Field excursion to study aspects of the St. Austell Granite and its related kaolinization and other mineralization, January 2002

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Introduction

The purpose of the field excursion was firstly to examine some aspects of the geology of the St Austell Granite around the area of Roche, especially two localities not much visited by geologists, and secondly to look at some aspects of the china clay industry, especially restoration and waste treatment. Three localities, the Tresayes Pegmatite Quarry, Great Wheal Prosper China Clay Pit and Gunheath China Clay Pit were visited before lunch, which was taken at the Rock Inn at Roche. In the afternoon, as the cloud base was very low, it was not possible to see the restoration and revegetation of some of the china clay waste tips. However, the time was spent profitably, driving mostly on the private haul roads of Imerys, through china clay 'country', especially the lower lying western part and visiting the Kernick Mica Dam, Melbur and Wheal Remfry pits, and a processing plant. This report describes the geology of the sites visited and gives an overview of the restoration and waste treatment currently used in the china clay industry.

Tresayes Pegmatite, Roche (SW 996587)

This is a new small nature reserve at Tresayes Downs near the hamlet of Trezaise, leased by the Cornwall Wildlife Trust from Goonvean Ltd. It is a former quarry known as Polpuff or 'The Glass Mine' (Cresswell Payne, 1946), from which feldspar was extracted, mainly in the early part of the 20th Century. The quarry was very overgrown, but has recently been cleared by the Wildlife Trust and the Cornwall RIGS Group, and a clean face of the pegmatite exposed. The quarry is approximately 30x60 m but may have been larger as the eastern and southeastern sides are covered by material forming part of a china clay waste tip.

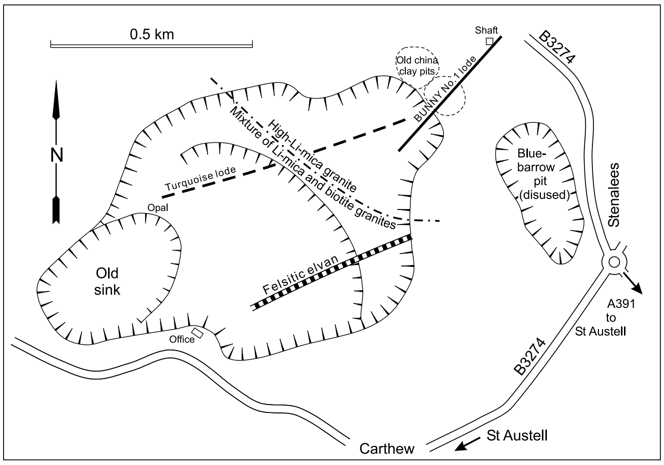

Figure 1. *Map showing the main geological features of Gunheath China Clay Pit.*

From the shape of the quarry and the visible exposures, the pegmatite appears to be fairly flat lying, although the upper contact in the western exposed face shows it locally to be dipping quite steeply to the west. It is intruded into the contact metamorphic aureole of the St. Austell Granite, near to the contact. The maximum visible thickness of pegmatite is 2.5-3.0m.

The dominant feature of the pegmatite is large feldspar crystals up to 0.5 m long mainly perpendicular to the upper and lower contacts. In three dimensions the crystals appear to be tabular, typically 0.5x0.1x0.4 m. Space between the large feldspar crystals is filled in by a second generation of feldspar, quartz, muscovite, tourmaline and rarely, other dark minerals, including cordierite, and others. Flat lying coarse quartz-rich veins cut the large feldspars in places, and later, thin aplite veins (3-10 cm) cut through the entire pegmatite. The lower visible contact of the pegmatite in the main exposure appears to be with an aplite, into which large feldspar crystals 'hang down'. Contact metamorphosed spotted slates can be found in other, overgrown, parts of the quarry.

The main uses of feldspar is in glass-making and ceramics, and it is assumed that the feldspar from this quarry was used for one or both of these purposes. The local name for the quarry implies that it was used for glass-making, older inhabitants of the area still referring to it as 'the glass mine'.

Great Wheal Prosper China Clay pit (SX 000587)

This china clay pit is owned by Goonvean Ltd. It is one of the smaller pits in the St. Austell area, and is situated within the Li-mica granite (Bristow and Exley, 1994) (also known as tourmaline granite, Manning *et al.*, 1996) near to its contact with the Devonian metasediments. The granite is variably kaolinized. The pit is elongated in a NNE-SSW direction, which presumably follows the distribution of kaolinization. This is co-incidental with a dominance of vertical to sub-vertical quartz-tourmaline veins, more massive quartz-tourmaline sheets and tourmalinite patches in the same orientation. A sheeted vein system consisting of fine (<1 cm) tourmaline veins is seen especially in the south side of the quarry. Areas with high concentrations of quartz-tourmaline sheets are the most kaolinized. A second set of thin (1 cm or so), approximately E-W quartz-hematite veins is also present. Isolated elongate patches of greisened granite, up to 1m in width and a few metres long also occur. Sections of head showing solifluction streaking are visible. The pit provides kaolin for both the paper and ceramic industries, and some of the sand-sized waste is used for local aggregate production.

Gunheath China Clay pit (SX 003567) (Figure 1)

The western part of the pit (not visited during the excursion) is in a mixture of low-Fe biotite granite and Li-mica granite (although grouped together as early lithionite granite by Exley, 1959, and tourmaline granite by Manning *et al*., 1996), variably kaolinized, typical of most of the western part of the St. Austell granite (for discussion of granite types, see Floyd *et al*., 1993, pp. 185-187; Hawkes *et al*., 1987; Manning *et al*., 1996). The northeastern part of the pit is in the southwestern side of the Hensbarrow high-Li-mica granite boss, analogous to the Nanpean stock of china stone granites, and is referred to as topaz granite by Manning *et al*. (1996). The highest Li-values (apart from the Meldon aplite) found in SW England are in this Hensbarrow boss (Hawkes *et al*., 1987). Hawkes *et al.* (1987) report mica concentrates containing 1.5% Li from this area. The contact between the granite types is not always easy to see; but, in the east corner of the pit, it is marked by a pegmatite analogous to the stockscheider pegmatite in Goonbarrow Pit, which lies on the other (northeastern) side of the Hensbarrow complex of high-Li-mica granites. Both the Stage 3 (for explanation of stages see Bristow and Exley, 1994) sheeted vein systems and the non-tourmaline bearing (Stage 4) cross-course veins appear to have greisen borders. Dextral displacement of the Stage 3 veins by the Stage 4 cross-course veins can be demonstrated in many places.

The workings of Bunny Mine (W, Sn) are seen in the northeast corner of the pit (Dines, 1956), exploiting a stockwork of veins trending NE. Bunny mine was the last working tin mine in this district, being worked to a depth of 130 m below surface until the end of the First World War. Magnetic separation was used to separate the tin from the wolfram, which occur in the ratio 2:1. The tin concentrate was unusually pale coloured, possibly due to the presence of varlamoffite. A good description of the dressing plant is given in Ussher *et al.* (1909, pp.135-6).

Gunheath Pit has yielded a range of unusual minerals, including turquoise, tin sulphides and hydroxides as well as many tin/tungsten/copper hydroxides, phosphates and sulphides. Manning (1983) described the tin sulphides and proposed some parageneses. Weiss (1989, translated and updated by Rothwell 1994) contains some coloured illustrations. Some of the minerals occurring in Gunheath Pit are listed in Table 1. In addition to those listed in Table 1, the following minerals are also recorded from Gunheath pit: ilmenorutile, bismuthenite, cuprite, kuramite, plancheite, arthurite, brochantite, cacoxenite, chalcosiderite, leucophosphite, scorodite, torbernite and variscite.

Restoration and waste treatment in the china clay industry

In the china clay industry the need for high quality china clay products has to be balanced with a commitment to protect and, where opportunities exist, to enhance the natural environment. To achieve this, environmental management systems based on the requirements of the international standard ISO 14001 are in place. This standard sets out guidelines on what companies should do to manage the environment in a responsible manner and in particular, to ensure that they comply with environmental legislation, control risks to the environment and continually improve their environmental performance.

For every one tonne of kaolin produced from the china clay industry in the St. Austell area there are nine tonnes of waste. Of this waste, 4.5 tonnes are rock, 3.5 tonnes are sand and one tonne is fine grained and rich in mica. Some of the sand and rock waste is sold for construction purposes locally, such as block-making, roadstone and concreting aggregate; but, far more is produced than can be consumed, and the waste accumulates in the large waste piles which are a characteristic feature of the whole of the china clay area. With the introduction of the Primary Aggregate Tax of £1.60 per tonne in April 2002, markets for aggregates made from china clay waste have developed further afield. These markets are likely to expand further in the future, taking up to a few million tonnes annually, with transport of the aggregates by ship from Par. However, a major part of the waste, along with the accumulated material from past china clay extraction, will still require to be held in piles (waste tips) adjacent to the pits. The fine grained waste is pumped to and stored in ponds known as mica lagoons.

Waste tips revegetate naturally but very slowly. Without assistance they remain barren for about thirty years before ling and heather begin to take hold. In a further ten years small shrubs appear, followed around ten years later by plants such as sallow and rhododendron, but a hundred years can pass before the tip becomes completely colonised by trees. China clay waste materials are deficient in nutrients, particularly nitrogen, making any initial growth hard to sustain. On steep sided tips the surface is very free draining and subject to erosion making nutrient addition very difficult. On flat-topped mica lagoons, which eventually dry out, the problems of erosion are less severe, but such structures lack naturally occurring nutrients.

Experiments and large-scale field trials have shown the most appropriate methods and plants for use in revegetation in each situation. At Maggie Pye (SW 935540) a disused mica residue dam was used initially as a major test site where experimental plots were laid out with a range of grasses, legumes and shrubs, each plot being given different fertiliser and aftercare treatments. This resulted in the selection of special blends of grass seed with nitrogen-fixing legumes, most frequently clover. Clover accelerates the rate of nutrient build-up and enables the sward to become established and if planned as eventual woodland, trees can be planted. The balance and management of plant types is crucial and the aftercare needed to ensure a sustainable plant cover continues for ten years or more. Trees succeed where shelter and nutrients are available, as demonstrated at Littlejohns Sand Tip (SW 990580). Here short-term trees such as pine and alder are used to provide initial shelter and nutrient, giving way to maturing long-lived native species such as oak.

In addition to problems of nutrient deficiency, traditional agricultural methods of seed and fertiliser application by tractor are impossible on steep-sided tips. For such situations a hydroseeding technique has been developed in which seed is suspended in a slurry of water and fertiliser along with a mulch material, and is sprayed from a specially adapted vehicle. The mulch protects the seed from the effects of adverse climatic changes and reduces losses by erosion.

Traditional agricultural methods are used to develop pasture land on mica lagoons, on back-filled pits and on re-shaped tips. These areas benefit greatly from being grazed. In the early 1970s St. Kilda Soay sheep were introduced to the new pastures. Being light, agile and independent they are well suited to improve the condition of the pasture, putting the land to commercial use at an early stage. Areas that are inappropriate for agricultural after-use are frequently planted as woodland

In locations where plant life of special significance has been disturbed or where particular amenity use is envisaged, the spread of native vegetation is encouraged by the transportation of seed. The two methods most commonly used are the removal to a new site of large cut clumps of the soil containing seeds and plant matter, or by flailing. Flailing involves the collection of seed-bearing branches and shoots from heathers and similar plants, which are cut and mixed with a mulch for spreading directly onto the new surface. Also involved are translocation of seed-rich soils, and seed collection (non-destructive) and sowing. The plant life provides a food source for insects and these in turn bring the small rodents that attract birds and other predators. Reclamation of the land provides a basis for the return of a full and balanced ecosystem.

In recent years, waste piles have changed considerably in their shape and design. The traditional steep-sided conical tips have not been allowed for a long time, because of the danger of instability and potential for slippage. Instead, tips are carefully engineered to prevent failure and designed to have shapes which are more similar to a natural landscape. Once completed and

Mineral	Comments
Cassiterite SnO_2	Occurs in the lodes of the old Bunny mine (striking NE) and as impregnations in the granite in the vicinity of the old Hensbarrow pit. Uncommon.
Stannite Cu_2FeSnS_4, Stannoidite $Cu_8(Fe,Zn)_3Sn_2S_{12}$, Mawsonite $Cu_6Fe_2SnS_8$	Manning (1983) suggests a paragenesis: stannite + stannoidite > stannoidite + bornite > mawsonite, with supergene alteration resulting in the formation of varlamoffite and turquoise. Occurs as a dark coloured impregnation in the high-Li-mica granite of the Hensbarrow boss and as coatings on joints. Difficult to identify in the field.
Varlamoffite $(Sn,Fe)(O,OH)_2$	The commonest tin-containing mineral in the NE part of the pit. Occurs as a creamy-yellow crust associated with turquoise and wlframite.
Wolframite $(Fe,Mn)WO_4$	Commonly found in the vicinity of the Bunny Mine workings. Occurs in radiating clusters, often associated with turquoise and varlamoffite.
Ferrocolumbite $(Fe^{2+},Mn^{2+})(Nb,Ta)_2O_6$	Black platy crystals. Occurs in pegmatites and is not related to the Sn/W/Cu mineralization.
Turquoise $CuAl_6(PO_4)_4(OH)_8.5H_2O$	Ferroan turquoise ('rashleighite') occurs in the famous 'Turquoise vein', which has been a feature of Gunheath pit for 40 years. It strikes between ENE and NE and extends from the old sink to the highest levels at the NE end of the present pit, adjacent to the workings of Bunny mine. Very little is of gemstone quality, but impregnation with resin can make it useable as a gemstone. Specimens from the vicinity of Bunny mine suggest that the wolframite and the turquoise are coeval. This is curious, as wolframite is typically a high temperature hydrothermal mineral and turquoise is typically a low temperature supergene mineral. Perhaps the turquoise is replacing an early high temperature precursor, such as a Cu sulphide.
Libethenite $Cu_2PO_4(OH)$	Dark green minutely crystalline mineral found in joints and fissures.
Dufrenite $Fe^{2+}Fe^{3+}_4(PO_4)_3(OH)_5.2H_2O$	Minutely globular clusters, variously dark brown, red or green. Associated with the Bunny mineralization.
Cyrilovite $NaFe^{3+}_3(PO_4)_2(OH)_4.2H_2O$.	Honey yellow crusts associated with the Bunny mineralization.
Lepidolite $K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$	Pale brown or silvery brown in colour, part of a solid solution series between zinnwaldite and lepidolite (see diagrams in Hawkes *et al*., 1987, pp16-17). A ferroan variety. Associated with quartz veins and greisens.
Zinnwaldite $KLiFe^{2+}Al(Al,Si_3)O_{10}(F,OH)_2$	Pale brown micaceous mineral found as a primary component of the high-Li-mica granite and the pegmatites. Commonest form of Li-mica.
Gilbertite	A variety of muscovite, greenish in colour and common in the pit. This gives greisens their typical green colour.
Wavellite $Al_3(PO_4)_2(OH,F)_3.5H_2O$.	Radiating crystalline masses found associated with 'rashleighite' in the lodes of Bunny Mine.
Fluorite CaF_2.	Violet encrustations of fluorite on joints in the high-Li-mica granite are common.
Apatite $Ca_5(PO_4)_3(F,OH,Cl)$.	Colourless or blue apatite can be found in pegmatitic vugs in the high-Li-mica granite.
Opal SiO_2,nH_2O,	Can be found towards the western part of Gunheath pit.

Table 1. *Reported minerals from Gunheath Pit.*

revegetated they can be made to blend in with the surrounding environment. Imerys is currently working in partnership with English Nature to re-create and restore 750 hectares of lowland heathland on china clay waste tips and hopes to augment this with approximately 800 ha of broadleaf woodland.

The mica-rich fine waste from virtually all of the china clay processing in the St. Austell area currently accumulates in the Kernick Mica Dam lagoon (SW 940550). This large structure has been taking fine waste mixed with water for more than 30 years. It is situated on the east side of the River Fal valley. Its lower sides are already vegetated. Within a few years it will reach its capacity, and a further location for depositing this waste will need to be found.

Much water is used in china clay extraction, and processing consumes more. Most of it is recycled, but some is discharged into water courses in the St. Austell area, such as the River Fal. The discharge is monitored for turbidity and pH. Settling ponds or chemicals to ensure flocculation and removal of fine particles are used before discharge is permitted.

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