3-D seismic exploration for the Victorio Peak treasure

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Summary

In January of 1994, we conducted an extensive seismic experiment to find caverns under Victorio Peak, a bioherm reef structure located approximately 80 miles northeast of Las Cruces, New Mexico. Within Victorio Peak there is reputed to be an extensive network of caverns, tunnels and fissures that contain a large and varied treasure consisting of gold bars, Spanish armor, jewels, coins, and human skeletons. We used an array of seismic sources that included a sledgehammer on the surface of the mountain, a sledgehammer impacting on the walls of two deep fissures within the mountain, as well as blasting caps located in boreholes drilled into the mountain. Approximately 2,000 source positions were recorded by 120 receiver channels consisting of geophones cemented into fissure walls and hydrophones deployed in a deep horizontal borehole drilled at the base of the mountain. The data analysis consisted of measuring reduced traveltime and amplitude of the direct arrival and isolating those source/receiver pairs that exhibited anomalously large direct arrival traveltimes and/or low amplitudes. We have currently identified and located a major amplitude anomaly under the peak that will be drilled and explored during the summer of 1994.

History of the Treasure and its Exploration

For many years, the Victorio Peak Treasure has been the subject of Indian lore, books, articles, government documents and television documentaries (James, 1953, Kootklowski, 1966, Anonymous, 1973,). Victorio Peak is located along an ancient trading trail between Santa Fe, New Mexico and Chihuahua, Mexico that the Spanish coined, “Journado del Muerto”--The Journey of Death. The Apache inhabited the valley around Victorio Peak for centuries because there was a fresh water spring at the base of the Peak--the only such spring within a 40 mile (64 km) radius. One explanation for the existence of the Treasure is that it was stolen by the Apaches from traders passing through the region and hidden in the mountain.

In 1937, the Treasure was purportedly discovered by Milton ‘Doc’ Noss, a traveling foot doctor from Las Cruces. Doc and several helpers took out about 200 gold bars from the peak. They all said that the Treasure consisted of over 16,000 gold bars, coins and jewels, and was guarded by 27 skeletons lashed to wooden posts. In 1939, in an attempt to widen the shaft leading from the top of the mountain to the caverns under the mountain, an engineer accidentally dynamited the shaft shut. From 1939 to 1955, Doc and his wife Ova attempted to dig out the debris from the dynamite blast. They were hampered by the remoteness of Victorio Peak and limited funds--it was illegal to own gold at the time. In 1949, while attempting to raise money from a Texas oilman, Doc was shot and killed. In 1955, the Army took over the peak and its environs as part of the White Sands Missile Range. In 1959, some airmen from Hollowell Air Force Base claimed to have discovered a cave full of gold at the peak and the Army/Secret Sewice covertly began digging at the peak in 1961. Ova Noss discovered the 'dig' and had it halted by state officials. In 1963 Ova Noss and a group of investors obtained access to the peak and conducted a brief (60 day) exploration. Besides drilling holes into the peak, a seismic survey and a gravity survey were conducted to geophysically locate the caverns. These and other attempts at the time were unsuccessful, and in 1964, the Army closed access to the peak by private citizens. Finally, in 1992, the government allowed a group called the Ova Noss Family Partnership to begin a re-exploration of the Peak.

During the last two years there have been two geophysical surveys of the mountain attempting to locate the caverns. The first was a Ground Penetrating Radar (GPR) survey consisting of over 500 antenna positions on the surface of the peak. While the GPR survey detected some voids, the complex structure of the peak did n.ot allow the voids to be accurately located. In 1993 the former head of the U.S. Army Tunnel Detection Team, Dr. Kent Young, conducted a divining rod survey of the peak. He also claimed to have detected voids, but later drilling did not confirm these posit ions.

Site Geology, Seismic Survey Planning and Data Acquisition

Victorio Peak is located on the White Sands Missile Range in Dona Ana County, South Central New Mexico. The peak is situated within the Hembrillo Basin, a broad topographic depression eroded into Pennsylvanian Age shales, sandstones and limestones, which compose the San Andres mountains.

The San Andres mountain peaks are erosional features, and are composed of bioherm reef structures. Victorio Peak is unique among these peaks because it is bisected by a granodioritic dike that was intruded as part of the Rio Grande Rifting in the Cenozoic. Figure 1 shows a cross-section of Victorio Peak created from the surface geologic map shown in Figure 2. The dike intrusion created massive fracturing of the reef and caused massive slumping on the north side of the dike. The fracturing provided flow paths for water, allowing solution cavities (caverns) to form under the peak. Several caverns have been charted, primarily on the north side of the dike. The reef is underlain by Paleozoic limestone and shale units that are also fractured. However, recent geologic analysis (Platt, 1994) suggests that large solution cavities could only have formed in the reef structure. Consequently, we designed our seismic survey to look for caverns within the reef. Even if the geologic analysis were wrong, and significant caverns were located away from the peak, by focusing on the reef we could at the very least find the entranceway that Doc Noss allegedly used.

From the surface geology, we can see that the total area covered by the reef and slumped units was under 300 m2. The complex structure of the peak and caverns, as well as the relatively small volume under investigation, suggested that imaging with direct arrivals was probably the most reliable technique to locate voids. To obtain direct arrivals traveling through the reef structure, it was necessary to position receivers at or below the base of the reef. We deployed two types of receivers. We drilled 71 30 Hz geophones into an east/west striking fissure that went from the surface. This fissure, excavated in 1993 using a vacuum truck, was thought to be the region collapsed by the dynamite blast in 1939. As shown in Figure 1, the fissure extended from the top of the peak down 52 m to the shale unit at the base of the reef. Figure 3 shows a photograph of a 3-component geophone instrumented on the fissure. Most of the geophone spikes were oriented horizontally, perpendicular to the fissure wall, but some three component geophones were also deployed. This configuration recorded data from approximately 500 surface and borehole shot positions on the south side of the fissure. The deployment was moved to the north side of the fissure wall for surface source positions north of the fissure.

The surface source positions were also recorded by a string of 24 hydrophones located under the reef and centered at the dike. The hydrophones were deployed within tubing in a horizontal borehole drilled by Cherrington Corporation. The hydrophones were spaced at 10 ft (3 m) increments. The hydrophones also recorded data from hammer blows taken at 1ft increments within the fissure. The data were recorded by a 24 bit 120 channel recording system provided by Geometries. The temporal sampling rate was 56 microseconds, and surface source positions were sampled at roughly 8 m increments. The total number of source positions was over 2,000 representing some 240,000 rays passing through the reef. This data volume is significantly larger than transmission tomography experiments conducted between boreholes, which typically contain 1,000 to 60,000 rays.

Theoretical Seismic Wave Around Air-Filled Cavities Propagation Through and Around Air-Filled Cavities

There has been a small body of research devoted to seismic wave propagation through and around air-filled cavities (McCann, et al, 1986, McCann, et al, 1987, Owen, 1983, Tsokas and Rocca, 1986). As expected, wave propagation through a cavity produces a decrease in the amplitude and a delay in the traveltime of the direct arrival. The scattering off a complex cavity surface was also shown to produce an imposingly complex secondary arrival wavetrain that all but precludes the use diffraction techniques for cave detection.

To estimate the effects of cavities at Victorio Peak, we constructed a 2-D velocity model shown in Figure 4 simulating an arbitrarily-shaped 2-D void. Figure 5 shows some synthetic seismograms (maximum frequency 250 Hz) for a vertical receiver line and a source depth centered at the void positioned to transmit acoustic energy through the void. Also plotted on Figure 5 is the rms amplitude of the direct arrival wavelet (larger times represent larger amplitudes) after correcting for geometric spreading. Note that the amplitude decrease behind the void is significantly larger than the traveltime delay. The scattering effects behind the void also reduce the frequency content of the direct arrival and make it more difficult to estimate direct arrival times.

Initial Data Analysis

The usable frequency range of the seismic data varied from 10 Hz to 1,000 Hz. Most of the surface hammer blows exhibited a frequency range from 10 Hz to 300 Hz, and the data were towpassed below 300 Hz. Shots taken blow the surface (in boreholes and in the fissure) exhibited frequencies up to 7,000 Hz. The hydrophones exhibited a large amount of noise at frequencies below 70 Hz, which was used as a lowcut for most of the hydrophone data analyas. The data were processed as follows:

1) The direct arrival peak time was picked and the rms amplitude of the direct arrival was computed in a window around the direct arrival.

2) A 'reduced' traveltime was computed as: $t_{pick}-t_{model}$, where = $t_{model} = R/V_{avg}$; R is the raypath length assuming straight rays, and V_{avg} is the average propagation velocity of direct arrivals traveling through the mountain (about 7,000 ft/s (2,140 m/s)).

3) A 'reduced' amplitude was computed assuming attenuation of the direct arrival due to geometric spreading.

Figure 6 shows a display of two common hydrophone gathers after the data processing outlined above. Source positions were obtained every 1 ft (0.3m) along the fissure wall. Note the dramatic decrease in amplitude west of source position 405,900 on hydrophone 12.

To estimate the location of this anomaly within the mountain, the following pseudo-tomographic imaging sequence was used:

1) The traces that exhibited direct arrival amplitudes (after spherical divergence correction) that were less than 40% of the average amplitude were selected.

2) The amplitude anomaly was projected in a tube along a straight ray connecting source and receiver for that particular anomalous trace.

Figure 7 shows three slices--plan view, looking north, and looking east intersecting at roughly the center of a large amplitude anomaly. Note how the anomaly abruptly terminates to the east and is very long in the north/south direction.

We have not incorporated source and receiver 'coupling', radiation patterns, or impedance mismatch effects for this data, which could theoretically be quite large. However, the consistency of this anomaly for various source and receiver configurations indicates that it is probably due to propagation effect rather than coupling.

Conclusions

An extensive seismic experiment at Victorio Peak has indicated the presence of at least one large cavern under the mountain. The alleged cavern produces over an 80% reduction in amplitude of the direct arrival over a range of hydrophones spanning approximately 100 ft (30 m), indicating that the anomaly may be associated with the large caverns containing the Victorio Peak treasure described by Doc Noss and his colleagues. Future drilling proposed this summer should verify the seismic data.

References

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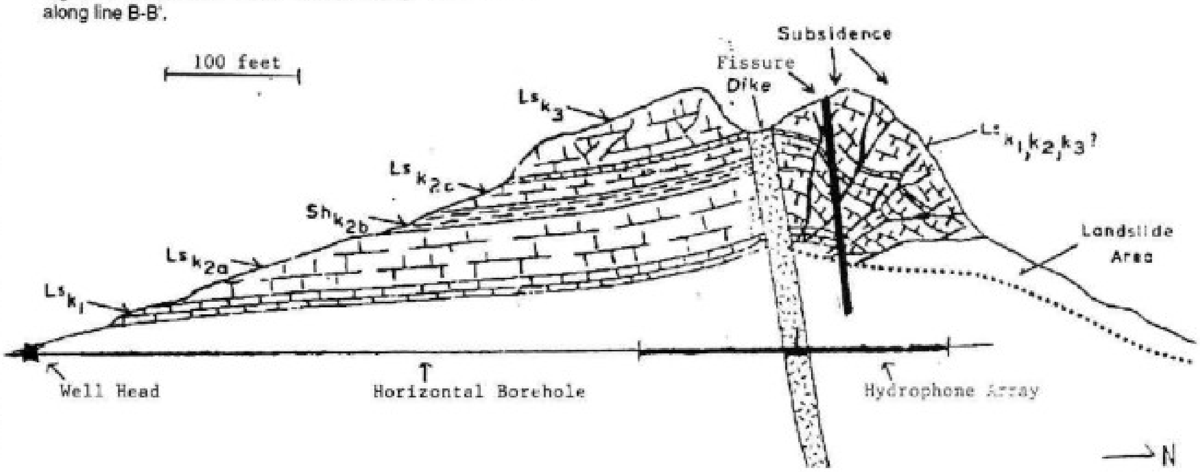
Figure 1: North-South Cross-Section through Victorio Peak along line B-B'.



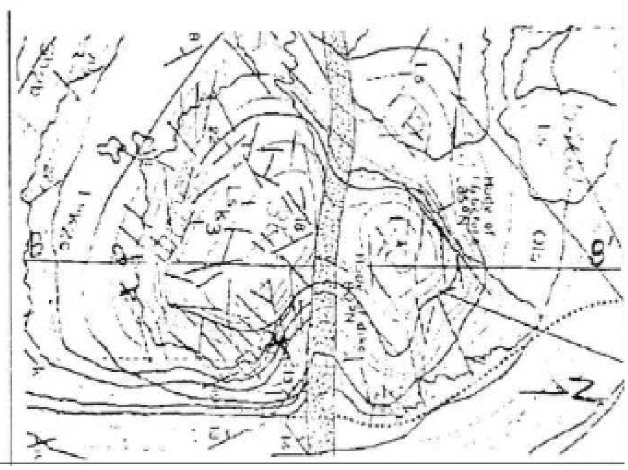


Figure 2: Surface Outcrop Map of Victorio Peak. Lines represent surface fractures.

Figure 3: Photograph of a 3-component deployed on the fissure wall.

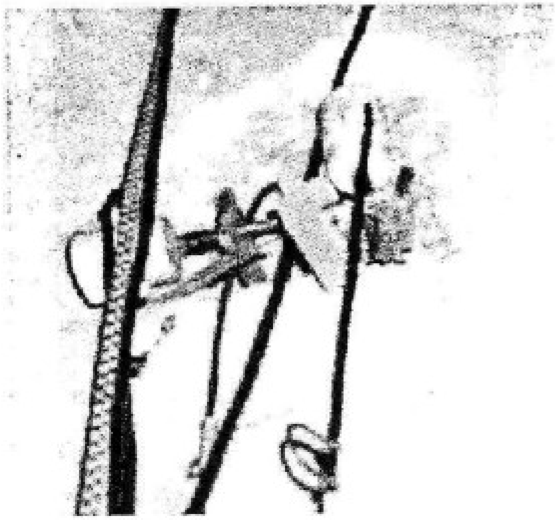


Figure 4: 2-D model of a cavity embeded in medium.

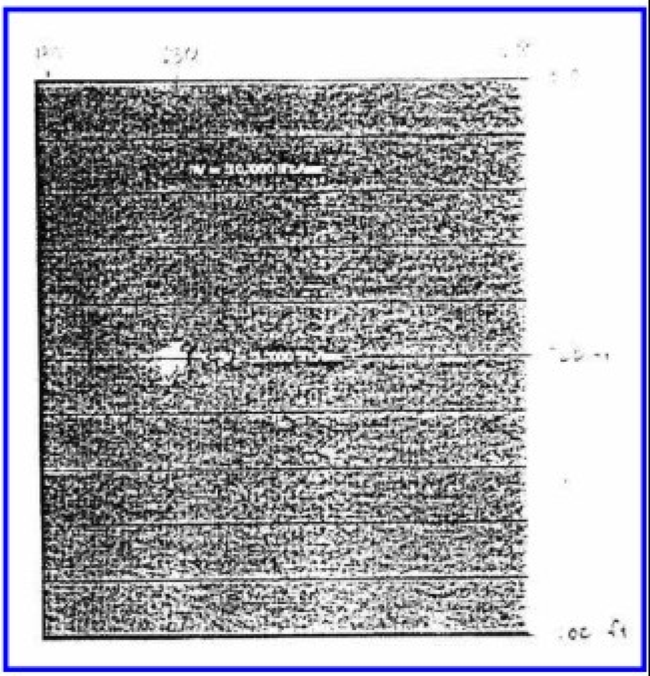


Figure 5. Acoustic synthetic seismograms computed from model in Figure 4.

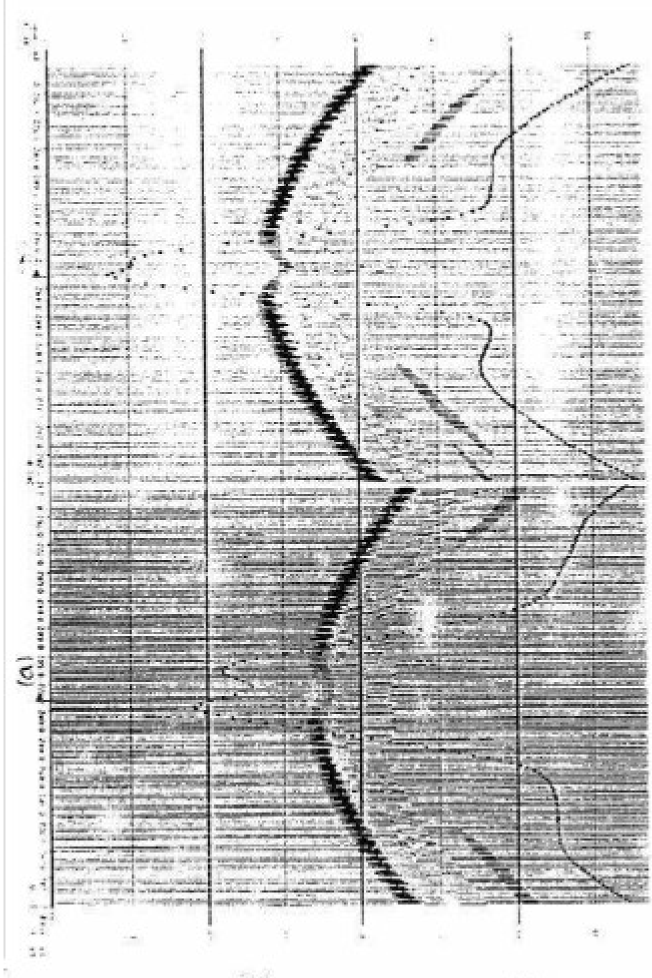


Figure 6 (a) Seismic Data received by hydrophone 8 from single hammer blows on the fissure wall. (b) Data received by hydrophone 12 from same hammer blows. Data are plotted in true relative amplitude

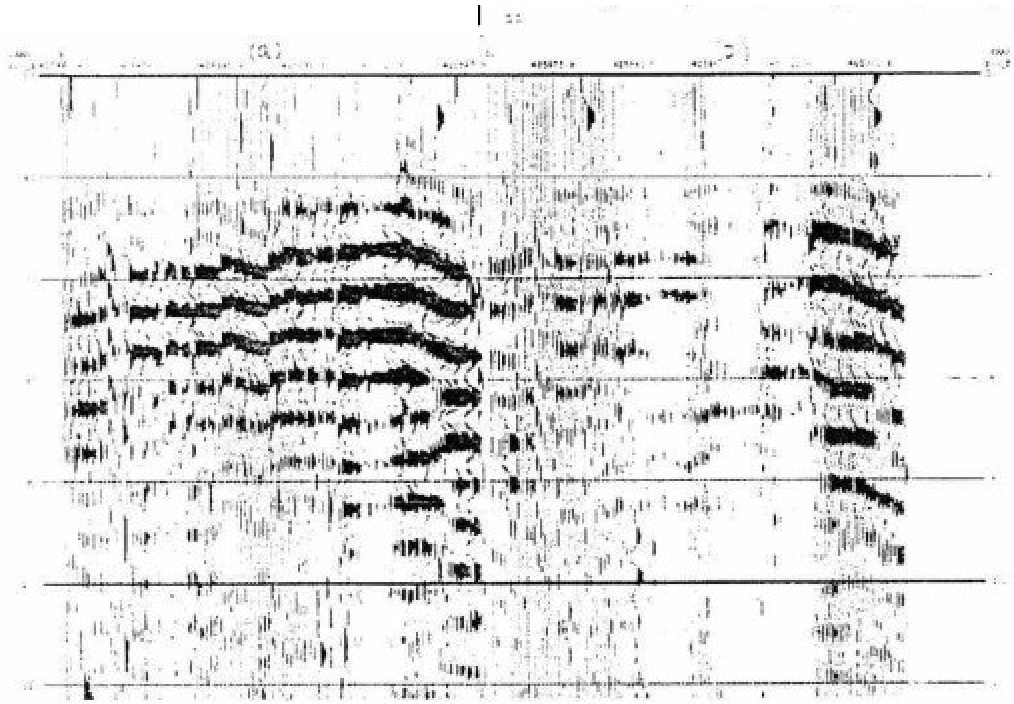


Figure 7: Planar cross-sections of amplitude anomaly centered at 375,650 Northing, 405,845 Easting, and Elevation 5385: (a) plan view. (b) looking north. (c) looking east.