IMPULSE RADAR STUDIES OF NEAR SURFACE GEOLOGICAL STRUCTURE by Gary R. Olhoeft, U.S. Geological Survey, Box 25046 DFC, Denver, CO 80225

Impulse radar has recently been tested in a wide variety of geological materials and environments to determine its suitability for probing near surface geological structure. Impulse radar systems operate by transmitting electromagnetic energy pulses into a material and receiving, versus time, any energy that is reflected. The time of reception of the reflected energy is the two-way travel time from the source to a reflector and back. The velocity of propagation in the material is determined by the dielectric permittivity, which may be independently measured by common depth point profiling to allow reception time to be equated with distance. Energy is reflected by any change in dielectric permittivity, which is commonly caused by changes in bulk density, water content, or state of the water. The larger the change in dielectric permittivity, the greater is the proportion of the transmitted energy that is reflected.

Over the last two years, a 100 MHz center-frequency, 100 watt peak power impulse radar system has been used to detect and map interfaces (changes in dielectric permittivity) with resolution of one third meter to depths of several to tens of meters in permafrost, five to twenty meters in basalt, fifteen meters in granite, and tens of meters in ice. As a typical example, Figures 1 through 4 illustrate the real time and computer processed data records of a portion of a profile across interbedded lava flows.

The radar system was operated using a single transmit-receive antenna suspended approximately 1/3 meter off the ground from the rear tailgate of a four-wheel-drive vehicle. The vehicle was driven at an independently bench-marked constant rate of about 5 km/hr, while data was taken at 51.2 scans/s and recorded on both graphic and FM tape recorders. A scan is a single record of received amplitude versus time. The graphic recorder plots scans as an absolute amplitude-modulated gray-scale with reception time on the vertical axis, while the horizontal axis becomes traverse distance as successive scans are plotted adjacent to each other. Figure 1 illustrates such a real time graphics record taken along Crater Rim Road in Hawaii Volcanoes NationalPark driving from (left edge of figure) the parking lot at Halemaumau

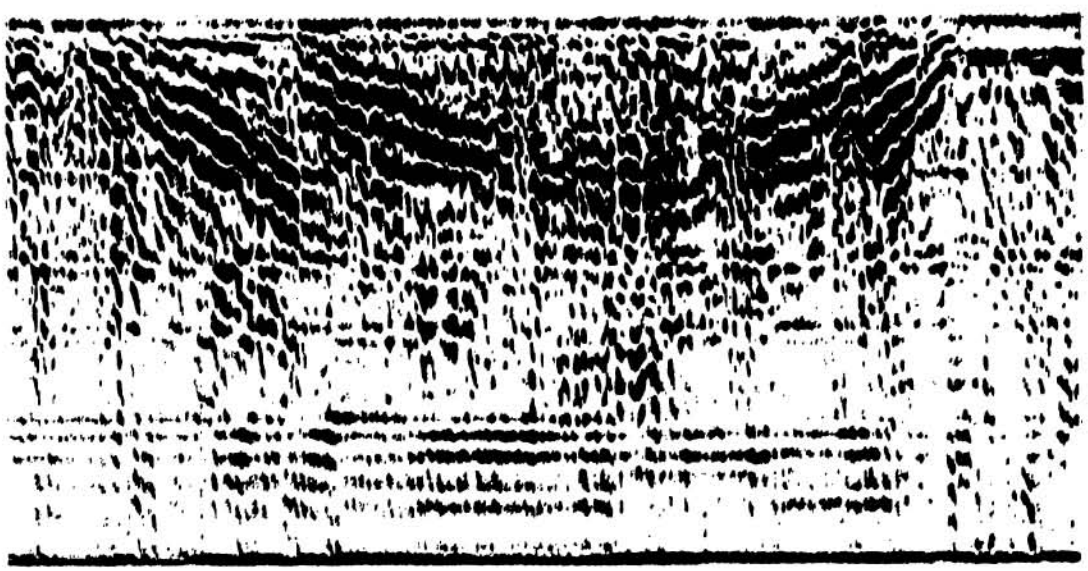

Figure 1: Real time graphic output of radar along Crater Rim Road.

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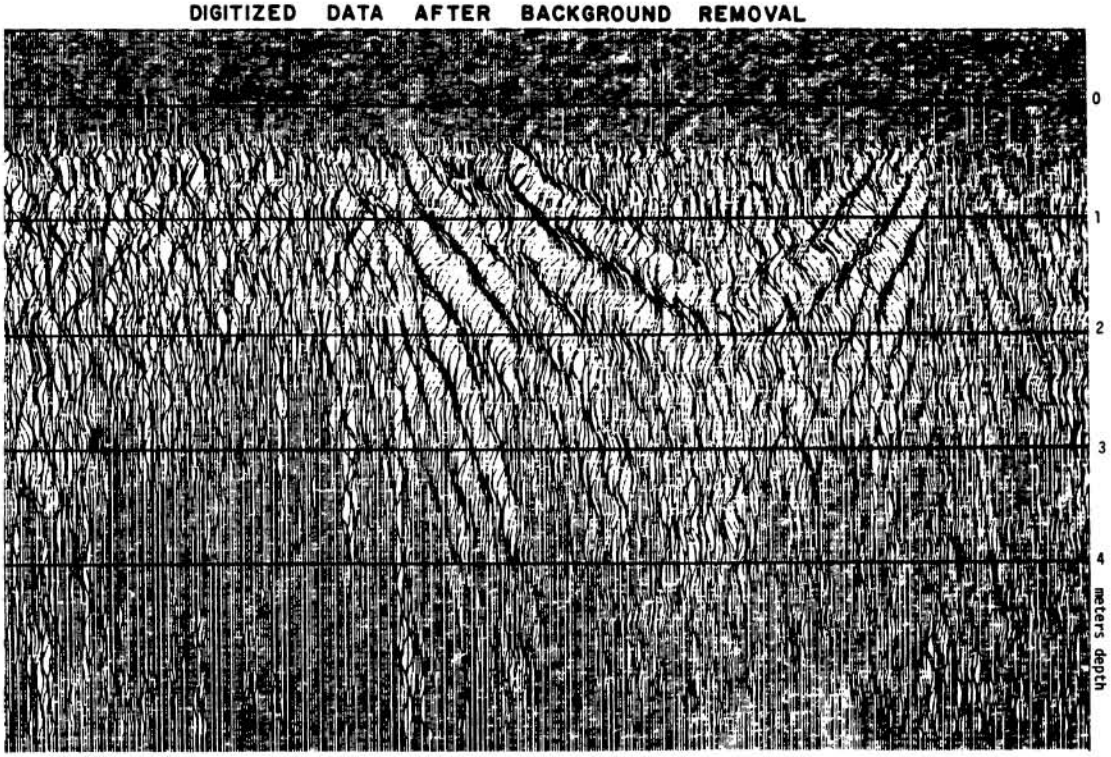

Figure 2: Computer digitized version of Figure 1.

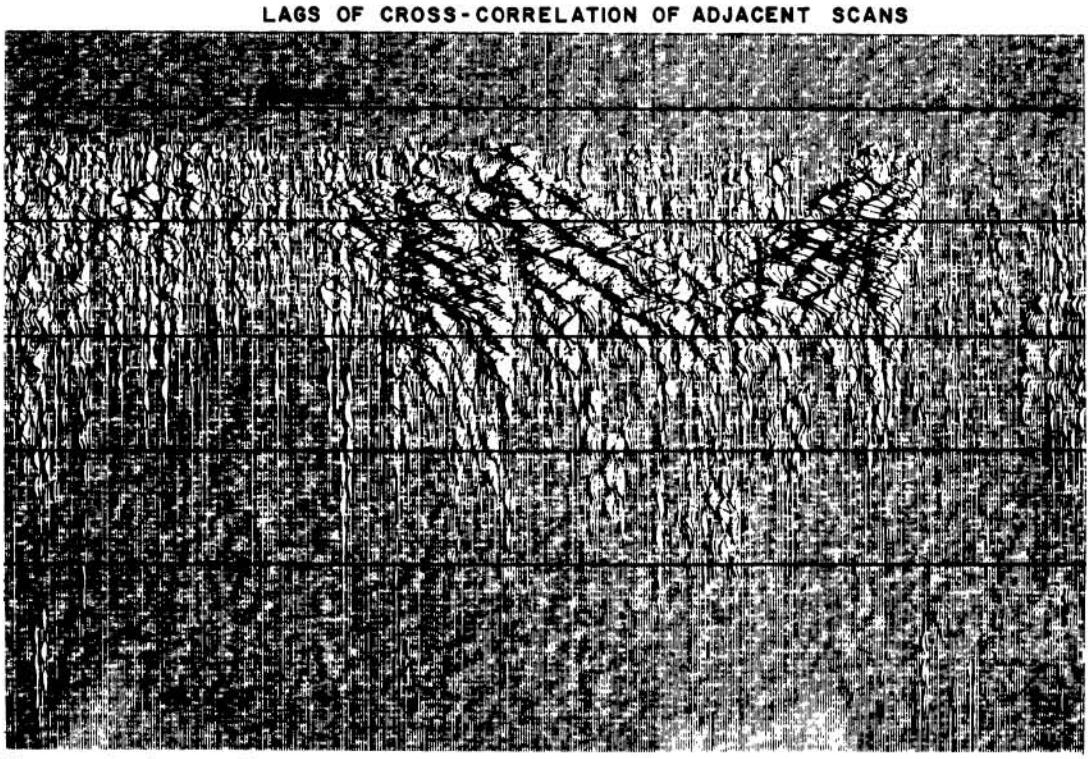

Figure 3: Lags of cross-correlation of adjacent scans in Figure 2.

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fire pit to the rim of Kilauea Caldera (right edge) in the direction of the Hawaiian Volcano Observatory. The horizontal bands across the figure in several places are constant-range reflections from the vehicle. Three dark bands separated by white lines represent a single reflection, as the transmitted pulse is received as a triplet.

Figure 2 illustrates a computer digitized version of Figure 1 after background removal. Background removal is the averaging of all scans, followed by replotting of each scan after subtracting the average scan. This removes all constant-range reflections such as the vehicle (and also the surface of the ground, so its location must be saved). Figure 3 illustrates a plot of the lags of the cross-correlation of adjacent scans from Figure 2. This removes incoherent signals which are not repeated from scan to scan, and thus leaves only the coherent geological structure. Figure 4 illustrates the final interpreted result on the same scale as Figures 2 and 3. The vertical depth scale is for a dielectric permittivity of 9. Note the vertical exaggeration by a factor of 57.

Originally, a topographic depression existed which was filled by a lava flow in 1971 and then covered by a second flow in 1974. The radar reflectors are interpreted to be thin layers of wet ash at the base of the 1971 flow and between the 1971 and 1974 flows. The fault in the radar data is not observable at the surface and is postulated to have formed when the weight of the 1974 flow fractured the earlier material. Surface expression of the fault would not be expected if it had occurred while the lava was flowing. Note that the real time graphic record is nearly as informative as the computer processed versions, though the latter are clearer to greater depth.

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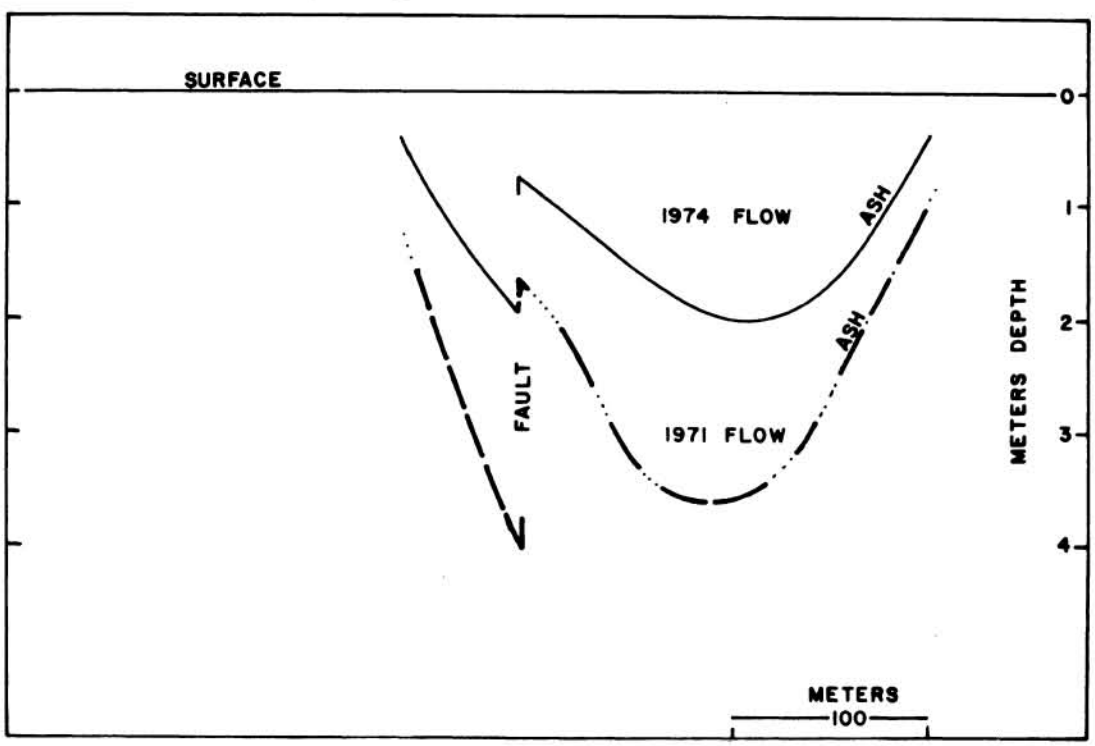

Figure 4: Interpreted profile on same scale as Figures 2 and 3.

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