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Mesozoic rocks in Southernmost Arizona*

By

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By Philip T. Hayes

Introduction

This paper presents a brief résumé of Mesozoic geology of southernmost Arizona based on published and unpublished literature and on work still in progress by U.S. Geological Survey geologists--John R. Cooper, Harald Drewes, Tommy L. Finnell, Robert B. Raup, Frank S. Simons, and the writer.

Triassic and Jurassic rocks

Until recent years it was believed that no strata of Triassic or Jurassic age were present in southern Arizona although most workers accepted the Jurassic age of plutonic rocks in the Mule Mountains near Bisbee and in the Dragoon Mountains to the North (fig. 1). Volcanic cobbles of unknown origin were known in basal Cretaceous strata in the Chiricahua Mountains (Sabins, 1957, p. 506) and near Tombstone (Gilluly, 1956, p. 67).

Within the past 20 years the picture has changed considerably. In 1947 Cooper (reported by Gilluly, 1956, p. 68; Cooper and Silver, 1964, p. 71-73) found andesitic volcanic rocks in the Dragoon Mountains area that rested on Permian limestone and were unconformably overlain by a conglomerate that he thought was almost certainly the Glance Conglomerate of Early Cretaceous age (fig. 1). Cooper and Silver (1964, p. 71) tentatively assigned a Triassic or Jurassic age to these rocks, which they named the Walnut Gap Volcanics. Gilluly (1956, p. 68-70) found somewhat similar andesitic volcanic rocks farther south in the Dragoon Mountains and tentatively assigned them to the base of the Lower Cretaceous, although he realized they could be Triassic or Jurassic or even Tertiary.

Within the past few years many additional areas were found to be underlain by Triassic and (or) Jurassic volcanic rocks and related sedimentary rocks (fig. 1). The first reported of these were the Canelo

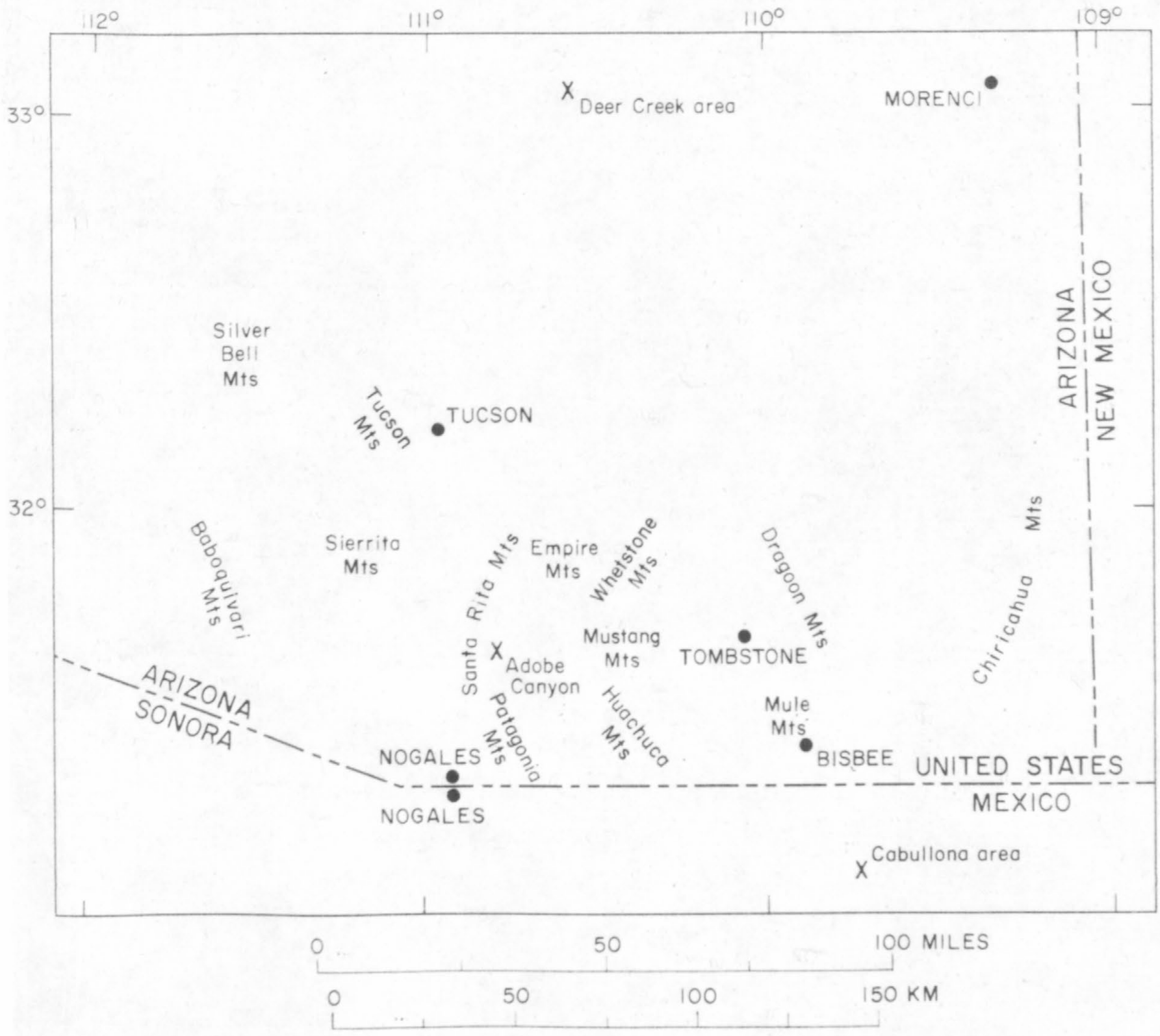

Figure 1.--Index map of southeastern Arizona

Hills Volcanics (Hayes and others, 1965), which extend from the international border for 35 miles (56 km) in a northwest-trending series of outcrops. These siliceous flows, tuffs, and related volcanic sediments (conglomerates, sandstones, siltstones, and shales) contain exotic blocks of Lower Permian limestone and are therefore younger than Early Permian. Locally they are overlain by basal Lower Cretaceous conglomerates. Thus, on geologic evidence they were assigned a Triassic and Jurassic age. Potassium-argon isotope age determinations on biotite from welded tuffs in the sequence of 144 and 173 m.y. support this age assignment. The composite thickness of this volcanic sequence approaches 10,000 feet (3,000 m).

Soon after the Canelo Hills Volcanics were dated, other volcanics, mostly pyroclastics of intermediate composition, were mapped in the Huachuca Mountains by the writer. These rocks overlie faulted Paleozoic strata on a surface with at least many hundreds of feet of relief. The volcanics were intruded by quartz monzonite, which itself is overlain by basal Cretaceous conglomerate that contains detritus of both the volcanics and the quartz monzonite.

Simons has recently mapped siliceous volcanics in the Patagonia Mountains (fig. 1) that overlie Permian limestones, and has found strikingly similar volcanics in nearby areas that are overlain by Lower Cretaceous rocks. He (in Simons and others, 1966) has assigned a Triassic and Jurassic(?) age to all these siliceous volcanics.

Drewes (1966a) has mapped a 10,000-foot-thick (3,000-m-thick) sequence of siliceous volcanics and sandstone in the Santa Rita Mountains (fig. 1) which were intruded by a monzonite. The monzonite was dated radiometrically as 184 m.y., and thus the volcanics were assigned a Triassic age (Drewes, 1966b).

John R. Cooper (oral commun., 1965) has mapped volcanic rocks in the Sierrita Mountains (fig. 1) which, on the basis of geologic relations and lithology, he believes are probably of Triassic or Jurassic age.

Similar occurrences have been mapped recently by Robert B. Raup in the Mustang Mountains and by Tommy L. Finnell (oral commun., 1966) in the Empire Mountains (fig. 1).

In southwestern Arizona, Triassic and Jurassic strata may also be present but have not yet been identified as such. The Ali Molina Metamorphic Complex of the Baboquivari Mountains is assigned a Mesozoic(?) age by Heindl and Fair (1965, p. I5-I6). It is possible, if not probable, that the Ali Molina and similar sequences elsewhere in southwestern Arizona are of Triassic and (or) Jurassic age.

Lower Cretaceous rocks

Lower Cretaceous strata of southern Arizona were first described in some detail by Ransome (1904, p. 56-73) for their exposures in the Bisbee district in the Mule Mountains (fig. 1). These beds were assigned to the Bisbee Group, made up of four formations. The thicknesses of the formations, as reported in the following paragraphs, are as remeasured by the writer and Edwin R. Landis.

In the Mule Mountains the Glance Conglomerate at the base of the Bisbee Group rests on an irregular erosion surface cut on metamorphic, sedimentary, and igneous rocks ranging in age from Precambrian to Jurassic (Hayes and Landis, 1964). The Glance is locally absent over high areas on the erosion surface but is as much as 650 feet (200 m) thick in depressions. The basal conglomerate fragments, which are as large as small boulders, are subangular and poorly sorted, and this composition closely reflects that of the underlying bedrock.

The Glance grades upward through a thin transition zone into the Morita Formation. The Morita, which is about 2,600 feet (800 m) thick in the Mule Mountains, is made up of repeated sequences of coarse arkosic cross-laminated sandstones which grade upward into pale-red siltstones, which, in turn, grade into relatively thick units of massive dark-reddish-brown mudstone. Mudstone is dominant in most of the formation, but sandstone that forms resistant ledges is dominant in about the upper

325 feet (100 m). Thin beds of impure oyster-bearing limestone are scattered throughout the upper half of the Morita; fossil wood is locally present--especially in the upper part.

Conformably overlying the Morita Formation is the Mural Limestone, which is subdivided into two members in the Bisbee area. The lower member, about 425 feet (130 m) thick, is a transitional unit between the Morita Formation and the upper member of the Mural. The upper member, about 280 feet (85 m) thick, is made up mostly of thick beds of fossiliferous marine limestone including some rudistid reefs. The lower part of the lower member is of Aptian age, and the remainder of the formation is of Albian age (Stoyanow, 1949, p. 36).

Conformably overlying the Mural is at least 1,800 feet (550 m) of strata, assigned to the Cintura Formation, that are similar in lithology to the Morita Formation. The Cintura is presumably of late Early Cretaceous age. Quaternary deposits cover the eroded top of the Cintura Formation, and no rocks of Late Cretaceous or Tertiary age are exposed over the Bisbee Group in the type area.

Rocks that are of similar age and lithology to the type Bisbee are known more than 95 miles (150 km) to the east of the Mule Mountains and more than 48 miles (75 km) to the west, as well as in many intervening localities. In most of these localities the rocks are called the Bisbee Group or Bisbee Formation, but local formational names are used in some ranges. Regional correlations of rocks within the Bisbee Group, and thus knowledge of lithofacies trends, are uncertain, and are subject to various interpretations.

In the southern part of the Chiricahua Mountains (fig. 1), northeast of the Mule Mountains, the Lower Cretaceous sequence is similar to the sequence at Bisbee except that it is thicker and there is more fossiliferous marine rock much lower in the section beneath the Mural Limestone equivalent. In areas farther to the east, in New Mexico, there is a yet greater proportion of marine rock in the Bisbee Group (Lasky, 1947, p. 16-26; Zeller, 1965, p. 55-75).

West of the Mule Mountains, in the Huachuca Mountains, the Bisbee Group is basically similar in character to the type Bisbee except that the basal conglomeratic sequence in places is very thick and locally contains a large proportion of volcanic conglomerate as well as thick sequences of volcanic flows and flow breccias of intermediate composition.

The Bisbee Group of the Whetstone Mountains (Tyrrell, 1957, p. 93-115; Creasey, 1967) differs to some extent, and precise correlation with the type area is less certain. The Mural Limestone is not recognized as such, but it apparently is represented by a few very thin beds of fossiliferous impure limestone. A lower unfossiliferous sequence of impure dark-gray platy limestones and calcareous shales may be correlated with fossiliferous marine rocks low in the stratigraphic section in the Chiricahua Mountains.

Identification of the Bisbee Group in the Santa Rita Mountains farther to the west is open to some question. The earliest Cretaceous is represented by as much as 4,000 feet (1,200 m) of internally variable conglomerates and intermediate volcanics (Drewes, 1966b) which may be approximately synchronous with similar rocks in the Glance Conglomerate in the Huachuca Mountains but which Drewes (oral commun., 1966) believes may be equivalent to much more of the Bisbee in areas to the east. In the northern part of the Santa Rita Mountains are arkosic sandstones, dark-gray mudstones, and a few thin carbonaceous limestones that contain brackish-water or marine fossils. These strata may represent similar rocks in the lower part of the Bisbee of the Whetstones, but Drewes (oral commun., 1966) believes that they could also be equivalents of a nonmarine strata of Late Cretaceous age farther south in the Santa Ritas. Unfortunately, the fossils found in these marine rocks are not sufficiently diagnostic to settle the problem.

Probable nonmarine equivalents of the Bisbee Group are also present in the Tucson Mountains farther to the west than the Santa Ritas, but precise correlations with all or part of the Bisbee Group cannot yet be made. There are probable Bisbee equivalents in ranges farther to the west, but these, too, are poorly known.

In the northern part of the Empire Mountains, to the north of the Santa Rita and Whetstone Mountains, Finnell (oral commun., 1966) recently discovered probable equivalents of the Morita Formation of the Bisbee Group lapping onto a highland composed of Precambrian rocks.

Much detailed work remains to be done on the Bisbee Group over a wide area. It is my tentative belief that the Bisbee represents a large delta complex deposited on the margins of an Early Cretaceous sea that lay mostly in Mexico. Its sediments were presumably derived from a large landmass in south-central Arizona.

Upper Cretaceous rocks

Marine and brackish-water strata of probable early Late Cretaceous age were known in the Morenci and Deer Creek areas more than 60 years ago (Lindgren, 1905, p. 73-74; Campbell, 1904, p. 245-247). These rocks, which are more than 90 miles (150 km) north of the international border, were deposited near the margins of a sea which lay to the east and northwest, and they are not discussed here.

Nonmarine strata of probable later Late Cretaceous age were recognized in the Tucson (Brown, 1939, p. 713-720) and Santa Rita (Stoyanow, 1937) Mountains about 30 years ago (fig. 1). Owing to a scarcity of fossils, complexity of structure, and a lack of detailed study, these rocks were poorly understood until recent years. Even now we have much to learn. However, recent fieldwork by Kinnison (1958) in the Tucson Mountains, by Cooper in the Sierrita Mountains, and by Drewes (1966a) in the Santa Rita Mountains, and work on nonmarine vertebrate and invertebrate fossils by Miller (1964) now make a few tentative generalizations possible.

Probably the most complete, and certainly the best described, sequence of Upper Cretaceous rocks in southernmost Arizona is that of the Adobe Canyon area on the east side of the Santa Rita Mountains. The following general description of those rocks is from unpublished data of Drewes.

The lowest exposed Cretaceous strata in the Adobe Canyon section are about 1,600 feet (500 m) of interbedded sandstone, siltstone, and mudstone that Stoyanow (1949, p. 59) called the Fort Buchanan Formation of the Sonoita Group. These rocks, I believe, are similar in lithology to the Bisbee of areas to the east as well as to some other rocks of probable Late Cretaceous age, but they differ from the overlying rocks in the Adobe Canyon area. However, a fragment of the right jaw of a hadrosaurian dinosaur of probable Late Cretaceous age was reported (Miller, 1964, p. 380-381) from a locality best reconstructed as 50-100 m below the top of this unit. Drewes (1966a) included these beds in the Upper Cretaceous, but I am inclined to think that the dinosaur bone collecting site may not have been precisely reported and that the rocks are possibly of Bisbee age.

At the top of this unit is a distinctive but lenticular conglomerate that forms the base of a 525-foot-thick (160 m) sequence of dark-gray shale and subordinate sandstone in which is found a varied fauna including fresh-water invertebrates, fish and turtle remains, and dinosaur teeth that together indicate a Santonian to Maestrichtian or late Late Cretaceous age. This unit is the basal part of the Fort Crittenden Formation of Stoyanow (1949, p. 59). Above this fossiliferous shale unit in the Adobe Canyon area is more than 6,000 feet (2,000 m) of variable grayish-red and brown sandstone and conglomerate and subordinate shale. Fossil wood is locally abundant in the unit. High in the unit there are several thin rhyolite tuff beds, and elsewhere in the Santa Rita Mountains a single thicker tuff bed.

Correlation of the Adobe Canyon section with the Upper Cretaceous sequence described by Taliaferro (1933, p. 22-32) near Cabullona, Sonora, is uncertain. The lowest exposed Upper Cretaceous strata at Cabullona are in a unit of sandstones and carbonaceous shales of continental origin at least 2,000 feet (600 m) thick. Near the top of this unit were found dinosaur bones that indicate an age similar to or slightly older than that of the lower shale unit of the Santa Rita Mountains. Next above is an interval about 1,200 feet (370 m) thick of sandstones and subordinate shales that contains fresh- or brackish-water pelecypods and gastropods. Above that is a unit about

2,000 feet (600 m) thick which consists mostly of dark shales that contain scattered marine fossils that apparently are not closely diagnostic as to age. Above the marine strata is 2,000 feet (600 m) or more of red shales and red and white sandstones. These strata are overlain by a thick tuff unit. Tentatively, I would suggest that the basal unit of continental rocks at Cabullona laps out northward and has no equivalents in the Santa Rita Mountains, but it may be equivalent to the rocks similar to the Bisbee there that Drewes believes may be of Late Cretaceous age. The invertebrate-fossil-bearing beds above may represent an approximate seaward equivalent of the fossiliferous shale unit of the Santa Rita Mountains.

In the Huachuca Mountains, between the Santa Ritas and the Cabullona area, is a unit lithologically similar to Upper Cretaceous beds of the Santa Ritas that rests with slight angularity on the Bisbee Group. Conglomerates in the base of the unit contain detritus apparently derived from Triassic and Jurassic rocks.

Correlation of the Santa Rita section with probable Upper Cretaceous rocks to the west and northwest is also uncertain. Primarily on the basis of similarities in lithology, Drewes (oral commun., 1965) correlates units in the Sonoita Group with units in a thick sequence of dominant red beds that Cooper is mapping in the Sierrita Mountains. Cooper (oral commun., 1965) believes that part of the red-bed sequence of the Sierritas is equivalent to part of the Amole Arkose of Brown (1939) in the Tucson Mountains. Rocks such as described by Heindl (1965a, b) and Heindl and Fair (1965) occur in several ranges to the west and southwest, and may be equivalent to the Upper Cretaceous of the Santa Ritas, but this is still very speculative.

Upper Cretaceous and Tertiary(?) rocks

Rocks of Late Cretaceous and Tertiary(?) age have been studied in detail in some areas and have been observed in others. No attempt is made here to give a lengthy description of the rocks in any one area or to give a detailed account of the problems of regional correlation, but a general description of the nature of the rocks and of their relations with adjacent rocks is given.

In nearly all areas where their basal contact can be observed, these Cretaceous and Tertiary(?) rocks rest with angular unconformity on older rocks whatever their age. The initial structural disturbances of the Laramide Revolution apparently preceded their deposition. The Cretaceous and Tertiary(?) rocks were, in turn, deformed and locally intruded by plutons during later phases of the Laramide Revolution and before deposition of later Tertiary sediments and volcanics.

In many areas, particularly in the Silver Bell and Tucson Mountains area, this Cretaceous and Tertiary(?) sequence can be conveniently subdivided into two or three distinctive major units.

The lower unit, where present, consists mostly of conglomerates, breccias containing exotic blocks, and of poorly sorted sandstones. The middle unit consists mostly of andesitic flows and breccias. The upper unit is characterized by rhyolitic and latitic tuffs. There is no uniform regional terminology for these rocks. For convenience, the basal conglomerate and breccia unit can be related to the Claflin Ranch Formation of Richard and Courtright (1960) of the Silver Bell Mountains (fig. 1), the andesitic middle unit can be related to the Silver Bell Formation of Courtright (1958), and the acidic tuffs at the top can be related to the Cat Mountain Rhyolite of Brown (1939).

Geologic history

Probably in Early Triassic time the region was faulted and differentially uplifted. During the Triassic and Jurassic, conglomerates, lavas, tuffs, and volcanic sediments were deposited locally on the irregular topography. The volcanics and older rocks were intruded in places by granitic plutons. On the basis of radiogenic dates and geologic evidence, it is suggested that there may have been two distinct periods of volcanism and subsequent intrusion during this time--one in the Triassic and one in the Jurassic. The Jurassic igneous activity was followed by uplift and subsequent erosion down to the level of some of the plutons. Early in Cretaceous time the topography was again very irregular. The Glance Conglomerate and correlatives were deposited over this irregular erosion surface, and by the end of Glance deposition the relief was almost completely masked. In the western part of the region lavas of intermediate composition were extruded locally during deposition of the Glance and correlatives.

During this time the region was slowly subsiding, with a slight tilt to the southeast. The Lower Cretaceous Bisbee Group was deposited along the margins of a sea that lay mostly in Mexico. After deposition of the Bisbee, the region was subjected to broad gentle folding for the most part, but in places there probably was uplift sufficient to allow local erosion down through the sediments deposited during the Early Cretaceous. Upper Cretaceous continental strata were then deposited over much of the western part of the region, and possibly over all of it.

Latest Cretaceous volcanics and orogenic sediments in most places were deposited with marked angularity on folded and faulted older rocks. The Laramide history of Late Cretaceous and Tertiary(?) thrust faulting, folding, volcanism, plutonism, and mineralization is complex. It was during this time that most of the important ore deposits of southern Arizona were emplaced.

Conclusion

The Mesozoic and Tertiary(?) history of southernmost Arizona is much more complex than has commonly been realized. Faulting, folding, volcanism, plutonism, and mineralization took place in Triassic and Jurassic time as well as in Late Cretaceous and Tertiary(?) time.

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