PRECAMBRIAN AND PALEOZOIC SEDIMENTARY ROCKS ON THE PAPAGO INDIAN RESERVATION, ARIZONA

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INTRODUCTION

Precambrian and Paleozoic sedimentary rocks crop out in isolated areas in several mountain ranges in the northeastern two-thirds of the Papago Indian Reservation. The most nearly complete stratigraphic sequences are found in the Vekol, Slate, and Waterman Mountains and in Kohtkohl Hill (fig. 55). In many areas the rocks have been crumpled and altered or are too limited in exposure to permit accurate identification. In this report, the stratigraphic sequences in the Vekol and Slate Mountains and in Kohtkohl Hill will be outlined and compared (fig. 9) to the sections in the Waterman Mountains (McClymonds, 16) and in central Cochise County (Gilluly, 1956).

Paleozoic rocks in these areas were first reported on the Arizona State geologic map (Darton and others, 1924) and were described briefly, in part, by Darton (1925). The rocks in the Vekol, Slate, and Waterman Mountains were described in unpublished theses (Hogue, 1940; Carpenter, 1947; Ruff, 1951; McClymonds, 1957). A partial section in the Vekol Mountains was discussed by Hadley (written communication, 1944). The fieldwork upon which this report is based was done as a part of an investigation of the ground-water resources of the Papago Indian Reservation by the U. S. Geological Survey for the Bureau of Indian Affairs.

STRATIGRAPHY

Vekol Mountains

The Vekol Mountains, about 30 miles southwest of Casa Grande, Ariz., consist of granitic, metamorphic, sedimentary, and volcanic rocks ranging in age from Precambrian to Tertiary. The rocks are exposed in a series of nearly parallel north-trending ridges. The largest ridge forms the southwestern half of the range and contains the most complete exposures of sedimentary rocks.

The oldest sedimentary rocks in the Vekol Mountains are the Apache group of late Precambrian age. In this area the Apache group includes, from older to younger, the Pioneer shale, Dripping Spring quartzite, and Mescal limestone, and is more than 1,500 feet thick. The Pioneer shale lies on a beveled surface of the Pinal schist, and the basal beds are locally a pebble conglomerate a few inches thick. The Pioneer shale is about 350 feet thick and is composed of grayish-red and grayish-green claystone and siltstone containing several sandstone units near the middle. The Dripping Spring quartzite is 870 feet thick and is made up of brownish-gray to light-gray fine- to medium-grained sandstone, firmly cemented by siliceous material. A 17-foot-thick basal conglomerate, similar to the Barnes conglomerate (Ransome, 1903), is included in the Dripping Spring quartzite. The Mescal limestone is 345 feet thick and is composed of gray and reddish- or brownish-gray aphanitic to very finely crystalline silty dolomite. Diabase sills are found throughout the Precambrian section below the Paleozoic contact.

The Paleozoic sedimentary rocks are more than 1,700 feet thick and include all commonly known formations in southern Arizona from the Cambrian through the Pennsylvanian. The basal formation, the Troy quartzite, of Middle Cambrian age,

is 195 feet thick and consists of coarse-grained crossbedded sandstone and quartzite. It lies on the Mescal limestone with apparent conformity, although locally the basal Troy is black and contains small basaltic(?) pebbles. The overlying Abrigo formation of Middle and Late Cambrian age is composed of interbedded dolomite and yellowish-brown mudstone, with sandstone units at the base and near the top. It is about 360 feet thick. A 20-foot-thick sandstone unit, 290 feet above the base of the Abrigo, is probably equivalent to the Southern Belle quartzite described by Stoyanow (1936) at the north end of the Santa Catalina Mountains.

The Martin formation of Late Devonian age lies with apparent conformity on the Cambrian Abrigo, and there is no indication of the hiatus spanning Ordovician, Silurian, and part of Devonian time. The Martin formation is more than 200 feet thick and is composed mostly of gray and brownish-gray to grayish-red very finely crystalline dolomite interbedded with gray and reddish-brown siltstone, sandstone, and, less commonly, limestone. The Escabrosa limestone of Mississippian age is gray, with a brownish or reddish hue in part, and is aphanitic to finely crystalline. A few beds of dolomite occur in the bottom, and nodular chert is present in many of the beds throughout the formation. The Escabrosa limestone lies conformably on the Martin formation and is 435 feet thick.

The boundary between the Escabrosa limestone and the Horquilla limestone of Pennsylvanian age is marked by a 16-foot-thick unit of grayish-red claystone, interbedded with grayish-purple siltstone and one bed of quartzite and jasper pebbles set in a mudstone matrix. A fossil karst topography at the top of the Escabrosa limestone was identified at some localities. The Horquilla is composed for the most part of light- to dark-gray finely crystalline limestone, with grayish-red and pale-olive claystone in thin beds or as shale partings. Nodular chert occurs in many zones throughout this formation. The Horquilla limestone is about 520 feet thick in the Vekol Mountains. The top of the Horquilla either is eroded or is covered by talus derived from overlying Cretaceous(?) red beds.

Slate Mountains

The Slate Mountains, about 11 miles east of the Vekol Mountains and about 32 miles west of the Waterman Mountains, consist of a north-south ridge composed predominantly of the Pinal schist. Several small hills at the north end include a nearly continuous sequence of Precambrian and Paleozoic sedimentary rocks up to Mississippian in age. A complete section of the Mississippian Escabrosa limestone and a partial section of the Pennsylvanian Horquilla limestone are exposed in isolated hills south and east of the Slate Mountains.

The Precambrian Apache group overlies the Pinal schist and is similar to the Apache group in the Vekol Mountains. In the Slate Mountains the Pioneer shale is about 425 feet thick, consisting of dusky-purple and reddish-brown mudstone and a 50-foot quartzite unit near the top. The overlying Dripping Spring quartzite is 1,085 feet thick and the basal beds are composed of lenticular conglomerate and quartzite. The Mescal limestone is only 200 feet thick in the Slate Mountains. The Apache group in the Slate Mountains is more than 1,700 feet thick, excluding the diabase sills which split the units at many places.

The Paleozoic rocks in the Slate Mountains are from Cambrian to Pennsylvanian in age and total almost 2,000 feet in thickness. The Cambrian Troy quartzite in the Slate Mountains is about 450 feet thick, considerably thicker than it is in the Vekol and Waterman Mountains. The upper 370 feet is made up of sandstone and quartzite,

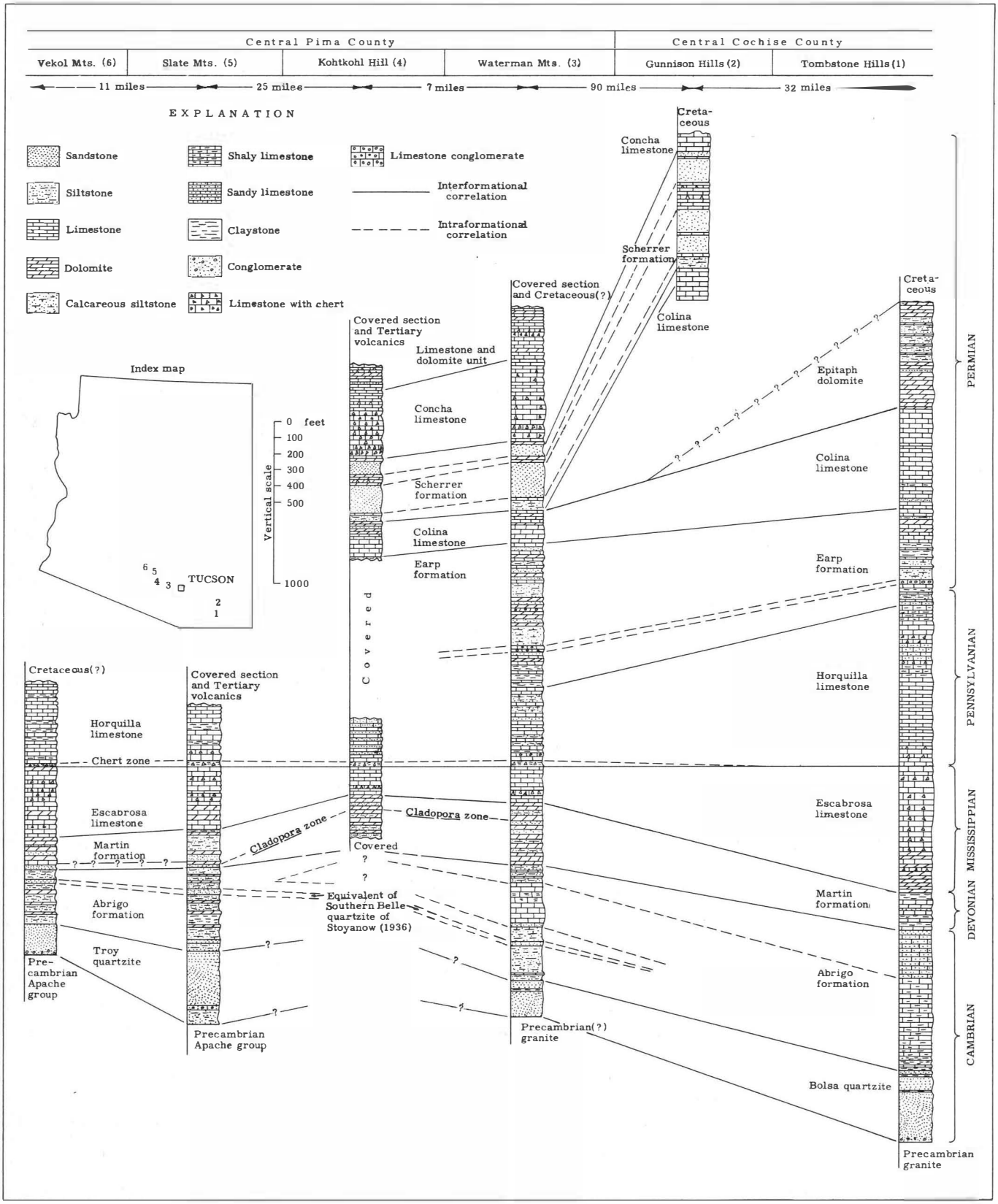

FIGURE 9. Chart showing correlation between Paleozoic formations in central Pima County and central Cochise County, Arizona. Stratigraphic columns (1) after Gilluly, Cooper, and Williams (1954) and (2) after Gilluly (1956).

much like the Troy of the Vekol sequence, but the lower 80-foot-thick unit is a pale-red to reddish-brown sandy siltstone which is unknown elsewhere on the Papago Reservation. The Abrigo formation is 520 feet thick and is composed of pale-brown and olive-green mudstone and claystone, interbedded with thin gray and grayish-brown quartzite and pale-red and grayish-brown very finely crystalline dolomite. The quartzite is prominent in the lowermost 26 feet and also forms a 38-foot-thick unit 350 feet above the base of the formation. This upper quartzite is probably equivalent to the Southern Belle quartzite of the Santa Catalina Mountains.

The Martin formation of Late Devonian age lies with apparent conformity on the Cambrian rocks. The Martin is about 235 feet thick and is composed of dark-gray very finely crystalline, muddy dolomite interbedded with siltstone and quartzite. Dolomite predominates in the lower part; the upper 140 feet is composed of poorly consolidated reddish-brown siltstone with a few dolomite beds near the top. At the north end of the Slate Mountains, about 150 feet of the Escabrosa limestone conformably overlies the Martin. The upper part of the Escabrosa has been faulted out or eroded in this vicinity. Southeast of the Slate Mountains, a complete section of Escabrosa limestone is nearly 400 feet thick. The lower part of the Escabrosa is made up of gray, very finely crystalline limestone interbedded with dark-gray dolomite; the upper part contains light- and dark-gray limestone and several zones of nodular chert.

The Pennsylvanian Horquilla limestone in the Slate Mountains is separated from the Escabrosa limestone by a mudstone and chert zone similar to that in the Vekol Mountains. In this area, however, no karst features were noted along the contact. The Horquilla consists of light- and dark-gray aphanitic to very finely crystalline limestone and a few beds of greenish-gray, gray, and grayish-purple mudstone and claystone. Some of the limestone units contain scattered chert nodules. Only the lower 380 feet of the Horquilla is exposed in the Slate Mountains; the uppermost beds are covered by valley fill.

Kohtkohl Hill

Paleozoic sedimentary rocks crop out 6 miles west of Silver Bell in Kohtkohl Hill (fig. 45). Kohtkohl Hill is capped by the Permian Concha limestone and an overlying limestone and dolomite unit also of Permian age, and the Permian Colina and Scherrer formations are exposed on its western slope. A low ridge to the southeast is made up of Devonian and Mississippian rocks and a small hill to the north contains Devonian, Mississippian, and Pennsylvanian rocks.

The Martin formation of Late Devonian age is the oldest unit in the vicinity of Kohtkohl Hill. The basal part of the Martin is covered; the 260 feet exposed is composed predominantly of gray and grayish-red to brownish-gray aphanitic to very finely crystalline dolomite and interbedded siltstone.

The Escabrosa limestone conformably overlies the Martin formation and is composed of gray to brownish-gray aphanitic to finely crystalline limestone. The Escabrosa is about 175 feet thick. A 20-foot-thick unit, about 40 feet above the base of the formation, contains lenses of chert.

The contact between the Escabrosa limestone and the overlying Horquilla limestone is covered by alluvium that contains many chert fragments. These fragments are similar to those in the red shale and chert zone at the base of the Horquilla in other areas, and a similar zone may be present here beneath the alluvium. The

Horquilla limestone is made up of interbedded limestone, silty limestone, and siltstone ranging in color from gray to grayish red, reddish brown, and pale brown. Most of the limestone is very finely crystalline, ranging from aphanitic to finely crystalline. Several beds contain chert nodules and some beds have large patches or lenses of yellowish-brown dolomite. Only 295 feet of the Horquilla is exposed in this vicinity, and the top is covered by alluvium.

Some red shale, which may represent the Earp formation, is exposed below the Colina limestone cliff on the western slope of Kohtkohl Hill, but the contact between the red shale and the Colina is covered. The Colina limestone is mostly dark-gray aphanitic to very finely crystalline limestone, with chert and sandstone nodules and some dolomite beds in the upper part of the formation. The Colina is 220 feet thick at Kohtkohl Hill.

The Scherrer formation apparently overlies the Colina limestone conformably, but the contact is covered at most places. The Scherrer formation is 390 feet thick and is made up of four units in the Kohtkohl section, each one similar to the units of the Scherrer in the Waterman Mountains. The lower unit is mostly reddish orange and ranges in texture from siltstone to very fine-grained quartz sandstone; it contains a few dolomite beds in the uppermost 16 feet; the unit is 52 feet thick. The second unit is 173 feet thick and consists of grayish-orange-pink and brownish-gray very fine- to coarse-grained quartz sandstone with a fairly firm calcareous cement. It is locally crossbedded on a small scale. The third unit is 68 feet thick and is composed of gray, very finely crystalline, sandy dolomite with small chert nodules and chert and sandstone stringers. The upper unit contains 74 feet of grayish-pink fine-grained quartz sandstone in the lower part and 23 feet of gray, very finely crystalline silty dolomite at the top. The Scherrer formation forms a slope between the more resistant beds of the Colina and Concha limestones.

The Concha limestone lies conformably on the uppermost dolomite beds of the Scherrer formation at Kohtkohl Hill. The Concha is composed of gray, very finely crystalline limestone with many bands of chert nodules, especially near the base, and is about 420 feet thick. A limestone and dolomite unit of Permian age, described by Bryant (1955), lies conformably on the Concha and is composed of interbedded limestone and dolomite with several sandstone beds near the base. The limestone of this unit is gray to brownish gray, very finely crystalline, and sandy to silty in the lower part. The dolomite is gray and aphanitic to very finely crystalline, containing scattered calcite blebs. Chert nodules exist in bands throughout the unit but are notably concentrated in the top 60 feet. Only the lower 152 feet of the limestone and dolomite unit is exposed; the upper part is covered by alluvium.

CONDITIONS OF DEPOSITION

Precambrian-Paleozoic Boundary

In southeastern Arizona, rocks of the Apache group crop out only north of Benson and Tucson (Lance, 4). West of Tucson the Apache group is exposed in the Slate and Vekol Mountains, and a partial section is exposed in the northeastern part of the Silver Bell Mountains. West of Tucson, no Apache rocks are exposed in the Picacho de Calera Hills (Bryant, 1952), the Waterman Mountains, or Kohtkohl Hill. In the Picacho de Calera Hills, Cambrian quartzite overlies the Pinal schist, and in the Waterman Mountains the quartzite apparently overlies a granite of uncertain, but presumably, Precambrian age.

The contact between the Apache group and the Troy quartzite is apparently conformable in the Slate and Vekol Mountains. However, the top 150 feet of the Mescal limestone as exposed in the Vekol Mountains is missing in the Slate Mountains, and the Troy quartzite in the Slate Mountains is about 250 feet thicker than it is in the Vekols. The basal 80 feet of the Troy in the Slates is composed of siltstone, which is not present in the Vekols and is generally not common in this formation in south-central Arizona. The changes in thicknesses of the Mescal and Troy suggest that a local trough of low relief was developed on the Apache group in the Slate Mountains area before the deposition of Cambrian sediments.

Paleozoic Era

During Paleozoic time south-central Arizona was in the main a fluctuating, but slowly sinking, marine platform in a northwestward extension of the Sonoran geosyncline (McKee, 1951). The region was below sea level except during Ordovician, Silurian, Early Devonian, and Late Mississippian times.

Cambrian Period

The Troy quartzite and its probable equivalent, the Bolsa quartzite, of the Middle Cambrian epoch were deposited as a broad sheet over much of south-central Arizona. The coarse material and the diastemic bedding planes indicate that the sediments were deposited moderately close to shore in a shallow sea on a rather stable platform. The Abrigo formation of the Middle and Upper Cambrian epochs also was deposited in a shallow, stable sea, but either farther from the shoreline or during a period of less severe erosion in the source area. In the Waterman Mountains the thick limestone sequence of the middle part of the Abrigo formation suggests accumulation in a deep part of the basin.

Devonian Period

The Martin formation is thicker and the "Cladopora zone" (fig. 9) is stratigraphically higher in the Waterman Mountains and Kohtkohl Hill sections than in the Vekol and Slate Mountains. It is probable that deposition of the Martin began earlier and in a deep basin to the east while the Vekol and Slate areas were still above sea level or receiving little sediment. The western sections also contain more siltstone and claystone than occurs in the Waterman area.

Mississippian Period

In contrast to the Abrigo and Martin formations, the Escabrosa limestone thickens toward the west. In the Waterman Mountains and at Kohtkohl Hill it is about 230 and 170 feet thick, respectively, whereas in the Slate Mountains it is 395 feet, and in the Vekols, 435 feet thick. Correlation of units within the Escabrosa between the four areas indicates that sedimentation was continuous and that the sequence in the Waterman area was deposited over an existing or slowly rising high.

Pennsylvanian Period

The occurrence of the red mudstone and conglomerate at the base of the Horquilla limestone is common in central and southeastern Arizona. This, and the presence of karst features at the contact, suggest that the region was temporarily above sea level. It is probable that during the period of emergence tens of feet of the Escabrosa were eroded in the Vekol and Slate Mountain areas and possibly hundreds of feet in

the Kohtkohl and Waterman areas.

Pennsylvanian and Permian Periods

The siltstone, shale, and carbonate beds of the Earp formation were laid down in a shallow, probably oscillatory, sea during a period of variable erosion in the source area. These conditions seem to have occurred also during the deposition of the lower part of the Scherrer formation, after the relatively short time of subsidence and lessening of terrestrial erosion when the Colina limestone accumulated. Erosion evidently was accelerated in the source area while the sandstones of the Scherrer formation were being deposited, with a break during the accumulation of the dolomitic middle member.

The Concha limestone was precipitated in a deep basin and probably quite far from the shoreline. The dolomites and clastic rocks and the thin-bedded nature of the limestone and dolomite unit overlying the Concha indicate that an abrupt change of environment occurred, but the area remained beneath the sea and probably, at least during deposition of the upper part of the unit, a moderate distance from the shore.

The 320 feet of the limestone and dolomite unit in the Waterman Mountains probably does not represent the youngest Permian beds deposited in south-central Arizona, but evidence of later sedimentation is lacking.

COMPARISON TO PALEOZOIC SECTION IN CENTRAL COCHISE COUNTY

The Paleozoic stratigraphic sequence in the Papago area is similar to the sequence in the Tombstone area in central Cochise County, and in the main the units can be readily recognized in the two regions (fig. 9). The occurrence of the Epitaph dolomite in Cochise County is the principal exception. Although individual units can be correlated, the Paleozoic strata in central Cochise County are thicker and contain a greater ratio of carbonate to clastic material than those in the Papago area.

In general, the Cambrian strata thin from about 1,300 feet in the Tombstone Hills to about 500 feet in the Vekol Mountains. The Martin formation has a moderately consistent thickness of about 250 to 400 feet. In contrast, the Escabrosa, Horquilla, and Colina limestones are two to three times thicker and the sequence of Mississippian through Permian rocks is one and one-half times thicker in the areas described in this paper than they are in the Waterman Mountains.

The increase in carbonate-to-clastic ratio from west to east is particularly evident in the Abrigo and Earp formations. The Abrigo formation includes large amounts of siltstone and quartzite in the Vekols; it contains more silty claystone, calcareous mudstone, and a middle limestone member in the Waterman Mountains. In the Tombstone Hills it is composed mostly of carbonate rocks. The Earp formation has a considerably lower carbonate-to-clastic ratio in the Waterman Mountains than in the Tombstone Hills, and these strata in the Waterman Mountains have been referred to as the Andrada formation (McClymonds, 1957) on the basis of their lithologic similarity to deposits of the same age in the Empire Mountains (Wilson, 1951; Havenor, 8).

Generally, the eastward thickening and increase in carbonate-to-clastic ratio reflects increasing thickness of sedimentation and distance from continental areas toward the central part of the Sonoran geosyncline (McKee, 1951).

Correlation of Permian strata from central Cochise County (Gilluly, 1956) and the Mustang Mountains (Bryant, 1955) to the Papago area implies that deposition of these sediments was continuous from southeastern to south-central Arizona. The lack of some or all of the Permian strata in comparatively unaltered sections in the Vekol, Slate, and Santa Catalina Mountains and in the Tombstone Hills indicates that these areas had been uplifted and partly eroded during the time between the end of the Permian and the beginning of the Cretaceous period.