

then eight years as their probable age in February 1885, they would now be almost fifteen years old, and the tree measured is now 4 feet  $4\frac{1}{4}$  inches round, three feet above the ground.

The *Eucalyptus globulus* on Observatory Park is now sixteen years old and is three feet ten inches round, three feet above the ground, or six and a half inches less than the tree at Lake George which is a year younger. The trees on Mount Victoria measured about sixty-three inches round after fifty years growth, and the measures on the Lake George tree seem to justify us in assuming that it enlarged uniformly year after year.

Therefore at 15 years old the Mount Victoria tree measured 19 in.

15 „ the Lake George tree measured  $52\frac{1}{4}$  in.

15 „ the Observatory Park tree measured 43 in.

The trees are all Eucalypts.

## ON KAOLINITE FROM THE HAWKESBURY SANDSTONE.

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Communicated by J. H. MAIDEN, F.L.S., F.C.S.

[With Plate XXIII.]

[Read before the Royal Society of N.S. Wales, December 2, 1891.]

MESSRS. Johnson and Blake conclude their paper† in which they found the mineral Kaolinite, by suggesting the advisability of further investigations, by a study of the physical properties, and

\* The probable age at this measure was 14 years  $8\frac{1}{2}$  months if allowance for  $3\frac{1}{2}$  months is made to bring the age up to 15 full years, it would measure  $53\frac{3}{4}$  inches round.

† American Journ. Sci., 2nd Series, Vol. XLIII., p. 351.

by instituting fresh analyses on material *properly purified*, or shown by the microscope to be homogeneous.

They appear to recognise the difficulty in arranging, with any great success, a series of results obtained from analysing impure material; and the error in this respect has certainly not been rectified by later additions to our knowledge of the composition and formation of kaolin.

Manifestly the primary basis for a mineral species is that it is in a crystallized or crystalline condition; and it is by becoming possessed of such, that I have carried out the following investigations, with the hope of being able to assist in the elucidation of this matter.

In a paper by Mr. J. H. Collins, F.G.S., "On the Nature and Origin of Clays,"\* in which he essays to arrange a new formula for Kaolinite; a number of analyses are given, these perhaps are fairly representative, but yet not free from the charge of not being properly purified, as the silica ranges from 41·6 to 49·1 per cent.

Prof. J. D. Dana in his "System of Mineralogy" has given under Kaolinite twenty-six analyses, the results of which are not concordant, the silica ranging from 43·13 to 49·1 per cent.; nor is it possible to arrange the formula given for Kaolinite ( $\text{Al}_2 \text{O}_3 \cdot 2 \text{SiO}_2 + 2 \text{H}_2\text{O}$ ) from hardly any of these analyses.

It is not my intention to discuss the composition of ordinary clay, only so far as it is necessary for the purpose of this paper. The economic value, composition, and quantity, is a matter that can well be left for future discussion. As the clay deposits of New South Wales are extensive, and the clay often of good quality, they will ultimately be in great demand for the purpose of the potter.

Mr. Collins in his paper (*loc. cit.*) states that true kaolin, instead of being made up largely of pearly scales as stated by Dana, "is in general, and always when properly prepared, absolutely free from them. The hexagonal scales 'which may be

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\* Min. Mag., Vol. VII., p. 205.

detected in all [improperly prepared] kaolin,' on which Johnson and Blake, followed by Dana, founded their orthorhombic mineral Kaolinite, *do not appear to have been separated and analysed.*" The italics are mine.

I have thus taken this opportunity of investigating and analysing what I consider to be Kaolinite, and which is seen to be under the microscope, entirely composed of six sided crystals and plates which have cleaved off. Unfortunately the quantity at my disposal was small, but I have still sufficient for a good number of microscopic slides. The mineral I found in a little pocket in the sandstone at Marrickville, near Sydney, with a small quantity of coal, which coal was blocking up the entrance. Being in the solid rock with nothing like a crevice near, it was well protected from all impurities. When first found it much resembled an accumulation of minute scales of mica; it had a pearly lustre, an unctuous feel, a mealy appearance, and was of a very light cream-colour—almost white. A trace of iron was removed by dilute hydrochloric acid, but the colour of the thus treated substance was not altered in any perceptible degree.

Under the microscope it appears to be composed of six sided crystals, the basal cleavage of which is so perfect that the whole crystal appears to separate into plates. Where the plates are isolated they are perfectly transparent, and where two or three are placed one above the other, the edges of the lower are distinctly seen through the upper plates. The general appearance is represented in Plate XXIII., fig. 1.

The angles of the crystals are, as pointed out by Descloizeaux,  $120^\circ$ , and if the faces are extended till they meet, the resulting angle is  $60^\circ$ ; several plates that I measured gave these as the correct figures, or very near it.

Under the blowpipe it exfoliates and increases considerably in size. It commences to expand at once, glows with a brilliant light, and becomes intensely white. With cobalt-nitrate solution gives a fine blue colour.

Hunt (as quoted by Dana), also found that the Kaolinite from the Chaudière Falls, which was obtained from the sandstone of the Quebec Group, where it fills seams or fissures, exfoliated in white cauliflower-like shapes.

Johnson and Blake (*loc. cit.*) also state that one of the specimens they investigated, and which came from a cavity in a coal seam at Summit Hill, Carbon Co., Pa., when ignited increased in bulk, and that the microscope shows this to be the result of the exfoliation of the crystals due to the expulsion of the water.

That this is the cause, is apparent from the appearance of the crystals after heating before the blowpipe. They do not fuse, and although more rugged in appearance, the general laminated structure of the larger crystals remains fairly perfect. The one great difference is, that they have become opaque, and that individual plates are almost absent (Plate XXIII., fig. 2.)

Descloizeaux in his "Mineralogy," states that the interior structure is fibrous; the plates of my mineral do not show fibrous structure, but they show that besides the perfect basal cleavage, (which has often been pointed out), two other cleavages, one parallel to the face of the rhombic prism, the other parallel to the brachypinakoid (Plate XXIII., fig. 4). I think this is most important, (I do not find that these other cleavages have been previously noticed) and probably accounts for the manner in which kaolin is formed, as by mechanical action the crystals would readily disintegrate, breaking along these cleavage planes. That this is so appears from Mr. Collins's paper; he states that he has noticed in a large number of samples of china clay from different localities, that when the clay has been properly prepared there is an entire absence of these scaly or flaky particles, but that when the reverse is the case, that they are always present. We know that the plasticity of kaolin depends on the fineness of the material.

Completely decomposed felspar has been stated by Dr. H. C. Sorby to break up into granules of kaolin from  $\frac{1}{6000}$  to  $\frac{1}{50000}$  of an inch diameter. Among these granules were some small needle-

shaped crystals, and beside these, small hexagonal scales or fibrous looking aggregates of micaceous minerals.

The inference to be derived from the foregoing, is that under favourable conditions Kaolinite is first formed and that the rhombic crystals (which may be exceedingly minute) by the three cleavages break up into an extreme state of division, by mechanical action, carbon dioxide, or other agency not yet determined. We do not find a different compound when formed into clay (kaolin) than what it is when crystallized Kaolinite; it is hydrous silicate of alumina when in crystals sufficiently large to be seen, and it is hydrous silicate of alumina when these crystals are thoroughly broken up, there is no chemical replacement of any of the elements when formed into clay (kaolin), and if it was not for impurities the composition of kaolin when in the finest state of division would not differ from that of Kaolinite when perfectly crystallized.

Johnson and Blake state "that it is possible also that the plasticity of clay is related to the form of the plates of Kaolinite, perhaps to their thickness, but this is a subject that requires further investigation."

Did this mineral cleave only in one direction (the basal cleavage) the plates most probably would remain as such, and be as persistent as mica; the composition of the product undergoes no alteration as in the formation of serpentine; and as the composition remains constant no matter how fine the division, it is evident that no alteration from Kaolinite has taken place.

To see how far this theory is likely to be correct, I took some of the crystals, moistened them with a drop or two of turpentine, and ground them in a mortar, then transferred the paste direct to the slide. I found that nearly the whole of the larger crystals had disappeared, and that but a few isolated plates remained and these nearly all showing pieces broken from their edges along the cleavages that break up these plates. Had the mechanical action of the grinding been continued a short time longer I am convinced that the whole crystallized appearance would have disappeared, and that the exact resemblance of the clay from the deposits

around Sydney, when they are seen under the microscope, would have been obtained. The plates do not break up irregularly in any instance that I can discover, but always in the angular condition which these cleavages give.

This, it must be admitted is a very unnatural method ; but, I am able to show the process going on purely in a natural manner. In the coarse sandstone of the same quarry from which I obtained the Kaolinite, an almost pure white powdery looking substance is filling up the interstices around the grains of quartz. I took a portion of this and examined it under the microscope, and I found it to consist of the same identical plates and crystals ; the crystals are few in number, but it consists largely of the plates, and these plates in the majority of instances show the cleavages very distinctly, most of them having portions removed from their sides, but always broken along these characteristic cleavage planes.

I also found a beautiful example of a plate of a crystal breaking up in this manner, in the clay from Cronulla Beach, Port Hacking, near Sydney (Plate XXIII., fig. 3.), so that we have been able to trace the Kaolinite through three stages ; the crystallized, the crystallized intermediate, and the clay.

It is not to be supposed that the Kaolinite that surrounds these particles of quartz, cementing as it were the whole together, and which must be in enormous quantities, distributed over a large area, is the only material of this kind to be found in this deposit, and the matter is one worthy of further inquiry.

Whether the deposits of clay in the immediate neighbourhood of Sydney, and throughout the Hawkesbury deposits were derived originally from the decomposition of felspar is not certain ; but that the Kaolinite that forms the subject of this paper, and the clay of these deposits are somewhat identical I am convinced ; the evidence so far clearly pointing to these deposits being originally derived from the same material as surrounds the grains of sand as spoken of above. The analyses of this Kaolinite gave about .5 per cent. of magnesia, but no lime. The following three

analyses I made by direction of the Curator of the Technological Museum, upon clay from some deposits near Sydney. The first a sample from Kogarah gave .551 per cent. magnesia, and only a trace of lime ; the second, from Balmain, contained .553 per cent. of magnesia, but no lime ; the third, from Cornulla Beach, Port Hacking, gave .640 per cent. magnesia, but no lime. Specimens of these clays together with their analyses are exhibited in the Museum Collection.

An analysis is published in the Report of the Department of Mines, New South Wales, for 1890, of clay from Kogarah, this also gave .93 per cent. of magnesia but only a trace of lime. This is sufficient to show the close relationship existing between the crystallized Kaolinite and these clay deposits.

It is probable that the Hawkesbury Sandstone has been principally derived from the decomposition of granite, and the large quantity of mica existing throughout assists this supposition. The felspar contained magnesia, and most probably barium, as I have myself succeeded in discovering barytes in this formation ;\* which was laid down contemporaneously with the shale beds, and the sandstone. I have since traced the existence of this barytes on the opposite side of Cook's River, showing its previous existence across the valley. The presence of barium in felspar is no new thing, and even in orthoclase and oligoclase, analyses are given by Dana where barium is recorded. It would be well in taking analyses of granite from New South Wales to be on the watch for barium, it is by no means a rare mineral in this colony.

These clay deposits may eventually be proved to be kaolin, but the further consideration of this subject will require to be left for a later paper, as in the present state of our knowledge to attempt to arrive at a decision would be premature, a searching inquiry is requisite to decide the matter, as the composition cannot be decided from material evidently impure.

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\* Pro. Linn. Soc., N. S. Wales, Ser. 2, Vol. VI., p. 131.

The constitution of kaolin is discussed in Percy's Metallurgy (Fuel), page 93, but the arguments are principally based on the above mentioned paper by Johnson and Blake.

A figure of Kaolinite as it appears under the microscope is given in Teall's British Petrography, Plate 44, but this only shows isolated plates and scales such as may be found in ordinary clay.

The following is one analysis I made of this mineral, it was fused with the carbonates of sodium and potassium :—

·563	gram.	gave	·261	gram.	Si O <sub>2</sub>
·563	„	„	·2255	„	Al <sub>2</sub> O <sub>3</sub> with a trace of iron.
·563	„	„	·008	„	Mg <sub>2</sub> P <sub>2</sub> O <sub>7</sub>
·563	„	„	·0727	„	H <sub>2</sub> O
		=	46·359	per cent.	Si O <sub>2</sub> .
			40·053	per cent.	Al <sub>2</sub> O <sub>3</sub>
			·512	per cent.	Mg O and 12·913 per cent. H <sub>2</sub> O
					= 99·837.

Another analysis gave almost identical results.

The water was estimated three times, but in no instance did I succeed in obtaining 13 per cent., the highest being 12·96 per cent., the last portions are only driven off by long continued heating.

The magnesia does not appear to be an impurity, as it is a constant quantity in all the samples of kaolin yet examined ; if a portion of the water be considered basic, and the Mg O be calculated into this water the oxygen ratio is nearly 3 : 4 : 2, and the formula is as usually written Al<sub>2</sub> O<sub>3</sub> 2 Si O<sub>2</sub> + 2 H<sub>2</sub> O. The alumina was a trifle high in all three estimations that I made.

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