

FG-253

Sulfide Mineralization in a Broadlands Geothermal Drill Hole, Taupo Volcanic Zone, New Zealand

GL03560

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Abstract

Base-metal sulfides have been deposited in rocks penetrated by a Broadland Geothermal drill hole. They occur in a permeable, silicified and fault-brecciated zone where the measured temperature is between 272 and 276° C. Textural evidence suggests that they are in equilibrium with the slightly saline solution of low-metal content now being discharged.

Introduction

In the course of geothermal power development based on natural high-temperature water areas in the Taupo Volcanic Zone in the North Island of New Zealand, over 150 holes have been drilled since 1950. Although the observed hydrothermal mineral assemblage is similar to that commonly associated with base-metal sulfide deposits in many parts of the world (Meyer and Hemley, 1967), only 3 drill holes in the Volcanic Zone have shown galena and sphalerite mineralization. These are at 270 m and 230° C in Hole W7, Waitapu (A. Steiner, B. G. Weissberg, personal communication), and from Holes Br7 and Br10 recently drilled at the Broadlands Geothermal Field.

The Broadlands-Ohaki (Fig. 1) geothermal area, about 3 km in diameter, is located on both banks of the Waikato River, some 22 km, northeast of Wairakei—the site of New Zealand's first geothermal power station. To date 12 investigation holes, between 760 and 1,396 m deep, have been drilled and in Br7 and Br10 in the south-east part of the field, base-metal sulfides have been encountered. Natural surface activity in the vicinity of these drill holes is limited to a few warm springs with a total water flow of less than 2 liters/sec (Grindley and Browne, 1968).

Geology and Mineralization

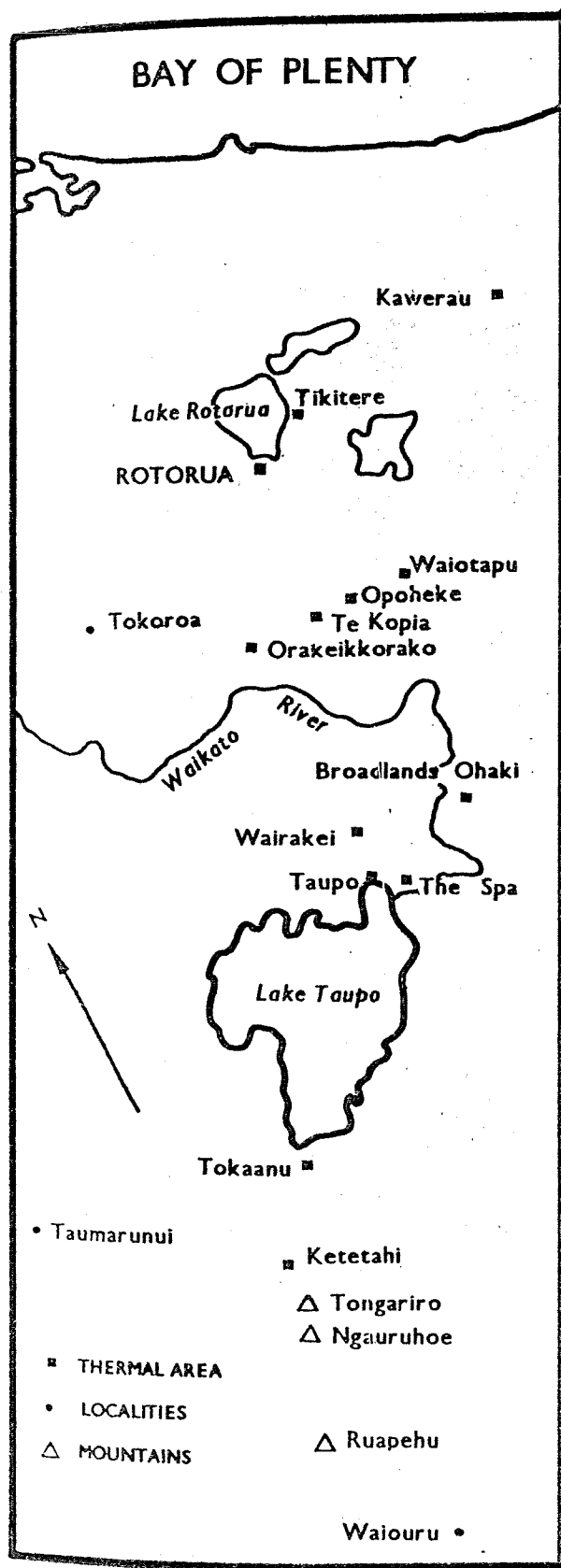
The approximate downhole distribution of major primary and secondary minerals associated with the base-metal sulfides in Br7 is shown in Figure 2. This information, based on 26 core samples, was obtained by thin section examination, infra-red spectrometry, D.T.A., and a quantitative X-ray diffraction method similar to that used by Tatlock (1966). Figure 2 also shows a generalized stratigraphic column and the temperature-depth curve.

Loosely consolidated sands, tuffs, and tuffaceous sediments 142 m thick overlie rhyolite flows totalling

481 m that have been altered to varying degrees by hydrothermal solutions. The upper part of the top sheet of rhyolite has been extensively altered to quartz, clay, pyrite, and leucoxene, but the lower part is denser and relatively less permeable, clearly serving as a "cap" to high temperature water contained in the rocks beneath. Below the upper rhyolite is a pumiceous tuff 96 m thick, which probably functions as an aquifer, and a lower sheet of rhyolite 202 m thick underlain by 15 m of crystal tuff, both of which contain the bulk of the base-metal sulfides. Below 936 m, relatively unaltered graywacke and argillite sediments, although reworked in the upper few meters, probably form part of the "basement" rocks of the area.

Sphalerite occurs in all the drill cuttings, taken at approximately 3 m intervals, between 802 and 943 m, at 955 m, and also in cores from 809, 839, 880, and 925 m. Galena, although less abundant overall, accompanies sphalerite in most drill cuttings but chalcopryite is present mainly as exsolution "blebs" in sphalerite. Some sphalerite also contains microscopic and submicroscopic inclusions (identified on an electron microprobe) of a silver telluride, cobaltite, and nickel-rich glaucodot, all apparently formed by exsolution. Pyrite is present at virtually all depths, including the base-metal zone, but co-existing pyrrhotite is rare. Measured temperatures in the mineralized zone range from 272 to 276° C. The base-metal sulfides vary from less than 0.5 to 5 percent and are apparently concentrated in small fissures marked by euhedral quartz crystals. In core samples, the sphalerite and galena form either thin, regular or irregular veins, which vary from 1-2 mm in width, or small euhedral crystals up to 1 mm in diameter lining cavities.

Hole Br10 is about 500 m north of Br7. Drill cuttings from depths of 953, 972, 1,014, 1,025, 1,027, and 1,045 m, where the temperature is between 265 and 275° C, contain galena, sphalerite and chalcopryrite.



Textural relationships between the sulfides in Br7 suggest an early generation of pyrite enclosed, but not replaced, by sphalerite. Sphalerite commonly encloses galena, but the reverse is not uncommon. Although some pyrite crystals contain zones of minute black inclusions of unknown composition, suggesting minor variations in depositional conditions, the textures indicate that most of the sulfides crystallized together.

The rocks containing the base-metal sulfides have been extensively altered by hydrothermal solutions (Fig. 2). They are highly silicified, containing small, clear, euhedral quartz crystals and "globules" of well crystallized sericite lining fractures and partly filling cavities in the rhyolite. Some of these cavities have been formed by the removal of plagioclase phenocrysts. Adularia (in crystals up to 6 mm), calcite, and iron-rich chlorite (rarely as small euhedral green booklets) have also been deposited in the mineralized zone. Minor secondary amphibole (tremolite?) locally forms pseudomorphs after plagioclase or hornblende. The rhyolite and crystal tuff in the mineralized zone have been extensively fractured and fault-brecciated, forming feeding fissures for the fluids that deposited the secondary silicate and sulfide minerals. These fissures now provide the 30,000 kg/hr of steam being discharged from the drill hole.

Conditions of Deposition

The significance of the Broadlands sulfides is the probability that they formed in geologically Recent time and prior to drilling were in equilibrium with solutions very similar to that analyzed (Table 1) and at temperatures close to those measured (Fig. 2). The absence of definite replacement textures and the perfectly euhedral, uncorroded shape of the sulfide and silicate minerals where they have been growing together in cavities indicates that they are in equilibrium with one another and with water of the composition now being discharged. Mineral deposition in the fractured, near-surface, permeable rocks in Br7 is probably caused by the formation of steam, loss of CO_2 , and sudden change of pH as the ascending fluid reaches its boiling pressure. An analysis of the water separated at atmospheric pressure from the mixed steam/water discharge is given in Table 1. The water is similar in composition to those from other New Zealand geothermal fields and, in particular, to the other Broadlands and Ohaki drill holes (Ellis and Mahon, 1968). Drill hole Br2, for example, which in April 1968 discharged 88,000 kg/hour of steam and 177,000 kg/hour water, produces water

FIG. 1. Location of Hydrothermal Areas, Taupo Volcanic Zone, North Island, New Zealand (from Steiner and Rafter, 1966). Corrected spelling is Orakeikorako.

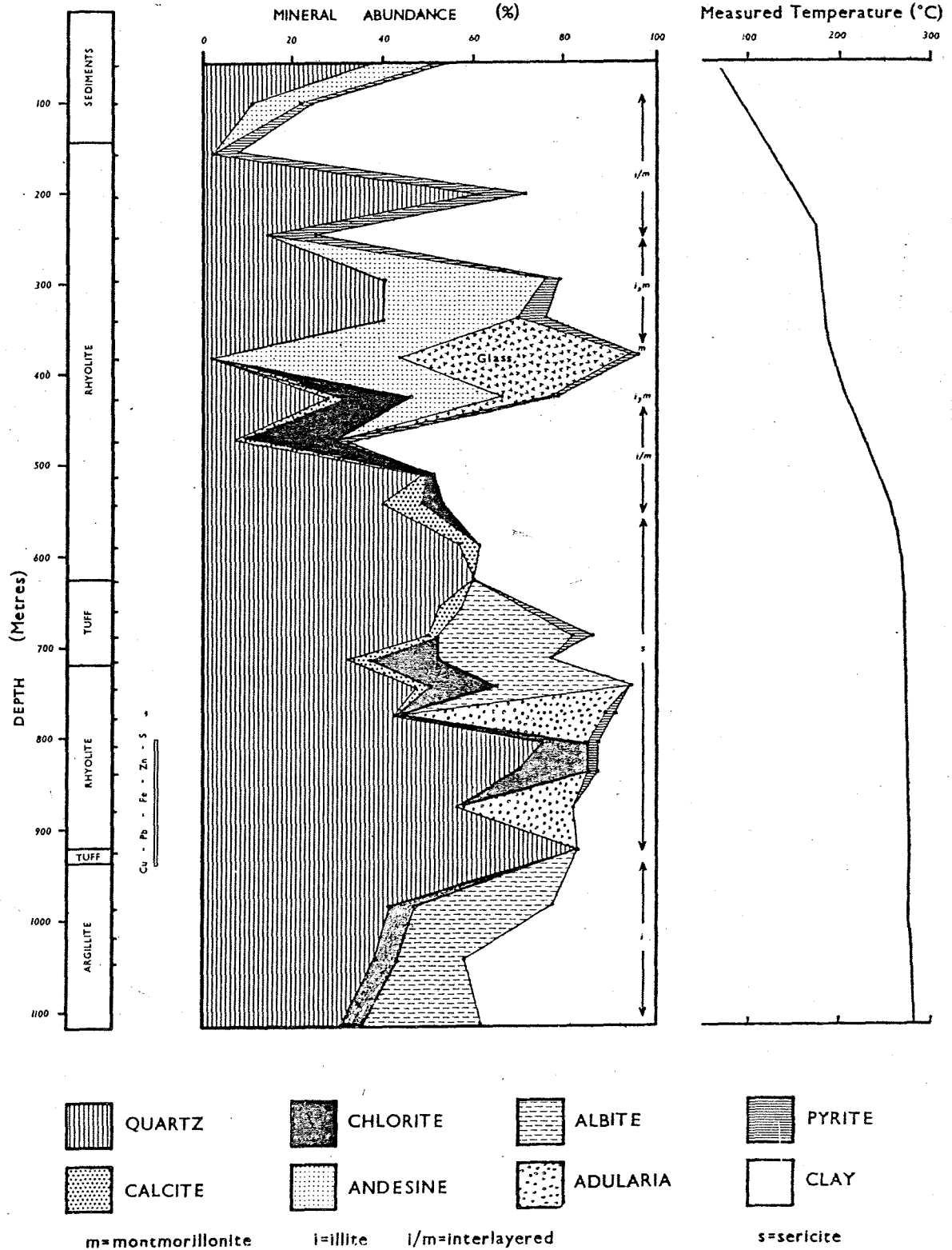


FIG. 2. Generalized geological column, graph of measured downhole temperature and approximate distribution of hydrothermal minerals associated with base-metal sulfides in drillhole, Br 7. Straight lines have been arbitrarily drawn between core samples.

TABLE I
Pressure

$\rho = 8.55$
constituent

- Cl
- Na
- HCO₃
- K
- CO₃⁻⁻
- Li
- As
- SO₄
- Sb
- W
- Zn

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TABLE 1. Analysis of Water Separated at Atmospheric Pressure from Discharge (enthalpy = 546 gm-cal/gm) of Broadlands Drill Hole, Br 7
May 1968

pH = 8.55 Constituent	Concentration (ppm)	Con- stituent	Concentration (ppm)
Cl	1,823	Cu	0.012
Na	1,300	Tl	0.010
HCO ₃	910	Pb	0.005
K	234	Ge	0.004
CO ₃ ⁻⁻	34	Ag	0.002
Li	15	Sn	0.0005
As	9	Au	0.0001-0.001
SO ₄	6	Ni	0.0004
Sb	1.5	Bi	0.0003
W	0.03	Co	<0.0001
Zn	0.015	In	<0.00005

Analysts: A. J. Ellis, J. A. Ritchie, and W. C. Tennant, Chemistry Division, D.S.I.R.

with a similar concentration of major elements (Ellis and Mahon, 1968) to Br7 water. The former (Ellis, personal communication) is lower relative to Br7 by a factor of 2-3 for Zn, Ag, and Pb, and by a factor of about 10 for Au and Sb, but it is enriched in Cu by a factor of about 10. Both Br7 and Br2 have much lower concentrations of metallic constituents than the high-temperature Salton Sea brine (Helgeson, 1967), that produced a remarkable deposition of base-metal sulfides in drill pipes during discharge.

White (1967) suggests that base-metal sulfide deposition may, in general, be connected with Na-Ca-Cl brines, but present observations suggest that deposition can also occur, over long periods of time, from slightly saline solutions of low metal content. According to Grindley (1966), hydrothermal activity in the Wairakei area may have begun in the middle Pleistocene, and there is evidence (Grindley and Browne, 1968) to suggest that the Ohaki-Broadlands field may have been active for a comparable length of time. This would certainly be long enough to deposit the observed base-metal sulfides.

Ellis (personal communication) has shown from experimental work that the metals in the hot solutions could be leached out of rocks and that their concentration level is governed by the solubility and consequent pH of the solutions. However, Steiner and Rafter (1966) consider, from isotopic evidence, that the sulfur originates from a magmatic source.

Acknowledgments

Assistance by the following is gratefully acknowledged: G. A. Challis, C. P. Collard, M. W. Gardner, G. W. Grindley, J. L. Hunt, W. A. Watters, A. Wodzicki, and C. P. Wood, N.Z. Geol. Survey; A. J. Ellis, Chemistry Division, D.S.I.R.; N. D. Dench, A. C. L. Fooks, W. B. Stilwell, D. K. Wainwright, Ministry of Works.

N.Z. GEOLOGICAL SURVEY,
P.O. Box 30368,
LOWER HUTT
August 22, 1968

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