

VOLCANOES OF NEW MEXICO: AN ABBREVIATED GUIDE FOR NON-SPECIALISTS

L. S. CRUMPLER and J. C. AUBELE

New Mexico Museum of Natural History and Science,
1801 Mountain Road NW, Albuquerque, NM 87104

Abstract - About two dozen areas are noted where the non-specialist may see volcanoes or volcanic landforms. Few materials about New Mexico's volcanoes have been published for the general public.

Introduction

This is a brief summary for the non-specialist about the volcanoes and volcanic fields of New Mexico, their locations (Fig. 1), and some pointers on what there is to see in each case. Most areas listed here are accessible to the public and represent convenient places for day trips to see a volcano or volcanic phenomena, as well as sites where professional research on volcanism may be done.

Because many of the details of volcanic fields that may be of interest to the non-specialist are as yet unrecorded, the following compilation is focused largely on where volcanic features occur rather than detailed accounts of each site. The list is relatively long, in keeping with the unofficial status of New Mexico as the "Volcano State."

Places to See Volcanoes and Volcano-Related Exhibits (Listed in alphabetical order)

Two types of volcanic venues are listed: (1) formal museum exhibits as guides to what one may see or look for in New Mexico's volcanoes, and (2) the principal volcanic areas where one may see volcanoes, volcanic land forms, and volcanic rocks. Many of the developed parks and monuments include both venues. Other undeveloped areas await exploration by amateurs and professionals and represent "do-it-yourself" opportunities for exploring volcanic land forms. In keeping with the abbreviated format of this discussion, detailed instructions on how to get to many of the undeveloped areas are not included here. Access is varied, and often changes with time, so the best guide for many undeveloped areas is a good set of maps, attending to the usual courtesy of respecting private and Native American land ownership, closing gates behind you, and so forth. Many of New Mexico's volcanic areas have been mapped or studied, some at greater levels of detail than others. But even those for which detailed geologic maps have been prepared, provide numerous opportunities for chance discoveries of unusual, poorly-documented, or previously undiscovered volcanic phenomena. An overview map showing the regional location of New Mexico's volcanoes and volcanic areas is provided in Figure 1. Also, for the non-specialist, a brief glossary of terms used is provided at the end of this article.

Bandera Crater & Ice Caves

Location: 25 miles southwest of Grants on NM 53
Fees: \$8.00 per adult
Telephone/Contact: 505-783-4303; 1-800-ICE-CAVE
See also: El Malpais

This is a small, privately-operated area within the larger El Malpais and Zuni-Bandera Volcanic Field. Trails from the visitor's center take one on a tour of a variety of volcanic features including Bandera Crater, various lava flow structures, and openings to lava

tubes, some of which are filled with ice protected by the insulating properties of the lava. The lava flows here are excellent examples of the lava flow type known as "aa", which is nicely contrasted with the pahoehoe type lava flow exhibited by the McCartys lava flow visible along NM 117. Dated at about 10,000 years before present, the Bandera Crater eruption is the third youngest eruption in New Mexico after the McCartys and Carrizozo lava flows. Therefore many features typical of young lava flows and scoria cones are still preserved.

Bandelier National Monument

Location: Off NM Highway 4, south and west of White Rock and east of Los Alamos.

Fees: \$10 per car

Telephone: 505-672-0343

See also: Jemez Mountains, Valles Caldera, Cerros del Rio

Exhibits: A variety of largely anthropology exhibits that include some discussion of the local natural history and volcanology.

This is a convenient place to visit and take a walking break as one drives through the Valles Caldera complex along Highway 4. Although the monument is focused on the cliff dwellings, this is an excellent place to see the thick ash flow tuff in a convenient setting. The cliff dwellings are excavated into canyon walls formed by thick ash flows that erupted during climactic collapse and formation of the Valles Caldera about 1 million years ago. Bandelier National Monument is also a starting point for numerous trails that wind in and out of canyons cut into the extensive Pajarito plateau formed by the ash flow on the east flank of the Valles Caldera. The trail down Frijoles Canyon takes the hiker through some of the pre-Bandelier lava flows and phreatomagmatic deposits of the Cerros del Rio that are exposed in White Rock Canyon and its tributary canyons.

Capulin Volcano National Monument

Location: 33 miles east of Raton on US Highway 64/87; 58 miles west of Clayton

Fees: \$5.00 per car

Telephone/Contact: 505-278-2201

See also: Raton-Clayton Volcanic Field

Exhibits: Visitor's center includes some exhibits about the volcanology and volcanic rocks; short video about Capulin's eruption, the natural history of the volcano and local area; and the surrounding Raton-Clayton Volcanic Field

Capulin (Spanish for wild cherry or chokecherry) Volcano is one of the few scoria cones in the U.S. with a paved road to the summit crater and therefore one of the most accessible volcanoes in the country. A rim trail permits visitors to explore the volcano and surrounding scenery. Another trail descends into the bottom of the summit crater. From the summit one may see the outline, and many of the structures, of the lava flows erupted from Capulin Volcano that spread out onto the surrounding surfaces. Capulin is just one of the volcanoes making up the Raton-Clayton Volcanic Field. From the summit of Capulin many of the other

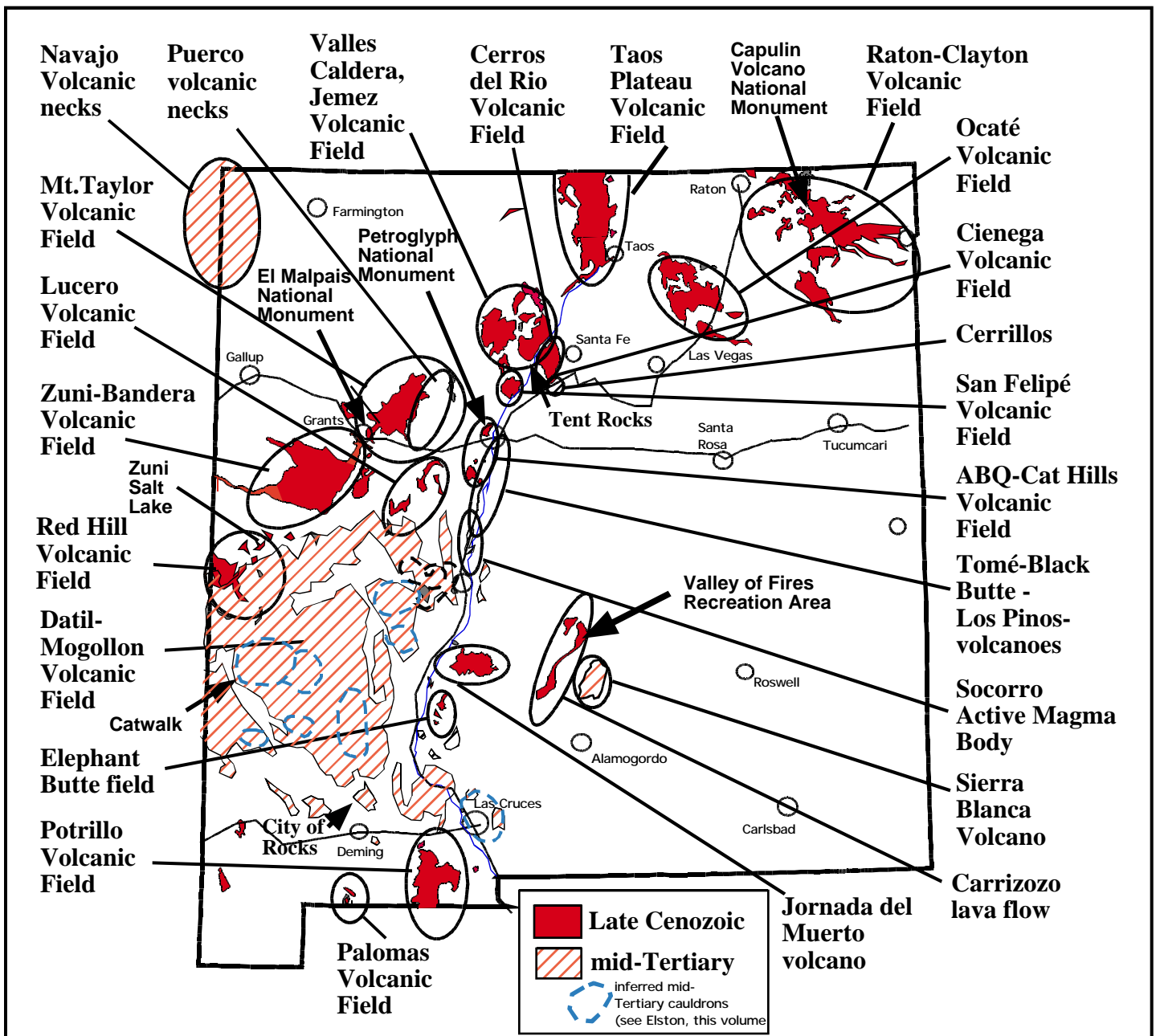


FIGURE 1. Location of the principal volcanic fields and volcanic areas of New Mexico. Volcanism in New Mexico may generally be divided into mid-Tertiary and late Cenozoic. Many of the late Cenozoic areas include primary landforms typical of basaltic and silicic volcanic eruptions.

volcanoes are visible. Although widely cited, the previous estimate of less than 10,000 years ago for the eruption of Capulin volcano is now known to be incorrect. Recent work indicates that Capulin erupted about 59,000 years ago. Capulin is a classic scoria/cinder cone type volcano and is rare in having a perfect cone shape with an unbreached summit crater.

Cat Walk

Location: NM 174, off Highway 180 at Glenwood
 Telephone/Contact: Gila National Forest, Silver City Office
 Fees: Public recreation area
 See also: Datil-Mogollon Volcanic Field

This trail allows the hiker to walk a short distance into the margins of the Bursum cauldron (one of the eroded cauldrons of the Datil-Mogollon volcanic field) complex at its southwestern edge. The rocks forming the canyon walls are massive exposures of an ash flow called the Cooney Tuff that erupted about 32 million years ago (from a cauldron that predated the Bursum). This ash flow is at least 200 meters thick. Walking into the margins of the Bursum cauldron at what might be considered a basement level in the eroded cauldron gives one a sense of the immense thickness and scale of the materials associated with the mid-Tertiary cauldrons of southwestern New Mexico. The Catwalk is managed by the Glenwood Ranger District, Gila National Forest and is designated a National Recreation Trail. Much of the trail consists of a metal meshwork suspended by anchors to the massive ash flows up to 20 feet above the canyon floor.

Cerros del Rio

Location: west of Santa Fe; take CR 62 from Caja del Rio road or from NM 599 west.

Fees: Forest Service managed public and grant lands

The Cerros del Rio, a volcanic field of scoria cones and viscous lava flows and flow-domes, is located west of Santa Fe adjacent to the Rio Grande (across the river from Bandelier National Monument). The field was generally active around 2.6 million years ago. Exposures in the summits of many of the cones afford views of the structure of scoria cones. Some of the eruptions were thick viscous flows with lobate shapes and relatively elevated and flat surfaces. Scattered throughout the field are isolated patches of pumiceous ash derived from the younger Valles Caldera across the Rio Grande to the west. White Rock Canyon has been carved by the Rio Grande, within the past 1 million years, through the lava flows and phreatomagmatic deposits of the Cerros del Rio volcanic field. This is an isolated area covered with a mixed piñon and juniper forest typical of north central New Mexico. As an added attraction, the region is laced with archeological sites.

City of Rocks State Park

Location: 24 miles northwest on US 180 from Deming to NM 61 and four miles northeast to the park entrance

Fees: \$4.00 per vehicle

Telephone: 536-2800

See also: Datil-Mogollon Volcanic Field

Exhibits: Actual volcanology-related exhibits! Rare exhibit of actual prepared samples of ash flows; map of the distribution of Datil-Mogollon cauldrons; description of the massive eruption of one of these cauldrons.

Most of the NM state parks are associated with lakes (in a state where only 2 percent of the area is covered by water). This state park was originally founded to preserve an unusual landscape consisting of monolithic residual blocks of ash flow tuff seemingly congregated like a "city" in the middle of a rolling grassy plain. The blocks are eroded from the Sugarlump Tuff (about 35 million years old), derived from one of the numerous ash flow calderas of the Datil-Mogollon province, one of the largest concentrations of the remains of large calderas in the Southwest. The modern visitor's center is also the principal public exhibit discussing the volcanologic origin of the Datil-Mogollon region. It has a small but excellent display of the origin of the ash flow tuffs, the locations of identified calderas of the Datil-Mogollon volcanic field, and a unique display that shows the visitor some of the minerals and structures that one may see in a sample of an ash flow when it is cut in half. Roads winding through the monoliths and picnic sites invite the visitor to explore the unusual monolithic landforms eroded from the ancient ash flow.

Datil-Mogollon Volcanic Field

Location: Extends over much of the southwestern quadrant of New Mexico and ranges in age of eruption from 20-40 million years. Most of the exposures occur within the Mogollon Mts. and Black Range, and the entire volcanic province probably includes the Magdalena Mts, San Mateo Mts., Socorro Mts. Little Florida Mts, Peloncillo Mts. and Organ Mts. The densest region of mid-Tertiary eruptions is generally bounded by the Rio Grande on the east, highway 60 on the north, interstate highway 10 on the south and highway 180 on the west.

See also: Cat Walk; City of Rocks State Park; Gila Cliff Dwellings; Rockhound State Park.

The best way to explore this vast collection of eroded and faulted calderas is with a map. The key to understanding this region is by

visualizing what the original volcanologic landforms may have looked like while using three-dimensional thinking. Imagine that you are exploring the Valles Caldera, except that the upper several tens to hundred meters of the surface have been stripped off and you are in a giant canyon that cuts a labyrinth into the inside of the caldera and ash flows. Now also imagine that Basin and Range faulting has sliced up the terrain, lifted up whole blocks of real estate, and dropped down adjacent blocks so that the whole area is slightly jumbled. It is a "trip through the Jemez Mountains" with x-ray vision. A good starting point is the drive from Hillsboro through the Black Range to Silver City. During this drive one passes through the center of the Emory cauldron, one of the largest documented examples of this type of volcano. With a little practice, a good map, and some imagination, it is not impossible to reconstruct the volcanic landscape as you go. As a result, you will be even better prepared for a drive through the Valles Caldera.

The Kneeling Nun, a famous natural landmark 20 miles east of Silver City, on US 180, is actually a part of an ash flow tuff believed to have been erupted from the Emory cauldron. City of Rocks State Park preserves exposures of an ash flow tuff from another of the cauldrons of the field. The Cat Walk and Gila Cliff Dwellings National Monument also provide close-up views of some of the volcanic deposits of the Datil-Mogollon volcanic field.

El Malpais National Monument and Zuni-Bandera Volcanic Field

Location: 72 miles west of Albuquerque, south of Grants

Fees: none

Telephone/Contact: 505-783-4774

See also: Bandera Crater and Ice Caves

Exhibits: Three visitor's centers are available for exhibits, information, maps, and books. The NW Regional Visitor's center located just south of I-40 at Grants (exit 85) is a good starting point for information of the region that includes a variety of exhibits about the natural history of the area. The east El Malpais visitor's center, 9 miles south on NM 117, across from Sandstone Bluffs overlook, is located in a serene setting with interpretative displays about the regional culture and wildlife. From the balcony there is one of the more impressive views of Mount Taylor. The west El Malpais visitor's center, 23 miles south on NM 53, has an excellent three dimensional display of the sequence of young lava flows that make up El Malpais and is well worth the stop in order to get a sense of the geological development of the volcanic field.

El Malpais and the Zuni-Bandera field encompasses volcanoes and volcanic flows that range in age from 700,000 to yesterday (geologically speaking). El Malpais includes the McCartys lava flow, New Mexico's youngest volcanic eruption (approximately 3000 years old), which is visible along much of NM 117. Prior to attaining monument status this was one of the most accessible lava flows. Currently many of the more interesting and well-preserved areas are fenced off from NM 117 and require considerable walking to explore properly. Alternatives are to visit the Lava Falls trail near the extreme southern end of the flow, the Zuni-Acoma trail which lies about mid-way along the length of the flow, or the Sandstone Bluffs overlook for a vista of the valley in which the lava flowed. For reasons that are not clear as yet, the surface of the lava flow along the Lava Falls trail appears much more weathered and eroded than elsewhere, where the flow is backer and glassy surfaces are retained. Nonetheless, many interesting small-scale phenomena of lava flow emplacement are to be found along the trail and adjacent areas of the lava flow. Many of the small-scale textural details of lava flows were defined on the basis of study of the McCartys lava flow.

The Chain of Craters Road is another way to explore the region. This road loops from highway 117 near the southern end of the youngest (McCartys) lava flow, across the interior of the field past young scoria cones of the Bandera area, and eventually connects with highway 53 at Bandera Crater. Those who wish to attempt this road should be aware that the road can be treacherous after periods of wet weather and relatively rocky near 117. Good ground clearance is desirable.

Gila Cliff Dwellings

Location: highway 15 north of Silver City

Fees: \$3.00 per person

Telephone: 505-536-9461

See also: Datil-Mogollon Volcanic Field

Exhibits: Visitor Center at trail head center has an excellent topographic relief model of the region; books and maps in the main visitor's center.

Although this monument is focused on an archaeological site, the rocks in which the dwellings were built are equally interesting. The trail to the cliff dwellings follows a canyon cut through layered and reworked volcanic rock and debris shed from adjacent higher topography. This volcanic rock and debris was derived from the eruption of one or more of the large cauldrons of the Datil-Mogollon volcanic field. Some geologists have interpreted this thick section of volcanic debris as the fill of a local caldera known as the Gila Cliff Dwellings cauldron that erupted about 29 million years ago.

Jemez Dam Overlook and San Felipe Volcanic Field

Location: North of Bernalillo; turn on NM 528N from US 550 about 1.5 miles west of Bernalillo.

Fees: none.

Telephone/Contact: Sandoval County Visitor Center, 243 Camino del Pueblo, Bernalillo, NM 87004, (800) 252-0191.

Note that the overlook is public access but it is surrounded by Santa Ana and San Felipe Pueblo land that is off-limits without permission.

This overlook (and the drive to it from I-25) is a good spot to view volcanoes. To the north, in the foreground, on the mesa top, lies the lava flows and volcanoes of the 2.5 million year old San Felipe volcanic field (sometimes called Santa Ana Mesa field). The San Felipe field is one of the central Rio Grande rift fields similar to the Albuquerque Volcanoes. The San Felipe field consists of a low shield volcano, San Felipe Peak, visible on top of San Felipe mesa, multiple scoria/cinder cones, and voluminous lava flows erupted from two parallel north-south fissures. Many faults, associated with the formation of the Rio Grande rift, have cut the flows so that from the overlook one can see a series of steps or levels of the lava flow-capped mesa. On the drive in or out of the overlook area, see if you can spot a strange "turtle-shaped" hill just north of the town of Bernalillo. This is Canjilon Hill, a complex volcanic center that includes maar deposits and volcanic intrusions. Canjilon is south of the main San Felipe field but is considered to be part of it. Canjilon represents the lower levels of a typical San Felipe volcano after erosion by the Rio Grande.

Canjilon Hill is on Santa Ana Pueblo land and San Felipe mesa is on San Felipe Pueblo land. Permission to see them close-up must be obtained from the pueblos, but they can be viewed from a distance.

Jemez Mountains

Location: Between the Nacimiento Mountains and the Rio Grande. Includes Jemez Pueblo land, private land, U.S. Forest Service, Jemez State Monument, Los Alamos Scientific Laboratory and the towns of Jemez Springs, Los Alamos and White Rock.

Contact: Jemez Ranger district, P.O. Box 150, Jemez Springs, NM 87025; (505)829-3535.

See also: Bandelier National Monument; Valles Caldera; Kasha-Katuwe National Monument

Exhibits: Jemez Ranger station at Jemez Pueblo visitors center and in Jemez Springs; trail head displays at Battleship rock and others.

The Jemez Mountains are a volcanic complex of many different types of volcanic rock and styles of volcanic eruptions ranging in age from about 14 million years to about 40,000 years. The formation of

the Valles caldera was just one of the most recent eruptions forming the Jemez Mountains. Heat from the volcanism continues to drive active thermal springs, sulfur springs, mud pots, and travertine deposition. Volcanologically, the Jemez Mountains are considered to be still active.

Jornada del Muerto Field

Location: South of San Antonio and the Bosque del Apache National Wildlife Refuge. A field vehicle with high ground clearance and four-wheel drive is desirable.

Telephone/Contact: Area includes ranch land and grant land. Permission must be obtained to enter the Armendariz Ranch on the eastern margin of the field. Roads change but the objective is to work south from San Antonio toward Val Verde and ultimately reach the northern edge of the flow field.

Fees, exhibits: none

The Jornada del Muerto field is of interest because it represents a young (about 750,000 years), single-vent lava field in which a small central volcano produced multiple lava flows. The topography of the combined vent and surrounding lava flow field forms a shield-type volcano profile. The central vent region is structurally unusual in that it is a flat-topped cone on a perched lava platform surrounded by a circular trough and rampart. Large lava tubes are prominent south of the central vent area. These tubes were mined for bat guano early in the century and a few ruins associated with the operation remain. The name of the area refers to the "route of the dead man" in reference to the frequent outcome of those who tried to save time on the trail from Mexico City to Santa Fe by taking the straight route rather than following the river bend. The area is barren, devoid of water, remote, and even today, difficult to reach.

A few volcanic centers and lava flows occur south of the Jornada field; including east of the river in the Elephant Butte Reservoir, near Eagle and near Truth or Consequences. To the northwest of the Jornada, near San Marcial, the volcanic Black Mesa is visible. All of these surrounding volcanoes appear to represent basalt volcanism that is a bit older (2-3 million years) than the Jornada.

Kasha-Katuwe Tent Rocks National Monument

Location: 40 miles southwest of Santa Fe and 50 miles north of Albuquerque; take the Cochiti Reservoir exit from I-25 to NM Route 22 and follow the signs to Cochiti Pueblo. Turn right at the pueblo water tower (painted like a drum) onto Tribal Route 92 (connects to Forest Service Road 266). Travel 5 miles on a dirt road to the Tent Rocks parking area, which is marked with a sign.

Time: Day use only; winter (November 1 to March 31), 8:00 a.m. to 5:00 p.m.; summer (April 1 to October 31), 7:00 a.m. to 6:00 p.m.

Fees: Private vehicle - \$5.00 on-site.

Telephone/Contact: Albuquerque Field Office, Bureau of Land Management, 435 Montano Road, NE, Albuquerque, NM 87107-4935, (505) 761-8700, (505) 761-8911 FAX

See also: Jemez Mountains; Valles Caldera

Exhibits: trail head display.

Recently given National Monument status, this is an excellent exposure of volcanoclastic (ash and debris) sediments shed off of volcanic domes nearby to the west. The rocks here are part of the Jemez Mountain volcanic complex, but they are not from the same eruption that resulted in the more extensive ash flow tuffs of the Bandelier or Battleship rock. Instead, the volcanic domes from which the tent rock sediments were derived erupted earlier (about 6-7 million years ago) in the history of the Jemez Mountains volcanic complex. A variety of trails lead one through slot canyons and along the base and top of ridges exposing thick sequences of light gray and white pumice and ash, and dark blocks capping pinnacle-shaped erosional land forms.

Kilbourne Hole and Potrillo Volcanic Field

Location: 25 km south-southwest of Las Cruces

Kilbourne Hole is one of several relatively young maars in this volcanic field that also includes Hunt's Hole, Potrillo maar, Malpais maar, over 100 scoria/cinder cones and Aden Crater (a beautifully preserved small shield volcano). The Potrillo maars are among the best exposed and preserved maar craters in the world. Kilbourne Hole is one of the classic maar craters (volcanic steam explosions) mentioned by geologists worldwide. The Potrillo Volcanic field ranges in age of eruptions from about 700,000 to 12,000 years ago.

Mount Taylor and Mesa Chivato

Location: north of Grants, accessible from San Mateo or from Grants.

Fees: Forest Service lands, Cibola National Forest, Grants District
Telephone/Contact: Mt. Taylor Ranger District, 1800 Lobo Canyon Road, Grants, NM 87020; 505-287-8833

See also: Rio Puerco Volcanic Necks

Mount Taylor volcano (known as "Turquoise Mountain" to the Diné; "Spinat" to the Acomas) is largely on U. S. Forest Service land and is readily accessible with a network of maintained gravel and unimproved roads. It is the second largest young volcano in New Mexico after the Valles Caldera. It is a classic example of what is known as a composite volcano. The general structure consists of thick debris flows along the base and thick, viscous lava flows on the upper flanks of the volcano. Interspersed with these more viscous lavas are scoria cones and fluid basaltic lava flows, some of which contain unusual mantle xenolith and large crystals. A large amphitheater-shaped valley in the summit is probably the remnants of a former late-stage crater. Mount Taylor last erupted about 2.5 million years ago in an eruption that was probably similar to that of the 1980 Mt. St. Helens eruption. From either La Mosca Peak or Mount Taylor Peak, there is an expansive view of the amphitheater and the surrounding state. An excellent way to see much of the volcano is to take the forest loop road (FR 239) around the north flank, across the north amphitheater rim, and down FR459 to return to the main road (FR 239). Alternately one may ascend on FR 459 (La Mosca Peak Road). At the saddle on the west end of the volcano amphitheater, turn right and drive to just below the 11,301 ft. summit (the only way to reach the summit is by hiking).

The large plateau to the north and northeast of Mount Taylor is a related volcanic field of scoria cones, several 1 km-wide maar (steam explosion) craters, viscous domes of an unusual volcanic rock called trachyte, and extensive basaltic lava flows. The Rio Puerco necks are part of the general Mount Taylor volcanic field.

New Mexico Museum of Natural History and Science

Location: 1801 Mountain Rd NW, Albuquerque

Fees: Adults, \$5.00; seniors, \$4.00; kids 3-12 \$2.00

Telephone: 505-841-2800

Exhibits: "Age of Volcanoes" walk-thru volcano and associated displays; map of Rio Grande rift; real-time seismicity displays

A permanent exhibit, "The Age of Volcanoes", summarizes the importance of volcanism throughout the Cenozoic in New Mexico. The exhibit is a stylized volcano environment featuring a "walk through a volcano". On display are images and samples of important volcanoes, volcanic rocks, and minerals associated with volcanism. The entrance is an actual cast of a basaltic lava flow section representative of commonly occurring lava sections along the margins of a basalt-capped mesas. The section, cast from flow units at the top of the La Bajada escarpment on I-25 between Albuquerque and Santa Fe, displays two flow units and preserves the non-uniform distribution of vesicles, or vesicle zonation, common to basaltic lava flow

sections. Panels discuss several concepts, including the increase in temperature with depth in the Earth, types of volcanoes as exemplified by New Mexico examples, and other interesting New Mexican volcanic land forms. An exhibit showing the relationship between minerals and rock types and their depth of formation ranks among one of the best explanations of the origins of common rocks, rock-forming minerals, and associated deposits.

Ocaté (Mora) Volcanic Field

Location: Covers area encompassed between Eagle Nest, Watrous, and Wagon Mound; bounded by NM 120, 38, and 161 and I-25; mostly private land, but some access at margins.

Situated to the east of the Sangre de Cristo range, this small field is similar in age (ranging from 9 million to 60,000 years old) and rock type to many of the eruptions within the Raton-Clayton volcanic field to the northeast. The field consists of basaltic to dacitic flows and associated vents ranging in age from late Miocene to Pleistocene (over an 8 million year period). Regional uplift and subsequent erosion, as in the western Raton-Clayton field, has resulted in inverted topography where the oldest lava flows occupy the highest local elevation. Three major levels of lava flow-capped mesas decrease in elevation from west to east. Maxon Crater, a shield volcano capped with a low and broad scoria vent complex, is the source for flows that moved 90 km down drainages to the confluence of the Mora and Canadian rivers. This volcano lies just west of the rest stop on I-25 between Watrous and Wagon Mound. The volcanic field can be circumnavigated by taking a loop from I-25 at Wagon Mound to Mora and back to Watrous on I-25. Those who ski at Angel Fire may not realize that they are just to the east of Agua Fria Peak, one of the westernmost of the Ocate volcanoes (erupted about 5 million years ago).

Petroglyph National Monument

Location: Las Imagenes Visitor's Center is located on Albuquerque's west side off Unser Boulevard five miles north of I-40

Fees: (\$1-2 for Boca Negra area; no fee for other areas)

Telephone/Contact: 505-899-0205

Exhibits: Wayside and trailhead maps and interpretative materials in the visitor's center include geologic discussions. The Monument is in the process of installing additional "wayside" exhibits at trailheads that will assist the visitor in interpreting the volcanic land forms and their significance. Several books on volcanism and interpretive materials are available at the Visitor's Center.

Although based on preservation of one of the largest collections of petroglyphs, this Monument is situated on the margins of one of the younger lava flows of the Rio Grande rift. Included within the Monument (and within the adjacent Albuquerque "open space" lands) are the Albuquerque volcanoes, a line of scoria and spatter cones developed along a very long fissure eruption approximately 150,000 years ago. Even by Southwestern volcanism standards, this fissure is unusually long. In contrast to their diminutive size and apparent simplicity of form, as seen from Albuquerque, the volcanoes preserve a wealth of detailed volcanic land forms not often visible in larger and more spectacular-appearing volcanoes. Add to this fact their proximity to a major metropolitan area and the Albuquerque volcanoes and their associated lava flows are easily one of the best places to see volcanic phenomena. The escarpment facing Albuquerque, where most of the petroglyphs are located, is the erosional margin of several individual lava flows that erupted from the volcanoes. This margin shows a wealth of lava flow details exposed in cross-section along the mesa edge. Numerous trails and ready access invite the visitor to explore this terrain in relative comfort. Of particular volcanologic interest are the source vents of the lava flows (the scoria cones known as the Albuquerque Volcanoes). These volcanoes are accessible from a small parking area off Paseo del Volcan, north of I-40.

Raton-Clayton Volcanic Field

Location: Area between Raton, Clayton and Springer; access via highways 64, 56, and I-25

Fees: Private lands; several public right-of-ways in interior.

Telephone/Contact: (See Capulin Volcano National Monument)

A drive from Raton to Clayton takes the visitor through a classic scoria cone volcanic field. Although most of the land is privately owned, visitor's may explore the volcanic landscape by stopping at Capulin National Monument. The Raton-Clayton volcanic field is the eastern-most Cenozoic volcanic field in the United States. Geologically, the volcanic activity in the field can be divided into three phases that extend from 9 million years ago to 40,000 years ago. Like the Ocate Volcanic Field, erosion in the region has resulted in the oldest lava flows occupying the highest local elevation. In addition to Capulin, another prominent volcano in this field is Sierra Grande, a large volcano that is shield-shaped in profile with an unusual rock composition. Historically, the Raton-Clayton field is where the Santa Fe trail first entered New Mexico, and the region abounds in pioneer history and volcanic landscapes.

Rockhound State Park

Location: South of Deming NM on the western slope of the Little Florida Mountains; a NM State Park with camping, picnic areas and trails

Fees: \$4 entry fee; \$14 camping fees

Telephone/Contact: P.O. Box 1064, Highway 143, Deming, NM 88031, (505) 546-6182.

See also: Datil-Mogollon Volcanic Field

Exhibits: New visitor's center with exhibits including discussion of local volcanism.

Visitors are welcome to collect 15-20 pounds of rock per person from this area. The Little Florida Mountains are part of the regional mid-Tertiary Datil-Mogollon volcanic province. A variety of quartz minerals (agate, common opal, jasper, chalcedony, and quartz crystals) occur in veins or pockets within the volcanic rock. This is also a good place to get a close-up view of the mid-Tertiary volcanic rocks.

Rio Puerco Volcanic Necks

Location: Rio Puerco valley between Mesa Prieta and Mesa Chivato.

Telephone/Contact: Albuquerque Field Office, of Land Management, 435 Montano Road, NE, Albuquerque, NM 87107-4935, (505) 761-8700, (505) 761-8911 FAX

See also: Mount Taylor and Mesa Chivato

Many people explore the Rio Puerco valley for its scenic or historic attractions. But the Rio Puerco volcanic necks are a relatively unexplored and rare collection of the interior structure of small scoria (cinder) cone type volcanoes. What is a volcanic neck? If a volcano is the "head", then the feeder plug is the neck; when the head is eroded away, the neck is all that remains. A trip around the world will not find a better example of volcanic necks. Exposures in the sides of the volcanic necks provide a unique and rare insight into some of the complexity of small volcanoes. Many of the outcrops challenge the deductive abilities in attempting to interpret the sequence of events and processes that formed them.

The Rio Puerco necks can be considered part of the larger Mount Taylor volcanic field activity and are the same age, approximately 2.5 million years old.

Shiprock

Location: 10 miles southwest of the town of Shiprock NM off US 666, north of Gallup.

Telephone/Contact: Navajo Parks/Recreation, P.O. Box 9000, Window Rock AZ 86515 (520) 871-6647. Note: this feature is on the Navajo Nation reservation and is considered sacred to the Navajos. Viewing is allowed, off limits to hikers, climbers.

Shiprock rises 1100 feet above the surrounding desert. This photogenic New Mexican landmark appears in almost all geology textbooks as "the" example of a volcanic neck (the eroded remnants of the interior of an old volcano). Several volcanic intrusions (called dikes) radiate outward from the neck. Small pinnacles near the main peak are smaller necks of subsidiary eruptions. Shiprock probably represents the interior of a composite volcano that erupted about 30 million years ago.

Sierra Blanca

Location: Near Ruidoso NM; land owned by Mescalero Tribe and U.S. Forest Service.

Fees: Ski Apache owned by the Mescalero Tribe located on NM 532

Telephone/Contact: Ski Apache (505)336-4356; U.S. Forest Service, Cedar Creek Ranger Station, Ruidoso, NM (505-257-4095. Note that portions of Sierra Blanca are Forest Service land and accessible to the public; however, the peak of Sierra Blanca is owned by the Mescalero Tribe and not accessible without permission.

When you "Ski Apache" you are skiing on an old volcano. Sierra Blanca is a volcanic "pile" consisting of intrusive rocks, ash, and flows that probably was once a composite volcano. It was active at about the same time as the general Datil-Mogollon volcanic field (about 38-26 million years ago). It is estimated to have been originally on the order of 3000 feet high and 20 miles in diameter but has been greatly eroded.

Taos Plateau

Location: San Luis Valley between Taos, Tres Piedras, Pilar, and San Antonio; mostly east of highway 285.

Contact: Many interesting areas are managed by BLM;

505-758-8851 BLM Taos Field Office, 505-751-4899; Rio Grande Gorge Visitor Center; 505-758-4060 Orilla Verde Visitor Station .

This is the largest volcanic field within the Rio Grande rift and includes volcanic eruptions that occurred from 2-5 million years ago. The field is accessible via several highways crossing the plains west of the Sangre de Cristo range at Taos. The broad plain west of Taos is dominated by several large and rounded volcanoes, including San Antonio Mountain and Ute Mountain, among others. These are unusual both for their great symmetry and the fact that their lower slopes are steeper than the slopes near the summits, resulting in a shape that resembles an overturned bowl. Generally, volcanoes that erupt viscous and stubby lavas like these tend to be relatively pyroclastic. However, these are unusual in that pyroclastic materials are a small volume of the observable edifices.

While everyone is familiar with the bridge over the Rio Grande Gorge west of Taos where a spectacular view of thick accumulations of basalt may be seen in the canyon walls, a relatively unexplored venue for the public is the lower reaches of the gorge near Pilar. The Rio Grande Gorge Visitor's Center at Pilar is a modern facility with a variety of information (but do not expect much geology!). From here one may drive up the gorge from Pilar and experience some of the spectacular land forms associated with the incision of the Rio Grande along the southern margin of the thick sequence of Servilleta basalts. The Rio Grande gorge is frequently mistaken for the Rio Grande rift by non-geologists. In reality, the entire Taos Plateau lies within the rift and the gorge has simply been cut down through the layered basalts by the river flowing down the center of the rift.

UNM Geology Museum

Location: University of New Mexico Earth and Planetary Sciences Department, Northrop Hall, UNM, Albuquerque, NM
 Telephone/Contact: Department office, 505-277-4202
 Exhibits: A variety of specimens and interpretative exhibits about the geology of New Mexico, including volcanic rocks.

This is a small but comprehensive museum that displays specimens and interpretive materials in geology. It is one of the best places to get an overview of the geology of New Mexico and includes several exhibits that interpret volcanic features and rocks.

Valles Caldera

Location: 40 km west-northwest of Santa Fe; NM NM Highway 4 traverses the eastern caldera floor

Contact: Jemez Ranger District, P.O. Box 150, Jemez Springs, NM 87025; (505) 829-3535; the Valles Caldera National Preserve Trust, Attn: Gary Ziehe, Executive Director, Phone: (505) 438-7891, Fax: (505) 438-7834

See also: Jemez Mountains, Bandelier National Monument

The Valles Caldera is a young caldera. Newly-acquired as a national land, expect to see various wayside displays and maps for the traveler along Highway 4 in the future that will help the visitor interpret the volcanic landscape. The cliff dwellings at Bandelier National Monument are an excellent place to see the character of the Bandelier ash flows that were deposited about 1 million years ago by the eruption of the Valles Caldera.

A drive through the caldera along NM Highway 4 from Jemez Springs to White Rock affords the quickest way to appreciate the caldera as a whole. Although every mile of the drive is through very youthful volcanic terrain, few visitors are prepared to appreciate the volcanology, because the scale of the caldera exceeds that which can be encompassed in any single view from the ground. The landforms associated the Valles Caldera are so obvious to the geologist that they are poorly documented from the perspective of non-specialists. For now, the best way to understand what one is seeing is to carefully note one's location on a geologic map while driving through. The trip along NM 4 takes one up the surrounding ash-flows as you drive up San Diego canyon, through the rim and into the caldera, past some of the interior volcanic domes that erupted within the caldera and within view of the resurgent Redondo Peak dome (the uplifted center of the caldera), across a portion of the open caldera floor, and out through the northeast caldera rim. Visitors frequently mistake the open valley, visible from overlooks along NM 4, for the complete caldera; in reality the valley that is visible is only a portion of the entire 18 to 20 km-diameter caldera.

Valley of Fires State Recreation Area

Location: 3 miles west of Carrizozo (and highway 54) on US Highway 380

Fees: none

Telephone: 505-648-2241

Known as the Carrizozo lava flow to geologists, this is one of the largest young lava flows in the world and the second youngest volcanic flow in New Mexico (around 5000 years old). Trails near the state recreation area off highway 380 loop through the margins of the lava flow allowing close inspection of some of the characteristics of an extensive pahoehoe lava flow field. The extreme northern end, near the source at Little Black Peak is within private ranch lands. The southern half lies within the White Sands Missile Range and is accessible only with permission from the U. S. Army.

White Rock Canyon

Location: Public park at edge of the town of White Rock

Contact, fees, exhibits: none

See also: Jemez Mountains; Valles Caldera; Cerros del Rio

This is a public overlook that is arguably of more geological interest and more scenic than the Rio Grande Gorge. From a small parking area one walks a few hundred feet to an overhanging look-out. The vast panorama of White Rock Canyon encompasses a view across the northwest margin of the Cerros del Rio field and beyond toward the Sangre de Cristo Mountains just east of Santa Fe. White Rock Canyon developed when the Rio Grande cut down through layers of volcanic ash and phreatomagmatic deposits capped by basaltic lavas and ash flows. Across the river is an excellent example of a scoria cone (Buckman Mesa) nearly cut in half by erosion. The San Ildefonso Pueblo's Black Mesa is visible to the north. The vista of the Cerros del Rio volcanic field extends to Cerro Montoso and the adjacent deeply incised Montoso maar now exposed at the edge of the canyon. Numerous landslide blocks of thick lava flows lining the canyon illustrate why the stratigraphy within the canyon is best examined with caution.

Zuni Salt Lake

Location: may be viewed from CR 601 (between Fence Lake at Highway 36 and Quemado at Highway 64) where the road passes near the western margin.

Telephone/Contact: this is an undeveloped area and is Zuni Pueblo land. Please just view this crater from the road. This is a sacred site to the Zuni and others. Generations of pueblo people from throughout the southwest, including the Hopi, have traveled here to collect salt. A Hopi mural depicting a journey to Zuni Salt Lake can be viewed at one of the visitor's centers at the Petrified Forest in Arizona.

Zuni Salt Lake is a relatively young (about 90,000 years old) volcanic steam and magma explosion crater of a type known as a maar. It is infrequently visited due to remoteness from most centers of population, yet readily accessible by graded backroads. Frequently pictured in volcanology texts, Zuni Salt Lake maar is unusual as maars go due to the presence on its floor of two small scoria cones that erupted following the initial maar eruptions. Salt has been deposited due to evaporation of what was once a larger lake. The stark comparison between the dark scoria cones and the brilliant white salt of the interior lake is a study in lighting contrasts.

The comparison between the violent explosion responsible for the crater and the relatively mild strombolian eruptions responsible for the scoria cones is also volcanologically revealing regarding the dynamics of maar formation. It is also of interest from the perspective that it is approximately similar in age and diameter to Meteor Crater, thus illustrating the contrast between two types of crater-forming processes, volcanic and meteorite impact. A graded road crosses the ejecta rim on the west margin where numerous accidental blocks of earlier basalt and fine ash dominate the landscape.

Useful Activities for the non-specialist

Volcanoes are an undiscovered avenue for non-specialists, primarily because there are few places on Earth that afford opportunities to see youthful volcanic phenomena. Not only does New Mexico have young volcanoes, it has an example of all the main morphological types as well (Table 1 and 2). For those seeking something new and different, it is well to keep in mind that New Mexico is one of those few places. Consider also, that, whereas bird-watching or mineral-collecting are relatively well-developed amateur activities, the diversity and exposure of volcanoes and volcanic landforms is just as great, yet relatively undiscovered. What amateurs may do is simply go look at volcanoes and observe what record of volcanic processes is preserved in their landforms and outcrops.

FIGURE 2. Fundamental Volcano Morphologies as Illustrated by New Mexico Examples



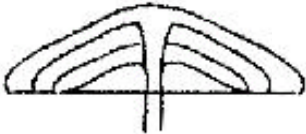

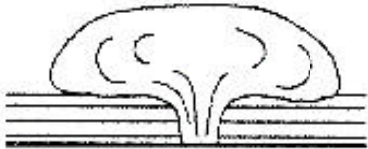

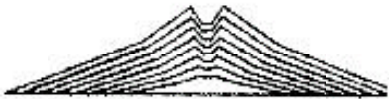









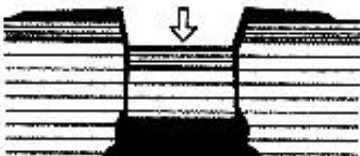

Volcano Type	VERY Simplified Conceptual Model	New Mexico Example
lava shield		San Felipé 
lava cone		Ute Mtn 
lava domes		Cerro La Jara 
composite cone		Mount Taylor 
scoria cones		Cat Hills 
lava flows		McCartys 
maars		Laguna de Alejandro 
volcanic necks		Rio Puerco necks 
caldera		Valles caldera 

TABLE 2. Representative examples of the principal types of volcanoes in New Mexico arranged by size.

• LARGE SIZE

Ash-flow calderas and cauldrons

- Bursum (Mogollon-Gila)
- Emory (Mogollon-Gila)
- Organ (Mogollon-Gila)
- Mt. Withington (Mogollon-Gila)
- Socorro (Mogollon-Gila)

• LARGE SIZE

Ash-flow calderas and cauldrons

- Bursum (Mogollon-Gila)
- Emory (Mogollon-Gila)
- Organ (Mogollon-Gila)
- Mt. Withington (Mogollon-Gila)
- Socorro (Mogollon-Gila)-Sawmill-Magdalena (Mogollon-Gila)
- Nogal Canyon (Mogollon-Gila)
- Twin Sisters (Mogollon-Gila)
- Schoolhouse Mountain (Mogollon-Gila)
- Valles Caldera (Jemez)

Composite volcanoes

- Sierra Blanca
- Agua Fria (Ocaté)
- Mount Taylor
- Laughlin Peak (Raton)

Volcanic fields

- Raton-Clayton
- Ocaté (Mora-Wagon Mound))
- Taos Plateau
- Mount Taylor field
- Zuni-Bandera
- Red Hill
- Cerro del Rio
- Potrillo field
- Cat Hills field
- Lucero field

• INTERMEDIATE SIZE

Exogenous domes

- San Antonio Mtn (Taos)
- Ute Mountain (Taos)
- Cerro de la Olla (Taos)
- Cerro del Aire (Taos)
- Cerro Montoso (Taos)
- Cerro de los Taos
- Ortiz Mtn (CdR field)
- Potrillo Mesa (CdR)
- Sierra Grande (Raton)

Endogenous domes

- Cerro del Medio (Valles Caldera)
- Cerro del Abrigo (Valles)
- Cerro Santa Rosa (Valles)
- Cerro Toledo (Valles)
- Bearhead Peak (Valles)
- Cerro San Luis (Valles)
- Cerro Seco (Valles)
- San Antonio Mtn (Valles)
- Banco Bonito (Valles)

- South Mountain (Valles)
- Cerro La Jara (Valles)
- East Grants Ridge (MT field)
- Cerros de Guadalupe (MT field)

Shield volcanoes

- Cerro Verde (Lucero field)
- San Felipe volcano (SF field)
- Jornada del Muerto volcano
- Aden Crater (Potrillo field)
- Cerro Rendeja (Zuni-Bandera)
- El Tintero (Zuni-Bandera)
- Isleta volcano (central Rio Grande)
- Wind Mesa (central Rio Grande)

Lava flows and flow fields

- McCartys (El Malpais)
- El Calderon
- Zuni Canyon
- Carrizozo (Valley of Fires)

Fissure vents

- Albuquerque volcanoes (central Rio Grande rift)
- Cerros de Alejandro (MT field)
- Laguna Cerro (MT field)
- Cat Hills (central Rio Grande rift)

• SMALL SIZE

Scoria (cinder) cones (young examples)

- Capulin Volcano
- Bandera Crater (Zuni-Bandera)
- El Calderon (Zuni-B andera)
- Chain of Craters (Zuni-Bandera)
- south vent Cat Hills

Maars (explosion craters)

- Zuni Salt Lake (Zuni-Bandera)
- Red Hill maars
- Hunts Hole (Potrillo)
- Kilbourne Hole (Potrillo)
- Potrillo Maar (Potrillo)
- Mt. Riley Maar (Potrillo)
- Malpais Maar (Potrillo)
- Alejandro maars (MT field)
- Grande maar (MT field)
- Montoso Maar (CdR)

Exceptional and complex intrusive features or eroded volcanoes

- Cerro Colorado (central Rio Grande rift-Rio Puerco)
- Shiprock (Navajo field)
- Canjilon Hill (San Felipe field)
- Rio Puerco volcanic necks (Mount Taylor field)
- East Grants Ridge cone (Mount Taylor field)
- Bear Mouth (Mount Taylor field)
- Buckman Mesa (Cerros del Rio field)
- Mush Mountain (Lucero field)

Reading volcanology texts and gaining experience with the actual features of interest are the best ways to develop a familiarity with the overall phenomena.

A goal of many amateur activities is to provide material that may be of use to the scientific community. What is needed is the identification and cataloging of examples of important volcanic phenomena. Not to be confused with rock hounding or mineral collecting, the study of volcanic features is concerned with identifying examples and understanding the dynamic process involved in the formation of common volcanic features, often as recorded in the rock evidence as outcrops or even as the landforms themselves.

The useful data can come in many forms, some of which are briefly outlined below. Also, the popular conception is that the only volcanoes that you can "do something with" are active volcanoes. In reality, inactive volcanoes often retain a wealth of information not observable in active ones. Even where they have been mapped geologically, most inactive volcanoes are relatively unexplored in terms of the details of volcanic features. Or if explored carefully, the features may not be cataloged or otherwise recorded for general use and later recovery.

Many volcanic processes are relatively intuitive, particularly those associated with lava flows. By simple deductive reasoning, taking into account the fluid process of a flowing and cooling material, one may trace the development of many features. Many smaller details of lava flows are poorly documented in the scientific literature. A collection of examples, by photograph and written documentation, can ultimately lead to a better understanding of the overall process of lava flow emplacement.

Likewise, the structures and landforms observable on many volcanoes, particularly small scoria cones, lend themselves to interpretation by the non-specialist. Volcanic bombs (pieces of fluid magma ejected during an eruption) come in many shapes and styles, and are potential objects of collection and categorization. A careful account of these sorts of details can discover common as well as unusual processes that occurred during the eruption of individual volcanoes. As with any casual endeavor, many observations often lead to more spectacular and interesting discoveries.

ACKNOWLEDGMENTS

Jeff Noblett and Richard Chamberlin provided helpful comments of this manuscript

Books and Articles for More Detailed Information

No existing texts discuss volcanoes of New Mexico at a level applicable to non-specialists. Currently the best source of information for many areas are various articles published in the New Mexico Geological Society's excellent Annual Field Conference Guidebook series. However, these tend to be professionally-oriented and may not provide the details sought by non-specialists, particularly with regard to the landforms of volcanological interest. For now, the above list of sites to visit and see volcanoes will have to suffice, with hopes that the situation may be rectified in the future. In addition, the following books contain abbreviated discussions of many volcanic areas in New Mexico:

- Maybery, M. V., Moore, R., and Hon, K., 1999, *The Volcanic Eruptions of El Malpais: A Guide to the Volcanic History and Formations of El Malpais National Monument*: Ancient City Press, Santa Fe, 83pp.
- Wood, C. A., and J. Kienle, 1990, *Volcanoes of North America*, New Mexico Chapter: Cambridge University Press, New York, p.290-313.

GLOSSARY OF VOLCANOLOGICAL TERMS USED

aa flow: (pronounced "ah-ah") lava flows having a rough, fragmental surface. The lava flow that erupted from Bandera Volcano is a classic example of aa.

ash flow tuff: The rock derived from an "avalanche" or flow of hot volcanic ash that compacts and welds after coming to a rest (also known as ignimbrite). The Bandelier Tuff and Battleship Rock in the Jemez Mountains are examples.

basalt: Dark, fine-grained volcanic rock that includes many lava flows and most mesa-capping lava flows. It consists of plagioclase feldspar, pyroxene, and some olivine. Porphyritic basalts may contain phenocrysts of feldspar (Albuquerque Volcanoes), olivine, or pyroxene. Two types are common in New Mexico: tholeiite (Albuquerque Volcanoes, McCarty's, Carrizozo) containing calcic feldspar, and alkali basalt (Bandera, Mesa Chicato) containing potassic feldspar.

caldera: A large volcanic collapse depression that is circular, or approximately circular in plan shape, the diameter of which is many times greater than any included vents. The Valles Caldera of New Mexico is one of the largest young calderas in the world. It is a type known as a resurgent caldera in which the floor was uplifted subsequent to collapse. Redondo Peak, near the center of the caldera, is the resurgent dome.

cauldron: A volcanic depression or volcanic subsidence-related feature regardless of size, shape, depth of erosion, or association with surface volcanism, hence is used in preference to "caldera" when the surface morphology has been removed by erosion. The Gila Wildernes and Mogollon Mountains region of Southwestern New Mexico is an enormous collection of mid-Tertiary age cauldrons whose original morphology was very similar to the much younger Valles Caldera.

cinder cone: (See "scoria cone/cinder cone")

composite volcano: A volcano consisting of a variety of eruption materials (ash, lava, mudflows, debris flows, and volcanoclastic deposits). Built from many eruptions over time. Also known as stratovolcano. Mount Taylor is an example.

crater: A steep-walled depression at the top, or on the flanks, of a volcano directly above the pipe or vent that feeds the volcano. Primarily the result of explosions during the eruption of the volcano. The craters of Bandera Volcano and Capulin Volcano are good examples.

lava flow: An outpouring of molten lava from a vent or a fissure; also a solidified body of rock that is so formed.

lava tube: A hollow space beneath the surface of a solidified lava flow formed by withdrawal of molten lava after the formation of a surficial crust. Lava tubes are in the lava flows of El Malpais region, but occur in many of the other young lava flows of New Mexico.

maar: A volcanic crater formed by violent steam explosions occurring when magma meets water at or near the surface. In this case the crater is the volcano; usually there are no volcanic flows or volcanic material surrounding the crater. World-famous examples of maar craters are New Mexico's Kilbourne Hole and Zuni Salt Lake. Maars are frequently occupied by small lakes; the name comes from the German "lake".

pahoehoe flow: (pronounced "pa-hoy-hoy"). A type of basaltic lava flow surface characterized by a glassy, smooth and billowing, ropy or undulating surface. The McCarty's lava flow exhibits this kind of flow surface.

phreatomagmatic deposits: volcanic material deposited by maar or maar-type eruptions. Examples occur in White Rock Canyon.

pyroclastic: A general term applied to volcanic materials such as cinder and scoria that have been explosively ejected from a volcano.

scoria/cinder cone: Conical edifice accumulated from volcanic ejecta such as cinder, scoria, and ash; when young, the sides are defined by the angle of repose; also commonly referred to as "cinder cone". New Mexico has numerous examples of scoria cones in all stages of preservation. One example is so symmetrical that it is a National Monument (Capulin). Other young examples include Bandera Crater volcano.

vesicles: Small cavities formed by the expansion of gas or steam bubbles during the solidification of volcanic (usually basaltic) rock.

volcanic bomb: An angular, round or irregularly shaped mass of formerly molten volcanic lava that is ejected during a volcanic eruption and solidifies as it flies through the air. Bombs of different shapes have been given names such as ribbon bomb, breadcrust bomb, cowpie bomb. Many cinder cones in New Mexico have ejected volcanic bombs during their eruptions.

volcanic field: An area that consists of multiple volcanoes and their lava flows and ash. Any concentration of volcanoes. An example is the Zuni-Bandera field.

volcanic neck: If a volcano is the "head", then the feeder plug is the neck: when the head is eroded away, the neck is all that remains. Shiprock and the Rio Puerco necks are classic examples.

xenolith: A term applied to rock fragments that are part of surrounding rock types and are caught up in a volcanic rock.



The vent area of the McCartys lava flow, El Malpais-Zuni-Bandera Field. Photo by L. Crumpler.



Cerro Guadalupe volcanic neck, Rio Puerco. Photo by Terry Ballone.