Tertiary stratigraphy of northern Catron County, New Mexico

Max E. Willard

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TERTIARY STRATIGRAPHY OF NORTHERN CATRON COUNTY, NEW MEXICO [1]

By
MAX E. WILLARD

INTRODUCTION

Reconnaissance mapping of volcanic rocks in the field trip area and remaining parts of Catron County was originally undertaken by the New Mexico Bureau of Mines and Mineral Resources as a part of its contribution to a revised State geologic map (Dane and Bachman, 1957). This text and the accompanying map (fig. 1) are based, in large part, on that reconnaissance. However, the writer thinks that the major subdivisions of the volcanic rocks in these parts of New Mexico have been recognized and mapped, and that these basic subdivisions will be a useful framework for subsequent detailed studies.

The Dog Springs and the Puertecito 15' quadrangles, in the northeastern part of the mapped area, were mapped in detail by D. B. Givens (1957) and W. H. Tonking (1957). The results of their work, as incorporated in figure 1, have been simplified and reinterpreted in terms of the larger stratigraphic units recognized during the regional reconnaissance. The geologic mapping southwest of Red Hill in the southwest corner of the accompanying map was done by Robert H. Weber, of the New Mexico Bureau of Mines and Mineral Resources. The results of reconnaissance mapping in the area of Tres Montosos by John Schilling are also included. The remaining parts of the area were mapped by the author.

SUMMARY OF STRATIGRAPHIC RELATIONS

Along their northern edge north of U. S. Highway 60, Tertiary volcanic and sedimentary rocks rest unconformably on the shales and sandstones of the Mesaverde group of Cretaceous age. In the Dog Springs and Puertecito areas, the Cretaceous rocks have been correlated with the Gallup sandstone and Crevasse Canyon formation of the Mesaverde group; elsewhere, they are undifferentiated. Along the Carrizo Creek at the west, and near the headwaters of the Rio Salado at the east, the underlying Mancos shale, Dakota(?) sandstone, and Chinle formation are exposed. The Mesaverde group and older rocks are designated as undifferentiated pre-volcanic rocks on figure 1.

Overlying the Cretaceous sedimentary rocks are sedimentary and volcanic rocks which were named the Datil formation by Winchester (1920, p. 6). At the north end of Bear Mountains the red and cream-colored arkoses and mudstones that make up the lower 684 feet of Winchester's Datil formation were separated from overlying volcanic rocks and named the Baca formation by Wilpolt and others (1946). The name Datil formation was retained for the volcanic rocks. Hence, for reconnaissance mapping, the Datil formation has been redefined, and a not very satisfactory attempt has been made to map the Baca formation and its apparent equivalents.

The complete volcanic sequence, as now known, is only partly represented in the Alamocito Creek-Bear Mountains area. Elsewhere, the redefined Datil formation, which in large part consists of a lower latite facies and an upper rhyolite facies, is underlain unconformably by altered purple and green basaltic andesite, reddish-brown latite, and interbedded latitic tuff, and is unconformably overlain by basaltic andesite flows. The contact between the Datil formation and the underlying "lower volcanic group" is exposed on the north and northeast slopes of the Luera Mountains. The contact of the "lower volcanic group" with the older rocks is not exposed. Southward along the east face of the Black Range, the lower volcanic rocks overlie Carboniferous limestone. Baca-like sediments are not present at either of the above localities, nor were they recognized elsewhere south of the field-trip area.

West and south of the Alamocito Creek valley the Datil formation is overlain unconformably by a thick section of basalt and basaltic andesite. In the field-trip area these basaltic rocks are well exposed on the Mangas and Bear Mountains. None of the flows that make up this sequence is traceable to source conduits; most are eroded and at places are disconformably overlain by Santa Fe sediments. Probably, however, many of the basaltic dikes and volcanic plugs shown on the map are intrusive equivalents of the Mangas-Bear Mountains flows.

The youngest of the volcanic rocks in the trip area are basalt and basaltic ash and cinders. The primary morphology of many of the flows and cones is still evident. Individual flows at places follow stream channels. These youngest flows rest on several of the older rock types, and to the south overlie and are interbedded with Santa Fe-like sediments and rhyolite tuff.

DESCRIPTION OF STRATIGRAPHIC UNITS

Nonvolcanic sediments (Tb)

This unit, as already noted, is tentatively assigned to the Baca formation of Wilpolt (1946). The Baca formation was named from exposures in sections 4, 5, 8, and 9, T. 1N., R. 4 W. in Socorro County. As defined by Wilpolt, it consists of the lower 694 feet of the Datil formation measured by Winchester at "the north end of the Bear Mountains." As has been pointed out by Kelley and Silver (1952), Tonking (1957), and Givens (1957), the thicknesses, added correctly, should total 684 feet. Unfortunately, 365 of the 684 feet of the "section" at he measured section were named for a canyon outside the area covered by Winchester's map. Curious also is the fact that the description given by Wilpolt was not of material at the type locality, nor in Winchester's measured section, but of material mapped by Wilpolt in the Joyita Hills-Carthage area. No measured section or description of the sediments in Baca Canyon has been recorded. Certainly this will have to be done before Baca can be considered as an acceptable stratigraphic name.

In the map area, the Baca formation ranges from 0 to several hundred feet thick (Tonking measured 700 feet, Givens 542 feet). It includes varying proportions of red-purple arkose and arkosic sandstone and conglomerate interbedded with red and light-gray sandy mudstones (fig. 2). Highly rounded pebbles and cobbles of quartzite, jasper, quartz, granite, and limestone occur in the conglomerate. The formation, being weakly cemented, breaks down easily on exposure, leaving a distinctive lag gravel that has been used in tracing the formation through areas containing few outcrops (figs. 3 and 4).

Volcanic material was not included in Wilpolt's description of the Baca formation in the Joyita Hills-Carthage area, and Givens (1957, p. 11) emphasized the absence of volcanic sediments in the Dog Springs quadrangle. As

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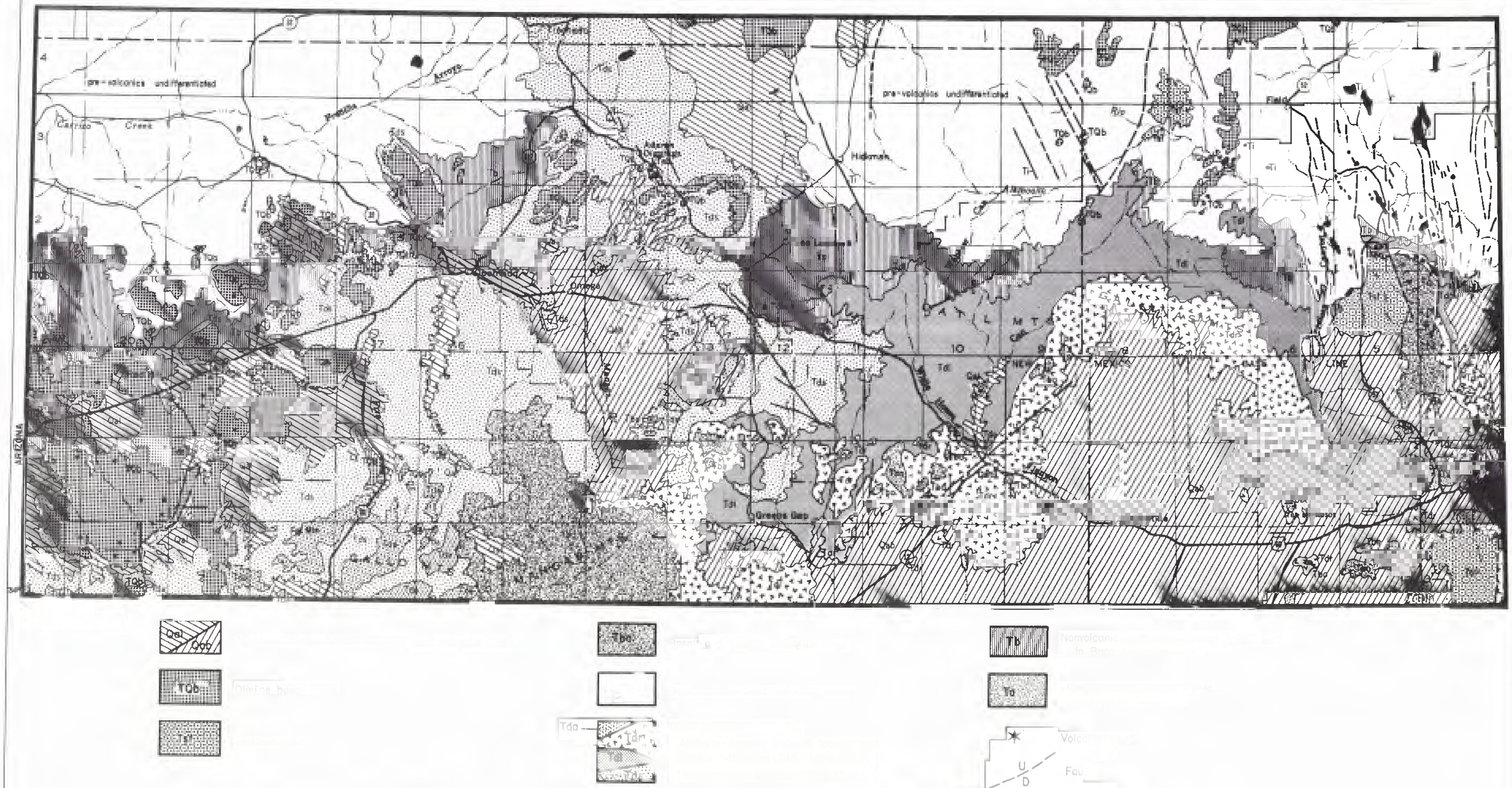

Fig. 1--DISTRIBUTION OF VOLCANIC ROCKS IN NORTHERN CATRON COUNTY, NEW MEXICO

Figure 2. Interbedded siltstone, sandstone, and conglomerate of the Baca formation north of Quemado.

pointed out by Kelley and Silver (1952, p. 119), the Baca in the Carthage area, as mapped by Wilpolt, contains in its upper part Datil-like volcanic debris. Winchester noted the presence of obsidian cobbles along with pebbles of granite, feldspar, and quartz in the bottom unit of his measured section "north of the Bear Mountains." Benzidine tests made by the author on material exposed in the upper parts of the section in Baca Canyon were strongly positive. Although not conclusive, the results of these tests suggest the former presence of volcanic ash.

As would be expected from the preceding, the upper and lower contacts of the Baca formation are defined poorly. At places in the field-trip area the lower contact is essentially conformable with the underlying Cretaceous rocks and includes lithologies very similar to parts of the Mesaverde group. Elsewhere they are unconformable and lithologically dissimilar. In general, the Baca beds are more arkosic than beds in the Mesaverde and commonly red or reddish brown in contrast to the yellowish shades of the Mesaverde. In the Puertecito quadrangle, Tonking (1957, p. 24) reports that the Baca has been folded with the La Cruz Peak formation — an equivalent of parts of the Mancos shale and Gallup sandstone.

The upper contact of the Baca, along the north edge of the main volcanic mass, is for the most part gradational into the Datil formation. As mapped, it includes in its upper beds of volcanic pyroclastics and water-deposited tuff similar to beds in the lower parts of the Datil formation in this area.

The Baca at its eastern limit in the field-trip area is coarse-grained, containing many conglomerate beds. Through the Dog Springs quadrangle, and as far west as Pie Town the grain size decreases. West of Pie Town the grain size again increases and, judging from the lag gravels and the few exposures, the Baca is largely conglomeratic. This conglomeratic character persists as far west as Red Hill. The red beds exposed along U. S. Highway 60, at the Arizona-New Mexico State line, have been assigned to the Baca formation by R. H. Weber. These redbeds are sandstone mainly but include some mudstone and shale. This suggests a second decrease in grain size along the exposed course of the formation.

Lower volcanic group (Ta)

In the field-trip area, as elsewhere, this group of volcanic rocks consists largely of black to greenish-black or purple basaltic andesite and andesitic pyroclastics that are altered greatly. In the Magdalena district and along the east front of the Black Range, massive gray to grayish-white latitic tuff beds are interlayered with the andesites. Farther south, in the area of Apache Warm Springs, this earliest group of volcanic rocks includes thick flows of porphyritic, banded, reddish-brown latite.

Outcrops of the lower volcanic rocks are limited to the eastern part of the map in the vicinity of Magdalena. Roadcuts 3 to 4 miles west of Magdalena, on the recently completed new section of U. S. Highway 60, contain characteristic exposures of faulted, jointed, and altered lower andesite. Andesites of the lower volcanic group are also at or very near the surface in the broad area east of Tres Montosos. These outcrops are not shown on the accompanying map (fig. 1).

In the map area the lower andesites are in fault contact with, or overlain by, the rhyolite tuffs and welded tuff of the upper parts of the Datil formation. South of the map area, along the east face of the Black Range, the lower group is overlain by latitic and rhyolitic flows that are equivalent to the latite facies (Spears member) of the Datil formation. The lower volcanic group is relatively thin, not uniformly present, and overlain by various facies of the Datil, all of which suggests the presence of an unconformity at its upper surface. It seems certain that its lower contact is unconformable, for it rests on Carboniferous limestone near Fluorine in the Black Range, and is reported (Loughlin, 1942) to rest unconformably on Abo

Figure 3. Lag gravel from the Baca formation in Largo Creek valley.

Figure 4. Cross section of lag gravel derived from the Baca formation.

sandstone south of Kelly in the Magdalena mining district. South of the Bear Mountains, north of Magdalena, it rests on Pennsylvanian limestone.

At no place were the lower volcanic rocks observed in contact with the Baca formation, but it seems certain that locally they are older than the parts of the Baca that are gradational into the Datil formation and may be in part equivalent to, or older than, the remaining parts. No diagnostic fossils have been collected from the Baca at its type locality, and none have been identified in the Datil formation. However, the Baca is presumed by Wilpolt to be equivalent to the Baca of the Carthage area, which has been assigned a middle Eocene age on the basis of a fossil mammal tooth. If the foregoing tentative age determination is correct, the lower volcanic rocks are similar lithologically and compositionally to altered andesites in the Peloncillo Mountains and Silver City region that have been dated as Late Cretaceous or early Tertiary (Gillerman, 1953).

Datil formation

General

Winchester's Datil formation (1920, p. 4) consists of the series of tuffs, rhyolites, sandstones, and conglomerates that are the mountain-forming series of the Datil Mountains. His section, however, was measured at the north end of the Bear Mountains at least 20 miles east of the mountains for which the formation was named, and, as already noted, the lower 684 feet of the section has been assigned to the Baca formation. The remaining part of the section, as described, does not include many of the rock types exposed at the same stratigraphic position in the Datil Mountains.

As noted by Tonking (1957, p. 26), Winchester did not measure the complete volcanic sequence exposed in the Bear Mountains. There are at least 1,350 feet of volcanic rock, largely basalt and basaltic andesite, above the top of Winchester's section. Tonking expanded the Datil formation in the Puertecito quadrangle to include the complete sequence of volcanic and sedimentary rocks above the Baca formation and below the sediments and volcanic rocks of the Santa Fe group. This is consistent with the common practice of assigning to the Datil formation all the volcanic rocks (except the most recent basalt and tuff) in this part of southwestern New Mexico.

The use of the name (Datil formation) in the restricted sense by some authors, and by others (such as Tonking) in the very broad sense, has created misunderstanding and confusion, and it is evident that a redefinition of the term is needed. It is questionable whether a redefinition can be justfied on the basis of a reconnaissance study such as this, but it is hoped that the following will be useful.

The reconnaissance study of the volcanic rocks in Catron County has shown that the volcanic section is divided into several parts by recognizable unconformities of regional extent. One, as already noted, occurs at the top of the "lower volcanic group." The second, and most easily recognized, occurs at the base of the thick sequence of basalt and basaltic andesite (Tbo) present in the upper half of the section. These basaltic rocks, in turn, are unconformably overlain by sedimentary and volcanic rocks of the Santa Fe group-Gila conglomerate.

Between the unconformity at the top of the "lower volcanic group" and the one at the base of the basaltic andesite is a thick sequence made up largely of rhyolitic and latitic rocks and lesser amounts of andesite and nonvolcanic and volcanic sediments (fig. 5). This group of rocks is here called the Datil formation and has been divided into a number of facies that are identified by composition rather than lithology. Most of the textural and structural features of eruptive rocks are present in each facies. Typically, a latitic facies makes up the lower parts of the formation and is commonly gradational into an overlying rhyolitic facies of tuff, welded tuff, and flows. The rhyolitic facies is overlain by, or interfingers with, an andesite facies consisting of flows, dikes, sills, and pyroclastics. Conglomerate, sandstone, and siltstone from various sources may be present at any stratigraphic position but are only locally of sufficient thickness to warrant their being designated as facies. In general, all facies contacts are gradational.

At few places is the whole assemblage of facies present; commonly, one or two make up the bulk of the formation.

Latite facies (Tdl)

This facies in the Gallinas and Datil Mountains consists of light gray to grayish purple latitic tuff, welded tuff, tuff breccia, agglomerate, conglomerate, and sandstone (fig. 6). Locally, it contains thin rhyolite tuff beds. It disconformably overlies, or is gradational into, the Baca formation, and is gradational upward into rocks of the rhyolite facies. To the west, in the area of Pie Town, the latitic pyroclastics grade into a series of water-deposited volcanic sediments. South, in the Luera Range, and along the east front of the Black Range, the latitic facies changes to a series of gray to reddish, banded, porphyritic latite flows interlayered with rhyolite tuff, welded tuff, and flows.

In the area shown on the map, the pyroclastic parts of the latitic facies range from siltstone to coarse agglomerate. The coarser parts contain angular to semirounded fragments as much as 2 feet across. The finer parts appear to be water-deposited tuffaceous sediments similar to the rocks of the volcanic sedimentary facies (Tds). The

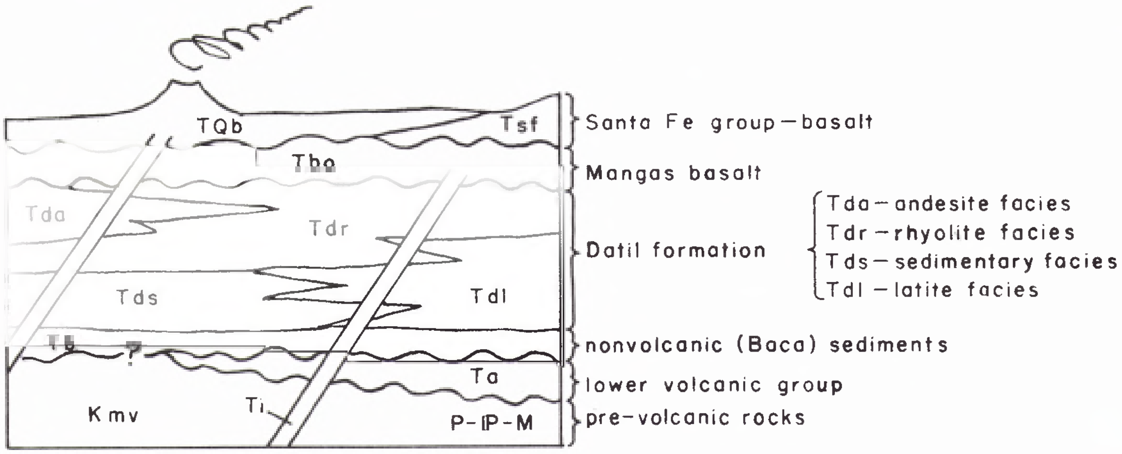

Figure 5. Synoptic diagram of volcanic stratigraphy in the field-trip area.

latitic fragments in these pyroclastic rocks are fine grained, appear to be tuffaceous, are in part welded, and characteristically contain phenoclasts of hornblende, biotite, plagioclase, sanidine, and quartz. The conglomerate and sandstone lenses interlayered with the pyroclastic rocks contain nonvolcanic deterital material plus volcanic fragments from the latite and from the "lower volcanic group." Locally, near the base of the facies, is a thin iron-stained well-indurated breccia that is composed largely of andesitic fragments roughly an inch across.

That part of the latite facies in the Puertecito and Dog Springs quadrangles was named the Spears member of the Datil formation by Tonking (1957) and Givens (1957).

Volcanic sedimentary facies (Tds)

The sedimentary facies of the Datil formation consists of gray to light-gray and locally greenish-gray to reddish-gray sandstones, siltstone, and mudstone, with small amounts of conglomerate and graywacke (fig. 7). This facies consists largely of latitic rock fragments, nonvolcanic detritus, and beds of rhyolite tuff.

Thinly laminated, water-deposited, tuffaceous sandstone and siltstone predominate in the Quemado area. In this area, the sediments are extremely friable and have been eroded into spectacular badlands. In the Gallo Mountains and farther south, the facies becomes more conglomeratic; pebbles and cobbles of various rock types are present, but latite and andesite predominate. The andesite fragments are similar to, and probably were derived from, the "lower volcanic group". In the area of Apache Creek, these sediments are bright greenish-gray owing to a chloritic alteration produced locally by later basaltic andesite dikes and flows.

In the western half of the map area, the volcanic sediments rest conformably on, or are gradational into, the underlying Baca formation. Locally, they interfinger with, or are overlain by, the latite or rhyolite facies. Elsewhere, they are disconformably overlain by either Mangas (Tbo) or late Tertiary-Quaternary basalt (TQb).

Compositionally, the tuffaceous sediments are similar to the pyroclastic rocks of the latite facies, and it seems likely that the two were derived from the same sources and that the textural and structural differences are the result of differences in distance from the source and the environment of deposition.

Rhyolite facies (Tdr)

The rhyolite facies in the map area is composed largely of light-colored, pink to light-gray, pumiceous and crystall tuff, both of which are, at places, welded. None of the various lithologic types is continuous over an appreciable area; they are lenticular. Locally, the facies contains beds of sandstone and conglomerate of volcanic and nonvolcanic material. Biotite, sanidine, and quartz phenoclasts are common in the rhyolites; hornblende is

Figure 6. Latitic pyrolclastics of the Datil formation resting on volcanic sediments that grade downward into the Baca formation. West end of the Datil Mountains.

Figure 7. Interbedded volcanic sediments and latitic pyroclastics in White House Canyon.

relatively rare. Some of the coarser parts of the facies contain angular fragments of pumice and andesite (fig. 8.). The facies is not uniformly resistant to erosion but in general is the principal cliff-forming unit of the Datil formation.

In the map area, the rhyolite facies is best exposed in the Gallinas and Datil Mountains, where it may be as much as 2,000 feet thick. East and west of these mountains, it is much thinner. In the Gallo Mountains, its western limit in the map area, it is thinly interlayered with the flows of the andesite facies (Tda).

South of the map area, the facies continues as one of the principal parts of the Datil formation, but the proportions of the various lithologic types change. In the San Mateo Mountains, it includes a thick section of reddish-brown banded, welded tuff and crystall tuff. In the Luera Mountains it also contains much welded tuff, but the welded tuffs are interlayered with nonwelded tuffs and numerous flows of porphyritic rhyolite that contains well-developed sanidine phenocrysts. Along the east slopes of the Black Range, flow-banded lithoidal rhyolite is interlayered with gray porphyritic latite. In the Gila Wilderness Area, the facies includes a thick section of spectacularly flow-banded porphyritic rhyolite that locally is spherulitic.

The Hells Mesa member in the Puertecito and Dog Springs quadrangles is equivalent to a part of the widespread rhyolite facies.

Andesite facies (Tda)

In the area shown on the map, the andesite facies consists of flows and dikes in rhyolite tuffs and volcanic sediments. Characteristically, these andesitic rocks are gray to black and weather to a reddish brown. Most flows are coarsely porphyritic; lath-shaped feldspar phenocrysts 1-inch long are common. Fine-grained massive andesites are present, however, and become the principal type south of the map area. Lithologically, these massive flows are very similar to the much later flows of Mangas basalt (Tbo), and differentiation of one from the other in the field often depends upon its relation to other units of the Datil formation and to unconformities.

At places in the area of Fox Mountain and Apache Peak, the andesites are vesicular, and locally the vesicules are lined or filled by secondary green mica, possibly celadonite. Volcanic sediments adjacent to the andesite also have been altered and as a result are pale grayish green.

Typically, the andesites form cliffs, but some of the coarsely porphyritic and jointed flows break down into piles of highly rounded "boulders of disintegration," many 10 feet across (fig. 9).

Flows in the Gallo Mountains interfinger with rhyolite pyroclastics. Southwest of these exposures the andesite is medium-grained equigranular, is less commonly interlayered with rhyolite, and at places rests on volcanic sediments (Tds). At the eastern limit of White House Canyon, near Datil, a flow of coarsely porphyritic andesite rests on latite (Tdl) and is overlain by rhyolite pyroclastics (Tdr). In the Luera Range, southeast of the San Augustin Plains, porphyritic andesite rests on the "lower volcanic group" (Ta) and is overlain by rhyolite. The general relations suggest that the flows of the andesite facies are present in several zones in the rhyolite facies, but regionally they are concentrated in its older parts.

Basalt and Basaltic Andesite (Tbo)

These basalts and basaltic andesites range from dark to medium gray; they are for the most part aphanitic and locally scoriaceous, and characteristically contain scattered small reddish-brown crystals of iddingsite. Olivine, although present, is megascopically rare when compared to its occurrence in the Tertiary-Quarternary basalts. Flow breccias are commonly present, and at places the andesites include thin interlayers of rhyolite tuff, tuff breccia, conglomerate, and sandstone.

In the field-trip area, these rocks are best exposed and attain their maximum thickness in the Mangas Moun-

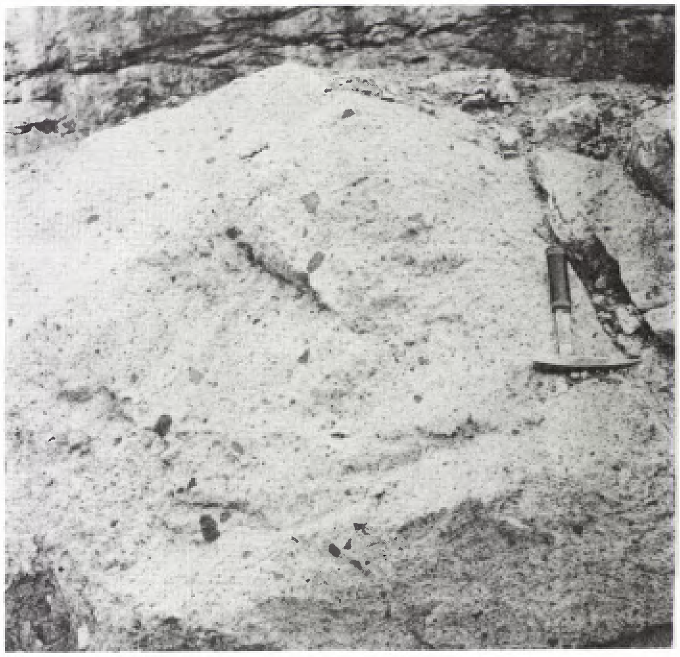

Figure 8. Tuff breccia in the rhyolite facies of the Datil formation east of Datil.

Figure 9. Andesitic boulders of disintegration south of U. S. Highway 60 west of Datil.

tains. They are also well exposed in the Bear Mountains and there were named the La Jara Peak member of the Datil formation by Tonking.

There are few characteristics that will distinguish one basaltic rock from another in hand specimen, and this is true particularly of the basaltic rocks of this unit. Locally, where its relation to other formations is not clear, it may be confused with flows of the "lower volcanic group" (Ta), the andesite facies of the Datil formation (Tda), or the Tertiary-Quaternary basalts (TQb).

In general, the Mangas-Bear Mountains basalts overlie unconformably all the older volcanic rocks and are unconformably overlain by sediments of Santa Fe group-Gila conglomerate type. Single flows or groups of flows may, within limited areas, appear conformable to the Datil formation. Regionally, however, they rest on all facies of the Datil formation, have flowed out on an erosion surface of considerable relief, and may be angularly discordant with adjacent layering in the Datil formation. The observed discordances are not the result of deformational processes but are due to the relationships of initial dips in the Datil formation, initial dips in the basalt, and the relief on the erosion surface between them. Locally, the basalts have clearly flowed around the highest parts of the prebasalt erosion surface.

Flows of Mangas-type basalt, although recognized at many places in Catron County and adjacent areas, never

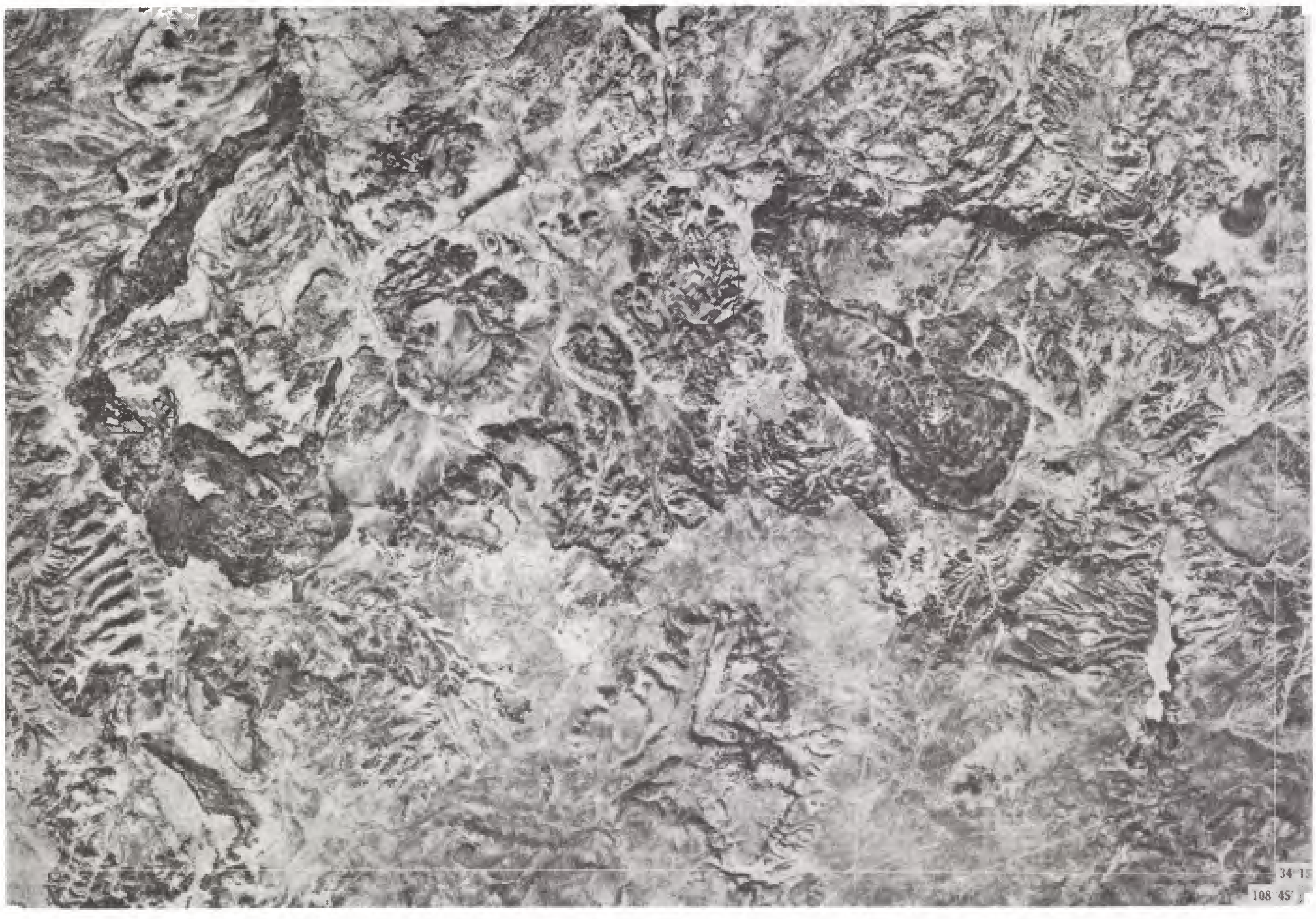

Figure 10. A part of the northwest quarter of the Canyon Largo 30-minute quadrangle showing three well developed Tertiary-Quaternary basalt cones and flows.

formed a continuous sheet over the entire region. They are products of geographically separated volcanic centers. Eruptions from these centers probably did not all occur at the same time, but they all did occur after an interval of erosion on the Datil formation and largely before deposition of the Santa Fe group-Gila conglomerate sediments.

The basaltic intrusives (Ti), especially in the eastern part of the area, probably are related to the basaltic andesite flows in the Mangas and Bear Mountains. Locally, they intrude the flows and are truncated at their contact with the Santa Fe group-Gila conglomerate sediments. Tonking (1957) concluded from relations in the Puertecito quadrangle that some of the dikes were intruded near the end of the Bear Mountains eruptions (La Jara Peak) and before deposition of the Santa Fe beds.

Tertiary-Quaternary Basalt (TQb)

The rocks of this group are typical, black, brecciated and scoriaceous basalt that commonly contains small olivine phenocrysts. Many of the flows can be traced to the vents from which they came. Cinder and composite cones are numerous, and many have been altered only slightly by erosion. The best preserved of these extinct volcanoes are between the crater of Salt Lake and U. S. Highway 60 (fig. 10). One of the most interesting is Red Cone, north of Red Hill. A flow from this volcano followed the course of an adjacent arroyo, forcing subsequent drainage to cut a new channel roughly parallel to the west of the original arroyo.

In the field-trip area, these youngest basalt flows rest at places on members of the Mesaverde group, the Baca formation, and the latitic and sedimentary facies of the Datoil formation. Givens (1957, p. 19) reported basalt of the Santa Fe group overlying and including gravel lenses of the Santa Fe group on Tres Hermanos Mesa in the Dog Springs quadrangle, and similar relations have been observed elsewhere in Catron County.

Santa Fe Group (Tsf)

In New Mexico, the same Santa Fe group has been extended and loosely applied to any deformed and partly consolidated alluvial beds of probable Tertiary age. In the field-trip area, beds with these very general characteristics have been called Santa Fe in the Puertecito, Dog Springs, and Magdalena area. Similar beds are extensive in Catron County south of the field-trip area and have been traced somewhat discontinuously into the area of the upper Gila River, Gilbert's type area for the Gila conglomerate. Hence, it would appear that the term Gila conglomerate probably should have been used in this southwestern part of New Mexico, especially outside the Rio Grande depression.

The Santa Fe group-Gila conglomerate sediments in the map area are derived locally and consist of white, pink, pale brown, red, alluvial, conglomeratic sandstones and siltstones. Because of their local derivation they are composed principally of detrital volcanic material, and this character persists throughout the county. Locally, the sedimentary beds are interlayered with thin beds of rhyolite tuff and flows of basalt.

REFERENCES CITED

Dane, C. H., and Bachman, G. O., 1957, Preliminary geologic map of the northwestern part of New Mexico: U. S. Geol. Survey Misc. Geol. Inv. Map I-224.

Gillerman, E., 1958, Geology of the central Peloncillo Mountains, Hidalgo County, New Mexico, and Cochise County, Arizona: New Mexico Inst. Mining and Technology, State Bur. Mines and Mineral Resources Bull. 57.

Givens, D. B., 1957, Geology of Dog Springs quadrangle, New Mexico: New Mexico Inst. Min. and Technology, State Bur. Mines and Mineral Resources Bull. 58.

Kelley, V. C., and Silver, C., 1952, Geology of the Caballo Mountains: University of New Mexico Publications in Geology, n. 4.

Loughlin, G. F., and Koschmann, A. H., 1942, Geology and ore deposits of the Magdalena mining district, New Mexico: U. S. Geol. Survey Prof. Paper 200.

Tonking, W. H., 1957, Geology of Puertecito quadrangle, Socorro County, New Mexico Inst. Min. and Technology, State Bur. Mines and Mineral Resources Bull. 41.

Winchester, D. E., 1920, Geology of Alamosa Creek valley, Socorro County, New Mexico: U. S. Geol. Survey Bull. 716A.

Wilpolt, R. H., MacAlpin, A. J., Bates, R. L., and Vorbe, Georges, 1946, Geologic map and stratigraphic sections of Paleozoic rocks of Joyita Hills, Los Pinos Mountains, and North Chupadera Mesa, Valencia, Torrance, and Socorro Counties, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 61.