Geneva beach, 700 feet; and the Warren shoreline, about 880 feet. Another and still higher shoreline exists in at least the Seneca and Cayuga valleys, but is not indicated on the map, as its east and west limits are not yet determined. This is the shore of Lake Newberry, having its outlet south of the present Seneca, by the 900 feet col—the Horseheads Channel.

The Iroquois shoreline is represented as continuous, although from Sodus Bay eastward it is broken and indeterminate.

The waters producing the Geneva beach certainly occupied a large area, but as so little is at present known of that lake, the shoreline is represented only along the west side of Seneca valley, where it has been continuously traced.

The Warren shoreline has been continuously traced eastward to beyond the meridian of Rochester, and good spits and bars have been found in the Cayuga valley. The theoretical limits are indicated as far east as the first spillway of the lowering waters.

II.—Do the Crystalline Gneisses represent portions of the Original Earth's Crust?

Presidential Address read before the Liverpool Geol. Soc., October 12, 1897.

By Joseph Lomas, A.R.C.S., F.G.S., Pres. Liverpool Geol. Soc.

IN order that progress may be made in any branch of geology, it is necessary, not only that the faculties of observation and inductive reasoning should be employed, but a proper use should be made of the imagination. By this means new lines of research are laid out. The theory we set ourselves to prove may eventually prove to be wrong, but it often happens that the pursuit of a false theory brings one as near the truth as the following up of a true one. It is in this spirit I wish you to regard the problems and speculations to which I now invite your attention.

The oldest rocks with which we are acquainted are the crystalline gneisses and schists which form the lowest divisions of the Archæan. Geologists are far from being in accord as to their origin. Some regard them as altered sedimentary rocks, metamorphosed to such a degree, that they have been fused to form igneous rocks anew; and whilst they were in a fluid or semi-fluid condition, at a great depth below the earth's surface, they received the characters of foliation and schistosity which most of them show. Others regard them as igneous rocks which have been altered by flow and shear. Others, again, prefer to look upon them as remnants of the crust of the earth when it first consolidated from the liquid state.

They are the only rocks which can be regarded as forming a continuous shell round the earth. On them, as a foundation, all the later formations have been deposited.

Professor Lapparent[1] refers to the remarkable uniformity of these primitive rocks. In Brittany, the Pyrenees, Alsace, Bavaria, the Alps, Saxony, Scandinavia, Great Britain, Spain, Algeria, North America, Brazil, and China, and wherever they are found, the same succession can be made out—gneissose or granitoid at the base and schistose above. Chemically they are very much alike, except that alkalies predominate in the gneissose rocks, and calcareous material in the schistose. He regards them as having been produced on the

[1] "Traité de Géologie," p. 675.

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solidification by cooling of the earth; and as having been formed in a sea of high temperature, charged with chemically active substances and subject to the frequent intervention of adjacent liquid magmas.

The continuity of these ancient rocks and their persistent characters certainly point to a cause of origin which was world-wide in its effects rather than local. The main difficulty is to find a worldwide cause which could produce the foliation so characteristic of these rocks in all parts of the globe.

Modern researches show that gneissose and schistose structures can be induced either by fluxion or shearing, or by both combined.

The ancient gneisses are usually found as low hummocky hills; when sufficiently denuded a core of granitoid rock is seen, and the foliations of the flanking parts are parallel to the axes of the ridges. Sir A. Geikie [1] remarks on the similarity of scenery which these rocks show in places where they crop out. A person situated in the central part of Anglesey might very well, so far as the landscape is concerned, imagine himself in the wilds of Sutherlandshire.

Professor G. H. Darwin [2] has demonstrated that in early times the moon was thrown off from the earth, and while it was still in proximity to the parent planet great tidal waves would result from its journey round the earth. The plane of the moon's orbit being but little removed from the earth's equator, the retardation of the diurnal motion of the earth, due to tidal friction, would be greater at the equator than at the poles. "Now, this sort of motion, acting on a mass which is not perfectly homogeneous, would raise wrinkles on the surface. . . . . In the case of the earth the wrinkles would run north and south at the equator, and would bear away to the eastward in northerly and southerly latitudes. . . . . The general configuration of the continents (the large wrinkles) on the earth's surface appears to me remarkable when viewed in connection with these results." [3] These conclusions of Professor Darwin were arrived at altogether independently of geological reasoning, and it may be worth while to consider whether we have any geological evidence to support his theory.

The result of the moon's action on the earth in early times, then, would be a screwing or twisting of the surface layers. This raised them into wrinkles or ridges north and south at the equator, and partaking more and more of an easterly direction as we approach the poles. It is probable that at this time the earth was in a highly heated condition, and thus flow and shear of the surface parts over the lower would combine to produce the wrinkles. Probably the wrinkles were formed very slowly, by the gradual accretion of small stresses acting over long periods, in a manner so well illustrated by our ex-President when speaking of the flow of rocks by alternate expansion and contraction.[4]

[1] "Ancient Volcanoes." [2] Phil. Trans. 1879, p. 589.

[3] Ibid. Also read in this connection, chap. ix, "Physics of the Earth's Crust," O. Fisher.

[4] "Origin of Mountain Ranges," by T. Mellard Reade; see also GEOL. MAG. 1894, pp. 203–14.

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Sir A. Geikie, in opposing the view that the fundamental gneisses and schists represent portions of the earliest crust that consolidated on the surface of the globe, says:[1] "The coarsely crystalline condition, even of those portions of the gneiss which seem most nearly to represent original structure, the absence of anything like scoriæ or fragmental bands of any kind, and the resemblances which may be traced between parts of the gneiss and intrusive bosses of igneous rock, compel us to seek the nearest analogies to the original gneiss in the deep-seated masses of eruptive material." I may remark that a coarsely crystalline condition is a measure of the rate of cooling of an igneous mass rather than of its depth below the surface.

Professor Bonney says:[2] "The crust itself must have solidified under conditions materially different from those of a lava stream at the present day; for not only is crystallization affected by pressure, but also radiation would then be comparatively slow, because the atmosphere would differ much less in temperature from the solidifying rock than the air now does from the surface of a lava stream. . . . . The weight of the atmosphere would be augmented by that of a shell of water of the area of the globe and two miles in thickness; or, in other words, the atmospheric pressure would be then about 350 times its present amount."

Another objection has been raised by Mr. T. M. Reade:[3] "The evidence that the Archæan rocks the world over have been buried under immense bodies of sediment, of which they may have formed the lower series before the deposition of the Palæozoics upon them, then, seems to be irresistible." In answer to Mr. Reade I may say that it would be most remarkable if every trace of these "immense bodies of sediment" had been removed before the earliest sedimentary rock now found was deposited. Undoubtedly there were sedimentary rocks earlier than the Cambrian, such as the Torridonian and Longmyndian, but wherever they are found they lie unconformably on the gneisses and contain fragments of the fundamental rocks, which show foliation. Foliation, then, could not be the result of overlying sediments, as the structure was developed before the oldest sedimentary rocks with which we are acquainted were laid down. I hope to point out later, that there is evidence to show that some of these gneisses have never been covered at any period of the earth's history.

According to Professor Darwin the primitive wrinkles would trend about N.E.–S.W. in our latitude. The ancient gneisses of Wales, Scotland, and Scandinavia, all have a strike about N.E.–S.W. Comparative geology is as yet in its infancy, and information regarding some of the places where Archæan rocks are exposed is not easily obtained. So far as I have been able to glean information on the point, I have not found an instance which is not in accord

[1] "Ancient Volcanoes," p. 116.
[2] "Story of our Planet," p. 341.
[3] "Origin of Mountain Ranges," p. 150.

with the above theory.[1] Some of the ridges would probably be of continental importance, but with smaller corrugations riding on them.

We will suppose now that the earth's crust has become solid, and the wrinkles remain as long parallel ridges and hollows. It is inconceivable that they should ever unfold again. They might rise or fall as parts of greater movements, or their symmetry and continuity might be destroyed by other foldings not parallel with themselves, but otherwise they could only become degraded by the forces of denudation. We must look upon these primitive ridges, aided to a certain extent by volcanic material which has welled up through the crust in later times, as the source of all the sedimentary rocks. The crests have become denuded, and the products of disintegration have been transported by various agents and laid down on the floors of the troughs. The material of the oldest sedimentaries must have been derived from the highest parts of the ridges, and that forming the newer sedimentaries must have been furnished by the deeper parts of the ridges. This rule, of course, only applies so long as deposition continues (in Wales practically to the end of the Silurian). If the sea-bottom becomes raised to form land, then the sedimentary rocks themselves become denuded, and the tracing of a particle to its ultimate source becomes a complex problem.

If the picture drawn above of the relief of the land in early times be true, the oldest sedimentary rocks should attest the fact by their characters and distribution. Professor G. M. Dawson, speaking of the Archæan sedimentary rocks of Canada, says:[2] "We find long bands of strata, referable to the Huronian and Grenville Series, occupying *synclinal troughs*, more or less parallel to each other and to the foliation of the Fundamental Gneiss, the strata, as well as the foliation, being in most cases at high angles, vertical, or even reversed." Many other instances might be quoted from America, where the sedimentary rocks of Pre-Cambrian age are described as being laid down in long parallel troughs with sides composed of Fundamental Gneiss. In Europe "the oldest beds of Bohemia form a *basin* some 90 m. long and 10–12 m. broad, the principal axis running in a south-west direction from Prague through Beraun to Pilsen. In consequence of this very regular structure, the oldest beds occur at the boundary and the newest in the middle of the basin, whilst the floor of the trough is made up of Archæan rocks, and, above them, of unfossiliferous, phyllitic schists, called the Przibram schists by Lipold, which include locally conglomerate, sandstone, and oolitic limestone."[3]

In Britain the same story is told. The Archæan rocks of Anglesey and the Lleyn Peninsula, and those of the Midlands, form ridges about N.E.–S.W., which bound a trough in which are contained the Cambrian and Silurian deposits. Further west the folds are repeated in the N.W. Highlands, and eastwards, under the capping of newer rocks, into Normandy, Scandinavia, etc.

[1] Mr. R. Gascoyne, who has just returned from Chili, informs me that the strike of the Archæans in that country is about N. and S.

[2] President's Address, Section C (Geology), British Association, 1897.

[3] Kayser-Lake, "Text Book of Comparative Geology," p. 39.

The characters of the oldest sedimentary rocks lend aid to the theory that they were laid down in long, parallel trough-like depressions. Dr. Hicks, speaking of the Lower Cambrian, says:[1] "The deposits must have accumulated with comparative rapidity in fairly shallow water." Shallow-water deposits imply proximity to land. We cannot obtain shallow-water rocks, extending as they do in separate troughs from Britain to Russia, on the assumption that they were laid down in a continuous sea extending across Europe. Dr. Hicks many years ago propounded this theory to account for the distribution of the Cambrian rocks.[2]

It is probable that the primitive ridges were not very lofty. They would, no doubt, form the counterparts of the troughs. Professor Lapworth has shown[3] how persistently a lofty fold is counterbalanced by a deep parallel depression, and a low ridge by a shallow trough. Dr. Hicks suggests[4] that high mountains existed in Pre-Cambrian times, and that some of them were probably snow-covered. So far as I can gather, the only reason why he postulates these high mountains is to explain the occurrence in the Cambrian conglomerates of boulders over a foot in diameter. In mountain-building, as in everything else about us, there has been a gradual evolution going on. The Tertiary is the epoch of mountain-building, and there has probably been a progression in the heights of mountains from ancient to modern times.

The tracing out of old shorelines, and the mapping of former distribution of land and water, form a branch of geology which has of late come into prominence.

Pioneer work has been done by Godwin-Austen, Professor Hull,[5] Jukes-Browne,[6] and others, but much will need to be done before we can draw maps which will show the distribution of land and water in Palæozoic times with accuracy. The maps published by Professor Hull and Jukes-Browne must not be taken as being absolutely correct, especially in the Palæozoic period. We may, however, regard them as approximations to the truth. I had occasion recently to copy out on tracing-paper the Palæozoic shorelines as given by Jukes-Browne. On accurately registering these and holding them up to the light, I was struck with the fact that in some districts there was a great closing up of shorelines. This was especially noticeable about Anglesey, where within a few miles of each other the Cambrian, Ordovician, Silurian, Carboniferous, and Permian shorelines are found. It would seem as though in Anglesey we were dealing with a very stable part of the earth's crust, a part which had kept its position relatively to the sea nearly the same through long ages. As there is every reason to

1 President's Address, Geological Society, 1897.
2 Q.J.G.S. 1875, p. 552.
3 President's Address, Section C, British Association, 1892.
4 GEOLOGICAL MAGAZINE, 1876, p. 157.
5 "Contributions to the Physical History of the British Isles."
6 "The Building of the British Isles."

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believe that Anglesey kept its head above water during the Mesozoic and Cainozoic Periods, it follows that portions of the Archæan rocks on the north-west of the island have never been submerged at all.

A second aggregation of shorelines is seen in the Midlands, closely following the Archæan ridge. This is not so striking an example as that in Anglesey, but it is sufficient to suggest that the solid cores of the primitive wrinkles have resisted great lateral crushings, while the sedimentary rocks deposited in the troughs have been crushed, folded, and cleaved to a great degree. We might almost compare the ridges to nodes in the great wave-like motions which have swayed the surface rocks up and down like long ocean swells.

In order to bring the arguments given above into better view, I may summarize the chief points touched upon.

1. The worldwide distribution of the fundamental gneisses and schists and their uniformity of characters suggest a cause which affected the world as a whole.

2. Professor Darwin has shown, altogether apart from geological reasoning, that primitive wrinkles would be formed on the crust by the action of the moon when nearer the earth. So far as I have been able to gather, the ridges formed by the oldest rocks now existing correspond in direction with the wrinkles Professor Darwin describes.

3. The lithological characters of the primitive rocks are such as would result from the flowing and shearing of rocks (in which crystals had already formed but were in a highly heated condition), on being raised into wrinkles by differential movements.

4. The earliest sedimentary rocks were deposited in long troughs, parallel to each other for the same latitude.

5. The ridges themselves never unfolded. Some of them have remained at approximately the same level through all time, and others have partaken of greater movements in later times. The continuity of the ridges has been destroyed in some places by later foldings not parallel to themselves.

And now, in conclusion, may I refer to a matter which arises directly out of the subject-matter of the Address? In many text-books, and even in geological papers, the young student is told in effect that "every part of the earth has been raised and depressed times without number." As our knowledge increases I believe that this loose and offhand method of dealing with earth-movements will give place to more precise and definite statements. It will then be found that changes of level have not taken place promiscuously, but according to certain laws, of which we have at present only the foreshadowing. I do not refer so much in this matter to local movements, which can be traced to obvious local causes, but rather to those extending over great areas. A large movement must have a deep-seated cause, which will leave permanent witness to its operation.

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All branches of science must necessarily pass through three stages—(1) the observation of facts; (2) the enunciation of theories to explain the facts; (3) the discovery of laws governing all. In geology many facts have been gleaned, many theories have been launched, and of these precious argosies, only the seaworthy, those built in conformity with natural laws, will arrive in port.

III.—On *Ceratodus Kannemeyeri* (Seeley).

By H. G. Seeley, F.R.S., Professor of Geology in King's College, London.

Dr. DANIEL RUSSOUW KANNEMEYER sent me a photograph of a dental plate in April, 1897, to which was appended the remark—"I conclude it to be *Ceratodus*, and its bones are said to be lying at Kraai Fontein. I have sent the man who found it to search for and fix the locality." The search was not successful; and since then the rinderpest has prevented any attempt to reach the locality, which is geologically at the top of the Karoo beds above the Coal of the Indwe district of Cape Colony, in strata which yield Zanclodont reptiles in other localities. It may therefore be classed as of Triassic age, belonging to the Stormberg Series, and well above the Permian rocks which have yielded Theriodonts. This determination is of some interest as contributing to define, by means of a well-marked Trias genus, the age of the upper limit in South Africa of strata which have yielded Theriodont and Dicynodont reptiles. Such a division between Trias and Permian agrees with the grouping of the rocks to which I was led by a physical examination of the country in 1889.

Failing for the time to obtain the other reputed remains, Dr. Kannemeyer has recently sent me the tooth, which differs as a species from all known types. In 1889 Mr. A. S. Woodward (Ann. and Mag. Nat. Hist., Sept., p. 243) mentioned and figured a small example of a tooth of *Ceratodus*, found at Smithfield in the Orange Free State, which he named *Ceratodus Capensis*. It is distinguished from the new form, which I associate with the name of Dr. Kannemeyer, by the narrow rounded ridges which diverge over the dental plate, as well as by the relatively broader form of the plate, and by its thinness; and *C. Capensis* differs from the common forms of the Muschelkalk and Rhætic beds of Europe by such characters as separate it from the new African species (see Figure).

The left superior dental plate of *Ceratodus Kannemeyeri* is thick and flat, with a nearly vertical serrated external border made up of three strong wedge-shaped denticles, with a slight convexity in front and a marked convexity behind them. The plate has a thick base, which is prolonged backward in a way seen in some species from the Trias of Germany, but the base does not extend to the inner anterior border of the dental plate, which may possibly be a line of union with the corresponding plate on the opposite side of the palate.

The specimen measures 4·5 cm. from front to back. The extreme transverse width over the first denticle is 3·5 cm., while over the

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