CHAPTER 4.0. GEOPHYSICAL MAPPING OF VOIDS AT LBNM

4.1 GENERAL INFORMATION

This chapter contains information describing each of the five individual sites where geophysical surveys were performed. Since many aspects of the surveys are similar at the other sites, only details that differ significantly are discussed at length.

The park consists of a variety of rock types such as basalt, andesite, dacite, and rhyolite [15]. One unit, basalt of the Mammoth Crater, created the majority of the caves at LBNM, including the five caves selected for geophysical surveys. This unit is considered to have formed during the late Pleistocene epoch [16], and is comprised of several different flows. The silica values in the basalt range from 48.3 to 55.1%. The remnant paleomagnetization is consistent throughout this unit suggesting that this unit formed within a 100-year time span [16]. In addition to lava tubes, this basalt unit also contains blisters, or small pockets of air ranging in size from a few cm to hundreds of cm. On top of the basaltic rock is a thin layer of pumice deposited during the last eruption [6]. There are also layers of scoria visible in outcrops. The most observable attribute of the park is the large cinder cones that are located throughout the park. Photographs of LBNM recorded during the survey are shown in appendix A.

The geophysical surveys were conducted over Monument Road Cave, Indian Well Cave, Golden Dome Cave, Hercules Leg Cave, and Bear Paw Bridge. Three locations (Golden Dome, Hercules Leg, and Indian Well Cave) are located in the Cave Loop vicinity at the southern end of LBNM. Figure 15 shows the location of the caves along Cave Loop Road. Surveys were also conducted at one location approximately 3.2 km (2.0 mi) northwest of the Visitor's Center (Bearpaw Bridge at Merrill Cave) and at one location (Monument Road Cave) along Hill Road near Devil's Homestead Flow (the location of this cave is not given per LBNM officials' request). Table 1 summarizes the geophysical methods used at each of the sites for determining cave locations.

All the selected caves differ in size and depth below the ground surface and were chosen in order to test the capabilities of the geophysical systems under different circumstances. Information regarding these caves comes from multiple resources including the book Lava Beds Caves by Charlie and Jo Larson [6], cave maps provided by LBNM personnel, personal observations made by the field personnel, and survey information obtained in the field.

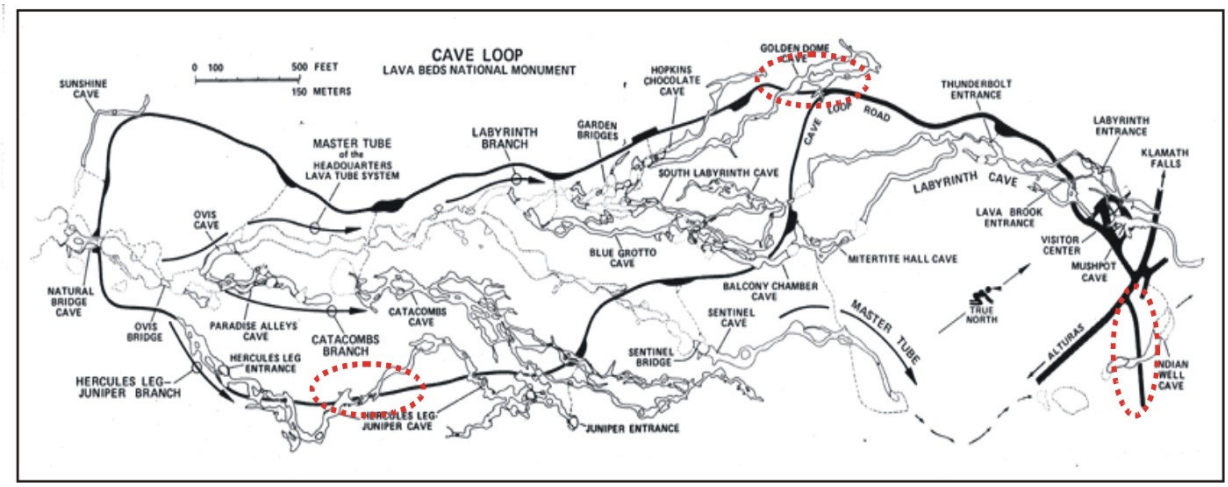

Figure 15. Map. Cave Loop Road site (survey locations outlined in red). [6]

Table 1. Geophysical methods used for mapping subsurface voids at LBNM.

Site/Method	Golden Dome Cave	Indian Well Cave	Monument Road Cave	Bear Paw Bridge	Hercules Leg Cave
GPR	•	•	•		•
Magnetic	•	•	•		•
HRSW	•	•	•		•
Electrical Resistivity		•	•	•	•
Electrical Conductivity					•

All above ground topographic and spatial surveying was accomplished with the Trimble 4700 Real Time Kinematic Differential Global Positioning System (DGPS). Geophysical survey points (i.e. geophone locations and survey line start and end points) as well as points of interest (i.e. cave openings, estimated cave location, and road locations) were surveyed. These points have been positioned on many of the figures. Additionally, DGPS data were coupled with magnetic and electrical conductivity data for sensor positioning purposes. Table 2 lists the base station coordinates used to acquire the DGPS data.

Table 2. DGPS base station coordinates.

ID	Coordinates (NAD 83/UTM Zone 10)		
	Easting (m)	**Northing (m)**	**Elevation (m)**
4770 USFS	624064.33	4619061.79	1430.3
Description	A metal cap marked 4770 USFS is located approximately 1.5 m north of the entrance to Mushpot Cave on a small rock		
640 LABE	NA	NA	1300.19
Description	A metal cap marked 640 LABE is located approximately 1.2 m south of the entrance to Monument Road Cave on a large rock. (Note: exact coordinates are not listed at the request of LBNM officials)		

A compass and chain surveying method was used to find the approximate location where the cave passed beneath the road. In addition, both the height and the width of the cave underneath the road and the thickness of overburden between the road and the roof of the cave were obtained. The equipment utilized in the survey included a compass, measuring tape, hand-level, and stadia rod.

In order to find the location of the cave under the road, a point was selected at the entrance to the cave that could be accurately compared to a known point on the surface. The directional trend of the cave was then ascertained using a compass and measuring tape. A stadia rod and level were used to obtain elevation changes. The path of the cave on the ground surface was then found along with the approximate position where it crossed the road. These points were surveyed using the DGPS and are listed above. Table 3 shows the cave parameters that were determined through compass and chain surveying and differential global positioning system surveying. Two separate caves at the Hercules Leg Cave site were surveyed. No survey information was collected at Bear Paw Bridge; however, information was obtained through other sources and is discussed later. Please note that all measurements are approximate. There are small discrepancies in the location and size of lava tubes when the survey information is compared to those locations listed in the book Lava Beds Caves (*6*). The lava tubes were surveyed at the end of the field project. Geophysical survey lines were situated with respect to the cave locations using the Lava Beds Caves (*6*) book. Cave locations displayed on geophysical data figures are those obtained through the compass and chain method.

The interpretations of the geophysical methods provide, where feasible, the depths and dimensions of the sources of the anomalies. These factors (depths and dimensions) are given to the greatest accuracy possible, sometimes to within 0.1 meter (.33 ft). However, each geophysical method provides different accuracies for these factors. It should be noted that providing these factors to the accuracy presented does not necessarily imply that the method is accurate to this degree.

Table 3. Cave parameters determined through surveying.

Location	Overburden Thickness (m) [1]	Width of Cave Under Road (m)	Height of Cave Under Road (m)	Point on Road Above Cave		
				Easting (m)	Northing (m)	Elevation (m)
Monument Road Cave	5.5	12.2	5.5	619712.33	4625420.4	1302.4
Indian Well Cave	8.8	7.9	8.5	624226.29	4618993.32	1428.6
Golden Dome Cave	4.0	4.0	2.7	623650.26	4618743.77	1467.8
Hercules Leg Cave – North	3.4	9.8	.91	623652.55	4618028.22	1499.7
Hercules Leg Cave – South	2.7	22.3	2.4	623645.36	4618011.38	1501.0

All coordinates are listed in NAD 83/ UTM Zone 10
1-Overburden thickness is measured from the road to the top of the cave.

4.2 GOLDEN DOME CAVE

4.2.1 Site Description

Golden Dome Cave is located at the north end of Cave Loop Road. The cave is oriented generally in a north-south direction. Lava tube slime, a type of mold found in humid microclimates, is found on the ceiling in this cave. This mold is hydrophobic and beads of water rest on its surface. The reflection of light off the beads is golden in color, hence the name Golden Dome. Other types of lava tube characteristics found in this cave include cupolas, cutbanks, lava flowstones, and "aa" lava floors [(6)]. There has been little collapse of the overburden into this cave. Through simple surveying techniques and maps, it has been determined that the cave has a height of approximately 2.7 m (8.9 ft) under the road and the overburden is approximately 4 m thick (13.1 ft). The width of the cave varies underneath the road, but at one point it is 9.8 m (32.2 ft) wide. This cave was selected because it would test the ability of the geophysical methods to detect a cave whose depth is greater than its width. Figure 16 is a picture showing the Land Streamer deployed along the road at Golden Dome Cave.

Figure 16. Photo. Land Streamer deployed above Golden Dome Cave.

4.2.2 Data Analysis and Interpretation

Ground Penetrating Radar

In general, voids in the subsurface are visible in the GPR cross sections in the form of reflection and diffraction hyperbolae. In the case of lava tube detection at LBNM, the voids are irregularly shaped with a highly uneven rock-air boundary. This will cause the lava tubes to produce diffraction hyperbolae at the rock-air interface in the GPR cross sections. Analyses of raw and processed profiles collected at LBNM show numerous diffractions and diffraction hyperbolae. GPR signals are scattered by voids, fracturing, inclusions, and other inhomogeneous features in the subsurface and provide a detailed but difficult section to interpret.

At each site, the GPR data were collected with the SIR-2000 system using two or three different antennae (100 MHz, 200 MHz, and 400 MHz) in two directions along each survey line. The length of the lines and distance between the lines varied at each site. Both wheel mode and automatic mode were used during this survey. The GPR data acquisition parameters for each site are listed in appendix B.
The GPR data were processed using RADAN, written by GSSI. During processing, the profiles were corrected for distance; the time range was limited to enhance near surface features and remove noise; the data were stretched to enhance details; a background filter was used to remove