organs destined for the same functions would necessarily be very great; and being quite in the dark as to what use the Chimæroid duplicate arrangement may serve (beyond that it is probably of a sexual character), we cannot say that the cephalic spines of *Hybodus* were not suited for a similar purpose.*

We thus see reason to believe that the Hybodonts were a family well distinguished from all now existing. They more or less resembled the Cestracionts in the structure of their teeth; but they agreed rather with ordinary Sharks in the form of the head and the position of the mouth; whilst the dorsal spines, not to mention the cephalic spines, point to a remote affinity with *Chimæra*. Nor is this conclusion other than we may well be prepared to receive; since in a single form of a distant geological period, we constantly find characters associated together, the analogies of which are now only to be found scattered in widely separated groups. It is therefore no more anomalous to seek for the nearest representative of the spine of *Acrodus* in *Chimæra*, and of its teeth in *Cestracion*, than it is to collect illustrations of the structures combined in a Plesiosaur amongst widely removed orders of existing reptiles.

EXPLANATION OF THE PLATES.

PLATE III.

Lower (?) Jaw of *Acrodus Anningiæ*, Agassiz, from the Lower Lias of Lyme Regis. In Mr. Day's cabinet.

PLATE IV.

Figs. 1–5. Teeth of *A. Anningiæ*, from the Lower Lias of Lyme Regis.
6. Anterior } spine of the same Fish.
7. Posterior }
8. Posterior spine of recent *Cestracion* from Japan.
9. Spine of *Chimæra monstrosa*, Linn.,† living on the west coast of Norway.

The specimens figured in this plate are all in the Geological and Zoological Collections of the British Museum.

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## IV. On the Copper-bearing Rocks of Alderley Edge, Cheshire.

By Edward Hull, B.A., F.G.S., of the Geological Survey of Great Britain.

THE age of the sandstones and conglomerates, containing copper and other ores, at Alderley Edge, has until lately been a matter of some uncertainty; and, as far as I am aware,

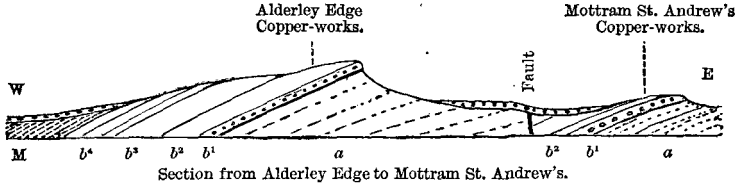
* The very rough shagreen with which *Hybodus* was covered is not so well exemplified by that of *Cestracion* as by that of *Centrina* (another genus of spined Sharks), in which the coarse, tooth-like asperities very much resemble those of the fossil.

† Dissected and drawn (from a specimen preserved in spirits) by Mr. Henry Woodward.

no detailed account of the formation has yet been published. Some few years since I made an examination, in company with Mr. E. W. Binney, F.R.S., of the beds in question, and on the first opportunity afterwards I hazarded an opinion, at a meeting of the Geological Society of Manchester, that the copper-bearing beds were referable to the age of the Lower Keuper Sandstone of the Trias. My brother-geologists, I had reason to think, received this opinion with some amount of distrust, as the rock, being in some places a quartzose conglomerate, and in others a soft whitish or yellowish sandstone, had much more the appearance of Bunter Sandstone than of the uppermost member of the Trias. My conjecture was not made, however, at hap-hazard, but was founded on evidence of position and petrographical characters, as the conglomerates, with their underlying bands of red shale, reminded me of the basement-beds of the Keuper division in the somewhat distant region of Alton Towers, and the Churnet Valley in Staffordshire.

A subsequent and more detailed examination of the Alderley Edge sandstones has entirely confirmed the view arrived at on my former visit; and, as the locality forms one of those rare examples of metalliferous beds in the New Red Sandstone, an account of it may not be without interest.

The 'Edge' or escarpment of Alderley rises from the eastern side of the plain of Cheshire gradually towards the east, but with a steep and abrupt ridge towards the north. This northern bank is richly wooded, and has a very beautiful aspect when viewed from a distance, as it contrasts strongly with the almost level plain which sweeps away to the northward and westward from its base. The ridge has here been upheaved along the line of a large fault, bearing east and west, throwing down at its base the Red Marl; and on the other side bringing up the soft sandstone of the Bunter, capped by a mural cliff of Lower Keuper Conglomerate, which often breaks out in conspicuous masses through the foliage. The beds rise from the plain towards the east at an angle of about from 5° to 10°, and the



Section from Alderley Edge to Mottram St. Andrew's.

escarpment is continued southward for some distance, facing the east. The general form of the Edge, and its component beds, will be understood from the woodcut.

*Succession of Beds in Descending Order.*

| | | | |
|---|---|---|---|
| M | Red Marl . . . . . | | Red and grey laminated marls. |
| $b^4$ | *Waterstones* . . . . | Lower Keuper Sandstone. 500 feet. | Brownish flaggy sandstones and marls. |
| $b^3$ | Freestone . . . . | | White and brown freestone. |
| $b^2$ | Copper-bearing sandstone . | | Soft white, yellow, and variegated sandstone. |
| $b^1$ | Conglomerate . . . . | | Hard quartzose conglomerate, underlain by bands of marl, forming the base of the Keuper series. |
| *a* | Upper red and mottled sandstone . . . . . | Bunter. | Soft fine-grained yellow and red sandstone, being the uppermost member of the Bunter Sandstone. |

The beds in the above series which claim the greatest share of our attention are those at the base of the Keuper series ($b^1, b^2$); for in these occur the copper and other minerals. The basement-bed is, however, remarkable for its petrographical peculiarities. It consists generally of a white firmly cemented conglomerate, the pebbles of which are mostly rounded fragments of whitish and coloured quartz-rock, in all respects similar to those which occur so largely in the middle division (Pebble-beds) of the Bunter. They are certainly not derived from the Millstone-grit, as they are much larger than the pebbles which occur in that formation, whereas a second reconstruction would have tended to diminish their size. For a length of time I have been of opinion that this conglomerate base of the Keuper has derived its pebbles of quartz from the Bunter Sandstone, on account of the unconformity of the members of the Trias as proved by actual sections in other districts.* But however this may be, it affords a striking contrast to the fine-grained *pebbleless* sandstone of the Bunter, which supports it and forms the flanks of the hill.

Copper, in the state of green and blue carbonates, is disseminated in this conglomerate, to a small extent at Alderley Edge, but in a much greater degree at Mottram St. Andrew's, about a mile to the north-east of the Edge, down in the plain. Its position there, so far below, and beyond the base of its contemporaneous beds at the Edge, is due to the great east and west fault already alluded to, which throws down the beds to the north. The conglomerate is here exposed in a quarry, resting on the soft red sand of the Bunter. It is about 6 feet thick, lies between two bands of marl, and drops at an angle of 6° towards the west. It was in this place that the copper-ore

* See Professor Ramsay's Presidential Address, Geological Society, 1863.

was first discovered about six years ago. In the direction of the dip the rock is systematically mined by means of a series of shafts, of no great depth, worked by windlasses. The ores coat the outside of the particles of sand and the pebbles of quartz, and the metal is extracted by a chemical process in the same way as at Alderley, presently to be described. The miners are all Cornish men, and were, of course, greatly astonished when they found copper-ore lying in nearly horizontal beds of sandstone, instead of the nearly vertical lodes to which they had been all their lives accustomed. Together with the copper-ores, there occur here cobalt-ore, black oxide of manganese, and carbonate of lead. The percentage of copper-ore varies from $2\frac{1}{2}$ to $12\frac{1}{2}$.

The beds which are worked for ore at Alderley Edge lie above the Conglomerate, and are marked $b^2$ in the above list of strata. The rock is exposed in a large open work, which is traversed at the spot where the reservoir is made by a wide channel filled in with Boulder-clay. The open work has now been abandoned, and the richer portions of the rock are followed in underground tunnels, the trucks of stuff being drawn up to the works on tramways by a stationary engine.

The sandstone is of a very soft uniform texture, and presents a face of about 40 feet, though fully 60 feet is metalliferous. It is stained in a series of rudely defined layers, variously coloured green, umber, or black, according to the nature of the ore-dye, and, together with copper, there occur ores of cobalt and manganese, carbonate of lead, galena, barytes, and oxide of iron. The following is the general arrangement of the courses of rock:—

| | ft. | in. |
|---|---|---|
| 1. Yellowish sandstone | 4 | 0 |
| 2. Shaley clay, with a band of copper-ore at the bottom | 2 | 6 |
| 3. Ferruginous sandstone, with large nodules containing carbonate of lead | 6 | 0 |
| 4. *Cobalt-bed.* Laminated sandstone, containing oxide of cobalt* | 4 | 6 |
| 5. White compact sandstone, with carbonate of lead | 5 | 0 |
| 6. Iron-stained sandstone, with cobalt, manganese, and iron | 12 | 0 |

Of the above minerals four are extracted—namely, the lead, cobalt, copper, and iron. The carbonate of lead is in the form of crystals, disseminated thoughout the rock, and not very easily to be distinguished by the eye. It is separated from the matrix by maceration and washing, and is then ready for smelting. In quantity it varies from 30 to 40 per cent. of the rock. The cobalt and manganese are generally associated in the rock, and are scarcely distinguishable from one another.

* Earthy cobalt, or 'Asbolan,' for an analysis of which see Bristow's 'Glossary of Mineralogy,' p. 120.

These are also separated, I believe, by washing; and the water used in the process, containing a large quantity of yellow or red ochre, is collected in a reservoir, where the ochre subsides, and, when accumulated in sufficient quantity, it is smelted for iron in small furnaces on the spot. Hence it will be seen that nothing is allowed to run to waste; and on this, in some measure, depends the economic success of the undertaking.

The process by which the copper is separated from the sand, and thrown down in a metallic state, is very beautiful, and probably the only one by which the result could be accomplished successfully in a commercial point of view, as its average percentage of ore is not more than 2·5. The rock is macerated in a solution of muriatic acid, filtered, and 'the copper-liquor,' of a rich sap-green colour, is pumped into reservoirs of wood. Into these old scrap-iron is thrown, and the acid, leaving the copper, seizes the iron, which it dissolves, while the copper is precipitated in a metallic state. On the completion of the process, the residuum, consisting of 80 parts of copper and 20 of iron, is collected and sent in sacks to St. Helen's and Swansea to be smelted.

Alderley is not the only district where the New Red Sandstone produces copper; but it is the only place, I believe, where it has been worked in that rock with profit. The ore has been extracted along the east side of the Peckforton Hills, at Grinshill, and near Ashbourn; but in none of these places is there such a variety or richness of mineral products as at Alderley.

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## V. On some Evidence of there being a Reversal of the Beds near Whitecliff Bay, Isle of Wight.

By William Whitaker, B.A., F.G.S., of the Geological Survey of Great Britain.

IN the well-known section at Whitecliff Bay the Chalk and the various Tertiary beds are seen to succeed one another in regular order northwards; and the dip, at first very high, so that the beds are almost vertical, decreases in that direction.

The Reading Beds, which here come next to the Chalk and consist wholly of brightly-coloured plastic clays of far more than the usual thickness, are followed by the brown London Clay, with its more sandy basement-bed. This last formation is also sandy towards the top, and indeed passes upwards into the grey loamy base of the Lower Bagshot Sand. Further up in the Lower Bagshot there is some brown finely bedded clay, not so stiff as the London Clay however.

This short description of part of the cliff-section is enough