Read at the Annual Conference of the Ussher Society, January 1995

THE STRUCTURE AND PARAGENETIC EVOLUTION OF CASSITERITE MINERALIZED VEINS AT ROSEVALE MINE, ZENNOR, WEST CORNWALL

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Dominy, S. C., Camm, G. S., Bussell, M. A. and Bennett, T. S. The structure and paragenetic evolution of cassiterite mineralized veins at Rosevale Mine, Zennor, west Cornwall.
Proceedings of the Ussher Society, **8,** 374-378.

The Rosevale Mine Main Lode structure is traceable underground for 300 m along strike and for some 40 m down dip. The lode trends north-east-south-west, dips steeply (65-75°) towards the south-east and may be up to 5 m wide, with the central vein ranging from between 0.1 to 2 m in width, it is best described as a lode zone. The paragenesis of cassiterite mineralization in this composite lode zone has been related to its structural evolution. Mineralization occurs in two stages, associated with black and blue tourmaline which are the dominant gangue components. The two parageneses are deposited in distinct fracture sets formed by successive reactivation of the lode zone. Studies of vein geometry reveal that the early black tourmaline stage was deposited in a ramifying network of veinlets, which was reactivated and overprinted by the later blue tourmaline stage. The main period of cassiterite deposition was related to the blue tourmaline stage, however, traces of cassiterite are associated with the earlier black tourmaline veins. Within the blue tourmaline veins dense microcrystalline textures were formed by rapid crystallization, as ore fluid pressures were reduced in response to fracture dilation. Pulses of ore fluid were drawn from a magmatic reservoir into the fractured carapace of the host granite. Hydraulic fracturing is believed to be the principal mechanism for vein formation, with evidence to suggest an element of sinistral shear during development. The latest stage lode zone reactivation was related to episodic strike-slip fault activity which led to the formation of clay gouge, quartz, earthy hematite veining and breccias. The overall offset on the fault is difficult to measure but appears to be right lateral. Faulting has led to the formation of coarse in-lode breccias composed of tourmaline vein fragments set in a quartz/clay matrix. Throughout the lode zone late-stage low temperature fluid flow has resulted in pervasive argillization of wallrocks.

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INTRODUCTION

Abundant fractures with varying spatial, temporal, alteration, mineralogical and structural characteristics are ubiquitous features of the south-west England orefield. The lodes are typically steeply-dipping mineralized fracture systems which may occur in swarms; over 35 sub-parallel lodes were observed in the Camborne-Redruth area (Dines, 1956). They are generally located near porphyry dykes and along the axis of the granite batholith although some are found at the batholith margins (i.e. on the granite/metasediment contact). The simplest structural type occupies a single fracture but complex multi-stage fracture systems are more common (Henwood, 1843; Farmer and Halls, 1993). Most of the lodes strike about east-west and dip steeply with values in excess of 70°, although variations may occur both laterally and vertically. Widths of the lodes vary from a few centimetres to 4-5 m, with one of the widest being reported in Dolcoath Mine (Main Lode, 12 m wide; Dines, 1956). The lateral extent of the lodes is highly variable but some are traceable for over 3000 m along strike (e.g. Pryces-Tincroft Lode, South Crofty Mine). In many cases the mineralization may be discontinuous, with barren zones leading into ore-bearing zones and with the lode branching along its strike. The vertical extent of the lodes is variable, with the Dolcoath Mine (Camborne) Main Lode having been worked for some 1000 m in depth (Dines, 1956).

Three principal mineralizing stages are recognised (Jackson *et al.,* 1989):- a pre-batholith stage of minor strata-bound and syn-sedimentary mineralization (Fe-Mn-Cu); a syn-batholith stage (or main-stage) characterised by early stockwork mineralization (Sn-W) followed by lode mineralization (Sn, Sn-Cu) and a post-batholith stage of epithermal (or crosscourse) vein mineralization (Zn-Pb-Ag etc.) with pervasive kaolinization of granite.

The textural, mineralogical and structural features of the lodes reveal evidence of protracted multi-stage development involving dilation, cavity filling, shearing, brecciation and replacement. Micro- and macro-features of the veins indicate at least three mechanisms for formation: 1) hydraulic fracturing when fluid pressure exceeds the confining pressure and tensile strength of the host rocks, 2) decrepative fragmentation of wallrocks, triggered by the hydraulic shock which accompanies decompression of the hydraulic column and 3) active faulting resulting in the differential movement of wallrocks and disruption of pre-existing vein material. In most cases the development of the lode systems involves a hybrid of two or more of these processes (Bromley and Holl, 1986; Farmer and Halls, 1993).

MINE HISTORY.

Rosevale Mine is located in the Foage Valley [SW 458 379] which runs inland from the Atlantic coastline (Figure 1). The mine is within the Morvah-Zennor mining district, which is one of the least reported in the literature, except for the recent work of Noall (1993). The earliest reported underground working in the Foage valley was on a lode called Wheal Chance during 1809, but little is known about the venture (Noall, 1993). Other mines in the area include Carnelloe, Wheal Dollar, Gurnards Head and Trewey Downs (Dines, 1956; Noall, 1993). Foage valley has witnessed ancient activity for stream tin and several parallel lodes have been identified on the west side of the valley by means of trial pits. However, the main period of development at Rosevale Mine took place during the nineteenth century, although its history is not well documented. Between 1906 and 1912 Rosevale was worked by local miners, who produced some 3.5 tons of tin concentrate. In 1912 the mine was leased by Rayfield Cornwall Syndicate Ltd who built an extensive processing plant including a set of pneumatic stamps, before. closing in 1914 (Burt *et al.,* 1987). Since 1974 the mine has been privately owned and is used as an industrial archaeology and field training centre. Two levels (Nos. 1 and 2) are accessible on Main Lode which has been extracted using shrink stope methods. No previous geological studies have been undertaken within the mine or in the immediate vicinity.

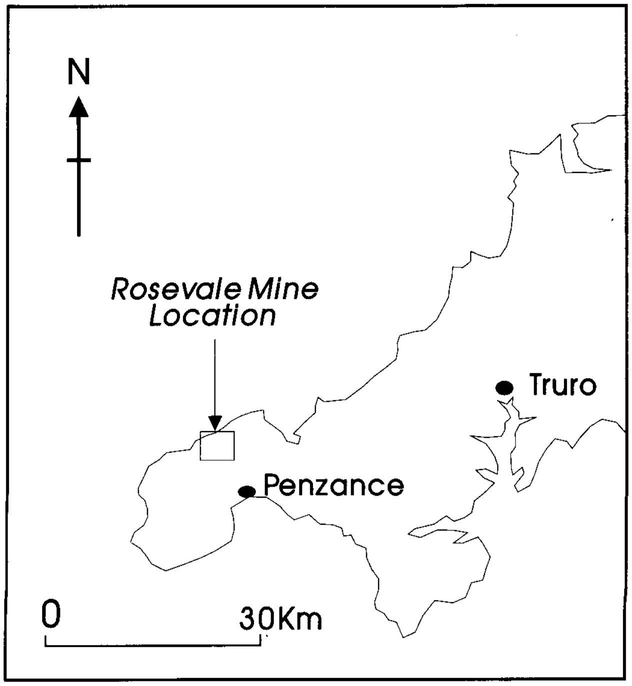

Figure 1: Map showing the location of Rosevale Mine.

This paper reports the preliminary findings and conclusions of an on-going project which commenced in mid-1994.

MINE GEOLOGY.

The lode zone is hosted in a medium-grained two-mica facies of the Land's End granite pluton (Willis-Richards and Jackson, 1989). The granite is composed of quartz, microperthitic K-feldspar, albite-oligoclase, biotite, muscovite and tourmaline. The Lode zone strikes north-east-south-west, sub-parallel to the major axis of the pluton, dips steeply (65-75°) towards the southeast and is traceable underground for 300 m. The lode zone reaches up to 5 m in width although the central mineralized fracture width varies from 0.1 to 2 m with a mean of 0.75 m (Figure 2).

Vein Texture and Mineralogy

The fractures are variably infilled by quartz, blue and black tourmaline and cassiterite. Quartz is generally present as narrow veinlets (<10 mm) or as breccia matrices. The black tourmaline is seen as mm scale veinlets which are observed within the wallrocks and are cut by the later blue tourmaline veins (>0.1 m in width). Cassiterite is generally associated with the blue tourmaline veins, forming minute grains and veinlets within a matrix of tourmaline and quartz.

The black tourmaline veinlets cut granite feldspars with no lateral displacement, suggesting a dominantly hydraulic mode of fracture dilation. Microscopic examination of blue tourmaline vein samples reveals dense microcrystalline aggregates, often forming micro-breccias and veins. These are typical "tinstone" textures of Flett (1903) and are indicative of rapid crystallization and episodic reactivation. Within the blue tourmaline-cassiterite veins highly localized sub-horizontal slickensides suggest that fracture formation involved a component of sinistral shear. This shear component is similar to that observed in the lodes of South Crofty Mine by Farmer and Halls (1992).

Pervasive wallrock sericitization is evident throughout sections of the lode zone with some highly localized tourmalinization. All the wallrocks have undergone pervasive argillization overprinting as a result of late-stage fluid activity. On No. 1 level a zone of tourmalinization which contained remnant alkali-feldspars has been argillized to a tourmaline-kaolinite rock. This material is very similar to the luxullianite of the St. Austell district (Lister, 1978).

Vein Structure

Within the lode zone vein widths vary (0.1 to 2 m wide) along strike and down dip, as do the values of strike and dip. Variation is often associated with vein splitting phenomena. Two types of split are observed: 1) footwall branches and 2) cymoid loops around granite horses (McKinstry, 1948).

The most prominent split off Main Lode is the No. 1 Branch Lode which has been stoped on Nos. 1 and 2 levels (Figure 3). On No. 2 level the branch strikes 020°, dips 75° to the north-west and is composed of a 0.6 m wide blue tourmaline vein. The exposure on No. 1 level strikes 020°, dips 70° to the north-west and has a width of 0.3 m. The No. 1 Branch Lode is believed to be the same structure that the early Wheal Chance workings were driven on. The hinge zone of the branch plunges approximately 60° towards the north-west and contains cassiterite-rich mineralization. Channel samples taken across the lode assay (by XRF) at 2.5% Sn over 0.75 m in the stope on No. 2 level and 1.5% Sn over 0.4 m on No. 1 level. Millimetre scale black tourmaline veinlets (known locally as "droppers") are observed on sections of the footwall, dipping sub-vertically and striking sub-parallel to the lode zone, they represent part of the earlier black tourmaline stage.

A second notable split feature (No. 2 Branch Lode) is seen on No. 1 level but not on No. 2 level. This implies that the split rejoins the mother vein below No. 1 level, forming an essentially open structure (Figure 3). The hinge zone on No. 1 level has been strongly dislocated by late-stage fault activity forming a coarse quartz-tourmaline breccia.

A cymoid loop structure occurs below No. 1 level, where the lode splits into two sections which are cut by No. 2 level drive (Figure 4). The hinge zone lies between Nos. 1 and 2 levels with the loop closing either side, the closing of the loop below No. 2 level is conjectural at the present time (Figure 4).

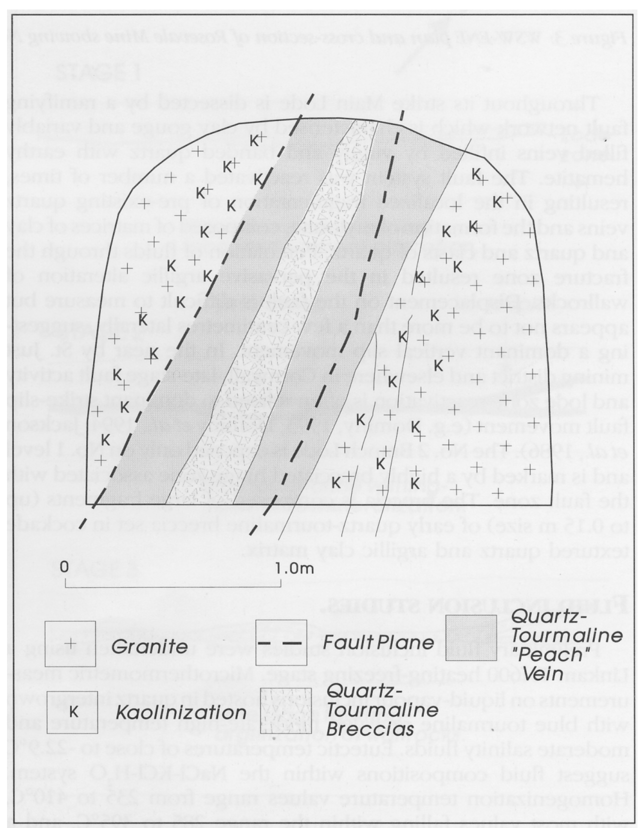

Figure 2: Schematic section of Main Lode.

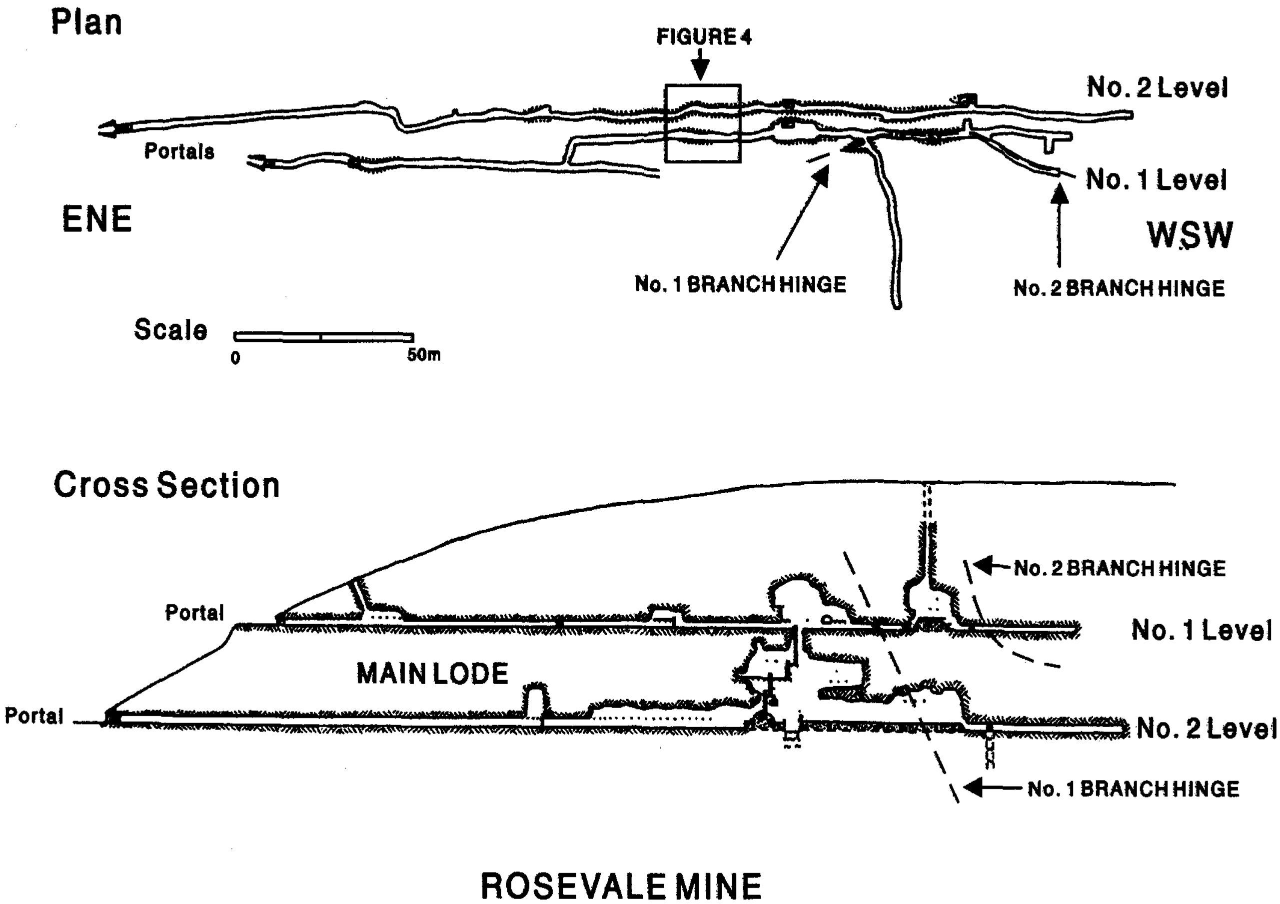

Figure 3: WSW-ENE plan and cross-section of Rosevale Mine showing Nos. 1 and 2 Levels and the major geological features.

Throughout its strike Main Lode is dissected by a ramifying fault network which is characterised by clay gouge and variably filled veins infilled by vuggy and banded quartz with earthy hematite. The fault system was reactivated a number of times, resulting in the localized fragmentation of pre-existing quartz veins and the formation of mylonite, composed of matrices of clay and quartz and clasts of quartz. Percolation of fluids through the fracture zone resulted in the pervasive argillic alteration of wallrocks. Displacement on the fault is difficult to measure but appears not to be more than a few centimetres laterally, suggesting a dominant vertical slip movement. In the near by St. Just mining district and elsewhere in Cornwall, late-stage fault activity and lode zone reactivation is often related to dominant strike-slip fault movement (e.g. Dominy, 1993; Dominy *et al.,* 1994; Jackson *et al,* 1986). The No. 2 Branch Lode is exposed only on No. 1 level and is marked by a highly brecciated hinge zone associated with the fault zone. The breccia is composed of large fragments (up to 0.15 m size) of early quartz-tourmaline breccia set in cockade textured quartz and argillic clay matrix.

FLUID INCLUSION STUDIES.

Preliminary fluid inclusion studies were undertaken using a Linkam TH600 heating-freezing stage. Microthermometric measurements on liquid-vapour inclusions hosted in quartz intergrown with blue tourmaline revealed moderate-high temperature and moderate salinity fluids. Eutectic temperatures of close to -22.9°C suggest fluid compositions within the NaCI-KCl-H_2O system. Homogenization temperature values range from 235 to 410°C, with most values falling within the range 285 to 395°C, and a salinity range from 11 to 24 eq. wt. % NaCl. These fluids are believed to be dominantly magmatic and were probably responsible for transporting the tin, these conclusions are in agreement with similar tourmaline-cassiterite veins elsewhere on Land's End (Jackson *et al.,* 1986) and in South Crofty Mine, Camborne (Dominy, 1994).

Inclusions hosted in quartz from late-stage fault related veins contain fluids of a NaCl-H_2O composition indicated by eutectic temperatures close to -20.8°C. Microthermometric studies of primary liquid-vapour inclusions revealed a homogenization temperature range from <100 to 210°C and a salinity range from <1 to 12 eq. wt. % NaCl. A small number of inclusions contain higher salinity fluids with values ranging from 14 to 20 eq. wt. % NaCl, these possibly represent basinal brines. The fluids associated with the fault system were dominantly meteoric in origin but may have involved mixing with some basinal brines expelled from a proximal sedimentary basin (Dominy *et al.,* 1994).

Studies of quartz from granite wallrocks revealed the presence of multiple planes of secondary fluid inclusions (FIPs), which represent healed microfractures (Krantz, 1986). Their occurrence suggests that fluid flow was not restricted to macrofractures, but permeated through wallrocks. Measurement of an oriented granite wallrock thin section on a universal microscope stage revealed that the inclusion planes show strong preferred orientation in the direction of the lode zone ranging from 032 to 057°. This corroborates with the findings of Westerman *et al.* (1992) in their study of granite hosted FIPs related to mineralization in east Cornwall. Preliminary microthermometric studies of plane hosted inclusions show two distinct homogenization temperature (Th) and salinity groupings; i) Th = 245-400°C and salinity 10-23 eq. wt. % NaCl and ii) Th = <100-205° and salinity <1-11 eq. wt. % NaCl. These two groups represent the stages of lode zone activity; i) tourmaline vein deposition and ii) strike-slip fault activity and quartz vein deposition. It can be concluded that the FIPs were

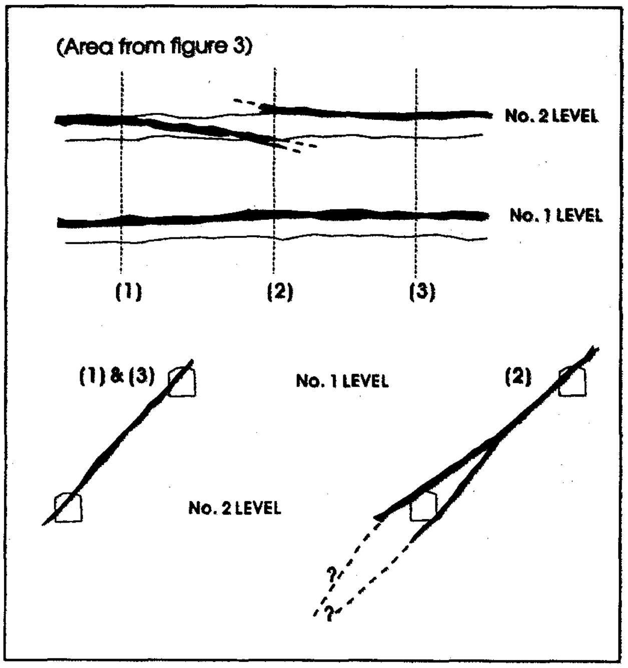

Figure 4: Schematic plan and cross section of the loop/split structure between Nos. 1 and 2 Levels.

related to the regional stress field dominant during each paragenetic stage and were probably a product of hydraulic fracturing (Lespinasse and Pecher, 1986). They can be used as a measure of palaeopermeability which exerts a control on the distribution and intensity of wallrock alteration (Dominy, 1994; Dominy *et al,* 1995).

LODE ZONE DEVELOPMENT

The development of the Main Lode can be described in terms of a narrow zone of brittle deformation (lode zone) which is about 5 m wide and at least 300 m long. The structural and paragenetic evolution of the system can be described in three stages (Figure 5):

Stage 1: The earliest stage of the paragenesis was characterised by the deposition of mm scale, 040-050°-trending black tourmaline veinlets associated with localized wallrock tourmalinization. Only minor cassiterite deposition took place during this stage of the paragenesis. A series of sub-parallel macro- and micro-fracture networks occur 2-4 m into the wallrocks and formed simultaneously with the master fracture set. The black tourmaline stage defined the north-east-south-west trending zone of brittle deformation. Vein formation was dominated by a mechanism of hydraulic fracturing related to magmatic fluid release from a plutonic source.

Stage 2: The blue tourmaline veins of the paragenesis (040-050°) were superimposed onto the black tourmaline fractures during lode zone reactivation. The veins contain fine masses of cassiterite associated with blue tourmaline and quartz. There is evidence to suggest that this reactivation was episodic and resulted in the comminution of cassiterite and blue tourmaline, forming breccias sometimes associated with further cassiterite deposition. High concentrations of cassiterite are located within the hinge zone of Main and No. 1 Branch Lodes, which represents a region of high fracture connectivity and fluid flow (Figure 3).

Stage 3: The final stage of development is marked by the deposition of variably north-east-trending vuggy quartz veins associated with a strike-slip fault system. Displacement of the tourmaline veins cannot be determined, but is considered to be small. Coarse breccias with fragments of tourmaline vein cemented by quartz developed within the lode zone and particularly within the Main Lode and No. 2 Branch Lode hinge zone. Low temperature fluids also led to the pervasive argillization of wallrocks.

EXPLORATION POTENTIAL

Rosevale Mine has not been worked for tin since 1914 and only now has any geological study been undertaken. Some ten channel samples collected underground have been analyzed by XRF for tin, the highest composite value assayed at 2.5% tin over 0.75 m, with the lowest values containing tin below detection level. This sampling programme has not been systematic enough to even attempt to produce a reserve classification, but clearly the chances of economic quantities of tin are minimal. Further mineralization may be present at depth, or in lode zones running parallel to that at Rosevale, but further exploration is highly unlikely in view of the current economic climate and environmental sensitivity of the area.

During 1963 parts of the Zennor area were investigated by Consolidated Gold Fields Ltd, who employed the late Prof. K. F. G. Hosking to report on exploration potential. Hosking drew particular attention to the lodes of Carnelloe Mine which are exposed in Veor Cove. He noted a number of highly hematized lode zones and stated that the mines were small and formerly operated by companies with limited capital. He concluded that part of Carnelloe Mine should be de-watered for evaluation. Encouraged by these findings Consolidated Gold Fields Ltd submitted a planning application to explore Carnelloe, the application was withdrawn in 1965 following local opposition (Trounson, 1993).

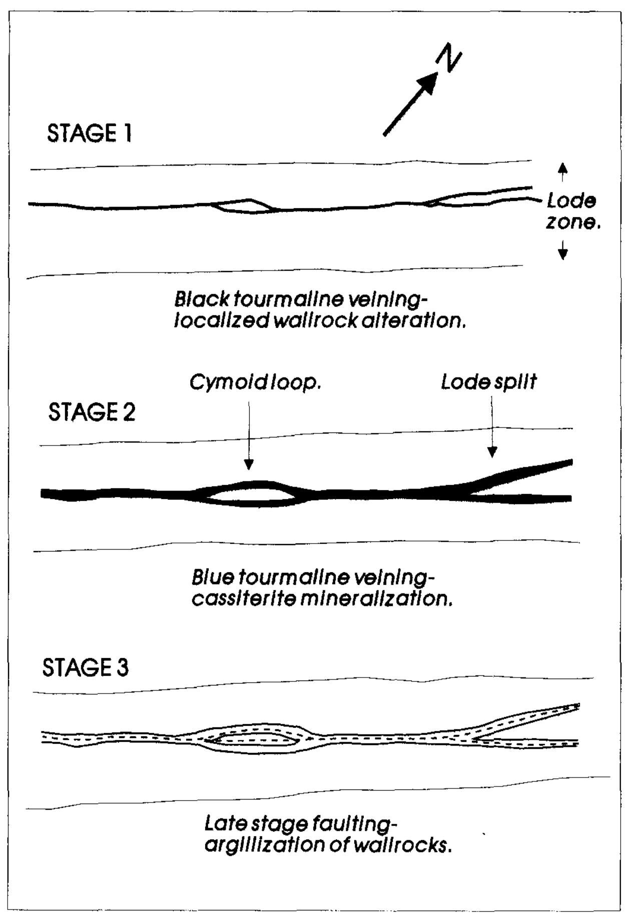

Figure 5: Schematic diagram showing the three principal stages in development of the Rosevale Main Lode Zone.

DISCUSSION

The tourmaline-cassiterite mineralization of Rosevale Main Lode is characteristic of others within the Land's End district (Jackson *et al.,* 1982) and elsewhere in Cornwall. The structure and mineralogy of Main Lode and its associated Branch Lodes is similar to the larger systems seen in the South Crofty Mine which are also explained in terms of a lode zone (Farmer and Halls, 1993). The Rosevale veins contain no sulphide-chlorite mineralization which is similarly a characteristic of the deeper tourmaline-cassiterite lodes of the Dolcoath and South Crofty Mines of Camborne-Redruth (Dines, 1956).

Rosevale Mine has not been worked below the depth of the valley bottom and generally, within the Zennor area, the mines are no deeper than 65 m (Noall, 1993; Trounson, 1993), which implies that the tin values may drop off at depth (Dines, 1956). The current exposure of the lode zone probably represents the root zone of tin mineralization, where the upper sections have been eroded away. Some sulphide-chlorite-bearing veins were recorded in Carnelloe Mine, which lies within metabasic rocks near the granite contact, some 1.5 km to the west of Rosevale.

The emplacement of the Land's End granite is put at 274 Ma (Chen *et al.,* 1993) with mineralization some 5-8 Ma later at 262265 Ma (Clark *et al.,* 1993). The minimum depth of mineralization was likely to be the order of 2.8 km, based on a value proposed by Jackson *et al.* (1982) in the Geevor Mine near St. Just.

The vein mineralogy is relatively simple with a multi-stage and complex structural history. The branch and cymoid loop features are related to the structural development of the lode zone with some control being exerted by pre-existing joints. The tin grades throughout the veins are generally low (<1% tin over 1 m) with enrichment related to fracture intersection and reactivation (e.g. the hinge zone between Main Lode and No. 1 Branch Lode). The general lack of rich cassiterite mineralization within the lode is corroborated by the lack of extensive underground stoping. Vein textures are dominated by microcrystalline intergrowths of tourmaline and cassiterite which form the matrices for hydraulic and cataclastic breccias (Flett, 1903; Farmer and Halls, 1993). Thus fracture propagation and mineral deposition were both rapid and episodic events, related to tectonically regulated pressure changes during lode zone activation.

Lode zone development can be explained by a model involving the hydraulic fracturing of the granite carapace by magmatic overpressuring regulated by regional tectonic stresses. The later dominance of tectonic input lead to fracture reactivation and the drawing of magmatic fluid from a plutonic reservoir (Allman-Ward *et al.,* 1982; Halls, 1987). Fluid inclusion studies confirm the role of moderate to high temperature aqueous fluids (>230°C), which must have contained small amounts of boron to facilitate localized wallrock tourmalinization and fracture infill by tourmaline. Throughout the mine the wallrocks have been pervasively sericitized which appears to be more common than the tourmalinization. Late-stage lode zone reactivation was related to strike-slip faulting and resulted in the formation of dilational fractures which were infilled with quartz. During this stage the lode zone acted as a region of low temperature fluid flow and resulted in the overprinting of pervasive kaolinization on the sericitized wallrocks. This alteration process resulted in the mobilization of iron and silica which was redeposited along the open fractures/shear planes associated with the fault activity (e.g. Dominy, 1993).

In conclusion, Rosevale Mine provides an excellent opportunity to study the geology of cassiterite-tourmaline-bearing veins which are becoming increasingly more difficult to locate in the field. These veins, formed within a narrow lode zone, were related to hydraulic fracture mechanisms regulated by the regional stress regime. Further field and laboratory studies are in progress.

ACKNOWLEDGEMENTS

The authors would like to thank Peninsula Mining Co. Ltd. and the Rosevale Historical Mining Society for this initiative to study the geology of Rosevale Mine. Thanks are due to Darryl Henderson and Stuart Emmett (Helston Mines Research Group), Jonnie Johnson, Brian Williams, Mike Kelly and Bob Orchard (Geevor Tin Mining Museum), and Terry Snell and Paul Oldfield for providing assistance during underground studies. Dr Chris Halls (Royal School of Mines) is thanked for useful discussions. This paper is part of an on-going project in the Zennor area and forms part of a wider research programme on the "Structural and paragenetic evolution of the Cornubian Orefield" at the University of Greenwich.

REFERENCES

ALLMAN-WARD, P., HALLS, C., RANKIN, A. H. and BRISTOW, C. M. 1982. An intrusive hydrothermal breccia body at Wheal Remfry in the western part of the St. Austell pluton, Cornwall. In: *Metallization Associated with Acid Magmatism.* John Wiley, Chichester. 1-28.

BROMLEY, A. V. and HOLL, C. 1986. Tin mineralization in southwest England. In: *Mineral Processing at a Crossroads,* Eds: B. A. WILLS and R. W. BARLEY. Martins Nijoff, Dordrecht. 195-262.

BURT, R., WAITE, P. and BURNLEY, R. 1987. *Cornish Mines, Metalliferous and Associated Minerals* 1845-1913. University of Exeter Press. 421pp.

CHEN, Y., CLARK, A. H., FARRAR, E., WASTENAYS, H. A., HODGSON, M. J. and BROMLEY, A. V. 1993. Diachronous and independent histories of plutonism and mineralization in the Cornubian Batholith, southwest England. *Journal of the Geological Society of London,* **150**, 1183-1191.

CLARK, A. H., CHEN, Y., FARRAR, E., WASTENAYS, H. A., STIMAC, J. A., HODGSON, M. J., WILLIS-RICHARDS, J. and BROMLEY, A. V. 1993. The Cornubian Sn-Cu (As, W) metallogenetic province: Product of a 30 MY history of discrete and concomitant anatectic, intrusive and hydrothermal events. *Proceedings of the Ussher Society,* **8**, 112-116.

DINES, H. G. 1956. The Metalliferous Mining Region of Southwest England. *Memoir of the Geological Survey of Great Britain.* Her Majesty's Stationery Office. 795pp.

DOMINY, S. C. 1993. The geology and genesis of the china clay deposits in southwest England with particular reference to their commercial properties. *Unpublished Ph.D. Thesis, Kingston University.* 302pp.

DOMINY, S. C. 1994. The Nature and Formation of Mineralized Fracture Systems in the Cornubian Orefield: Mineral Distribution and Mechanisms. *Unpublished Research Report No. 94/02.* University of Greenwich, June 1994. 59pp.

DOMINY, S. C., SCRIVENER, R. C., LEBOUTILLIER, N., BUSSELL, M. A. and HALLS, C. 1994. Crosscourses in South Crofty Mine, Cornwall: Further studies of paragenesis and structure. *Proceedings of the Ussher Society,* **8**, 237-241.

DOMINY, S. C., BUSSELL, M. A. and CAMM, G. S. 1995. The lode zone concept: An aid to the structural interpretation of complex vein systems. Transactions of the Institution of Mining and Metallurgy (Section B), In Press.

FARMER, C. B. and HALLS, C. 1993 Paragenetic evolution of cassiterite-bearing lodes at South Crofty Mine, Cornwall, United Kingdom. *Proceedings of the Eighth Quadrennial IAGOD Symposium.* E. Schweizerbart'sche Verlag, Stuttgart. 365-381.

FLETT, J. B. 1903. Notes on some brecciated stanniferous veinstones from Cornwall. *Summary of Progress of the Geological Survey for 1902.* 150-162.

HALLS, C. 1987. A mechanistic approach to the paragenetic interpretation of mineral lodes in Cornwall. *Proceedings of the Ussher Society,* **6**, 548-554.

HENWOOD, W. J. 1838. On the metalliferous deposits of Cornwall and Devon. *Transactions of the Royal Geological Society of Cornwall,* **5**, 1-386.

JACKSON, N. J., WILLIS-RICHARDS, J., MANNING, D. A. C. and SAMS, M. 1989. Evolution of the Cornubian orefield, southwest England. Part II: Mineral deposits and ore forming processes. *Economic Geology,* **84**, 1101-1133.

KRANTZ, R. L. 1986. Microcracks in rocks: A review. *Tectonophysics, 100,* 449-480.

LESPINASSE, M. and PECHER, M. 1986. Microfracturing and regional stress field: A study of the preferred orientations of fluid inclusion planes in a granite from the Massif Central, France. *Journal of Structural Geology,* **8/2**, 169-180.

LISTER, C. J. 1978. Luxullianite in situ within the St. Austell granite, Cornwall. *Mineralogical Magazine,* **42**, 295-297.

MCKINSTRY, H. E. 1948. *Mining Geology.* Prentice-Hill, New Jersey. 680pp.

NOALL, C. 1993. *The St. Ives Mining District,* Volume 2. Dyllansow Truran, Redruth. 157pp.

TROUNSON, J. H. 1993. *Cornwalls Future Mines:* Areas *in Cornwall of Mineral* Potential. University of Exeter Press. 164pp.

WESTERMAN, J. M., RANKIN, A. H. and GROCOTT, J. 1992. Fluid migration pathways and processes in the granitic rocks of the British Isles. Abstracts Volume, Mineral *Deposits Studies Group Research in Progress Meeting,* University of Leicester, June 1992. 9.

WILLIS-RICHARDS, J. and JACKSON, N. J. 1989. Evolution of the Cornubian orefield, southwest England. Part I: Batholith modelling and ore distribution. *Economic Geology,* **84**, 1078-1100.