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ore at this part of Australia will reach, if not surpass, that of all the old tin-mining countries combined.

DISCUSSION.

Mr. DAINTREE commented on the enormous value of the 170 miles of frontage for stream-tin works exposed in Queensland. The value of these alone would, according to Mr. Gregory's calculation, be some £13,000,000; taking an equal value for those of New South Wales, there would be lying on the surface something like twenty-five times the whole amount of tin annually produced in Cornwall. In addition to this, there were lodes of immense length and richness. At the same time large tracts of similar granite to that containing the stanniferous veins were still unexplored in other parts of Queensland. What amount also of tin-bearing drift might exist under the tracts of basalt was still unascertained. The tin and other minerals were, he observed, limited to the palæozoic and metamorphic districts traversed by dykes, such as those mentioned in Mr. Ulrich's paper; and although very large areas of granite similar to that of the Severn river were to be found in other parts of Queensland and Australia, the stanniferous portions would be confined to the areas traversed by such dykes.

3. *On the INCLUDED ROCK-FRAGMENTS of the CAMBRIDGE UPPER GREEN-SAND.* By W. JOHNSON SOLLAS, Esq., and A. J. JUKES-BROWNE, Esq.

(Communicated by Prof. Ramsay, F.R.S., F.G.S.)

[Abridged.]

FROM time to time fragments of various rocks have been noticed in the formation of such size and angularity as to have suggested the idea to two preceding observers (Mr. Bonney and Mr. Seeley) that they might have been brought to their present position by the agency of ice. While ignorant of the suggestions of these gentlemen, we were forced independently to the same conclusion, and commenced, together, an examination of the subject. Our first step was to make an examination of all the erratics from the formation which had been preserved in the various local collections. The following is a descriptive list of the most important of these fragments.

Descriptive List of Rock-fragments.

No. 1. A large cuboidal block of coarse yellowish felspathic grit, very hard and compact, measuring $10 \times 7 \times 7$ inches, subangular, not much decomposed; incrustated with coprolite, *Exogyra*, *Spondylus truncatulus*, *Plicatula sigillum*, and *Ostrea vesiculosa*. Derived probably from the Millstone-grit of the north of England. Collection, Woodwardian Museum, signified after this by the initials W. M.

No. 2. A very angular, roughly rhombohedral prism of purplish-red indurated shale, moderately hard, measuring $9 \times 5 \times 5$, not

much water-worn or decomposed; incrustated with coprolite and *P. sigillum*. Derived probably from Old Red Sandstone of Scotland. Collection W. M.; in Mr. Browne's collection is a smaller piece.

No. 3. A large subangular block of soft friable grey sandstone, measuring $14 \times 12 \times 6$ inches; rather rounded and water-worn; incrustated with coprolite, *P. sigillum*, and *Ostrea*; probably of Carboniferous origin. Collection W. J. Sollas.

No. 4. A subangular block of a fine conglomerate, consisting of small stones set in a purple quartzose matrix, measuring $6 \times 4 \times 3\frac{1}{2}$ inches, much rounded and water-worn; incrustated with coprolite, *P. sigillum*, and *Ostrea*. Resembles closely some of the Old Red conglomerates near their junction with the Silurian strata in Scotland. Collection A. J. Browne.

No. 5. A long square prism of black compact limestone, measuring $8 \times 4 \times 4$ inches, rather decomposed outside and pierced by a small boring animal; incrustated with coprolite, which penetrates all its cracks and hollows. Very similar in character to the Carboniferous black marbles. Collection W. M.

No. 6. An obtuse-angled prism of hard reddish sandstone, with included fragments of felspar, measuring $6 \times 8 \times 4$ inches; very angular, with sharp edges; incrustated with *Serpula*, *O. vesiculosa*, *P. sigillum*, and coprolite. Collection W. J. Sollas.

No. 7. An angular broken fragment of black basalt, with numerous crystals of olivine; in size $6 \times 5 \times 3$; rather decomposed on the outside and weathered white; resembles some of the olivine basalts on the east coast of Scotland. Collection W. J. Sollas. This stone has none of the characteristic Upper Greensand incrustations; it was obtained, however, with other stones which had, and the workmen declared they had all come from the "coprolite bed."

Besides the foregoing larger fragments, several smaller pieces are highly interesting:—

No. 8. A cuboidal subangular tablet of compact brown siliceous limestone, measuring $3 \times 3 \times 1\frac{1}{2}$ inches; smoothed, and abundantly scratched in various directions; incrustated with *P. sigillum* and *O. vesiculosa*. Collection W. M.

No. 9. A roundish granitic fragment, about $5 \times 4 \times 2$ inches; worn and decomposed, but showing on one side a flat surface with what seem to be traces of ice-polishing; incrustated with coprolite and *P. sigillum*. Collection W. M.

No. 10. A small flattish fragment of green sandy mica-schist, about $3\frac{1}{2} \times 2$ inches; smoothed on its flat faces and faintly striated; incrustated with coprolite and *P. sigillum*. Collection A. J. Browne.

No. 11. A rounded and water-worn fragment of tough decomposed green trap, about $4 \times 3 \times 2$; incrustated with *Ostrea* and *P. sigillum*, very similar to some of the green traps on the east coast of Scotland, for example those of Fife.

No. 12. A small broken fragment of granite composed of felspar, black mica, masses of fibrous hornblende, and irregular crystals of quartz, much decomposed. Collection W. M.

Fragments of gneiss, mica and hornblende schists, talcose

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schists, granites, vein-quartz, grits, quartzites, and slates are very numerous.

We may form the following generalizations from the characters which these stones present.

I. Most of them are subangular, and many are extremely friable. The presence of these latter rocks is remarkable; fragments of soft sandstone (No. 3, for example), of various shales and talcose schists, are frequently met with, which could never have borne even a brief journey by water along the ocean-bed.

II. Many of them are of large size, especially as compared with the fine silt in which they were imbedded, the larger ones measuring more than a cubic foot. It is obviously impossible that any ordinary marine current could have moved along such blocks as these, especially from such great distances as we shall show they have probably come.

III. They are of very various lithological characters, and derived from several Palæozoic formations; among the most abundant are mica-schists, basalts, granites, felspathic shales, vein-quartz, and coarse grits; and we may refer them to gneissic, schistose, volcanic, and sedimentary rocks, probably of Silurian, Old-Red-Sandstone, and Carboniferous age. Such strata are not found anywhere *in situ* in the neighbourhood; and we must go to a great distance before we find any at all corresponding to them, either to Scotland or to Wales. This consideration, that numerous rock-fragments, some of which are very friable, have been brought from various localities at great distances, and yet retain their angularity, seems to us almost sufficient evidence in itself for their transportation by ice. We dismiss, at once, all notion of the agency of trees; for it is scarcely conceivable that so many stones from so many different formations could have been repeatedly borne to sea by such exceptional means of transport. The majority of these erratics present no signs of ice-scratches; but when we reflect on the small proportion of ice-scratched stones in the moraine matter borne away by an ordinary iceberg, and on the small percentage of ice-scratched boulders in many deposits of recent glacial drift, we see nothing in this fact inconsistent with their glacial derivation, especially when we remember that many of our Upper Greensand boulders are composed of soft or decomposable rocks from which ice-marks, even if once existing, would probably have been erased by the subsequent action of water. We think, therefore, that even without any more positive evidence we should have in this assemblage of large rock-fragments, mostly subangular and derived from various and distant formations, great reason to attribute their occurrence in their present situation to the transporting power of ice. Some of the stones present a few scratches in different parts of their surface, which are difficult to account for, except by the agency of ice; and others have flat faces which look as if they had once been striated surfaces. The stone numbered 8, especially, which is preserved in the Woodwardian Museum, we find to be unmistakably scratched in various directions, the striæ

passing directly under the incrusting *Plicatula sigillum*, and therefore, evidently, produced before the growth of the shells. The stone is composed of a peculiarly hard and compact siliceous limestone; and the scratches do not run in one parallel direction across the fragment as in glacier-scratched stones, but are distributed in various groups of parallel lines all over the surface, and especially round the edges and corners. This fragment is a remarkable one; for while some of its striæ are evidently ice-scratches, the majority are of a very curious nature and uncertain origin.

It may be added that occasionally a large number of fragments are found associated in one spot; six large stones, of various constitution, were found huddled together at Waterbeach.

Having then arrived at the conclusion that the Upper Greensand erratics have been brought hither by floating ice, there next arises the question as to whence they have come; and we think, after considering all sides of the case, that the facts point unmistakably to Scotland and the North for an answer. Along the eastern coast of Scotland, in Aberdeen, Forfar, and Fife, we have successively granite, mica-schist, and basalt, Silurian, Old Red Sandstone and Carboniferous rocks; while in Fifeshire, Edinburgh, and Berwick there is a vast extension of volcanic rocks, from which the erratic trap, basalt, and obsidian of the Upper Greensand might have been derived. It is true that obsidian is not found in Scotland now; tachylite, however, occurs in small quantity on the Fifeshire coast; and we do not know what volcanic rocks may have existed along the extension eastwards of the Scottish coast towards Scandinavia. Some of the rocks are strikingly Norwegian in character, far more closely related to some of the hornblendic rocks of south Norway than to any in Scotland. In deciding thus on a northern origin for our erratics we are supported both by Mr. Bonney and Mr. Paley, who have given some attention to the question.

Mr. Bonney has shown that the Cambridge coprolites were originally formed in the topmost beds of the Gault, and that the denudation of these beds has given rise to the thin seam which bears the name of the Upper Greensand; and it therefore becomes a question as to when the included erratics were brought down, whether during the deposition of the Gault, or during its denudation and the formation of the Greensand. Since we know that the Gault clay was formed in a comparatively quiet sea, and that, after some thickness had been deposited, change of conditions and extensive denudation ensued, it is reasonable to attribute these occurrences in part to the cold current of which we have evidence in the Cambridge erratics. Some of the stones are covered by Gault coprolite, and hence must have fallen into the upper beds of the Gault, during the deposition of which cold conditions must have prevailed.

The fauna, consisting partly of Gault fossils and partly of true Upper Greensand forms, agrees very well with these conclusions. The marine fauna is an abundant one, being, as we should expect from the origin of the stratum, a mixture of deep-sea and littoral forms; but the shells are by no means large, nothing like the splendid

fossils, for instance, which characterize the Gault of Folkestone. The representative Cephalopoda seldom attain a large size; of Gastropoda and Lamellibranchs such genera as *Rostellaria*, *Trochus*, *Natica*, *Avicula*, *Spondylus*, *Arca*, and *Pholadomya* are certainly dwarfed; while the small *Plicatula* and *Ostrea*, which are known to be truly Upper Greensand fossils, are very diminutive indeed. *Terebratula* is fine and numerous; *Rhynchonella*, *Dentalium*, and *Nucula*, usually considered extra-tropical forms, are also numerous, the two former especially so; *Echinoderms* are rare, *Crustacea* not very common, and both are small, as also the coral *Smilitrochus* and the still more diminutive *Micrabacea*.

In the Greensand of the Isle of Wight the fauna is very different: Brachiopods are far less numerous, while Echinoderms and Cephalopoda become finer; *Cardium*, *Cucullæa*, *Gryphæa*, *Pectunculus*, *Thetis*, and *Trigonia* occur as new and seemingly more tropical forms. The Gault unfortunately is thin and unfossiliferous in this locality, so that we have not the opportunity of comparing the fossils of its upper layers with those of the Cambridge Greensand; but the fine Ammonites and Hamites of the Folkestone Gault are well known and bespeak a more favourable climate.

Supplementary Notes.

i. Since the reading of the above communication we have had the good fortune to find a block of massive Labradorite about a cubic foot in size and incrustated with coprolite; this would seem to be a Norwegian erratic.

ii. Mr. Seeley states that he has found the well-known concretions of the Magnesian Limestone in our formation; and since these concretionary forms are peculiar to the Magnesian Limestone of N. E. England, their occurrence strengthens our conclusions as to the northern derivation of the Cambridge erratics, as does also the occurrence of *Poteriocrinus*, likewise met with by Mr. Seeley.

iii. Since the boring at Kentish Town passed through 14 feet of Upper Greensand and 130 feet of Gault above Palæozoic rocks, the thicknesses being those of the southern area of the beds in question, while at Hitchin there is only 1 foot of Greensand and over 200 of Gault, and this Greensand is of the Cambridge coprolitic type, it is probable that these two different types of Greensand were deposited in different areas and separated by land now under the Hertford Downs. In this way we would explain the evidence of cold conditions in the Cambridge and Bedford area, while a comparatively warm sea existed over Southern England.

DISCUSSION.

Mr. SEELEY gave some history of the specimens in the Woodwardian Museum, on which the paper was partly founded, some of which had been collected by the late Mr. Lucas Barrett, and others by himself. He thought that some of the scratches on one of the specimens from Granchester might be of modern origin, and doubted

whether the place of derivation of most of the blocks was Scotland. Besides the rocks mentioned, he had found fragments of Magnesian Limestone and columns of *Poteriocrinus*. He could not agree with the authors as to the physical geography of Britain during the Upper-Greensand period. He considered that it was from the denudation of the great barrier mentioned in the paper that much of the material of the Upper Greensand was derived, and disputed the value of conclusions as to climate founded on so small an area of induction.

Mr. J. F. WALKER did not agree with the authors as to the absence of large ammonites in the Cambridge Greensand, and of fossils in the Gault of the neighbourhood of Cambridge; the latter had been found by Mr. Keeping at Upware. He inquired in what state of combination the phosphoric acid was supposed to be brought from Scotland.

Mr. SOLLAS, in reply, stated that the scratches referred to by Mr. Seeley could not be of modern formation, since they were in many cases partly covered by incrusting *Plicatula sigillum*, and pointed out the difficulty attending the supposition that the blocks were derived from any other than a northern source. He thought that the large ammonites were derived from a lower bed in the Gault than that from which he had supposed a large portion of the Upper-Greensand fossils had been derived. He considered that the phosphoric acid had been conveyed along the sea-bottom in a cold current, perhaps as a calcic phosphate.

Mr. JUKES-BROWNE also replied, and drew attention to a section he had prepared, which showed that the London and Harwich anticlinal had been covered with a great thickness of Gault at the time of the deposit of the Upper Greensand.

Prof. RAMSAY, in winding up the discussion, expressed an opinion that the forms of pebbles of glacial origin might be recognized by an experienced eye even though the striæ had been worn off, and that some of the pebbles exhibited showed traces of such an origin. He called attention to the fact that the deposit of glaciated pebbles in any particular locality did not in any way involve the existence of arctic conditions at that spot, though they might exist elsewhere.

NOVEMBER 20, 1872.

Lieut. Charles Cooper King, Royal Marine Artillery, Royal Military College, Sandhurst, and H. L. Florence, Esq., 16 Christchurch Road, Streatham Hill, were elected Fellows of the Society.

The following communications were read:—

1. *On the GEOLOGY of the THUNDER-BAY and SHABENDOWAN MINING-DISTRICTS on the NORTH SHORE of LAKE SUPERIOR.* By H. ALLEYNE NICHOLSON, M.D., D.Sc., M.A., F.G.S., F.R.S.E., &c., Professor of Natural History in University College, Toronto.

HAVING recently had an opportunity of accompanying an exploring party to the north of Lake Superior, I take this occasion to give a