Manod Quarry

[SH 708 448]

Introduction

Manod Quarry, a large disused working on the hillside overlooking the road between Ffestiniog and Blaenau Ffestiniog (Figure 5.43), provides an excellent site for the study of 'Alpine-type' veins which occur regionally in the Ffestiniog–Porthmadog belt. The quarry worked a large intrusion of quartz-latite which was emplaced into the Allt L■yd Formation of Arenig age, and the overlying Nant Ffrancon Subgroup of Arenig to Caradoc age (British Geological Survey, 1997).

The intrusion is host to a series of veins, several of which are exposed at the northern end of the quarry. In addition, numerous boulders on the waste tips just below the quarry contain representative examples of the vein assemblage, including anatase, brookite, quartz, albite, rutile, synchysite-(Ce) and titanite (Bevins and Mason, 1998). The relationships between the three TiO_2 polymorphs are of particular interest.

Little work has yet been undertaken on this group of veins, despite the fact that such mineralization was amongst the earliest to be described in detail from Wales. Sowerby (1809) wrote the first account of the occurrence of brookite in the area, the specimen almost certainly having been collected from the now famous locality at Prenteg, near Tremadog, to the west of Manod (Starkey and Robinson, 1992). This 'oxide of titanium' was systematically described by Lévy (1825), based on specimens both from Prenteg and the Dauphine region of France; hence Prenteg, along with the Dauphine occurrence, is a joint type locality for brookite.

Since that time, the only attention given to this style of mineralization has largely been that by specimen collectors. At Prenteg, the renowned mineralogist Sir Arthur Russell collected specimens as early as 1905, while some years later, quarrying for roadstone at the same locality produced many fine samples (Starkey and Robinson, 1992).

Manod Quarry itself has been almost totally neglected by researchers, despite the many fine specimens collected by amateurs over the years. Occurrences of the various mineral species present were noted by Bevins (1994), while Green and Middleton (1996) compared a similar assemblage at the nearby Tan y Grisiau Station locality to that at Manod. In reality, the site has for many years been overshadowed by Prenteg; however, in view of access problems which have affected the latter site, not least accessibility in both safety and legal terms, Manod was considered by Bevins and Mason (1998) to be the most practical site for the study of both the geological features and the mineralogy of this important class of mineralization.

Description

Quartz-dominated mineral veins occur frequently within the large, competent quartz-latite body at Manod Quarry (Figure 5.44). The veins tend to occur in sub-parallel bunches of limited strike length and often occupy joint fractures in the quartz-latite. They typically strike east–west and are steeply dipping to vertical, forming open fissures, bridged across in places by quartz but often revealing extensive plates of freely grown crystals. Mineralogically, the most complex veins tend to be thin (< 15 mm wide), while thicker veins, up to 8 cm, have a simpler mineralogy, usually being filled solely with quartz.

In the open cavities, quartz forms crusts of water-clear crystals occasionally reaching 1–2 cm in length. Associated with the quartz is abundant chlorite, the latter being an early phase and often included in quartz, giving the crystals a greenish tint. A very rare pink phase, forming small (1–2 mm) grains in quartz and therefore an early component of the paragenesis, has recently been identified as titanite (authors' unpublished data).

All three TiO_2 polymorphs occur in the Manod Quarry veins. Anatase occurs most noticeably on quartz, as aggregates of twinned tabular crystals, stepped parallel to the c-axis and exceptionally up to 4 mm in size. These stepped crystal groups are sapphire-blue in colour, but broken sections reveal brown internal cores. Thin, tabular, yellowish-brown anatase crystals, often in confused groups and reaching 1 mm across, are also common. Brookite is earlier in the paragenesis than anatase, forming characteristic striated blades exceptionally up to 10 mm, associated with quartz and chlorite but also occurring alone as striking orange coatings on thin joints in the adjacent quartz-latite. Brookite crystals have invariably been shattered and healed, with numerous, small, new crystal terminations developed along fractured surfaces. Both anatase and brookite have locally been altered to rutile, which forms sub-metallic golden needles, often aggregated together into 1–2 mm reticulated masses.

All three TiO_2 polymorphs are overgrown by albite, which is abundant and typically forms striated tabular, white to colourless crystals up to 10 mm. Synchysite occurs rarely as minute (1 mm) rosettes and is a late-stage development, while a single tabular apatite crystal, of uncertain paragenetic position, has been noted. The assemblage has been overgrown to varying degrees by late-stage, coarsely crystalline calcite, a feature common to many 'Alpine-type' mineral veins in this area.

Interpretation

Much of the published information regarding the 'Alpine-type' veins in North Wales has been of a descriptive nature and presented little interpretation of the genesis of the mineralization. Green and Middleton (1996) merely stated that the 'Alpine-type' vein assemblage formed as a result of low-grade regional metamorphism. However, Starkey and Robinson (1992) investigated the analogous mineralization at Prenteg in some detail, including analysis of fluid inclusions present in quartz and brookite crystals. They determined a minimum temperature for vein emplacement of 160°–170° C, the fluids involved being of moderately low salinity. The lack of a suitable geobarometer, such as an equilibrium assemblage of metamorphic minerals, however, precluded a pressure correction for the fluid-inclusion data; hence they represent a minimum temperature of crystallization. According to Starkey and Robinson (1992), illite crystallinity (IC) values obtained from the mudstones hosting the dolerite sill at Prenteg indicate a formation temperature of around 165° C, a figure compatible with the fluid-inclusion data. Therefore, Starkey and Robinson (1992) concluded that the actual temperature of vein emplacement was not significantly higher than the minimum value obtained from fluid inclusions. However, it is by no means certain that the illite crystallinity values are directly related to, and of the same age as, the process of 'Alpine-type' vein generation. Indeed, the temperature estimate appears to be low when IC data from Roberts and Merriman (1985) are considered. According to these authors, IC values at Prenteg are $< 0.25\Delta°2\theta$, indicative of epizonal conditions, implying temperatures perhaps as high as 250°–300° C. This is in accordance with secondary mineral assemblages in metabasites in this part of North Wales, which are indicative of greenschist-facies conditions (Roberts, 1981). The discrepancy in temperatures between the 'Alpine-type' veins and the low-grade metamorphic indicators in the host rocks can be interpreted as either indicating that the events are not directly related (although the veins may represent a late-stage event during thermal decline, perhaps consistent with their suggested syn-Acadian age) or that the two events may be related but that the fluid-inclusion data are of little relevance because of the lack of application of a pressure correction.

Starkey and Robinson (1992) stated that the mineral assemblage at Prenteg was deposited in the order apatite, rutile, anatase, monazite, chamosite, quartz, brookite and albite. This contrasts with the Manod assemblage, where the TiO_2 sequence is brookite-anatase-rutile, with the rutile clearly replacing brookite (Bevins and Mason, 1998). Moreover, the habit and colour of anatase at both Manod and other adjacent localities (tabular, brown-cored, sapphire-blue) contrasts with the dark-brown tetragonal bipyramids from Prenteg.

At Tan y Grisiau Station it is recorded that the TiO_2 sequence is rutile-brookite-anatase (Green and Middleton, 1996). Here, the rutile occurs as typical hair-like inclusions in quartz and other minerals, whereas at Manod it forms reticulated sheaves of crystals which replace brookite. Thus, each of the three studied 'Alpine-type' vein localities in the Ffestiniog–Porthmadog belt has its own unique sequence of TiO_2 polymorph crystallization.

Starkey and Robinson (1992) discussed the relative stabilities of the three TiO_2 minerals, commenting on the possibility that the presence of albite could stabilize the brookite structure, so that brookite would tend to occur wherever significant albite was present. However, at Manod the rutile replacements of brookite occur just as regularly in the absence of albite as in close proximity to it. Therefore, the paragenetic relationships between these three minerals 'and their associates in the Ffestiniog–Porthmadog belt remains to be qualified.

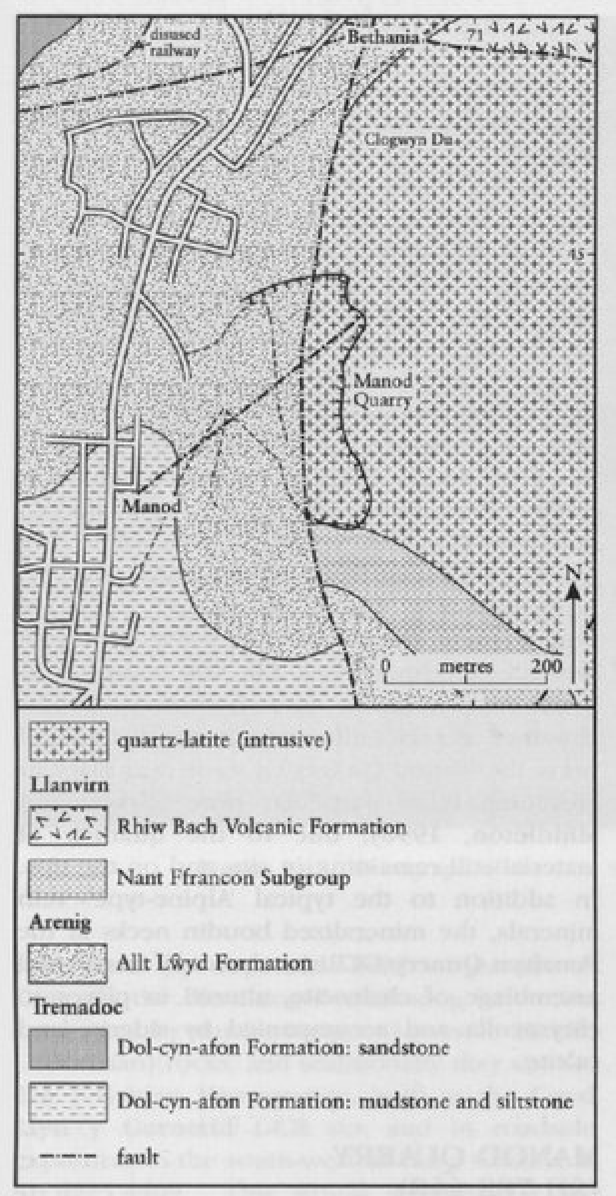
The maximum age of the 'Alpine-type' veins of the Manod Quarry GCR site is clearly constrained by the strata that host them, which are of Llanvirn to Caradoc age. The minimum age is more problematic, but two lines of evidence support the hypothesis that they are syn-tectonic with respect to the Acadian deformation, which would give them a Lower Devonian age. The most compelling evidence for this age is their tendency to occur in zones of extension and brittle fracture that have clearly developed as a response to regional Acadian strain, such as boudin necks and tension cracks in competent units. Secondly, all pre-Acadian quartz veins in North Wales are strongly deformed and recrystallized. In contrast, within the 'Alpine-type' veins, groups of crystals of great delicacy are invariably well-preserved, the only signs of disturbance being occasionally observed fracturing and healing of crystals. This observation applies whether the veins are hosted by large intrusive bodies or by thinner beds such as tuffs. These observations combine to suggest: (a) formation in localized extensional environments occurred during compressive deformation; and (b) because of formation in such 'protected' structural locations, the mineralization was preserved in its original state, in contrast to the effects observed in the clearly pre-tectonic veins.

Similar veins are known from other parts of the Welsh Caledonides, for example on Mynydd Ysgyfarnod, in the northern Harlech Dome region (T.F. Cotterell, pers. comm.), and in dolerite at Hendre Quarry in the Berwyns (Starkey *et al.,* 1991), and in parts of Central Wales, where they occur in sandstone units. In the latter case the mineralization is limited to quartz, although texturally it is identical. However, the tract of country from the Migneint through the Ffestiniog district westward towards Porthmadog contains the best-known and most frequent occurrences. The stratigraphy through this tract, the southern slate-belt of Snowdonia, is dominated by ductile mudstones, but also carries frequent competent beds and intrusions, which in the model inferred above would make ideal hosts for such mineralization during high regional tectonic strain. Further research is required in order to test the viability of this genetic model.

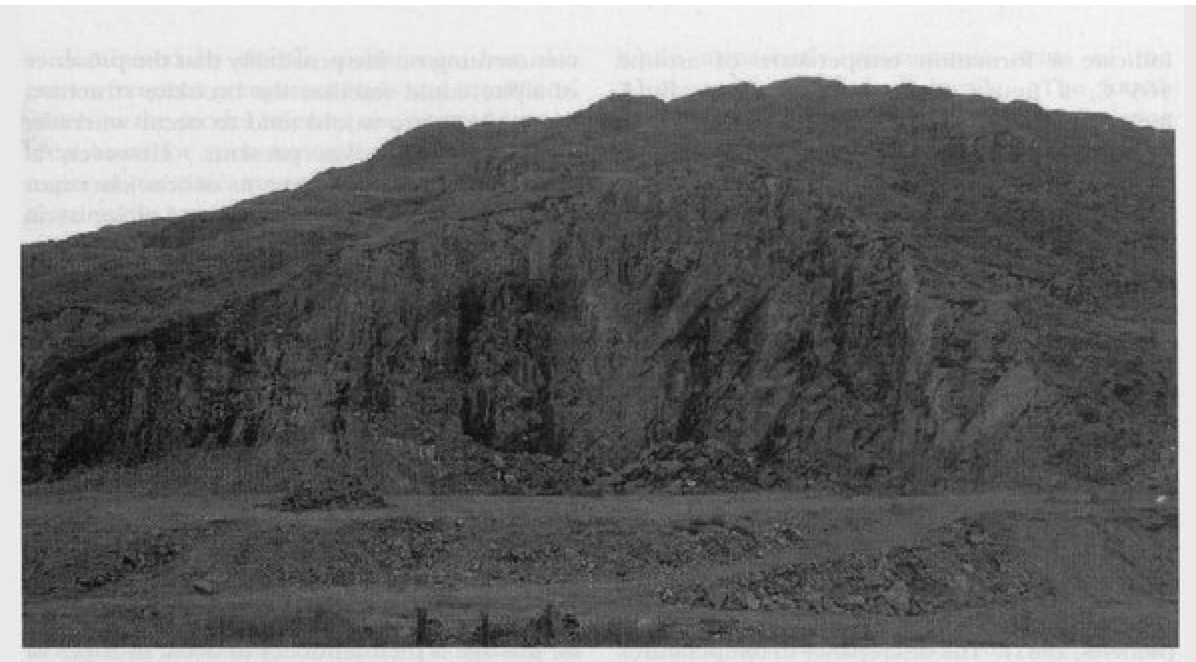
Conclusions

Quartz-chlorite-dominated mineral veins at Manod Quarry contain albite and minor amounts of a range of comparatively rare minerals, including anatase, brookite, rutile, synchysite-(Ce) and titanite. These veins have been compared with the Alpine cleft veins of the central Alps. These so-called 'Alpine-type' veins of the Ffestiniog–Porthmadog belt present an interesting enigma: they contain concentrations of typically immobile elements, particularly in the form of the three TiO_2 polymorphs anatase, rutile and brookite, and are particularly common in this belt, which features a mudstone-dominated sequence but within which a variety of competent beds and intrusions are present. The detailed paragenetic sequences, particularly of the TiO_2 minerals, vary from site to site, and to date little detailed work has been undertaken with regard to their genesis. In addition, although a likely syn-Acadian age has been proposed for these veins, the model requires further research to test its validity.

References



(Figure 5.43) Map of the Manod Quarry GCR site. After British Geological Survey 1:50 000 Sheet 119, Snowdon (1997).



(Figure 5.44) Photograph of the Manod Quarry GCR site. (Photo: R. Mathews.)