

MAPPING HYDROTHERMALLY ALTERED ROCK ON MOUNT RAINIER,  
WASHINGTON: APPLICATION OF AVIRIS DATA TO VOLCANIC HAZARD  
ASSESSMENTS

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Hydrothermally-altered rocks on stratovolcanoes are closely linked to edifice failures and the generation of destructive volcanic debris flows (Scott and others, 1992; Lopez and Williams, 1993). Altered rocks (1) form zones of weakness along fractures, dikes, and volcanic bedding surfaces, and (2) contain hydrous clay minerals that modify debris flow physical properties, increasing flow cohesion and extending flow reach. As illustrated by the 1980 edifice failure and eruption at Mount Saint Helens (Lipman and Mullineaux, 1981), and the disastrous 1985 debris flows from Nevado del Ruiz, Columbia (Lopez and Williams, 1993), mass-waste events of catastrophic proportions are not uncommon. Edifice collapses and destructive debris flows can be triggered by eruptions or earthquakes, but can also occur without any precursory activity.

The Cascade volcanoes of the Pacific Northwest are prime settings for volcanic debris flow generation, and because of the potential hazards, Mount Rainier, Washington, was designated as a Decade Volcano study area in 1993. Mount Rainier lies on the outskirts of the Seattle-Tahoma metropolitan area and has been the source of many large Holocene debris flows. Included among these was the massive Osceola Mudflow (ca. 5600 years BP), which traveled 113 km into areas near Puget Sound that are now densely populated (Scott and others, 1992; Crandell, 1971).

This paper describes the use of NASA Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data for mapping altered rocks on Mount Rainier. AVIRIS data were acquired on July 19, 1994, under favorable conditions of relatively low mid-summer snow cover. The data were calibrated by using a band ratio-based atmospheric correction, followed by calibration to reflectance using laboratory spectral measurements of unaltered rock samples from Mount Rainier. The calibrated data were analyzed using least-squares spectral band fitting and linear spectral unmixing techniques.

Despite the extensive snow and ice cover on Mount Rainier, and the relatively limited rock exposures, AVIRIS data were very useful for mapping known areas of hydrothermally-altered rock. Argillically altered Quaternary volcanic rocks (secondary silica +/- kaolinite-smectite +/- sulfates) were discernable on the AVIRIS image in many areas where they have been mapped in outcrop, including a broad zone that trends E-W and bisects the volcano

through its summit (Zimbelman et al., 1994). Preliminary results distinguish two subtypes of argillic alteration--a relatively clay-rich subtype that is prevalent in younger rocks located on the upper flanks and summit of the mountain, and a relatively silica-rich (esp. cristobalite) subtype that is present in somewhat older rocks on the lower flanks. The clay-rich alteration displays broad spectral features near  $2.2\ \mu\text{m}$  produced by mixtures of alunite, kaolinite, smectite, jarosite, and silica (Figure 1, "A"). Spectra of the silica-rich alteration subtype are relatively subdued because of abundant cristobalite, which is spectrally featureless (Figure 1, "B"). The two subtypes of argillic alteration were not recognized prior to these AVIRIS mapping results and their distribution and significance is still being investigated. Fe-oxide rich rocks were mapped on the basis of characteristic spectral bands near  $0.85\ \mu\text{m}$  (Figure 1, "C"). Such rocks are widely-distributed on the edifice and probably were produced by ordinary degassing of lavas during flowage and cooling. Chlorite and sericite alteration in Tertiary rocks at the base of the edifice was mapped by using diagnostic spectral features near  $2.32$  and  $2.20\ \mu\text{m}$ , respectively (Figure 1, "D" and "E"). In addition to the altered rocks, several linear E-W spectral anomalies corresponding to local differences in snow particle size were observed on the upper flanks of Mount Rainier. Causes of the anomalies remain to be determined and could include structural controls on crevasse development, or perhaps, alignments of intermittent fumeroles.

Unstable slope conditions and glacial cover at many Cascade volcanoes present severe challenges for ground-based geologic mapping. Effective remote sensing methods for identifying altered rocks will significantly enhance the ability to evaluate volcanic debris flow risks. Ongoing work at Mount Rainier will focus on combining the AVIRIS results with geophysical and geochemical data to aid in the assessment and mitigation of debris flow hazards.

## References

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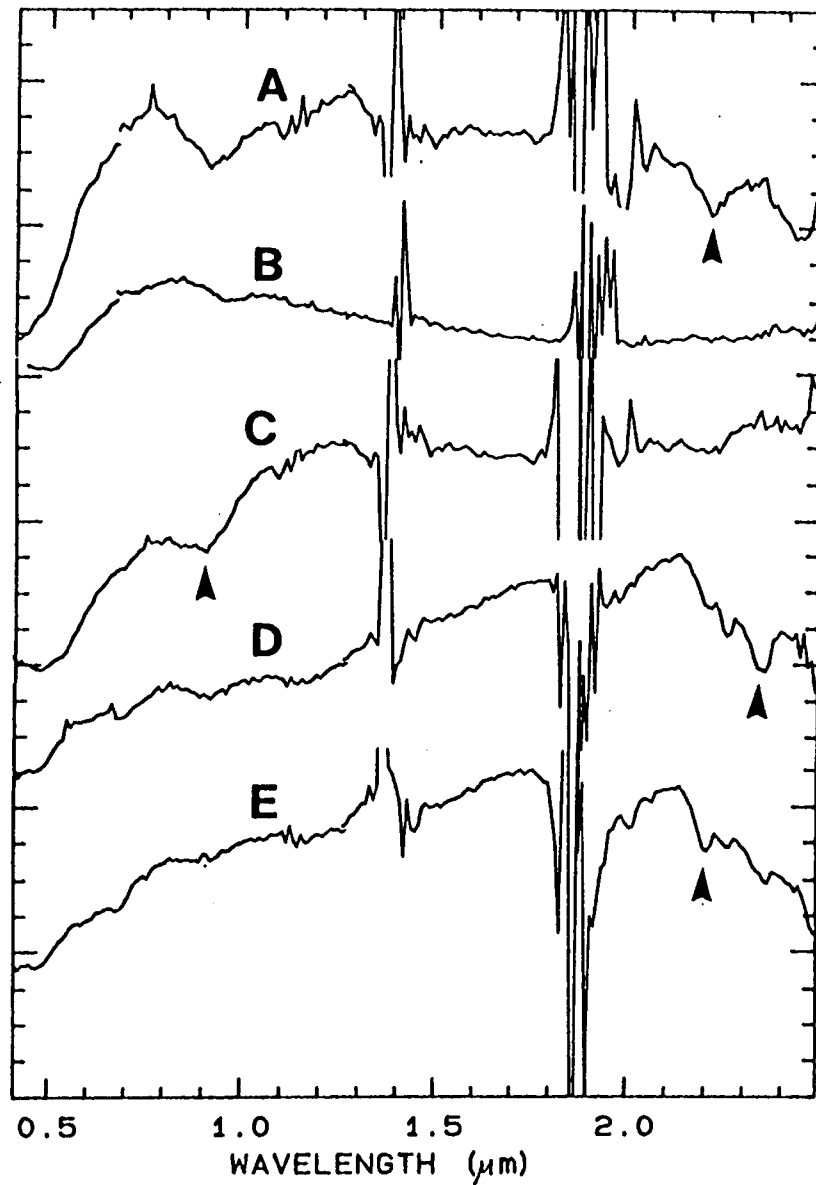


Figure 1. Representative AVIRIS spectra of alteration subtypes. "A", clay-rich argillic alteration; "B", silica-rich argillic alteration; "C", Fe-oxide-rich alteration; "D", Chlorite alteration; "E", sericite alteration. Arrowed spectral features are discussed in the text.