NOTE ON ITACOLUMITE OR FLEXIBLE SANDSTONE.

By E. G. Hogg, M.A.

A.

The existence of flexible sandstone appears to have been known of since 1780, when specimens were brought to Europe from Brazil by the Marquis of Lavradio, Viceroy of Rio de Janeiro. The bed-rock in which the flexible sandstone occurs was found by Von Eschwege to be largely developed near Mt. Itacolumi in the State of Villa Rica, Province of Mina Garaes, Brazil, and is described by him as a fissile sandstone containing plates of talc, chlorite, and mica. This rock contains a little gold, and has been shown by Heusser and Claraz to be the parent source of the Brazilian diamond. The beds generally rest on the crystalline schists and frequently pass into conglomerates. According to Fr. Hartt (Geology and Physical Geography of Brazil, 1870) the bed-rock is probably an altered Lower Silurian formation, while Prof. O. A. Derby classes it as of Huronian age. In this bed-rock the flexible sandstone occurs in some abundance; it is distributed in such a manner as to point strongly to the conclusion that the sandstone is only flexible when it has been considerably metamorphosed. Professor Derby* states that on one side of a fissure the rock may be often found without any trace of flexibility, while on the other it is laminated and flexible. He concludes that flexibility is not an original characteristic of the rock, but is a "phase of weathering" or decay brought about by percolating waters.

Mr. R. D. Oldham, F.G.S., Director of the Indian Geological Survey, † has discussed at some length the occurrence of flexible sandstone at Kaliana, near Dadri in Jhind. [It is probable that the specimen exhibited by the Lord Bishop of Tasmania came from this locality.] Mr. Oldham states: "at Kaliána the flexible stone occurs on a hill composed of vertically bedded glassy quartzites: it is confined so far as my investigations and enquiries went, to one single spot where, for about 20 feet across the strike, and for about 30 yards along it, the rock has become flexible; near the margin of this area the flexible stone passes downwards into the ordinary quartzites, but in the centre the decomposition had extended downwards to the floor of the quarry, a depth of fully 15 feet; here, too, the rock was much softer, more decomposed and flexible than near the margin."

* Amer Journal of Science, Vol. XXIII. (1884), pp. 203, etc.

† Records of the Geological Survery of India, Vol. XXII, Part I, pp. 51, etc.

This view of the connection between the decomposition and flexibility of the sandstone is, to a certain extent, borne out by Mr. Tuomey in his Report on the Geology of S. Carolina. He observes that the itacolumite of that state "passes even in the same mass into compact quartz, to be distinguished from common quartz only by its stratified structure," and that "the passage from the arenaceous to the compact variety is gradual, and it is in this passage that it assumes the form of itacolumite" (flexible sandstone).

It must be noticed that the term itacolumite has two different significations; it is with some writers "flexible sandstone," with others the bed-rock in which "flexible sandstone" occurs.

It would appear that so far as the field relations are concerned—though more evidence on this point is much to be desired—itacolumite only becomes flexible when it has undergone a certain amount of decomposition, probably due either to weathering, or to the percolation of water or other solvent. Such weathering or solvent action may remove, either *in toto* or in part, certain of the original constituents of the rock. Of course, as a result of chemical combination, these constituents may be replaced, to a more or less extent, by other bodies.

It is worth noticing that so far as our knowledge on the subject goes, flexible sandstone only occurs in metamorphosed deposits, which are undoubtedly of very ancient origin.

B.

In this section of the note I must acknowledge how much I am indebted to the paper of Mr. Oldham, previously referred to. I now propose to give a digest, mainly drawn from Mr. Oldham's paper, of two theories brought forward to explain the peculiar properties possessed by flexible sandstone.

It seems best to refer to the generally accepted theory, *i.e.*, the theory found in recent times in many extensively purchased treatises and manuals on geology. This theory would ascribe the flexibility of itacolumitic sandstone to the talc, chlorite, and mica stated to occur in it. It is only fair to notice that the partisans of this older view were unacquainted with the modern methods of petrological analysis. This older view of the cause of flexibility can be traced to Von Eschwege, to whom is due the fanciful name of itacolumite. But apart from the difficulties depending on the physical properties—in the matter of elasticity—of mica, it appears quite clear from Mr. Oldham's paper that flexibility is exhibited by the itacolumite, even when mica is absent, or is quite subsidiary. If the cause of the flexibility lie in the presence in the slab of flakes of mica, chlorite or talc, whose planes are parallel to those of the laminations of the slab, it is difficult indeed to see how to account for the stretching of the slab when tension, and its compression when pressure, is applied. I have recently been able to examine a specimen of flexible sandstone in the possession of Mr. T. S. Hall, M.A., Acting-Professor of Biology in the University of Melbourne, and in this specimen both of the phenomena of extension and compression are present. After all, if the rock shows flexibility when mica, chlorite and talc are either entirely absent, or are quite subsidiary, it seems quite clear that the older theory must be abandoned.

The theory with which we have now to deal is, I believe, the one usually accepted amongst modern geologists. Though not without its own difficulties it is in many ways more convincing than the one due to Von Eschwege.

Mr. Oldham's view, as stated in his own words, is that: "the flexibility of the rock is due, not to the flexibility of any of its constituents, but to some peculiarity in the mode of aggregation of the individual grains of quartz and other material of which it is composed." A similar idea was put forward by Klaproth § as far back as 1785, and at a later date by the Rev. Dr. Haughton, F.R.S.

Mr. Oldham appears to have carefully examined the rock in thin microscopical slides. As a result of his labours, he states : "If a slice of flexible sandstone is examined under the microscope, by reflected light, it exhibits a structure most conspicuous in all the specimens of flexible, and equally conspicuous by its absence from all specimens of non-flexible, stone I have examined. The rock consists of irregular aggregates of grains of quartz separated from each other by fissures and crevices which extend deep into the stone and give one the impression of ramifying through its mass further than they can be actually traced. Should one of these aggregates of quartz grains be touched with a needle it will be found loose and easily moveable from side to side, but it cannot be displaced without fracture, either of itself or of the surrounding particles. In fact the rock consists of a number of irregular aggregates of quartz which hold together by projections on one fitting into hollows in another, while the clear space between them allows of a certain amount of play."

Mr. Oldham gives two plates supporting his view of the structure of the rock. Mr. Oldham then proceeds in development of his theory as follows :—"In the Kaliána rock there is, besides the quartz and accessory minerals, a certain proportion of felspathic paste, more conspicuous in sections cut transverse, than in those cut parallel to the bedding. This paste does not surround the individual grains of quartz, but occupies spaces between aggregates of grains, and it is

§ Schrift Berl. Ges. Natfur. Freunde VI., 322 (1785).

to the decomposition and removal of this paste that the flexibility of some specimens is due. In such a rock the development of a flexible structure depends on the proportion and mode of distribution of the felspathic mud."

I have, I think, stated the essentials of Mr. Oldham's theory, viz., the peculiar mode of aggregation of the quartz grains, and the removal of a certain proportion of the "felspathic mud" in which, to a more or less extent, the quartz grains are included. The partial removal of this enveloping mud creates free spaces which the quartz grains may occupy when stress is applied to the surface of the slab.

A theory, apparently identical with that of Mr. Oldham, was put forward in 1887 by Herr O. Mügge.||

Through the kindness of Mr. Morton, secretary of this Society, I recently secured a small piece of flexible sandstone, believed by Mr. Morton to have been brought from India. In external appearance it does not differ appreciably from the specimen exhibited by the Lord Bishop this evening. The microscopic slides prepared show that the rock consists mainly of quartz grains which had suffered little attrition before deposition. Biotite and muscovite are both present, but from their feeble development they can hardly be regarded as a main cause of the flexibility of the stone. In addition the slide shows the occurrence, in fair quantity, of a matrix of isotropic character containing much included matter. The inclusions are, for the most part, quartz grains of microscopic dimensions and a small amount of opaque matter, the nature of which I have failed to determine. This opaque matter is, however, so subsidiary, as to suggest that it does not play any part in the explanation of the flexible nature of the rock.

The slides appear to me to clearly show that part of the paste originally enclosing the un-and sub-rounded grains of quartz has been removed. The slides do not throw any light on the interlocking structure of the quartz on which Mr. Oldham's theory largely depends. This negative result is possibly due to the fact that my slides were not cut in the direction required to show up to advantage the interlocking structure, and the small piece of sandstone in my possession did not admit of the preparation of many slides. On consideration it does not appear clear that the "interlocking" of the quartz is the fundamental point in any theory brought forward to explain "flexible sandstone" It would seem rather that a *vera causa* is to be found in the partial removal of the matrix, whereby the quartz grains have free play to move when the slab is stressed in any manner. As regards the origin of an interlocking structure in the quartz Mr. Oldham is silent, and indeed any theory to explain this

|| Neu. Jahrb. I Band., 1887, pp. 195-7.

difficulty is very hard to formulate. Mr. Oldham, it is only fair to say, attributes much weight to the removal of the matrix in a suitable proportion. I cannot do better than again quote from his paper. "The development of a flexible structure depends on the proportion and mode of distribution of the felspathic mud; if absent or only present in very small proportion, decomposition will not extend deep into the rock, the quartz grains will be detached and fall off, leaving the undecomposed rock with a mere film of weathered stuff on the surface; if it is too evenly distributed, the quartz grains will not be in sufficiently intimate contact with each other, and as the rock weathers it will decompose into grains of sand easily detached and removed; if finally it should be suitably distributed, but too large in amount, the voids left by its removal will be so large that the quartz aggregates will not interlock with each other."

Mr. Oldham goes on to state, "the number of conditions which must be fulfilled satisfactorily accounts for the rarity of flexible sandstone, and to a certain extent for the capriciousness of its distribution in rocks which are of the same age and have, to all appearance, the same composition and structure."

With this statement of Mr. Oldham I am quite in accord; the removal of the matrix in just a suitable proportion seems necessary. With regard to the isotropic matrix, it would appear that we have to look to a double metamorphism. The rock was, we will assume, a normal sandstone initially; intense heat may have led to a partial fusion whereby the external surfaces of the quartz grains may have been transformed into a glassy material; at a later date solvent action may have removed this matrix in such suitable proportion as to give flexibility without disintegration. This is, of course, mere hypothesis, but the importance of explaining the isotropic base of the rock is at least as serious as the interlocking structure of the quartz.

Mr. Oldham, in support of his view, attaches much importance to the appearances presented by the flexible sandstone near Chárli, south of the Pemganga River in Berar. He states "it is an ordinary soft sandstone of rounded grains of quartz with a little felspar, held together by a cement of carbonate of lime, which forms 35·9 per cent. of the whole mass. Here there is no comparatively soluble material whose removal leaves the rest of the rock as a mass of irregular aggregates interlocking with each other, for on removal of the cement by solution, the rock falls into sand. But if the fractured surface of the rock is examined, an abundance of sheeny patches point to a crystallisation of the cementing matrix, and these planes afford a number of planes along which solution proceeds with greater rapidity than elsewhere, and as a result the rock becomes divided into irregular aggregates of sand and calcite."

It seems to me that the sample of the Chárli sandstone needs much consideration before it can be regarded as a real support to Mr. Oldham's views as to the flexibility of the Kaliána rock. The difference between the two cases is fairly obvious; in the Kaliána stone the quartz grains interlock, and the matrix is partially removed; in the Chárli rock the interlocking takes place not between the quartz grains, but between the facets of the crystals of calcite forming the base. The two explanations have, however, an important feature in common, viz., the occurrence of free cavities which may ramify into the rock in all directions.

In this context it may be well to mention the occurrence of flexibility in a rock which is not sandstone. Mr. G. W. Card * in 1892, drew attention to a flexible limestone of Permian age developed at Marsden, in the County of Durham, and at a point south of Sunderland. The rock is very finely laminated, is very soft and friable, and in general appearance not unlike a fine-grained sandstone It appears (according to Sedgwick) to have resulted chemically from deposition in successive layers.

From sections prepared for the microscope it would appear that a low power reveals a large number of irregularly shaped empty spaces, in the main ranged linearly in directions parallel to the bedding, but also occurring promiscuously through the section. The material of the slide is mainly an aggregate of grains of dolomite, with a very few grains of quartz and specks of blue and brown material. Mica is very rarely present. The larger grains of dolomite appear to be intergrown in such a way that the convexity of one fits into the concavity of another. As a cause of flexibility, Mr. Card suggests: In the first place room for internal movement is provided for by the abundance of empty spaces, and in the second the structure revealed by high magnifying power suggests the possibility that many of the grains are interlocked in such a manner as to permit of a certain amount of movement upon one another. Owing, however, to the small size of the grains, Mr. Card was unable to demonstrate whether the grains actually possessed such power of movement or not.

Mr. Card's paper is of the greatest interest; the rock it describes differs much both in point of age, composition, and mode of origin, from Mr. Oldham's flexible rocks; again, the reality of the interlocking structure is far from certain, while the existence of cavities allowing free play of molecular movement seems well established.

* Geol. Mag. (3) IX., 1892, pp. 117, etc.

The instances I have cited may now be summed up. The Kaliána rock shows (?) interlocking structure of quartz with removal of matrix ; the Chárli rock shows cavities with possible interlocked structure of matrix. The rocks described by Mr. Card show cavities with possible interlocking of main material of rock (dolomite).

It would appear from these results that interlocking is often doubtful, and in the main subsidiary ; that flexibility depends on (1) the nature of the matrix ; (2) the removal of such matrix in suitable proportion, as set forth by Mr. Oldham, so as to allow of free movement of the other constituents of the rock.