grey or nearly white, occasionally dark grey or purple, from organic matter or the material, probably Silurian slates, from which they were derived. Although they contain a few nodules of siliceous clay ironstone in some places—very sparingly—and not unlike those of the Coal Measures, the small quantity of iron the clays contain will be inferred when I mention that all qualities are largely used for the manufacture of tiles and coarse pottery; for which, of course, ferruginous clays would be utterly useless.¹ Yet of these clays Mr. Swanston pens the following remarkable passage, on the assumption that they are of the same age and origin as the Antrim iron-ores:—

“Should subsequent researches prove these to be the same, it may safely be inferred that one reason why the Lough Neagh beds still retain their clayey character is owing to the simple fact that the *later* outflows of Miocene basalt did not reach them, and convert them into iron-ores, etc., similar to those so largely developed to the east and north of Antrim” (!). The *simpler* fact that they are non-ferruginous clays is the easier mode of explanation. *Ex nihilo nihil fit.*

If the Lough Neagh clays were of intra-Miocene age, and formed in the same way and time as the Antrim ore deposits, they would be found resting only on basalt, or absent where basalt does not occur. They however overlap the previously denuded basalt, and their continuation is found in several places resting on Triassic rocks.

Mr. Swanston is doubtless unaware of these facts, which are, I need not observe, completely antagonistic to his doctrine as to the age of the clays. And but that I fear to trespass on the kindness of the Editor of the GEOLOGICAL MAGAZINE, whose space is valuable, it would be easy to give numberless other facts as overwhelming proofs of the post-Miocene age of the Lough Neagh clays, and of the lake itself.

Returning to the Crumlin shells. I must now, at the cost of repetition, point out that even if they are hereafter proved to be Glacial fossils, such a matter can hardly be evidence in favour of the intra-Miocene age of the lake: yet this is apparently the conclusion to which Mr. Swanston's arguments would lead us.

With regard to the *silicified wood*, I can only say that it has never been found in any of the numerous clay-pits to the south of the lake. And in the only case where Barton records its existence *in situ*, it may have belonged to the drift. Excavations and borings in the same locality in the true lacustrine clays revealed none of it; and the origin of this wood is a matter still enveloped in great obscurity.

VIII.—ON PLAGIOCLINAL MOUNTAINS.

By CHARLES CALLAWAY, M.A., D.Sc. (Lond.), F.G.S.

THE object of this paper is to show that the received explanations of the structure of mountain chains will not account for the formation of certain Precambrian ranges, and to state facts in support of a new theory of the origin of some mountains. A brief summary of the ordinary views of the subject will first be necessary.

¹ The analysis of these clays, given by Sir Robert Kane, shows them to be remarkably free from iron.

Most mountain chains are produced by the puckering of the earth's crust into parallel flexures, and the greater systems consist of a combination of these earth-waves. Each wave usually rises higher, and the crests approximate more closely, towards the axis of the chain. The Alleghanies of North America well illustrate this structure. Towards the east, the anticlinals are squeezed up to such a height by lateral thrust that they sometimes fall over on one side, like an ocean wave rolling in upon a shallow shore. But, towards the Mississippi Valley, the waves gradually flatten out into low broad undulations. Of course, denudation has acted powerfully upon the flexures, by marine action during their emergence from the ocean, and by sub-aerial forces since their elevation. No trace of the original curved outline of the earth-waves appears in the shape of the ground. The tops of the anticlinals were planed off by the waves of the sea, and rivers have since scored and fretted the surface into a seemingly lawless irregularity.

But amidst this apparent disorder, one law is clearly seen. This law is that *primary mountain ridges run parallel with the geological strike*. A range sometimes consists of a denuded anticlinal; sometimes of a synclinal converted into a prominence by the erosion of the anticlinals on each side; sometimes of combinations of both, or parts of either. But in all these cases, the strike of the mountain chain corresponds with the strike of the beds of which it is composed. Amongst examples of this law which will at once occur to geologists, are the Pennine chain, the Cotteswolds, the North and South Downs, the Swiss Alps, and the Andes. The normal structure of mountains may be called *orthoclinal*.

The reason of this correspondence between geographical and geological strike is not far to seek. Take the case of an anticlinal mountain. Here the ridge is simply the upper half of a mutilated earth-wave. During the emergence of the land, the anticlinals were first exposed to the action of the sea. Notwithstanding the erosion of the ocean-waves, the anticlinal axes succeeded in raising themselves, though in a very mutilated state, into dry land. Subsequent sub-aerial action would score and carve the slopes of the saddle into ravines and valleys, but it would not interfere with its strike. Synclinal ridges are formed in a similar manner; but with one difference. During emergence, the waves plane off the top of the anticlinal, and expose softer strata which lie beneath. The anticlinals thus become lines of weakness, along which denudation works with great rapidity till it reaches a lower level than the synclinals, which stand up as ridges. The alternative between anticlinal and synclinal ridge is, then, mainly determined by the relative hardness of the strata. In both cases, the strike of the chain will be parallel to the original earth-waves, that is, to the geological strike.

In reconstructing portions of the geology of Shropshire, the writer has observed some remarkable exceptions to the above rule. The southern half of the county is grooved by a series of parallel valleys trending to the S.W. The intervening elevations, of course, strike in

the same direction. These, taken in order from E. to W., are the Clee Hills, Wenlock Edge, the minor ridges of Chatwall and Hoar Edge, the Wrekin and Caer Caradoc chain, the Longmynd, and the Stiper Stones. Most of these elevations form parts of a great broken S.W. anticlinal, of which the Caer Caradoc and Wrekin chain is the axis. The escarpments to the E. of the axis face, of course, to the N.W.; the escarpments to the W. of the axis break down to the S.E. All the ridges follow the ordinary rule, except the Wrekin and Caer Caradoc chain, to which attention is specially directed.

This chain is nearly 30 miles in length, and is broken by three broad gaps of from 4 to 8 miles in breadth. The chief elevations, taken from the N.E., are Lilleshall Hill, the Wrekin range, Caer Caradoc range, and Wartle Knoll. The last, being of inconspicuous elevation and of doubtful structure, may be neglected. The other three agree in displaying the same peculiarity of structure. The beds of which they are composed *strike across the axis*.

Lilleshall Hill is one mile in length by one-sixth of a mile in breadth at the base. Its trend is S.S.W. The beds of volcanic ash of which it is composed strike W.S.W. The difference between the geographical and the geological strike is about 45° .

The *Wrekin* chain, consisting of four elevations, the Ercal, Lawrence Hill, the Wrekin, and Primrose Hill, is three miles in length by half a mile in its greatest breadth. It consists of alternations of lavas and tuffs dipping to the N., the ridge trending to the S.W. In this case also the divergence of the two strikes is about 45° . An inconspicuous elevation, lying two miles W. of the Wrekin, named *Charlton Hill*, ranges due N. and S. In this ridge is a band of conglomerate striking E. and W., the divergence of strike amounting to a right angle.

The *Caer Caradoc* chain is about six miles long by about half a mile in its greatest breadth. Its chief summits are the Lawley, Caer Caradoc, and the Ragleth. Its strike is to the S.W. The average strike of the grits, tuffs, and felstones which make up the chief part of the range is E. and W.; intrusions of greenstone sometimes twisting round the strike 20° to 30° , and, on the S.E. side of the Ragleth, causing it to coincide with the trend of the ridge. These disturbances are only local, the usual E. and W. strike being resumed at a distance from the disruptive masses. A great spur which springs from the S.E. side of the range, and juts out for two miles to the E., is composed of beds of grit, breccia, and felstone, which strike in the same direction as the spur.

It is clear that, with local exceptions, the bedded rocks of the Wrekin and Caer Caradoc chain strike across the axis at angles varying between 45° and 90° .

It would be evident, *a priori*, that such a mountain range could not be formed on the normal plan. The geographical strike bears no causal relation to the original earth-waves. It has been determined not by axes of upheaval, but by *parallel faulting*.

A great S.W. line of dislocation commences near Lilleshall Hill

on the N.E.; passes through the Wrekin and Caer Caradoc chain; is continued to Stanner Rock and Hanter Hill, W. of Kingston; passes under an anticlinal N.W. of Brecon; appears to sweep round to the W., and to be connected with the Precambrian ridge of St. Davids. In Shropshire it is a complex system of faults. There appear to be in all about six primary dislocations parallel to each other and to the mountain ridges. For our present purpose, we shall not require more than a pair of these.

Commencing with Lilleshall Hill, we find that it is bounded by faults on both sides. On the S.E., the Hollybush Sandstone (Caradoc in the Survey) has been thrown down; on the N.W., the lower beds of the Trias. The structure of the ground is the same in the Wrekin range, save that faulted bands of quartzite are interposed between the axial rocks and the Hollybush Sandstone and the Trias on either side. The Caer Caradoc chain is in like manner bounded by two nearly parallel faults. On the N.W., the lower slates of the Longmynd series rest against the axis; on the S.E., the Shineton Shales, the Hollybush Sandstone, and the Caradoc Sandstone are successively thrown down.

It is evident that in each case *a wedge of the solid crust* has been separated from the main mass by two nearly parallel faults, and thrust up through overlying Cambrian and Silurian strata. Or it is probable, in the case of the Wrekin at least, that the wedge was first pushed up in Pre-Cambrian times.

As the rocks of this chain consist, not of eruptive greenstones (according to the late Sir R. Murchison and the Geological Survey), but of bedded lavas, tuffs, grits, conglomerates, and other stratified material; and as they are flanked on each side by strata, some of which are at least as old as the Lower Cambrian; it is clear that these mountain ridges are of *Precambrian age*.

The writer has been greatly interested to find that certain other Precambrian elevations, described in recent times by Prof. Phillips, Dr. Holl, and Dr. Hicks, display a similar abnormal structure.

The *Malvern Hills* trend N. and S., but the schists and granitoid rocks of the chain strike across the axis in a S.E. direction. A great dislocation throws down Triassic sandstones against the eastern flank, and the author is convinced from a personal examination that the ridge is also bounded by a fault on the W. side. These rocks are still more ancient than those of the Wrekin chain. The range has evidently been formed in the same way. A solid slice seven miles long, composed of strata striking to the S.E., has been isolated by two parallel N. and S. faults, and pushed up as the original ridge out of which the Malvern Hills have been sculptured by frost and rain.

A third Precambrian ridge exhibiting a similar structure occurs at St. Davids, and has been described by Dr. Hicks. It extends for about two miles from the city to the S.W., and has an average width of rather less than a mile. It consists of quartziferous and granitoid rocks distinctly bedded, and striking across the axis to the S.E., that is, at about a right angle with the strike of the ridge.

This series has been named the Dimetian. It is flanked on both sides by a younger Precambrian formation, the Pebidian. In Dr. Hicks' sections in the *Quart. Journ. of the Geol. Soc.* 1877 and 1878, the junction between the two groups is not represented by a fault; but it is difficult to explain the vertical and sometimes inverted position of the lower beds of the Pebidian without the aid of such an hypothesis, and a recent inspection by the writer confirms this view. But this is only a minor point. In any case, the Dimetian ridge is on the type of the Shropshire and Malvern chains.

The same peculiarity has been noticed in North Wales. Professor T. McKenny Hughes, in describing certain Precambrian rocks near Bangor, observes that "the bedding is generally in an easterly direction, sometimes a little S., sometimes a little N. of E., but always oblique to or across the trend of the hills." No information is given on the influence of faults in determining the structure of these ridges.

In summing up these facts, it has been shown that, in the three cases examined by the writer, the trend of the elevations has been determined by parallel faulting; in the other example, the influence of faults has not been ascertained; in all four, the strike of the beds is transverse to the strike of the ridge.

On the hypothesis of parallel faulting, it is not difficult to suggest a reason why these transverse strikes should be found only in Precambrian mountains. In every observed case in Britain, there is a great interval between the newest Precambrian and the oldest Cambrian. The marked discordance of strike is one proof of this. An equally emphatic evidence is seen in lithological characters. The Precambrian rocks are everywhere intensely altered, and the alteration in many instances took place before the Cambrian epoch. But the overlying Cambrian strata are frequently as unaltered as ordinary Tertiary beds. It is highly probable that the fragments of Precambrian land which jut up here and there through newer formations represent a succession of epochs perhaps as long as from the Cambrian to the present day. Palæontological facts point in the same direction. The gap between the simple Protozoan of the Laurentian and the highly organized Trilobites of the Lower Cambrian is perhaps as wide as the hiatus which stretches between the Trilobite and the Mammal.

It follows from this that Precambrian formations have been sliced up by faults much more frequently than younger deposits. It is not necessary to assume, though the assumption would not be rash, that faults were more frequent in Precambrian times than they are at the present day; but it is evident that the Precambrian crust was traversed by Precambrian faults in addition to those from which it has suffered in common with newer deposits.

In Precambrian times, the surface of the earth was ridged by mountains as at present, and it is fair to assume that they were formed on the normal plan. But during an immense succession of epochs, they have been partially worn down, and the chief part of the Precambrian surface has been buried beneath great accumula-

tions; which, in their turn, have been puckered into earth-waves which bear no relation to the old strikes of the crust.

Faults, as might be expected, display a tendency to run parallel with earth-waves. When the crust is being forced into sharp curves, cracks will naturally occur at right angles to the lateral pressure. Hence the faults which traverse Cambrian and Postcambrian strata, being parallel to the newer flexures, will be *transverse to the underlying Precambrian strikes*.

It is now easy to see how a pair of parallel faults traversing at the surface rocks of (say) Silurian age, and cutting down through Cambrian and Precambrian strata, will account for the origin of Precambrian ridges with transverse strikes. The upheaval of the isolated wedge, and the denudation of the overlying Cambrian and Silurian beds, require no explanation. The continued prominence of the ancient ridge would be secured by the superior induration of its metamorphic or altered volcanic constituents.

To distinguish mountains of this type from anticlinal and synclinal ridges, the term *plagioclinal*¹ is suggested.

This peculiarity of structure may prove to be of practical aid in detecting Precambrian formations. A plagioclinal axis is not necessarily Precambrian, but its transverse strike should suggest inquiry.

The facts here announced militate against an extreme school of geologists, who deny that faults have had any perceptible share in shaping the landscape. They have certainly very largely contributed to determine the scenery of South Shropshire. That the original surface produced by great dislocations has been modified by subsequent denudation does not materially affect the question. It would be equally just to argue that, because the Romance words in the English language have been modified by time, the Norman Conquest has not affected our modern tongue.

NOTICES OF MEMOIRS.

I.—THE TUFO AND TRIPOLI OF THE SULPHUR ZONE OF SICILY.²

TWO years ago Sig. E. Stöhr, when placing the sulphur deposits in the Messinian II. of C. Mayer, and the "tuff" in the Messinian I., remarked that perhaps this last should be removed lower down, and in the December number of the Bollettino R. Com. Geol. d'Italia he says, that the discovery of fossiliferous beds in a sulphur mine, near Grotte, in the Province of Girgenti, has confirmed this opinion.

Immediately below the sulphur beds is a bituminous schist, then the tuff and tripoli, and in this "tuff," which is described as an almost plastic clay, are a great number of Foraminifera, the subject of Sig. Stöhr's paper. Of the 115 species found, 23 are new, and are mostly described and figured by Dr. Schwager in an appendix.

¹ From *πλάγιος*, *oblique*, and *κλίω*, *to incline*.

² Sulla posizione geologica del tuffo e del tripoli nella zona solfifera, per E. Stöhr. Boll. R. Comit. Geol. d'Italia, vol. ix. No. 11-12, 1878.