Benallt and Nant Mines

[SH 223 283], [SH 210 266]

Introduction

Mining for manganese in south-west Ll■n was once an important industry, these mines producing over half of the total Welsh output (Down, 1980). Two separate major orebodies were exploited, one by the Benallt–Rhiw mine complex and the other, close to the coast, at Nant Mine (Figure 5.7). Working began at Benallt and Rhiw on a small scale in the late 1880s, only employing a handful of men and producing a few hundred tons of ore. The scale of working intensified in the early 1900s, when the Rhiw Mine was operated by the British Manganese Co. Ltd, and the Benallt Mine by the North Wales Iron and Manganese Co. Ltd. With rich ores being raised in considerable amounts at that time, transport became an issue, and a railway was constructed down to the coast, where the ore was loaded onto ships from a pier. The major opening up by the Benallt company of another orebody, known as the 'Nant Mine' (Figure 5.8) and located dose to this pier, followed in 1914. By this time, Benallt and Rhiw were worked extensively by opencast methods, with complexes of underground galleries linked by a maze of levels and shafts.

By 1925, the mines had all closed, and there was a hiatus through to the outbreak of the Second World War. In 1939, small-scale operations took place at Benallt and Rhiw, but in 1941, with the decline in manganese imports due to the war in the Atlantic Ocean, Benallt was requisitioned by the Ministry of Supply in a major development that involved the importation of colliers from South Wales and tin-miners from Cornwall. Development underground resulted in the location of a major ore-zone, which produced 30 000 tons of ore, a discovery ensuring the mine's operation through the war years. Additionally, the Royal Canadian Engineers drilled *c.* 2500 m of exploration boreholes, which considerably improved the geological interpretation of the orebody. This drilling programme was influenced partly by the results of magnetometry traverses, and the orebodies discovered as a result were an important early example of the successful application of this geophysical method in mineral exploration.

Benallt was finally abandoned at the end of 1945, by which time it had yielded 113 838 tons of manganese ore (although some output was combined with Nant). With the production from Nant, and the old Rhiw workings, the total output exceeded 150 000 tons (Down, 1980).

The early mineralogical interpretation of these manganese deposits was that they were composed principally of rhodochrosite (Dewey and Dines, 1923). Later studies (Woodland, 1939b) were to modify this interpretation, with the recognition of important quantities of manganese-bearing chlorite-group minerals. Groves (1952) finally established that the Benallt ore was in fact a complexly intergrown mixture of manganese silicates with manganese-iron oxides, with little carbonate present, except at Nant, where rhodochrosite is of some importance.

These mines attracted early attention from specimen mineralogists for the unusual and well-crystallized suite of manganese and other minerals (Russell, 1911), and the wartime re-opening presented the opportunity for further studies (Campbell Smith *et al.,* 1944a,b, 1946, 1949; Campbell Smith, 1945, 1948; Campbell Smith and Claringbull, 1947; Smith and Frondel, 1968). In addition to the discovery of a number of rare minerals new to Wales, these studies described type specimens of banalsite, pennantite, and cymrite, all new mineral species from the Benallt–Nant mining complex. Very few sites worldwide are a type locality for more than one mineral.

Exploration continued intermittently in the post-war years, and in 1971 a magnetic survey was carried out (Cornwell, 1979). This was more for mapping than economic purposes, and no indications of major blind orebodies were reported. In the 1970s, exploration was also carried out by Noranda-Kerr Ltd over layered basic intrusive rocks immediately to the east of the site, the targets being possible magmatic Cu–Ni mineral deposits, but concentrations were found not to be of economic interest (Brown and Evans, 1989).

More recently, an important exploration and research project was undertaken by the Mineral Reconnaissance Programme of the British Geological Survey (Brown and Evans, 1989), in which the areas between Nant and Benallt, and also the area to the north of Benallt, were examined. Methods included magnetometry, soil- and rock-sampling, and the drilling of five boreholes, the latter being collared over detected magnetic anomalies. The results of this programme led to the conclusion that there were no major, near-surface orebodies remaining and there was little chance of any great extensions to the mineralization at depth. However, the work led to the hypothesis that, as in the Harlech manganese bedded ores, this deposit was the result of submarine hydrothermal exhalation in a sedimentary environment.

Gibbons and McCarron (1993) provided an overview of the earlier proposals for the origin of the Benallt and Nant manganese deposits. Finally, the previously unreported presence of reduced copper mineralization was noted by Bevins and Mason (1998).

Description

In the Benallt-Nant area, Ordovician strata unconformably overlie a complex suite of granitic to dioritic igneous rocks, which constitute the Sam Complex (Gibbons, 1980). The manganese mineralization is hosted by turbiditic mudstones and siltstones, with associated ironstone bands, of Arenig to Llanvirn age. These rocks form part of a package of sedimentary rocks and intercalated basaltic and andesitic lavas, cherts and crystal tuffs. Recent evidence from drill cores suggests that the lavas were intruded into wet sediments just below the seafloor (Brown and Evans, 1989). A series of dolerite sills, which intrudes the package, are probably cogenctic with the lavas. The host rocks and included ore-beds have undergone polyphase Acadian deformation. A basic dyke, the Ty Canol Dyke (Groves, 1952), was intersected during wartime operations, and its WNW–ESE trend led Groves (1952) to interpret it as a member of the 'Tertiary' (Palaeogene) basic dyke-swarm of north-western Britain (see also Bevins *et al.,* 1996a).

The Benallt–Nant orebodies differ from the persistent stratabound horizon worked in the Harlech Dome in that they occur as strike-elongated, irregular, approximately ellipsoidal masses. A single such mass formed the sole ore-zone at Nant Mine, while at Benallt the ore occurred in a number of smaller zones. According to Groves (1947), the Benallt orebody lay between basalt in the hangingwall (the Lower Clip Lava) and an E-dipping dolerite sill (the Footwall Sill) in the footwall. The Nant orebody was entirely thrust-bounded and juxtaposed against dolerite on both sides.

Benallt Mine was an extremely complex mine in geological terms, due to the apparent tectonic disruption of a single ore-bed, so that larger ore-zones were created when smaller ones were juxtaposed together by folding, with the mudstones in between being squeezed out (Groves, 1952). The ores at both the Benallt and Nant mines are broadly similar in textural terms, with relict sedimentary features preserved, including ooidal and pisoidal textures. However, the Benallt ore is more oxide- and silicate-rich in contrast to that at Nant, where the manganese carbonate rhodochrosite was important.

In addition to the fine-grained, silicate-oxide-carbonate ores, which consist of pennantite, jacobsite, hematite, rhodonite, rhodochrosite, collophane and rare strontianite, the deposits are cut by veins and breccia-zones carrying a wide range of minerals, well crystallized in places. Many fine specimens were recovered from the underground workings when the mine was active (Bevins, 1994). These include the principal ore minerals, such as pennantite and the magnetic Mn-Fe oxide jacobsite, the gangue barium feldspars celsian and paracelsian (the latter forming striking white, prismatic crystals exceptionally up to 5 cm in length) and the type samples of another barium feldspar, banalsite. A large number of often complex manganese silicates also occur in these veins, including clove-brown alleghanyite, often intergrown with tephroite, in crystals up to 2 cm, cinnamon-brown bannisterite, similarly coloured ganophyllite, bementite, and a number of hydrated silicates, some of which may be secondary, comprising braunite, cymrite (type locality), birnessite and neotocite. Recent significant discoveries include those of Cotterell (2006a) describing the first British occurrence of caryopllite and the first Welsh occurrence of pyroxmangite from Nant Mine, Dossett *et* al. (2007) reporting the first Welsh occurrence of powellite, and Cotterell (2008) describing the first British occurrence of the rare manganese oxide hydroxide feitknechtite at Benallt Mine.

Two zeolite-group minerals are also present, namely harmotome, which occurs as microscopic crystals with barite on banalsite, and natrolite which cements breccia-zones, and formerly yielded excellent crystals, exceptionally up to 5 cm. A number of complex Mn-Fe (Ti) oxides have also been recorded, comprising bixbyite, hausmannite, pyrophanitc and the aforementioned jacobsite. Other Mn and Mn-Ba oxides may be secondary and comprise manganite, manganosite, pyrochroite, pyrolusite and romanèchite.

Previously unreported copper mineralization, comprising the secondary minerals chalcocite, native copper and cuprite, with minor malachite alteration, was noted recently occurring in small veinlets in a dark, cherty matrix on one of the tips at Benallt Mine (Bevins and Mason, 1998). The cherty material was almost certainly derived from the volcanic sequence overlying the manganese ore-bed.

Interpretation

The mineralization at Benallt–Nant is extremely complex, although comparison with other mineralized areas in North Wales serves to aid interpretation of the genesis of this diverse assemblage. It is clear from both earlier (Groves, 1952) and more-recent (Brown and Evans, 1989) studies that the original ore deposit consisted of a fine-grained sedimentary horizon comprising carbonates, oxides and possibly silicates of Mn, Fe, Ba and minor Sr. This then underwent a diverse range of changes.

Firstly, severe tectonism modified the morphology of the deposits, leaving the manganese ore as a series of juxtaposed lenses. Secondly, brittle fracturing, and probably concomitant chemical remobilization, resulted in the crystallization of a diverse suite of Mn-, Fe-and Ba-dominated silicates and oxides, as euhedral, coarse-grained crystals in veins accompanied by calcite and quartz. 'These veins were dearly tensile fractures, as considerable open spaces would have been required for the well-developed euhedral crystals to form. Thirdly, weathering caused modifications in the development of hydrated Mn and Mn-Ba oxides.

Veins, whose chemical composition strongly reflects that of their host rock, are widely reported from the Welsh Caledonides (Fitches, 1987; Mason, 1997). The so-called 'Alpine-type' veins, consisting of quartz, albite, TiO_2 polymorphs and rare-earth-element-bearing minerals, described from the Manod Quarry and Coed Llyn y Garnedd GCR sites, are interpreted as being the result of localized hydrothermal remobilization and migration of elements from host rock to adjacent tensile fractures, which constituted favourable sites for mineralization. The process resulting in the generation of such veins is interpreted as being operative under low-grade regional metamorphic conditions, varying from simple burial metamorphism through to combinations of regional and dynamic metamorphism connected with regional polyphase deformation (see Bevins and Robinson, 1993).

The fact that the minerals occurring within the veins cutting the deformed manganese ores at Benallt–Nant have compositions which reflect that of the ore itself strongly suggests that these veins may belong to the 'Alpine-type' suite, their different composition merely reflecting the source geochemistry. This interpretation does, however, require detailed assessment, in particular collection of fluid-inclusion data from the Benallt–Nant veins and a comparison made with that already obtained by Starkey and Robinson (1992) from the 'Alpine-type' veins from Prenteg, near Tremadog.

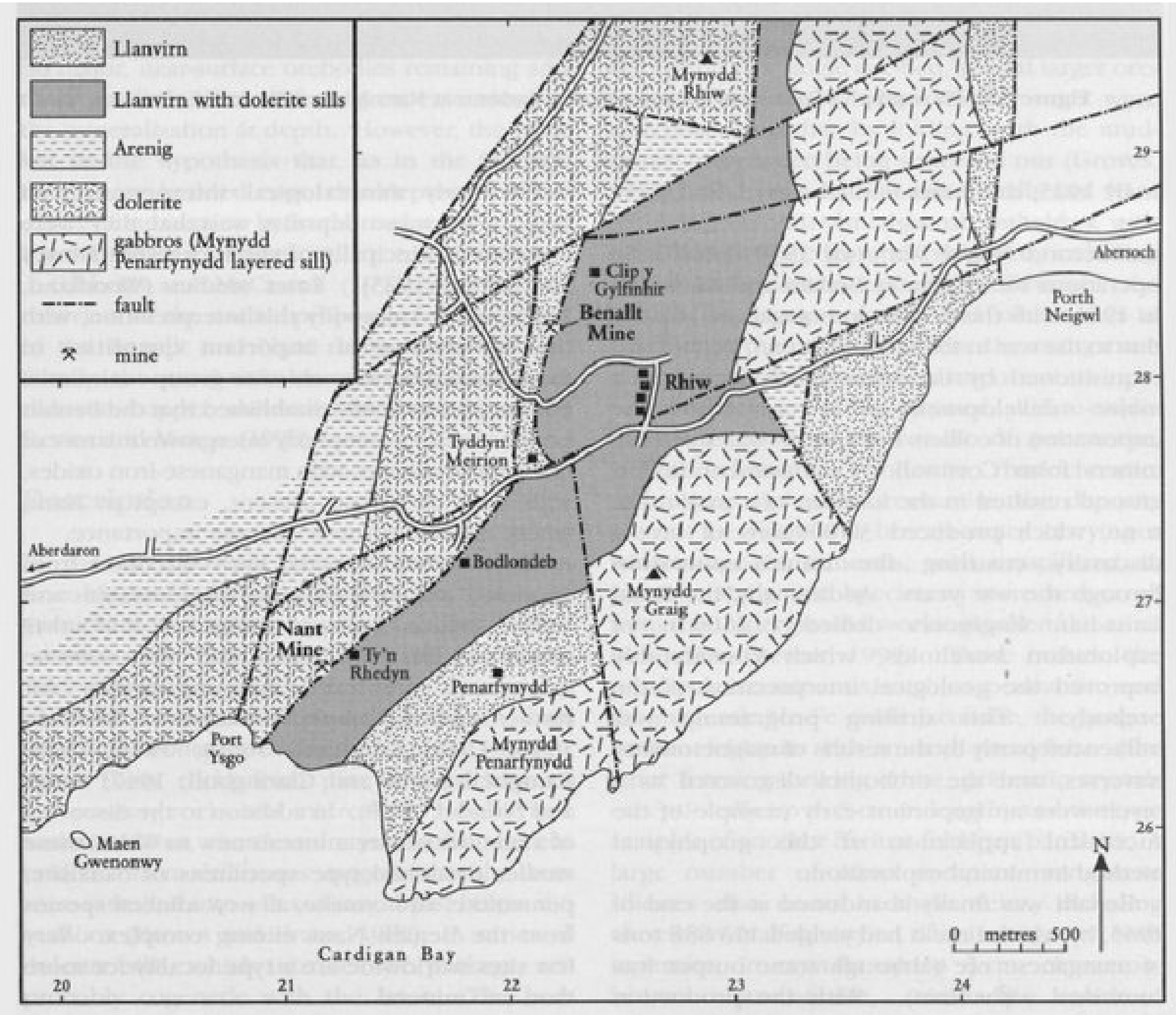
The original genesis of the ore is now interpreted as being of exhalative origin, in a subaqueous environment with hemipelagic sedimentation (Brown and Evans, 1989). This is the same model as was proposed by Bennett (1987) for the Harlech manganese deposit of Lower Cambrian age, and implies that early submarine exhalation of metalliferous brines was of frequent occurrence during Cambrian to early Ordovician times in this part of the Welsh Basin. Brown and Evans (1989) commented on the contrasting ore mineralogy between Benallt and Nant, suggesting that the relative abundance of carbonates at Nant, in contrast to silicates and oxides at Benallt, could reflect the positions of the two sites with respect to the exhalative centre. Clearly, however, further work is required to elaborate upon this model in such a complexly deformed terrain.

The genetic significance of the recently discovered copper mineralization remains to be established. The mineral species present are usually found as supergene replacements of existing chalcopyrite mineralization, for which there is little evidence at this site. However, drilling by the British Geological Survey, near to Tyddyn Meirion, about 350 m south of Benallt (BH 1A of Brown and Evans, 1989), intersected a black chert horizon which, upon analysis, revealed anomalous levels of copper (up to 99 ppm), with an associated Pb (233 ppm) and As (80 ppm) anomaly. This suggests that some base-metal enrichment is present in these cherty rocks, which locally may manifest itself as discrete minerals.

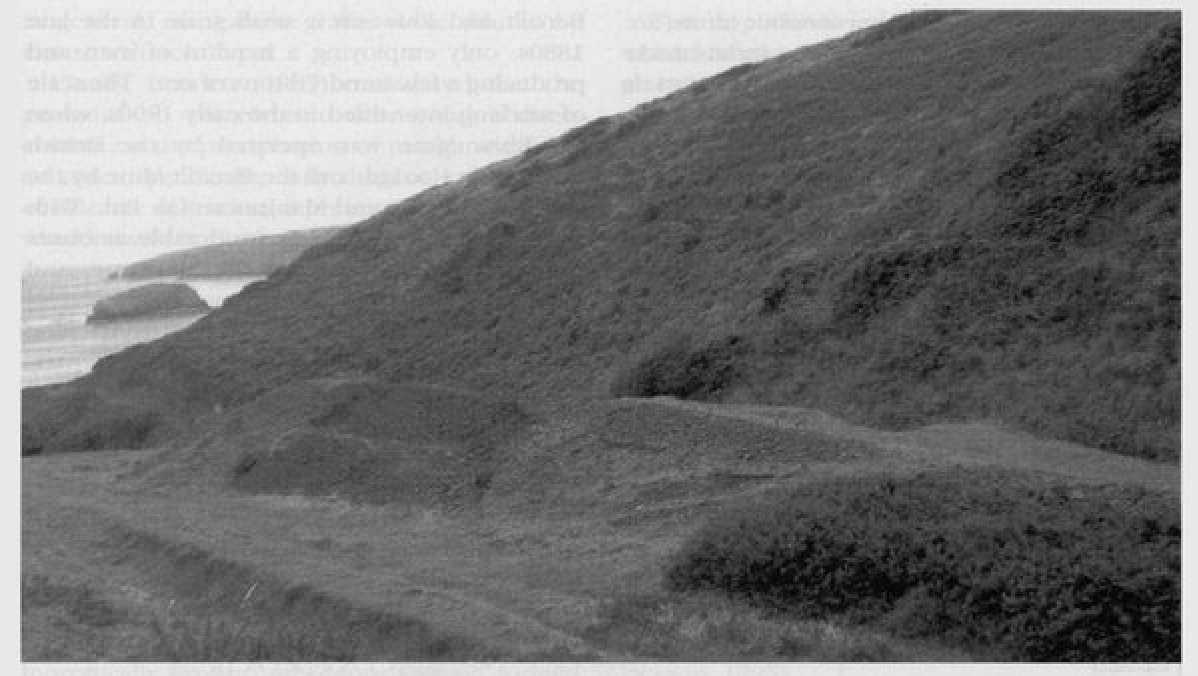
Conclusions

The Benallt and Nant Mines GCR site contains an unusual suite of manganese and barium minerals, including the type locality for a number of new species. In geological, mineralogical and metallogenic terms, the Benallt–Nant manganese ores compromise one of the most complex ore deposits in Wales. Originally deposited from hydrothermal brines exhaled onto the early Ordovician seabed during an episode of volcanism, they have been modified both by intense deformation and by metamorphic remobilization of manganese and other elements, leading to a wide range of rare minerals, sometimes occurring as well-formed crystals in tensional veins

References



(Figure 5.7) Map of the Benallt and Nant Mines GCR site. After British Geological Survey 1:10 000 Sheet SH22NW, Rhiw (1991).



(Figure 5.8) Photograph of old spoil-heaps in Nant y Gadwen at Nant Mine. (Photo R.E. Bevins.)