Hazard Characteristics of Hydrothermally Altered Rocks on Stratovolcanoes: A Remote Sensing Framework for Debris Flow Hazard Assessments

By

J. K. Crowley, and J. C. Mars, U. S. Geological Survey, Reston, Virginia 20192

D. R. Zimbelman, Natural Hazards Research and Applications Information Center, University of Colorado, Boulder

C. A. Finn, and R. O. Rye, U. S. Geological Survey, Denver, Colorado 80225

Abstract

Among the most devastating volcanic phenomena are large rock avalanches and debris flows that begin high on a volcano and surge for many tens of kilometers down the surrounding river valleys. Such events are closely linked to the presence and distribution of hydrothermally altered rocks, which serve both to weaken a volcanic edifice, and to produce clay-rich mudflows that travel especially long distances. For example, the Osceola Mudflow, which occurred approximately 5000 years ago, removed some 3 km^3 of rock from the summit of Mount Rainier, and traveled over 100 km downstream to Puget Sound. Catastrophic collapse events are not always triggered by eruptive activity, and many events appear to have taken place essentially without warning.

Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data acquired over nine Cascade stratovolcanoes have proven useful for mapping altered rocks based on associated clay and hydrous sulfate mineral spectral properties (Crowley and Zimbelman, 1997). These data, coupled with digital elevation models and ground-based mapping information, indicate that particular geomorphic features, including volcanic summits, ridges, amphitheaters, and breached craters, have distinctive hazard characteristics. For example, intensely altered summit rocks, present on Mount Rainier, Mount Adams, and Mount Shasta, have the potential to generate extremely large debris flows affecting any volcanic sector, i.e., the direction of flow is not constrained by the topography. In contrast, where altered rocks occur within breached craters, (e.g., Mount Baker, Mount Saint Helens, and Mount Hood), avalanches and debris flows are more likely to be constrained to the breach direction. Isolated ridges of altered rock would ordinarily be capable of generating flows of limited volume. However, where a ridge is contiguous to an altered summit, relatively small ridge failures might trigger a much larger summit collapse. Amphitheaters (arcuate cliffs) composed of altered rock are important debris flow source areas, and can be distinguished from glacial cirques, which have

a similar morphology, but different spectral characteristics. Amphitheaters seen on AVIRIS imagery of Mount Rainier and Mount Adams may signify preferred azimuths for major edifice failures. Amphitheaters also are a source of frequent smaller avalanches and debris flows, including an event at Mount Adams during 1997.

At least three distinct types of altered rock have been recognized with the Cascades AVIRIS imagery, including advanced argillic (sulfate-clay) and argillic (clay-silica) mineral assemblages in the Quaternary volcanics, and chlorite-quartz-sericite assemblages in surrounding Tertiary rocks. Although the lower rank argillic and Tertiary chlorite-quartz-sericite alteration forms may not be associated with large collapse events, their role as source areas merits further study. By examining the mineralogy of debris flow deposits and possible source rocks in a given watershed, it may be possible to link source areas with individual debris flows. This would aid in establishing how local structures and source mineralogy influence debris flow generation, and shape the size and sedimentological character of flows.

The combination of spatial and spectral information afforded by AVIRIS imagery provides a basic framework for making debris flow hazard assessments. Studies of the Cascade volcanoes will aid in extending this type of analysis globally as advanced satellite remote sensing data become available in the next decade.

Reference:

Crowley, J. K., and Zimbelman, D. R., 1997, Mapping hydrothermally altered rocks on Mount Rainier, Washington, with Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data: GEOLOGY, v. 25, p. 559-562