THE CRETACEOUS SYSTEM OF SOUTHEASTERN ARIZONA

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Rocks of the Cretaceous system crop out in widely separated areas throughout southeastern Arizona. The more important areas of outcrop are near Bisbee, Tombstone, Deer Creek, Morenci, and in the Empire, Santa Rita, Patagonia, Huachuca, and Tucson Mountains, and the Canelo Hills (fig. 4a). In most of these areas the outcrops are considered to be Early Cretaceous in age, probably representing the Aptian and Albian stages. The Deer Creek, Morenci, and Santa Rita outcrops contain upper Cretaceous fossils and the Tucson Mountain outcrops contain both lower and upper Cretaceous fossils.

LOWER CRETACEOUS ROCKS

Bisbee and Tombstone Areas

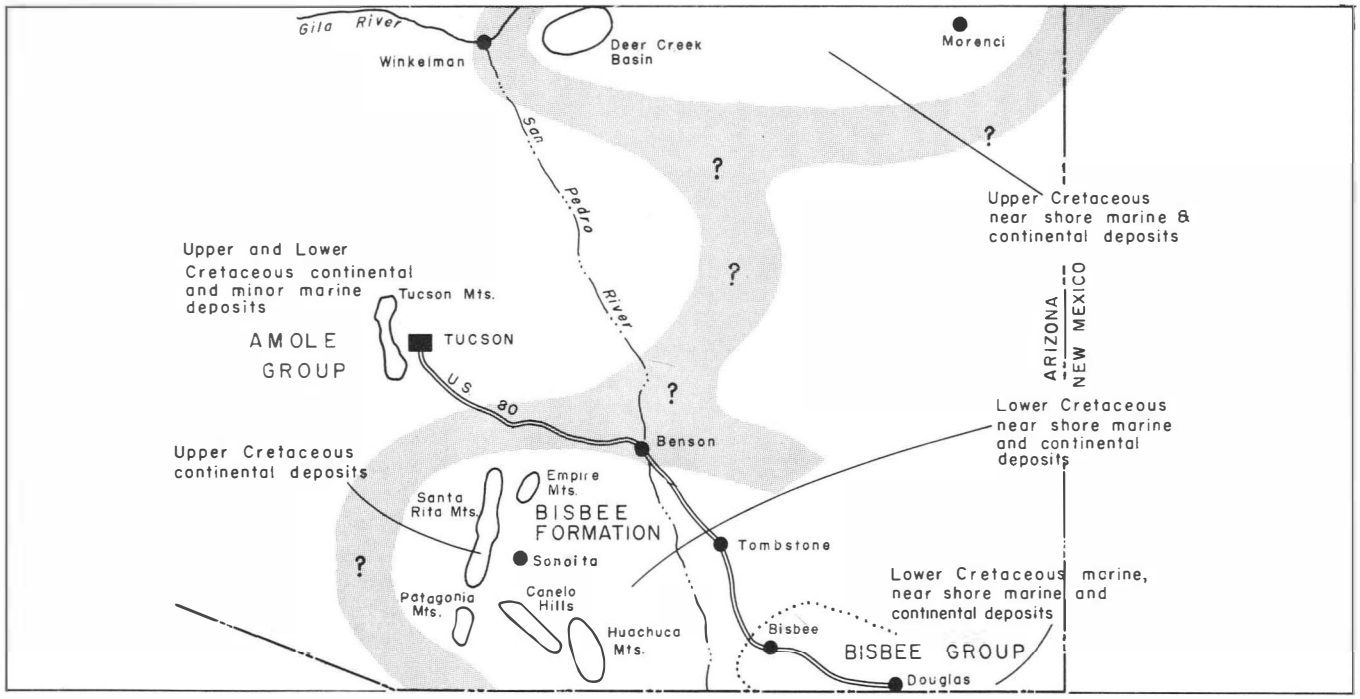
The Cretaceous rocks in the Bisbee area were named the Bisbee group by Ransome (1904), who originally described them to contain four formations -- in ascending order, these are the basal Glance conglomerate, the Morita formation, the Mural limestone, and the Cintura formation. Stoyanow (1949) designated the lower part of the Mural limestone as the Lowell formation and restricted the term "Mural limestone" to the upper part.

The Glance conglomerate rests unconformably on Paleozoic and Precambrian rocks, and its composition generally reflects the underlying rocks. It has an average thickness of about sixty feet and a maximum thickness of 6, 000 feet. Locally it may be missing. The dominantly clastic Morita formation overlies the Glance conglomerate and consists of about 1, 800 feet of red shale and fine to coarse, red to brown sandstone with a few limestone lenses. The Lowell formation (Stoyanow, 1949) consists of alternating beds of sandstone and limestone, and attains a thickness of 1, 100 feet. The Mural limestone above the Lowell formation is 300 feet thick; it has thin-bedded limestone at the base, succeeded by a massive limestone. The uppermost member of the Bisbee group is the Cintura formation, which consists of a few impure limestone beds at the base, overlain by alternating shale and brown to red crossbedded sandstone beds. The Bisbee group is Aptian and Albian in age (Stoyanow, 1949).

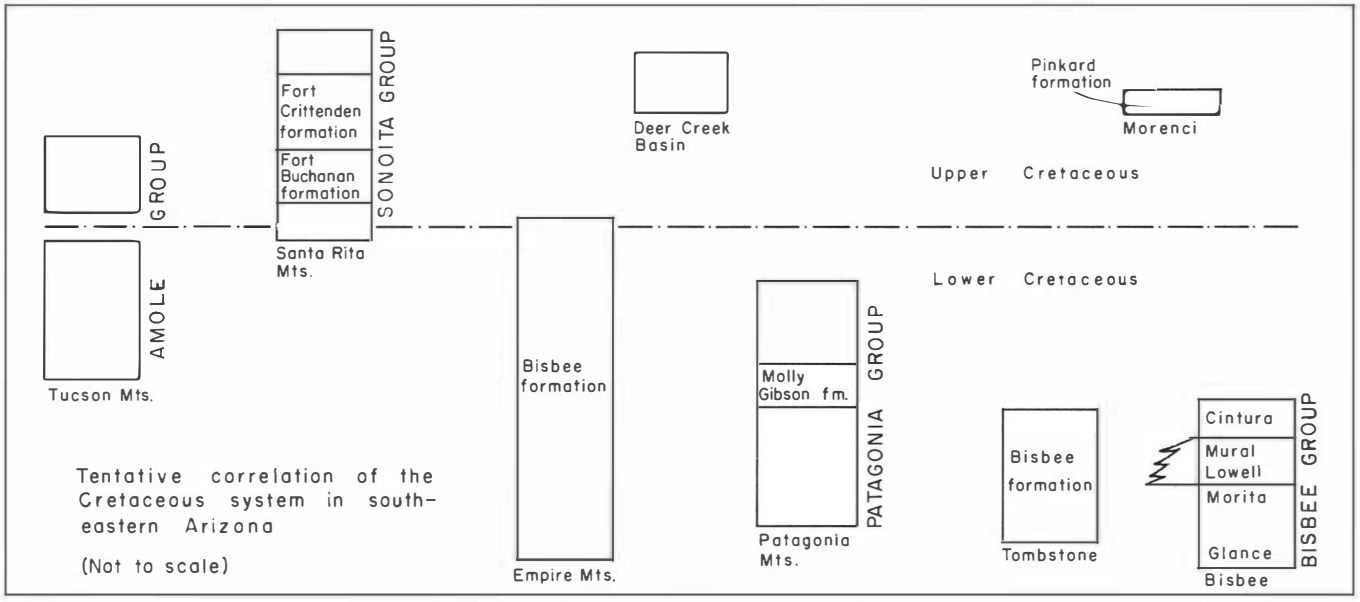
Twenty miles northwest of Bisbee, in the Tombstone area, Gilluly (1956) noted that the Lowell formation and the Mural limestone pinch out and the sequence there consists of the Glance conglomerate and the undifferentiated Morita and Cintura beds which he calls the Bisbee formation. These sedimentary rocks are of near-shore marine and terrestrial origin. Gilluly (1956) also suggests that acidic lava flows, pyroclastic rocks, and flow breccias in the area may be conformable and interfinger with the Glance conglomerate.

Empire Mountains

The Empire Mountains (Galbraith, 25), about forty miles northwest of Bisbee, are surrounded by extensive Cretaceous outcrops. On the northern flank of the Empire Mountains, Brennan (1957) measured about 15, 000 feet of sedimentary and volcanic rocks of probable Cretaceous age in a patchwork of complex fault blocks. However, he considered the true thickness to be nearer 8,000 to 10,000 feet because of probable duplication by faulting and difficulty in correlating between fault blocks.



A. Index map showing locations of areas of outcrop of Cretaceous deposits in Arizona.



B. Chart showing tentative correlation of the Cretaceous system in southeastern Arizona.

FIGURE 4. Index map and correlation chart of Cretaceous deposits in southeastern Arizona.

The basal member of his section is an arkosic conglomerate which rests unconformably on granite. The conglomerate appears to grade upward into arkosic sandstone and shale, which are cut off by faulting. Probably overlying these strata are alternating beds of green sandstone and mudstone, followed by more than 7,000 feet of alternating red sandstone and red mudstone, which near the top include a pebble conglomerate and a black oyster-bearing limestone. On top of this sedimentary sequence is a considerable thickness of pyroclastic rocks and rhyolite flows. Brennan (1957) suggests that this section may correlate with the Cretaceous clastic formations at Tombstone by calling this unit the Bisbee (?) formation.

On the eastern flank of the Empire Mountains the Cretaceous (?) rocks attain a thickness of 8,700 feet (Galbraith, 1949). The sequence consists of a basal limestone pebble conglomerate, derived from underlying Paleozoic rocks. The conglomerate is overlain by alternating sandstone and shale beds. The sandstone becomes coarser and more arkosic upward in the section and alternates with a few green, and many red shale and siltstone beds. The upper part of the section includes a few thin limestone beds containing oysters and some black shale. Farther to the south, lava flows may exist in the upper part of the section.

The Cretaceous (?) beds on the western flank of the Empire Mountains consist of two units separated by a fault -- a northern sequence of arkose and shale beds similar to Cretaceous (?) strata on the east side of the Empire Mountains, and a southern sequence of cobble to boulder conglomerate beds. The northern sequence is overlain by acidic lava flows and tuffs (Galbraith, 1949).

Patagonia Mountains

Within the Patagonia Mountains, about 25 miles south of the Empire Mountains, the Cretaceous Patagonia group (Stoyanow, 1949) crops out and consists of 5,850 feet of sedimentary and volcanic rocks. Red shale and sandstone at the base of the sequence appear to grade upward into sandy shale which is succeeded by andesitic and rhyolitic lava flows. Above the volcanic rocks there are 3,400 feet of red to brown shale, and these beds are overlain by the Molly Gibson formation (Stoyanow, 1949) which consists of 1,000 feet of shale and a sequence of dark blue to light gray limestone. The Molly Gibson formation contains the ammonite Stolicskaia, an upper Albian guide fossil (Stoyanow, 1949). The limestone is overlain by 1,500 feet of a dark blue to black hornstone and interbedded siliceous shale which Stoyanow considered to be part of the Patagonia group.

Canelo Hills and Huachuca Mountains

A few miles east of the Patagonia Mountains Cretaceous rocks crop out in the Canelo Hills and the Huachuca Mountains. In the Canelo Hills, Feth (1947) measured 1,200 feet of gray and brown sandstone which are overlain by 1,360 feet of red clastic beds with a few thin limestone strata. Feth (1947) named the upper 1,360 feet of this Cretaceous sequence the Canelo red beds. The area is complicated by faulting and it was necessary for Feth to piece the section together from discontinuous exposures.

In the east-central Huachuca Mountains, the Cretaceous rocks are reported to consist of red siltstone and mudstone with interbedded sandstone and conglomerate (Weber, 1950). There are volcanic rocks, rhyolites and trachytes, interbedded with the sandstone. The thickness of the sedimentary and volcanic rocks is 1,500 feet and both the top and bottom of the section have been cut off by faulting.

UPPER CRETACEOUS ROCKS

Deer Creek and Morenci Areas

In the Deer Creek basin, Ross (1925) described upper Cretaceous marine fauna in a section which includes coal beds and volcanic rocks. The Deer Creek fauna correlate with the fauna of the Pinkard formation (Lindgren, 1905) in the Morenci area. The Cretaceous sequence in the Deer Creek basin has a thickness of 1, 500 feet, of which 1,000 feet are volcanic rocks overlying the sediments. In the Morenci area the Pinkard formation is composed of 500 feet of sandstone and siltstone with some conglomerate and rests unconformably on the Pennsylvanian Tule Springs formation.

Santa Rita Mountains

Upper Cretaceous rocks on the eastern slope of the Santa Rita Mountains, about five miles west of the Empire Mountains, were designated as the Sonoita group by Stoyanow (1936). This group consists of the lower Fort Buchanan and the upper Fort Crittenden formations. The Fort Buchanan formation overlies andesitic lava flows and is approximately 2,000 feet thick. It consists of a basal conglomerate 400 feet thick and more than 1,500 feet of alternating gray sandstone and red shale. The Fort Crittenden formation is more than 2,500 feet thick. At the base there is a thin conglomerate which is followed by 600 feet of alternating yellow shale and limestone containing the mollusks Unio and Viviparus, and dinosaur teeth and bones of the genus Gorgosaurus (Stoyanow, 1949). Overlying this fossiliferous zone are over 500 feet of alternating shale and sandstone and 1, 000 feet of conglomerate.

LOWER AND UPPER CRETACEOUS ROCKS

Tucson Mountain Area

The Cretaceous rocks of the Tucson Mountains were divided by Brown (1939) into three units -- undifferentiated andesitic volcanic rocks, the Recreation red beds, and the Amole arkose. In the central part of the range, the Amole arkose consists dominantly of arkose and shale of continental origin, with some beds of possible near-shore marine origin. The Amole arkose is more than 2, 000 feet thick and grades downward into the Recreation red beds. The Recreation red beds consist predominantly of sandstone and are about 1, 200 feet thick. They apparently grade downward into andesite-pebble conglomerate with thin, interbedded(?) rhyolite flows. Colby (1958) suggests that the volcanic conglomerate is contemporaneous with, rather than older than, the Recreation red beds. The andesite pebbles in the conglomerate are similar to and may be derived from andesite found in a sequence of volcanic rocks in the northern part of the range and Brown (1939) placed the volcanic sequence at the base of the Cretaceous section. Courtright(1958) and Kinnison(12) discuss parts of the volcanic sequence as being post-Amole and possibly of Tertiary (?) age.

In the southern part of the range, Kinnison (1958) estimated that the clastic sedimenta similar to the Amole arkose are more than 5, 000 feet thick. At least a part of this section was mapped by Brown (1939) with his volcanic unit. Kinnison (1958) divided the southern section into four formations and suggested that the term "Amole" be elevated to group status. The base of the Amole group rests on Permian limestone with a limestone conglomerate. There is an angular unconformity within the Amole group and Kinnison (1958) suggests that the Amole group may include two sequences of lithologically similar clastic rocks separated by the andesite-pebble conglomerate, possibly the volcanic sequence that supplied the pebbles, and the Recreation red beds.

Brown (1939) placed the Amole arkose in the Upper Cretaceous on the basis of Mactra identified by Stoyanow (in Brown, 1939), but fresh water molluscs from the same area were suggested to be probably of Lower Cretaceous age (McKee, 1951). Kinnison (1958) reported ostracods (Metacyris) not younger than Early Cretaceous in the lower part of the section in the southern part of the range and birch pollen dated as not older than Late Cretaceous in the upper part of the section. A few questionable identifications of pollen suggested that the sequence may extend up into the early part of Tertiary time.

CORRELATION

Accurate description and measurement of sections and correlation of the Cretaceous deposits to the west and north of the Bisbee area are made difficult by the paucity of fossils, the complex structure, and the absence of distinctive horizons. Possible relationships between Cretaceous rocks are shown in figures 4a and 4b.

The clastic sequences of conglomerate, sandstone, and arkose found in the Empire, Patagonia, and Huachuca Mountains, and the Canelo Hills are all similar, and all are associated with acidic lava flows and pyroclastic rocks. The acidic volcanic rocks which occur at the top of these sequences may be correlatives of the clastic sedimentary rocks in the Bisbee group and the Bisbee formation. If the volcanic rocks represent a part of Albian time, then the underlying clastic rocks may be pre-Albian. In the Patagonia Mountains the andesitic volcanic rocks are overlain by the Molly Gibson formation, which is uppermost Albian in age, and the upper Cretaceous in the Santa Rita Mountains overlies andesitic flows. In the Tucson Mountains, the volcanic rocks may lie at the base, within, or above the Cretaceous section and probably there are at least two volcanic sequences. The upper one, within the section, may represent the time interval lost by the unconformity between Upper and Lower Cretaceous strata in the southern part of the Tucson Mountains and the volcanic rocks in the northern part of the Tucson Mountains may be also possibly Albian in age.

The Lower Cretaceous rocks in the Bisbee, Tombstone, Empire, Patagonia, Canelo, and Huachuca areas were deposited in a transgressing sea advancing from the southeast from Mexico into Arizona. The outcrops in the Mule Mountains around Bisbee are marine limestone and near-shore marine and continental clastic deposits. The rocks in the Tombstone area, the Empire Mountains, the Patagonia Mountains, the Canelo Hills, and the Huachuca Mountains represent near-shore marine clastic, and continental deposition around the perimeter of the Bisbee Sea and correlate with the lower and upper units of the Bisbee group. These near-shore marine deposits with their associated continental beds have been called the Bisbee formation (Gilluly, 1956; Brennan, 1957) locally, and the name might be extended to the other areas of similar deposits.

The deposits in the Tucson Mountains are predominantly of terrestrial origin, whose source areas were probably to the west, but there are also near-shore marine deposits resulting from minor marine invasions from the east. Limited fossil evidence in the Tucson Mountains suggests that strata of both Upper and Lower Cretaceous age occur and the uppermost deposits may extend into the Tertiary.

The upper Cretaceous deposits in the Deer Creek and Morenci areas include continental, swamp, near-shore marine, and marine deposits and may represent an invasion from the north of the upper Cretaceous seas of the western interior region (Pike, 1947). The upper Cretaceous sedimentary rocks in the Santa Rita Mountains are of continental origin.