DIATREMES AND A RING INTRUSION ON THE SAN CARLOS INDIAN RESERVATION

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INTRODUCTION

Several small basalt plugs intrude the late Cenozoic sediments and volcanic rocks of the lower Safford Basin (see Late Cenozoic geology of the lower Safford Valley--a preliminary report, this volume) on the San Carlos Apache Indian Reservation. Associated with these intrusives and probably also with major structural zones, is a number of diatremes and a small, well-exposed circular dike. All but two of the diatremes so far discovered are aligned along a roughly north-south trend; a pediment surface and capping gravels partially cover three of them, however, and it is probable that others lie hidden outside this trend.

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DIATREMES

Diatremes in the Navajo-Hopi country are described by Hack (1942), Shoemaker (1956), and Williams (1936) as funnel-shaped volcanic vents filled with pyroclastic debris. These are thought to have been originally drilled by explosive or "fluidization" processes (Galbraith, 1959, p. 162-3, Reynolds, 1954), and those vents which reached a mature stage have become choked with tuff, agglomerate, and fragments of wall rock derived from below by entrainment or from above by collapse. Vent fillings are more or less stratified, depending upon the depth of the exposed section. Upper portions of the Navajo-Hopi diatremes are relatively fine-grained and well stratified; lower levels in the pipes are characterized by large blocks of wall rock and volcanics in a jumbled mass. Vent fillings have, in many cases, been intruded by later basalt dikes.

San Carlos Diatremes

The San Carlos diatremes are roughly circular and range from 300 to 1200 feet in diameter. In all cases they intrude the soft, poorly consolidated silt, clay, and limestone of the basin material with no disturbance of sedimentary beds. An exception is a small diatreme which occurs in a broad fault zone along the mountain flank northwest of Coolidge Dam.

It is believed that successive stages of development are represented by the San Carlos diatremes. Vent fillings vary from large, angular blocks of sediment and volcanics in a poorly stratified matrix of agglomerate cut by basalt dikes, to well-bedded tuff and agglomerate with small sedimentary inclusions. The three vents described are considered to be representative of progressive stages of diatreme development and of subsequent exposure by erosion.

Salt Creek Diatreme

The best exposed of the San Carlos vents, this diatreme represents a mature stage of development, during which previously ejected, surrounding pyroclastics were deposited in the crater by inwash. The outcrop area is roughly circular, (Fig. 1A) and is 1100 to 1200 feet in diameter. A greenish-brown, well stratified tuff-agglomerate with poor but recognizable sorting fills the vent. Beds strike tangentially and dips generally decrease toward the center. Angular fragments of scoriaceous basalt averaging 1 to 2 inches in diameter are common in the agglomerate. Blocks of a red and white gneissoid rhyolite 1 to 12 inches in diameter imbedded in the agglomerate are uncommon, and are believed to have been derived from the basement. Contacts with the intruded sediments are sharp, and bedding is undisturbed where exposed in two stream beds.

Local variations in attitude are due to movement within the diatreme. Several small faults show dragging and crushing effects but no alteration; the same effects are exhibited by numerous fault zones which are defined only with difficulty. These displacements are probably due to subsidence of the magma column at depth and consequent settling of the overlying fill. Large blocks of sediments are incorporated in the central part of the vent and may represent collapse of stratigraphically higher country rock.

The level of exposure of the Salt Creek diatreme is not as high as those of some of the Hopi diatremes in which fine sediments and travertine are interbedded with the pyroclasics (Lowell, 1956). Steep dips at the edges and gentle dips at the center probably indicate a foreset-topset bed relationship, with the steeper dips representing earliest deposition. A considerable local gradient existed when the Salt Creek tuff-agglomerate was deposited, although dips may have been increased by later subsidence; Shoemaker (1956) states that dips in the Navajo and Hopi tuffs generally increase with depth.

Triplets Wash Diatreme

This diatreme is exposed in the edge of the late Cenozoic sediments on the north side of the Gila River; roughly half of its circumference is exposed and it is truncated above by the pediment surface. It is elliptical in plan (Fig. 1B), with axes of approximately 350 and 500 feet. The pipe filling is composed of agglomerate, poorly sorted and with poorly defined bedding, containing abundant fragments of basalt throughout. Irregular stringers and dikes of basalt cut the agglomerate and partially enclose it.

Sedimentary fragments up to 10 inches in diameter are common in the agglomerate, and several large blocks of bedded sediment are contained in the vent. A 35-foot block exposed on the southwest face is highly altered and silicified, probably by adjacent basalt dikes.

A large pillar of coarse volcanic and sedimentary breccia stands slightly south of the center and represents the main pipe which became filled with its own ejecta. The average size of fragments is one foot, but many angular blocks four feet or larger in size occur in the jumbled mass.

Basalt dikes from 10 to 20 feet thick outcrop around the outer edges of the diatreme. Dips are inward at 50 to 60°. Several sets of dikes and a complex pattern of stringers cut the agglomerate; alteration and baking are widespread. Surrounding sediments have been disturbed by intrusion of the peripheral dikes.

The Triplets Wash diatreme is exposed at a level considerably lower than that of the Salt Creek diatreme. Coarse, unstratified debris rapidly accumulated after cessation of activity and choked the vent. Inwash of surrounding pyroclastics presumably, at a higher level, produced bedded tuff-agglomerates similar to those at Salt Creek. Renewed activity of the lava column caused the emplacement of dikes around the border of the vent and along fractures in the agglomerate.

Ruin Vent

This lava dome is thought to be a diatreme because of its location with respect to known diatremes. It is situated almost directly across the Gila River from the Triplets Wash diatreme and occupies a roughly circular area about 3600 feet in diameter. In appearance it is a low, rounded mound of red scoriaceous lava, dissected into several isolated hills. Underlying the lava is a sequence of greenish-gray tuff and agglomerate which interfingers laterally with the normal silt and clay of the basin fill. A flow of basalt overlies crumpled tuffs on the west side of the vent.

The dome itself is composed of bombs and blocks of highly scoriaceous basalt up to five feet long. Spatter and pahoehoe features and cooling cracks are common in the larger bombs near the tops of the hills. Most of the lava, however, has been reduced to rubble by weathering.

The Pleistocene(?) pediment capping gravel, which is present throughout the valley, is absent on the Ruin vent. Furthermore, it appears that the lava was never buried by the gravel. The few fragments of non-volcanic rock which occur on the lava dome are artifacts and can be related to the Indian walled structures which stand atop two of the hills. The Ruin vent is therefore of comparatively late origin and probably represents a stage of diatreme development in which surface extrusion occurred but subsidence did not. In describing such diatremes in the Hopi Buttes, Hack (1942, p. 350) says: "In many places the initial explosion pit is overlain by domes of lava which have pushed outward, spilling over the sides, crumpling and pushing out the underlying and bordering tuffs and sediments."

RING INTRUSION

A circular basalt dike approximately one mile in diameter outcrops in the basin sediments on the north side of the Gila. It is closely associated with a group of basalt plugs, one of which obscures a 40^{o} segment of the circle. The dike and enclosed sediments surround a central volcanic vent (Fig. 1C).

Ring dikes and cone sheets have been reported from many parts of the world, notably the British Isles and New Hampshire. Billings (1943) defines ring dikes and cone sheets in terms of attitude and thickness; since the dike here described dips inwardly, as do cone sheets, but is much thicker than any of the cone sheets described in the literature, it seems best to designate it simply as a "ring intrusion".

The San Carlos ring intrusion is perhaps better exposed than many cone sheets and ring dikes previously described. The soft limestone and silt of the basin fill have been stripped away, leaving the dike exposed as a circular ridge with an average relief of a hundred feet. Attitudes of the dike are variable; beds dip most steeply along the southwest side , but dip toward the center around most of its circumference. Thickness of the dike averages about 200 feet.

An unusual feature in intrusions of this type is the dome of sediments which the ring encloses. Typical basin-fill sediments arch over the central vent and dip away in all directions. Dips range between 10 and 20^{o}. Sediments outside the ring are undisturbed.

The central vent is roughly circular and is about 500 feet in diameter. It is topographically lower than the surrounding sediments. Angular to subrounded fragments of ejecta ranging from 1/2 to 6 inches in size are cemented in a white carbonate matrix. The western part of the vent filling is predominantly a tightly bound agglomerate of bombs and lapilli with little secondary cement. At the south edge of the vent is an area, 300 feet in diameter, of larger and more angular debris with a higher ratio of carbonate cement to fragments. This probably represents the last active extrusive outlet of the vent.

Relations between the ring intrusion and the neighboring plug to the west are undetermined as the area of contact is covered with talus. Two small sills and a dike outcrop within the ring and appear to be related to the vent and to the circular dike, respectively.

Mechanics of Origin

Interpretation in terms of conventional ring-intrusive mechanics (Anderson, 1937) is difficult in view of the sedimentary dome which the ring encloses. There can be little doubt that the central pipe acted at one stage as a volcanic vent; it also appears that considerable upward force was exerted at the same point during one stage, since the apex of the dome lies above the vent. Both the ring and the enclosed dome have the same center; it therefore appears that they are related to the same upward force. Undisturbed beds outside the ring point to the formation of a circular fracture before or contemporaneous with the formation of the dome. The protracted stress necessary to cause doming of the overlying rocks is not the type associated with vent drilling. The development of a zone of weakness beneath the apex of the dome might, however, allow fluidization-drilling to proceed through an area of initial weakness. If fluidization-drilling did occur at the central vent, the rounded and mixed debric characteristic of such activity has derived, at least in part, from collapse of lavas extruded at a higher level.

PETROLOGY

Dike rocks of the San Carlos diatremes and of the ring intrusion are olivine basalts with titanaugite as the dominant pyroxene; the flow associated with the Ruin vent, however, contains normal augite. The plagioclase of all the dikes is labradorite (An55). The olivine is forsterite (Fo_{90}).

The vent fillings are composed of angular fragments of quartz, feldspar, basalt, and mica. The finer-grained portions of the Triplets Wash diatreme exhibit a microbrecciated texture wherein individual grains are isolated by a calcite matrix.

CONCLUSIONS

Diatremes in the San Carlos area show marked resemblances to those in the Navajo-Hopi country. A crude lineation of vents indicates intrusion along a weak zone or break in the basement rocks beneath the Safford Valley. Fragments of metamorphosed rhyolite contained in the Salt Creek diatreme were probably derived from depths at which conditions promoting plastic deformation prevail. Variations in aspect between diatremes are attributed to differences in depth of erosion and in degree of development.

The San Carlos ring intrusion is the result of dike formation along a ring fracture caused by the upward stress of a magma column. Doming of the dislocated plug of sediments was followed by gaseous or explosive vent drilling through apical fractures.

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