others, and not having afforded any fructification, must be regarded as uncertain.

The generic characters of the three first species may be stated as follows:—

Stems dichotomous, with rudimentary subulate leaves, sometimes obsolete in terminal branchlets and fertile branches; and in decorticated specimens represented only by punctiform scars. Young branches circinate. Rhizomata cylindrical, with circular root-areoles. Internal structure of stem, an axis of scalariform vessels enclosed in a sheath of imperfect woody tissue and covered with a cellular bark more dense externally. Fruit, naked sac-like spore-cases, in pairs or clusters, terminal or lateral.

The Scottish specimens conform to these characters in so far as they are known, but not having as yet afforded fruit or internal structure, they cannot be specifically determined with certainty. More complete specimens should be carefully searched for, and will no doubt be found.

In Belgium, M. Crepin has described a new species from the Upper Devonian of Condroz under the name *P. Condrusianum*, [1875]. It wants however some of the more important characters of the genus, and differs in having a pinnate ramification giving it the aspect of a fern. In a later paper [1876] the author considers this species distinct from *Psilophyton*, and proposes for it a new generic name *Rhacophyton*. In a note he states that Mr. Carruthers informs him that he regards *Psilophyton* as founded on the axes of *Lepidodendra* and on the fruit of ferns of the genus *Rhodea* of Stur. For this statement I have no published authority on the part of the English botanist, and it is certainly quite destitute of foundation in nature. My original specimens of *Psilophyton* are low plants with slender stems growing from *rhizomata*, and their leaves and fruits are attached to them, while *Rhodea* is merely a provisional genus formed to include certain ferns of the Hymenophyllid group, but otherwise of uncertain affinities. In the same note M. Crepin intimates that Mr. Carruthers has abandoned his *Psilophyton Dechenianum*, published in the Journal of Botany for 1843, and in which he had included Salter's *Lepidodendron nothum* and *Lycopodites Milleri* and "rootlets," as well as Goeppert's *Haliserites Dechenianus* and a peculiar plant given to him by Sir P. Egerton! * Such a change of opinion I must admit to be judicious. The fact that these plants could, even conjecturally, be identified by a skilful botanist, shows however how imperfectly they are known, and warrants some investigation of the causes of this obscurity, and of the true nature of the plants.

The characters given by Mr. Carruthers in his paper of 1873 for the species *P. Dechenianum*, are very few and general:—"Lower branches short and frequently branching, giving the plant an oblong circumscription." Yet even these characters do not apply, so far as known, to Miller's fucoids or Salter's rootlets or Goeppert's *Haliserites*. They merely express the peculiar mode of branching already referred to in Salter's *Lepidodendron nothum*. The identification of the former plants with the *Lepidodendron* and *Lycopodites* indeed rests only on mere juxtaposition of fragments, and on the slight resemblance of the decorticated ends of the branches of the latter plants to *Psilophyton*. It is contradicted by the obtuse ends of the branches of the

* Mr. Carruthers has elsewhere identified *Lepidodendron nothum* and *L. Gaspianum* with *Leptophleum rhombicum*, and this with an Australian species collected by Mr. Daintree in Queensland, but which I subsequently found to be a species allied to the well known *Lepidodendron tetragonum* of the Lower Carboniferous, and which had been previously discovered by Mr. Selwyn in the Carboniferous of Victoria. See Carruthers' paper in the Journal of the Geological Society, vol. 28, and my criticism in vol. 29, which last was however only printed in abstract, and with some comments under the head of "Discussion," to which if present I could have very easily replied.

Lepidodendron and *Lycopodites*, and by the apparently strobilaceous termination of some of them.

Salter's description of his *Lepidodendron* is quite definite, and accords with specimens placed in my hands by Mr. Peach:—"Stems half an inch broad, tapering little, branches short; set on at an acute angle, blunt at their terminations. Leaves in seven to ten rows, very short, not a line long and rather spreading than closely imbricate." These characters however, in so far as they go, are rather those of the genus *Lycopodites* than of *Lepidodendron*, from which this plant differs in wanting any distinct leaf-bases, and in its short crowded leaves. It is to be observed that they apply also to Salter's *Lycopodites Milleri*, and that the difference of the foliage of that species may be a result merely of different state of preservation. For these reasons I am disposed to place these two supposed species together, and to retain for the species the name *Lycopodites Milleri*. It may be characterized by the description above given, with merely the modification that the leaves are sometimes one-third of an inch long and secund.

Decorticated branches of the above species may no doubt be mistaken for *Psilophyton*, but are nevertheless quite distinct from it, and the slender branching dichotomous stems, with terminations which, as Miller graphically states, are "like the tendrils of a pea," are too characteristic to be easily mistaken, even when neither fruit nor leaves appear. With reference to fructification, the form of *L. Milleri* renders it certain that it must have borne strobiles at the ends of its branchlets, or some substitute for these, and not naked spore-cases like those of *Psilophyton*.

The remarkable fragment communicated by Sir Philip Egerton to Mr. Carruthers,* belongs to a third group, and has I think been quite misunderstood. I am enabled to make this statement with some confidence, from the fact that the reverse or counterpart of Sir Philip's specimen was in the collection of Sir Wyville Thomson, and was placed by him in my hands in 1870. It was noticed by me in a paper on New Devonian Plants, in the Journal of the Geological Society of London in 1871, in the following terms:—

"In his recently published 'Paléontologie,' Schimper (evi-

* Journal of Botany, 1873.

dently from inattention to the descriptions and want of access to specimens) doubts the Lycopodiaceous character of species of *Lycopodites* described in my papers in the Journal of this Society from the Devonian of America. Of these *L. Richardsoni* and *L. Matthewi* are undoubtedly very near to the modern genus *Lycopodium*. *L. Vanuxemii* is, I admit, more problematical; but Schimper could scarcely have supposed it to be a fern or a fucoid allied to *Caulerpa* had he noticed that both in my species and the allied *L. pennæformis* of Goeppert, which he does not appear to notice, the pinnules are articulated upon the stem, and leave scars where they have fallen off. When in Belfast last summer I was much interested by finding in Prof. Thomson's collection a specimen from Caithness, which shows a plant apparently of this kind, with the same long narrow pinnae or leaflets, attached, however, to thicker stems, and rolled up in a circinate manner. It seems to be a plant in vernation, and the parts are too much crowded and pressed together to admit of being accurately figured or described; but I think I can scarcely be deceived as to its true nature. The circinate arrangement in this case would favour a relationship to ferns; but some Lycopodiaceous plants also roll themselves in this way, and so do the branches of the plants of the genus *Psilophyton*."

No figure of the plant was given, and Mr. Carruthers, if he noticed the reference, very probably did not connect it with the plant which he received from Sir Philip Egerton. His figure however, published in the Journal of Botany for 1873, leaves no room to doubt that he has had in his possession the counterpart of Thomson's specimen, of which a figure is given in this paper. My interpretation of it differs considerably from his, and as the matter is of some palæontological interest, I shall proceed to describe the specimen from my point of view.

The specimen consists of a short erect stem, on which are placed somewhat stout alternate branches, extending obliquely outward and then curving inward in a circinate manner. The lower ones appear to produce on their inner sides short lateral branchlets, and upon these and also upon the curved extremities of the branches, are long narrow linear leaves placed in a crowded manner, and which are the "tufts of linear bodies" referred to by Mr. Carruthers. The specimen is thus not a spike of fructification but a young stem or branch in vernation, and which when unrolled would be of the form of those peculiar pinnate

Lycopodites of which *L. Vanuxemii* of the American Devonian and *L. pennæformis* of the European Lower Carboniferous are the types, and it shows, what might have been anticipated from other specimens, that they were low tufted plants, circinate in vernation. The short stem of this plant is simply furrowed, and bears no resemblance to the detached branch of *Lycopodites Milleri* which lies at right angles to it on the same slab (see figure). As to the affinities of the singular type of plants to which this specimen belongs, I may quote from my Report on the Lower Carboniferous plants of Canada, in which I have described an allied species, *L. plumula*:—

"The botanical relations of these plants must remain subject to doubt, until either their internal structure or their fructification can be discovered. In the mean time I follow Goeppert in placing them in what we must regard as the provisional genus *Lycopodites*. On the one hand they are not unlike the slender twigs of *Taxodium* and similar Conifers, and the highly carbonaceous character of the stems gives some colour to the supposition that they may have been woody plants. On the other hand, they might, in so far as form is concerned, be placed with algae of the type of Brongniart's *Chondrites obtusus*, or the modern *Caulerpa plumaria*. Again, in a plant of this type from the Devonian of Caithness to which I have referred in a former memoir, the vernation seems to have been circinate, and Schimper has conjectured that these plants may be ferns, which seems also to have been the view of Shumard."

On the whole these plants are allied to Lycopods rather than to Ferns; and as they constitute a small but distinct group, known only in so far as I am aware in the Lower Carboniferous and Erian or Devonian, they deserve a generic name, and I would propose for them that of *Ptilophyton*, a name sufficiently distinct in sound from Psilophyton, and expressing very well their peculiar feather-like habit of growth. This genus may for the present be defined as follows:—

Branching plants, the branches bearing long slender leaves in two or more ranks, giving them a feathered appearance; vernation circinate. Fruit unknown, but analogy would indicate that it was borne on the bases of the leaves or on modified branches with shorter leaves.

I would name the present species *Pt. Thomsoni*, and would characterize it by its densely tufted form and thick branches, until specimens more fully developed shall be found. The other species will be:—

Pt. pennæformis, Goeppert, L. Carboniferous.
Pt. Vanuxemii, Dawson, Devonian.
Pt. plumula, Dawson, L. Carboniferous.

Shumard's *Filicites gracilis*, from the Devonian of Ohio, and Stur's *Pinites antecedens*, from the Lower Carboniferous of Silesia, may possibly belong to the same genus. The present specimen is apparently the first appearance of this form in the Devonian of Europe.

Mr. Salter described in 1857 * fragments of fossil wood from the Scottish Devonian, having the structure of *Dadoxylon*, though very imperfectly preserved; and Prof. McNab has proposed † the generic name *Palæopitys* for another specimen of coniferous wood collected by Hugh Miller, and referred to by him in the "Testimony of the Rocks." From Prof. McNab's description, I should infer that this wood may after all be generically identical with the woods usually referred to *Dadoxylon* of Unger (*Araucarioxylon* of Kraus). The description, however, does not mention the number and disposition of the rows of pores, nor the structure of the medullary rays, and I have not been able to obtain access to the specimens themselves. I have described three species of *Dadoxylon* from the Middle and Upper Erian of America, all quite distinct from the Lower Carboniferous species. There is also one species of an allied genus *Ormoxylon*, besides the somewhat exceptional *Prototaxites*, which occurs in the Lower Erian, not far above the top of the Upper Silurian. All these have been carefully figured, and it is much to be desired that the Scottish specimens should be re-examined and compared with them.

Prof. Alleyne Nicholson has kindly placed in my hands some ancient plants which though not Scottish nor Devonian are of interest in this connection. One of these is a specimen from the Lower Ludlow of Bow Bridge. From its regular ramification, its apparently woody structure, and its traces of rudimentary leaflets, it may not improbably belong to the genus *Psilophyton*. If so, this genus occurs at about as low a horizon in Europe as in Canada.

* Journal London Geological Society.
† Transactions Edinburgh Botanical Society, 1870.

The remarkable plants from the Skiddaw slates described by Nicholson as *Buthotrephis Harknessi* and *B. radiata* * have also been examined by me, as well as some additional specimens from the same formation collected by Dr. G. M. Dawson. Nicholson says of the latter species:—"If its vegetable nature be conceded, it can hardly be referred to the Algae." It seems not unlikely, as Nicholson indeed suggests, that both plants may belong to the same species, and that this had the habit of growth of *Annularia* and resembled *A. laxa* of the American Devonian. If a land plant, it is probably the oldest at present certainly known.†

With these plants, Prof. Nicholson sent a fibrous body from the Upper Llandeilo of Hart Fell, near Moffat, which at first sight had the appearance of a fragment of coarse-grained wood. On microscopic examination of it, however, I concluded that it had been a bundle of spicules of a sponge of the type of *Hyalonema*. This I still believe to be its true nature.

In studying the plants of the older rocks, the botanist requires to be on his guard as to the Algæ and Zoophytes of these formations which simulate land plants. In the latter group I know no forms more deceptive than those of Hall's genus *Inocaulis*, which is regarded as a relative of the Graptolites. A specimen now before me, from the collection of Col. Grant, of Hamilton, Ontario, in its ramification and appearance of foliage, bears the closest resemblance to a lycopodiaceous plant, and I have seen what appears to be the base of a *Dictyonema* from the Niagara formation, which might readily be mistaken for a small and peculiar species of *Psilophyton*.

Messrs. Jack and Etheridge have given an excellent summary of our present knowledge of the Devonian Flora of Scotland, in the Journal of the London Geological Society. From this it would appear that species referable to the genera *Calamites*, *Lepidodendron*, *Lycopodites*, *Psilophyton*, *Arthrostigma*, *Archæopteris*, *Caulopteris*, *Palæopitys*, *Araucarioxylon*, and *Stigmaria* have been recognized.

* Geological Magazine, Vol. VI.

† Since the above was written, Lesquereux has described supposed land plants from the Cincinnati Group (Lower Silurian) of Ohio. Saporta has discovered what he regards as a fern in rocks of similar age in France, and Claypole will shortly describe an apparently lepidodendroid tree (*Glyptodendron*) from the Clinton Group of Ohio; but neither of these is quite so old as the Skiddaw plants.

The plants described by those gentlemen from the Old Red Sandstone of Callender, I should suppose, from their figures and descriptions, to belong to the genus *Arthrostigma*, rather than to *Psilophyton.* I do not attach any importance to the suggestions referred to by them, that the apparent leaves may be leaf-bases. Long leaf-bases, like those characteristic of *Lepidofloyos*, do not occur in these humbler plants of the Devonian. The stems with delicate "horizontal processes" to which they refer may belong to *Ptilophyton* or to *Pinnularia.*

In conclusion, I need scarcely say that I do not share in the doubts expressed by some British Palæontologists as to the distinctness of the Devonian and Carboniferous Floras. In Eastern America, where these formations are mutually unconformable, there is, of course, less room for doubt than in Ireland and in Western America, where they are stratigraphically continuous. Still, in passing from the one to the other, the species are for the most part different, and new generic forms are met with, and, as I have elsewhere shown, the physical conditions of the two periods were essentially different.*

It is, however, to be observed that since, as Stur and others have shown, *Calamites radiatus* and other forms distinctively Devonian in America, occur in Europe in the Lower Carboniferous, it is not unlikely that the Devonian Flora, like that of the Tertiary, appeared earlier in America. It is also probable, as I have shown in the Reports already referred to, that it appeared earlier in the Arctic than in the Temperate zone. Hence an Arctic or American Flora, really Devonian, may readily be mistaken for Lower Carboniferous by a botanist basing his calculations on the fossils of temperate Europe. Even in America itself, it would appear from recent discoveries in Virginia and Ohio. that certain Devonian forms lingered longer in those regions than further to the North-east;† and it would not be surprising if similar plants occurred in later beds in Devonshire or in the South of Europe than in Scotland. Still, these facts, properly understood, do not invalidate the evidence of fossil plants as to geological age, though errors arising from the neglect of them are still current.

* Reports on Devonian Plants and Lower Carboniferous Plants of Canada.

† Andrews, Palæontology of Ohio, Vol. II. Meek, Fossil Plants from Western Virginia, Philos. Society, Washington, 1875,

I trust that Scottish workers in this interesting though difficult branch of investigation, will be encouraged by the success they have already attained to still more diligent search. In collecting, the smallest and most obscure fragments should not be neglected. Such specimens, when placed in due relation to others previously obtained, may reveal the most important truths; or if by themselves unintelligible, may be rendered valuable by subsequent discoveries. The greatest care should be taken to rescue every portion of the specimens found, and to keep together those that belong to the same plant; and every fragment likely to show microscopic structure should be carefully preserved. Painstaking work of this kind will be sure to be rewarded by important discoveries; and I know by long experience that none other is likely to be successful.

TRAVELLING NOTES ON THE SURFACE GEOLOGY OF THE PACIFIC SLOPE.

By George M. Dawson, D.S., Assoc. R. S. M., F. G. S.

When on my way to resume my geological duties in British Columbia, in May last, I availed myself of the opportunity to obtain a passing glimpse of Northern California, Oregon, and Washington Territory; leaving the Central Pacific Railway, for that purpose, at Roseville Junction, near Sacramento, and travelling northward, by train and stage coach, to the extremity of Puget Sound, whence a steamer runs to Victoria, Vancouver Island. The region was a very interesting one to me, constituting the southern extension of that which I have been engaged in studying in British Columbia, and characterized in the main by the same great physical features. It is proposed now to give the substance of a few notes taken by the way, on the superficial deposits and general aspect of the country, connecting these with facts already observed in British Columbia, some of which are published in the reports of the Geological Survey, but treated of at greater length in a memoir read before the Geological Society of London, in June last. Dr. A. S. Packard, Jr., of the United States Entomological Commission, passed through the same region, in August last, and has published some notes on the surface geology in the *American Naturalist* for November, under the title of "Glacial Marks on the Pacific and Atlantic Coasts Compared." To this article I shall again refer.

In descending the western slope of the Sierra Nevada, hard clays, packed with boulders and stones, are seen in some cuttings near Blue Canon Station (elevation, 4,693 feet) and at other places, probably as far down as Dutch Flat Station (3,395 feet). These are doubtless old moraines, due to the former glaciers of the Sierra, which, according to the American geologists who have examined this range, were at one time very extensive.

Leaving the rolling foot-hills, the train glides out on the wide and generally fertile Sacramento Plain, in the midst of which the city of the same name is situated. Near the base of the foot-hills, large areas are covered with the so-called "Hog Wallows," about which some discussion lately occurred in *Nature*, it being suggested by some that they were connected with ancient ice action. Mr. Gabb * is no doubt right, however, in attributing them to the accumulation of drifting sand and soil around clumps of vegetation, which in some cases may have afterwards perished from climatic or other causes, leaving only these peculiar hillocks to mark their former positions. The banking up of sand and soil about patches of cactus and sage is seen frequently in the dry plains east of the Rocky Mountains, as well as in Nevada, to which Mr. Gabb refers.

Leaving the main line of railway at a right angle at Roseville, and turning northward, one continues to travel over the same wide, flat, or gently undulating plain of Central California, bounded to the right by the snowy peaks of the Sierra, to the left by the more rounded summits of the Coast Range. Soon after leaving Maryville—an important town—a rugged and picturesque group of hills, called the Butte Mountains, appear on the left, some miles distant. They owe their outline apparently to prolonged atmospheric waste, and are singularly different from the dome-like summits of a glaciated country. At Reading, about 120 miles north of Roseville, the railway comes to an end, and for 275 miles, the stage coach must carry us through a country remarkably broken and tumultuous. Crossing the Sacramento by a good ferry, soon after leaving Reading, a broad,

* *Nature*, Vol. XVI, p. 183.

broken flat or plateau, with a height, according to the barometer, of 760 feet is reached. Through this little rocky hills project, and its general elevation is probably nearly that of the body of water which must formerly have filled the central "Gulf of California" for a prolonged period. The road continues to follow the Sacramento Valley in a general way for some distance, crossing first a considerable tributary, and then re-crossing the main stream. The upper part of the river is very tortuous, and flows in a deep, steep-sided valley, up which, as the road gains a considerable elevation, distant views of the snow-clad cone of Mount Shasta are, from time to time, obtained.

Leaving the Sacramento where it turns westward, we climb, by a small lateral valley, to the summit of a plateau with an elevation of about 2,300 feet, and at Strawberry Valley find ourselves apparently close to the base of Shasta. A little further on volcanic rocks are seen near the road, piled together in a way suggesting the action of a glacier. Dr. Packard, who stayed here to accomplish the ascent of the mountain, describes three small glaciers which still remain near its summit, the upper four thousand feet of which is covered with snow. These glaciers are still engaged in piling up moraines, and have left others evidencing their former extension. This mountain, at one time, must have been an important centre of local glaciation, though the phenomena of its vicinity are apparently quite distinct from those of the almost universally glaciated north.

Shasta reaches an elevation, according to Prof. Whitney, of 4,442 feet, and, in its grand isolation, and the remarkable symmetry of its conical form, is very impressive.

Leaving Shasta, the road gradually descends into the broad valley of a tributary of the Klamath River, and passing through a wide gap in a range of hills, Yreka—once an important centre of alluvial gold mining—is reached. About fourteen miles from Yreka, a flat resembling a terrace was observed skirting one of the hills, with an estimated elevation of 250 feet above the flat-bottomed valley, or about 2,775 feet above the sea.

Beyond Yreka the Klamath River is crossed, and on the line between California and Oregon the Siskiyou Range is slowly ascended, the summit on the road being, by my aneroid, 4,500 feet in height, and the actual descent from this place to the stage stable on its western base being nearly 3,000 feet.

After passing Jacksonville, situated on a branch of the Rogue

River, in a small, but fertile and beautiful valley, the main stream of the Rogue River is crossed by a good bridge. Between this river and the South Umpqua, is a rugged and irregular country, in which steep-sided hills are huddled together, but in which also several narrow but fertile valleys are concealed. The Umpqua once reached, is followed to Roseburg, whence a railway stretches to Portland, near the junction of the Columbia and Willamette rivers.

From the Sacramento River to this point all the streams crossed flow westward to the coast, transverse to the proposed Oregon and California Railway, the completion of which will be a very difficult matter. So far no traces of general glaciation, or deposits like the northern drift, have been encountered. The hills appear to have been subjected to prolonged sub-aërial weathering, the rocks, when bared on their slopes, being generally soft and decomposed at the surface. The soil covers the hills almost uniformly from base to summit, except where the slopes are remarkably steep; and is probably in most instances a product of waste of rock nearly in place. The bottoms of the valleys, though occasionally flat, and suggesting the existence of former lakes, or that the sea may at one time have flowed into them, are generelly characterized by broad coalescing fan-shaped deltas of the lateral streams. The summits and higher slopes of the hills are generally stony and gravelly, while the valleys have a clayey or loamy soil, which graduates into the former irregularly on the slopes. There is a remarkable absence of any well-marked terraces or benches; though, besides those already mentioned, a probable terrace was observed about thirteen miles above Roseburg, on the Umpqua, with an estimated elevation of 540 feet above the sea. The general impression conveyed by the country is, however, that there are no true terraces, which may arise from the fact that the region has never been flooded, or if flooded, that sufficient available material (detritus) for the formation of distinct terraces has not been at hand, or, lastly, on the supposition that the process of obliteration seen actively in progress in the somewhat similarly circumstanced dry southern interior of British Columbia, has here been so long continued as to remove almost entirely the old water marks. The hills are everywhere seamed with gullies which form the terminations of small valleys, all of which are connected, uniting as they descend toward the main stream. The almost complete absence of lakes or ponds, or even hollows holding swamps, is very remarkable, and contrasts strongly with the innumerable lake-basins of British Columbia.* The water indeed seems never to rest from its sources in the mountains till it reaches the sea. This is either due to the prolonged action of the streams themselves in completely filling rock-basins, if such there have been, and removing all other impediments to their flow, or is the result of the original absence of those great masses of material accumulated during a stage of the glacial epoch, which in the north (as I hope elsewhere to show) have in many places been mainly concerned, at a later period, in forming lakes by the blocking of old valleys with detritus. The local colouring of the soil, in its close resemblance to that of the decomposed parts of the underlying rocks, indicating the absence of foreign material, appears also to favour the latter conclusion.

North of Roseburg the railway passes for some distance, with heavy grades and sharp curves, through a generally hilly country, crossing several branches of the Umpqua, and then reaching the upper part of the great and fertile Willamette Valley, which runs northward to the Columbia, between the Cascade Mountains with their flanking hills, and the lower ranges of the coast.

Prof. Thomas Condon, of the University of Oregon, has published some account of the state of this country in the later geological times. This I regret not to have had the advantage of reading; but, as the paper is entitled "The Willamette Sound," it would seem to imply his belief in the former submergence of this region. Prof. Le Conte indeed states that Prof. Condon has traced an old sea-margin from the coast up the Columbia River to and beyond the Cascade Range. This he compares with the sheet of nearly land-locked water which must have covered Central California at the same period. †

About two miles south of Creswell station, I noticed what appeared from a distance to be a series of pretty distinct terraces, on a hill-side, at an estimated elevation of from 100 to

* This of course applies to the region traversed, west of the Cascade Mountains. East of that range the Klamath and other extensive lakes appear on the map. These differ singularly in their form from the long river-like lakes of British Columbia, and may possibly be due to mountain elevation taking place more rapidly than the draining streams are able to lower their channels.

† Elements of Geology, 1878, p. 530.

200 feet above the road, which is here about 650 feet above the sea. The valley is wide and flat-bottomed, gradually sloping downward to the north, and quite different from any met with on the line of route since leaving the plain of central California. The soil is usually pale-coloured and often clayey, and north of Eugine, is seen in several places in cuttings to be underlain by beds with large and small rounded stones. Beyond Albany, the country is for some distance more undulating, and in many places more or less perfectly bedded deposits of gravel and sand, with occasional small boulders, occur. These much resemble some varieties of modified drift, and are probably due neither to local glaciers nor to the present or former streams, but to the transport of material by ice during a general submergence. It is here that we first meet with distinct traces of that invasion of the land by the sea during a period of cold, which has been universal further to the north.

The Willamette and Columbia Rivers, immediately below Portland, flow through a flat country, its general aspect, with that of the rivers themselves and the vegetation of their banks, being much like that of the Fraser below New Westminster. The tide affects the Willamette up to Portland. Seven miles below this place, on the left bank, very distinct terraces occur, with elevations estimated by the eye as 100, 180, and 300 feet above the river, the highest being about the general level of the surface of the country here. In several other places more or less perfect terraces appear, at various elevations, less than about 300 feet.

Leaving the banks of the Columbia at Kalama, our route continues northward between the two ranges before referred to. The only portion of the Northern Pacific Railway yet built on the West Coast, connects this place with Tacoma, 105 miles distant, and near the extremity of Puget Sound, which with a ramifying form occupies the northern part of the same great valley. The valley of the Cowlitz river is at first followed up for some distance, several small streams which afterwards unite and flow west through the Coast Range are then crossed, and in a short distance water flowing northward to Puget Sound is reached; no strongly-marked watershed being observed. At Olequa Station, twenty-eight miles from the Columbia, is a well marked terrace or beach with an elevation of about 100 feet,*

* The elevation of places on this part of the route, though taken by barometer, were checked at the sea level at both ends, and are correct within a very few feet.

with a second about 30 feet higher. In following the Cowlitz, banks in cuttings sometimes 50 feet in height, show fine, yellowish horizontally-bedded sands. These are pretty hard, and are interbedded in places with thin and thick layers of gravel, composed of water-rolled stones, some as large as the two fists. The sandy drift exactly resembles that seen in low banks near the water level on the Willamette and Columbia, but as we go northward, and ascend, the gravelly layers continue to increase in importance. Forty miles from the Columbia the railway passes over a distinct and wide bench with an elevation of 337 feet, the general level of the country—which is here nearly flat—being about 380 feet. Gravel beds are abundant at Centreville (54 m.) with a general elevation of about 160 feet. Here the rolled gravel of the subsoil contains some small boulders up to ten inches in diameter. At 65 miles from our initial point, elevation 230 feet, boulders two feet in diameter are first seen, and a few miles further northward gravelly banks are found, of rudely mingled coarse materials, including boulders up to three and four feet in diameter, with overlying or interstratified layers of fine yellowish sand. The country here becomes undulating, with many low ridges and hillocks, and *begins to show small ponds and swamps.* A few miles south of Yelm Prairie (74 m., elevation 295 feet), some ridges, in their composition resemble the closely-packed gravel and boulder deposits of Spring Ridge and Beacon Hill near Victoria. From this point to Tacoma, the county is generally flat or gently undulating, and declines gradually toward the head of the Sound, the superficial deposits being in general not so coarse as those just described.

At Tacoma, the banks along the shore show a great thickness of firm finely-bedded sandy and clayey deposits, which form the substratum of the plateau above, but which I had not time to examine. At Seattle—the centre of the coal mining industry—about 30 miles northward on the east shore of the Sound, the drift consists of sands, gravels and clays, without any apparent regular sequence, but with occasional large and many small boulders scattered through them. The sands are frequently current-bedded, and in one place curiously contorted layers of fine, hard, clayey sand, alternated with others nearly horizontal, as though floating ice had from time to time disturbed the regularity of the deposit. Some beds resemble in all respects true boulder-clays, being thickly packed with large and small stones, which lie in all positions. These beds, however, seem to form a part of the general series, and do not appertain specially to any particular horizon. No clearly glaciated stones were seen, though from the shape and appearance of many, it is probable that a careful search would bring such to light, as at Victoria. Fine exposures of drift also occur at Port Townsend near the entrance to the Sound, and elsewhere along its banks.

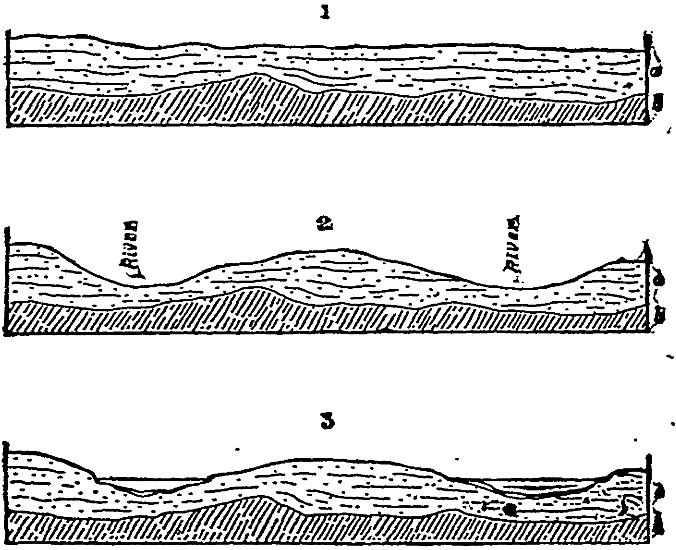
The drift deposits of Puget Sound, as a whole, very much resemble those of the southern part of Vancouver Island and shores of the Strait of Georgia further north, which are described in the paper above referred to. There is good evidence to show that at one time a great glacier-sheet, fed both from the mainland and mountains of Vancouver Island, filled the whole Strait of Georgia, and passing southward, overlapped the low south-eastern corner, at least, of Vancouver Island. It would also appear that when this glacier began to retreat, the sea was at a level considerably higher than at present, and that as soon as the heavily-glaciated rocks of the lowlands were uncovered, the drift deposits—boulder clays, gravels and sands—were laid down on them. These are found in some places near Victoria to include marine shells. From a careful examination of the south-eastern corner of Vancouver Island, my impression is that its glaciation though heavy, was not long continued, and it is probable that in this case the front of the glacier did not at any time reach far southward into the low country of the Sound, or westward along the Strait of Fuca. Be this as it may, however, it is pretty evident that during the submergence above referred to, the great valley, including the Sound, and country to the south, of which the drift deposits have just been described, was a wide strait; along the margins of which local glaciers may have discharged in some places, and in which sea currents, aided by debris-bearing icebergs and coast-ice piled up the deposits now found. It is probable that the same sheet of water passed yet further southward, forming the Willamette Sound, of Condon, with a wide opening to the open ocean by the valley of the Columbia River. If the Strait of Fuca was not at this time encumbered by glacier ice, the high Olympic mountains of the north-western corner of Washington Territory must have formed a snowy sea-washed island.

No great mass of glacier ice can have excavated the present channels and water-ways of Puget Sound, as a glance at their complicated form on any good map will show; nor do the circumstances allow them to be accounted for by the excavating action of systems of local glaciers. If, however, the Strait of Georgia ice-sheet ever traversed the low country now occupied by the Sound, it may have planed and levelled it to some extent.

Mr. George Gibbs has described the passages and inlets of Puget Sound as excavated in many places in drift deposits, which appear not only to form their present banks, but to underlie their beds. Guided by the general form of the inlets, and this description, I ventured in a note on some of the more recent changes in level of the coast of British Columbia and adjacent regions, printed in the *Canadian Naturalist* for 1877, to suggest that they were cut out by rivers during a post-glacial elevation of the land, and afterwards filled up by sea-water on its depression to the present level.

Though aware of the danger of generalising hastily for a region which has not been thoroughly examined, I now venture to again advance this idea with somewhat greater confidence. In their outline on the map, these inlets resemble the fjords with which the whole coast north of the forty-ninth parallel is dissected, but the latter penetrate into the heart of a rugged and mountainous country, and though they may have been cleared of drift material during a post-glacial elevation, have probably been excavated in the hard rocks of the Coast Range of British Columbia during a prolonged period in the later Tertiary, when the land was at a high level. The canals of the Sound are excavated in a low drift-encumbered country, based on soft Tertiary rocks, which, owing to the thickness of later deposits are seldom seen. The average height of the surrounding drift-plateau is from 180 to 200 feet. The channels are deep—often over 100 fathoms—but not uniformly so, as shallower bars cross them in many places which would give rise to a series of great lakes if reelevation should now occur. Here bars, like those so often found near the entrance of the fjords to the north, are generally in observable connection with their cause, in the opposition of tidal currents, the slackening of these currents as they enter wider channels, or other circumstances bringing about the deposition of suspended sediment. They are probably due to the most modern period. In the wide flats surrounding the mouths of streams and rivers, near the present water level, we have evidence of the comparative permanence of the present relations of sea and land.

To recapitulate, a wide hollow deeply scored by rivers, probably extended from the south of Vancouver Island to the Columbia, in later Tertiary times. The northern part of this, now occupied by Puget Sound, may or may not have been planed down by an ice-sheet, but was deeply filled and levelled up with drift during the glacial submergence and retreat of the great glaciers. Being afterwards elevated to a height possibly 600 feet or more greater than the present, streams again began to excavate their channels, guided no doubt in the first instance by such ill-defined longitudinal hollows as the sea-currents, flowing north and south, had before formed. This action continued long enough for the production of deep and wide river valleys in the drift deposits, and in some cases in the more prominent parts of the underlying Tertiary rocks. Lastly, a resubsidence to the present stage having occurred, the sea water filled the river valleys, of which the gently-sloping sides soon became eroded at the water-line into sea-cliffs, and tide flats were formed at the mouths of the streams and wherever ditritus was abundant along the shores.



Diagrams illustrating stages in the production of the Inlets and Passages of Puget Sound.

No. 1. Eroded (perhaps glacier-planed) surface of the Tertiary rocks (*b*) covered uniformly with drift material (*a*) at the close of the glacial epoch.

No. 2. Wide and deep valleys cut into the drift deposits by streams. Land standing at a greater elevation than at present.

No. 3. Valleys filled by the sea owing to subsidence. Shore cliffs and recent submarine deposits in course of formation.

ON SOME JURASSIC FOSSILS FROM THE COAST RANGE OF BRITISH COLUMBIA.

By J. F. Whiteaves.

The fossils which form the subject of the present paper were collected by Mr. G. M. Dawson at three localities in British Columbia during the summer of 1876. By far the greatest number of specimens are from the left bank of the Iltasyouco River, four miles above its junction with Salmon or Dean River; two are from the falls of the Iltasyouco, three miles below the last mentioned locality, the rest are from Sigutlat Lake. The Iltasyouco River, it may be mentioned, is a stream about six miles in length, which flows from Sigutlat Lake into the Salmon River, which it joins in Lat. 52° 53′ and Long. 126° 15′ approximately. The geological structure of the district and the lithological characters of the rocks are described by Mr. Dawson in the Report of Progress of the Geological Survey of Canada for 1876-77, now in course of publication, for which these notes were originally written. The collection consists of twenty-seven species of Mollusca and one of Annelida. With very few exceptions, the fossils are both imperfect and in a poor state of preservation, so that their generic position even is sometimes doubtful. The Ammonites, in particular, are almost all mere fragments. The following is a provisional list of the species, with short descriptions of such as appear to be new, and critical remarks on others.

1. *Terebratula* ——?—Shell (or rather cast) compressed, very gently convex; outline ovate or obovate; length greater than the width at all stages of growth; thickness through the closed valves about equal to one half the width; no mesial fold or sinus. The shape varies in different individuals; the maximum width being nearly always in advance of the middle, but one specimen is broadest at a little distance from the hinge line and somewhat pointed in front. Two half grown examples are ovately-orbicular, and not longer than wide, but the rest are much more elongated. Beak of the ventral valve incurved (but scarcely so much so in the cast as to entirely conceal the delti-

dium or beak of the dorsal valve); obliquely and concavely truncate; foramen rather large; lateral ridges distinct. Dorsal valve with an impressed line or groove in the centre, which extends nearly half-way to the front margin, and indicates the position and shape of the mesial septum; on either side of this there is a single (?) divergent muscular scar, of nearly the same length. The shape of the scars is subspathulate or elliptic-ovate, but they each commence as a simple impressed line. Surface marked with coarse, distant, concentric striæ or plications.

Sigutlat Lake and Iltasyouco River, abundant.

The only Terebratula yet recorded from rocks which are known to be of Jurassic age in North America, is described and figured by Meek, though without any specific name, in the first volume of the Palæontology of California. It was obtained on the western slope of the Sierra Nevada, and appears to be distinct from the present species, as it (the Nevada shell) has a more globose form and a short mesial fold and sinus. An ovate, elongated Terebratula occurs in the coal-bearing rocks of the Queen Charlotte Islands, in beds which may be Jurassic, but young specimens from the last mentioned locality are much wider than long, which is not the case with any of those collected by Mr. Dawson. In the absence of any knowledge of the test of this species, it is very difficult, and indeed almost impracticable to separate it by any valid character from some European Terebratulæ, such as *T. ovoides*, Sowerby, and *T. punctata*, Sowerby (including *T. subpunctata*) as described and figured by Davidson; more especially from the first of these.

2. *Gryphœa calceola, var Nebrascensis*, Meek & Hayden. Iltasyouco River, one typical and characteristic convex valve, with the test preserved, showing both the internal and external surface markings; also an exfoliated specimen with both valves in situ, and a few casts.

3. *Camptonectes* (?) *extenuatus*, Meek & Hayden. A cast of the convex valve of a small Pecten from the Iltasyouco River, precisely similar to the specimen figured under the above name on Plate III. (fig. 6), of the "Palæontology of the Upper Missouri." The surface markings of *C. extenuatus* are unknown, as is also the shape of its ears, and its generic position too is quite problematical, though its aspect is more that of a *Syncyclonema* than of a *Camptonectes*. Casts of the flat valve of a thin compressed Pecten are rather frequent in the Iltasyouco

River porphyrite, which may belong to the same species. These are strikingly like *Syncyclonema Meekiana*, from the Queen Charlotte Islands, in the condition in which that fossil is most commonly obtained, but the exterior of the test of the convex valve of *S. Meekiana* is known to be both closely and nodosely cancellated.

4. *Lima duplicata*, Sowerby (Sp). Two left valves of a Lima both from Sigutlat Lake, which if not identical with the *Plagiostoma duplicata* of the "Mineral Conchology," are remarkably like it in shape, and so far as can be ascertained at present, in sculpture also. One specimen has the test partly exfoliated; in the other the shell is considerably decomposed, but its original surface markings are sharply impressed on part of the rock which was broken from the specimen, and which originally enveloped most of one side of it. The sculpture consists apparently of about twenty-eight acute, angular, radiating costæ, each of which alternates with a single, fine, raised line, just as in *L. duplicata.*

In the Quarterly Journal of the Geological Society of London for 1866 (Vol. XXII., p. 82) Mr. Tawney has described a species with very similiar shape and style of ornamentation, from the Lower Lias of South Wales, under the name *Lima subduplicata.* Mr. Charles Moore, however, in a paper on "Abnormal Secondary Deposits," published in the Journal of the same Society for the following year, places *L. subduplicata* as a synonym of *L. duplicata* on page 509, though on page 530 of the same paper it is said to be identical with *L. dentata* Terquem, which is admitted to be distinct from *L. duplicata.* It may be, therefore, that more than one species have been confounded under this name, but if not, few if any Mesozoic molluscs have a wider range in time than *L. duplicata.* Originally described from the Coralline Oolite of Yorkshire, it is abundant in the Cornbrash, Forest Marble, Great and Inferior Oolite of many parts of England, as the writer can testify from direct observations in the field. Munster says it is found in the Lias of Germany associated with *Rhynchonella rimosa*, and Goldfuss mentions it as occurring in the Inferior Oolite of Hanover and Brunswick. It is included by Rev. P. B. Brodie in a list of Lower Lias fossils from near Wells, (Somerset), also by Mr. C. Moore, in lists of species from the same formation in South Wales, and from several localities in Somersetshire in the zone of *Ammonites Bucklandi.*

5. *Inoceramus*——(?) Falls of the Iltasyouco River, a fragment only of a species with wide, rounded, concentric folds. Mr. Dawson made a rough sketch of the specimen as it originally appeared in the rock, and, judging by this, the shell appears to have been very similar to the *Inoceramus venustus*, Sowerby, of the English Lias.

6. *Eumicrotis curta* (?) Meek & Hayden. Iltasyouco River, two imperfect right valves, both marked with distinct raised lines. Almost certainly indentical with *Monotis substriata*, Munster, as suggested by Meek. Stoliczka has shown that Beyrich's generic name *Pseudomonotis* has two years' priority over *Eumicrotis* Meek, so that the name of this shell ought probably to be written *Pseudomonotis substriata*, Munster, Sp.

7. *Pteroperna*——(?) Two specimens of a smooth, oblique and elongated species of *Pteroperna*, with a long and deeply emargnate posterior wing, both from the Iltasyouco River; probably new to science, but not in a sufficiently good condition to be properly characterized.

8. *Pinna subcancellata*, N. Sp.—Shell moderately convex, wedgeshaped, elongated: squarely truncate behind, or nearly so; hinge line straight; ventral margin also straight for the greater part of its length, but rounded at its junction with the posterior end. Surface marked by coarse, irregularly and unequally disposed concentric plications, which, in the upper two-thirds of the shell, are crossed by about eighteen radiating, but nearly longitudinal raised lines. The amount of convexity of the valves cannot be precisely defined, as the only specimen yet obtained is distorted by pressure. Falls of the Iltasyouco River, a solitary example with both valves *in situ*. The beaks are broken off, but the sculpture of both sides of the fossil is well shown. Perhaps only a variety of *Pinna Hartmanni*, Zieten, from which it differs in being more squarely truncated at the anal end, and in having the radiating costæ confined to the upper two-thirds of the shell.

9. *Modiola formosa* Meek & Hayden. One very good specimen from Sigutlat Lake. Very near to *M. cancellata*, Goldfuss.

10. *Modiola pertenuis*, Meek & Hayden. Three left valves of a small, smooth Modiola, (two from the Iltasyouco River, the other from Sigutlat Lake), one of which appears to be a distorted but otherwise tolerably typical example of *M. pertenuis*, while the two others are probably only a short, broad

variety of the same species. It is not easy to see how *M. pertenuis* can be distinguished from *M. minima*, Sowerby, of the European Lias, as figured and described in the Mineral Conchology and by Goldfuss.

11. *Grammatodon inornatus*, Meek & Hayden. Iltasyouco River, two single valves. Apparently very near to *Arca Lineata* Goldfuss, from the Lias of Germany.

12. *Grammatodon* (?) *Iltasyoucoensis*, N. Sp.—Shell moderately convex, but slightly depressed near the middle below; very inequilateral; anterior end short, narrow and obtusely pointed; posterior end elongated, widening gradually both above and below; truncated almost squarely at its extremity. Hinge line straight, ascending gradually behind the beaks, and sloping downwards rather abruptly in front of them. Beaks broad, depressed, curved inwards and forwards, situated very near to the anterior end, but not quite terminal. Right valve (the only one known) with indications of one or two elongated, linear posterior teeth, placed parallel to the hinge line, and of at least three obliquely transverse anterior teeth. Surface marked with close-set, crowded and extremely fine, radiating striæ, which are scarcely visible to the naked eye, and which become almost obsolete on the ill-defined posterior area.

Iltasyouco River, a single specimen of the right valve, with the lower half of the posterior end broken away. The pallial line and muscular impressions are not visible, and the hinge characters are imperfectly shown, so that it is doubtful whether this shell is a *Grammatodon* or a true *Macrodon*.

13. *Cucullæa* (?) Sp. Undt.—A small, rather ventricose, subrhomboidal species, with prominent, nearly central, incurved beaks. An obtuse keel runs from the beaks to the base, and separates an obliquely flattened posterior area from the main body of the shell. The surface is marked by close-set, raised striations, which are crossed by rather more distant, radiating lines.

14. *Yoldia* (or *Corbis*) Sp. Undt.—A single valve of a small shell from the Iltasyouco River, with no vestiges of the hinge teeth or of any of the markings of the interior remaining. The outline of the specimen is remarkably like that of *Nucula speciosa*, Munster, from the Muschelkalk of Germany, which is probably a *Yoldia* or *Portlandia*, but it is also almost equally similar in its shape to *Corbis uniformis*, Phillips, from the

Yorkshire Lias. It is not a *Tancredia*, in the writer's judgment, though its contour is not very dissimilar to a fossil doubtfully referred to that genus by Meek and Hayden, under the name *T. inæquilateralis;* but the latter species has a much flatter shell, and is more angular at the junction of the hinge line with the posterior end.

15. *Trigonia Dawsoni*, N. Sp.—Shell gently convex, compressed; outline ovately-subtrigonal; anterior end very short, broadly rounded, as is also the ventral margin; beaks elevated, recurved, anterior, subterminal; hinge line sloping concavely downwards behind the beaks; extremity of the somewhat elongated posterior end truncated rather obliquely. Surface of the main body of the shell marked by about twelve curved, nodulous costæ, all of which commence at the margin of the posterior area. The five nearest the beaks curve downwards, and terminate at the anterior end. The middle ones, though curved, are nearly transverse, and end at the centre of the ventral margin, while the three last incline decidedly backwards. The posterior area is marked either by crowded, transverse, regularly arranged and continuous raised striæ, or by coarse, irregular and broken up or angularly bent, short, transverse folds. Iltasyouco River and Sigutlat Lake, frequent and well preserved. A well marked and characteristic species, which the writer has much pleasure in naming after its discoverer, Mr. G. M. Dawson. It would appear that *T. Dawsoni* occurs also in the Jurassic rocks of the western slopes of the Sierra Nevada, for on page 49 of Vol. I of the "Palæontology of California," after describing *Trigonia pandicosta* from that locality, Mr. Meek says:—"there are in the collection fragments of apparently two other species of this genus. One of these is considerably larger than that described, and has the costæ distinctly nodose. They are, however, not angularly deflected, but curved gradually forward."

16. *Astarte ventricosa*, Meek. Iltasyouco River, three or four rather imperfect specimens, whose specific characters are obscurely shown, and whose identification is, therefore, somewhat uncertain. They vary considerably in shape, two being rather longer than wide; in the others the height and length are nearly equal. The pallial border of the test is distinctly crenulated.

17. *Astarte fragilis*, Meek & Hayden. A badly preserved specimen of an Astarte, from the Iltasyouco River, which although much larger than the type of *A. fragilis* from Dakota,

and more convex on the posterior part of the hinge margin, is probably referable to that species.

18. *Pleuromya subelliptica*, Meek & Hayden. Six or seven specimens of an elongated, nearly smooth *Pleuromya*, from the Iltasyouco River, which, though very variable in shape, on the whole agree tolerably well with Meek and Hayden's description of *Myacites subellipticus* from the Black Hills, much better in fact than they do with the figures of that species. *M. subellipticus* is said to be very similar in shape and sculpture to *Panopæa peregrina*, D'Orbigny, from the Oxfordien beds of Russia, and so are some of the Iltasyouco River *Pleuromyæ*, but the latter, in shape at least, are equally like some forms of *P. Terquemea* Buvignier as figured by Agassiz under the name *P. tenuistriata*, but in that shell the concentric striations are much more numerous and regularly arranged than they are in the specimens collected by Mr. Dawson.

19. *Pleuromya unionides*, Rœmer, Sp. Six casts of a ribbed Pleuromya, (one from Sigutlat Lake, the others from the Iltasyouco River), which have been carefully compared with Goldfuss' and Agassiz's descriptions and figures of the above mentioned European Liassic species, and which do not appear to be separable from it even as a local variety. The Sigutlat Lake specimen, and three of those from the Iltasyouco River are much distorted, and have their original shape much altered by pressure, but two from the latter locality seem to have retained their normal form. *Pleuromya Carlottensis*, from the Queen Charlotte Islands, has a shorter, higher and more ventricose shell; its beaks are more elevated and curve forwards as well as inwards; its posterior extremity, too, is more pointed. *P. Carlottensis* is, perhaps, synonymous with *P. Alduini*, Bngt. (Sp.) of the European Jurassic.

20. *Planorbis veternus*, Meek and Hayden. While breaking a large piece of the Iltasyouco River porphyrite containing a valve of *Gramatodon inornatus* and a cast of the shell supposed to be referable to *Pleuromya unionides*, the writer was so fortunate as to obtain a perfect specimen of this shell, *in situ*, in one of the fragments. *Planorbis veternus*, and three other species of fresh water shells, were first found in loose pieces of rock at the base of the Black Hills in Dakota, and some doubt previously existed as to the true geological horizon of these fossils. Writing in 1864, Mr. Meek says, "they may possibly be Tertiary

species, but differ from all those we have seen from rocks of that age in the North West. It is only provisionally we place them along with the Jurassic forms." The finding of *P. veternus*, in place, associated with fossils that are almost undoubtedly Jurassic, make its age tolerably certain, and strikingly confirm Mr. Meek's conclusions. Mr. Moore has described another species of Planorbis, (*P. Mendipensis*), from the Charter House Liassic lead mine in the Mendip Hills of Somerset, in rocks of a very similar geological horizon.

21. *Stephanoceras Humphreysianum*, Sowerby, Sp. Sigutlat Lake, one specimen, the only tolerably perfect ammonite in the collection. Prof. A. Hyatt, to whom all the ammonites were sent for examination, says of this fossil,—"If found in Europe it would be unhesitatingly referred to this polymorphic species and identified with the typical forms."

22. *Stephanoceras Braikenridgii* (?)—Sowerby, Sp. Iltasyouco River, two small fragments. "These are very interesting fragments, with all the marks of the mature forms of *Steph. Braikenridgii*, but ought to be queried because the young characteristics are not visible."—Hyatt.

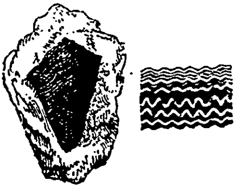
23. *Stephanoceras*——(?) Seven fragments of a small *Stephanoceras*, from the Iltasyouco River, which Prof. Hyatt has compared with European specimens, and pronounces the former to be closely allied to *S. Gervillei* (*Ammonites Gervillei*, Sowerby) and *S. Platystomum*, Reinecke, (sp.) but adds that the young look rather like the early state of *S. macrocephalum* or *S. Herveyi*. The penultimate whorl is rather finely ribbed, and the outer surface of the body chamber is quite smooth, at least in the cast; the umbilicus is not distinctly shown, but it must have been exceedingly small. The shape of the lip is indicated to a certain extent by an obliquely transverse, slightly flexuous, incised groove, which curves forward from the umbilicus, and is produced into a bluntly pointed, beak-like process in passing over the periphery.

24. *Perisphinctes anceps?* Reinecke, Sp. Iltasyouco River, a solitary fragment, which, according to Prof. Hyatt, "has the peculiar abdominal ribs and knob-like spines of *P. anceps*. The abdomen may have been channelled, and, if so, the above identification could be given without the query."

25. *Belemnites?*——Seven or eight imperfect specimens of a Belemnite with an exceedingly slender parallel-sided guard.

These are in such a bad state of preservation that it would be a hopeless task to try and identify the species, or to describe it with sufficient accuracy if new. At the commencement of the phragmocone, the largest example does not measure quite three lines in diameter, while several of the specimens would lie loosely in the cavity of a wheaten straw. The surface of the whole is so much worn that it is impossible to tell whether there was a median or an apical groove, or none at all. Iltasyouco River.

26. *Belemnites* (?)—— At the same locality as the preceding shell, and associated with it, are portions of what seems to be either another species of Belemnites, or at least a different varietal form, and unfortunately, in quite as bad a state of preservation. The guard, though elongated and narrowly cylindrical in shape, is much thicker and more conical than is that of the fossil last described, and it is not improbable that the present species may prove to be conspecific with a Belemnite fron Dakota, supposed by Meek and Hayden to be a slender variety of their *Belemnites densus*, and figured on Plate V. (figs. 1 a, 1 b, 1 c,) of the "Palæontology of the Upper Missouri." Detached phragmocones, probably belonging to both species, are not unfrequent also at the Iltasyouco River. These, though not very well preserved, appear to show that the fossils of which they formed a part are referable to *Belemnites* proper and not to *Belemnitella.*



27. The nature of the curious fragment represented in the wood cut is uncertain, but it may have been a portion of an *Aptychus*, a fragment of the pen of a calamary allied to *Teudopsis*, or a piece of an aviculoid shell.

28. *Serpula*—— (?)—Three casts of the shelly tube of a species of Serpula. The most perfect specimen has been secreted by the animal on nearly the same plane, and is twice bent, so as to present the appearance of a flexuous-sided triangle with the angles blunted and half of one of the sides wanting. The others are simply flexuous, and no vestige of the test or of its surface markings is preserved on any of them. Locality, Iltasyouco River.

The fossils above enumerated are of much interest as affording the first instance yet observed of the occurrence of a well marked fauna of Jurassic age in British Columbia. It is true that fossils, probably from a very similar geological horizon, were collected by Mr. Selwyn in 1875, at Rock Island Gates below Hudson's Hope on the Peace River, but the specimens, which were described in the Report of Progress for 1875-6, are very few in number, and so imperfect that none of the species could be satisfactorily determined.

If the identifications in the present paper be correct, it would appear that nine of Meek & Hayden's species from the Jurassic rocks of Dakota, are found also in the Coast Range of British Columbia. These are:—

Gryphæa calceola, var., *Nebrascensis.*
Camptonectes extenuatus.
Eumicrotis curta.
Modiola (Volsella) formosa.
" " *pertenuis.*
Grammatodon inornatus.
Astarte fragilis.
Pleuromya subelliptica.
Planorbis veternus.

It would seem, therefore, that the sea of the Jurassic epoch once covered an extensive, and probably contiuuous tract of country on the western portion (at least) of this Continent; and there are strong reasons for supposing that the marine faunæ of the Triassic and Cretaceous periods were no less widely spread. The Upper Trias is known to extend from Mexico, through California and Nevada, to British Columbia, and *Monotis subcircularis*, Gabb, one of its most characteristic fossils, has recently beeen found in the northern part of Vancouver Island; also, on the mainland of British Columbia, at a few miles from Fossil Point, on Peace River, and on Upper Pine River, east of the mountains.* Two species of fossils which were originally described from the Cretaceous rocks of Texas, have been found by Mr. Selwyn in deposits of the same age on the Upper Peace River, and among the extensive collections of Cretaceous fossils obtained by Mr. Richardson from Vancouver and adjacent Islands, there are several species which occur also in Texas, Nebraska or New Jersey. From these, and from similar circum-

* The last mentioned locality, represented by specimens collected for Mr. Dawson by Mr. J. Hunter, of the Railway Survey.

stances, it seems highly probable that nearly the whole of North America must have been submerged during the deposition of the later portion of the Cretaceous series. It has been supposed, indeed, that towards the close of the Mesozoic period the Rocky Mountains formed a land barrier between two oceans, each of which was tenanted by a distinct local fauna, but this hypothesis is not borne out by the facts of the case as we now know them, and the existence of Cretaceous rocks at very high elevations both in the Cascade range and in the Rocky Mountains, goes far to prove that some of the loftiest peaks of these two mountain chains owe their elevation to movements of Post Cretaceous date.

Trigonia Dawsoni and *Astarte ventricosa*, fron the Iltasyouco River, are also found in the Jurassic rocks of the western slope of the mountains in Nevada; and it may be that there is no physical or geological break between the coast range of British Columbia and the Sierra Nevada. Mr. Gabb has pointed out that the Jurassic fossils of Nevada are probably of the age of the Lias, and some of the Iltasyouco lamellibranchs, as has already been stated, are barely distinguishable from European Liassic species. On the other hand, the few Ammonites collected by Mr. Dawson, so far as very fragmentary specimens enable one to judge, appear to be conspecific for the most part with well known forms from the English Inferior Oolite, though one, which has been doubtfully referred to *Perisphinctes anceps*, may indicate an horizon as high as the Oxford Clay or Coral Rag. On the whole, however, the evidence, as far as it goes, is in favour of the supposition that these fossils from British Columbia belong to the lower rather than to the upper part of the Jurassic series.

NOTES ON THE LOCUST IN THE NORTH-WEST IN 1876.

By George M. Dawson, D.S., Assoc. R. S. M., F.G.S.

Having collected and published in the *Naturalist*, notes bearing on the appearance and movements of the locust, or devastating grasshopper, in Manitoba and the North-west Territory in 1874 and 1875; I propose briefly to put on record information obtained for 1876. The insect having drawn upon itself the attention of the western farmer, has at last become the subject of investigation by a Scientific Commission appointed last year by the Government of the United States. With the intelligent cooperation of the farmer, we are likely soon to know all that can be known about the locust, and what may be done to prevent its destructive increase.

Absence on the West Coast, and the pressure of other business, with the long time necessarily occupied in communicating with some parts of the far west, have prevented the earlier appearance of these notes.

Fortunately for the Province of Manitoba and the North-west Territory, the history of the movements of the locust within their limits in 1876 is not a long one. In 1875, as chronicled in the *Naturalist*, the locust hatched abundantly in Manitoba and its vicinity, and also in considerable numbers in the country near the foot of the Rocky Mountains. The swarms of Manitoba flew southward, while a great invasion of winged swarms *from* the south, occurred in the region west of Manitoba, where eggs were extensively deposited. From these eggs, with those which any small colonies of locusts remaining as residents in the country may have deposited, the swarms of 1876 were produced. No invasion of the region north of the 49th parallel from the south, occurred, except in the extreme west, where at Fort Walsh, flights are reported as arriving from Montana in the middle of July.

Over the greater part of the area defined northward by the 52nd parallel, and extending from the Rocky Mountains eastward to the 100th meridian, important hatching grounds were scattered. These appear to have been specially numerous in the valley of the South Saskatchewan, as it is reported to have been owing to the destruction of the grass by the locusts that the northern herd of buffalo was forced so much further east than usual in 1876. True to their instincts, the broods, on arriving at maturity, flew southward and south-eastward, forming with additions from south-western Manitoba, and parts of Colorado, Wyoming and Dakota, the great army which overspread the Western States.

In the summer of 1876, the cultivated lands of Manitoba were threatened with locust invasions from two quarters, from both of which dangers they, however, fortunately escaped. The great hordes produced in the north-west might have overspread and devastated the province, as they have formerly done on several occasions. These, however, swept past by its western boundary and going southward, arriving in many of the south-western states too late to do much damage; whereas, had they visited Manitoba the loss would have been very great, owing to the less advanced condition of the crops. In south-western Minnesota locusts have bred annually since 1873, according to the reports of Mr. A. Whitman and Dr. Riley. In 1876 considerable swarms were produced, and these, on reaching maturity, set out on a migration to the north and north-westward, and might well have reached Manitoba. The determination of the locusts to move in this direction was evidenced (as has often before been noticed) by their waiting for favourable winds. They were, however, continually repulsed, and eventually borne back by the winds to their hatching places, and thence south and south-west to Iowa and Nebraska.

In an interesting article by Dr. Riley on the "Rocky Mountain Locust," in part reprinted in the last number of the *Naturalist*, I am glad to see that the preservation of the dry prairie grass in autumn and its firing, for the purpose of destroying the young insects in their breeding grounds in the far west, is warmly advocated. This was suggested in my notes on the invasion of 1874, and may yet, I believe, be carried out with good result.

Dr. Riley, in his valuable work on the Locust,* is in error with regard to the northern range of the insect, as represented in his coloured maps, especially that facing the title page; where

* The Locust or Grasshopper Plague, Chicago, 1877.

the areas designated as *frequently visited*, and *permanent breeding grounds* are made, together, to cover a breadth of about twenty degrees of longitude in the north, and to run beyond the 60th parallel of north latitude. The range of the locust is really limited to the north by the southern margin of the forest-clad country, and may be roughly defined by a line nearly as follows:—From the intersection of the 96th meridian and 49th parallel of latitude, to the south end of Lake Winnipeg, thence to Manitoba Lake, and following this lake and Winnipegosis Lake; from the north end of the latter westward to the Forks of the Saskatchewan, and thence nearly following the course of the Saskatchewan till the wooded country at the base of the Rocky Mountains is attained. It is not meant to affirm that single specimens of *Caloptenus spretus* may not be obtained beyond this limit, or even that small colonies may not exist from time to time; but the edge of the northern forest, with its climatic accompaniments, seems to constitute an absolute barrier to the destructive abundance of the insect. Further north, in the Peace River country, where prairies and tracts of lightly wooded land are extensive, I cannot learn, — though careful enquiry has been made on the subject, — that the locust swarms have ever been seen. At nearly all the Hudson Bay Company's posts more or less cultivation is carried on, and some record would have been kept of the appearance of the locust, had it occurred. Mr. S. D. Mulkins, of Battleford, to whom I wrote on this subject, says:—"From all the information I can collect, I cannot find that the grasshopper has ever visited any of the Hudson Bay Company's posts north of latitude 53° I have never heard that they have ever penetrated to the Peace River country. To do so they would have to cross a wide belt of pine forest. Whether it is the scarcity of food in such places, or that there is something in the air that they do not like, the fact is, that they never in this country, to my knowledge, or that I can find out, have penetrated the wooded region. At Ft. à la Corne, Prince Albert Mission, Turtle Lake, Lac la Biche, Lac la Nun and Lac Ste. Anne, they have never been seen; and these places are all on the verge of the great forest, or just within its southern limit."

The immunity of the Peace River plains from the locust plague, constitutes a point of great importance in their favour, and may eventually render them, area for area, of considerably greater value than those of some parts of the Saskatchewan—a circumstance to be taken into consideration in planning a railway route.

In the following paragraphs, is given a brief digest of the more important facts bearing on the swarms of 1876 in the North-west, obtained in answer to circulars and by correspondence With the exception of the few notes placed last, the information from Manitoba is purely negative.

Mr. C. Mair has favoured me with the following note:—"In going to the Saskatchewan, last summer, I met the first hordes about the 26th of July, on the ground this side of the Little Saskatchewan. They were generally facing eastward, and seemed ready for flight. A few days afterwards, we met great flights of the insects, the air appearing to glisten with their motion. I felt no doubt whatever that their destination was Manitoba; but, as it afterwards appeared, they sheered off southwards before entering the Province, and did great damage in the States and Territories adjoining our boundary. From all I can learn at Carleton, etc., no eggs have been laid in our territory along the North Saskatchewan, and unless they come from the south, we shall be free from them this year."

Mr. A. L. Russell, of the Special Survey, sends the following notes: On June 19th, saw a few hoppers just out of the egg, a little west of Winnipeg. On July 16th, they were drifting past Fort Ellice, in clouds, to the south-eastward. At a place about forty miles north-west of Ellice, they were very numerous on August 4th, 5th, and 11th, flying north-westward on the 4th, south-eastward on the 5th and 11th. In this region of country they were to be seen almost daily from July 6th to August 10th. About a third of them were infected with parasites.

Mr. W. F. King writes, with regard to Battleford, that this place has been known to white men only since 1874, and that grasshoppers have not been seen there since. Like Prince Albert, it is protected by a belt of timber. July 29th, passed through a tract of a mile or so in width of unwinged grasshoppers, near Stony Creek (ten miles east of Little Saskatchewan River). None on the Little Saskatchewan, and only a few on the way thence to Fort Ellice. Very plentiful at Ellice in July, particularly about the 20th. Went away about the 25th. No grasshoppers seen on the way from Ellice to Battleford in August, though abundant in this region of country during July. Very abundant towards the foot of the Rocky Mountains and in the whole upper part of the South Saskatchewan Valley, where they are said to have eaten up all the grass, driving the buffalo eastward to the vicinity of the Touchwood Hills, Souris Valley, etc.

Fort Calgarry, Bow River, N. W. T. (John Bunn.) Did not appear here during the summer of 1876, but were reported as abundant on the plains to the eastward.

Fort Walsh, N. W. T. (J. M. Walsh.) Produced from the egg, hatching about the middle of May, and remaining till the middle of August, when they flew north-westward. Other swarms arrived on the wing from Montana, about the middle of July, and for some time thereafter. These also passed on to the north-west. All crops destroyed. No eggs left.

Fort Pitt, N. W. T. (W. McKay.) There were no grasshoppers within a distance of 300 miles west of this.

Prince Albert, N. W. T. (Bishop of Saskatchewan.) No visitation of grasshoppers.

Battleford, N. W. T. (T. Little.) Did not appear in 1876, and are never known to have reached this region.

Carleton House, N. W. T. (L. Clarke.) Grasshoppers were seen in huge swarms about 150 miles south of this, flying still southward. Did not appear here.

Swan River Barracks and *Livingston, N.W.T.* (F. Norman, J. H. Kittson, M.D. and R. Miller, M.D.) Produced from the egg, from about the 25th of May till June 1st, remaining till the 7th of August, when they departed north-eastward. (One report says they died in the country.) A few arrived from the south-west about the second of June, and alighted. Foreign swarms on the wing were observed passing overhead from the 20th to the 27th of July; but, owing to strong wind, they did not alight. These also went north-eastward, or eastward. About the 8th of August, great swarms appeared from the south-west, many alighting. These departed about the 10th of August, flying southward. All crops destroyed. No eggs deposited. For twelve years before July 1875, no grasshoppers were seen here. In 1876 the green crops were entirely destroyed before the middle of June, when the insect was no larger than the ordinary housefly. Myriads are said by the Indians to have perished in lakes Winnipegosis and Winnipeg.

Swan Lake House, N. W. T. (D. McDonald) Not seen here in 1876; and during Mr. McDonald's experience of four years very few have visited this part of the country.

Little Saskatchewan, N. W. T. (K. McKenzie.) Second week of July a large flight observed going south one point west. Hatched in this country, and north-west of Lake Manitoba.

Manitoba House, N. W. T. (J. Cowie.) Produced from the egg about the first of June, leaving about the first of August, going south-eastward, or south-westward, according to the direction of the wind. On the first of August, foreign swarms were also observed, and these continued passing and occasionally alighting for about a week, going south-westward. Crops slightly injured. No eggs deposited.

Woodside, Man., (T. Collins.) None hatched here; but foreign swarms, more or less extensive, continued to pass over for six or eight weeks, coming from the north and north-west, and going southward. Some alighted; but it is stated that though in quantity, and remaining long enough to have destroyed the greater part of the crop, "strange to say, they did nearly no damage. They did not seem to have the same energy, nor did they eat voraciously as in former years."

Gladstone, Palestine P. O., Man., (C. P. Brown.) None hatched. Swarms observed to arrive on the wing on the 27th of July. These alighted and remained about nine days. Seen passing over for several days before, but did not alight. "They probably would not have alighted on this day, but for some misty showers or shadows of large clouds. They appeared to fall only in patches, probably the spaces covered by the shadows." Also continued to pass over for about two weeks after this date, but few came down. The insects came from north-west by north, and most of them probably went south-easterly. Loss of crops perhaps 5 or 6 per cent. No eggs deposited.

Oak Point, Lake Manitoba, Man., (J. Clarke.) Observed about the middle of July for two weeks, passing overhead at intervals, when the weather was clear and warm. Supposed to come from the western plains. General direction of flight, south-eastward. No eggs deposited. Many grasshoppers observed to fall into the lake, and in several places were afterwards washed up in windrows a foot thick along its margin.

Winnipeg, Man., (F. E. Cornish.) A few passed over in August, from north-west, going southward.

St. Boniface, Man., (Hon. M. A Girard.) None. Swarms from the west observed occasionally flying overhead, without alighting, during latter part of July and to middle of August.

Little Britain, Man., (Hon. D. Gunn.) No grasshoppers here. Ten or twelve miles west of Selkirk, however, a little colony covering about 1½ acre hatched out, and were found more than half grown in the middle of July.

Lower Fort Garry, Man.. (W. Flett.) None hatched here. A few seen passing overhead about the middle of August. They came with a south-west wind.

Crookston, Minn., (E. M. Welsh.) None hatched here. Were observed to pass overhead without alighting about the middle of July. Near the first of August some alighted, and stayed a day. Came from the north-west and north, and went south-eastward. No damage to crops. No eggs deposited.

THE MECHANICAL EFFECT OF ARCTIC ICE IN PRODUCING OCEAN CURRENTS.

BY HENRY YOULE HIND, M.A.

The area of the North Polar Ocean where salt water ice is annually formed to a mean thickness of four feet, may be assumed equal to 4,000,000 square geographical miles.

This area is less by 521,600 square miles than that of the superficies enclosed by the 70th parallel of north latitude, which is supposed to encircle a space equal to the Arctic water area frozen each year.

In order to compensate for the land area within the 70th parallel, it is necessary to add Hudson Bay and Straits, part of Davis Strait, the South-East Greenland Sea area, the White Sea, etc., in a word, wherever salt water ice is formed within the Northern zone.

During the process of freezing, salt water ice is raised about one-tenth of its volume above the level of the sea. The ice consists of three varieties: common floe ice, hummocky ice, and floe-berg ice. To form "old hummocky ice," as described by Captain Sir George Nares, a large area of sea water is required, for this kind of ice is produced by the over-riding and piling up of ordinary floes, which are then cemented together by wintry frost. Floes are piled on floes, but the areas the over-riding floes occupied are frozen again.

Floe-berg ice is from 80 to 100 feet thick. A full description of it and its vast extent will be found in the journals and proceedings of the Arctic Expedition. This floe-berg ice and the "hummocky ice" are constantly streaming down from the north. Many floes associated with icebergs, finally appear in the seas washing the coasts of Labrador and Newfoundland, which they reach *via* the Hudson Straits, the Davis Straits, and the East Greenland Currents, the last named sweeping round Cape Farewell, and all uniting to form the Labrador Current.

Subjoined is a rough estimate of the area occupied by these three varieties of ice within the limits of the 4,000,000 square miles: —

I. Floe Ice.—Apppiroximate area formed each year, 2,000,000 square miles. Thickness, 3½ to 5½ feet: mean thickness, 4½ feet. Average elevation of this ice above the level of the sea, five inches, or one-tenth of its volume. Reduced to a uniform thickness of one foot, this area would be equivalent to 833,330 square miles.

II. "Hummocky Ice."—Estimated area, 1,000,000 square miles. Estimated average winter increase above water line, one foot.

III. Floe-berg Ice.—Estimated average area in polar waters, 500,000 square miles. Estimated average winter increase above floatation line, one foot.

RECAPITULATION.

Ice above the Surface of the Sea reduced to a Mean Thickness of One Foot.

Ordinary Floe Ice - - -	833,330 sq. miles.
Hummocky Ice - - -	1,000,000
Floe-berg Ice - - -	500,000
Total - - -	2,333,330 sq. miles.

This area, one foot thick, is equal to 382 cubic miles of ice. We arrive at nearly the same result if we assume that the mean thickness of the ice formed during the winter within the 70th parallel of latitude is five feet. Making allowance for land within this limit as before, by including Hudson Bay, Davis Straits, East Greenland Sea, etc., the area of ice thus formed may be estimated to be equal to 4,521,600 geographical miles. One-tenth above water gives the quantity of ice mechanically raised above the level of the sea by the process of freezing, equal to 2,260,800 square miles, one foot thick: a close approximation to the first estimate.

In order to gather some knowledge of the effect likely to be produced upon Ocean currents by the uplifting of so large a body of water in the form of ice above the level of the sea, we may compare it with the Gulf Stream, bearing in mind that a part only of the waters of the Gulf Stream move north-easterly after reaching the 40th degree of longitude. A large portion is directed towards Southern Europe and the northern part of Africa, as shown on Dr. Petermann's charts.

The "Challenger" found the width, depth and rapidity of the Gulf Stream, where the expedition crossed it, to be as follows: *

Width - - -	15 nautical miles.
Depth - - -	600 feet.
Speed - - .	3 miles an hour.

This gives a volume of discharge equal to 108 cubic miles per day. Hence, according to the foregoing estimate, the quantity of water required to fill the void created by the rising of the Polar ice above the sea level, would consume the equivalent of the entire discharge of the Gulf Stream for 84 hours, or 3½ days.

The drainage area of the Polar basin is estimated to be 4,495,000 square miles, or about the same as that of the Northern Sea area covered during the winter with ice. But practically, land drainage by rivers, *glaciers* and *glacial rivers* is reduced to a minimum during the winter season. The precipitation takes place in the form of snow, and the land drainage in the Arctic zone may be estimated as not exceeding two inches during the six winter months. As a partial set off against the land drainage, there is the evaporation which takes place from the snow falling on the Polar ice. The precipitation is small within the Polar circle, and the climate of North Greenland is dry, according to Rink, Hayes, Nares, etc.

* "Challenger" Reports, No. VII.

The snow acts by weight, except during a thaw, and in this capacity it would frequently assist the formation of ice above the surface, for when it falls on young ice and presses it to the level of the water, the snow becomes saturated like a sponge by capillary action ; it then freezes and forms a light ice, thus diminishing, if not entirely neutralizing, the effects of precipitation under such circumstances. Assuming the precipitation and drainage during the winter months to amount in the aggregate to three inches within the 70th parallel, there would still remain a volume of ice mechanically raised above the mean level of the Polar Sea, in excess of precipitation, equivalent to the entire discharge of the Gulf Stream during sixty-three consecutive hours, or two days and fifteen hours.

But the mechanical up-lifting of 382 cubic miles of ice is only part of the work of winter cold in the Polar Seas. There has to be taken into consideration the enormous quantity of heavy brines squeezed out of the entire body of ice by the process of freezing, and the effect these produce upon the salinity and specific gravity of the Polar waters, hereafter alluded to. The total bulk of the ice formed each year, estimated as before stated, is equal to 3,706 cubic miles, an equivalent to the entire discharge of the Gulf Stream for 34 consecutive days; and from this vast mass a large percentage of salt is expressed by the freezing process.

The formation of Polar ice is by no means uniform with the same mean temperature : its daily increase diminishes as its thickness increases. During the first half of the season when fresh ice or floe ice is formed, the quantity raised above the level of the sea is considerably greater than during the second half, especially if snow be absent. The quantity of heavy brines squeezed out is also dependent upon similar conditions ; and it follows that great variation in results from both of these causes must take place during different seasons.

The currents towards the North Polar circle, to supply the void created by the rising ice, should be greater in October and November, than from December to March, and greater again from March to May,* according to the snow fall and the extent of its retarding influence on the formation of ice.

Regarding the current in Davis Straits, we find that the north

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* See Koldeway on the protection afforded by snow, and the effect of its disappearance before storms in the early spring.

flowing Greenland warm current extends as far as Port Foulke, in latitude 78° 20′ N., the winter station of Dr. Hayes. Capt. Sir George Nares states that "Port Foulke is at present the best known station for winter quarters in the Arctic regions. A warm ocean current, combined with the prevailing northerly winds, acting at the narrow entrance of Smith's Sound, keeps the ice constantly breaking away during the winter, and causes an early spring and a prolific seal and walrus fishery. The moisture and warmth imparted to the atmosphere by the uncovered water, moderates the seasons to such an extent, that the land is richly vegetated, and therefore attracts to the neighbourhood, and supports life in greater abundance than other less favoured localities."

An inspection of Dr. Petermann's chart of the Gulf Stream for July, enables one to see at a glance where the warm waters rise to the surface in the Spitzbergen Seas in four different sea areas. They must approach these areas as under-currents. Where "Polynias" exist in winter does not appear to be so well ascertained.

If the data I have assumed are even approximately true, the influx of warm water towards the Arctic circle, either by Davis Straits or by the Spitzbergen Seas, is in part the result of the mechanical up-lifting, during a mean period of six months, in the form of ice above the level of the sea, of a body of water sufficient to cover an area of 23,000 square miles, one hundred feet deep, at a temperature below 28 degrees Fahrenheit.

The colder the season and the greater quantity of ice formed, the stronger must be the north flowing current into the Arctic Seas, arising from up-lifted ice and descending brines. A very cold year may exert, by this means, a counteracting influence on the next succeeding year; but the retardation which must take place in the progress of the south flowing Tidal Wave, subsequently referred to, by increase of ice in the Polar Sea, is a very important element in the enquiry, and may give rise to unexpected oscillations of local climate, wholly apart from the influence of winds.

The work of up-lifting the ice of the Polar Seas is effected during a mean of six or seven winter months, and is equivalent to a demand for two and a half times the daily capacity of the Gulf Stream to be poured into the Arctic circle during that period, or at the rate of the entire volume of the Gulf Stream in seventy days, being some years more, and some years less.

To this work must be added that of the brines expressed during the process of freezing, which increase the specific gravity of Arctic waters during the winter months, when land drainage is at a minimum.

The amount of heavy brines formed by the process of freezing must not be measured merely by the whole quantity of ice estimated to be formed annually. Salt water ice continues to express brines as the temperature diminishes, and *to form heavy brines by osmotic action* during variations in temperature below the freezing point of salt water. From this property, salt water ice may be regarded as an intermittent but a productive source of heavy brines throughout the winter. These will not only carry part of their salt, but also part of their cold downwards, either to the bottom or to a zone where their specific gravity is the same as that of the medium to which they sink. They will also gather way, as sheets, horizontally, or vertically, towards the lighter and warmer southerly lying seas, which they will ultimately displace by virtue of their density, either from increased salinity or low temperature, or both combined, and thus institute south flowing and accelerate north flowing currents.

Among the leading consequences which appear to flow from the mechanical effect of ice within the Arctic and Antarctic circles, the following may be outlined:

1. A series of cold winters, by increasing the thickness of ice in the Polar Seas, will retard the progress of the Tidal Wave towards Smith's Sound, through Robeson Channel, and move the place of meeting of the tides, which now occurs near Cape Frazer, further up Kennedy Channel, and ultimately, *ceteris paribus*, into the Palœocrystic Sea itself. By parity of reasoning, a similar argument applies to Behring Straits and the channels towards Polar areas in the Spitzbergen Seas.

2. The quantity of ice coming down Kennedy Channel will diminish with the northerly movement of the place of junction of the Tidal Waves.

3. The warm currents from the south will advance further to the north up Smith Sound and elsewhere, ameliorating the climate of North-west Greenland, etc.; but an increased quantity of ice will be poured into Baffin Bay and Davis Strait, through the different sounds and straits to the west, and also from East Greenland round Cape Farewell, thus increasing the strength of the Labrador current and the severity of the climates of the shores it washes.

4. The advancing warm current, apart from the effect of winds,* will ultimately check the formation of ice, and a retrograde movement will begin, if new channels have not been opened. The place of meeting of the tides will move southerly, and the oscillation described may continue for centuries. If, however, a new channel should be formed for the efflux of ice in the Spitzbergen Seas or the west side of Baffin Bay, very considerable local changes in climate would result.

5. If, owing to a gradual up-rising or depression of the land area within the Polar circle, an increased or diminished quantity of Polar ice should be produced, the mechanical effect would be strongly felt in opposite directions, according to the character of the oscillation. These supposed conditions may have thus greatly influenced Arctic climate during past geological ages. Similar reasoning applies to the Antarctic circle and the mechanical influence of Antarctic ice.

If, for instance, an up-rising of the land, or its equivalent, a lowering of the ocean level took place, one effect would be that in the course of time the Polar Sea would become brackish and ultimately fresh or glacial, more salt would be expressed by freezing, and conveyed away by cold currents, than could be introduced by the inflowing compensating currents through diminished channels of ingress, which would gradually assume the form of outward flowing river beds. The tidal wave would be impeded, Northern Europe would become colder, and North America warmer.

On the other hand, a sinking of the land would greatly facilitate the southerly progress of the Tidal Wave from the north, move the place of junction farther to the south, and gradually clear the Polar Sea of ice, thus greatly ameliorating its climate. Northern Europe would become warmer, and North America colder.

According to this view, the existing evidence of rising land in the Arctic regions, points to a gradual increase of Arctic cold in Northern Europe.

6. The north flowing warm currents should be greater in the winter than towards the close of summer, and they probably assume the form of intermediate moving sheets or stripes of water, similar to the horizontal cold sheets and vertical cold

* See Report by Capt. Sir George Nares, on the effect of an "Open Season" and of Winds.—Arctic Journal, page 36.

stripes of water in the body of the Gulf Stream. That this arrangement exists in the Labrador current is rendered probable from the habits of innumerable, indigenous and non-migratory schools of fish, which winter, not only in the ice-encumbered seas on the Atlantic coast of Newfoundland, but also throughout the sea area confronting the coast of Labrador, where the sea not unfrequently freezes in one unbroken sheet, ten to thirty miles out from the nearest land. This arrangement would also be in accordance with the temperature of zones observed by Scoresby in the Arctic Sea, in the Gulf of St. Lawrence by Dr. Kelly, and in the Baltic Sea by Professor F. L. Ekman, thus comprehending closed as well as open seas.

ON THE OCCURRENCE OF APATITE IN NORWAY.

By Messrs. W. C. Broegger and H. H. Rensch.

[Translated and abridged from the "Zeitschrift der Deutschen Geologischen Gesellschaft"; Vol. 27, Part 3.]

The Norwegian deposits of apatite, some of which had for years yielded a large quantity, had been but little studied up to the year 1874. This account is the result of a six-weeks' journey during July and August, 1876, made at the expense of the government, in order to study in detail some of the most important deposits.

Apatite in Norway has up to the present time been found especially in veins in the primary range of the southern coast between Langesundsfjor and the town of Arendal, and also at a few points to the north of the old mining town of Kongsberg in the district of Snarum.

In proceeding to the description of the several deposits (more than twenty in all) visited by us, let us observe that we shall arrange them according to the nature of their respective rocks. In this way the remarkable connection that undoubtedly exists in our opinion, between the gabbro and the Norwegian deposits, of apatite, will be at once evident to the reader.

We will first describe the veins intersecting the gabbro; and then those traversing the crystalline schistose rocks of the primary range and partially the granite, commencing with those that occur in the immediate neighbourhood of the gabbro.

1.—Deposits in the Gabbro.

Oedegarden (Bamle District).

This deposit, which is the richest at present worked, was discovered in March, 1872. Its richness caused great speculations, whereby the price of many deposits already known was raised enormously, and in the districts wherein apatite occurs a genuine apatite-fever was developed among the inhabitants. Up to the date of our visit (in July 1874) it had already yielded, according to the exact figures of the proprietor, over 3,200 tons (of 2,000 lbs.) of the approximate value of $112,500. The apatite has been shipped chiefly to England and Germany, and recently to France and Sweden also. It is sold for £6 5 0 to £6 6 0 stg. per ton.

The veins of Oedegarden lie at the foot of a low rocky ridge running N. E. and S. W., which forms one side of a small valley, whose centre is occupied by a little bog. The ridge consists of hornblende rocks in highly inclined, not very distinct, strata, chiefly hornblendic gneiss (the plagioclase white with twin-striping) which is in part very poor in quartz. Sometimes the quartz disappears entirely, and the rock becomes the diorite-slate of the German lithologists. On the other side of the bog the same rocks occur, alternating with ordinary gneiss and quartzite. At the foot of the ridge there occurs a small zone of a light rock, without a trace of cleavage or stratification. This rock is a peculiar variety of gabbro, which we shall name "spotted gabbro." This medium—to finely—granular rock consists, in varying proportions, of brown lustrous hornblende (distinctly cleavable parallel to the planes of the hornblende-prism) and white to greyish-white labradorite. In the "spotted gabbro" the latter mineral is without cleavage planes, compact or granular, with a splintery fracture, lustre vitreous to slightly fatty, and in splinters translucent. Its aspect recalls at the first glance quartz or moist snow. Before the blowpipe it fuses somewhat more readily than ordinary labradorite to a water-clear or milk-white glass. Hardness, 6, sometimes a little less. An analysis made by S. Wlengell exhibits the ordinary composition of labradorite: SiO_2 54.00, Al_2O_3 (and a trace of Fe_2O_3) 24.13, CaO 7.89, MgO 0.95; loss by heating, 1.22 per cent. The alkali was not determined.

The specific gravity of the "spotted gabbro" varies somewhat on account of its varying composition. A clear-coloured, cleavable variety, the one that was analysed, is 2.78. A darker, finely-granular variety is 2.89 (the sp. gr. of the common dark violet gabbro of Hiasen is 3.08). The peculiar relationship which exists between the "spotted gabbro" and the apatite bearing veins in several deposits will be more closely discussed further on.

The ordinary dark violet gabbro, moreover, also occurs at four points near Oedegarden.

The small zone of "spotted gabbro" is intersected by two coarsely granular veins of granite, which, judging by its appearance, belong to the older granites that are never otherwise met with outside of the primary hills. This circumstance indicates that the gabbro here must be older than the gabbro masses that intersect the Sparagmite and Silurian formations in other parts of our country.

The rich veins characteristic of this locality occur in the "spotted gabbro"—not at all in the strata of the primary hills, or in the granite or in the small portions of common dark gabbro. They can be briefly designated as *apatite-bearing mica-veins*. A brown magnesia-mica is in many veins almost the only mineral, generally accompanied by green enstatite along with small lumps of apatite. As the quantity of mica decreases and that of apatite increases, the character of the veins changes. The richer veins are distinguished by the fact that the mica almost exclusively occupies the sides, and apatite the centre. In regard to the relative position of the veins a certain regularity is observed, as they almost all dip slightly towards the ridge, viz., towards S. S. W., S. and S. E.

The veins are very numerous, and, moreover, so often branched and connected by cross-veinlets, that the entire deposit resembles a net of veins covering a stretch of 1600 meters.

After these brief preliminary remarks, we bring the reader to the largest and most interesting veins.

The first vein to be described is a mass of mica about twelve feet wide, chiefly in fine scales which contains crystals of a greyish-green hydrous enstatite and lumps of apatite several feet in diameter. Some of its finer veinlets consist of raven-black hornblende, instead of mica. The country rock—the "spotted gabbro"—is here coarsely schistose, and contains very small grains of rutile, arranged parallel to the other minerals. The cleavage, which is not parallel to the strike of the vein, becomes in the case of one of the stringers gradually more indistinct, until the rock passes into a finely granular, almost compact, greenish rock. The portion of country-rock enclosed by the net-work of veins is partly a peculiar variety of the "spotted gabbro," which on account of its appearance has received from the miners there the appropriate name of "sandrock." Its peculiarity is that the labradorite crumbles between the fingers into very small grains like the grains of a friable sandstone; and it often contains small scales of a brown mica, instead of hornblende or diallage. Its sp. gr. is 2.79. Farther eastward this sandrock borders the mica mass.

Several mica veins, the largest being quite 25 feet thick, were come upon farther eastward by digging through the clay that overlies the foot of the ridge. Still farther eastward a long prospecting trench cut through the soil in a N. W. and S. E. direction exposed not fewer than twelve veins. They all dipped slightly towards the ridge and were tolerably parallel to one another, the largest being six feet thick. Only one of these veins seemed to contain much apatite; the others consisted of phlogopite enclosing some lumps of apatite and hydrous enstatite.

The second important vein to be described is very rich in apatite. It dips slightly (about 30°) towards S. E.; and its outcrop was traced by exposures for about 160 feet. The banded arrangement of the minerals forming the vein, which is usual in the richer veins of this deposit, is very marked here; the sides being lined with a slight belt of brown phlogopite, while the centre is almost exclusively filled with apatite. In the vein the thickness of pure apatite was 7—8 feet; this being the greatest yet observed at Oedegarden. The cross-stringers here exhibit the only instance known to us in this deposit where the apatite comes directly in contact with the country rock.

The third vein is a six-foot mass of mica-bearing apatite, which is forked and shattered towards the east, and has been traced for about 70 feet.

No. 4 resembles No. 2.

No. 5. One larger and several smaller veins, striking in different directions, are here close together. As usual, the centres of the veins consist of apatite, separated from the country rock by brown phlogopite. They are enclosed on both sides by a zone of the above-mentioned "sandrock," whose limits are somewhat sharply defined against the ordinary "spotted gabbro."

In this neighbourhood there occurs a small 8-inch vein, which is distinguished by its minerals from the ordinary veins of Oedegarden, in as much as only its western part consists, as usual, of phlogopite and apatite, whereas in the eastern portion the phlogopite is replaced by hornblende. In contact with the country rock the hornblende is finely granular, but becomes coarsely crystalline towards the centre of the vein which is occupied by apatite.

Hornblende occurs also in several other veins of Oedegarden, sometimes replacing the phlogopite, and at other times accompanying it; in the stringers raven-black and finely-granular, but brown and coarsely crystalline in the veins.

No. 6, which gave the best specimens of hydrous enstatite, and No. 7 are both slightly-dipping veins of phlogopite, apatite and enstatite, arranged in bands, as usual.

In contact with the country rock the phlogopite is always in fine scales and often speckled with small grains of apatite. The individual scales are usually grouped without system; but sometimes there can be observed traces of a parallel structure, whose direction lies at an angle with the edges of the veins. Towards the middle of the veins the phlogopite becomes always more coarsely crystalline: we have seen plates at least half a foot square. These are often crumpled, twisted and broken, and sometimes are surrounded by apatite.

No. 8 is an ordinary mica-vein, bearing apatite, and is visible on the surface for a stretch of 60 feet. Where the vein wedges out in its continuation towards the west there occurs a zone of "sandrock" 86 feet long representing the vein, which still continues underground—as has been proved by pits.

No. 9 has yielded the greatest quantity of apatite of all the veins of Oedegarden up to the present time. It has been traced 300 feet in length, and 120 feet in depth; its dip is 25° at the surface, but lower down is 30°. Above ground the vein has altogether disappeared for a length of more than 60 feet, whilst underground the connection has been proved. Of all the veins this is the most regular; for the apatite, which occupies the middle of the vein, and is separated from the country rock by a usually thin zone of phlogopite and hydrous enstatite, has occurred partially in bunches, but generally in sheets. The thickness of the vein has varied a good deal.

A profile of the strike of this vein would closely resemble those of the other veins of Oedegarden.

For a short stretch between this and the following vein the "spotted gabbro" is replaced by a compact white labradorite, containing innumerable red specks of rutile.

No. 10 exhibits very interesting relations. The vein-mass, which consists of phlogopite with crystals of hydrous enstatite scattered here and there, encloses, in its upper portion, large bean-shaped lumps of dark apple-green and brown kjerulfine. Deeper down large lumps of the country-rock (partially "sandstone") and of apatite are enclosed by the vein-mass. Still deeper the vein has much the same character, although sometimes compact apatite occupies its centre.

Besides the minerals already mentioned, we observed in the veins of Oedegarden rutile rarely, sometimes in crystals. And on the dump of vein No. 2 we found rutile and brown titanite with green kjerulfine.

Calcspar, quartz, pyrites and copper pyrites were found in stringers, and tourmaline and albite in a geode (vein No. 1).

Finally there occurred in the clay that overlaid the foot of the ridge, as a secondary formation, specks of a blue mineral consisting chiefly of iron and phosphoric acid, apparently vivianite.

Oedegardskjern.

The bold N. W. Shore of the small lake that lies a little to the S. E. of the deposit just described consists of a kind of rock closely resembling the "spotted gabbro" of Oedegarden.

Here there have been principally mined three large vertical veins, which can partially be characterised as "apatite-bearing veins of enstatite." The most westerly of them is a vertical vein, up to six feet in thickness, of granular green enstatite, locally intersected by stringers of an almost compact bluish-black variety. Towards the lake the vein carries on its western side much apatite, which farther on separates from the large vein-mass as a distinct vein, along with some green bronzite and rutile; both veins are intersected by stringers of quartz. Close to the large vein there are several stringers, consisting partly of apatite-bearing hornblende and partly of a mixture of rutile with some hornblende and calcspar.

Farther eastward there occurs a vertical vein striking N. N. W., which has yielded about 60 tons of apatite. It consists at the sides of hornblende, and in the middle of apatite and some rutile. Small bits of the country-rock were enclosed in the apatite.

Still farther eastwards there occurs a third vertical vein of granular green and compact bluish-black hydrous enstatite, sometimes crystallised towards the middle of the vein, which part is occupied by apatite and rutile. In the neighbourhood there are smaller veins of red feldspar and rutile along with some of compact red feldspar, rutile, hornblende, apatite and the same green enstatite that occurs at Oedegarden and in many other deposits.

Fogne (Gjerrestad District).

This deposit has been already described by Joh. Dahll. The country rock is a "spotted gabbro" similar to that of Oedegarden, but often of coarser grain and more schistose. One vein consists chiefly of magnetic pyrites and pyrites with some apatite (often crystallised); another large vein consists of rutile and green pyroxene (both sometimes crystallised) along with apatite.

Hiasen (Gjerrestad District).

Hiasen is a small cone of gabbro that rears itself above the surrounding strata of the primary hills. The deposit can be briefly described as apatite-bearing veins of hornblende; which were very profitably worked in the years 1858-1859.

Asildsdal (Hiasen). The rock in which the veins occur is a hardly recognisable gabbro. The veins are large, but irregularly branched and split up. They consist of ordinary coarsely radiated hornblende, which carries apatite in lumps. On the dumps we also found ilmenite, spathic iron, feldspar, quartz, scapolite, tourmaline and calcspar. In one of the pits the vein of hornblende changed into a mass of calcspar.

Persdal (Hiasen). The veins are irregularly bifurcated, and sometimes more than five feet thick; they consist of coarsely radiated hornblende, sometimes with lumps of apatite, and sometimes without it. The country rock is a "spotted gabbro." Some of these veins also contain magnetic pyrites, which sometimes forms the chief mineral. (*Note.*—An illustration of these latter veins is inserted here.) On the right, one sees the coarsely radiated hornblende, whose individuals are arranged at right angles to the edge of the country rock; moreover, the vein mass consists chiefly of magnetic pyrites, wherein numerous dirty yellowish-green crystals of apatite lie, whose corners and edges have been rounded and apparently fused. On the right hand of the drawing, isolated fragments of hornblende are also observed in the magnetic pyrites. Another small adjacent vein consists exclusively of coarsely crystalline prisms of hornblende, arranged perpendicularly to the side-walls.

The above-mentioned fact, that the crystals of apatite enclosed in the magnetic pyrites have been rounded on the corners and edges, has been met with by us also in other localities where magnetic pyrites is the principal mineral of the apatite-bearing veins. On Hiasen we saw for the first time, on a small scale, an interesting circumstance, which we shall mention more minutely farther on, in describing the following deposit. In the common dark gabbro, namely, there occurred, close to the veins, some very small stringers of hornblende (not over half an inch thick) carrying apatite, enclosed on both sides by a zone, up to three inches thick, of a "spotted gabbro"—similar to that of Oedegarden. As already mentioned, the veins of Hiasen that are described above occur in a "spotted gabbro," which encloses it on both sides; whereas the rock of Hiasen is otherwise a common dark gabbro. The "spotted gabbro" does not extend to equal distances on both sides of the veins; whilst in one direction it stretches far towards the peak, it is necessary to go only a few steps in the other in order to encounter the common dark gabbro.

Regardsheien and Ravneberg (Soendeloer District).

Regardsheien and Ravneberg are two portions of one and the same ridge of rock, on whose precipitous declivity towards the Soendeloevsfjord, the veins of apatite crop out, which (next to those of Oedegarden) are at present most full of promise. The ridge consists chiefly of gabbro, which intersects the strata of the primary range; and the veins occur in the gabbro. Even in sailing past, their position can be made out from the vessel, as sometimes the piled-up dump beneath marks their locality, and sometimes the rich veins themselves show as a clear stripe upon the dark rock.

On Regardsheien there are five large veins, 150 to 200 feet long, and ½ to 1½ feet thick. The veins, which pinch out, as usual, are approximately parallel, overlying one another at a small angle; four dipping slightly (30°), but the fifth more strongly, inwards towards the ridge. In their course, they send numerous small off-shoots into the country rock. The veins consist of apatite-bearing hornblende, the sides being coarsely-radiated hornblende and the middle apatite, whose greatest width is one foot. The hornblende is often full of brown scales of mica, which occurs also in larger quantity. Sometimes the entire width of the vein is occupied alone by apatite or alone by hornblende.

On Ravneberg occur three groups of veins. The vertical *gangstock* of the central group, whose veins are all connected with one another, consists of a coarsely crystalline hornblende and mica; both being mixed with lumps of apatite and green enstatite like that from Oedegarden. The other veins of this group are regular and continuous, rarely one foot thick; one dips slightly towards the ridge, the others are vertical. They consist almost exclusively of reddish or greenish apatite, on both sides usually separated by a thin crust of green enstatite from the country-rock. The green enstatite was also found in larger crystals, sometimes surrounded by apatite, but usually jutting out from the *saalband* towards it. Quartz was also sparingly observed.

On the cape jutting into the Soendeloevsfjord there is a group of very pure veins of apatite; only on its *saalbander* do hornblende, mica and enstatite occur. The apatite is usually of clear colour, white or greenish, but brick-red where in contact with the crystals of hornblende (possibly caused by its iron-compounds?).

At a greater elevation there occurs yet a third group of veins, very similar to the preceding ones. The declivity is so precipitous that the quarries can be reached only by ladders.

What we observed on a small scale at Hiasen is displayed at Regardsheien in larger and bolder characters. The principal rock of this deposit is, as already mentioned, a common dark gabbro (with violet twin-striped labradorite). But in the immediate neighbourhood of the veins we do not meet with this dark gabbro, but with the above-mentioned "spotted gabbro." This rock surrounds on both sides, as a zone of varying width, not only the larger veins, but also their smallest stringers and bifurcations, always exactly following their contour. But this constant relation is accompanied by certain irregularities. Sometimes the zone is broader on one side of the vein than on the other. In the case of one of the largest veins, which sends out so many off-shoots as to form an enclosing network, wherever this is very dense, the following observation may be made: the "spotted gabbro," which usually surrounds every branch and off-shoot with an especial zone, forms here a general larger zone around the entire net, wherein the dark gabbro between the off-shoots entirely disappears. The smaller veins of Ravneberg behaved similarly to those of Regardsheien. The zone of "spotted gabbro" is here usually about six inches thick on each side, while that of the large *gangstock* is much thicker. We observed here that small stringers of hornblende (some of them barren of apatite), hardly one cm. thick, were surrounded by as broad a zone of "spotted gabbro" as the larger veins. Each of the two other groups of veins of Ravneberg was surrounded by a large portion of "spotted gabbro."

The manner and method of the occurrence of "spotted gabbro" in the deposits just described throws more light on the Oedegarden deposit.

We have studied this rock in close contact with the apatite-bearing veins. On Oedegarden it is no longer every single vein that is surrounded by an especial zone of "spotted gabbro." The entire Oedegarden vein-system, with its numerous and large veins, occurs in a small band of this gabbro. Only at a couple of points could we discover the dark violet gabbro, which is elsewhere so common in this region. The boundary between these two varieties of gabbro is always tolerably sharp: on Regardsheien we broke out hand specimens of medium size, one-half of which consisted of the ordinary dark gabbro, and the other of the spotted variety, while the centre was a transition stage between the two. In regard to the relation between the "spotted gabbro" and the other neighbouring rocks, we observed on Oedegarden that the labradorite sometimes, although very rarely, showed cleavage planes with twin-striping. In this case the rock can only with difficulty be distinguished from the adjacent quartz-free (oligoclase) hornblendic gneiss, all the more so because the schistose texture of the latter is easily recognisable only at some distance from the boundary of the gabbro. We ourselves therefore at first took the "spotted gabbro" of Oedegarden for a portion of the gneiss altered by contact with the veins—which it certainly cannot be.

Besides the above-described deposits there are some others known to occur in the gabbro; but we had no opportunity to examine them.

II. Deposits that do Not Occur in the Gabbro.

As already mentioned, we shall describe first those that lie in the immediate neighbourhood of the gabbro.

Krageroe.

This deposit of apatite, formerly the richest in Norway, has been already briefly described by Joh. Dahll. As a detailed description of the apatite veins of Krageroe, the fruit of many years' research, is expected from our distinguished geologist Tellef Dahll, we shall call attention only to those details that seem to be of value for the comprehension of the other deposits. Mr. Tellef Dahll was our experienced guide.

The Krageroe deposits may be generally described as segregations of hornblende, containing apatite. They yielded in the years 1854-58 about 5,200 tons of apatite, of the value of about $112,500 ; for the price of apatite was then lower than now. There were three large segregations, lying at the base of a cone. The peak of the cone consists of gabbro, which is only a few paces removed from all the veins.

In the Vuggens mine a vein seven feet thick, with a slight dip, here penetrates partly the granite and partly the strata of the primary rocks. Both sides of the vein consist of a rather finely granular hornblende, containing small lumps of apatite. The middle of the vein is occupied by coarsely radiated hornblende enclosing lumps of apatite up to two feet in diameter, which sometimes have a plainly hexagonal section. On the boundary between the finely granular and the coarsely radiated hornblende there sometimes occurs, especially in the foot wall, rutile along with a greenish-grey steatite and an imperfectly fibrous mineral resembling asbestos. The two latter are sometimes combined together into large radiated masses, projecting towards the middle of the vein, and having a contorted internal structure. In their combination large crystals of hornblende occur, whose principal axis lies in the same direction as the fibres of the asbestos-steatite. In the coarsely radiated hornblende of the middle of the vein there occur irregular geodes, into which the ends of the hornblende crystals project, generally coated by quartz and calcspar; the latter being the younger deposit. The hornblende crystals are sometimes broken and cemented again with quartz.

The two other segregations of Krageroe showed similar conditions. The lumps of apatite sometimes reached an enormous size. Besides the minerals already mentioned, ilmenite (in crystals celebrated because of size), titanite, albite, calcspar and apparently several other minerals were found when the mines were worked.

Oedegarden (Bamle District).

S. E. from the largest of the Oedegarden veins and on the other side of the ridge at whose foot lie the apatite veins previously described, there occurs on the declivity towards Havredal an irregular vein of hornblende ½ to 4 feet thick, which has been traced for about 100 feet, intersecting the vertical strata of a hornblendic gneiss poor in quartz. The vein consists of hornblende and a mineral resembling hornblende along with some quartz, brown mica and lastly apatite and rutile in lumps. The apatite is red and similar to that of Krageroe; of whose hornblende veins this whole deposit reminds us.

In the Jungfernschurf, near to Oedegarden, there occurs in the crystalline slates a small portion of a coarsely granular granite, poor in mica, which is intersected by a diabase vein perfectly similar to the numerous veins of the Christiania valley. A vertical vein, one foot thick, of grey and flesh-red apatite along with some hornblende and green enstatite intersects the granite as well as the slates. Several similar stringers occur in the granite, wherein stringers of green enstatite abound.

Near Roenholt, a little to the north of the Oedegardskjern veins, described on page 429, there is a very interesting occurrence. A coarsely granular granite intersects the highly inclined strata of hornblende slates (strike being about N. E. and S. W.). Both granite and slates are interwoven by veins, consisting chiefly of a green pyroxene,* rich in magnesia—in part a very fine malacolite—of rutile, brown coarsely crystalline hornblende † and, finally, apatite. The pyroxene, rutile and apatite occurred sometimes in large crystals. The rutile crystals were sometimes bent and twisted. The thickness of one of the veins, around which the slates were folded, was four feet. The veins send numerous off-shoots into the granite, and sometimes even enclose fragments of it, whereby the relations are very much complicated.

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* The angles of the two cleavage planes were 87° 23′ and 92° 39′.

† The angle of the very lustrous cleavage planes was 124° 24′.

(*Note.*—A number of other deposits are then briefly described. But the authors remark that they are of no practical importance and were not critically studied; therefore it is not thought necessary to translate these descriptions.)

Our apatite deposits have all been formed in the same way. The veins show in regard to their mineral contents conditions differing from one another; we will, therefore, attempt to point out, especially on this point, connections and transitions.

There occur at Oedegarden almost pure veins of mica, apatite-bearing veins of mica, mica-hornblende veins and veins of hornblende, all under precisely similar conditions; in many small deposits of hornblende and also in the great segregations of hornblende at Krageroe hornblende, and not mica, is the chief mineral. The veins of Ravneberg, which remind one very much of those of Oëdegarden, form with their vertical mica-hornblende segregation a perfect transition to the segregations of Krageroe.

The apatite-bearing veins of hornblende often carry magnetic pyrites: transitions from the one to the other may be observed, as it gradually increases in quantity. At Bamle we saw small veins consisting exclusively of magnetic pyrites; in one and the same deposit also the magnetic pyrites occurs at one time merely as an accessory, at another as almost the only mineral.

In the apatite-bearing veins of hornblende feldspar or quartz, or both together, occur not unfrequently. Here also through several deposits it can be traced out how the feldspar or quartz increases in quantity until it predominates; which justifies the designations "apatite-bearing feldspar veins," or "quartz veins." When both minerals predominate and mica is also present we have the so-called "apatite-bearing granite veins," which are hardly to be distinguished, except by the apatite, from the numerous ordinary granitic veins of the region.

Scapolite occurs sometimes as merely accessory, at others as a more important element, and in one deposit as almost the only mineral. The oft-mentioned crystals of green enstatite recur in their characteristic shape and with the same chemical composition in the various deposits, and connect them together. Enstatite also sometimes occurs with the apatite as almost the only mineral, so that the deposits merit the name of "apatite-bearing enstatite veins."

An equally common and characteristic mineral is rutile. This also in rare cases predominates.

When one considers how very greatly the mineral contents and the external aspect generally of apatite-bearing veins vary, neither the deposits of Asildsdal with their masses of calcspar, nor those of Oxoiekollen with their predominating albite, can offer sufficient grounds for distinguishing these deposits from the other apatite-bearing deposits. For calcspar and apatite are also found in several other deposits; and in other respects Asildsdal and Oxoiekollen are not abnormal.

Also the circumstance that in several deposits one and the same vein sometimes exhibits in its various parts an entirely different mineral composition, can only be another ground for regarding the veins as identical formations. The above instances have proved that all grades of transition occur between those deposits where apatite occurs only sparsely and as an accessory, and others where it forms the chief mineral. This is shown also in one and the same deposit.

Also in other respects, viz. in the arrangement of the minerals, in the shape of the veins, etc., could a similar transition series be produced as proof of the identical nature of the veins.

Our apatite deposits are veins. The occurrence of apatite in beds, sometimes forming small strata in the sedimentary rocks, has been described in several countries. In Sweden apatite has been described as a noxious admixture with the iron ores of the Graengesberg, which are said to be "beds" in gneiss. The apatite occurs in our veins in an entirely different manner.

Our apatite-bearing veins occur without difference in the eruptive, as well as in the stratified rocks of our primary range. In the latter case they are perfectly independent of the strike and dip of the strata, with one exception, viz., the kjerulfine deposit at Havredal; which, however, as it agrees in all particulars with the apatite-bearing veins, cannot be separated from them. The veins traverse gabbro, granite, hornblende slates and hornblende gneiss, mica schists and quartzite. This fact that perfectly identical veins occur in different rocks (e. g. the characteristic veins of hornblende with apatite and magnetic pyrites occur at Hiasen, etc., in gabbro, and at Hougen, etc., in hornblende slates), seems to us completely to contradict the idea of the veins being formed by separating out from the country-rock (in which way Scheerer has explained the formation of our coarsely crystalline veins of granite). These granite veins, like many of our apatite-bearing veins, show sometimes a symmetrically banded arrangement of their ingredients; the feldspar occupying the sides and jutting out in coarse crystals towards the middle, which is filled with quartz.

Dr. T. Sterry Hunt has assigned* quite a different mode of formation to the apatite-bearing veins of Canada, which, according to the description, must be perfectly similar to ours. He distinguishes three different varieties of veins as occurring in the Laurentian formation: 1. Lead-bearing veins, which are said to be much younger than the other two varieties; 2. Granitic veins, which would seem to be comparable to our ordinary coarsely crystalline granitic veins, as Dr. T. S. Hunt has himself pointed out; 3. Calcareous veins, which are generally associated in their occurrence with the eozoon limestones, which Dr. Hunt considers to be sedimentary. This third group of veins, which is common in Canada, and also sometimes occurs in the northern part of the United States, is usually rich in calcspar, and corresponds to our apatite-bearing veins. The similarity is surprising.

Dr. T. Sterry Hunt tries to explain the formation of the calcareous veins, as well as the granitic veins already mentioned, by hot solutions charged with the ingredients of the stratified rocks having deposited the dissolved matters in vein fissures; he terms veins formed in this way "endogenous." He seeks to establish his theory especially upon the fact that almost all the vein-minerals occur also in the stratified country-rock, as well as by the fact that calcareous veins occur especially in the limestone and the granitic veins, especially in the gneiss and micaceous schists. These conditions are not met with in our veins. We are not aware of apatite or any other mineral containing phosphoric acid having been found in the country rock of the veins. This holds good not only of the phosphatic minerals, but also of rutile and many other minerals occurring in the apatite-bearing veins. And in no other respect, although our attention was especially turned to this point, could we observe any definite relation between the minerals of the veins and those of the country-rock. In a rock of such constant composition as gabbro there occur large, almost pure veins of enstatite, veins of mica, segregations of hornblende and mica, veins of apatite, etc. The apatite-bearing veins and the numerous granitic veins occur also side by side in the same rocks. On the other hand, it could be

* Geology of Canada, 1866, pp. 186–233.

proved that veins of similar mineralogical composition may occur in entirely different sorts of rocks (*vide supra*).*

Our apatite-bearing veins are of eruptive origin.. We shall first discuss a point which would seem to oppose their eruptive origin. In many deposits, some of them being the principal ones, there occurs, as already mentioned, a symmetrical arrangement of the vein-minerals. Thus, for instance, in the Oedegarden veins brown phlogopite and sometimes also crystals of green enstatite, in many hornblende-deposits hornblende, and in several apatite-bearing enstatite veins enstatite occupies the sides of the veins, while their centre consists of apatite and very often also of other minerals. This banded arrangement might seem perhaps to indicate a regular gradual deposition of the minerals out of watery solutions. Frequent exceptions, however, occur even in the most regular deposits; wherein no such systematic arrangement is observed. Sometimes, the vein minerals throughout the entire extent of the veins are mixed with one another equally and without arrangement, at other times the veins do not contain the same minerals in their different portions. In veins that consist chiefly of a single mineral, apatite and other minerals are often distributed equally through the entire vein mass. The symmetrical structure of our veins can, with regard to regularity, be in no way compared to that which is so splendidly displayed in many metallic veins.

We explain the banded arrangement of the minerals in our apatite veins by the assumption that under favourable conditions the minerals that now occur on the sides of the veins (usually hornblende or mica) were first crystallised out of the magma under pressure.

The veins exhibit also the phenomenon so often observed in eruptive veins, that the vein-minerals are fine-grained on the walls next the country-rock, while in the centre of the veins they have formed larger crystals.

In the Oedegarden veins, moreover, the fine scales of mica near the walls are sprinkled with small grains of apatite. Both minerals must therefore have crystallised out together, before the large crystals of mica that project into the apatite, and finally the central apatite itself was formed out of the still liquid vein

* Limestone occurs very seldom as a rock, so far as we know, in the entire region where the apatite-bearing veins occur.

stone. A vein at Krageroe exhibits still more distinctly a similar sequence of crystallisation of the minerals in the hornblende veins. The side portions consist of a mixture of finely granular hornblende with grains of apatite; from this rather sharply defined zone the large crystals described above project into the central vein-mass. We explain this arrangement in the following way, viz., that the zone of the finely granular mixture crystallised while the vein-mass was still in motion: on the cessation of its upheaval, there first solidified, along with apatite, the above-mentioned large crystals and the coarsely radiating hornblende that occurs in their continuation, along with rutile, and, finally, the rest of the coarsely radiating hornblende and the apatite associated with it.

The coarsely crystalline hornblende in the middle of this Krageroe vein exhibits another phenomenon that seems irreconcilable with a gradual deposition of the minerals from solution, viz., large spheroidally arranged crystals of hornblende radiating from a centre inside of the vein; the formation of these may be readily explained by the assumption that the crystallisation of the liquid vein-mass took place not only on the walls of the country-rock, but also about a centre inside of the magma. We recollect, moreover, that in several of our deposits of apatite fragments of rock occurred in the vein mass and surrounded by it. Joh. Dahll states that at a considerable depth in Lykkens mine at Krageroe rock fragments occurred in such quantity that a genuine breccia was formed. But the most remarkable of these observations is the discovery of small (about two inches long), angular, sharply defined fragments of rock, which were enclosed in the apatite of our Oedegardskjern vein. These fragments consist of granular quartz and some hornblende; the country-rock here is a gabbro somewhat similar to the "spotted" gabbro of Oedegarden. Since neither the vein nor the surrounding rocks contain quartz and the fragments are in no respect similar to the mineral aggregates that we have otherwise met with in the veins, but are similar to several of our ordinary quartzites, we can therefore scarcely doubt that they are also true fragments of rock, which cannot, on account of their character, be derived from the country-rock. We are inclined to regard them as fragments of rock that have been broken loose at a considerable depth and brought to the surface by the liquid vein-mass.

A phenomenon which also seems best explained by the assumption of the eruptive nature of the veins, is seen in the twisted and bent crystals of various minerals that frequently occur in several deposits. In the Oedegarden veins bent crystals of enstatite often occurred. Still more frequently are the large plates of mica in veins of apatite crumpled and twisted. At Roenholt bent and twisted crystals of rutile occurred embedded in the other minerals of the vein. A pair of bent and twisted crystals of apatite an inch long, which—to judge by other crystals found at the same place—must have been surrounded by a homogeneous mass of quartz, seemed very remarkable. The crystals of apatite when first formed, while the mass of quartz was still plastic, may have obtained their present contorted shape from the pressure caused by the motion of the quartz.

We must also mention the broken crystals of enstatite at Oedegarden that are cemented by apatite, and the fragments of crystals of hornblende that occur in magnetic pyrites on the *saalbaender* of many veins. Both occurrences make it probable that the entire vein mass did not simultaneously solidify. This is also indicated by the banded arrangement of the veins. It is probable that the apatite and magnetic pyrites were still a plastic mass when the minerals of the *saalbaender* had already crystallised out. And when these latter, in consequence of the motion of the vein mass, were broken they were cemented by the apatite or magnetic pyrites.

We may here recall to mind the crystals embedded in magnetic pyrites, that were rounded and even fused on the edges and corners.

As already mentioned, where the apatite-bearing veins occur in strata, they are perfectly independent of their strike and dip; showing in this respect the usual behaviour of eruptive veins.

We must mention still another point wherein these veins differ from ordinary metallic veins, viz., in the entire lack of empty spaces filled by crystals dividing them into two symmetrical halves. Even ordinary geodes are met with only as rare phenomena in the apatite-bearing veins.

Apatite has been long known as a mineral crystallisable out of a hot liquid mass. Forchhammer obtained small crystals out of a fused mixture of salt, chalk and bones; small crystals of apatite are among the commonest associates of melaphyre. Therefore it cannot be astonishing that apatite occurs in empty veins.

The apatite-bearing veins bear a certain relation to the gabbro. We must here recall to mind that the apatite-bearing veins occur in a region where gabbro frequently intersects the strata of the primary rocks. All the important deposits of apatite occur either in gabbro or in its immediate vicinity. As the gabbro has suffered far more alteration by the eruption of apatite veins than the other rocks have, perhaps the assumption is justified that the gabbro may have been not perfectly solidified when the veins burst forth.

The eruption of the apatite-bearing veins occurred either simultaneously with or immediately after the outbreak of these gabbro masses. A number of observations would seem to suggest that the vein masses when they burst out were hydrous and accompanied by solutions and gases. We mentioned that the veinlets of Regardsheien and Ravneberg were sometimes surrounded by as broad a zone of the "spotted gabbro" as the larger veins themselves; and also that in some cases this zone is broader on one side of the vein than on the other; farther, that the direction of the small off-shoots is continued by veinlets and stringers of a schistose gabbro inside of the granular "spotted" variety. Finally, we would recall to mind that in several deposits the "spotted gabbro" extends far from the veins. When these considerations are all borne in mind, it seems clear that the alteration of the gabbro is due only in small part to the heat of the molten veins, but rather to the steam accompanying the eruption, which could operate at some distance from the limits of the vein.

The practical result of our examination is, in brief, that one can reasonably expect to find the apatite in and in the neighbourhood of the gabbro, especially where one or more of its characteristic associates, such as rutile and the frequently described crystals of green enstatite, are found. As regards the yield of our apatite deposits, it has been found, so far, that only the deposits in the neighbourhood of the gabbro have yielded any considerable output.

Erratum.—On page 391 line 27, read 14,442 instead of 4,442.