ABSTRACTS OF OTHER PAPERS READ AT THE ANNUAL CONFERENCE, JANUARY 1995

THE CARRICK LUZ SHEAR ZONE: MOHO OR LEAKY TRANSFORM?

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The upper (eastern) tectonic unit (Crousa Downs Unit) of the Lizard Complex, Cornwall, preserves a superb section through a piece of almost undeformed oceanic crust in a northwards-younging sequence of peridotite-gabbro-sheeted dykes. It is separated from the lower (western) tectonic unit by a fault running from Porthoustock to Carrick Luz. On the BGS 1:50 000 map (Sheet 359) this fault swings to an east-west strike and terminates as a low-angle feature at the coast at Carrick Luz. This contact was interpreted as an extensional shear zone running along the petrological Moho (1). New work here shows that the gabbro-peridotite contact is in fact an intrusive dyke-like body of strongly deformed gabbro mylonites which strikes along the coast from Carrick Luz to Spurnic Cove, where it runs inland to link up eastwards with the main gabbro body. The dyke approximates to an irregular sub-vertical sheet between 10 and 100 m wide. The sheet and its internal fabric are folded about a horizontal axis. The spectacular mylonites exhibit criteria indicating strong dextral shear.

Analysis of gabbro dykes which intrude tectonised peridotite in the vicinity of Carrick Luz indicates that a change in their distribution and orientation occurs across the main gabbro dyke. Thin (<2 m) dykes within the peridotite to the north-west trend roughly perpendicular to and those to the south-west roughly parallel to the main dyke contact. The dykes can be modelled as being intruded in a stress field corresponding to the north-west end of a right-lateral mode 2 fracture (2).

The geometry of the shear zones, basaltic dykes and gabbro dykes within the Crousa Downs unit (3) suggests that generation of the oceanic crust took place at an oblique spreading centre. In this model the Carrick Luz zone represents a north-west trending plate boundary across which east-north-east directed extension was occurring. The basaltic dykes which form the sheeted dyke complex were intruded into a north-north-west transtensional fracture array generated in the newly forming oceanic crust overlying the rifting upper mantle. The Reykjanes Ridge represents a good present-day analogue to this system.

REFERENCES

1. GIBBONS, W. and THOMPSON, L. 1991. Ophiolitic mylonites in the Lizard Complex: ductile extension in the lower crust. *Geology,* **19**, 1009-1012.

2. POLLARD, D.D. and SEGALL, P. 1987. Theoretical displacements and stresses near fractures in rock: with applications to faults, joints, veins, dykes and solution surfaces. In:*Fracture mechanics of rock,* Ed: B.K. ATKINSON. 277-349, Academic Press, London.

3. ROBERTS, S., ANDREWS. J.R., BULL, J.M. and SANDERSON, DJ. 1993. Slow spreading ridge-axis tectonics: evidence from the Lizard Complex, *UK. Earth and Planetary Science Letters,* **116**, 101-112.

THE RELATIONSHIP OF ACID VOLCANISM, ELVANS AND GRANITES IN SOUTH-WEST ENGLAND

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Field, petrological and geochemical studies of rhyolites, quartz-porphyry dykes (`elvans') and acid igneous clasts from the Permian breccias have been undertaken in the course of multidisciplinary mapping projects in Devon and east Cornwall. The results, particularly rare earth geochemistry and neodymium isotope analyses, have been used to identify parent magma sources in terms of the major granite plutons of the region. Using Ar-Ar and Rb-Sr isotope data, the chronology of acid igneous activity is considered in relation to regional tectonics. In the case of the Dartmoor Granite, rare earth data are used to suggest a link between the main emplacement event and quartz-porphyry dykes.

TWO GIANTS AND THEIR LAIRS: THE SOUTH CROFTY, CORNWALL AND SAN RAFAEL, PERU, TIN (-COPPER) DEPOSITS.

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South Crofty (1993 production 2206 tonnes Sn) and San Rafael, Puno, south-eastern Peru (1993 prodn. 13687 t Sn, 1994 prodn. 19-20000 t Sn) are representative *supergiant* members of the sulphide-cassiterite deposit clan which constitutes the great bulk of currently economic hardrock tin reserves and resources. Despite their differing ages, *viz,* earliest Permian- latest Carboniferous (mainstage Sn 286-288 Ma) and latest Oligocene (23.924.4 Ma) respectively, the two deposits display numerous ore-genetic and metallogenetic parallels. Both comprise swarms of sub-parallel, structurally and paragenetically complex, and laterally and vertically extensive lodes, straddling the contact between largely post-kinematic granite stocks and sub-greenschist facies Palaeozoic metaclastics. The host structures reflect regional rather than local stress fields, and record transcurrent dislocation parallel to the foreland boundaries of the Variscan and Central Andean orogens respectively. The lodes in both camps comprise early tourmaline-quartz (microbreccia) and later chlorite-quartz parageneses, and exhibit clearly-defined Cu-over-Sn zoning. The parental granites in each area are strongly peraluminous and, on a district scale, incorporate enclaves indicative commingling and mixing of the anatectic magmas with mantle-derived mafic melts, including both K-rich basaltic and lamprophyric members, Cassiterite deposition occurred from aqueous fliuds of moderate salinity at temperatures below ca 450°C.

Important differences exist, however, between the two camps.

Thus, the San Rafael cordierite-biotite monzogranitic magmas were hotter and 'drier' than those which generated the muscovite-biotite Cam Brea granite. Whereas over ca. 80% of the cassiterite at South Crofty was deposited with early tourmaline, the corresponding stage at San Rafael is barren, perhaps because temperatures were too high (>500°). The extreme richness of the San Rafael lodes (reserves +7 Mt at 5.05% Sn, Dec. 1993) may record abrupt dilution of juvenile by meteoric fluids during an episode of reverse faulting, giving rise to over 90% of the 'wood tin' documented globally. Similar deformation had, we infer, previously abetted the incursion of mafic melts into the epizonal magma chamber, resulting in oxidation of the highly-reduced granitic residual magmas, thereby releasing Sn from the latter. Although a much earlier (Triassic-Early Jurassic) episode of Sn-Mo-W mineralisation occurred in the San Rafael region, no preSn wolframite-rich veins developed in the deposit. However, the San Rafael stock experienced intense Na and K metasomatism prior to lode formation, a feature not evident at South Crofty. Moreover, the hiatus between granite emplacement and major cassiterite deposition was ca 5-7 m.y. at South Crofty, but no more than 0.5 m.y. at San Rafael. A critical control on the scale of Sn concentration in these two very similar hydrothermal systems was the depth, both of intrusion, <1 km at San Rafael but probably 2-3 km at South Crofty, and of generation of the Sn-bearing aqueous fluids.

GEOCHRONOLOGICAL AND GEOCHEMICAL CONSTRAINTS ON THE EVOLUTION OF THE LIZARD COMPLEX, CORNWALL

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New U-Pb age dates for three distinct zircon populations from a granodioritic Man of War Gneiss sample, and incremental-heating $^{40}Ar/^{39}Ar$ age spectra for hornblende from amphibolites of the Lower Landewednack Schists and the mafic minerals of the Kennack Gneiss (Kennack Sands), together with mineral equilibria in these members of the basal structural unit of the Lizard Complex, constrain the timing, P-T conditions and environment of ophiolite emplacement. The Man of War Gneiss yields a crystallisation age of 499 +8/-3 Ma, the oldest date yet determined for a Cornubian rock, and is therefore interpreted as a fragment of late Cadomian basement. $^{40}Ar/^{39}Ar$ age spectra for both the Landewednack Schists and Kennack Gneiss record cooling through ~500°C at ca. 366 Ma and Ar-loss at ca. 220 Ma, and amphibolite-plagioclase thermobarometry record maximum metamorphic conditions of ca. 609°C and 300-400 MPa, insufficient to generate the felsic component of the Kennack Gneiss *in situ.* We infer that high-T, intra-oceanic thrusting of the ophiolite occurred in the Frasnian, during closure of a narrow ocean, shortly after its crystallisation (375 34 Ma; Davies, 1984) and was associated with intrusion of commingled and mixed anatectic and mantle-derived magmas along the sole thrust to form the Kennack Gneiss. Subsequent low-T/low-P obduction of the ophiolite and a slice of arc-type Cadomian basement, the Man of War Gneiss, is recorded by prehnite-pumpellyite facies metamorphism in the Menage Melange (Barnes and Andrews, 1984).

THE ACCELERATED DEGRADATION OF CONCRETE IN SOUTH-WEST ENGLAND.

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Following the decline in the use of natural stone at the beginning of the century, most domestic and small commercial properties in Cornwall and west Devon have been built with concrete blocks and mass concrete. Until the mid 1950's concrete blocks were often locally made, sometimes by individual builders, and shuttered concrete was mixed on site. Before the Second World War concrete products were rarely transported more than 20 km.

In many parts of Cornwall and west Devon ample supplies of cheap and often suitably graded sand and gravel were available as waste materials from the region's metalliferous mining industry. The use of sulphide-bearing mining and ore processing wastes as aggregates is central to the problem of accelerated concrete degradation in the region. Accelerated degradation of concrete is a consequence of *in situ* oxidation of pyrite and concomitant sulphide attack on aggregate and cement. Two degradation mechanisms are recognised assaciated with:

1. Wastes from hypothermal, granite-metapelite-metabasite hosted tin and copper mineralisation, and
2. mesothermal mudstone-hosted lead mineralisation.

In case 1, degradation is caused by oxidation of liberated sulphide minerals in tailings sand/re-crushed mining waste and direct sulphide attack on carbonated cement paste. It results from failure of cement-aggregate bonds and pore volume collapse. Deterioration occurs rapidly after construction though the concrete may remain serviceable for many years. Initial pyrite concentrations of more than 0.5% are generally required for major degradation to occur.

Lead mining wastes, usually conveniently-graded jig tailings, were extensively used in block making in the Perranporth district and east Cornwall. These materials carry little liberated sulphide but have abundant altered wall rock with fine, disseminated pyrite. Degradation proceeds more slowly and serious effects may not be apparent even after 50-60 years. Initial pyrite concentrations of less than 0.2% may be enough to cause major damage.

THERMAL AND FLUID FLOW MODELLING OF THE DARTMOOR GRANITE AUREOLE.

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Dartmoor Granite has a remarkably narrow thermal aureole (~0.5 km) as measured by mineralogical and organic thermal indicators (Cornford *et al.,* 1987, PUS). A 2-dimensional thermal and fluid flow model has been constructed using Platte River's BasinMod software to simulate fluxes adjacent to the granite margin.Fluid flow through rock porosity and faults is allowed, and anisotropic heat flow modelled. The combination of variables that produces the narrow aureole is discussed, and conclusions drawn concerning burial and pressure/temperature conditions at the time of intrusion.

AN IN-SITU GLACIAL ERRATIC BOULDER AT FREMINGTON, NORTH DEVON: ITS PROVENANCE AND SIGNIFICANCE.

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Recent controversy over the timing and extent of Quaternary glaciations in the British Isles has indicated the need for a re-examination of many of the key sites. The Fremington Clays of Barnstaple Bay are considered by many to represent the maximum extent of terrestrial glacial activity in south-west England, although unequivocal evidence for deposition by land-based ice remains elusive.

Re-excavation and detailed analysis of the Fremington Clay in 1994 resulted in the discovery of a unique, *in situ* erratic boulder of indisputable glacial origin. The sedimentary context of the erratic is recorded and described. Petrographic analysis indicates that the boulder is a highly altered microgabbro. The uniqueness of the

mineral suite facilitates comparison with other recorded outcrops to the north. A number of provenance areas are suggested.

The significance of the find is discussed in the context of the Quaternary history of south-west England.

INTEGRATION, INTERROGATION AND VISUALISATION OF GEOLOGICAL DATA FROM EAST CORNWALL USING GEOGRAPHICAL INFORMATION SYSTEMS.

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Geographical Information Systems (GIS) allow the rapid and quantitative spatial analysis of geoscientific data, with the different data sets being treated as layers within the overall database. The database discussed is based around a high resolution stream sediment geochemical survey (>800 samples) of the part of Cornwall north and east of lines joining Newquay, Bodmin and Fowey. In addition there are layers based on published data such as mapped geology, topography and mineral occurrences.The presentation highlights incosistencies between the geochemistry and mapped geology, for example, the continuation of the Middle Devonian to the west of Liskeard. The use of GIS to aid in visualisation of geological data is demonstrated for a number of areas in east Cornwall.

Besides simple overlay it is possible using GIS to develop and test complex models integrating the data layers. As an example, the authors have modelled the occurrence of gold in south Devon and identified a number of geological factors governing gold occurrence, based on weights of evidence and logistical regression techniques. These weights can be used to produce maps that indicate the probability of gold occurrence in east Cornwall. While this modelling is governed on the limited information available in south Devon, it is also possible to inductively generate probabilities using external databases, for example geological controls on major gold deposits worldwide.

ABSTRACTS OF POSTER PRESENTATIONS

SOURCES OF SILVER IN THE EAST LOOE RIVER - NATURAL OR ANTHROPOGENIC?

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Both the East and West Looe Rivers have very high concentrations of silver in their lower reaches. Enhancement in silver in the West Looe river is caused by contamination from, and natural enrichment around, the disused lead mines at Herodsfoot. The source in the East Looe river is of comparable intensity but of enigmatic origin.

We have traced the silver back to the storm water outfall from Liskeard where sediment values are 25 ppm Ag, 200 ppm Cu and 500 ppm Pb. The poster will present mineralogical data from the outfall to discriminate between a natural vein source and an anthropogenic origin.

EXTENSIONAL COLLAPSE IN THE FOOTWALL REGION OF THE LIZARD OPHIOLITE, EASTERN MOUNTS BAY: A METAMORPHIC CORE-COMPLEX ANALOGUE?

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Detailed structural field-mapping along the Mounts Bay coastal-section has revealed a group of late-Variscan extensional structures which have, until recently, largely been overlooked by previous workers. Although the extensional style is variable and partitioned, it is likely that they represent broadly coeval deformation which is related to gravity collapse.

- Structures verge down the dip of pre-existing regional foliations.
- They are dominated by low-angle detachments or shear zones in which the sense of displacement is consistently directed top to the south-east, which show local cross-cutting relationships with ductile features.
- The low-angle detachments are associated with a suite of folds and domino faults which do not show overprinting relationships and hence suggest synchronous brittle and quasi-ductile behaviour causing strain hardening.
- The late ductile deformation is cut by granite sheets, making it pre-final emplacement in age.
- They are cut by moderate to steep post-orogenic normal-faults.
- Many stages of quartz and, more rarely, calcite veins are observed, indicating high pore-fluid pressure throughout orogenesis.

The features documented along the section form a distinct and continuous group which shows increasingly brittle deformation styles towards the south-east. There are also strong geometric similarities between these structures and soft-sediment slump and slide features, suggesting that in bulk rheological terms, the overthickened crust is acting as a viscous wedge spreading under the influence of gravity.

The extensional structures appear to systematically become more brittle away from the Tregonning-Godolphin Granite and towards the Lizard Ophiolite. Kinematic indicators suggest extensional collapse directed away from a ductile region, through a zone of ductile folds, shears and transposing cleavages, and into a region deforming through brittle faulting. The ductile structure in the northwest transposes all earlier structures, but as the extension becomes more brittle to the southeast, earlier compressional features are still preserved. The ductile-brittle transition appears to be analagous to the core, carapace and cover of core complex models. Early brittle extension estimates