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QUATERNARY PLACER CASSITERITE DEPOSITS IN CORNWALL: THE ROLE OF PERIGLACIAL PROCESSES IN THEIR DEVELOPMENT

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INTRODUCTION

There is a long history of placer mining for cassiterite in southwest England, dating back to the Bronze Age (De la Beche 1839, Durrance and Laming 1982); the deposits are therefore considerably disturbed by mining activity. Recent exploration has, however, made new data available for interpretation (Camm *et al.,* 1981; Hosking and Camm, 1983; Camm and Hosking, 1984; 1985). Research has continued into the mechanism of transportation and deposition by examining heavy mineral concentrations from the superficial deposits. The evolution of the Cornish landscape during the late Mesozoic has been the subject of considerable debate in recent years. Although both erosional and depositional remnants of these early stages of geomorphological development have been acknowledged for some considerable time, it is only recently that the Oligocene, Miocene and Pliocene deposits of Cornwall have been analysed in detail (Walsh *et al.,* 1987; Jowsey *et al.,* 1992; Head, 1993). In the eastern part of the province it can be demonstrated that the granite was unroofed by late Permian times, which facilitated the release of cassiterite into the geomorphological systems. However, the majority of tin placers in Cornwall are not associated with these early phases of geomorphological evolution, but with Quaternary deposits. The purpose of this paper is to report briefly on the nature of some of these Quaternary stanniferous placer deposits, and to draw some conclusions about the relationship between periglacial processes and placer development.

SAMPLING AND ANALYSIS OF PLACER DEPOSITS

Bulk samples were collected from a range of sites. Periglacial head was sampled at two sites: one, [Cot Valley, St. Just; SW 3489 3085], proximal to primary deposits of stanniferous veins, the other regarded as distal, being some 14 km away from tin mineralisation and separated from the nearest source in part by a physical barrier [Carne Cliff, Veryan, SW 9051 3824]. A further sample was collected from a supposed raised beach deposit above 130 m OD [Trewirgie, Redruth, SW 6972 4127]. These samples were compared to a palaeo-placer basal sample collected in recent years from an offshore deposit [Par Channel, off St. Austell, SW 065 456]. The samples were sieved into grain size fractions (clasts in excess of 64 mm diameter were not included in the samples) and subsplits assayed by XRF to determine grain size/tin distribution. Samples were concentrated and heavy mineral concentrates were examined by SEM.

FIELD DESCRIPTIONS

At the Cot Valley site, tourmalinised highly angular gelifracts are present along with large highly angular clasts of granite, both unsupported in a clay-rich matrix. The clasts exposed are monomict in character and appear to be preferentially orientated. The exposure at Carne Cliff comprises angular gelifracts of metapelite of overall smaller size than those at Cot Valley, but again unsupported in a clay rich matrix, and crudely imbricated. At Trewirgie the supposed raised beach has a fining-upward sequence with highly rounded polymict clasts which are matrix-supported. Both the bedrock and overlying sediment at this site are cryoturbated. The Par Channel sample was obtained from a drill hole and was therefore not seen *in situ.* The method of drilling by vibracorer did however reveal supported angular, subangular, subrounded, and very occasional rounded clasts, of tourmalinised metasediments and granitoids in a sandy silt matrix.

RESULTS AND INTERPRETATION

The Head assay value from Carne Cliff, a distal periglacial head product, gave an assay value below the detection limit of 10 ppm Sn: the proximal sample from Cot Valley a value, in contrast, of 185 ppm Sn. The raised beach deposit at Trewirgie was considerably enriched at 293 ppm Sn; this site is on the eastern end of the Camborne/Redruth ore field and hence the relatively high tin grade is to be expected if some form of concentration has taken place. The highest Head grade was obtained from the basal gravel sample from an unworked palaeo-placer offshore at Par Channel, with a grade of 1436 ppm Sn. Grain size versus tin distribution is shown graphically for all samples in Figure 1. In both the proximal Cot Valley and distal Carne Cliff samples, the <63 micron material, (coarse silt to clay fraction) accounts for a high percentage of the weight. This fraction can be seen to support the clasts or gelifracts. The product is probably derived from deeply-weathered bedrock resulting from Tertiary weathering

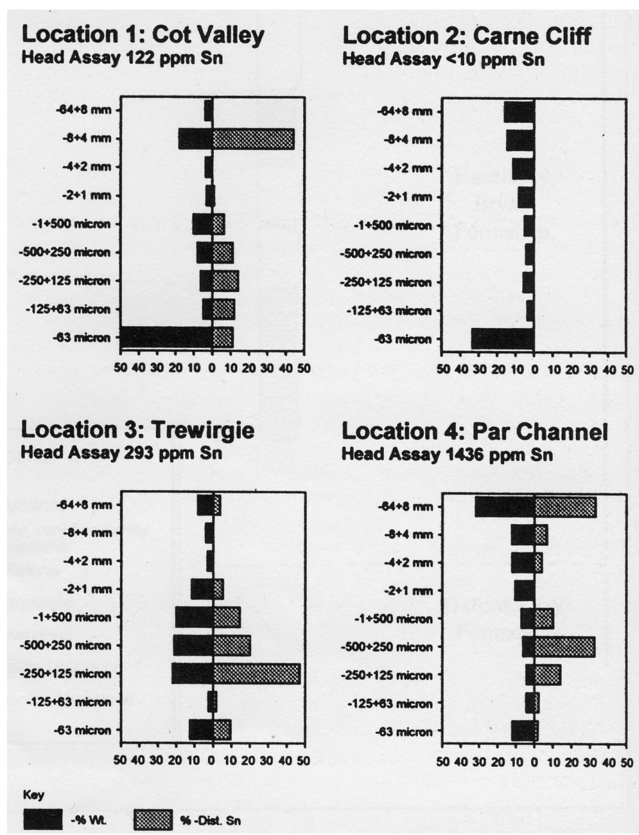

Figure 1. Graphs of texture vs. tin distribution for four samples of Quaternary placer deposits from various locations in Cornwall.

as well as periglacial weathering processes. The tin distribution in the proximal sample from Cot Valley shows a higher concentration in the 8 mm to 2 mm size range (equivalent to fine gravel) than the other size ranges. The Carne Cliff distal sample has tin values in all size ranges below the detection limit of 10 ppm Sn. There is a decrease in size/weight distribution down to 63 microns, after which there is a marked increase to over 30% in the <63 micron size range. The size distribution in the Carne Cliff sample probably represents the weathering characteristics of the parent rock. The sample clearly shows that cassiterite has not been transported to that area. In the Trewirgie sample, both the tin and size distribution in the upper sizes (>2 mm) are low, with a fairly even grain size distribution in size between 1 mm and 125 micron, but there is a marked increase in tin abundance with decreasing size. This may be the product of a natural liberating and concentrating action showing low tin concentrations in the upper and lower grain size ranges. It may be assumed that the increasing liberation in the finer size range down to an optimum size is governed by hydraulic equivalence. The results for palaeoplacer from Par Channel are directly comparable with those of the proximal periglacial head sample from the Cot Valley. The genesis of the offshore placer may therefore be closely related to the periglacial head material.

Surface textural features of sample concentrates from Cot Valley, Trewirgie and Par Channel were examined by SEM and compared with previous studies by Krinsley and Margolis (1969), Krinsley and Doornkamp (1973) and Whalley and Krinsley (1974). The proximal material from the Cot Valley has liberated unabraded cassiterite grains (Figure 2a); the quartz grains however show a conchoidal fracture but no attrition or abrasion marks. These are probably the result of a) clean liberation of cassiterite from a deeply weathered product and b) frost action in the case of the quartz. A cassiterite grain from Trewirgie (Figure 2b) is rounded, suggesting that it has been subjected to a high energy environment. However quartz grains from the same site are highly rounded and exhibit a form of chatter marking, diagnostic of marine surf action, (Krinsley and Margolis 1969; Krinsley and Doornkamp, 1973). With the highly rounded clasts in the basal section, a rapid fining-upward sequence and the SEM evidence, a conclusion may therefore be drawn that the sample from Trewirgie is truly a raised beach deposit, probably formed by a high marine stillstand at 130m OD. The concentrate from the basal gravel from the Par Channel shows cassiterite grains with partially abraded surfaces. The degree of sphericity is not high and the accompanying quartz grains show conchoidal fracture and some abrasion surfaces (Figure 2c). These appear to be indicative of a fluviatile process, with some degree of protective transportation agency, as the cassiterite is some 8 km from a known source and in a fluviatile regime a higher degree of rounding may have been expected.

This work suggests that periglacial head in a proximal environment carries fine-grained liberated cassiterite as well as locked grains and that high level stanniferous raised beaches occur. In addition, stanniferous palaeo-placer deposits some distance from the parent source of cassiterite, would appear to be transported initially by some other method rather than exclusively in a high-energy environment such as a fluviatile regime. Any cassiterite grains with high sphericity may be derived from palaeo-littoral deposits.

The total tin grade for each sample, except the distal sample from Carne Cliff, illustrates the increasing concentration of cassiterite as it moves through the periglacial transport system. Grade increases from a regolith containing Sn values below the detection limit, to 185 ppm Sn in the head material, 293 ppm Sn in the raised beach or palaeo-littoral deposit and ultimately to 1436 ppm Sn in the palaeo-placer.

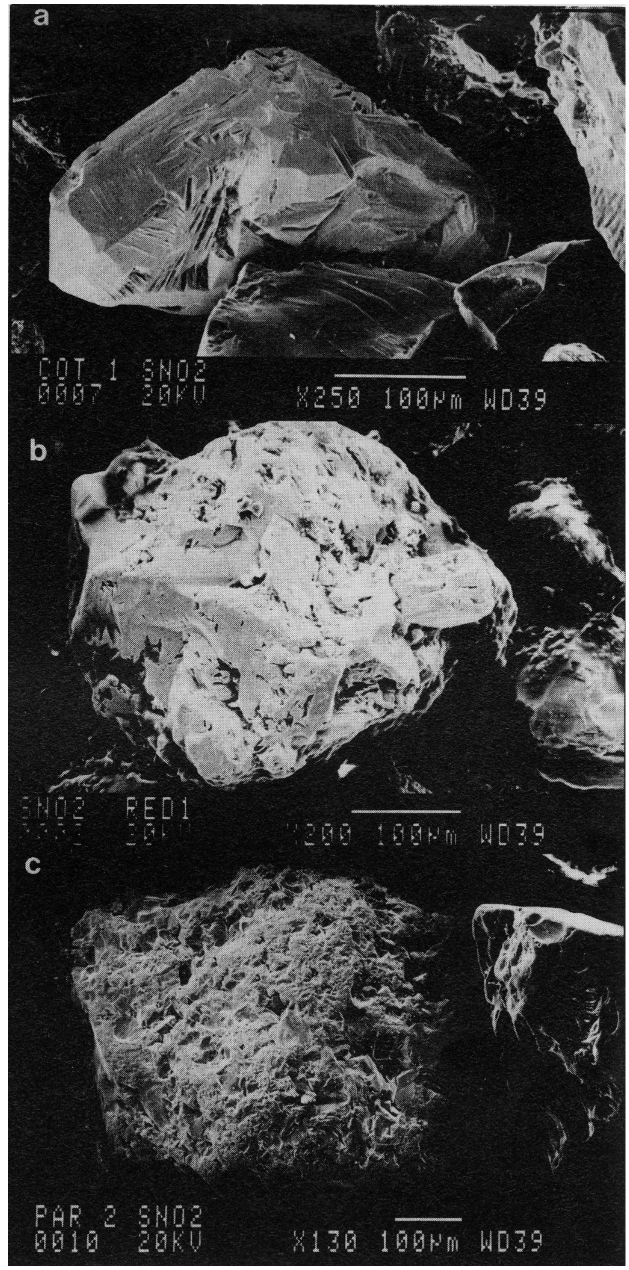

Figure 2. Scanning Electron Photomicrographs of sand-sized grains from Quaternary placer deposits in Cornwall (a) Geniculate twin of cassiterite and angular quartz grains from Cot Valley, St. Just; (b) Subrounded cassiterite grain from Trewirgie, Redruth; (c) subrounded cassiterite crystalline aggregate and quartz grain with conchoidal fractures, Par Channel, off St. Austell.

DISCUSSION

Since the work of Pryce (1778), the fluvial mechanism for the transportation and concentration of cassiterite into stanniferous placer deposits has been generally recognised. However, the periglacial head samples, proximal to a primary tin source reported above are enriched in Sn and the cassiterite grains show no signs of abrasion. In addition, this same sample contains quartz grains showing conchoidal fracture, indicative of periglacial liberation. Similarly, a basal tin-bearing sediment from an offshore deposit some 8 km from a known primary source shows less abrasion than would be expected.

These observations conflict with the general models of fluviatile placer development, and suggest that alternative transportational systems should be sought. Camm and Hosking (1984; 1985) tentatively suggested that such an alternative system may have existed in the periglacial land systems of the Pleistocene, comprising a range of slope and fluvial processes.

The efficiency of slope processes under periglacial climates is attested by the rapid downslope movement of large sheets of gelifluction debris in the Arctic. The thickness and lateral extent of head deposits in south-west England are testimony to extensive mass movements of identical nature during the Quaternary. Deep weathering in the Tertiary combined with hydrothermal argillic alteration of granite and metasedimentary rocks produced a significant depth of clay-rich and silt-rich regolith. Recently published work by Harris *et al.* (1993) clearly demonstrates the enhanced volumetric displacement of regolith under periglacial conditions associated with fine-grained soils, such as those developed from the metasediments and tropically weathered granites of Cornwall and Devon. They also conclude that much of this mass movement by gelifluction occurs during the spring thaw phase, when surface saturation occurs over a frozen (though not necessarily perma-frozen) subsoil. The nature of these movements in Cornwall appears most likely to have been as relatively thin-skinned matrix-dominated flows, in which clastic debris would have been quite well-supported and asperities protected. Field evidence (Harris, 1981) throughout the south-west shows that such flows occurred for great distances (several- kilometres on slopes of tow angle: 1 to 3°). If, as in Cornwall, the regolith was enriched in Sn there would be a significant reserve of cassiterite. The large aerial extent of such disseminated mineralisation would produce a significant resource of cassiterite in the regolith ready for transportation by gelifluction and debris flow. Cassiterite, either liberated from weathered parent rock by chemical means, or by thermal or frost-shattering can be transported in a clay-rich medium. If the slope angle was sufficient, it would enable debris flows to move a vast volume many kilometres from the parent source without commi-nution.

The corollary to this movement would be the depletion of regolith Sn at higher altitudes and its re-distribution (albeit at relatively low concentrations) at lower elevations. If the mass movement process involved sufficient water, then one might expect some winnowing and attendant concentration into 'pseudo-placer' deposits (para-autochthonous placers).

Fluvial processes operated in the south-west throughout the Quaternary, but it is probable that at least two climatically-controlled extreme regimes existed, with a spectrum of intermediate ones. The two extremes may be identified as the present temperate fluvial regime and the maritime Arctic regime (subarctic nival regime of Clark, 1988). Palaeoclimatic reconstructions for the UK as a whole (Williams, 1968) suggest that whilst the northern and central parts of the country were dominated by high pressure systems, with attendant widespread permafrost, the climate of the south-west may have been more akin to that of western Svalbard, Norway, today. Isolated examples of low-altitude ice-wedge casts (Scourse, 1987) do suggest a permafrost regime at some time during the Quaternary, but the limited distribution of patterned ground and other permafrost-dependent paleoforms may indicate the short time during which the south-west was in an 'arctic nival regime' (C'lark, 1988).

Studies of modern subarctic nival regimes (Clark, 1988) suggest that such periglacial rivers have highly time-concentrated flow patterns, dominated by a single flow peak in the spring, which is generated by rapid thaw of the snow cover. This debris-transportational system is bedload dominated, and such rivers rapidly yield large amounts of sediment to nearshore littoral and deltaic systems. Given the nature of these rapid runoff events, the associated deltaic and river terrace facies usually comprise beds of poorly sorted, subangular gravels with a poorly sorted sand matrix.

In contrast, modern temperate fluvial (interglacial), systems in the south-west have lower overall transportational capacity, which is dominated by solute and suspended loads in the mid and lower reaches, producing well-sorted sandy silt and clay facies.

Both gelifluction and periglacial fluviatile processes produced both para-autochthonous and allochthonous stanniferous placers in Cornwall. This suggests greater transport distances than previously recognised. The placer deposits at low levels are true alluvial deposits and with the prolonged fluviatile action and resultant enrichment are expected to contain the highest grades. Deposits at a higher level where fluviatile activity was less prolonged (unless rich initially from a parent source) must be expected to be of a much lower grade.

CONCLUSIONS

Cassiterite tends to occur in a bimodal form in Cornish placers: one with a higher sphericity is probably reworked from much older (Tertiary) higher altitude placer deposits, found along Tertiary raised beaches; the second form is predominantly angular, unabraded cassiterite found in abundance in Quaternary gravels in south-west England, both on and off-shore.

The results presented here suggest that periglaciation has had a very active role in the transportation and formation of the stanniferous placers in Cornwall. Cassiterite grains may be transported significant distances from source in debris flows. Combined with the debris flow, transportation distances of at least 10 km from the apparent source are possible. The implications of this study are that areas undergoing current periglacial regimes or have been exposed to a palaeoclimate such as this, with placer terrains, should be re-examined, as the heavy mineral may well have been transported a greater distance than previously thought.

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