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A NEW TYPE OF MAAR VOLCANO FROM THE STATE OF DURANGO – THE EL JAGÜEY-LA BREÑA COMPLEX REINTERPRETED

*Eric R. Swanson**

INTRODUCTION

The Quaternary, Guadiana Valley volcanic field covers nearly 2,000 km^2 in the central part of the State of Durango, Mexico, and contains more than 100 basaltic vents. Two of the volcanic features, El Jagüey and La Breña, are located 45 km to the north-northwest of the city of Durango at the northern end of the volcanic field.

In general, the valley's Quaternary basalt has received little attention. Albritton (1958) studied the Quaternary stratigraphy of the Guadiana Valley and described six units including basalts separated by sediments containing pre-Wisconsin age Pleistocene fossils. Radiocarbon ages from paleosols beneath one exposure of the older basalt range from 10,000 to 15,000 years old (Swanson *et al.*, 1978). Only a few chemical analyses of the basalts have been published, but their petrochemistry, including that of El Jagüey and La Breña is currently under study by James Luhr and his associates (J. F. Luhr, personal communication, 1987; Aranda-Gómez *et al.*, 1988).

The El Jagüey-La Breña volcanic complex (Figure 1) was previously studied by Sánchez-Rubio (1978), who described several vents, reported some chemical analyses and noted the presence of ultramafic xenoliths. His volcanic history consists of a fairly simple sequence including: (1) opening of a small nearby crater, (2) explosive opening of El Jagüey and La Breña, and (3) flooding of the floor of La Breña by basaltic lava. He mentioned that the forms of the volcanoes are typical of those produced by phreatomagmatic explosion and that subsidence was a distinct possibility. A more recent study (Aranda-Gómez *et al.*, 1988) reaffirmed El Jagüey and La Breña as maar volcanoes, generally confirmed the volcanic history previously described, but recognized a pre-maar scoria cone. They concluded that El Jagüey was the first maar to form, but that its deposits were buried beneath those erupted from La Breña. The difficulty of this position is, of course, that the ejecta attributed to La Breña directly overlies the rather extensive exposures of pre-maar scoria and associated basaltic lava. Their scenario requires all of El Jagüey's deposits to have been removed from the contact area in the very brief period of time between maar eruptions.

The author is familiar with the El Jagüey-La Breña complex, through numerous studies in the Durango area, beginning in 1972. This short note is intending to show the results of observations made at the El Jagüey-La Breña complex; a detailed report is being prepared for publication elsewhere. This paper concludes that, contrary to previous interpretations, El Jagüey is the only maar volcano (albeit one of the world's most unique examples), and that the entire volcanic complex formed when the development of a common scoria cone was interrupted by the sudden introduction of groundwater. The entire El Jagüey-La Breña complex is a maar volcanic form not previously recognized, but which is in many ways an older, larger analog of a maar formed on Iwo Jima in 1957 (Corwin and Foster, 1959).

**Division of Earth and Physical Sciences, The University of Texas at San Antonio, San Antonio, Texas 78285, U.S.A.*

DESCRIPTION

El Jagüey (Figures 1 and 2) is a funnel-shaped maar about 0.75 km in diameter. It has a shape typical of vents produced by phreatomagmatic explosions and controlled by the slumping and explosive ejection of debris in the manner described by Lorenz (1973). Pyroclastic surge beds line the inside of the vent and extend onto the surrounding plains in all directions but west. An older scoria cone underlies surge beds of the maar's west rim and the opposite wall exposes a petrographically similar basaltic lava flow (Figure 2).

La Breña is an immediately adjacent, nearly circular, collapse structure 1.4 km in diameter. The walls of La Breña caldera also expose the scoria cone, basaltic lava flow and El Jagüey's pyroclastic surge beds. Its floor is covered by a post-collapse spatter cone and an associated lava flow.

The older scoria cone is prominently exposed on the west side of the junction between La Breña and El Jagüey. Bedrock exposures along the rest of the west rim are poor except for those offered by a small quarry recently cut into La Breña's western flank in which scoria beds are beautifully revealed. The eastern wall of La Breña caldera exposes two basaltic lava flows. The upper basaltic flow contains spiracles indicating it flowed over the wetted surface of the lower unit. Both lava flow units are petrographically identical and the upper unit is at the same level as the basalt flow exposed on the east side of El Jagüey.

Laterally around the caldera wall, basalt exposures give way to scoria, but the contact between the two lithologies is not exposed.

La Breña and El Jagüey are flanked to the north by a small, poorly exposed scoria cone (Figure 2). Because surge beds are not found west of El Jagüey, the cone's age remains speculative. There is, however, no evidence that scoria from this vent ever blanketed El Jagüey or La Breña, and the age of the volcano is probably similar to that of the larger adjacent scoria cone to which it may be parasitic.

The floor of La Breña caldera is completely covered by a spatter cone complex and associated lava flow. Chemical analyses reported by Sánchez-Rubio (1978) and generally supported by Aranda-Gómez and others (1988) show the basalt erupted in the caldera and that exposed as lava and scoria in the caldera walls are nearly identical, nepheline normative basalts. Additionally, they are petrographically identical down to their weathering characteristics and the types and sizes of the abundant spinel lherzolite and rarer granitoid xenoliths they carry.

Although La Breña has the appearance of a collapsed maar volcano, there are no related pyroclastic surge beds. The surge beds found along the caldera's eastern side show the same sequence of lithologies as surge beds lining El Jagüey

Figure 1.- Air photograph of the El Jagüey-La Breña volcanic complex. North upwards; scale can be estimated from Figure 2.

maar, they dip and thin away from El Jagüey and they can be traced continuously into El Jagüey.

PYROCLASTIC SURGE BEDS

The pyroclastic sequence exposed along the east rim of La Breña caldera thins rapidly from a maximum thickness of 60 m at El Jagüey's southern rim to 10 m at La Breña's southern rim. The basal layer of the surge sequence is a volcanic breccia consisting mostly of large lithic fragments, some up to 3 m in diameter. Units above the breccia layer consist almost entirely of finer lithic-rich pyroclastic surge beds except for a distinctive scoria bed, 30 to 60 cm thick and located from 2 to 3 m above basal breccia. This sequence of lithologies was consistently found over the entire area covered by the surge deposits. It is the product of a rather simple maar-forming sequence consisting of a vent-clearing explosion followed by closely-spaced phreatic eruptions, interrupted only briefly by a purely magmatic event that deposited the thin, air-fall, scoria layer.

All of the surge beds are lithic- and crystal-rich. The most abundant fragments are dense basalt, followed by rhyolitic welded ash-flow tuff, scoriaceous or dense sideromelane and poorly consolidated sediment. The most abundant mineral fragments are olivine, quartz, spinel and sanidine. The types and relative abundance of lithic fragments are the same in all units sampled regardless of grain size or stratigraphic position. These rocks and minerals are identical to those found in the mafic lithologies exposed in the walls of the El Jagüey-La Breña complex and to that of a nearby, thick, lithic-rich, ash-flow tuff which is thought to fill a large mid-Tertiary caldera and undoubtedly underlies the entire study area (Swanson and McDowell, 1984). Rarer lithic fragments such as limestone, breccia, andesite, spinel lherzolite and granitoids have all been observed as xenoliths in the area's ash-flow tuff and basalt and were probably reworked from these two units.

The same is presumably true for some galena pyroclasts separated from one sample! The type of lithic fragments found indicates that the phreatic explosions took place near the contact between the Quaternary basalt and underlying Tertiary rhyolitic ash-flow tuff (probably separated by a thin layer of basin-filling sediment). The consistent relative abundance of lithic fragments, regardless of stratigraphic position, indicates

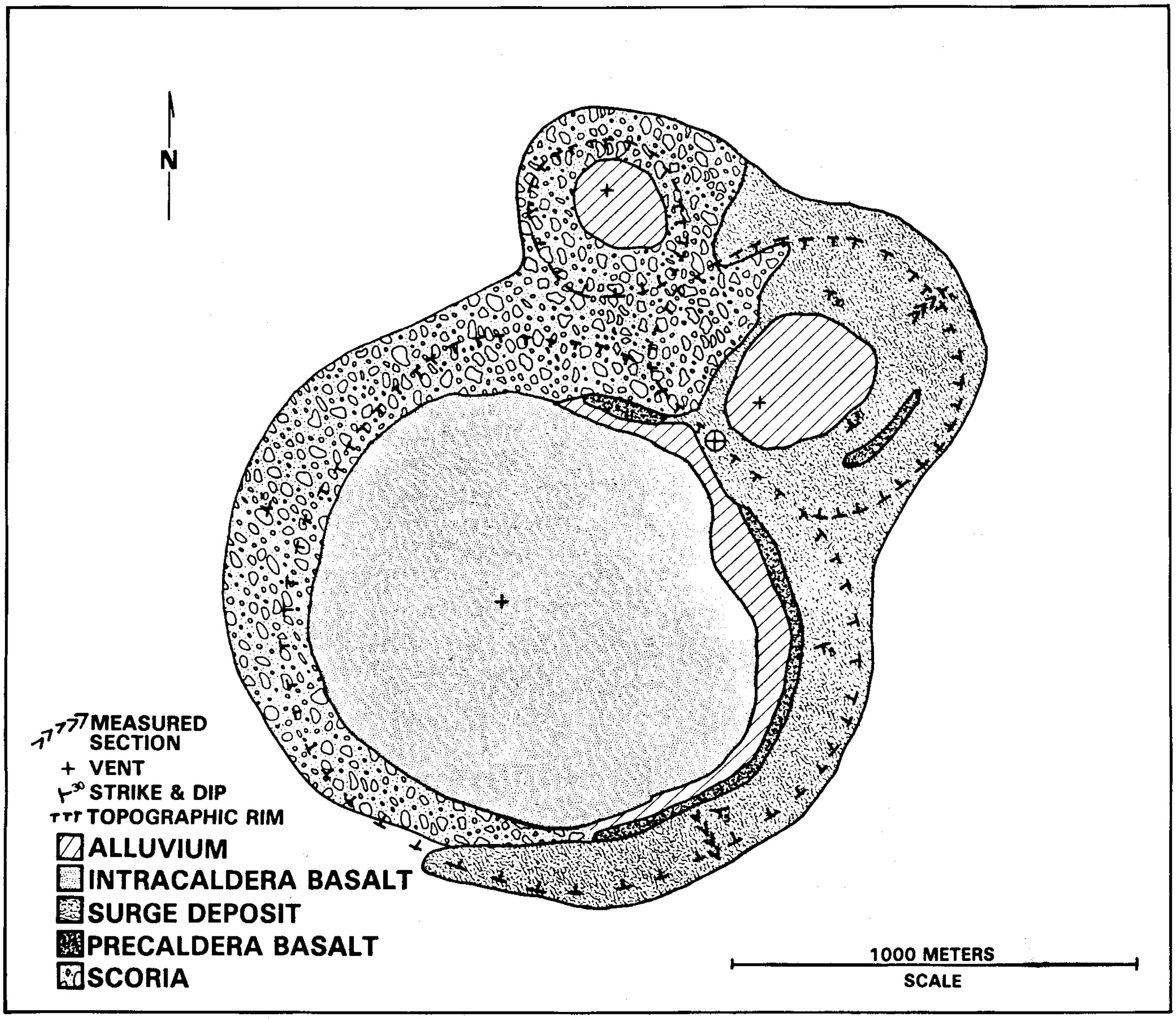


Figure 2.- Geologic map of the El Jagüey-La Breña volcanic complex.

that there was no significant vertical change in the explosion site as the eruption progressed.

DISCUSSION

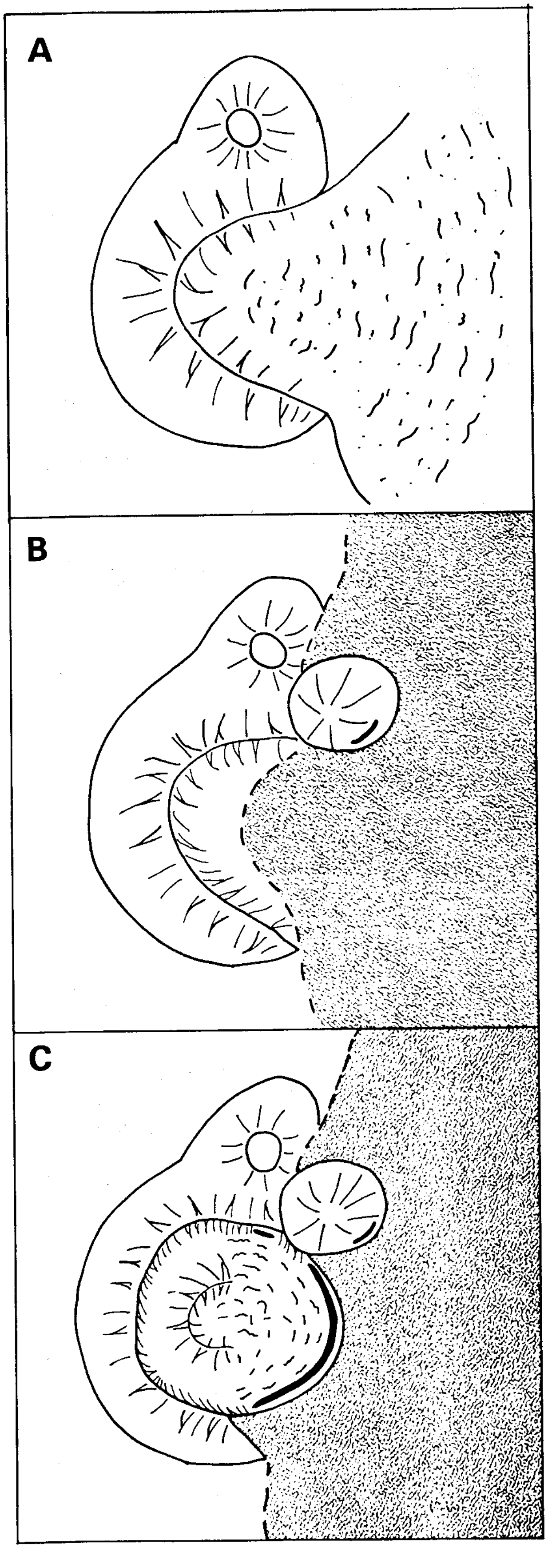
The oldest rocks are those belonging to the scoria cone and basaltic lava exposed in the walls of La Breña and El Jagüey. Studies of hundreds of scoria cones (Wood, 1980) have shown that they almost invariably produce an associated lava flow. Commonly the base of the cone is intruded and a part of the cone rafted away. It seems likely then that the scoria, the basalt exposed in the complex's walls and even the intracaldera basalt are related. This conclusion is supported by evidence already presented concerning the petrographic and chemical similarities between these three units. Volcanic activity, therefore, began and ended as purely magmatic events interrupted by the phreatic explosions that produced El Jagüey maar. But, what was the source of the water?

El Jagüey is enigmatic in that it is the only maar in the entire volcanic field. In addition, it is found in one of the highest topographic positions in the Guadiana Valley; higher, in fact, than nearby purely magmatic vents! These facts together with the evidence that initial activity was magmatic suggest that water encroachment caused the sudden change in eruption style. El Jagüey is only one kilometer from the base of the Sierra de la Silla, and arroyos draining the mountains feed directly into sediment north of El Jagüey. Spiracles in the pre-maar basaltic flow indicate that it flowed over the wet surface of an earlier flow. It is suggested, then, that the surge eruption was triggered by runoff from heavy rainfall, typical of that produced by showers that commonly occur during the summer rainy season.

The runoff from the nearby mountains infiltrated basin-fill sediment lying between the older welded tuff and the recently emplaced lava flows of an actively developing scoria cone to cause the phreatic explosions.

The explosion took place on the northern side of the scoria cone because that was the direction from which the water encroached.

Collapse as a result of maar volcanism is a well recognized phenomena and appears to be important in the formation



of many large maar volcanoes with steep walls and flat floors. Collapse of a nearby area, however, appears to be rare. A smaller, but similar style collapse, without development of a scoria cone took place on Iwo Jima in 1957 and was described by Corwin and Foster (1959). Their report states that about 50 minutes after a brief series of eruptions formed a small (32 m), funnel-shaped crater, a slightly larger, adjacent hole formed by collapse. La Breña appears to be a much larger example of this rare maar type.

Surge deposits around the Iwo Jima maar are thicker by a factor of 4.4 on the rim adjacent to the collapse pit. Ejected blocks indicate that the explosion was directed away from the collapse area, more widely dispersing the eject in the direction of the blast (Corwin and Foster, 1959). Surge deposits at El Jagüey have similar thickness relationships suggesting that the blast was directed somewhat away from the breached scoria cone. The complete absence of surge deposits to the west, however, can not be explained unless the old scoria cone remained standing long enough to block any eastward-directed eruption clouds.

Collapse apparently occurred shortly after the eruption as in the Iwo Jima example.

VOLCANIC HISTORY

The volcanic history of the complex began with construction of a large scoria cone over the future site of La Breña caldera. As magma rose in the vent, the cone's east flank failed and was rafted away (Figure 3, A). As the eruption progressed, groundwater encroachment from the north triggered a series of phreatic explosions that formed El Jagüey maar (Figure 3, B) and removed supporting material from beneath the scoria cone. After preventing the westward dispersal of pyroclastic surges, the breached scoria cone foundered to form La Breña caldera (Figure 3, C). Following caldera formation, the flow of lava resumed from a spatter cone complex on the caldera's floor (Figure 3, C).

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Figure 3.- Development of the El Jagüey-La Breña volcanic complex. (A) Formation of a breached composite scoria cone, (B) Eruption of El Jagüey maar, (C) Formation of La Breña caldera and eruption of lava from a spatter cone complex within the caldera.

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