Abstracts of other papers/posters presented at the Annual Conference, January 2001

Molluscan shell beds from the Lower Lias (Sinemurian) of Somerset; sedimentological significance

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The sedimentology of the Lower Jurassic (Lower Sinemurian) Kilve Shales (Lias Group) on the Somerset coast is relatively poorly documented. Given the importance of this succession as part of a designated Global Stratotype Section for the base of the Sinemurian Stage we have been examining the field sedimentology and preservation of ammonites to assess the potential climatic signal preserved within these rocks. Thin (less that 10 cm thick) shell beds are common within the Kilve Shales and comprise comminuted ammonite shell debris along with bivalves, foraminifera, crinoid and wood debris. The shell beds have clearly defined lower bed boundaries which are in part bioturbated and the shell beds appear to mark the boundaries between light to medium grey mudrocks below with dark grey laminated mudrocks above. The shell beds can be traced laterally over at least 10-15 m but show variation in thickness. These shell beds are likely to be the result of decreased sedimentation rates, leading to winnowing and thereby the formation of relatively condensed horizons.

Some of the ammonites from this succession are extremely well-preserved with primary aragonite shells made up of micron scale nacre tablets. Such preservation is extremely rare in Jurassic sedimentary rocks. Other shell samples are partially recrystalised by calcite, baryte and strontianite. The presence of strontianite cements is significant in that it would affect the potential for using Sr isotope dating of this succession without careful screening for diagenetic alteration. In addition, aragonite preservation potentially allows the palaeoclimate of the Lower Jurassic of Somerset to be assessed through future oxygen isotope studies.

Manganese mineralisation in the Early Carboniferous rocks of Devon

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The Dinantian strata of Devon and Cornwall comprise a series of outcrops extending from east Cornwall, through the Chillaton district of west Devon, around the northern margin of the Dartmoor Granite and into the middle Teign Valley. Within these outcrops, Visean cherts, commonly associated with mantle-derived basic volcanic rocks (spilitic lavas and tuffs), host small deposits of stratiform manganese ores. These deposits were worked in the 19th and early 20th centuries, but are without economic significance at the present day.

In terms of ore genesis, these deposits show complex histories, with silica and manganese oxides, carbonates and silicates replacing a variety of host rocks including siltstone, volcanic rocks and, possibly, limestone. Brecciation of the ores is much in evidence, and there is considerable late-stage alteration of carbonate and silicate phases to manganese oxide minerals. Minor minerals include pyrite and galena. However, the sites differ significantly in the variety of textures and mineral paragenesis, in particular with respect to the relationships between the silicification, manganese carbonate mineralisation and manganese oxide mineralisation.

Samples were studied from spoil at Hogstor mine (Chillaton district), and Higher Ashton and Hill Copse mines (Teign Valley district) by optical petrography, and then by backscattered scanning electron microscopy with energy-dispersive X-ray microanalysis and X-ray diffraction analysis.

In samples from Hill Copse Mine, mineralisation is associated with cherts interbedded with silicified clastic sediments (siltstone, mudstone), containing volcanic fragments and bioclastic debris. The rock has been brecciated and extensively silicified, and cut by quartz veins and subsequent veinlets of manganese oxides. The manganese oxide appears to be late-stage, and fills residual porosity in the brecciated fabric.

At Higher Ashton Mine the mineralisation is more complex with multiple episodes of brecciation and mineralisation. Fine-grained early manganese oxide (hausmannite, Mn-nsutite and romanechite) is impregnated, overgrown and replaced by manganese silicate (identified by XRD as caryopilite). Brecciated fragments of this mineralisation were subsequently encrusted by fibrous silica intergrown with oscillatory rims of caryopilite. Further brecciation was followed by formation of patchy euhedral quartz filling between brecciated fragments of earlier manganese ore. Subsequently, rhodochrosite cements the remaining void spaces in the brecciated fabric, fills cross-cutting veins and partially replaces the earlier caryopilite and manganese oxide.

The situation at Hogstor Mine is different in that the manganese mineralisation is initially associated with the replacement of a

host, probably silty limestone, by a rhomb-mosaic of kutnahorite. Later silicification and oxidation has resulted in the pseudomorphic replacement of the kutnahorite by an intimate intergrowth of quartz and manganese oxide (vernadite and romanechite). The original kutnahorite mineralisation is now only preserved as minute relicts and corroded inclusions within the quartz.

The complex and differing styles of mineralisation reported above reflect the movement of hydrothermal fluids in a variety of environments, and with much evidence of contemporaneous tectonic activity. Given the restricted stratigraphical range of the deposits and the components of the Visean strata in the southern Culm Basin, it is suggested that the primary manganese mineralisation was sourced from epithermal brines associated with the contemporaneous basic magmatism. Alteration of the primary deposits was effected firstly by the compressional Variscan tectonic events and low-grade regional metamorphism, and secondly by the emplacement of the Cornubian granite batholith and the subsequent extensional tectonic regime.

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Metasediment-hosted polymetallic mineralisation from shallow workings on North Tincroft Lode, New Cook's Kitchen Mine, Cornwall

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Recent studies of *in-situ* mineralisation in the Camborne-Redruth area have primarily been based upon data collected from the lower levels of South Crofty Mine. Lodes at this depth (~600-700 m below surface), around and below the granite-country rock contact, typically comprise a hypothermal (>300°C) assemblage dominated by tourmaline, quartz and cassiterite. In contrast, due to access constraints, there is little recent data from the area relating to near-surface mineralisation (<200 m below surface). Lodes at this depth are frequently hosted by metasediments and preserve a polymetallic cassiterite-sulphide-chlorite assemblage.

North Tincroft Lode (New Cook's Kitchen Mine) forms a segment of an ENE-WSW-striking structure that can be traced ~2 km laterally across the Camborne-Redruth mining district and ~800 m vertically through country rocks into the underlying Carn Brea Granite. Recent access to old shallow workings (<50 m below surface) in the Mylor Slate Formation allowed the examination and sampling of *in-situ* segments of the lode, up to 2 m in width, situated ~100 m vertically above the granite-country rock contact. Lode specimens were analysed by optical microscopy, SEM, XRD and XRF, revealing a complex polymetallic mineralogy that defines two major paragenetic sequences.

The first is a breccia in which clasts of slate are cemented by sphalerite, arsenopyrite, chalcopyrite, cassiterite, wolframite, minor lead/bismuth/silver sulphides and a gangue of chlorite, quartz, tourmaline, fluorite and orthoclase. The lode margins are sharp and the wallrock is variably silicified and, in places, extensively impregnated with cassiterite, wolframite and minor sulphide veinlets. The second paragenesis generally occurs within a vein along the hangingwall or footwall of the lode, but in some cases forms the full lode width. It comprises fine-grained (<200 μm) cassiterite, arsenopyrite, chalcopyrite and sphalerite (± galena inclusions) within a dense, non-brecciated, chlorite ± fluorite ± quartz gangue and is accompanied by significant monazite, anatase and ilmenite.

The above assemblage spans the traditional hypothermal/mesothermal/epithermal classification and has similarities with descriptions of metasediment-hosted mineralisation elsewhere in Cornwall. Previous models, involving mixing between magmatic-hydrothermal and meteoric fluids, may be valid but circulation of hydrothermal fluids over a protracted interval beyond the Permian is unlikely to have contributed significantly to mineralisation.

An investigation into the controls on the formation of greisen-bordered veins, St. Michael's Mount, Cornwall

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An array of greisen-bordered sheeted veins are exposed in the roof of a small granite stock at St. Michael's Mount, Cornwall. These structures were investigated for spatial distribution and thickness relationships with the aim of determining the controls on their development. The dominant vein set strikes 068-248° with three minor vein sets orientated 048-228°, 121-301° and 148-328° respectively. Greisen alteration envelopes range from 0.01 to 0.51 m in width and comprise nearly 25% of the exposed granite. Data analysis confirms that vein spacing follows a Kolmogorov fragmentation distribution, indicating that each vein influenced the position of subsequently forming fractures. Vein widths are found to conform to a power law distribution in the order of $N = 0.12t - 1.7$. Scaling relationships between vein length and maximum aperture for WSW-ENE trending single segment veins are linear (aspect ratio 0.0026) and show an excellent positive correlation, indicating opening by mode 1 (pure extension). No correlation was identified between the width of veins and the width of their greisen envelopes. Vein width distribution data from this investigation were compared with studies on Variscan Sn-W bearing granites in central Iberia, from which it is concluded that the St. Michaels Mount veins are poorly connected at depth. This indicates that Sn-W mineralisation was derived from *in-situ* hydrothermal fluids, which remained static for long periods of time, and is confirmed by mineral textures observed in the veins. The results of this investigation are entirely consistent with emplacement of the sheeted greisen-bordered veins by autogenous hydraulic pulsation, driven by increased fluid pressure in the apical region of the cooling granite stock during a period of weak horizontal compressive stress.

KAOLIN AND HALLOYSITE IN PORCELAIN AND TABLEWARE

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There are three well known areas for the mining and production of kaolin and halloysite suitable for utilisation in porcelain and tableware. The three deposits considered are the kaolinised granite of Lee Moor, Dartmoor Granite, southwest England, halloysite from an altered rhyolite dome of Matauri Bay, New Zealand and a mixture of kaolinite and halloysite from a kaolinised granite in Longyan, Fujian Province, China. These three deposits supply much of the high quality clay for use in porcelain. A comparison of their morphology (the shape of kaolin is platy and pseudo-hexagonal whilst halloysite is tubular in nature), particle size distribution, chemistry, mineralogy, modulus of rupture (measurement of strength), fired brightness and casting concentration are shown in Table 1 along with the host rock and some production figures:

DEPOSIT AND PRODUCT NAME	LONGYAN 325#	SSP (IMERYS/ECC)	Premium (IMERYS/NZCC)
Country	China	England	New Zealand
Operating Company	Longyan Kaolin Co.	Imerys	NZ China Clay
Sales Ktpa	50	15	20
Host Rock	Granite	Granite	Rhyolite
Morphology of Clay	Kaolinite and Halloysite	Kaolinite	Halloysite
Particle Size Distribution			
Wt.% -2 microns	30	85	99
Wt.% +10 microns	30	1	0
Chemistry (wt.%)			
SiO_2	48	48	50.4
Al_2O_3	38	37.0	35.5
Fe_2O_3	0.29	0.41	0.25
TiO_2	0.02	0.01	0.05
CaO	0.16	0.10	tr
MgO	0.30	0.25	tr
K_2O	1.71	1.20	tr
Na_2O	0.10	0.15	tr
LOI	12.4	12.8	13.8
Mineralogy (wt.%)			
Kaolinite/Halloysite	79 (Mix of both)	95 (Kaolinite)	92 (Halloysite)
Micaceous Material	17	4	0
Quartz	3	0	8 (some Cristobalite)
Other Minerals	1	1	0
Modulus of Rupture			
Dried at 110 C, MNm-2	1.6	5.5	3.4
%Casting Concentration	63.5	57	55

Table 1. *Comparison of Longyan, English and New Zealand Clays.*

The three deposits exhibit a wide range of properties with respect to their morphology, particle size distribution and strength. The Chinese Longyan kaolinite/halloysite assemblage is coarse grained, compared to SSP and NZCC and consequently has a lower strength. Both the Cornish and Chinese clays are formed from the alteration of kaolinised granites whilst the New Zealand halloysite is the result of the alteration of an extrusive volcanic rhyolitic plug. The latter has cooled quickly producing a very fine grained matrix.

The one unifying factor is the usefulness of these three clays in porcelain is their low iron and titania levels giving good fired brightness and translucency. The particle size distribution is important in determining the strength but this is not considered a key factor, as the iron and titania levels, as other materials such as bentonite can be added to a porcelain body to give the desired strength.

Kaolinites and halloysites with such low iron and titania levels are fairly rare in the world and there is much interest in identifying new sources. Economically these type of clays are high value added products and attract premium prices in the case of SSP and NZCC, with the Longyan 325# material being a cheaper option.

ESTUARY DIAGENESIS; IMPLICATIONS FOR METAL MOBILITY

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Particulate mine waste has been released into the estuaries of Cornwall as the result of mining probably since the Bronze age. This waste has accumulated and today forms the inter-tidal sediments. The chemistry and mineralogy of each estuary reflects the mining activity within the catchment with, for example, high Pb levels in the Gannel Estuary. Recently we have started to document a wide range of diagenetic minerals growing within the estuarine sediments. These diagenetic phases are present (a) replacing and/or infilling void spaces in cellular plant debris, (b) infilling primary porosity within the estuarine sediments or (c) nucleating around metal artefacts discarded into the estuarine sediments. The Gannel Estuary sediments have Pb values of up to 16000 ppm. Although detrital galena and plumbogummite are common in the sediments, it is clear that the lead has also been diagenetically mobile with the growth of abundant Pb sulphate phases (probably the mineral anglesite). In addition, diagenetic mineral growth is both complex and common around metal artefacts with high Mg calcite, siderite, Fe oxides, Fe monosulphides, barite, Zn phases (simonkolleite and zincite) and Cu phases all being present. The textures observed suggest that mineral precipitation is microbially mediated. The presence of these new minerals and the microbial activity has implications for metal mobility within estuarine systems.

INDUSTRIAL MINERAL PRODUCTS FROM MINING WASTE IN SW ENGLAND: A MARKET APPRAISAL

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The mineral resources exploited in SW England include vast amounts of metal ores (Sn and Cu, lesser amounts of Pb, Zn, Fe and a few others), plus numerous industrial minerals. The latter include china clay (kaolin), ball clay, slate, sand and gravel, hard rock aggregates, china stone, dimension stone, silica sand and chalk. Exploitation of all of the resources creates waste, which accumulates in or around the site of extraction. Some waste piles are very visible, such as those in the china clay area of the St. Austell Granite or the tailings heap at Wheal Jane in the Carnon Valley, near Truro. Others operations create less waste, which is less conspicuous. Some waste is back-filled into the open pit. Much waste from the older metal mining operations has been artificially or naturally revegetated with varying success, or has been left, along with the mining buildings to blend into the post-mining landscape.

Many potential uses for mining waste in south west England have been identified previously and the technical feasibility has been long established; but, for most of the waste, viable markets have not been found and it remains unused. Niche markets are possible for some types of the waste. Examples include: feldspar, mica and rare metals from china clay waste; horticultural products from the lignite from ball clay waste; pulverised slate waste as a filler in paints; a ceramic flux from the natural powder produced during the cutting of granite; and, agricultural lime from the fines created during limestone crushing. With the imposition of the primary aggregates tax in 2002, significantly more mining waste may find suitable markets outside the SW region in the future.

'European Geopark' - a new designation for linking geoconservation and sustainable development, with potential opportunities in the SW of Britain

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'European Geopark' is a new designation registered in all countries of the European Union, and a potential model for the proposed UNESCO Geoparks programme. Both designations will link geoconservation with sustainability. The criteria for 'European Geopark' status include the presence of conserved and managed geological sites, important for 'scientific quality, rarity, aesthetic appeal or educations value', active research and education and a suitability for sustainable economic development linked to this resource. So long as there is adequate *in-situ* geology of importance other liked sites of archaeological, ecological, historical, or cultural importance can also be included.

In the south west of Britain both the whole of Cornwall, with its (European Union) Objective One status, and Torbay, partly covered by Objective Two status, would seem to fit the economic criterion. Cornwall's geology is not only of scientific importance (with over 70 geological Sites of Special Scientific Interest - SSSIs - and over 100 Regionally Important Geological Sites - RIGS) but the geology is, literally, the bedrock for much of Cornwall's history and culture. In Torbay the marine Devonian sites were of fundamental importance in the historical founding of the Devonian System in the early 19th century, and the area includes a concentration of 11 geological SSSIs and several RIGS. Both areas therefore have great potential for the establishment of 'European Geopark' status.

Concretion modelling and visualisation: A novel application for Datamine software

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Concretions are common diagenetic features and represent the localised precipitation of cements around nuclei (pre-existing grains, fossils etc). While our understanding of mechanisms of concretion growth has improved in recent years, there has been less work on the rates of, and spatial controls of, concretion growth around macrofossils. Traditional studies of concretions involve the cutting of longitudinal or horizontal slabs which, while providing for the detailed investigation of each slab, limits the ability to fully analyse and interpret this information in three dimensions (3D).

In this study, Datamine GUIDE and GVP graphics software has been used to convert the information presented by the slabs into a fully linked 3D model. Tracings are made of the surfaces of individual, orientated slabs and digitised directly into the GUIDE software, producing a series of perimeters representing the original features of the slab. Perimeters are then loaded into the GVP visualiser, which honours the dimensions and relative spatial position of features and allows true 3D visualisation and investigation of specific spatial relationships, such as the internal complexity of macrofossil nuclei and septarian fractures. All the perimeters representing an individual object or structure are then wireframed as a triangulated surface and the process repeated until a complete 3D model of the objects and structures present within the concretion has been constructed.

Coastal landslides in Permian breccias north of Torquay

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The UK National Landslide Database contains the records of over 9,000 landslides identified in Britain. From this record it is possible to identify a number of stratigraphic units that are particularly landslide prone, which has important considerations for planning future development in the country. One of the geological units with a high incidence of landsliding are the Permian breccias with an average of 20 landslides/100 km (Jones and Lee, 1994). However, investigations of the outcrop of Permian breccia to the north of Torquay indicate that the overwhelming majority of the bedrock landslides occur on the coast, and that any inland failures are in materials that have already been subject to periglacial gelifluction and are not *in situ*. With a few important exceptions, the coastal failures are predominantly relatively small scale rock falls and translational slides that result from basal undercutting by the sea. One particular exception is at Watcombe, 'Valley of the Rocks', where there is a major landslide complex that appears to be structurally controlled. In general, however, the Permian breccias would not appear to be a unit which should be regarded as particularly landslide prone.

A comparison between the stability and stratigraphy of the Triassic mudstone cliffs of East Devon

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Triassic mudstone is the predominant lithology exposed at the base of the marine cliffs in East Devon, in both the Mercia Mudstone Group and the Aylesbeare Group. A recent study of the significant vertical variations in the Mercia Mudstone Group has resulted in a proposed new stratigraphy. This is compared with the differences in form and stability of the red mudstone cliffs along the coastal section from west of Sidmouth to east of Seaton. The lithological controls on cliff erosion are complicated by localised structures in the mudstones (faults and joints), by the presence in many places of unconformable and permeable Cretaceous deposits in the upper cliffs and also by ephemeral beach protection from wave attack. A review of previous geotechnical investigations of the Mercia Mudstone Group and a comparison with an intensively studied landslide near Budleigh Salterton in the Littleham Mudstone (Aylesbeare Group) was also presented.

The engineering significance of limestone beds in lower Lias clays

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The Lower Lias clays in south west England are interbedded with limestones, the abundance of which varies with stratigraphic position. Examples from two sites near Taunton show the role of the limestones in geotechnical problems on the Lias clays. At one, site, dipping limestone beds controlled the thickness of clay affected by seasonal moisture variations, leading to differential subsidence. At the second site extensive landslip movements had occurred. The geometry of the failure surfaces was controlled by competent limestone beds, leading to non-circular and often stepped slips. A less obvious but extremely important factor was the role of the limestone beds as aquifers controlling the pore water pressures within the impermeable clays, and hence the slope stability. Limestone beds within a few metres depth of each other act independently: some show large seasonal variations in water level whilst others remain dry and free-draining. Identification of the significant limestone aquifer allowed a targeted drainage scheme to be carried out. It was also noted that presumed periglacial cambering movements produced a downslope dip in the limestone beds, increasing the potential for instability: this may occur at other sites.

Engineering geology of cliff stabilisation and management at Connaught Gardens Cliff, Sidmouth

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A case history of a recent project at Connaught Gardens Cliff, Sidmouth involving engineering geological assessment, cliff stabilisation works and cliff management was presented. The assessment of cliff stability was based on engineering geological inspection and mapping survey, assessment of stability and the risks of instability, and identification of stabilisation works followed by management and aftercare. The cliff stabilisation works carried out in 1999 involved removal of loose materials, geogrid reinforcement, rock bolts and localised underpinning, masonry and dentition.

Safety was a major aspect of the works, which involved specialist working at height and public safety. A Project Safety Plan and a Project Health & Safety File were prepared to document these requirements. A cliff management and aftercare plan was another requirement to provide a system for ongoing management and safety review.

Preserving Cornwall's underground geological, archaeological and ecological heritage

Cornwall Underground Access Advisory Group (CUAAG)

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Minerals extraction, from prehistoric times to the cessation of deep mining at the end of the 20th Century, has formed one of the dominant elements in Cornwall's cultural and economic identity and there are in excess of 3000 individual sites at which minerals have been worked.

During the last twenty years, there has been a significant change in perception of the archaeological and cultural value of abandoned mine sites within the county. Preservation projects have become more widespread and many sites now form the basis of the recent application for UNESCO World Heritage Site status.

However, whilst preservation of the surface expression of former mine sites has become relatively common, there has been a continued loss of access to the corresponding subsurface workings. There has been a presumption, particularly in recent times, that all mine opening should be sealed during safety works. These methods, whilst reducing potential hazards, result in a permanent barrier that may be undesirable for a variety of reasons, including loss of all future access to sites of geological, mineralogical and archaeological importance and destruction of niche habitats.

(CUAAG) is a grouping of professionals from across the conservation, education, research, and contracting sectors (e.g. Local Authorities, Cornwall Archaeological Unit, National Trust, Cornwall Consultants, CSMA Consultants Ltd, Camborne School of Mines, Carn Brea Mining Society). It is concerned about these developments and seeks to highlight these issues and promote viable alternative strategies to safety works which, where possible, do not totally negate the possibility of future access.

Whilst much has already been lost, even more can be preserved if current practices are modified in favour of maintaining access to mine workings unless an over-riding need for permanent plugging or capping can be demonstrated. A more enlightened approach to safety works, using the principles outlined by CUAAG has already been adopted at a number of major sites within the county and a new strategy document became available early in 2001.

Possible multiple phases of intrusion as seen in dykes in Cawsand Bay, south-east Cornwall

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Dolerite dykes occur within the metasediments of the Staddon Formation of the Meadfoot Group (Lower Devonian-Emsian) in the BGS reference section for these rocks between Sandway Cellars [SX442 511] and Redding Point [SX460 518]. Initial field studies suggest that there are at least two distinct phases of intrusion. Field mapping has been completed on the section, and has provided initial evidence of the structure of the area. Further work will be undertaken to relate these dykes to other igneous rocks in the area (the Kingsand Rhyolite Formation crops out to the south-west of the study area) and to provide a fuller understanding of the mechanisms of dyke emplacement.

A petrological comparison of the Isles of Scilly and Land's End Granite plutons

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The Isles of Scilly and Land's End granites are representative of the older and younger plutons found within the Cornubian Batholith. Although most plutons within the batholith are geochemically very similar, a large number of different granite types, in terms of texture, accessory mineralogy, and phenocryst populations, are observed. The most significant difference between the Isles of Scilly and Land's End granites concerns the occurrence of alkali-feldspar (orthoclase) phenocrysts, which are on average <2 cm in length in the Isles of Scilly Granite but range from 1.5 to 15 cm within the Land's End Granite. Muscovite is much more abundant within many granite types on the Isles of Scilly and tourmaline appears more abundant within the Lands End Granite. The occurrence of country rock xenoliths and microgranular enclaves is common within the granites of the Land's End Granite but both are rare within the granites of the Isles of Scilly. Both plutons have been affected by late-stage schorl veining and greisenization. The Isles of Scilly Granite appears to have had a more prolonged deformation history with sub-horizontal extensional shear-zones being present which are not seen in the Land's End Granite. Field relationships within both plutons suggest that each is the result of a protracted history of emplacement of batches of granite magma which vary considerably in terms of volume.