GEOLOGICAL ASPECTS OF THE ST. AUSTELL GRANITE

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Kaolin, or china clay, unlike most of the other clays mined in the United Kingdom, is residual in character, not sedimentary, being formed in situ in the mass of granite by decomposition of the original felspar. Granite occurs over a very considerable area of Great Britain but only in the granite bathylith of S.W. England, in Devon and Cornwall, does sufficient kaolinisation occur to justify extensive exploitation which has been proceeding now for over 180 years. The granite intrusion welled up from great depths under a cover of sedimentary rocks of much greater age, which cover had already undergone great tectonic stresses prior to the granite's arrival.

The age of the unfossiliferous sedimentaries in the far west of the area has been tentatively placed as Cambrian. To the east the Culm Rocks of Devon are of Lower Carboniferous age. The east-west succession is broken in several places by considerable unconformities. This cover has been estimated to have been from 2,000 to 3,000 ft. in thickness at the time of the intrusion which was, at the earliest, Post-Carboniferous. There are no younger rocks in evidence in the area until certain Tertiary beds (remnants at Bovey Tracey and Neath), followed by Quaternary gravel remnants on the higher ground and round the coasts in sheltered or up-lifted locations. The history is one of unusually prolonged aerial denudation which has left no traces and which has proceeded until the bosses of the granite mass have been exposed in each of the main hill masses of the peninsula. Of these there are seven main masses ranging from the greatest and highest of them all, Dartmoor, down, literally to the furthest west mass now only visible in its disintegrated parts as the Isles of Scilly.

The St. Austell mass is almost centrally placed in this chain. Its southern border is within two miles of the coast so that several harbours are within easy reach, and it is well served by road and rail. The highest point of the mass, at Hensbarrow Beacon, rises just above 1,000 ft. Most of the Clay pits, of which there are now about 40 active, lie between 400 and 900 ft. above sea level. Depths of the pits vary greatly but the average is between 200 and 250 ft., so that none as yet is below sea level.

The method of working is exclusively of the hydraulic open-pit type, the whole mass of the stripped-down granite being broken down by high-pressure water jets, assisted by some blasting. The other constituents of the granite, namely quartz, tourmaline, micas, etc., are waste products and have to be removed. As they form
about 85% of the mass, their disposal is one of the problems of the industry.

In addition the soil, sub-soil, and discoloured granite capping material, all lumped together as "overburden", have to be removed to obtain a representative sample of the true kaolin. The stained capping represents the result of surficial disintegration and decomposition proceeding downwards. Doubtless some kaolin is formed during this process but the latter is purely non-selective, and affects all the less stable minerals simultaneously. Such kaolin is rarely of any use and has no connection with the normal kaolinisation of the granite mass as a whole, which was undoubtedly due to the pneumatolytic processes characteristic of practically the whole granite mass of the West Country.

After the first consolidation of the granite further earth movements and regional stresses continued for a long period, so that the solid mass was riven again and again by cracks, producing a strongly jointed structure, which was easily intruded by the residual fractions of the still liquid magma from below.

These post-consolidation intrusions are the aplites, pegmatites and elvans (or felsites). In chemical composition they are like the main magma, and extremely fine-grained to coarse porphyritic in texture. They occur as dykes or sills intrusive to, and often occupying main joint planes of the mass and are in their turn faulted and altered by the later arrivals. Those which contain felspars may be kaolinised.

The next stage was the invasion by the pneumatolytic phases which are characterised by many of the quartz veins, and gave rise to the three main forms of alteration, tourmalinisation, greising, and kaolinisation. The metalliferous veins come into this category. Tourmalinisation is characterised by the formation of abundant tourmaline and quartz at the expense of the felspar and mica; greising by the formation of white mica and quartz at the expense of the felspar; kaolinisation by the formation of kaolin, white mica, and quartz at the expense of the felspar.

It will be seen that the felspars are the chief victims in all these processes, free silica is the chief product quantitatively, with white mica also prominent. In the case of greising, characteristic accessory minerals also formed are topaz and the green mica, gilbertite, which gives an unusual green colour in certain of the pits. None of these processes pervade the whole mass of the granite, nor are they hard and fast types; transitional forms occur. Very little of the St. Austell granite can however be considered, petrologically, unaltered or "fresh".

At the eastern end of the mass, near Luxulyan the rock seems fairly fresh. It is not absolutely uniform in character but it has been described as follows:—
ST. AUSTELL GRANITE

"A grey porphyritic granite in which the large felspars vary from an inch up to five inches in length. In certain tracts none of the very large felspars are present. The felspars are orthoclase, with some albite, and abundant plagioclase. They contain very little lime and belong therefore to the oligoclase-albite series. Large porphyritic crystals of quartz are not at all rare but are less perfectly formed than the felspars. The finer-grained matrix consists of biotite, muscovite, albite, orthoclase, quartz and a varying amount of tourmaline. Apatite, zircon, and magnetite are constant accessory minerals, whilst cordierite, topaz, andalusite and fluor spar are often present."

It will be seen that this granite is unusually rich in minerals of fluorine and boron; hence the commonly-held opinion that these elements were intimately associated with kaolinisation. After kaolinisation these minerals are still more prominent, especially tourmaline, but fluor spar also becomes significant, especially in the china stones, which occur in a specialised area near St. Stephens where they are quarried directly. Owing to the absence of the dark iron minerals and the lowered fusibility of the mass due to the fluor spar these rocks can be crushed and fired directly without any separation at all.

The quartz veins of the area are the most prominent features of the clay pits. They stand out in relief from the softer areas under the force of the water jets. They can be classified roughly into three groups. First the large almost pure quartz veins which came early in the pneumatolytic phase. Their purity is such that several of them are mined for their silica content which must be therefore 98-99% with almost no iron.

Secondly the quartz-tourmaline veins which are of all shapes, sizes and dispositions and are known in the pits as "blue" veins. Kaolinisation is most intense on either side of these veins and so tends to be connected in every observer's mind with that process. They are considered genetically identical with the tin-wolfram veins of western Cornwall, which are often accompanied by local kaolinisation wherever they penetrate granitic rocks.

The predominant strike of these veins is from WNW to ESE, which also agrees with that of the tin veins, but there is another series of these veins dominant in the area between the township of Bugle and the Dorothy pit with an average strike of NE by E to SW by S. It is by no means a coincidence that this area is the one best known in the St. Austell mass for its tin mining in former days. There is a third, very late, series of quartz veins of an average strike of N to S, which has little or nothing to do with the kaolinisation and has an association with iron. There are also many individual veins of erratic character.

If this account has been followed it will be appreciated that each pit, nay even each face in each pit, must present a very complicated
appearance to the poor miner seeking to work a more or less consistent sample of china clay; truly a very confused picture from a simple mass of granite usually tinted a uniform pink or red on geological maps.

How can we determine where to work these deposits and how to extract the clay? In the not-very distant past one could only make shallow pits, over restricted areas, often only through the soil, subsoil, and overburden. Many good clay deposits under hard capping rock were thus overlooked. From the scanty information thus disclosed the mine captain or the owner had to decide his future operations. Later, churn drilling, both by hand and assisted by power, was tried on a limited scale. A good deal of useful information was thus obtained but on the one all-important question of quality the results were not of much use owing to the contamination of the clay by the particles of iron or steel introduced by the abrasion of the tools. This abrasion is very great owing to the hard quartz grains in the mass.

Core-drilling seems to be the only answer, but this has not proved very successful for two practical reasons. The material is a very intimate mixture of hard quartz grains embedded in soft clay. Drilling a hole through or taking a core from such a mixture is extremely difficult owing to the disintegrating effect the water has on the clay constituent of the rock. It has been suggested that the only feasible method would be to drill and remove the cuttings with compressed air. This might work but would be very expensive and has not, to my knowledge, yet been tried.

In recent years geo-physical methods have come to our assistance. Clay absorbs the mineralized ground water in any area, giving it low electrical resistance compared with normal granite. Electrical resistivity tests therefore can give us very rapidly and cheaply a comprehensive structural picture, but here again they cannot inform us about the important properties, colour and quality.

However, the method can limit sharply the areas worth further examination, it can probe to considerable depth, and it can also prove the barren areas where we know we shall be safe in putting our waste products or where we may confidently site our drying kilns, power plants and other permanent works. In the restricted circumstances in which many of our works are forced to operate nowadays, the latter information is most valuable. The application of this method is in its infancy as yet and this is probably neither the time nor place to discuss it any further.

Let us now turn to the substance of kaolin itself. Orthoclase is a potassic aluminium silicate, $K_2O \cdot Al_2O_3 \cdot 6SiO_2$, which in the process of alteration becomes the simple hydrated silicate of aluminium, $2Al_2O_3 \cdot 4SiO_2 \cdot 4H_2O$. 


It is hardly necessary to remind this audience that there are many species of aluminous silicates. Determination of the particular species in the presence of any other closely allied mineral may be extremely difficult by chemical means, yet small amounts of such minerals may seriously affect the properties of the principal mineral. Montmorillonite can be quoted as an example in the case of kaolin. Such a problem is more amenable to physical methods of diagnosis, chiefly optical in character.

The plastic quality of kaolin, so important in many uses of the mineral, is considered today to be due to the tabular crystal form, in addition, of course, to the small particle size. As a measure of this plasticity a study is made of the viscosity of standard clay-water mixtures, usually called “slips” in the industry.

For ceramic purposes the firing qualities of the clay have to be examined and in all types of clay its colour, either in its raw state or after firing, is of importance. All these studies involve lengthy investigations which can only be undertaken by trained personnel in a properly equipped laboratory.

Scientific research also comes into the picture in connection with the refining of clay. This involves dispersal of the clay in a pulp of controlled density whilst the impurities drop out of the mixture. Subsequently the refined clay is thickened, pressed, and dried, all processes which demand, as time goes on, more advanced methods and more intensive scientific study.

These aspects of the industry are only mentioned in order to emphasise its complexity. All these details have to be correlated with the clay exposed in the working faces. There is bound to be a considerable time lag between the sampling and the formation of any opinion as to the clay’s suitability for the work. In the meantime, production has to go on and, as a practical miner rather than a research worker, it is this aspect of the matter which affects me the most.

Do these facts suggest that a more detailed examination of the direct geology of the deposits would be worthwhile? In other words would it be good business to add another scientific department to those mentioned? In my opinion an accurate geological survey of all our pits backed up by the existing research departments would give great returns in a very short time. The official Geological Survey of Great Britain is neither financed nor equipped to instigate original surveys of specific minerals and their occurrence. Our Survey has always followed up industry’s operations. Other countries, notably Canada and the U.S.A., have a different outlook and practice but so long as the present policy is pursued here industry must apparently take suitable action in its own interests.