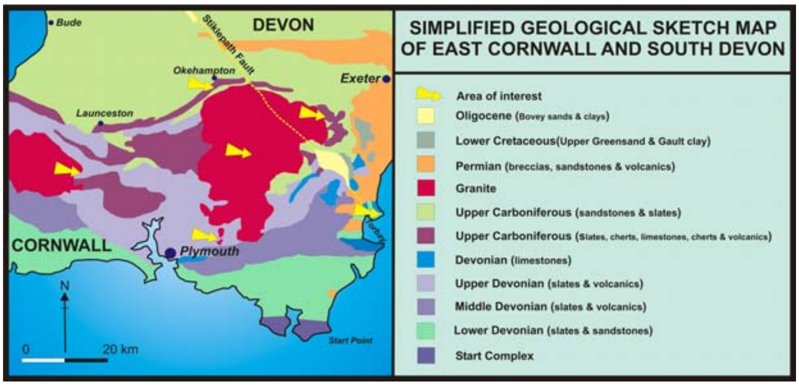
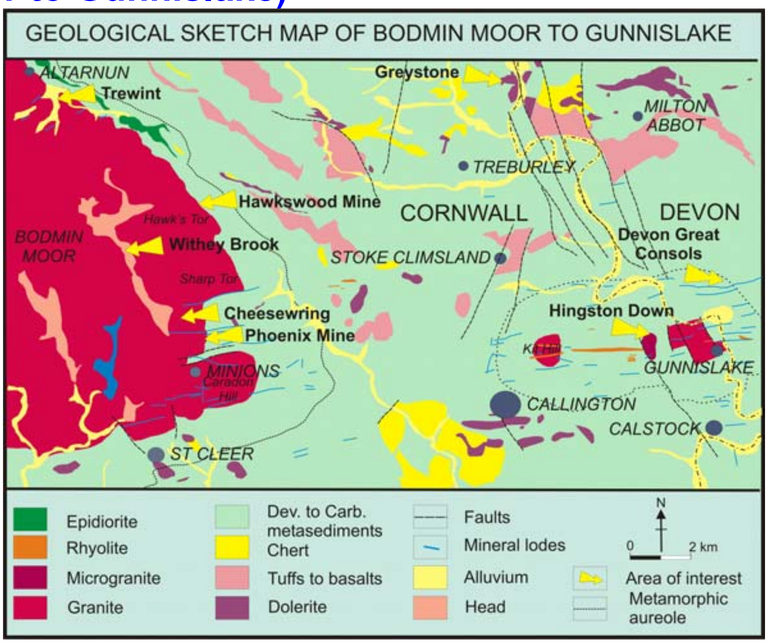
EAST CORNWALL, SOUTH DEVON AND DARTMOOR



The geology between Bodmin Moor and Dartmoor, including part of South Devon comprises Carboniferous and Middle Devonian metasediments of sandstones, mudstones, black shales, cherts and volcanics, all of which have been subjected to thrusting. Into these has been intruded the Bodmin and Dartmoor mass, as well as satellite stocks of Kit Hill, Hingston/Gunnislake in Cornwall and Hemerdon in Devon. Within these sediments lie stratiform manganese silicate and carbonate deposits as well as indications of lead-zinc-copper volcanic massive sulphide (VMS) deposits. The setting is similar to the Iberian Pyrite Belt (IPB) in southern Spain and Portugal. Skarn deposits with mixed copper, zinc and arsenic sulphides, and one of which has tin silicates, have formed from the same volcano-sedimentary sequences and lie on the northern edge of the Dartmoor granite near Okehampton, inside the metamorphic aureole. The granite related main-stage mineralization ranges from large copper deposits on the south-eastern corner of the Bodmin granite around Minions to a tungsten-tin stockworks at Hemerdon to the southwest of the main Dartmoor mass; to tin, tin-iron progressing eastwards into iron deposits on Dartmoor as well as placer deposits of cassiterite and woframite on Bodmin Moor. On the East side of Datmoor in the Teign Valley occurs Pb,Zn, Ba, Ag, low temperature crosscourse mineralization. On the south coast of Devon near Torquay lies the epithermal gold-palladium occurrence at Hope's Nose, hosted in Devonian limestones.

East Cornwall (Bodmin Moor to Gunnislake)

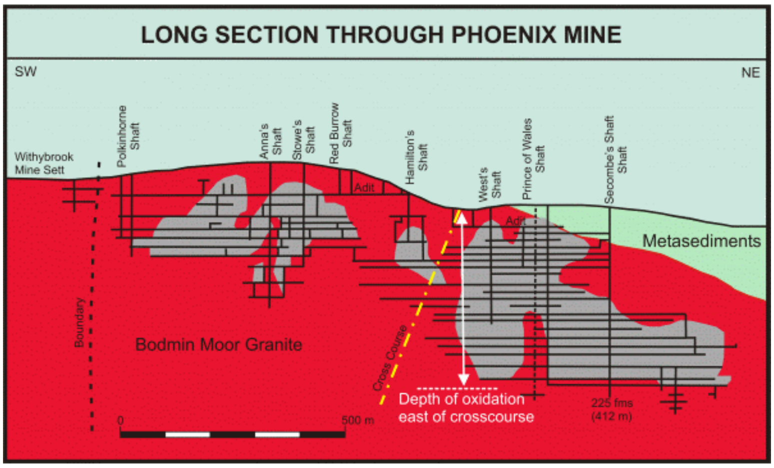


The geology of this area ranges from the granites of Bodmin Moor and the small outcrops of Kit Hill and Hingston Down/Gunnislake to Devonian and Carboniferous metasediments and volcanics. Mineralization styles vary from Devonian/Carboniferous volcanic related stratiform manganese and lead/zinc mineralization and to granite related early greisen tin and tungsten to main stage tin, copper, arsenic mineralization; and later Tertiary Age lead, zinc and silver mineralization, mainly in the Tamar Valley near Calstock. Placer deposits of both eluvial and alluvial tin and tungsten deposits have been worked on Bodmin Moor.

Minions Cu/Sn/W Mineralization

To the northwest of Caradon Hill, near Minions lies Phoenix Mine under the Cheesewring quarry. The mine initially worked cassiterite from the gossans and later enriched areas of copper ores were discovered below, all hosted in the Bodmin Granite. The interesting feature of this mine was the great depth of oxidation of the mineralization in the northeast section of the mine near the cross-course. It must be assumed that oxidizing meteoric water was able to penetrate to that depth, presumably via the cross-course fault or associated fractures. The mine was famous not only for cuprite, but also phosphates of copper minerals such as chalcosiderite, andrewsite and libethenite.

Phoenix Mine

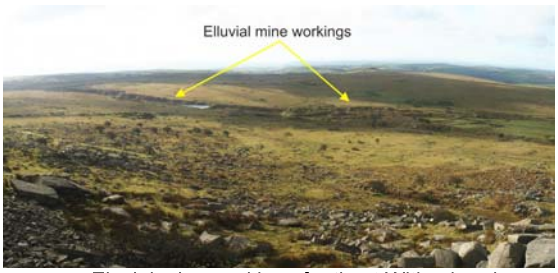


Chalcosiderite

Cheesewring Quarry

The Cheesewring Tor

On the high ground above Phoenix mine from the vantage point of the Cheesewring Tor there is abundant evidence of early eluvial tin mining extending to small opencast mining of shallow ore at Witheybrook. Lower ground to the north had been worked for placer alluvial tin ores at Witheybrook Marsh.

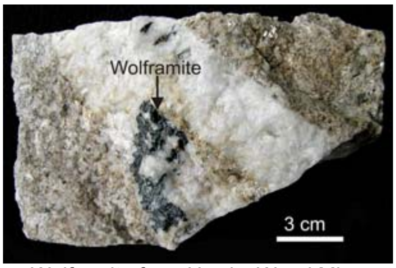


Eluvial mine workings for tin at Witheybrook

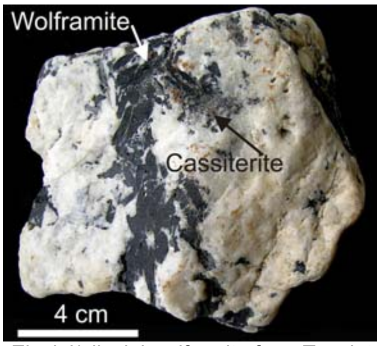
Witheybrook Marsh

Around the fringe of the Bodmin Moor Granite near the contact are small areas of mineralization, predominantly of sheeted greisen veins with cassiterite and wolframite, sometimes altering to scheelite. At Hawks Wood mine these were exploited by adit mining, elsewhere the predominantly tungsten rich eluvial/alluvial deposits had been exploited by placer mining. At Trewint, now a small sand and gravel operation, both minerals were extracted as a by-product in the past.

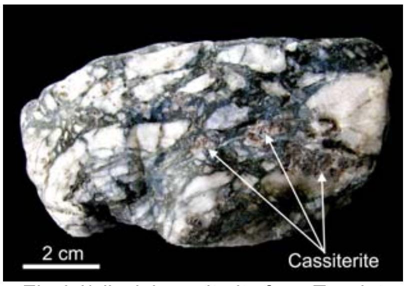

Trewint gravel operations



Wolframite from Hawks Wood Mine

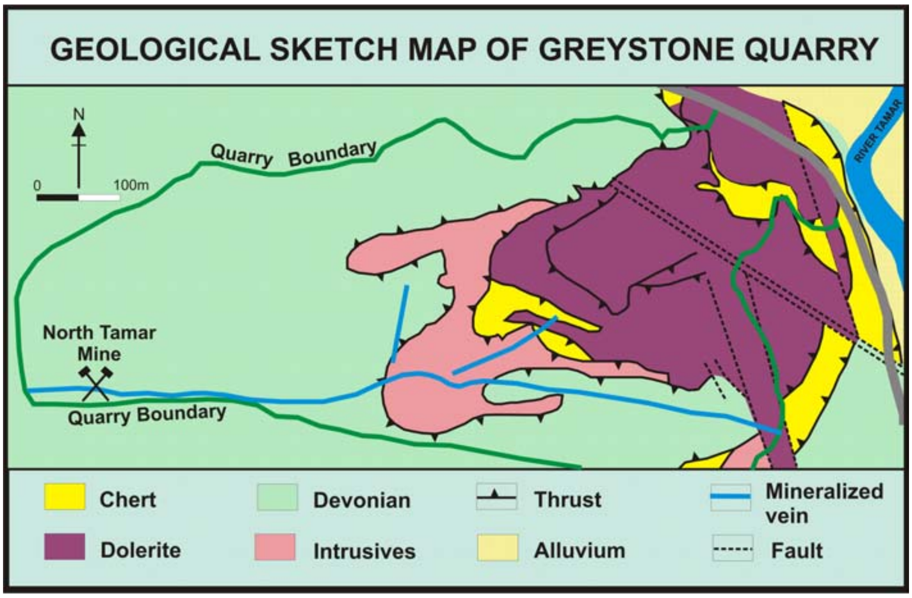


Eluvial/alluvial wolframite from Trewint

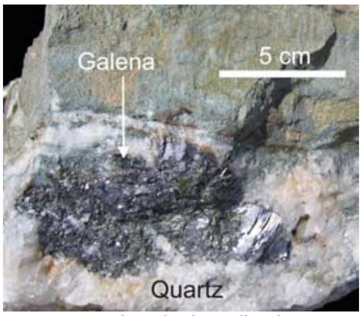


Eluvial/alluvial cassiterite from Trewint

Greystones Quarry Pb/Zn Mineralization

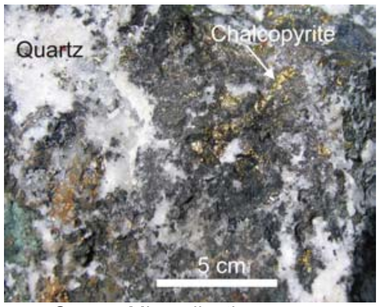


The quarry exposes mudstones of the South Devon Basin of Devonian and Carboniferous Age, into which has been intruded basic igneous rock of both extrusive and intrusive in type in the form of sill like bodies. The Devonian sediments of are grey slates with the Carboniferous sediments of dark grey to black siliceous slates, cherts, sandstones, pillow breccias and lavas (dolerite). Manganese exhalative mineralization produced during the time of volcanicity has been found in the quarry converted by metamorphism into rhodonite and other manganese minerals. The rocks in the quarry have been cut by at least four thrusts, which has produced an inverted geological sequence. A lead-bearing vein striking east-west is exposed in the southern wall of the quarry which extends to west the to an old 18th century mine of North Tamar. The vein appears to be a series of 'en echelon' type structures in a fault zone. Cu bearing quartz veins striking NE-SW and NNE-SSW and are intersected by the lead lode and other NNE-SSW quartz veins with sphalerite, aragonite and copper-antimony minerals. It is possible that the lead lode may represent metamorphic remobilisation of exhalative mineralization as it does not conform to the NNE-SSW basinal brine derived mineralization seen elsewhere if the Conubian Orefield. Supergene oxidation has produced a great variety of mineral species, some rare, from this location.



Lead mineralization

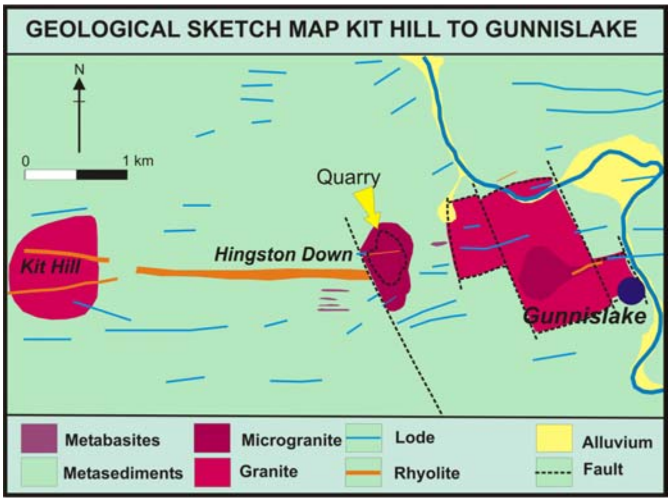

Manganese mineralization



Copper Mineralization

Hingston Down Quarry Sn/Cu/W/ Mo Mineralization

Hingston Down granite, 3 km east of the small granite stock of Kit Hill and just west of the Gunnislake granite near the border with the two counties, has faulted contacts. The granite is classed as a fine-grained microgranite and is dated at 282Ma. The mass is cut by later granitic veins and aplites. The quarry as it has advanced into the hillside has intersected mineralised lode structures of Hingston Down Consols. The granite is also mineralized with sulphide pods of arsenopyrite, chalcopyrite, pyrite and quartz +/- sphalerite, stannite, wolframite, scheelite and fluorite and is occasionally molybdenum rich. The mineralization appears to be joint controlled

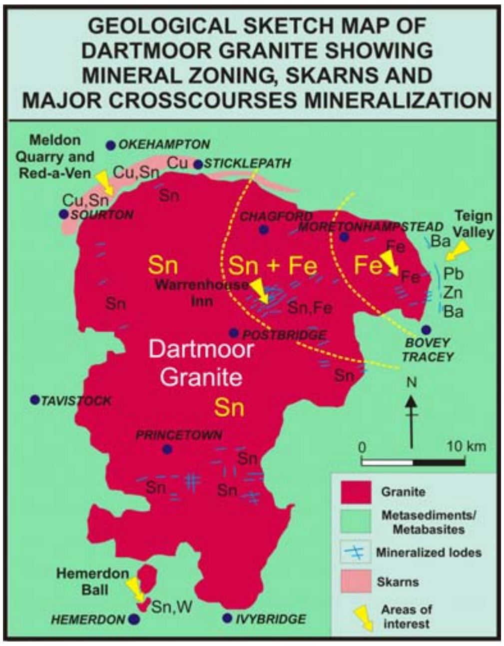



Hingston Down quarry

Molybdenite

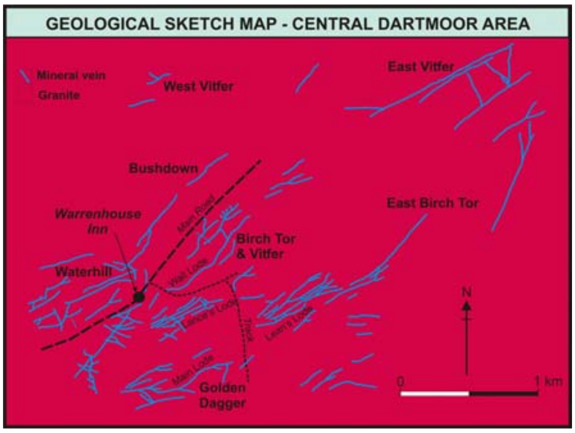
Dartmoor

There has been extensive placer mining for casiterite over the entire Moor and periphery and substantial tonnages were recovered. It was during the medieval period that the area was the largest producer of tin ore in the British Isles. The depth of mineralization on the Moor itself is not considerable and it may be supposed that the mineralization represents the 'roots' of mineral deposits long eroded away leaving the heavy resistate cassiterite on the surface. Across the Moor some form of zoning is evident with Sn in the west, Sn and Fe in the centre and Fe mineralization in the east. A small satellite granite stock to the south west of the Moor hosts a sheeted-vein deposit of tin and tungsten and around the northwest the immediate aureole rocks host skarn deposits of base copper, metal suphides and tin. On the eastern edge of Dartmoor lies the crosscourse mineralization of Pb, Zn,Ag and Ba in the Teign Valley.



Central Dartmoor Sn Mineralization

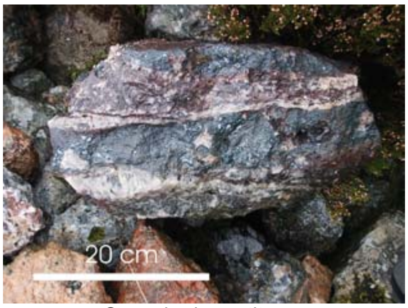
The mining district is situated approximately slightly to the east of the middle of Dartmoor where a swarm of cassiterite-bearing hydrothermal veins have been exploited for their tin content from prehistory. Evidence of early mining takes the form of both placer and eluvial mining followed by open workings on the subcrop of the hydrothermal veins after they were exposed most probably in medieval times. Later mining went underground and the last mining operations on the Birch Tor, Vitfer and Golden Dagger ceased in about 1930. The hydrothermal veins are hosted in coarse megacrystic granite and are steeply dipping fissure veins. Early tin mineralization may have been associated with tourmalinized breccias and later lower temperature fluids are responsible for specular hematite infilling after re-brecciation due to subsequent reactivation. The mineralization is simple in type of cassiterite, hematite, tourmaline and chlorite with an almost total absence of sulphides.



General view looking SE Birch Tor and Vitfer Area

Open cast mining for cassiterite

Wallrock alteration



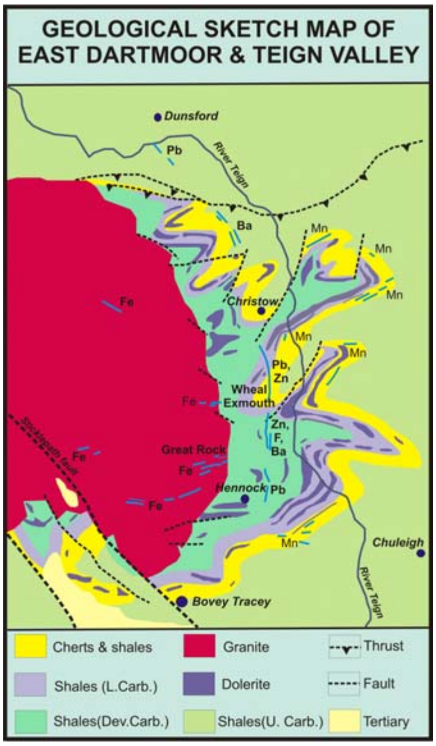
Specular hematite

Quartz tourmaline

East Dartmoor Fe and Base Metal & Barite Mineralization

Fe Mineralization

It seems that the Dartmoor Granite provided a special environment for the formation of deposits dominated by oxides and silicates. The evidence suggests that the hematite mineralization at the eastern margin of the Dartmoor Granite represents the highest and coolest level of activity of a hydrothermal system, which probably extends deep into the pluton. The type of mineralization seen at Birch Tor in central Dartmoor represents a deeper level of hydrothermal activity that has been exposed by erosion and removal of the higher parts of the system. This model could account for the presence of placer tin deposits over wide areas of western Dartmoor in which cassiterite-bearing veins have not been recorded. Tourmaline and then cassiterite were precipitated from highly saline fluids at between 250°C and 400°C, while the specular and micaceous hematite mineralisation resulted from fluids of low salinity, with temperatures in the range 160°C to 200°C. The hematite worked for use in paint consists of steel-grey plates in the size range 10 to 200 microns, occurring as felted masses within the veins, together with variable amounts of coarser hematite and, at Great Rock, minor amounts of quartz, tourmaline, pyrite, sericite and kaolinite. Great Rock only closed in the 1960s.




Specularite veins in Great Rock Mine


Lode section in Great Rock Mine

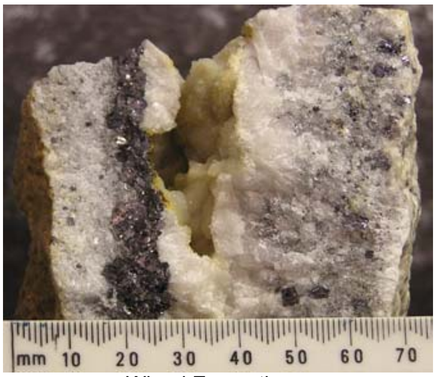

Specular hematite ore

At Great Rock the hematite veins cut through, and therefore post-date, the coarse granite and the later aplite sheets. Typically, a lode comprises a swarm of veins and veinlets, which are mostly parallel or subparallel, but in places coalesce. The vein zones may be several metres in width, with components varying from millimetre-scale stringers to workable orebodies up to 1.2m wide.

Pb/Zn and Ba Mineralization

Wheal Exmouth Mine Dumps

Wheal Exmouth Mine

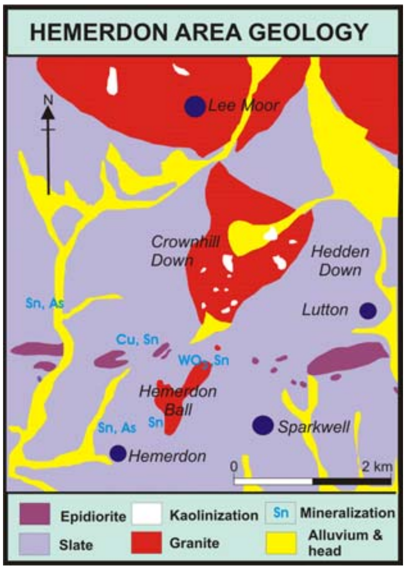


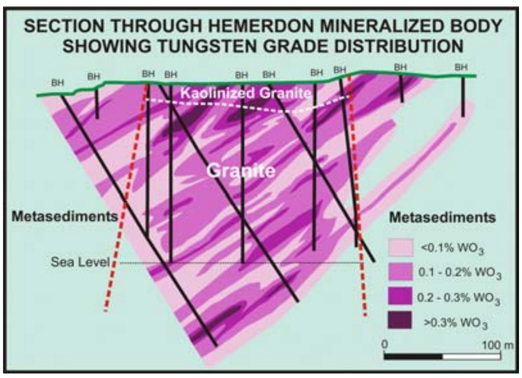
Wheal Exmouth ore

The general geology of the Teign Valley is one of Upper Devonian mudstones and Lower Carboniferous shales, cherts and volcanics with manganiferous horizons. A zone some 8 km long and 200 wide, which parallels the granite contact hosts NNW-SSE trending cross-course mineralization of Pb.Zn. Ag, Ba with minor Sb. The main gangue minerals are chalcedonic quartz and barite, minor calcite and fluorite, which would indicate, low temperature epithermal mineralization. The width of these lodes varies from less than 0.6m to 15 m. One of the major mines was Wheal Exmouth, which produced not only lead but also substantial amounts of silver, as the galena was silver rich. The mine has a distinctive hexagonal chimney. Metals were probably derived from the expulsion of brines from sedimentary Permo-Triassic sedimentary basins. Fluid inclusion data from material from the Teign Valley indicates temperatures in the range of 110-160^{o}C. Brines were circulated by gravity driven mechanisms after subsidence in the sedimentary basins caused by extensional faulting. Part of the metal deposited in the mineralised belt may have been derived in part from stratiform mineralization enrichments in Lower Carboniferous host rocks.

Hemerdon Sn/W Mineralization

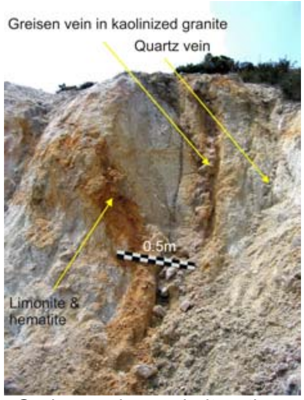
This deposit at Hemerdon Ball was extensively explored during late 1970's to early 1980's by AMAX Exploration as a potential resource of tungsten. The deposit is a stockwork/sheeted greisen vein deposit hosted in a dyke-like granite body some 120m long and dipping steeply eastwards surrounded by metasediments. Early mining had taken place during both the First and Second World Wars as tungsten was a strategic metal. The southern and western area of the granitoid body are only slightly altered but the NNE part is highly kaolinized and greisenized. The mineralised area extends for some 600X400m within the granite although the greisenization extends into the metasediments. Two veins are discernable, one of quartz veins without greisen borders and stockwork in type with minor mineralization and greisen bordered veins, often sheeted in sub-parallel sets. The main mineralization is of wolframite with arsenopyrite and minor cassiterite. Due to surface weathering by meteoric waters the arsenopyrite has been oxidized and the iron and arsenic remobilised to form scorodite, an iron arsenate mineral, in the upper part of the resource. The argillic (clay) alteration extends down to a depth of some 50m. Drilling had revealed a potential resource of some 50 million tonnes at 0.7% WO_3 and 0.025% Sn to a depth of some 200m with mineralization continuing down to c.400m.



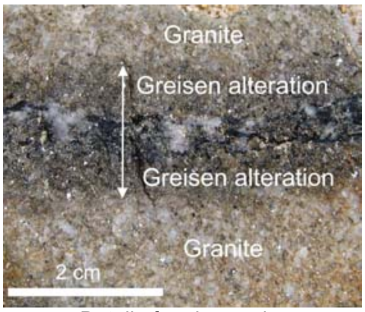


View of part Hemerdon open pit

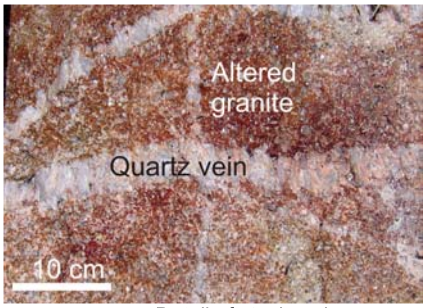
Greisen veins in rock face



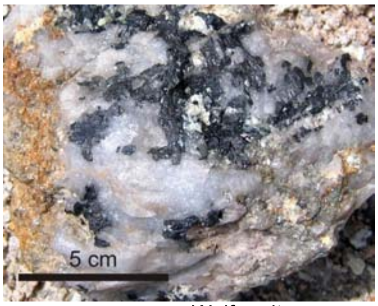
Greisen veins and alteration



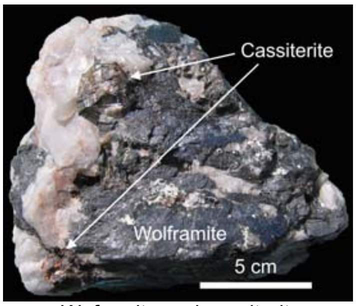
Detail of greisen vein



Detail of stockwork



Wolframite

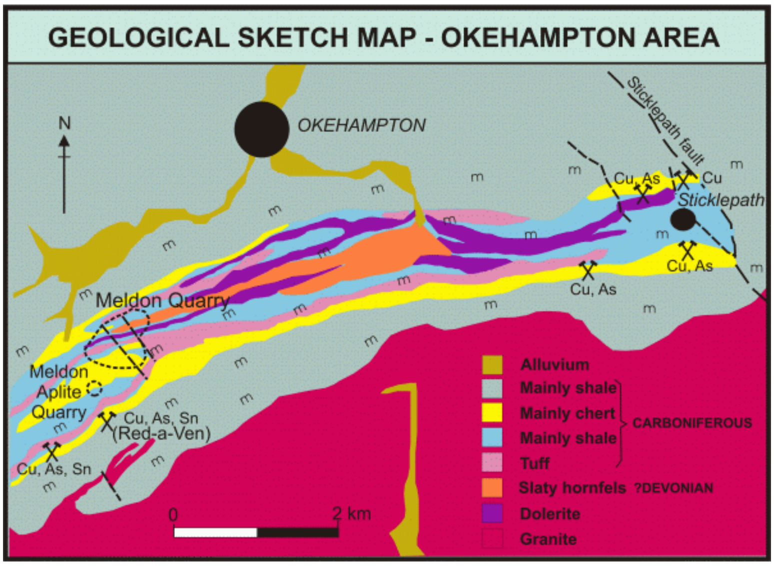


Woframite and cassiterite

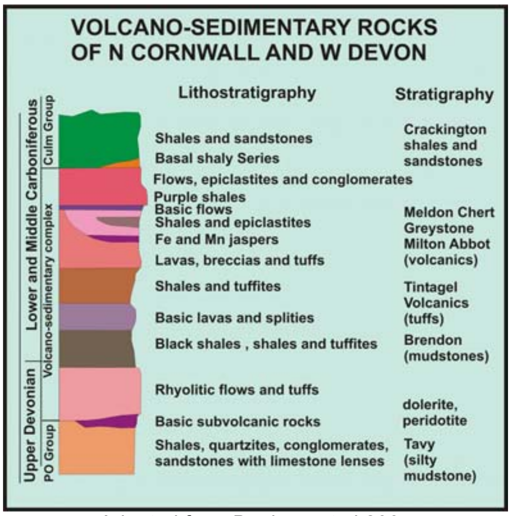
Scorodite

Red-a-Ven & Meldon Cu/Zn/As/Sn Mineralization

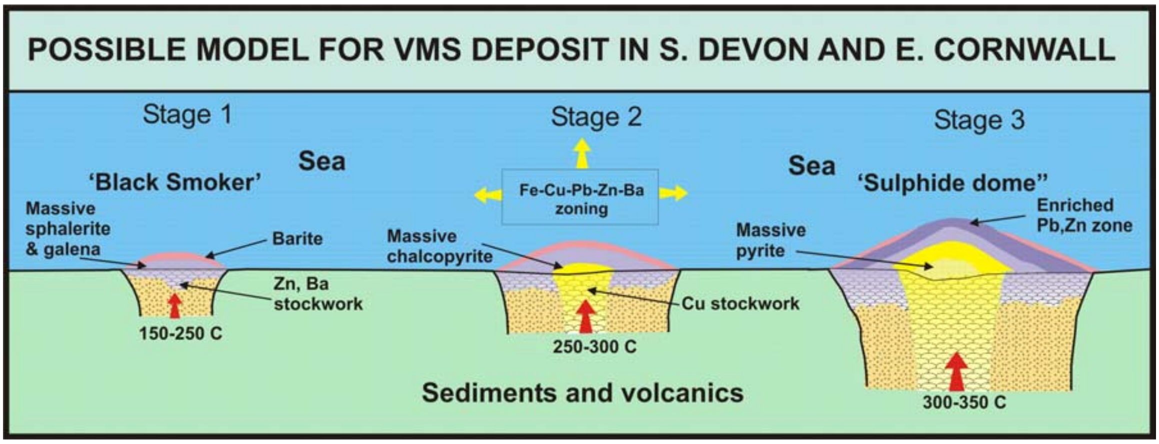
Around the northern edge of Dartmoor lie siliceous and calcic rocks now converted to skarns running in a belt from just east of Sticklepath to just southwest of Sourton, a distance of just over 10 km. Within this belt lie bedded, or stratiform, mineralised deposits of Cu and Zn in the Lower Carboniferous outcrop at or below the Meldon Chert. The mineralization is primarily of sulphides of pyrite, pyrrhotite, arsenopyrite, loellingite, sphalerite, chalcopyrite, rare scheelite, minor Ni sulphides and occasionally additionally as at Red-a-Ven, a complex tin silicate (Malayite). Similarities have been drawn with this area, which extends into N.E. Cornwall with the Iberian Pyrite Belt. The Meldon Chert Formation and the Crackington Formation are geologically comparable to lithologies in the Iberian

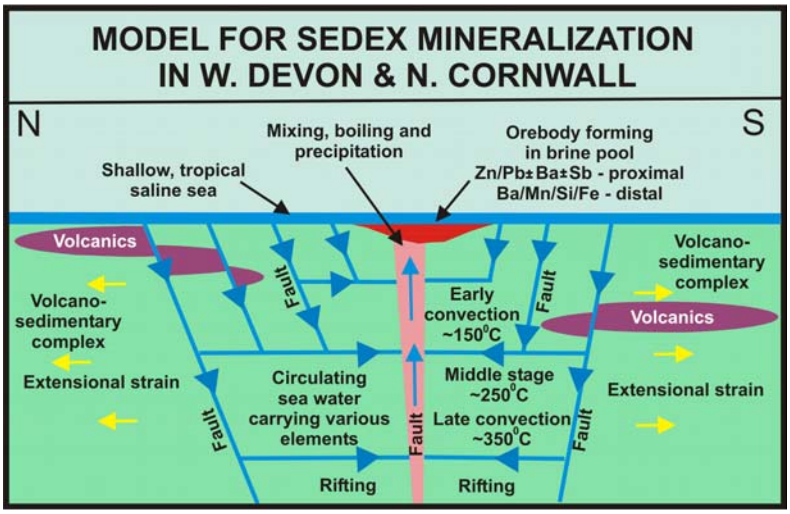


Pyrite Belt. VMS sulphide deposits of the Iberia are formed on, or close by, black smokers on the sea floor venting metal rich solutions, other metal rich deposits can form from submarine exhalative metal-bearing fluids during basin development, which was subjected to rifting. To the south of Dartmoor, in Devonian rocks in the South Hams area, evidence has been found for exhalative mineralization. Here massive pyrite and ankerite rock up to 25m in thickness associated with volcanics was intersected in boreholes. Mineralization of this type is similar to the Rammelsberg ore deposit in Eastern Europe. Either of these models, or a combination of the two, may fit for this region.



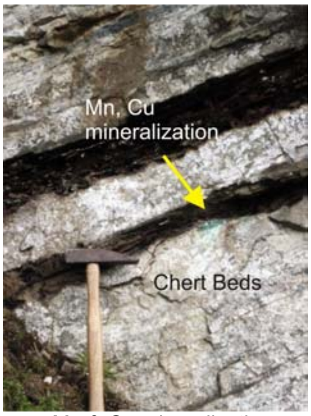
Adapted from Benham et al 2004



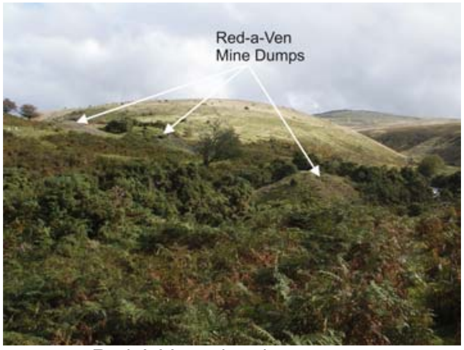


Banded cherts

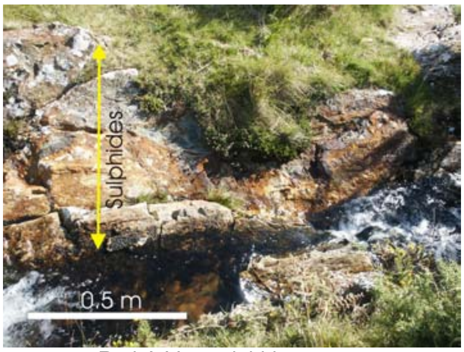
Detail of banded cherts



Mn & Cu mineralization



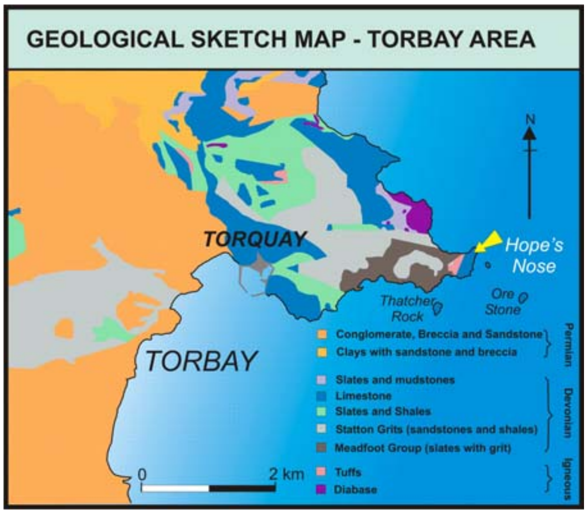
Red-A-Ven mine dumps

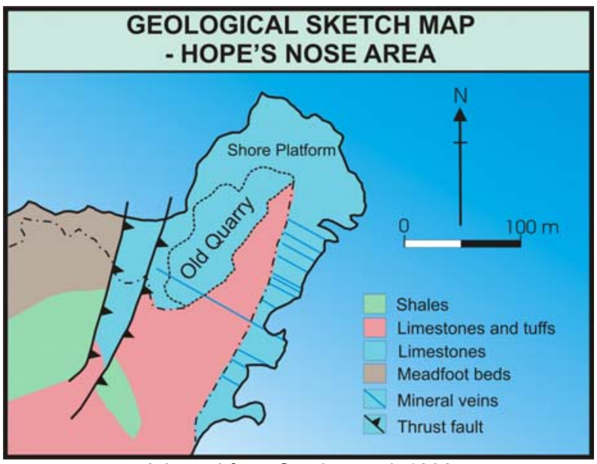


Red-A-Ven sulphide exposure

Hope’s Nose Au/PGM Mineralization

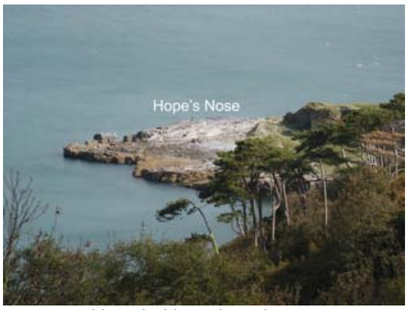
Hope’s Nose is situated to the east of Torquay on a small promontory. The headland area has been quarried for limestone, which was exported by sea. The geology of the headland is one of marine shales, sandstones together with interbedded lavas and tuffs. During the Middle Devonian extensive carbonate platforms developed to form the Torbay reef complex. Hope’s Nose is a part of this platform. Exposed on the headland is a bedded fossiliferous limestone overlain disconformibly by a thin, poorly bedded, dark grey and shaley limestone with intercalations of tuffs horizons. The massively bedded limestone is cut by calcite veins striking NE-SW, some of which have been faulted. Alteration of the wallrocks is of patchy hematization and towards the centre of the vein white calcite occurs with a ferroan dolomite with the borders of the veins having sericite micas. These veins can contain gold and palladian rich gold as well as arsenides and nickel, cobalt, copper, silver, mercury, bismuth as including gold selenides, with very minor amounts of sulphides. Calcium chloride rich fluid inclusions indicate a range of homogenisation temperatures from 65-120^{o}C. The salinities are similar to Pb-Zn-F mineralization in cross-courses found elsewhere in the Cornubian Orefield being derived from basinal brines. During rifting, substantial thicknesses of Permo-Triassic sediments accumulated in basins. This sedimentation was combined with volcanism and gave rise to the Au and Pd enrichment in fluids in an oxidising environment. The salinities of these fluids indicate that highly oxidising conditions are required for transportation and subsequent mixing in reducing conditions are required for deposition with the





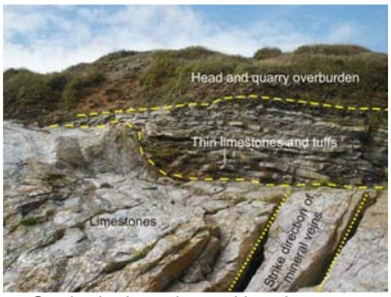
Adapted from Stanley et al. 1990

presence of organics, possibly in the form of carbonaceous shales or being neutralized in-situ by ponding or in contact with calcic brines. The fluids carrying and precipitating these metals would be classed as epithermal in character.

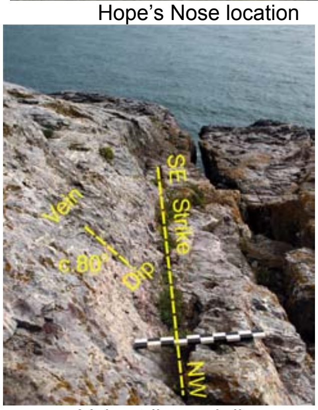


Hope’s Nose location

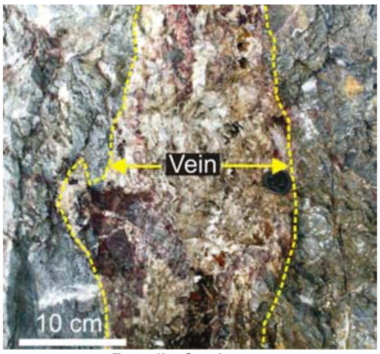
Hope’s Nose Quarry



Geological section at Hope’s nose

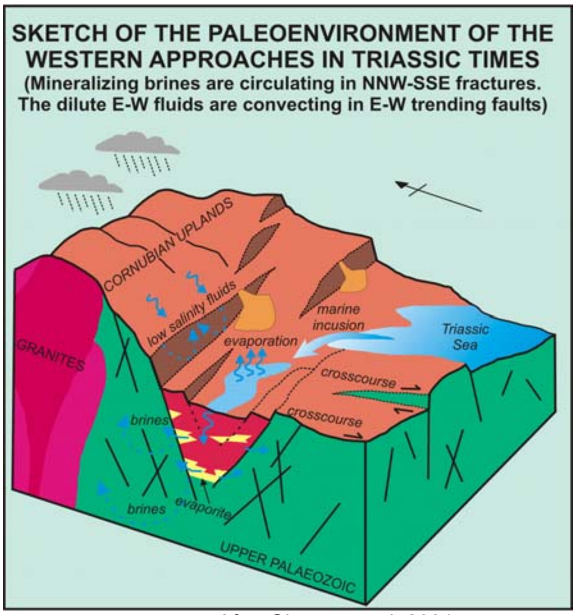


Vein strike and dip



Detail of vein.

Gold and calcite



After Gleeson et al. 2001