

conditions, root-pressure, as demonstrated by these experiments, seems quite adequate to supply water to the tops of even the tallest trees.

No attempt will be made at present to explain how this force may be developed. We are interested, however, in determining if a diurnal rhythm of respiration rate exists corresponding to the observed rhythm of secretion, to extend the quantitative study of the phenomenon to roots of species other than tomato, including roots of some trees, and especially to extend the curve of secretion rate as influenced by imposed pressure far enough so that some estimate of the maximum secretion

pressure can be obtained and compared with the osmotic values of the tissues involved. It is hoped thus to throw some light not only on the question of sap movement but also on the mechanism of secretion.

¹ Hales, S., "Vegetable Staticks, or an Account of some Statical Experiments on the Sap in Vegetables" (London, 1727).

² Knight, T., *Phil. Trans. Roy. Soc. London*, B, 333 (1801).

³ Dixon, H. H., and Joly, J., *Phil. Trans. Roy. Soc. London*, B, 186, 563 (1895).

⁴ Askenazy, E., *Verh. natur. med. Ver. Heidelberg*, n.f., 5, 325 (1895).

⁵ Molisch, H., *Bot. Z.*, 60, 45 (1902).

⁶ White, P. R., *Plant Physiol.*, 9, 585 (1934).

⁷ White, P. R., *Plant Physiol.*, 12, 183 (1937).

⁸ White, P. R., *Plant Physiol.*, 12, 793 (1937).

⁹ White, P. R., *Plant Physiol.*, 12, 803 (1937).

¹⁰ White, P. R., paper presented before the thirteenth annual meeting, Amer. Soc. Plant Physiol., Atlantic City (1936).

Clay

FOR fifty years or more a number of people have been endeavouring to give a satisfactory answer to the question, "What is clay?" Instead of a simple answer which meets all requirements, no adequate definition has been found. Geologists define as clay many substances which potters would reject. Chemists look for a definition based on chemical composition and fail to obtain satisfaction because many commercially useful 'clays' differ so greatly in composition that no satisfactory correlation seems possible. The highly plastic blue clay used by glove manufacturers seems to have little in common with the hard grey fireclays of the Coal Measures and even less with the china clays of Devon and Cornwall, or the kaolin of the text-books. Plasticity—which is supposed by many people to be the chief characteristic of all clays—is almost absent from some kaolins the composition of which causes them to be regarded as the purest of all clays and the 'typical clay-substance' of numerous authors and investigators. On the other hand, many substances become plastic when suitably treated, though their compositions are so different from any kind of clay that the inclusion of plasticity as an essential part of any definition has often led to confusion.

An important step forward was taken when Seger succeeded in separating extremely small particles of almost constant composition from several varieties of clays used in the manufacture of bricks, tiles, and pottery. Further investigations along this line seemed to show, however, that Seger's 'pure clay' or 'clay-substance' does not exist in the sense that 'pure silica' or any other 'pure' chemical compound exists. The variations in composition and properties of the 'purest clays'

obtained from various sources differed too greatly for clay to be regarded as a definite chemical compound.

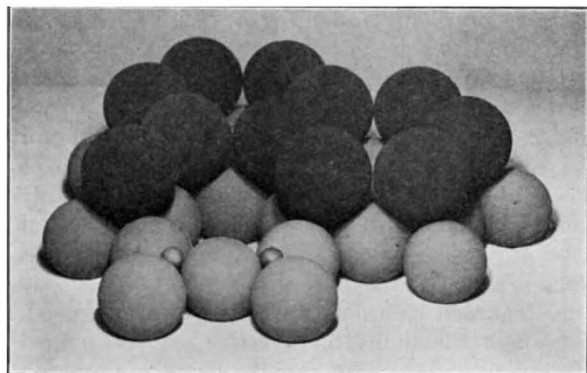
The whole subject remained in this inchoate state until a few years ago, because the 'purest' clay particles obtainable are so small as to be, for the most part, outside the range of the most powerful microscopes. Many seem to be readily converted into the colloidal state, if they do not exist in it when found, and as their precise shapes cannot be ascertained by direct observation they were regarded as amorphous. It seemed, indeed, as though the limits of investigation, as applied to clay particles, were rapidly being approached when a new line of research was opened out by the discovery that X-rays enabled the crystalline form of substances to be recognized even when the particles were of sub-microscopic dimensions. This line, so ably developed by Sir William Bragg and his son W. L. Bragg, has now changed the whole outlook on the constitution of clays and has successfully revealed the principal features of the structure of clays, though many details still await explanation.

The present position was described on November 19 by Sir William Bragg in a Friday evening discourse at the Royal Institution and may be summarized as follows:

Many mineral and other silicates have been found, by X-ray analysis, to consist of sheets or layers of atoms piled one upon the other, much as a series of balls of different sizes may be placed in a pre-arranged heap (see accompanying illustration). In both complex silicates and clays, the atoms (represented as spheres at the apices of tetrahedra) form a pattern of rectangular cells or units, and the various sheets or layers must

fit perfectly in combination even if they differ slightly when in separate existence. Such differences are easily overcome when two or more layers are laid on each other or when they grow together. The lengths of the sides of these imaginary rectangles have been measured, and from them the probable structure of various clays deduced.

The structure of the halloysite crystal (which is a characteristic constituent of some fireclays) has been determined by Mehmel, and the dimensions (in angstroms) of the unit (rectangular) cell are $a = 5.20$, $b = 8.92$, $c = 10.25$, and $\beta = 100$. The value of c corresponds to four oxygen or hydroxyl sheets piled on one another. The structure of several typical clays and other minerals is shown in Table 1, each sheet or layer being enclosed in a rectangle of dimensions $a \times b = 5.2 \text{ \AA} \times 8.8 \text{ \AA}$. The height of the cell depends mainly on the number of sheets and on their thickness.



ARRANGEMENT OF THE ATOMS IN A SHEET OF HYDRATED SILICA. THE O-ATOMS FORM THE LOWEST LAYER; THE OH-GROUPS, SHOWN DARKER, REST ON THEM. THE SILICON ATOMS OCCUPY THE SPACES BETWEEN; TWO SILICON ATOMS HAVE BEEN MADE VISIBLE BY THE REMOVAL OF OVERLYING SPHERES.

It should be noted that when halloysite is slightly heated, its two middle sheets of hydroxyl collapse into one sheet consisting of four oxygens and two hydroxyls. Four oxygens and eight hydrogens are expelled in the form of water, though no water, as such, exists in the clay. This expulsion of 'combined water' has long puzzled chemists, though they were aware that it originated in the decomposition of hydroxyl groups. As shown in Table 1, the slightly heated halloysite (meta-halloysite) has the same structure and composition as kaolinite and, presumably, as kaolin and china clay. Further heating of halloysite and kaolinite appears to result in the formation of free alumina and free silica, and the expulsion of water as steam, but further investigation is necessary to prove this.

Several well-known clays appear to be derived from, or closely related to, montmorillonite, which, as shown in Table 1, consists of two sheets of silicon atoms with a sheet of aluminium atoms and two sheets of oxygens and hydroxyls between. The greater thickness of the montmorillonite cell, as compared with pyrophyllite and mica, is attributed to further intervening sheets of water. The structural analogy of montmorillonite with hydrated silica, brucite, and gibbsite is clearly shown in the table.

TABLE 1.

Hydrated silica	Brucite	Gibbsite	Halloysite	Kaolinite
4 OH 4 Si 6 O	6 OH 6 Mg 6 OH	6 OH 4 Al 6 OH	6 OH 4 Al 6 OH 4 OH 4 Si 6 O	6 OH 4 Al 4 O + 2 OH 4 Si 6 O
	thickness = 4.73	thickness = 4.86	thickness = 10.25	thickness = 7.2
Pyrophyllite	Montmorillonite	Mica (Muscovite)		
6 O 4 Si 4 O + 2 OH 4 Al 4 O + 2 OH 4 Si 6 O	6 O 4 Si 4 O + 2 OH 4 Al 4 O + 2 OH 4 Si 6 O water layer or layers	6 O 3 Si + Al 4 O + 2 OH 4 Al 4 O + 2 OH 3 Si + Al 6 O 2 K		
thickness = 9.4	thickness = 9.2-21.4	thickness = 10.0		

In Sir William Bragg's opinion, the main problem of the constitution of clays has now been solved: there are only two different groups of clays: (a) those allied to halloysite, kaolinite, nacrite, and dickite; and (b) those allied to pyrophyllite, the latter including montmorillonite, beidellite, bentonite, and fuller's earth, which differ chiefly in their metal contents, for example, in the extent to which gibbsite is replaced by brucite.

The suggested structures explain the colloidal properties of the smallest clay particles, the relatively 'enormous' effect of minute additions of alkalis or acids to clay pastes and suspensions, and they aid greatly in explaining variations in plasticity. Recent measurements by Bradley, Grim and Clark¹ have shown the existence of a well-defined set of hydrates in which the c axis increases regularly with the water molecules introduced into the unit cell. The looseness of these water molecules gives easy movement to the clay particles and yet prevents the complete loss of shape of the mass.

This peculiar ability of absorbing water molecules and arranging them in successive sheets in the layer-like structure of the clay crystal, causing

an increase in the c axis but not altering the lengths of the a and b axes, is, according to Sir William Bragg, "the cause of plasticity". The same structural arrangements also explain the remarkable property of 'base exchange' of some derivatives of montmorillonite clays (zeolites).

To sum up, the structures of the chief clay minerals shown in Table I enable clear, reasonable and simple explanations of the chief properties of clays to be formulated. Many details remain to be added, because it is difficult to obtain perfectly pure materials and because of the complications

due to the numerous substitutions which are usually present. Now that the general structure of clays has been so clearly elucidated, it should not be difficult to fit the details into their proper places.

All who are interested in the molecular structure of clay, whether theoretically or in connexion with the manifold uses of this very important material, should be very grateful to Sir William Bragg for his masterly solution of a problem which has, for so long, baffled many men of science.

A. B. SEARLE.

¹ *Z. Krist.*, 97, 216 (1937).

Obituary Notices

Sir R. F. Johnston, K.C.M.G., C.B.E.

WE regret to record the death of Sir Reginald Fleming Johnston, formerly commissioner for Wei-hai-wei and a distinguished Chinese scholar, which took place in Edinburgh on March 6 at the age of sixty-four years.

Johnston, who was educated at the University of Edinburgh and Magdalen College, Oxford, where he obtained a second class in the Final Honour School of Modern History, entered the Civil Service of the Hong-Kong Government in 1898 as a cadet. After serving as private secretary to the Governor and acting clerk to the Council and Assistant Colonial Secretary, he was appointed in 1904 secretary to the Government of Wei-hai-wei, then held under lease by the British Government. He remained there until 1919, when his special and profound knowledge of China and the Chinese led to his appointment as tutor to the Manchu Emperor P'u Yi, now the ruler of Manchukuo. This appointment came to an end with the flight of the Emperor in 1924. In 1926, Johnston was appointed secretary to the British Indemnity Delegation, and in the following year returned to Wei-hai-wei as Commissioner, his appointment coming to an end with the transfer of the territory to the Chinese Government. On his retirement, when he was already a C.B.E. and C.M.G., he was promoted to K.C.M.G.

On his return to England, Johnston accepted the chair of Chinese at the School of Oriental Studies in the University of London, an appointment which he held from 1931 until 1937.

As a Chinese scholar, Johnston's knowledge of the language and the people, of their ways of thought and their beliefs, was exceptionally wide, deep and sympathetic, although in this last respect it was distinctly perceptible that his understanding grew and mellowed as time went on. When he left Hong-Kong for Wei-hai-wei, he had already acquired no little insight into the widely varied conditions of life and the character of the peoples of the Far East. He made two extensive journeys of which the first in 1902 traversed Tonking, Yunnan, the Chinese Shan

States, the States of the Upper Laos and the plain of eastern Siam, ending at Bangkok. A later and more ambitious journey occupied nearly a year, during which Johnston lived for the most part in close touch with native life. This journey was described in "From Peking to Mandalay". On his transfer to Wei-hai-wei Johnston found himself in the Province of Shantung in close touch with the springs of all that is most traditional and changeless in the life of the Chinese peasantry. His studies here bore fruit in his scholarly and informative "Lion and Dragon in Northern China" (1910). This was followed in 1913 by his "Buddhist China", a sympathetic study of Chinese religious belief and philosophic thought, while his "Letters to a Missionary" (1918) affords a contrast in its trenchantly critical tone. "Twilight in the Forbidden City" (1934) records his experiences as tutor of the Emperor, whom he visited in Manchukuo in 1935, before proceeding to Mukden for the purpose of studying the archives of the Manchu.

Major F. G. Jackson

MAJOR FREDERICK GEORGE JACKSON, the Arctic explorer who died on March 13, was born in 1860 and educated at Denstone College and the University of Edinburgh. Attracted by an open-air life, he spent some time on a Queensland cattle ranch before the Arctic regions attracted his attention. A few months on a whaler in the Greenland Sea whetted his appetite and he offered his services to Nansen for the voyage of the *Fram*. But the *Fram's* complement was full and so Jackson decided to organize his own expedition. His plan was to attempt to reach the Pole by sledging north from Franz Josef Land, beyond which he, among others, believed that there existed a land which Payer, in 1873, had called Petermann Land.

In order to test equipment and to gain experience, Jackson decided first to undertake a winter journey in Arctic Russia. He began with a journey through the little-known Waigatz Island and then, failing to achieve his plan of exploring Novaya Zemlya, he