Case Histories III

Thursday Morning, September 27th

Volcanic Rocks and Seismology, Surface and VSP

CH5.1

William P. Iverson, B. N. Fuller, and Scott B. Smithson, University of Wyoming*

Summary

Seismic data from the University of Wyoming Volcanics Reflection Research Project (UWVRRP) are presented to demonstrate some of the problems with recording seismic data through volcanic rocks. Volcanic covered regions are notorious for poor seismic reflection data. The most prevalent problem noted in this study is due to the numerous high velocity contrast layers present in volcanic sections, causing extreme reverberations accompanied by numerous mode conversions and scattering of the primary wavelet. Vertical seismic profiles through volcanics prove that reflection do occur, but are obscured in surface recordings by reverberations and scattering. Attenuation is not a problem, at least in terms of decibels per kilometer, volcanic rocks studied here have no more Q type attenuation than sedimentary rocks. The major seismic problems in volcanics are near surface reverberations and mode conversion scattering. Examples from Washington State, Idaho, and New Mexico are presented to demonstrate our conclusions.

Introduction

The University of Wyoming Volcanics Reflection Research Project (UWVRRP) was initiated in 1982 by Scott Smithson. The goal of the project was to determine why volcanic rocks seem to prohibit the recording of seismic reflection data. The primary tool of the project was the vertical seismic profile (VSP). Considerable downhole and surface seismic records were recorded by the Geology Department seismic crews in the western United States. Extensive theoretical and modelling studies were conducted in the College of Engineering. Work from UWVRRP has been published by Pujol et al (1989) and Fuller (1987). This paper presents examples demonstrating some of the most critical problems for recording seismic data through volcanic rocks.

Washington State

Seismic data was recorded near Moses Lake, Washington, in the central Columbia Basin Basalts. Figure 1 shows a vertical component VSP recorded entirely within the basalt flows. Note the obvious downgoing P energy, indicating that seismic energy definitely goes into the ground. Fuller (1988) examined the amplitudes of the downgoing wavelets as a function of depth. The average Q through volcanic rocks is comparable to that in sedimentary rocks. Problems with seismic propagation in basalts could not be attributed to a simple Q model attenuation phenomena. Other observations must be made. Notice the changing character of the downgoing wavelet. By the time 1000 m depth is reached, a primary wavelet has changed dramatically in comparison to first arrivals observed in VSPs recorded in sedimentary sections. The changes are particularly noticeable in the downgoing wave following the first arrival, which is quite long in time, and of much higher amplitude than the reflected waves. If we are sending such a long, fuzzy signal into the subsurface, then the lack of coherent surface data is not surprising.

The horizontal component of the same Moses Lake VSP is shown in Figure 2. Abundant downgoing shear events, both mode converted P-SV and reverberations are apparent on this VSP. One possible problem with seismic propagation through this basalt section could be the uncontrollable loss of energy to shear events. There is also ample indication of reverberations in the near surface, causing further loss of wavelet resolution. Surface records also verify the problem with near surface reverberations, as shown by Figure 3. The only possible reflection events in this record appear at near normal incidence. The interference effects of mode converted waves in this VSP are discussed in Pujol el al., (1989).

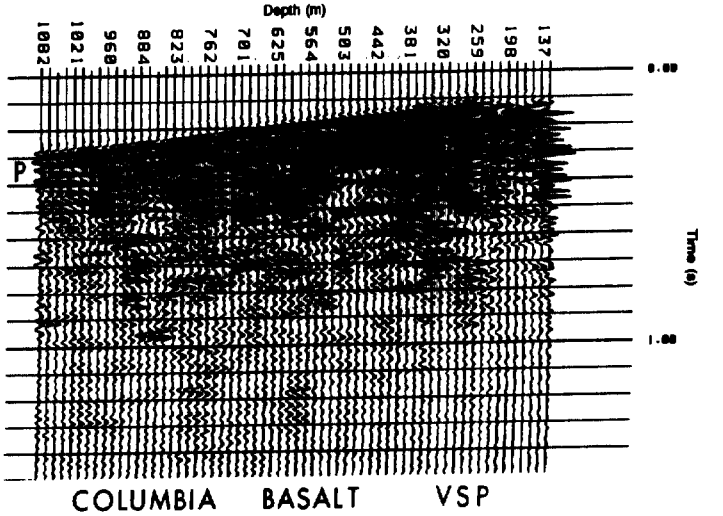

Figure 1. Vertical component of VSP through basalt.

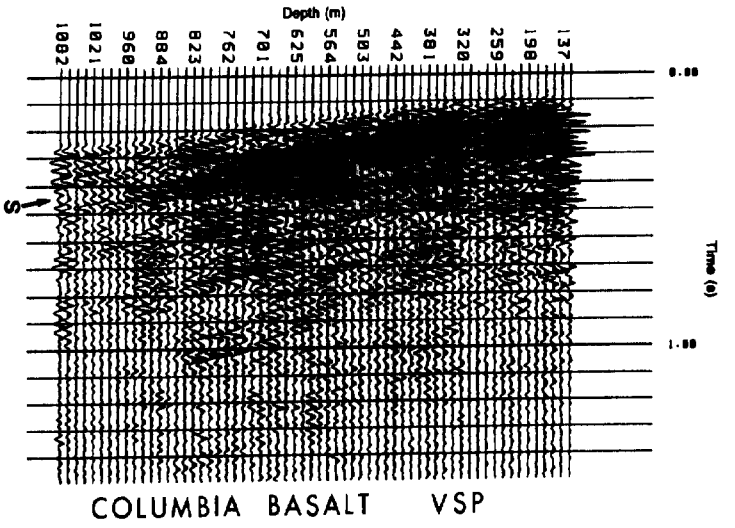

Figure 2. Horizontal component of VSP through basalt.

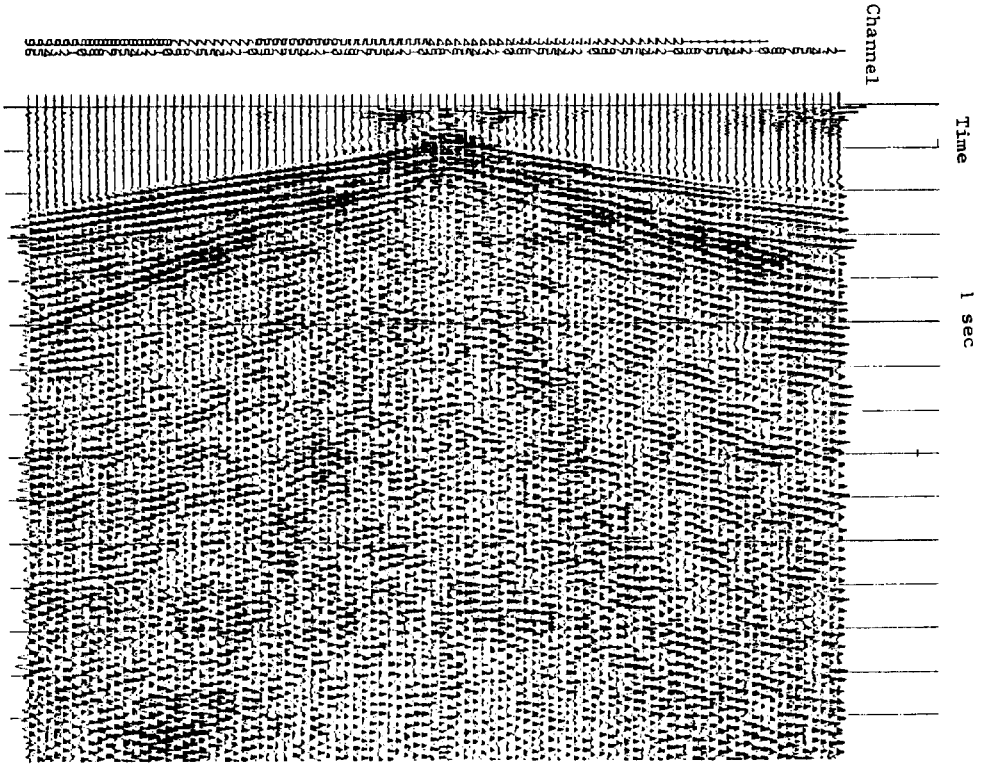

Figure 3. Surface field record from vicinity of previous VSP data.

Idaho

Seismic data were recorded at the Idaho National Engineering Laboratory (INEL) in southern Idaho within the Snake River Plain basalts. A vertical component VSP is shown in Figure 4. Notice the obvious reverberation of the downgoing energy. No primary wavelet can be recognized from these data. In fact, at the bottom of this well, the maximum amplitude is not clearly at the first arrival.

Reverberations have now been demonstrated as one of the primary problems with seismic in basalts. We attribute these dominant reverberations to the layered nature of basalt flows. Individual basalts flows are of variable thickness, and in places there is sufficient time between flows to expect development of soils which remain very low velocity zones within the basalt section. Extremely high acoustic impedance contrasts exist throughout these basalt sections, particularly in the near surface. With such high impedance contrasts, even moderate angles of incidence can reach critical angle and/or enhance P-S mode conversions.

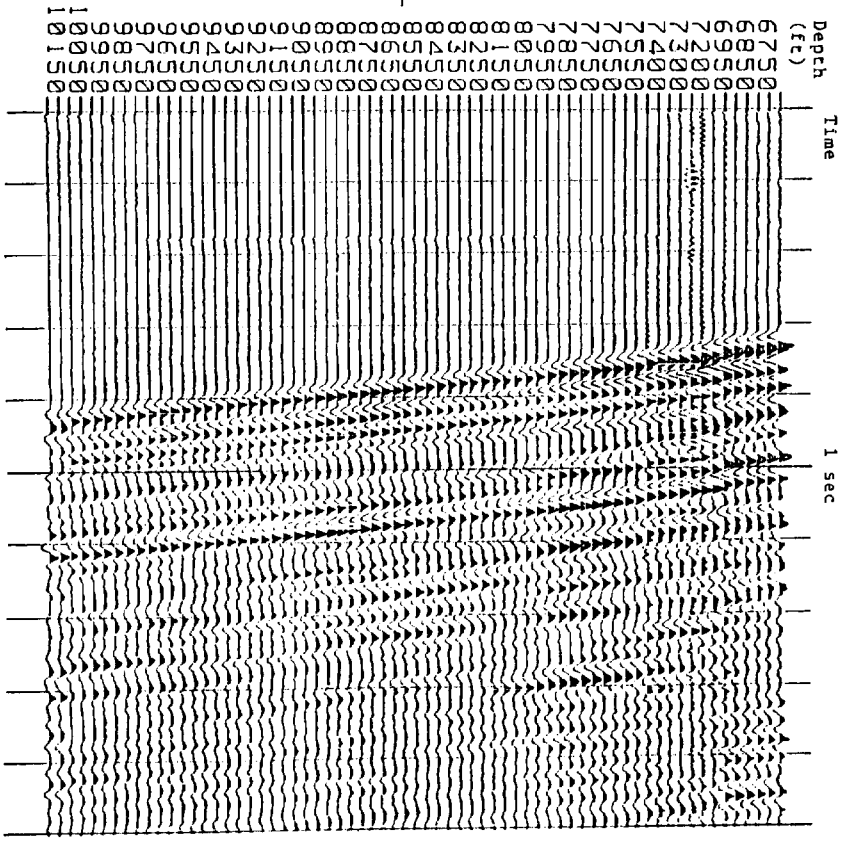

Figure 4. Vertical component of VSP through basalt.

New Mexico

A three component VSP was recorded near Datil, New Mexico. The SH component VSP from this site is shown in Figure 5. Once again note the numerous reverberations of the downgoing energy. The strongest downgoing energy here is the shear conversion from the near surface. But there is also abundant downgoing shear at earlier times, obviously from P-S mode conversion at numerous depths below 2000 feet. Such mode conversions seem to be another consistent observation about the volcanics problem. Both P-SV and P-SH mode conversions are common, creating a very different wavefield picture when compared to VSP's in more hospitable sedimentary rocks.

Conclusions

From the observations made in these few volcanics sites in the western United States, we conclude that the major problems with acquiring seismic data through volcanics are reverberations and wavelet scattering. Energy easily goes into the earth at volcanic sites, but it is very difficult to send in a crisp wavelet. High energy sources will probably be ineffective in resolving the problem because the reverberations and mode conversions will also become stronger.

References

Fuller, B. N., 1987, Seismic reflection data acquisition problems in the Columbia River Plateau and the Snake River Plain. M.S. thesis, University of Wyoming, Department of Geology and Geophysics, Laramie, Wyoming.

Pujol, J. M., Fuller, B. N., and Smithson, S. B., 1989, Interpretation of a VSP conducted in the Columbia Plateau basalts: Geophysics, 54, 1258-66.

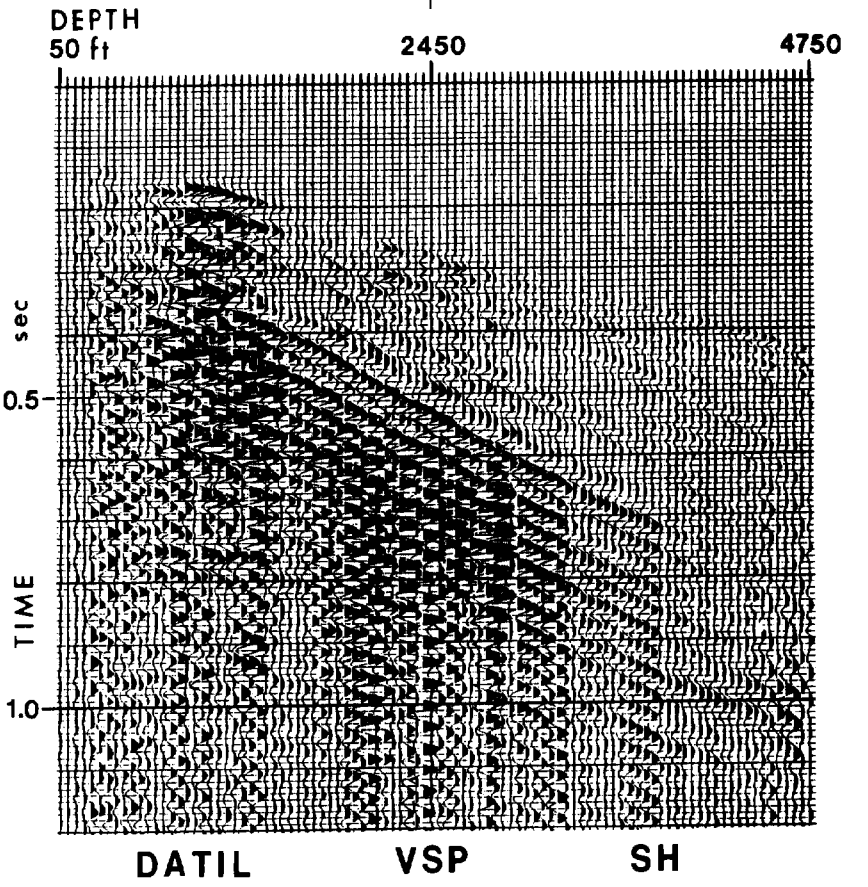

Figure 5. Horizontal component of VSP through volcanics at Datil, N.M.