

the highest hills remained uncovered by the sea, and when the mountains again rose, a set of smaller glaciers was formed. The thickness of the ice in existing Swiss glaciers was known to be very great, in the Grindelwald it had been ascertained to amount to 700 feet, and in other instances was probably thicker. The observations of Agassiz and Prof. James Forbes on the height to which grooved and polished surfaces span up the sides of Alpine valleys, had led to the conclusion, that the ice had once been much more extensive, and that in the glacier of the Aar, for example, it must have amounted to 2,000 feet. The same method of observation had been applied to North Wales, and it had been ascertained that in the Pass of Llanberis the grooves and roundings of the rocks extended to a height of 1,300 feet above the bottom of the valley. The drifted deposits which overlie these rounded surfaces must have formed during the slow depression which followed, and the glaciers must still have existed, since these deposits, though marine, are still of a moraine character. The cold climate continued during the period of depression, and for some time after it, and there was beautiful evidence in the side valleys of the gradual decrease of the glaciers until they died away amongst the higher mountains in the form of moraines stretching across the valleys, one within the other. The scratches made by the first set of glaciers passed down the valleys, those of the smaller glaciers crossed the first obliquely.

*On the Anthracite Deposits, and the Vegetable Remains occurring in the Lower Silurians of the South of Scotland: by PROF. HARKNESS.*

These strata form the high land south of the Firths of Forth and Clyde, and have a general inclination to the N.N.W. The highest beds are on the northern side of the range; and consist, near Girvan, of limestone and sandstone, with fossils of the Llandovery rocks. To the southward fossils are rare, but near the lowest part of the series, at Glenkiln, nine miles from Dumfries, organic remains are found in beds of anthracite, resting on 1,500 feet of unfossiliferous purple and grey sandstones and shales. The fossils are *Graptolites sagittarius*, *Diplograptus pristis* and *D. ramosus*. *Siphonotreta nuda* occurs with the Graptolites in a thin bed of black shale at the base of the anthracitic beds. At Duff-Kinnel, crustaceans of the genus *Dithyrocaris* have been found. These fossils do not account for the carbonaceous matter in the black shales, but indications of "fucoids" have been found; and it is supposed that much of the hydrocarbon of these beds has been lost through the influence of mechanical forces. Fucoids of the genera *Palæochorda* and *Chondites* are found in the ripple-marked flags of a much higher part of the series, north of New Galloway, unaccompanied by anthracite, but associated with a zoophyte (*Proto-turgularia*) and tracks of Annelides. The Anthracite beds were supposed to have derived their carbonaceous matter from sea-weeds floating like the gulf-weed of the present day.

Prof. Ramsay considered these black schists were of the age of the lower part of the Bala or Llandovery series. Prof. Forbes remarked that the fossils usually called "fucoids" were rather to be regarded as zoophytes; and the "Nereites" were believed by German paleontologists to be flexible bodies similar to Graptolites and not tracks of Annelides.

*On the Sub-division of the Palæozoic Rocks of Scotland: by MR. D. PAGE.*

Passing by the oldest systems, the author proceeded to describe the typical development of the Old Red Sandstone, remarking that the classification of strata should always be founded on the district which exhibited their characters in the highest degree. The system was considered to extend downwards to the lowest stratum, containing remains of fishes, and to consist of three divisions:—1. The lowest, or Grey Sandstone series, 2. The Old Red Sandstone and conglomerate, (*par excellence*); 3. The Yellow Sandstone series. The spiny-finned fishes (*Cheiracanthus*, &c.) were most abundant in the lower division; bony-case fishes (*Cephalaspis*, *Coccoosteus*, &c.) in the middle; and *Holoptychii* in the upper series. The "fucoids" were regarded as merely structural peculiarities of the rock, but according to Dr. Fleming, true plants also occurred. The whole system was considered of marine origin, and the conglomerates were believed to have been transported from a great distance by the agency of ice, because the material is not sorted as it would be in a free flowing sea. The Carboniferous system represented the limestone, mill-stone grit, and coal measures of England, but in the east of Scotland there was a peculiar set of sandstones below the carboniferous limestone, called the "calcareous sandstone" by McLaren, and representing the carboniferous slate of Ireland. These lower coal-measures included also the fresh water limestone of Burdiehouse, and numerous beds of trappean ash, the sandstones were often ripple-marked, and apparently sub-aerial in

their origin. The beds of coal were not workable, and were associated with peculiar fire-clay and shale, *Araucario* were more prevalent than tree-ferns, and *Megalichthys* and *Palæoniscus* the characteristic fishes. No shells occurred in the fire-clay, but only in the shales with the fish remains, indicating periodical inundations of the sea. 2. The carboniferous limestone was sometimes a very thin band, or several bands, at most amounting to 60 or 70 feet, the associated shales were fully developed, and the whole contained encrinites, reptoræ, minute trilobites, and other marine fossils, affording even when but a few feet thick an unerring guide to the miner. 3. The millstone grit was very thin, but in some places exactly like the grit of England. 4. True coal-measures, containing a greater variety of coal than in any other field—caking, free-burning, splint, and cannel coal of every variety, besides the "black band," which, if not "coal," passed insensibly into cannel, and was so coaly as to have been interdicted from being worked; "mussel-banls" were of frequent occurrence; and there were indications of rapid formation and drift in the fish-scales and sea-shells. The Permian system was not represented in Scotland, unless the "flat coal" of the Fifeshire coast could be regarded in that light.

Dr. Griffiths remarked, that the term "yellow sandstone" had been already, and long ago, employed by himself for a lower division of the carboniferous system in Ireland; it was several thousand feet in thickness, and included shales, thin, unworkable coal, and limestone, with marine fossils, all characteristic of the carboniferous system.

*On the Foliation of some Metamorphic Rocks in Scotland: by PROFESSOR E. FORBES.*

It was of great importance to geologists to distinguish between lamination, cleavage, and foliation: the first resulted from original planes of deposition; the second was a superinduced structure, dividing rocks into laminae of bedding, thirdly, foliation was the division of a rock into laminae of different mineral condition. Cleavage had been attributed, by Prof. Sedgwick, its first definer, to electrical action; by Mr. Sorby, to a mechanical force, and by Mr. D. Sharpe, to mechanical and chemical influence. The foliation of mica slate, or separation of its mineral constituents into distinct layers, had been attributed to metamorphic action on layers of different constitution; Mr. Darwin had considered it identical with cleavage, and due to the same cause, —the one passing into the other. the same view has been maintained by Mr. Sharpe. Professor Forbes agreed with those who considered it a superinduced structure quite distinct from cleavage or lamination. The author then referred to examples of foliated structure. In a roadside quarry at Crianlarich, near the head of Loch Lomond, where the metamorphic limestone is not distorted, and exhibits distinct lines of bedding, of a pale blue colour, caused by the presence of iron; also lines of different mineral matter, the laminae frequently curved round nuclei, and dark lines of crystals of calcareous spar produced, perhaps, by the metamorphism of bands and fossils. In the upper part of the quarry the limestone becomes foliated with mica,—the foliation being at first parallel with the bedding, then becomes wavy and contorted, is affected by small faults, and contains nuclei of calcareous spar, and at length passes into a mica slate. At Ben Os there is a calciferous band in the mica slate, which, having the same strike with the Crianlarich beds, may eventually prove a guide in unravelling the structure of the country. Two miles from Inverarnon there is a bed of porphyritic trap in mica slate, and the foliation on the sides of the trap is conformable. Four miles from Inverarnon, in a quarry of trap, which sends large and small veins into the mica slate, there is evidence of a second foliation having taken place, following the same veins of trap. Near Tarbert the mica slate is foliated and contorted; and a bed of calcareous grit cuts through it, without disturbing the relations of the curves and laminae. In a slate quarry at Luss, the foliation accords in the main with the cleavage, as observed by Mr. Sharpe, in the corresponding district; but whilst the foliation curves round the nuclei of quartz, the cleavage abuts against them. Foliation has also been noticed in the baked rocks of Salisbury Crags. Prof. Forbes concludes, 1, that foliation was a superinduced structure; 2, that it was distinct from cleavage; 3, that it was not of mechanical origin, but a chemical phenomenon, 4, that it was, perhaps, induced by more than one agency.

Sir C. Lyell remarked, that the Plutonic action, which had changed loose sand into quartz rock, shells into marble, and clay into feldspathic rocks, had often left the planes of stratification still visible. The unaltered sedimentary beds were frequently affected by irregularities as great as those of the altered rocks, and by crumpings which it seemed impossible to explain. If these were rendered metamorphic, there would be danger of attributing to chemical action peculiarities which existed whilst the beds were yet unaltered.