

Project Title: Hydrothermal Systems, Cascades Volcanoes

Statement of Problem

Hydrothermally-altered rocks are present on many active volcanoes in the High Cascades and are widespread in the Oligocene-Pliocene volcanic and plutonic rocks of the Western Cascades in the northwestern United States. Hydrothermal alteration is a manifestation of ore-forming processes and is characteristic of mineral deposits formed in continental-margin arcs. Hydrothermal alteration can result in severely weakened volcanic edifices that may be susceptible to failure and catastrophic landslides. Hydrothermal alteration also can result in rocks highly enriched in sulfur and potentially toxic metals that can be leached into surface and ground waters. This project aims at understanding the processes that form hydrothermal alteration in active volcanoes, including depth, duration, temperature, and sources of fluid components. It also addresses the metallogeny of the Oligocene-Pliocene Cascade arc (Western Cascades) and compares it to the Quaternary arc. Results will be used to develop genetic models of ore deposition, the degassing of magmas, the hydrologic structure of volcanoes, and the contribution of rock-alteration effects to volcanic hazards, and to gain a better understanding of the regional controls on metallogenesis of the Oligocene-Quaternary Cascades arcs.

Objectives

Hydrothermal alteration occurs when rocks interact with hot fluids resulting in mass transfer between rocks and fluids and crystallization of hydrothermal minerals in the rocks. In active volcanoes, these fluids originate from many sources, including degassing of magmas, convecting heated meteoric ground waters, precipitation, or mixtures from all of these sources. Hydrothermal alteration resulting from interaction with extremely acidic fluids produces rocks highly enriched in sulfur and potentially toxic metals and metalloids, such as As, Hg, Se, Tl, and Zn. Extreme acid alteration (acid leaching) results in rocks that have no acid-buffering capacity, and oxidation of hydrothermal sulfide minerals in these rocks can form natural acidic waters highly enriched in potentially toxic metals. Hydrothermal alteration of stratovolcanoes is characteristic of the upper parts of magmatic-hydrothermal systems that form important mineral deposits, including major world sources of copper, gold, and silver. Many large mineral deposits are associated with the Oligocene-Pliocene Cascade arc in Washington, Oregon, California, and Nevada. In contrast, little mineralization is known in the Quaternary arc. Hydrothermal alteration of active volcanoes also can result in weakened volcanic edifices which may be susceptible to failure and catastrophic debris flows. Clay-rich hydrothermally-altered rocks can produce cohesive debris flows that travel much farther than debris flows that lack clay minerals. Hydrothermally-altered rocks are present in many of the Quaternary Cascades volcanoes, but with the exception of Mt. Rainier, the distribution, composition, and origin of hydrothermal alteration products generally are poorly known.

Some of the scientific questions to be addressed in this project include: what controls the distribution and mineralogy of hydrothermally-altered rocks? What are the volumes of hydrothermally-altered rocks and why do these vary from volcano to volcano? How do structure and lithology control hydrothermal alteration? What is the timing and duration of the hydrothermal systems and the interaction between volcanism and hydrothermal systems during volcanic construction and destruction? What are the sources of the hydrothermal fluids?

What are the metal contents and metal sources of hydrothermally-altered rocks? What are the mechanisms and favorable alteration characteristics for slope failure? Why is there apparent lack of significant mineral deposits in the Quaternary Cascade arc, whereas mineral deposits are abundant and significant in many parts of the Miocene-early Pliocene arc? How do we distinguish barren versus mineralized volcanoes?

Relevance and Impact

Potential applications of the data and models generated during the full project include: (1) improved understanding of the regional metallogeny of the Miocene-Pliocene (Western) and Quaternary Cascades arcs for use mineral resource assessments, (2) improved information on the distribution and origins of hydrothermal alteration on active Cascades volcanoes to support improved hazards evaluations; (3) geochemical backgrounds in volcanic terranes applicable to geoenvironmental studies of abandoned mine lands in similar geologic settings; and (4) improved understanding of the genesis of base- and precious-metal deposits, including porphyry copper-gold, gold- and copper-rich breccia pipes, high-sulfidation gold, low-sulfidation gold-silver (Comstock, hot-spring), and stratiform sulfur.

Major products are anticipated to include a series of topical reports on the metallogeny of the Cascades, active hydrothermal systems in the Cascades as modern analogues of ore-forming systems, and hydrothermal alteration of Cascades volcanoes and volcanic hazards. In addition, several syntheses will be written that contain highly integrated quantitative models for both hydrothermal alteration on the surface and mineralization in the interiors of Quaternary Cascade stratovolcanoes and comparative metallogeny of the Tertiary Western Cascades and Quaternary Cascades arcs to other continental-margin arcs worldwide.

Strategy and Approach

This project began in FY00 as small planning effort with a two-day workshop on hydrothermal alteration and hydrothermal processes focusing on the Cascade volcanoes. The workshop was jointly sponsored by the Mineral Resources and Volcano Hazards Programs, and attended by about 50 geoscientists, primarily from the USGS but also including several consultants, members of the National Park Service, and representatives from several universities. This workshop was used for project planning in FY01. FY01 also was mostly a planning year, at the request of the MRP Program Coordinator. The main activity was a 10-day field conference attended by more than 20 geoscientists. The first part of the trip visited several mining districts in the Tertiary Western Cascades (Bohemia, Quartzville, North Santiam, and Detroit Dam, OR, and St. Helens, WA). The second part of the trip examined several Quaternary volcanoes (Mount Rainier, Mt. St. Helens, Lassen Peak, Brokeoff Volcano) that expose variable levels of erosion and differing amounts of hydrothermal alteration. This field trip was used for planning in FY2002.

Three inter-related tasks were initiated in FY02: (1) metallogeny of the Cascades, (2) active hydrothermal systems in Cascade volcanoes, and (3) hydrothermal alteration and volcano hazards. These tasks aim at development of highly integrated quantitative models for both hydrothermal alteration on the

surface and mineralization in the interiors of stratovolcanoes of both the Quaternary and Eocene-Pliocene Cascade arcs.

Task 1 seeks to better characterize and understand the metallogeny of the Tertiary and Quaternary Cascades arcs in northern California, Oregon, and Washington. It builds on preliminary results of MRP-funded projects of the early 1990s. It addresses fundamental questions regarding regional metallogeny through a comparative study of the weakly mineralized Quaternary High Cascades to more highly mineralized parts of the Eocene-early Pliocene arc. Work includes digital compilation of existing data, such as geologic and geophysical maps of the study area, building of district deposit MRDS records, field studies of selected mining districts and igneous centers, and collection of new geochemical and geochronologic data for selected mining districts and igneous centers. The results of these studies will provide knowledge about mineral deposit generation in continental-margin arcs that are broadly applicable to magmatic arcs worldwide.

Task 2 is studying active and dormant hydrothermal systems on High Cascades volcanoes to better characterize hydrothermal alteration and mineralization in the volcanoes. It combines results and interpretations of field mapping and sampling, mineralogy, stable isotope, chemical leach analysis, and chemical modeling studies. The goal will be to understand better the geochemical and hydrogeochemical processes active in the volcanoes, and the role these processes play in mineralizing systems, volcanic hazards (such as slope stability in altered areas), and environmental issues (such as natural acid-rock drainage).

Task 3 aims at improving information on the distribution and origins of hydrothermal alteration on active Cascades volcanoes to support improved hazards evaluations. This task is working closely with experts on individual volcanoes from the Volcano Hazards Program. Work includes geologic mapping, mineralogical characterization, remote sensing, and geophysical studies of hydrothermal alteration on selected volcanoes (Mounts Rainier, Adams, Baker, and Shasta, and Lassen Peak), and integration of these data with existing data on the geology and eruptive histories of the volcanoes to model the potential role of hydrothermal alteration in volcanic hazards. Hazards evaluations, assessments, and pronouncements will remain the responsibility of the Volcano Hazards Program.