Thermobarometry of the Bleikvassli Zn-Pb-(Cu) deposit, Nordland, Norway

Abstract The Bleikvassli massive sulfide ore deposit is hosted by Proterozoic pelitic, quartzofeldspathic, and amphibolitic rocks of the Uppermost Allochthon of the Scandinavian Caledonides. Staurolite-garnet-biotite and kyanite-staurolite-biotite assemblages indicate that metamorphism reached the kyanite zone of the amphibolite facies. Geothermobarometry was conducted on rocks in and around the deposit using a variety of silicate and sulfide calibrations. Temperature determinations are most reliant on the garnet-biotite exchange reaction, with analyses obtained from 259 garnet rims and adjacent biotite. Results from nine calibrations of the garnet-biotite geothermometer are considered, but compositional limitations of many calibrations involving high Ca and Mn contents in garnet and AlVI and Ti in biotite make many of the coexisting mineral pairs unsuitable. Average temperatures calculated from the two calibrations that most closely address the garnet-biotite compositions observed at Bleikvassli are 584 °C ± 49 °C and 570 °C ± 40 °C. The application of two calibrations of the garnet-staurolite geothermometer on a limited number of samples yields 581 °C ± 2 °C and 589 °C ± 12 °C, assuming $a_{H_2O} = 0.84$, based upon calculations of the modal proportions of gaseous species. Pressure determinations are less constrained. Phengite and plagioclase-biotite-garnet-muscovite geobarometers give average pressures of approximately 5.0 kbar and 8.5 ± 1.2 kbar, respectively. Pressures obtained from the sphalerite-hexagonal pyrrhotite-pyrite barometer average 7.7 ± 1.0 kbar. In consideration of these results, the peak metamorphic conditions at the Bleikvassli deposit are estimated to be 580 °C and 8 kbar.

Introduction Metapelites and sulfide ores in and adjacent to the Bleikvassli Zn-Pb-(Cu) deposit provide excellent assemblages for the application of a variety of geothermobarometers. Although two thermobarometric studies have been conducted near Bleikvassli (Smith-Meyer 1987; Brattli 1996), the geological complexity of the region makes their application to the immediate Bleikvassli mine area questionable. An additional study at the Bleikvassli mine by Cook (1993) involved a limited number of samples. The presence of staurolite-garnet-biotite and kyanite-staurolite-biotite assemblages in and around the Bleikvassli mine suggests peak conditions corresponding to the kyanite zone of the amphibolite facies (Yardley 1989). Using Thompson’s (1976) garnet-biotite geothermometer and Ghent’s (1976) garnet-aluminosilicate-plagioclase geobarometer, Smith-Meyer (1987) determined values of 517 °C–617 °C and 7.0–8.6 kbar within the Rödingsjället Nappe Complex about 10 km south of Bleikvassli (Fig. 1). Cook (1993) obtained temperatures of 540 °C–570 °C using garnet-biotite and garnet-staurolite geothermometers and pressures of 7.5–8.5 kbar from sphalerite-hexagonal pyrrhotite-pyrite, phengite, and plagioclase-biotite-garnet-muscovite geobarometers for the Bleikvassli Mine Sequence. However, Cook’s (1993) study was based upon mineral analyses from only eight samples. In correlative rock units 10–20 km north of the mine (Fig. 1), peak metamorphic conditions were estimated by Brattli (1996) to have reached 680 °C and 7.5–8.5 kbar. These values were based upon silicate and carbonate stabilities as well as...
garnet-biotite geothermometry utilizing the calibration of Ferry and Spear (1978). The 680 °C temperature which Brattli obtained was calculated from analyses of garnet cores and biotite inclusions. Garnet rims yielded a temperature approximately 100 °C lower.

The current study extends the geothermobarometric studies of Cook (1993) at the Bleikvassli deposit by analyzing considerably more samples. The data were obtained to facilitate research addressing the origin and extent of a metamorphic sulfidation-oxidation halo surrounding the orebody (Larsen et al. 1995; Spry et al. 1995; Rosenberg 1998). The accurate determination of the pressure and temperature of peak metamorphism required for this type of study necessitates the evaluation of a large number of samples along with the careful consideration of the various geothermobarometers. Geothermometry was conducted using garnet-biotite and garnet-staurolite calibrations. Pressure estimates were obtained from the plagioclase-biotite-garnet-muscovite, plagioclase-garnet-aluminosilicate-quartz, sphalerite-hexagonal pyrrhotite-pyrite, and phengite geobarometers.

Fig. 1 Generalized geologic map of the north-central Norwegian Caledonides showing the location of the Bleikvassli deposit. (1) Brattli’s (1996) and (2) Smith-Meyer’s (1987) study areas (after Skauli 1990)

Geologic setting

The Bleikvassli deposit is located at 65°55’24”N latitude and 13°52’47”E longitude in the northern Norwegian Caledonides, about 50 km south of Mo i Rana (Fig. 1). It occurs within the Rödingsfjället Nappe Complex (RNC) of the Uppermost Allochthon, the highest structural unit within the Caledonides.

The 6.5 million tonne stratiform orebody contains approximately 4.0% Zn, 2.0% Pb, 0.15% Cu, and 25 g/t Ag from 4.9 Mt mined between 1957 and 1994 (Olav Bakke personal communication). Southern and northern ore lenses connected by a zone of disseminated sulfides compose a body at least 1500 m in length (Fig. 2). The elongate lenses dip moderately to steeply toward the west and plunge toward the NE. The southern end of the orebody terminates very sharply, probably due to tectonic truncation. The northern part continues beneath Lake Bleikvatn, as demonstrated by the presence of a conductive unit identified by geophysical surveys. A 500 m segment of the orebody outcrops in the southern ore lens (Fig. 2). The ore reaches its greatest thickness of about 15 m within the southern lens, most likely due to tectonic thickening. In the northern section, thicknesses reach only 2–3 m (Skauli 1992).

Detailed mineralogical and petrographical descriptions of the southern part of the orebody at Bleikvassli are given in Vokes (1963) and briefly summarized here. Within the main orebody are smaller lenses of massive sulfide ore, intimately interlayered and generally concordant with the associated wall rocks. Between the lenses, and extending into the hanging wall, are regions of disseminated ore. Wall-rock mineralization occurs primarily in the hanging wall. Footwall mineralization, where present, comprises irregular disseminations, veins, and pods. The deposit is complexly deformed, displaying isoclinal folds and extensively sheared zones (Skauli 1992).