Maare of La Mesa

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MAARE OF LA MESA

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INTRODUCTION

The Afton Craters, also known as Kilbourne Hole, Hunts Hole, and Potrillo Maar, are large craterform depressions on the west-central portion of La Mesa surface in southwestern Dona Ana County, New Mexico (fig. 1). The origin of the Afton Craters has been a matter of debate for over half a century, yet all previous work was confined to the deepest of the three, Kilbourne Hole.

Lee (1907) published the first geologic report on Kilbourne and Hunts Holes which he described as phreatic explosion pits caused by conversion of groundwater to steam by an intruding dike. Darton (1916, 1933) included Kilbourne Hole in an article on explosion pits of the southwest. Dunham (1935) briefly described these craters in his discussion of the geology of Dona Ana County. Reiche (1940) mapped the geology of Kilbourne Hole, challenged the explosion hypothesis, and proposed solution collapse as the major mechanism of origin. Shoemaker (1957) compared bomb sag structures of maar-like craters in Mexico to those of Kilbourne Hole and Zuni Salt Lake, New Mexico.

In 1963 the writer and C. C. Reeves, Jr. began a study of the smaller and heretofore ignored Hunts Hole. Regional reconnaissance (De Hon and Reeves, 1965) led to the discovery of a previously unrecognized crater similar to Kilbourne and Hunts Holes. This crater, termed the Potrillo Maar (Reeves and De Hon, 1965), is now considered one of the Afton Craters.

REGIONAL SETTING

Kilbourne and Hunts Holes are approximately 25 miles southwest of Las Cruces on the western edge of La Mesa. Potrillo Maar lies 10 miles south of these and straddles the international boundary of New Mexico and Chihuahua, Mexico (fig. 1).

La Mesa is a comparatively flat bolson plain 300-400 feet above the floor of the Rio Grande Valley. Sand dunes and irregular deflation basins are the most numerous features on the surface. Local relief of 50-300 feet is produced by scattered cinder cones and the Kilbourne, Hunts, and Potrillo maare. Outcrops are scarce on La Mesa, but good exposures of the underlying fill are found along the Mesa escarpment above the Rio Grande and in the walls of the maare.

La Mesa is structurally deformed by a series of northwest- and northeast-trending faults. Where not recognizable by eroded fault scarps, the faults are commonly marked by elongate shallow depressions on the downthrown side (fig. 1). Alignment of 12 cinder cones in the Black Mountain-Santo Tomas chain and a 7-mile long series of depressions south of the volcanic chain is suggestive of structural control (fig. 1). Alignment of cinder cones, depressions, and maare along the southern extension of the Fitzgerald fault indicates that the maare are structurally controlled.

GENERAL FEATURES

At least three unfilled maare occur on La Mesa. In general, they are 1-3 miles in diameter, roughly circular, and surrounded by a raised rim or rampart. The outer slopes are generally moderate to gentle and completely mantled by blowsand. The inner slopes, or walls, are moderate to vertical. At the base of the inner wall, an apron of talus slopes to a nearly flat floor.

The rocks exposed within the maare of La Mesa consist of two different sections. Those below the general level of La Mesa are bolson-fill sediments that are easily correlated to the section exposed along the Mesa scarp. Those rocks exposed above La Mesa, which form the raised rims, are volcanic and related to maar development.

The sedimentary section underlying the volcanic rims is flat-lying and undisturbed. These sediments are chiefly fine-grained, buff to reddish silts with thin stringers of medium- to coarse-grained calcified sands. A thin section of the mixed gravels (Ruhe, 1962) containing rounded acidic clasts occurs under the caliche cap. A dense, 8-foot thick laminated caliche generally caps the section and is locally overlain by a single flow of olivine basalt.

The rim volcanics are composed chiefly of fine- to medium-grained tuffs derived from sediments penetrated by the vent and entrained in the escaping gases. A minor amount of essential ejecta is present in the form of scoriaceous bombs, cored olivine bombs, pumice, and ash.

The lowest part of the rim material, first described by Reiche (1940), is an eruptive breccia which has a varying thickness, often being locally absent. The breccia consists of accidental and essential blocks,
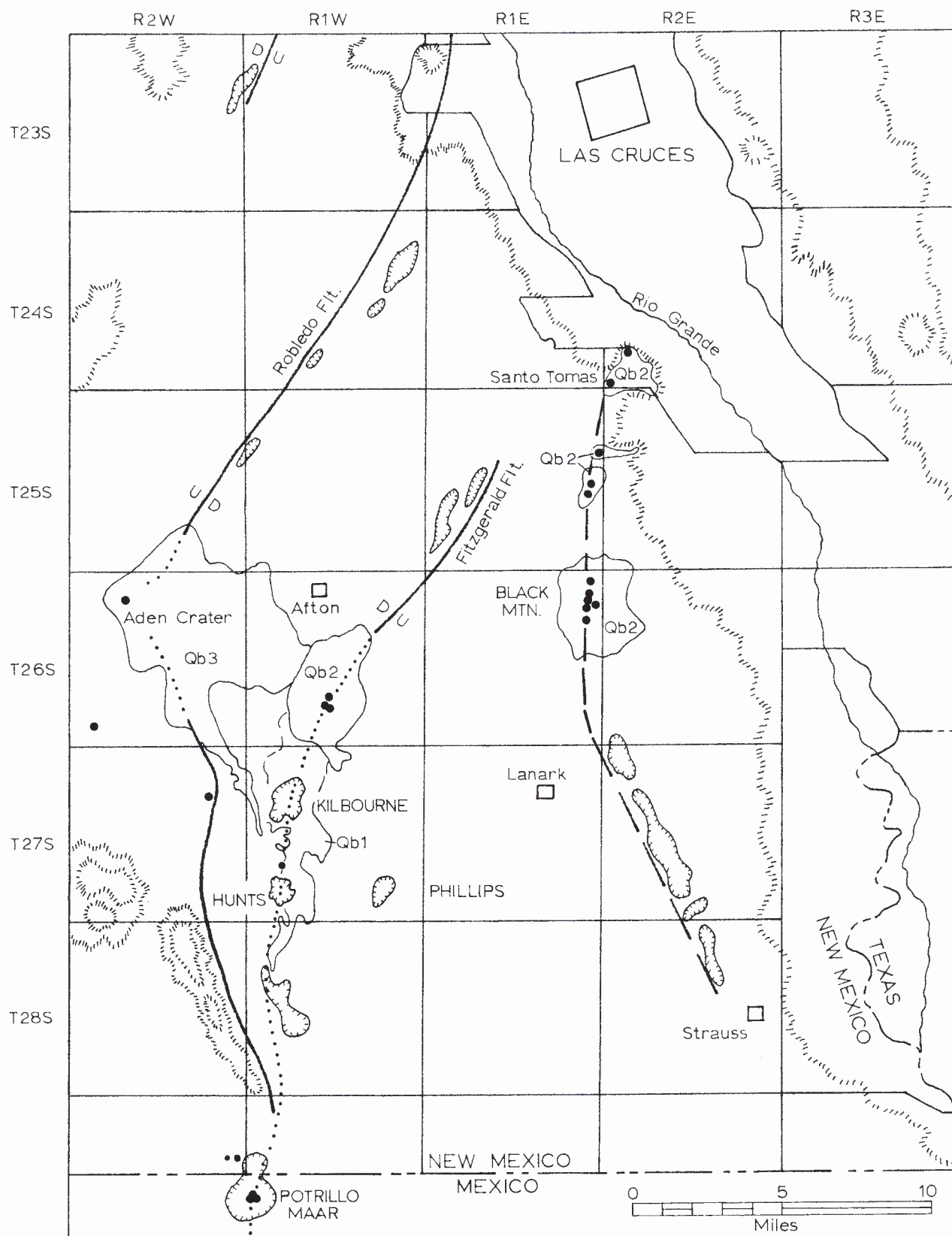
FIGURE 1

Index map of La Mesa showing faults (solid lines, dashed where probable, dotted where uncertain), basalt flows (Qb), and volcanic cones (large dots).

lapilli, and bombs in a matrix of tuff. Essential material of basaltic cinders, rounded scoriaceous bombs, and cored bombs of basaltic envelopes enclosing olivine and enstatite masses of juvenile origin as well as accidental xenoliths of shale, sandstone and gneiss. Accidental blocks include igneous, metamorphic, and sedimentary material traversed by the conduit. Among these ejecta are fragments of gray limestone conglomerate (Cretaceous Noria Limestone), brown and red hard sandstone, gray biotitic dacite, reddish hornblende rhyolite, dense angular blocks of olivine basalt, and caliche.

The major part of the rims consists of a well stratified arenaceous tuff (fig. 2). Reiche (1940) thought

FIGURE 3
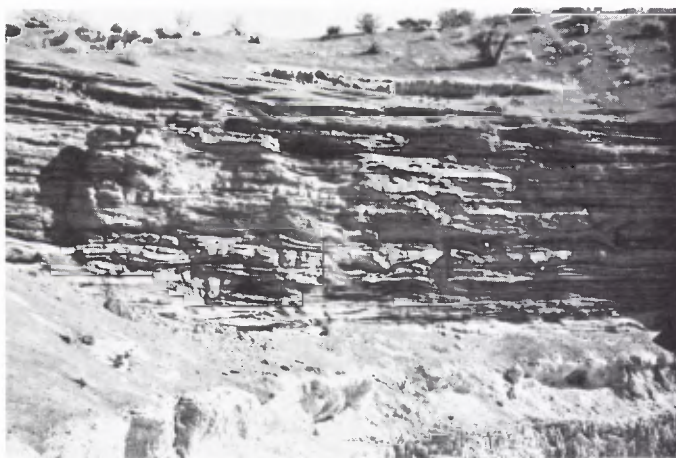
Accretionary lapilli at Kilbourne Hole.

FIGURE 2

Stratified tuffs of the east Kilbourne rim. Notice bomb sag structures about 5 feet above the caliche.

this stratification represented 125 feet of additional fluvial aggradation of the Mesa surface. However, the character of these deposits is clearly volcanic.

The bedded rim deposits are composed of gray to yellowish-brown sands and silts with minor amounts of lapilli and blocks like those found in the breccia. The finest sized material exists as interstitial ash or glass.

The tuffs are usually cross-bedded, though some horizons are continuous and even-bedded for many hundreds of feet. The direction of festoon bedding when present is always away from the centers of the craters, indicating a central source. Repeated sequences of graded bedding are present throughout the rims. Vertical gradations can be noted from coarse cinder seams to thin, fine tuff and ash beds. Typically, the highest layer of the sequence is a layer of accretionary lapilli (fig. 3) which forms by accretion of ash in a volcanic ash/steam cloud (Moore and Peck, 1962). Bomb sag structures (fig. 4), first described by Shoe-

FIGURE 4

Bomb sag in stratified tuff of the Kilbourne rim. The deformed layers are continuous under the basalt block.

maker (1957) at the Kilbourne rim, are common features at all the local maare. The stratified deposits of tuff, typical of maare, form by aerial fallout and penecontemporaneous "volcanic rains."

The uppermost 10 feet of the rim deposits exhibit a crenulate or cylindrical structure (fig. 5) similar in composition to the underlying tuffs, but all traces of stratification have been removed. This unit is called a lahar (De Hon and Reeves, 1965) based on the ability of mud flows to develop similar structures (Blackwelder 1928) and the presence of conditions necessary for flowage. The structures also resemble cicada-induced soil structures described by Hugie and Passey (1963). Because cicada burrows were recently discovered in Pleistocene soil zones on La Mesa and the adjacent Jornado del Muerto (personal communi-

FIGURE 5

Weathered surface of the uppermost rim tuffs exhibiting cylindrical structure.

cation, John Hawley, 1965), this unit may represent a cicada zone, the extreme thickness being due to intermittent deposition and burrowing.

KILBOURNE HOLE

Kilbourne Hole, the deepest and best known of the Afton Craters, is located in the northwestern part of T. 27 S., R. 1 W., 8 miles due west of the abandoned railroad station of Lanark. Kilbourne (fig. 6) is roughly elliptical in outline, 1.8 miles long, and 1.4 miles wide from rim crest to rim crest. The flat floor is 280 feet below the level of the surrounding plain, and the raised rim reaches as high as 170 feet above the plain. The interior slopes are nearly vertical. The raised rim is best developed along the northern and

eastern sides of the crater but is missing at one spot in the southwest edge and another in the southeast.

A buried basalt flow, 15 feet thick, rests above the caliche and under the rim volcanics. The basalt is present along all sides of the wall except for small gaps along the southeast and southwest walls. Where present, talus from the flow completely masks the underlying sedimentary section. The basalt is apparently breached along the northern wall by a vent (Lee, 1907; Reiche, 1940).

The eruptive breccia above the basalt reaches a maximum thickness of over 50 feet in the north but thins southward and is very thin to absent in the southern end of the Hole. This unit receives considerable attention because of olivine which occurs in the cored olivine bombs. Glassy enstatite bombs are also common.

The stratified rim tuffs which overlie the breccia reach a maximum thickness of 125 feet. Even though the outer flanks of the rampart are mantled by sand, small patches of tuff have been found 1 mile east of the rim crest. The tuff exhibits slight dips away from the center of the crater where it overlies breccia deposits. Along the northern rim the tuff is folded into a shallow anticline and syncline.

Slump blocks of basalt several hundred feet long are common at various elevations along the wall. At the foot of the eastern wall a 900-foot long block of tuff rests on the floor 100 feet below the tuffs of the rim. Several smaller slump blocks of tuff are found along the northern and northeastern wall.

HUNTS HOLE

Hunts Hole (fig. 7), 2 miles south of Kilbourne, is nearly circular in outline and 1 mile in diameter. The

FIGURE 6

Aerial view of Kilbourne Hole, view to the northeast. Photo by Robert Nymeyer Studios, Carlsbad, New Mexico.

FIGURE 7

East side of Hunts Hole, view to the north. Basalt-capped spur in middle foreground, raised rim in background.

floor is 133 feet below the plain, and the rim reaches a maximum height of 100 feet above the plain. The rim is best developed along the northeastern and eastern edge of the crater. The inner slopes are moderate to steep. A small spatter cone occurs just north of the rim between Hunts Hole and Kilbourne Hole.

The buried basalt flow in Hunts Hole, a part of the same flow exposed in Kilbourne Hole, is exposed along the eastern wall only. A prominent basalt-capped spur extends 700 feet from the east wall toward the center. The basalt from a vent somewhere north of Kilbourne extends 3 miles south of Hunts Hole. The total length of the flow is over 10 miles, while the width pinches and swells many times throughout the course. The flow has apparently followed a series of linear pre-maare basins.

The eruptive breccia at Hunts Hole is present only along the northeastern wall where it reaches a maximum thickness of 20 feet. While accidental blocks and scoriaceous bombs are plentiful, cored bombs are extremely scarce.

The bedded tuff, completely circling the crater, is 45-50 feet thick except where the rim has been eroded. The tuff exhibits a local dip away from the Hole where it overlies the breccia, but elsewhere it is horizontal. The tuff at Hunts Hole exhibits all of the features described earlier as well as several layers of plant cast remains, many of which remain in growth position.

Two sets of nearly perpendicular joints are prominent in the tuff. The joints, disposed in a radial and tangential pattern about the crater, control backwasting by separation along joint planes.

POTRILLO MAAR

Potrillo Maar (fig. 8) is located 10 miles south of Hunts Hole, straddling the international boundary. Potrillo Maar is elliptical in shape, 3 miles long and 2 miles wide, with a maximum relief of about 200 feet from the floor to rim crest. Due to the lack of buried basalt, the inner slopes are moderate. Blowsand obscures much of the outcrops even along the inner wall. The central part of the maar floor is occupied by a basaltic flow and a cluster of cinder cones, and two small cones are found at the northern end of the maar. The larger cone lies northwest of the rim and is surrounded by a thin flow. The smaller cone to the west is composed of reddish scoria.

The rim deposits are similar in all respects to those of Hunts Hole and Kilbourne Hole maare (Reeves and De Hon, 1965). Eruptive breccia, however, was not found in the areas visited during the investigation. Olivine bombs are common in the rim deposit, espe-

FIGURE 8

Aerial view of the central cone complex on the Potrillo Maar floor.

cially along the northeast rim. A small exposure of tuff occurs 1.5 miles northeast of the rim along the abandoned Southern Pacific Railroad.

PHILLIPS HOLE

Phillips Hole, 3 miles east of Hunts Hole, has not been included as one of the Afton Craters; however, it is a depression of considerable size. Phillips Hole is elliptical in outline, 2 miles long, 1.4 miles wide, and 70 feet deep. There is no raised rim and the interior slopes are gentle.

Whether Phillips Hole is a maar cannot now be determined, but it is larger and differently shaped than blowouts or fault-aligned depressions of the region. Phillips Hole may be a maar which, lacking a buried basalt to control erosion, has engulfed the rim deposits by backwasting.

DEVELOPMENT AND AGE

Maare are formed by short lived gas volcanoes which are characteristically deficient in essential ejecta. Until recently, neither the term "maar" nor the form itself has received much attention in this country. Lunar research, which is directed to all terrestrial crater-forming processes, focused considerable attention on maare. Muller and Veyl (1957) presented a description of the 1955 formation of the Nilahue Maar in Chile, but Shoemaker (1962) has given the best résumé of maare development.

Comparison of features present in La Mesa maare makes it possible to outline the stages of development of the local maare. After separation of the volatiles

from an underlying magma, the gases forced their way to La Mesa surface along the pre-existing Fitzgerald-Potrillo fault. As the gases pierced the surface they carried considerable amounts of groundwater and underlying rock. This initial deposit of debris, termed the "vent opening breccia" (Rittmann, 1962), is represented by the eruptive breccia present in the Hunts Hole and Kilbourne Hole maare. Cored olivine bombs are common in the rim deposits of maare of the Eifel District, Germany (Grabau, 1924).

Continued venting and gas coring of the vents after initial perforation enlarged the orifices and added new material to the original low walls of breccia. Venting occurred as a series of short staccato-like eruptions of progressively lesser intensity. Stratification of the maare deposits resulted from aerial fallout and working by penecontemporaneous volcanic rains.

Soon after the vents became quiescent (and in some cases before) downfaulting or slumping, accompanied by normal backwasting of the wall, slowly engulfed the rim deposits, enlarged the diameters, and filled the craters. Where resistant rocks were present, as at Kilbourne and Hunts Holes, backwasting was retarded; but where absent, as in Potrillo Maar, back wasting was accelerated. Phillips Hole may represent a very advanced stage in which all of the rim has been engulfed.

The late stage of lava extrusion, as present in Zuni Salt Lake and Wau en Namns, also occurs in the Potrillo Maar (fig. 8), but does not occur in either Kilbourne or Hunts Hole.

The ejecta of the Afton Craters lie above the olivine basalt which postdates the formation of La Mesa. The mixed rounded gravels underlying the caliche cap were dated as Kansan-Illinoisan by Strain (1959). Because remains of a ground sloth (*Nothrotherium shastense*) found in an old fumarole of the Aden lava cone are dated as 11,000 years B.P. (Simons and Alexander, 1964), maare activity on La Mesa is of post-Kansan-Illinoisan but pre-Late Wisconsin age.

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