# Near-surface Geophysical Imaging of Barringer (Meteor) Crater, Arizona


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## ABSTRACT

We investigated the shallow subsurface at Barringer (Meteor) Crater, Arizona using seismic and gravity techniques. We found compressional (P)-wave velocities of 450-2500 m/s for a 55 m deep section from seismic refraction analysis. The low uppermost P-wave velocity layers thin away from the crater rim (toward the south). Shear (S)-wave velocities (estimated from ground-roll inversion) vary from 200-700 m/s for the top 16-20 m increasing to 900-1000 m/s at 38 m depth. The prominent change in S-wave velocities (at around 500-600 m/s) is interpreted as the transition from the low-velocity ejecta blanket (a sheet of debris thrown out of the crater during the impact) to the bed-rock Moenkopi sandstone. This S-wave transition takes place at a depth range of 12-20 m near the crater rim with a thinning away from the rim. This consistent P- and S-wave low velocity structure is interpreted as the ejecta blanket. Near-surface reflection seismic analysis provided relatively deeper information indicating at least four sub-horizontal reflectors intersected by a number of faults. Staking velocity analysis estimates P-wave velocities up to 3500 m/s (for the top 500 ms) showing a similar P-wave thinning structure (especially for top 200 ms). Ultrasonic measurements on hand samples provide a range of P-wave velocities of 800-1600 m/s for the Moenkopi and are consistent with seismic refraction results.


## Objectives

- To understand seismic wave propagation through brecciated materials
- To estimate thickness of ejecta blanket (a sheet of debris thrown out of crater during meteorite impact)
- To characterize the near-surface physical properties
- To develop general survey methodologies to image a highly complex near-surface
- To image near-surface reflectors and faults

## Barringer (Meteor) Crater, Arizona

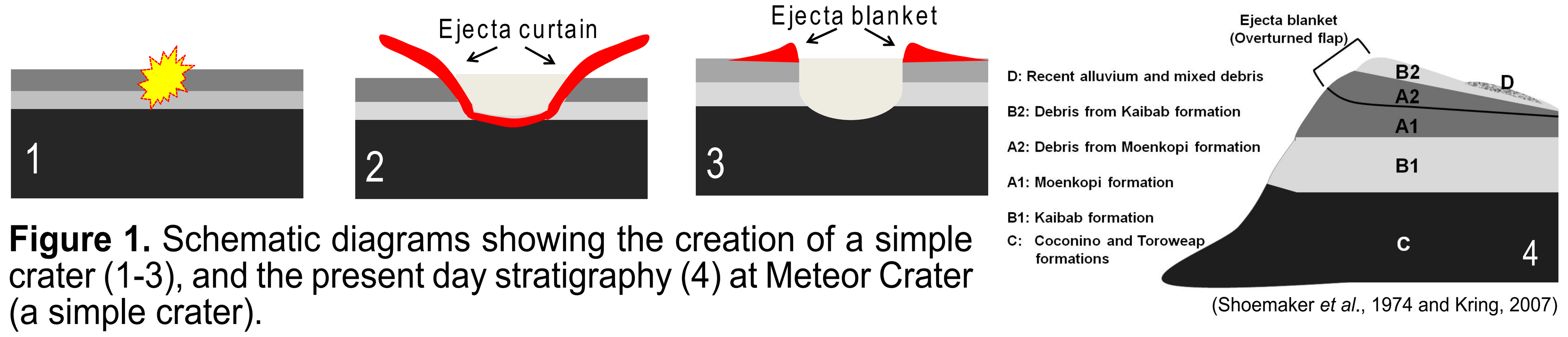


**Figure 1.** Schematic diagrams showing the creation of a simple crater (1-3), and the present day stratigraphy (4) at Meteor Crater (a simple crater).

(Shoemaker *et al.*, 1974 and Kring, 2007)

## Seismic Survey

**Table 1:** Seismic acquisition parameters

| | |
|---|---|
| Seismic Line | AWD |
| Source Type | 40 kg Accelerated weight drop (AWD) |
| Receiver Type | Planted vertical geophone |
| Source Interval (m) | 3 |
| Receiver Interval (m) | 3 |
| Total Receivers | 216 |

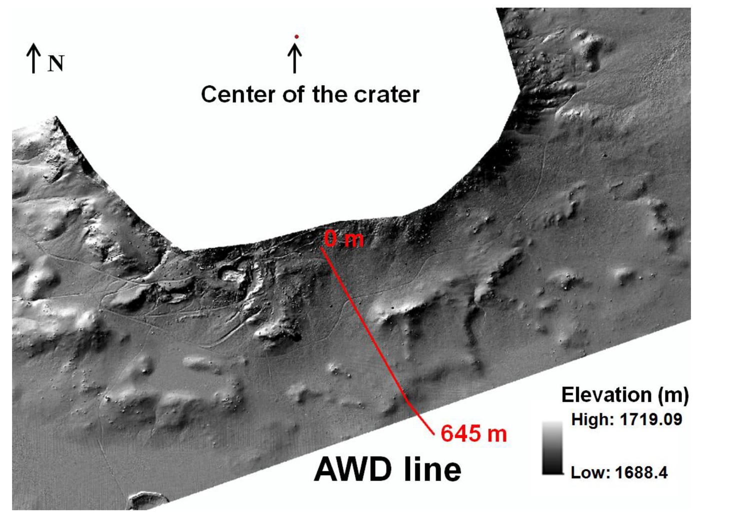


**Figure 2.** Image of LiDAR data for southern portion of Meteor Crater. Red line represents the seismic line used in this paper.

## Ultrasonic Measuements

**Table 2:** Ultrasonic measurements of Moenkopi hand specimens showing P-wave velocities.

| Rock formation | P-wave velocity (m/s) |
|---|---|
| Moenkopi 1 | 815 ± 33 |
| Moenkopi 2 | 1255 ± 106 |
| Moenkopi 3 | 1570 ± 89 |

## P-wave Velocities from Seismic Refraction Analysis

P-wave velocity structure was estimated through- 1) picking First-breaks, 2) generating initial P-wave velocity model, and 3) iterative travel-time tomography.

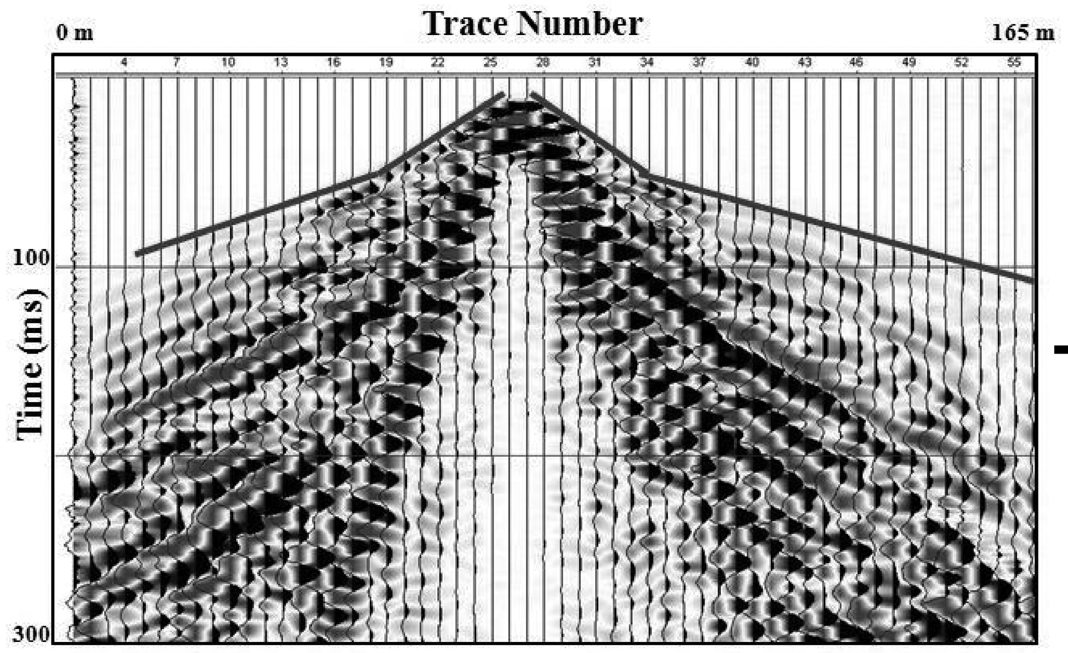


**Figure 3.** A raw shot gather (AGC applied). Trends of first-break picks are shown by black solid lines.

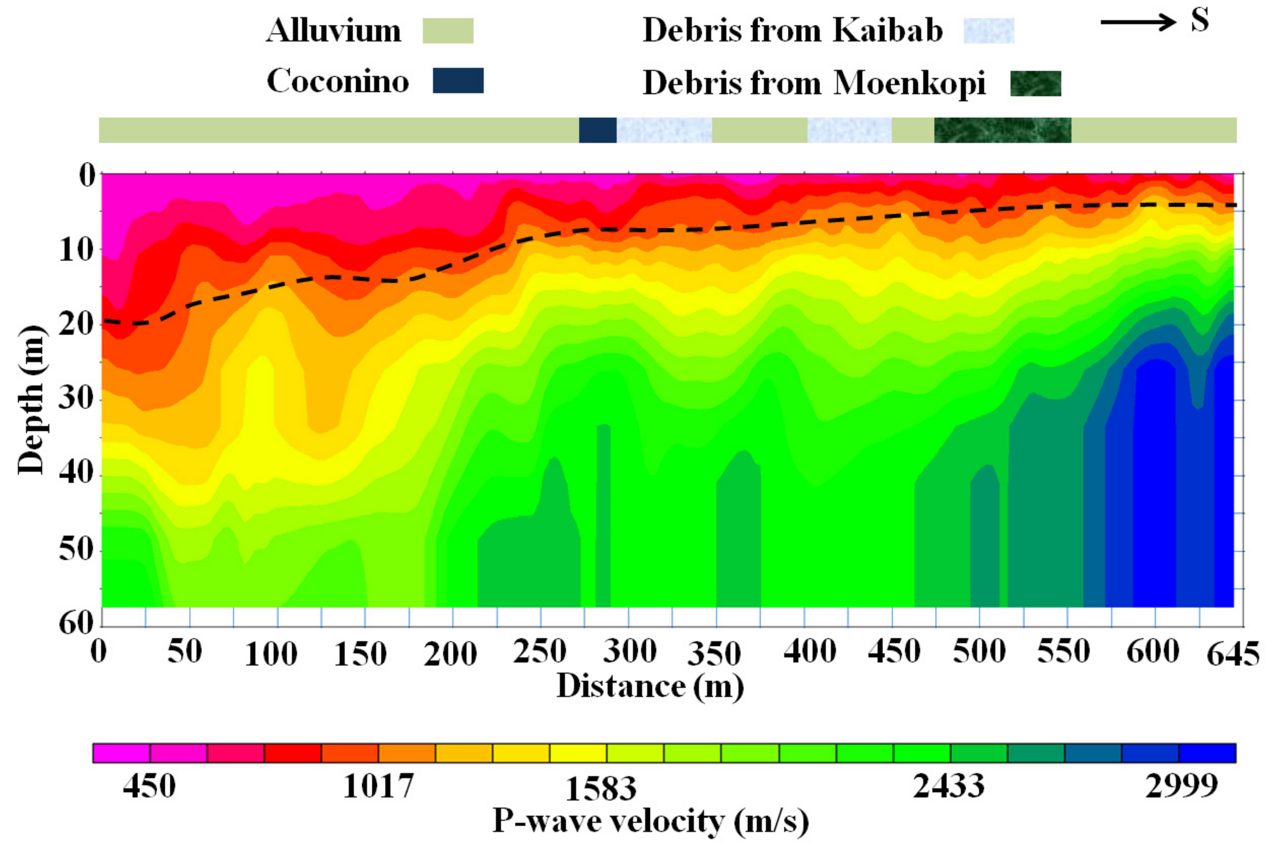


**Figure 4.** A 2D P-wave velocity profile (black dashed line indicating the trend of low-velocities).

## S-wave Velocities from Ground-roll Inversion

We used Multichannel Analysis of Surface Waves (MASW) method (Park *et al.*, 1999; Xia *et al.*, 1999) to obtain near-surface S-wave velocity structure.

### Step I

To create multimodal dispersion curves using dispersive ground-rolls (or Rayleigh waves).

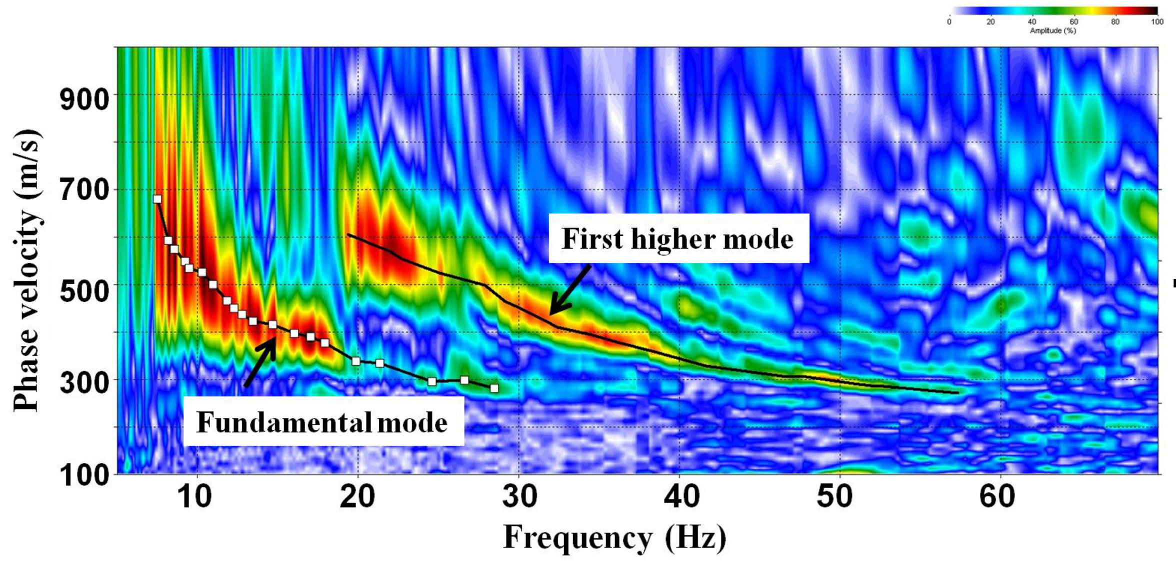


**Figure 5.** Dispersion curve for a single shot gather for an offset range of 10.5-82.5 m from source.

### Step II

To invert dispersion curves for S-wave velocity structure.

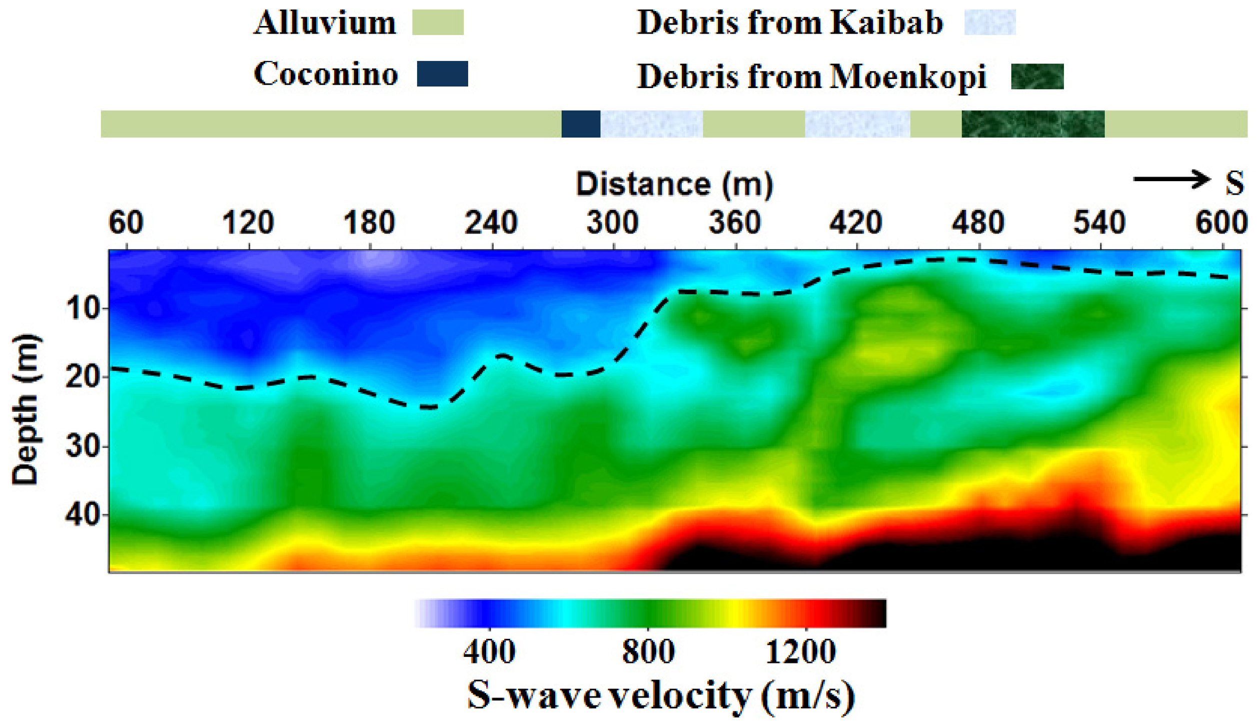


**Figure 6.** A 2D S-wave velocity profile (black dashed line showing transition from ejecta blanket to bed-rock.

## Gravity Analysis

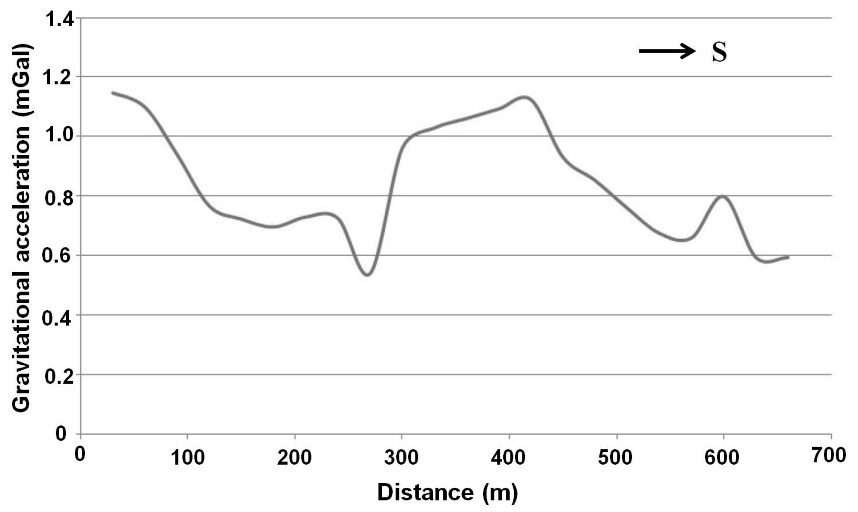


**Figure 7.** The figure shows esidual gravity anomaly along the AWD line.

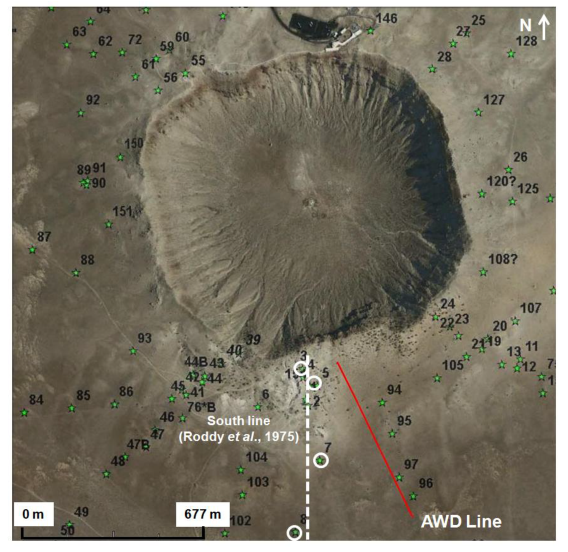


**Figure 8.** Overlay image of the AWD line and locations of the drill-holes (Roddy *et al.*, 1975).

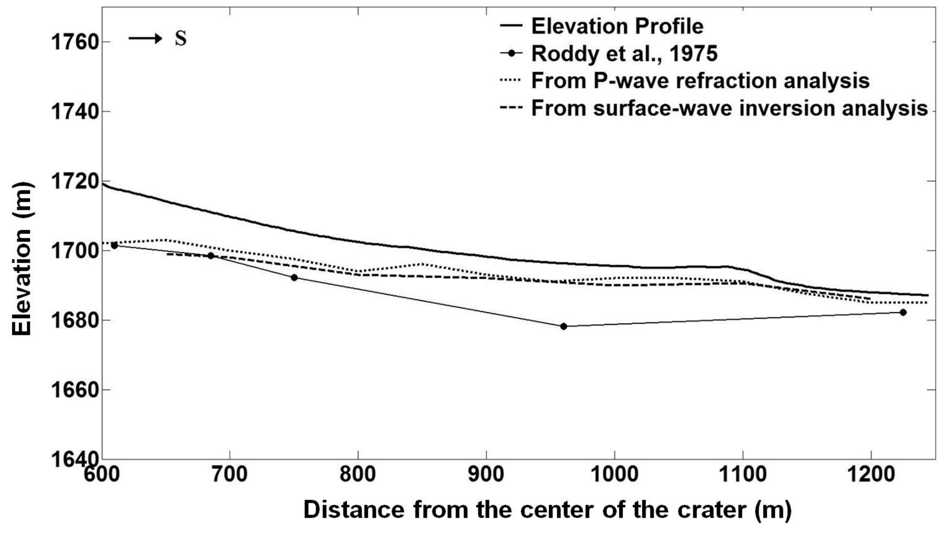


**Figure 9.** Transition depths (from the ejeta blanket to bed-rock Moenkopi) obtained from different analyses and drill-holes (ploted from actual elevation).

## Near-surface Seismic Reflection Analysis

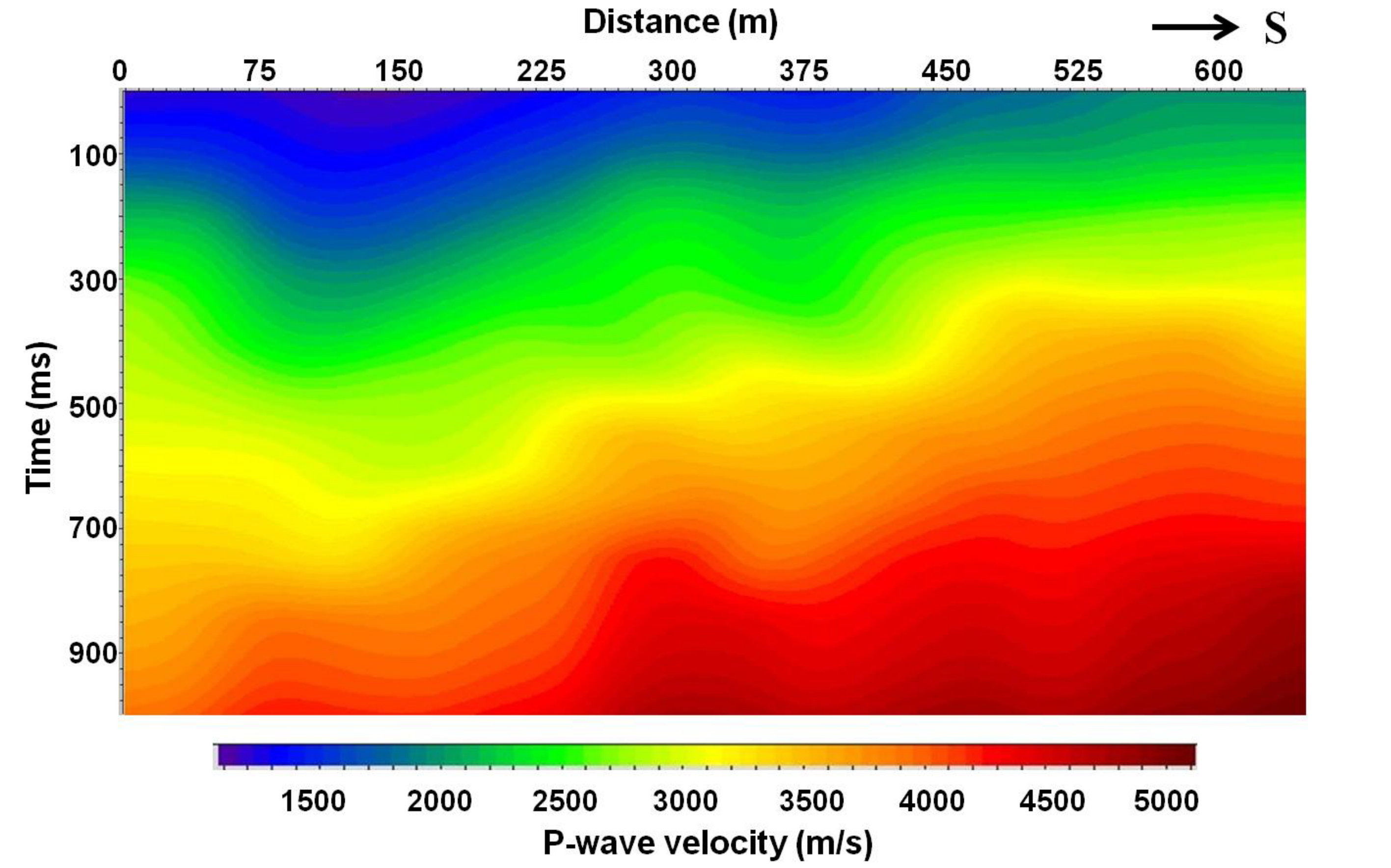


**Figure 10.** Estimated P-wave NMO velocity structure along AWD line.

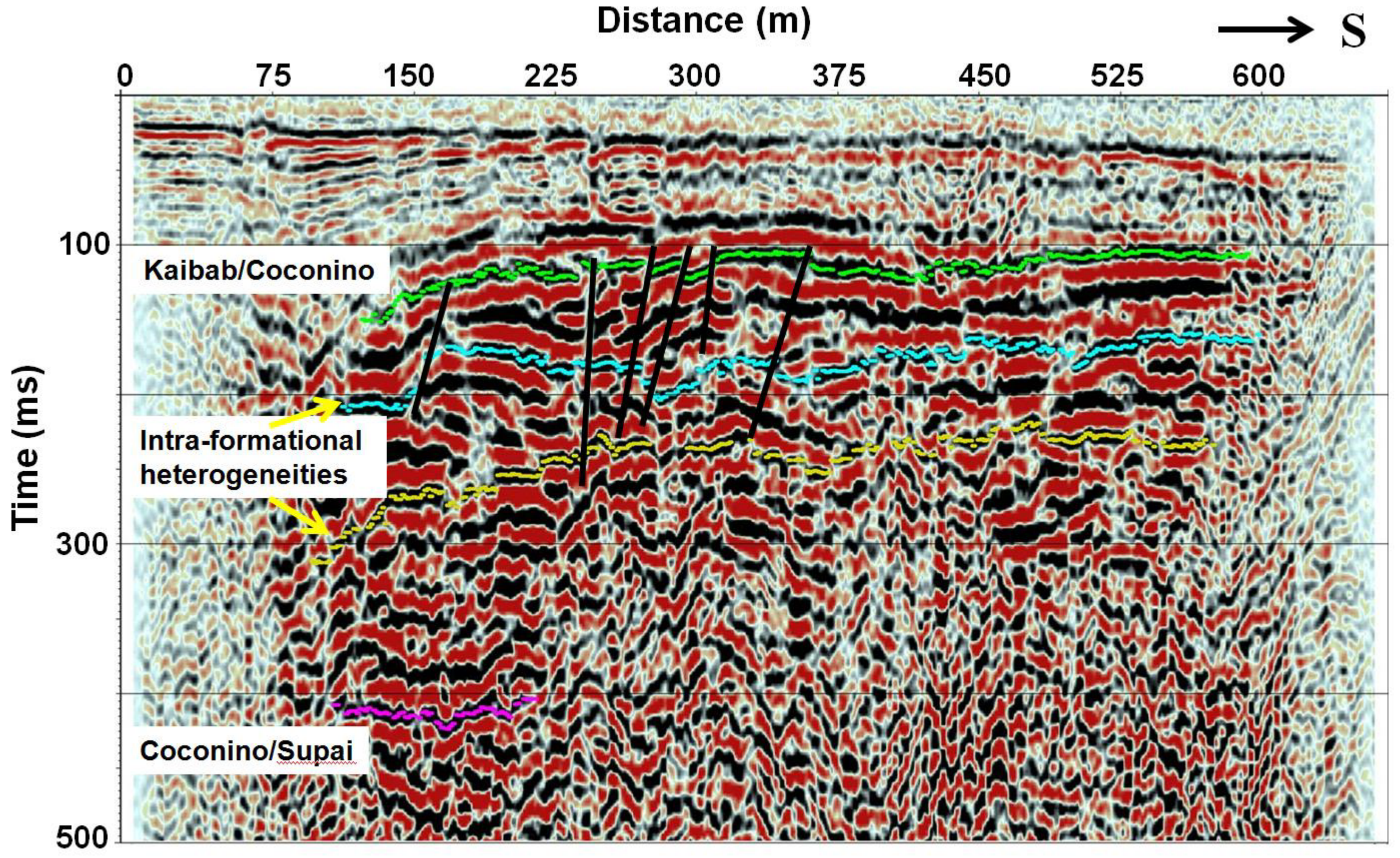


**Figure 11.** Final CMP-stacked section for the AWD line. Four reflector horizons are marked along with interpreted faults.

## Conclusions

- High-resolution P- and S-wave velocity structures are estimated.
- Thinning of both P- and S-wave low-velocity layers is identified and the thinning structure is interpreted as the ejecta blanket.
- The tickness of the ejecta is also estimated.
- P-wave NMO velocity structure shows a similar thinning pattern.
- Few sub-horizontal reflectors intersected by number of faults are identified using near-surface seismic reflection analysis.
- Near-surface geophysical methods as outlined above may be useful in studying other sites with similar complex brecciated structures.


## Acknowledgments

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