**Valles Caldera, New Mexico shallow seismic refraction surveys for constraining depths-to-bedrock**

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**Experiment design**

The purpose of this experiment was to collect high-resolution shallow seismic refraction data between June 5th and June 11th, 2012 in order to characterize the vadose zone from the topographic-surface to bedrock across prominent drainages of Redondo Mountain, the main resurgent dome within the Valles Caldera, northern New Mexico. We also collected a subset of 2-D refraction lines across an explosion-pit in the younger Banco Bonito rhyolite flow to the south of Redondo Peak (Figure 1).

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*Figure 1: Shaded relief map of Redondo Mountain (computed from 1 m x 1 m bare-earth LiDAR) and survey areas involved in this study.*



*Figure 2: Contour map of three catchments investigated in this study. The blue outlines represent the boundaries of each catchment. Surveys are labeled by their SEG-Y name in red-text. Elevation contours are colored by elevation value (dark blue being high-elevation and green/yellow being low-elevation).*

Seismic data collected on Redondo Mountain (Figure 2) focused on upper and lower extents of three prominent catchments: La Jara, Jaramillo, and History Grove. Line lengths ranged from 117.5 to 477.5 meters. Each line was completely independent of the others, except for the Banco Bonito survey, which was comprised of two sub-profiles that intersected at (nearly) perpendicular orientations (Figure 3).

Where possible, we used a 40-kg Propelled Energy Generator seismic source; however, due to rugged terrain, a sledgehammer and steel plate sourced the majority of the shots. We summed 10 source impacts at each source location during recording to produce each shot record. Receiver spacing was 2.5 m. Sources were located at intervals of ~12.5 m at the ends and through the receiver spreads in order to increase the density of subsurface refraction paths. Field acquisition parameters were determined by tests in the field at the beginning of the project to produce the best results under extant conditions and normal equipment and personnel limitations

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**Line 7000\_2**

**Line 7000\_1**

*Figure 3: Zoomed in map (colored by topographic slope; blue: higher; red: lower) of the Banco Bonito explosion pit surveyed in this study. The survey consisted of two orthogonal lines; however, all channels were live for each shot. Geophone stations were spaced 2.5 m apart.*

**Data Acquisition Parameters**

**Recording Equipment:**

* 24-Channel Geode data loggers, up to 5 Geodes used, maximum 120 channels. Geode data loggers acquire 24-bit data after analog-to-digital conversion.
* PC compatible software interface/controller.
* Up to 120 Single L-40 40-Hz geophones (plus spares) manufactured by Mark Products. These vertical-component geophones are critically damped at 0.555 and have a sensitivity of about 21 V/m/s. Frequencies below 40 Hz are increasingly attenuated.

**Energy Source:**

* 8-kg sledgehammer and steel plate on ground surface.
* Where it was practical to use: PEG-40kg Propelled Energy Generator manufactured by R.T. Clark Companies, Inc. This source operates by propelling a ~40-kg mass onto a base plate (on the ground) using large elastic bands to increase delivery force. In tests by IRIS/PASSCAL, this source delivered around 25,000 pounds of force per impact.
* For each source position, 10 impacts were summed to produce 1 shot record.

**Recording Geometries for Lines 1000, 2000, 3000, 4000, 5000, 6000, 7000\_1, 7000\_2**

Lines 1000, 2000, and 3000 were acquired in the upper-regions of La Jara, Jaramillo, and History Grove, respectively (Figure 1). Conversely, Lines 4000, 5000, and 6000 were acquired in the lower-regions of La Jara, History Grove, and Jaramillo, respectively (Figure 1). In general, profiles began on one slope of a drainage, changed direction at the lowest point of the drainage, and continued up the other slope of the drainage to form V-shaped profiles. Line 1000 was sufficiently long to require up to 120 channels; other lines generally only required 48 channels. Each shot was recorded into all active channels. Banco Bonito lines 7000\_1 and 7000\_2 were acquired simultaneously with N – S and W – E orientations, respectively (Figure 3). These profiles were obtained from rim to rim within an explosion pit in the young rhyolitic flow. The profiles crossed each other near the center of the explosion pit, and each shot was recorded on both profiles simultaneously. Shooting progressed along the N – S sub-profile from beginning to end followed by similar shooting on the W – E sub-profile. This configuration produced both inline (e.g., Line7000\_1, channels 1-48) and “broadside” recordings (e.g., Line7000\_1, channels 49-96) for each shot.

**Line 1000 Endpoints (UTM 13N)**

* Station 101: 361669.6 E, 3972018.0 N
* Station 292: 361264.8 E, 3972087.0 N

**Line 2000 Endpoints (UTM 13N)**

* Station 101: 361540.4 E, 3973922.8 N
* Station 172: 361681.0 E, 3973843.9 N

**Line 3000 Endpoints (UTM 13N)**

* Station 101: 362789.8 E, 3972934.0 N
* Station 196: 362571.8 E, 3972900.0 N

**Line 4000 Endpoints (UTM 13N)**

* Station 99: 362134.1 E, 3970696.0 N
* Station 154: 362085.9 E, 3970576.0 N

**Line 5000 Endpoints (UTM 13N)**

* Station 100: 362985.2 E, 3971818.0 N
* Station 147: 362900.8 E, 3971744.0 N

**Line 6000 Endpoints (UTM 13N)**

* Station 115: 361851.7 E, 3974802.0 N
* Station 186: 362023.1 E, 3974838.0 N

**Line 7000\_1 Endpoints (UTM 13N)**

* Station 96: 356838.4 E, 3966868.0 N
* Station 143: 356846.2 E, 3066980.0 N

**Line 7000\_2 Endpoints (UTM 13N)**

* Station 201: 356805.4 E, 3966918.0 N
* Station 248: 356919.2 E, 3966914.0 N

**Station Spacing**

* Nominal station spacing = 2.5 m. Station locations were surveyed using a Real-Time-Kinetic GPS system to determine UTM coordinates.

**Source Spacing**

* Nominal source spacing = 12.5 m. Actual source locations were offset at every station in order to avoid cable and equipment damage. In some cases, greater offsets were necessary to avoid obstacles.

**Seismic Data**

Shot records for each of the seven profiles are consolidated into SEG-Y-format files.

**Line 1000**: 42 shots; Field File IDs (FFIDs) 1001 - 1043

**Line 2000**: 16 shots; FFIDs 2001 - 2016

**Line 3000**: 29 shots; FFIDs 3002 - 3030

**Line 4000**: 17 shots; FFIDs 4001 - 4017

**Line 5000:** 14 shots; FFIDs 5001 - 5014

**Line 6000:** 35 shots; FFIDs 6001 - 6035

**Line 7000:** 30 N-S: shots; FFIDs 7001 - 7014; E-W: FFIDs 7015 - 7030

The individual records have geometry information entered in the trace headers with entries as shown in the SEG-Y EBCDIC header (example below). Each SEG-Y file contains all shot records for a particular line.

**Example EBCDIC header:**

C 1 University of Arizona, Reflection Seismology

C 2 LINE: 1000 AREA: Upper La Jara MAP ID: UTM 13N

C 3 INSTRUMENT: 24-Channel Geometrics Geode Systems from PASSCAL

C 4 DATA TRACES/RECORD: 96/120

C 5 SAMPLE INTERNAL: 0.25 ms SAMPLES/TRACE: 8000

C 6 RECORDING FORMAT: SEGY MEASUREMENT SYSTEM: Meters

C 7 SAMPLE CODE: IBM REAL GAIN TYPE: FIXED

C 8 SOURCE: PEG-40Kg Weight Drop, 10 Hits SP-INTERVAL: 12.5 m

C 9 SOURCE: 8Kg sledgehammer and steel plate, 10 Hits SP-INTERVAL: 12.5 m

C10 SPREAD: Channels 1-96/120 GROUP INTERVAL: 2.5 m

C11 GEOPHONES/GROUP: 1 FREQ: 40 Hz MFG: Mark Prod. MODEL: L-40

C12 MAP PROJECTION: UTM ZONE ID: 13N COORDINATE UNITS: Meters

C13 LINE START COORDS: Station 100: 361669.6 E, 3972018 N

C14 LINE END COORDS: Station 286: 361274 E, 3972076 N

C15 TRACE HEADERS BELOW: Header, Format, Start Byte

C16 Trace sequence number in line: Int (4-byte) Start: 1

C17 Trace sequence number in SEG Y file: Int (4-byte) Start: 5

C18 Original field record number (FFID): Int (4-byte) Start: 9

C19 Trace number in original field record: Int (4-byte) Start: 13

C20 Energy source point number: Int (4-byte) Start: 17

C21 CDP ensemble number: Int (4-byte) Start: 21

C22 Trace identification code (1 = data): Int (2-byte) Start: 29

C23 Number of source impacts this trace: Int (2-byte) Start: 33

C24 Distance source point to receiver: Int (4-byte) Start: 37

C25 Receiver elevation: Int (4-byte) Start: 41

C26 Surface elevation at source: Int (4-byte) Start: 45

C27 Scalar for elevations in bytes 41-68: Int (2-byte) Start: 69

C28 Scalar for coords in bytes 73-88 and 181-188: Int (2-byte) Start: 71

C29 Source coordinate – X (times 10000): Int (4-byte) Start: 73

C30 Source coordinate – Y (times 10000): Int (4-byte) Start: 77

C31 Group coordinate – X (times 10000): Int (4-byte) Start: 81

C32 Group coordinate – Y (times 10000): Int (4-byte) Start: 85

C33 Number of samples in trace: Int (2-byte) Start: 115

C34 Sample interval in microseconds (us): Int (2-byte) Start: 117

C35 Low-cut frequency (Hz): Int (2-byte) Start: 149

C36 X coordinate of CDP position of trace: Int (4-byte) Start: 181

C37 Y coordinate of CDP position of trace: Int (4-byte) Start: 185

C38 Shot-point number: Int (4-byte) Start: 197

C39 SEG Y REV1

C40 END EBCDIC