General Geology and Development of Lava Tubes In New Mexico's El Malpais National Monument

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The El Malpais area of New Mexico is one of the newest National Park Service units. It is located in the northwest part of the state near the town of Grants at an elevation of approximately 2200 meters. The El Malpais, (Spanish meaning "bad country") is a high, lightly forested grassland surrounded with typical southwest mesa topography. A mix of open juniper-ponderosa pine woodland covers the bare to thinly soil covered lava areas whereas a bunch grass-sage-rabbitbush vegetation mantles the deeper soil covered areas. A three-agency cooperative agreement has resulted in U.S. Forest Service wilderness and Bureau of Land Management special management areas surrounding the Park Service monument core.

Deformed preCambrian metasedimentary rocks and flat-lying Mesozoic sedimentary rocks underlie the monument. A series of Pliocene- to Holocene-age lava fields overlie the older rocks. The basaltic lavas have compositionally changed throughout their eruptive history such that the older basanites and alkali-olivine basalts range between 45 to 48% SiO_2 while the younger olivine basanites, basalts, and mugearites range from approximately 46 to 51% SiO_2. This has resulted in lava flows which change composition along their length. Scattered throughout some of the lava units are both deep crustal olivine and pyroxene and partly melted Mesozoic quartz-rich sedimentary rock xenoliths. The oldest and youngest flows containing the known caves have been dated at 1.3 to 0.75 million years old by potassium-argon methods and 1,000 to 400 years old by archaeological methods.

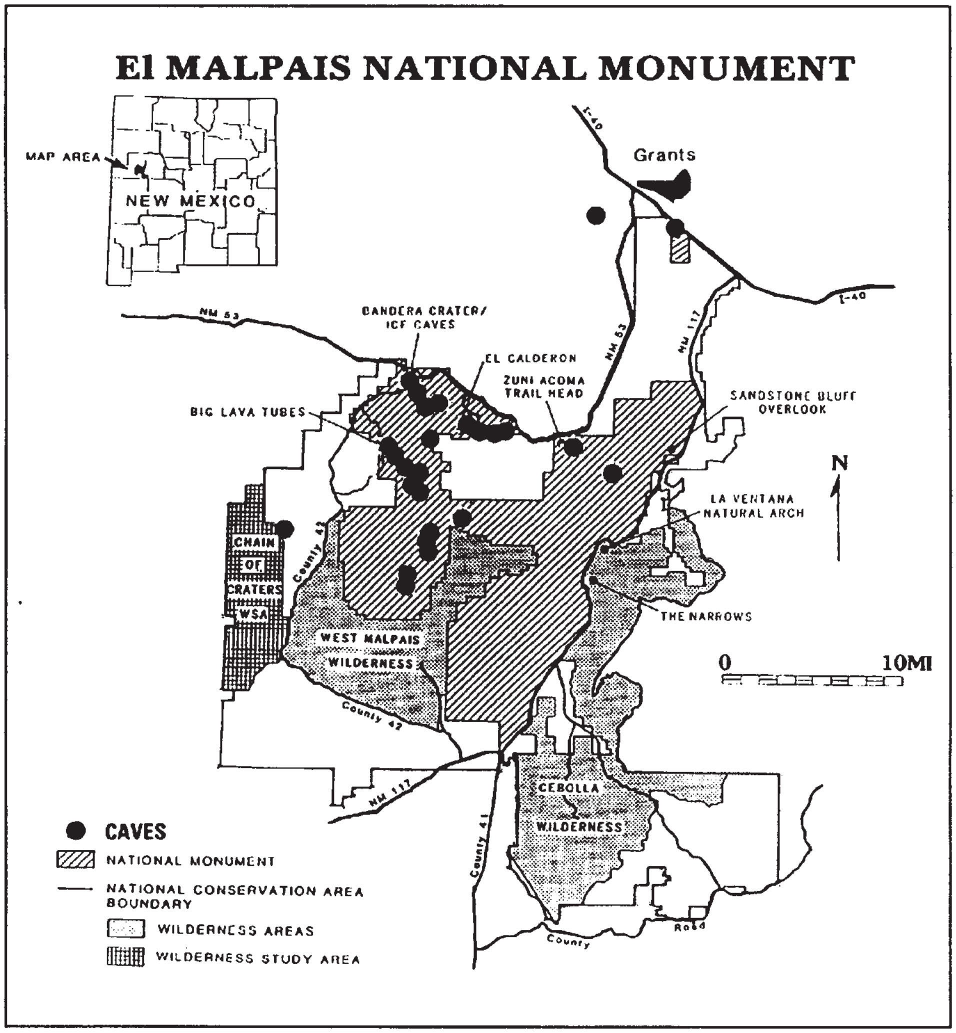

Figure 1 – Map showing the location of El Malpais National Monument in New Mexico. Diagonal lines are Park Service areas, shaded areas are Bureau of Land Management wilderness, and the cross hatched area is Forest Service wilderness. Large circles mark some of the major cave areas.

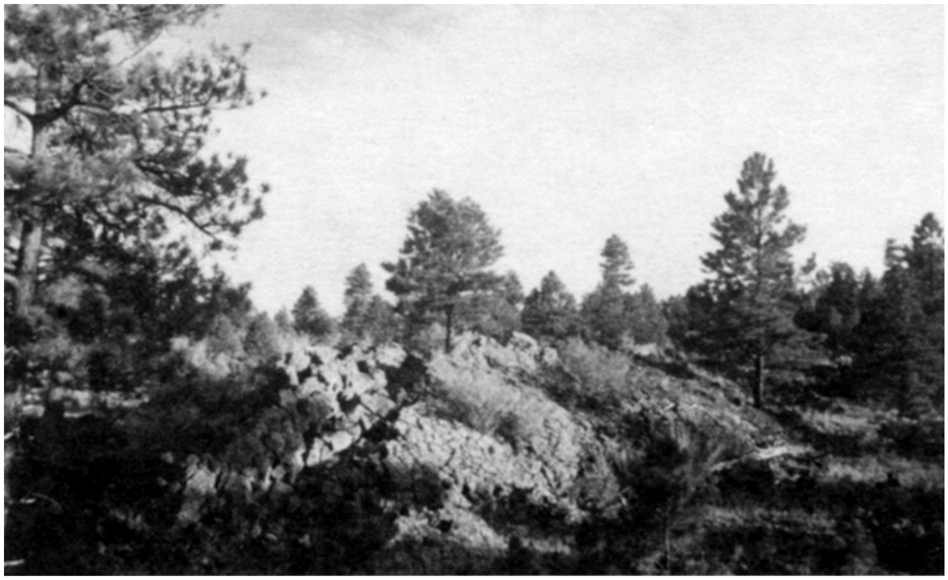

Figure 2—The area of the El Malpais is a 2,000-meter-high ponderosa pine forest with large open areas of sage brush. The tumulus shown here is over 40 meters long and 7 meters high and probably overlies a lava tube that has no natural entrance at present.

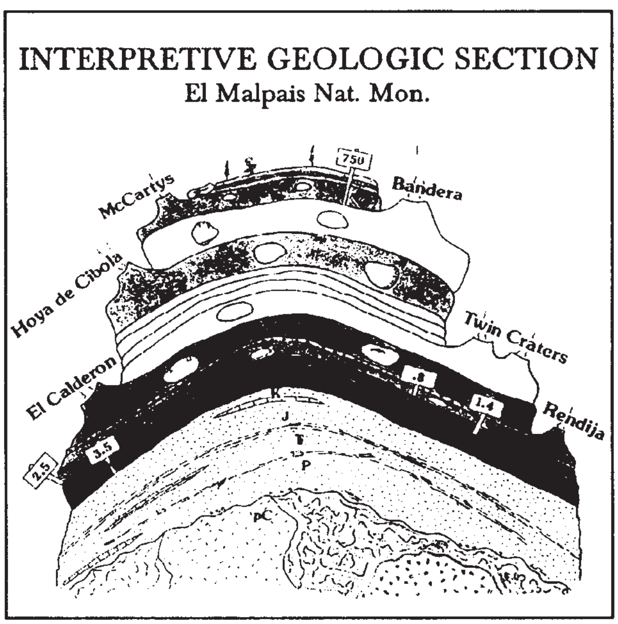

Figure 3—This interpretive geologic column of the rock units exposed in the area of the El Malpais. Bedrock units dating from the preCambrian on up through the last 600 years of the Holocene are present. Numbers in boxes are the approximate ages of the lava flow units in Ma. The Rendija, El Calderón, Twin Craters, Hoya de Cibola, Bandera, and McCartys flows contain major lava tube systems in the Monument.

In the major cave area, five approximately kilometer-diameter volcanoes with Spanish names such as El Calderón (The Caldron) and La Tetra (The Teapot) have disgorged lava flows containing tubes in varying states of preservation. Many of the tube systems' roofs failed shortly after their draining. The resulting landforms can be divided into three types of collapse features: long, sharp-edged collapse trenches; shallow sagged, partially collapsed, partly squeezed down tube-cum-trenches; and alluviated trenches. The sharp-edged trenches have clean walls and partially preserve cave passage profiles under overhanging trench edges and in reentrants. The shallow sagged trenches have

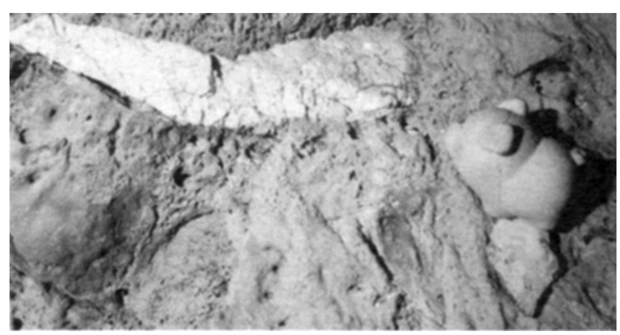

Figure 4—In Xenolith Cave, fragments of bleached and partly fused Dakota Sandstone have been ripped from the bedrock surrounding the volcano's throat and transported upwards. (Mr Bill is approximately six centimeters long.)

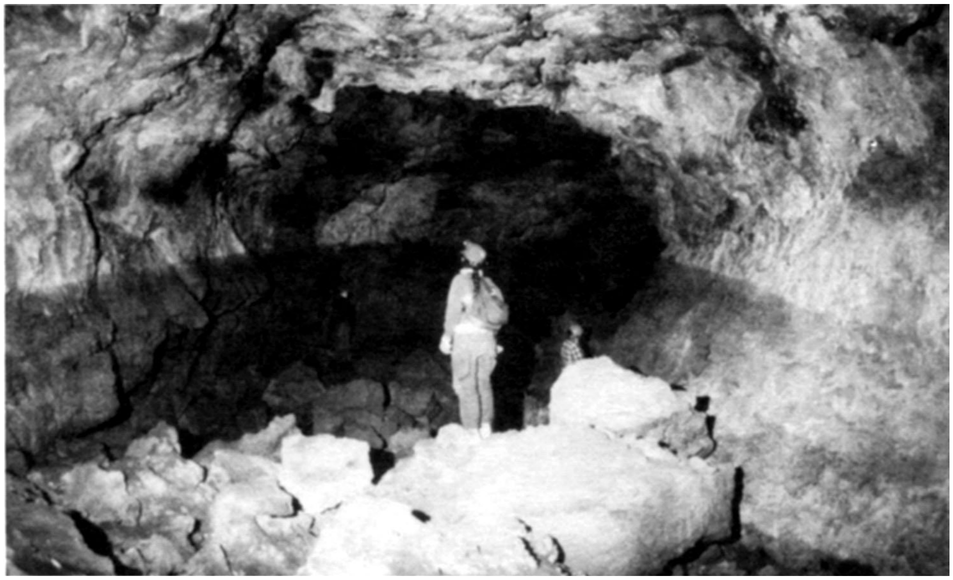

Figure 5—Pat Rice of the U.S. Geological Survey in a typical nine-meter-diameter passage in Junction Cave, one of the more popular caves in the Monument. Plugging of the lower end of the cave by breakdown and in-washed silt has led to ponding of flood waters and subsequent high water "bath tub rings" along the cave walls. Note the large amount of ceiling breakdown present on the floor and the extensive calcite crusts lining the upper passage walls and ceilings above the bath tub ring.

not undergone chaotic collapse but have plastically sagged, either closing or leaving very low passages. Alluviated trenches are scarce but have been thinly veneered with sediments and subsequently vegetated. These trenches can be either sharp-edged or sagged in origin. One of the main cave forming flows, the Bandera Crater flow, is 45 kilometers long and contains 28 kilometers of identifiable tube, most of which is collapsed or sagged trench. This and the other major flows contain dozens of caves ranging from 50-meter-long natural bridges to 3,400-meter-long caves and over-one-kilometer-long systems. Tube sizes generally are large with many caves having 8-meter-wide and 12-meter-high passages but several of the caves contain passages up to 15 meters in diameter. As is common with other lava tube terrains, most of the caves have areas of extensive roof and wall lining collapse. As a result, a substantial portion of the caves have few primary wall and floor surfaces

Figure 6—Gypsum usually forms crusts in lave tubes of the El Malpais, but at Oe Puna Beach in Four Windows Cave it has built up 0.3-meter-high banks that have been subsequently eroded by dripping water to form rillenkarren.

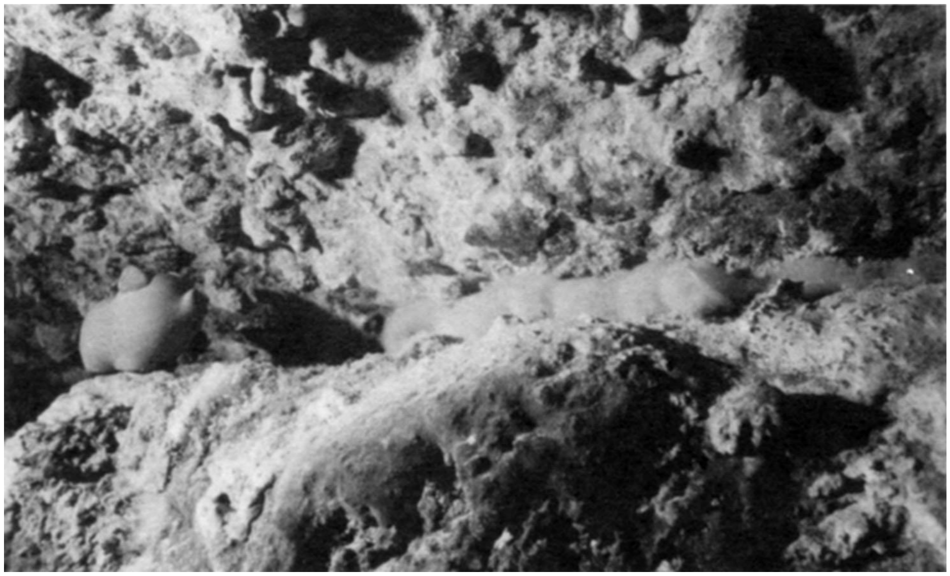

Figure 7—At the back of Braided Cave, Mr Bill inspects a four-centimeter-high seam of mirabilite (hydrous sodium sulphate) angel hair which forms each spring. As summer dries the cave, the mineral disintegrates and falls to the floor as powder, only to be redeposited as angel hair the following spring.

intact. Where the tube interiors are intact, the pahoehoe walls and floors show a variety of features and textures. Rafted blocks are present in several of the caves. Many of the caves are braided or dendritic in pattern; however, unitary tubes are present.

Ten minerals and rocks have been identified by x-ray diffraction as speleothems in the Monument's caves. These include:

ice	H_2O	common, especially seasonally
gypsum	$CaSO_4 \cdot 2H_2O$	very common
epsomite	$MgSO_4 \cdot 7H_2O$	uncommon
mirabilite	$Na_2SO_4 \cdot 10H_2O$	rare
thenardite	Na_2SO_4	rare
calcite	$CaCO_3$	very common
trona	$Na_3H(CO_3)_2 \cdot 2H_2O$	rare
burkeite	$Na_6(SO_4)_2(CO_3)$	rare
cristobalite	SiO_2	uncommon
basalt		ubiquitous

The sources of the minerals is varied. The gypsum, epsomite, mirabilite, thenardite, calcite, trona, and burkeite appear to have drawn their carbonate and sulfate from wind-blown dust derived from weathering of the Mesozoic sedimentary rocks. The cristobalite appears to have been leached from the unstable pumice and glassy ash. Ice is present as permanent deposits in at least four caves and appears as seasonal decorations in a great number of other caves.

Speleothems in El Malpais National Monument					
Bubbles			•		
Coralloids	•		•		
Crusts	•	•			
Crystals		•		•	
Flowstone	•		•		•
Helictites			•		
Moonmilk	•				
Stalactites			•		•
Stalagmites	•	•	•		•
	CO_3	SO_4	SiO_2	CO_3/SO_4	O_2

Chart of speleothems and their mineral compositions in the lava tubes of El Malpais National Monument.

Native Americans utilized the caves quite extensively, leaving cultural remains in many caves. Spaniards, Mexicans, and gringos apparently did

Figure 8—Cottonballs of mirabilite and thenardite (anhydrous sodium sulphate) on the floor of Braided Cave. (Microbus is five centimeters long.)

not make great use of the lava tubes except U.S. Army troops quarrying ice from Bandera Ice Cave, thus left little record of their passing in the caves.

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