C12 Tregargus Quarries

[SW 949 541]

Highlights

Tregargus Quarries are unusual in that they contain the two late-magmatic variants (non-megacrystic lithium–mica–topaz granite and fluorite granite) of the St Austell sequence; examples of late- and post-magmatic mineralization and alteration are developed.

Introduction

The Tregargus Quarries (Figure 5.10) are sited in fluorite granite which contains patches of non-megacrystic Li-mica–albite–topaz granite (Types E and F, (Table 5.1)). These facies, which are surrounded by megacrystic Li-mica–albite–topaz granite (Type D, (Table 5.1)), are part of the western intrusion of the St Austell mass recognized by Richardson (1923), Exley (1959), and others subsequently. This intrusion was emplaced alongside an earlier biotite granite boss centred on Luxulyan (Figure 5.10), a distinction not identified by the early Geological Survey work (Ussher *et al.,* 1909). The western intrusion was originally biotite granite also, but it was largely metasomatically altered by the incoming Li-mica–albite–topaz granite magma (Hawkes and Dangerfield, 1978; Dangerfield *et al.,* 1980; Hawkes *et* al., 1987), which had itself been generated from biotite granite at depth (Stone, 1975; Manning and Exley, 1984; Pichavant and Manning, 1984).

Fluorite granite ('china stone' or 'Cornish stone') such as that at Tregargus, was thought by Ussher *et al.* (1909) and Howe (1914) to be an intermediate stage in the breakdown of granite to china clay, but Coon (1913a, 1913b) regarded it as a late variety modified by circulating water. Exley (1959) believed it to be the youngest member in a differentiation sequence, but the current view (Manning and Exley, 1984); Pichavant and Manning, 1984) is that it is a by-product of the complex metasomatic processes by which the Li-mica–albite–topaz granite altered its biotite granite host.

Post-magmatic greisening and tourmalinization are seen in the veins of the quarries, and there is considerable early kaolinization. The last process has given rise to much controversy. One school of thought, exemplified by Hickling (1908) and Sheppard (1977), argued that it resulted from extensive deep weathering, but a second (for example, Collins, 1878, 1887, 1909; Butler, 1908; Ussher *et al.,* 1909; Howe, 1914; Exley, 1959, 1964, 1976) held that it was due to hydrothermal fluids of magmatic origin. A third, currently popular thought, attributes kaolinization to a combination of processes of both kinds (Coon, 1911, 1913a, 1913b; Tomkeieff, discussion in Exley, 1959; Bristow, 1977; Durrance *et al.,* 1982; Bristow *et al.,* in press).

All of these evolutionary concepts are put into historical context in the Petrogenesis' section of this chapter.

Description

The Tregargus Quarries are just under 1 km north-west of St Stephen, a village 7 km west of St Austell, and are towards the southern limit of an elliptical area, roughly 3.5 km from north to south and 1.25 km from east to west, which, for convenience, is here called the Nanpean area (Figure 5.10). Within it occur two of the four main varieties of St Austell Granite (Exley, 1959; Exley and Stone, 1982; Exley *et al.,* 1983; Manning and Exley, 1984) which have been extensively worked for china stone, the latter formerly being used as a flux in pottery manufacture.

In the Nanpean area most of the rock contains lithium-mica (zinnwaldite – Stone *et al.,* 1988), albite and topaz. Its texture is not megacrystic, and it encloses irregular patches, up to 400 m across and at least 70 m deep, of fluorite granite. The latter have rapidly transitional, non-intrusive contacts with the former, which the fluorite granite resembles in texture and composition apart from having no iron-bearing minerals (the mica is muscovite) and an average of 2% fluorite (Table 5.1). The two most important areas are immediately west of Nanpean and around Tregargus.

The rock in the Nanpean area escaped the potassium metasomatism which gave rise to large feldspar megacrysts elsewhere in the St Austell mass, but they do show, in varying degrees, greisening, tourmalinization and kaolinization. The first is both pervasive through the rock, but restricted to the replacement of some of the K-feldspar, and localized, where it occurs as true greisen borders a few centimetres thick alongside quartz and quartz–tourmaline veins. Tourmalinization, although pervasive in other places, having produced much (4%) tourmaline within the megacrystic Li-mica granite (Type D, (Table 5.1)), is localized in veins at Tregargus.

Kaolinization, and its relationship to joints and faults, is best seen in the non-megacrystic Li-mica granite, the fluorite granite largely remaining fairly fresh, although, where it has been affected, it used to be graded from fresh 'hard purple' to altered 'soft white' by quarrymen before being sold for pottery making (Exley, 1959; Keeling, 1961).

The predominant rock at the Tregarkus Quarries is fluorite granite, and all grades of china stone occur, although not much 'hard purple'. The non-megacrystic Li-mica granite (Type E, (Table 5.1); locally known as shellstone) is to be found in irregular areas, no larger than a few square metres, but in such a way that the relationships between the two types may be seen. All the rock has been altered and veined in the manner described above. Among less-usual minerals found in the quarries are autunite, gilbertite and killingite.

Interpretation

As has been indicated in the 'Petrogenesis' section, the St Austell Granite, which is unique in Britain, has had a more complicated evolution than the other Cornubian granite masses, starting with the intrusion of a boss of coarse-grained megacrystic granite characterized by biotite and zoned oligoclase ($An_{25–30}$) (Type B, (Table 5.1); Exley and Stone, 1982), centred on Luxulyan. Subsequently, a second intrusion was emplaced to its west, cutting across both the earlier granite and its metamorphic aureole. The second intrusion also consisted of biotite granite, and it is thought to have included several facies (Hawkes and Dangerfield, 1978; Manning and Exley, 1984; Hill and Manning, 1987). The later intrusion, however, did not rise as far as the first so that a large, but thin, area of its thermally metamorphosed Lower Devonian roof still remains north of St Dennis, penetrated by granite in several places (Figure 5.10).

Much of the biotite in the second intrusion has been replaced by lithium-mica (now known to be zinnwaldite; Stone *et al.,* 1988), and the four main varieties of St Austell Granite were thought at one time to constitute a magmatic differentiation series of biotite granite (Type B) megacrystic Li-mica granite (Type D) non■ megacrystic Li-mica granite (Type E) –+ fluorite granite (Type F) (Richardson, 1923; Exley, 1959). However, subsequent work has shown that this is not the case. It is now believed that, as a consequence of fluorine and water concentration, a residual 'magma' separated at depth from the biotite granite magma and that this contained relatively high concentrations of Li and Na rather than Fe and Ca, similar to the state, of affairs in the Tregonning–Godolphin area in west Cornwall (Stone, 1975; Manning, 1982; Pichavant and Manning, 1984). This residual magma intruded the second St Austell boss to give the non-megacrystic Li-mica–albite–topaz granite now seen in the Nanpean area (and also near Hens-barrow Beacon; see (Figure 5.10)). Under the influence of highly volatile fluids (particularly of fluorine and water) emanating from this intrusion, biotite and oligoclase of the earlier rocks were altered. Iron was replaced by Li to give zinnwaldite, and Ca was replaced by Na to give albite (An_7); other adjustments, especially of Al, took place concurrently and gave rise, *inter alia,* to topaz. Excess Ca combined with F to produce fluorite, and hence local patches of fluorite granite, and excess Fe combined with B to form tourmaline (Manning and Exley, 1984; Pichavant and Manning, 1984). The megacrystic Li-mica granite (Type D, (Table 5.1)) in most of the western intrusion is thus interpreted now as a metasomatic aureole of the Nanpean (Type-E) Li-mica granite.

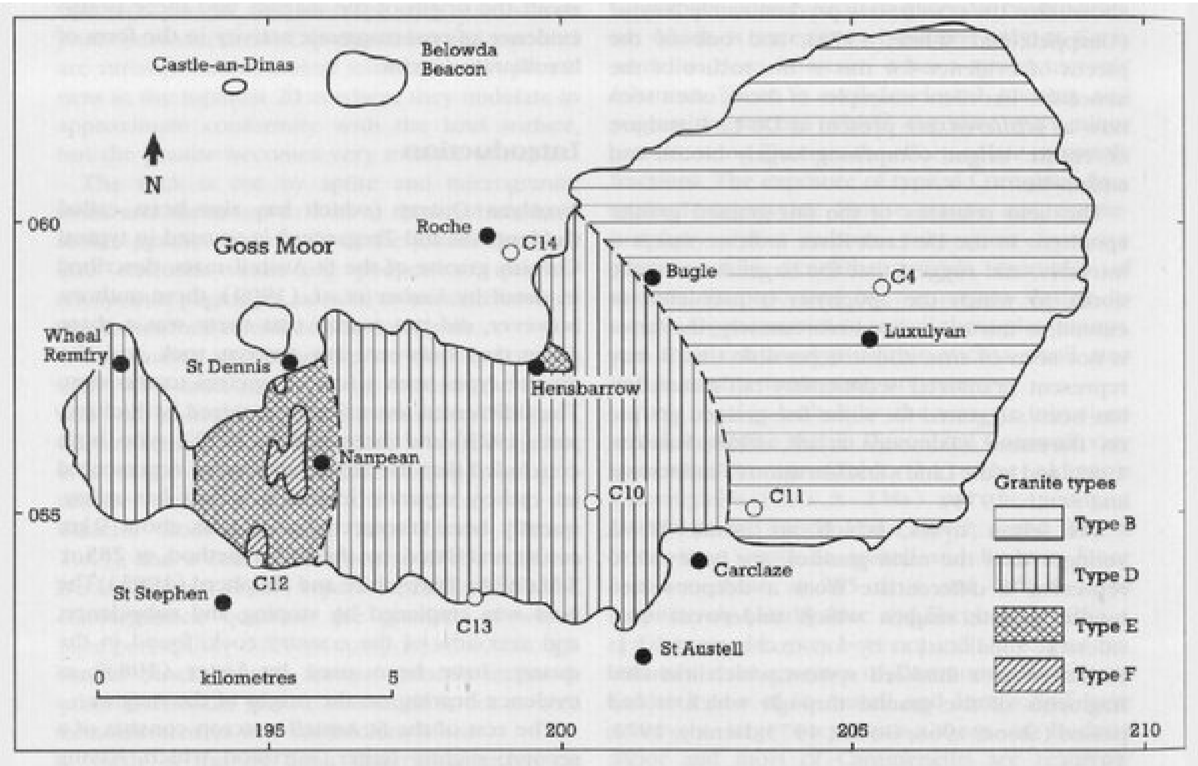
Some mineralization was associated with the intrusion of the coarse biotite granites in Devon and Cornwall, but the main period followed about 10 Ma later, at about 270 Ma BP (Jackson *et al.,* 1982). It is believed, on field and other evidence, to have been consequent on the intrusion of the Li-mica–albite–topaz granite (Manning and Exley, 1984; Darbyshire and Shepherd, 1987; Bristow *et al.,* in press). The existence of both pervasive and vein-concentrated greisening and tourmalinization throughout the western intrusion attest to the circulation of volatiles, especially water, F and B, and to a sequence of metasomatism, alteration and replacement continuing through the late-magmatic and into the post-magmatic stages (Figure 5.4).

The fact that kaolinization is often found beneath unaltered rocks and to great depths effectively seemed to have ruled out weathering as a cause, until Sheppard (1977) described stable isotope ratios which indicated clearly that meteoric water was of the greatest importance. This led to a revival of interest (Bristow, 1977) in a combined magmatic/hydrothermal and weathering mechanism such as had been proposed by Hickling (1908), Coon (1911, 1913a, 1913b) and, more positively, by Tomkeieff (discussion *in* Exley, 1959). These authors envisaged an initial hydrothermal alteration, breaking down feldspar to mica and increasing porosity, followed by weathering to complete the process. The recognition of convection cells, circulating meteoric water driven by radiogenic heat (Figure 5.8), and the probability of such activity during the Mesozoic and Cenozoic (Durrance *et al.,* 1982), has enabled a detailed chronology of the intrusion–mineralization–kaolinization continuum to be built up (Bristow, 1987; Bristow *et al,* in press; (Table 2.2)). During this, the original magmatic water was progressively replaced by meteoric water from the country rocks, bringing elements which, at appropriate temperatures, formed the various mineral deposits and finally brought about low-temperature processes such as kaolinization which have continued through to the present. Evidence of all the chronological stages of (Table 2.2), except stages 1 and 2, is present at Tregargus.

Conclusions

This site contains the only examples now readily accessible of the two youngest varieties of the chief members of the St Austell suite. The granite here originally contained the dark mica biotite, but because of concentrations of certain elements in the final granite magma and its associated solutions, reactions were set up which converted the original mineral composition and produced a different granite enriched in new elements, including lithium and fluorine. Formerly variously attributed to hydrothermal alteration and magmatic differentiation, the Li-mica–albite–topaz granite is now thought to have been derived from a late-stage magma originating at depth, and the fluorite granite to have been the result of complex metasomatic exchanges with earlier biotite granite. Also to be seen are greisen and quartz–tourmaline veins and kaolinized rock. These have spatial relationships with both the fracture system and fresh rock which show that they have resulted from solutions, now known to be largely of meteoric origin, which have travelled up from deeper levels and penetrated the walls of the fractures.

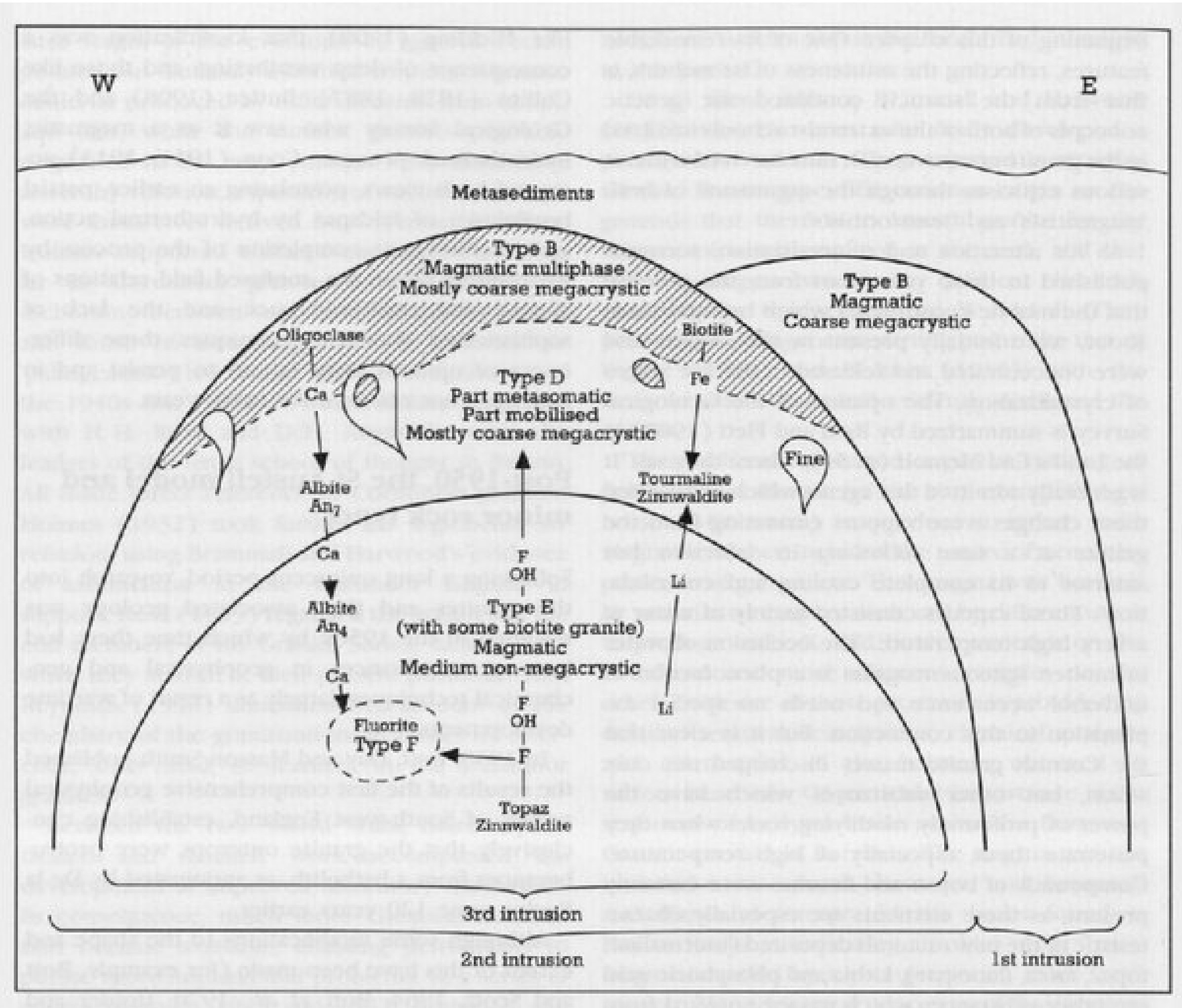
References



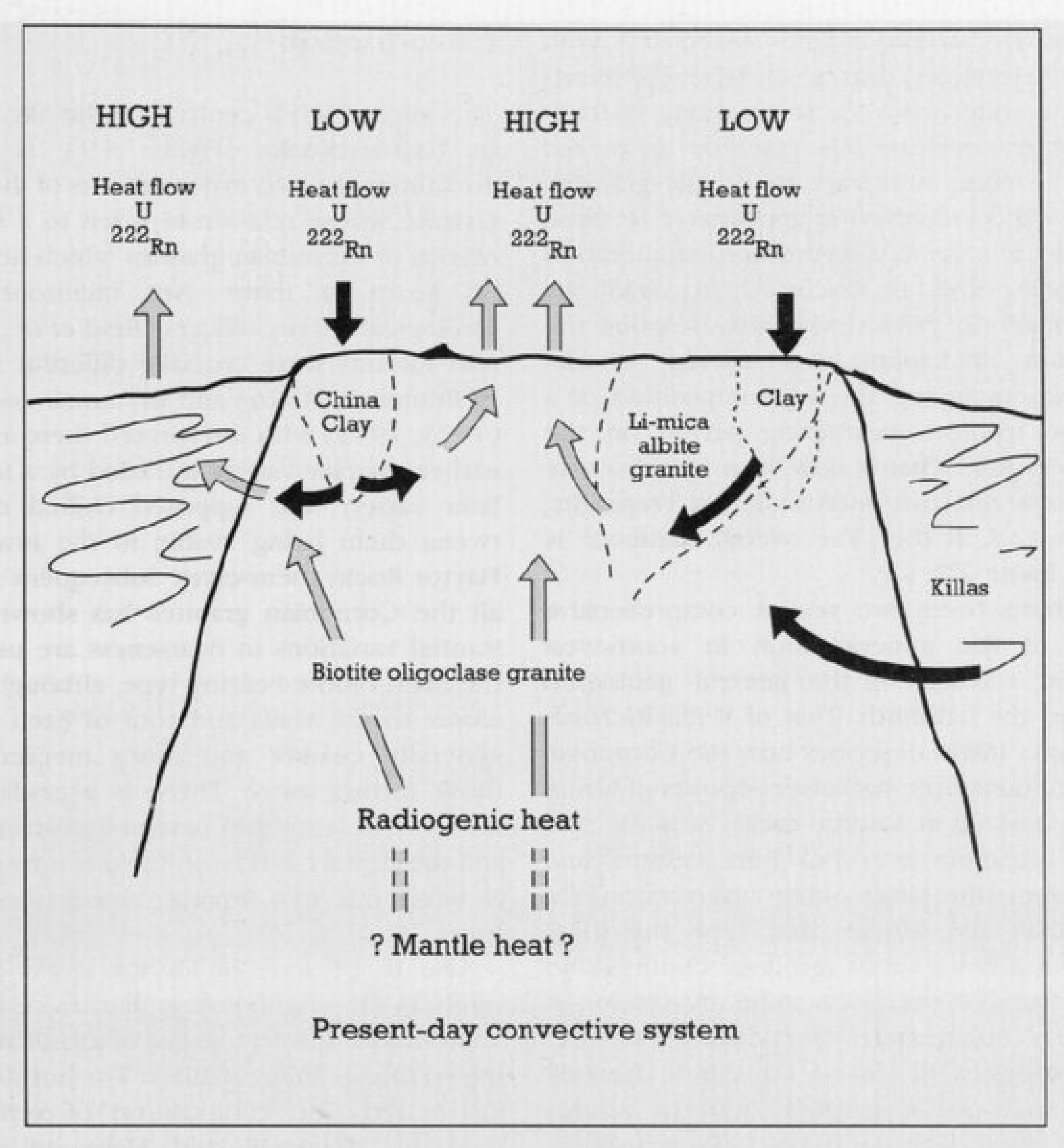
(Figure 5.10) Map of the St Austell Granite outcrop, showing the chief granite types, localities mentioned in the text (filled circles) and the following sites: C4 = Luxulyan Quarry; C10 = Wheal Martyn; C11 = Cam Grey Rock; C12 = Tregargus Quarries; C13 = St Mewan Beacon; and C14 = Roche Rock.

Type	Description	Texture	Minerals (approximate mean modal amounts in parentheses) K-feldspar	Plagioclase	Quartz	Micas	Tourmaline	Other	Other names in literature
A	Basic microgranite	Medium to fine; ophitic to hypidiomorphic	(Amounts vary)	Oligoclase-andesine (amounts vary)	(Amounts vary)	Biotite predominant; some muscovite	Often present	Hornblende, apatite, zircon, ore, garnet	Basic segregations (Reid et al., 1912); Basic inclusions (Brammall and Harwood, 1923, 1926)
B	Coarse-grained megacrystic biotite granite	Medium to coarse; megacrysts 5-17 cm maximum, mean about 2 cm. Hypidiomorphic, granular	Euhedral to subhedral; microperthitic (32%)	Euhedral to subhedral. Often zoned: cores An_{22}-An_{30}, rims An_8-An_{15} (22%)	Irregular (34%)	Biotite, often in clusters (6%); muscovite (4%)	Euhedral to anhedral. Often zoned. 'Primary' (1%)	Zircon, ore, apatite, andalusite, etc. (total, 1%)	Includes: Giant or tor granite (Brammall, 1926; Brammall and Harwood, 1923, 1932) = big feldspar granite (Edmonds et al., 1968), coarse megacrystic granite (Hawkes and Dangerfield, 1978). Also blue or quarry granite (Brammall, 1926; Brammall and Harwood, 1923, 1932) = poorly megacrystic granite (Edmonds et al., 1968), coarse megacrystic granite (mesocrystic type) (Hawkes and Dangerfield, 1978), coarse megacrystic granite (small megacryst variant) (Dangerfield and Hawkes, 1981). Also medium-grained granite (Hawkes and Dangerfield, 1978), medium granites with few megacrysts and megacrysts very rare (Dangerfield and Hawkes, 1981). Biotite-muscovite granite (Richardson, 1923; Exley, 1959). Biotite granite, equigranular biotite granite, and globular quartz granite (Hill and Manning, 1987).
C	Fine-grained biotite granite	Medium to fine, sometimes megacrystic; hypidiomorphic to aplitic	Subhedral to anhedral; sometimes microperthitic (30%)	Euhedral to subhedral. Often zoned: cores An_{10}-An_{15} (26%)	Irregular (33%)	Biotite 3%; muscovite (7%)	Euhedral to anhedral. 'Primary' (1%)	Ore, andalusite, fluorite (total, <1%)	Fine granite, megacryst-rich and megacryst-poor types (Hawkes and Dangerfield, 1978; Dangerfield and Hawkes, 1981)
D	Megacrystic lithium-mica granite	Medium to coarse; megacrysts 1-8.5 cm, mean about 2 cm. Hypidiomorphic, granular	Euhedral to subhedral; microperthitic (27%)	Euhedral to subhedral. Unzoned, An_7 (26%)	Irregular; some aggregates (36%)	Lithium-mica (6%)	Euhedral to anhedral 'Primary' (4%)	Fluorite, ore, apatite, topaz (total, 0.5%)	Lithionite granite (Richardson, 1923). Early lithionite granite (Exley, 1959). Porphyritic lithionite granite (Exley and Stone, 1964). Megacrystic lithium-mica granite (Exley and Stone, 1982)
E	Equigranular lithium-mica granite	Medium-grained; hypidiomorphic, granular	Anhedral to interstitial; microperthitic (24%)	Euhedral. Unzoned, An_4 (32%)	Irregular; some aggregates (30%)	Lithium-mica (9%)	Euhedral to anhedral (1%)	Fluorite, apatite (total, 2%); topaz (3%)	Late lithionite granite (Exley, 1959). Non-porphyritic lithionite granite (Exley and Stone, 1964). Medium-grained, non-megacrystic lithium-mica granite (Hawkes and Dangerfield, 1978). Equigranular lithium-mica granite (Exley and Stone, 1982). Topaz granite (Hill and Manning, 1987)
F	Fluorite granite	Medium-grained; hypidiomorphic, granular	Sub-anhedral; microperthitic (27%)	Euhedral. Unzoned, An_4 (34%)	Irregular (30%)	Muscovite (6%)	Absent	Fluorite (2%), topaz (1%), apatite (<1%)	Gilbertite granite (Richardson, 1923)

(Table 5.1) Petrographic summary of main granite types (based on Exley et al., 1983)



(Figure 5.4) The St Austell model. Diagram showing the first intrusion of Type-B granite (Table 5.1) cut by multiphase second intrusion of biotite granite, with metasomatic aureole of Type D caused by intrusion of Type E.



(Figure 5.8) Diagrammatic representation of water circulation in Cornubian granite. Areas of low heat flow, U and ^{222}Rn concentration are associated with china clay and indicate draw-down; areas of high heat flow, U and ^{222}R11 concentration indicate uprise (based on Durrance et al., 1982).

Stage	Process	Age (millions of years) *	Depth (km)	Temperature (°C)	Salinity of fluids	Source of heat	Direction of least stress	Main changes in mineralogy			Associated metalliferous mineralization	Comments
								Feldspar	Quartz	Mica		
I	Emplacement of biotite granite, forming main batholith	290-285	?3	500-600	-	Magmatic	Variscan (E-W)	-	-	-	-	Biotite granite which now forms eastern part of the St Austell granite
II	First phase of post-magmatic alteration and mineralization	285-275	2-3	500-?200	Moderate	Magmatic	Initially E - W, then N - S	Limited greisenization alongside veins	-	-	Sn, W	Early greisenization and mineralization e.g. Castle-an-Dinas (W)
IIa	Emplacement of evolved lithium-rich granites and biotite granites in western part of St Austell granite	275-270	2-3	500-600	-	Magmatic	N - S	-	-	-	-	Granites belonging to this phase may underlie much of the batholith. Granites hydraulically fractured
IIIb	First part of second phase of post-magmatic alteration and mineralization	275-270	?2	400-300	Moderate	Mainly magmatic, some radiogenic	N - S or NW - SE	Greisenization: converted to quartz, mica and topaz by F-rich fluids, mica of gilbertite type. Tourmalinization: replaced by tourmaline	Repeatedly fractured and fractures annealed by fresh growths of quartz	Some re-crystallization, biotite loses iron which is taken up by tourmaline growth	Sn, W, Cu	Main phase of metalliferous mineralization
IIIc	Emplacement of felsitic elvan dykes	275-270	?2	400-500	Moderate	Magmatic	N - S	-	-	-	Sn, W, Cu	Further input of magmatic heat
IV	First phase of argillic alteration and NW-SE or N-S quartz-hematite veins and faulting	270-260	? 1-2	350-200	Moderate to high	Mainly radiogenic, possibly some magmatic or mantle heat	E - W	Na feldspar: altered to smectite/illite assemblage, little kaolinite. K feldspar: altered to illite, maybe some smectite	Free silica released by argillation, forms overgrowths on quartz and now iron-stained non-tourmaline bearing lodes (NW - SE and N - S)	Much iron liberated from biotite which is carried out of the granite to form iron lodes. Some mica hydrated to gilbertite	Fe/U/Pb/Zn	Note: Salinity, lack of kaolinite and change in stress direction. Low temperature metalliferous mineralization
Quiescent period?												
V	Second phase of argillic alteration. Main period of kaolinization. ?Deep Mesozoic supergene alteration?	260 to present	0.2-1.5	50-150	Low	Radiogenic	Variable E - W or N - S, later becoming vertical	Na feldspar: altered readily to kaolinite. K feldspar: altered less readily to kaolinite. Smectite: altered readily to kaolinite	Free silica released by argillation, forms overgrowths on quartz and some minor quartz veins	Some iron liberated from biotite, not carried out of granite so colours matrix. In areas of intense kaolinization mica/illite altered to kaolinite	Fe/U (minor)	Note: Fresh water and main episode of kaolin formation. Isostatic uplift may have played a part
VI	Early Tertiary chemical weathering (also Mesozoic?)	25-60	0.0-0.2	20-50	Low	High surface temperature	Vertical	Altered kaolinite, is b-axis disordered in Eocene/Oligocene weathering	Some solution of silica from quartz grains	Some iron liberated from biotite, not carried out of the granite so colours matrix. In areas of intense kaolinization mica/illite altered to kaolinite	-	Tertiary weathering mantle is source of material for ball clays and associated sediments

* Radiometric dates from Bray (1980), and Darbyshire and Shepherd (1985, 1987)

(Table 2.2) Main evolution and alteration stages of the St Austell Granite (after Bristow et al., in press)