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IS THERE GOLD MINERALIZATION ASSOCIATED WITH THE CARRICK THRUST?

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INTRODUCTION

There is well documented evidence from the 16th Century onwards of Cornish Tinners recovering gold from their workings and although production has been small, the potential of the region to yield resources of this precious metal cannot be ignored (Camm, 1995). Recent published studies of precious metal mineralization in south-west England have largely concerned northern and eastern Cornwall, and south Devon (e.g. Leake *et al*., 1989, 1992; Clayton *et al*., 1990). The purpose of this contribution is to provide a preliminary assessment of whether regional metamorphic fluids might have contributed to gold mineralization in south Cornwall.

GEOLOGY

Variscan tectonics

The Variscan basement of south Cornwall comprises the Lizard complex, the Gramscatho Group, and the Cornubian granite (Figure 1). The Gramscatho Group represents the sedimentary and volcanic infill of a Devonian deep marine basin that was locally floored by oceanic lithosphere, now partially preserved within the Lizard ophiolite. Variscan convergence brought about the closure of this basin by earliest Carboniferous times, and was associated with the emplacement of a series of thrust nappes towards the north-north-west (Leveridge *et al.,* 1990). Thrust-related burial brought about low-grade regional metamorphism and progressive deformation (D1 and D2) of the Gramscatho Group sediments and volcanics (e.g. Barnes and Andrews, 1981). Peak metamorphic conditions, synchronous with Dl deformation, have been estimated at 320 ±10°C and 3.2 ± 0.3 kbar on the basis of pumpellyite-actinolite mineral assemblages, and the integrated study of syn-D1 fluid inclusions, chlorite geothermometry and vitrinite reflectance (Barnes and Andrews, 1981; Wilkinson, 1990). Minimum temperatures at the end of D2 deformation were approximately 270°C at 1.2 kbar fluid pressure (Wilkinson, 1990). An extensional tectonic regime was subsequently established by latest Carboniferous times and was associated with the reactivation of major thrust faults, the onset of granite magmatism and high temperature W-Sn-Cu mineralization (Shail and Wilkinson, 1994; Alexander and Shail, 1996).

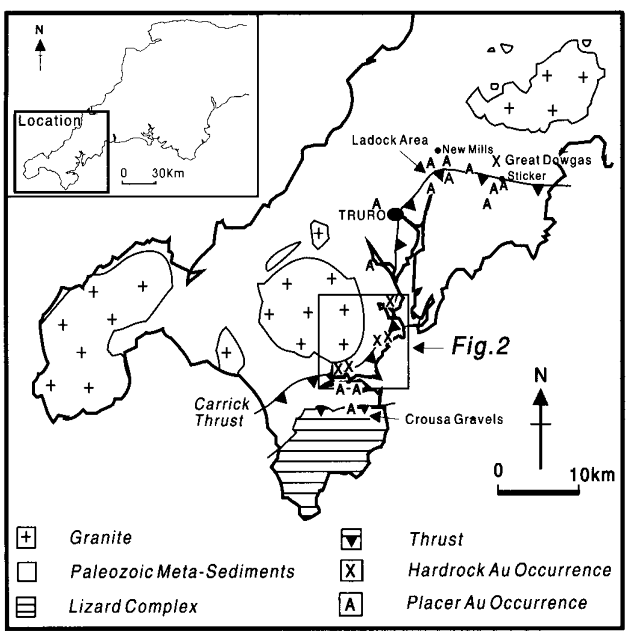

Figure 1. Hardrock and placer gold occurrences within the vicinity of the Carrick Thrust, south Cornwall (trace of the thrust after Leveridge et al., 1990).

A model for thrust-related gold mineralization

Metamorphic fluids, generated from large volumes of rock during low-grade regional metamorphism, have the potential to carry low levels of precious metals (Cox *et al*., 1987). These fluids can be subsequently focussed through much smaller volumes of rock, such as major faults or shear zones, to achieve large fluid-rock ratios. If such conditions can be combined with an efficient precipitation mechanism, then significant mineralization is possible (Cox *et al*., 1987).

The application of this model to south Cornwall was briefly considered by Wilkinson (1990), as part of a detailed investigation of the origin and evolution of Variscan crustal fluids. Major structures, such as the Carrick Thrust (Leveridge *et al*., 1990), were highlighted as important channelways for regional metamorphic fluids generated during D1/D2 deformation. It was suggested that the mudstone-dominated Mylor Slate Formation (Carrick Thrust footwall) would provide a reducing environment for metamorphic fluids derived from, and originally in equilibrium with, the sandstones and mudstones of the Portscatho Formation (Carrick Thrust hangingwall). As a consequence, the frontal ramp of the Carrick Thrust was regarded as the most likely site for gold precipitation due to the destabilization of metal complexes within the metamorphic fluids (Wilkinson, 1990). The Portscatho Formation sandstones are consistent with being a source for gold-bearing solutions as they are rich in acid volcanics derived from a dissected ancient volcanic arc (e.g. Floyd *et al*., 1991). A metamorphic origin for auriferous fluids has also been suggested for parts of North Cornwall by Clayton *et al*. (1990).

GOLD IN SOUTH CORWALL

Historical records of gold occurrences associated with both placer and hardrock mining activity show a high degree of correlation with the trace of the Carrick Thrust (Figure 1). Cassiterite placer mining in south Cornwall has often revealed the presence of gold, albeit in low concentrations. However several localities, primarily streams draining localities, primarily streams draining southwards from the thrust trace, are recorded as having higher gold concentrations. This is especially the case in the area south of a line running from Ladock [SW 892 510] in the west, to Sticker [SW 977 503] in the east. Gold has also been recorded in the north of the Lizard Peninsula from streams in the Manaccan area [SW 763 251]. The source of the gold has been problematical in all cases. In order to further examine this association, we have examined historical records in some detail and carried out sampling of ore material and sulphides in footwall rocks adjacent to the Carrick Thrust in the Falmouth area.

Historical records of gold occurrences

Historic records of mining activity show that six mines adjacent to the Carrick Thrust were auriferous (Figure 2). The Cunnack Manuscript (Brooke, 1993) mentions the Ino or Brogden Iron Mine [SW 746 279] as carrying gold values of 1218 dwts (1820 g) per ton. Wheal Anna Maria [SW 758 283], mining a copper lode has a record of gold on assay of 0.5 oz (14 g) per ton in a copper concentrate assaying 24% Cu (Hamilton Jenkin, 1967). At Pennance Mine [SW 791 296], dump material assayed by Christoe and Sons of Truro in 1935 produced a value of 18 grains (1.2 g) Au per ton (Hamilton Jenkin, 1967). Just to the north of this mine, in an old quarry on the Rosecraddock Estate [SW 785 315], free gold in a quartz "reef" associated with a black siliceous rock was observed by Stephens (1898). He also mentions that the ores of both Swanpool Mine [SW 801 312] and Wheal Clinton [SW 814 336] were auriferous. The highest gold values recorded by Collins (1904), from exploratory work undertaken by Dean (1865), occurred at Great Dowgas Mine [SW 962 508], where values of 7.5 dwt (11.6 g) per ton were obtained from auriferous pyrite within the Coffin Lode. This subvertical lode strikes east—west, sub-parallel to the trace of the Carrick Thrust, and comprised a crush (fault or stockwork?) zone some 10 to 20 metres in width containing veins infilled by quartz, pyrite and cassiterite; pyrite occurred locally as a massive infilling (Dines, 1956).

Gold has been found in many streams in an area south of a line from Ladock to Sticker (Camm, 1995). Sufficient gold was recovered from the Ladock River to encourage investigations in the last century to locate the source, but these were unsuccessful. Significant gold values are absent to the north of New Mills [SW 894 524], which is located north of the inferred thrust trace (Camm, 1995).

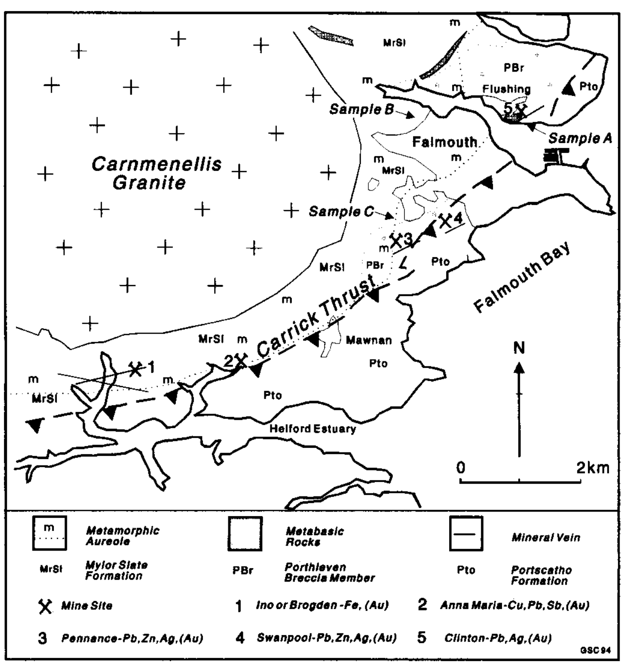

Figure 2. Gold bearing localities in the vicinity of the Carrick Thrust in the Falmouth area (trace of the thrust after Leveridge et al., 1990).

On the Lizard peninsula, the auriferous streams drain predominantly northward, notably at Mudgeon Vean [SW 734 253] (Collins, 1904), Durra Stream draining into Gillan Creek [SW 765 248], and a stream near Nare Point [SW 794 248] (Hambly, 1887).

NEW SAMPLING AND ANALYSES

Further sampling and investigations of the mine sites situated around the trace of the Carrick Thrust in the Falmouth area have been undertaken. Many of the mine dumps have now been removed or dispersed and it therefore necessitated, in many cases, looking at float for signs of obvious ore material. The majority of samples analyzed carried gold values which substantiated the historical data. In addition, we have collected sulphide samples from new localities in the district; these also returned anomalous gold values.

Locality		Au	Ag	As	Pb	Zn	Cu
Ino/Brogden (1)	SW 746 279	0.19ppm	<0.5ppm	310ppm	46ppm	163ppm	168ppm
Pennance Mine (3)	SW 788 297	2.05ppm	10ppm	3.90%	1.20%	2.60%	970ppm
Wheal Clinton (5)	SW 814 336	10.5ppm	197ppm	12.90%	23.70%	1.20%	2100ppm
Flushing (A)	SW 812 338	1.6ppm	<0.5ppm	390ppm	1.20%	1260ppm	187ppm
Penryn Bypass (B)	SW 792 340	0.03ppm	<0.5ppm	70ppm	139ppm	65ppm	184ppm
Rosecraddock (C)	SW 787 317	0.18ppm	14ppm	1.80%	1.60%	420ppm	600ppm

Sample descriptions: (1) hematite/limonite/goethite in quartz matrix; (2) pyrite/arsenopyrite/minor galena/sphalerite in quartz matrix; (5) galena/pyrite/arsenopyrite with minor sphalerite/chalcopyrite in quartz matrix; (A) podiform pyrite with minor galena and quartz; (B) pyrite concentrate from black shale; (C) pyrite with minor arsenopyrite/galena in quartz matrix. Analytical techniques: Samples for Au analysis were subjected to acid attack with HNO3/KClO3 followed by removal by evaporation and prolonged boiling with 1:1 HCl/H2O. After filtration to remove gangue, the gold was preconcentrated with a tellurium carrier by reduction and coprecipitation using ascorbic acid followed by SnCl2. After filtration onto a cellulose membrane filter the product was teken up in a small volume of acid prior to AAS analysis; detection limits are better than 0.01ppm. Low levels of other elements were determined using AAS after acid extraction. As and major levels of other elements were determined by a PW1400 XRF spectrometer using fused lithium meta/tetraborate beads and a method which avoids loss of volatile S and As.

Table 1. Analyses of samples from mine dumps (1, 3, 5) and new locations (A, B, C)

Ore samples collected from mine sites, apart from Ino Mine, are characterised by a very high pyrite content, with major arsenopyrite, galena, sphalerite and minor chalcopyrite (Table 1). The ore sample from Ino Mine was predominantly hematite and limonite. The sulphide samples collected from the new localities were all pyrite-rich. The sample from Flushing (locality A) was collected from cleavage-parallel podiform pyrite of probable combined diagenetic/metamorphic origin. The sample from the Penryn Bypass (locality B) was derived from pyritic black slates and the pyrite concentrated by gravity methods (Table 1). The sample from Rosecraddock Quarry (locality C), was from an area rich in sulphides within the quarry face.

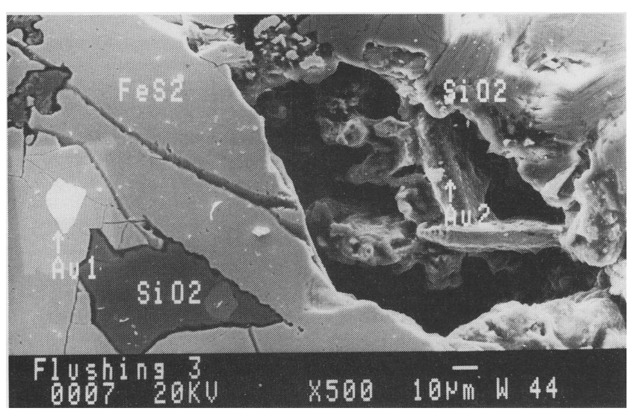

Figure 3. SEM image of gold locked in pyrite (Au 1, arrowed), and remnant gold in quartz after pyrite dissolution (Au 2, arrowed); sample A, Flushing [SW 812 338]

Gold was only visible by SEM in pyrite within sample A (Flushing), and is shown in Figure 3. EDAX analysis indicated that the gold in this sample contained silver. One small area of free gold was however seen with quartz where the pyrite has oxidised. Attempts were made to locate 'visible' gold by SEM in ore samples from the Clinton and Pennance Mines, but in both samples, high lead levels associated with disseminated galena have so far precluded the identification of the precious metal.

DISCUSSION

Historical records and our preliminary analyses suggest that there may be a connection in south Cornwall between precious metal mineralization and the Carrick Thrust, as originally envisaged by Wilkinson (1990). The gold appears to be intimately associated with pyrite and other sulphides. These sulphides may be disseminated within dark mudstones, or occur within syn-metamorphic quartz veins and late- to post-Variscan lodes; it is clear that several parageneses are represented and may be superimposed. We suggest that a significant proportion of the gold may have been initially derived from metamorphic fluids focussed along the the Carrick Thrust. Subsequent remobilization may have been brought about by contact metamorphism and hydrothermal activity adjacent to the Carnmenellis Granite. The apparent close association of Au with complex mesothermal mineralization containing Pb in the Falmouth area may help explain part of the source of the gold found historically in the Ladock Valley. It was reported that lead veins were exposed when mining the placer deposits. It is suggested that these may well have been auriferous. The gold derivation on the Lizard Complex may reflect a more complex history. Although it may be thrust-related, it has probably been mobilised by early fluviatile or marine transport mechanisms and transported south and so is now probably hosted in the Crousa Gravels.

Further work is required to test the hypothesis of a gold-thrust association by the analysis of favourable lithologies for gold and other trace elements, as well as fluid inclusion composition and geothermometry. The preliminary data appear encouraging.

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