C4 Luxulyan Quarry (Golden Point, Tregarden)

[SX 054 591]

Highlights

Luxulyan Quarry contains the coarse, megacrystic biotite granite of typical Cornubian type which forms the earliest variety in the complex magmatic sequence at St Austell. Its fresh xenoliths of pelitic and semipelitic sediment provide evidence about the origin of the magma, and there is also evidence of post-magmatic activity in the form of luxullianite *in situ.*

Introduction

Luxulyan Quarry (which has also been called Goldenpoint and Tregarden) is situated in typical Cornish granite of the St Austell mass, described in detail by Ussher *et al.* (1909); these authors, however, did not realize that there was a sharp distinction between this eastern rock and the granite types seen a few kilometres to the west. The differences were first recognized by Richardson (1923) and later Exley (1959), who both concluded that the Luxulyan Granite represented an earlier, separate intrusion which has subsequently been interpreted as a boss about 9 km across and dated, by the Rb/Sr method, at 285 ± 4 Ma BP by Darbyshire and Shepherd (1985). The boss was emplaced by stoping and subsidence, and xenoliths of the country rock, found in the quarry, have been used by Lister (1984) as evidence bearing on the origin of the magma.

The rest of the St Austell outcrop consists of a second, slightly larger, intrusion which, having been emplaced to the west of the Luxulyan Granite, was itself intruded by a magma of entirely different composition and was altered by a complex interchange of elements in a volatile-rich environment. The changes and mechanisms are noted in general terms in Chapter 2 and the Tetrogenesis' section above, and in detail in the appropriate site descriptions. It is sufficient here to note that, although widespread in the western area, they have affected the Luxulyan area to only a moderate degree (Figure 5.4).

Among the few volatile-induced modifications, however, was the formation of luxullianite. This rock, described by Bonney (1877a), Flett *in* Ussher *et al.* (1909) and by Wells (1946), was known only from boulders until found *in situ* by Lister (1978, 1979a, with a contribution by Alderton (1979)). Lister (1979b) also used material from this site in her study of quartz-cored tourmaline.

Description

The granite at Luxulyan (Figure 5.10) has been described (Dangerfield and Hawkes, 1981) as 'coarse megacrystic' and as Type B (Table 5.1) (Exley and Stone, 1982). It is characterized by biotite and zoned oligoclase (An_{25-30}), and contains abundant K-feldspar megacrysts between 20 and 100 mm in length. These are generally aligned and commonly include zones (containing quartz, plagioclase and biotite) indicative of growth following a potassium-rich metasomatism process. Other minerals include muscovite, tourmaline and trace quantities of apatite, topaz, andalusite, fluorite, zircon and iron ore. The rock is closely comparable with the other coarse biotite granites of Cornwall and Devon and its mineralogy and chemistry show that, despite its early arrival in the St Austell sequence, it is a highly evolved, high-level variety (Table 5.2).

Evidence bearing upon the emplacement of this granite is seen in the abundant, rounded xenoliths, which are usually about 20 mm across, but range up to about 130 mm. These are mainly composed of quartz and abundant biotite, but sometimes contain andalusite. The majority have lost any foliation that they might have had, but have not yet been sufficiently 'granitized' to develop feldspar. They are clearly of pelitic or semipelitic origin and derived from the stoping of its walls by the magma. Fresh cordierite has been recorded from this quarry (Ussher *et al.,* 1909).

Luxullianite, an attractive rock composed of red K-feldspar, acicular tourmaline and quartz, and formerly used as an ornamental stone, occurs in often discontinuous, near-vertical sheets which sometimes anastomose. These strike approximately ENE–WSW, and are up to a metre or two in thickness. The jointing is both more extensive and less regular than in many Cornubian exposures, and some joints show evidence of post-magmatic activity in the form of reddening and veining by quartz and tourmaline. Sometimes, such tourmaline has cores of quartz or feldspar (Lister, 1979b). There are also small pods, up to 0.5 m in diameter, of pegmatite consisting of the chief minerals of the granite but mostly deficient in plagioclase. A major joint, with a veneer of tourmaline striking 070°, serves as the quarry wall beneath the crushing plant.

Kaolinization, not due primarily to weathering, is confined to a zone striking N–S and tapering downwards in width from about 10 m. This separates the north-eastern quarry from the rest of the site.

Interpretation

The granite at Luxulyan is typical of the eastern part of the St Austell outcrop, which, having been recognized as significantly different from the granite in the western part (Richardson, 1923; Exley, 1959), was interpreted by the latter as the first member of a magmatic differentiation series. This interpretation followed from its relative enrichment in Ca and Fe (exhibited in oligoclase and biotite) and impoverished in Na (in albite), Li (in zinnwaldite), B (in tourmaline) and F (in topaz) (Table 5.1) and (Table 5.2). Later work has shown, however, that much of the western granite has a similar texture to that in the east and a composition intermediate between the medium-grained Li-mica–albite–topaz granites (Type E, (Table 5.1)) and the biotite granite. Hence the present interpretation is that the first member of the western intrusion was also a biotite granite, much of which was metasomatized by incoming Li-mica–albite–topaz granite derived at depth (see Chapter 3 and the Petrogenesis' section of this Chapter). The first importance of the Luxulyan site therefore lies in its exposure of the rock held to be the earliest in both hypotheses.

Theories about the derivation of the Cornubian granite magma agree that it resulted essentially from partial melting of a lower crustal source. However, the extraordinary enrichment of the batholith, relative to average granites, in such elements as Sn, W and Cu, Li, Sr and Ba, U and Th and B and F have led to speculation as to whether their provenance was middle or lower crustal or subcrustal (Simpson *et al.,* 1976, 1979; Watson *et al.,* 1984), and to what extent they were incorporated either from already enriched crustal material or from some subcrustal source. A study of xenolith material, some of which came from Luxulyan Quarry, has suggested that Sn, W, U and Ta were not derived from pelitic sediments, that V, Ba, Sr, Cu and Zn might have been, and that some elements which could easily have escaped from the magma (for instance, Li, Th and F) were in fact retained and concentrated in biotite-rich xenoliths. Those elements not derived from assimilated sediments must have been magmatic. Luxulyan xenoliths are thus of importance in the petrogenetic history of the Cornubian granites (Lister, 1984).

Granitic rocks generally similar to luxullianite have been found in various parts of south-west England, and it is agreed, from textural evidence, that they were formed by the post-magmatic alteration process described as lourmalinization'. Flett (in Ussher *et al.,* 1909), however, when contrasting luxillianite with the tourmalinite of the Roche Rock 6–7 km to the WNW, observed that 'In luxullianite the process of metasomatic replacement has stopped at the half-way stage'. There has also been disagreement over the nature of the replacement and the original mineralogy. Thus, Bonney (1877a) thought that brown tourmaline had replaced biotite, but both Flett (1909) and Wells (1946) believed that biotite had never been present, brown tourmaline occurring instead. Again Bonney thought that acicular, blue, secondary tourmaline formed from feldspar, but Flett and Wells considered that it replaced both feldspar and brown primary tourmaline. Lister's (1978) examination of the first *in situ* luxullianite to be described makes it clear that biotite and primary tourmaline coexist, and that secondary tourmaline came from a hydrothermal generation and did not involve the breakdown of the primary crystals. However, the chemical changes between unaltered granite and luxul-lianite described by Lister (1978) differ from earlier suggestions, principally in showing a decrease in SiO_2 and an increase in K_2O and, following a discussion by Alderton (1979), she agreed that probably there had been a combined process of tourmalinization and K-feldspathization. It is worth noting as Charoy (1982) points out, that there is 'tourmalinization and tourmalinization', and that Lister and Alderton were not comparing like with like. As for tourmaline in veins, Lister (1979b) noted that some from this quarry contained cores of 'polycrystalline quartz and/or feldspar' and attributed this to skeletal growth resulting from undercooling of the tourmalinizing melt.

Regarding other alteration processes, Luxulyan is typical of the eastern St Austell area in showing only minor greisening and kaolinization, although it is interesting that the kaolinized zone in the quarry is of the wedge shape, described by Bristow (1977) as characteristic of such zones found throughout the Cornubian granites, although often on a much larger scale and at such a depth that this shape is revealed only when the zones are worked or from boreholes.

The biotite granite at Luxulyan is typical of Cornubian granites, and is enriched in elements such as Sn, W, Cu, Li, Sr, Ba, U, Th, B and F. It is uncertain to what extent these were contributed by crustal or mantle sources, but research on biotite in xenoliths from Luxulyan suggests that Sn, W and U (as well as Ta) did not come from sediments and were thus not crustal, that B, Sr and Cu (and also V and Zn) could have done so, and that magmatic Li, Th and F were trapped and thus concentrated in the biotite in xenoliths.

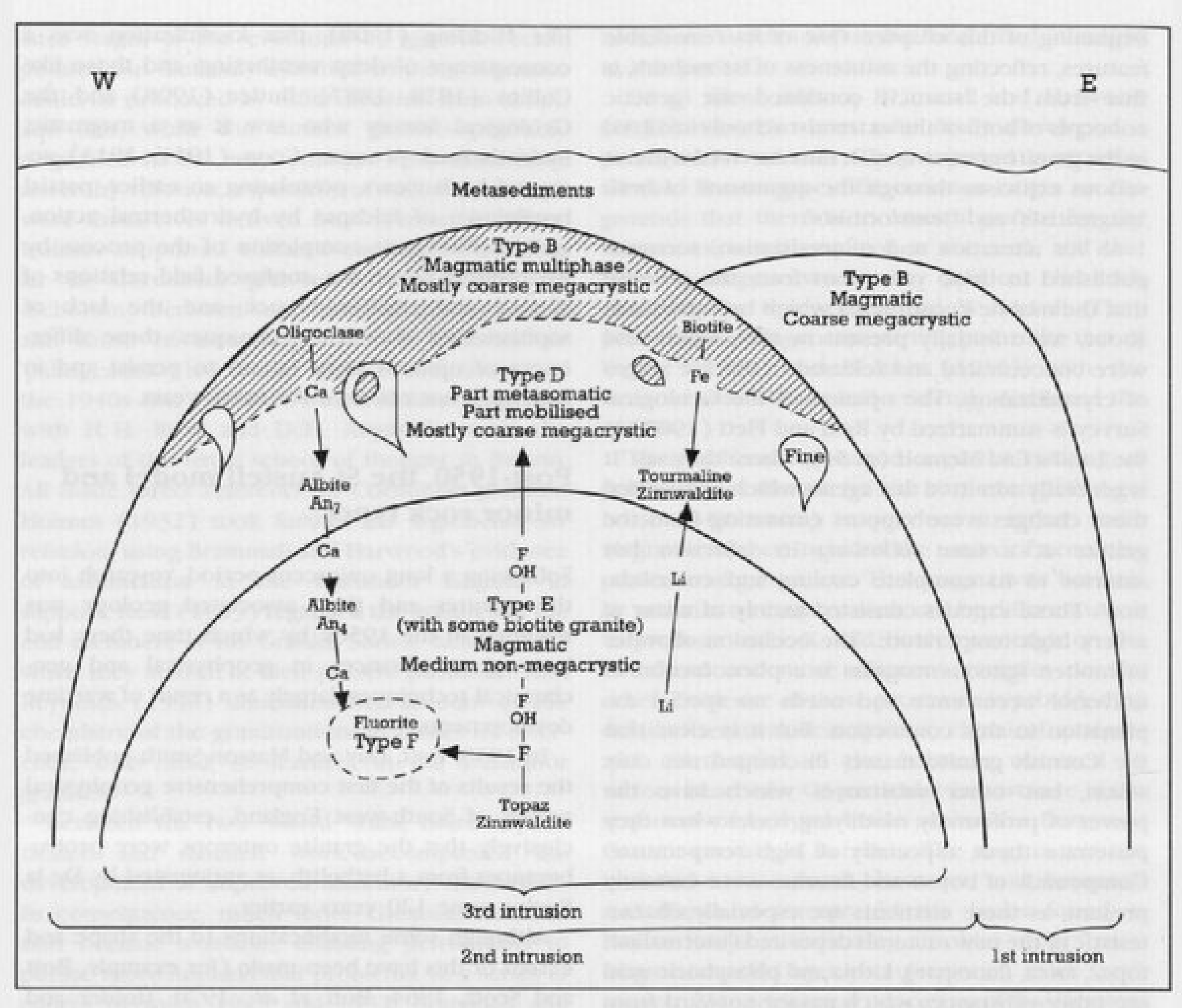
A similar type of granite formed the major part of a second intrusion to the west, but this was metasomatized to give the albite–Li-mica–topaz variety now present.

Luxullianite from the quarry has shown that there are two generations of tourmaline in these rocks, that tourmaline and biotite are not necessarily mutually exclusive and that the tourmalinization process may be accompanied by K-feldspathization.

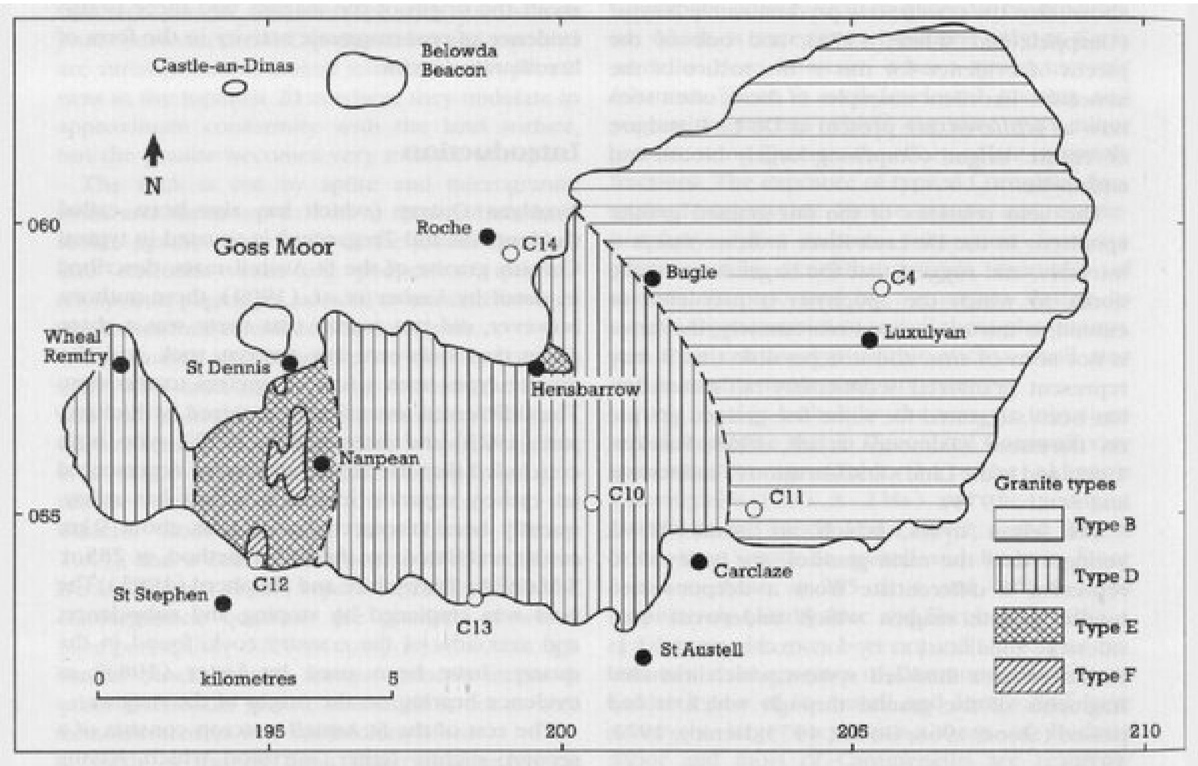
Conclusions

Luxulyan Quarry provides an exceptional opportunity to examine the typical Cornubian biotite granite in a locality close to the succeeding lithium- and volatile-rich rocks of the St Austell complex of intrusions. The site shows xenoliths here consisting of metamorphosed, muddy sedimentary rocks. It is thought that the incorporation of these rock fragments has made a significant contribution to the final chemistry of the granite. The nearby village gives its name to the rock type luxullianite. This rock, made up of red feldspar, quartz and the dark mineral tourmaline (a complex boron-bearing aluminium silicate), was formed by alteration of the original St Austell Granite by hot fluids associated with the final phases of granite magmatic activity, which, flowing out from the solidifying granite, chemically altered and recrystallized the minerals which made up the granite and the rocks around it.

References



(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 5.10) 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_{35}-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} (28%)	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} (28%)	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)

	Type B			Type C		Type D		Type E	Type F	Granite porphyry	Microgranite
	Bodmin Moor	Carnmenellis	Geevor Mine	Geevor Mine	Bodmin Moor	St Austell*	Cligga Head	Tregonning -Godolphin	St Austell*	Tregonning -Godolphin	Meldon micro -granite dyke, NW Dartmoor †
	(N = 10)	(N = 12)	(N = 7)	(N = 1)	(N = 3)	(N = 8)	(N = 3)	(N = 10)	(N = 6)	(N = 2)	(N = 1)
SiO_2	72.43	72.63	71.20	73.70	74.08	73.01	72.73	71.10	74.20	72.60	72.60
TiO_2	0.21	0.28	0.35	0.06	0.07	0.14	0.13	0.06	0.07	0.20	0.04
Al_2O_3	15.03	14.65	14.20	14.10	14.78	14.72	14.85	16.11	15.81	14.50	16.40
Fe_2O_3	0.32	0.50	0.80	0.60	0.13	0.47	0.34	0.35	0.08	1.88	0.84
FeO	1.48	1.24	1.38	0.44	0.88	0.74	0.94	0.81	0.17	1.21	
MnO	0.04	0.05	0.03	0.03	0.03	0.03	0.03	0.07	0.01	0.05	0.09
MgO	0.44	0.48	0.60	0.05	0.18	0.14	0.33	0.09	0.08	0.26	0.05
CaO	0.84	1.12	1.12	0.56	0.44	0.44	0.41	0.59	1.31	0.28	1.28
Na_2O	3.11	3.11	2.82	2.86	2.74	3.42	3.21	3.73	4.06	0.12	2.77
K_2O	5.06	4.36	5.11	4.77	5.73	5.36	5.03	4.84	4.66	7.66	3.95
Li_2O	0.06	0.07	0.06	0.07	0.04	0.18	0.11	0.27	0.01	0.03	0.94
P_2O_5	0.25	0.18	0.24	0.32	0.25	0.33	0.15	0.50	0.46	0.26	0.48
B_2O_3	-	-	0.41	0.47	-	-	0.27	0.14	-	-	-
F	-	-	-	-	-	(0.38)	0.36	1.22	(1.36)	-	1.40
H_2O	1.01	-	0.73	1.38	0.88	-	1.13	-	-	-	-
Nb	-	17	30	40	-	57	-	93	81	21	67
Zr	121	137	185	40	34	(90)	65	46	(11)	94	38
Y	41	48	30	20	40	-	-	10	-	18	-
Sr	94	93	98	23	43	41	178	61	64	34	47
Rb	419	462	480	760	444	982	695	1218	615	814	2293
Ba	196	397	230	15	102	(83)	180	204	(43)	699	197
La	31	16	-	-	12	8	-	~3	-	14	15
Ce	38	-	-	-	2	34	95	38	19	68	27
U	-	-	-	-	-	-	-	19	-	20	24
Th	-	-	-	-	-	-	-	22	-	31	-
Pb	46	47	15	10	42	-	-	16	-	6	5
Ga	-	40	30	30	-	-	40	40	-	20	35
Zn	62	72	45	35	48	-	103	48	-	45	31
Ge	-	-	-	-	-	-	-	11	-	4	11
Sn	23	14	19	17	29	-	40	36	-	71	14
Cs	28	34	-	-	48	-	-	127	-	33	223
K/Rb	100	78	88	52	107	45	60	33	63	78	14

* Values in parentheses from the work of Exley (1959)
† Total Fe as Fe_2O_3
Oxide values in weight %
Trace element values in ppm

(Table 5.2) Average analyses of granites from the Cornubian batholith (after Exley et al. 1983)