

**Preliminary Title:** Crustal assimilation and volatile evolution in rhyolite and phonolite dikes: isotopic and geochemical variations along 8000-ft exposure

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## **Description of Project**

The Homestake Mine offers an unparalleled opportunity to measure chemical and isotopic variations in rhyolite and phonolite dikes over the depth of the mine—a vertical distance of 8000 feet. Quantification of these parameters may have broad applications to rhyolite and phonolite dikes in other igneous provinces in terms of standardization with depth of chemical evolution within dikes and progressive volatile evolution from dikes.

Subalkalic rhyolite is unique in the northern Black Hills alkalic igneous belt because it is highly variable in terms of its trace-element and isotopic concentrations, indicating that variable amounts of different source materials were present in these magmas. In contrast, this is not so in the alkalic series, which includes phonolite and other alkalic rocks. Rare-earth element and trace-element concentrations of subalkalic rhyolite from the entire Black Hills alkalic igneous belt indicate that upper crustal Proterozoic metagraywacke likely was assimilated by the magmas (Duke and Frost, 2004). In addition, considerable crustal assimilation is revealed by strontium and lead isotopic ratios of subalkalic rhyolite (Beintema and Montgomery, 1986), whereas strontium and neodymium isotopic ratios of phonolites are near Bulk-Earth, suggesting that there was little, if any, crustal contamination by phonolitic magmas (Duke and Frost, 2003).

In the Homestake Mine, progressive digestion of xenoliths of Proterozoic black schist and quartzite was documented in magmatic-hydrothermal breccias abutting rhyolite dikes from the 6400-ft level to the surface (Cooper and Lisenbee, 1997). Medium-grained, corroded garnet with biotite inclusions were identified in subalkalic rhyolite at Custer Peak, and SEM analyses of this garnet are similar to those of almandine garnets in Proterozoic metagraywacke (Duke, 2005). At the surface, partial crustal assimilation is observed in subalkalic rhyolite at Windy Flats, near Custer Peak, and at other locations near Lead.

Gas was initially released at the 6400-ft level in the Homestake Mine; this is equivalent to a depth from the surface of 3.3 km at the time of emplacement of the magmas. At this level, evidence of gas release was observed in the form of breccia at tips of small rhyolite dikes (Cooper and Lisenbee, 1997). CO<sub>2</sub> was initially evolved from the magma at the current 2900-ft level (Uzunlar, 1993), but various other gases (*e.g.* fluorine) also were present in these magmas, as evidenced by fluorite cubes in subalkalic rhyolite (Duke *et al.*, *in prep*, 2006).

A two-fold study is proposed, using the same samples, which will be obtained from the cleanest, least-brecciated interior portion of rhyolite dikes from the 8000-ft level to the surface. Similar samples from the center of phonolite dikes will serve as a standard for comparison. A pilot study of two or three samples, spread out over the entire depth, is important in order to determine further study. It is possible that isotopic or other chemical differences might not be great enough to be detected. It is suspected, however, that significant variability will be observed in the rhyolite dikes over this distance, but very little difference in the phonolite dikes. In addition, it must be initially ascertained as to whether or not there is a significant difference among subalkalic rhyolite dikes at the same depths. Alkali rhyolites differ substantially from subalkalic rhyolites and will not be included in the current study. If the pilot study is fruitful, further sampling will take place at various depths.

(A) *Quantification of crustal assimilation*

The following geochemical concentrations will be determined in order to quantify crustal assimilation: 1) Sr, Nd, and Pb isotopes (and possibly Hf and Os), 2) major oxides, and 3) trace-elements (including REEs, Au, Ag, W, Sn). If funding allows, Re/Os isotopic studies will include analyses of sulfides in breccias with higher gold concentrations to pinpoint the source of the breccia-related gold—mantle or crust.

(B) *Volatile Evolution*

Using the same samples from (A) and obtaining analyses for CO<sub>2</sub>, H<sub>2</sub>O, F, Cl, Br will allow for 1) identification of specific gases evolved, 2) measurement of quantity of specific gases evolved, and 3) assessment of the depth at which each gas was released.

**Space Requirements/Technical Issues**

To obtain necessary samples, access to the 8000-ft level is required; however, preliminary collection above the current water level can be done at any time. Homestake Mining Company may also have drill core that could be used in this study.

**Estimated time of access**

Preliminary sampling above the water level could begin when access is allowed to the 4850 level, but time of sampling to the 8000-ft level depends on when the mine will be drained.

## References

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