Since the MicroVibrator is a frequency domain seismic source, rather than a shot source, the data is processed so that the final data traces from each geophone are similar to that observed with explosives or other impulsive sources. In order to process the data, the geometry and coordinates of the source and receiver positions along the seismic profile are transferred to a computer. An attempt was made to reverse the localized filtering effects that near surface materials have on the seismic signal using a process called deconvolution and amplitude recovery.

The effects of the surface topography and variations in the upper layer of the ground are substantially removed using techniques called datum and static shift removal. Nonlinear effects of the data acquisition geometry (velocity analysis and normal move-out correction) are accounted for and removed in order to correctly image subsurface features. Directional filters are applied to the source (shot) records to eliminate unwanted signals generated by the seismic source (surface wave / linear noise attenuation). The data, which were recorded in shot point mode, were sorted to produce CMP gathers. All of the traces in each gather were then summed to produce a CMP stack. This process significantly improves the signal to noise ratio. The data were spectrally whitened to adjust the amplitudes of all frequency components and filtered to keep those reflection frequencies with the best signal to noise ratios (spectral balance).

The descriptions of the HRSW reflection data acquisition, processing, and interpretation procedures apply to all of the cave sites in this report.

Figure 20 is a plan map (*6*) that shows the approximate location of the survey line and direction of data collection with respect to the Golden Dome Cave. Table 5 provides locations of every tenth geophone over Golden Dome Cave.

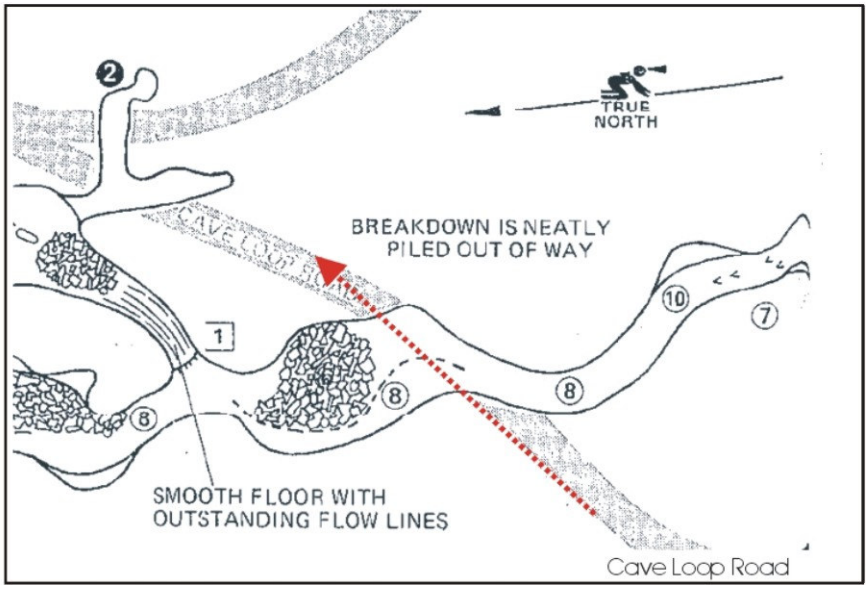


Figure 20. Map. HRSW survey line over Golden Dome Cave. [6]

Table 5. Geophone coordinate locations at Golden Dome Cave.

ID	Easting (m)	Northing (m)	Elevation (m)
Geophone 101	623636.5	4618729.71	1468.7
Geophone 111	623640.7	4618733.97	1468.3
Geophone 121	623644.92	4618738.25	1468
Geophone 131	623649.15	4618742.54	1467.8
Geophone 141	623653.33	4618746.83	1467.6
Geophone 151	623657.55	4618751.11	1467.3
Geophone 161	623661.76	4618755.4	1467
Geophone 171	623665.97	4618759.7	1466.7
Geophone 181	623670.18	4618764	1466.4
Geophone 191	623674.38	4618768.27	1466.1
Geophone 196	623676.47	4618770.43	1465.9
All coordinates are listed in NAD 83/UTM Zone 10			

The data collected over Golden Dome Cave is shown in figure 21. The HRSW data is displayed in two different ways to aid interpretation. The top cross section in each of the HRSW figures is comprised of an amplitude envelope display with wiggle traces superimposed for interpretation purposes. The horizontal scale is in m but also shows the shotpoint numbers. The distance between each of the traces is half that of the shot points. The shot records start at number 101. The vertical scale is displayed in time (ms). The same field data, shown in the lower section, is presented using an amplitude envelope with a 140/150 Hz lowcut filter, a different color scale, and no superimposed wiggle traces. There is no depth scale on the figures because the only rock velocities are those obtained for stacking the traces in the gathers (stacking velocities). Although this velocity can be used to provide depth estimates, it has to be accepted that this may not be the "true" velocity of the seismic wave within the rock layers and significant depth errors can occur. Figures displaying the uninterpreted HRSW data are available in appendix D.

Zero time on the section is at an elevation of 1475.2 m (4839.9 ft). The known cave on this profile is centered at shot point 132, based on surveying measurements, and is thought to extend approximately 1.8 m (5.9 ft) on either side of the shot point location. On this line, reverberating reflections indicate the presence of a shallow layer with a high velocity contrast, possibly a thin, shallow scoria bed.

The stacking velocity in the vicinity of the known cave is approximately 1585 m/sec (5200 ft/sec), and the interpreted depth is 4.0 m (13.1 ft) using this velocity. The ground surface corresponds to about 12.5 ms on this section; therefore, the reflection from the top of the cave should occur at about 17 ms on this profile. An arcuate (hyperbolic) reflection can be seen at the calculated point, shown in blue, although this event does not stand out against the background. Faint diffractions extend from both edges of the location of the lava tube, although they are more evident on the deeper part of the section (below 40 ms). The interpreted width of the lava tube

measures some 3.5 m (11.5 ft) across on the seismic section based on analysis of the tails of the reflection patterns.

Two suspected lava tubes are interpreted on this profile, both highlighted in red. The first is centered at shot point 160, and, using the stacking velocity given earlier, appears to be approximately 4.9 m (16.1 ft) deep and 4.2 m (13.8 ft) across. The second is centered on shot point 188, is approximately 4.6 m (15.1 ft) across and occurs at a depth of about 6.1 m (20.2 ft). Both are manifested on the data by arcuate reflection events and faint diffractions.

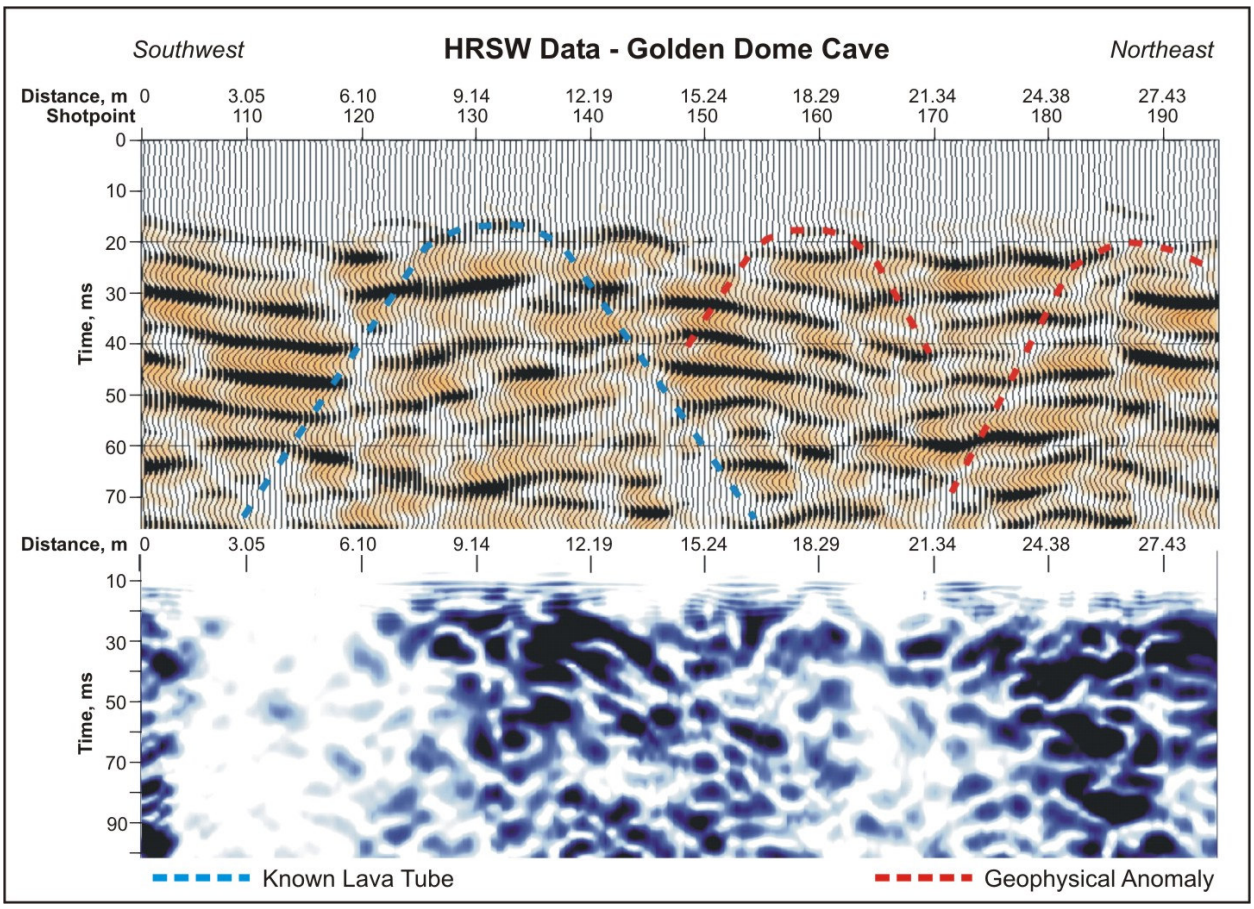
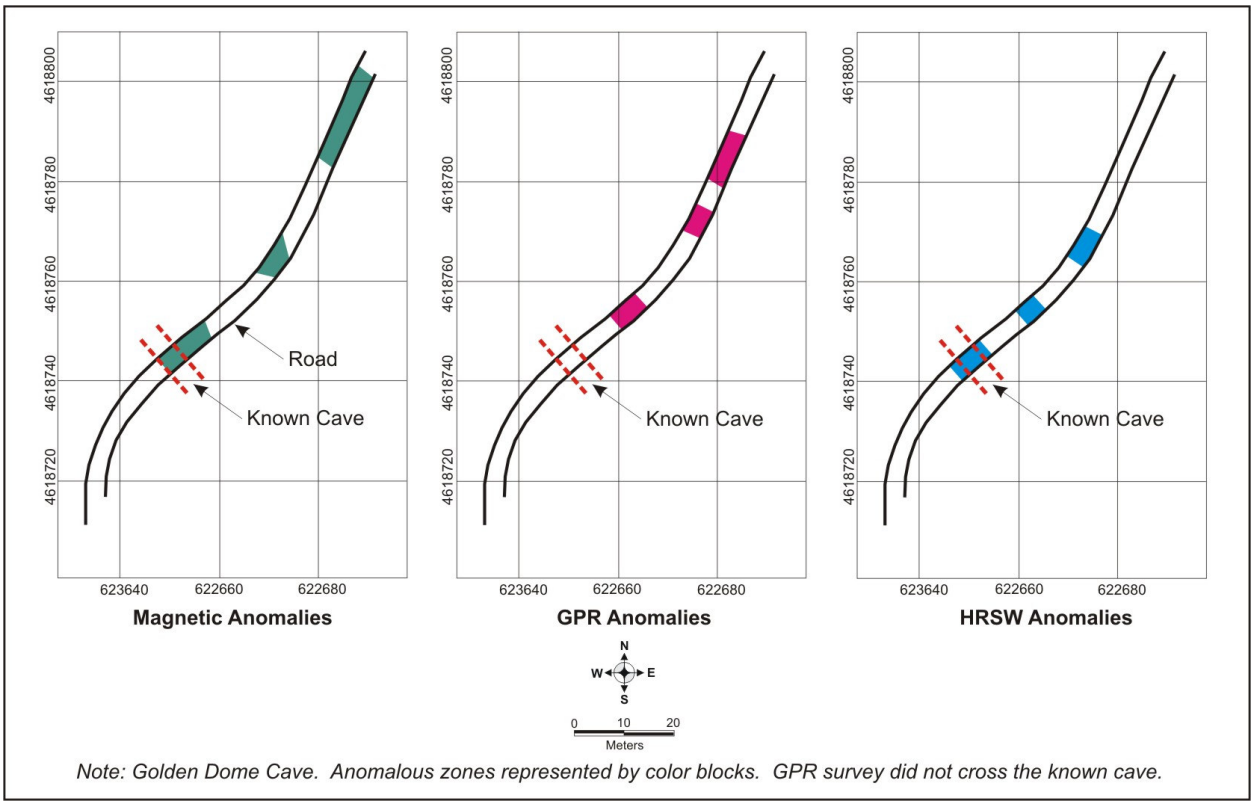


Figure 21. Cross Section. HRSW data collected over Golden Dome Cave.

4.2.3 Comparisons

Figure 22 shows an individual map for each geophysical method tested at Golden Dome Cave with anomalous zones shown as colored blocks. The anomalous zones indicate areas with a high probability of containing an anomaly. Since GPR data was not collected over the Golden Dome Cave, it was not seen in the data. However, both the magnetic and the HRSW data located the cave. An anomaly just northeast of Golden Dome Cave was interpreted using the HRSW reflection data and the GPR data. These anomalies correspond well in location and approximate size. The middle magnetic anomalous zone corresponds to the most northern anomalous zone in

the HRSW data and the most northern magnetic anomalous zone corresponds to the most northern GPR anomalous zone. All anomalous zones at this site were identified with at least two different methods.



Note: Golden Dome Cave. Anomalous zones represented by color blocks. GPR survey did not cross the known cave.

Figure 22. Map. Comparison of anomalous zones at Golden Dome Cave.

4.3 INDIAN WELL CAVE

4.3.1 Site Description

Indian Well Cave, pictured in figure 23, is located under the service road that leads to the LBNM Headquarters. The cave received its name from the well in the bottom of an alcove located in the cave's deepest spot. The well is replenished each year from melting ice and snow. Inside the cave there are numerous boulders and large rocks resulting from the collapse of the lining of the cave [(6)]. The depth to the roof of the cave, and the overburden thickness, vary greatly with location. Under the service road, the suspected height of the cave is approximately 7.6 to 11.3 m (24.9 to 37.1 ft), with the overburden thickness being approximately 9.7 m (31.8 ft). This cave was selected as a survey site because it is a rather large cave and it is located approximately 10 m (32.8 ft) below the subsurface. This will test the ability of the geophysical methods abilities to detect large voids at this depth.

Figure 23. Photo. The entrance of Indian Well Cave.

4.3.2 Data Analysis and Interpretation

Ground Penetrating Radar

Figure 24 is a plan view map [6] that illustrates the approximate location of the GPR survey lines over Indian Well Cave. The exact coordinates of the three GPR lines are listed in table 6.

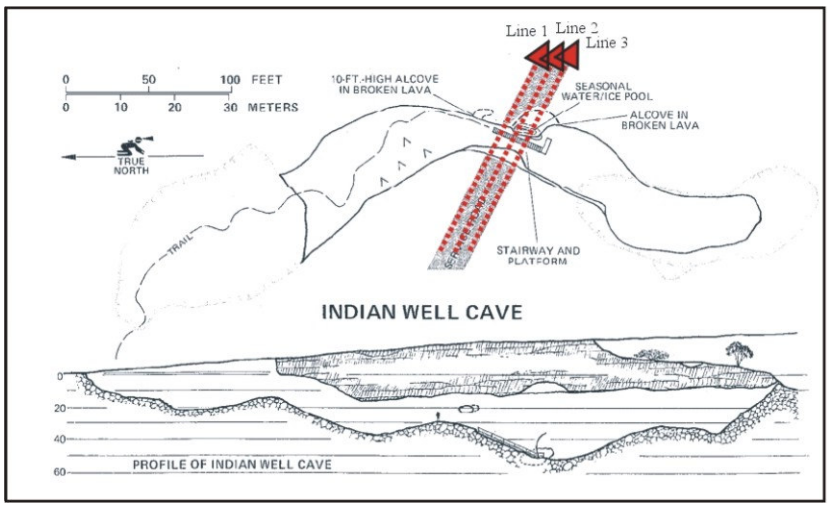


Figure 24. Map. GPR survey line over Indian Well Cave. [6]