

**Draft Copy of Abstract on  
Volcanism and Polymetallic Mineralization  
at  
Parys Mountain**

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# Volcanic sequence and position of massive sulfides and quartz-rock at Parys Mountain, Wales

**T.J. Barrett**

Ore Systems Consulting, 29 Toronto St. S., Markdale ON, Canada N0C1H0

**S.C. Tennant**

11 Camplea Croft, Chelmsley Wood, Birmingham, England B37 5DU

**F. Daliran**

Institute of Mineralogy and Geochemistry, University of Karlsruhe, Kaiserstr. 12, 76128 Karlsruhe, Germany

**Abstract.** Drilling programs in 2005-2008 at Parys Mountain intersected various styles of polymetallic mineralization, ranging from massive sulfides to sulfide-bearing quartz rocks, hosted by Lower Paleozoic shales and volcanic rocks. Application of immobile-element methods to 400 new whole-rock analyses from these and earlier drill holes allows four chemically distinct rhyolite types (A to D) to be identified and correlated across the property. The mineralization, which occurs on both limbs of a large synclinal structure, is spatially associated with a thin unit of rhyolite B that marks the initiation of volcanism. Although chloritization, silicification and sericitization in the vicinity of the mineralization are extreme, the rhyolite B time marker can still be identified based on its precursor ratios. The quartz-rock is viewed as the product of low-temperature hydrothermal activity that took place within a few hundred metres laterally from the areas of massive sulfide deposition. In the western part of the property, a sill of rhyolite C split the massive sulfide interval, producing two discrete sulfide horizons. This was followed by a thick outpouring of rhyolites A and D, then the accumulation of graptolitic shales, which now form the core of the syncline.

**Keywords.** Volcanism, massive sulfides, alteration, immobile elements, Paleozoic, Wales

## 1 Introduction

Although strong evidence exists for Bronze Age mining activity at Parys Mountain, large-scale mining began in the 1760s. Over the following century, Cu was recovered from open pits and then underground workings located mainly on the north side of the Parys Mountain. Much of the underground mining in the 1800s focused on the Carreg-y-doll, a zone of sulfide-mineralized, quartz-rich rock located between felsic volcanic rocks and shales. The first diamond drilling on the property began in the 1960s. This located deep polymetallic massive sulfide lenses, now termed the Engine Zone and Garth Daniel Zone, and additional zones of quartz-rock. In 1990, the Robertson Group estimated probable and possible resources as 6.45 Mt at 2.34 % Cu, 2.60 % Pb, 5.35 % Zn, 39 g/t Au and 0.23 g/t Au (Emberton, 1990).

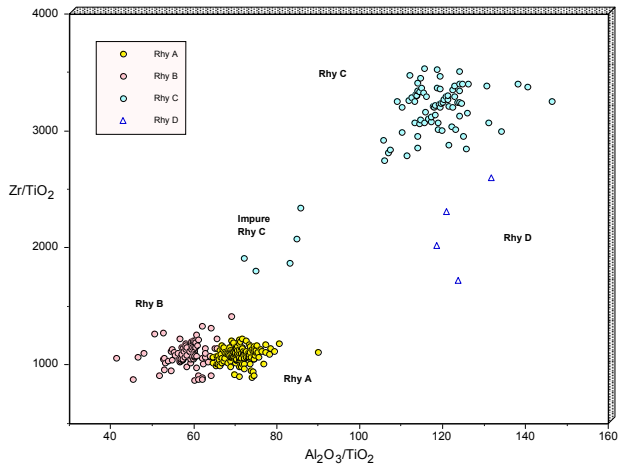
Based on a major lithochemical and stratigraphic study carried out in the late 1990s by Barrett et al. (1999) and Tennant (1999), several main felsic volcanic units were identified and correlated across Parys Mountain. The results, combined with previous structural studies by Carter (1988) and Westhead (1993), support the presence of a major east-west-striking syncline at Parys Mountain, and also an overturned, northeast-striking panel of rocks at the western end of the property. Such folding can also account for the occurrence of massive sulfides and mineralized quartz-rock in different areas. Volcanism at Parys Mountain occurred in the Lower Silurian (R. Parrish, in Barrett et al., 1999), and is the same age as the overlying graptolitic shales in the core of the inferred syncline. By contrast, the shales that occur north and south of the main mass of rhyolites are lower to mid-Ordovician.

In the last few years, new drilling has been carried out in the Garth Daniel area along the northern side of Parys

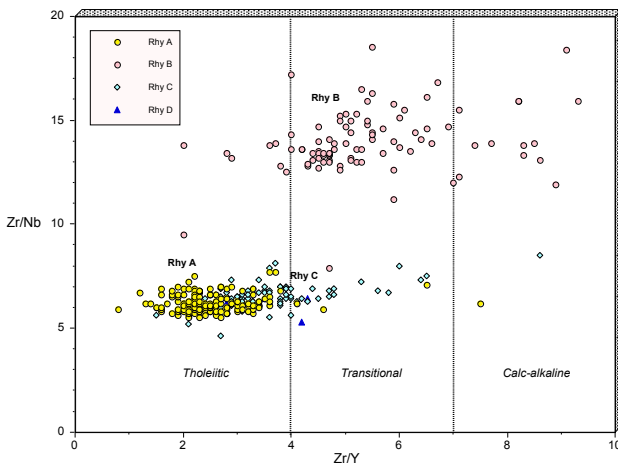
Mountain (4 long holes), and in the Chapel and Morfa Du areas near the western end of the property (17 short holes). Various styles of polymetallic mineralization were intersected, including high-grade “bluestone” (e.g., 5.5m at 3.73 % Cu, 6.06 % Pb, 12.51 % Zn, 78 g/t Ag, 0.37 g/t Au). However, the stratigraphic picture is complicated by a combination of folding, faulting and severe hydrothermal alteration. To better understand the stratigraphic sequence and position of the mineralization, these and several other holes were logged and 400 new lithochemical samples were taken. Whole-rock analyses were carried out by ACME Laboratories in Vancouver, using ICP-MS and ICP-AES techniques following a fusion step.

## 2 Lithochemical

Whole-rock results are shown in Figure 1, where two immobile-element ratios are plotted. Use of ratios removes the effects of alteration, which change the absolute abundances of individual immobile elements. Four main rhyolite types are present, termed A to D (the data set also contains minor mafic rocks). Variations within each of the rhyolite groups is probably due either to minor amounts of magmatic fractionation, or, in the case of volcanoclastic samples, to limited amounts of sorting during transport. Although rhyolites A and B appear to partly overlap in terms of major-element ratios, they can be readily distinguished using immobile trace-element ratios such as Zr/Nb (Fig. 2). The lithochemical results have been used to define and correlate volcanic units in the vicinity of the highly altered mineralized zones (see section 3).



**Figure 1.** Classification of felsic volcanic rocks at Parys Mt.



**Figure 2.** Magmatic affinity of felsic volcanic rocks at Parys Mt.

## 2 Mineralization

The White Rock, which is up to 30 m thick, is an amalgamation of irregular quartz-rich masses, multiple generations of discordant quartz-sulfide veins, small lenses of semi-massive sulfides, and pockets of hydrothermal breccia. It formed mainly within the upper shales, and possibly also at the seafloor surface. Much of the added quartz has filled open fissures, but the host shales are also silicified (Fig. 3). The White Rock commonly contains 10-30 % sulfides as veins, patches and heavy disseminations. Locally, intervals of semi-massive or massive sulfide up to a few metres thick are present (Fig. 4). The latter may have been deposited on the paleo-seafloor, as they are closely comparable in terms of sulfide textures and metal grades to clastic massive sulfide beds in the Engine Zone and Garth Daniels Zone (Fig. 5). These beds consist of sphalerite, galena, chalcopyrite, pyrite and sulfosalts; the gangue is quartz. Both the White Rock and the massive sulfide beds are spatially associated with thin intervals of rhyolite B that mark the onset of volcanism at Parys Mountain. The simplest interpretation for their different mineralogy is that White Rock was formed from low-temperature vents that were situated within a few hundred metres laterally of the areas of massive sulfide deposition. It is likely that small-

scale explosive activity and reworking occurred at this time, as suggested by the volcanoclastic nature of rhyolite B, the presence of clastic sulfide beds and debris flows containing sulfide and white-rock clasts; and numerous pockets of hydrothermal breccia within the White Rock.



**Figure 3.** Quartz-sulfide veins and silicified shales. Morfa Du.



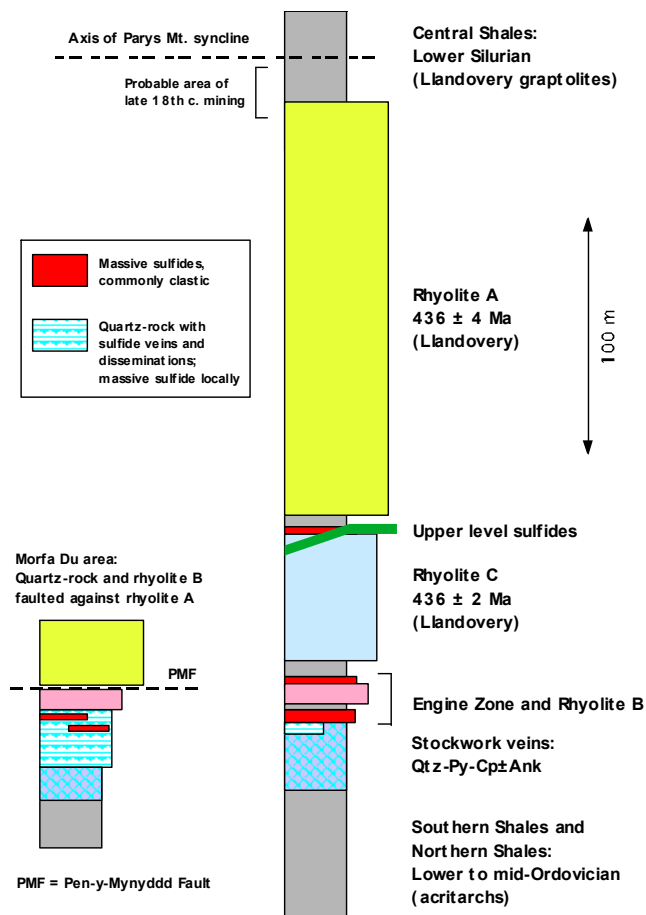
**Figure 4.** Near-massive sulfides in top slot overlain (downhole) by quartz-rock (slots 2 and 3), then chloritized rhyolite B (slot 4). Assay at 44.75-45.70m: 0.95m at 1.47 % Cu, 14.13 % Pb, 25.52 % Zn, 115 g/t Ag and 2.99 g/t Au.



**Figure 5.** Massive sulfides (top slot) overlying silicified and sulfidized rhyolite B (slots 2 and 3). Garth Daniels area, hole AMC-17. Assay at 496.6-502.1m: 5.5m at 3.73 % Cu, 6.06 % Pb, 12.51 % Zn, 78 g/t Ag and 0.37 g/t Au.

### 3 Stratigraphic relations

The inferred original sequence of seafloor volcanic and mineralizing events is summarized in Figure 6. In the Garth Daniel Area along the northern side of Parys Mountain, where high-grade sulfide intervals have been intersected, the lithological sequence is very similar to that in the normal-facing Engine Zone, which requires that the former area is overturned to the south. The polymetallic massive sulfides of the Garth Daniel Area occur at or close to rhyolite B (Fig. 5), which is situated between shales and rhyolite A (rhyolite C is absent). Holes in this area also encountered a Cu-bearing interval of White Rock up to 20 m thick (grades reach 3.5 % Cu over 6.1 m in hole H30). The White Rock interval, also known as the Carreg-y-doll, was the focus of much of the 19<sup>th</sup> century mining. It is stratigraphically underlain (to the north) by shales hosting an extensive Cu-bearing vein system (up to 50 m of 1 % Cu), and is lithologically identical to the White Rock at Morfa Du on the western part of the property, although in the latter area, contents of Zn and Pb are notably higher.



**Figure 6.** Simplified stratigraphic column for Parys Mt.

The overturned rocks at Morfa Du are separated from the right-way-up rocks of the Chapel area by the late Pen-y-Mynydd Fault. In the Chapel area, as in the Engine Zone on the 280 m level, two sulfide horizons are separated by a lens of massive rhyolite C. This is interpreted as a syn-mineralization sill that split apart one original sulfide lens,

which in detail interfingered with thin beds of shale and volcanoclastic rhyolite B, both intensely altered. The rhyolite C lens is up to 50 m thick and 500 m wide, and extends downdip about 300 m. A sill of high-Ti basalt was emplaced more or less at the contact between rhyolite C and overlying rhyolite A, partly cutting out the upper sulfide lens (Fig. 6). This basalt sill is locally highly sericitized and pyritized. Where rhyolite C thins out, massive sulfides of the Engine Zone are overlain by up to 150 m of largely coherent rhyolite A. In the Morfa Du area, which is overturned, shales are stratigraphically overlain by up to 30 m of mineralized quartz rock, then a unit of rhyolite B (not always present), followed by the Pen-y-Mynydd Fault (Fig. 6). The shales contain an increasing proportion of quartz-sulfide veins upwards, towards the paleoseafloor; this same feature is seen on the north (overturned) side of Parys Mountain, although the Cu content of the veins is higher in the latter area.

Sulfide deposition was effectively halted by the outpouring of rhyolite A. Several hundred metres to the east of the Engine Zone, rhyolite A passes laterally into rhyolite D, which was erupted from a separate volcanic vent (Barrett et al., 2001). Rhyolite A contains sulfide-veins in its lower portion, but is otherwise unmineralized and generally is only weakly altered. However, the late 18th century mining appears to have taken place near the contact between the surface of these rhyolites and the overlying Llandoverly shales in the core of the syncline, suggesting that a second hydrothermal system eventually developed.

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