Cambrian and Ordovician rocks of southeastern Arizona and southwestern New Mexico

Philip T. Hayes

1978, pp. 165-173. https://doi.org/10.56577/FFC-29.165

in:

Land of Cochise (Southeastern Arizona), Callender, J. F.; Wilt, J.; Clemons, R. E.; James, H. L.; [eds.], New Mexico Geological Society 29 th Annual Fall Field Conference Guidebook, 348 p. https://doi.org/10.56577/FFC-29

This page is intentionally left blank to maintain order of facing pages.

CAMBRIAN AND ORDOVICIAN, ROCKS OF SOUTHEASTERN ARIZONA AND SOUTHWESTERN NEW MEXICO

PHILIP T. HAYES
U.S. Geological Survey
Denver, Colorado

GEOLOGIC HISTORY AND SETTING

The Cambrian and Lower Ordovician rocks of southeastern Arizona were deposited near the eastern shore of a shallow shelf sea that encroached from the west or southwest across an area of generally low relief carved in diverse metamorphic, igneous and sedimentary rocks of Precambrian age. The sea, which apparently had a very broad intertidal zone, entered the region in late Early Cambrian or early Middle Cambrian time and extended eastward to about the position of the present Arizona-New Mexico boundary by about the end of Middle Cambrian time (fig. 1). The position of the eastern shoreline of the sea fluctuated during Late Cambrian time, but before the end of the Cambrian began a more rapid eastward advance across western New Mexico. The region was covered by this sea until latest Early Ordovician time.

The region was probably slightly emergent during most of Middle Ordovician time and was subjected to some erosion, more to the north than to the south. A sea again encroached, this time from the southeast, near the end of Middle Ordovician time and reached at least as far as the eastern edge of southern Arizona and possibly extended across much of it. No sedimentary rocks and thus no record of events exists for the Silurian in Arizona, but a Silurian sea did reach into southwestern New Mexico; southeastern Arizona may have been inundated at that time or may have been slightly emergent. The entire region was emergent and tilted slightly southeastward during Early and much of Middle Devonian time, when Cambrian and Ordovician rocks were eroded to progressively lower stratigraphic levels towards the west and north. Consequently, late Middle Devonian and Late Devonian seas, which subsequently covered the region, left their deposits on Middle Cambrian strata in the western part of southeastern Arizona (fig. 2), on Upper Cambrian strata in most of southeastern Arizona that are progressively younger eastward, on Lower Ordovician strata in most of easternmost Arizona and part of westernmost New Mexico, on Middle and Upper Ordovician strata in a very small part of the same area, and on Silurian strata farther east in southwestern New Mexico.

The Cambrian and Ordovician rocks of southeastern Arizona have been affected by many other tectonic and erosional events in post-Devonian time. In some areas these rocks were faulted, intruded, locally mineralized and locally eroded away during Triassic and Jurassic time. They were removed from large areas in the northern part of southeastern Arizona and in part of southwestern New Mexico by erosion during Cretaceous time (fig. 3). They were locally thrust-faulted, folded, intruded, thermally and hydrothermal!) altered and possibly wrench-faulted during Late Cretaceous and early Tertiary (Laramide) time. They were very locally intruded, metamorphosed and apparently faulted again in mid-Tertiary time. Finally, along with other rocks of the region, they were involved in Basin and Range faulting and subsequent local erosion in late Tertiary and Quaternary time.

What is now known of the Cambrian and Ordovician rocks of the region has been gleaned from study of the variously faulted and altered rocks in mountain-range outcrops that fortuitously make up about 0.5 percent of the present land surface; very few drill holes exist to provide information on these rocks under the great thicknesses of younger rocks in the intermontane basins.

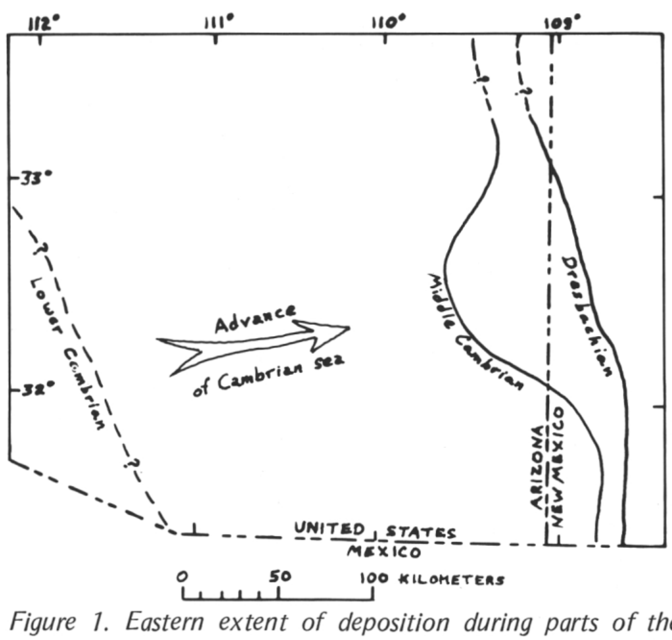

Figure 1. Eastern extent of deposition during parts of the Cambrian.

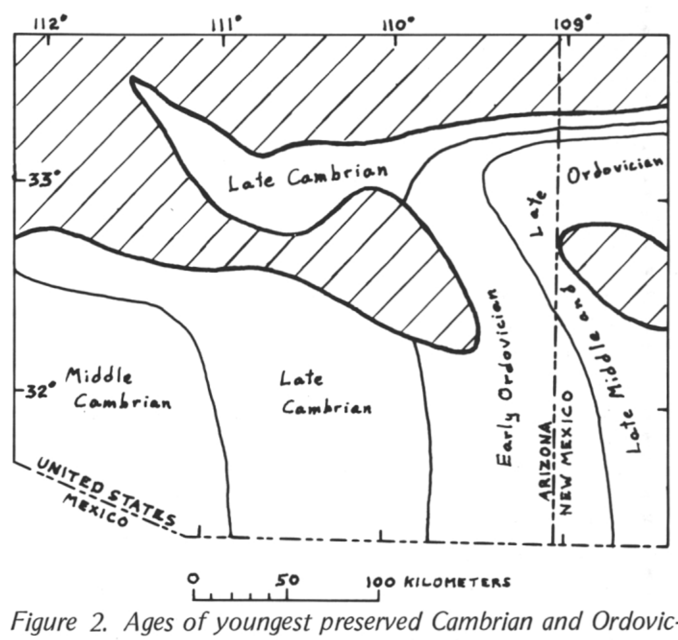

Figure 2. Ages of youngest preserved Cambrian and Ordovician rocks. Patterned where such rocks are absent.

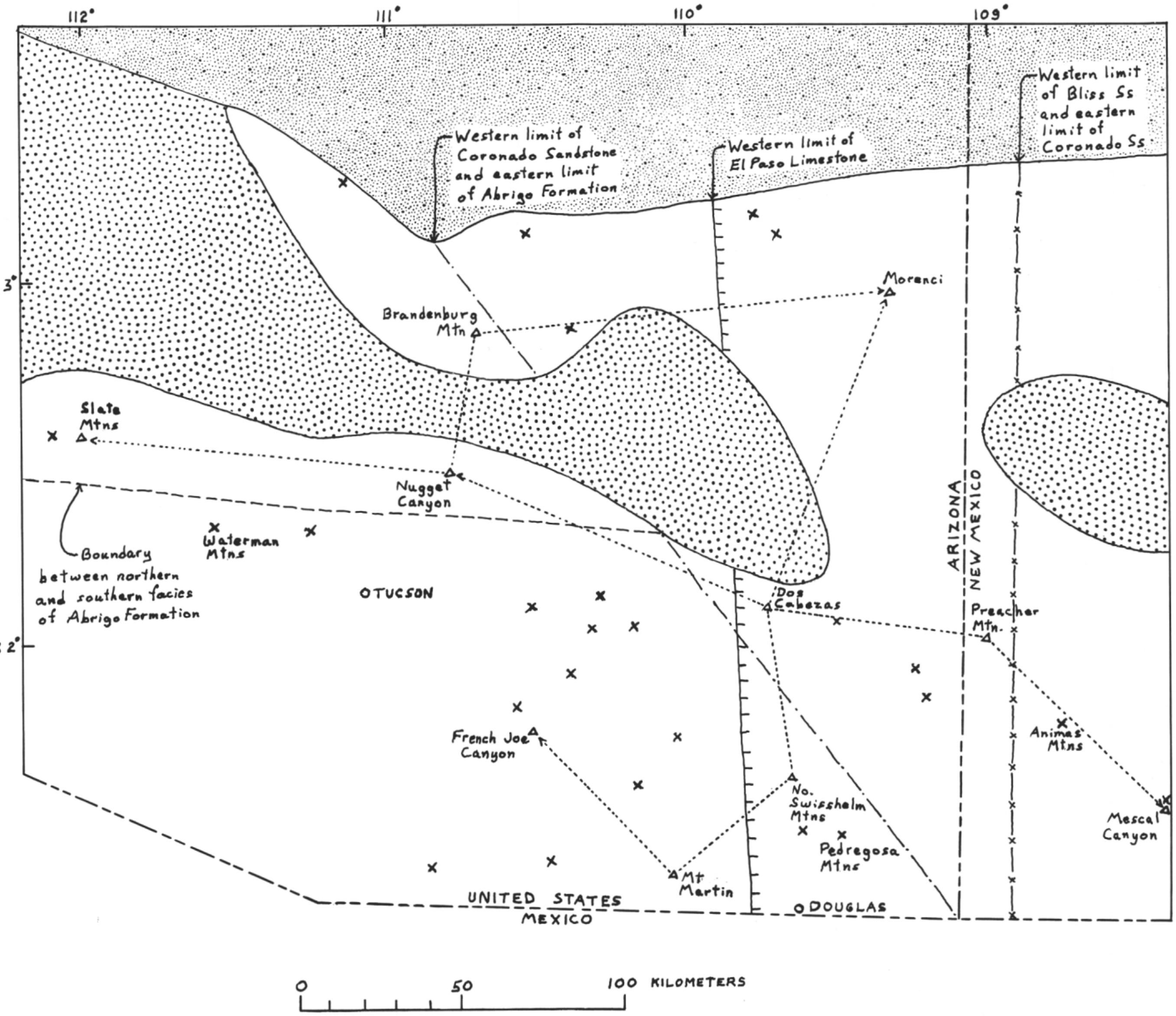

Figure 3. Locations of measured stratigraphic sections illustrated in this report (triangles), other important Cambrian outcrops (X's), and geographic limits of formations and facies discussed in text. Fine stipples indicate area in which Cambrian and Ordovician rocks were removed by Paleozoic erosion and coarse stipples indicate areas in which those rocks were removed by Cretaceous erosion.

STRATIGRAPHY

Throughout the southwestern part of southeastern Arizona, Cambrian rocks are subdivided into two formations: the Bolsa Quartzite and overlying Abrigo Formation. In the southeastern part of this area, in the Swisshelm and Pedregosa mountains, these formations are overlain by Lower Ordovician rocks assigned to the El Paso Limestone (figs. 3, 4), but elsewhere Ordovician rocks are missing. In the eastern part of southeastern Arizona and at the westernmost edge of New Mexico, the Cambrian is represented by the Coronado Sandstone and the lower member of the overlying El Paso Limestone. In most places the Cambrian is overlain by the upper member of the El Paso Limestone of Early Ordovician age and, near Morenci, the El Paso is overlain by the Second Value Dolomite of late Middle or early Late Ordovician age. Farther east in New Mexico, uppermost Cambrian sedimentary rocks are included in the Bliss Sandstone; it rests on Nrecambrian rocks and is overlain in succession by the Ordovician El Paso and Montoya Groups. These latter-named rocks in New Mexico are described only briefly here in order to show their interpreted relations to the rocks in Arizona.

Bolsa Quartzite

The Bolsa Quartzite was named by Ransome (1904) for exposures in the Mule Mountains near Mount Martin (figs. 3, 4) and has since been recognized by many workers over a large part of southeastern Arizona. In the southern part of the region, where local relief on the underlying Precambrian is generally fairly low, the Bolsa is generally 100 to 200 m thick but, locally, it may be slightly thicker or thinner. In the northern part of the region, where local relief on the Precambrian is commonly more pronounced, it is absent in places over Precambrian hills.

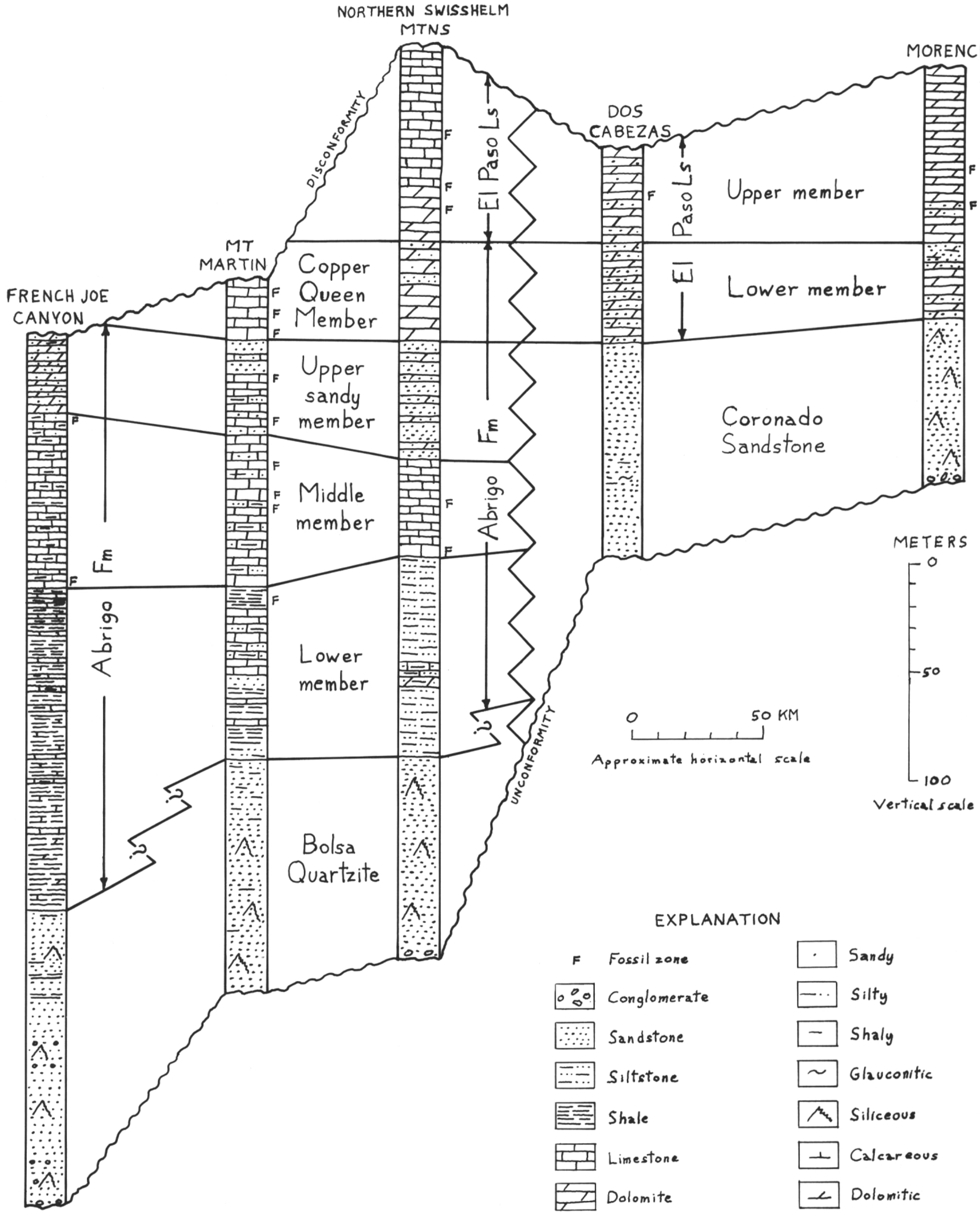

Figure 4. Correlated graphic sections of Cambrian and Lower Ordovician rocks between French Joe Canyon of the Whetstone Mountains and the Morenci area. Section locations are shown in Figure 3.

The formation consists almost entirely of resistant beds of rather dark-weathering silica-cemented orthoquartzite, but local pebble or cobble conglomerate occurs at the base. Grain sizes in the orthoquartzite decrease upward from dominantly coarse- and medium-grained sand in the lower part to dominantly medium- and fine-grained sand in the upper part. The lower part is commonly slightly feldspathic, the upper part non-feldspathic. Bedding thicknesses are mostly between 15 cm and 1.5 m, with most thicker beds near the base and thinner beds near the top. I nterbeds of siltstone or shale are common in the upper part of the formation at most localities. Small- and medium-scale planar cross-laminations are abundant in the formation, particularly in the lower part. Animal tracks, trails and burrows are locally common, especially in the upper part. The Bolsa Quartzite is interpreted to represent deposition either in an offshore bar or a beach environment.

No fossils closely diagnostic of age have been found in the Bolsa Quartzite. However, because of its conformable relations with overlying beds of late Middle Cambrian age in the Abrigo Formation, the Bolsa is believed to be of Middle Cambrian age. Possibly the lower part of the formation in the western part of the region is of Early Cambrian age.

The contact between the Bolsa Quartzite and the overlying Abrigo Formation is conformable, but generally rather sharp. Locally in the southern part of the region, a transition zone as much as 45 m thick occurs in which Bolsa-like quartzite beds are interbedded with shale characteristic of the lower part of the Abrigo; at these places the top of the Bolsa is picked at the top of the highest conspicuous quartzite bed that is below the lowest carbonate bed of the Abrigo Formation.

Abrigo Formation

The Abrigo Formation was originally named by Ransome (1904) for exposures in the Mule Mountains at Mount Martin (figs. 3, 4). It has since been divided into four members which are described separately below.

Lower member

The lower member of the Abrigo Formation is roughly equivalent to the Cochise Formation of Stoyanow (1936) and was called the shaly member" by Hayes and Landis (1965) at the Abrigo type locality. This member, which is present wherever the Abrigo is present in southeastern Arizona, is between 70 and 150 m thick in most areas, but in the Waterman Mountains (fig. 3) it is about 200 m thick.

The lower member changes in lithology from dominant silty shale and thin-bedded limestone in the south near Mount Martin to siltstone and fine-grained sandstone in the north at Nugget Canyon and Brandenberg Mountain (figs. 3, 5). The shale in the member is generally fissile, micaceous and slightly calcareous. It is usually medium gray to olive gray where fresh, but weathers to a yellowish brown. In some areas it has been altered to hornfels. The limestone in the member commonly contains wavy laminae, is commonly glauconitic and slightly hematitic, is mostly medium gray on fresh fractures, and weathers to light gray or yellowish gray. Silty limestone is commonly interlaminated with non-silty limestone. Dark-yellowish-brown-weathering silty or sandy dolomite is common in the member in areas between the northern and southern facies, but is rare in the south. The coarse siltstone and fine-grained sandstone in the north weather to a variety of colors from yellowish gray to dark reddish brown; they occur in beds a few centimeters to 2 m thick, are commonly laminated, and are generally only weakly resistant.

The carbonate rocks in the lower member include intraformational flat-pebble conglomerates, mudcracks and occasional burrows. Tracks, trails and burrows are common in the sandstone and siltstone facies, as are small- and medium-scale cross-laminations; slump structures are locally found. The lower member of the Abrigo Formation is interpreted as representing deposition in an intertidal environment. The sandy and silty northern lithofacies indicates proximity to a northern source of sediment or to a river mouth.

Fossils, chiefly trilobites, have been found in different parts of the southern lithofacies of the lower member at several localities. On the basis of these fossils, the member is assigned a Middle Cambrian and mostly late Middle Cambrian age. The sandy facies has yielded no diagnostic fossils but is assumed to be equivalent in age.

Middle member

The middle member of the Abrigo Formation is present at most localities where the Abrigo occurs, but has been thinned by erosion of the upper part in western areas where the overlying upper sandy member is absent. Where completely preserved, the middle member ranges in thickness from 42 to 94 m, but no regionally consistent pattern of thickening or thinning is found.

Like the lower member, the lithology of the middle member changes from south to north. In the south the member consists almost entirely of thin-bedded limestone and silty limestone, which is locally dolomitized; in the north it consists entirely of resistant sandstone, and in intervening areas it is made up of various proportions of sandstone and dolomite or limestone. The limestone of southern and intermediate exposures contains distinctive wavy laminae of brown-weathering silty limestone that stand out in relief from the enclosing laminae of gray-weathering non-silty limestone. The dolomite of intermediate exposures is generally sandy or silty, and is nearly all thinly laminated and, in places, cross-laminated. The sandstone of northern and intermediate exposures is generally fine- to medium-grained. Most sandstone beds are fairly resistant but some are friable. In the north the sandstone is mostly clean, is well sorted and has quartz cement; in intermediate areas the sandstone tends to be more poorly sorted, may be glauconitic and (or) hematitic, and commonly has calcite or dolomite cement.

The middle member commonly includes intraformational limestone or dolomite flat-pebble conglomerates, some of which are edgewise; some animal trails and burrows; and cross laminations. The limestone facies of the member is interpreted as representing intertidal- flat to shallow-subtidal deposition, and the sandy facies is interpreted to represent sandy beach deposition. The intermediate facies, of course, is interpreted to be a mixture of both intertidal-flat and sandy beach deposits.

Diagnostic fossils, chiefly trilobites of the *Cedaria* Zone, have been collected from several parts of the middle member at different localities representing both the limestone facies and the intermediate facies. Fossils from the lower few meters of the member at two localities, Mount Martin and northern Swisshelm Mountains (figs. 3, 4), indicate a latest Middle Cambrian age, but most of the member is definitely of Dresbachian or early Late Cambrian age. The sandy facies is presumed to be of equivalent age.

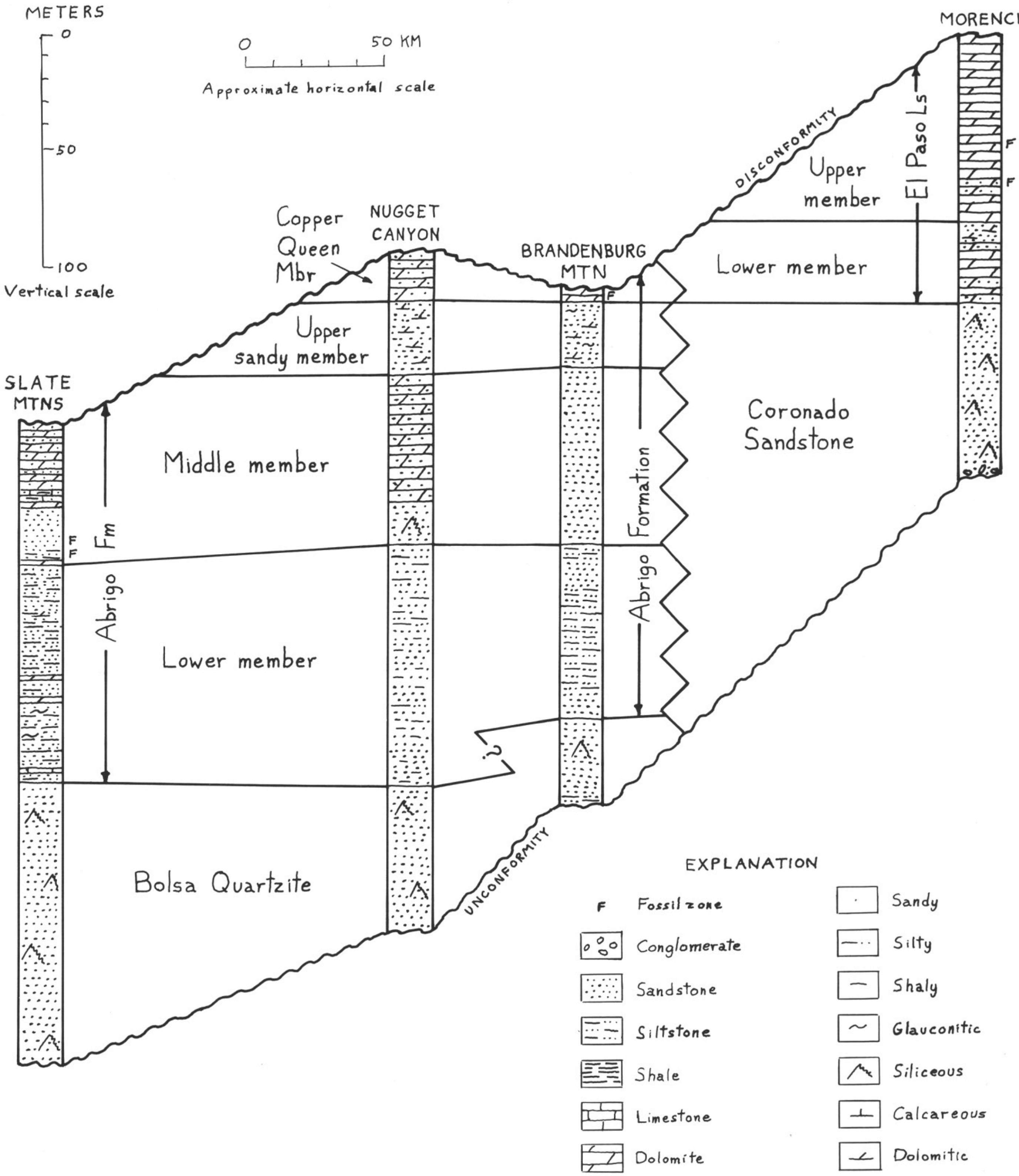

Figure 5. Correlated graphic sections of Cambrian and Lower Ordovician rocks between the Slate Mountains and the Morenci area. Locations of sections are shown in Figure 3.

The contact between the middle member and the overlying upper sandy member of the Abrigo Formation is conformable but sharply defined in the south and north. In intermediate areas it is picked where non-sandy or slightly sandy dolomite of the middle member gives way upward abruptly to conspicuously sandier and darker-weathering dolomite.

Upper sandy member

The upper sandy member of the Abrigo Formation is completely preserved only within about 75 km of the northeastern limit of the Abrigo Formation (fig. 3); its upper part has been eroded to the south and west and the member is missing entirely, probably owing to erosion, at four western localities. Where completely preserved its thickness ranges from 30 to 55 m.

Toward the north the member consists almost entirely of brown-weathering dolomitic quartz sandstone, whereas to the south it is made up of light-brownish-gray-weathering quartzose dolarenite (or occasionally quartzose limestone) interbedded with subordinate dolomitic quartz sandstone. The sandstone and the quartz sand in the dolomite are mostly medium grained. Some sandstone and dolomite beds are glauconitic and a few sandstone beds are hematitic. Most sandstone beds and many dolomite beds display small- to medium-scale planar cross laminations. Some dolomite beds are edgewise conglomerate with dolomite pebbles. The member is interpreted to have been deposited in a storm-tossed intertidal and supratidal environment during a period of increased influx of sand from the northeast.

Fossils, chiefly trilobites of the *Crepicephalus* Zone, have been found in the member at many southern and central localities and indicate a late Dresbachian (early Late Cambrian) age. The member is assumed to be of similar age in the north where it is apparently non-fossiliferous.

Oddly, the upper contact of the upper sandy member is more easily recognized where it is conformably overlain by the Copper Queen Member of the Abrigo than in many places where it is unconformably overlain by the Martin Limestone of Devonian age. This is because the Copper Queen, which is made up of non-sandy or only slightly sandy limestone or dolomite, differs more from the upper sandy member than does the sandy cross-laminated dolomite that commonly is at the base of the Martin. Where diagnostic fossils cannot be found, the dolomite in the Martin can most easily be recognized by the lower angle of its cross-laminations and by its somewhat paler color. Where the contact is well exposed it can be seen to be knife sharp along a surface that commonly has a few centimeters of relief.

Copper Queen Member

The Copper Queen Member at the top of the Abrigo Formation is present only in the eastern part of the Abrigo occurrence area and is completely preserved only where the Abrigo is overlain by Ordovician rocks as it is in the northern Swisshelm Mountains (fig. 3). Elsewhere it has been thinned by erosion on top or is absent, presumably because of erosion. Where completely preserved it is 36 to 46 m thick.

At localities near its type area on Mount Martin (figs. 3, 4), the Copper Queen Member is made up almost entirely of fairly resistant, medium-gray, mostly laminated, slightly sandy limestone. At other localities the member is represented by dominant light-brownish-gray, generally slightly sandy or silty dolo mite and subordinate cross-laminated dolomitic sandstone. The member is interpreted as having been deposited in somewhat agitated shallow-subtidal marine waters.

Trilobites of the *Ptychaspis* Zone and the brachiopod *Billingsella* sp., collected from several horizons in the Copper Queen Member at Mount Martin, indicate a Franconian (Late Cambrian) age for the entire member in that area. Specimens of *Billingsella* have also been collected from the lower part of the member at other localities. In areas in and near the northern Swisshelm Mountains (figs. 3, 4), where the member is conformably overlain by the El Paso Limestone of Early Ordovician age, the upper part of the Copper Queen Member is apparently devoid of fossils; here, the member is assumed to be of latest Cambrian (Trempealeauan) age because of its conformable relations with the Franconian lower part of the member and with the overlying Ordovician rocks.

In most areas in southeastern Arizona, the Copper Queen Member of the Abrigo Formation is disconformably overlain by Devonian rocks, and the contact can generally be readily recognized. Where the Copper Queen is conformably overlain by the El Paso Limestone of Ordovician age, in and near the northern Swisshelm Mountains, the contact between the Copper Queen Member and the El Paso is arbitrarily placed just below the horizon of the lowest lenses of white chert in an unfossiliferous dolomite sequence of the El Paso. This contact is assumed to be at or near the Cambrian-Ordovician boundary.

Coronado Sandstone

The Coronado Sandstone, originally called the Coronado Quartzite, was named by Lindgren (1905) for exposures near Morenci (fig. 3). For many years the name Coronado was used only in the Morenci area, but it is now applied to the basal Cambrian sandstone unit throughout much of the easternmost part of southern Arizona and the adjacent westernmost part of New Mexico. The Coronado ranges in thickness from about 110 to 190 m in areas where it is conformably overlain by younger Cambrian rocks.

The formation consists almost entirely of pale-red to olive-brown weathering sandstone in its type locality and is at least 70 percent sandstone in all exposures. Siltstone and shale make up most of the remainder, but the formation includes some sandy dolomite at Dos Cabezas (fig. 3). The sandstone in the formation ranges from arkosic in the lower part to orthoquartzitic in the upper part; much of the sandstone is glauconitic. Quartz is the most common cement, but dolomite and hematite cements occur locally. Small- to medium-scale cross-laminations are seen in many sandstone beds and animal tracks and burrows are occasionally seen. The Coronado is interpreted as representing primarily beach and possibly dune sands deposited near the strandline of the Abrigo sea.

No fossils closely diagnostic of age have been found in the Coronado. However, because the Coronado is conformably overlain by strata that locally contain fossils of late Late Cambrian (Franconian) age and because western sections of the Coronado bear a distinct lithologic resemblance to the sandy facies of the Abrigo Formation (fig. 6), the Coronado is believed, in its thicker sections, to be equivalent to the lower three members of the Abrigo and possibly to the uppermost part of the Bolsa Quartzite (figs. 4, 5, 6). Thus the Coronado is believed to be of late Middle Cambrian and early Late Cambrian age.

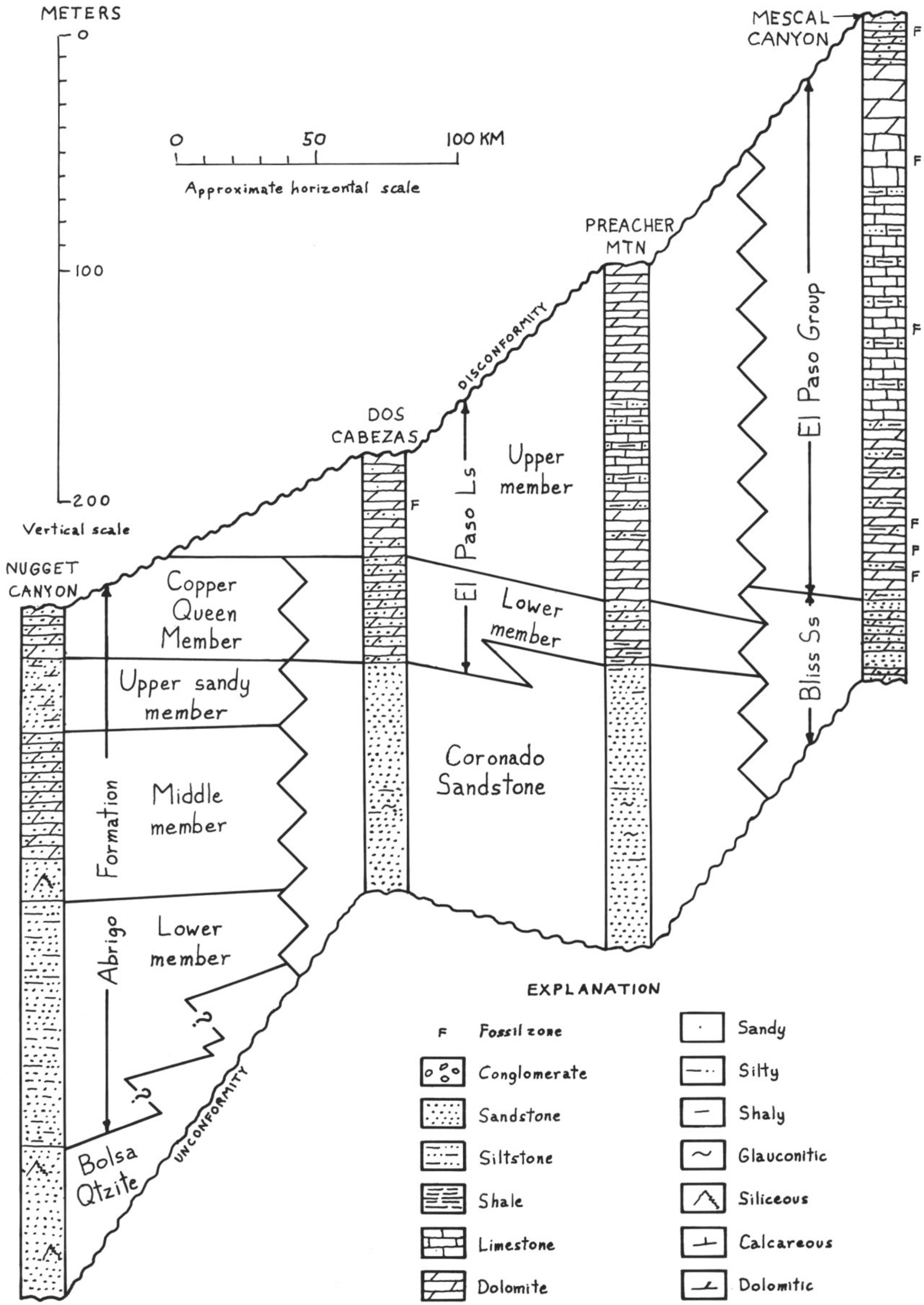

Figure 6. Correlated graphic sections of Cambrian and Lower Ordovician rocks between Nugget Canyon of the Santa Catalina Mountains and Mescal Canyon of the Big Hatchet Mountains. Locations of sections are shown in Figure 3.

In most areas the Coronado Sandstone is conformably, but generally sharply, overlain by Upper Cambrian beds at the base of the El Paso Limestone.

El Paso Limestone

The El Paso Limestone was named and later redefined by Richardson (1904, 1908) for exposures near El Paso, Texas, about 250 km east of Arizona; the term was first used in Arizona by Sabins (1957). The El Paso is regarded by some workers as a group in New Mexico (fig. 6), but its formational status is retained in Arizona. The El Paso Limestone extends westward no more than 80 km into the eastern part of southeastern Arizona. In its southwesternmost exposures in Arizona it overlies the Abrigo Formation, but in most of southeastern Arizona and in westernmost New Mexico it overlies the Coronado Sandstone; farther east in New Mexico the El Paso overlies the Bliss Sandstone (figs. 3, 6). The El Paso is as much as 133 m thick where it overlies the Abrigo and as much as 270 m thick where it overlies the Coronado. At Mescal Canyon, in the Big Hatchet Mountains of New Mexico, about 65 km east of Arizona, the El Paso is 245 m thick.

For the most part the El Paso Limestone is made up of limestone and (or) dolomite which generally contain scattered lenses and nodules of chert; but an informal lower member, present in areas where the El Paso overlies the Coronado Sandstone, consists mainly of sandy or silty dolomite interbedded with dolomitic sandstone. This lower member, which is 26 to 55 m thick, probably is equivalent to the Copper Queen Member of the Abrigo Formation of areas to the west and to the lower two-thirds or so of the Bliss Sandstone of western New Mexico (figs, 4, 5, 6). Thus, where it overlies the Coronado, this lower member of the El Paso is older than the basal El Paso as it is mapped to the west and east. The lower member is locally glauconitic and commonly displays conspicuous small- and medium-scale cross-laminations. Intraformational flat-pebble conglomerate is also common in the member. Cross-laminated dolomite and flat-pebble conglomerate are less common in the upper member. Algal mats and mudcracks were locally observed in the upper member. The El Paso Limestone as it occurs in southeastern Arizona is interpreted as having been deposited in an alternating shallow-subtidal and intertidal-flat environment.

Marine invertebrate fossils, mainly brachiopods, collected from the lower part of the lower member of the El Paso Limestone at several localities are of Late Cambrian age; fossils have not been found in the upper part of the member. On the basis of fossils and lithology, the lower member is believed to be very nearly synchronous with the Copper Queen Member of the Abrigo Formation. Fossils, chiefly cephalopods and gastropods, found in the upper member at four Arizona localities all indicate an Early Ordovician age for the member. Presumably, the Cambrian-Ordovician boundary is at or near the contact between the lower and upper members. In areas where the El Paso overlies the Abrigo Formation or Bliss Sandstone, the entire El Paso is presumed to be of Early Ordovician age.

Near Morenci (fig. 3) the El Paso Limestone is disconformably overlain by the Second Value Dolomite of the Montoya Group of younger Ordovician age. Elsewhere the El Paso is disconformably overlain by Devonian strata. The generally light-colored carbonate rocks of the El Paso are readily distinguished from the dark-weathering sandy dolomite of the Second Value or from the generally dark-weathering Devonian limestone and shale.

Montoya Group

The Montoya Group of latest Middle and Late Ordovician age is represented in Arizona by only the Second Value Dolomite and that only near Morenci where 4.6 m of the formation is preserved beneath disconformably overlying Devonian shale. Younger formations of the Montoya Group, the Aleman Formation and Cutter Dolomite, are known to crop out only as far west as the Animas Mountains of New Mexico, about 30 km east of the Arizona line, and have not been measured west of the Mescal Canyon area of the Big Hatchet Mountains (fig. 3).

Where exposed near Morenci, the Second Value Dolomite consists of dark-medium-gray, partly dolomitized, coral-bearing crinoidal marine limestone that is patchily sandy in the basal 0.6 m.

Both the Second Value Dolomite of the Morenci area and the underlying El Paso Limestone were included in the now abandoned Longfellow Limestone of Lindgren (1905).

THE GRAPHIC SECTIONS

The 10 highly generalized graphic sections used here (figs. 4, 5, 6) to show the general lithology and my ideas on regional stratigraphic relations of Cambrian and Lower Ordovician rocks in southwestern Arizona and westernmost New Mexico were chosen because they are, for the most part, reasonably well exposed, uncomplicated by structure, and representative of the several lithofacies in the region. Many other outcrop areas and exposed sections in the region deserve further study, but the sections shown here are recommended as the ones that should be most informative to those beginning new studies of the subject rocks. Specific information on locations, more detailed descriptions of these and other sections, and references to other reports concerning them are given in Hayes and Cone (1975).

SOURCES OF INFORMATION AND STATE OF KNOWLEDGE

Most of this report was summarized from data and conclusions presented by Hayes and Cone (1975). References to most of the many papers that have dealt with both local and regional aspects of the Cambrian and Ordovician stratigraphy of the region are included in that report. All of these papers have contributed to our present, but still incomplete, understanding of the subject. If and when deep exploratory drilling is done in the intermontane basins of the region, the new information will undoubtedly modify current views on regional relations. Meanwhile, perhaps the most needed work on outcrops would be the discovery and identification of guide fossils in many areas, particularly those to the north, and detailed paleoenvironmental studies of well-exposed sections. The regional correlations presented in this paper are based on meager paleontologic data and broad interpretations of lithofacies trends; the correlations are, thus, open to considerable revision. The current paleoenvironmental interpretations are based on reconnaissance study of dozens of localities rather than on meticulous study of a few carefully selected localities; such detailed studies are now in order.

REFERENCES

Hayes, P. T., and Cone, G. C., 1975, Cambrian and Ordovician rocks of southern Arizona and New Mexico and westernmost Texas: U.S. Geol. Survey Prof. Paper 873, 98 p.

Hayes, P. T., and Landis, E. R., 1965, Paleozoic stratigraphy of the southern part of the Mule Mountains, Arizona: U.S. Geol. Survey Bull. 1201-F, 43 p.

Lindgren, Waldemar, 1905, The copper deposits of the Clifton-Morenci district, Arizona: U.S. Geol. Survey Prof. Paper 43, 375 p.

Ransome, F. L., 1904, Geology and ore deposits of the Bisbee quadrangle, Arizona: U.S. Geol. Survey Prof. Paper 21, 168 p.

Richardson, G. B., 1904, Report of a reconnaissance in trans-Pecos Texas, north of the Texas and Pacific Railway: Texas Univ. Mineral Survey Bull. 9, 119 p.

Richardson, G. B., 1908, Paleozoic formations in trans-Pecos Texas: Am. Jour. Sci., v. 25, p. 474-484.

Sabins, F. F., Jr., 1957, Stratigraphic relations in Chiricahua and Dos Cabezas Mountains, Arizona: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 466-510.

Stoyanow, A. A., 1936, Correlation of Arizona Paleozoic formations: Geol. Soc. America Bull., v. 47, p. 459-540.