TIN MINERALIZATION AND STRUCTURE AT TRELIVER, ST. AUSTELL, MID-CORNWALL

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INTRODUCTION

Primary exogranitic and secondary placer deposits characterize tin mineralization in the Treliver area. The area is underlain by metasediments and volcanics, and is located on the north-western edge of the St. Austell granite near Indian Queens (Figure 1). The greatest historical production was related to the placers with lesser amounts from small open pit and underground workings. During the 1980s a soil geochemistry programme revealed significant tin anomalies in the Treliver area [SW 903 605]. At that time exploration sought low-grade targets suitable for open pit mining with a potential for at least 4 million tonnes. Follow-up trenching and diamond drilling confirmed skarn mineralization at depth. Historical research combined with field observation of a small open pit indicated that a 19th century mining operation, incorrectly described as an iron mine, exploited stanniferous calc-silicates (Dines, 1956). The location lies within an arcuate belt of metasediment-hosted tin mineralization described by Camm and Dominy (1997).

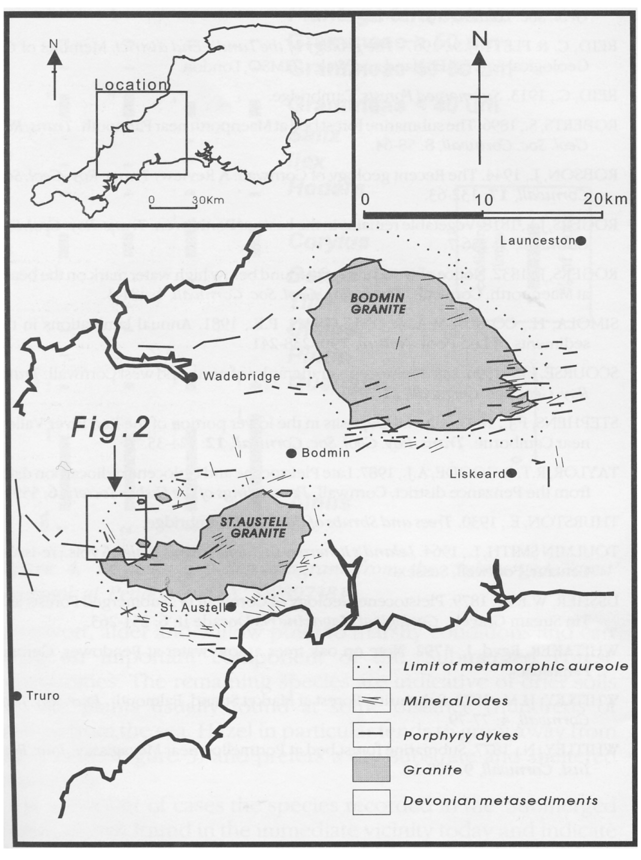

***Figure 1**: Location of the study area.*

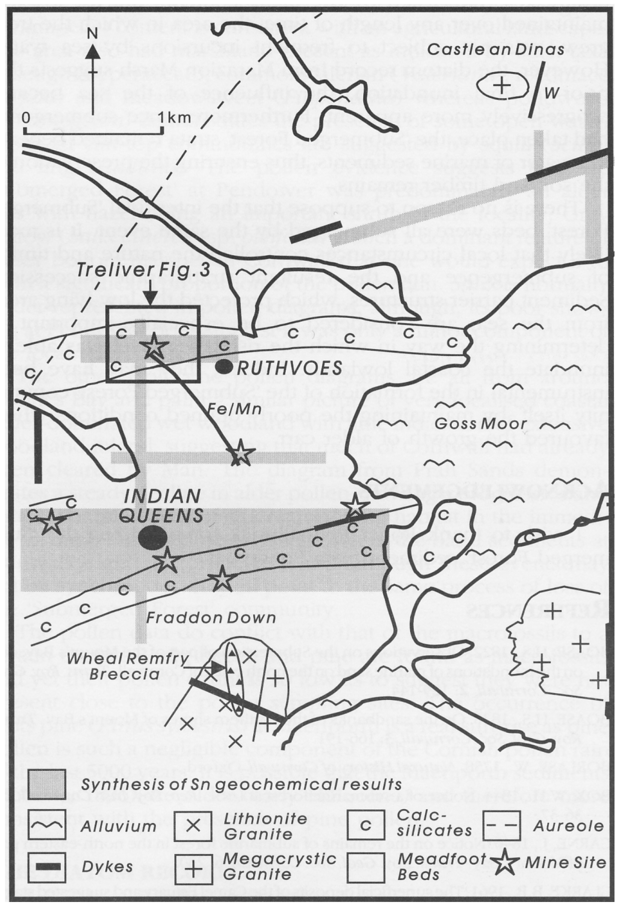

***Figure 2:** Geological map showing the location of Treliver, old mine sites and regional geochemical tin anomalies.*

Elsewhere in the region, skarns with variable amounts of tin have been exploited from sedimentary and volcanic hostrocks. Disseminated and massive deposits occur in the hornfelsic and boron-metasomatized metavolcanic-sedimentary envelope close to the Lands End (Botallack - Jackson *et al.,* 1982) and Dartmoor (e.g. Belstone and Ramsley - Hosking, 1969; Dearman and El Sharkawi, 1965) granites. These deposits are typified by a variety of tin-bearing silicate minerals including grossular garnet, malayite and amphibole (Alderton and Jackson, 1978; van Marcke deLummen, 1985). Other stanniferous skarns occuring on the northern margins of the St. Austell include Parka Consols (Collins, 1912; Bromley and Holl, 1986) and Mulberry (Dines, 1956).

The skarn systems reveal an early phase of contact metamorphism

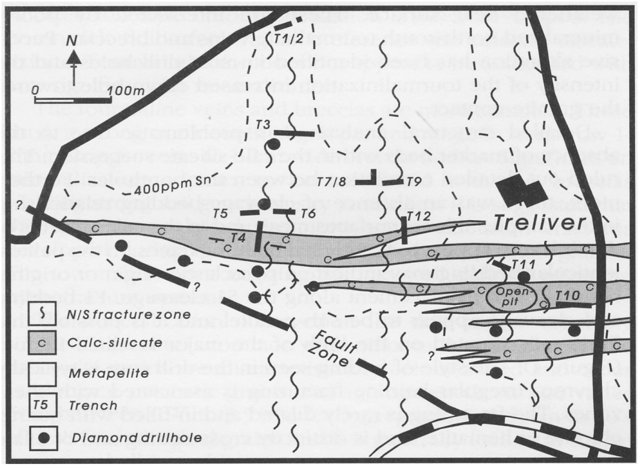

Figure 3: *Simplified geology and location of drill holes, trenches and geochemical anomaly in the Treliver area.*

and internal metasomatic redistribution of Ca, Fe and Mg, followed by metasomatism induced by fluids of granitic origins bearing Sn, Fe, and B (Alderton, 1993). The enrichment of Sn and other metals in the rocks suggests a strong chemical control on the mineralization.

Fluid inclusion and stable isotope data for south-west England skarns is limited. Jackson *et al.* (1982) reports temperatures of 360-380°C for axinite in a stanniferous calc-silicate body near St. Just. Oxygen and hydrogen stable isotope analyses reveal that the fluid compositions lie within the field for magmatic waters (Alderton, 1993).

LOCAL GEOLOGY

The area lies to the northwest of the St. Austell granite mass, which is dated at about 277 Ma (Chen *et al.,* 1993). The granite is a complex body with a number of small highs and ridges rising towards the surface. The Treliver area is situated within the Lower Devonian Meadfoot beds (Figure 2). These are a succession of slates and siltstones with rare, but persistent limestones of marine origin, which are mapped as calc-flinta (calc-silicates). The rocks have been structurally and mineralogically modified by the intrusion of the granite. Quartz-tourmaline rocks (metatourmalinite) are common in the metasediments throughout the area. Hydrothermal vein and breccia bodies composed of quartz-tourmaline (tourmalinites) intrude and crosscut the metasediments.

SOIL GEOCHEMISTRY

A 100 m square grid was initially used for reconnaissance. This was followed up by a 25 m infill grid to determine the regional potential

Trench	Start Coords.	Length	Geological Summary
TVT1	E1921250 N611125		Steep >60° southerly dipping metapelites and argillized metapelites, N-S striking micro/ 51.0m macro metatourmalinite veins and later quartz/Fe veins. Sn mineralization associated with N-S metatourmalinite veins.
TVT2	E1916950 N610200	30.5m	Steep >60° southerly dipping metapelites and argillised locally intensely hematitic stained metapelites, N-S striking micro/macro metatourmalinite veins and later quartz/Fe veins. Sn mineralization associated with N-S metatourmalinite veins.
TVT3	E1916950 N608600	63.0m	Steep >45° southerly dipping metapelites and argillised locally intensely hematitic stained metapelites, N/S striking micro/macro metatourmalinite veins and breccias and later quartz/Fe vein. Sn mineralization associated with N-S metatourmalinite veins.
TVT4	E1916675 N606825	47.0m	Complex inter-bedded sequence of steep >60° southerly dipping argillized metapelite/ metaphylites with intensely limonitic/hematic stained calc-silicate hornfels. Sn mineralization associated with calc-silicates.
TVT5	E19116420 N607425	30.0m	Steep >45° southerly dipping metapelites and argillized locally intensely hematitic-stained metapelites, N-S striking micro/macro metatourmalinite veins and breccias and later quartz/ Fe vein. Very weak Sn mineralization associated with N-S metatourmalinite veins.
TVT6	E1917275 N607425	37.0m	Steep >60° southerly dipping metapelites and argillized locally intensely argillized and hematitic stained metapelites, N-S striking numerous narrow and weakly pervasive tourmaline veins. Sn mineralization associated with N-S tourmaline veins.
TVT7	E1918550 N607850	23.4m	Variable 30-60° southerly dipping metapelite with ill-defined late quartz veins. Trace tin mineralization.
TVT8	E1918250 N607825	27.3m	Variable 30-70° southerly dipping metapelites locally argillised and hematitic stained with ill-defined late N-S striking quartz veins. Trace tin mineralization.
TVT9	E1918675 N607825	37.1m	Variable 45° southerly dipping metapelite, locally argillized and limonitic stained. N-S narrow tourmaline veins. Weak tin mineralization associated with narrow tourmaline veins or limonitic staining,
TVT10	E1921425 N605975	60.0m	Variable 35-60° southerly dipping metapelites and locally argillized and hematitic stained. Locally hard indurated calc-silicate hornfels and transitional metapelite/calc-silicate facies. Ill defined cross-cutting hydrothermal breccias. Sn mineralization associated with calc-silicates and hematization.
TVT11	E1920400 N606575	33.0m	Variable to steep dipping 65° southerly dipping metapelites locally traversed by numerous N-S oriented vertical dipping tourmaline veins. Sn mineralization associated with N-S tourmaline veins
TV12	E1919000 N606850	44.0m	Southerly dipping 50-60° calc-silicates and metapelite with ill-defined quartz veins. Calc-silicates varied in character from massive to deeply weathered and limonitic. Sn mineralization associated with limonitic calc-silicates

Table 1: *Summary of trench data from the Treliver area.*

and the configuration of the anomaly. Correlation co-efficients for A and B soil horizons showed that the best correlation was for the B-horizon.

Sieved samples, -1 jam +250 jam and -250 mm fractions were produced. After mathematical recombination to whole soil sample composition, a better correlation was obtained from the entire -1 mm fraction; this material was therefore used for geochemical analysis. This relationship is explained by the fact that cassiterite was present in the soil horizon up to 1 mm in size, which resulted from the proximal primary source.

Elements analysed by X-ray Fluorescence Spectrometry (XRF) were Sn, Cu and W with As being determined by Atomic Absorption Spectrometry (AAS). Analysis of the 3,960 soil samples indicated that there were three populations: a local background with a mean of 180 ppm Sn, an anthropogenic population with a mean of 300 ppm Sn and an anomalous population with a mean of 450 ppm Sn. The regional study showed both east-west and north-south Sn anomalies (Figure 2). At Treliver, a strong east-west anomaly with crosscutting north-south anomalies and with swells at the intersection points was revealed. Other elements did not indicate any strongly preferred trend.

TRENCHING

Twelve trenches were excavated to a depth of 2-3 m testing the underlying bedrock over Sn soil anomalies (Figure 3). These were orientated to check the east-west and north-south anomaly trends. Sidewalls were mapped and channel sampled. A summary of trench results is shown in Table 1.

DIAMOND DRILLING

Following completion of the trenching program, thirteen diamond drill holes were used to test the mineralization at depth (Figure 3). Holes were angled at -55° from the horizontal and ranged from 80 to 180 m in length. Drilling confirmed that tin mineralization existed in depth and was associated with both the tourmalinite veins/breccias and calc-silicates. The greatest thickness of mineralization was observed where the tourmalinite veins/breccias intersect the calc-silicates. The intensity of mineralization diminishes east and west along strike from this intersection zone. Drilling yielded localized high-grade intersections of 7.5% Sn over 1 m, though 0.42% over 9 m is somewhat more typical of the mineralization tenor.

STRUCTURE

The predominant tin mineralization is hosted within east-west striking calc-silicate rocks, which have been extensively weathered near surface. These are intersected by poorly mineralized north-south tourmalinite veins and breccias. Pervasive alteration has been identified in most drill holes and the intensity of the tourmalinization increased down-hole towards the granite contact.

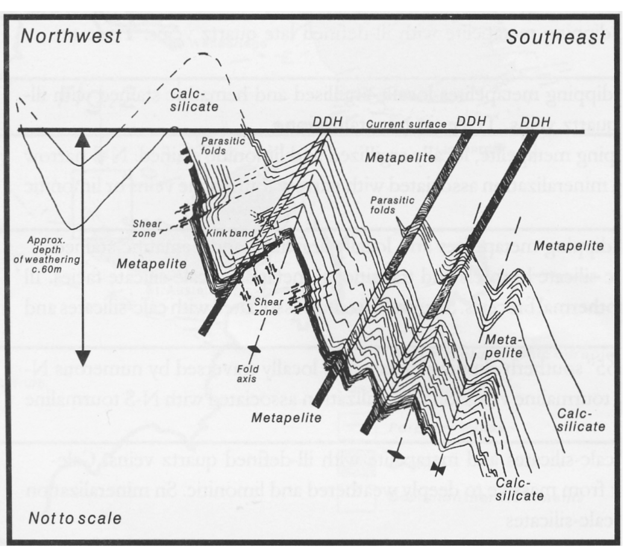

Figure 4. Preliminary interpretation of the Treliver area structure.

Detailed structural analysis was problematic due to the absence of marker beds within the calc-silicate succession. This ruled out detailed correlation between the boreholes. Furthermore, there was an absence of cleavage-bedding relationship in the samples. Planar surfaces measured in the calc-silicates of the drill core appear to be original bedding traces. In the pelites, lenticular bedding may indicate a pyroclastic origin or original bedding with displacement along the S1 cleavage. Fl bedding and cleavage appear to be sub-parallel and it is possible that Treliver is situated on the limb of the major isoclinal F1 fold (Figure 4). The style of folding seen in the drill core is typically chevron. Irregular hairline fracturing is associated with shear zones. The fracturing is rarely dilated and in-filled with quartz, chlorite or hematite, and is distinctly cross-cutting and of a late appearance.

The metapelites appear to be uniform in strike, essentially east-west, with local variations of no more than ±20°. Similarly, the dips recorded in the trenches are southerly, usually in excess of 40° and predominately between 60 and 70°. In rare instances, the dip attains a sub-vertical attitude.

With depth, the uniform southerly dipping image is more complex in some boreholes, with bedding running parallel to the drill core axis and hence northerly-dipping. In addition, microfolds typically chevron and more open flexuring are well developed in many boreholes. The metapelites, depending on degree of metamorphism, are typically laminar argillaceous sediments. Compositional banding is well developed, comprising alternating siliceous and argillaceous layers usually about 2 mm thick. This compositional variation is exaggerated by later boron-rich metasomatic events producing "zebra banded" hornfels. Thermal spotting is locally developed, with porphyroblastic andalusite pseudomorphed by tourmaline. This evidence suggests that the granite-country rock contact lies within 200-300 m from the surface. This is supported by a gravity survey in the area.

The calc-silicates, although conformable with the metapelites, are genetically different. Originally mapped as impure lime: stones (calc-flinta), they are likely to be of pyroclastic origin (Bromley, pers. comm.). Bedding and compositional banding are less well defined, absent locally, and elsewhere very varied. This may be interpreted as another indication of their volcanic-sedimentary origin. Metamorphic alteration of these rocks is widespread, displaying typical greenschist facies mineralogy (actinolite-chlorite-clinozoisite/epidote-albite-quartz). In addition, rutile, hematite, axinite and cassiterite are extensively developed at the expense of tourmaline. The transitional metapelite/calc-silicate facies are usually siliceous, with a comparatively simple mineralogy. Textually they exhibit strong, sedimentary bedding features typical of tuffaceous pyroclastics.

Geochemical analysis of 142 calc-silicate samples from the mid-Cornwall area indicated metal values ranging up to 5,300 ppm Sn, 60 ppm Cu, 970 ppm As, 3610 ppm Zn and 180 ppm WO_3. Those at Treliver range up to 9,400 ppm Sn and are depleted with respect to Cu, Zn and As.

MINERALIZATION

Two styles of tourmalinization have been identified at Treliver; 1) pervasive alteration and 2) veins and breccias. Pervasive alteration is probably controlled by the geometry of the granite-country rock contact and has been identified in most boreholes. It is most noticeable in the metapelite where the tourmaline has progressively pervaded and replaced the argillaceous components. This leaves siliceous bands, producing the characteristic weak zebra banded texture. The degree of tourmalinization increases in depth indicating a front some 300500 m from the granite-country rock contact. In the calc-silicates, this style of tourmalinization is rarely developed. The boron-rich fluids forming in preference the calcium silicate, axinite. Tourmalinization does not appear to be associated with any significant Sn mineralization.

The tourmaline veins and breccias are more complex. These show a strong north-south alignment and range from narrow 12 mm stringer veins to 1-2 m wide breccia bodies. Significant tin mineralization appears to be associated with the breccias yielding strong soil geochemistry anomalies. It is suggested that the breccias exploited the north-south extension fractures developed during the emplacement of the St. Austell granite. The tourmaline veins utilizing the less well defined adjoining hydrofracture systems.

The mineralization observed in the drill core is relatively simple. Cassiterite is common with minor rutile and sphene. The cassiterite grains are characteristically colour zoned and occur as elongate prismatic grains and aggregates. Grain size varies from between 0.75 to 3.5 mm for aggregates, and down to 10's of μm's for individual grains and it is generally locked in coarse quartz and albite, which is also seen to vein lithologies in the area. Tin-bearing silicate minerals were not identified in any of the samples studied.

Cassiterite was observed in two forms: 1) as massive veinlets and 2) as impregnations within lenses parallel to lithological banding. These lenses are often associated with tuffaceous bands, which create stratabound tin mineralization in the calc-silicates.

DISCUSSION

From the drilling and surface data obtained at Treliver, a preliminary interpretation of the local structure is possible. It indicates complex regional northwest-southeast and northsouth-trending fracture systems and a more flat dipping westnorthwest-eastsoutheast system at Treliver. Measurements of the core suggest a north or northwest dipping axial plane. A stylised cross-section is shown in Figure 4.

The core indicates that both brittle and semi-ductile deformation has occurred. Principal features localizing tin mineralization are the axial planes, parasitic folds and minor structures such as shear zones and kink bands. The major tin mineralization appears to be associated with:

1) highly broken and decomposed calc-silicates,

2) folded calc-silicate rocks close to the axis of interpreted minor or parasitic folds, and

3) brecciated metatourmalinite, tourmalinized hornfels and calc-silicates fractured in a N-S direction.

The timing of the epigenetic mineralization is suggested to be closely associated with the ore fluids released from the granite cupola. The lack of sulphides indicates that it was predominantly an oxide mineral assemblage. It is assumed that the tin mineralization was introduced through the N-S fracture set hosting the tourmaline breccias and veins, which were formed above topographic highs in the granite roof. Where these intersected the calc-silicates, fractures around fold 'noses' acted as loci for cassiterite concentration.

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