

## A REVIEW OF TIN STOCKWORK MINERALIZATION IN THE SOUTH-WEST ENGLAND OREFIELD

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A style of mineralization encountered in the south-west England orefield less typical than the characteristic composite lodes, is found in the stockworks, which have produced variable tonnages of low grade tin and/or tin-tungsten ores. Stockwork-hosted vein assemblages are relatively simple, dominated by cassiterite and wolframite associated with arsenopyrite and chalcopyrite, with gangue minerals of mica, tourmaline and quartz. The stockworks are characterised by zones of high density, narrow, steeply-dipping and sub-parallel vein systems. Along strike, fracture persistence is variable, ranging from <10 m to in excess of 50 m, with changes in strike being only minimal. Where veins of different orientations intersect, the amount of displacement is minor. Stockworks are located on the margins and within the roof zones of the granite or within metasediments close to a granite stock/ridge. Wallrock alteration is highly variable with greisenized wallrocks being common in endogranitic systems and sericitized, tourmalinized and/or argillized in the exogranitic systems. Fluid inclusion studies of endogranitic systems show that mineralization and alteration was related to fluids with minimum trapping temperatures of between 100 and 400°C and salinities in the range of <5 to 45 eq. wt. % NaCl. Vein system formation was initially related to the flow of hot aqueous fluids which were expelled from an overpressured magmatic reservoir. This resulted in a fracture formation mechanism dominated by hydraulic processes regulated within a regional stress regime. Later stages of fracture formation/reactivation involved more tectonic activity and the flow of low temperature meteoric fluids.

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### INTRODUCTION

Cornwall was formerly one of the world's greatest tin and copper mining districts with extraction starting hundreds of years ago. The main tin production was from steeply-dipping, narrow and discontinuous composite lodes (e.g. Farmer and Halls, 1993; Dominy *et al.*, 1995), but a less common style of orebody is found in the stockworks, sometimes known as sheeted vein systems. Prior to the tin crisis in 1985 stockworks had attracted attention because of the prospects they offered for large tonnage reserves (Moore, 1977; Camm, 1982). The aims of this paper are to provide a review of stockworks, describe selected deposits presenting some new information and discuss deposit genesis. The geographical location of all deposits mentioned in the text are shown in Figure 1.

The earliest mention of stockworks in south-west England addressed the cassiterite-bearing Carclaze deposit near St. Austell (Jars, 1787; Von Oeynhausen and Von Dechen, 1829; Collins, 1878). The fullest account of the province's stockworks was by Collins (1912), who described both granite and metasediment-hosted systems. He described five types of tin-bearing stockworks: 1) in granite not associated with ordinary lodes, 2) in granite associated with workable lodes, 3) in elvans (porphyry dykes), 4) in killas (metasediments) not associated with workable lodes and 5) in killas associated with workable lodes.

Stockwork vein mineralogy is generally simple, being dominated by cassiterite and wolframite with lesser amounts of stannite, native bismuth, chalcopyrite, arsenopyrite, pyrite and lollingite. Gangue minerals are typically quartz, mica, tourmaline and fluorite with rarer topaz, apatite, beryl and chlorite.

Within granite-hosted systems (endogranitic) wallrock alteration (<0.01 to 0.5 m in width) is common, with greisenization resulting in the formation of a mica and quartz-rich rock (e.g. Cligga Head). The metasediment-hosted systems (exogranitic) generally show more restricted wallrock alteration (up to 0.1 m) with haloes of sericitization, hematization and/or tourmalinization. However the host rocks of the Whiteworks and Mulberry stockworks have been

sericitized and locally tourmalinized to a width in excess of 15 and 50 m respectively.

Fluid inclusion studies on quartz from endogranitic stockworks reveals a wide range of minimum trapping temperatures from 100 to 400°C (mean range between 250 and 350°C). Salinity values similarly show a large variation ranging from <5 to 45 equiv. wt. % NaCl. Evidence for vapour phase separation in the Cligga Head and St. Michaels Mount systems is rare (e.g. Jackson *et al.*, 1977; Dominy, 1989), but is observed in the Hemerdon deposit (Shepherd *et al.*, 1985). CO<sub>2</sub> has also been recorded in inclusions from Hemerdon and is linked to the transport and deposition of wolframite (Shepherd *et al.*, 1985; Shepherd and Miller, 1988). Inclusion data for the exogranitic systems are scant, studies of vein quartz from the Mulberry exogranitic system reveals a minimum trapping temperature range from 215 to 385°C and a salinity range from 6 to 21 eq. wt. % NaCl (Dominy and Camm, unpublished data).

### CLASSIFICATION

Bates and Jackson (1980) define a stockwork as "a mineral deposit consisting of a three-dimensional network of planar to irregular veinlets closely enough spaced that the whole mass can be mined". A true stockwork is composed of randomly oriented vein networks as observed within the North American porphyry copper systems (e.g. Titley *et al.*, 1986), but these are rare in south-west England.

The term sheeted vein system is often used to describe swarms of steeply-dipping, sub-parallel, narrow and closely spaced veins which occasionally cross each other. There is thus overlap in the definition of stockworks and sheeted vein systems, this point is identified by Taylor (1979), who states that the term stockwork is misleading and that in south-west England the majority of this type of mineralization occurs as closely spaced sub-parallel vein swarms.

Stockwork systems are either granite or metasediment-hosted

and are termed either endogranitic or exogranitic respectively (e.g. Bromley and Holl, 1986). In south-west England they occur in three main environments: 1) in metasediments above unexposed stocks and cupolas (e.g. Mulberry), 2) in roof zones of large plutons (e.g. Bostraze-Balleswidden) and 3) in small porphyry stocks (e.g. St. Michaels Mount and Cligga Head). The scale of the deposits is significant, with the endogranitic systems being generally larger than the exogranitic systems. This implies that fracture propagation and density is controlled by the nature of the host rock, the proximity of an energy source (e.g. granite magma) and the regional stress pattern (e.g. Moore, 1975).

In this work we define stockworks in south-west England as "swarms of variably Sn-(W-) bearing, closely-spaced, narrow, sub-parallel, steeply dipping veins which show little to no displacement at their intersections which may be either endo- or exo-granitic".

**ENDOGRANITIC SYSTEMS**

Mineralized stockworks are more common in small granite cusps than in the roof zones of larger plutons. Three of the 12 exposed granites contain stockwork mineralization, while Carn Brea, St. Agnes Beacon, Kit Hill and Hingston Down show evidence that they may have previously carried greisen stockworks in the upper parts, now removed by erosion. The Excelsior Tunnel was driven under Kit Hill less than 100 m below its summit and encountered fewer greisen-bordered quartz veins than the outcrop above (Dines, 1956; Richardson, 1992). This suggests that the present erosion level of Kit Hill is near the base of the system. Greisenization and associated stockwork mineralization appears to be confined to the upper 200 m and on the flank of the stock (Moore, 1975). Veins from endogranitic stockworks sometimes pass out of the granite into the surrounding metasediments. Where this occurs they pass through the contact, developing a selvage of muscovite mica, and then thin before dying out. They maintain their mineralogical characteristics, containing cassiterite and wolframite hosted in quartz, but may contain more sulphide minerals such as stannite and chalcopyrite (e.g. Cligga Mine

and St. Michaels Mount).

**Bostraze-Balleswidden**

The Bostraze-Balleswidden endogranitic system is in the roof of the Lands End pluton some 1.5 km east of St. Just (Figure 1). It is traceable for over 550 m along strike and is up to 70 m wide: underground working at Balleswidden mine has proven veining to a depth of 160 m (Rowe and Foster, 1887; Noall, 1973). The fracture zone trends north-west-south-east and is typified by steeply-dipping, closely spaced quartz veining with pervasively greisenized and kaolinized wallrocks. The earliest veins observed are the greisen-bordered and quartz-tourmaline types, these have been cut by later epithermal-textured quartz/silica veins (e.g. Dominy, 1993). The variably mineralized cassiterite-wolframite-bearing greisen-bordered quartz veins were worked between 1837 and 1873 at Balleswidden Mine, which produced some 12,000 tons of tin concentrate (Trounson, 1989).

The quartz-tourmaline and quartz-greisen veins strike from 115 to 165°, with the majority between 125 and 135° and dip from 60 to 85° towards the south-west. Some 35 veins occur in the main 30 m wide stope, with vein widths ranging from between 10 and 500 mm, most are however <30 mm wide. The greisen bands are generally <60 mm wide with about 55% being <20 mm wide. Numerous <10 mm wide, sub-parallel white mica-rich bands traverse the face at a high angle of dip, generally >80° towards the southwest.

The greisens contain a central clear to milky quartz vein with rare vuggy development and minor tourmaline with small amounts of cassiterite and wolframite. The macroscopic features of the veins show no significant internal disruption or wallrock movement. The vein quartz falls into two petrographic categories; i) euhedral quartz crystals projecting into the vein centre and ii) granular aggregates of interlocking anhedral quartz grains.

Euhedral quartz is not common in the veins, but small crystallized cavities imply localized open space filling. Petrographic studies of the granular quartz aggregates show that some veins contain

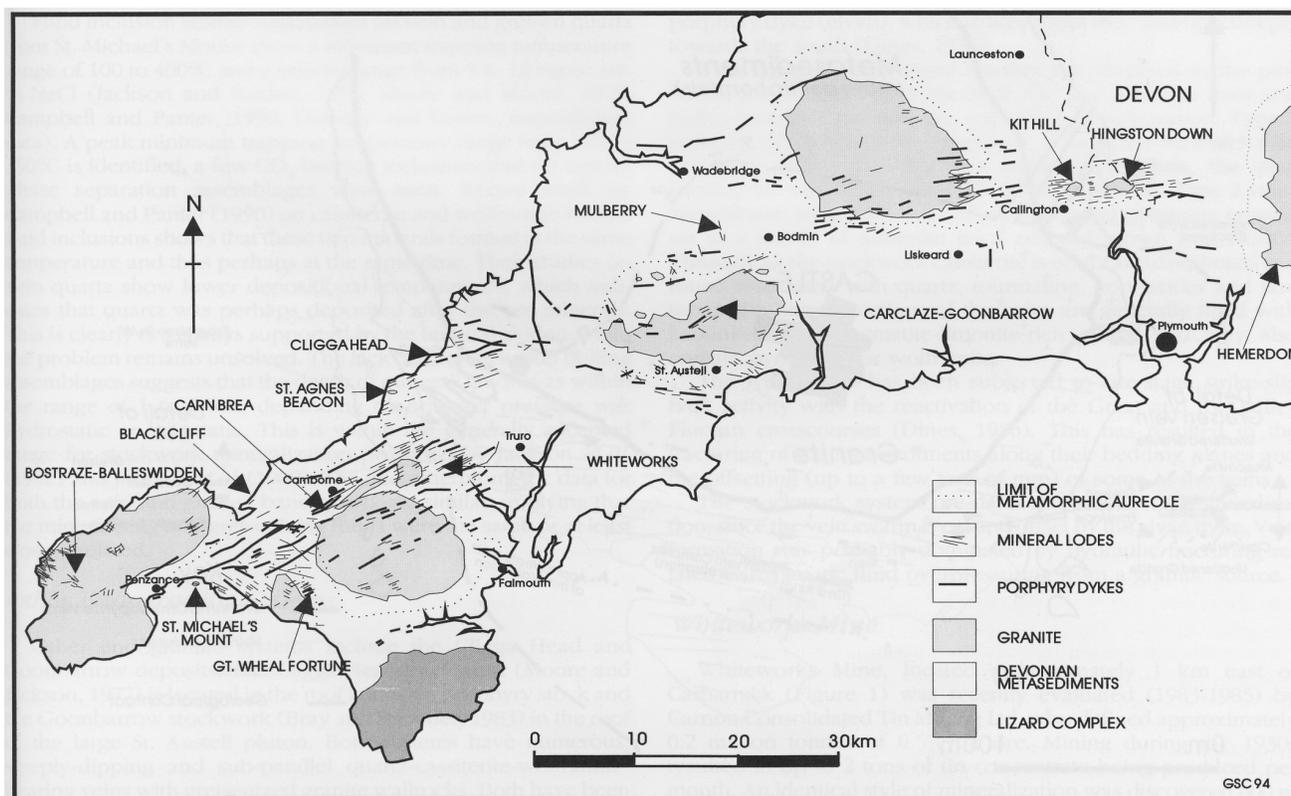


Figure 1: Map showing the location of stockwork mineralization mentioned in the text (after Hosking, 1964).

intergrown equidimensional crystals with 120° grain boundaries, which suggests textural equilibrium. Vein deformation is observed as stress-induced undulose extinction where internal recovery is accomplished by the formation of new sub-grains. These new grains are typically lenticular in shape and oriented parallel to the vein axis. Bunches of small (<0.1 mm) acicular tourmaline crystals straddle the veins and are generally rooted in the mica-rich vein selvages. Microscopic study of vein quartz reveals the presence of anhedral to euhedral cassiterite grains up to 5 mm in size. The euhedral crystals generally line small vugs and are intergrown with acicular black tourmaline. Anhedral and subhedral cassiterite fragments are generally intergrown with and surrounded by quartz. The textural characteristics of the quartz veins suggests that they formed by hydraulic fracturing, in response to magmatic fluid overpressuring (e.g. Halls, 1987).

Fluid inclusion populations in greisen-hosted quartz veins are characterised by liquid-vapour, liquid-only and vapour-only types. Microthermometric studies show a minimum trapping temperature range from 200 to 400°C and a salinity range from 5 to 35 equiv. wt. % NaCl (Dominy, 1993). Jackson *et al.* (1982) report a minimum trapping temperature range of 390 to 415°C and a salinity range of 17 to 23 equiv. wt. % NaCl for inclusions in cassiterite from the Balleswidden dumps. Some evidence of intermittent vapour phase separation is observed within the inclusions (planar arrays of vapour- and liquid-only inclusions), from which it can be calculated that the depth of formation was equivalent to a hydrostatic head of about 2.6 km. This is close to the value of 2.8 km proposed by Jackson *et al.* (1982) based on studies of vein quartz from the Balleswidden Mine dumps.

*St. Michael's Mount*

The island of St. Michael's Mount is located in Mount's Bay some 3 km east of Penzance (Figure 1). It provides an excellent example of

stockwork mineralization hosted in the roof of a porphyry granite stock that shows local facies variations and marginal pegmatite bodies (e.g. Jackson and Power, 1995). The southern side of the island exposes the granite porphyry and on the northern side metamorphosed Mylor Slates (Figure 2). The form and dimensions of the granite stock are unknown, but Willis-Richards and Jackson (1989) suggest that it does not represent the apex of a downwardly-widening granite body and that it is possibly connected to the underlying batholith by a narrow feeder zone.

The granite porphyry hosts a spectacular east-west-trending greisen-bordered vein system which is over 75 m in width. The veins are well exposed on the granite platform to the south of the castle (Figure 2). The individual quartz-greisen veins trend between 050° and 070° with their dip being consistently near-vertical. The veins vary in width from a few mm up to 0.15 m and may be traceable along strike for over 50 m. Towards their ends the veins often narrow considerably and in some cases become microfracture zones. Orientation and width variations are observed along the vein strike, with strike change being usually fairly small (i.e. <10°), although width changes can be large and rapid (i.e. from 0.15 m to 0.01 m over 1.5 m). Offshoots/branches from the main veins are also observed which initially strike away from the normal trend and then gradually assume the normal strike direction.

There is an average vein density of 2 per metre. Composite data from traverses show that the entire system is composed of 65% granite, 30% greisen alteration halos and only 5% quartz-filled fractures. The centre of the vein system shows high vein density values (up to 6 per m) which reduces towards the north and south extremities of the system to about 2-3 per m.

The quartz veins are generally located symmetrically within the greisen bands, however a number of veins may have bands on one side only, or they may move through the greisenized wallrocks along their strike. In regions of high vein density, >4-6 veins per metre,

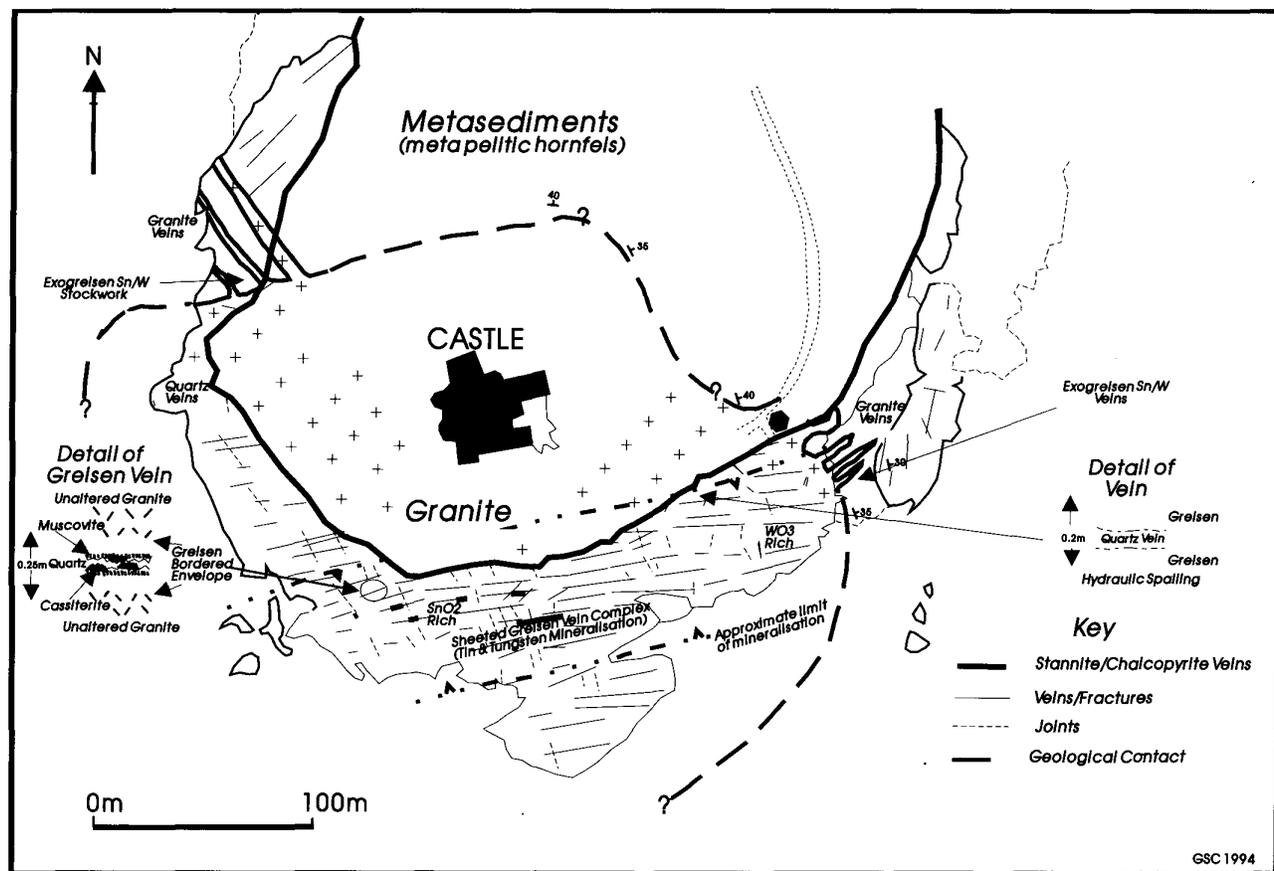


Figure 2: Geological map of St. Michael's Mount.

then there may be no intervening granite and the veins are bordered by a continuous greisen zone. The width of the greisen bands varies from between a few mm and up to 0.3 m or more, with variations occurring over relatively short distances. There is no observable relationship between the width of individual veins and their greisen bands, however a large number of narrow veins are likely to be surrounded by a continuous greisen mass.

Within the granite the veins are dominated by quartz in-fill with sporadic cassiterite and wolframite aggregates and minor stannite, arsenopyrite, topaz and mica. Where the veins pass through the contact zone into the metasediments they commonly develop wide selvages (up to 15 mm) of muscovite orientated normal to the vein axis. The cassiterite and wolframite are generally coarse-grained and tend to occur in zones separated by several metres of barren ground. Cassiterite is generally observed close to the vein walls and occasionally in the greisens, whilst the wolframite tends to be distributed in bunches along the vein centres. The relationship implies that cassiterite deposition predates wolframite deposition, however this is not supported by fluid inclusion studies which imply that the minerals were cogenetic (Campbell and Panter, 1990). Cassiterite appears to be mostly concentrated in the west-central section of the southern platform, where the quartz veins are most numerous and the greisen alteration is most intense (Figure 2). To the east of the central zone the veins are less numerous, but appear to be wider, containing quartz with scattered aggregates of wolframite. Cassiterite is uncommon in this area but it becomes more abundant in the vicinity of the eastern granite/metasediment contact zone.

The vein quartz shows interlocking and bridging textures indicative of formation by hydraulic fracturing (e.g. Halls, 1987). At the eastern end of the sheeted vein system exposure a small number of spalling phenomena are seen, these are characterised by narrow (<5 mm) arcuate quartz veinlets which run alongside and cut the main quartz vein for up to 1 m. These formed after main vein dilation, probably in response to localized high fluid pressures.

Fluid inclusion studies undertaken on vein and greisen quartz from St. Michael's Mount show a minimum trapping temperature range of 100 to 400°C and a salinity range from 5 to 12 equiv. wt. % NaCl (Jackson and Rankin, 1976; Moore and Moore, 1979; Campbell and Panter, 1990; Dominy and Camm, unpublished data). A peak minimum trapping temperature range from 250 to 350°C is identified, a few CO<sub>2</sub>-bearing inclusions and no vapour phase separation assemblages were seen. Recent work by Campbell and Panter (1990) on cassiterite and wolframite-hosted fluid inclusions shows that these two minerals formed at the same temperature and thus perhaps at the same time. Their studies on vein quartz show lower depositional temperatures, which indicates that quartz was perhaps deposited after the ore minerals. This is clearly not always supported by the textural evidence and the problem remains unsolved. The lack of fluid inclusion boiling assemblages suggests that the depth of mineralization was within the range of 1 to 3 km, depending on whether pressure was hydrostatic or lithostatic. This is within the generally accepted range for stockwork mineralization proposed by Jackson *et al.* (1982) and Jackson *et al.* (1989). The microthermometric data for both the vein and greisen band quartz are similar, implying that the mineralizing and greisenizing fluids were the same or at least closely related.

### *Other Endogranitic Systems*

Other endogranitic systems include the Cligga Head and Goonbarrow deposits. The Cligga Head stockwork (Moore and Jackson, 1977) is located in the roof zone of a porphyry stock and the Goonbarrow stockwork (Bray and Spooner, 1983) in the roof of the large St. Austell pluton. Both systems have numerous, steeply-dipping and sub-parallel quartz-cassiterite-wolframite-bearing veins with greisenized granite wallrocks. Both have been mined underground, with activity at Cligga being concentrated on 4-6 m wide swarms of ore-bearing veins (Anon., 1938) and at Goonbarrow

on narrower zones of ore-bearing veins (e.g. Old Beam Mine; Dines, 1956).

### **EXOGRANITIC SYSTEMS**

Metasediment-hosted stockworks are located within Devonian host rocks proximal to buried or exposed granite stocks. This type appears less common than the larger endogranitic systems which often contain higher tonnages of ore.

#### *Great Wheal Fortune, Conquerors Branches.*

Great Wheal Fortune is located 1 km north-east of Breage (Figure 1) and is hosted in Mylor Slates. The system lies within the metamorphic aureole of the nearby Tregonning-Godolphin granite. The veins were worked by open pit as early as 1760 (Cunnack, 1993) with activity ceasing during the 1890's. There are no records of the grades that were encountered in the stockwork, though Collins (1912) quotes an estimated figure of 0.27% Sn and suggests that some 200,000 tons of rock were mined.

The fracture zone splits into two sub-parallel sections separated by a 3-5 m wide lens. Overall, the fracture zone is >30 m wide with the lower open pit approximately 25 m wide, 15 m deep and 45 m long and the upper pit slightly larger. The main mineralized zone strikes approximately 060°, with individual veins striking from 050° to 070° and dipping from 80° to 85° towards the north. Veins vary from <5 to 50 mm in width with inter-vein spacings from 0.1 to 1 m. An average fracture spacing of 0.1 to 0.15 m gives a density of between 6 to 10 fractures per m. Exposed fracture walls show that dip may vary over a very short down-dip extent, thus giving the walls a curved form. Some of the wider veins (e.g. >10 mm) may be continuous for distances of over 10 m without intersecting other veins; variations in strike and/or dip are seen to result in intersections with other veins. Where vein sets intersect each other the amount of displacement is minimal. There are also a number of individual highly discontinuous veins that cannot be traced along strike for more than 2 m. The zone is displaced 9 m left laterally by a 12 m thick porphyry dyke (elvan), which strikes about 095° and dips steeply towards the south (Dines, 1956).

Two types of mineralized fracture are observed in the pits, both are dominated by white/buff coloured gilbertite mica and highly localized and variable wallrock tourmalinization. Type 1 veins are <10 mm wide with cassiterite in the vein core which may extend to either wall within a quartz-mica matrix, the mica laminae are oriented at about 90° to the vein walls. Type 2 veins are >10 mm wide with large >8 mm euhedral cassiterite crystals set in a matrix of gilbertite mica and red/brown iron oxides. Throughout the stockwork cassiterite is erratically distributed and found associated with quartz, tourmaline, iron oxides and rare topaz. Tin-barren sections of the veins are generally filled with kaolinite and/or hematite-limonite-rich gouge and may also contain pyrite and/or wolframite.

The whole area has been subjected to late-stage strike-slip fault activity with the reactivation of the Great and the Valley Flucan crosscourses (Dines, 1956). This has resulted in the fracturing of the metasediments along their bedding planes and the offsetting (up to a few tens of mm) of some of the veins.

The stockwork system pre-dates the main stage mineralization, since the vein swarm is cut and offset by the elvan dyke. Vein formation was probably dominated by hydraulic fracturing related to magmatic fluid overpressuring from a granitic source.

#### *Whiteworks Mine*

Whiteworks Mine, located approximately 1 km east of Carharrack (Figure 1) was recently evaluated (1983-1985) by Canon Consolidated Tin Mining Ltd, who defined approximately 0.2 million tonnes of 0.5% tin ore. Mining during the 1930s resulted in up to 2 tons of tin concentrate being produced per month. An identical style of mineralization was discovered 600 m to the east of Whiteworks, which probably represents either a parallel structure or a branch off the main system (P. G. Oldfield, pers. comm.).

Very little has been written on the location except for an entry in Dines (1956), a note on cassiterite morphology in Morton and Hosking (1989) and its exploration potential in Trounson (1989).

The orebody, hosted in Devonian Mylor Slates, is between 6 and 8 m wide and can be traced underground for 75 m. The vein system is characterised by a 8-10 m wide zone of 070° trending, vertical to steeply dipping (70-80° north or south), sub-parallel veins which are up to 0.2 m wide. An individual vein may be traced for over 30 m along strike and 10 m down dip and have an average thickness of 10 mm. Across the zone the average vein density ranges from 3 to 6 per m with a central core region displaying the highest values. The veins are filled with three generations of tourmaline and subordinate amounts of quartz. Cassiterite is present as small (<5 mm) clots and veins, with localized euhedral crystals up to 10 mm in size; the wood-tin variety has also been reported by Hosking *et al.* (1987). The host slates are intensely sericitized with the zone of alteration being in excess of 15 m in width.

The initial stage of development was characterized by the formation of the sub-vertical fracture sets, wallrock sericitization and the deposition of brown tourmaline and quartz. The wallrocks were pervaded by millimetre-scale tourmaline veinlets, which followed primary bedding and cleavage planes. Localized areas of high net-veining in the wallrocks resulted in the formation of breccias which show relatively small amounts of clast rotation. The breccias are variably clast or matrix-supported, with the clast-supported type being most common. They are similar to the A-zone breccia ore of the former Wheal Jane mine B-Lode, which is believed to have been feldspathized prior to sericitization and formed as a result of fluid overpressuring which resulted in hydraulic fracturing (Rayment *et al.*, 1971). Reactivation of the earlier brown tourmaline-filled fractures resulted in the deposition of blue-black tourmaline and minor cassiterite. The final stage of development was related to further fracture-reactivation and resulted in the deposition of blue-green tourmaline and erratically distributed zones of cassiterite mineralization. The blue-green tourmaline veins locally contain spaces which are filled with euhedral cassiterite, acicular tourmaline and small amounts of quartz and white mica.

Late-stage strike-slip faulting within the fracture zone gave rise to a narrow clay gouge within some of the tourmaline veins. North-south crosscourse faults cut the fracture zone showing undeterminable displacement, some of these structures are reported to contain visible native silver set in a clay matrix (P. G. Oldfield, pers. comm.).

Study of the Whiteworks vein system reveals that vein formation was dominated by hydraulic fracturing as a result of magmatic fluid overpressuring from a proximal granitic source. Later stages of the tourmaline paragenesis may have involved fracture reactivation by regional stresses, creating dilatancy and allowing pulses of magmatic fluids to be drawn from a source at depth. The late crosscourse structures were dominated by strike-slip movement and the flow of dominantly meteoric fluids.

### Other Exogranitic Systems

The Mulberry tin stockwork is located 2 km to the north-west of Lanivet. The host Devonian metasediments are cut by numerous 080°-trending veins which dip from the vertical to 80° west. The veins vary from between a few mm to 0.1 m in width with vein density varying from 4-6 per m; an individual vein may be traced for over 25 m. Some vein branching can be observed where two adjacent veins may be connected with a sub-horizontal vein. These veins are infilled by cassiterite, wolframite, arsenopyrite, stannite, quartz and pyrite. Wallrocks are tourmalinized and sericitized.

The Blackcliff stockwork near Hayle represents a very small exogranitic system hosted in a turbidite sequence. The mineralized veins are located within a 2-3 m thick arenaceous unit and characterised by quartz and cassiterite infill. The veins do not extend vertically for more than 1 m, can be traced laterally for only a few m and have a relatively low density of 2-4 per m. The origin of the

mineralization is uncertain but may be linked to the nearby Wheal Lucy vein system (Dines, 1956).

### DISCUSSION

Stockworks are an early style of mineralization which generally pre-date main-stage tourmaline veins and porphyry dyke swarms (Whiteworks being an exception). Radiogenic dating of endogranitic stockwork systems reveals a range of 262 to 284 Ma which is generally after the emplacement of the main Cornubian Batholith (274-293 Ma; Clark *et al.*, 1993), but before the porphyry dykes (270-280 Ma; Darbyshire and Shepherd, 1985). This style of mineralization is characteristically different from the main tin mineralization in Cornwall which is generally hosted in composite lode zones.

The endogranitic deposits show a distinctive chemistry (enrichment in Li, F, Rb and As; Hall, 1971) which is evidence of the close relationship with evolved granite magmas. These magmas represent the end-stages of the crystallization process and are typical of the apical/roof zones of large plutons and smaller porphyry stocks. The mineralization and pervasive wallrock greisenization was caused by magmatic fluids which were expelled during repeated stages of fracturing and crystallization. In some cases fracturing resulted in vapour-phase separation and led to the formation of high and low density phases sometimes enriched in CO<sub>2</sub>. Fluid inclusion studies reveal that mineralization and alteration was caused by hot aqueous fluids (>200-400°C), with salinities in the range from <5 to 45 equiv. wt. % NaCl. Mineralization and alteration may have been simultaneous (e.g. Cligga Head; Campbell and Panter, 1990) with repeated hydrothermal events having slightly different physical and chemical characteristics.

Veins within endogranitic greisen-bordered systems are commonly infilled by quartz associated with cassiterite, wolframite etc. The quartz textures from these veins form interlocked and fracture-bridging arrays with sporadic aggregates of ore minerals (e.g. St. Michael's Mount). In this case, fracture opening was greater than that of mineral growth and the nucleation of the ore minerals was governed by diffusion in a more or less static fluid (Halls, 1993a). Autogenous hydraulic injection fed by a magmatic reservoir is suggested as a mechanism for fracture propagation (Halls, 1987). The model for this formation is based on the tensile failure (hydrofracturing) of the granite carapace in response to magmatic fluid overpressuring (e.g. Allman-Ward *et al.*, 1982; Halls, 1987). In other cases the veins are filled by syntaxial arrays of quartz which bridge the fracture walls and within which wolframite etc. is confined to parallel growth within the quartz matrix (e.g. parts of the Cligga Head system). In this case the fracture formation was formed by a crack-seal mechanism operating as a sink, drawing ore fluids from a surrounding granite source (Halls, 1993a). Thus the role of tectonic stresses in fracture formation cannot be discounted and it is likely that fracture formation is a hybrid between magmatic overpressuring variably regulated by the regional stress field and seismic interaction (Halls, 1993b). The exogranitic veins show less indicative textures but nonetheless are likely to be related to the mechanism discussed above.

The hydrothermal fluids generated during formation were generally at magmatic temperatures and being confined at lithostatic pressures were thus able to produce gross metasomatic changes in the wallrocks, which led to pervasive textural and mineralogical reconstitution. The role of meteoric fluids appears to be of little importance in stockwork formation; later reactivation which led to intra-vein shearing and sulphide deposition (e.g. stannite and chalcopyrite at St. Michaels Mount) involved meteoric fluid input.

The scale of the exogranitic and endogranitic deposits poses an interesting question as to what controls large scale fracture formation. Halls (1993a/b) suggests that an important variable is the energy driving the system, which is related to expansive work done in a hydrous granitic residue. This energy was regulated by the regional stress field which outlines the interplay between magmatic and tectonic activity. The strength properties of the host rock must also be taken into consideration since granite is more competent (or crystalline) than the

host metasediments. In general terms, the formation of endogranitic systems may be related to higher energy processes than the more distal exogranitic systems.

Should the price of tin rise in the future; then tin stockworks could become exploration targets once more and the delineated Redmoor and Hemerdon deposits go into production.

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