

ART. VII.—*Experiments on Itacolumite, (Articulite), with the explanation of its flexibility and its relation to the formation of the Diamond*; by CHARLES M. WETHERILL, Ph.D., M.D., Professor of Chemistry in the Lehigh University.

THE rock which derives its name from the mountain Itacolumi in Brazil is certainly one of the most interesting with which we are acquainted. As the companion (probably the matrix) of the diamond, a study of its origin and nature might possibly solve the problem of the formation of that gem; and its flexible character is at such variance with our ordinary experience of the stability of rock, that it is wonderful to those even who are most familiar with it.

According to the authorities, itacolumite is a laminated quartz rock of the talcose series, owing its lamination to a little talc or mica (Dana), to which material its flexibility is also due (Dana,

Percy and others). It occurs in extensive formations in Brazil, the Urals, and in the United States in Georgia, and in North Carolina, and appears particularly to accompany the diamond.

The specimens which I have examined are: 1st. A number of slabs of various size from Saraw Mt., Stokes Co., N. C., given to me by Captain Samuel W. Dewey. 2d. Small fragments of a large slab in the Museum of the Smithsonian Institution, to which it was presented by Charles DeSelding, who obtained it in Rio de Janeiro, its locality being Minas Geraes, the celebrated diamond region of Brazil. These two specimens have the same general appearance; with the exception of color, which for the North Carolina rock is a light yellow, and for the Brazilian mineral a light reddish brown, and of the granular condition, which is finer for the North Carolina specimen.

They may be split more readily in one direction yielding slabs, and there are occasionally small fissures at right angles to these layers. There is also in one of my specimens a plane forming an angle of 15° with the plane of readiest cleavage and perpendicular to the planes of the fissures. It appears to be a joint and is covered with small crystals of quartz.

Scattered through the rock are small scales of mica which are comparatively few in number but of uniform size, thin, and determine the cleavage of the rock. These plates lie in parallel planes, as they would settle naturally from a liquid. Where they are abundant in any plane the rock splits there readily. If a piece of the itacolumite, thus split, be rubbed down perpendicularly to the cleavage plane, no scales of mica are perceived upon this new surface, because the observer is looking at the edges of the micaceous plates, but the lamellar nature of the rock is thus made very apparent.

The chief constituent of the rock under the microscope is quartz in very sharply fractured and fine grains, together with a little mica. Occasionally are to be seen very minute black grains. One specimen when rubbed down shows small pieces of compact white quartz, giving it the appearance of a section of sausage. The specific gravity of the North Carolina specimen, taken in the ordinary manner, is 2.61; but 2.69 after freeing its pores from air by a vacuum [sp. gr. of quartz 2.65]. The analysis yields the following results:

Vol. at red heat (water),	-	-	-	-	0.17
Silica, - - - - -	-	-	-	-	95.89
Sesquioxyd iron, - - - - -	-	-	-	-	2.78
Lime, - - - - -	-	-	-	-	0.84
					<hr/> 99.68

Besides which, the qualitative analysis yielded traces of KO, NaO, MnO, MgO; but no Al_2O_3 . The ferric oxyd, obtained

also by attacking another portion of mineral by hydrofluoric acid, was 2.03 p. c. The iron is not distributed very uniformly through the rock, as may be readily seen by an inspection of specimens.

I found it impossible to separate completely the mica from the quartz byedulcoration. When the result of the washing is examined with the microscope, scales of mica are seen, generally colorless, but sometimes dark brown, and all polarizing light, as do also the grains of quartz.

This fineedulcorate when heated on platinum foil B.B. cakes together slightly, and a slight dust adhering to the platinum does not fairly melt but exhibits signs of intumescence. With salt of phosphorus very fine grains of silica are seen floating in the bead. With borax a clear glass without intumescence results. An experiment for HF1 with the itacolumite mica yielding negative results.

The mica examined with the spectroscope gave the reactions of KO and NaO only. No different result was obtained after the mineral had been attacked by liquid hydrofluoric acid, and the residue evaporated to dryness with sulphuric acid before exposure to the flame.

The relative hardness of the siliceous grains in the mineral appears to be that of agate which may be scratched slightly by them. On one occasion the bottom of an agate mortar received a very decided scratch which gave color to the supposition of a minute diamond as the cause. The rock is quite porous when compared with other sandstones; water placed in an excavation will filter very readily through the stone, even in a direction perpendicular to the plane of stratification. Gases diffuse very easily through these pores; if a slab of the itacolumite one quarter of an inch in thickness, be cemented to the top of a glass cylinder, which is then filled with hydrogen, water rises very rapidly into the tube.

When the mineral is raised to a red heat, it acquires a red color when cool; when plunged hot into water it does not become more friable. Under the HO flame it fuses to a nearly colorless glass. Heating to redness does not impair the flexibility of the stone.

The specimen from Brazil was not analyzed. It presented the same physical character as the North Carolina mineral. Its color was different, being reddish brown.

In the Brazil sandstone, the siliceous grains are larger. To the eye the quantitative relation of the silica to the mica is the same for both specimens; if there be any difference, it is in favor of a somewhat larger proportion of *mica* in the Brazilian itacolumites.

Explanation of the flexibility.—The flexibility of this rock is attributed universally to the mica which it contains, an inference which the microscope shows to be unwarranted. This flexibility is due to *small and innumerable ball and socket joints*, which exist throughout the mass of the stone very uniformly. Each joint permits a slight movement which is always greater in one direction. The accumulation of joints suffers a limited motion in every direction. This mobility is not perceptible in thick slabs unless they are large as to their other two dimensions. From such a slab it is easy to obtain a small and thin piece in which the flexibility may be observed; and the thinner the section the greater is the motion. Where small joints or fissures occur, the motion is greater at those points.

This jointed structure is so wonderful that it would warrant the name "articulite" to be given to the mineral, especially if we should find it again in other sandstones by observing them in very thin slabs.

To determine the nature of the motion, at first, various thin sections of the stone were taken, cut in three directions, viz: one parallel to the plane of stratification, one perpendicular to this plane, and one perpendicular to each of the above planes.

The sections were made by cementing layers of the rock upon a glass slide with shellac, rubbing down to the required thinness upon a slab of the itacolumite, and removing the resin by alcohol.

These sections were fastened to a piece of cork in such a manner that they might be moved, and the motion observed under the microscope. The sections behaved alike and the play of the joints was at once seen. I subsequently found that thin sections were not at all needed for this purpose, since the articulations may be perceived with the microscope in any fragment of the mineral. A piece is fastened to the stage, which is then inverted and slightly tapped to remove any loose grains of sand. Upon adjusting the instrument and touching the specimen gently with a quill point, it is perceived to be composed of small botrioidal masses or congeries of grains of sand. The observer can scarcely divest himself of the impression that he sees a loose layer of sand, until the stage is again inverted and jarred, which demonstrates that the grains are interlocked. By managing the reflected light, with which the object is illuminated, the plates of mica can be distinctly seen; they are very few in number and *take no part whatever in determining the motion*. The articulation is *not* that of basaltic columns. The component grains are arranged so that most of the groups have cavities and projections, and so that the projection of one group engages in the cavity of its neighbor.

By observing the thin edge of the specimen regular cavities

are seen, out of which groups of sand particles have fallen. The rock may even be dissected by the needle point and shown to be made up of such congeries, and the groups may also be resolved into their constituent grains.

The millimetric length and breadth of the groups varies from 0.26×0.26 to 0.26×0.32 , and the size of the individual grains composing the groups averages between $(0.026)^2$ to $(0.04)^2$ mm.

Many are as large as $(0.08)^2$ and some as small as $(0.013)^2$. The general cubic capacity of a group or grain could be determined by multiplying the above areas by one of the linear dimensions given.

Each group appears to be composed of from 20 to 50 grains of sand not very strongly agglutinated. The individual grains are very "sharp" fragments of silica, not flat plates, and of great uniformity with respect to size.

The scales of mica are flat and nearly square fragments. They average in area $(0.08)^2$ mm. and vary from $(0.26)^2$ to $(0.065)^2$ mm.

The Brazil mineral presents almost exactly the same character under the microscope as that from North Carolina, with the exception that the individual grains, as well as the congeries, are somewhat larger in the former. The oxyd of iron in the mineral is not the *cement* by which the grains are united, for a thin section of the rock boiled in HCl for five hours did not become more friable. The cement would appear rather to be siliceous (hydrated silica); because a piece boiled in a solution of caustic soda becomes partially disintegrated, especially at the edges, and is much more friable as to its mass.

When dilute solution of hydrofluoric acid is poured upon a thin section it is immediately resolved into grains, affording a complete disintegration of the section.

The flexibility of the itacolumite (N. C.) is shown in a striking manner with a cylindrical piece sawed out from a thick slab of the sandstone and rubbed down upon another piece to the required shape. The planes of stratification were taken parallel with the cylinder's axis.

The specimen measures 198 mm. ($7\frac{3}{4}$ in.) by 13 mm. ($\frac{1}{2}$ in.) in diameter. It can be compressed and elongated in the direction of its axis, the extent of the motion being a little over $\frac{1}{2}$ mm. When one end is fixed, the other end may describe a circle of 34 mm. ($1\frac{3}{8}$ in.) diameter, and may be made to touch every point in the area of the approximate spherical zone. The rod can also be twisted about its axis, the torsion being 10° .

Catenary.—When the rod is supported upon two nails 185 mm. apart, it assumes the form of a curve very like the catenary. The greatest deflection from the line joining the points of support varies from 3 to $3\frac{1}{2}$ mm. as the rod is rotated about its axis

on the nails. My colleague and Prof. of Mathematics in the University, Col. E. W. Morgan, very kindly undertook the discussion of this curve with the following results. The curve was traced upon paper with a pencil under the stone resting upon two points of support at its extremities and the ordinates were measured for comparison with the ordinates of different curves.

Prof. Morgan at first compared with the circle, as the curvature was so slight, but it departed sensibly from that curve in such a manner as a true catenary would do. He then compared it with a loaded catenary (which is a parabola) with similar results. The beam loaded with equidistant equal weights (ellipse) was next essayed but the curve did not agree with it. Nor did it coincide with the true catenary. It was nearer to the loaded catenary than to any known curve. The result therefore of the calculation indicated that the curve of the stone lay between the catenary and the ellipse.

Prof. Morgan next prepared an experiment with a small beam of white pine loaded with equal equidistant weights for the ellipse, with a fine and flexible gold chain for the catenary, and with the stone cylinder. These were placed upon the same supports (185 mm. apart) and so arranged that the greatest deflection for each curve should be to the same point.

Upon comparing the chain with the loaded beam it was evident that the latter curve was a true ellipse, and consequently the comparison would be attended with no uncertainty due to a supposed defect in the slip of pine. The chain and stone were compared next, and then the stone and beam. Although the experiment was not of a character to afford very delicate measurements, it showed with great clearness that the curve of the stone is very nearly a catenary, and that it lies between this curve and the ellipse.

This result which was not anticipated by either of us, for we expected that the curve would prove to be a catenary, is very interesting and agrees with the jointed condition of the stone, as well as with the character of the joints shown by the microscope.

In a flexed beam the forces are partly compressive and partly tensile, as we consider the upper or the lower portions of the beam, and when the beam is loaded with equidistant equal weights, the conflict of these forces causes the beam to assume the form of the ellipse. The itacolumite cylinder takes the catenary form by reason of its ball and socket joints. But the rod has a definite thickness and a *series* of joints parallel with its axis, in this respect unlike a true chain. Furthermore, as the microscope shows, the sockets are *rough*, as they are formed by grains of sand, and the protuberances fitting into them are also rough. Consequently, when the stone bends by its weight between the

supports there is a compressive action toward the top, and a tensile one along the bottom of the cylinder, as in the case of a beam, and this gives an elliptical character to the curve. As the diameter of the rod increased or diminished, I should expect to find the curve of the stone approach the ellipse or the true catenary.

The relation of itacolumite to the diamond.—The most interesting relation of this rock is to the diamond which it accompanies. This gem, found at first in the "gurgulho" or disintegrated rock, has at length been discovered *in situ* in the itacolumite itself; thus showing that this sandstone is at least one of the sources of the diamond.

The physical conditions which have led to the peculiar jointed character of the itacolumite may have had an important bearing upon the crystallization of the diamond, and hence it is of interest to ascertain what those conditions were, with the hope of throwing light upon the origin of the gem.

I confess to be at a loss to offer a very reasonable hypothesis with respect to these conditions. It is difficult to see why the siliceous fragments cohere to form definite groups or congeries. If we suppose that planes having a certain relation to the crystalline axes cohere by long continued contact more readily than planes having a different relation, why does this partial cohesion occur with such surprising regularity; why also is it not perceived in other sandstones? It would appear that the sand which formed this rock contained something diffused in a regular manner (and which was subsequently removed), which prevented the uniform contact of the siliceous grains. It is possible to conceive that *petroleum* might have that effect when added to sand of a certain degree of moistness, forming a kind of emulsion, and that the petroleum was afterward slowly removed by a process which permitted a crystallization of a portion of its carbon. When water was dropped upon dry sand, the mixture when stirred, formed lumps of uniform size; if, before stirring, a little petroleum was added, the lumps appeared to form more readily. The lumps are left out of aqueous contact by the coating of petroleum around each one, while the siliceous particles forming the lumps have water between their component grains. Cohesion could take place between the particles, but not between the lumps. Under the microscope the sand thus treated bears a striking resemblance to itacolumite.

I made this supposition before acquaintance with DeChancourtois's hypothesis that the diamond may have been formed from hydrocarbons, and that its origin is thus connected with the existence of petroleum-bearing schists. My hypothesis therefore receives a certain support from the views of DeChancourtois.

I have heated several of my specimens of itacolumite to ascertain whether any petroleum odor was evolved, but with negative results. If the diamond proceeded from a slow and gradual oxydation of the hydrocarbon perhaps we should not expect to find any petroleum left.

In this connection the small and rarely occurring black specks, seen with the microscope, are to be noted; are they minute black diamonds, and have they any relation to the experiment where the agate mortar was so deeply scratched?

Bethlehem, Pennsylvania, April 6.