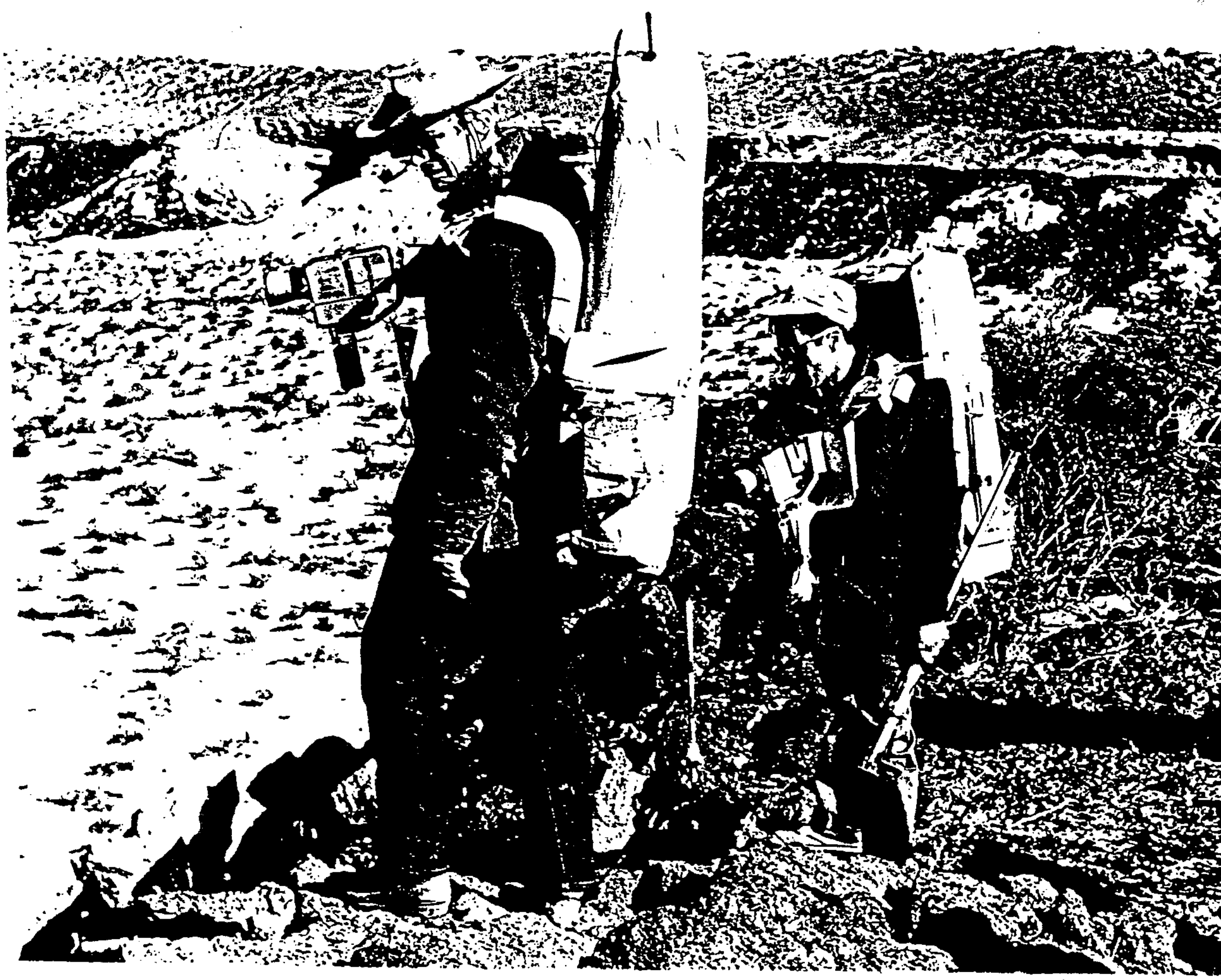
EL PASO GEOLOGICAL SOCIETY

1998

GEOLOGICAL EXCURSIONS OF THE EL PASO AREA: VOLUME II: KILBOURNE-HUNTS HOLES AND VICINITY, NEW MEXICO

Edited by

Jerry M. Hoffer and Robin L. Hoffer



COVER

Apollo 17 astronauts Eugene A. Cernan (left) and Harrison H. Schmitt (right) went through training exercises at Kilbourne Hole during December 1971 in preparation for their moon landing on December 12, 1972. They returned 253 lb of lunar rock and soil samples and covered 18.9 mi in the lunar rover during their 75-hour visit.

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COMMENTS FROM THE EDITORS

At a meeting of the El Paso Geological Society Executive Committee in late 1989, it was suggested that we should publish a series of mini-guidebooks dealing with specific geological features in the El Paso area that could be visited in a period of a day or less. The purpose would be to produce a low cost, concise guidebook that would be more appealing and useful to the teachers and students within the local schools.

The first guidebook, *Geological Excursions of the El Paso Area: Volume I --Geology of the Aden Crater Area*, was published in 1990. After a hiatus of nearly eight years *Volume II: Kilbourne-Hunts Holes and Vicinity* is now completed.

Kilbourne Hole is known world-wide because of its occurrence of rare mantle and lower crustal xenoliths brought to the surface during its explosive formation. We have received numerous calls from local residents during the past several years wanting to know where they could obtain information on Kilbourne Hole. None of our guidebooks dealing with Kilbourne, which were published in 1973 and 1981, are currently in print. Therefore, we decided the subject of Volume II should be devoted to Kilbourne and Hunts Holes.

Jerry and Robin Hoffer
August 1998

ROAD LOG TO BLACK MOUNTAIN, GARDNER CONES AND KILBOURNE-HUNTS HOLES, NEW MEXICO

by

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Starting Point: Intersection of Trans-Mountain road (Loop 375) and Interstate-10 (on east side). Driving distance is 87 miles with five stops or with optional trip to Gardner Cones 94.6 miles and six stops, (see Index Map, Figure 1).

Mileage	Cumulative	
0.0	0.0	Intersection I-10 (north) and Trans-Mountain road; turn right (toward Las Cruces)
3.1	3.1	Vinton Exit; continue straight ahead
2.4	5.5	Texas Highway Department rest area on left
0.4	5.9	Anthony; exit here and stay in left lane to stop light; turn left over the Interstate and proceed into Anthony
1.5	7.4	Stop light; turn right on Texas 20
0.2	7.6	Stop light; continue straight ahead
0.2	7.8	Turn left onto New Mexico 478
4.5	12.3	Enter Berino
0.4	12.7	Berino; turn left on New Mexico 226 and cross railroad tracks
1.6	14.3	Cross Rio Grande
0.9	15.2	Turn right on New Mexico 28
1.5	16.7	Turn left on Afton road
1.4	18.1	Cross cattle guard
1.0	19.1	Solid Waste Disposal Station on right
3.3	22.4	Turn left on dirt road to Black Mountain (see. Fig. 2)
0.6	23.0	Bear left and pass by old water tank

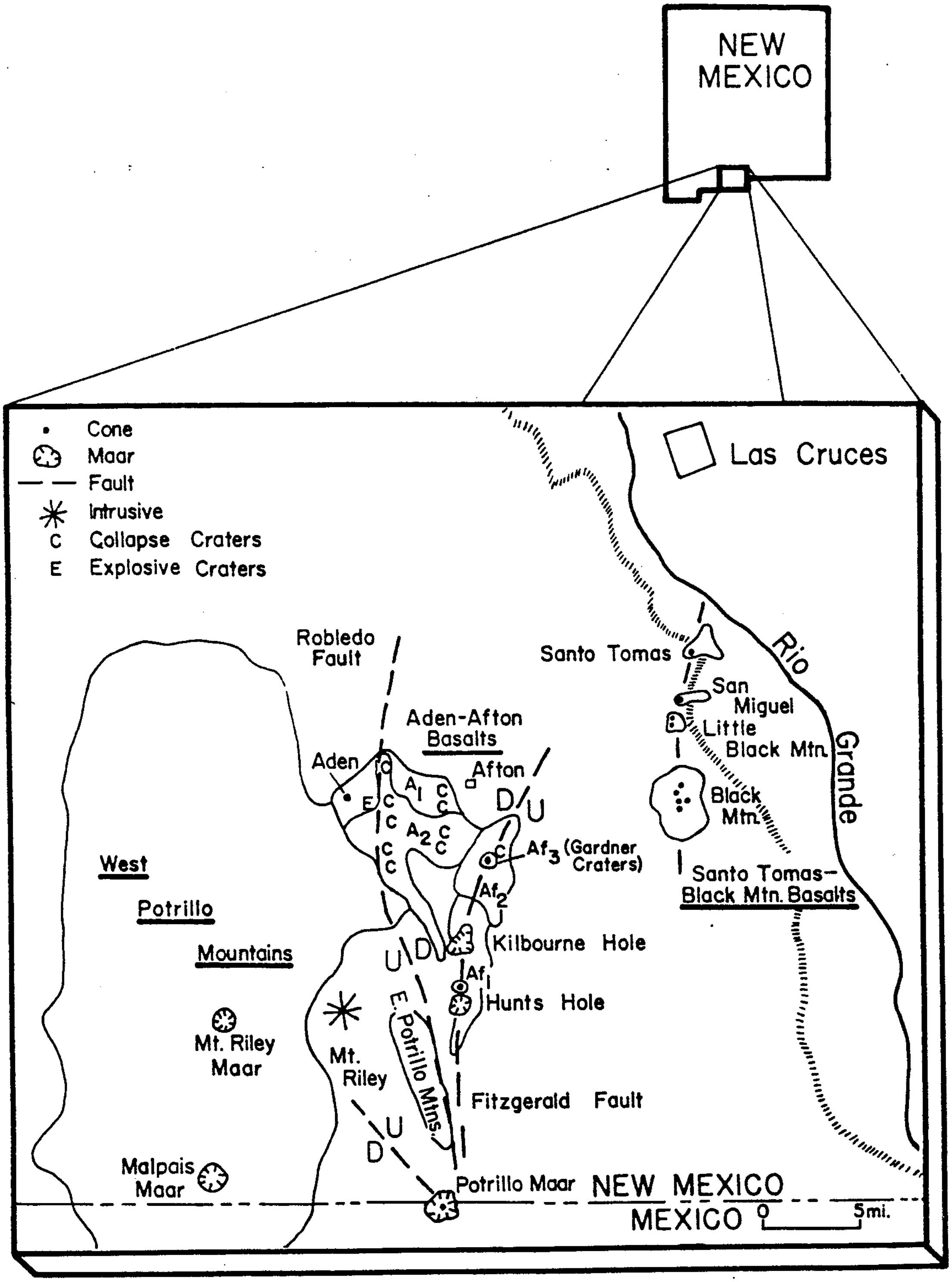

Figure 1. Index map of the field trip area.

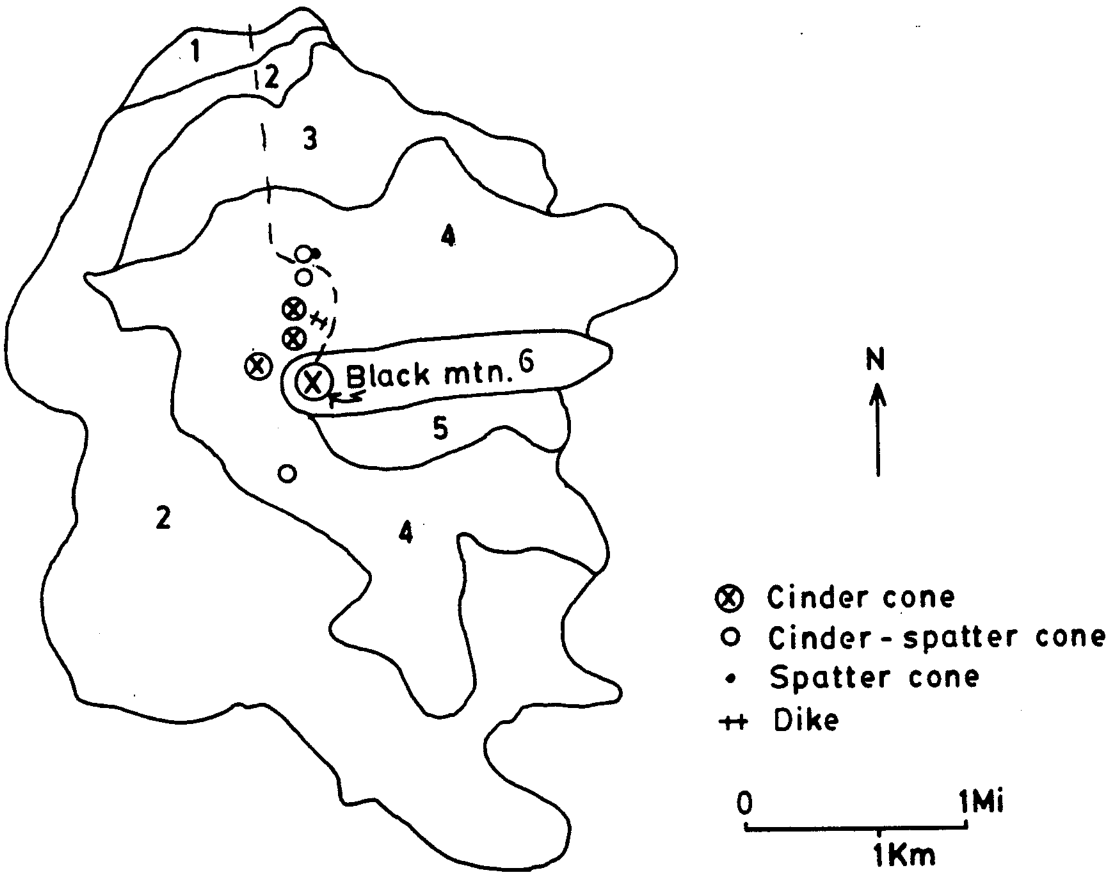

Figure 2. Volcanic features in the Black Mountain area.

Mileage	Cumulative	
0.2	23.2	Straight ahead – view of spatter-capped cinder cone (on right), sand covered cinder cone (center) and Black Mountain cinder cone (left)
0.9	24.1	Cinder cone with spatter rim to the left
0.3	24.4	Basalt dike at 3:00 (see Figure 3)
0.3	24.7	**Stop 1**. Black Mountain quarry

The Black Mountain area consists of eight volcanic cones and at last six major lava flows (Hoffer, 1969, 1990). Positive determination of the cone or cones from which each flow originated is almost impossible because of the cover of blown sand. Only the youngest flow, the Black Mountain flow, can be traced to a specific cone where it probably was erupted from a lateral vent.

In the center of the area are four cinder cones, the largest being the Black Mountain cone. The cone is almost symmetrical in outline with a diameter of almost 800 ft and a height of 130 ft.

Three cinder-spatter cones are located north (two) and south (one) of Black Mountain. Typically, these cones possess a low sloping base composed of cinder and spatter capped by a rim of agglutinated spatter. The layers of spatter and driblet dip steeply inward

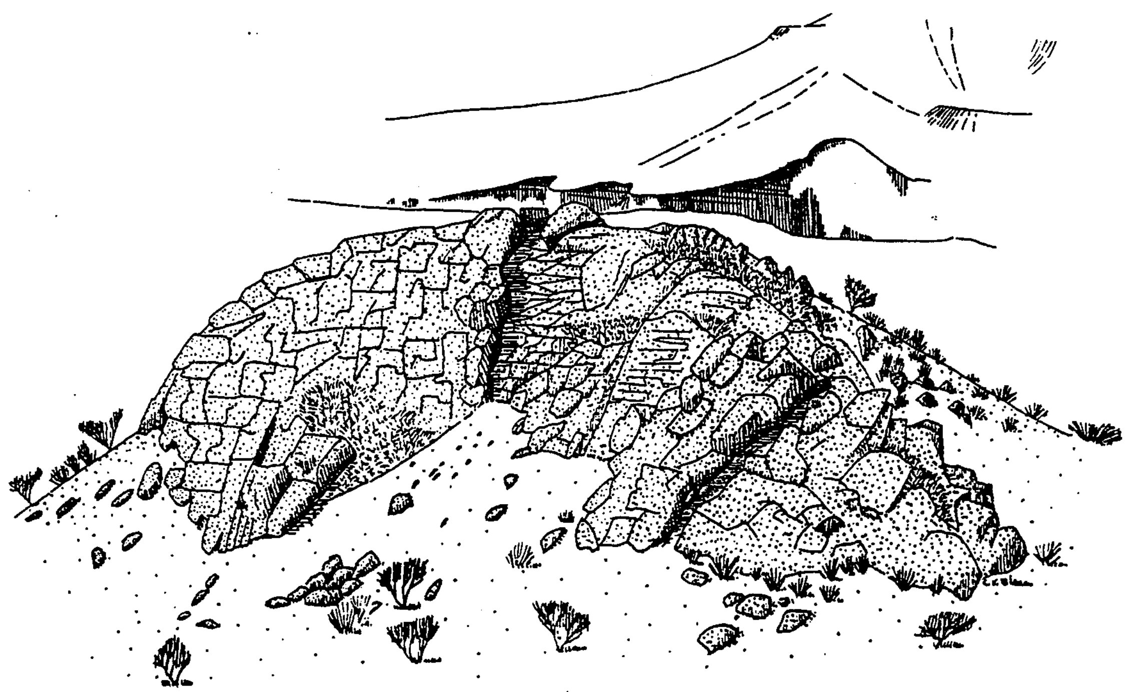

Figure 3. Dike structure located just north of Black Mountain.

toward the center of the cone. The cones range in diameter from 90-240 ft and in height from 15-42 ft.

A small cone composed of spatter and capped by small flow units occurs on the northeast flank of the northern-most cinder-spatter cone.

Just north of the Black Mountain cone is a small elongate ridge approximately 30 ft. high and 60 ft. long. Columnar joints, developed on each side of the hill, are nearly horizontal at the base, but dip into the center of the hill near the top. In the central position of the mass are individual flows (or flow units), 1 to 2 ft. thick which are oriented almost vertically.

On the basis of the jointing and the presence of subvertical flow structures in the interior, the ridge is thought to represent a dike which probably supplied lava for one or more of the flows at Black Mountain. One of the flows from the interior of the dike has mineralogy similar to the Black Mountain flow.

The age of the volcanic activity of Black Mountain is as young as 77,000± 4,000 yrs to 85,000±7,000 yr. based upon the surface exposure dates (Anthony and Poths, 1992).

Mileage	Cumulative	
0.2	24.9	Return to road and exit quarry; retrace dirt road back to black top
2.3	27.2	Turn left on blacktop road and head west
1.7	28.9	Road to right leads to Little Black Mountain and San Miguel; continue straight ahead

The Little Black Mountain and San Miguel flow are located 4 and 5 mi north, respectively, of Black Mountain. Each center has only a single extrusive flow of olivine basalt.

The Little Black Mountain flow covers an area of <1 mi^2. Located near the west-central portion of the flow are two small cones; the southernmost is a well exposed cinder-spatter cone. but the northern cone is virtually buried by sand. The cone displays a well-developed, steep rim of spatter resting on a gently sloping base of spatter and cinder and is approximately 700 ft in diameter and approximately 90 ft in height. The sand-covered cone to the north is smaller being about 500 ft in diameter and 60 ft in height. The exact thickness of the basalt flow at Little Black Mountain is not known because the base is not exposed as most of the outcrops are covered by sand.

The San Miguel flow, locally termed the "Finger flow" because of its narrow elongate shape, was extruded from a small cone, 50-60 ft high, on the La Mesa surface and flowed into the Rio Grande Valley (Hoffer, 1969). This flow, probably extruded on a graded surface associated with an early stage of river valley entrenchment covers an area of approximately 0.5 mi^2, being a little more than 2 mi long and averaging 400 m (1200 ft) wide. Because of the cover of sand at the west end of the flow, the exact nature of the cone and point of extrusion are not known.

Age dates for the Little Black Mountain lava flow range from 117,000 ± 9000 years to 137,000 ± 9000 years (Williams, pers. comm., 1995). No age dates are currently available for the San Miguel basalt flow.

Mileage	Cumulative	
1.1	30.0	Cattle guard
1.7	31.7	EPNG pipeline plant
0.4	32.1	Cattle guard; blacktop pavement ends
0.9	33.0	Turn left on B4
2.5	35.5	Cattle guard
0.7	36.2	U.S. Coast Guard tower on left
1.2	37.4	Slow down – sharp right turn
1.0	38.4	View of West Potrillo Mountains (11:00-1:00), Mount Riley and Cox (10:30), and East Potrillo Mountains (9:30-10:30)
0.8	39.2	Cross under power lines
0.5	39.7	Intersection; turn left
0.1	39.8	Cattle guard

Mileage	Cumulative	
0.2	40.0 (*47.6)	Right turn and cross railroad tracks, cattle guard, and then turn left onto A-17 (right turn goes to Aden Crater). Straight ahead (south) for optional trip to the Gardner cones. Caution, do not proceed unless you have a high-clearance vehicle. The trip is 7.6 mi, round-trip, over rough road.
2.0	42.0 (*49.6)	Cattle guard
1.4	43.4 (*51.0)	Cattle guard
4.2	47.6 (*55.2)	Turn right and head south toward Mtn. Riley and Cox and Kilbourne Hole.
2.4	50.0 *(57.6)	Intersection; continue straight ahead
0.8	50.8 *(58.4)	Cattle guard
0.8	51.6 *(59.2)	Intersection; continue straight ahead
3.1	54.7 *(62.3)	Cattle guard
1.1	55.8 *(63.4)	Road to the right; continue straight ahead
0.5	56.3 *(63.9)	Note base-surge deposit along the road from Kilbourne Hole
0.5	56.8 *(64.4)	Turn right into Kilbourne Hole
0.1	56.9 *(64.5)	**Stop 3** . Kilbourne Hole overlook.

Figure 4. Bomb-sag structure in the tuff deposits, east side of Kilbourne Hole.

*Use mileage in this column if you took the optional trip to the Gardner cones.

Mileage	Cumulative	
		Turn around and drive south to Hunts Hole
1.5	58.5 (66.1)	Small spatter cone, just north of Hunts Hole, on the left.
0.2	59.6 (67.2)	View of Mtn. Riley and Cox (1:00-1:30); continue south
0.9	59.6 (67.2)	Cattle guard
1.0	60.6 (68.2)	**Stop 4**. Hunts Hole.

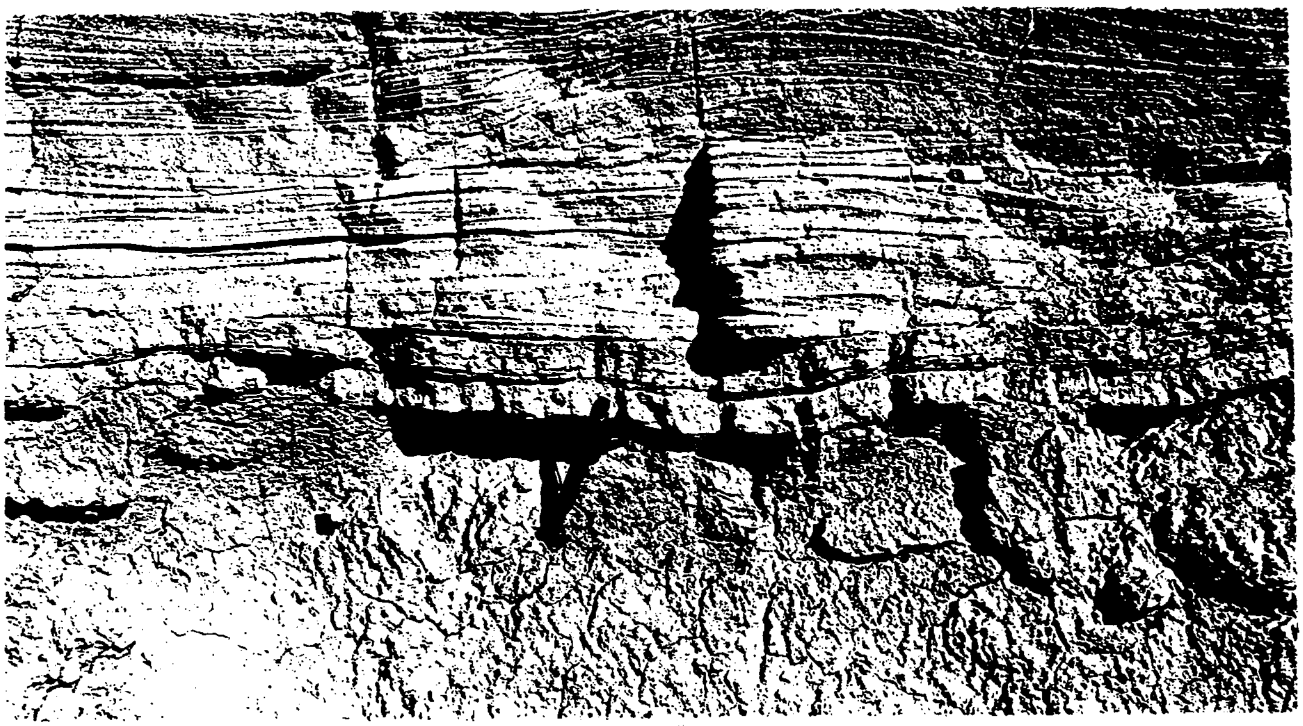

Figure 5. Airfall deposits (top of pen) overlain by base-surge deposits at Hunts Hole.

Mileage	Cumulative	
0.3	60.9 *(68.5)	Intersection; turn left
0.8	61.7 *(69.3)	Cross lava flows (Afton basalt)
6.2	67.9 *(75.5)	Cattle guard
4.8	72.7 *(80.3)	Intersection; turn right and cross cattle guard

Mileage	Cumulative	
0.3	60.9 *(68.5)	Intersection; turn left
0.4	73.1 *(80.7)	Turn left and cross railroad tracks
4.9	78.0 *(85.6)	**Stop 5.** Overview of the Rio Grande Valley and the Organ, Franklin, and Juárez Mountains
1.0	79.0 *(86.6)	Cattle guard
0.8	79.8 *(87.4)	Entering La Union (Alvarez Ave.) on paved road
0.4	80.2 *(87.8)	Stop sign; turn left on Main Street
0.2	80.4 *(88.0)	La Union Elementary School on right
0.8	81.2 *(88.8)	Stop sign; turn right on New Mexico 28
2.7	83.9 *(91.5)	Bear left and continue on New Mexico 28
1.3	85.2 *(92.8)	Stop light; continue straight ahead
0.3	85.5 *(93.1)	Cross railroad tracks and turn right at stoplight onto Texas 20 in Canutillo
0.5	86.0 *(93.6)	Stop light; turn left onto Loop 375 and head east
1.0	87.0 *(94.6)	Junction I-10 and Trans-Mountain road (Loop 375); end of field trip

SUPPLEMENTAL ROAD LOG FROM AFTON (A-17) TO GARDNER CONES

Mileage	Cumulative	
	40.0	Continue straight ahead on dirt road
0.2	40.3	drive up onto basalt flow and then down
0.3	40.6	Drive up onto another flow surface; Gardner cones at 12:00; Mtn. Riley-Cox in distance; East Potrillo Mtns. at 10:00-11:00
0.1	40.7	Lava flow front at 3:00
0.2	40.9	Bear sharp right
3.0	43.9	Continue to follow the poorly marked road to the south (stopping now and then to find the road!) and stop along fence where basalt crosses the road; cross the fence area and examine the volcanic features of Gardner Cones. Return to A-17; to continue road log utilize the mileage indicated in brackets, i.e. (...)
3.8	(47.6)	

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GEOLOGY OF THE AFTON LAVA FLOWS AND THE GARDNER CONES

by
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AFTON LAVA FLOWS

The Afton flows consist of three separate periods of basaltic lava emplacement south and southeast of Afton (see Index Map in Roadlog). The oldest flow (Af_1) covers approximately 13 square mi, measuring 9 mi in length and averaging slightly less than 2 mi in width (Hoffer, 1976). This flow is exposed in the rim of both Kilbourne and Hunts Holes where it obtains a maximum thickness of 25 ft. A sample of this flow south of Hunts Hole was age dated by the cosmogenic helium method and yielded ages ranging from 114,000 ±7,000 years to 120,000 ± 8,000 years (Williams, pers. comm., 1995).

The middle basaltic lava flows (Af_2) crops out over an area of 9 square miles north and south of the Gardner cones. Its most prominent features include small marginal pressure ridges, shallow collapse depressions, and a major north-trending trough-shaped depression. This lineament can be traced north of the basalt field where it is expressed as a series of fault scarps and elongate depressions termed the Fitzgerald Fault (Hoffer, 1976).

The youngest basalt flows (Af_3) consist of 3 to 4 local flows covering 0.5 square mi which were emplaced as eruptions associated with the Gardner cinder and cinder-spatter cones.

GARDNER CONES

General Description

The Gardner volcanic cones are located approximately 5 mi south-southeast of Afton. The cones occur in a cluster of four individual volcanoes which include two cinder cones (numbers 2 and 3), a cinder–spatter cone (number 1), and a cinder-cone with a conical peak (number 4). The cones range in height from just over 100 ft to 143 ft. in elevation (Figs. 6 and 7).

The southwestern cone (number 1) is a cinder cone with a well-developed spatter rim which produced a 200 foot diameter bowl-shaped crater at the top of the cone. The floor of the central crater lies 15 to 20 ft below the spatter rim.

Local lava flows, covering approximately 0.5 square mi around the craters, appear to have originated from several of the cones as flank eruptions. Two small lava flows have been traced to the southern flank of cinder cones numbers 2 and 3.

The most unusual cone is number 4 which is the northern most volcano. Near the top of the conical peak on the southeast rim of the cinder-spatter cone occurs a dense, light-gray intrusive basaltic body. Basaltic spatter and cinder can be seen in contact both above and below the intrusive phase (Fig. 8). The dike-like body reaches its maximum thickness of 15 ft on the west side of the cone and thins toward the east where it disappears into the spatter after about 40-50 ft.

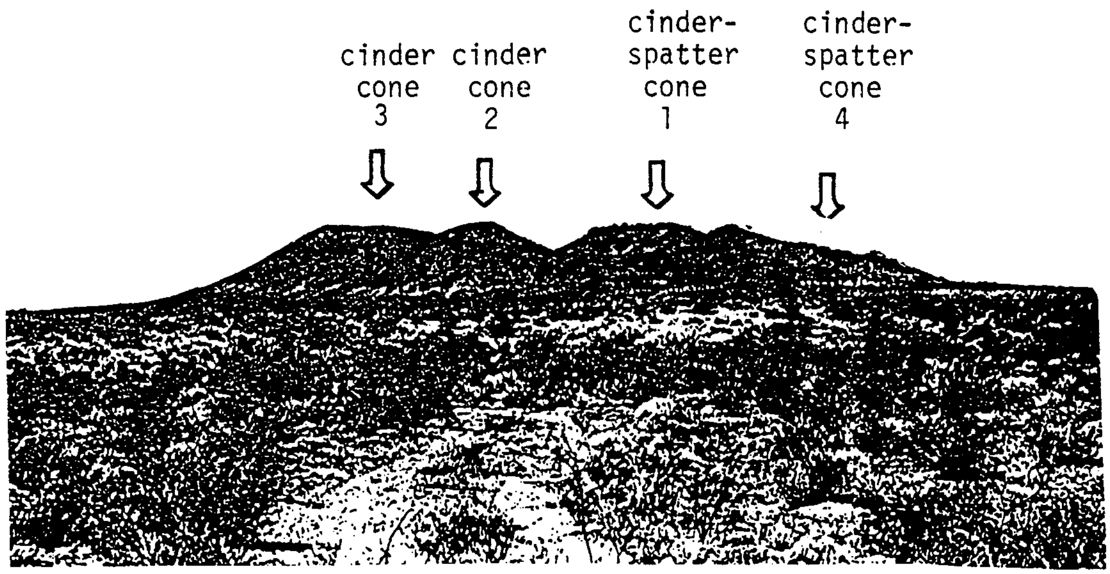

Figure 6. View of the Gardner cones from the north (numbers refer to cones in figures 6 and 7

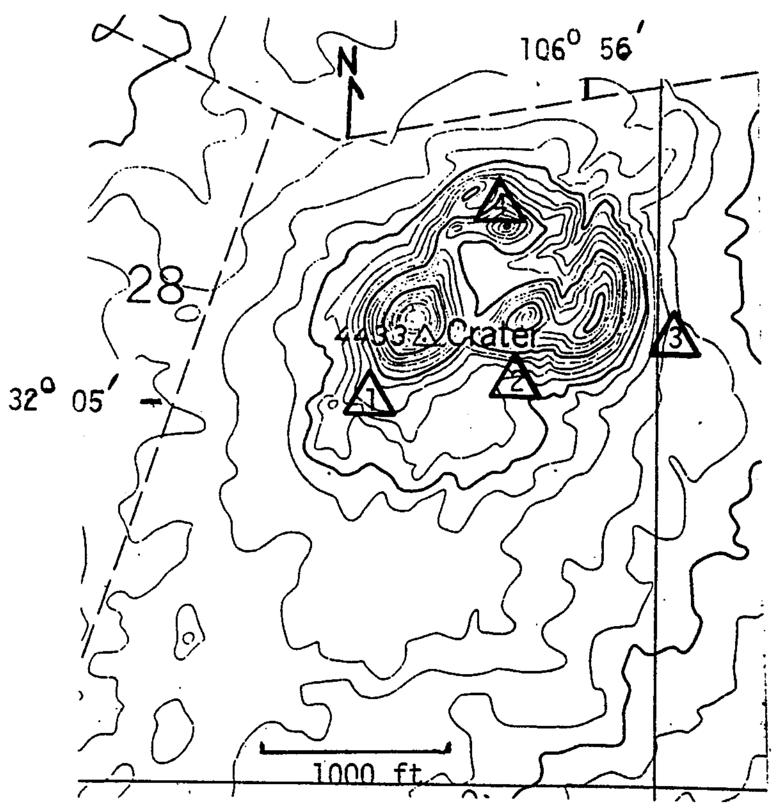

Figure 7. Topographic map of the Gardner volcanic cones (C.I. = 10 ft).

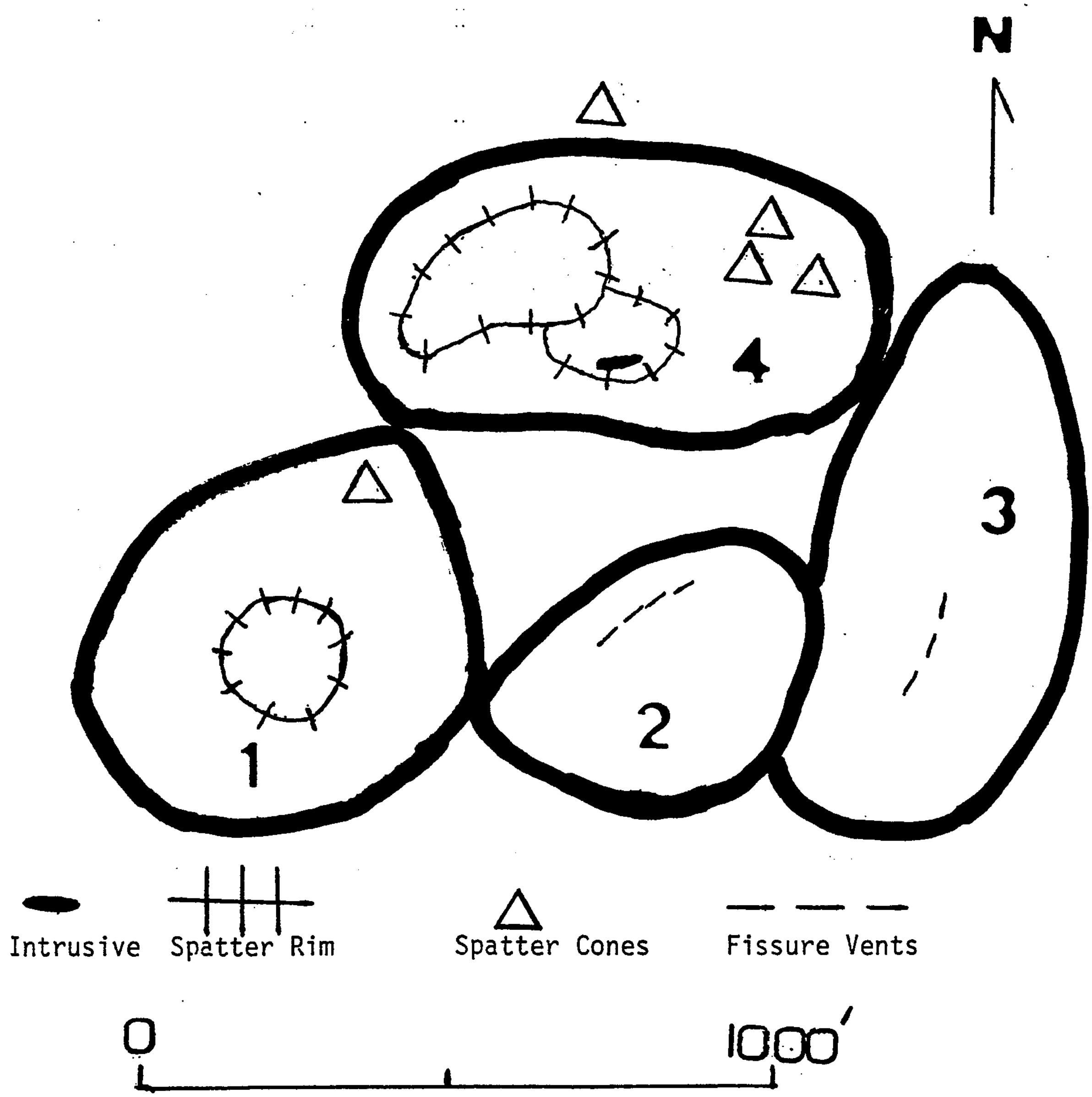

Figure 8. Sketch map of volcanic features on the Gardner cones.

The intrusive is light gray in contrast to the black to brown color of the spatter. Petrographically, both the intrusive and volcanic cinder are basaltic, but the cinder is vesicular whereas the former is not. The bleached color of the intrusive appears to be the result of deuteric alteration after its emplacement.

Volcanic Activity and Structures

Volcanic materials exposed in the Gardner cones area include cinder, spatter, bombs, and lava flows (Af_3) of olivine basalt. Volcanic features include cinder cones, cinder cones with moderate-sized vents (150-300 ft diameter) rimmed with spatter and smaller spatter rims located on the lower slopes of the cone or outside the base of the cone, and an intrusive phase of dense basalt injected into spatter layers.

The age of the volcanism is probably less than 100,000 years based on two lines of evidence. Anthony and Poths (1992) have reported a cosmogenic He date of 81,000 ± 4,000 year from a basalt flow stratigraphically below the cones (Af_2). Cone morphology and apparent reflectance in visible in short wavelength infrared indicate an age of no more than 100,000 years (Hoffer et al., 1998).

In general, the type of volcanic feature produced by a basaltic magma is dependent upon the rate of escape of the dissolved gases (mainly water) in the magma. Gas solubility in a magma is controlled mainly by pressure. If a magma moves quickly to the earth's surface (low pressure environment) from depth (high pressure environment), gas solubility decreases and its rate of escape rapidly increase. Therefore, rapid magma ascent will produce high fountaining at the vent. This will fragment the magma into small blebs which vesiculate and solidify into cinder. The cinder will accumulate unwelded around the vent and produce a cinder cone.

Occasionally large masses of molten magma are ejected from the vent. Because of the fluidity of these fragments, their shapes are streamlined during flight forming spindle or fusiform bombs. The bombs are denser than cinder and form during a period when the amount of gas in the magma has started to decline (MacDoñald, 1972). Several large fusiform bombs, over 4 ft in length, occur on the lower northwest slope of cinder cone number 3 (Fig 9).

As the rate of gas escaping from the magma continues to decline, showers of still-fluid blebs striking the ground will flatten out and mold themselves to the underlying surface.

Figure 9. Large fusiform bomb on the lower northwest slope of cinder cone 3. The bomb is 5.5 ft long and 3.5 ft across (note hammer for scale).

Figure 10. Spatter rim on top of cone 1 which completely encircles the 15-20 foot deep crater.

Frequently their plastic edges stick together and the accumulation of flattened and welded is termed *spatter* or *agglutinate* (Fig. 10).

During further declining rates of escaping gas, the magma flows out onto the surface as a lava flow. The presence of vesicles in the solidified flow were formed during the final period of magma degassing.

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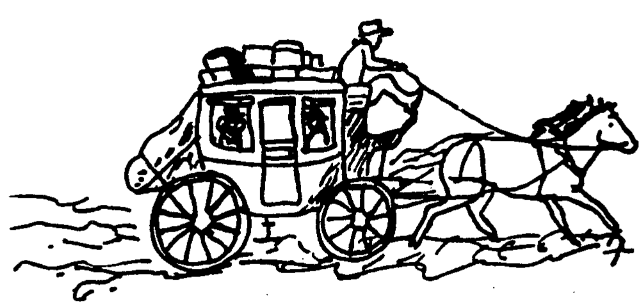

GEOLOGY OF KILBOURNE HOLE

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INTRODUCTION

The most spectacular craters in the Afton area are the maar volcanoes, Kilbourne and Hunt's Hole, formerly called the Afton craters (Lee, 1907). A similar crater, called Potrillo Maar, located approximately 9 mi south of Hunts Hole astride the international boundary (Reeves and De Hon, 1965). Two other maar volcanoes have been identified in the nearby West Potrillo Mountains and referred to as Mt. Riley Maar and Malpais Maar (Hoffer, 1976; Page, 1973) (see Fig. 1).

A summary of the major features of the five maar volcanoes are shown in Table 1.

Table 1. Summary of Maar Volcanoes, Potrillo Basalt Field (Hoffer, 1981).

Name	Topographic Classification	Shape and Dimensions	Tuff Stratigraphy	Post-Explosion Features
Malpais Maar	Tuff ring	Circular; 4100 ft diameter	Well-bedded ash, lapilli tuff, tuff breccia	Cinder cone and basaltic dikes and lava flows
Riley Maar	Tuff cone	Circular; 3000 ft diameter	Poorly bedded, lapilli tuff; tuff breccia (no air-fall or base-surge deposits); fragments and feldspar xenoliths	Small basalt flow in interior
Kilbourne Hole	Maar	Elliptical; 9500 ft by 7500 ft	Well-bedded ash and lapilli tuff; ultramafic nodules enclosed in basalt	Collapse
Hunt's Hole	Maar	Nearly circular; 5300 ft diameter	Same as Kilbourne Hole	None
Potrillo Maar	Maar	Elliptical; 16,000 ft by 11,000 ft	Well-bedded ash; lapilli tuff, minor tuff breccia	Several cinder cones and basalt flows in interior

DESCRIPTION

Kilbourne Hole is a depression 2 mi long and 1.5 mi wide. The floor of the depression is 250 to 300 ft below the surface of the surrounding desert and is bordered on the north, south and east sides by a 10 to 170 ft. high rim.

The deposits exposed in the maar, from bottom to top, included the following units (Hoffer, 1976) (Fig. 11).

1) Sand, silt, and clays of the Santa Fe Group, thickness exposed 65 ft.
2) Olivine basalt flow (Afton flow Af_1), 20-25 ft in thickness.
3) Lower slopes of tuff are covered with coarse basalt eject up to 4 ft in diameter.
4) Bedded tuffs consist of base surge deposits (cross-bedded) and air-fall deposits (thin parallel layers).
5) Holocene blown sand, containing mostly clear, rounded quartz grains cover the crest of the rim and outer slopes.

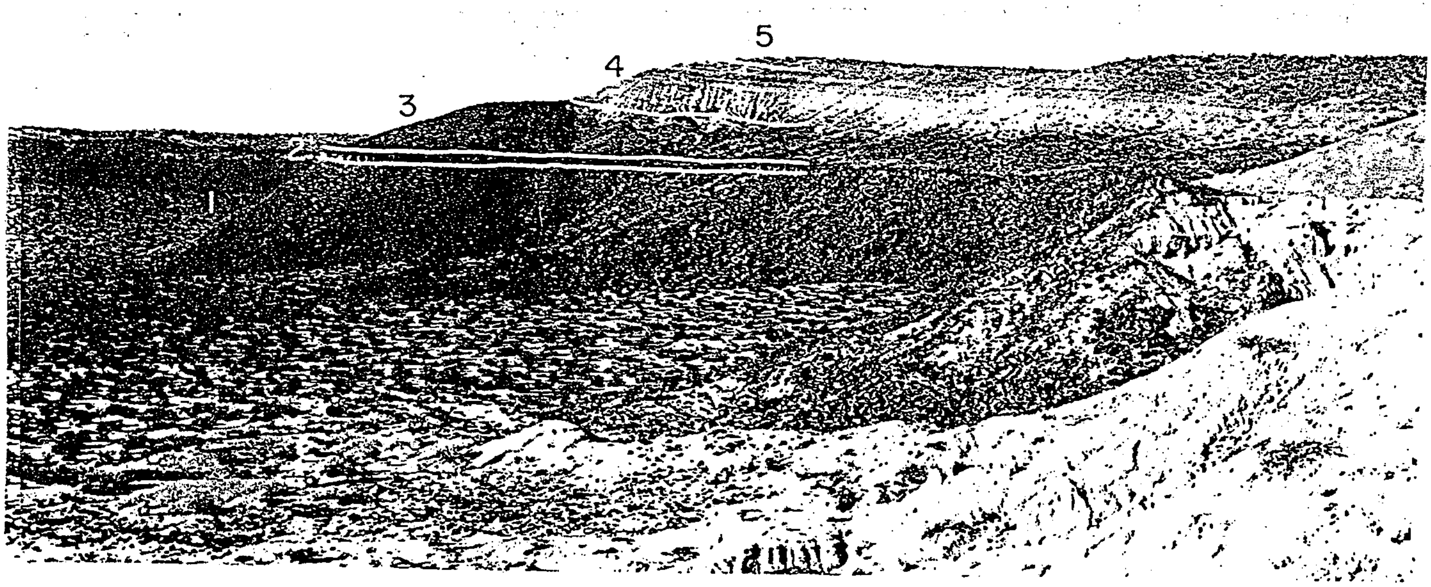

Figure 11. Kilbourne Hole view to the north showing major units exposed. The section consists of 1) Santa Fe group, covered by basalt talus; 2) basalt flow; 3) coarse ejecta mantling rim tuffs; 4) rim volcanics of air-fall and base-surge origin; and 5) Holocene blown sand.

ORIGIN

The origin of Kilbourne Hole has been variously attributed to: 1) subsidence from subsurface solution (Reiche, 1940), 2) volcanic explosion (De Hon, 1965b; Darton, 1911; Shoemaker, 1954; and Lee, 1907), or 3) volcanic eruption followed by caldera-like collapse (Seager, 1987).

Most previous workers visualized the crater was excavated by explosive blasts, Seager (1987) cites two lines of evidence that favors caldera collapse as the most important process in the formation of Kilbourne Hole. The first is the presence of large downfaulted masses of tuff- material located at the base of the inner crater wall and beneath the crater floor (Seager, 1987). The second is the small volume of pyroclastic material in the maar rim and surrounding area compared to the volume of the crater (Seager, 1987) (Fig. 12).

The formation of Kilbourne Hole would thus consist of the following events. First, perforation of Santa Fe Group and Afton Basalt with the formation of basalt breccia. Second, formation of a tuff-ring from pyroclastic surge and air fall deposits during eruptions. Third, caldera-like collapse of part of the tuff ring to form a the maar structure (Seager, 1987). The present crater has since been modified by subsequent slumping, erosion, and alluvium (Fig. 13).

AGE OF MAAR FORMATION

The age of Kilbourne Hole is clearly younger than the Afton Basalt which based upon recent cosmogenic helium dates that range from 114,000 ± 7,000 years to 120,000 ± 8,000 years (Williams, pers. comm., 1995). Gile (1987) estimated the age of Kilbourne to be about 24,000 years, based upon the extent of pedogenic carbonate development in the soils of the rim ejecta. This date is supported by two cosmogenic helium dates from an ejecta block of nearby Hunts Hole of 14,000 ± 7,000 years and 17,000 ± 9,000 years (Williams, pers. comm., 1995).

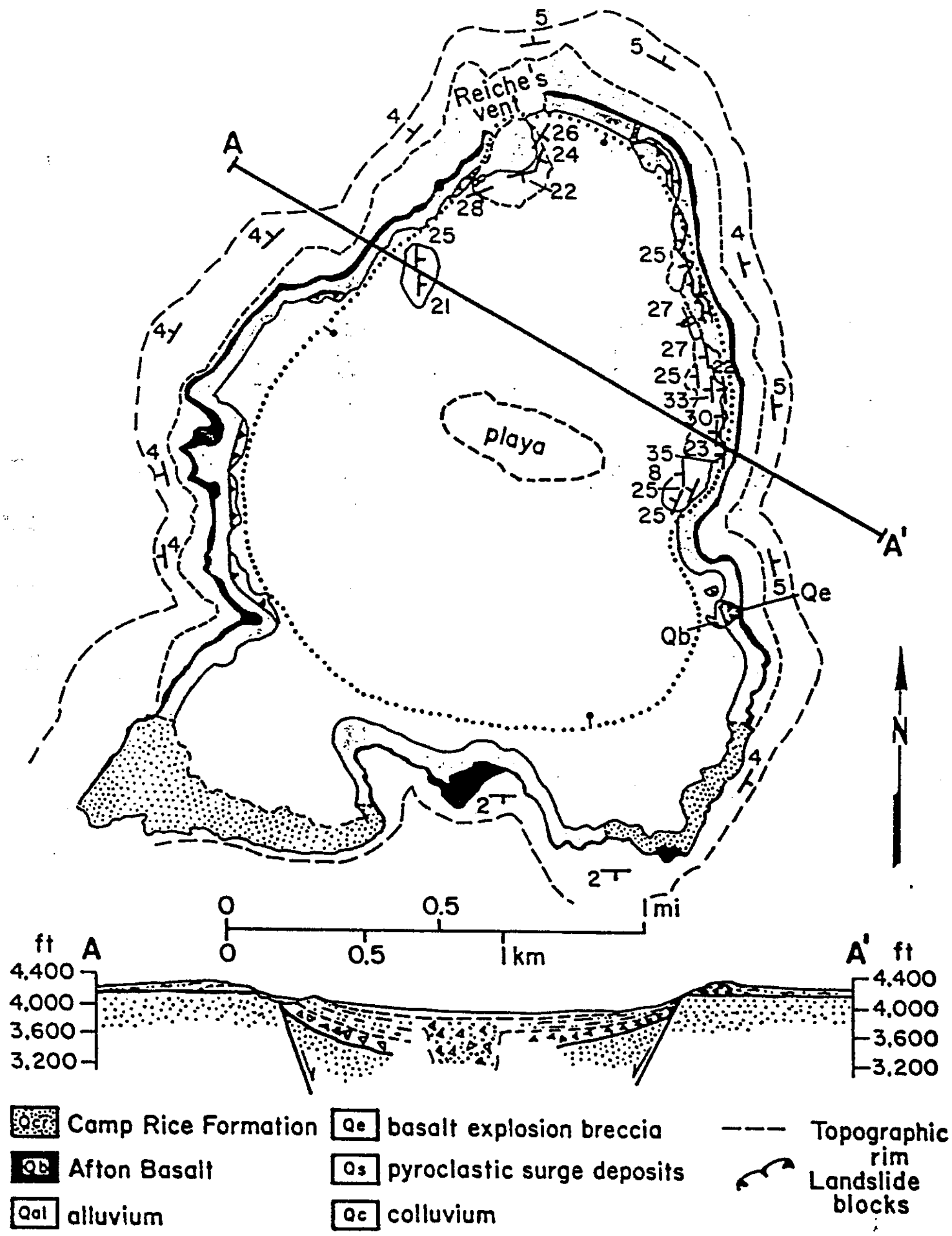

Figure 12. Geologic map and cross section of Kilbourne Hole. All units are Quaternary (from Seager, 1987).

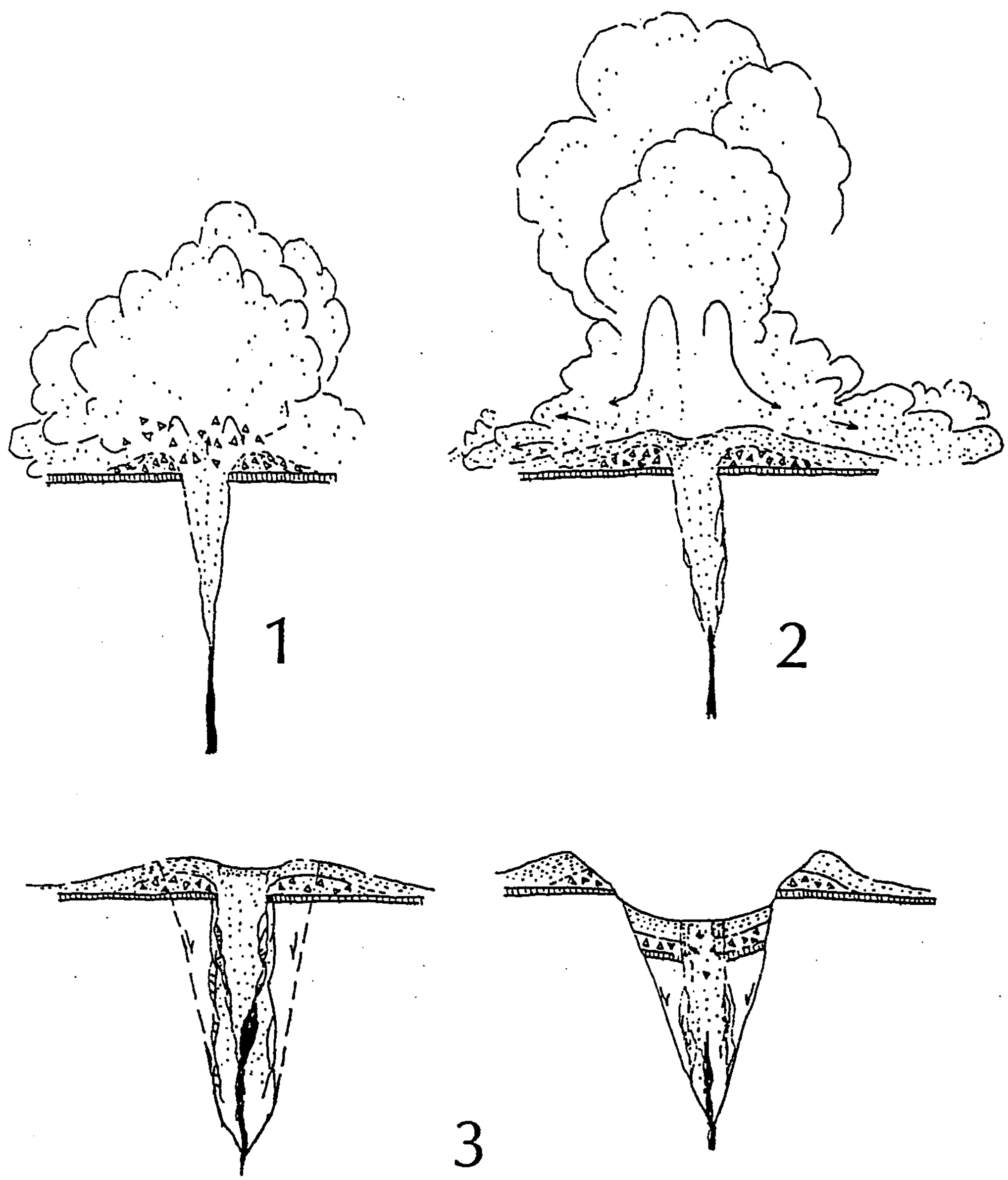

Figure 13. Diagrammatic evolution of Kilbourne Hole. 1) Initial perforation of Camp Rice Formation and Afton Basalt and formation of basalt explosion breccia; 2) formation of tuff-ring through accumulation of pyroclastic-surge deposits during Surtseyan-type eruptions; 3) caldera-like collapse of part of tuff ring to produce the maar structure. The modern crater has been widened somewhat by slumping and erosion, and the crater floor has been buried to a great extent by alluvium (from Seager, 1987).

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HUNT'S HOLE MAAR VOLCANO, Doña ANA COUNTY, SOUTH-CENTRAL NEW MEXICO

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INTRODUCTION

Hunt's Hole is the smallest of three circular maar volcano craters excavated in the westernmost part of the flat surface of the Mesilla bolson (La Mesa surface), approximately 64 km west of El Paso, Texas (DeHon, 1965; Fig. 14). The other craters on this surface are Kilbourne Hole (Brenner, 1979), the largest of the three, indicated 2.1 mi north of Hunt's Hole, and Potrillo maar 10.2 mi to the south. The three craters are aligned north and south along the Inferred down-to-the-west Fitzgerald fault. The fault is not exposed in the craters or the La Mesa surface, but is expressed by a line of depressions on the desert floor. Hunt's Hole is 1.5 mi long, 1.2 km wide, and 249 ft deep, and is excavated in mudstone and sandstone of the Pleistocene Santa Fe Group which is partly overlain by a basalt flow forming the south end of the Aden-Afton basalt field (Hoffer, 1975). The oldest flow (Af_1) of the Aden-Afton basalt field is exposed in the eastern half of Hunt's Hole. Radiometric analyses of this flow provide ages of 141,000 $\pm$ 75,000 years and 103,000 ± 84,000 years However, the age of phreatic eruption is indeterminable, but probably is less than 50,000 years based on the degree of dissection and lack of weathering of the base-surge tuffs.

Hunt's Hole formed as a result of steam-magma (phreatomagmatic) eruptions, which are characteristic of maar volcanoes. The term "maar" refers to small volcanic cones and craters, commonly with central lakes in Germany where they were first described. During

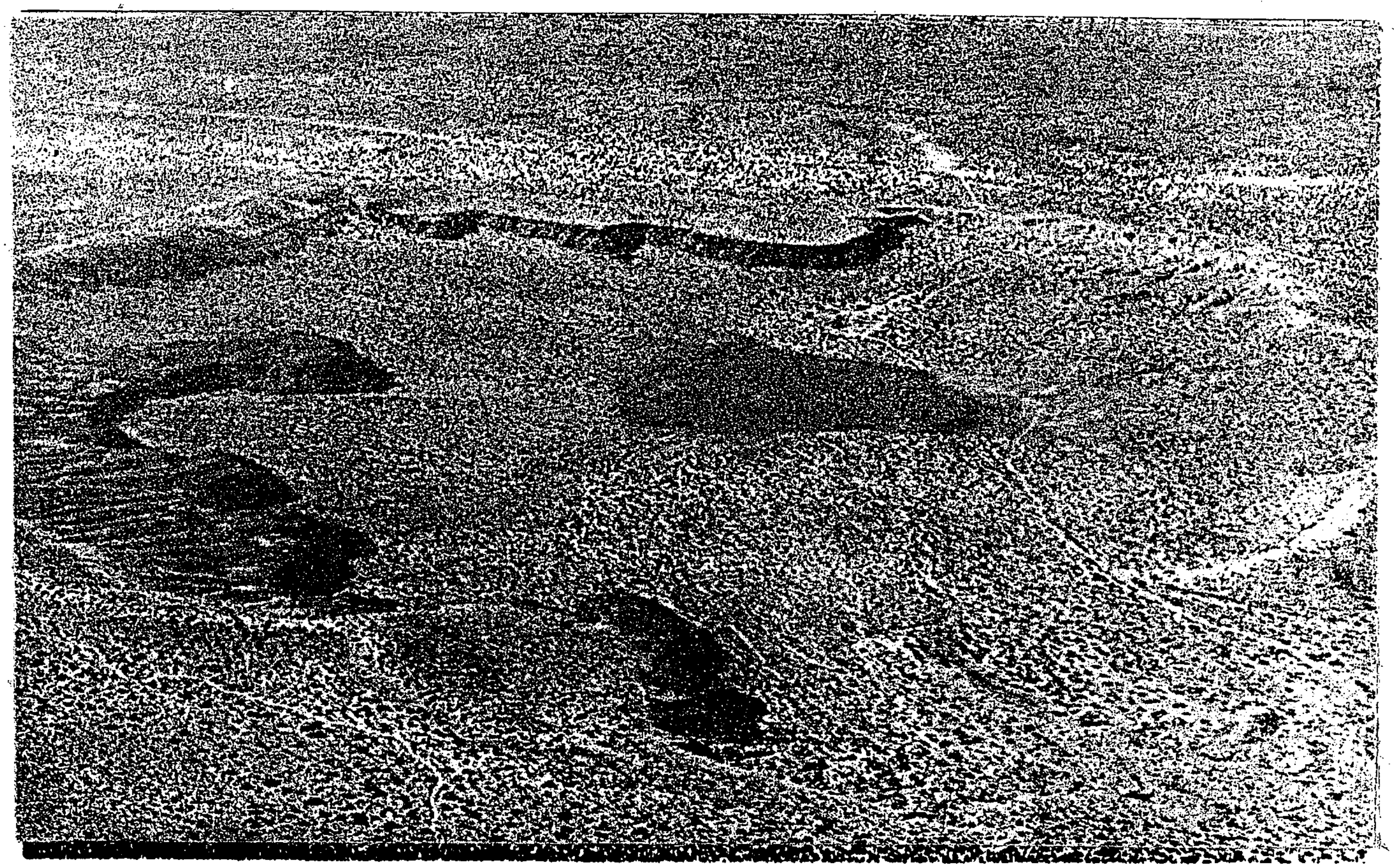

Figure 14. Aerial view of Hunt's Hole looking toward the southeast. The dark, cliffed outcrops in the left-hand part of the photograph are pre-tuff basalt flows of the Aden-Afton basalt field. Tuff and eolian sand dunes are light colored.

eruption, maar volcanoes form a vertical eruption column, which partially collapses Into an outward-moving cloud that transports tuff away from the vent. The outward-moving cloud is called a base surge. If the eruption is continuous, base surges form continuously. The tuffs deposited by base surges typically construct a ring or cone around the central vent and are cross bedded.

Cross-bed foreset beds at Hunt's Hole dip away from the vent and generally form a radial pattern (Fig. 15). The cross beds form dunes with an average height of about 15 in., and wavelengths of 75 in. The upcurrent side of the dunes dips an average of 7° toward the vent, and the downcurrent side about 23° away from the vent, making the dunes asymmetrical. Similar structures in base-surge tuffs elsewhere are generally smaller, near-symmetrical, and the dips on either side are less than 15%. These structures have been interpreted as antidunes characteristic of upper regime flow. However, the form and vertical and lateral continuity of Hunt's Hole dunes suggests that they are more like lower-regime "mega-ripple-drift" structures (Fig. 16); that is, they form climbing dune sequences. If this interpretation is correct, this is the first described occurrence of lower-regime bedforms in base surge tuffs.

The purpose of this short paper is to describe the setting of these base surge dunes, summarize the general features of the stratigraphy and other sedimentary structures at Hunt's Hole and interpret the geologic history of the tuffs and the crater Itself.

PREVIOUS STUDIES

Hunt's Hole was first studied by Lee (1907) who interpreted it as a phreatic explosion pit. Other studies include those of Darton (1916, 1933), Dunham (1935), Reiche (1940), and Shoemaker (1957). The base surge origin of the tuff ring, however, was not recognized until later by DeHon (1965a and b) and Reeves and DeHon (1965). These studies,

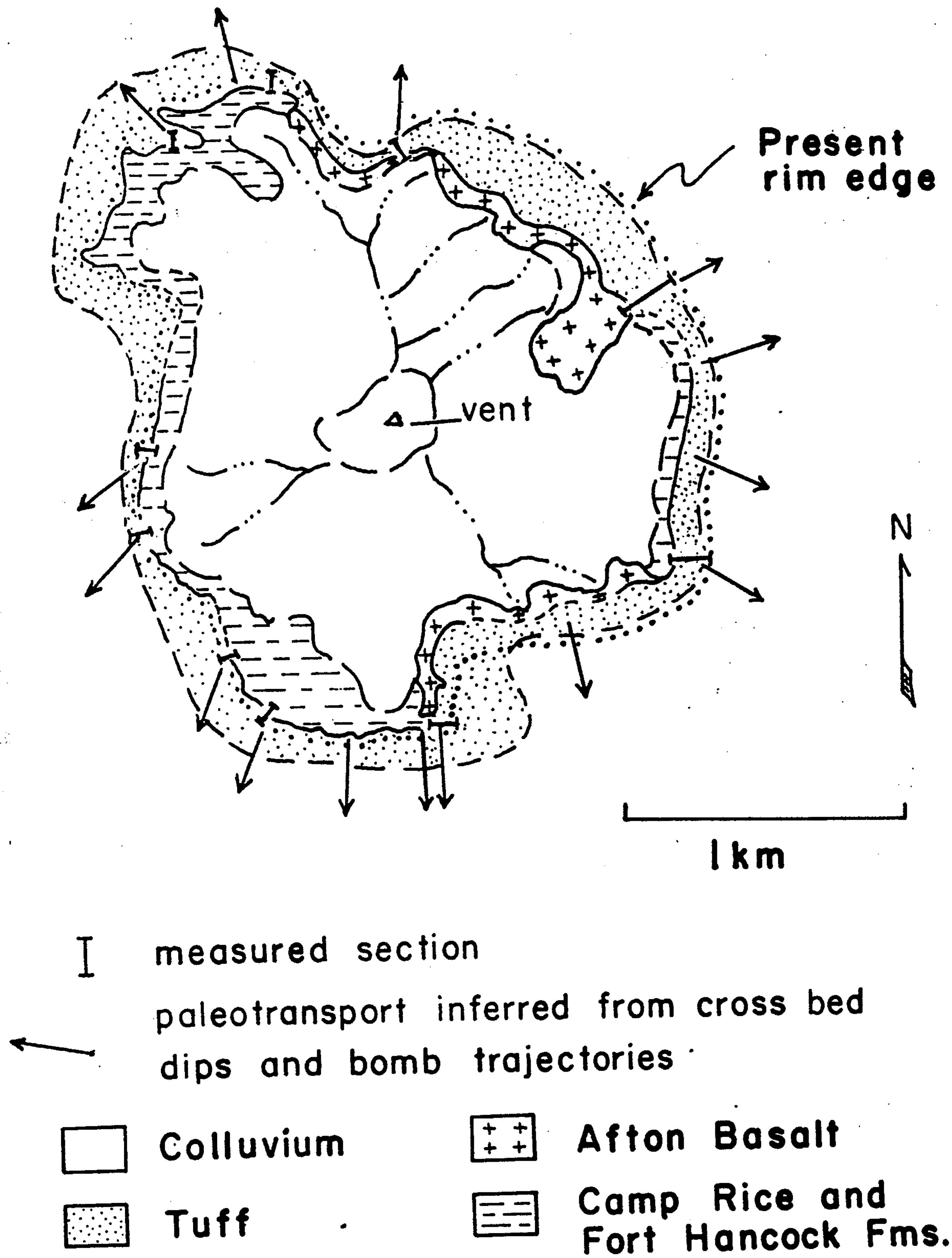

Figure 15. Geologic map of Hunt's Hole. Modified from DeHon (1965b)

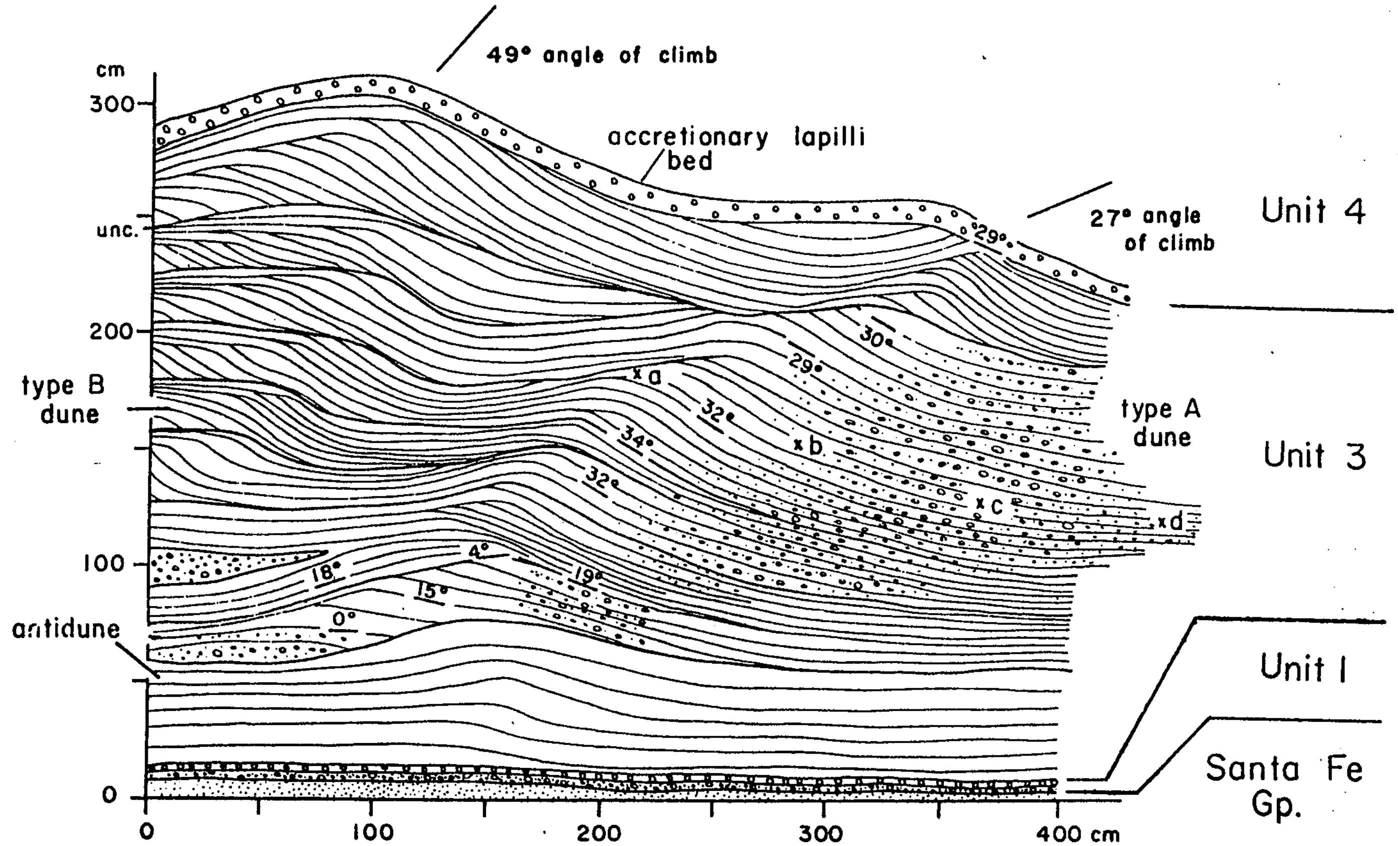

Figure 16. Field sketch of a dune sequence typical of the tuff ring surrounding Hunt's Hole. The dunes form ripple-drift (climbing) sequences consisting of lower regime (type A and B) and upper regime (antidunes) types.

however, concentrated on general features and the origin of the crater. More recent studies (Stuart, 1979; Stuart and Brenner, 1979) have concentrated on the bedforms and origin of cross bedded dune structures.

HUNT'S HOLE TUFF RING

Distribution

Base-surge tuff forms a ring deposit surrounding Hunt's Hole (Fig. 15). The tuff was deposited on a nearly horizontal erosion surface cut across the Aden-Afton Af_1 basalt flow and a sandy, locally caliche-capped, soil zone developed on Santa Fe Group sandstone and claystone. The basalt flow trends northerly, terminating to the east and west (Fig. 15). It forms the distal end of a southward -extending lava flow. The pre-base surge surface was not absolutely flat but consisted of two broad swales separated by low ridges in the vicinity of the crater. The swales are northeast-southwest trending and appear to deepen a few meters toward the northeast rim. These irregularities may have had a minor influence on the lower-most tuff beds, but no specific effects, other than variations in thickness, were observed.

Present thickness of the tuff rim is 9.8 to 59 ft although it was probably thicker and originally more extensive. The rim edge has been eroded back as evidenced by outcrops of the underlying basalt and Santa Fe Group sedimentary rocks crater-ward of the present rim edge. The thickness of the tuff reflects proximity to the eruptive vent and location relative to the prevailing westerly winds. Thus the tuff is thickest to the east and in more proximal localities such as along the north-central and west-central parts of the rim. The more distal southern and northwestern parts of the rim are characterized by thin accumulations. The eruptive center appears to have been located at the present playa in the center of the crater. This is inferred from cross bed dip directions and bomb-impact trajectories (Fig. 15).

Stratigraphy

The tuff was measured at eight localities around the crater, supplemented by fewer comprehensive measurements at intermediate points. Five bedding units were identified and correlated around part or all of the rim. Figure 17 illustrates this stratigraphic sequence in representative thick and thin sequences.

Unit I — Air Fall Tuff

Unit I sharply overlies basalt, and sandy caliche soil zones of the underlying Af_1 basalt and Santa Fe Group, respectively. It varies in thickness from 2 to 8 in. and occurs as a distinct unit in all but the eastern portion of Hunt's Hole (Figs. 17 and 18). It consists of two thin beds, a basal massive, laminated or normally-graded fine-sand size tuff 0.8 to 6 in. thick, overlain sharply by a massive to graded accretionary lapilli bed 2.5 to 8.0 cm thick. These beds are unconformably overlain by coarser deposits of unit 2 along the eastern side of Hunt's Hole. Unit I beds are interpreted as airfall deposits because of their lateral continuity and grading.

Unit 2 - Airfall to Base Surge Tuff-Breccia

Unit 2 beds occur along the eastern and northern parts of Hunt's Hole sharply overlying and perhaps in erosional contact with unit 1. Unit 2 varies in thickness from 2.5 in. to 36 ft, and consists of massive, laminated and low-angle cross bedded coarse tuff and pebbly tuff-breccia with scattered boulders (bombs). Locally, unit 2 beds are contorted along the northern rim. The massive units may be airfall beds, and the laminated and cross bedded layers probably are base surge deposits.

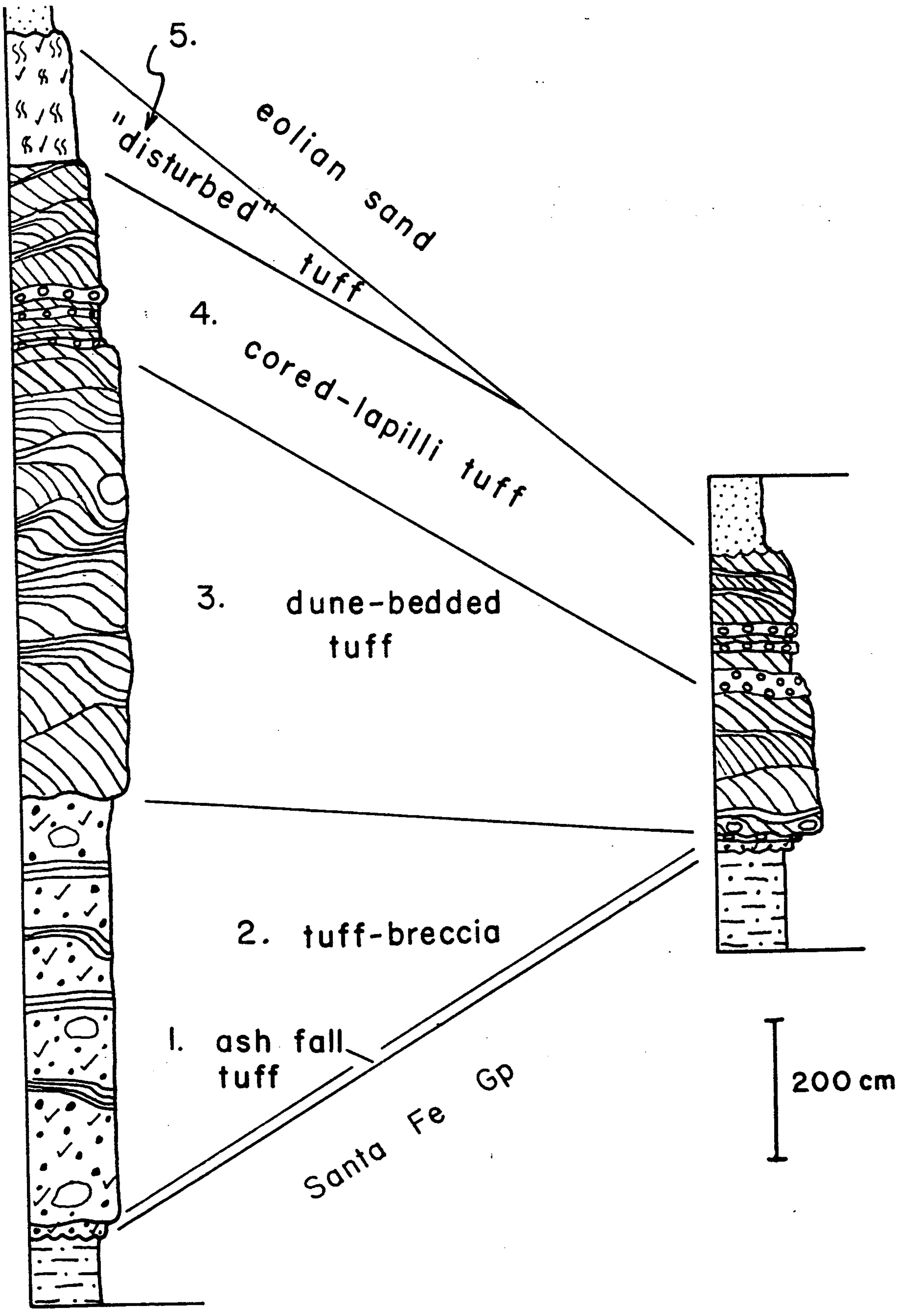

Figure 17. Representative thick and thin stratigraphic sequences in the tuff ring showing correlative units.

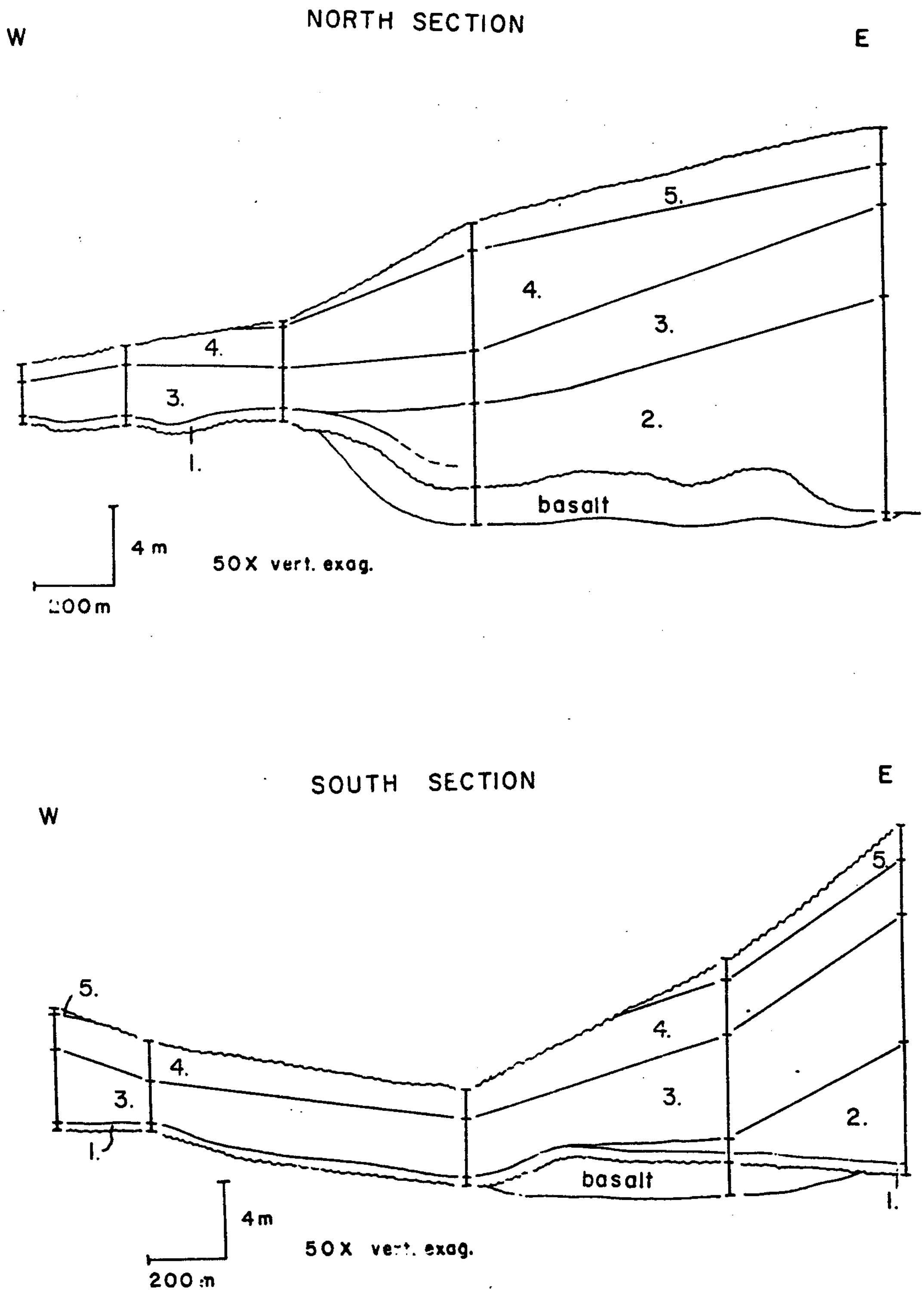

Figure 18. Stratigraphic sections along the northern and southern parts of the Hunt's Hole rim. Numbers refer to units described in Figure 17.

Unit 3 - Dune Cross Bedded Tuff

Unit 3 is the most distinctive tuff layer at Hunt's Hole because of pervasive medium-scale cross bedding. The unit sharply to transitionally (eastern rim) overlies unit 1 or 2, and grades upward into unit 4. Unit 3 occurs in all parts of the rim varying in thickness from 7 to 21 ft. The tuff is generally fine-sand size at the base grading upward Into interbedded fine-sand size tuff and granular pumice-lapilli tuff. A few layers of and accretionary lapilli are interbedded with these tuffs along the western rim. The basal portion of unit 3 is slightly more consolidated than the overlying beds, thus forms a relatively resistant ledge. All tuffs of this unit, however, are very friable. The cross bedding indicates that these beds are base-surge deposits.

Unit 4 - Accretionary-Lapilli Tuft

Unit 4 transitionally overlies unit 3 and is sharply overlain by unit 5. Unit 4 is incompletely exposed but varies in thickness from 6.5 to 8.9 ft where it is overlain by unit 5. Unit 4 consists of interbedded cross bedded, fine- to medium-sand size tuft with scattered pumice-lapilli layers, and massive, laminated or normally graded accretionary-lapilli tuff layers. Individual accretionary lapilli average about 1 cm in diameter. They differ from those described by Moore and Peck (1962) in consisting of a massive ash-ball core surrounded by only a single lamination of accreted fine ash. Accretionary lapilli described by Moore and Peck (1962) consists of multiple accreted layers. Accretionary-lapilli tuff forms wavy beds of fairly uniform thickness, from 0.8 to 6.0 in thick. The wavy bed form probably developed by uniform accumulation of an accretionary-lapilli layer over mounded tuff surfaces (dunes). Layers within these beds are continuous over the dune crests and troughs although some are thinned by scouring at the top. These characteristics indicate that the tuff formed as an air-fall deposit evenly coating the mounded tuff surface, although laminated beds may have formed by deposition from or reworking by base-surge currents.

Unit 5 Disturbed Tuft

Unit 5 is poorly exposed along the crater rim sharply overlying unit 4, and is covered locally by post-eruption eolian sand. Unit 5 attains thicknesses up to 6.6 ft and forms a single massive, fine-sand-size tuff bed with no internal bedding surfaces. The bed is characterized by crenulate structures (DeHon, 1965b) which appear to be curved, rosette-like laminations of tuff that fill intersecting tube-like structures.

The origin of these structures is uncertain but probably they are biogenic. There is no evidence of subaqueous deposition, therefore, they may be bioturbation features of large insects, possibly beetles, or small animals. Since these features occur at the top of the tuff sequence, bioturbation occurred after or in the final stage of volcanic activity. The tuff was probably water-saturated and soft making it a suitable burrowing habitat.

CRATER FORMATION

The origin of the Hunt's Hole crater is poorly known although some reasonable possibilities can be suggested alternative hypotheses were considered in the master's thesis of DeHon (1965b) as summarized below:

1) Meteor impact
2) Collapse
   a) subsidence due to solution of underlying rocks
   b) subsidence due to the removal of volcanic materials
3) Volcanic explosion
   a) cratering by phreatic explosion
   b) cratering by juvenile volatiles

The number of maar craters in this part of the Mesilla bolson precludes the first possibility. The rock underlying the crater are sandstones and shales not subject to solution. Thus solution subsidence is unlikely. Removal of erupted volcanic materials is possible, but the volume of tuff at Hunt's Hole is dwarfed by the volume of the crater. This process, therefore, is unlikely as a major source of crater subsidence. Mechanisms of volcanic explosion are the most likely of the group. Blasting during eruption could have pulverized rock forming the crater. However, there are few bombs in the tuff and little evidence of such an event.

DeHon (1965a and b) concluded that some form of coring or rasping by jets of sediment-laden steam gradually formed the crater at the same time the tuff was deposited. Thus the crater most likely developed passively (unlike the dramatic explosions at Mt. St. Helens) during most or all phases of eruption.

After the volcano became extinct, normal weathering and erosional processes modified the crater, partially filling it and causing the rim to retreat. In addition, slumps along the rim edge caused rim retreat and crater filling.

CONCLUSIONS

The different units making up the Hunt's Hole maar tuff ring record a series of eruptive events during which tuff-accumulated, and the crater itself formed. Unit 1 consists of thin, continuous airfall units. Apparently the eruption was very small initially, forming a dilute eruption cloud and depositing a tuff layer over only a few km^2. This activity ceased but was followed by a moderately violent eruption probably of relatively dry material. This formed the tuff-breccia deposits of Unit 2. As more water entered the vent, the ejecta became wetter and finer-grained, and base surges developed forming unit 3. These eruptions appear to have been continuous because there are no major unconformities within unit 3, although minor scour surfaces developed. Since a continuous supply of relatively uniform tuff was available during formation of unit 3, the dune forms migrated downcurrent and upward forming, ripple-drift sequences. Surge velocities probably were moderate to low compared to other maar volcano eruptions.

Periodic lessening of the eruption intensity reduced base-surge activity allowing the eruption cloud to deflate. Accretionary lapilli that formed in the cloud were then deposited, forming parts of unit 4. This fluctuation in eruption intensity resulted in the interbedding of accretionary lapilli and base surge dune deposits.

Unit 5 was deposited during waning stages of the eruption after which the maar abruptly became extinct. Burrowing insects or animals possibly reworked this tuff forming the crenulate-lamination-filled tubular structures common in unit 5. The maar has since been eroded at the margins and filled in the center, and the rim has retreated outward to its present position.

The occurrence of lower-regime ripple-drift structures indicate that large-scale lower-regime bedforms can be preserved in base surge tuff. Previously, it was thought that upper-regime structures only are preserved. Preservation of lower-regime structures apparently depends on the fortuitous combination of tuff coarseness surge fluid characteristics (viscosity and density), and surge velocity, in addition to periodic coating of lower-regime dunes by cohesive fine tuff. Based on the absence of descriptions of these structures in the literature, the conditions necessary for their formation must occur only rarely.

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GEOLOGY OF MOUNT RILEY-COX PLUTON

by

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INTRODUCTION

Mount Riley and Mount Cox are two distinct peaks representing a single pluton. Mount Riley, to the northeast, is the larger of the two mountains, and attains a maximum elevation of 5,915 ft. Mount Cox, southwest of Mount Riley, has a centrally-located peak 5,957 ft high. Both mountains are steep, rugged and covered with a mantle of talus (Fig., 19).

Mount Riley and Mount Cox are included in this guidebook because they can always be seen from any place in Kilbourne-Hunts Hole area. If you become disoriented or lose your sense of direction, look for these two peaks to determine your present location (Fig. 20)

Figure 19. Alluvial fan on the southwest side of Mount Cox; Mount Riley to the right.

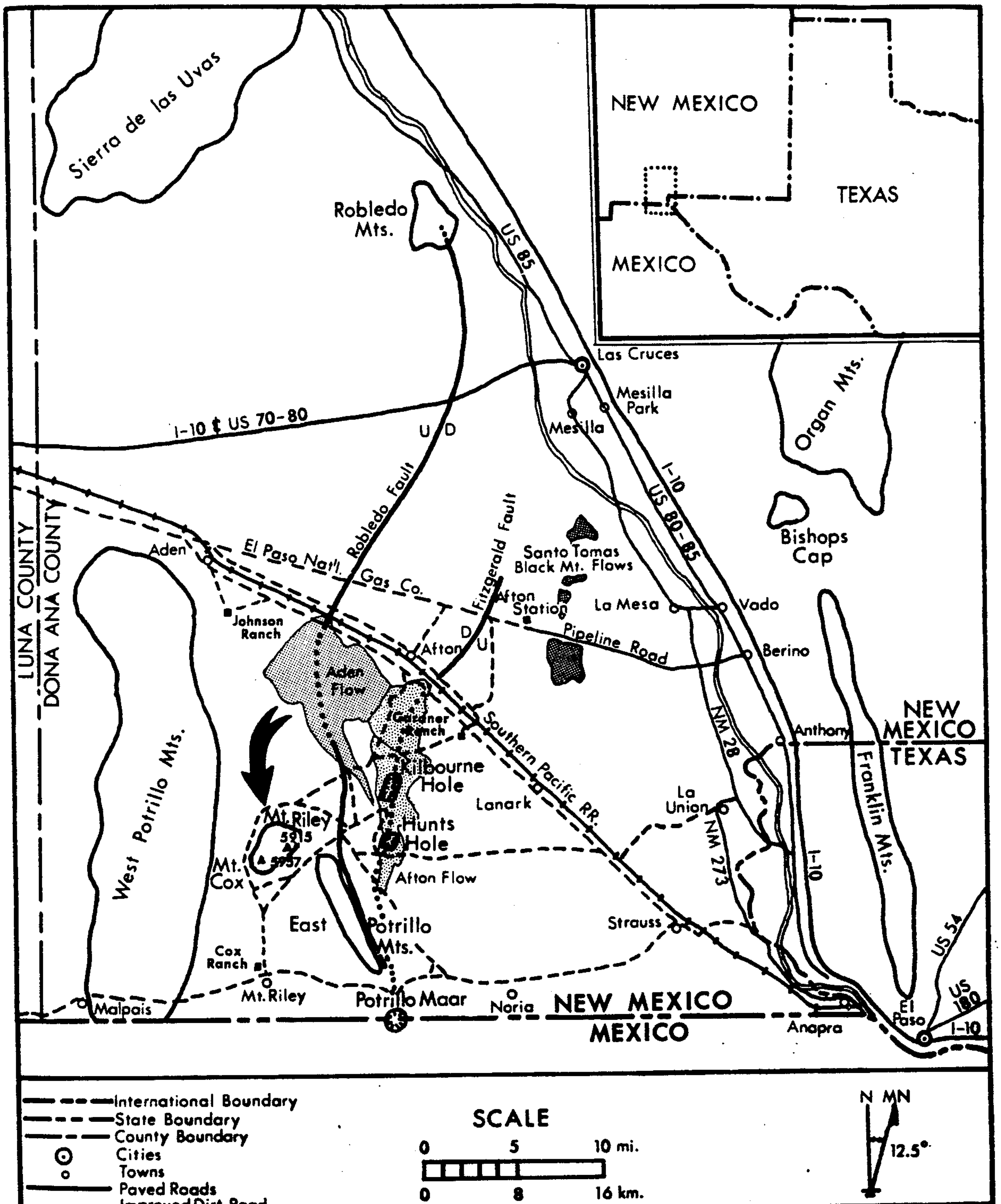

Figure 20. Index map of southwestern Doña Ana County, New Mexico.

GEOLOGY

The Riley-Cox pluton is a steep-sided conical protrusion of dense microporphyritic rhyodacite of probable Tertiary age. The pluton is a shallow stock-like body intruded into Cretaceous(?) arkosic sandstone, unfossiliferous gray limestone, and pebble conglomerate.

A similar sequence of Cretaceous rocks has been described by Kottlowski and Foster (1962) in the Tres Hermanas Mountains west of Columbus, New Mexico. Other intruded rocks include Mesozoic shales, siltstone, and conglomerate, and a sequence of interbedded Tertiary extrusive and sedimentary units (Fig. 21). In most places, the intruded rocks dip into the intrusion (40°) indicating that the pluton is a discordant structure. Contact metamorphism is minor with only slight recrystallization, realignment of grains, brecciation, and silicification.

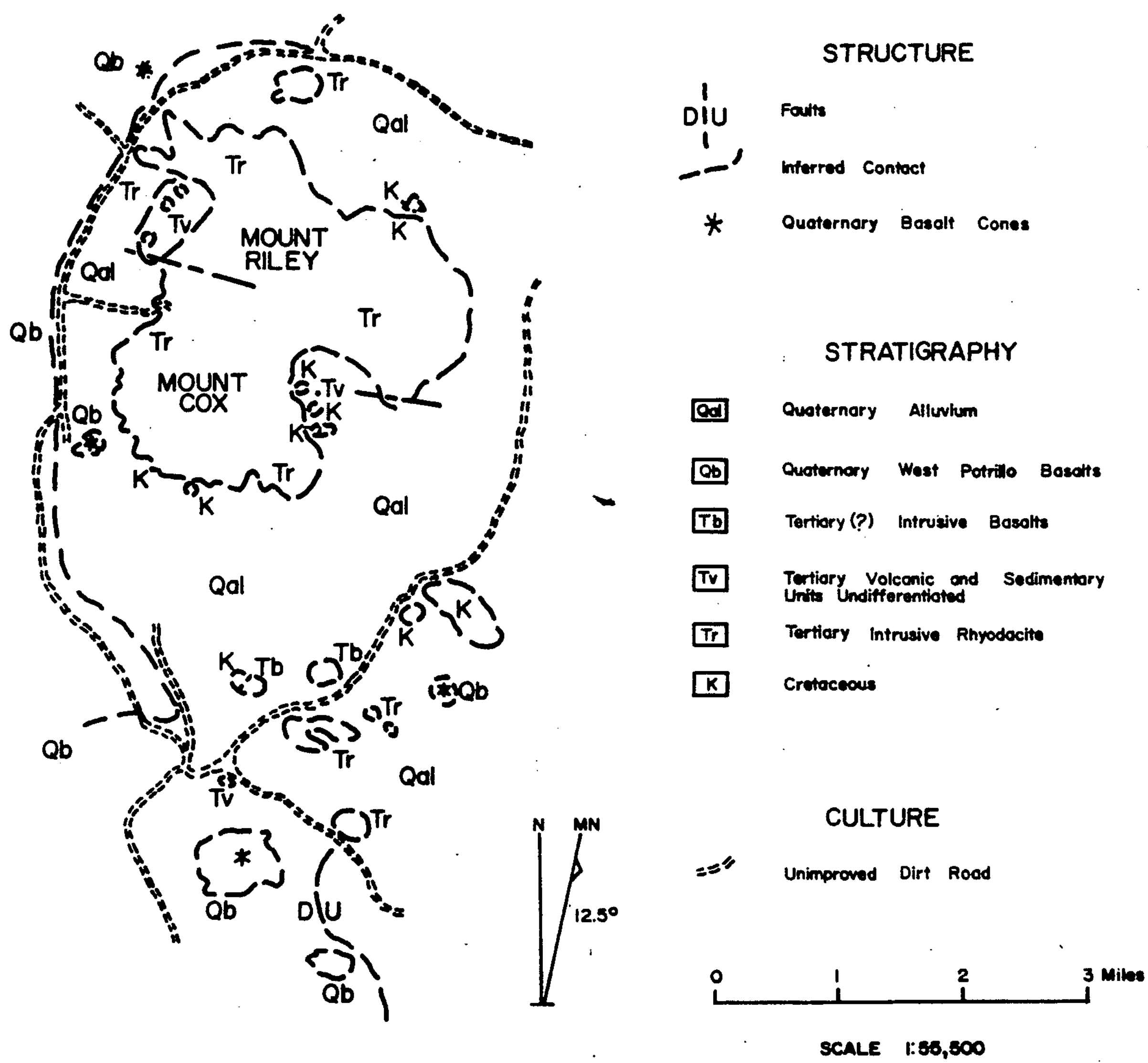

Figure 21. Geologic map of the Riley-Cox pluton.

Abutting Mount Cox on the west side is a West Potrillo Quaternary basalt cone. Fragments of the rhyodacite are included in a basalt dike that is associated with the cone. An equivalent age relation between the rhyodacite of Mount Cox and the cone is hereby established; it can be concluded that the basalts are younger than the rhyodacite.

Two major joint systems, generally perpendicular to each other, traverse the pluton. The joints trend N50°W, are very closely spaced, and are partly responsible for the mantle of talus on the slopes of the mountains. A small vertical fault(s) which roughly (N85°W, cuts the southwestern and southeastern sides of Mount Riley. Fracture zones along the fault show minor brecciation and recementation by siderite and calcite.

COMPOSITION

The rocks of the Riley-Cox are holocrystalline, porphyritic, with a trachytic groundmass (Millican, 1971). The minerals include biotite, hornblende, plagioclase and orthoclase phenocrysts averaging about 4 mm in length. Plagioclase microlites disposed in subparallel manner with anhedral orthoclase, quartz, and magnetite constitute the aphanitic groundmass. The quartz shows the greatest variation causing the pluton to be rather inhomogeneous in composition (andesite-rhyodacite).

Chemical analysis of the Riley-Cox Pluton indicates a rock similar to that of a rhyodacite. The Riley-Cox pluton and the Valley Andesites are similar mineralogically and chemically. This indicates that the bodies may have had a common origin and are possibly of similar ages. By a radiometric age date, the intrusion of the Campus Andesite is known to have formed during the Eocene, 47 m.y. ago (Hoffer, 1970). Present evidence indicates that the Riley-Cox pluton and the Valley Andesites are about the same age, but older than the West Potrillo Volcanics in the surrounding areas.

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