Devonian Rocks and Paleogeography of Central Arizona

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By CURT TEICHERT

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Stratigraphic, lithologic, and paleoecologic studies of the Devonian rocks of central Arizona, as a basis of reconstructing Devonian paleogeography

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DEVONIAN ROCKS AND PALEOGEOGRAPHY OF CENTRAL ARIZONA

By Curt Teichert

ABSTRACT

The Devonian rocks described in this report lie in Gila, Navajo, Yavapai and Coconino Counties, Ariz. The main outcrop belt extends, in places discontinuously, for about 90 miles along the foot of the southwestern edge of the Colorado Plateau from the upper Salt River area northwestward across Salt River Draw and Canyon Creek to the foot of the Mogollon Rim as far as the vicinity of Pine. Southwest of this belt lies a disturbed area where Devonian and later Paleozoic rocks are folded and faulted, and their outcrops, therefore, are discontinuous. Important sections studied in the disturbed belt are in the Globe area, south of Theodore Roosevelt Lake at Limestone Hills, in Chasm Creek, and in the Jerome area. A partial section at Elden Mountain in the San Francisco volcanic field in Coconino County was studied.

Over most of the area the Devonian rocks rest unconformably on Precambrian rocks and have a relief of several hundred feet. The surface on Precambrian rocks was almost leveled and covered with sediments during Devonian time.

The oldest Devonian rocks in central Arizona are channel-filling sandstones, which are here named the Beckers Butte Member of the Martin Formation. This member is Early or Middle Devonian in age. It is overlain by the Jerome Member of the Martin, which consists mostly of carbonate rocks and locally, of admixtures of sandstone, siltstone, and shale. The upper unit of the Jerome is early Late Devonian in age. The Beckers Butte and Jerome Members are herein combined in the Martin Formation, which is at least in part equivalent to the Late Devonian Martin Limestone of the Bisbee area in southeastern Arizona.

The Beckers Butte Member is a channel fill that ranges in thickness from a few feet to 200 feet. Typically, it consists of medium- to coarse-grained crossbedded poorly sorted sandstones. Partial fillings of three major channels are known: in Canyon Creek and extending south of the Salt River, on Aztec Peak, and at Roosevelt Dam. In places, shale and impure dolomite, as much as 20 feet thick, occur at the top of the Beckers Butte Member, which has yielded a fairly rich psilophyte flora of Early or Middle Devonian age in one locality on the Salt River. Discontinuous distribution of this shaly unit probably indicates a clay-pan topography during the closing stages of deposition of the Beckers Butte Member and shortly before the onset of marine conditions.

The Jerome Member rests conformably on the Beckers Butte Member. It has been subdivided into three units, which in ascending order are the fetid dolomite unit, the aphanitic dolomite unit, and the upper unit. The fetid dolomite unit is as much as 55 feet thick and consists of fine- to medium-grained dolomite, which is finely interlaminated with organic matter derived from planktonic organisms. In one undolomitized locality the original rock can be seen to have been aphanitic laminated limestone.

The aphanitic dolomite unit consists almost entirely of aphanitic and subaphanitic dolomite and, locally, of intercalations of aphanitic limestone and fine-grained sandstone. It is as much as 159 feet thick but is typically between 100 and 150 feet thick. The unit is largely unfossiliferous, although brachiopods, ostracodes, and calcispheres are found locally. Many beds contain detrital quartz grains and secondary chert.

Both the fetid and the aphanitic dolomite units have typical lithology and occur in all Devonian sections along a broad belt extending from the Jerome area in the northwest to the upper Salt River area in the southeast and also at Limestone Hills, Theodore Roosevelt Lake, and the Globe and Superior areas. Indications are, therefore, that these rocks once extended over an area of about 14,000 square miles. Toward the northeast both units wedge out along a line running several miles southwest of the Mogollon Rim and continuing southeastward into the upper Canyon Creek area.

The upper unit of the Jerome Member is as much as 385 feet thick and has a more varied lithology than the other units. In the Jerome area it consists entirely of dolomite rock, mostly fine- to medium-grained and commonly saccharoidal, and contains subordinate beds of aphanitic dolomite. This pure carbonate facies extends southeastward as far as the East Verde River. At Theodore Roosevelt Lake a considerable sandy component in the upper unit occurs, and the amount of sand increases southeastward in the direction of Globe. This terrigenous material probably came from an unknown source in the southeast.

Toward the northeast the upper unit is transgressive over a considerable area of the Defiance uplift, beyond the area of distribution of the fetid and aphanitic dolomite units. Along and close to the onlap belt, the upper unit commonly contains appreciable amounts of sandstone and shale, which tend to decrease in a southwesterly direction away from the onlap belt. At the end of the deposition of the upper unit, two islands of unknown but probably small extent—Pine Island and Christopher Island—remained above sea level near the southeastern edge of the onlap belt.

In the entire area of investigation, the carbonate rocks of the upper unit resemble those of the type section at Jerome, where this unit consists entirely of carbonate rocks. They are very fine grained to medium-grained dolomites and contain intercalated aphanitic dolomites and limestones. Mottling is a characteristic feature of many of the nonaphanitic rocks.

In general, the fossil content of the rocks of the upper unit increases from bottom to top, and the uppermost 100–150 feet is in most places characterized by richly fossiliferous horizons containing varied stromatoporoid, coral, and brachiopod faunas. Among genera represented are: *Actinostroma, Gerronostroma, Stictostroma, Amphipora, Breviphyllum, Tabulophyllum, Disphyllum, Hexagonaria, Pachyphyllum, Tabellaephyllum, Alveolites, Aulopora, Striatopora, Syringopora, Thamnopora,*

Schizophoria, Nervostrophia, Devonoproductus, Stenocisma, Camarotoechia, Atrypa, Spinatrypa, Platyrachella, Cyrtospirifer, Tenticospirifer, Theodossia, and Brachythyrina. These fossils occur locally in great abundance as thanatocoenoses (death assemblages of fossils preserved in life position) or as taphocoenoses (burial assemblages), which include many brachiopod coquinas. These and other observations indicate gradual deepening of the sea during deposition of the upper unit of the Jerome Member.

Other fossil groups such as Protozoa, Mollusca, Ostracoda, Echinodermata, and fishes are present but subordinate. Conodonts were extracted from only one sample, which yielded, among other forms, *Polygnathus normalis* Miller and Youngquist and *Palmatolepis triangularis* Sannemann. Most limestones contain calcispheres of considerable morphological variety and locally of rock-building importance.

Several gross lithological features of the Jerome Member, especially its carbonate rocks, were investigated in detail. No straight-line relationships exist between insoluble residue content and degree of dolomitization. Limestones tend to be pure, whereas dolomites contain highly variable amounts of insoluble residues. In aphanitic dolomites a positive correlation between total carbonate and MgO content tends to occur.

The insoluble residues of carbonate rocks of the Jerome Member are vertically graded. Rock cycles that begin with medium- to coarse-grained insolubles and in which the insolubles become finer towards the top where silt and clay or clay only are present can be recognized. In the Jerome type section, 10 such cycles are present. These may reflect cyclical climatic changes.

The sandstones of the Jerome Member are generally fine grained and well sorted and thus contrast with most rocks of the Beckers Butte Member, which are medium to coarse grained and poorly sorted.

Electron-microscope study of the texture of aphanitic carbonate rocks disclosed significant differences between aphanitic limestone and aphanitic dolomite. The limestone consists of densely packed irregularly polyhedral crystals mostly 1–3 microns in diameter; the dolomite consists of a more massive aggregate of crystalline dolomite in which rhombohedral cleavage is prevalent and that contains many individual rhombohedral crystals of greatly varying sizes, as small as 1 micron or less.

The rocks of the Jerome Member of central Arizona were deposited on a gradually subsiding platform in the area southwest of the Defiance uplift. The fetid dolomite unit, the lowest of the three units in the member, formed as a lime mud interlaminated with much organic material, possibly in a large embayment. The rocks of the aphanitic dolomite unit formed as lime mud in very shallow open water, possibly in an almost tideless sea on a wide shelf that was intermittently and locally exposed to the air when strong offshore winds lowered sea level. Gradual deepening of the sedimentation area took place during deposition of the upper unit. Sedimentation of calcareous deposits continued in offshore areas such as near Jerome. In east-central Arizona a supply of terrigenous material was furnished partly from the Defiance uplift and partly from an unidentified source southeast of the area covered by the present investigations. The upper part of the upper unit was laid down in water below the zone of wave turbulence.

Most rocks of the Jerome Member have had a complex diagenetic history under conditions of very low pressures and temperatures. No rocks of the Martin Formation in central Arizona have ever been covered by more than 3,000–3,500 feet of post-Devonian sediments. Aphanitic dolomites are probably not of primary sedimentary origin. They are more probably the result of penecontemporaneous or eodiagenetic dolomitization of lime mud before lithification. Volume shrinkage during this process contributed to compaction of the sediment; hence, aphanitic dolomites are nonporous. Fossils may be preserved as "ghosts" in these rocks.

Granular dolomits were formed from limestones through formation of authigenic dolomite crystals, which grew in number until they completely replaced the parent rock. In such rocks all fossil structures were completely destroyed unless they became silicified.

Nondolomitized aphanitic limestone tended to become recrystallized through grain growth. In extreme stages of this evolution, the rock consists of finely crystalline ("sparry") calcite in which are embedded small lumps or "pellets" of aphanitic limestone. Fossils are often recognizable as "ghosts" in the crystalline calcite. Recrystallization through grain growth also takes place in aphanitic dolomite in a manner similar to that in limestone, though more rarely. The dolomite in aphanitic dolomite rock also can be reconstituted into dolomite rhombohedra similar to those formed in aphanitic limestone. All these processes are postlithification (mesodiagenetic or telodiagenetic).

Luster mottling is found not only in sandstones having a carbonate matrix but also in pure carbcnate rocks, in limestones, and in dolomites and mixed rock types. In carbonate rocks this texture is due either to partial dedolomitization of dolomite or to parallel optical orientation of crystal grains in clusters in which the optical orientation differs from one cluster to another.

Introduction and migration of silica are important aspects of diagenesis. Silica occurs as chert nodules and layers, spherulitic replacements, authigenic quartz, and as replacement of fossil skeletons, especially those of *Amphipora*, corals, and brachiopods. In many rocks, brachiopod shells are only incompletely silicified and consist of a layer of siliceous material enclosing a calcite core. Some, but not all, of the diagenetic silica is derived probably from solution and partial replacement (by calcite or dolomite) of detrital quartz grains. This process is reversible or cyclical in that diagenetically deposited silica may in turn be invaded by calcite or dolomite.

The age of the Martin Formation in central Arizona is Early or Middle to early Late Devonian. The beginning of sedimentation of the Beckers Butte Member cannot be dated more closely than Early or Middle Devonian on the basis of psilophyte flora in the member, although a Middle Devonian age is more probable on grounds of regional geology. The upper half of the upper unit of the Jerome Member contains many fossils of a general Frasnian (early Late Devonian) age and some of late Frasnian age. The lower age limit of the Jerome Member cannot be accurately defined, and where the boundary between the Middle and Late Devonian in the Martin Formation occurs is not known at present.

Study of facies distribution and isopach pattern of the rocks of the Martin Formation indicates that a continuous broad shelf area extended southwest of the Defiance uplift into central Arizona and that no major land mass was present here, as was suggested by some writers. This conclusion is based on (1) the areal distribution of the Beckers Butte Member, (2) the distribution and facies character of the fetid and aphanitic dolomite units of the Jerome Member, which have specialized sedimentational and complex diagenetic histories, (3) the lateral distribution of terrigenous siliceous-detrital material in the upper

unit of the Jerome Member, suggesting northeastern and southeastern sources rather than a source in central Arizona, and (4) distribution and composition of fossil faunas in the upper part of the upper unit, which suggest a deepening of the sea during the closing stages of the deposition of the Jerome Member.

INTRODUCTION

LOCATION AND GEOGRAPHY

The present study concerns the Devonian rocks in northern Gila County, southwesternmost Navajo County, northeastern Yavapai County, and southernmost Coconino County in Arizona. The geographic subdivisions in this part of the State are the following: North-central Arizona (Yavapai County), east-central Arizona (Gila County), south-central Arizona (Maricopa and Pinal Counties), and northeast Arizona (Coconino, Navajo, and Apache Counties).

The Devonian rocks studied in this report lie in north-central and east-central Arizona and in a very small corner of southwestern Navajo County. A single outcrop is situated in Coconino County (Elden Mountain). However, for convenience the entire area containing outcrops of Devonian rock studied in this report is referred to as central Arizona (fig. 1).

Devonian rocks crop out partly as continuous belts and partly in scattered localities along the southwestern edge of the Colorado Plateau and in immediately adjoining parts of the Basin and Range province of Arizona. Southeast of the area Devonian rocks are deep in the subsurface, and first crop out in the area underneath the Mississippian Redwall Limestone at a point about 1½ miles southeast of the confluence of the White and Black Rivers. Partly because of a regional southeasterly dip in this area and partly because of the deepening of the bed of the Salt River toward the west, the altitude of the belt of Devonian rocks above river level increases along the walls of the spectacular Salt River gorge to a point north of the bridge of U.S. Highway 60 over the Salt River, where the base of the Devonian section lies at an altitude of about 4,000 feet, or 600–700 feet above the bed of the river (fig. 2). The base of the section is at an altitude of about 5,200 feet in the lower Salt River draw area and along the entire length of Canyon Creek, where the section is well exposed along the eastern side of the valley.

The rocks are well exposed along this entire belt but are mostly accessible with great difficulty; so, localities at which stratigraphic sections could be measured and adequately sampled are relatively far apart. The beds are horizontal, or very nearly so.

Farther northwest the Devonian belt converges toward the edge of the Mogollon Plateau and runs close to the foot of the Mogollon Rim, where good outcrops occur in the valleys of Hunter, Christopher, and the upper Tonto Creeks and the valleys of the upper East Verde River and some of its tributaries. The base of the Devonian section here lies generally at altitudes between 5,400 and 5,600 feet; the differences in altitude are due largely to irregularities in the pre-Devonian erosion surface. This outcrop belt ends near Pine, where the rocks are generally more easily accessible but exposures poorer than in the Salt River and Canyon Creek area. The beds are either flat or dip gently toward the Mogollon Rim, except in the Christopher Mountains south of Christopher Creek, where steeper northerly dips are more common.

Tectonically, the rocks along the entire belt from the upper Salt River to Pine form part of the Paleozoic foundation of the Colorado Plateau. Opinions differ on the exact position of the southwestern boundary of the Colorado Plateau. According to Ransome (1933) and Eardley (1951, p. 141), the belt of Devonian rocks here discussed forms part of the Mexican Highland region. According to Wilson and Moore (1959), it lies in a transition zone between the Colorado Plateau and the Basin and Range province of southeastern Arizona.

At least in a general way, the southwestern boundary of the Colorado Plateaus province is most logically accepted as being in the position suggested by Bromfield and Shride (1956, p. 614) because it separates an area of virtually undisturbed rocks to the northeast of the boundary line from an area of folded, faulted, and uplifted rocks to the southwest. The suggestion of Heindl and Lance (1960, p. 15) to include a marginal belt of the disturbed area in the Colorado Plateaus Province seems little justified.

Southwest of the Colorado Plateau as defined by Bromfield and Shride (1956), rocks have been much disturbed by younger orogenies, and outcrops of Paleozoic rocks—more especially of Devonian rocks—are scattered and far apart. This area of disturbed rocks includes the rugged mountainous region of the Sierra Ancha and the Mazatzal Mountains separated by the wide valley of Tonto Creek, the principal tributary of the Salt River. The only known outcrops of Devonian rocks are at Aztec Peak, at an altitude of more than 7,600 feet.

South of the Sierra Ancha, stratigraphic sections—some incomplete—were measured on the south side of Theodore Roosevelt Lake and near Globe. Information on scattered outcrop areas near upper Pinto Creek and in the Superior area was taken from other sources.

At the northwestern end of the Mazatzal Mountains, isolated areas of Devonian rocks crop out southeast of the junction of the East Verde and Verde Rivers, where

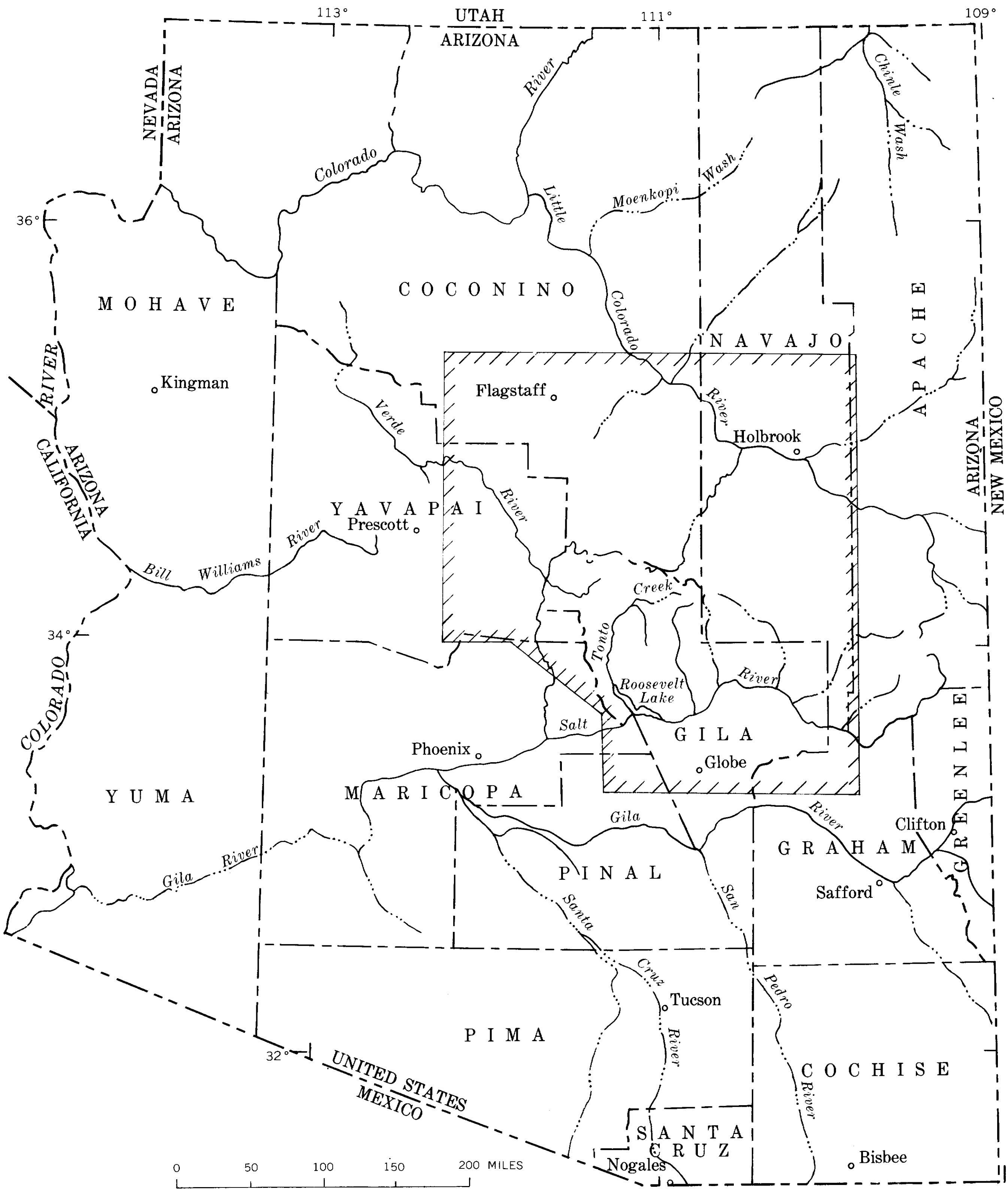

Figure 1.—Location of area covered by this report.

they are best exposed in the Limestone Hills. This area can be reached on horseback from Verde Hot Springs.

South of the Salt River and east of U.S. Highway 60, the Paleozoic rocks are buried under the basalts of the Natanes Plateau but appear in a few places as inliers, where the cover of volcanic rocks was perhaps thin and has been eroded away. Two inliers near Sawmill Creek were studied, as was one isolated section on a hill at Ninemile Creek, 10 miles southeast of U.S. Highway 66.

West and southwest of Pine and north and west of Verde Hot Springs, the Paleozoic rocks are covered by an extensive field of volcanic rocks. Devonian rocks occur only as small inliers in the valley of the Verde River and near Squaw Peak south of Camp Verde. Here, an incomplete section was studied just below Squaw Peak, and a more complete one was studied in Chasm Creek farther south.

Devonian rocks occur farther north at Mingus Mountain, where they have long been known in the Jerome mining district and where they are easily accessible in many places. An almost uninterrupted belt of outcrops of Devonian rocks extends northwestward from this area to the Grand Canyon, but this belt has not yet been studied, except near Jerome and at the junction of Sycamore Creek and Verde River, about 8 miles north of Jerome.

Finally, a small area of Devonian rocks at Elden Mountains, north of Flagstaff, has been included in this study. Because it is remote from other outcropping

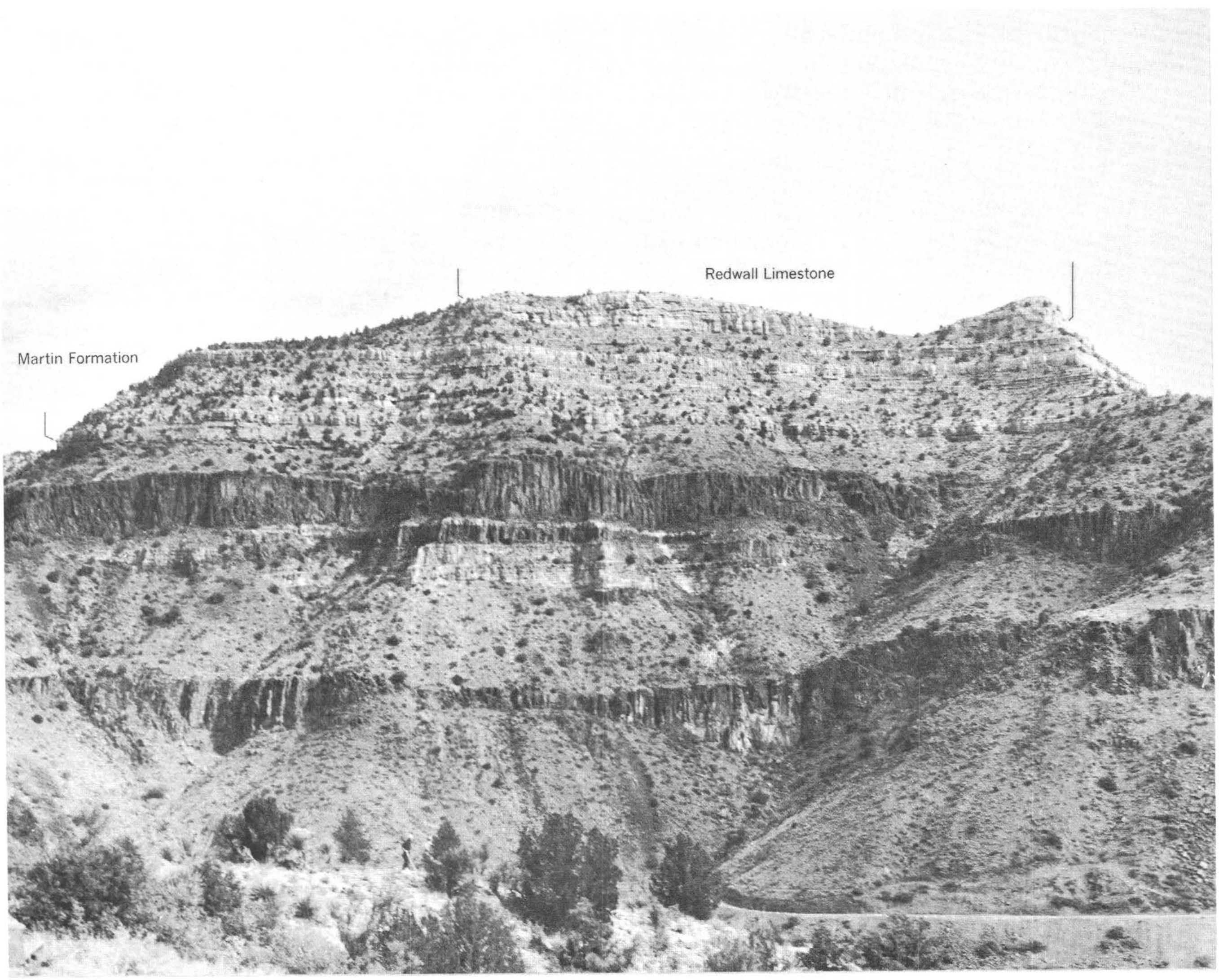

FIGURE 2.—Martin Formation and Redwall Limestone resting on Precambrian complex. North side of Salt River gorge north of crossing of U.S. Highway 60, seen from south side. The Martin Formation immediately overlies slope-forming Mazatzal Quartzite. On the slope below, the vertical cliffs having columnar structure are diabase; the stratified rocks are Mazatzal Quartzite (A. F. Shride, oral commun., 1956).

rocks of Devonian age, accurate information on the nature of these rocks seemed desirable.

The general distribution of Devonian rocks in part of the area discussed in this report is shown on the geologic maps of Gila County and of Yavapai County issued by the Arizona Bureau of Mines (Wilson and others, 1958, 1959).

PREVIOUS WORK

In the area considered in this report, rocks of Devonian age were undoubtedly first seen in 1871 by geologists of the U.S. Geographical Survey West of the 100th Meridian (Wheeler, 1872). Gilbert (1875) and Marvine (1875) published brief observations on the stratigraphic succession near Camp Verde, in Canyon Creek, and in the Salt River gorge south of Camp (now Fort) Apache, but the geologists seem to have included most rocks now known to be of Devonian age in the Redwall Limestone, the age of which was given as "Upper Carboniferous." Gilbert and Marvine possibly included some of the basal sandstones of Devonian age and other rocks of early Paleozoic age in their "Tonto sandstone" and "Tonto shale."

The first recognition of the presence of the Devonian System in the area was by Reagan (1903), who studied the stratigraphy of the Fort Apache Indian Reservation. Under the heading "The Devonian," Reagan described "alternating chert and flint strata followed by massive, very fossiliferous light colored, fine grained, marble limestone, which in turn is followed by a grit." Of fossils he mentioned "*Orthis laevis*, *Spirifer fornacula* and *Acervularia davidsoni*" and remarked that these correspond "very much to the Devonian formations at the falls of the Ohio." Underlying the Devonian sequence Reagan reported 70 feet of "red to brown fossiliferous, coarse-grained lime rocks," which he placed in the "Upper Silurian," and below these a formation of "coarse- to fine-grained, often crossbedded vitreous sandstones and sandy shales, varying in color from brown red, purple, and white," which he referred to Gilbert's Tonto Shale. Most of these rocks undoubtedly belong to the Devonian System as understood by later authors.

Lee (1905, p. 97–98) reported very briefly on the stratigraphic sections at Roosevelt ("Tonto basin dam site") and Windy Hill, where he included the rocks immediately above the Apache Group in the "lower Carboniferous." He seems to have collected no Devonian fossils.

Next, Ransome (1915, 1916) identified strata of Devonian age from several places in central Arizona, especially the Theodore Roosevelt Dam site and the Jerome area. He also referred to and reinterpreted Gilbert's earlier observations from Canyon Creek. Ransome reported thin-bedded limestones and sandstones or quartzites from Roosevelt, which he correlated with the Martin Limestone, described by him earlier (Ransome, 1904b) from the Bisbee area in southeastern Arizona. However, he observed that the beds at Roosevelt are more sandy and less fossiliferous than the Martin Limestone of the Ray quadrangle. A small fauna of Devonian age was reported that, according to Kirk (1931), could be correlated with that of the Martin Limestone of Bisbee and that of the Ouray Limestone of southwestern Colorado.

In the Jerome region Ransome (1916, p. 160–163) discovered 500 feet of "thin-bedded compact limestone" containing Devonian fossils. He dated this unit as "Devonian, at least in part," but did not assign it to the Martin Limestone. A small marine fauna composed of corals and brachiopods was reported from these beds. Ransome also described a section from the East Verde River near the crossing of the road from Payson to Pine that he regarded as at least partly Devonian in age. This section is at approximately the locality of section 32 of the present report. Ransome restricted the name Martin Limestone to the predominantly carbonate sequence. The sandstones below this sequence, which had already been recognized by Gilbert, Marvine, and Reagan, he correlated partly with the Tapeats Sandstone of Cambrian age and partly with the Troy Quartzite, which he believed to be of Cambrian age.

Another important contribution by Ransome (1916, p. 153–154) was his discovery of a thick sandstone series near Aztec Peak in the Sierra Ancha. He considered (p. 154) this sandstone to be "the stratigraphic equivalent of the Troy quartzite," but his columnar section (Ransome, 1916, pl. 25, section VI) indicates that he seemed to regard some of the upper part of this sandstone sequence as a correlative of the Devonian Martin Limestone.

The germ of the concept of the Defiance Positive Area is found in a paper by Gregory (1917, p. 18), who stated that much of the Navajo country is underlain by an "elevated mass which outlived its contemporaries through Cambrian, Silurian, Devonian, and early Carboniferous time, only to be itself buried by the streams of Permian time."

Reber (1922) reported 300–500 feet of limestone in the Jerome district, "all or part of Devonian age," which he correlated with the Temple Butte Limestone of the Grand Canyon.

Darton (1925) summarized some of the earlier observations and added that he found "distinctive strata containing Devonian fossils in a wide area of central and south-central Arizona including the Salt River Basin, Black River Valley, Natanes and Mogollon plateaus" and in several other localities situated outside the area discussed in the present report. He was the first to recognize a widespread erosional unconformity at the base of the Devonian in central Arizona.

Lausen and Wilson (1925) described reddish-brown sandstones, which are locally crossbedded and as much as 150 feet thick, from the area south, west, and north of Payson and applied to them the name Sycamore Creek Sandstone, which was taken from an unpublished manuscript by Stoyanow. They reported that Schuchert and Stoyanow found fossil fish remains of Late Devonian age in the sandstones and that the sandstones are overlain by "thin-bedded, flaggy limestones."

Stoyanow (1926) gave further details on the Sycamore Creek Sandstone, which he called Sycamore Creek Formation, identifying the type locality and reporting the presence of *Macropetalichthys*. He pointed out the significance of these finds for the dating of the basal sandstones of the Devonian and regarded it as doubtful whether, in the absence of faunal evidence, any part of the basal sandstones that Ransome had correlated with the Troy Quartzite and Tapeats Sandstone might in fact be Cambrian. Stoyanow also noted that similar sandstones were widely distributed elsewhere in the Tonto and Verde River basins, and he briefly described a Devonian and Mississippian section totaling 324 feet in thickness from Windy Hill, on the south shore of Theodore Roosevelt Lake.

In 1930 Stoyanow stated briefly that the Devonian sequence in northwestern Arizona differed significantly from that of southeastern Arizona, and he proposed the name Jerome Formation for the northwestern sequence. He suggested that it was the equivalent of the Elbert Formation and the lower Ouray Limestone of Colorado.

Hinds (1936, p. 32–36) discussed Precambrian and Cambrian relationships in central Arizona and referred all sandstones overlying Precambrian rocks and underlying Martin Limestone to the Troy Quartzite, which he regarded as Cambrian in age.

Stoyanow (1936) described the Devonian stratigraphy near Jerome in somewhat greater detail. He redescribed the Windy Hill section and increased his figure for the thickness of the exposed Devonian part of the section to 347 feet. He also published observations on the Devonian rocks south of the Salt River. His observations on the Elden Mountains section are reviewed on page 44. Stoyanow (1930) gave data in support of his limited observations, according to which the lithologic character of the Devonian rocks in the Jerome area is very different from that of the Martin Limestone near Bisbee, and he described the previously named Jerome Formation in greater detail. He reduced the former Sycamore Creek Sandstone or Formation to the status of a member and reported a sandy facies in the upper part of the Jerome Formation north of Jerome, which he referred to as the "Island Mesa beds."

Stoyanow's proposed stratigraphic terms are critically reviewed on page 15. It is of interest to note here that he reported fish remains in several horizons in the lower part of the proposed Jerome Formation and coral and stromatoporoid "reefs" in the upper part.

Furthermore, Stoyanow reported units equivalent to the lower part of the Ouray Limestone near Globe on the basis of finds of *Camarotoechia endlichi* on Pinal Creek. The section in this locality had been described in some detail by Stauffer (1928b), who referred all Devonian rocks to the Martin Limestone.

In the same paper Stoyanow (1936) proposed the name Mazatzal Land for an "ancient land in central Arizona," which he believed had been present throughout much of Paleozoic time.

Stoyanow (1942) summarized his views on the Paleozoic paleogeography of Arizona. He ventured the opinion, as had Darton (1925), that Devonian and Mississippian rocks thin considerably towards central Arizona both from the southeast and from the northwest. This thinning was described as most noticeable in Gila County in the general area between Globe, the upper Salt River, and the East Verde River near Payson and Pine. This area is now occupied mostly by Precambrian rocks, which are traversed by Tonto Creek and are thickest in the Mazatzal Mountains to the west of Tonto Creek and in the Sierra Ancha to the east. Stoyanow maintained that as this Precambrian complex was approached, not only the thickness of the Devonian rocks decreased but also the facies became more sandy, as shown on his map (1942, pl. 5, fig. f). He therefore concluded that this area of central Arizona represented an old positive area—Mazatzal Land—that had persisted from Precambrian time. A narrow strait to the north, northeast, and east of Mazatzal Land connected the northwestern (Cordilleran) and southeastern (Sonoran) seas, where deposition was more continuous and the deposits were thicker. The strait was not continuous but was interrupted by a narrow rise near the present headwaters of Tonto Creek. The rocks deposited in the southeastern part of this strait were correlated with the Martin Limestone of southeastern Arizona. The name Jerome Formation was used for the Devonian strata northwest of Mazatzal Land.

In several publications Huddle and Dobrovolny (1945, 1946a, 1952) described the Devonian stratigraphy between the upper Salt River and Pine. Their results are more fully discussed in appropriate places in this report. In general, these authors supported Stoyanow's paleogeographical conclusions, although they considerably reduced estimates of the size of Mazatzal Land. Huddle and Dobrovolny measured many geologically important Devonian sections and assigned all rocks of that age to the "Martin formation"; the predominant rock types, according to their descriptions, are limestone and dolomite limestone. In a separate publication the same authors (1946b) described briefly a biohermal facies as common in the upper part of their Martin Formation. Huddle and Dobrovolny's conclusion was that Mazatzal Land had been a large island from which three prominent prongs projected northeastward—named Pine Ridge, Christopher Mountain Ridge, and Chediski Ridge—that determined in an important way the character of the Devonian rocks. These ridges probably subsided northeastward under a cover of younger sediments in a trough termed the "Mogollon Sag." The Mogollon Sag corresponds in position to Stoyanow's central Arizona strait (not so named by him), but it probably received a greater thickness of sediment. Huddle and Dobrovolny emphasized again the progressive increase in arenaceous matter in the Devonian sedimentary rocks toward the Mazatzal Land. Furthermore, they described the Defiance uplift as a narrow northeast-trending ridge separated by a basin from the Zuni uplift, which trends parallel to the Defiance uplift.

In the meantime different ideas were being developed by Eardley (1949, 1951) and by McKee (1951). From the literature as well as many unpublished data, McKee compiled isopach maps for the Devonian and other Paleozoic systems. On the basis of the maps, he rejected the concept of Mazatzal Land and believed that central and southwestern Arizona were once covered with Devonian and Mississippian deposits that were removed by erosion following uplift, probably as late as Miocene and Pliocene. He found confirmation of this view in the large number of pebbles and cobbles derived from the Paleozoic in upper Tertiary gravels along the southern margin of the Colorado Plateau. (See also Price, 1950.) The area of Stoyanow's Mazatzal Land is thus considered to be a basin of sedimentation containing original thicknesses of Devonian rocks of 400–500 feet.

More or less simultaneously, Eardley (1949, 1951) made a very similar interpretation. He called the Central Arizona sedimentation area "Arizona Sag," which represented a semistable area between the Cordilleran and Sonoran geosynclines and the more stable positive areas in northeastern and southwestern Arizona. The northeastern area was called "Defiance Positive Area" by McKee, and on his maps this area occupies a dominant position underlying the eastern half of the Colorado Plateau in Arizona, including much of the Black Mesa basin. McKee discounted evidence of increasing sandiness of the Devonian rocks in central Arizona.

More recently Anderson and Creasey (1958) gave a brief description of the Devonian rocks of the Jerome district, which they described under the name of Martin Limestone. They divided the Martin Limestone at Jerome into four stratigraphic units composed mostly of dolomite, dolomitic limestone, limestone, and some interbeds of siltstone and shale. The sequence rests on brown crossbedded coarse-grained sandstone, which Anderson and Creasey correlated tentatively with the Tapeats Sandstone of Early and Middle Cambrian age in the Grand Canyon area, as did Stoyanow before them. This view was supported by Krieger (1959).

Lehner (1958) described the Devonian rocks of the Clarkdale quadrangle that includes portions of the Jerome district. In his descriptions and subdivisions, Lehner followed Anderson and Creasey (1958) very closely. He classified the basal sandstone as Tapeats (?), and he recognized the same four subdivisions of the Martin Limestone, which he designated as units A, B, C, and D, respectively.

The discovery of an isolated Devonian outcrop at Elden Mountain, northeast of Flagstaff, was made by Brady (1933, 1934). Much earlier a large tilted block of Paleozoic sedimentary rocks surrounded by volcanic rocks was mapped in this area by Robinson (1913), who believed all the pre-Permian rocks to be Mississippian in age (Redwall Limestone). Brady reported 125 feet of sandy limestone and sandstone below the Redwall Limestone. Finds of fish plates suggested to him that the rocks correlate with Stoyanow's Sycamore Creek Formation on the East Verde River. Additional data on the East Verde River locality were given by Stoyanow (1936, p. 501); according to him, the section is 148 feet 10 inches thick and consists entirely of limestone. Coral and brachiopod remains were reported from some horizons. He also described some arthrodiran plates from these beds but did not name them.

Turner (1958) included rocks as far south as the Mogollon Rim in his discussion of the Devonian of the Black Mesa basin. He believed that broad facies changes take place in the southern part of the basin and that although the rocks are now included in the Martin Limestone, a more appropriate nomenclature would have to be developed as exploration proceeds. Turner further called attention to reports of "petroliferous odor" of Devonian rocks along the Mogollon Rim in the Pine-Payson area, and he accordingly included this area among those considered favorable for the occurrence of oil and gas.

More recently, Elston (1960, p. 28–29) briefly summarized the Devonian paleogeography in northeastern Arizona, but his discussion included only a small part of central Arizona. He stated that the existence of Mazatzal Land seems to have been conclusively established, and on his isopach map (Elston, 1960, fig. 5) he showed thickening of the Devonian rocks north of Mazatzal Land in the "Holbrook Sag," which seems to be identical with the "Mogollon Sag" of Huddle and Dobrovolny (1952).

Finally, Brown and Lauth (1960) regarded the Devonian rocks between the Mogollon Rim and Holbrook as a "potential [oil] producing area." They referred to an extensive depositional trough south of Flagstaff that extends southeastward to the New Mexico State line, where Devonian rocks may be 500–600 feet thick. For this feature the name "St. Johns Sag," coined by Kelley (1955) for a post-Devonian trough, is preferred. Brown and Lauth suggested that reefs may be present in this trough.

In the same year, Cross and others (1960, p. 87) produced a relief map purporting to depict the paleogeography of Arizona in Devonian time. Outside the Defiance uplift this map showed one large and one small island in central Arizona, three small islands in the Grand Canyon area, and a land mass and a small island in the southwestern part of the State.

Before the present investigation, fossils in the Devonian rocks of central Arizona received little systematic attention. Small collections—identified by Girty, Kindle, and Kirk—were mentioned by Ransome (1916) and by Darton (1925). Stoyanow (1936) listed 24 species, mostly corals and brachiopods, from his Jerome Formation. The fish remains from the Elden Mountain section were described by Hussakof (1942). In 1948, Stoyanow described a small unique fauna composed of four new genera of pelecypods and gastropods from the "Island Mesa beds" but gave no information on their locality and exact position in the sequence. Paleontologic information from scattered localities between the Salt River and East Verde River was given by Huddle and Dobrovolny (1952).

The age of the marine faunas had been established as Late Devonian, comparable to that of the Independence Shale of Iowa. (See also Cooper, 1942.) A well-preserved psilophyte flora was discovered near the base of the Devonian section in the upper Salt River area and was reported by Teichert and Schopf (1958). This flora indicated that the lower part of the Devonian sequence is as old as Middle or possibly Early Devonian, although no break in the sequence could be discovered.

SCOPE OF PRESENT INVESTIGATIONS AND METHODS OF STUDY

The present investigations began in 1953 on behalf of the Shell Oil Co. as a contribution toward evaluation of the oil possibilities of the Black Mesa basin. For this purpose the Devonian and Mississippian rocks along the southern and western periphery of the basin were studied in some detail. In 1956 the Shell Oil Co. released the results of these studies to the U.S. Geological Survey, and additional fieldwork was done in that year and again in 1957. During 6 weeks in 1956 I was assisted in the field by R. L. Harbour. Most of the laboratory work was completed on July 1, 1960. Manuscript and illustrations were also completed on July 1, 1960, but some minor additions and changes were introduced on the basis of field observations made in October 1960 and in April 1961. It was impracticable to introduce references to any publications that appeared later than April 1961.

The present study emphasizes detailed investigations of measured sections, combining field observations with microscopic examination of thin sections and reexamination of hand specimens together with some laboratory determinations, such as Ca/Mg ratio determinations, heavy-mineral analyses, mechanical analyses, and insoluble residue studies.

From the review of previous work in central Arizona, given in the preceding section, the following seemed to be important points for inquiry:

1. The question of the existence of "Mazatzal Land" contrasted with that of the "Arizona Sag."
2. The extent of the "Defiance Positive Area" in Devonian time.
3. The probable nature of the Devonian sedimentary rocks underlying the Black Mesa basin.
4. The nature and age of the basal Devonian rocks—especially sandstones—and their relationships to the Troy Quartzite and the Tapeats Sandstone.
5. The reported occurrence of reefs and bioherms in the Devonian.

To get answers to all these questions required a broad regional study of the Devonian rocks of central Arizona based on detailed lithological and paleontological studies of reasonably closely spaced stratigraphic sections.

Selection of sections for measurement and detailed study was of necessity determined by the nature of the outcrops and their accessibility. Only part of the area under investigation is topographically mapped at a scale of 1:62,500. For areas not so mapped use was made of the following: Map of San Carlos Indian Reservation, 1945, 1:125,000, published by the Office of Indian Affairs; map of Fort Apache Indian Reservation, 1938, 1:125,000, published by the Office of Indian Affairs; map of Tonto National Forest, 1938, 1:250,000, compiled by the Albuquerque office of the U.S. Forest Service.

During fieldwork in 1956, aerial photographs prepared by the Army Map Service at a scale 1:50,000 were used with much success in locating suitable outcrops.

As most geologists will agree, the results of measuring and interpretation of stratigraphic sections are somewhat subjective. Many personal factors and variables, such as weather, temperature, fatigue, time limitations, and others, enter into the task. For this reason no two geologists will ever describe one and the same stratigraphic section in identical terms, and even one observer who measures the same section twice in different field seasons will note differences and discrepancies in the two descriptions. The subjective nature of many stratigraphic techniques has been discussed recently by Schenck and Graham (1960).

Decisions of an interpretative nature based on only superficial examination of rocks must continuously be made in the field in order that a logical grouping of rock units in a section may be determined. Most rock subdivisions in stratigraphic sections are somewhat arbitrarily and subjectively defined in the field, and those in one section are not necessarily fully comparable qualitatively with those in another section. Nevertheless, a subdivision in this sense should be the smallest group of strata or beds—in some places, only one bed—within a formation that can be recognized in the field. Such a rocks subdivision, herein called a subunit, should ideally consist of only one type of rock, well defined in regard to composition, color, texture, hardness, and weathering, or it may consist of two types of rock that are so defined and may either alternate regularly or be subordinate one to the other. Examples of the last mentioned type of rock subunit are a dolomite having scattered shale partings or a limestone containing chert nodules.

Rock subunits must be defined in the field on the basis of superficial examination with a hand lens, aided perhaps by hydrochloric acid or simple stain tests, but later more detailed laboratory study of samples may reveal that what had appeared as a subunit in the field may consist of more than one rock subunit.

Measurements of sections were made mostly with the help of an Abney level, which either was attached to a 5-foot rod or was held in the hand; correction for angle of dip of the beds was made where necessary. In places, where slopes were very smooth, a measuring tape was used. Samples were taken, as a rule, not at regular intervals but insofar as possible from every stratigraphic subunit. Two or more samples were generally collected from subunits thicker than 15 feet. Except those samples collected from relatively inaccessible sections, individual samples weighed 250–500 grams, enough for all ordinary laboratory investigations. Not all samples were later used, but no decision regarding the later use of samples was made in the field.

Some sections measured in 1953 were studied and sampled in less detail than the sections measured in 1956. Also, sample splits available from collections made during the 1953 field season were generally too small for laboratory tests.

Sketch maps (pl. 32) show the location of all measured sections. They serve to facilitate efforts of others to find all localities mentioned and described in this report if used with the specified base maps.

Thin sections were made of all samples, and information derived from them has been incorporated in the section descriptions. Thus, almost all grain-size estimates, both of detrital and or carbonate rocks, are based on thin-section observations. The Wentworth scale was used for all rocks, including carbonates. Use of different scales as advocated, for example, by DeFord (1946) and by Folk (1959), is impractical, especially where detrital-siliceous rocks alternate with carbonate rocks or where carbonate rocks contain appreciable amounts of detrital siliceous material. Both situations occur in many places in the Devonian rock sequences of central Arizona. Also, where grain sizes are shown graphically on plotted sections, as in this report, introduction of different scales for clastic siliceous and for carbonate rocks would be confusing.

Analyses of many rock samples for calcium and magnesium content were obtained according to the method described by Shapiro and Brannock (1957). The results were recalculated in MgO percent of total carbonate and are so represented in the graphs.

Insoluble residues were prepared and mechanical analyses were made of selected rock suites, and the heavy minerals were separated in several sandstone samples.

Measured sections were plotted so as to show at a glance as many physical properties of the rock as possible. The following rock characteristics may thus be read directly from the diagrams in plates 28–31 for each rock subunit distinguished in the field:

1. Lithology—through use of 31 rock symbols.
2. Thickness.
3. Bedding.
4. Quality of exposures.
5. Fossil content—through separate symbols for 17 fossil groups, important particularly for correlation and for environmental interpretations.
6. Grain size in terrigenous clastic rocks and crystallinity scale in carbonate rocks, both graphed according to the Wentworth scale.
7. Approximate color value and hue according to the standard "Rock-Color Chart."

All subunits in all plotted sections are numbered, and additional details for each subunit can be found in the formal section descriptions on pages 105–169. Reference to the section descriptions is especially recommended for fossiliferous beds because the fossil symbols merely indicate presence of a particular group of fossils but not their relative abundance or state of preservation. Thus the symbol for brachiopods may indicate a few brachiopod fragments or a rich well-preserved fauna. Information on this point, together with listings of species where available, is presented in the section descriptions.

COLOR OF ROCKS

Pettijohn (1957, p. 346) remarked that "more emphasis is placed on the color of shales than most sedimentary rocks," and even so, few results of research on the causes and significance of the color of rocks of any kind have been published. Patnode (1941) showed that the color of shale is related to reduction number and nitrogen content and hence in some way to the amount of contained organic matter, although he measured reflectivity—that is, color value—rather than color as such. MacCarthy (1926) studied the relationship between the FeO/Fe_2O_3 ratio and the color of rocks—mostly of clay, shale, and slate but including some sandstone and limestone. He found that colors in the red, yellow, orange, and blue hues are related to the state of oxidation of the iron, but he did not evaluate his results geologically.

Danchev (1958) pointed out that color in sedimentary rocks may be either "hereditary" (determined by the color of the rock or rocks from which sedimentary particles are derived) or diagenetic (determined by secondarily formed mineral substances).

Weller (1960, p. 129–140) is among the few who have given color more than a brief mention in textbooks. He discussed at some length the color-forming role of organic matter and of iron compounds and the origin of blue and green colors.

Krynine (1948, p. 145) called color a "powerful tool" in describing rocks, and more detailed study and proper interpretation of rock colors will undoubtedly sometime be recognized as important aids in the understanding and reconstruction of sedimentary and diagenetic environments. Although investigations of this nature are beyond the scope of this report, considerable attention has been paid to accuracy of color terminology, and a few special comments are offered on the method of representing colors in plotted sections. Widespread use of subjective color terminologies, which differ among authors, is an obstacle to comparison of color data contained in different publications. The situation has probably improved only slightly since DeFord (1944) called color description by geologists "completely anarchistic."

In the present report, color of rocks is described in terms of the "Rock-Color Chart" by Goddard and others (1948), which, Weller's objections (1960, p. 140) notwithstanding, is the only presently available tool for objective rock description. (See also Grunau, 1959, p. 6.) All colors were identified from hand specimens in the laboratory under uniform lighting conditions. This control insures a degree of uniformity of color terminology that is impossible to achieve in the field. Some consistent discrepancies occurred between color determinations made in the field and in the laboratory. Commonly, a medium-gray rock having a color chart value *N*5 was described in the field as dark gray (*N*3); and a dark-gray rock having the value *N*3 was described as black (*N*1). A high degree of subjectivity also is the rule in field identifications of the red and yellowish-red hues made without use of the color chart. Thus, pale red is generally identified as pink, and a wide variety of yellowish-red hues are called buff. Shales described as green are as a rule some shade of olive and thus have a yellow rather than a green hue. Sedimentary rocks are rarely, if ever, green.

Field determinations of colors made without the use of a color chart may differ greatly, depending on conditions under which they are made. The observer's judgment of color hue, saturation, and value of one and and the same rock will differ according to cloudiness, time of the day, and conditions of illumination. Nonscientific color recognition, as it still largely prevails in geological practice, has been aptly described by Boas (1959, p. 6):

> When we speak of the color of an object as that color seen by normal vision, under certain illumination, at a given distance, we are stating how to observe the color. We are admitting that the color seen is relative to a number of circumstances which can be varied independently of one another and that the sensory datum is a function of them all.

The colors of Devonian rocks of central Arizona are almost entirely in the red and yellowish-red hues and in the neutral gray axis, although some rocks range both into the yellow and greenish-yellow hues and into the red-purple hue. Such common field identifications as pink, brick red, purple, and cream are in the red hue; buff, tan, cream, and brown (most shades) are in the yellow-red hue. Most of the yellow hues are commonly identified as green.

In the descriptions of stratigraphic subunits, colors have been identified with the help of the "Rock-color Chart" according to hue, color value, and chroma. Thus, in the combination 5*R* 6/2, *R* stands for red hue, and the number 5 indicates an intermediate hue—red hues are valued from 1*R*, which is close to the purple hue, to 10*R*, which is close to the yellow-red hue. The numeral 6 indicates the relative lightness of the rock, which is rated 1 on the black end and 10 on the white end. The numeral 2 indicates color saturation (chroma)—pale colors are indicated by 2, intermediate saturation by 4, and bright colors by 6.

Lack of a color symbol in the description of a subunit indicates that either no sample or no sample adequate for exact color description was available for laboratory study.

All three color properties cannot be indicated by symbols on a plotted section, and only hue and value (lightness) are shown. Hue is indicated by the width of a strip on the left hand side of the plotted column in such a way that colors of the gray axis are shown as very thin strips whereas hues from purple to yellow are indicated by increasing widths of the strip. Color values are indicated by shading and hatching. The general color of a subunit can thus be estimated at a glance by remembering that wider strips indicate increasingly brighter hues from gray through purple, red, and yellow and that the degree of shading of the strip roughly indicates the lightness value of the color, black representing the value of medium dark gray and darker and absence of shading representing a very light gray value.

Omission of saturation (chroma) on the diagrams means that for some samples somewhat different colors are grouped together such as pale brown (5*YR* 6/2) and light brown (5*YR* 5/6). The symbol for both these colors on the plotted sections would be the same.

For mottled rocks the symbol indicating the predominant color was chosen.

HISTORICAL SUMMARY AND EVALUATIONS OF STRATIGRAPHIC NOMENCLATURE

The number of stratigraphic formations which has been proposed for rocks of Devonian age in Arizona is not great. Because they have been named over a long period of time by geologists working in widely separated parts of the State, however, a certain lack of coordination is noticeable. In the following discussion, the history of stratigraphic nomenclature of Devonian rocks in Arizona will be briefly reviewed and critically appraised as far as possible.

NORTHERN ARIZONA

Walcott (1880) was probably the first to recognize Devonian rocks in Arizona, when he reported 100 feet of "sandstones and impure limestones" of this age in the Grand Canyon. In 1890, he named this sequence Temple Butte Limestone but did not describe it in greater detail. Walcott (1883) earlier observed that the Devonian rocks in the Grand Canyon have irregular thickness and are locally absent. This observation was confirmed by Noble (1914). Later, Noble (1922) gave the thickness of the Devonian section at the Bass Trail, Grand Canyon, as 75 feet, all of which was reported as limestone with the exception of 10 feet of magnesian limestone at the top.

In 1934, McKee measured the type section at Temple Butte (see Stoyanow, 1936, p. 503) and reported 77 feet of limestone, sandstone, and shale. McKee (1939) described briefly the Temple Butte Formation in the lower Grand Canyon area, where he reported thicknesses of 743 feet at Meriwitica Canyon and of 1,272 feet at Grand Wash Cliffs.

In 1953 I measured a thickness of 84 feet of Temple Butte along the Kaibab Trail where the rocks are composed entirely of dolomite and calcitic dolomite. No limestone occurs in this section, and the Devonian rocks in the Kaibab Trail part of the Grand Canyon are better referred to as the Temple Butte Formation.

An attempt to extend the name Temple Butte, to beds lying outside the Grand Canyon area was made by Reber (1922), who proposed to apply the name to the Devonian rocks of the Jerome district. In this application he was followed, somewhat diffidently, by Ransome (1933).

In the area south of the Grand Canyon, Brady (1933, 1934) discovered a sequence of Devonian age at Elden Mountains that had previously been included in the Mississippian (Robinson, 1913). Hussakof (1941, 1942) named these rocks the Mount Elden Formation and determined their age on the basis of fossil fishes as early Late Devonian. Restudy of this section in 1956 (see measured section 44 of this report) showed that it consists entirely of dolomitic rocks that are lithologically very similar to the rocks of the upper unit of the Jerome Member, Martin Formation, of this report and to those of the Temple Butte Formation on the Kaibab Trail. No new stratigraphic name seems to be required for the sequence at Elden Mountains.

SOUTHERN ARIZONA

The second rock unit of Devonian age named in Arizona was the Martin Limestone. Ransome (1904c, p. 33) named this unit from Mount Martin on Escabrosa Ridge, southwest of Bisbee, Ariz., and stated that it has a thickness of 340 feet there. The most characteristic rock, according to Ransome, is a "dark-gray hard compact limestone," commonly fossiliferous, containing minor amounts of lighter gray limestone and some calcareous shales "of a decided pinkish tint." Petrographically, the formation was stated to be a fairly pure calcium carbonate.

Fossil collections from the Martin Limestone were described in the same paper by H. S. Williams (Ransome, 1904c, p. 35–42), who concluded that the fauna was most probably Middle Devonian in age. All of Ransome's collections came from localities in the central and northwestern parts of the Bisbee quadrangle.

In 1916, Ransome extended the name Martin Limestone to rocks lying beyond the Bisbee quadrangle in the Tombstone area, in the Ray and Globe quadrangles, and near Theodore Roosevelt Dam.

Darton (1925, p. 57–62) described under the heading "Martin limestone" all Devonian rocks in central and southeastern Arizona.

Stoyanow (1936) extended the name Martin Limestone from Bisbee to rocks lying as far north as Globe and Theodore Roosevelt Dam.

The type section of the Martin Limestone does not seem to have been restudied or redescribed since the time of Ransome's studies (1904b). In 1953 and again in 1956, I paid brief visits to the type locality of the Martin Limestone at Mount Martin near Bisbee and measured and sampled part of the formation in May 1956.

The typical Martin Limestone is almost entirely a medium-gray to medium dark-gray aphanitic to fine-grained limestone. (See fig. 3.) Dolomite is entirely subordinate in the Martin Limestone, occurring only in the uppermost 20–30 feet. "Rock-color Chart" values are *N* 4 to *N* 5, although in the field one would be inclined to describe the rock as dark gray. The lower part of the formation is generally thin bedded; the upper part is thicker bedded. Fossils occur at least throughout the upper two-thirds of the formation, with the exception of the uppermost 50–60 feet, which seems to be unfossiliferous. Among the larger fossils, brachiopods predominate. Microassemblages include many calcispheres, ostracodes, and unidentified fragmentary remains (pl. 15, fig. 3; pl. 16, fig. 3).

From the Bisbee area generally northward, important facies changes take place. In the Tombstone area, only little more than 20 miles to the northwest, Gilluly (1956) described a Devonian section 229 feet thick that is composed of nearly 50 percent shale, more than 10 percent sandstone, and only 30 percent blue-gray to gray limestone. In the Dragoon Mountains, about 30 miles north of Bisbee, the Devonian section is a mixed one composed of sandstone, limestone, and dolomite (Gilluly, 1956). In the Chiricahua and Dos Cabezas Mountains, the Devonian consists of alternating shale and limestone for which Sabins (1957) proposed the name Portal Formation. Epis, Gilbert, and Langenheim (1957) gave the name Swisshelm Formation to the Devonian sequence in the Swisshelm and Pedregosa Mountains, which there consists of siltstone, marl, sandy dolomite, and limestone.

The dark limestone facies of Bisbee, therefore, probably cannot be traced farther north than the Tombstone area, where it is subordinate in the section to clastic rocks. In the rest of Cochise County, the Devonian section consists entirely of dolomite, sandstone, and shale.

Pye (1959, p. 29) regarded the Swisshelm Formation as representing a transitional sandy facies between a western carbonate facies of the Martin and an eastern fine-clastic facies of the Percha Shale. He suggested that the Portal could be included in the Percha.

The suggestion has been made to restrict the name Martin Limestone or Martin Formation to the upper part of the Devonian section in some areas of southern Arizona. Thus, Stoyanow (1936, p. 488) proposed the name Picacho de Calera Formation for a sequence of sandstone, limestone, and dolomite underlying the restricted Martin Limestone in the Picacho de Calera Hills, 25 miles northwest of Tucson. This area is outside that discussed here.

The Santa Rita Limestone of Stauffer (1927, 1928a) of Middle(?) Devonian age is too ill defined and poorly known to be critically evaluated, as was pointed out by Stoyanow (1936, p. 495).

CENTRAL ARIZONA

Ransome (1916) was the first author to apply the name Martin Limestone to rocks extending into central Arizona. In the Globe quadrangle Ransome noted that "the beds here separated as Martin limestone" may be divided into a lower division of hard compact light yellowish-gray unfossiliferous limestones, which are sandy in their lower part, and into an upper division of dark-gray to yellowish-gray limestones which contain shaly partings. Only the upper division is fossiliferous. The section at Theodore Roosevelt Dam was described in somewhat similar terms, although it is less fossiliferous. Fossil determinations by E. M. Kindle are quoted that support a Late Devonian age for the Martin Limestone fauna, a view which has been confirmed by all later investigators.

Ransome briefly described the Devonian sequences on the East Verde River near the Payson-Pine road and those near Jerome, but he did not refer to them directly as Martin Limestone. He remarked, however, that the lower part of the Devonian section at Jerome resembles the lower part of the Martin Limestone at Ray. In 1933, he referred to the same section as Temple Butte(?) Limestone. Lindgren (1926) left these rocks unnamed.

Stoyanow (1936), as has been stated, applied the term "Martin limestone" to the Devonian rocks in the Globe area and at Theodore Roosevelt Lake, but he doubted the applicability of the term "limestone" in the Globe area, because here the Devonian rocks contain some arenaceous material.

Short and others (1943), in a study of the Devonian of the Superior area, retained the name Martin Limestone but divided the formation into three members: (1) a lower dolomite member, (2) a middle yellow limestone member, and (3) an upper yellow shale member. One of the coauthors of that report, E. N. Harshman, suggested that the lower dolomite member be named the "Crook formation," thus by implication restricting the name Martin Limestone to the upper two members.

Huddle and Dobrovolny (1945; 1952, p. 73), in a study that included the Devonian rocks of central Arizona between the upper Salt River and Pine, preferred the name "Martin formation" to "Martin Limestone" because Devonian strata there contain 40–50 percent sandstone and shale. The name "Martin limestone," however, was retained by Peterson, Gilbert, and Quick (1951) for rocks in the Castle Dome area, by Peterson (1954) for those in the Globe area, by Bromfield and Shride (1956) for those in the San Carlos Indian Reservation, by Gilluly (1956) for those in Cochise County, and by Anderson and Creasey (1958) for Devonian rocks in the Jerome district. In the Devonian correlation chart published by the Geological Society of America (Cooper, 1942), the name Martin Limestone was used for southeastern Arizona only. McNair (1951) used the name Martin Limestone for Devonian rocks found as far north as the southern Hurricane Cliffs on the north side of the Grand Canyon.

In addition to the stratigraphic units discussed in the foregoing paragraphs, the following formations established or used by Stoyanow for Devonian rocks in central Arizona deserve special attention and discussion: Sycamore Creek sandstone, Jerome formation, Island Mesa beds, and Lower Ouray formation.

SYCAMORE CREEK SANDSTONE OF LAUSEN AND WILSON (1925)

The name Sycamore Creek Sandstone was introduced by Lausen and Wilson (1925), who credited it to an unpublished manuscript by Stoyanow. Lausen and Wilson described the unit as consisting of generally dull reddish-brown sandstone and some buff-colored beds that are made up of coarse quartz cemented by iron oxide and calcium carbonate. Crossbedding is locally common, as are pebbly layers. Finer grained beds yielded fish remains, which were later described by Stoyanow (1936). Lausen and Wilson reported "thin-bedded, flaggy limestone" resting above the Sycamore Creek Sandstone and containing a small Devonian invertebrate fauna in the higher parts. The thickness of the Sycamore Creek Sandstone was given as "seldom over 150 feet."

Stoyanow (1926) identified the type locality of the unit as "Sycamore Creek, an affluent of the East Verde River, flowing southeastward from the divide near Natural Bridge, which separates it from Pine Creek, another tributary of the East Verde." The identification of the locality is further confirmed by reference to Ransome's brief description (1916, p. 159–160) of the same section. Thus, the Sycamore Creek in question is clearly the one that originates approximately 2 miles west of the center of Pine quadrangle and flows south then west and southwest until it joins the East Verde River close to BM (bench mark) 4523 at the bridge on the Pine-Payson Road. Well-exposed outcrops of Devonian rocks occur in the valley of the upper Sycamore Creek east of BM 5735 and BM 5274 (see measured section 33 of this report), but the outcrops described by Ransome and by Stoyanow are undoubtedly those found immediately north of the East Verde River.

The sandstone that crops out in roadcuts in the East Verde valley was correlated by Ransome (1916) with the Tapeats Sandstone of Early and Middle Cambrian age, but Stoyanow (1926, p. 313) reported finds of *Macropetalichthys* in the upper part of this sandstone and concluded that, in the absence of faunal evidence of Cambrian age for the lower part, the entire sandstone unit should be regarded as of Devonian age. Stoyanow stated that a similar sandstone containing arthrodiran remains occurs in the Verde and Tonto basins and had formerly been identified as Tapeats Sandstone of Cambrian age; he proposed to designate this unit as Sycamore Creek Formation. He does not refer to the previous use of Sycamore Creek Sandstone by Lausen and Wilson (1925).

In 1936 Stoyanow gave further details on this unit, which he then proposed to call Sycamore Sandstone Member of the Jerome Formation (1936, p. 499). He stated that on the East Verde River this member rests directly on the Tapeats Sandstone, though he recognized that the "discrimination between the Cambrian and Devonian on the basis of lithology is rather difficult." He did not indicate thicknesses for the Devonian and supposedly Cambrian parts of the basal sandstone. He emphasized the wide distribution of fish (arthrodiran) remains not only in the basal sandstone unit but also in stratigraphically higher sandstone in this and other stratigraphic sections.

Peculiarly, in 1942 Stoyanow assigned the same basal sandstones on the East Verde River to the Tapeats Sandstone (Stoyanow, 1942, p. 1268). Plate 1, figure 1, of the same paper shows Tapeats Sandstone resting on granite and Jerome Formation "with basal limestone resting directly on the Cambrian." This locality is discussed in the description of the Beckers Butte Member of this report (p. 29).

The name Sycamore Creek Sandstone or Sycamore Sandstone Member has not been used in the literature dealing with central Arizona since Stoyanow's last discussion of it. Huddle and Dobrovolny (1952) described sandstone units at the base of Devonian sections at several localities but did not name them. They believed that the Sycamore Creek Formation as originally defined by Lausen and Wilson (1925) included sandstones of both Devonian and Cambrian age.

The present investigation indicates that basal sandstone units of Devonian age are obviously widely distributed from the type locality of the Sycamore Creek Sandstone southeastward for at least 80 miles as far as the upper Salt River area, but unfortunately the name is preoccupied by the Sycamore Limestone of Taff (1903) of Mississippian age in Oklahoma. The formation is here redefined and redescribed as Beckers Butte Member of the Martin Formation.

JEROME FORMATION AND ISLAND MESA BEDS

The name Jerome Formation was proposed by Stoyanow (1930) for rocks of Late Devonian age at Jerome. Details were given later by Stoyanow (1936, p. 495), who described a section of 505 feet of limestone and some shale that he subdivided into 20 units and that rests on Tapeats Sandstone of Cambrian age. According to Stoyanow, the lower third of the section is characterized by "lithographic limestone"; the upper two-thirds is described as "limestones" that, however, are more varied and are partly arenaceous, partly fossiliferous, and interbedded with some shale.

Stoyanow pointed out that rocks typical of the Jerome Formation could be traced southeastward from the type area as far as the headwaters of the East Verde River, where he recognized a sandy unit at the base of the formation—the "Sycamore sandstone member," which is discussed in foregoing paragraphs. North of Jerome, Stoyanow reported increasing sandiness in the upper part of the Jerome Formation and proposed the name "Island Mesa beds" for this supposedly sandy facies.

In 1942, Stoyanow traced the Jerome Formation southeastward as far as the headwaters of Tonto Creek, Tonto Natural Bridge, and the Payson area, where he also recognized the "Island Mesa beds," but he did not again refer to the Sycamore Sandstone Member. He mentioned that "coral reefs" occurred in several places in the higher parts of the Jerome Formation.

Both "Jerome formation" and "Island Mesa beds" are listed in the Devonian correlation chart published by the Geological Society of America (Cooper, 1942) in the column for north-central Arizona. The name Jerome Formation was also used by McKee (1939), who applied it to Devonian rocks along the southern border of the Colorado Plateau, and by Gutschick (1943), who used it for the Devonian rocks underlying the Redwall Limestone in Yavapai County.

Huddle and Dobrovolny (1952) mentioned Stoyanow's use of the names Jerome Formation and Island Mesa Beds but did not use these terms. Instead, they referred to all Devonian rocks in central Arizona as Martin Formation. Also, Anderson and Creasey (1958, p. 49–51) did not accept Stoyanow's term Jerome Formation and used the name Martin Limestone for these rocks.

Stoyanow did not indicate type localities for either the Jerome Formation or the Island Mesa Beds. However, his measured section of the Jerome is probably somewhere on the slopes below and on the northeast side of Jerome in the south-central part of the Clarkdale quadrangle. The section in this area is described in more detail on pages 43 and 44.

The Island Mesa Beds (Stoyanow, 1936, p. 500) are described as a sandy facies of the upper part of the Jerome Formation that is recognizable "12 miles northeast of Jerome and southwest of Island Mesa." The name Island Mesa is used on the "Geologic Map of the State of Arizona" (Darton, Lausen, and Wilson, 1924) for the mountain that is shown on the map of the Clarkdale quadrangle as Black Mountain. The type locality is not known because no Devonian rocks occur anywhere near the area 12 miles northeast of Jerome and no Devonian rocks are found on Island Mesa (or Black Mountain). When he described a small molluscan fauna from the "Island Mesa beds," Stoyanow (1948) gave no further details of the locality. The present investigations have shown that this molluscan fauna occurs not in arenaceous rocks but in saccharoidal dolomite and that the concept of the Island Mesa Beds was most probably based on erroneous lithologic identifications. Therefore, the name should not be used.

LOWER OURAY FORMATION OF STOYANOW (1936)

Stoyanow (1936, p. 489) reported 54 feet of shale and limestone overlying the Martin Limestone on Pinal Creek north of Globe; he stated that the limestone contains *Camarotoechia endlichi* (Meek) and two species of *Orodus*. He referred to these beds as the Lower Ouray Limestone, which he believed had the same extent as the restricted Ouray Limestone of Colorado of Kirk (1931). The outcrops referred to by Stoyanow, which had previously been described by Stauffer (1928b), are on the southwest bank of Pinal Creek, 3–3½ miles downstream from the northern edge of Globe. (See Peterson, 1954.) In 1953 and again in 1956, I measured this section and collected fossils from all fossiliferous beds but failed to find *Camarotoechia* (now *Paurorhynchus*) *endlichi*. Because *P. endlichi* is a large and characteristic species that would be difficult to overlook, the report of its occurrence at Pinal Creek is probably erroneous.

The different nomenclatures used in describing the Devonian rocks of central Arizona and the stratigraphic nomenclature used in this report are compiled in table 1.

TABLE 1.—*Comparative table of stratigraphic nomenclature applied to Devonian rocks in central Arizona*

<table>
<tr><th>Stoyanow (1926)</th><th colspan="2">Stoyanow (1936)</th><th>Hussakof (1942)</th><th>Short and others (1943)</th><th colspan="3">Huddle and Dobrovolny (1945, 1952)</th><th colspan="2">Anderson and Creasey (1958)</th><th colspan="2">Lehner (1958)</th><th colspan="3">This paper</th></tr>
<tr><td rowspan="4">Limestone</td><td rowspan="5">Jerome formation</td><td rowspan="2">Island Mesa beds</td><td rowspan="5">Mount Elden formation</td><td rowspan="2">Martin formation</td><td rowspan="5">Martin formation</td><td colspan="2">Upper member</td><td rowspan="4">Martin limestone</td><td>Upper unit</td><td rowspan="4">Martin formation</td><td>Unit D</td><td rowspan="5">Martin Formation</td><td rowspan="4">Jerome Member</td><td rowspan="2">Upper unit</td></tr>
<tr><td colspan="2">Middle member</td><td>Middle unit</td><td>Unit C</td></tr>
<tr><td rowspan="3"></td><td>Crook formation</td><td rowspan="3">Lower member</td><td>Light buff-weathering beds</td><td>Lithographic unit</td><td>Unit B</td><td>Aphanitic dolomite unit</td></tr>
<tr><td rowspan="2"></td><td>Brown beds</td><td>Lower unit</td><td>Unit A</td><td>Fetid dolomite unit</td></tr>
<tr><td>Sycamore Creek sandstone</td><td>Basal sandstone</td><td colspan="2"></td><td colspan="2"></td><td colspan="2">Beckers Butte Member</td></tr>
</table>

EASTERN ARIZONA

In the Clifton-Morenci area near the New Mexico State line the Devonian System is represented by the Morenci Shale (Lindgren, 1905). This unit is probably an extension of the Percha Shale of New Mexico, but its exact correlation with the Devonian formations of central Arizona has not yet been established.

ACKNOWLEDGMENTS

During the field season in 1953, I was accompanied by Harry Burgess and D. V. LeMone, then undergraduate students of the New Mexico School of Mines. During the 1956 season I was accompanied in the field by R. L. Harbour, who measured several stratigraphic sections and prepared field descriptions, which have been incorporated in the more detailed section descriptions of this report. In 1956 and again in 1957, I benefited greatly from field conferences with A. F. Shride and Medora Krieger, with whom I visited several critical localities. A. F. Shride was also most helpful in discussions of the general pre-Devonian geology of the area between the Salt River and the Mogollon Rim. Christina Lochman-Balk, of the New Mexico School of Mines, visited some localities with me in the upper Salt River area and helped to clarify some basal Devonian relationships.

In paleontological studies I received valuable support from Kenji Konishi (calcispheres and related microfossils), W. A. Oliver, Jr., (corals and stromatoporoids), Helen Duncan (tabulate corals), P. E. Cloud, Jr., (brachiopods), Jean Berdan and I. G. Sohn (ostracodes), B. F. Glenister, of Iowa State University (conodonts), and J. M. Schopf (plants). Laboratory work was done by I. A. Breger (organic content of fetid dolomite), J. C. Hathaway (electron microscopy), R. F. Gantnier (heavy minerals), J. A. Thomas (Ca/Mg ratio determinations, mechanical analyses of sandstones, and determinations of insoluble residues of carbonate rocks), E. J. Young (mineral identifications), Gertrud Teichert (microphotography, fossil photographs), John Stacy (drawings), and N. S. Taylor (thin sections). To all these persons I express my thanks for help received.

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OUTLINE OF THE DEVONIAN SYSTEM IN CENTRAL ARIZONA AND PROPOSED STRATIGRAPHIC NOMENCLATURE [1]

Rocks attributable to the Devonian System in central Arizona range in thickness from a few feet to more than 500 feet; in some places no sediments were laid down during the Devonian Period. The rocks represent a large variety of types including conglomerate, sandstone, siltstone, and shale and a wide range of carbonate rocks from almost pure limestone to high-magnesium dolomite. Also, much impure carbonate rock occurs that contains varying and in places large quantities of detrital siliceous material.

These sedimentary rocks range from either Early or, more probably, Middle Devonian to early Late Devonian (late Frasnian) in age. In central Arizona they lie on a surface of considerable relief that is underlain by a variety of rocks of Precambrian and locally of Cambrian age. They are overlain by the Redwall Limestone of Mississippian age.

The oldest unit of Devonian age is a channel sandstone that consists typically of medium- to coarse-grained sandstone and contains subordinate conglomer-

[1] The stratigraphic nomenclature used in this report is the accepted usage of the U.S. Geol. Survey. In my opinion, all stratigraphic units should be upgraded in rank, thus: the Martin Formation to group, the Jerome and Beckers Butte Members to formations, and the "units" of the Jerome Member to members.

atic layers, mainly near its base. Crossbedding is very common, and thickness varies considerably and abruptly because much of the unit occurs in channel fills. The unit is most typical and best exposed in east-central Arizona, and the name Beckers Butte Member of the Martin Formation is here given to it.

In many places, the Beckers Butte Member is shaly near its top and locally contains thin beds of impure dolomite. A psilophyte flora has been found in this member that is either Early or more probably, Middle Devonian in age. The entire Beckers Butte Member, therefore, is Early or Middle Devonian in age.

In the Jerome district of north-central Arizona, the Precambrian rocks are overlain by coarse-grained crossbedded sandstone that most authors (Stoyanow, 1936; Huff, 1955; Anderson and Creasey, 1958; Krieger, 1959) regarded with reservation as an equivalent of the Tapeats Sandstone of Cambrian age. However, this age assignment is now considered to be correct.

In the Jerome area the rock sequence between the Tapeats Sandstone and the Redwall Limestone consists entirely of dolomite rock (fig. 3), except for a single subordinate sandstone bed. This sequence comprises the part of the Paleozoic succession that has in the past been variously referred to as the Temple Butte Formation, the Martin Limestone, or the Martin Formation and that was named Jerome Formation by Stoyanow (1936). The name Jerome Member of the Martin Formation is given here, because the lithology of this section is quite different from that of the Martin Limestone at Bisbee, 260 miles to the southeast; however, too little is known about the distribution and lithology of the Temple Butte Limestone to apply this name with confidence so far from the Temple Butte type locality in the Grand Canyon area.

Anderson and Creasey (1958) divided the Martin Limestone into four well-defined units. The lower unit consists of a fine- to medium-grained laminated dolomite that emits a strong fetid odor when struck with a hammer. Next above is the "lithographic unit," which consists of aphanitic dolomite and scattered shaly partings and varying amounts of detrital quartz and chert. In this report, Anderson and Creasey's "lower unit" is the fetid dolomite unit of the Jerome Member; their "lithographic unit" is the aphanitic dolomite unit of the Jerome. These units of the Jerome Member can be traced southeastward over considerable distances into east-central and south-central Arizona—that is, across the entire area discussed in this report. In east-central Arizona both units are typically formed along the East Verde River and as far east as Diamond Point. They are absent from a northeastward-trending belt along the Mogollon Rim, where Devonian sections are generally thinner, but they reappear in typical lithology in the middle Canyon Creek area and extend uninterruptedly to the southeasternmost Devonian outcrops on the Black River. Both units are also present at Theodore Roosevelt Lake, and at least the aphanitic dolomite unit has been recognized in the Globe and Superior areas.

Above the "lithographic unit" in the Jerome section, Anderson and Creasey distinguished a middle and an upper unit. The middle unit is characterized by con-

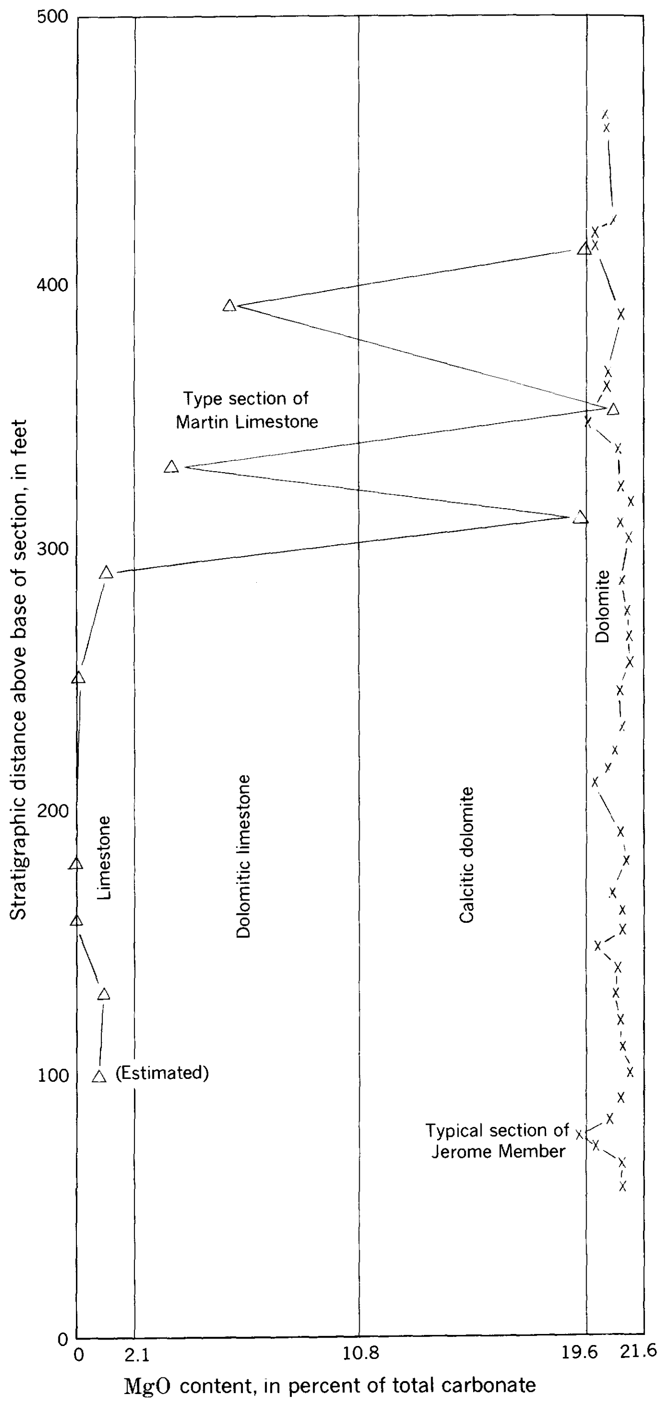


FIGURE 3.—MgO content of rocks of the Martin Limestone at its type section (△) and of the Jerome Member at its typical section (×).

spicuously mottled dolomite. The upper unit is distinguished by a diverse lithology that includes all the rock types in the underlying units.

Mottled dolomite rock also typifies the upper part of the Devonian sequence in east-central Arizona. A gradual increase of terrigenous rocks (sandstone, siltstone, shale), however, occurs in this direction; areas of undolomitized or little dolomitized limestone exist, and considerable interfingering of different kinds of siliceous-detrital and carbonate facies occurs. All the Devonian rocks above the aphanitic dolomite unit, the top of which is everywhere well defined, are therefore included in one upper unit of heterogeneous lithology.

The greatest part of the carbonate component of this upper unit of the Jerome Member is similar in lithology to rocks of the middle and upper units as defined by Anderson and Creasey. Because the fetid dolomite and the aphanitic dolomite units in east-central Arizona have lithologies identical with those of the corresponding units at Jerome, because most of the carbonate rocks of the upper unit resemble those in the upper part of the section at Jerome, and because none of these rock types are known from the type section of the Martin Limestone at Bisbee, the Devonian rocks above the Beckers Butte Member in east-central Arizona are here referred to the Jerome Member. Because the units in the Jerome are partly modified by the occurrence of clastic siliceous facies, they are here called the Martin Formation rather than the Martin Limestone.

The Jerome Member in east-central Arizona is in places extremely fossiliferous, corals and brachiopods being the predominant types of fossil organisms. Certain types of microorganisms ("*Umbella*," calcipheres) are locally abundant. Other fossil groups are generally less well represented, such as crinoids (stem parts only), bryozoans, pelecypods, gastropods, ostracodes, and others. Stratigraphically important coral associations have been determined by W. A. Oliver, Jr. (written commun., 1959) to be of Frasnian age. The brachiopods contain elements generally associated with the Independence fauna of Ohio and the Sly Gap fauna of New Mexico, both of which are probably Chemung equivalents (P. E. Cloud, Jr., written commun., 1960). A small conodont fauna, identified from one locality only, also indicates a late Frasnian age (B. F. Glenister, written commun., 1960). All these critical faunal assemblages were obtained from the uppermost part of the upper unit of the Jerome Member; so, this unit in its entirety is not younger than late Frasnian in age.

To preserve continuity with the previous literature, the name Martin Formation is applied to the entire sequence formed by the Beckers Butte Member and the several units of the Jerome Member. The age of the Martin Formation thus defined ranges from Early or Middle Devonian to early Late Devonian (late Frasnian).

The exact relations between the Martin Formation of central Arizona and the Martin Formation of southeastern Arizona still remain to be established. The upper unit of the Jerome Member can be correlated with the greater part of the Martin Limestone. However, no lithologic equivalents of the fetid and aphanitic dolomite units of the Jerome Member nor of the Beckers Butte Member occur in the Martin type section. Detailed correlation of the Devonian sections in central and in southeastern Arizona will have to await restudy of the type area of the Martin Limestone. From the available evidence the Martin Formation as here defined seems to represent a somewhat longer time span than the Martin Limestone of the Bisbee area.

Table 2 presents a summary of the stratigraphy of the Devonian System in central Arizona as used in this report and the most important data on thickness, lithology, fossil content, and age correlation of individual stratigraphic units. Thicknesses of members and units measured at different localities have been compiled in table 3.

ROCKS OF THE MARTIN FORMATION

The following description summarizes rocks of the Martin Formation; more detailed information is presented in the 47 measured sections (p. 105–109) and is graphically summarized in the columnar sections on plates 28–31. Measured stratigraphic sections are numbered 1 through 47 and are so referred to in the text.

In addition to discussions of the general character of the rock sequences and their lateral facies distribution, unusual and geologically important rock types are described in more detail. Fossil faunas and floras are also discussed, insofar as they are important as rock constituents. Their age and paleoecology are discussed in a separate section (p. 27–29, 55–67).

As far as possible all important rock types have been illustrated either as hand specimens or as thin sections.

TERMINOLOGY AND CLASSIFICATION OF CARBONATE ROCKS

Carbonate rocks constitute the bulk of the Devonian formations of central Arizona, and the study of their microfacies is emphasized in this report. They occur in considerable variety and include the full range of rock types from pure limestones to pure dolomites. In view of the importance and prevalence of these rocks in the Devonian System of central Arizona, some remarks on their classification and terminology are desirable.

TABLE 2.—*Subdivisions of the Martin Formation in central Arizona*

Member	Unit	Thickness (feet)	Predominant lithology	Important fossils	Age
Jerome	Upper	0–385	Typically fine- to coarse-grained mottled dolomite and calcitic dolomite; some aphanitic dolomite; limestone subordinate. East of Verde River, the unit contains varying amounts of sandstone, siltstone, and shale; locally, it contains more limestone and scattered biostromes.	Stromatoporoids: *Amphipora, Actinostroma, Anostylostroma, Idiostroma, Gerronostroma, Stictostroma.* Corals: *Disphyllum, Breviphyllum, Tabulophyllum, Hexagonaria, Tabellaephyllum, Alveolites, Aulocystis, Aulopora, Striatopora, Syringopora, Thamnopora.* Brachiopods: *Devonoproductus, Rhipidomella, Schizophoria, Cyrtospirifer, Platyrhachella, Tenticospirifer, Atrypa, Spinatrypa, Camarotoechia, Cranaena*(?). Pelecypods: *Congeriomorpha, Tusayana.* Gastropods: *Aglaeoglypta, Arizonella, Arastra.* Fishes: *Hesperaspis, Coccosteus, Dinichthys, Pyctodus, Dipterus.* Conodonts: *Polygnathus, Palmatolepis, Hindeodella, Synprioniodina, Spathognathodus.* Position uncertain: "*Umbella,*" calcispheres.	Late Frasnian (top of unit).
	Aphanitic dolomite	0–159	Almost entirely aphanitic dolomite; the unit contains a few shaly partings; in places, it is sandy. Some beds are rich in chert.	Generally unfossiliferous; contains a few calcispheres, brachiopods, and ostracodes.	?
	Fetid dolomite	0–55	Laminated fine- to medium-grained dolomite that emits a fetid odor.	Unfossiliferous.	?
Beckers Butte		0–166	Medium- to coarse-grained sandstone, poorly sorted, locally conglomeratic or arkosic; commonly it is highly crossbedded; it is commonly shaly near the top and contains scattered impure dolomite beds.	Close to top: Psilophyte flora of *Hostimella*?, *Aphyllopteris*?, fertile structures, megaspores.	Early or Middle Devonian.

Like other rocks, limestone and dolomite may be classified according to (1) chemical composition, (2) structural and textural features, or (3) origin and depositional environment. Three mutually independent and overlapping systems of carbonate rock classification may thus be devised, but unless the particular set of criteria used to classify the rocks is clearly recognized and stated, confusion will result.

No complete review of carbonate rock terminology is intended because simplicity of terminology is of paramount importance. Recent papers on limestones by Bathurst (1958) and by Hadding (1958a, b) illustrate that carbonate rocks can be described in simple language and with use of a minimum of special technical terms.

CLASSIFICATIONS BASED ON CHEMICAL COMPOSITION

Carbonate rocks range in composition from magnesium-free calcium carbonate to dolomite rock that may carry an excess of magnesium. The composition of any rock in this series may be indicated by giving the ratio of calcite to dolomite, the MgO percentage of total carbonate, or the mole ratio CaO/MgO. (See Guerrero and Kenner, 1955, and Pettijohn, 1957.) Chilingar (1957) recently used the ratio of the metallic elements Ca and Mg; he classified the carbonate rocks into eight groups ranging from calcitic limestone to magnesian dolomite. The present report uses the classification of Guerrero and Kenner, and the rocks are generally classified by their MgO content. This method has been chosen as best suited to graphic representation of calcitic dolomites and dolomites, which are the predominant rock types studied. Carbonate rocks are therefore grouped as follows:

Type	*Percent MgO*
Limestone	0– 1.1
Magnesian limestone	1.1– 2.1
Dolomitic limestone	2.1–10.8
Calcitic dolomite	10.8–19.5
Dolomite	19.5–21.6

The tetrahedral diagram of Mather (1955) gives a sufficiently detailed and accurately descriptive breakdown of carbonate rocks containing an admixture of detrital material (sand, silt, and clay).

TABLE 3.—*Thickness, in feet, of Martin Formation and its subdivisions*

[abs, not deposited; ne, not exposed]

Section		Total Martin Formation	Beckers Butte Member	Jerome Member				
No.	Name			Total	Fetid dolomite unit	Aphanitic dolomite unit	Fetid and aphanitic units	Upper unit
1	Sawmill Road	159	ne	159	ne	ne	ne	159
2	Black River	271½	18	253½	34	95	129	124½
3	Flying V Canyon	359	15	344	29	113	142	202
4	Salt River Asbestos mine	280	8	272	24	95	119	153
5	South of Salt River Bridge	122+	119	3+	3+	ne	3+	ne
6	Salt River Draw (south)	480	42	438	16½	130	146½	291½
7	Salt River Draw (north)	140+	ne	140+	ne	ne	ne	140+
8	East side, Canyon Creek	516	146	370	15	116	131	239
9	Oak Creek Farm Road	142	abs	142	abs	abs	abs	142
10	Spring Canyon (west)	36	abs	36	abs	abs	abs	36
11	Spring Canyon (east)	75	abs	75	abs	abs	abs	75
12	Lost Tank Canyon	386	84	302	19	71	90	212
13	Southwest Branch of Lost Tank Canyon	303	ne	303	ne	5½	75½	227½
14	West bank of Canyon Creek	143	abs	143	abs	abs	abs	143
15	East side of Canyon Creek	133	abs	133	abs	abs	abs	133
16	Naeglin Rim	197	abs	197	abs	25	25	172
17	Upper Colcord Canyon	222	abs	222	abs	63	63	159
18	2 miles south of Turkey Peak	199	abs	199	abs	24	24	175
19	Christopher Mountain Ridge	144	abs	144	abs	abs	abs	144
20	Hunter and Sharp Creeks	174	abs	174	abs	abs	abs	174
21	Hunter Creek	117	abs	117	abs	abs	abs	117
22	Four-tenths mile west of Christopher Ranch	110	abs	110	abs	abs	abs	110
23	Christopher Creek	100(?)	abs	100(?)	abs	abs	abs	100(?)
24	Christopher Creek Camping Area	0–15	abs	0–15	abs	abs	ans	0–15
25	Boy Scout Ranch No. 1	39+	abs	39+	abs	abs	abs	39+
26	Doubtful Creek	175	abs	175	abs	abs	abs	175
27	Tonto and Horton Creeks	321	abs	321	abs	55	55	266
28	Kohl Ranch	292	abs	292	abs	15	15	277
29	Thompson Wash	282+	abs	282+	abs	100+	100+	182
30	Diamond Point	448	90	358	20	158	178	180
31	Webber Creek	437	114	323	18½	35½	54	269
32	East Verde River	437	68	369	19	150	169	200
33	Upper Sycamore Canyon	467	65	402	8	109	117	285
34	Tonto Natural Bridge	389	abs	389	abs	94½	94½	294½
35	Pinal Creek	262	ne	262	ne	59	59	203
36	Theodore Roosevelt Dam	486	101	385	20	102	122	263
37	Windy Hill	382+	ne	382+	ne	78+	78+	304
38	Limestone Hills	480	86	394	21	155	176	218
39	Chasm Creek	305+	40+	265	40	135	175	90
40	Squaw Peak mine	63+	41	22+	14	8+	22+	ne
41	Jerome	450	abs	450	21	122	143	307
42	Upper Hull Canyon	530	abs	530	55	159	214	316
43	Verde River at Sycamore Creek	367+	ne	367+	ne	58+	58+	309
44	Elden Mountains	181	ne	181	ne	ne	ne	181
45	South of Iron King mine	135	abs	135	abs	abs	abs	135
46	Sevenmile Creek	258	6	252	32½	76½	109	143
47	Mormon Tank	373+	100+	273+	abs	163	163	110+

It is somewhat unfortunate and has long been recognized as a terminological inconvenience that both a mineral and a rock carry the name dolomite. The fact that rock called dolomite only rarely consists entirely of the mineral dolomite is apt to lead to confusion. A proposal to abandon the term as applied to rocks was first made by Grabau (1913, p. 298), who suggested dolomith or dolomyte for dolomite rock, but he did not use either of these terms himself. Shrock (1948a) proposed the term "dolostone," but this too has found little acceptance; dolomite as a rock term continues to be used by most authors. Vatan (1958) protested against dolostone on etymological grounds.[2]

[2] When naming a rock which is composed predominantly or entirely of one mineral, it has long been customary to form the rock name by addition of the suffix "ite" to the mineral name, as in quartzite, proxenite, and others. By analogy, the term "dolomitite" would seem a logical choice for the rock, dolomite to be retained for the mineral. However, tradition will probably effectively prevent replacement of the term "dolomite" for rocks, and the term is used for the rock in this report. Where an ambiguity is likely, the term "dolomite rock" is used.

CLASSIFICATION BASED ON STRUCTURAL AND TEXTURAL FEATURES

Widely diverging systems of classifying carbonate rocks on the basis of structural and textural features have been proposed, but most of these systems classify limestone rather than dolomite, which is predominant among the Devonian rocks of central Arizona. Among recent classifications based on textural features, those by Bramkamp and Powers (1958) and by Folk (1959) seem to be most generally applicable. The classification of Bramkamp and Powers is based mainly on grain size and includes both limestone and dolomite. Folk's classification is based on separation of three fundamental constituents: major individual particles—called allochems—matrix, and cement. Different combinations of these constituents enabled Folk to distinguish 11 types of limestone. This scheme gains complexity from the introduction of many new rock terms. Inasmuch as a completely graded series of rocks can always be assembled between any two sedimentary rock types, multiplication of terms for sedimentary rocks offers no ideal solution for their classification and description. Also, Folk's classification is not applicable to dolomites, and I therefore prefer the scheme offered by Bramkamp and Powers, which has the added advantage of including mixed sandy-carbonate rocks as well as dolomites and dolomitic limestones.

The classification of Bramkamp and Powers uses well-known familiar rock terms, which are more precisely defined with the help of modifying adjective—for example, "sandy partially recrystallized calcarenite." Such a system is sufficiently flexible to allow its extension to other rock types not covered by the original classification—for example, the ultra fine grained aphanitic dolomites that are widespread in central Arizona.

CLASSIFICATIONS BASED ON ORIGIN AND ENVIRONMENT

Because the history of a rock can be determined through study of its physical and chemical properties, an element of subjectivity is inherent in any genetic and environmental classification of sedimentary rocks. In such a classification, a census is first made of all possible environments and modes of origin; a suitable number of rock categories is set up, and rock types are attributed to them, according to the judgment of the observer. The prototype of this kind of classification is that offered by Grabau (1913), in which he set up such major categories as pyrogenic, atmogenic, hydrogenic, and biogenic rocks. To Grabau we owe the terms "calcirudite," "calcarenite," "calcilutite," which are now widely used and generally understood.

Pettijohn (1957) made a basic distinction between autochthonous and allochthonous limestones. The autochthonous include reef and biohermal limestones and biostromes; the allochthonous include calcarenites, calcirudites, and calcilutites, whose particles have probably been transported. Such a classification, though desirable and necessary, must remain flexible, and it is subject to changing interpretations. Beales (1958) believed that some calcarenites are not transported but were precipitated in place. This conclusion is almost certainly true for some calcilutites, as is indicated on page 41. Thus, calcarenites as well as calcilutites may be either autochthonous or allochthonous. In dealing with environmental and genetic classifications, we must remember that the units of classification are derived secondary concepts based on generalizations and that exceptions to every rule (or generalization) always occur.

In the following discussion, rock terms implying environmental and genetic classification are used with caution and only where possibility of misjudgment is remote. Thus, a microcrystalline limestone is referred to as such and not as calcilutite, unless its detrital origin is certain.

BECKERS BUTTE MEMBER

The Beckers Butte Member of the Martin Formation is here named for Beckers Butte, where the oldest Devonian rocks in central Arizona are exposed. Beckers Butte is a prominent peak, about 4,800 feet high, capped by Redwall Limestone, and situated in the triangle formed between the Salt River and Flying V Canyon (pl. 32). The sandstone is of extremely variable thickness, rests on an irregular surface of Precambrian rocks, and is overlain by the Jerome Member of the Martin. Below the Redwall, a complete section of Devonian rocks occurs that is similar to that which can be more easily observed across from Beckers Butte on the west side of Flying V Canyon, especially in the road cuts of U.S. Highway 60 (bottom of section 3). These outcrops are here designated as the type section of the Beckers Butte Member, because this is the only place where fossils have so far been found in this member (fig. 4).

The lithology of the rocks here included in the Beckers Butte Member and the fossils from this locality have been described by Teichert and Schopf (1958, p. 210–211). The Beckers Butte Member as now defined consists of subunits 1–6, which were called units in that paper (p. 209, fig. 1*B*) and was described as follows:

Above a slightly irregular surface of weathered diabase lies a sandstone unit (1) which is 5 feet 6 inches to 6 feet thick. The lowermost 6 inches of this unit consist of very coarse-grained, poorly sorted, mottled gray and brown sandstone, with quartz and quartzite pebbles up to 6 mm in diameter. These pebbles are generally subrounded to rounded and are embedded in a matrix consisting of subangular to subrounded quartz grains. Upward, the rock becomes increasingly finer-grained and better sorted, with a few layers of coarser material in the lowermost 2 feet. This finer-grained sandstone is brownish gray, indistinctly laminated, with occasional indications of current bedding. The grains range from silt size to about 0.5 mm in diameter, and the rock contains as much as 15 percent calcareous cement. In the upper half of the unit are a few limonitic bands and nodules. The upper surface of this unit is undulating, with a relief of as much as 9 inches. This basal unit seems to be of very irregular lateral distribution. Within 100 yards of the point where the base of the Devonian sequence intersects the highway level, the basal unit wedges out, and the next higher sandstone unit rests on the diabase.

The next unit (2) is about 3 feet thick and consists of alternations of different kinds of sandstone, predominantly fine to medium grained, light gray, and generally distinctly fissile. Usually, these rocks are poorly sorted; grains range from silt size to about 1 mm, and the larger grains are normally subrounded to well rounded. The silt-size fraction forms a tightly packed matrix. There is no calcareous cement.

Unit number 3 is a bed, 2 feet thick, of massive, hard sandstone. This rock is poorly sorted, containing quartz grains from silt size to about 1 mm; most larger grains are well rounded, and medium-sized grains are subangular to subrounded. Detrital grains are embedded in a matrix of fine-grained dolomite. The surfaces of the larger quartz grains are frosted through surficial solution and partial replacement of silica by dolomite in the manner recently described by Walker (1957). Unit 4 includes 5–6 inches of medium-grained, friable, and crumbly sandstone and 6–7 inches of dark shale with some carbonaceous matter that suggest very poorly preserved plant fragments. Well-rounded, frosted, detrital quartz grains up to 2 mm in diameter are dispersed in the shale. This is the lowest bed in the sequence in which indications of fossil plant matter were observed.

A hard layer of fine-grained, light-gray sandstone, 8–12 inches thick, forms unit 5, and above it follows a unit (6), 2 feet thick,

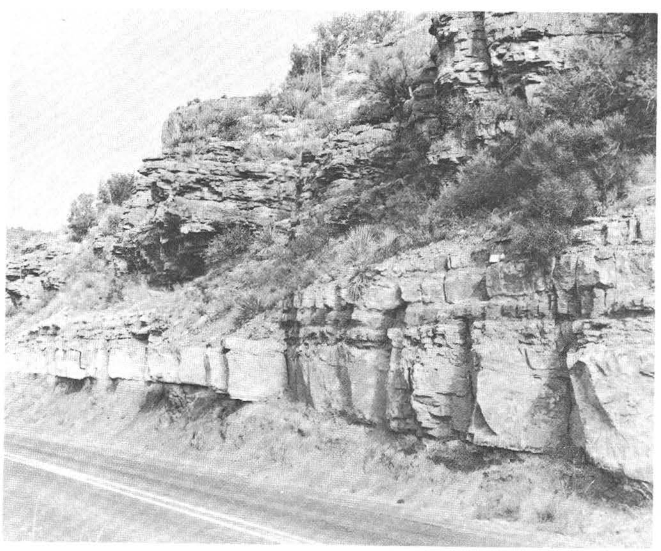


FIGURE 4.—Beckers Butte Member resting on weathered Precambrian diabase. The massive basal sandstone subunit is 4 feet thick. Thin-bedded rocks in upper part of slope belong to the fetid dolomite unit of Jerome Member. On U.S. Highway 60, north side of Salt River gorge, near entrance to Flying V Canyon.

which consists of alternating dark-gray and buff dolomitic shale and yellowish-gray, argillaceous dolomite layers. A few rounded to subangular sand and silt grains are dispersed in the shale. The shale contains coalified plant fragments, scattered plant spores, and more finely dispersed carbonaceous matter. The main plant bed, from which most of the material examined in this study was collected, is in the upper part of this unit (pl. 1). The dolomite bed immediately below the main plant bed may be taken as typical. It contains 15.5 percent insoluble residue, mostly in the clay fraction.

The section is given in greater detail here than in the more generalized description of section 3 (p. 107). Compared with its formation at several other localities, the Beckers Butte Member at Flying V Canyon is thin, and it has not been studied everywhere in the same detail.

Details of the upper part of the Beckers Butte Member, in particular the psilophyte zone and its stratigraphic relations to the base of the overlying Jerome Member, are shown in figure 5.

In most measured sections the thickness of the Beckers Butte Member ranges from 8 to 146 feet; a greater thickness is known at Aztec Peak in the Sierra Ancha, where A. F. Shride (oral commun. 1960) measured more than 200 feet of Beckers Butte Member. These variations in thickness result from deposition of the member on an irregular Precambrian surface, which is described in detail by Shride (oral commun. 1960). At the type locality, the Beckers Butte Member rests on an almost plane surface of deeply weathered diabase (Shride, McKee, and Harshbarger, 1952, p. 139) (fig. 4). More commonly, however, the Beckers Butte rests on an irregular surface, and its thickness changes abruptly within short distances. Thus, at measured section 4 (Salt River) the sandstone is only 8 feet thick, but within a few hundred feet of this locality, it is 30–40 feet thick.

Typically, the Beckers Butte Member consists predominantly of poorly sorted quartz grains that range in size from fine to coarse (fig. 6; pl. 1, figs. 1 and 2). In this respect it differs from most sandstone subunits of the Jerome Member, which are generally well sorted (pl. 24). Feldspar and chert also are locally minor constituents. The grains are generally poorly rounded, and most are angular to subangular.

Most rocks of the Beckers Butte Member are at least slightly calcareous, and some have considerable amounts of calcareous or somewhat dolomitic cement (pl. 1, fig. 3). Carbonate content is generally lower in sandstones in channel fills than in those outside the channels, where sedimentation occurred only after the channels had been filled. Thus, in section 8 (Canyon Creek), where the Beckers Butte Member is 146 feet thick, carbonate content is 0.8–1.3 percent, and in section 5 (south of Salt River), where the thickness is 122+ feet, carbonate con-

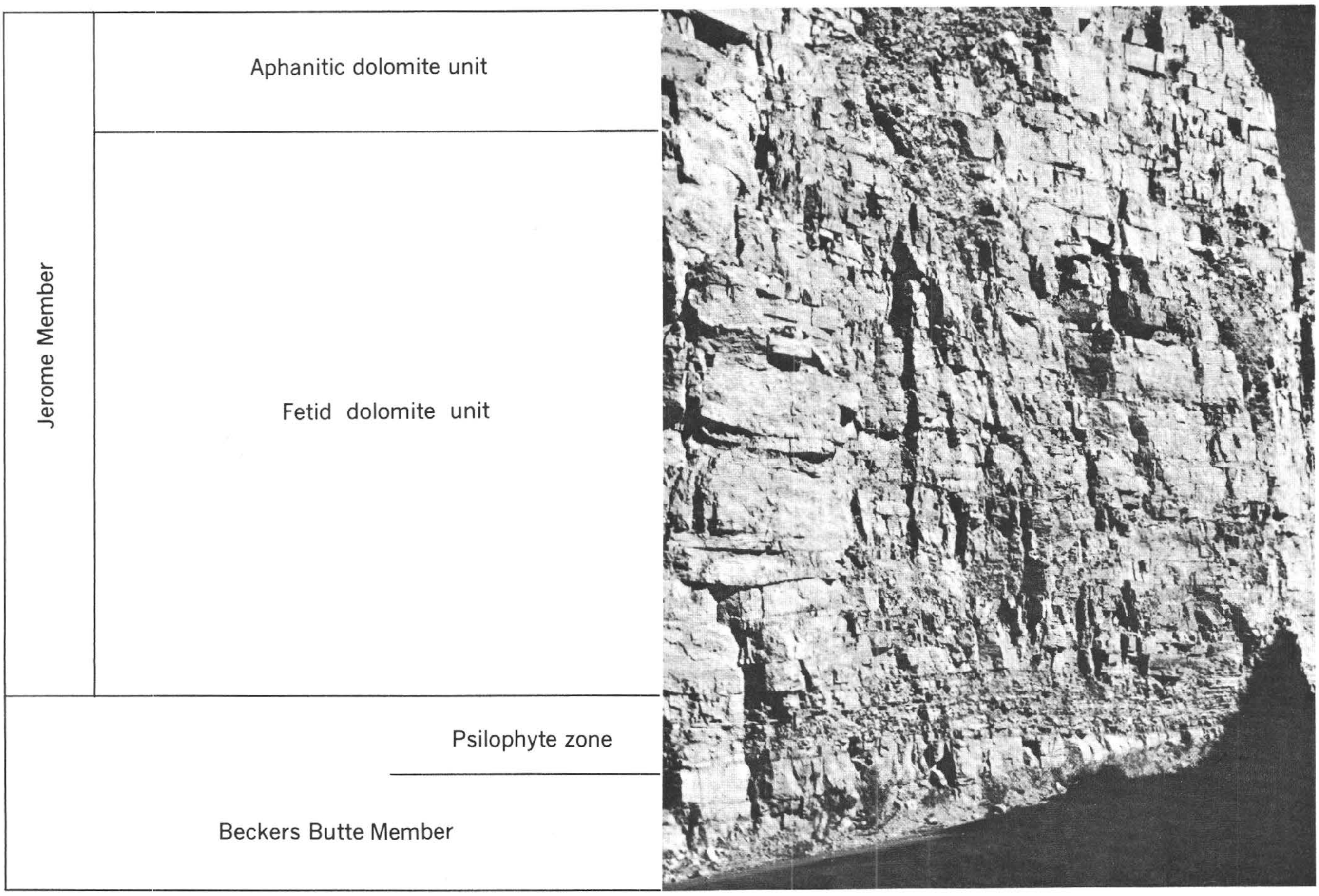


FIGURE 5.—Contact of Beckers Butte Member and Jerome Member on U.S. Highway 60 at mouth of Flying V Canyon.

tent increases from 1.3 percent at the bottom to 6.8 percent at the top of the section. On the other hand, in section 2 (Black River), where the Beckers Butte is only 18 feet thick, carbonate content ranges from 6.5 to 40.8 percent. This trend seems to be general. (See also fig. 6.)

Conglomeratic beds are significantly scarce in the Beckers Butte Member. Even basal conglomerates, where present, are generally not more than a few inches thick, and the pebbles are generally not more than a few inches in diameter. The predominant rock type among the pebbles is quartzite or an admixture of local rock types where the Beckers Butte Member rests on Precambrian rocks other than the Mazatzal, Dripping Spring, or Troy Quartzites.

Crossbedding is very common in the Beckers Butte Member, especially in the channel fills. It is less conspicuous or absent in the upper part of the member or where the member is thin.

The Beckers Butte Member has a wide distribution within the area covered by this report. Care must be exercised, however, not to confuse it with basal or marginal sandy facies of the three units of the Jerome Member or with the lithologically somewhat similar Troy Quartzite of Precambrian age, which it overlies in many places. The Beckers Butte Member is easily recognizable and definable where it is overlain by a complete section of the Jerome Member, beginning with the fetid dolomite unit. This stratigraphic combination can be traced from the Black River (section 2) in the southeast along the walls of the Salt River Canyon and northward into Salt River Draw (section 6) and Canyon Creek (section 8) as far as Lost Tank Canyon (section 12). Excellent exposures occur in the upper part of the long cliff that extends along the east side of Canyon Creek from near its junction with the Salt River and then northward as far as near Cliff House Canyon. In these cliffs the Beckers Butte Member rests on various members of Troy Quartzite and maintains a fairly uniform thickness of about 150 feet. The outcrops in this cliff seem to represent a longitudinal cut along one of the major channels that form a characteristic feature of the Beckers Butte.

Farther to the northwest the typical lithology of the Beckers Butte Member is found as far as the East Verde River area (section 32, East Verde River, and section 38, Limestone Hills). Figure 7 shows the exposures on the East Verde River, where the Beckers Butte is 68

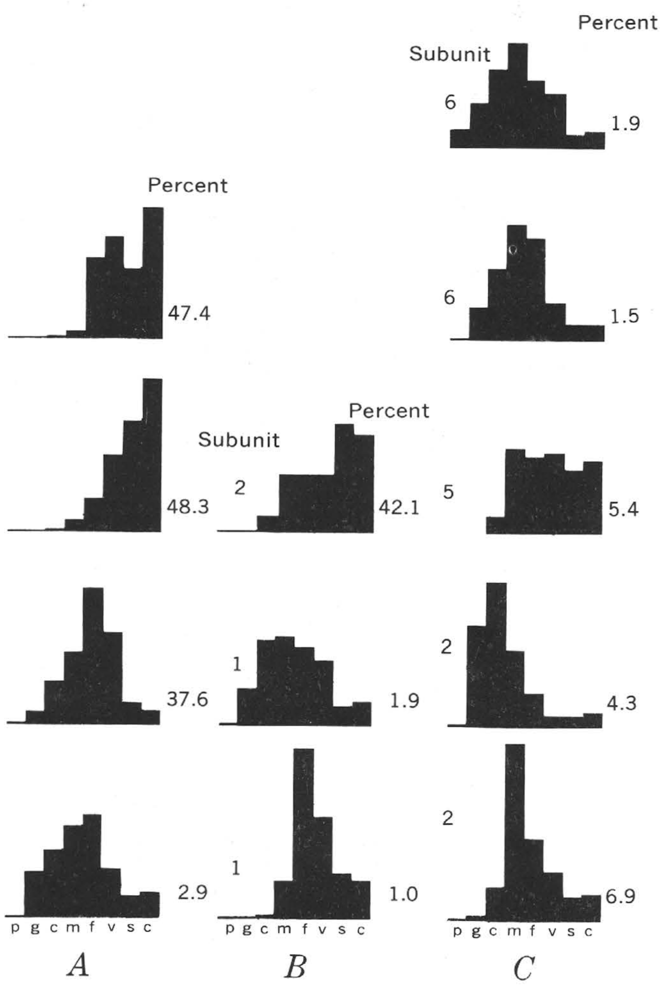


Figure 6.—Grain-size distribution of: *A*, Tapeats Sandstone, section 42 (Jerome); *B*, Beckers Butte Member, section 39 (Chasm Creek); and *C*, Beckers Butte Member, section 5 (south of Salt River Bridge, east of U.S. Highway 60). Letter symbols: p, pebbles; g, granules; c, coarse; m, medium; f, fine; v, very fine; s, silt; c, clay. Figures on left of histograms *B* and *C* indicate subunit of measured section (samples in undescribed section 42 were taken at irregular intervals); figures on right indicate percentages of HCl solubles (matrix is mostly carbonate).

feet thick, rests on granite, and is overlain by the fetid dolomite unit of the Jerome Member.

Channel fills equal in thickness to those in Canyon Creek occur south of the Salt River and east of U.S. Highway 60 (section 5), but probably the best and most easily accessible exposure of a channel of Beckers Butte Member is on the south shore of Theodore Roosevelt Lake, just southeast of the dam (section 36) (fig. 8). The Paleozoic section in this general area was first studied in some detail by Ransome (1916, p. 150–152). Later contributions were made by Hinds (1936, p. 33) and by Huddle and Dobrovolny (1952, p. 105–106).

Because of the general lithologic similarity in many places of the Beckers Butte Member and the Troy Quartzite on which it rests, the two have not always been differentiated. Thus, Ransome (1916, pl. 25) showed 160 feet of "Troy sandstone" resting on a 50-foot basalt flow. Almost certainly some, or perhaps even all, of this sandstone is Beckers Butte. Troy Quartzite filling channels in the basalt and the Mescal Limestone is shown by Hinds (1936, p. 33, fig. 5*C*). These relations correspond closely to the conditions as observed on the south side of the dam, except that it is the Beckers Butte, not the Troy, that fills the channel.

Huddle and Dobrovolny (1952, p. 106) described 15 feet of "basal sandstone" (Beckers Butte) at Roosevelt that rests on Troy Quartzite of unspecified thickness. This thickness for the Beckers Butte Member must have been obtained for beds lying somewhere outside the main channel.

The base of the Devonian and contact relationships between the Beckers Butte Member and Troy Quartzite are best studied southeast of the dam (fig. 8), where the sandstone channel of the Beckers Butte was first recognized by R. L. Harbour and then studied by both of us in 1956. This channel is 90 feet deep and steep sided. It is filled almost entirely with fine- to coarse-grained poorly sorted generally crossbedded sandstones, and contains very little conglomerate and only a few layers of shale. (For details, see description of subunits 1–7 of section 36.)

The channel is cut through the basal member of the Troy Quartzite and the upper member of the Mescal Limestone (A. F. Shride, oral commun., 1960; equals Roosevelt Member of Hinds, 1936, p. 32) into the basalt that separates the middle and upper members of the Mescal. In the roadcut illustrated in figure 8, the Beckers Butte Member rests on this basalt. Outside the channel the Beckers Butte thins abruptly to little more than 10 feet. Overlying the Troy Quartzite is 8 feet of thin interbedded layers of sandstone and shale.

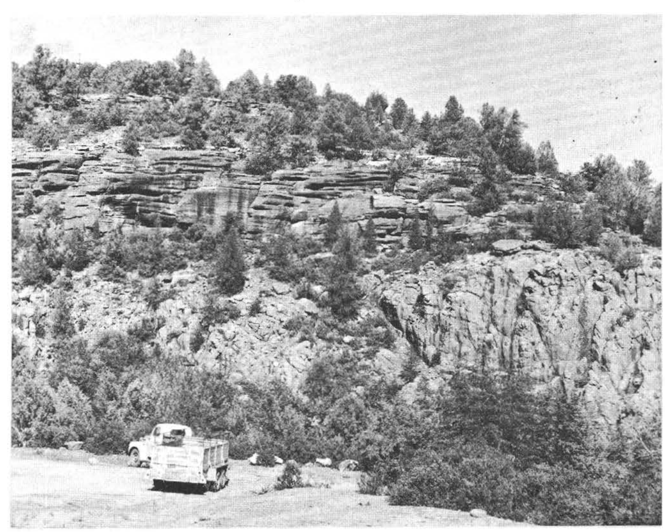


Figure 7.—Section on northwest side of East Verde River, northeast of crossing of Pine-Payson Road. Prominent cliffs are the lower part of the Beckers Butte Member, which rests on granite (cliffs on right side). The uppermost cliff at the top of the slope is the fetid dolomite unit of the Jerome Member.

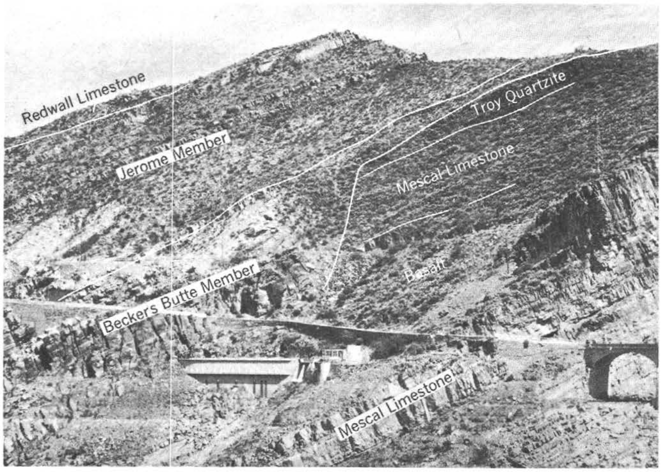


FIGURE 8.—Stratigraphic section on south side of Theodore Roosevelt Lake, directly southeast of Theodore Roosevelt Dam, showing channel of Beckers Butte Member 90 feet deep, overlain by Jerome Member and Redwall Limestone. (Section 36 of report is located here.)

These layers are in turn overlain by 3 feet of thin interbedded shale and impure dolomite, which probably corresponds to the psilophyte zone on the Salt River (section 3), although no plant remains have as yet been found in it.

Although superficially somewhat similar to the Troy Quartzite, sandstone of the channel fill is easily distinguished by its susceptibility to disaggregation in hydrochloric acid, whereas the Troy Quartzite has siliceous cement and cannot be so disaggregated.

Another extensive channel-fill deposit of Beckers Butte Member occurs at Aztec Peak (A. F. Shride, oral commun., 1960). About 1,100 feet of sandstone was described at this locality by Ransome (1916), but according to Shride about 200 feet of this belongs to the Beckers Butte Member, which fills a channel in Troy Quartzite.

Where the Beckers Butte Member is in contact with the Jerome Member, the contact plane everywhere is unmistakable, although some gradational features are seen. In some places thin layers of fine-grained argillaceous dolomite are intercalated with shaly sandstones and shales at the top of the Beckers Butte Member, and it is in these transitional beds that the psilophyte flora of the Salt River Canyon occurs.

A gradational unit at the top of the Beckers Butte Member also occurs at Lost Tank Canyon (section 12), Chasm Creek (section 39), and at Theodore Roosevelt Dam (section 36), as has been mentioned on page 24. Moreover, a similar shale subunit is probably concealed in covered intervals in the sections south of Salt River bridge (section 5), Webber Creek (section 31), and Limestone Hills (section 38). In several other localities, however, this subunit is definitely missing, and the basal fetid dolomite unit of the Jerome Member has a sharp lithological boundary with sandstones of the Beckers Butte—for example, in the Salt River section (4), at East Verde River (section 32), at Diamond Point (section 30), and in the upper Sycamore Canyon (section 33). The distribution of the uppermost shale and dolomite unit is therefore patchy, either because of initially irregular deposition or because of erosion prior to the deposition of the Jerome Member.

The carbonate component at the top of the Beckers Butte Member is present at Webber Creek (section 31). Here a yellowish-gray very fine grained limestone having a luster texture occurs just below a covered interval of 14.5 feet and probably represents the top of the Beckers Butte. Somewhat lower, a calcitic sandy dolomite occurs; it alternates with shale and is similar in lithology to the top beds in the Salt River Canyon.

None of the limestone and dolomite intercalations in the top of the Beckers Butte Member have the fetid odor that is characteristic of rocks of the fetid dolomite unit of the Jerome Member; the boundary between the two members is therefore most conveniently placed at the base of the first fetid dolomite bed.

COMPARISON WITH SANDSTONES OF THE JEROME MEMBER

Recognition and correlation of certain sandstones with sandstone in the Becker Butte Member are difficult in marginal areas. As successive younger units of the Jerome Member overlap the Precambrian basement to the northeast, a basal transgressive sandstone facies may occur at all stratigraphic levels. (See fig. 40.) Some of these transgressive sandstones are lithologically very similar to the rocks of the Beckers Butte Member but in some places can be distinguished by fossil content. In contrast to the Beckers Butte, they are marine littoral deposits and locally contain fish remains.

In the general area of occurrence of the Beckers Butte Member, a sandstone can be safely identified as Beckers Butte where it is overlain by the basal (fetid dolomite) unit of the Jerome Member. Where the fetid dolomite unit is absent, sandstone resting on Precambrian rocks can be identified only with difficulty as either marginal facies of the Beckers Butte or sandstone of the basal part of the Jerome Member. Correlations are particularly uncertain in relatively thick sections, such as sections 27 (Tonto and Horton Creeks), 28 (Kohl Ranch), and 29 (Thompson Wash). In these localities basal sandstone units are overlain by dolomites of varied lithology. The aphanitic dolomite unit is recognizable only in section 27, though its thickness is greatly reduced.

COMPARISON WITH THE TAPEATS SANDSTONE OF THE JEROME AREA

Correlation problems of a somewhat different kind arise when the Beckers Butte Member is traced to the

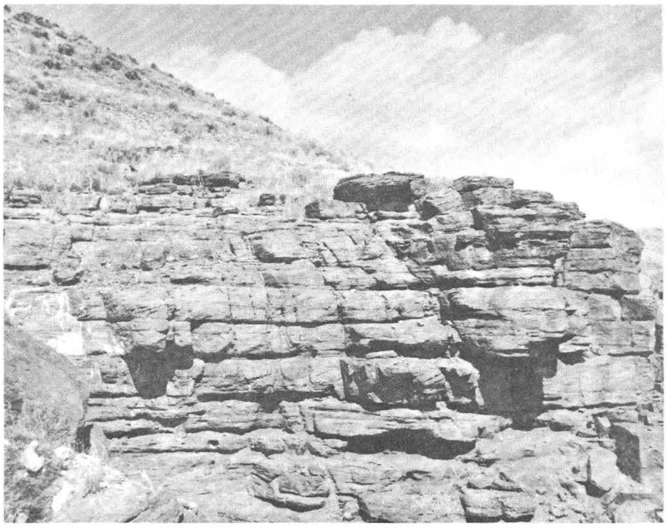


FIGURE 9.—Crossbedded Tapeats Sandstone underlying a typical section of Jerome Member 1½ miles northeast of Jerome. (For the exact locality, see pl. 32, sections 41 and 42.)

northwest up the Verde River to the Jerome area.

In the Mingus Mountain area, the oldest sedimentary rocks above the Precambrian are sandstone and siltstone beds (fig. 9), which are as much as 100 feet thick according to Anderson and Creasey (1958, p. 48); they are overlain in turn by the fetid dolomite unit of the Jerome Member (Martin Limestone of authors). As Anderson and Creasey pointed out, Reber (1922), Ransome (1932), Stoyanow (1936), and McKee (1951) believed that these sandstones and siltstones are Middle Cambrian in age and are equivalent to the Tapeats Sandstone of the Grand Canyon, whereas Fearing (1926) and McNair (1951) included them in the basal part of the Martin Limestone of Devonian age (Jerome Formation of Stoyanow). Krieger (1959) reported that fossiliferous Tapeats Sandstone can be traced from the Grand Canyon southward as far as Walnut Creek in the Juniper Mesa. Lithologically similar but unfossiliferous sandstones are "nearly continuous" between Walnut Creek and Jerome, and Krieger therefore supported a Cambrian age for the basal sandstones in the Jerome section.

The arguments in favor of a Cambrian as well as of a Devonian age have been well discussed by Anderson and Creasey (1958, p. 48–50), who slightly favored the Cambrian.

Fortunately, correlation with the Tapeats was confirmed through discovery of *Corophioides*-type, U-shaped vertical burrows in the basal sandstone on the east side of Mingus Mountain near Allen Spring. Burrows of the same type are common in Tapeats Sandstone at the Juniper Mesa, in the Grand Canyon, and elsewhere, where they occur in immense numbers in several sandstone beds. Richter (1926, p. 216) has convincingly argued that the animals that made the *Corophioides*-type burrows must have been relatively sessile, that is, they formed permanent dense populations. Richter further reasoned that burrowing animals living under such crowded conditions must have been plankton feeders living on a sea floor under normal marine conditions, where bottom currents assured a constant supply of fresh food.

Even though *Corophioides*-type burrows are known from rocks ranging from Cambrian to Triassic in age, they assume the importance of index fossils when found in a limited area in rocks of similar stratigraphic position and deposited under similar conditions of sedimentation.

Although the correlation of the basal sandstone at Jerome with the Tapeats Sandstone is no longer in doubt, it is interesting to compare the basal sandstone lithologically with the Beckers Butte. The principal difference between the two is their color. The Tapeats Sandstone at Jerome is grayish red (5*R* 4/2), whereas typical sandstone in the Beckers Butte Member is much lighter colored, commonly ranging through the yellowish-red, yellowish-gray, and medium-gray hues. These hues correspond to colors generally described as pinkish gray, yellowish gray, brownish gray, medium gray, and light brown.

Very dark colors seem to be characteristic of beds in the Jerome area. Farther south outcrops of basal sandstone underlying the carbonates of Devonian age are found at Squaw Peak and in Chasm Creek. At Squaw Peak (section 40) most of the basal sandstone is pinkish gray to yellowish gray (5*YR* 8/1–5*Y* 8/1), and at Chasm Creek (section 39) yellowish gray is the predominating color of the basal sandstone. At Limestone Hills the sandstone ranges in color from light and pale brown to pale red and grayish orange pink, and almost all colors are in the range of yellowish-red hues.

Petrographically, the Tapeats Sandstone of Jerome and the Beckers Butte Member are very much alike. The sorting is generally poor, as shown by a comparison of histograms of typical samples (fig. 6). The carbonate content of the Tapeats is high and corresponds to that of the higher sandstone parts of the Beckers Butte lying outside the channels.

Both at Jerome (section 41) and at Hull Canyon (section 42), the top part of the Tapeats Sandstone of Stoyanow (1936) and of Anderson and Creasey (1958) is lithologically very similar to the top part of the Beckers Butte Member in some localities. Thus, in the Jerome section, 22 feet of coarse grayish-red sandstone is overlain by 14 feet of silty shale and argillaceous dolomite. In lower Hull Canyon the basal detrital subunit is about 71 feet thick. The lower 41 feet consists of coarse crossbedded sandstone; it is overlain by 10 feet of silty sandstone that in turn is overlain by 20 feet of shaly siltstone. No dolomite interbeds were seen in this locality, but the siltstone may be dolomitic.

The presence of silty and shaly beds, which contain some impure dolomites, above the typical Tapeats Sandstone is very reminiscent of the lithology occurring at least locally at the top of the Beckers Butte Member, as described in the foregoing paragraph; it is therefore uncertain whether they should be included in the Tapeats. However, an intensive search yielded no trace of plant remains, and these beds have tentatively been included in the Tapeats. Clarification of their stratigraphic correlation, however, should remain a subject of further investigation.

Heavy-mineral suites in the Tapeats Sandstone and the Beckers Butte Member are very similar in composition (fig. 10). R. F. Gantnier (written commun., 1958) characterized the suites of successive samples from two typical localities as follows (samples taken at slightly irregular intervals from bottom to top):

Tapeats Sandstone (Hull Canyon, section 42):

TL–366. Most of the grains are subrounded, but they vary from angular to rounded. Much of the ilmenite is fresh; all gradations from fresh to completely altered to leucoxene are common. The heavy minerals apparently have been reworked, with tourmaline, zircon, staurolite, and rutile being more abundant in the early source rocks than in the later.

T57–339. Most of the grains are angular to subangular with only a few subrounded and very few well rounded. Ilmenite is nearly completely altered to leucoxene. There apparently has been little transportation or reworking and no addition of new material.

T57–340. Most of the grains are subrounded to subangular; but several are well rounded, and a few are angular. The presence of fresh ilmenite, magnetite, and pyrite with gradational grains to completely altered to leucoxene and hematite suggest several reworkings with the addition of new material. As most of the hematite grains are angular, magnetite was probably introduced from the later source rock.

T57–341. The grains are mostly subrounded to subangular, except for the leucoxenes, which are usually wellrounded. It appears that there has been considerable reworking or transporting of the grains, with at least two sources of material. The earlier source was probably rich in ilmenite, as indicated by the abundance of leucoxene, with clear ziron, and little or no pyrite. The later source of additional minerals contained milky zircon, pyrite, and little ilmenite. The other minerals appear to have been present in approximately equal amounts in all source rocks.

Beckers Butte Member (south of Salt River Bridge, section 5):

H56–12. The ilmenite and magnetite grains are subangular to subrounded, and the other minerals are subrounded to rounded, indicating either cyclic reworking or transportation over a considerable distance.

H56–13. Most magnetite grains are angular to subangular. The zircons are subhedral to euhedral. Other minerals are mostly subrounded to well rounded.

H56–14. Most of the grains are angular to subangular, indicating less transportation or reworking than in the two preceding slides.

H56–15. Most of the grains, except ilmenite and magnetite, vary from angular to rounded. Some of the ilmenite and all of the magnetite grains are very angular. The material apparently has been partially reworked with the introduction of fresh material.

H56–16. Ilmenite is less common than in preceding slides and is nearly completely altered to leucoxene. Approximately 50 percent of the zircons are white and translucent. Most of the grains are subrounded, but some are subangular or well rounded. The translucent zircons show more evidence of rounding than the clear ones, which are mostly subhedral to euhedral. Apparently, there have been at least two stages of deposition and reworking and two source areas for minerals.

The two sandstone suites do not seem to differ materially either in respect to heavy-mineral composition or to the general aspect of the heavy-mineral grains. In both suites evidence of reworking and addition of new material is apparent in most samples, and many samples have intermediate stages of less reworking and of little or no addition of new material.

Thus, the heavy minerals in the two sandstones of different age came from igneous and metamorphic rocks and were either transported directly from their sources and deposited or, more generally, had a history of intermediate depositional and erosional stages. Both sandstones were ultimately derived from Precambrian rocks that include the Troy Quartzite as a possible source of the reworked minerals.

MODE OF DEPOSITION, AGE, AND PALEOGEOGRAPHY

Outcrops of the Beckers Butte Member over much of the area studied are too scattered to allow construction of a reliable isopach map. However, the available data on distribution and thickness of the Beckers Butte have been recorded in plate 27. The distribution of the member is apparently restricted to an area southwest of a line running approximately northwestward through the upper Tonto Creek and upper Canyon Creek area. The member probably once extended in this direction for some distance, as the small thicknesses of the member along the upper Salt River and Black River seem to indicate.

Southwest of this line the Beckers Butte Member extended originally for a considerable distance but was absent from an area of unknown size near Pine and Pine Creek.

The present northeastern boundary of distribution of the Beckers Butte Member most likely coincides closely with the boundary of its original distribution. The land that was the principal source area of the sandstone of the Beckers Butte lay to the northeast. This area became more clearly defined and gradually reduced in size during Late Devonian time and is known as the

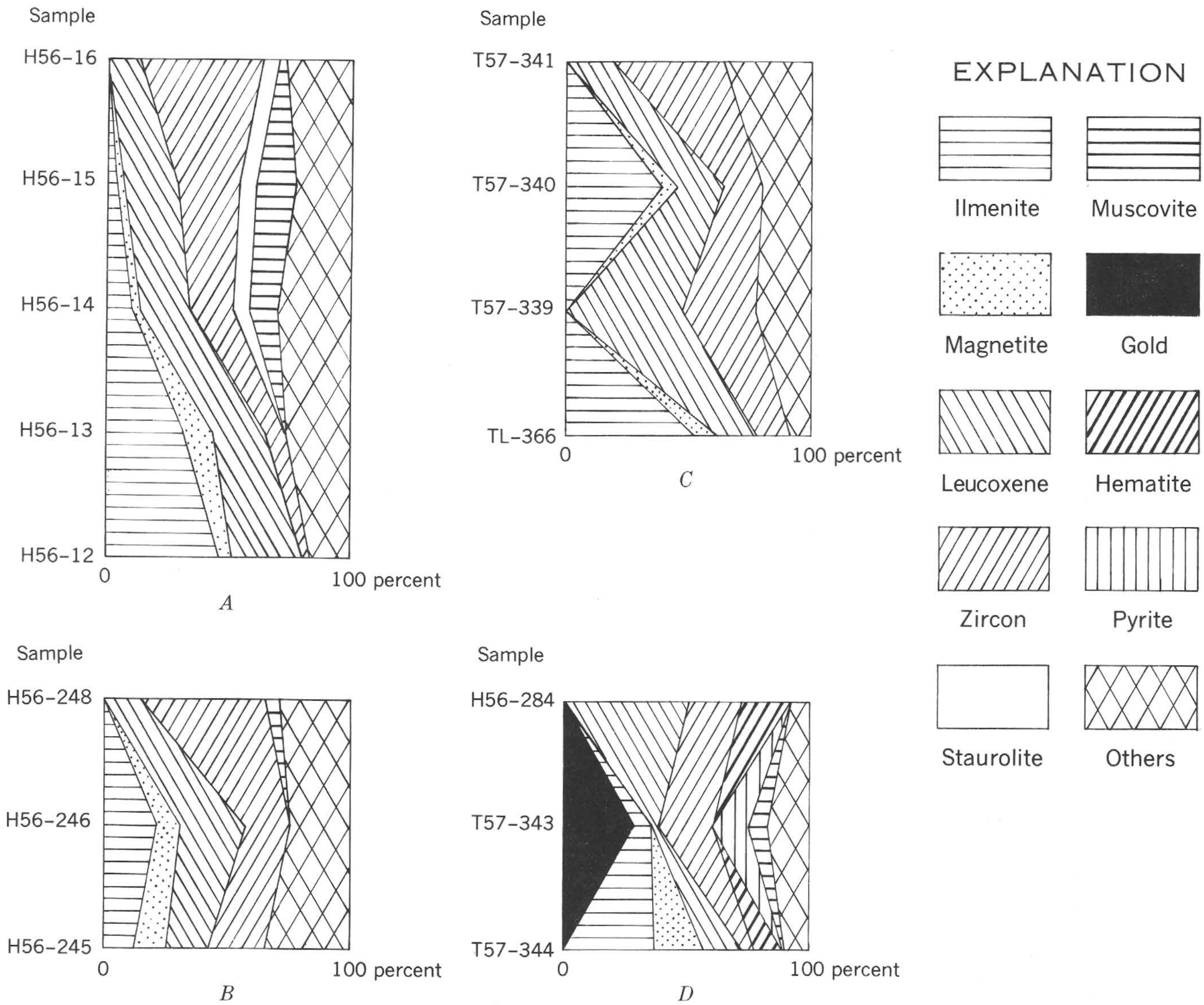


FIGURE 10.—Distribution of important heavy minerals. *A*, Beckers Butte Member, channel fill, section 5 (south of Salt River, east of U.S. Highway 60); *B*, Beckers Butte(?) Member, section 39 (Chasm Creek); *C*, Tapeats Sandstone, section 42 (Hull Canyon); *D*, Tapeats Sandstone, section 41 (Jerome).

Defiance uplift or Defiance Positive Area. (See McKee, 1943.)

The northeastern boundary of the area of distribution of the Beckers Butte may have continued generally northwestward from Pine Island to the southwest part of the Jerome district. The Chasm Creek and Squaw Peak occurrences (sections 39 and 40) would then be within the area of sedimentation of the Beckers Butte Member. This suggested correlation, however, is highly conjectural at this time, and further field investigations west of the Verde River between Verde Hot Springs and Jerome are necessary to solve the relationships of the basal sandstones in this area.

Deposition of the Beckers Butte Member was preceded by a period during which the Precambrian surface was eroded to the extent that is now visible in some isolated localities such as Theodore Roosevelt Dam and Aztec Peak. Available figures for thicknesses of the Beckers Butte Member suggest that the predepositional relief of the Precambrian surface was as much as and perhaps slightly exceeded 200 feet, except in some areas such as Pine Island, where relief was greater. The surface was covered, and its depressions were filled by predominantly sandy material that was carried by rivers from the northeastern land mass and was augmented, in ever decreasing amount, by material derived from erosion of elevations within the sedimentation area; the area was entirely covered only in the closing stages of the deposition of the Beckers Butte.

The universal presence of crossbedding, absence of marine fossils, and occurrence of the psilophyte flora near the tops suggest that the Beckers Butte Member is mostly of fluviatile origin; it was at first laid down in larger river channels, and as these filled up, it spread as a comparatively thin sheet over the entire area. Available data, although scattered, are consistent with the assumption that at the end of the time of its deposition, the Beckers Butte Member had spread as a continuous blanket over most of the area southwest of the present limits of its distribution and had formed a vast sandy and silty plain from which rose Pine Island and perhaps a few additional smaller eminences.

At the conclusion of sandstone deposition, transportation of detrital material diminished in volume, and one may picture the sand plain dotted with shallow clay and evaporite pans, the presence of which is indicated by the spotty occurrence of shale interbedded with impure dolomites at the top of the Beckers Butte Member. At the same time a psilophyte flora took root near the clay pans and perhaps elsewhere. These delicate plants, so readily destroyed, have so far been found at only one locality, but this flora probably once spread over a wide area.

An observer standing somewhere near the present Beckers Butte and looking generally north and northwest might have viewed a panorama remarkably like the vivid and imaginative painting of a "Lower Devonian landscape" by Burian (in Augusta, 1957, pl. 5), in which the distant mountains would represent the Defiance positive area.

The age of the psilophyte flora cannot be determined more accurately at present than as Early to Middle Devonian (Teichert and Schopf, 1958). The apparently conformable contact between the Beckers Butte Member and basal unit of the Jerome Member makes difficult the assumption that a major time interval occurred between the end of the deposition of one member and the beginning of the deposition of the next. The entire Beckers Butte Member is therefore more likely to be of Middle Devonian age.

With the exception of the fossil flora, no other fossil remains have been discovered in the Beckers Butte Member. Reports of fish remains from rocks said to belong to this member are somewhat contradictory. Stoyanow (1926, p. 313) mentioned the occurrence of *Macropetalichthys* in the "basal sandstones" (Sycamore Creek Sandstone) along the East Verde River near the Pine-Payson Road. In 1936 Stoyanow (1936, p. 499) again referred to the fish remains in the basal sandstone, which he then called "Arthrodiran sandstone," and reported that the best collecting places were in the "headwaters of the East Verde River," where "the Arthrodiran sandstone rests on the limestone member 20 of the Jerome formation." Limestone member 20 of Stoyanow (1936, p. 497), however, is identical with the fetid dolomite unit of the Jerome Member of this report. The fish remains, therefore, probably came out of rocks belonging to the aphanitic dolomite unit of the Jerome, which is much younger than the Beckers Butte Member exposed on the Pine-Payson Road.

Finally, Stoyanow (1942, pl. 1, fig. 1) published a photograph showing basal sandstone resting on granite and overlain by Jerome Formation at "East Verde Crossing." The sandstone is here marked as Tapeats, and yet this place is close to the type locality of the "Sycamore Creek Sandstone" of 1926 from which fish remains had been reported.

In conclusion, reports of fish remains in the Beckers Butte Member do not seem to have been well substantiated as yet.

The facies and distribution of the Beckers Butte Member are somewhat comparable to those of the Beartooth Butte Formation of Wyoming and Montana, which underlies the Jefferson Dolomite in many localities (Sandberg, 1961). However, the Beartooth Butte is of Early Devonian age; an unconformity exists between it and the Jefferson Dolomite of Late Devonian age, whereas transition from the Beckers Butte to the Jerome Member is, at least locally, gradational.

JEROME MEMBER

Stoyanow (1936), when proposing the name Jerome Formation, failed to designate a type section or to indicate the exact locality to which the section description published by him refers. I, therefore, designate section 41 of the present report as a typical section of the Jerome Member of the Martin Formation. It is exposed in a small canyon 1.1 miles northeast of the center of Jerome.

In the following paragraphs, the three units of the Jerome Member are described individually, beginning with their characteristics at the typical section. The description is then extended to rocks in other parts of the area, and characteristic rock types are described and illustrated for each unit. This description is followed, again separately for each unit, by a discussion of the evidence (where available) of age and of mode of origin.

FETID DOLOMITE UNIT

Everywhere that the entire Jerome Member is present, its basal part consists of fine- to medium-grained gray laminated dolomite that generally emits a strong fetid odor when struck with a hammer. This unit is here called the fetid dolomite unit. Lithologically, it is closely related to the overlying aphanitic dolomite unit. Both occur generally together—that is, where one is present, the other is almost always also present.

The thickness of the fetid dolomite unit ranges from a few feet to 55 feet. The smallest thickness, 8 feet, was observed in Upper Sycamore Canyon (section 33);

the greatest, 55 feet, in Hull Canyon, west of Jerome (section 42). In the typical section of the Jerome Member, its thickness is 21 feet. This is the "lower unit" of the Martin Limestone of Anderson and Creasey (1958). The extraordinarily uniform lithology of this unit over the entire area of investigation makes unnecessary the separation of its description in the type area from that in other areas.

The lower boundary of the fetid dolomite unit is sharp everywhere (fig. 5). Although dolomite interbeds occur locally in the top part of the Beckers Butte Member, the contact of the member with the fetid dolomite unit is well defined because the fetid dolomite is free from shale intercalations, has a massive appearance, and is generally cliff forming. Furthermore, the dolomite beds at the top of the Beckers Butte have no fetid odor.

The upper boundary of the fetid dolomite unit is less well defined than the lower boundary and is doubtful at some localities because the rocks of the upper part of the unit do not everywhere have the characteristic odor and because lamination occurs also in some parts of the overlying aphanitic dolomite unit.

The gross lithological features of the fetid dolomite unit are shown in figure 5. The rocks are thin- to medium-bedded and in outcrops tend to form one or two low cliffs (figs. 4 and 7).

The fetid dolomite unit is a very finely crystalline to finely crystalline dolomite. Individual crystals are mostly hypidiomorphic, but small clusters of idiomorphic rhombohedra are seen in some thin sections.

The most characteristic feature of the rocks of this unit is lamination. On weathered surfaces individual layers, each several millimeters thick and of varying hardness, can be distinguished. In thin section the rock is generally seen to be very thinly (0.1–1.0 mm) laminated. When well preserved, the laminae can be seen to be composed of extremely thin layers of a brown amorphic substance. These layers are generally 10–20 microns thick but may in places be considerably thinner. They are irregularly wavy. As seen in thin sections, some extend laterally for not more than a centimeter, others are much longer, and layers might run together or anastomose (pl. 2, fig. 1). The megascopic appearance of lamination probably is due to groupings of these very thin laminae.

The substance forming the laminae may be responsible for the fetid odor given off when the rock is struck or crushed. Locally, however, the fetid odor is weak or absent, especially in the upper few feet of the unit, although such rocks are commonly laminated in the same manner as the rest of the rock (fig. 11).

In spite of thorough dolomitization, original sedimentary structures related to the lamination are locally preserved. Plate 1, figure 5, shows a preserved minute channel less than 1 mm deep that has been carved into the top of one layer and that is reflected in a downward bending of the succeeding laminae for a vertical distance of several millimeters. This rock does not emit a fetid odor. Most probably, therefore, the original organic substance of the laminae has been altered or destroyed.

FIGURE 11.—Very fine grained laminated dolomite (millimeter-rhythmite of Sander, 1951) from the upper part of the fetid dolomite unit of the Jerome Member. The rock has no conspicuous fetid odor. Chasm Creek (section 39, unit 6). × 1.4.

Single bands of lighter colored medium-crystalline unlaminated saccharoidal dolomite are locally intercalated in the predominantly medium-gray laminated rock. In the upper few feet of the unit, brecciated rock and minor slump structures are fairly common.

Locally the uppermost part of the fetid dolomite unit is transitional to the overlying aphanitic dolomite unit.

Aphanitic dolomite may occur in the top of the fetid dolomite unit, and intraclastic or brecciated structures may be found that are similar to those seen in certain beds of the aphanitic dolomite unit (pl. 1, fig. 4).

Almost everywhere the fetid dolomite unit is rich in chert, which occurs mostly as irregularly scattered nodules of variable shape and size, in places as much as 1½ feet in diameter. More rarely the nodules occur in layers parallel to the bedding. In places they appear to have been formed on the sea floor during periods of nonsedimentation. Figure 12 shows flattened chert nodules occurring between the thin-bedded rocks below and the more massive beds above. The surface of the bed on which the nodules rest is flat and not indented, but the lowest laminae of the bed immediately above the nodules are bent around the upper side of the nodules.

Thin sections show that in some rocks formation of authigenic silica has taken place on a very small scale. Small patches of silica of spherulitic or irregularly crystalline texture occur in irregular distribution and are locally surrounded by broken and shattered dolomite crystals or may themselves enclose tiny dolomite pieces (pl. 4, fig. 5). Some deposition of silica, therefore, has taken place after dolomitization. Whether or not this mode of formation accounts for all the chert in the fetid dolomite unit has yet to be established.

Detrital quartz is rather scarce in this unit; so, the silica must have been introduced into it from some other stratigraphic unit or geological terrane.

In many places, the upper few feet of the unit consists of highly porous dolomite. Rock of this type is generally not well laminated, although some rocks combine distinct lamination with porosity. In some rocks the pores, or vugs, are filled with white crystalline calcite.

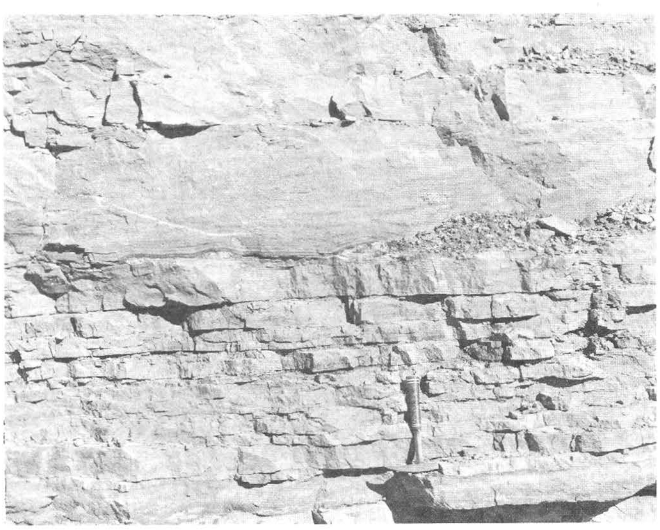


FIGURE 12.—Basal part of fetid dolomite unit of Jerome Member. The hammerhead rests on the top bed of the Beckers Butte Member. Note flattened chert nodules at the boundary between the thin-bedded dolomite below and the more massive dolomite above. East side of Pine-Payson Road north of East Verde River (east side of Sycamore Creek).

Limestone has been found in the fetid dolomite unit only on Webber Creek (section 31, subunit 11). This occurrence is of particular interest because it provides evidence of the primary sedimentary facies of the fetid dolomite unit.

At this locality the fetid dolomite unit is 18½ feet thick. The lower 15 feet has the typical dolomitic lithology of the unit; this rock is very finely crystalline and laminated and contains chert nodules and calcite vugs. Some bedding planes are slightly rippled, but whether these structural features are true ripple marks or are caused by slumping cannot be determined. This lower part emits only a slightly fetid odor. It is overlain by 2 feet of medium-gray to medium-dark-gray limestone that is distinctly laminated and emits a strong fetid odor when struck with a hammer. The top of the unit consists of 1½ feet of calcitic dolomite that contains chert.

Two thin sections cut from the limestone represent two slightly different rock variants. One of these (pl. 2, fig. 2) has a very fine grained to aphanitic groundmass and contains scattered small lenses of finely crystalline calcite. Extremely thin horizontal laminae composed of a dark substance occur in the aphanitic groundmass. These are generally not more than a few microns thick and are spaced from 0.1 to several millimeters apart. In cross section, they are irregularly wavy. In addition to the dark laminae, thin bands occur, which consist of a more translucent variety of calcite that seems to be arranged in minute transverse fibers and shows some degree of extinction between crossed nicols. These layers, which are about 30–100 microns thick, are commonly bent and contorted. Their origin is not clear.

Cross sections of what appear to be roughly hemispherical bodies about 125 microns in diameter that have walls about 20 microns thick and are composed of the same substance are seen in thin section. These small bodies are relatively common, although most of them are compressed in varying degrees. The walls have the same fibrous structure as the aforementioned transparent layers. The affinities of these objects are at present unknown. These bodies are probably of organic origin but do not seem to be calcispheres, although they have a fibrous wall structure in common with many of the calcispheres.

A second variety of rock (pl. 3) from the same limestone may be described as "clotted limestone" in the sense of Wood (1941). This term was proposed for Cayeux's "structure grumuleuse" (Cayeux, 1935, p. 271). About one half or slightly more of the rock consists of very finely crystalline calcite in which are embedded grains or clots of aphanitic limestone 20–200 microns in diameter. The smaller grains are angular to rounded; the larger ones are generally flat and elongated, but some are irregularly rounded.

The outlines of the aphanitic grains are not sharp, although such grains are clearly set off from the calcite matrix. The grains are rarely, if ever, in contact with each other. Even the smallest grains are separated from others by some clear calcite.

The entire rock contains irregular horizontal dark laminae, along which small centers of enrichment of an opaque substance are found in places. These laminae are as irregular as those in the first rock type described but lack the layers of lighter colored material having a fibrous texture. Concentrations of tiny lenses of finely crystalline calcite which may be as much as 1.5 mm high and 3–4 mm long, although most of them are shorter, occur along some laminae.

Apparently, this rock type originated from an aphanitic limestone through a partial recrystallization or grain growth (Bathurst, 1959) that resulted in a general coarsening of the grain size over very large parts of the rock. The clear calcite cannot, in this rock, be interpreted as secondary cement secreted in preexisting voids. Such an interpretation requires the assumption that, prior to the formation of the cement, the aphanitic grains were suspended in air.

If the rocks of this undolomitized lens may be regarded as representative of the facies of the fetid dolomite unit before dolomitization, the fetid dolomite would seem to have been originally an aphanitic or very fine grained limestone that was finely laminated by thin films of a dark organic substance and contained microfossils of hemispherical shape and of unknown affinities.

The original rock in its predolomitization state was thus somewhat similar to some rocks of the overlying aphanitic dolomite unit. Locally, aphanitic limestones also occur in the aphanitic dolomite unit, except that in no place are they laminated by organic films.

The organic material composing the thin dark laminae was investigated from 1960 to the time of this report by I. A. Breger of the U.S. Geological Survey, who stated (written commun., February 11, 1960) that

> the organic constituents are all of lower molecular weight, and there has been no contribution from land plants. I would surmise that deposition was at a considerable distance from any shoreline and that the organic matter was derived primarily from marine organisms. Such substances as proteins or carbohydrates as may have been present may have gone into solution during acid digestion of the dolomite. Initial chromatography, however, indicated the absence of amino acids.

Breger's emphasis on distance from shoreline is in agreement with what we know about the distribution of the fetid dolomite unit. The marine organisms from which the organic matter in the rock is derived may have been algae or diatoms that lived in the mud or plankton that was killed off periodically through toxic conditions arising in the shallow waters covering the mud.

Whether the fetid odor of the rock is due to its contained organic substance is open to question. The rock as such is practically odorless, and the fetid odor is noticeable only when the rock is struck with a hammer or treated with hydrochloric acid. As already pointed out by Gothan (1940), in many rocks it is not even clear if the odoriferous substances are formed at the moment when the rock is struck or treated with HCl or if they are present in the rock and are liberated by these actions.

The dolomite rock that characterizes the fetid dolomite unit owes its present appearance to three, and locally four or even five, stages of diagenetic processes:

1. Lithification of the original lime mud and formation of aphanitic limestone.
2. Recrystallization of part of the aphanitic matrix through grain growth and formation of lenses of fine-grained calcite.
3. Dolomitization—metasomatic replacement of almost all of the rock by very finely and finely crystalline dolomite.
4. Formation of authigenic silica, which may have led to the growth of the larger chert nodules.
5. Local solution and introduction of secondary calcite resulting in vuggy porosity; the vugs are either void or filled with calcite.

Stage 1 is very early diagenetic or penecontemporaneous. Stages 2–4 are mesodiagenetic (see discussion of diagenesis on p. 78–81) and may have extended over a considerable period of time. Stage 5 may be very late diagenetic and may be active at the present time.

The fetid dolomite unit occurs in the Jerome area, at Chasm Creek and Squaw Peak, Theodore Roosevelt Lake, and Limestone Hills, and farther east from East Verde River up Sycamore Creek and across to Diamond Point, Lost Tank Canyon, and down Canyon Creek and Salt River Draw into the upper Salt River area as far as Devonian outcrops can be traced. It is absent from a northeastern belt extending from the upper Tonto Creek along Christopher Creek and as far southeast as the upper part of Canyon Creek. The distribution of the unit spans the entire area of investigation; the unit extends over a length of 150 miles and a width of as much as 50 miles. Because of the small thickness of the unit and its complex diagenetic history and rather specialized lithologic features, this widespread distribution is remarkable. Near the northeastern area of nondeposition, the fetid dolomite unit may be represented by some basal sandstones that are associated with or replace the typical rocks of the aphanitic dolomite unit. Because the two units cannot be separated where represented by sandy facies—near their wedge edges—the stratigraphic relationships within this belt are discussed in the section describing the aphanitic dolomite unit (p. 47–51), as are some further implications of its origin, including those related to the original environment of deposition (p. 81–84).

APHANITIC DOLOMITE UNIT

TYPE SECTION

At Jerome and at all other localities where all three units of the Jerome Member are typical, the fetid dolomite unit is overlain by a sequence that consists almost entirely of aphanitic dolomite. This sequence is the lithographic unit of the Martin Limestone of Anderson and Creasey (1958), and the name aphanitic dolomite unit is used for it in the present report. The thickness of the unit ranges from a few feet to 159 feet, but where fully exposed its thickness is never less than 35 feet. More commonly the thickness is between 100 and 150 feet.

In the Jerome section (section 41), the aphanitic dolomite unit is 120 feet thick. It corresponds to unit 19 of Stoyanow's section (Stoyanow, 1936, p. 497). It is made up almost wholly of beds of aphanitic dolomite of varying thickness and microscopic texture that have a perfect conchoidal fracture. The beds are separated by thin interbeds of shale. A sandstone bed, 2 feet thick, containing much dolomitic cement occurs 15 feet below the top of the unit. This is the "red marker bed" of Anderson and Creasey (1958). It is the only sandstone bed in the unit at this locality. Rocks throughout the unit are well bedded, and the thicknesses of individual dolomite beds range from a few inches to about 2 feet. The shale partings between the dolomite beds are as much as 2 inches thick but are generally less than 1 inch thick. Some subunits of the unit do not have shale partings.

The color of the dolomite ranges from medium gray and intermediate red hues to light-gray and yellowish-gray and yellow hues.

The microscopic texture of the dolomite is greatly variable. In some beds the rock appears to be perfectly homogeneous and isotropic; in others sedimentary structures can be clearly recognized (pl. 4, fig. 6). Brecciation and intraformational erosion are recognizable in some beds on a megascopic scale (fig. 17). The ultrafine textures of aphanitic dolomite have been investigated with the electron microscope (p. 76).

Little detrital quartz is found in this unit in the Jerome area, and where present the grains are very fine to fine. The basal part of the unit is 26 feet thick and contains small pebble-shaped rounded nodules composed of light-gray chert having a brown limonitic rind; the nodules are similar to those observed by Huddle and Dobrovolny (1952) in the Salt River area. In addition, this part as well as most of the rest of the unit contains variable amounts of syngenetic or diagenetic chert; most of the chert occurs as irregularly scattered lumps in the dolomite, but it locally occurs in small nodules arranged along the shale partings between the dolomite beds.

The porosity of these rocks is very low. Small calcite-filled vugs occur in some beds but are generally scarce.

The only fossils seen in thin sections are somewhat indistinct dolomitized forms of calcispheres found in subunits 10 and 14 of section 41. (See pl. 6, fig. 4.)

In the Jerome section the lower boundary of the aphanitic dolomite unit is well defined. An abrupt change from the fine- to medium-crystalline saccharoidal dolomite of the fetid dolomite unit to the aphanitic dolomite containing brown-rind chert pebbles occurs at the base of the aphanitic dolomite unit. The upper boundary of the unit is less sharp than the lower and could be placed either at the top of subunit 14 or the top of subunit 16. Placement is uncertain because, whereas these are both aphanitic dolomite, the intervening subunit 15 is very finely crystalline and slightly mottled and thus resembles some of the rocks of the overlying upper unit. The transition from the aphanitic dolomite unit to the upper unit is therefore gradational.

GENERAL LITHOLOGY OUTSIDE THE JEROME AREA

The aphanitic dolomite unit consists almost entirely of carbonate rocks but includes, in addition, a little shale, commonly interbedded with carbonate rocks and, locally, some sandstone.

Almost all carbonate rocks are aphanitic and are either pure dolomite or slightly calcitic dolomite. Aphanitic or very fine grained limestone forms very scattered interbeds in predominantly dolomitic sequences. Both dolomite and limestone locally contain varying amounts of detrital quartz grains as well as chert.

The most common rock within this unit is aphanitic dolomite, which has a megascopic appearance similar to lithographic limestone. Such aphanitic dolomite breaks typically with a smooth conchoidal surface (fig. 13). The bedding is everywhere well defined and ranges from thin to thick bedded; the thicknesses of individual beds are between 6 inches and 2 feet (figs. 5 and 14).

Here and there, individual beds are thinly laminated. Such lamination is indicated in some places by color variations or may be caused by variations in the texture of the dolomite matrix, by differences in grain size within alternating layers (pl. 4, fig. 1), or, more rarely, by thin layers of quartz grains of detrital origin that alternate with the dolomite layers.

Especially in the lower part of the unit, dolomite beds are commonly separated by layers of shale as much as 2 inches thick. Invertebrate trails are locally found in these shales, which proves that the shales represent sediments originally deposited as clay and are not residuals from solution of carbonate rock.

Mud cracks are rather common, both in the dolomite and in the shaly interbeds (fig. 15). Dolomite rock having mud cracks on bedding planes tends to be thinly

FIGURE 13.—Aphanitic dolomite having a conchoidal fracture and containing much detrital quartz. Aphanitic dolomite unit, section 12, Lost Tank Canyon, subunit 16. × 1.75.

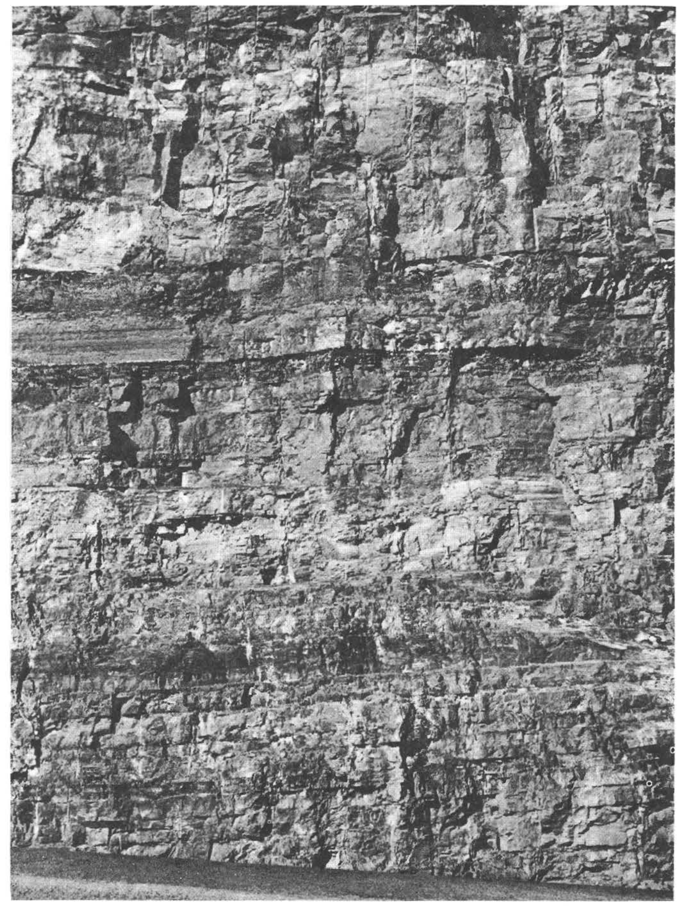


FIGURE 14.—Fresh outcrop of aphanitic dolomite unit on U.S. Highway 60, close to mouth of Flying V Canyon.

laminated (fig. 16). The thickness of the laminae is about $\frac{1}{16}$–$\frac{1}{8}$ inch and, in the rock shown in figure 16, what appear to be small shrinkage cracks irregularly penetrate several laminae.

The color of the aphanitic rocks in weathered outcrops tends to have rather uniformly very light values of gray, yellowish red, and yellow. On fresh surfaces there is a greater variety of colors ranging from medium values of gray and red to high values of red, yellowish red, and yellow. Aphanitic dolomite is generally lighter colored than aphanitic limestone. Thus, in measured section 32, the limestone is in part medium dark gray (*N* 4) and grayish red (5*R* 4/2), whereas such low-value colors are rarely seen in dolomite. In many sections the stratigraphically higher rocks definitely tend to be lighter colored than the rocks below. Thus, in section 39 the relatively low values *N* 5 and *N* 6 characterize the lower part of the aphanitic dolomite unit, whereas *N* 7, *YR* 7, and *Y* 7 values are common in the upper part.

Most aphanitic rock types are quite homogeneous in texture, but conspicuously fragmental beds are interspersed. Breccias and microbreccias are, in fact, not uncommon in the aphanitic dolomite. These are rocks in which angular to subangular clasts of aphanitic dolomite are "floating" in a matrix composed of aphanitic dolomite having a slightly different color or degree of transparency (fig. 17). Typical, megascopically recognizable breccias consist of clasts as much as 15 mm in diameter, and only a few exceed this size. They are generally rather tightly packed, and the volume of the clasts exceeds that of the matrix.

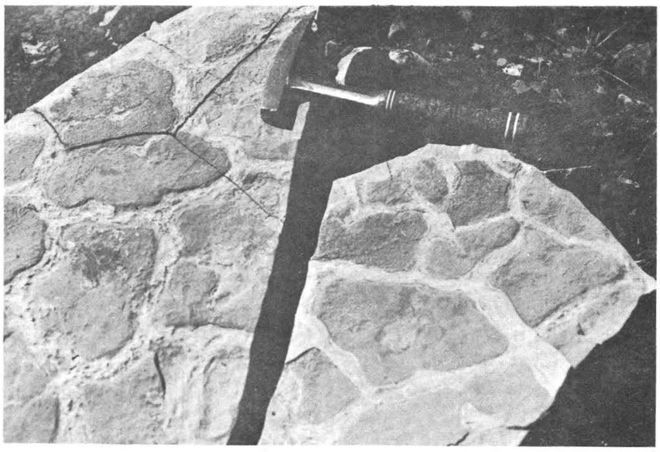


FIGURE 15.—Mud cracks in aphanitic dolomite near the top of the aphanitic dolomite unit of the Jerome Member, section 32, East Verde River. The rock is finely laminated and is of the type shown in figure 16.

Microbreccias are breccias that are recognized with difficulty, or not at all, with the naked eye or with a low-power magnifying glass; individual clasts range from about 1 mm to as little as 0.05 mm in size.

Subunit 12 of section 39 is typical of the coarse-grained microbreccias in which clasts of aphanitic dolomite are embedded in aphanitic dolomite matrix; the ratio between clasts and matrix is about 1:1. The clasts are of two kinds, of which one is slightly darker and less transparent. The size of both kinds ranges from 0.1 mm, or perhaps less, to as much as 2 mm; the average size is about 1 mm. They are angular to rounded. The matrix of this rock is primarily aphanitic but contains numerous tiny dolomite rhombohedra having a maximum size of 35 microns, although most are smaller. Small dolomite crystals are also present in the clasts where, however, they are far less abundant. This distribution appears clearly in the photomicrograph (pl. 4, fig. 3). If the clasts are of intraclastic origin—and there is no evidence to the contrary—their formation undoubtedly took place when only few dolomite crystals had formed in the original dolomitic mud. After the formation of the clasts, re-

FIGURE 16.—Thinly laminated aphanitic dolomite near the top of the aphanitic dolomite unit of the Jerome Member, section 32, East Verde River.

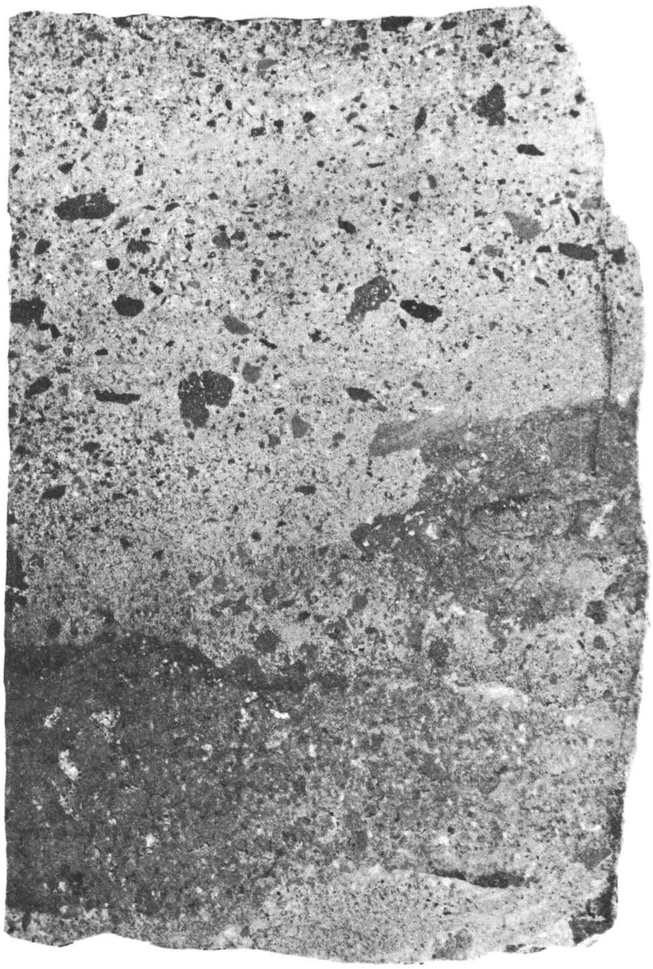


FIGURE 17.—Aphanitic dolomite having an intrastratal erosion surface. Small fragments of the lower, darker rock have been torn loose and become embedded in the upper lighter rock. Both types of rock also contain clasts having other derivations. Aphanitic dolomite unit, section 4, Salt River, subunit 7. × 1.5.

crystallization of the dolomitic matrix continued but did not affect the clasts.

A somewhat different rock is that of subunit 3 in section 37 (Windy Hill) (pl. 4, fig. 4). This consists of an aphanitic dolomite matrix containing abundant aphanitic dolomite clasts that rarely exceed 1 mm in size. There are swarms of clasts that are as small as 50 microns and yet are definitely recognizable. Here, too, the clasts are less transparent than the matrix, as they are more finely aphanitic. Crystal size of the matrix appears to be about 5–7 microns; that of the clasts is less than 3 microns. Whether the difference in crystallinity of clasts and matrix is due to the external origin of the clasts or to the recrystallization (or grain growth) of the matrix is difficult to determine in this particular subunit.

Another type of intraclastic breccia is exemplified by subunit 13 of section 38 (Limestone Hills) (pl. 5, fig. 4). In addition to scattered, small very finely aphanitic clasts, which generally range from 1 mm to about 20 microns in size, well-defined oblong to rounded areas that contain finely crystalline dolomite occur. Several of these are seen in the upper part and just right of center of the section illustrated in plate 5, figure 4. Their shape and distribution in the rock suggest a clastic origin. In the same thin section, one of the finely aphanitic clasts has a core composed of finely crystalline dolomite. Therefore, the finely crystalline dolomite bodies are possibly recrystallized aphanitic dolomite clasts, although the nature of the process of selective crystallization that formed them remains obscure. Another type of microbreccia is illustrated by subunit 20 of section 3 (pl. 4, fig. 6). In this rock the sediment apparently was broken but almost no transportation or redistribution of fragments occurred; fractures and other open spaces were filled with finely crystalline dolomite.

Grain growth, resulting in the recrystallization of cryptocrystalline dolomite into coarser aggregates, is relatively common in aphanitic dolomite. The rock shown in plate 7, figure 1 is a dolomite that contains much detrital quartz. Much of the aphanitic matrix (shown on the right-hand side of the photograph) has been converted into coarser-grained dolomite, and almost all quartz grains are surrounded by thin rims of very fine grained dolomite, which contrasts with the darker aphanitic matrix. The rims were also observed in some rocks of the upper unit of the Jerome Member and are discussed on page 50.

Another type of breccia is one that has been infiltrated by silica as, for example, the rock of subunit 9 of section 39 (Chasm Creek). This rock is mostly an agglomeration of angular to subangular pieces of aphanitic dolomite as much as 2 mm in size. In between these particles, three different substances may be present, as is shown in figure 2 of plate 4: (1) aphanitic dolomite matrix, shown in lower right corner; (2) areas of crystalline dolomite, such as the large area in the upper left of the picture and smaller areas near the center; and (3) microcrystalline silica, which fills narrow spaces betwen clasts, shown to the left and right of center, and fills larger areas such as the somewhat circular one in the right center. In another part of the same thin section, the almost black and the dark-gray matter are aphanitic dolomite, the white parts are microcrystalline silica, and the turbid very finely granulated parts are very finely crystalline dolomite. The silica and the finely crystalline dolomite are rather intimately intermixed.

Evidence of what appears to be dedolomitization is seen in such rocks as subunit 3 of section 37 (Windy

Hill) (pl. 5, fig. 3). The rock is a rather uniform extremely finely aphanitic dolomite showing traces of sedimentary lamination. Scattered through it are very small and irregularly shaped patches of crystalline calcite, which are generally not more than ¼–½ mm in size. Their distribution pattern in the rock does not suggest any relation to primary sedimentary features; nor can it be assumed that they are secondary fillings of primary voids. They probably represent calcite replacements of dolomite matrix.

The aphanitic dolomite unit includes a few nonaphanitic rocks, which may be very fine grained to fine grained. An example is subunit 10 of section 33 (Upper Sycamore Canyon) (pl. 5, fig. 5). An interesting feature of this rock is the presence of small vugs, 1–2 mm in diameter, that are each filled with a single crystal of calcite. The vugs are surrounded by a ring of dolomite crystals noticeably larger than the average crystals of the rock. These crystals obviously had room to grow into a small void before the calcite was deposited, and this occurrence of calcite, therefore, contrasts with that of calcite formed under dedolomitization conditions.

Vuggy porosity is not very common in the rocks of the aphanitic dolomite unit, which typically lacks any kind of porosity, even when seen under an electron microscope. Not uncommonly, where present, vugs are filled with crystalline dolomite rather than with calcite.

The nature of aphanitic dolomite is described on pages 40 and 41 as part of a broader discussion of the nature of aphanitic carbonate rocks.

DISTRIBUTION

The distribution of the aphanitic dolomite unit coincides largely with that of the fetid dolomite unit (see pl. 27); that is, wherever the base of the aphanitic dolomite unit is exposed, it is underlain by the fetid dolomite unit in almost all places. Known exceptions are in the area of the upper Tonto Creek (sections 27 and 28), where the aphanitic dolomite unit is present, represented partly by a basal sandy facies, and where the fetid dolomite unit is missing. Possibly, however, the basal sandstones here in part represent the fetid dolomite unit. The aphanitic dolomite unit, having a more or less typical lithology, can be traced from the Jerome area southeastward to Chasm Creek (section 39), Limestone Hills (section 38), the Theodore Roosevelt Lake (sections 36, 37), the Globe area (section 35), and the upper Canyon Creek (sections 8, 14, 15) and Salt River districts (sections 4–7).

In the upper Tonto Creek area, certain basal sandstones that may or may not be associated with aphanitic dolomites are interpreted as marginal facies of the aphanitic dolomite unit. Thus, at Thompson Wash (section 29) the basal part of the Jerome Member consists of about 100 feet of sandstone, including very crossbedded strata containing abundant fish remains; the strata are here regarded as marginal siliceous-detrital facies of the aphanitic dolomite unit. Both at Kohl Ranch (section 28) and at the junction of Tonto and Horton Creeks (section 27), basal sandstones occur, overlain by thin (4 feet and 15 feet, respectively) layers of aphanitic dolomite.

The aphanitic dolomite unit is absent from the entire area in which the fetid dolomite unit is missing—that is, east of the upper Tonto Creek along a belt extending south of the Mogollon Rim and as far as the uppermost part of Canyon Creek.

OCCURRENCE OF LIMESTONE

Limestone that may be more or less dolomitic occurs in some beds a few feet thick at Diamond Point (section 30) and Webber Creek (section 31). The rock is aphanitic and is indistinguishable under the petrographic microscope from some of the aphanitic dolomite described in the foregoing paragraphs. It has a faintly "pelletal" or clotty texture and locally contains calcispheres and some extremely fine shell fragments, probably of very thin-shelled ostracodes; the rock is therefore similar to the aphanitic dolomite shown in figure 3 of plate 6.

Some limestone has undergone extensive recrystallization, as, for example, has the rock shown in figure 1 of plate 5. This rock is a rather pure aphanitic limestone that contains little siliceous-detrital material and has a primary intraclastic texture in which the clasts are mostly well rounded. Much of the matrix has been recrystallized, but signs of grain growth are observed in most of the clasts.

A rich ostracode concentration is known from subunit 22 of section 32 (East Verde River) (pl. 6, fig. 2). This is a mixed assemblage of single detached valves and of entire shells in which both valves are in the original position. A peculiar lack of orientation marks the position of the various shells and shell fragments, although the convex side of most of the single valves faces downward. The assemblage gives the impression of having accumulated in very quiet water.

OCCURRENCE OF SILICA

Silica occurs in the aphanitic dolomite unit in several different forms: (1) detrital quartz, (2) chert nodules; and (3) authigenic silica as (a) nodules or layers, (b) spherulitic replacement, and (c) "cloudy" impregnations. These types of occurrence are briefly discussed in the following pages.

DETRITAL QUARTZ

Quartz grains of detrital origin are generally common and in places very abundant. They are rarely larger than 1 mm in size and are as small as silt size. A clayey component is present in all samples (see pls. 23 and 24) and in some makes up 100 percent of the insoluble residue.

Quartz-grain assemblages in the dolomites are not well sorted. Most grains larger than about 0.2 mm are well rounded, and locally they may be tightly packed so as to form sandy layers. But these layers are rare. The larger quartz grains almost invariably have a "frosted" surface. Frosted sand grains were noted by Short and others (1943, p. 26) in a sandstone bed in the aphanitic dolomite unit in the Superior area, and these authors concluded that wind action caused the frosting.

It would be tempting to assume that wind transportation was the cause of the erratic distribution of the sand grains in the aphanitic dolomite unit over such a wide area. However, according to Bagnold (1941, p. 76), suspension flow in air of sand grains even as small as 0.25 mm seems to be inappreciable, although it is important for very fine sand.[3] Larger grains must have been transported along the sea floor from the beaches of the Defiance uplift, as discussed on page 83.

The larger size frosted quartz grains may possibly be derived from land dunes, from which they were washed into the sea. Since the land probably contained little vegetation at that time, the emerged Defiance uplift area could conceivably have been covered with extensive areas of blown sand. However, recent investigations by Kuenen and Perdok (1961) have cast considerable doubt on the validity of the traditional assumption that eolian transportation results in frosting of sand grains.

More likely, however, the frosting is due to surficial etching and carbonate replacement. This possibility is discussed on page 86, as this process has affected all carbonate rocks of the Jerome Member.

CHERT NODULES

Huddle and Dobrovolny (1952, p. 75) described the abundance of small chert nodules having yellow-brown rinds in what corresponds to the basal part of the aphanitic dolomite unit. They describe the nodules as being "about the size and shape of beans, averaging about 10 millimeters in length" and having dark-gray centers. The present investigation has shown that this "brown rind" chert zone is uniformly distributed across the entire area of investigation and that it is present wherever the aphanitic dolomite unit has the typical carbonate facies. In most places this zone forms the basal unit of the member, but in some sections the lowest occurrence of "brown rind" chert is as high as 20 feet above the base—for example, in Chasm Creek (section 39). In section 4 (Salt River) it occupies the interval from 17 to 25 feet in the nearby Flying V Canyon section (section 3), from the base to 14 feet. At Sevenmile Creek (section 46), where the entire Martin Formation is much attenuated, the same zone is only 7½ feet thick, and its base lies 3 feet above the base of the aphanitic dolomite unit; the nodules in this locality are very flat.

In general, the brown rind chert nodules characterize the lower 25–30 feet of the aphanitic dolomite unit. Their average size is as described by Huddle and Dobrovolny, but nodules as large as 1 inch in diameter have been observed.

The wide distribution of these small nodules, their uniform appearance—which is distinct from that of other chert accumulations—and their restricted occurrence in a narrow stratigraphic interval might suggest a detrital sedimentary origin. However, it must be pointed out that if these nodules were transported from some pre-existing chert deposit, they might be expected to be associated, at least locally, with rock pebbles of a different kind. Such association, however, does not exist. Also, a mechanism by which such pebbles could have been distributed so evenly over such a large area is difficult to imagine.

At present, the best guess is that the "pebbles" are probably syngenetic in origin, but the problem merits further study.

AUTHIGENIC SILICA

Chert is present throughout the aphanitic dolomite member as nodules, disconnected layers, and irregular masses, which may be several feet in diameter. These chert bodies show no pattern of distribution, except that many are associated with bedding planes, and seem to be entirely unfossiliferous. This chert type was not studied in detail. The origin of the chert bodies is a moot question to which this study has not provided a satisfactory answer. Electron micrography might eventually help to determine the time relationship between dolomitization and the formation of chert, but such investigation was not undertaken.

[3] The results of Bagnold's calculations are in complete agreement with observed facts. As is well known, large quantities of dust from the Sahara are being blown far out into the Atlantic Ocean. The particles in this eolian sediment average about 25 microns and range from 5 to about 50 microns. Similar size material has been transported over long distances elsewhere (Hellman, 1879, 1913; Radczewski, 1939). Free (1911, p. 45) compiled a list of maximum sizes of particles in 45 samples of airborne dust. Among these, only one sample, collected by Liversidge (1902, p. 241), contained particles as large as 1 mm. However, a scrutiny of Liversidge's report reveals lack of data on the circumstances under which this sample was obtained, other than it came from a dustfall on December 15, 1880—22 years before Liversidge studied it.

Much less commonly, silica occurs as spherulitic replacements, as shown in plate 6, figure 5. The illustrated rock is a very fine grained dolomite that consists of anhedral dolomite crystals 20–60 microns in diameter. Scattered throughout the rock are irregular blotches of quartz, most of which are distinctly spherulitic. Some of the blotches are rosette shaped; others are very irregular and are several millimeters in diameter. Silicification was probably effected by grain-by-grain replacement of dolomite. The smallest silica particles have the shape and size of individual dolomite grains, and possibly some dolomite grains in the same thin section have only partly been replaced by silica.

If replacement has occurred in adjacent grains, the silica was precipitated in optical continuity. The spherulitic texture has been formed only in large patches, where dozens or even hundreds of dolomite grains were replaced. In contrast to authigenic quartz crystals, as described on page 86, the spherulitic silica has no impurities or inclusions of dolomite. In some places, however, one or a few dolomite grains have been left unaltered inside an area that has been completely replaced.

The sequence of events outlined above is not in agreement with Carozzi's statement (1960, p. 320) that silicification processes require the presence of calcium carbonate and that complete dolomitization apparently precludes silicification. However, as early as 1907, Strahan and others (1907, p. 11–20) demonstrated that in the course of the diagenetic history of Carboniferous limestones in England, dolomitization preceded the formation of chert. Later, Storz (1931, p. 318, 341, pl. 18, fig. 146) described many examples of silicified dolomites.

The occurrence of silicified dolomites is interesting perhaps because it demonstrates the possibility of migration of silica-bearing solutions through extremely fine grained and nonporous carbonate rocks. It further demonstrates the fact that silicification followed dolomitization, because silicification begins with the replacement of individual dolomite grains. A somewhat similar process that has occurred in a very fine grained dolomite in the fetid dolomite unit is described on pages 30 and 31.

That this process (silicification of dolomite) is reversible is indicated by the specimen illustrated on plate 5, figure 2, which shows a relatively large irregular area consisting of partly spherulitic and partly irregularly fine grained quartz. The quartz is entirely surrounded by aphanitic dolomite, which is presumably replaced. Irregularly placed around its edge are narrow belts of aphanitic dolomite that is somewhat more transparent than the original aphanitic rock. The shape and alinement of the belts suggest that they represent areas in which the original silica was replaced. Other quartz vugs in the same slide also show evidence of redolomitization, although to a lesser extent.

Correns (1950) discussed the conditions that affect the solubility of $CaCO_3$ and SiO_2 and the relationship of the solubility to the pH. Within the range of pH values to be expected in marine sedimentation areas, slight shifts in the pH can change a state from one in which calcium carbonate is kept in solution and silica precipitated to one in which silica is in solution and calcium carbonate precipitated. But more recent investigators have cast doubt on some of Correns' conclusions (see Walker, 1960), and no similar studies on the silica-dolomite relationships are extant. Whereas calcification of silica is relatively common, dolomitization of silica is probably much rarer.

In addition to chert and spherulitic replacement, a third type of silica replacement occurs in the form of "cloudy" impregnations of the kind referred to on page 36 in the description of certain autoclastic rock types (pl. 4, fig. 2). No definitive evidence is available that indicates that the silica has replaced anything in such rocks, although locally intimate intermixtures of cryptocrystalline silica and aphanitic dolomite are found. Possibly the silica was here introduced penecontemporaneously, and its precipitation was contemporaneous with the origin of the clastic structure. This process has been named and described as "Durchkieselung" by Storz (1931).

OCCURRENCE OF CLASTIC ROCKS

The aphanitic dolomite unit includes subunits of both sandstone and shale. The few sandstone beds that occur here and there in the normal stratigraphic sequence of aphanitic dolomites are generally very fine grained to fine grained and have varying amounts of dolomite cement (pl. 5, fig. 6). This rock (subunit 5 of section 37, Windy Hill) also contains a sprinkling of glauconite grains that are of the same general size as the quartz grains but are much better rounded and sometimes broken. The glauconite is the yellowish-green variety that Gorbounova (in Strakhov, 1958b, p. 198) supposed to be characteristic of silty to argillaceous relatively deep-water environments. Cloud (1955, p. 489), on the other hand, concluded that "glauconite provides no intrinsic evidence about turbulence of the water in which it was formed or came to rest." In the present investigation, the derivation of the glauconite, which appears to be an uncommon constituent of these sandstones, is not clear. It probably was not formed in place under prevailing conditions of sedimentation, and glauconite-bearing sedimentary rocks from which the glauconite grains could have been derived are too far away to be considered as a possible source.

In the Jerome section (No. 41) a sandstone subunit occurs near the top of the aphanitic dolomite unit (the "red marker bed" of Anderson and Creasey, 1958), but it is less well sorted (see pl. 23) and contains more dolomitic cement and no glauconite.

Elsewhere, sandstone beds occur intermittently throughout the section. Most are clean, fine grained, and well sorted, but less well sorted sandstone also is intercalated (pl. 24).

The siliceous-detrital facies found near the marginal wedge belt of the aphanitic limestone unit—particularly at sections 16, 17, 27, 28, and 29—comprises a variety of sandstones. Many of these sandstones are very poorly sorted and contain angular detrital grains. Some tend to be arkosic, and others grade into graywackes. (See descriptions of subunits 3 and 4 of section 27, subunits 1 to 3 of section 28, subunits 1 to 3 of section 29, and others in similar stratigraphic position.) But because of discontinuity of outcrops, the relationships of these rocks with the carbonate facies of the aphanitic dolomite unit are not always clear.

Shale is a normal constituent of the aphanitic dolomite unit and occurs as interbeds between aphanitic dolomite beds, especially in the lower half of the unit. The shale beds range in thickness from less than an inch to 6 inches but are most commonly about 2 inches thick. They are well exposed only in relatively fresh quarries and roadcuts, where mudcracks and invertebrate trails are visible locally. Search for spores has been unsuccessful.

FOSSILS

The aphanitic dolomite unit is generally poorly fossiliferous. The aphanitic dolomites are almost entirely unfossiliferous. Ghosts of calcispheres were seen in thin sections of rocks from section 3, subunit 8, and from section 41, units 10 and 14 (pl. 6, figs. 1 and 4). The original textures of the walls of the calcispheres have been destroyed through dolomitization. "*Umbella*" is possibly represented in subunit 10 of section 32. These and other forms are described separately in the section on micropaleontology (p. 103–105).

Limestones, dolomitic limestones, and some calcitic dolomites are generally rich in calcispheres and ostracodes, as well as in unrecognizable microfossil debris (pl. 6, figs. 2 and 3; pl. 15, fig. 5; pl. 20, fig. 1). Apart from calcispheres, identifiable fossils however, are scarce. Silicified brachiopods, possibly *Atrypa*, occur 7 feet above the base of the unit in section 2, but this occurrence is unique. The only identifiable ostracodes were obtained from subunit 22 in section 32, where they are abundant and well preserved in very fine grained limestone. Jean Berdan studied this small fauna and reported that the most abundantly represented form belongs to the genus *Hypotetragona.*

The marginal sandstone facies at Thompson Wash (section 29) contains abundant fragmentary remains of bony fish plates, which are preserved as external casts in the rock. Although very characteristic of this particular facies, unfortunately they are indeterminable.

The occurrence of fish remains has been noted by previous authors, but there is doubt about the exact localities and horizons. Stoyanow's (1926) reported discovery of arthrodiran plates in the basal sandy facies of the Jerome Formation ("Sycamore Creek sandstone") of Sycamore Creek near the East Verde River has been discussed on page 14. Later, Stoyanow (1926, p. 499) reported additional localities of "Arthrodiran sandstone" in the headwaters of the East Verde River that represent "a wider range of forms belonging to the Arthrodira," but he gave no generic identifications. He stated that the "Arthrodiran sandstone" rests on limestone member 20 of the Jerome Formation, which, as is evident from his stratigraphic section (1936, p. 497), corresponds to the fetid dolomite unit of this report. The "Arthrodiran sandstone" thus is in the basal part of the aphanitic dolomite unit. I have not found fish plates so low in the section in this area; I do not doubt that they occur there, however, because the zone containing them would correspond in stratigraphic position to the crossbedded, fish-bearing sandstone at Thompson Wash (section 29).

MODE OF DEPOSITION AND DIAGENETIC HISTORY

The central problem posed by the aphanitic dolomite unit is the determination of the genesis of its principal rock type, aphanitic dolomite. In an attempt to understand the genesis, it is useful first to reconstruct the general environment of its deposition. The present investigations have shown that the aphanitic dolomite unit once extended in uniform lithology over an area of several thousand square miles. The predominant type of sediment was carbonate mud and locally some clayey sediment and, more rarely, fine sand. A narrow littoral zone of coarser terrigenous sediments was deposited along the shore of the Defiance uplift.

The occurrence of mud cracks on bedding planes of the dolomite and on shaly interbeds shows that the sediment surface, at least locally and intermittently, was exposed to the air; therefore, sedimentation in the entire area probably took place in extremely shallow water, perhaps not more than a few feet below low water level. Local emergences of the sea floor might have been due to occasional exceptionally low tides, perhaps caused by coincidence of low spring tides with strong offshore winds. An alternative explanation would be a tideless sea, not more than about 2 feet deep, where the bottom was exposed sporadically at times of persistent strong offshore winds.

The almost perfect preservation of certain primary sedimentary structural features, especially intraclastic brecciation and the like, raises the question whether the original sediment was a primary dolomitic mud.

The formation and origin of dolomite rocks have been the subject of extensive speculation, sharp deduction, and intensive laboratory studies by chemists and geologists. The geochemist's conclusion is summed up in the following statement by Graf and Goldsmith (1956, p. 185):

> It is practically impossible at present to make useful statements about the effects of such variables as salinity, pH, and Fe^{++} concentration upon the rate of dolomite formation.

Illing (1959) believed that cryptocrystalline dolomite may have been deposited as primary dolomite, or "protodolomite" (Graf and Goldsmith, 1956) mud. Primary precipitation of dolomite mud to form aphanitic (or in the Russian terminology, pelitomorphic) dolomite has been postulated by several Russian geologists, including Vishnyakov (1951), Strakhov (1958a), Rukhin (1958, p. 125–131), and Teodorovich (1955, 1959). Strakhov (1958a) distinguished two principal types of dolomite: stratified dolomite and metasomatic dolomite. According to Strakhov, "stratified dolomites" are generally of considerable lateral extent (as much as several hundred kilometers); they are generally mineralogically pure dolomites, and their texture is micrograined to very fine grained; organic remains are either absent or very rare and if present are poorly preserved. Ostracodes and brachiopods are commonly characteristic assemblages and are different from the assemblages in adjacent limestones. Most important, indications of any kind of metasomatic replacement of preexisting calcium carbonate by dolomite are lacking. In contrast to "stratified dolomites," metasomatic dolomites, according to Strakhov, are supposed to be irregularly lenticular; dolomite rhombohedra form in clusters, fossils are dolomitized, and no commonly characteristic fossil assemblages are recognizable.

Precipitation of primary dolomite mud is, according to Strakhov, a process characteristic of arid zones and is aided by increased CO_2 pressure, which he assumed existed in the atmosphere during Paleozoic time.

It would be tempting to apply these criteria to the interpretation of the origin and distribution pattern of the carbonate rocks of the Jerome Member, but unfortunately, many features of these rocks do not support such a simple interpretation.

The gross lithology of the aphanitic dolomite unit corresponds to a certain extent to "stratified dolomites" as described by Strakhov. Features that are in agreement with his description are (1) the extent of the rocks over thousands of square miles, (2) perfect bedding, (3) the predominantly aphanitic texture, and (4) the scarcity of fossil assemblages, which, where present, consist mainly of ostracodes, calcispheres (not mentioned by Strakhov), and scattered associated brachiopods. The following features are at variance with Strakhov's description: (1) the local formation of limestone "islands" or lenses in the aphanitic dolomite unit and (2) the occurrence in many places of aphanitic dolomites interbedded with coarser grained dolomite of Strakhov's "metasomatic" type and with calcitic dolomite in the upper unit of the Jerome. Finally, as suggested by experiments carried out by Graf and Goldsmith (1955), the role of CO_2 pressure for dolomite formation has probably been greatly overestimated.

The "metasomatic" types in the Jerome are not lenticular but are well bedded and extend laterally over considerable distances, as is discussed in greater detail on pages 42–55.

Limestone of the aphanitic dolomite unit is invariably aphanitic and is characterized by rich microfossil assemblages of calcispheres, ostracodes, and unidentified fragmentary remains. Most aphanitic dolomite is barren, but organic remains are still recognizable in some of it, although the remains are commonly much recrystallized and transformed into "ghosts." In such aphanitic dolomites containing only faintly recognizable fossil remains, the fossils have an appearance similar to fossil structures occurring in more coarse-grained dolomite rocks, where they have been entirely or largely obliterated during dolomitization. The indications for a "metasomatic" origin of the aphanitic dolomites can possibly be supported by electron-microscopic studies (p. 76).

Dolomitization of the type that changed the submicroscopic crystalline texture of the sediment and destroyed some very delicate fossil structures such as calcispheres and thin ostracode shells but preserved the coarser lithological structures such as intraclasts, autobreccias, microlaminations, and others probably proceeded at a very early diagenetic stage, commonly called penecontemporaneous. This assumption is discussed in connection with the description of the rocks of the upper unit of the Jerome Member (p. 85).

UPPER UNIT

For the purpose of regional description, all rocks of the Jerome Member that lie above the aphanitic dolomite unit are considered as one unit having a rather complex lithology and many laterally intergrading facies. The rocks of this member are sandstone, siltstone, shale, limestone having different grain sizes ranging from aphanitic to biostromal, and dolomite ranging in grain size from aphanitic to coarsely saccharoidal.

The upper unit of the Jerome as here defined corresponds to the middle and upper units of the Martin Limestone as described by Anderson and Creasey (1958,

p. 50) in the Jerome area and to the middle and upper members of the Martin Formation as defined by Huddle and Dobrovolny (1952, p. 73) in east-central Arizona, especially the Salt River area. The middle and upper members, or units, in these two widely separated areas, however, are of greatly different lithology. The middle unit of Anderson and Creasey consists of fine- to medium-grained mottled dolomite rock; the middle unit of Huddle and Dobrovolny consists of a lower sandstone and an upper limestone unit. The upper unit of Anderson and Creasey is characterized by diverse lithology; it consists entirely of carbonate rocks having greatly varying texture, composition, and appearance. The upper member of Huddle and Dobrovolny is composed mostly of sandstone, siltstone, shale, and some interbedded limestone units. The relationship of the middle and upper units or members in one classification to those in the other is unknown and cannot be ascertained. Any correspondence would be coincidental.

Study of the cross sections *A–A′* to *I–I′*, given in plates 28–31, indicates that in many places the rock sequence above the aphanitic dolomite unit can be subdivided into two or three lithologically distinct units, but none of these parts persist laterally far enough to be recognizable in all parts of the area of investigation. This sequence, therefore, must be regarded as one unit having a greatly varying and, in places, abruptly changing lithology.

In sections where the Jerome is fully formed—that is, where all its three units are present—the upper unit ranges from 125 to more than 300 feet in thickness. Toward the northeast, beyond the limits of distribution of the fetid and aphanitic dolomite units, it laps onto Precambrian basement rocks that have a slightly undulating topography, and in this onlap area it ranges in thickness from a few feet to 250 feet. In the northwestern part of the study area, the upper unit is represented by a very pure carbonate facies that is composed almost entirely of dolomite rock. In the southeastern part of the area and in the onlap area on the northeast, siliceous-detrital beds having a variable but locally considerable thickness are present; the distribution of these beds is discussed in more detail on pages 47–55.

Because of the facies differentiation of the upper unit in different parts of the area, description of this unit has been arranged in a manner that deviates from that adopted for the more uniform fetid and aphanitic dolomite units. In description the upper units is divided into areas that have certain facies features in common, and description of rocks and fossils is integrated for each area. The broader implications of facies distribution in the upper unit is discussed in the chapter on sedimentation (p. 84–85).

TYPE SECTION

In the type section of the Jerome Member (section 41) the upper unit as here defined is 308 feet thick. The lower 113 feet corresponds to the middle member of Anderson and Creasey (1958). All the rocks are dolomite containing more than 19.5 percent MgO (fig. 3). The total carbonate content varies from about 67.5 percent to 98 percent (pl. 23). In most rocks impurities constitute less than 10 percent.

As Anderson and Creasey observed, the rocks in the lower part of the unit are characterized by conspicuous mottling. The mottling is mostly red, yellowish red, and yellow in hue, but medium- to light-gray colors are also present. Bedding is thin to medium, and texture is mostly fine grained to subaphanitic. Different grain sizes are intimately mixed in some rocks. The rock (a thin section of which is shown in plate 7, figure 4) is subaphanitic in megascopic aspect. In fact, it consists of a crystalline dolomitic groundmass that is composed of crystals 0.02–0.05 mm in diameter and is permeated by clouds of less transparent material composed of dolomite crystals less than 0.02 mm in size. Since this "cloudy" material has an orientation approximately parallel to the bedding planes, it probably represents a recrystallized primary structure of the sediment.

The rocks of the lower part of the upper unit are rather pure carbonates containing an insoluble fraction mostly of about 5 percent (pl. 23). Detrital quartz can only rarely be recognized as a conspicuous component in thin sections.

Fossils are not uncommon in this part of the section, but all are too poorly preserved for identification. However, the remains that are recognizable suggest a varied fauna of brachiopods, gastropods, fishes, and assorted microfossils such as ostracodes and calcispheres (pl. 8, fig. 3). This abundance of fossil remains contrasts with the scarcity of fossils in the underlying aphanitic dolomite unit.

The upper 195 feet of the upper unit is more varied in lithology than the lower part. Texture ranges from aphanitic to medium grained, and the fine- to medium-grained rocks tend to be saccharoidal—that is, they have a large proportion of idiomorphic dolomite crystals—and on weathering tend to disintegrate into a fine sand composed of individual dolomite grains or crystals.

The insoluble fraction of this part of the upper unit varies considerably from bed to bed (pl. 23), and in many rocks the detrital quartz component is much in evidence in thin section. Quartz grains larger than 1 mm in diameter are scarce. Most larger grains are considerably etched, and their peripheries are replaced by dolomite. Grain-size analysis of insoluble residues reveals a well-defined cyclic pattern of deposition in this part of the section (pl. 23), which is discussed on pages 71–73.

A few thin shaly interbeds, which have not been studied in detail, are present.

Some beds in the upper part of the upper unit have a considerable porosity resulting from the presence of vugs that are either empty or filled with crystalline calcite. In subunit 32 the vugs form cavities as much as half an inch in diameter.

Fossils are present in many beds, though they are mostly poorly preserved except where silicified. The best fossiliferous horizon is subunit 31, which contains an abundance of silicified corals of diverse types (*Tabulophyllum?* sp., and cyathophylloid and amplexoid corals as identified by W. A. Oliver, Jr., written commun., 1959). This subunit is about at the level of unit 7 in Stoyanow's section (1936, p. 498) of the Jerome Formation, from which he reported a more diversified fauna composed of "*Syringopora* and *Aulopora* in commensality with *Stromatopora*. Zaphrentoid corals. Fish plates. Brachiopods." Thus, some lateral variation in paleontologic facies seems to exist, but as far as I have been able to ascertain, these fossiliferous dolomites were never formed into bioherms or reefs, as asserted by Stoyanow. In the section here studied, these beds could not even be called biostromal, although biostromes may possibly have been formed elsewhere at about this stratigraphic level.

FACIES WEST AND NORTH OF JEROME

In 1953, the Devonian section in Hull Canyon (section 42), about ¾–1 miles southwest of Jerome, was studied in some detail; however, sampling was not done according to the same standard applied in 1956, and no detailed section description, therefore, is given. In the upper part of this section are two richly fossiliferous dolomite beds about 80 and 100 feet, respectively, below the top of the Jerome Member. This position is slightly higher stratigraphically than the coralliferous dolomite, subunit 31, in the Jerome section (section 41).

These two beds contain a rich coral fauna, which has been identified by W. A. Oliver, Jr., as follows:

Lower horizon (TP 376):
- *Breviphyllum* sp.
- cyathophylloid corals
- zaphrentoid corals
- *Disphyllum* spp. (3 species)
- *Hexagonaria* spp. (2 species)
- "*Aulopora*" spp. (2 species)
- thamnoporoid coral

Upper horizon (TP 378):
- *Tabulophyllum?* sp.
- horn corals undet.
- *Hexagonaria* spp. (3 species)
- *Alveolites* sp.
- "*Aulopora*" sp.
- thamnoporoid coral
- stromatoporoid undet.

Both beds are richly fossiliferous—almost biostromal—but no biohermal buildups occur. The lower bed also contains *Amphipora?* sp., *Cyrtospirifer* sp. and *Platyrachella* sp. The upper bed contains, in addition to the foregoing fossils, stromatoporoids and *Platyrachella* sp. A layer containing abundant specimens of *Thamnopora* occurs about halfway between the two beds.

The section at Hull Canyon is made up entirely of dolomite rock and therefore bears close lithologic resemblance to the section at Jerome.

Toward the north the place closest to Jerome where the Jerome Member was examined in detail was on the north side of the Verde River, just west of the junction of Sycamore Creek about 8 miles north of Jerome (section 43). Here, the Tapeats(?) Sandstone crops out at the foot of the cliffs close to the riverbank, but an east-trending fault that extends parallel to the outcrop and the riverbank cuts off the contact between the sandstone and the basal part of the Jerome Member. The fetid dolomite unit is not exposed, and the oldest rocks seem on the north side of the fault are some of the lower beds of the aphanitic dolomite unit.

Except for the top 10 feet, the upper member here consists entirely of dolomite rock, in which saccharoidal texture is prevalent. Most beds are very finely to finely crystalline, but some are medium and coarsely crystalline. Rock colors are almost entirely yellowish red and yellow in hue. Significant amounts of detrital quartz grains are restricted to a few beds such as in subunits 21 and 25.

In contrast to the section at Jerome, no aphanitic dolomites occur in the upper unit at the Verde River locality. Also, mottling is less common than at Jerome, and where present it is more like irregular and spotty lamination. Invertebrate trails occur in the unit on the bedding planes; possibly, the primary cause of the mottling is the action of burrowing organisms in the original calcareous mud.

Weathering disaggregates many of the dolomite rocks, even the fine-grained and very fine grained varieties, into a sandy or silty powder consisting of individual dolomite grains. This disaggregation is due mainly to the removal of interstitial calcite, aided perhaps by the weakening effect of the vuggy porosity of many of the rocks (pl. 8, fig. 2). This type of weathering is especially pronounced in the upper part of the upper unit. It may have been responsible for the impression (Stoyanow, 1936) that the uppermost part of the Jerome Member becomes increasingly more sandy [4] north of Jerome, whereas in fact the total carbonate content is very uniform throughout the entire area. A 10-foot sandstone subunit at the top of the section may be of local extent only.

The section along the Verde River (No. 43) does not contain many fossiliferous beds; the more important such beds are in subunits 23 and 26. Subunit 23 includes one abundantly fossiliferous bed containing "*Aulopora*" sp., *Thamnopora* sp., and unidentified rugose corals, stromatoporoids (W. A. Oliver, written commun., 1959), and brachiopods.

Of greater interest is subunit 26, in which members of a small, unique fauna described by Stoyanow (1941) were found. Stoyanow did not indicate the exact stratigraphic position of this fauna, but he stated that it came from the "Island Mesa beds," which he previously described (Stoyanow, 1936) as a sandy facies of the Jerome Formation and in which he included the upper 125 feet of the formation in this locality. The fauna contains, among other species, *Congeriomorpha andrusovi* Stoyanow and *Arizonella allecta* Stoyanow and is restricted to the lower 2 feet of subunit 26. From the upper part of the same unit W. A. Oliver, Jr., (written commun., 1959) identified the corals *Breviphyllum*? sp. and *Hexagonaria* sp. From the same horizon, B. F. Glenister and R. M. Liebe (written commun. by Glenister, 1960) reported the following conodonts:

Polygnathus normalis Miller and Youngquist
Palmatolepis triangularis Sannemann
Hindeodella sp.
Synprioniodina sp.
Spathognathodus sp.
Falcodus? sp.
indeterminate fragments

This assemblage is of late Frasnian age.

The section (No. 44) at Elden Mountains, about 20 miles northeast of the upper Verdi River, is of interest because of its isolated geographic position and because it provides a valuable control point in the midst of the San Francisco volcanic field. After the presence of Devonian rocks had been recognized by Brady (1933, 1934), Stoyanow (1936, p. 501) reported 148 feet of partly arenaceous and shaly limestones. During the present investigation, a sequence of about 181 feet of dolomite and slightly calcitic dolomite rocks was measured (section 44). These are mostly fine to medium grained and generally rather pure and have an insoluble fraction amounting to less than 10 percent in most samples (pl. 23). The general lithology is typical for the upper part of the upper unit of the Jerome Member.

Fossils are generally poorly preserved. *Amphipora* was recognized in one or possibly two subunits (1 and 9); brachiopods and ostracodes, in others. Stoyanow reported the presence of "*Cladopora*" (probably *Thamnopora*) and *Atrypa* as well as fish remains, including teeth. Hussakof (1942) described the following fishes from an unidentified horizon of the Mount Elden section:

Coccosteus arizonensis Hussakof
Dinichthys 2 spp.
Pyctodus bradyi Hussakof
Dipterus sp.

This assemblage is dated as early Late Devonian by Hussakof.

THE AREA SOUTHEAST OF JEROME

There are no significant changes in the lithologic character of the upper unit for a considerable distance southeast of Jerome, as far as can be judged from the widely spaced outcrops. (See also fig 31.)

At Chasm Creek (section 39), 28 miles southeast of Jerome, only the lowermost 76 feet of the upper unit was seen. The rocks here are mostly finely crystalline dolomites, medium to thick bedded, and extremely hard. Brachiopods and gastropods are present in some beds (subunits 20 and 22), but they could not be freed from the rock or identified. The color is mostly yellowish red and light gray in hue.

Southeast of Chasm Creek no outcrops occur until the junction of East Verde and Verde Rivers is reached; there a section at Limestone Hills (section 38) was investigated. The thickness of the upper unit is only 218 feet, but possibly the full thickness was not seen. The lithology differs somewhat in detail from that at the typical section at Jerome. Mottling is not conspicuous in the dolomite beds, although it does occur in some. The rocks of the unit are uniformly rather finely crystalline except for an aphanitic limestone in the lower part (subunit 18) that is highly fossiliferous (pl. 8, fig. 1), though most of the fossils are fragmentary. This limestone is notable in that it is the only rock seen in this survey that contains remnants of echinoids. Another limestone unit (subunit 21) contains some indeterminable fish plates and is noteworthy for its luster mottling (pl. 9, fig. 1) of the kind described on pages 72 and 73.

The remainder of the section above subunit 21 is composed of dolomite rock that is mostly fine grained and generally admixed with varying amounts of detrital quartz. Fossils are scarce except at the top of the section, which has yielded the corals *Breviphyllum* sp. and *Hexagonaria* sp. (W. A. Oliver, Jr., written commun., 1959), and large numbers of the brachiopods

[4] In German and French geological terminology, saccharoidal dolomite is called sandstone—*Dolomitsandstein, sable dolomitique.*

Camarotoechia sp. and *Cranaena?* sp. These brachiopods form a coquina containing very little dolomitic cement (fig. 31).

UPPER EAST VERDE RIVER AND PINE CREEK AREAS

Sedimentation in this area was influenced by a land area of undetermined size on which no Devonian sediments were deposited and which is here called Pine Island. The complex geologic conditions, doubtless complicated by younger tectonic movements, are evident from the descriptions of Stoyanow (1942, p. 1266–1270). He called this area the Pine Creek Ridge and regarded it as part of the "Payson Headland," the bulk of which was, according to him, situated to the south. Huddle and Dobrovolny (1952, p. 80) referred to the area as Pine Ridge, which they interpreted as one of three northeast-pointing prongs of Mazatzal Land. Detailed study of several stratigraphic sections in this critical area, however, supports a somewhat different paleogeographical interpretation. Sections 34 (Tonto Natural Bridge) and 33 (Upper Sycamore Canyon) are of particular interest.

The section at Tonto Natural Bridge has been referred to in several earlier publications, but it had never previously been studied in detail.

Rocks of the upper unit at Tonto Natural Bridge are an even more heterogeneous assemblage than those of the aphanitic dolomite unit at the same locality. (See cross section *H–H′* of pls. 22 and 30.) Nearly all the physical properties of the rocks—insoluble residue, MgO content, and grain size of the carbonate rocks—change abruptly in vertical sequence. The section has a greater percentage of calcitic dolomites than is common in the upper unit, and although there is not much sandstone, many of the dolomites contain high percentages of siliceous-detrital material. A few limestone subunits (21 and 39) are probably representative of the rocks of the upper unit before dolomitization. These subunits are aphanitic to very fine grained; most contain abundant fragmental microfossils—especially calcispheres and ostracodes—and a sprinkling of dolomite rhombohedra and scattered small authigenic doubly terminated quartz crystals (pl. 8, fig. 5).

The top subunit of the section is a very calcitic dolomite that contains abundant stem fragments of a large crinoid, which are the only megafossils in the Tonto Natural Bridge section. Remains of the same large crinoid species occur associated with brachiopod and coral assemblages in the upper part of the upper unit in some other localities.

Dolomites containing a greater or lesser amount of detrital quartz (pl. 7, fig. 3; pl. 9, fig. 3) occur in the upper unit. Quartz grains, particularly the large ones, show varying degrees of peripheral etching and dolomite replacement. An extreme example in which the original shape of the quartz grains has been greatly altered by dolomite replacement is shown on plate 9, figure 4.

In some dolomites a considerable amount of calcitic substance—partly of very minute size—fills vugs; the substance possibly represents recrystallized remnants of the original aphanitic matrix (pl. 8, fig. 4).

From the presence of calcispheres, crinoids, and ostracodes in undolomitized or little dolomitized rocks at this locality one may conclude that the entire sequence of Tonto Natural Bridge was formed in a marine environment; the high terrigenous detrital component suggests that sedimentation was probably close to land.

Whereas outcrops are discontinuous south of Pine Island, probably largely because of faulting, outcrops east of Pine Island are continuous and give a clearer concept of the depositional environment.

The onlap of the Jerome Member on the east side of Pine Island can be observed near the junction of the Pine-Payson Road and the road from Kohl Ranch to Pine (Pine quadrangle, BM 5676), where Redwall Limestone rests on Precambrian Mazatzal Quartzite (fig. 18). From here eastward the Devonian section thickens very abruptly, and about 1 mile to the east, it is 467 feet thick; 65 feet of this thickness is Beckers Butte Member, and the rest is Jerome Member (section, fig. 18). Half a mile south of BM 5676—near BM 5735—outcrops of conglomerate and massive dolomite beds are found on the west side of the highway, where they lie on a smooth surface of Mazatzal Quartzite. Downhill from the road at this point the slope is formed by Mazatzal Quartzite, which is overlain by about 200 feet of pale-red sandy saccharoidal dolomite at the bottom of the creek. The dolomite is capped by Redwall Limestone. A few hundred yards to the south, the base of the dolomite is at the level of the road, and in outcrops west of the road, the dolomite is underlain by gray and brown sandstone. These rocks, as well as the conglomerates on the west side of the highway, represent the onlap facies of the upper part of the upper unit of the Jerome Member.

Increase in thickness of the beds from this area eastward is so rapid that one might suspect downfaulting rather than onlap, were it not for the fact that the Redwall Limestone truncates the Devonian-Precambrian contact (fig. 18); nowhere else in this area—or anywhere in Arizona for that matter—is there any evidence of pre-Redwall faulting after Precambrian time. Abrupt stratigraphic abutments of the Devonian rocks against Precambrian high areas were previously shown on very generalized diagrams published by Stoyanow (1942, p. 1267) and by Huddle and Dobrovolny (1952, p. 81).

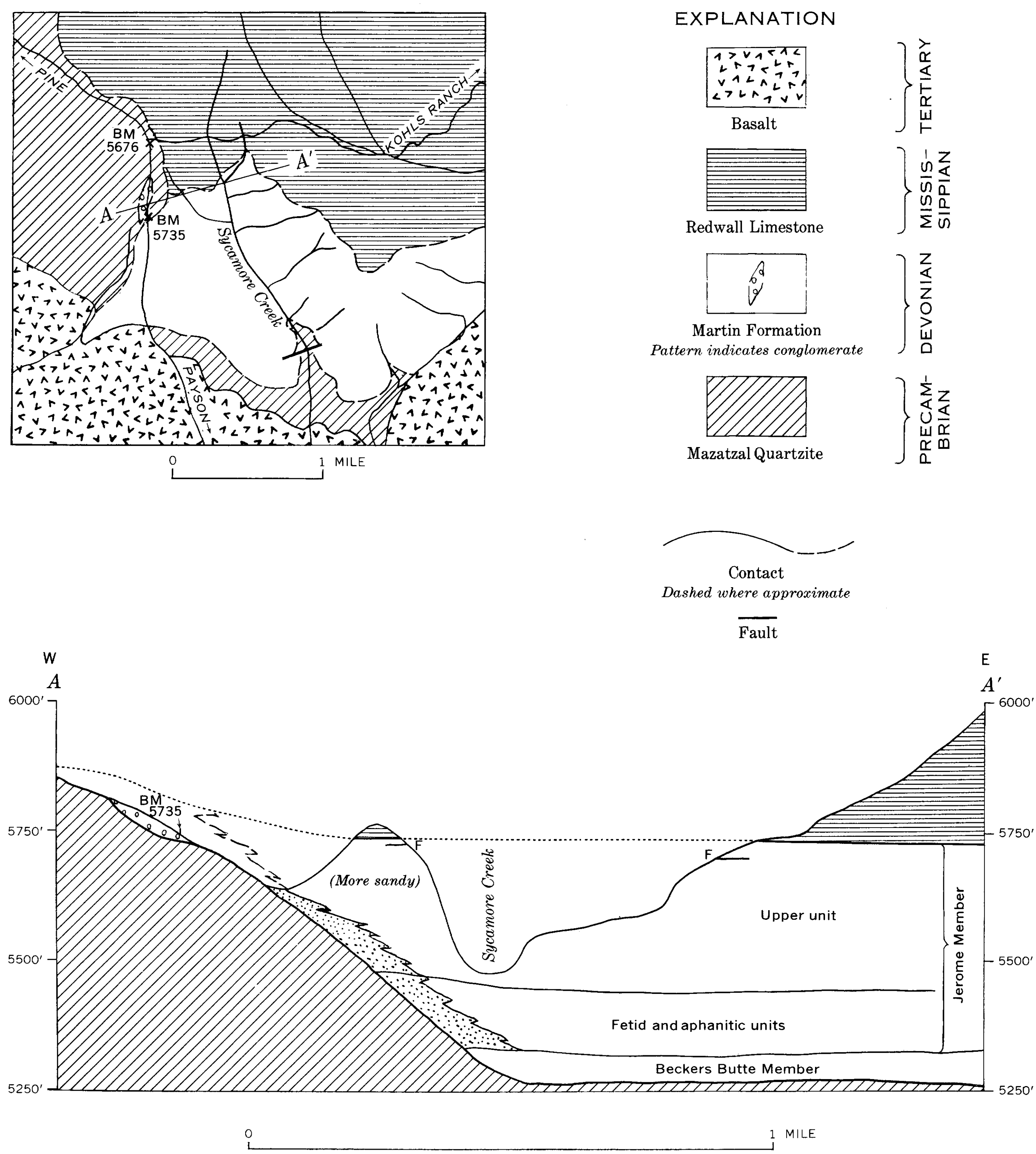


FIGURE 18.—Geology of area southeast of Pine. South of BM 5676 the Martin Formation rests on the Mazatzal Quartzite. Immediately east of BM 5676 the Redwall Limestone rests on the Mazatzal Quartzite. The section illustrates the abrupt pinchout of the Martin Formation westward toward Pine Island. F indicates the *Theodossia* horizon of section 33, subunit 37. The hill immediately west of Sycamore Creek is composed of sandier material.

In section 33, measured in the upper part of Sycamore Canyon about 1 mile east of the Pine-Payson Road, both the Beckers Butte and the Jerome Members are complete and typically formed. About 281 feet of the upper unit rests on the fetid and aphanitic dolomite units, here 117 feet thick. The twofold division that is typical in the Jerome area is vaguely recognizable. The rocks of the lower part of the unit from the base to about subunit 22 are somewhat mottled, and two aphanitic subunits (27 and 35) were observed in the upper part. Most of the dolomite rocks are very fine to medium grained and saccharoidal. No limestones are present except near the top of the unit. Subunits 38 and 40 are noteworthy for being completely devoid of fossil remains, even microfossils, whereas the interbedded dolomites, subunits 37 and 39, contain brachiopods; subunit 37 contains brachiopods in large quantities (*Theodossia* and others; equals horizon F in fig. 18).

Most of the dolomites in the same section contain varying amounts of detrital quartz; more quartz is found in the lower than in the upper part. A 20-foot bed of sandstone having a matrix composed of calcitic dolomite occurs at the base of the upper third of the unit.

On the whole, although it is close to a land area—Pine Island—the entire section of the Jerome Member in this locality contains remarkably little terrigenous material.

East and southeast of Sycamore Canyon, the upper unit has thicknesses of generally more than 200 feet. At Webber Creek (section 31), thickness is only 200 feet, and the beds contain a considerable proportion of sandstone and some shale. All dolomite beds tend to be mottled, and no true aphanitic rocks are present, except limestone subunit 31. Large mud cracks were observed in fallen blocks of subunit 22, which are either a very fine grained highly calcitic dolomite or possibly a slightly dolomitic limestone.

The sandstone beds in this locality are fine to medium grained, and subunit 36 contains large ripple marks, having crests 1–1½ inches apart. Abundant fragmentary fish plates were found near the base of the unit in a fine-grained somewhat silty saccharoidal dolomite (subunit 20). This subunit is possibly identical with the "Arthrodiran sandstone" mentioned by Stoyanow (1936, p. 499) found near the headwaters of the East Verde River.

Fossils are somewhat more common in the upper part of the unit. Most noteworthy is limestone subunit 31, which contains a microfauna including the genus "*Umbella*" Maslov. Other than this locality, "*Umbella*" has been recorded only from Belgium and from various localities in southeastern European Russia (pl. 20, fig. 2; pl. 21). This genus is discussed on pages 103–105. An *Atrypa* assemblage occurs in the middle of the uppermost subunit (No. 37).

South of Webber Creek the upper unit is poorly exposed in the triangle between the East Verde River, Sycamore Creek, and east of the Pine-Payson Road (section 32). Siliceous-detrital beds are of little importance. Most of the unit consists probably of dolomite and calcitic dolomite. Fossils in the upper part of the unit include *Amphipora*, *Hexagonaria*, *Thamnopora* (fig. 26), and *Atrypa*.

East of the upper East Verde River, the upper member retains more or less the same characteristics. In the excellent exposures along Diamond Rim, little siliceous-detrital material is present, except for a few thin sandstone beds and a 13-foot shale subunit (No. 43 of section 30) near the top. Although present, mottling is not particularly conspicuous in the dolomite beds in this section. The amount of siliceous-detrital material in the dolomite beds varies greatly, but it is generally less in the upper part than in the lower part of the unit. Fossils are common throughout the uppermost 50 or 60 feet and abundant in the top limestone subunit (No. 46), which carries a rich thanotocoenotic assemblage of stromatoporoids, *Disphyllum*, *Syringopora* (W. A. Oliver, Jr., written commun., 1959; fig. 24 of this report), and *Atrypa*.

THE NORTHEASTERN ONLAP BELT

Along the northeastern onlap belt, the marginal sandy facies of the aphanitic and fetid dolomite units wedges out, and the upper unit is transgressive over the Precambrian of the Defiance uplift (pl. 27). Good exposures are found in the upper Tonto Creek area, along Christopher Creek, and in uppermost Canyon Creek; all occur along a belt following the foot of the Mogollon Rim, where these relations can be studied (pl. 29; cross section *G-G′*, pl. 30). In the onlap belt of the upper unit, basal sandstone beds are mostly present, and near the margin of the fetid and aphanitic dolomite units, the basal sandstone facies of the upper unit is locally indistinguishable from the marginal sandstone facies of the two lower units. Boundaries accordingly are somewhat arbitrary on the maps of some localities.

In one area of undetermined but probably small size, the upper unit is missing, as can be seen in good outcrops 2 miles east of the junction of Christopher and Tonto Creeks on the road to Christopher Creek Camping Area (section 24). Here, Redwall Limestone, brecciated by pre-Pennsylvanian weathering, rests on a slightly irregular surface of Precambrian quartzite. In pockets below the Redwall, as much as 15 feet of sandstone is present locally that is considered to represent the upper unit of the Jerome. Indications are that an area of partial absence of the upper unit extends northward from these exposures for an unknown but probably small distance. Absence of the upper unit is due to nondeposition as well as perhaps to a slight amount of pre-Redwall erosion. This area is 2–3 miles east of the "Cristopher Mountain Ridge" of Huddle and Dobrovolny (1952, p. 91, fig. 25, and pl. 13). The name Christopher Island is here proposed for the area because of its proximity to Christopher Creek. Christopher Mountain is at least locally covered with Devonian rocks, as is discussed in following paragraphs.

West of the Christopher Island area the facies relations at three important localities were studied: section 29 (Thompson Wash), section 28 (Kohl Ranch) and section 27 (junction of Tonto and Horton Creeks). In all these localities, the fetid and aphanitic dolomite units are represented in part or entirely by sandstone facies and, in sections 28 and 29, the boundary between these units and the upper unit is somewhat arbitrary. In each locality all basal sandstone units have been included in the aphanitic dolomite unit, although they may in part belong to the upper unit. In section 27 basal sandstone subunits are overlain by 6 feet of dolomite and 9 feet of mottled aphanitic dolomite, all of which are included in the aphanitic dolomite unit.

In the three localities the upper unit is characterized by considerable sandiness and generally by abruptly varying lithologies. A typical sandy dolomite rock is illustrated on plate 9, figure 7. In the coarsely crystalline dolomitic matrix, outlines of pellets or clasts can clearly be distinguished, and they have no relation to the crystallinity pattern. Their presence suggests that the original rock was a fine-grained or aphanitic pelletal or clastic limestone. The quartz grains are well rounded and have much overgrowth. In some beds the quartz grains are greatly shattered, evidence indicating that they were either transported by torrents or perhaps redeposited from preexisting sandstone.

In the three sections (Nos. 27, 28, 29) the upper unit is characterized by large amounts of limestone and dolomitic limestone; dolomitization of the limestones of the upper unit was less complete in this area than elsewhere. The formation of layers composed mostly of euhedral dolomite crystals of minute size caused microlamination of the rock (pl. 9, fig. 2) and illustrates one way in which the rock was dolomitized. Intermixed in these layers are silt-size quartz grains, which tend to be more abundant than in the nondolomitized limestone matrix.

Stylolites, which elsewhere are scarce in these carbonate rocks, were observed in one fine-grained dolomite from section 29, subunit 12 (pl. 8, fig. 6).

As in most other places fossils are present in the upper half of the unit, though they decrease in abundance from southwest to northeast. The upper half of the unit in section 29 is very fossiliferous; predominating faunas are stromatoporoids, rugose and tabulate corals, crinoids, and brachiopods. The fossils are mostly silicified, and one bed (subunit 21) is a completely silicified limestone and, in part, a brachiopod coquina.

In the Kohl Ranch section (No. 28), one very fossiliferous limestone unit (No. 32) that is rich in corals and brachiopods occurs at the top; a few less fossiliferous beds occur lower in the section.

In section 27 (Tonto and Horton Creeks), subunit 19 near the top of the section is the only bed containing abundant megafossils. It contains a very rich thanatocoenotic association of *Disphyllum* sp. and "*Aulopora*" sp. (fig. 25). This is a persistent horizon which can be traced for more than half a mile along the slope east of Tonto Creek north of its junction with Horton Creek. Search for microfossils might be rewarding in other subunits, as is shown by the record of an "*Umbella*" or "*Umbella*"-like fossil in the medium- to coarse-grained standstone of subunit 9 near the bottom of the unit (pl. 9, fig. 6). This is an unusual type of occurrence for this kind of fossil, which is generally restricted to aphanitic to very fine grained limestones.

The upper unit thins east of Tonto Creek. A good section is exposed in Doubtful Creek (section 26) immediately below the Kohl Ranch-Young Road, where the upper unit is represented by 175 feet of rock, mostly dolomite, resting on altered volcanic rocks of Precambrian age. All the rocks in this section are of similar color hues—predominantly pale red, pinkish gray, grayish orange, and pink and light gray.

A feature of this section is the number of small intraformational disconformities, which are generally uncommon in other measured sections of the upper unit. The top subunit is a sandy limestone. The rest of the section, except for a few clastic beds, is composed of dolomite, most of which contains varying amounts of detrital quartz. The proportion of detrital material increases somewhat from the bottom to the top of the section (pl. 22). No identifiable fossils were found in this section, but fragmental brachiopods were noted in subunit 15.

Between Doubtful Creek and the Christopher Creek Camping Area, outcrops of the Jerome Member are very poor or lacking. A poorly exposed section consisting of about 39 feet of unfossiliferous sandstone and calcitic dolomite was measured near the stables of Boy Scout Ranch No. 1 (section 25). Its base is not exposed, and although the thickness of the missing part cannot be accurately estimated, it is probably not great. Thus, thinning of the Jerome from the Doubtful Creek area to near the Christopher Creek Camping Area is probably gradual.

On the south side of Christopher Creek in this area, outcrops of dolomite beds dip about 20° N. and overlie a basal sandstone bed several feet thick. No good section was located. Silicified brachiopods were seen in one bed, and the nearness of Redwall Limestone outcrops was suggested by the presence of boulders of crinoidal limestone containing single rugose corals.

Presence of tilted Devonian and probably also Mississippian beds at the foot of the northern slope of Christopher Mountain is evidence that these sedimentary rocks formerly extended into the area south of Christopher Creek. As the beds on the north side of the creek at Boy Scout Ranch No. 1 are horizontal, an east-trending fault may extend along the creek or a steep flexure may exist in this area. On the south side of this fault or flexure, the Paleozoic beds have been uplifted. The occurrences of Devonian and Mississippian rocks at the top of Christoper Mountain (described in section 19), near its eastern termination, give further evidence for the uplift. These occurrences suggest that Christopher Island did not extend appreciably south of the small area where the island is now exposed. Since the island constituted a source of the detrital material found in the sedimentary rocks surrounding it, the continuation of the island must be sought to the north of section 26, where it is now concealed by the Paleozoic rocks of the Mogollon Rim.

East of Christopher Island the facies and thickness pattern is almost a mirror image of that on the west side. (See line of cross section *F–F′* in pl. 27.) The Devonian beds generally have a slight northerly dip and rest with an angular unconformity of as much as 90° on Mazatzal Quartzite. Outcrops, though mostly poor, reveal the presence of sandstone and sandy dolomite and a gradual increase in thickness, which is perhaps somewhat less gradual than on the west side. Fossils are absent from rocks nearer the island (sections 23, 22, and 21). The sandiness in these sections is greater than that occurring over a comparable distance to the west of the island. A typical sandy dolomite from this area is shown in plate 10, figure 1, A luster-mottled dolomite from section 22 is shown in plate 10, figure 2.

Fossils do not appear until about 2½ miles east of Christopher Island, where, in section 20, the rugose corals *Disphyllum* and *Stringophyllum*? occur in the top subunit, a sandy dolomite. The carbonate rocks in this section are composed of dolomite and are sandy; sandstone occurs only in the lowermost part (subunits 1, 2, and 5).

Farther east the Jerome Member occurs at the eastern end of Christopher Mountain, at an altitude of about 6,700 feet, which is roughly 900 feet above the bottom of Christopher Creek. The section here has a minimum thickness of 144 feet, nearly all of which consists of dolomite (section 19). The dolomite in the lower half of the section (subunits 2–8) has a surprisingly high carbonate content, commonly more than 90 percent (pl. 22). Total carbonate content varies considerably among the units in the upper half of the section. Abundantly fossiliferous beds containing *Amphipora*, globular stromatoporoids, corals, brachiopods, gastropods, and calcispheres indicate normal marine sedimentation at a moderate distance from the shore. Excluding those in limestone unit 15, all fossils, especially the stromatoporoids, are highly dolomitized and are generally recognizable only on weathered rock surfaces.

Because of poor outcrops below the base of the exposed part of this section, its total thickness cannot be estimated, but it probably does not greatly exceed 150 feet.

Southeast of Christopher Mountain the line of outcrops and of measured sections is roughly parallel to the edge of the onlap area of the upper unit. (See cross sections *E–E′*, *D–D′*, and *C–C′* on pl. 29 and the northwestern end of *A–A′* on pl. 28.) However, the first three of these cross sections (*E–E′*, *D–D′* and *C–C′*, pl. 29), though short, are at high angles to the onlap edge and thus provide some information on facies shifts in a direction perpendicular to the shore. (See p. 92–94.)

Along the belt from Colcord Canyon south of Turkey Peak and along Naeglin Rim, the general character of the Jerome Member changes little (sections 16, 17, 18), although it varies in detail. The upper unit rests on Precambrian rocks, and its thickness along this belt varies little from 200 feet. The bulk of the rocks is composed of dolomite, generally fine to medium crystalline, and contains a generally decreasing amount of siliceous-detrital material from bottom to top and only a few interbedded sandstone layers.

Toward the top of these sections, limestone beds occur that are everywhere fossiliferous. At Colcord Canyon, limestone subunit 17 contains a rich microassemblage that includes calcispheres, tintinnids (?), pteropods, and ostracodes (pl. 16, fig. 2; pl. 17, fig. 2). Other members of the limestone assemblages, which occur also in associated calcitic dolomites, are *Amphipora*, *Thamnopora*, *Schizophoria*, *Atrypa*, *Platyrachella*, and probably others. The top subunit (No. 21) of section 18 (2 miles south of Turkey Peak) contains a rich superbly preserved taphocoenotic assemblage consisting predominantly of *Schizophoria* cf. *S. iowensis* (Hall), *Atrypa devoniana* var. *bentonensis* Stainbrook, *Spinatrypa* cf. *S. rotunda* Stainbrook, *Cyrtospirifer whitneyi* (Hall), and, less abundantly, *Thamnopora* sp. (fig. 29).

The sandstones in the same sections are generally medium grained and not well sorted; the grains are considerably angular (pl. 10, fig. 5), and the rocks have no carbonate cement.

Dolomites range from fine-grained pelletal to coarse-grained saccharoidal. Plate 10, figure 6, illustrates an interesting rock type consisting of two distinct modal forms of dolomite crystals. Mostly euhedral dolomite rhomobohedra having an average size of 1 mm diameter are embedded in a "matrix" of anhedral dolomite crystals about one tenth their size. Thoroughly mixed rocks such as the sandy dolomite shown in plate 11, figure 2, in which grain size of the crystalline dolomitic matrix is roughly equal to that of the terrigenous quartz grains also are included.

Some unusual rock types are present in the Naeglin Rim section (No. 16), especially in subunits 6 and 7. Subunit 6 crops out in knolls suggesting biohermal buildups, but no fossils are evident either megascopically or in thin section. The bulk of the rock is a dolomite breccia as seen both megascopically and microscopically (pl. 11, fig. 1). Small bodies of elliptical or ovoid outline, illustrated in the lower left of plate 11, figure 1, are either dolomitized ooids, or more probably calcispheres because no oolites have been recognized anywhere among unaltered carbonate rocks of the Jerome Member.

The rock of this subunit is composed of fragments consisting of aphanitic to very fine grained dolomite. All the larger clasts are angular, but many small ones—about 1 mm in size—are rounded, indicating that the water was slightly turbulent.

Detrital quartz grains are scattered through the rock, the larger of which are generally well rounded (pl. 11, fig. 3). Some quartz grains (as shown on the same illustration) are surrounded by a halo of finely crystalline dolomite, which contrasts sharply with the surrounding aphanitic matrix. The origin of this feature is not clear. The halos could be considered to be a dolomitized peripheral shell of the quartz grains whose original size is indicated by the outer circumference of the halos. However, this interpretation is contradicted by observations on a similar rock from south of Turkey Peak (section 18, subunit 1). In this rock the groundmass is an aphanitic dolomite containing many rounded clasts of somewhat darker aphanitic dolomite and numerous quartz particles ranging in size from silt to very fine sand. In addition, larger grains of various composition and as much as 2–3 mm in diameter are present. Plate 11, figure 4, shows a representative thin section in which the typical groundmass and fine quartz detritus and three larger grains—composed of quartz (top), chert (lower left) and aphanitic dolomite (lower right)—are present. All three grains are surrounded by halos composed of finely crystalline translucent dolomite, but the same type of dolomite is present also in irregular clouds throughout the groundmass. Clearly the dolomite surrounds some of the smaller quartz grains, and a larger compact area of it is seen below the chert grain in the lower left corner of the thin section.

The described conditions can probably be best explained by assuming recrystallization of aphanitic dolomite and the formation of a two-stage dolomite rock. A somewhat similar rock from the Carboniferous of the Russian Platform was described by Khvorova (1958, pl. 57, fig. 336).

Evidence to support this assumption is found in a rock type occurring in the upper part of the overlying subunit (No. 7). This rock is an intimate mixture of finely crystalline and aphanitic dolomite (pl. 10, fig. 3). A few calcispheres occur in the aphanitic portions. The crystalline dolomite was formed by grain growth of the aphanitic dolomite and is not secondary cement, because without the crystalline dolomite the aphanitic rock particles form an open network that could not have existed in nature.

From Naeglin Rim northeastward, the section diminishes in thickness. Fortunately, good outcrops are present near the head of Canyon Creek close to the foot of the Mogollon Rim. Two miles south of the O. W. Ranch on the west bank of the creek is a fine outcrop of a channel fill in Precambrian rocks (section 14). Surprisingly, the channel contains little sandstone but is mostly filled with sandy dolomite and calcitic dolomite (pl. 12, fig. 3). Possibly this was not strictly a channel but rather was a wider panlike depression in which sandy lime mud was deposited and later dolomitized.

Good exposures (section 15) of the Jerome Member occur 1 mile upstream from this locality, where the Jerome rests with only a slight unconformity on Dripping Spring Quartzite. The basal sandstone is thicker here than in the "channel" of section 14. Most of the original sediment in this area was composed probably of very finely intraclastic calcareous mud that contained much detrital quartz. Some of this mud is still preserved as limestone (pl. 11, fig. 5), but in other beds, it has changed to fine- or medium-grained saccharoidal dolomite (pl. 13, fig. 3).

In both sections (Nos. 14 and 15), fossiliferous beds occur in the uppermost part. The assemblages include stromatoporoids, *Thamnopora*, *Atrypa*, *Platyrachella*, and calcispheres; all are typical members of associations found in the uppermost part of the upper unit elsewhere.

Southeast of sections 14 and 15 and lower down Canyon Creek valley, the rocks of the marginal onlap belt were studied at sections 45, 10, 11, and 9. In this area thickness and lithology vary greatly because of the channeling of the Devonian rocks into the underlying Precambrian. In measured sections the thickness of the upper unit ranges from 36 feet at section 10 to 135 feet at section 45. In spite of the small thickness, the lithology is diverse in these sections, and the rocks consist of sandstone, limestone, biostromal limestone, silicified limestone, and dolomite. Almost all the carbonate-rock units are very fossiliferous. At the top of biostromal subunit 2 in section 10 is a very rich assemblage of horn corals, *Disphyllum*? n. sp., and *Tabulophyllum* n. sp. The limestone beds of section 10 are especially rich in calcispheres. Among megafossils the common association of atrypids and *Schizophoria* and a biostromal limestone of stromatoporoids and tabulate corals occur. Large colonies of *Spongophyllum* occur in the lower part of section 45; characteristic associations of *Macgeea*, *Tabulophyllum*, *Thamnopora*, *Amphipora*, and massive stromatoporoids, *Atrypa*, and spiriferids are also found in the upper part of the same section.

In the poorly exposed outcrops of Devonian rocks about halfway between sections 10 and 45, about due east of the abandoned Chediski farm, large numbers of a very massive species of *Chaetetes*,[5] forming large cylindrical colonies, were found.

These faunal associations, which correspond to those commonly found in the top part of the upper unit, indicate that the area near sections 10 and 11 remained land during much of the time when the rocks of the upper member were being deposited and may well have furnished the material for some of the sandstones in the lower parts of that unit in sections to the west and to the south.

Farther southeast good outcrops occur in the escarpments east of the so-called Oak Creek Indian Farms and on the north side of the road leading from this locality to Grasshopper. The thickness of the upper unit seems to be variable, because a section of about 80 feet in thickness was measured by Huddle and Dobrovolny (1952, p. 101) very close to my section 9, which has a thickness of 142 feet. Both sections lie in sec. 32, T. 8 N., R. 16 E. Out of the total of 142 feet in section 9, more than 72 feet consists of limestone or silicified limestone, which is an unusually high limestone ratio, particularly if the fact is considered that the section has only one 5-foot unit of calcitic dolomite (subunit 14). The rest of the exposed rocks consist of sandstone.

It is, thus, not surprising that the rocks of this section are abundantly fossiliferous. Nearly all limestone beds are rich in calcispheres (pl. 17, fig. 1; pl. 18, fig. 1). Other microfossils include ostracodes (unidentifiable) and pteropods, probably *Styliolina* (pl. 13, fig. 1). Some limestones show considerable recrystallization of the type shown from another locality on plate 12, figure 6.

[5] Helen Duncan (written commun., 1961) identified the *Chaetetes* but questions the inclusion of *Chaetetes* as a faunal element in these Devonian rocks; she suspects that the specimens were obtained from younger rocks. Field evidence, however, suggests that these corals are indeed indigenous to Devonian rocks.

Fossil assemblages vary much from subunit to subunit. One 2-foot limestone bed in section 9 that is almost biostromal contains *Actinostroma* sp., *Anostylostroma* sp., and *Stictostroma* sp. (identifications by W. A. Oliver, Jr.). Unit 14 possibly contains *Arizonella*, a gastropod that is a member of a unique assemblage occurring in the upper part of section 43 (discussed on page 62 of this report). The brachiopods are represented by typical associations of species of *Schizophoria*, *Atrypa*, and *Spinatrypa*. *Theodossia* cf. *T. hungerfordi* occurs near the top in subunit 25 together with a rich assemblage of *Hexagonaria occidens* Stumm and *Thamnopora* sp.

The limestones are mainly aphanitic to very fine grained. Recrystallization through grain growth is evidenced by calcispheres that are completely surrounded by clear crystalline calcite. Plate 10, figure 4, illustrates a similar type of limestone that does not contain calcispheres but contains much silt-size to fine-grained detrital quartz. The fine-grained quartz is concentrated mostly in the unaltered aphanitic limestone, but some quartz grains are surrounded by crystalline calcite.

The lower sandstones, up to subunit 6, are siliceous and well cemented (pl. 12, fig. 5). In the upper part of the section, sandstones are more commonly calcareous. Plate 12, figure 4, illustrates part of a calcareous sandstone bed in which the cement, recrystallized into crystals several millimeters in size, constitutes more than 50 percent of the rock.

A comparison of this section with section 10 of Huddle and Dobrovolny (1952, p. 102) shows differences in detail but also great similarities, particularly in fossil content.

THE AREA FROM MIDDLE CANYON CREEK TO THE UPPER SALT RIVER

The southwestern edge of the outcrop belt of Devonian rocks is continuous from the southeastern corner of Navajo County east of the middle part of Canyon Creek, across the middle Salt River Draw, and into the upper Salt River area. Excellent outcrops in Lost Tank Canyon also belong to this belt but are separated from outcrops on the east side of Canyon Creek by the broad valley cut into Precambrian rocks by the Salt River. Along the entire belt, where completely exposed, all three units of the Jerome Member are present. The member is underlain by the Beckers Butte Member, which varies greatly in thickness. The relations of the Devonian rocks in the area are illustrated by cross sections C–C′ in plate 29 and A–A′ and B–B′ in plate 28.

Outcrops in Lost Tank Canyon (sections 12 and 13) are of great interest because the more eastern of these (section 12) is not more than 2½ miles from the area where the fetid and aphanitic dolomite units wedge out; yet all units exposed in the outcrops have typical thickness and lithology. The only indication that the rocks exposed here were close to the shore is the presence of sandstone subunits (Nos. 17, 20 of section 12) in the basal part of the upper unit. These basal sandstones are absent to the west in the upper part of Lost Tank Canyon (section 13). In both localities sandstone units are present in the upper part of the upper unit. The carbonate units are less dolomitic and more fossiliferous. Biostromal limestone beds contain *Gerronostroma* and *Idiostroma* (identified by W. A. Oliver, Jr., written commun. 1959). *Amphipora* is abundant in dolomite units in the lower and middle part of the upper unit, but in these places as in many others its skeletons can be generally detected only on weathered surfaces (fig. 19). Immediately above the biostromal subunit 34 in section 12 is an aphanitic limestone that is very irregularly dolomitized. In one thin section made from this rock (pl. 12, figs. 1 and 2) dolomite rhombohedra are scattered in some areas but crowded in others where they have almost entirely replaced the original rock.

Brachiopod assemblages in section 12 are few. There is a coquina composed of *Theodossia* cf. *T. hungerfordi* in subunit 44 (fig. 27) and a coquina of *Atrypa* in subunit 45, but brachiopod faunas are much richer and more varied to the west. In section 13, four distinct assemblages are found: (1) *Cyrtospirifer-Platyrachella-Spinatrypa* (subunit 19); (2) *Theodossia* cf. *T. hungerfordi* (subunit 21); (3) *Schizophoria-Cyrtospirifer-Theodossia-Atrypa-Spinatrypa* (subunit 23); and (4) *Theodossia* sp. (subunit 24). These are among the richest brachiopod assemblages found in the upper unit. They are easily accessible in outcrops close to the Heber-Young highway.

Sandstones in the upper unit are mostly fine grained and well sorted. Plate 13, figure 5, illustrates one example in which sutured contacts were formed between an unusually large number of grains.

As mentioned on page 51, the Devonian outcrops in Lost Tank Canyon lie northwest of a continuous outcrop belt of Devonian rocks that extends generally southeastward and then disappears under younger volcanics south of the Salt River or dips below younger Paleozoic rocks only a mile or so above the junction of White River and Black River. Information available for this belt is presented in cross section A–A′ on plate 28. Data from descriptions of sections 6 (Rockhouse Butte) and 8 (Cliff House Canyon) by Huddle and Dobrovolny (1952) were used as supplemental information.

The lithology of the upper unit along this belt is very variable. Clastic detrital units occur at irregular intervals, though they generally increase in proportion southeastward. Limestone beds are not uncommon in the upper part of the unit and tend to form minor biostromal subunits. Dolomite rocks, which generally make up about one half of the total thickness of the upper unit, represent the lithology typical of the upper unit of the Jerome Member where the member is predominantly carbonatic. Although mottling is not a predominant feature, the color and texture of the rocks are similar to those of the rocks of the typical Jerome Member. The rocks are very fine to medium grained and predominantly medium to light gray and yellowish gray in hue.

Particularly complex and abundant vertical facies changes are common in the upper unit in the area east of middle Canyon Creek and middle Salt River Draw (fig. 20).

FIGURE 19.—Fine-grained dolomite, slightly calcitic, containing *Amphipora* skeletons, which are recognizable on weathered surface although their microstructure has been obliterated through dolomitization. Section 12, Lost Tank Canyon, upper unit, subunit 28. × 1.5.

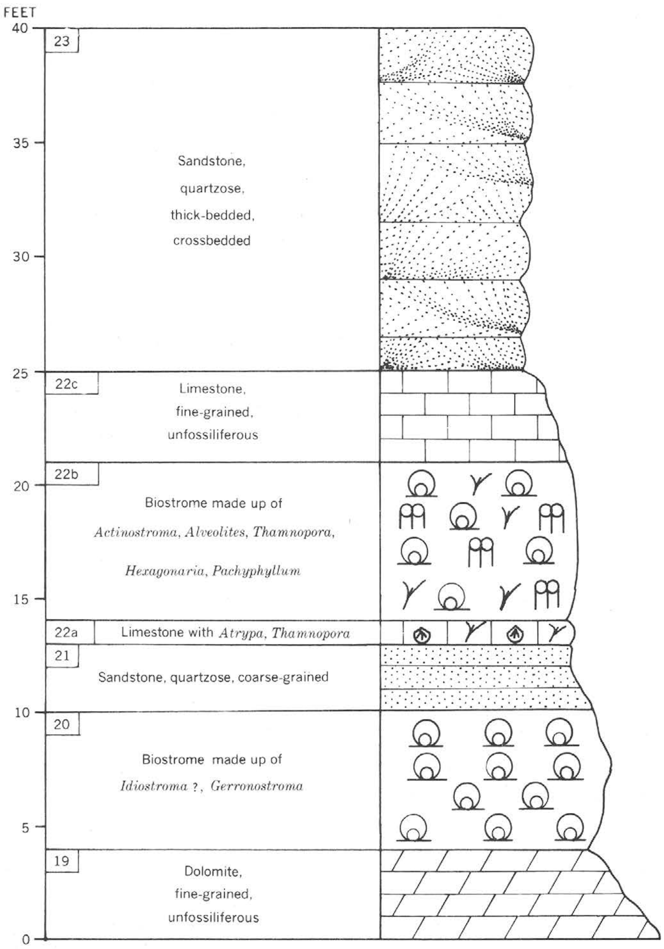


FIGURE 20.—Typical facies sequence of the upper unit of the Jerome Member in the middle Canyon Creek area; abrupt changes of contrasting rock types, are illustrated. Section 8, east side of Canyon Creek, subunits 19–23.

This area, in which sections 6, 7, and 8 are located, is relatively inaccessible, and these sections were not studied and sampled in the same detail as most others. A large nondolomitized area probably exists here; accordingly, further study would provide additional data on the primary sedimentary facies of the carbonate rocks of the upper unit. Some of the primary sedimentary facies is exemplified by subunit 18 of section 6 (lower Salt River Draw), which consists of a very fine grained to aphanitic rock containing abundant microfossils such as calcispheres, tintinnids(?), pteropods, and unidentified fragmental remains (pl. 13, fig. 4; pl. 16, fig. 1). Also, stromatoporoid biostrome units are present everywhere in the area and as far south as Sawmill (section 1; pl. 27).

In the area east of middle Canyon Creek, the lower half of the upper unit is characterized by considerable amounts of sandstone, some of which is medium grained and crossbedded. Locally this sandstone is poorly sorted and contains angular grains.

In the upper Salt River area (sections 2, 3, and 4), siltstone and shale are more abundant, whereas sandstone is less abundant. This distribution is due to the fact that the sections from Canyon Creek to Black River (cross section *A–A′*, pl. 28) lie along a line that diverges slightly from the edge of the onlap belt of the upper unit. Most probably sections 2–4 indicate conditions of deposition that existed farther offshore than those indicated by sections 6–8.

Huddle and Dobrovolny (1952) recognized the presence of a "green shale zone" at or close to the top of the Jerome Member in the upper Salt River area. This zone is well exposed in roadcuts along U.S. Highway 60 on the north side of the Salt River Canyon (fig. 21). As shown on cross section *A–A′* on plate 28, it can be traced northwestward into Salt River Draw, but it seems to disappear east of Canyon Creek and is absent in Lost Tank Canyon. It represents a tongue of the siltstone-shale facies in the upper part of the upper unit of the Black River section (section 2).

Traces of burrowing by mud-feeding animals are abundant in the shale, although they can be recognized only in freshly weathered rock specimens. Included are unidentified horizontal, more or less straight burrows and U-shaped, horizontally oriented burrows of the U-in-U type (fig. 30*E*), which may be identified as *Rhizocorallium.*

Fossil content of the rocks of the upper unit is considerable in the Canyon Creek-Salt River Draw area, partly because of the greater abundance of limestone beds and partly because of the greater abundance of primary life. The presence of biostromal limestones has already been mentioned (p. 52). They are built up mostly by the stromatoporoids *Idiostroma*? sp., *Gerronostroma* sp., and, locally, *Pachyphyllum* sp. Corals are abundant in some beds—for example, subunit 22 of section 8, from which W. A. Oliver, Jr., identified eight species of corals and one species of *Actinostroma.* According to Oliver (written commun. 1959), the age of this fauna is Frasnian. In nearby section 7, *Tabellaephyllum peculiaris* Stumm, also identified by Oliver, was obtained from the top of subunit 5; it is a species that was formerly known only near Bisbee, Ariz. The brachiopods of this area have not been studied in detail. Subunit 26 of section 8 consists of a coquina that is composed of *Theodossia* and is similar to the one in Lost Tank Canyon, but it contains a much richer admixture of compound rugose and of tabulate corals. In addition spiriferids and atrypids are generally present in these upper beds.

Microassemblages include the common association of calcispheres and ostracodes along with scattered pteropods and tintinnids(?).

Near the Salt River the beds change into a facies that is virtually unfossiliferous as a result, at least partly, of the high state of dolomitization of the carbonate rocks. Section 3 has yielded only poor *Schizophoria* remains in subunit 33; section 4 has only one densely packed *Atrypa* layer in subunit 20 and calcispheres and *Amphipora* in subunit 18. In shale and siltstone beds of section 3 straight and branching invertebrate tracks, some of them large, are observed (fig. 22).

In the silty facies farther southeast, brachiopods are very abundant. Thus, some of the siltstone units in section 2 are very fossiliferous. By far the most predominant are atrypids, including *Atrypa* cf. *A. clarkei* Warren, *A. devoniana* var. *bentonensis* Stainbrook, and *Spinatrypa* cf. *S. rotunda* Stainbrook. Also present, though rarer, are *Cyrtospirifer* cf. *C. whitneyi* Hall and *Devonoproductus*? sp. Corals seem to be absent in the Jerome Member in this area.

A richly fossiliferous section was studied near Sawmill (section 1), 10 miles south of the Salt River, roughly south of Flying V Canyon (section 3). The sequence here is an alternation of sandstones and limestones or dolomitic limestones. Most conspicuous in outcrops along roadcuts is biostromal subunit 4, section 1, composed entirely of colonies of *Stictostroma* and other, unidentified, stromatoporoids, and of *Pachyphyllum* sp. (W. A. Oliver, Jr., written commun., 1959). The top subunit (No. 8) of section 1 is especially rich in atrypids (*Atrypa* cf. *A. devoniana* var. *bentonensis* Stainbrook, *Spinatrypa* cf. *S. rotunda* Stainbrook, "*Atrypa*" *owenensis* Webster).

THE ROOSEVELT-GLOBE AREA

Sections of the Martin Formation are well exposed on the south side of Theodore Roosevelt Lake, especially immediately southeast of the dam (fig. 8). The Beck-

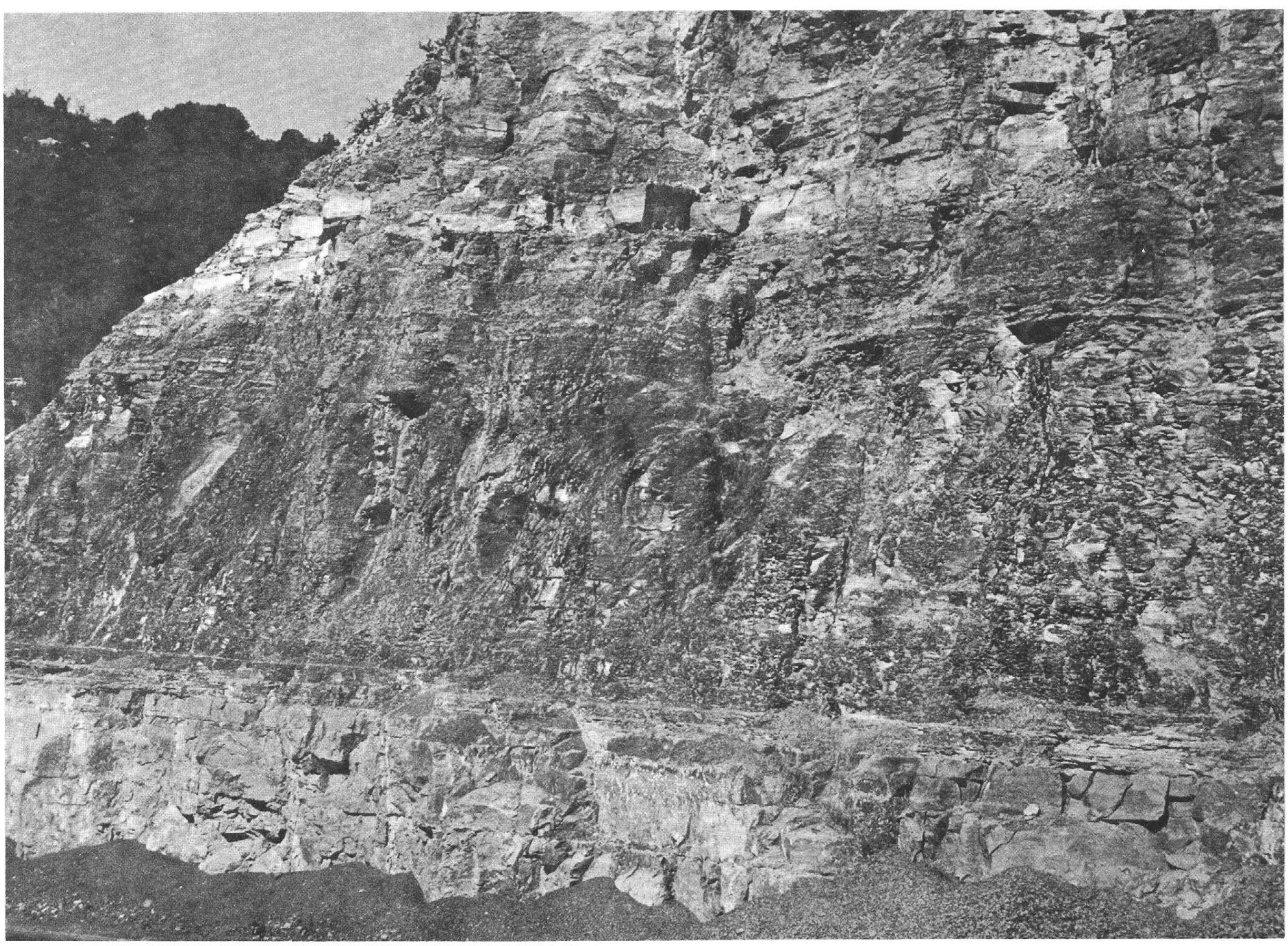


FIGURE 21.—Top of Jerome Member in Flying V Canyon, roadcut of U.S. Highway 60. Light-colored beds on top are Redwall Limestone; below them are thin-bedded sandstone and thick shale subunits (33 and 34, thickness 58 ft) of section 3. Sandstone at base.

ers Butte Member at this locality (described on p. 24) is overlain by a complete section of the Jerome Member, which in turn is capped by Redwall Limestone (section 36). An equally well exposed and complete section of the Jerome Member on the north side of the dam has not been studied in detail.

The upper unit on the south side of the dam is 263 feet thick; about half of it consists of sandstone and shale. The siliceous-detrital component forms much of the lower part and all of the upper part of the unit. The middle part consists predominantly of dolomite and calcitic dolomite, some of which is sandy and crossbedded. This part is rather fossiliferous, although most fossils are poorly preserved. The section on the north side of the dam contains a coquina composed of *Schizophoria* at about this same stratigraphic level (fig. 28).

The succession of rocks in the upper unit at Windy Hill, 4.5 miles to the east of Theodore Roosevelt Dam, is similar. In 1957, drought had lowered the level of Theodore Roosevelt Lake sufficiently to expose the base of Windy Hill. The lowest stratigraphic subunit then exposed in this section was the dolomite of the aphanitic dolomite unit containing the "brown rind chert."

In the upper unit, the basal sandstone is 68 feet thick (compared with 96 feet at Theodore Roosevelt Dam). The basal beds contain no intercalations of dolomite and are composed entirely of sandstone; some of this basal sandstone is crossbedded. The middle and upper parts of the upper unit have almost the same lithology as those at Theodore Roosevelt Dam. The middle part is mostly dolomitic and contains scattered layers of crinoid plates, brachiopods, and fish plates. The upper part consists of siltstone and shale, as at Theodore Roosevelt Dam, but is topped by a small thickness of unfossiliferous dolomite.

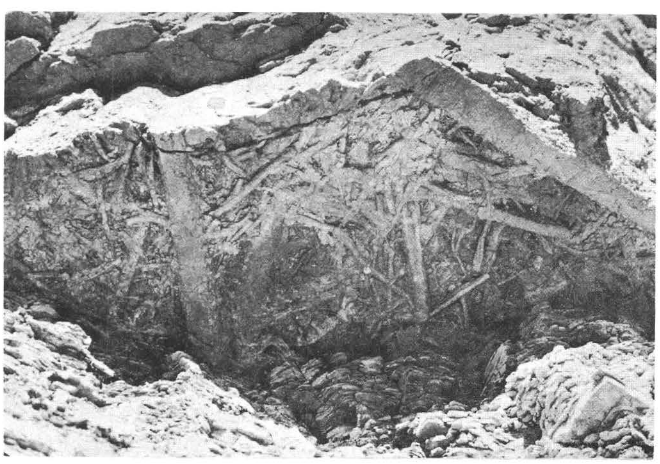


FIGURE 22.—Underside of siltstone bed on which are casts of large invertebrate tracks, photographed almost vertically from below. The large straight track on the left is about 4 inches wide. Upper unit of Jerome Member, in roadcut on west side of Flying V Canyon, near section 3.

The geologic map of Gila County (Wilson and others, 1959) shows another area of Devonian rocks on the north side of Theodore Roosevelt Lake, opposite Windy Hill, but this locality was not visited.

No outcrops of Devonian rocks occur southeast of Windy Hill for about 20 miles—as far as the upper Pinal Creek and Pinto Creek area, where Devonian and Mississippian rocks are present in small fault blocks (Peterson, 1954).

At Pinal Creek, about three-quarters of a mile southeast of Hoore's quarry and about 3½ miles northwest of Globe, the upper unit is much thinner (203 feet) than elsewhere. It consists predominantly of silty rocks; carbonate rocks here are few (section 35). Both the siltstones and the dolomites in the section are richly fossiliferous, but the fauna consists almost entirely of brachiopods in which the atrypids predominate.

An intrastratal solution surface was observed between subunits 9 and 10 (fig. 23). Intrastratal erosional phenomena of this kind were only rarely observed in rocks of the upper unit.

FOSSIL FAUNAS AND PALEOECOLOGY

NOTE ON TERMINOLOGY

Many stratigraphers and paleontologists use the term "biocoenosis" for fossil assemblages in which individual fossils occupy the same place and position they had when the animals were alive; they use the term "thanatocoenosis" for fossil assemblages in which individual fossils have obviously been transported. (For example, see Shrock and Twenhofel, 1953, p. 22.) An example of biocoenosis would be a fossil coral reef; an example of thanatocoenosis, a coquina limestone. Thus, Boucot (1953) stated that "an excellent example of a thanatocoenosis is the miscellaneous assortment of organic debris gathered on most marine beaches." Such usage, however, is not correct.

The term "biocoenosis" was proposed by Möbius (1877; translation 1880, p. 723) for "a community where the sum of species and individuals, being mutually limited and selected under the average external conditions of life, have, by means of transmission, continued in succession of certain definite territory". Such a community is the "total number of mature individuals of all species living together in any region." Therefore, a biocoenosis, according to Möbius, is not a two-dimensional concept, but rather the time dimension must be added. Occupancy for a period of time is a necessary adjunct of a biocoenosis.

Manifestly, there can be no such thing as a fossil biocoenosis. Although the time factor may be substantiated through stratigraphic observations, no assemblage of fossils represents "all species living together in any region," because every biocoenosis has constituent species that cannot be fossilized.

Realizing this, Wasmund (1926) suggested the term "thanatocoenosis," primarily for fossil assemblages in which individual fossils had retained position and orientation of the living animals. Wasmund did not fail to point out that primary thanatocoenoses are different from the biocoenoses from which they originate and that they may be secondarily modified or destroyed. "Thanatocoenosis," therefore, is an available term for occurrences in which large numbers of fossils are found in the positions and orientation that the animals had in life. They are the remains of animals that were united in death. Hessland (1943, p. 55) called this a "preserved biocoenosis" (konservierte Biozönose) lacking allochthonous additions. This term is virtually the same as the "fossil community" of Craig (1953) and the "life assemblage" of Boucot (1953).

Hedgpeth (1957, p. 40) recently deplored the inconsistent usage of the term "thanatocoenosis" by paleontologists, and Hutchinson (1957, p. 686) pointed out

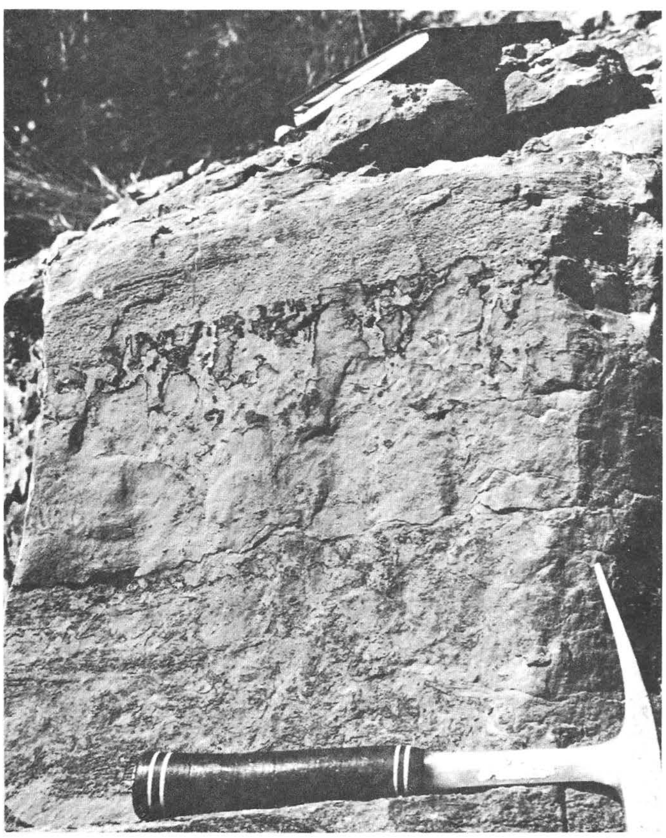


FIGURE 23.—Intraformational solution surface in lower part of upper unit of Jerome Member at Pinal Creek (section 35). The hammer rests on subunit 8 (silty dolomite). Just above the hammer point is the bottom of subunit 9 (fine-grained, laminated dolomite); the top of subunit 9 was greatly eroded before deposition of subunit 10 (silty dolomite), which fills the solution pockets at top of subunit 9.

that fossil associations "are not associations of living but of dead organisms; they are thanatocoenoses, not biocoenoses." However, not all fossil associations fall into this category.

If the remains of the animals in a biocoenosis after their death are transported and dispersed, no thanatocoenosis is preserved in the sediment or, later, the rock. Remains of animals from one biocoenosis may be sorted and separated and become buried in different places, or remains from different biocoenoses may be washed together and buried in one place. For such assemblages the term "taphocoenosis," or burial assemblage, proposed by Quenstedt (1927) seems appropriate. This useful term, although long familiar in German literature, as Schmidt (1958) observed, has been overlooked or neglected by English-language geologists. Instead, the term "thanatocoenosis" is often misleadingly used for taphocoenotic assemblages.

Hessland (1943, p. 55) and Davitashvili (1945) independently proposed the term "necrocoenosis" for nonthanatocoenotic fossil associations, and the same term was coined again by Tasch (1953, 1955). However, in the definition of Tasch (1955, p. 207), the term refers to any kind of fossil assemblage. On the whole, the word "necrocoenosis" seems inappropriate as applied to invertebrate fossils because the Greek noun nekròs means a dead person or a human corpse.

The term "paleobiocoenosis," introduced by Hecker (1960, p. 19), is a synonym of thanatocoenosis in its proper meaning. The term "paleothanatocoenosis," proposed by the same author in the same place, seems redundant because all thanatocoenoses are ancient.

For the foregoing reasons, the following recommendations are made: (1) Application of the term "biocoenosis" to any kind of fossil associations should be avoided; (2) the term "thanatocoenosis" should be applied to strictly "residual biocoenoses" such as fossil coral reefs, oyster banks, and the like; and (3) the term "taphocoenosis" should be used for nonthanatocoenotic fossil assemblages in which, as a rule, the exact place of derivation of individual component specimens is unknown.

DISTRIBUTION AND OCCURENCE OF FOSSIL GROUPS

Although the fossil fauna of the upper unit of the Jerome Member is variable in its distribution, it is uniform in its general aspect and composition. No complete census of the fossil species can be made until the large fossil collections have been studied in greater detail. In most faunas the skeletons and shells are silicified. Incomplete silicification is rather common, especially in brachiopods. In such shells only a thin outer film has been converted to silica; within the film the rest of the shell consists of crystalline calcite (pl.

14, fig. 2). This type of preservation is particularly common in limestones and dolomitic limestones in the upper part of the unit. Such shells are virtually impossible to extract from the rock, because if the rock is placed in dilute hydrochloric acid, even if very weak, the CO_2 bubbles that form break the shells into fragments.

In many rocks, however, the shells are very well preserved, as shown in figures 24–31, and excellent faunas can be obtained.

In the following paragraphs, the occurrence of fossils according to phyla is discussed and, where possible, their relationship to definite lithologies and their areal distribution are indicated.

Protozoa

The Protozoa are possibly represented by tintinnids, if the interpretation of the fossils in question is correct (pl. 13, fig. 2; pl. 16, figs. 1 and 2). They are described more fully on pages 97–99. These tiny bell-shaped shells occur in aphanitic limestones and have so far been found only in rocks from Salt River Draw (section 6) and Colcord Canyon (section 17). The preferred facies of these somewhat questionable forms agrees with that of the true tintinnids of the Mesozoic, which generally occur in fine-grained to aphanitic limestones.

Some authors have referred to the Protozoa all those fossils that are here treated as undifferentiated calcispheres as well as larger spherical calcitic bodies, which are included in the genus *Umbella* Maslov (non d'Orbigny). These fossil forms are here regarded as having an uncertain origin and are discussed on pages 103–105.

Stromatoporoidea

The occurrences of stromatoporoids fall into two sharply divided classes of rocks that are characterized respectively by *Amphipora* and by large massive forms.

Amphipora is a rather small form that builds delicate dendroid colonies, characteristically consisting of a reticulate coenostem having an axial canal, and thus is easily distinguishable from tabulate corals having a similar size and skeletal form. The genus was found at nearly every locality where the upper unit of the Jerome Member was studied. As is typical for *Amphipora* (Teichert and Talent, 1959, p. 10; Jux, 1960, p. 245, pl. 23, fig. 2), individuals occurred generally in great numbers and excluded most other forms of life. In any given section of the upper unit of the Jerome Member, the genus characterizes generally one or more thin beds that are commonly not more than a few inches thick.

Observations on mode of occurrence of *Amphipora* elsewhere suggest that such beds may have a considerable horizontal extent and that they could be traced possibly between adjacent sections and even farther. In the Jerome Member, however, extensive dolomitization has made their preservation a matter of chance. In fine- to medium-grained dolomites, the presence of *Amphipora* colonies is indicated locally only by vague outlines of their skeletons on weathered surfaces (fig. 19), even where thin sections reveal that dolomitization has completely obliterated all microscopic organic structures. Dolomitized *Amphipora* beds, therefore, are easily overlooked, and the record of occurrences of *Amphipora* in measured sections is probably very incomplete.

Amphipora is mainly a Devonian fossil, although older and younger occurrences have been documented (Lecompte, 1956, p. F142). Until comparatively recently the genus was almost unrecognized in North America, but it is now known from many localities—particularly in the western part of the continent—from rocks of Middle and Late Devonian age. (See map by Helen Duncan, in Cloud, 1959, p. 948.)

In contrast to the very common occurrence of *Amphipora*, the distribution of large spherical forms of stromatoporoids is more narrowly restricted. In Devonian rocks these forms are major constituents of biostromal and biohermal limestone buildups. In the upper unit of the Jerome Member, the following genera of massive stromatoporoids have been identified by W. A. Oliver, Jr. (writtent commun., 1959) : *Actinostroma*, *Anostylostroma*, *Gerronostroma*, and *Stictostroma;* associated with these locally is a larger dendroid form, *Idiostroma*. These genera tend to form biostromal limestone units most of which are not more than a few feet thick. In any given section of the upper unit, generally only one, but in places two, such biostromal units may be present. The stromatoporoids may build up a biostrome alone or they may be joined by compound rugose corals, most commonly by *Pachyphyllum*, and in places by tabulate corals.

The biostrome facies in the upper unit of the Jerome Member (pl. 27) occurs in a belt that extends southward from the Spring Creek area along Canyon Creek and Salt River Draw and as far as the Sawmill area (section 1). Massive stromatoporoids occur outside this belt but not in biostromal buildups. I saw no true reefs or bioherms such as reported by Stoyanow (1936) and by Huddle and Dobrovolny (1946b, 1952), but I do not doubt that biohermal buildups may occur locally. Gradational transition between lenticular biostromes and bioherms would make the distinction a matter of definition.

Anthozoa

Most commonly rugose and tabulate corals occur together, but locally and in individual beds, one group may predominate or exclude the other. The following is a synoptic list of species present in the upper unit (compiled in part from a written report by W. A. Oliver, Jr., 1959):

Solitary rugose corals:
- *Breviphyllum* sp.
- *Stringophyllum*? sp.
- *Tabulophyllum* sp.
- *Tabulophyllum*? sp.
- Cyathophylloid corals
- Zaphrentoid corals
- Amplexoid corals

Phacceloid rugose corals:
- *Disphyllum* sp. 1
- *D.* sp. 2
- *D.* sp. 3
- *D.* sp. 4
- *Disphyllum*? n. sp.

Massive rugose corals:
- *Hexagonaria occidens* Stumm
- *H.* sp. 1
- *H.* sp. 2
- *H.* sp. 3
- *H.* sp. 4
- *Pachyphyllum* sp. 1
- *P.* sp. 2
- *Spongophyllum* sp.
- *Tabellaephyllum peculiaris* Stumm

Tabulate corals:
- *Chaetetes* sp.
- *Striatopora*? sp.
- *Thamnopora* sp. 1
- *T.* sp. 2
- *T.* sp. 3
- *Alveolites* sp. 1
- *A.* sp. 2
- *Aulocystis* ? sp.
- "*Aulopora*" sp. 1
- "*A.*" sp. 2
- *Syringopora* sp.
- unidentified thamnoporoid corals

Thus, some 30 species of corals are present in the upper unit; most of them have not yet been studied and described in detail.

From bottom to top of the unit, coral faunas increase in abundance and variety; the richest faunas are generally found in the upper 100–150 feet of the unit. The solitary Rugosa are not generally conspicuous in fossil assemblages, but they occur locally in great numbers—for example, at the top of the biostromal limestone in section 10 (Spring Creek Canyon).

Disphyllum is widely distributed, either alone or in association with massive Rugosa or tabulates (figs. 24 and 25).

Among the massive Rugosa, *Hexagonaria* and *Pachyphyllum* are the most widely found. *Pachyphyllum* was among the earliest reported fossils of Devonian age in this part of Arizona and was often identified as *Acervularia davidsoni*. (See Reagan, 1903, pl. 30.) This genus also is found with the stromatoporoids in the biostromal facies but occurs commonly also in other coral associations. *Hexagonaria* occurs generally in mixed assemblages in association with other corals and with brachiopods. *Spongophyllum* has been found in section 45 only. According to W. A. Oliver, Jr. (written commun., 1960), the species may be the same as *S. martinense* Stumm of the Martin Limestone of southeastern Arizona.

Among tabulate corals *Thamnopora* is by far the most commonly represented genus, and in many beds it occurs alone (fig. 26). Like *Amphipora*, the branches of *Thamnopora* colonies are seen in many outcrops on weathered surfaces, even on entirely dolomitized rocks. The habitat of the colonies is similar to that of the "Rasenriffe" (meadow or turf reefs) of German literature, which are not reefs but are horizontally extensive dense growths or thickets of branching corals, generally composed of one species. (See, for example, Hotz and others, 1955, p. 64, 76, 95.) Branching tabulate and phacelloid rugose corals formed this kind of biota in Devonian times in many parts of the world.

Thamnopora also appears as a constituent of fossil assemblages in association with other corals and with brachiopods. In some beds such as the top unit at section 1 (Sawmill) and the top subunit in section 18 (south of Turkey Peak) it is the only coral in association with brachiopod assemblages.

Some of the very mixed associations are described on pages 65 and 66.

Bryozoa

Fragments of fenestellid Bryozoa are exceedingly rare in calcitic dolomite or dolomitic limestone. They form a negligible part of the fauna, and no identifiable specimens were collected.

Brachiopoda

The total number of brachiopod species, when properly studied and identified, will almost certainly be found to exceed 20. The most important species in the upper unit of the Jerome Member are the following (identifications by P. E. Cloud, Jr., 1960, or by author and verified by Cloud):

- *Schizophoria iowensis* (Hall)
- *S.* cf. *S. iowensis* (Hall)
- *Nervostrophia* sp.
- *Devonoproductus* cf. *D. vulgaris* Stainbrook
- *Stenoscisma* n. sp. (possibly new genus)
- *Camarotoechia* sp.
- *Atrypa devoniana* var. *bentonensis* Stainbrook
- *A.* cf. *A. pronis* Fenton and Fenton
- "*Atrypa*" *owenensis* Webster
- *Spinatrypa* cf. *S. rotunda* Stainbrook
- *S.* cf. *S. albertensis* (Warren)
- *Platyrachella* cf. *P. mcbridei* (Calvin)
- *Cyrtospirifer whitneyi* (Hall)
- *Tenticospirifer* aff. *T. cyrtinaformis* (Hall and Whitfield)
- *Theodossia* cf. *T. hungerfordi* (Hall)

Brachythyrina aff. *B. strigosa*
Cranaena? sp.

The composition of the brachiopod faunas varies very much from place to place and also from bed to bed in a stratigraphic section. (See p. 52.) Brachiopods are probably the most common fossils in the upper unit of the Jerome Member. In the lower part of the unit, they are generally poorly preserved and have not been collected. In the upper part, brachiopods tend to be more or less completely silicified, and many excellent assemblages have been obtained by dissolving fossiliferous rocks in hydrochloric acid.

Two types of brachiopod assemblages can be distinguished: (1) mixed assemblages in which several species occur together and that as a rule contain associated coral faunas, and (2) restricted assemblages that consist of only one species or of a few species belonging to one genus (for example, *Atrypa* and *Spinatrypa*) and that tend to form coquinoid limestones or true coquinas.

Mixed assemblages generally contain species of several different genera (*Schizophoria*, *Atrypa*, *Spinatrypa*, *Cyrtospirifer*, and others), and the associated corals are commonly *Pachyphyllum* and *Thamnopora*. These assemblages are discussed on pages 65 and 66.

Coquina-type deposits are common in many stratigraphic sections. They consist entirely or predominantly of one species, but their aspect and composition are rather variable from place to place. Coquinas consisting entirely of shells of *Theodossia* cf. *T. hungerfordi* are common in and near the upper Canyon Creek area (section 8, subunit 26; section 12, subunit 44; section 13, subunit 24; section 16, subunit 16). These occurrences are at different levels within the uppermost 80 feet or so of the upper unit. Such coquinas, therefore, seem to be lenticular. Figure 27 shows a typical example. Although many shells have the position convex side down, the orientation is partly random; many shells have the opposite position, convex side up; and others occupy intermediate attitudes. In this type of

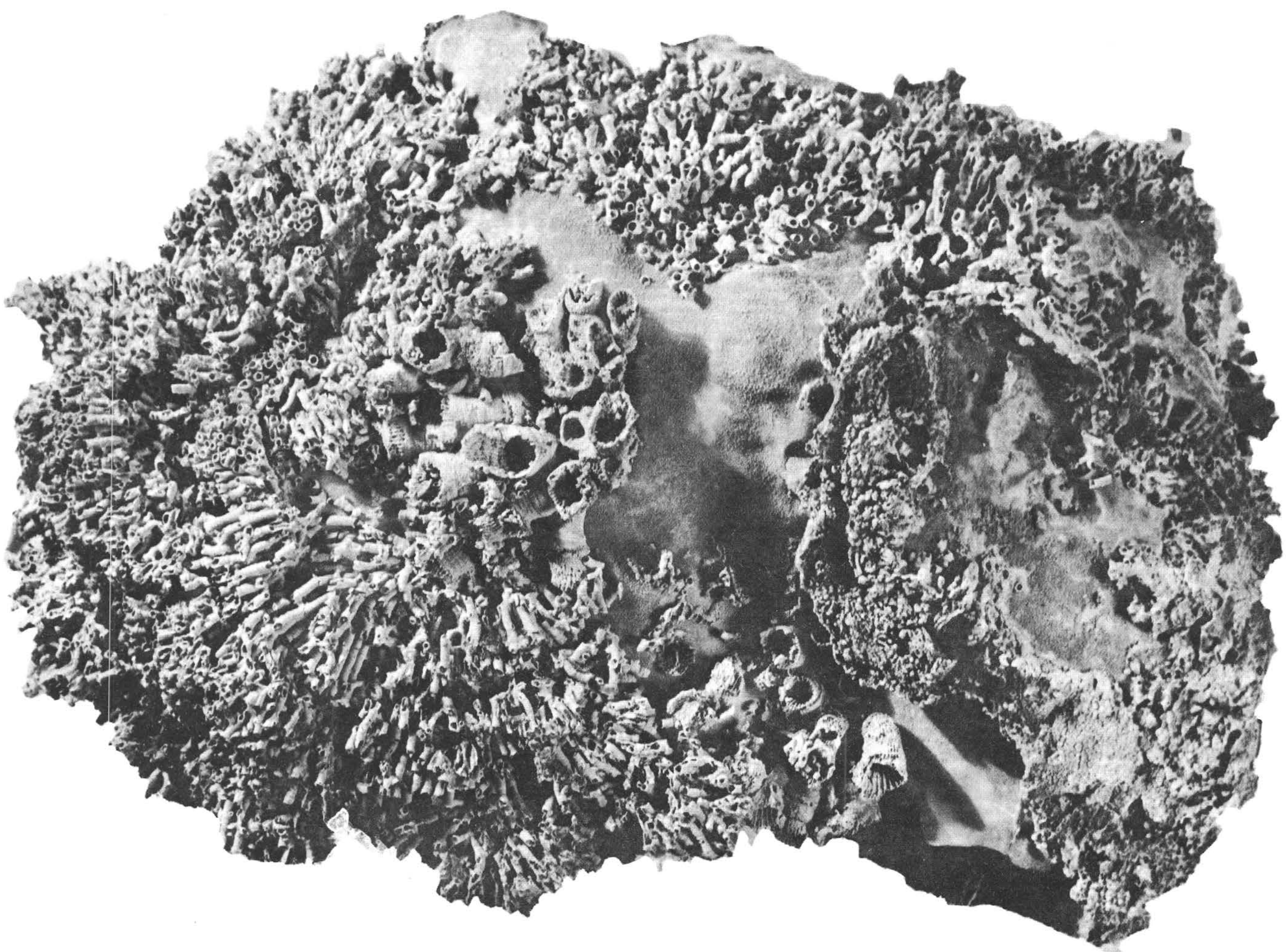


FIGURE 24.—Thanatocoenosis of a massive stromatoporoid (right) and a *Disphyllum* colony (center), surrounded by growth of *Syringopora*, in dolomitic limestone. Section 30, Diamond Point, top of upper unit of Jerome Member (subunit 46). × 0.78. USNM 138890.

coquina, the ventral and dorsal valves of almost all shells have become separated.

In the Roosevelt area coquinas of *Schizophoria iowensis* occur with disarticulated valves more or less in random orientation; most of them have the convex side facing either up or down, though some have intermediate positions (fig. 28).

Coquinas of the type discussed are true taphocoenoses, although the excellent preservation of the shells and their random attitude in the rock suggests that no prolonged transportation has taken place. A feature of these taphocoenoses is that within each the fossils are all of comparable size. Because they came to rest and were buried at no great distance from their original biotope and because, as indicated by the preservation of the shells, only weak currents having little winnowing effect were active, coquina deposits of this type are probably derived from shell banks whose composition did not differ much from that of the coquinas.

A second type of coquina is illustrated by a sample from the top of section 18 (fig. 29); it contains a mixed assemblage in which *Atrypa* and *Spinatrypa* predomi-

FIGURE 25.—Thanatocoenosis of *Disphyllum* sp. and *Aulopora* sp., intricately intergrown, in dolomitic limestone. Section 27, Tonto and Horton Creeks, near top of upper unit of Jerome Member (subunit 19). × 0.51. USNM 138892.

nate, *Cyrtospirifer* is third in abundance, and scattered specimens of *Schizophoria* and a rare *Thamnopora* occur. Individuals are tightly to loosely packed. Both valves of many shells are hanging together, and the valves of some specimens, firmly connected at the hinge, are slightly agape (fig. 30*A* and *C*). The relative position of the valves must have been acquired soon after death, as is the rule in pelecypods. In brachiopods, because of different construction of their hinge apparatus, this condition is less easily understood. In fact, Shrock and Twenhofel (1953, p. 275) stated that "the shells of recently dead brachiopods and of many fossil forms are likely to be closed unless the valves were actually disarticulated or torn apart. This situation is the reverse from that found in pelecypods* * *." However, gaping articulated brachiopod shells, like gaping articulated pelecypod shells, indicate little transportation and rapid burial, and the association discussed here from section 18, therefore, may be assumed to be a true thanatocoenosis. The brachiopods preserved in this rock represent a natural community whose biotope was the place in which it became fossilized.

FIGURE 26.—*Thamnopora* colonies, not in growth position, in calcitic dolomite. Section 32, East Verde River, upper part of upper unit of Jerome Member. × 1. USNM 138893.

Another example of a thanatocoenotic assemblage occurs in the top subunit of section 1 (Sawmill) and consists of large numbers of individual brachiopods representing several species of *Atrypa*. Among them are also articulated, gaping shells (fig. 30*B* and *D*).

A coquina of unique composition, near the top of section 38 (Limestone Hills), consists entirely of tightly packed specimens of *Camarotoechia* sp., *Cranaena* (?) sp., and some *Cyrtospirifer* sp. (fig. 31). The shells are mostly delicate and articulated, and the valves are closed. No appreciable transportation could have taken place, and this rock undoubtedly represents a shell bank in a state very close to its original composition and geometrical arrangement.

Much quantitative work remains to be done on associations of this type, which occur scattered throughout the upper part of the upper unit of the Jerome Member in the entire area investigated.

In impure carbonate rocks and in calcareous and dolomitic siltstones, brachiopod species are fewer than in purer carbonate rocks; in places atrypids alone are present—for example, in the silty facies of the upper unit in sections 2 (Black River) and 35 (Pinal Creek). At Pinal Creek atrypids are associated with *Devonoproductus*, which elsewhere is exceedingly rare. At this locality, most of the valves of both the atrypids and the productids are in articulated, closed position, indicating that their biotope was the silty, muddy bottom that later formed the rock in which the fossils are enclosed.

A comparison of the habitats of important brachiopod genera in the Jerome Member with those of the same genera in Middle Devonian beds of eastern and central United States, as described by Cooper (1957, p. 270), discloses some significant differences. For example, *Atrypa* is characterized by Cooper as a "lover of limy sediments" in eastern America. While this is true for most occurrences of the genus in the Jerome *Atrypa* is also among the few brachiopods that thrived in very silty carbonate mud. *Schizophoria*, on the other hand, in the Jerome is almost restricted to very pure carbonate rocks, whereas in eastern America, according to Cooper, it is uncommon in limestones. The Spirifers, too, are found mainly in carbonate rocks in Arizona, whereas, according to Cooper, they occur in all sediments execpt black shales in the East. Cooper's observations were made over a very much larger area than the present study area and are perhaps of more general validity, but observations in the Jerome show that local environmental influences may produce local paleontological facies patterns.

Mollusca

Fossil mollusca are much less numerous and varied than the brachiopods in the Jerome Member as a whole. A few unidentifiable gastropod remains occur at scattered localities. The only well-preserved molluscan fauna is found in the upper part of the upper unit on Verde River at Sycamore Creek (section 43). It was described by Stoyanow (1949) and consists of the following species:

Pelecypods:
- *Congeriomorpha andrusovi* Stoyanow
- *Tusayana cibola* Stoyanow

Gastropods:
- *Aglaeoglypta maera* (Conrad)
- *Arizonella allecta* Stoyanow
- *Arastra torquata* Stoyanow

This assemblage has not been recognized anywhere else, although *Arizonella* has been doubtfully identified from section 9, subunit 14. The mollusks are associated with the corals *Breviphyllum*(?) sp. and *Hexagonaria* sp., none of which were in growth position. This association is somewhat puzzling. The two pelecypods, both new genera described by Stoyanow, are as yet known only from the type locality. Both clearly have myalinid affinities. They have thick hinges and heavy hinge features such as are possessed more commonly by forms living near reefs or in turbulent water; *Eumegalodon* is a well-known example from such environments in Devonian rocks. The Verde River fauna, however, occurs in saccharoidal dolomite, which most probably represents dolomitized fine-grained limestone. Paleoecological evaluation of this fauna must await further study of its distribution.

Poorly preserved pelecypods were found in sandstone of the upper member of the Jerome Member at Mormon Tank (section 47). They appear to be pteriids, possibly representing *Limoptera* or some related genus. No forms similar to these have so far been reported from Devonian rocks anywhere in Arizona.

Cephalopods are exceedingly rare. One unidentifiable fragment of a straight nautiloid was seen near the top of section 9 (Oak Creek Farm Road), and a tiny specimen of an unidentifiable goniatite was found in a rock from section 2 (Black River), subunit 17 (pl. 18, fig. 2).

Pteropods had not previously been reported from Devonian rocks in western Arizona. Shells, probably

FIGURE 27.—Coquina composed of silicified shells of *Theodossia* cf. *T. hungerfordi* (Hall) and *Cyrtospirifer* sp. cemented by calcitic dolomite. Section 12, Lost Tank Canyon, upper part of upper unit of Jerome Member, subunit 44. × 1.1. USNM 138894.

belonging to *Styliolina*, were recognized in a few thin sections of aphanitic limestone (pl. 13, fig. 1), but no readily identifiable specimens were found.

Ostracoda

Ostracode remains are not uncommon in aphanitic limestones, where their shells are seen in cross section, but the only identifiable assemblage comes from subunit 22 of section 32 (East Verde River) in the top of the aphanitic limestone unit. According to Jean Berdan and I. G. Sohn (written commun. 1960) these ostracodes belong to the genus *Hypotetragona*, which has a range from Middle Devonian to Permian. Further intensive search in the aphanitic limestone facies both of the aphanitic dolomite unit and of the upper unit should yield more diversified faunas.

Echinodermata

Crinoid ossicles, mostly columnals, occur in many limestones and dolomites, although rarely in sufficiently large numbers to justify calling them crinoidal limestones or dolomites. Crinoids apparently were a rather subordinate group in the biotas of the Jerome Member.

Echinoid spines were found in aphanitic limestones of subunit 18, section 38 (Limestone Hills), near the base of the upper unit (pl. 8, fig. 1). The only recognizable remains are small spines, less than 0.5 mm thick. They consist of radially oriented wedge-shaped calcitic elements having uniform crystallographic orientation. Devonian echinoids are rare; none have previously been reported from Devonian rocks in Arizona. The preservation of the specimens is insufficient for generic identification.

Conodonts

The only conodonts so far recorded from the Jerome Member are in section 43, subunit 26, where they occur only 2 feet above a layer containing the unique molluscan fauna discussed above. It should be emphasized

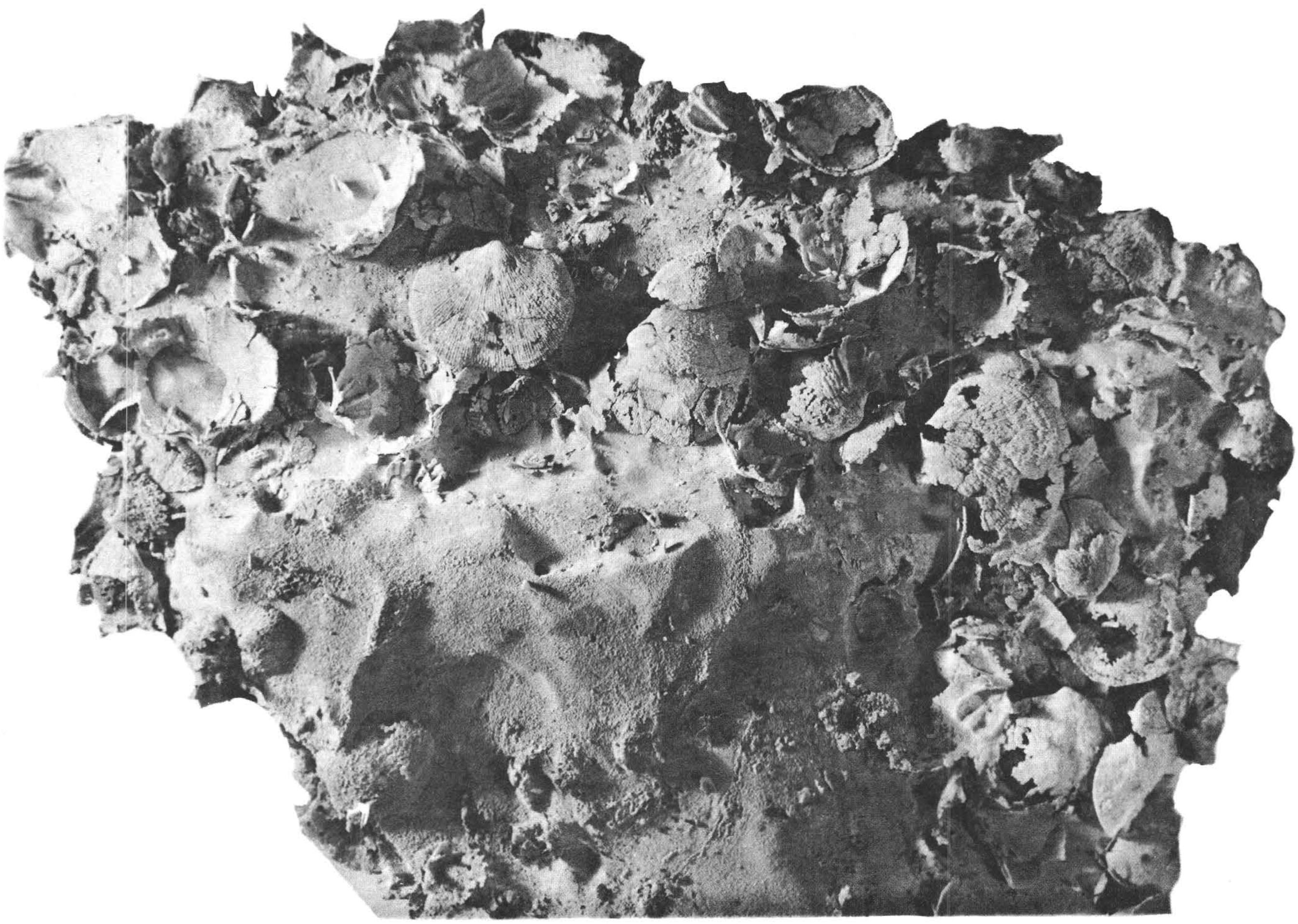


FIGURE 28.—Coquina composed entirely of silicified shells of *Schizophoria iowensis* (Hall) cemented by calcitic dolomite. Upper part of upper unit of Jerome Member, northwest of Theodore Roosevelt Dam. × 0.84. USNM 138895.

that the present investigations did not include a study of the conodonts, but ultimately the rocks of the Jerome Member may yield a good conodont fauna.

Fishes

Fragments of bony plates of armored fishes occur in many places and at different horizons. However, they are generally too incomplete to be identified, and no identifiable fish remains were obtained in the course of the present investigations.

Fish plates, or impressions of them, occur in both sandstones and carbonate rocks. In the upper unit they are perhaps more common in limestones and dolomites than in sandstones.

At Webber Creek (section 31) fish remains are abundant in a silty fine-grained dolomite (subunit 20), a few feet above the base of the upper unit. They were also observed in dolomites and sandy dolomites at Jerome (section 41, subunit 22), Limestone Hills (section 38, subunit 21), Theodore Roosevelt Dam (section 36, subunit 31), Windy Hill (section 37, subunit 18), Pinal Creek (section 35, subunit 10), and elsewhere.

In nearshore deposits fish remains seem to prevail in the basal terrigenous deposits, whereas among strata formed farther out from the coast, they are more common in carbonate rocks. Their fragmentary nature seems to indicate either that they were transported long distances or perhaps that they are the remains of smaller fishes that were the prey of larger ones such as *Dinichthys*. Presence of *Dinichthys* in the Jerome Member at Elden Mountain was first noted by Stoyanow (1936, p. 502) and later confirmed by Hussakof (1942), who described two species which he left unnamed. So far, however, no remains attributable to *Dinichthys* have been recorded from any other locality in the Jerome. The Elden Mountain fish fauna as described by Hussakof is listed on page 44.

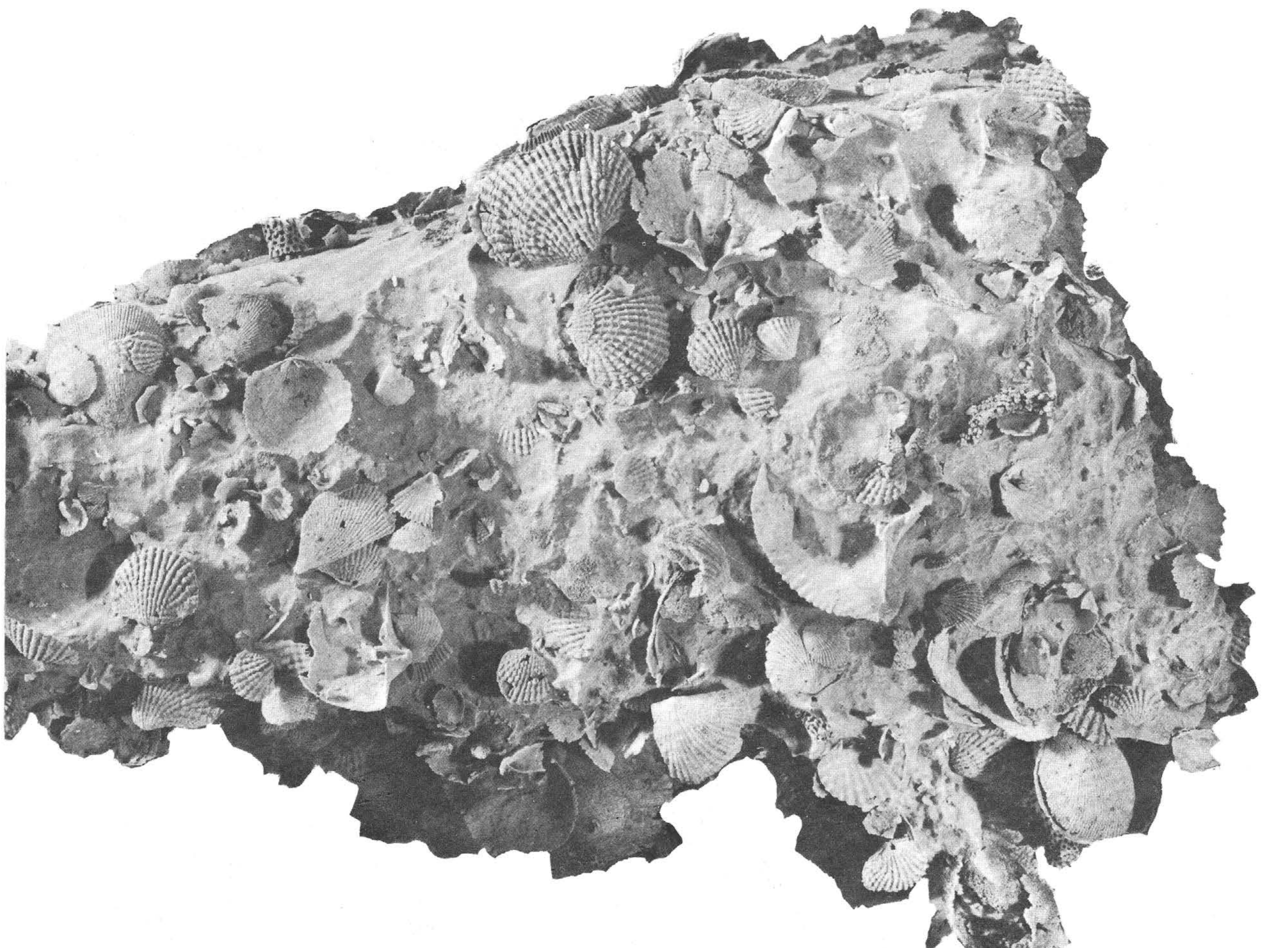


FIGURE 29.—Top view of bedding plane of limestone containing a silicified taphocoenotic assemblage of *Schizophoria* cf. *S. iowensis* (Hall), *Atrypa devoniana* var. *bentonensis* Stainbrook, *Spinatrypa* cf. S. *rotunda* Stainbrook, *Cyrtospirifer whitneyi* (Hall), and scattered *Thamnopora* sp. Section 18, south of Turkey Peak, top of upper unit of Jerome Member, subunit 21. × 0.95.

Calcispheres

Calcipheres, here regarded as of uncertain taxonomic position, are very abundant in aphanitic and finely crystalline limestones; they occur in some limestones in such quantity as to be almost rock forming. (See pls. 15–21.) In dolomitized limestones their forms are commonly obliterated, although "ghost" structures are seen in some aphanitic dolomites. Calcispheres, whatever their nature and affinities, contributed in an important way to the sedimentation of lime muds of the upper unit of the Jerome Member and probably formed the bulk of its original sediment before dolomitization.

Mixed assemblages

The foregoing discussion has emphasized the autecology of individual groups and their relations to characteristic lithologies. The Jerome fauna has been shown to consist of as much as 80 species; not all of them, however, are yet represented by material sufficiently well preserved to permit their formal descriptions.

The following paragraphs present observations on the synecology of some of the more important groups. Data on the occurrence and general composition of fossil assemblages in the stratigraphic sections are presented in easily comprehensible manner in cross sections *A–A′* to *I–I′* (pls. 28–31).

The most common and important associations of megafossils are those of brachiopods and corals. These are extremely common at or near the top of the Jerome Member where they occur in limestones or dolomitic limestones. The assemblages vary somewhat in composition. Among the brachiopods, atrypids predominate almost everywhere. Associated with them may be spiriferids—especially *Cyrtospirifer*, *Platyrachella*, *Tenticospirifer*, and *Brachythyrina*—whereas *Theodos-*

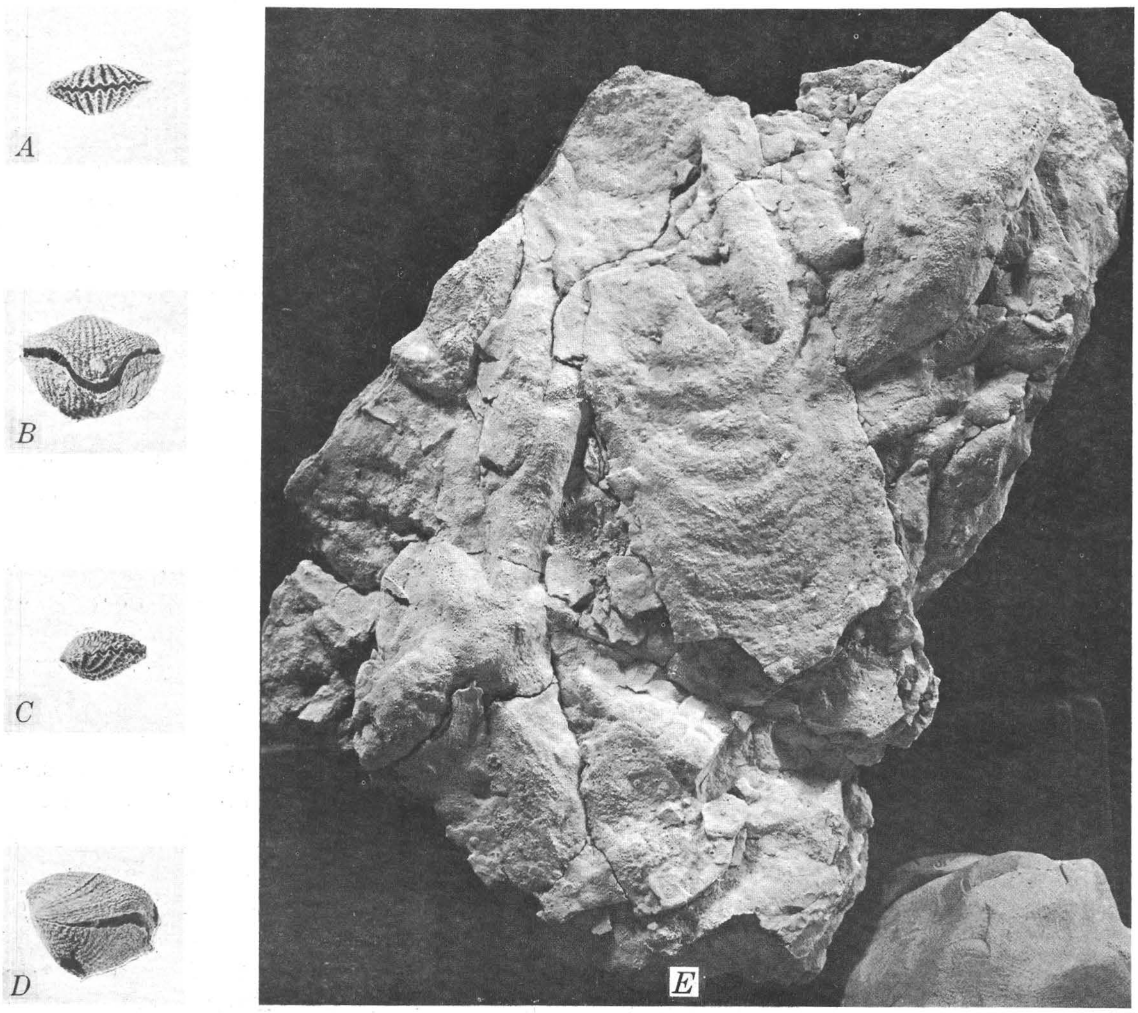


FIGURE 30.—Articulated gaping brachiopod shells as indicators of rapid burial under quiet-water conditions, and *Rhizocorallium* and other burrows. × 1. *A* and *C, Atrypa devoniana* var. *bentonensis* Stainbrook. Section 1, Sawmill, subunit 8. USNM 138897. *B* and *D Spinatrypa* cf. *rotunda* Stainbrook. Section 18, south of Turkey Peak, subunit 21. USNM 138898. *E, Rhizocorallium* and other burrows in uppermost shale of Jerome Member (subunit 31 of section 3). Flying V Canyon, roadcut of U.S. Highway 60.

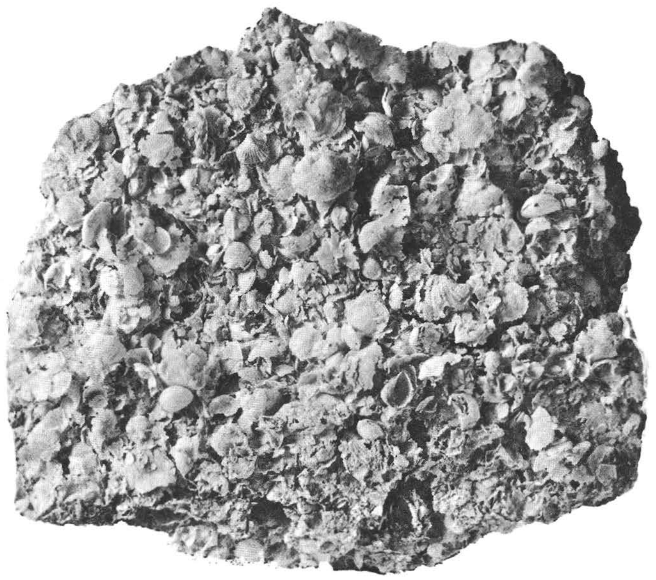


FIGURE 31.—Coquina of silicified shells consisting mainly of *Camarotoechia* sp. and *Cranaena*(?) sp. and containing very little dolomitic cement, which has been dissolved. Section 38, Limestone Hills, top of upper unit of Jerome Member, subunit 34. ×0.50. USNM 138896.

sia tends to be restricted to coquinas. (See page 59.) No typical brachiopod-coral associations ever occur with atrypids, however. Brachiopods may be associated either with tabulate corals only—as in sections 1, 7, 9, 10, 18, 28, 29, and 30, where the predominant associated corals are *Thamnopora* and *Aulopora*—or with rugose corals only—as in sections 8, 9, 32, and 38, where the Rugosa are predominantly *Pachyphyllum* and *Hexagonaria;* they may be also associated with both tabulate and rugose corals—as in sections 7 and 43. Any one of these types of associations is likely to be found either at the very top of the Jerome or at least within the uppermost 100 feet.

The fossils in these associations are everywhere well preserved. Many of the corals are in a growth position; brachiopod shells having articulated but gaping valves occur, as described on page 61. In general, therefore, such fossil associations are either thanatocoenoses or they represent only very slightly transported taphocoenoses.

The biostromes that occur in the upper half of the upper unit of the Jerome Member also are thanatocoenotic assemblages. Their bulk is made up of massive stromatoporoids, which are everywhere associated with varying proportions of corals. By far the commonest type of association consists of stromatoporoids and tabulate corals, especially the genera *Thamnopora* and *Alveolites*. Both these genera contributed to the buildup of many biostromal limestones.

Among rugose corals occupying the biostromal biotope, *Pachyphyllum* is most abundant. *Hexagonaria* also occurs here but tends to be more commonly associated with brachiopod faunas.

In some biostromes all three groups—stromatoporoids, tabulate and rugose corals—are represented, but such occurrences are comparatively rare. (See sections 8, subunit 22; 10, subunit 2; 13, subunit 17.)

Nonbiostromal coral associations are also found and may, in places, have subordinate numbers of stromatoporoids. They occur mostly in calcite dolomite not far below the top of the formation. (See sections 7, subunit 3; 16, subunit 19; and 29, subunit 16.) Coral colonies occur mostly in growth position and are scattered.

Small ostracodes and calcispheres form an important and very uniform taphocoenotic association of a very different type of which many examples are known from the upper part of the aphanitic dolomite unit and the lower part of the upper unit. This association is very characteristic of aphanitic and very fine grained limestone. The possible role of the calcispheres in the formation of some limestones of this type is discussed on page 82. In addition to ostracodes, other accessory fossils found in the assemblage are tintinnids(?), pteropods, and scattered crinoid fragments, and many of the rocks contain large amounts of unidentifiable fossil debris. Limestone bearing the ostracode and calcisphere associations is widespread. (See sections 8, 9, 17, 30, 31, 32, and 34.) Occurrences of calcispheres alone, without associated ostracodes and other fossils, are even more widespread.

Trails and burrows

Trails and burrows are found rarely in the aphanitic dolomite member and more commonly in the upper unit of the Jerome Member.

Simple, slightly sinuous trails occur in the clayey interbeds of the lower part of the aphanitic dolomite unit, where they are difficult to find and to study.

In the upper unit, trails and burrows of various types occur. Straight intersecting trails as much as 4 inches wide occur in shale layers, and in fresh outcrops their casts may be well preserved on the underside of overlying sandstone or dolomite beds (fig. 22).

The uppermost shale subunit of the upper unit on the Salt River shows evidence of intensive burrowing by different types of sediment feeders. The more or less horizontal undulating burrows of varying thickness, some of them having faint scratch marks, are commonest. More rarely, *Rhizocorallium* is found (fig. 30). These are U-burrows of the U-in-U type, which were constructed parallel to the bedding plane and are as much as 3.5 cm wide and probably more than 10 cm long.

Richter (1926) and Seilacher (1953) showed that the animals that constructed the *Rhizocorallium* type of burrows must have been plankton feeders; therefore, the burrows indicate a marine environment because sessile plankton feeders cannot exist under stagnant lacustrine conditions.

The upper shale unit of the upper unit in the Salt River area, thus, indicates a muddy bottom under marine conditions, where the mud below the sediment-water interface was inhabited by large numbers of sediment and plankton feeders that continuously reworked and destratified the sediment.

SOME GROSS LITHOLOGICAL FEATURES OF THE JEROME MEMBER

RELATIONSHIPS BETWEEN DOLOMITIZATION, INSOLUBLE RESIDUE, AND TOTAL CARBONATE CONTENT

Some significant facts about the gross lithology of the carbonate rocks of the Jerome Member are shown in figure 32. The diagrams represent characteristic, widely spaced stratigraphic sections; the three units are complete in all but one section (No. 34). On the diagrams the MgO percentage of total carbonate has been plotted against total carbonate percentage of the rock. To the value for total carbonate, 2–3 percent of other solubles should be added in order to obtain a more accurate percentage of HCl insolubles.

745-106 O—64——4

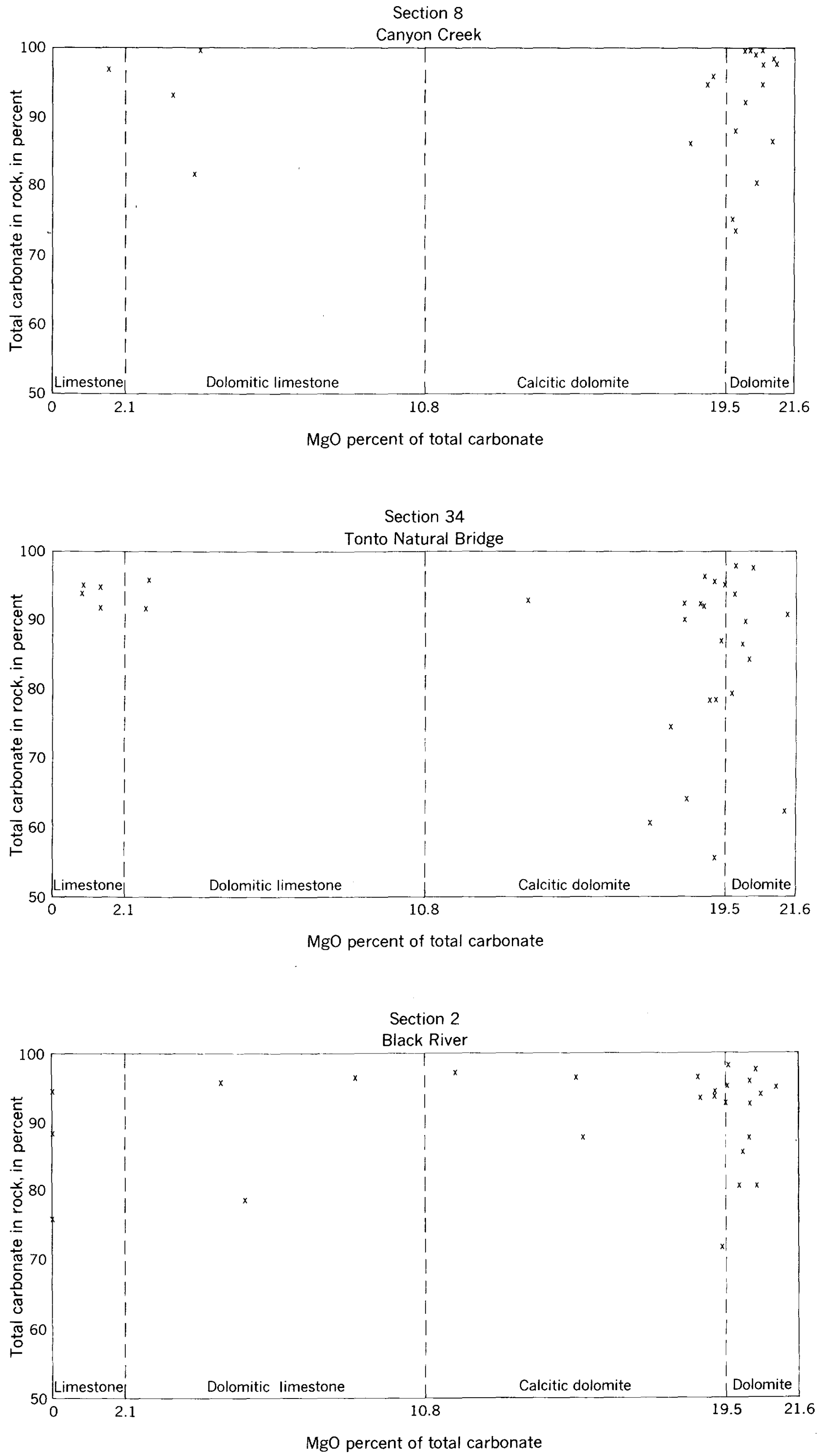
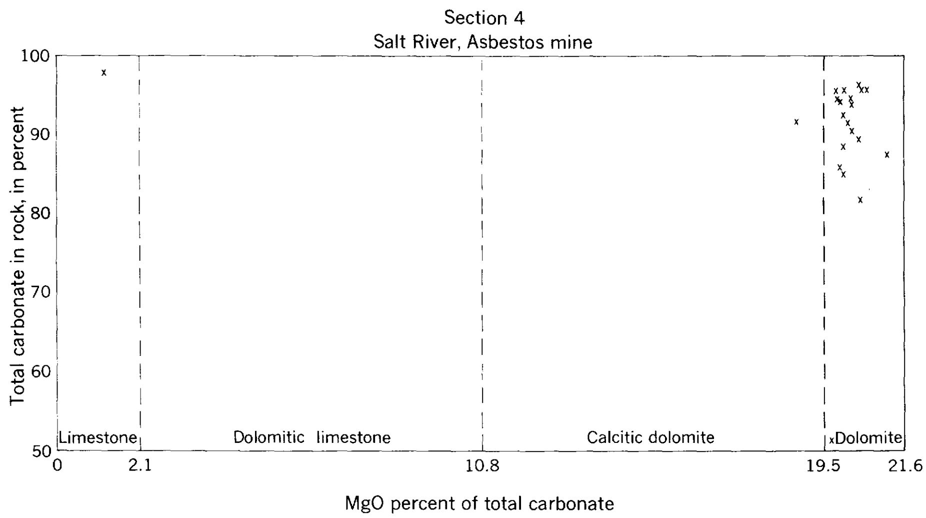
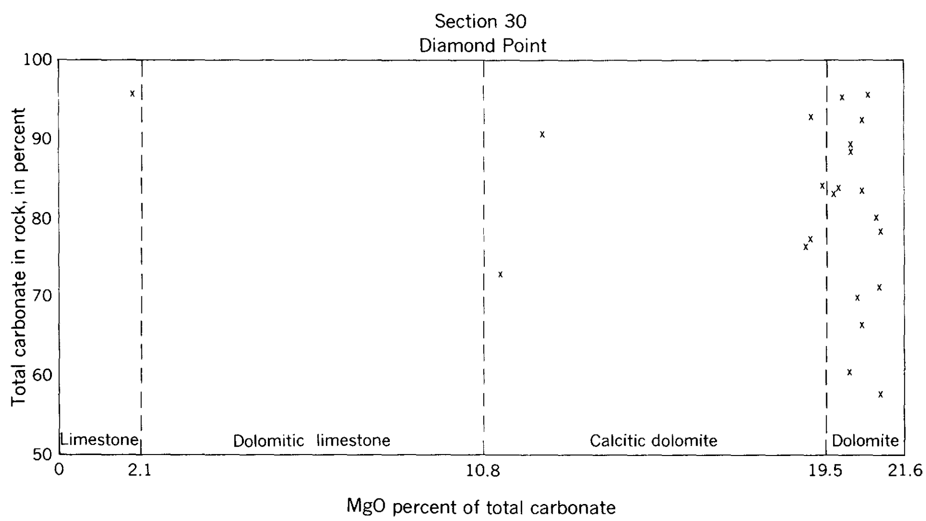
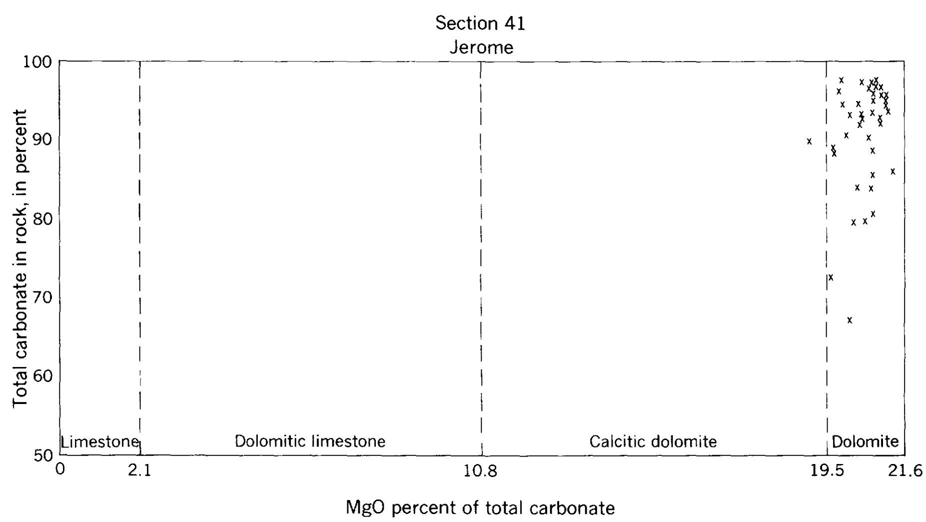


FIGURE 32.—MgO percent of total carbonate plotted against total carbonate percent of rock for samples from six typical sections







of the Jerome Member. The noncarbonate component comprises siliceous-detrital material ranging in grain size from sand to clay.

The following important facts can be read from the diagrams: (1) the predominating rock type is a dolomite containing less than 20 percent insolubles; (2) limestones and slightly dolomitic limestones tend to have less than 10 percent insolubles; and (3) intermediate rock types—highly dolomitic limestones and highly calcitic dolomites—are rare, and values for most calcitic dolomites are clustered close to those for the lower limit of dolomite (19.5 percent MgO).

Almost all the carbonate rocks at the typical section of the Jerome Member are pure dolomites containing less than 20 percent insolubles, and of these most contain less than 10 percent insolubles. The carbonate rocks at section 4 on the Salt River are very similar to those at the typical section; the sections differ only in the presence of one pure limestone and one very impure dolomite subunit at section 4. All other rocks are dolomites containing less than 20 percent insolubles.

The Black River section (No. 2) has more intermediate rock types (very dolomitic limestones and very calcitic dolomites) than do any of the other sections. Here, 6 out of 26 subunits are composed of rocks of this type.

Canyon Creek (section 8) is another typical section in which intermediate carbonate types are lacking. At Diamond Point (section 30), nearly half the dolomites have more than 20 percent insolubles, but as indicated in plate 22, almost all the impure dolomites are found in the upper unit.

The proximity of Tonto Natural Bridge (section 34) to Pine Island, a short distance to the north, is indicated by the high percentage of dolomites containing more than 20 percent impurities. The dolomites contrast strangely with a small cluster of very pure limestones and very slightly dolomitic limestones that are scattered throughout the section. The gross pattern of dolomitization in this section differs somewhat from that in other localities, because most of the dolomites have less than 19.5 percent MgO and must be classed as slightly calcitic dolomites.

The foregoing discussion, as well as further study of the curves for total carbonate and MgO percentages of several additional sections (pl. 22), shows no close correlation between the degree of dolomitization and the insoluble content, except that almost all limestones and slightly calcitic dolomites have less than 10 percent insolubles, whereas dolomites, at least in places, contain a much wider range of impurities. A distinctly greater proportion of impure than pure calcium carbonate rocks are dolomitized. However, the large number of fairly pure dolomite excludes any generalizations.

Rather surprisingly, a crude positive correlation seems to exist between total carbonate content of a rock and its MgO percentage; pure carbonate rocks are generally more highly dolomitized than impure ones. However, a more detailed examination indicates that the relations are not simple.

For example, at the typical section of the Jerome Member (pl. 23), all but one of the dolomites contain more than 19.5 percent MgO. A general parallelism between the curves indicating total carbonate content and those indicating MgO percentage exists for values of rocks throughout a considerable part of section 41, from subunits 4–31. Notable exceptions are for values of samples from subunits 7 and 27. In marked contrast are the curves of the values for the uppermost part of the section—subunits 32–37. Here the correlation is reversed—lower total carbonate corresponds to high MgO percentages, and vice versa. Interestingly, this reversal of the carbonate–MgO relations coincides with one complete insoluble residue cycle—cycle 9. These cycles are discussed on pages 71 and 72.

Other sections in which total carbonate content and MgO percentage show a rough positive correlation are sections 4 (Salt River asbestos mine), 18 (Turkey Peak), 19 (Christopher Mountain Ridge), 26 (Doubtful Creek), and 36 (Theodore Roosevelt Dam) (pls. 22 and 23). In all these sections, dolomite dominates almost or entirely to the exclusion of limestone or even calcitic dolomite. In sections where all three units of the Jerome Member are present, the parallelism between the trend of the total carbonate content and the MgO content is generally somewhat more pronounced for values from the lower two units, whereas, in the upper unit this trend is reversed in many places; sections 4 (Salt River asbestos mine) and 41 (Jerome) indicate these relations for the three units.

Where the upper unit is more or less pure dolomite, the conformity of the two concentrations is generally very great, as indicated, for example, by sections 18 (Turkey Peak) and 26 (Doubtful Creek). Detailed comparison of the concentrations reveals reversals of the trends in some subunits—for example, at the top of section 18.

Where limestone subunits are present in a section, the relations are less consistent and trends are lost. Thus, in section 19 (Christopher Mountain Ridge), where two limestone beds occur near the top, the lower bed consists of 100 percent pure carbonate whereas the upper one has about 35 percent insolubles. Similar conditions exist in section 2 (Black River).

In carbonate rocks of the Arbuckle Group of Late Cambrian and Early Ordovician age, Dunbar and Rodgers (1957, p. 223–224) found "a tendency for mixed rocks to be more impure." On the basis of analyses published by Decker and Merritt (1928), they showed that limestones and high-magnesium-dolomites of the Arbuckle Group are relatively pure, whereas dolomitic limestones tend to have impurities ranging from 10 to 50 percent. Their results are comparable with those of Steidtmann (1917, p. 437), who, on the basis of analyses of 1,148 carbonate samples, concluded that intermediate limestone-dolomite rocks averaged higher in insoluble residues than either pure limestones or pure dolomites. Such relationships do not exist in the Devonian carbonate rocks of Arizona.

On the other hand, on the basis of analyses published by Lesley (1879) for Lower Ordovician corbonate rocks of Pennsylvania, Fairbridge (1957, p. 155–156) and Dunbar and Rodgers (1957, p. 223) demonstrated that a positive correlation exists between the amount of impurities and the degree of dolomitization. Bisque and Lemish (1959) found the same relations in limestones of the Cedar Valley Limestone of Iowa. However, no pure dolomite occurs among the samples used by Dunbar and Rodgers. Almost all the samples had less than 10 percent insolubles. The rocks studied by Bisque and Lemish were mostly low magnesium carbonates containing a maximum of about 15 percent MgO.

The same relations were noted and discussed also by Amsden (1960, p. 16–20) for carbonate rocks of the Silurian and Devonian Hunton Group of Oklahoma, although significant exceptions were mentioned. The rocks of the Hunton Group are even lower in magnesium than those studied by Bisque and Lemish. They are composed predominantly of limestone, magnesian limestone, and some slightly dolomitic limestone. Amsden suggested that the apparent correlation between HCl insolubles and magnesium content "might be explained under a hypothesis of 'secondary' origin by assuming that the argillaceous and silty calcilutites of the Hunton were more susceptible to dolomitization." Amsden believed that dolomitization occurred possibly at some time after the deposition of the Hunton Group and was possibly the type of "continental dolomitization" discussed by Fairbridge (1957, p. 153), although magnesium may have been introduced into the rock from the outside.

In comparing the relations of insolubles to magnesium content in the Jerome Member with the relations described by Dunbar and Rodgers, Bisque and Lemish, and Amsden, it must be remembered that in the Jerome dolomites high in magnesium content predominate. These relations may have a bearing on the problem of dolomitization (discussed on p. 85).

A situation somewhat similar to that in the Jerome Member seems to exist in the Lower Ordovician Ellenburger Group of Texas. Chemical composition and insoluble residues of 75 carbonate rock samples were analyzed by Goldich and Parmelee (1947) and, as Graf (1960, p. 25) pointed out, no evident correlation between dolomite content and insoluble residue percentage exists in these rocks. Just as in the Jerome Member, the Ellenburger rocks studied by Goldich and Parmelee were predominantly either limestones or high-grade dolomites; only a few intermediate types were represented.

INSOLUBLE-RESIDUE CYCLES IN CARBONATE SEQUENCES

The insoluble residue of the carbonate rocks consists of sand, silt, and clay. Mechanical analyses of the residues from several stratigraphic sections have revealed a pronounced rhythmicity in grain size distribution (pl. 23). The pattern is most clearly seen in section 41 (Jerome), which represents a virtually pure carbonate facies.

The section (pl. 23) can be divided into 10 divisions in such a manner that each division has as its base a rock unit containing a relatively coarse residue. Upward in each division, the residue is progressively finer, and near the top only clay, and locally some silt, is present. These divisions will be referred to as insoluble residue cycles. Thicknesses of individual cycles are remarkably uniform throughout the middle part of the section but are more variable in top and bottom parts of the formation (table 4).

TABLE 4.—*Thickness, in feet, of insoluble residue cycles in the Jerome Member (section 41)*

Cycle	Thickness	Cycle	Thickness
1	21	6	40
2	19	7	46
3	86	8	44
4	45	9	96
5	42	10	32

Cycle 1 is not typically formed in this locality, but too little information is available on other localities to make valid comparisons. This cycle corresponds wholly or at least in major part to the fetid dolomite unit.

All other cycles show a typical grading of insoluble residue from bottom to top. Most boundaries between cycles seem to coincide with boundaries of rock units as recognized in the field. However, it is not possible to be positive about this observation, because sampling was done with no thought of insoluble residue cycles.

The rock succession of cycle 4 is interrupted halfway by a 2-foot sandstone bed, the so-called red marker bed. Its presence does not seem to influence the grading of the insolubles in this cycle; but here again, this conclusion might have been modified if samples had been taken closer to the sandstone bed.

A comparison of the distribution of insoluble residue cycles with the total carbonate curve indicates a certain correlation between the quantity and the coarseness of residue—that is, the less pure the rock, the coarser the residue. (See cycles 4, 5, 8, and perhaps 9.) However, the relation is not clear cut. In cycle 4, for example, the three well-graded samples come from rocks containing very nearly equal amounts of insoluble residue, and in cycle 2, the relationships are very irregular.

A very clear correlation between the amount and the coarseness of insoluble residue exists in the two cycles found in the fragmentary Elden Mountains section (section 44) (pl. 23).

At the extreme opposite end of the area of investigation, information on residue cycles is available from sections 2 (Black River) and 4 (Salt River asbestos mine). The most complete sample coverage exists for section 4. Here the first cycle (1) seems to extend from the fetid dolomite unit into the base of the aphanitic dolomite unit. A sandstone bed (unit 9) very neatly divides the insoluble residue cycles 2 and 3. Conditions in cycle 5 are peculiar because of the great diversity of its rocks, which are composed of siltstone, dolomite, and limestone. In spite of interruptions by two thick siltstone beds and a change from dolomite to limestone upward in this cycle, the insoluble residues show good grading. In almost all cycles, some degree of correlation exists between the amount and the coarseness of residue. This correlation seems to be more consistent at Salt River than at Jerome.

In section 2 (Black River) the first cycle seems to coincide with the fetid dolomite unit, although more information is needed to establish this relationship. It is followed by two good cycles in the aphanitic dolomite unit. The upper unit consists mostly of siltstone, but it has one good cycle in carbonate subunits 9, 10, and 11.

The histograms depict relative amounts of residue having various size ranges within a sample. Variations of absolute amounts from sample to sample can be estimated by simultaneously comparing the histogram with the corresponding total-carbonate curve. The variations in absolute amounts of material within each individual size class are unimportant, because in every sample the power of the transporting agent is indicated more by size of the largest detrital grains than by the quantity. This point has been well explained by Carozzi (1950, 1951) in the discussion of his concept of the clasticity index (*indice de clasticité*), which is determined by the maximum diameter of detrital grains. Successive clasticity indices indicate variations in time of the power of the transporting agents without regard to factors of depth or distance from the coast (Carozzi, 1950, p. 5).

The cycles of graded insoluble residues should not be confused with graded bedding in limestones, as recently described by Kuenen and Ten Haaf (1956) and by Aubouin (1960), or with carbonate-rock cycles, as described from the Mississippian Redwall Limestone by McKee (1960).

Lacking information on insoluble residue cycles from much more closely and evenly spaced control points, we cannot know conclusively if and how these cycles are correlative and whether their presence in a stratigraphic section reflects local conditions or the action of regional causative factors.

Similar insoluable residue cycles seem to have been found by Wanless and others (1957) in Ordovician limestone sequences of Iowa, Illinois, and Indiana. The authors reported the presence of "nine cycles of abrupt coarsening of quartz grains, followed by gradual decrease in grain diameter" in four sections of the Platteville Limestone in these States. Wanless and others interpreted the cycles as indicating bathymetric changes, "suggesting widespread contemporaneous shifts in sea level."

To consider tectonism to be a causative factor in the formation of the insoluble residue cycles in the Jerome Member would be open to doubt, mainly because the cycles are not clearly correlated with other lithologic changes and are not influenced by sporadic intercalations of other terrigenous sediments such as sandstone beds. Whereas the intercalation of a sandstone bed in a sequence of carbonate rocks indicates that some sudden change occurred in the conditions in the source area or in the transportation pattern of the sediments, the insoluble residue cycles seem to reflect major environmental changes. Such changes, therefore, are more likely to have operated in the source area than in the sedimentation medium, and the insoluble residue cycles, for instance, may have been caused by long-range cycles in precipitation. Such an hypothesis might help to explain the unequal thickness of the cycles in stratigraphic sections composed predominantly of carbonate rocks, which were deposited probably at a relatively uniform rate.

LUSTER MOTTLING

"Luster mottling" is a term that has long been applied to certain calcareous sandstones in which the detrital quartz grains are enclosed in an aggregate of fairly large calcite crystals generally a centimeter or more in diameter. Such rocks are also variously referred to as "crystal sandstone" or "sand calcite"; they have been called "Fontainebleau sandstone" by Australian authors because luster mottling is characteristic of the Oligocene Fontainebleau Sandstone of the Paris basin (Woolnough and Somerville, 1925, p. 81; Clarke, Prider, Teichert, 1955, p. 165).

One of the best discussions of this rock texture is by Sweeting (1925, p. 413–415) in his description of the megascopic appearance and microscopic characteristics of the "Tilgate Stone," a calcareous "grit" of Cretaceous age occurring in Sussex. Sweeting stated that "the quartz occurs in closely packed minute fragments poikilitically enclosed in well defined areas of calcite which are optically continuous." Lapparent (1923, p. 81) referred to the texture itself as "poecilitique."

Luster mottling in calcareous sandstones is due to recrystallization of the calcareous matrix and is an end result of long continued grain growth of the calcite crystals. The term is here used also in describing rocks that consist of clusters of calcite or dolomite crystals having parallel optical orientation within each cluster but in which individual smaller crystals have retained their identity. Megascopically, the appearance of such rocks is the same as that of "crystal sandstone," because the light is reflected from the crystal clusters in the same manner as from one crystal surface.

Among rocks of the Martin Formation, luster mottling is found not only in sandstones but also in limestones, dolomites, and carbonates of intermediate type. The only previous reference to luster mottling in a carbonate rock seems to be by Khvorova (1958b, p. 263, pl. 30, fig. 4), who described this type of texture in a partly dedolomitized (calcitized) dolomite.

Typical calcite sandstone occurs in the upper unit of the Jerome Member (pl. 14, fig. 5). Quartz grains are embedded in a rather turbid variety of calcite, which is arranged in units that have a somewhat irregular outline and are as much as a few centimeters in diameter; each calcite unit has uniform crystal continuity.

The carbonate rocks having luster mottling are of several different types and compositions. Plate 14, figure 4, illustrates a slightly sandy carbonate rock in which optically continuous calcite is arranged in large areas enclosing dolomite rhombohedra having random optical orientation.

There is evidence that rocks of this type are in a state of dedolomitization. Although many dolomite rhombohedra have well-defined euhedral shapes, others have irregular outlines; the marginal parts of many seemingly euhedral dolomite crystals have been replaced by calcite and are in optical continuity with the surrounding calcite matrix, although the original outline of the dolomite crystal is still visible.

Not all luster-mottled carbonate rocks are of the type just described, because luster mottling is also present in pure dolomites and in pure limestones. An example of luster mottling in a dolomite is illustrated in plate 10, figure 2. This rock consists of partly interpenetrating clusters of dolomite crystals that are in identical optical orientation within each cluster. The same kind of texture in a limestone is shown in plate 14, figure 1. In the rock the individual crystals are much smaller than those in the dolomite; so each cluster consists of a much larger number of optically identically oriented crystals.

The genesis of luster mottling in carbonate rocks is difficult to understand, especially why, since the mottling occurs at all, it is not more common. The occurrence of luster mottling as part of a dedolomitization pattern as well as in otherwise very ordinary dolomites and limestones indicates that more than one mode of origin in the rocks occurs. All such rocks apparently must have a complicated diagenetic history.

SILICEOUS DETRITAL ROCKS

The siliceous detrital rocks were not studied in detail Their regional distribution is discussed on pages 92 and 93, but their petrography is briefly discussed here.

Most siliceous detrital rocks of the Jerome Member are fine-grained and very fine grained sandstones and siltstones (pl. 24). The sandstones are generally clean well-sorted quartz sandstones (pl. 5, fig. 6) containing varying amounts of calcareous or dolomitic cement and having generally rounded to subrounded grains. Cross-bedding is not conspicuous, but invertebrate tracks on bedding planes are relatively common. In all these features the sandstones of the Jerome contrast sharply with the rocks of the Beckers Butte. However, poorly sorted sandstones having subangular quartz grains also occur in the Jerome. Most of them are very calcareous, and the angularity of grains is at least partly the result of diagenetic processes.

Two features of the sandstones of the Jerome Member deserving special attention are the common occurrence of overgrowth on grains and the less common occurrence of sutured grain contacts. That these two phenomena are closely interrelated has been demonstrated by Siever (1959) and Thomson (1959), both of whom also discussed the geochemical implications.

Good examples of overgrowth in sandstones of the Jerome Member are shown on plate 12, figure 5, and sutured grain contacts are shown on plate 9, figure 5; plate 13, figure 5; and plate 15, figure 1. A combination of both phenomena is seen in the specimen illustrated on plate 10, figure 5. Solution of silica may lead to very tightly packed grain aggregates in which all grains have lost their original form. Plate 15, figure 1, shows a sample in which the surface of a larger chert granule has been indented by the surrounding very small quartz grains, producing a series of concavo-convex contacts. Grain contacts are either long, concavo-convex (in the terminology of Taylor, 1950), or sutured. Taylor (1950) studied sandstones of Jurassic and Cretaceous age from the subsurface in Wyoming and found that sutured contacts formed first in rocks found in wells at depths between 4,535 and 6,832 feet. No sutured contacts occurred in sandstones buried at depths of less than about 4,500 feet. Long grain contacts were most common in rock at a depth of about 4,535 feet and were progressively more scarce with increasing depth.

The occurrence of sutured grain contacts in the sandstones of the Jerome Member follows no recognizable pattern. Such contacts are most common in the upper unit and are found in sandstones in both the lower and upper parts of that unit. As is discussed on page 81, none of these rocks were ever buried beneath more than about 3,000 feet of younger rocks. Sutured grain contacts, therefore, can form under pressures less than those found by Taylor. The erratic occurrence of sutured grain contacts is perhaps better understood in the light of observations by Heald (1956, p. 22–23), who suggested that the degree of pressure solution is positively related to the clay content of the matrix.

It should be pointed out that descriptive terms for angularity of grains in sandstones of the type here described are meaningless because such terms refer to diagenetically acquired features of the grains. In many rocks the original shape of the grains at the time of deposition cannot be estimated. A clear distinction, therefore, should be made between sedimentary or primary grain contacts (the tangential contacts of Taylor) and diagenetic or secondary grain contacts which may be long, concavo-convex, or sutured.

The upper unit of the Jerome Member, especially along the onlap belt and in the southeastern part of the study area, contains many very sandy carbonate rocks, including all gradations to highly calcareous or dolomitic sandstones. The rock illustrated in plate 14, figure 3, has the megascopic appearance of a fine-grained sandstone. Microscopically it has a matrix composed of very fine grained limestone and many aphanitic limestone clasts. Apparently, considerable autochthonous carbonate sedimentation occurred at this place while a considerable amount of fine-grained quartz sediment was being supplied from an outside source.

Heavy-mineral analyses were obtained from only a few samples of sandstone in the Jerome Member, chiefly to find possible differences in heavy-mineral content between these sandstones and those of the Beckers Butte Member. Two diagrams (fig. 33) show the occurrence and range of heavy minerals in the Beckers Butte and in sandstones of the Jerome in two typical stratigraphic sections. The percentage distribution of the five most common minerals also is shown on the left side of the diagrams. The only significant difference between the two sandstones is the more abundant tourmaline in the upper unit of the Jerome. This greater abundance may indicate a possible change of source area, a suggestion that is consistent with the paleogeographic evolution of the area.

TEXTURE OF APHANITIC CARBONATE ROCKS

INTRODUCTION

Aphanitic carbonate rocks are important constituents of the Jerome Member. They are widely distributed in the aphanitic dolomite unit and, to a lesser extent, in the upper unit. Whereas aphanitic limestones have been studied by geologists in many parts of the world, aphanitic dolomites have received little attention. Both rock types occur in the Jerome. Their megascopic appearance is either similar or identical; they look very much alike when examined with a petrographic microscope, but electron micrographs revealed significant textural differences between different types of rock.

The nature and origin of aphanitic limestones and, to a lesser extent, of aphanitic dolomites have been much discussed in geological literature from Walther (1904) to Hadding (1958b), but the discussion remained largely speculative because little was known about the textures of these rocks. A variety of terms has been used to describe the rock type, as well as its texture.

Cayeux (1935), as others before him, described the rock type as lithographic and sublithographic and its texture as cryptocrystalline. Barnes and others (1945) used the terms "lithographic" and "sublithographic" for such textures, and Strakhov (1958a) and other Russian authors used the term "pelitomorphic." The term "dense," once more popular for these rocks, now seems to be generally discredited (Rodgers, 1954, p. 230). Folk (1959) called the texture of aphanitic limestones microcrystalline and broke this category down into very finely crystalline (grain size 3.9–15.6 microns) and aphanocrystalline (grain size less than 3.9 microns).

According to Tyrrell (1950), a rock texture should be called microcrystalline if individual crystals can be distinguished only with the aid of an optical microscope; the term "cryptocrystalline" is used when individual crystals are too small to be distinguished under the microscope. The term "aphanocrystalline" of Folk, thus, is largely synonymous with cryptocrystalline as defined by earlier authors.

Kindle (1923) proposed the term "vaughanite" for "fine-textured limestones * * * which contain few fossils * * * and break with a more or less conchoidal fracture." Although lithographic limestones are included in this category, Kindle suggested that this term should not be used for the rock type as such because relatively few vaughanites meet the qualifications for lithographic limestones. Kindle suspected that vaughanites represent lithified calcareous muds of the type named "drewite" by Field (1919).

Aphanitic limestones were, by implication, included in Grabau's (1913) hydrocalcilutytes, or calcilutytes, now more commonly referred to as calcilutites. (See,

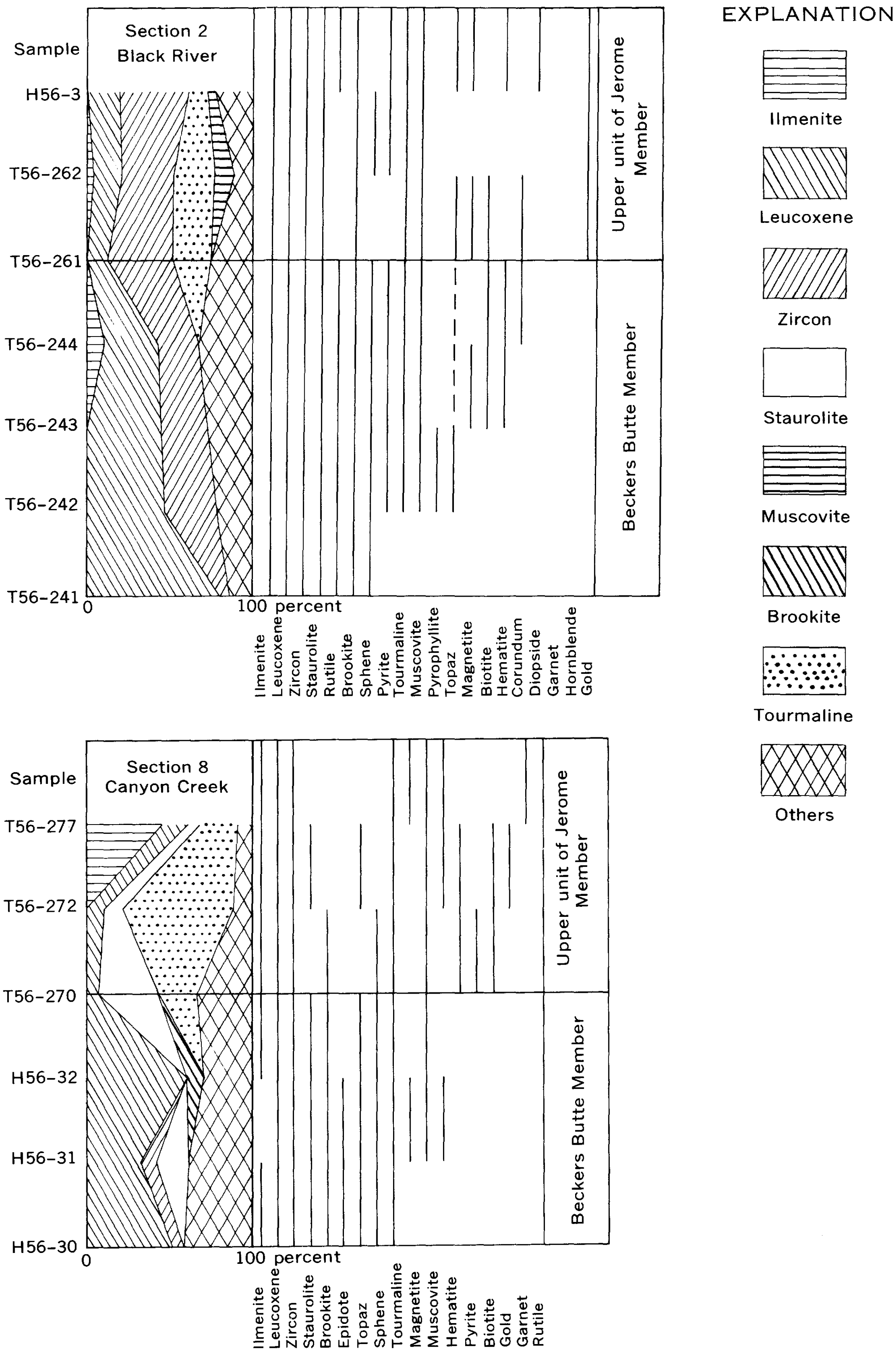


FIGURE 33.—Distribution of heavy minerals in the sandstones of two typical sections of the Martin Formation. The left column of each diagram gives percentage distribution of the five most common minerals in successive samples; the right side represents the vertical range of all heavy minerals.

for example, Pettijohn, 1957, p. 408–409.) The "micrite" of Folk (1959) is by definition a limestone composed almost entirely of calcite grains 1–4 microns in diameter. It includes not only calcilutite and aphanitic limestone but also chalk. In the terminology of Hatch, Rastall, and Black (1938), aphanitic carbonate rocks are included in the categories of calcite mudstone and dolomite mudstone.

Instead of employing terms that are either ill-defined (vaughanite), imply origin (calcilutite, pelitomorph) have technological use (lithographic), or are too broad in meaning (micrite), I refer to these rocks as aphanitic carbonate rocks, which if necessary may be further divided into aphanitic limestones, aphanitic dolomitic limestones, aphanitic calcitic dolomites, and aphanitic dolomites. The texture of aphanitic carbonate rocks can be called cryptocrystalline if the rocks are composed of crystals or crystalline particles of submicroscopic size. The particles are generally less than 5 microns in diameter. If the crystalline nature of the aggregate cannot be established with certainty, a more neutral term such as "ultra-fine-grained" is more appropriate.

Megascopically, aphanitic limestones and dolomites have a homogeneous, smooth appearance, and under the hammer they break characteristically with a well-defined conchoidal fracture (fig. 13). They are typically thin to medium bedded, and their color ranges predominantly from dark medium to very light gray, although pinkish and orange hues also occur. Megafossils are generally scarce or absent. Among microfossils, ostracodes, Foraminifera, and calcispheres are locally present. Detrital quartz ranging in size from silt to medium grained locally forms a not insignificant constitutent (fig. 13).

In most aphanitic carbonate rocks, no sedimentary structures are visible, but some rocks have recognizable pelletal, clotty, calcarenitic, or brecciated structure. (See description of rocks of the aphanitic dolomite unit). These pellets, or clasts, also consist of aphanitic carbonate rock but generally differ slightly in shade of color.

In conventional petrographic thin sections, an aphanitic rock, with the exception of the pelletal and clastic types, appears as a homogeneous film, suggestive of an isotropic substance. It shows no extinction between crossed nicols but appears somewhat darker than when viewed in unpolarized light. Even high enlargement does not lead to a resolution of the image, because the average particle size of the rock is significantly smaller that the thickness of a standard petrographic thin section. At any one point on such a thin section, from 6–60, or even 100, discrete particles of different crystallographic orientation may be superimposed.

As to the origin of aphanitic carbonate rocks, Pettijohn (1957, p. 309) called this, with considerable justification, "a moot question." Aphanitic limestones have been variously interpreted as chemical precipitates, as results of the action of bacteria or algae, or as extremely finely clastic rocks, comparable to claystone that were transported either by water or by wind. This largely speculative discussion is not reviewed here. The origin of aphanitic dolomites has been discussed in recent Russian literature (Vishnyakov, 1951; Strakhov, 1958a; Rukhin, 1958; and others), where the tendency seems to be to regard them as primary precipitates.

ELECTRON-MICROSCOPE INVESTIGATIONS

To find new clues to the question of the origin of aphanitic carbonate rocks, their texture must be studied in greater detail than is possible under the petrographic microscope; accordingly, several such rocks were studied with an electron microscope. This tool has so far had little application in the study of carbonate rocks, apart from the work of Kabelac (1955) and of Seeliger (1956); these authors published two small electron micrographs of an Upper Jurassic "Splitterkalk" from South Germany. More recently, d'Albissin (1959) used electron micrographs to study the effects of deformation on aphanitic limestones in small-scale folds.

The rocks selected here for study are aphanitic limestones, magnesian limestones, dolomitic limestones, very slightly calcitic dolomites, and dolomites, all of Devonian age, from various localities in central Arizona. John C. Hathaway of the U.S. Geological Survey prepared replicas of fresh rock surfaces for examination under the electron miscroscope and described the method used as follows (written commun., 1959):

> Fragments of each sample were mounted on glass slides with acetate cement so that one fractured surface was parallel to the slide. The surfaces were then shadowed with platinum at angles from 30 to 60 degrees. Carbon was then evaporated vertically on the surface to form the replicas. Each surface was given a coat of wax to protect the carbon film during removal of the rock by solution in concentrated HCl. When effervescence ceased, the replicas were transferred to 48 percent HF and allowed to remain for at least 2 hours. The replicas were then washed in distilled water and the wax coating removed with xylene.

Replicas taken from the following samples (table 5) were examined visually with the electron microscope and with the help of photographs made by John C. Hathaway.

More than 50 photographs, including several stereopairs, were prepared from these samples in magnifications ranging from ×2,400 to ×32,000.

All dolomites and slightly calcitic dolomites are from the aphanitic dolomite unit of the Jerome Member.

The samples of limestone, magnesian limestone, and dolomitic limestone come from relatively thin beds of the upper unit that are intercalated in predominantly dolomitic sequences.

TABLE 5.—*List of samples studied with the electron microscope*

[Amounts of MgO are given as percentages of total carbonate]

Sample	Locality	MgO	Rock type
	Section 34, Tonto Natural Bridge:		
T56–474	Subunit 8	0. 9	Limestone.
–476	Subunit 10	. 9	Do.
–475	Subunit 9	2. 7	Very slightly dolomitic limestone.
H56–207	Section 30, Diamond Point, subunit 19.	1. 9	Magnesian limestone.
	Section 4, Salt River Asbestos mine:		
T56–292	Upper part of subunit 7.	18. 8	Very slightly calcitic dolomite.
–290	Upper part of subunit 6.	19. 9	Dolomite.
	Section 36, Theodore Roosevelt Dam:		
H56–73	Lower part of subunit 12.	20. 3	Do.
–75	Middle part of subunit 12.	19. 5	Do.
–27	Section 3, Flying V Canyon, upper part of subunit 8.	20. 7	Do.
T57–444	Section 37, Windy Hill, subunit 1.	20. 1	Do.

The textures of these rocks are best examined with the aid of stereopairs of electron photomicrographs at magnifications ranging from ×4,000 to ×8,000 (pls. 25 and 26). The size of the photographic prints is 9½×7¾ inches, which makes them suitable for examination under a mirror-type stereoscope such as used for viewing aerial photographs. The size of the area that can thus be scanned stereoscopically is about 60×49 microns at ×4,000 and 30×25 microns at ×8,000. Higher magnification does not always lead to significant refinement in resolution. At ×32,000 the area viewed under the sterescope is about 8×6 microns, and this magnification was used occasionally to obtain more minute details of the structure of individual grains or crystals.

The different rock types listed in table 5 are indistinguishable megascopically, except for slight variations in color. Aphanitic dolomites of the type represented by samples T56–290, H56–73, and H56–75 were described as lithographic limestones or dolomitic limestones by previous investigators in the area.

All limestones consist of an aggregate of tightly packed grains that, as viewed stereoscopically, are rather irregular polyhedra ranging in diameter from 0.4 to about 7.0 microns (pls. 25*A* and 26*B*). Measurements of grain diameters were taken along six traverses across a typical photograph of sample T56–474 at ×4,000. The aggregate length of these traverses was 360 microns (a little more than one-third of a millimeter) along which 127 grains were measured. The count reveals a peak number of grains having diameters of about 1.6 microns; the number of grains tapers off abruptly toward those having smaller diameters and more gradually toward those having larger diameters. The diameter of 56 percent of the grains counted was less than 2.5 microns, and that of only 12 percent was larger than 4.5 microns. It should be kept in mind, however, that the maximum diameter of all grains is not shown in the photograph. Parts of some grains are hidden by adjacent grains, and the diameter of the visible part of the grains is smaller than their greatest diameter. The count, therefore, is biased in favor of the small grains, and the true greatest number of grains may be those 2 microns in size.[6] On the other hand, examination of the stereopairs of photographs shows that entire grains as small as 0.2 microns, and possibly even smaller, exist.

The surfaces of the irregularly polyhedral grains either are plane or are concavely or convexly curved. The surfaces of many grains are smooth, but those of others have irregularities in the form of tiny randomly distributed "cliffs," some of which are as short of 0.05 microns and not more than 0.03 microns high, although most are generally several times longer and somewhat higher.

Grains on broken surfaces are composed of extremely thin lamellae that are 0.02–0.06 microns thick. Such surfaces have a characteristic terraced appearance (fig. 34) that reveals the crystalline nature of the grains. The irregularities of some surfaces, described in the previous paragraph, apparently also reveal the lamellar texture of the grains and are due to a plucking action where part of the surface of the grain was torn off as the rock was split.

Some limestones grains, mostly those about 6 microns in diameter, tend to break along smooth fracture surfaces somewhat resembling the conchoidal fractures of the rock itself, although the size ratio between the two types of fracture may be on the order of 1 : 10,000.

The electron-microscopic texture of aphanitic dolomites differs from that of limestones. Dolomites also consist of an aggregate of polyhedral grains; but these tend to be bounded by flat regularly shaped planes, and many grains have a well-defined rhombohedral

[6] The problem of determining the true grain-size distribution from electron photomicrographs is similar to that of determining grain-size distribution of sandstones from thin sections. However, available statistical methods (see Münzer and Schneiderhöhn, 1953) could not be applied without modification because the true diameter of all particles that are fully exposed on the rock surface can be measured. Whereas in thin sections all measured cross sections are random, the cross sections measured in electron photomicrographs are only partly random.

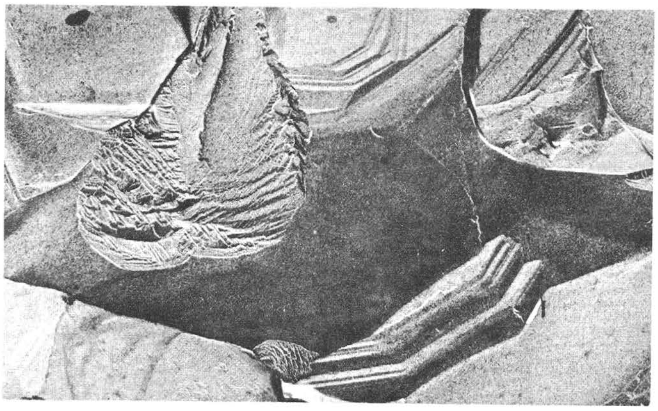


FIGURE 34.—Electron micrograph of subaphanitic magnesian limestone. Sample H56–207, section 30, Diamond Point. × 5,000.

shape (pls. 25*B* and 26*A*). Grain diameters are difficult to determine because in many areas the rock has a "massive" appearance where "grain size" is determined by spacing of cleavage planes. The smallest dolomite rhombohedron observed is about 0.1 micron in diameter.

Viewed stereoscopically, the surface of an aphanitic dolomite appears to be more "rugged" than that of an aphanitic limestone because of the greater angularity of the grains and because the polyhedra tend to break along plane surfaces.

Conchoidal fracture of individual grains is rare in dolomites, whereas lamellar structure is common (fig. 35). The lamellae are of the same order of magnitude as those occurring in limestones—that is, they are between 0.02 and 0.06 microns thick—and the surface of some grains is densely pitted.

On comparing the dolomites with the limestones, one must take into account that most dolomites contain some calcium carbonate and most limestones contain some dolomite. The rare grains having smoothly curved surfaces and apparently conchoidal fracture that are seen in dolomites, thus, may be calcium carbonate particles; conversely, the rare grains having a well-formed lamellar structure that are seen in limestone may be particles of $(Ca,Mg)CO_3$.

The texture of aphanitic limestone as well as of dolomite, as revealed by electron micrography, is probably of diagenetic, not sedimentary, origin. The origin and diagenesis of these rocks are discussed on pages 81–84.

DEPOSITIONAL ENVIRONMENT AND DIAGENETIC HISTORY OF THE CARBONATE FACIES OF THE JEROME MEMBER

ROLE OF DIAGENESIS

All sedimentary rocks are the products of, first, sedimentary and, second, diagenetic processes. To reconstruct the history of a rock, criteria must be recognized that allow us to trace the course of both processes, but this is not always possible. The rock properties that allow reconstruction of the sedimentary environment constitute the sedimentary facies (Teichert, 1958). Features from which the diagenetic history of a rock can be induced should, as far as possible, be excluded from the formal facies concept, or they should be clearly distinguished as diagenetic facies. For example, a rock that consists entirely of secondarily formed dolomite crystals has lost its sedimentary facies. Its sedimentary history and environment can no longer be accurately reconstructed from its texture and composition.

The diagenetic history of a rock is determined by what may be called the diagenetic environment, and study of the diagenetic environment plays an important part in the interpretation of diagenetic history. Since the term "diagenesis" has acquired many meanings in the course of time, a brief historical digression is necessary.

The term "diagenesis" (*Diagenese*)[7] was coined by Gümbel (1868 p. 838) for processes he believed to have been responsible for the formation of gneiss, which he regarded as a deposit formed in a hot sea. This use now has only historical interest. In 1888 Gümbel (p. 56, 334, 380, 1056) upheld the original definition of diagenesis but included in it the discussion of processes that are now generally called lithification.

Diagenesis as a modern scientific concept stems from Walther (1894), who defined it as (translated) "all those physical and chemical alterations which affect a rock after its deposition, excluding the effects of mountain pressure and volcanic heat." This definition did not specifically exclude weathering, but this exclusion has been generally understood.

A slightly more precise and more restricted definition of diagenesis was given by Andrée (1909; 1911, p. 73) (translated):

> Diagenesis of sediments [comprises] those molecular and chemical rearrangements * * * which affect the sedimentary material under the influence of the sedimentation medium and, after emergence from this medium, of ordinary rock moisture or circulating vadose waters, unless these contain dissolved foreign matter (that is, matter derived from sources outside the sediment).

Andrée thus regarded as diagenetic processes all alterations that begin immediately after the deposition of a sediment and that take place in a closed system, but he did not put any limitations on the size of such a closed system. Obviously, diagenesis begins when sedimentation is still in progress—that is, in a succes-

[7] According to Hucke (1951), the word is derived from Greek διαγιγνομαι (diagignomai), to go through, to pass. According to Murawski and Beringer (1957), its meaning is δια γενεσις (dia genesis), after genesis. Both etymological interpretations go back to the same roots.

sion of strata, diagenesis of the lower beds began earlier than that of the upper beds. How far does material have to migrate laterally before it can be identified as coming from "sources outside the sediment"? This question has never been clarified, and establishment of definite standards is perhaps impossible.

Although a full historical treatment of the concept of diagenesis is not intended, it should be pointed out that the term has long been accepted by German and other European geologists for all alterations that take place in a sediment from the moment of its deposition, through its conversion into rock, and in the rock itself, unless they are produced by addition of extraneous material, by weathering, or by those processes that are generally regarded as metamorphism. In this definition, material is generally not considered as extraneous if it is derived from rocks within one major and natural unit of sedimentary rocks—such as a sedimentary basin—

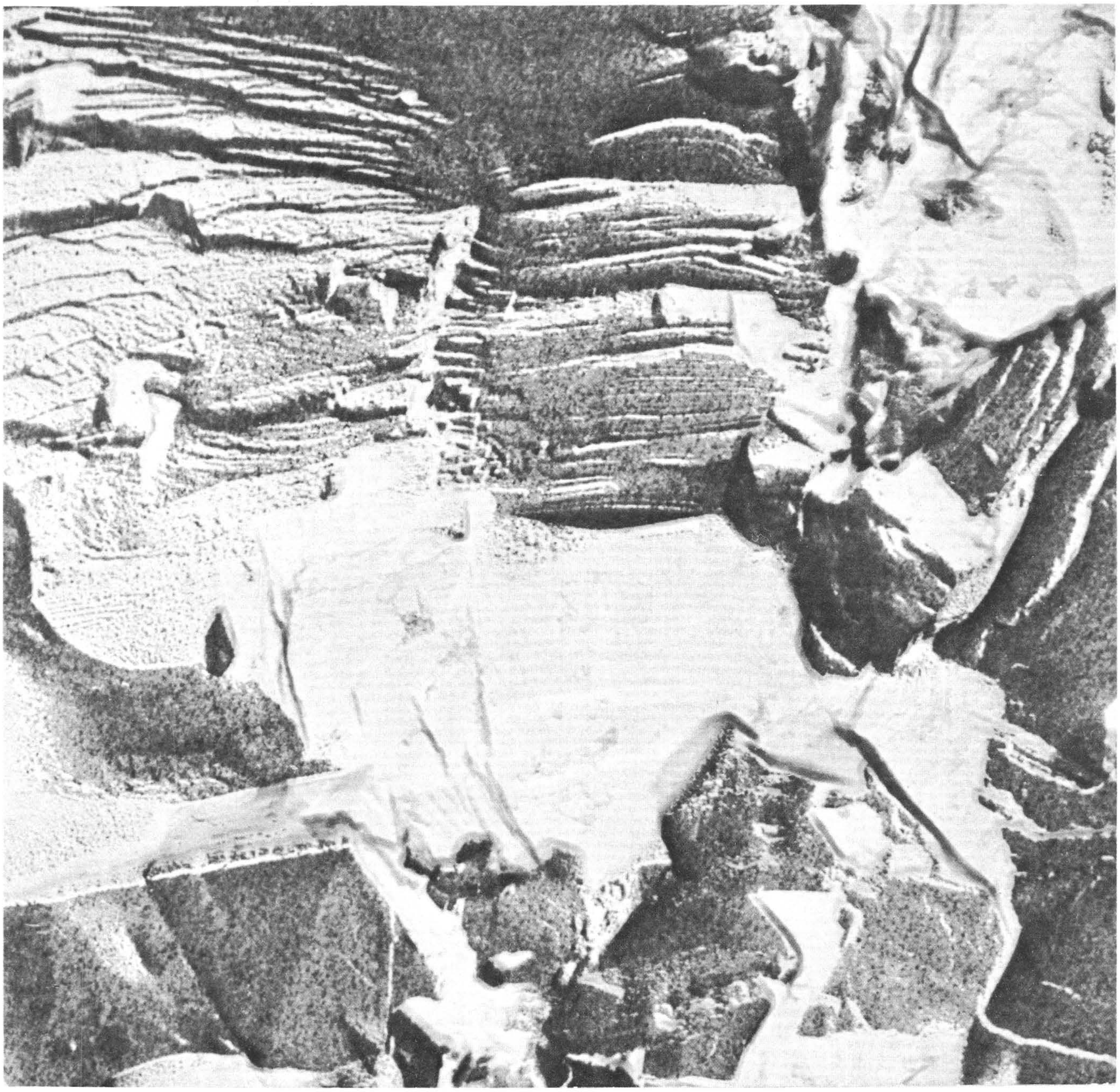


FIGURE 35.—Electron micrograph of aphanitic dolomite. Sample T56–290, section 4, Salt River. Well-formed dolomite rhombohedra in lower left; lamellar texture in upper half. × 39,000.

or from a major tectonic unit—such as a fault block or thrust sheet.

Van Hise's (1904, p. 32) definition of metamorphism—"any change of constitution in any kind of rock"—includes all diagenetic processes after lithification. Other geologists, such as Hucke (1951), proposed to extend the scope of the definition of diagenesis to include weathering and metamorphism. However, most geologists found it useful to distinguish diagenesis that proceeds under conditions of "low" pressure and temperature from metamorphism that occurs under conditions of "high" pressure and temperature.

Among geologists in the United States, a growing tendency in recent years has been to restrict use of the term "diagenesis" to late diagenetic processes and to refer to early diagenetic processes as lithification. (See Pettijohn, 1957, p. 648.) This usage is somewhat misleading because not all early diagenetic processes lead to lithification. Emery and Rittenberg (1952) and Russian authors (see Chilingar, 1958) showed that chemical properties of the unconsolidated sediment may change with increasing distance from the water-sediment interface. Sooner or later, lithification may set in, but lithification is only a special case of early diagenesis.

Recognizing this conflict in definition, Russian authors defined the early diagenetic processes in the unconsolidated sediments as syngenesis. For a summary, see Rukhin (1958, p. 226–227). Syngenesis is followed by diagenesis, which, according to Rukhin, is characterized by those processes that transform the sediment into a rock. Diagenesis in this sense is thus at least partly synonymous with lithification as used in American literature, whereas syngenesis comprises the prelithification or early lithification processes. Russian authors also distinguish epigenesis, which comprises all processes that affect the finished rocks, including weathering and metamorphism.

A comparison of the most common modern usages of diagenesis and related terms is given in figure 36.

Unfortunately, the terms "syngenesis" and "epigenesis" have very definite and long-established meanings in igneous petrology and economic geology. Thus, Amstutz (1959) includes in syngenesis the sedimentation process itself. Epigenesis has long been understood to refer to all alterations affecting a rock, including those introduced by the addition of extraneous substances.

There is, of course, complete gradation of all physical and chemical alterations and rearrangements that affect a sediment from the deposition of the first sedimentary particle until obliteration and removal of the rock by weathering or its complete remaking by metamorphism. If distinguishing and naming several more or less arbitrarily defined stages in this chain of processes is desired, the coining of new terms is to be preferred to inconsistent redefining of old ones.

I propose to retain the term "diagenesis" in the traditional manner to apply to all physical and chemical alterations that take place within a body of sediments

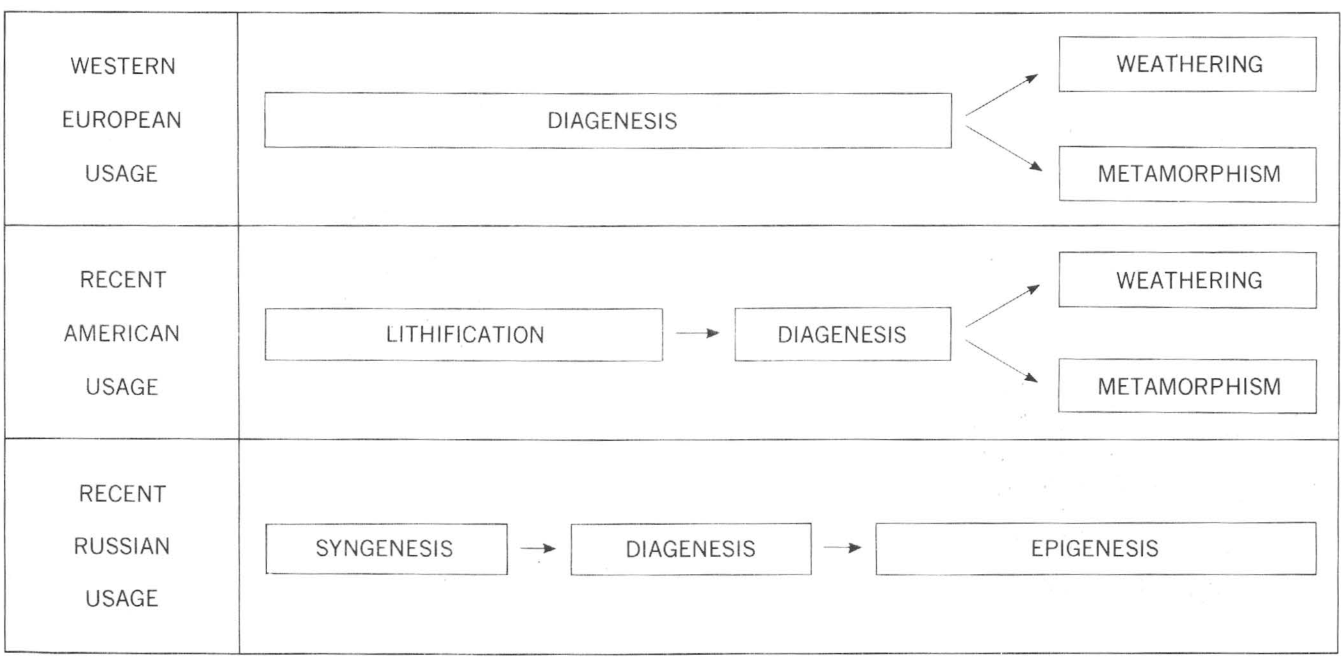


FIGURE 36.—Comparison of some current terminologies for diagenetic and related purposes.

as well as the sedimentary rocks derived from them, from the moment of its deposition until the onset of processes that are commonly attributed to metamorphism or weathering.

Diagenetic processes vary widely in their results and the speed with which these results are attained. Some sediments, such as some clays and certain kinds of chalk, never became lithified. In other sediments, lithification may be accomplished in a season or a few years, and lithification and erosion (that is, weathering) may be simultaneous or overlapping processes; examples are beach rock and sun-baked clay in dry river beds. Sujkowski (1958) recently listed several such occurrences. In general, only a loose differentiation between early, middle, and late diagenetic stages is possible; these categories may be named eodiagenesis, mesodiagenesis, and telodiagenesis,[8] respectively. The boundaries between these stages are as fluid as those between diagenesis and metamorphism, and the succession and speed of events depends on the rock, the time, and the environment. Thus, lithification may be eo-, meso-, or telodiagenetic, or it may not occur at all. Dolomitization may be eo-, meso-, or postdiagenetic. Processes generally labeled penecontemporaneous occur in the early phases of eodiagenesis.

Definition of more precise limiting conditions of the diagenetic environment with regard to time and certain physical conditions (pressure and temperature) to which the Devonian rocks of central Arizona have been subjected will now be attempted.

According to McKee (1951, pl. 3, map C), the thickness of the combined Paleozoic rocks in the study area was between 3,000 and 3,500 feet. These figures include from a few to more than 500 feet of rocks of Devonian and of Cambrian(?) age in various places. A former cover of about 1,500 feet of sediments of Triassic age should be added to this total (McKee and others, 1959, pl. 9, figs. 1 and 3). Post-Triassic rocks were either absent or negligible in the area. Thus, none of the Devonian rocks, apparently, were ever buried more deeply than 5,000 feet, and the maximum depth of burial was in places considerably less than 4,000 feet. Thus, in the upper Tonto Creek and Upper Salt River area, where the Mississippian Redwall Limestone is thin, maximum depth of burial of rocks at the top of the Devonian section was about 2,500 feet.

Translated into terms of temperature and pressure, the extreme conditions to which some, but not all, rocks described in this report were exposed were 15°C above prevailing surface temperatures and 300 atmospheres (or 4,500 pounds per square inch), respectively.

[8] Krotov (1952) introduced the term "telogenesis" in a somewhat similar sense for late diagenetic processes, but he restricted its application to special conditions prevailing in lakes and barred basins.

The greatest pressure and temperature were reached in some parts of the area in the course of some 50–80 million years between the Late Devonian and some time in the Permian Period and were maintained at an even level for another 150 million years or so until the Laramide orogeny; the orogeny uplifted and subsequently led to the erosion of much of the Devonian and younger Paleozoic rocks. Consequently the time span available for the action of diagenetic processes was about 200–250 million years.

Chemical and physical processes acting imperceptibly over such a long period of time cannot easily be attributed to neatly defined successive stages, and a determination of a particular time in which most diagenetic processes have taken place is difficult. Sujkowski (1958) pointed out that "diagenesis works in jumps and steps." In general, only the time sequence of diagenetic events can be determined.

FETID AND APHANITIC DOLOMITE UNITS

At the beginning of the deposition of the Jerome Member, the southwestern edge of the Defiance uplift was roughly parallel to and a few miles southwest of the present Mogollon Rim. To the southeast it lay probably close to the present upper Salt River. A featureless plain that was at least 50 miles wide—but probably much wider—and at least 100 miles long and was mostly sandy but dotted with claypans in and around which a flora of psilophytes had taken root extended southwest of the edge of the uplift.

A layer of lime mud rich in organic matter was deposited across the plain; the mud was compacted and dolomitized and is now represented by the lowermost unit of the Jerome Member—the fetid dolomite unit. The diagenetic history of this unit is discussed on page 32, but the nature of sedimentation is considered further here. Since, as a rock unit today, the fetid unit averages about 20 feet in thickness, the original lime mud must have formed a fairly uniform layer between 30 and 40 feet thick that covered the entire plain. Penetrating the lime mud were closely spaced thin layers of organic matter derived from marine organisms that were probably mainly or entirely planktonic. The sedimentation area at this time was perhaps a large embayment into which plankton and algae drifted with the wind, but if so, the possible location of its southeastern and southwestern shores is not known.

The preceding interpretation of the origin of the fetid unit is supported by the fact that the laminated dolomite rock has many characteristics of dolomites normally associated with evaporitic sediments (Carozzi, 1960, p. 436). Although no evaporites occur in the fetid dolomite unit, sedimentation may be assumed to have taken place under somewhat restricted conditions.

The water in which the original sediments accumulated could not have been deep because the fetid dolomite unit only slightly transgresses the edge of the Defiance uplift; the edge of the unit lies only slightly northeast of the margin of distribution of the Beckers Butte Member. The depth at which deposition occurred could have been as much as the combined original thickness of the sediments of the aphanitic dolomite and fetid dolomite units—that is, possibly 250–300 feet—but this thickness would certainly represent a maximum depth. Perhaps half this thickness is a more realistic estimate of the depth.

We may assume, then, that the plain southwest of the Defiance uplift was ultimately covered by 100–150 feet of water, possibly in a large embayment. Accumulation of lime mud and organic matter proceeded below the turbulent zone, as is indicated by the generally undisturbed fine to ultrafine lamination of the beds and the scattered slump features.

At the time of the deposition of the unit, only a small supply of terrigenous detrital material was available. Some terrigenous beds may have been deposited near the northeastern shore, but if such deposits existed, they are difficult or impossible to distinguish from the sandy facies of the overlying aphanitic dolomite unit.

Almost all the original calcitic mud became dolomitized into very uniform fine- and even-grained dolomite and calcitic dolomite. The general succession of diagenetic processes in this rock is discussed on page 32. Some aspects of diagenesis are reconsidered after the conditions of sedimentation of the aphanitic limestone unit are discussed in the following paragraphs.

The contact between the fine-grained dark fetid dolomite of the fetid dolomite unit and the first aphanitic lighter colored beds of the aphanitic dolomite unit is generally sharp and well defined. A sudden change in conditions of sedimentation must have taken place; the most pronounced changes were the cessation of the supply of organic matter and the increase in the supply of terrigenous sediment in the form of detrital quartz grains.

Deposition of small amounts of clay alternated with the deposition of lime mud, as is indicated by shaly partings between the carbonate rocks, especially in the lower part of the aphanitic dolomite unit. The lateral extent and continuity of the clay layers are unknown because the beds are well exposed only in quarries, along roadcuts, and in some creek beds, such as Lost Tank Canyon. The amount of clay deposited gradually decreased, and few or no shaly interbeds occur in the upper part of the aphanitic dolomite unit.

The cessation of the supply of organic material could be explained by a breakdown or flooding of one of the barriers of the hypothetical embayment and the establishment of open circulation. An alternative and perhaps more plausible explanation is that the sea became considerably shallower. Rocks of the aphanitic dolomite unit seem to have formed from an extremely fine grained lime mud in very shallow water. Parts of the bottom of the depositional basin were occasionally exposed to the air, as is evidenced by the occurrence of mudcracks on some bedding planes of both the dolomite beds and the shaly intercalations. Mudcrack patterns in dolomites (fig. 15) are somewhat similar to those described and illustrated by Ginsburg (1957, p. 94) that occur in alternating lime and algal sediment in the Florida Keys. The cracks are subaerial in origin, but Ginsburg called attention to observations by Straaten (1954), who found incomplete mudcracks in sediment deposited under a permanent cover of water. The occurrence of crack patterns formed under water on sediment surfaces was most fully discussed by Shrock (1948b, p. 197) and by Schäfer (1954). The mudcracks in the aphanitic dolomite unit originated subaerially, a fact indicated because they are rather common and have a general pattern typical for subaerially formed mudcracks.

Autobrecciation of slightly indurated lime mud surfaces was common, as is shown by the abundance of autoclastic aphanitic rocks; several examples of this are discussed on page 35. Very little other evidence indicates that the water was agitated, as by current action.

The sediments could have been deposited either close to or in the intertidal zone or on a vast mudflat under a foot or two of water in a nearly tideless sea where small fluctuations of sea level were controlled by changing winds. Deposition on a mudflat is perhaps the preferred explanation because it accounts for the prevalence of autobrecciation as well as for the scarcity of bedding-plane erosion. It would also help to explain presence of large detrital quartz grains that could not have been transported by the wind except by saltation movement. (See discussion on p. 38.)

The source of the calcium carbonate is difficult to determine under conditions of sedimentation heretofore discussed. Apparently little life, except for ostracodes and very few brachiopods, existed on the mudflats. The enigmatic calcispheres were most probably planktonic and probably contributed at least part of the calcium carbonate. Contributions by algae are easier to hypothesize than to prove. Electron micrographs of recent aragonitic muds from the Bahamas and a Pacific atoll in which the aragonite needles may have been precipitated by algae show no resemblance to electron micrographs of aphanitic limestone, but aragonitic mud subjected to pressures of a few thousand psi and to temperatures of several hundred degrees centigrade changes into an aggregate of polyhedral calcite grains that is not unlike some aphanitic limestones (Hathaway and Robertson, 1960).

Some of the lime mud apparently changed eodiagenetically into aphanitic limestone, and individual beds in some of the measured sections are locally preserved as such (subunit 13 of section 30; subunits 10 and 22 of section 32; and subunits 9 and 10 of section 34). Almost all these rocks contain ostracode fragments, calcispheres, or both.

Most of the lime mud, however, was converted into the aphanitic dolomite or slightly calcitic dolomite that now forms most of the aphanitic dolomite unit. As described on page 41, primary sedimentary structures were preserved during dolomitization, but fossil structures were very largely destroyed or obscured. This dolomitization process was probably very early diagenetic, or penecontemporaneous. In other words, aphanitic dolomite originated directly from dolomitization of the lime mud. This is probably the prevailing opinion of contemporary students of sedimentary rocks. (See also Cloud and Barnes, 1948, p. 91–92.) Contrasting opinions are discussed on page 41.

Zen (1960) demonstrated that limestone as well as dolomite may be in equilibrium in a sedimentary environment but that intermediate types are not. Calcite is the equilibrium carbonate under surface conditions. Dolomite is relatively more stable at depth, where it forms from calcite through reaction with seawater. These conclusions agree with the facts of the lithology of the aphanitic dolomite unit, where rather pure dolomites exist alongside rather pure limestones, but no intermediate types exist.

Carozzi (1960, p. 284) recently suggested that such fine-grained dolomites must have been formed by volume-for-volume rather than molecule-for-molecule replacement of the calcareous sediment by dolomite, as is indicated by their general lack of porosity. However, if dolomitization occurred before lithification, loss of volume would result in compaction. Engelhardt (1960, p. 56–58) also pointed out that porosity cannot occur under conditions of very early diagenetic dolomitization.

The difference in crystallinity between the aphanitic dolomite unit and the finely crystalline fetid dolomite unit is difficult to interpret. The original sediments of both units must have been similar except for the organic constituents in the sediments of the fetid dolomite unit. Possibly, dolomitization of these sediments was not penecontemporaneous but occurred after lithification or during late stages of lithification, perhaps contemporaneously with the eodiagenetic dolomitization of the aphanitic dolomite unit. This suggestion finds support in the fact that some dolomites are porous, at least in the upper part of the fetid dolomite unit.

Some fine-grained rather than aphanitic rocks also occur locally in the aphanitic dolomite unit (pl. 5, fig. 5). Engelhardt (1960, p. 56–58) found it difficult to explain the origin of nonporous fine-grained dolomite rocks. However, most rocks of this type are possibly recrystallized aphanitic dolomites; recrystallization was not considered by Engelhardt. A secondary porosity may have occurred in such rocks at some later diagenetic stage. Dolomite crystals grew freely into the void spaces, which were later filled with clear calcite.

The occurrence of chert in the aphanitic dolomite unit poses several problems, some of which have been discussed in the description of that unit (p. 38). Most of the chert must be of middle or late diagenetic origin because no synsedimentary source of the silica is known. After consolidation of the sediment, silica in solution must have migrated into the rocks from some outside source. Internal origin through solution of detrital quartz and replacement of quartz by carbonate in the manner suggested by Bourcart and others (1933) and by Walker (1957, 1960) may account for only a very small part of the chert. The terminal stage in this process is represented by a metasomatic limestone (as discussed by Shvetsov, 1959, p. 738), which originates through complete calcitization of a rock such as dolomite or sandstone. Shvetzov said that "such rocks are not scarce in nature," but he gave no examples.

As has been described in foregoing sections, peripheral etching of quartz grains and loss or replaceemnt of some of the substance of the grains is common, but evidence of complete replacement of entire grains has not been noted with certainty (Walker, 1960, pl. 1, fig. 5). "Ghost" clasts in fine-grained dolomites, especially in the upper unit, are interpreted as primary aphanitic-limestone clasts rather than replaced quartz grains.

At least part of the detrital quartz having a grain size of about 0.25 mm or less was blown onto the mudflats by offshore winds. Larger grains and perhaps smaller chert pebbles were rolled along the flats by the wind or by wind-generated currents.

The northeastern shoreline of the sedimentation area remained more or less stationary and in the same geographic position as at the time of deposition of the fetid dolomite unit. Sandstone that locally contains fish plates was being deposited close to the shore. Exact correlation of this sandy facies with the carbonate facies is for the most part impossible.

The present thickness of the aphanitic dolomite unit suggests that the uncompacted mud was 200–300 feet thick. Most, if not all, of the compaction must have taken place while sedimentation was still in progress; sea level at the end of the period of deposition of the unit was undoubtedly approximately at the level now occupied by the top of the unit.

UPPER UNIT

SEDIMENTATIONAL HISTORY

Although the boundary between the aphanitic dolomite unit and the upper unit is generally well defined in the field, no reliable evidence is available in most places to indicate the nature of the change in sedimentation that must have taken place at this boundary; however, evidence does exist that a change from carbonate deposition to deposition of terrigenous siliceous-detrital material occurred locally. Wherever the lower part of the upper unit is composed of carbonate rock, the rock is invariably dolomite; the boundary is drawn generally at the base of the first nonaphanitic commonly fine-grained, dolomite. Almost everywhere in the lower part of the upper unit, the present features of this type of rock are entirely diagenetic in origin, and the primary sedimentary facies of the rock has been destroyed. This part of the unit is also almost entirely unfossiliferous; so, neither the rocks nor the fossils indicate the nature of the orginal sediment.

The upper unit laps onto the Precambrian basement beyond the area of sedimentation of the two lower units; this evidence indicates that sea level must have risen relative to the land and that the sea transgressed across the Defiance uplift area in a general northeasterly direction. This assumed rise in sea level brought about a slight deepening of the sea in the area southwest of the Defiance uplift. This assumption seems to agree well with paleontological evidence. Although fossil content varies considerably in a horizontal direction, the number and variety of fossils generally increases gradually from bottom to top of the unit. The upper part of the unit over much of the area of investigation was deposited undoubtedly in an open shallow shelf sea in an environment that was especially favorable to coral and brachiopod growth.

At stratigraphic distances of about 50 feet above the base of the upper unit, fossiliferous limestones are known from some localities such as subunit 18 of section 6 (Salt River Draw), subunit 13 of section 30 (Diamond Point), and subunit 10 of section 32 (East Verde River). These rocks are aphanitic limestones that are slightly dolomitized in places and contain calcispheres, ostracodes, scattered tintinnids(?), and pteropods. Such rock types differ little from the undolomitized aphanitic limestones of the underlying dolomite unit. A more unusual rock occurs in subunit 18 of section 38 (Limestone Hills), which lies at 35 feet above the base of the upper unit. This rock, too, has a groundmass of aphanitic limestone, but it contains abundant remains of brachiopods, gastropods, crinoids, and echinoids (pl. 8, fig. 1). This assemblage indicates a richer benthonic life than any observed in rocks of the aphanitic dolomite unit, but it is only a small window into the predolomitization world.

We can therefore conclude that sedimentation was continuous from the aphanitic dolomitic unit into the upper unit and that the character of sedimentation changed little at this boundary; however, dolomitization of the upper unit was delayed until a later diagenetic stage. Soon after the deposition of the aphanitic dolomite unit, however, conditions became favorable for a richer and more varied bottom life.

This change took place gradually, as is shown by the appearance, at first sporadic, of corals and stromatoporoids in stratigraphic sections. The earliest appearance of these groups, represented by tabulate corals and *Amphipora*, is 50 feet above the base of the upper member in section 13 (southwest branch of Lost Tank Canyon). More commonly, however, first appearances of coelenterates are about 100 feet or more above the base of the member, as is indicated in table 6.

TABLE 6.—*First appearance of coelenterates above base of upper unit of Jerome Member*

Section	Association	Feet above base of upper member
4	*Amphipora*	60
6	Massive stromatoporoids, *Amphipora*, tabulate corals	95
8	Massive stromatoporoids, rugose corals	140
12	*Amphipora*, tabulate corals	135
13	*Amphipora*, tabulate corals	50
29	Tabulate and rugose corals	90
30	Tabulate corals	120
31	Massive stromatoporoids, tabulate corals	138
38	Massive stromatoporoids, tabulate corals	88
41	Tabulate corals	180
43	Tabulate and rugose corals	171

Thus, the environmental conditions only gradually improved sufficiently to allow corals and stromatoporoids to migrate into the area. Among the first arrivals were *Amphipora* and *Thamnopora*, which formed "meadows" of the type described on page 58. These fossils are most common in the middle part of the upper unit. Such biocoenoses must have required reasonably clear water, at least for long periods at a time, and by this time the sea floor was presumably well below the zone of turbulence caused by ordinary waves.

Continuing improvement of environmental conditions for benthonic life is indicated by the rich thanatocoenoses of stromatoporoids, corals, and brachiopods; improvement is further suggested in the upper third of the unit by coquinas of brachiopods which have been transported only short distances. Evidence from most of the area suggests that sedimentation in this uppermost part of the upper unit occurred quietly on a deepening shelf. The sea transgressed over low-lying areas of the Defiance uplift, approximately as far as the present city of Holbrook, and Pine Island and Christopher Island were only then cut off from the mainland.

During much of the sedimentation of the upper unit the Defiance uplift reduced in size, must have been an area of slightly undulating topography that was a source, though not a significant one, of terrigenous sediment. A source somewhere in the southeast, outside the study area, was more important, as is indicated by the increase in amounts of sandstone, siltstone, and shale in that direction. (See the discussion on p. 96–97.) Attention is again called to the faunal change from mixed stromatoporoid-coral-brachiopod assemblages to predominantly pure brachiopod assemblages in the same direction.

Glimpses of the original nature of the carbonate sediment from which the rocks of the upper member were formed may be obtained from the limestone beds that are intercalated with the predominating dolomites in many sections. These limestones are typically aphanitic to very fine grained and contain rich microassemblages of calcispheres, "*Umbella*," ostracodes, pteropods, and much unidentifiable "hash." The predominant carbonate sediment of the upper unit must have been a fine mud that gradually became richer in organic remains and had a tendency to form stromatoporoid-coral biostromes. The biostromes are rarely dolomitized and are preserved as massive limestone.

The lime muds were first compacted into aphanitic or very fine grained limestones, some of which are preserved in many places throughout many of the stratigraphic sections. Most of the limestones of the upper unit, however, have been dolomitized. The manner in which the rocks of the upper unit have been dolomitized poses many puzzling questions that are still unanswered.

DOLOMITIZATION

In contrast to the underlying aphanitic dolomite unit in which dolomitization produced rocks of generally very uniform lithology, the rocks of the upper unit have been affected by dolomitization in many different ways, producing a great variety of rock types. Dolomitic rocks in the upper unit range from aphanitic to medium grained saccharoidal. Most of the rocks are dolomites or slightly calcitic dolomites. In many sections undolomitized limestones are intercalated in predominantly dolomite sequences. One major area of undolomitized or little dolomitized limestone is situated in the upper Salt River Draw area east of Canyon Creek near Chediski; however, this area was not studied in detail.

Intermediate rock types such as highly dolomitic limestones and highly calcitic dolomites exist but are uncommon. Typically, dolomitization of rocks of the upper unit proceeded by the formation of dolomite nuclei, which grew into euhedral rhombohedra. In some limestones the rhombohedra are small and scattered, and a gradation exists from this type of rock to high-grade dolomite rocks that consist typically of aggregates of idiomorphic and hypidiomorphic dolomite rhombohedra. In intermediate rock types varying amounts of dolomite rhombohedra are present, and enough of the original limestone is left unaltered to allow reconstruction of the primary sedimentational environment.

In rocks in which this kind of dolomitization occurs, dolomite is an authigenic mineral that differs from most other authigenic substances except silica in that it tended to replace the entire parent rock. Fossils and other primary sedimentary structures were generally entirely obliterated during this process; the final product of the process was an entirely crystalline dolomite in which residual calcite may be found composing a thin lining of the dolomite rhombohedra (pl. 8, fig. 2).

The formation of authigenic dolomite was probably not an early diagenetic process but took place in the solid limestone during middle or late diagenesis. This conclusion follows from the manner in which dolomite crystals grew across microfossils and small-scale sedimentary structures. The cryptocrystalline texture of the limestone and microscopic shell structures were completely replaced by the crystalline dolomite, and not even "ghost" structural features remain.

The proportion of dolomite rock to total carbonate rock generally decreases somewhat from the bottom to the top of the upper unit (pls. 22 and 23); more limestone beds are present in the upper part of the unit. In the Jerome area, however, the entire upper unit consists of dolomite rock.

The presence of some aphanitic dolomite beds in the upper part of the upper unit is difficult to explain. If such rocks are interpreted as penecontemporaneous dolomites, in analogy to the dolomites of the aphanitic dolomite unit, it must be explained why conditions for penecontemporaneous dolomitization existed only locally, temporarily, and at intervals during the time of deposition of the upper member. Such an explanation cannot yet be offered.

SILICA

In the upper unit of the Jerome Member, silica in the form of chert is less common than in the aphanitic dolomite unit. No special study of the occurrence and distribution of chert in the upper unit was made.

The occurrence of authigenic quartz, mostly as doubly terminated small crystals, is mentioned on page 45. One noteworthy occurrence of the quartz is in a limestone bed in section 34 (Tonto Natural Bridge), 199 feet above the base of the Jerome Member (pl. 7, fig. 2). The limestone is aphanitic and contains some brachiopod shells and calcispheres. The quartz occurs in well-formed doubly terminated crystals which are as large as half a millimeter in length. The crystals contain many minute inclusions of a highly birefringent material, apparently calcite. In addition to the quartz crystals, well-formed dolomite rhombohedra are scattered throughout the rock.

The presence of finely dispersed calcite in the quartz crystals shows that the crystals were formed as metasomatic replacements of the limestone rather than as secondary overgrowth on quartz grains of detrital origin. The secondary-overgrowth mode of formation was first described by Irving and Van Hise (1884). Cayeux (1916, p. 196–197) recognized that authigenic quartz can be formed in sediments in both ways.

Authigenic quartz crystals are fairly common in limestone. More recently they were described by Topkaya (1950), Black (1949), and Füchtbauer (1950). Some references to earlier observations are given by Boswell (1933). However, published information does not always clearly indicate whether the "authigenic" quartz was built around detrital grains or if it was newly formed. Füchtbauer (1950, p. 245) described doubly terminated quartz crystals from fossiliferous Triassic limestone near Göttingen, West Germany. He also specifically mentioned calcite inclusions in the crystals.

Topkaya (1950, p. 94), who studied authigenic quartz from several carbonate rocks in the Swiss Alps, concluded that the quartz formed in the solid rock at temperatures of less than 100°C after lithification of the sediment and that the silica was derived from material within the rock. In the Jerome Member, particularly in the stratigraphic section at Tonto Natural Bridge, abundant detrital quartz occurs from which the material for the formation of authigenic quartz could have been derived. (Evidence for the corrosion of detrital quartz in a carbonate medium is discussed on page 83.) Whereas this source is hardly sufficient to explain major chert accumulations (Walker, 1960), more than enough silica should have been available from it to account for the relatively small amounts of authigenic quartz and for the silicification of fossils.

Silicified fossils are common, especially throughout the upper part of the upper unit; locally entire limestone beds are replaced metasomatically by silica, and fossil structures are preserved. Silicification of brachiopod shells in many places is incomplete, and only a thin film on the inner and outer surfaces of the shells is affected; a space between these films consists of crystalline calcite (pl. 14, fig. 2). This type of preservation is particularly common in dolomitic limestone and calcitic dolomite. Apparently, the original shell material of the fossils was recrystallized into coarser calcite and escaped dolomitization. Replacement of part of this calcite by silica was a later diagenetic process.

Corals also are commonly silicified. In one specimen (pl. 15, figs. 2 and 4) the entire skeleton as well as the secondary calcite filling inside the skeleton were replaced by fine-grained quartz. Careful comparison of the photomicrograph taken in ordinary light and one taken between crossed nicols shows that some septa and dissepiments were changed to very finely crystalline quartz, whereas others now form part of larger quartz crystals whose boundaries cut across fossil structures and the intervening spaces alike. The entire fossil is more coarsely crystalline than the silicified rock in which it is embedded.

Turner (1899, pl. 5) illustrated a similar silicified rock containing a foraminifer that was also clearly recognizable when the slide was viewed between crossed nicols; the matrix inside the shell was replaced by an aggregate of quartz crystals that were finer than the replacing crystals outside the shell. Irving (1911, p. 641) suggested that such textural details were retained during replacement because they represented irreplaceable impurities. He did not discuss the nature of these impurities.

The skeletal elements (septa, dissepiments) of rugose corals such as the one described in the foregoing paragraph were originally calcite that had been deposited in either spherulitic or lamellar form (Hill, 1956, p. F235). The free space inside the corallum must have been filled with secondary clear crystalline calcite. The skeletal structure of the fossil was thus retained owing to differences in the crystalline form of the replaced calcite rather than to the presence of nonreplaceable impurities.

A very different type of silicification of a coral was recently described by Lund (1960) in a specimen from Miocene rocks in Florida. Here the entire coral substance was first removed by solution, and the remaining cavity was filled with an outer layer of quartz and an inner filling of chalcedony.

Some findings of Storz (1931) may help to explain selective silicification of fossils in carbonate rocks, although Storz himself did not deal with this subject. He demonstrated (1931, p. 305) that selective silicification in carbonate rocks occurs preferably when the rock is a mixture of coarse-grained and fine-grained aggregates. The greater the difference in size grades, the more pronounced is the silification. Silica-bearing solutions migrate through the rock until they are under conditions favorable for precipitation. Such conditions, according to Storz (1931, p. 238), may be present where differences in texture or in shape or composition of mineral aggregates occur. Another important consideration is that in some places the most easily dissolved carbonate is attacked and replaced first (Storz, 1931, p. 362).

The foregoing observations may explain selective silicification of fossils, especially in fine-grained rocks, because a fossil constitutes a coarser aggregate of carbonate minerals than does the matrix; the aragonite or calcite prisms composing the fossil are probably more easily dissolved than those of the rock itself. This suggestion, however, needs verification by laboratory experiments.

DISCUSSION OF ISOPACH MAPS AND NOTES ON WELLS

Field data on the distribution and thickness of the Beckers Butte Member are insufficient and too widely spaced to warrant construction of an isopach map. However, the available information has been compiled in plate 27*A* to show the great variation in thickness of this member and its disappearance toward the northeast.

To show features of the Jerome Member in desirable detail, three isopach maps were constructed: (1) for the entire Jerome Member (pl. 27*B*), (2) for the combined fetid and aphanitic dolomite units of the Jerome Member (pl. 27*C*), and (3) for the upper unit (pl. 27*D*). Well data were utilized in the construction of the map of the upper unit in the northeastern part, where the Devonian lies deeply buried under younger Paleozoic and Mesozoic rocks. For convenient reference, the wells have been given letter designations and are referred to as "A" well, "B" well, and so on.

Following are the names of the well used, source of information, and the thickness of the Jerome Member, in feet, in the wells:

	Well name (source of information)	*Thickness*
"A" well.	Great Basin Oil Co., Taylor-Fuller No. 1 (Huddle and Dobrovolny, 1945, section 21)	0
"B" well.	Northern Aztec Land and Cattle Co. "A" (well log obtained from American Stratigraphic Co.)	250
"C" well.	Union Oil Co. of California and Continental Oil Co. of New Mexico-Arizona, Land Co. No. 1 Well (Huddle and Dobrovolny, 1945, section 20)	0
"D" well.	Union Oil Co. of California and Continental Oil Co. Aztec Land and Cattle Co., No. 1 Well (Huddle and Dobrovolny, 1945, section 19)	20
"E" well.	Lion Oil (Monsanto) No. 1 Cabin Wash (well log obtained from American Stratigraphic Co.)	36
"F" well.	A. M. Lockhart, Aztec Land and Cattle No. 1 (cuttings examined in Museum of Northern Arizona, Flagstaff)	[1] 80
"G" well.	Pan-American Petroleum Corp., New Mexico-Arizona Land Co., B-1 (well log obtained from American Stratigraphic Co.)	93

[1] Thickness possibly 89 ft.

The isopach map for all the Jerome Member shows the thin margins of the Devonian rocks toward the northeast, in the general area south of Holbrook. The trend of the edge is somewhat more complicated than previously realized. Log data for "A" well and "C" well (the equivalent of sections 21 and 20 of Huddle and Dobrovolny, 1945) have been known for many years. In both these wells, Redwall Limestone rests on Precambrian, and no Devonian rocks are present. Recently 250 feet of Devonian rocks was unexpectedly penetrated in "B" well, situated between "A" and "C" wells, only a little more than 3 miles southwest of the "A" well. The Devonian rocks penetrated in "B" well are mostly dolomite and shale. They were deposited either in a local depression of the Precambrian surface or in an embayment extending eastward from an open shelf sea to the west. The embayment interpretation is shown on the map.

The absence of Devonian rocks in "C" well may indicate (1) a small island, if Devonian rocks should prove to be continuous from "B" well to "F" well, or (2) a spur (on the end of which "C" well is located) extending westward from the main area of the Defiance uplift.

Toward the southwest, a broad belt of rocks having thicknesses less than 100 feet apparently occurs, although control points used to determine its presence are few. Where the Jerome Member crops out at the foot of the Mogollon escarpment in Gila County, the thicknesses are somewhat more than 100 feet. In southwestern Navajo County, thicknesses are less than 100 feet, and the 100-foot contour is shown projecting far into the southwest corner of the county on the map.

The overall isopach picture shows a gradual southwestward increase in thickness of the Jerome Member. In sections 16, 17, and 18, thicknesses are about 200 feet. In sections 8 and 12 thicknesses are 300 feet or more, and more than 400 feet of strata are recorded from Huddle and Dobrovolny's section 8 (Cliff House Canyon; see Huddle and Dobrovolny, 1952, p. 100–101) and from the lower Salt River Draw (section 6). The pattern of thickness of the stratigraphic sections measured in the belt from the upper Christopher Creek area southeastward to the junction of White River and Black River indicates an approximate northwesterly trend of the isopachs; thickness increases toward the southwest.

Along the lower course of Christopher Creek and around its junction with Tonto Creek, the isopach pattern is complicated by the presence of Christopher Island, where Devonian rocks are either absent or, at most, are represented by a few feet of conglomerate and sandstone. Isopach lines on the map are closely crowded around this area; thicknesses increase abruptly west of the area.

About 25 miles west of Christopher Island is a probably larger island—here called Pine Island. The margin of the Jerome Member on the east side of this area is described in more detail on page 45. The island was called Pine Ridge by Huddle and Dobrovolny, who interpreted it to be a northern promontory of a southern landmass. However, the thickness of the Jerome Member increases toward the south and southeast of the Pine area: it is 402 feet in Upper Sycamore Canyon (section 33), 389 feet at Tonto Natural Bridge (section 34), and 394 feet near the junction of East Verde and Verde Rivers (Limestone Hills, section 38). These findings are in harmony with observations made in the eastern part of the area discussed above and indicate that the original deposits had a thickness of about 400 feet in the triangle between the Verde and Salt Rivers; the area is now occupied by the Mazatzal Mountains and the Sierra Ancha. Further reasons for this interpretation are indicated by the pattern of distribution of thickness and facies, especially of the fetid dolomite and aphanitic dolomite units of the Jerome Member, which are discussed in the following paragraphs.

About halfway between the middle course of the Salt River and the San Carlos River, the Devonian section thins, and at Seven Mile Creek, about 15 miles northeast of Globe, the entire Devonian sequence is only 258 feet thick. The Beckers Butte Member and all units of the Jerome Member are present at this locality.

In the northwestern part of the area, along the upper Verde River and on Mingus Mountain, the thickness of the Jerome Member is more than 400 feet at Jerome (section 41) and probably more than 500 feet in Upper Hull Canyon (section 42).

Only the upper part of the Jerome Member is known at Elden Mountains, in the northern part of the area (section 44), and because this section consists of rocks having a decidedly offshore facies, the total thickness of the member here is probably comparable to the 450 feet at Jerome.

A more detailed picture of the pattern of distribution and thickness can be obtained by plotting separate isopach maps for the lower and upper parts of the Jerome Member. Since the fetid dolomite and aphanitic dolomite units are closely related stratigraphically, their thicknesses have been combined into one isopach map (pl. 27 *C*). As the map shows, the two units wedge out along a line that extends in a winding course from the southwest corner of Navajo County northwestward to the headwaters of Tonto Creek. From the creek the boundary follows probably more or less the foot of the Mogollon escarpment in the direction of Pine Island. This boundary marks the edge of the Defiance uplift that existed during the deposition of the lower part of the Jerome Member. Thus, at that time the Defiance uplift extended 40–50 miles farther southwest than at the end of Jerome time, and Pine Island formed a mere promontory of this uplift.

The isopach pattern on the map is consistent with the postulate of an earlier more extended Defiance positive area, because at all available control points the thickness of the combined fetid and aphanitic dolomite units increases consistently from the margin in a general southwesterly direction. The units have a combined thickness of 50 feet 0.5–5 miles from this margin, 100 feet 1–7 miles away, and 150 feet about 4–8 miles away. Across the greater part of the triangular area between the Verde and Salt Rivers and as far south as Superior, thicknesses are uniformly a little more than 150 feet. In some sections measured close to the edge of the two units, numerous intercalations of sandstone occur in the aphanitic dolomite unit (for example, sections 17 and 18); elsewhere both units are composed entirely or almost entirely of siliceous-clastic rocks (for example, sections 28 and 29).

The thickness of the two units increases insignificantly northwestward from about 175 to slightly more than 200 feet. The area in which the beds are 150 feet thick approximately follows the Verde River; the courses of the areas in which the units are of another given thickness cannot be known with any degree of certainty.

A third isopach map (pl. 27*D*) shows the distribution of the upper unit of the Jerome Member. The northeastern edge of the lower two units is also shown in this map because it indicates the southwestern edge of the area in which the upper unit rests directly on Precambrian rocks. The unit here is generally less than 100 feet thick, except perhaps in depressions such as the one in which "B" well is located; it consists of dolomite and some siliceous-clastic rocks. The edge of the fetid and aphanitic dolomite units follows very roughly the area in which the upper unit is 100 feet thick.

From the edge of the dolomite units toward the southwest, the upper unit generally increases in thickness. The few available data suggest that a former area of maximum thickness existed in the region between Tonto Creek and Salt River, which is now largely occupied by the Sierra Ancha. The thickness of the unit in this area was probably slightly in excess of 300 feet.

Toward the southeast across the Salt River, the upper unit thins somewhat. The 200-foot isopach can be reconstructed with some confidence and is drawn as extending from the upper Salt River, approximately at Flying V Canyon (section 3), southwestward to Globe. Beyond Globe thicknesses at the few control points are consistently less than 200 feet.

Pine Island and Christopher Island formed during the time of deposition of the upper unit. During deposition of the fetid and aphanitic dolomite units, these areas were still part of the mainland of the Defiance uplift. Their existence is responsible for the somewhat irregular pattern of thickness of the upper unit in the upper Tonto Creek and East Verde River area.

Northwest of Pine Island, upstream along the Verde River, and in the Jerome area, the unit increases slightly to somewhat more than 300 feet, and a similar thickness is estimated for this unit at the incompletely exposed section in the Elden Mountains.

AGE AND CORRELATION OF THE MARTIN FORMATION

BECKERS BUTTE MEMBER

The oldest fossils in the Martin Formation occur at the top of the Beckers Butte Member and constitute an assemblage of psilophyte plants briefly described and evaluated by Teichert and Schopf (1958). The assemblage contains abundant remains of naked branching axes of types commonly assigned to *Hostimella* sp. and to *Aphyllopteris* sp. Spineless psilophytes are characteristic of both Lower and Middle Devonian rocks. Associated with these plants are fertile structures that resemble *Cooksonia*, *Hicklingia*, and *Rhynia*. Although these sporangia are generally smaller, many of them occur in pairs attached to a short dichotomized stalk, and one specimen has five successive dichotomies within a distance of 6 mm. Some of the specimens resemble *Hedeia* and may be congeneric with it. Other, curved or somewhat falcate, sporangia resemble *Dawsonites*.

Most of the spores in this fossil horizon are not well preserved. Some resemble spore types described by Lang (1926) from the Old Red Sandstone of Scotland. Some sporelike spheroidal bodies having attached filaments may be related to the genus *Leiosphaera* Eisenack, which was first described from Silurian rocks of the Baltic region.

The only other psilophyte flora from western North America is the one described by Dorf (1933, 1934a, 1934b) from the Beartooth Butte Formation of Wyoming, but the only elements it has in common with the flora of the Beckers Butte Member are smooth *Hostimella*-type branches. The microfossils of the Beartooth Butte have apparently not yet been studied. On the basis of its associated fish fauna, the age of the Beartooth Butte has been determined to be Early Devonian (Bryant, 1932 and later papers).

The exact time relationships between the Beckers Butte Member and the Beartooth Butte Formation are thus in doubt, although both are older than Late Devonian. More recently, Sandberg (1961) showed that the Beartooth Butte is widely distributed in western Wyoming and Montana. Like the Beckers Butte it consists mainly of channel deposits connected by thin layers of sediments deposited outside the channels; it is overlain by rocks of Late Devonian age.

No fish remains have been found in the Beckers Butte Member; the member is probably entirely fluvial except for local shale and dolomite beds at the top, which were deposited probably in shallow clay pans. Because it is uncertain whether psilophyte flora of the Beckers Butte Member is Early or Middle Devonian in age, the correlation of this member with the Beartooth Butte must remain in doubt.

As Teichert and Schopf (1958) indicated and the present report more amply documents, no evidence of an unconformity between the Beckers Butte Member and the Jerome Member is known. Indeed, a somewhat gradational contact is indicated locally by the presence of intercalated thin dolomite beds at the top of the Beckers Butte, although the contact between it and the lowest unit of the Jerome Member is generally sharp and well defined. Because of the conformity between the Beckers Butte Member and the Jerome Member, Teichert and Schopf (1958) considered the Beckers Butte more likely to be Middle Devonian than Early Devonian in age; this consideration is strengthened by detailed studies of the regional distribution and lithofacies of the two members presented in the present report.

If the foregoing arguments are valid, the Beckers Butte Member and the Beartooth Butte Formation are somewhat different in age. Sandberg (1961) suggested that the Beartooth Butte Formation has a general correlation and environmental continuity southwestward with the Water Canyon Formation of central Utah (Williams, 1948, p. 1138), which is also of Early Devonian age. Additional study of the area between central Utah and central Arizona is required to determine the physical relationships of these formations with the Beckers Butte Member of the Martin Formation.

JEROME MEMBER

Fortunately, all fossil assemblages having a precisely datable age are concentrated in the upper part of the upper unit of the Jerome Member, making it possible to put a rather accurate upper time limit to its stratigraphic correlation. Because no precisely datable fossils occur in the lower part of the upper unit or in the aphanitic dolomite and fetid dolomite units of the member, evidence for the age of the upper part of the upper unit is discussed first.

The regional stratigraphic study of the upper unit has shown that over most of the area of its distribution, the upper unit contains many abundantly fossiliferous beds, especially in its upper half, and generally the uppermost 150 feet. The most richly represented groups in these fossil horizons are stromatoporoids, corals (both rugose and tabulate), and brachiopods. Future studies may be expected to show that conodonts constitute another important group; so far they have only been studied in one locality. Both corals and brachiopods, as well as the single conodont assemblage, furnish accurate and mutually corroborative evidence of the late Frasnian age of the uppermost 100–150 feet of the Jerome Member.

W. A. Oliver, Jr., (written commun., 1959 and 1960) examined collections from 42 beds, and his identifications are inserted in the appropriate places in the section descriptions. The most important assemblages for correlation are the following:

Section 1 (Sawmill), subunit 4:
  Pachyphyllum sp.
Section 7 (upper Salt River Draw), subunit 5:
  Tabellaephullum peculiaris Stumm
Section 8 (east side of Canyon Creek), subunit 22:
  Hexagonaria occidens Stumm
  Hexagonaria sp.
  Pachyphyllum cf. *P. woodmani* (White)
  Alveolites sp.
  Thamnopora sp.
Section 10 (Spring Canyon), subunit 2:
  Disphyllum? n. sp.
  Tabulophyllum n. sp.
  Alveolites sp.
  Thamnopora sp.
Section 32 (East Verde River), subunit 34:
  Pachyphyllum sp.
  Thamnopora sp.
Section 32 (East Verde River), subunit 30:
  Pachyphyllum sp.

Oliver assigned a Frasnian (early Late Devonian) age to these six assemblages, all of which are from the upper part of the upper unit of the Jerome Member. The genera *Tabulophyllum*, *Pachyphyllum*, and *Tabellaephyllum* are of special importance for dating.

With the exception of *Tabellaephyllum peculiaris*, *Hexagonaria occidens* Stumm, and *Pachyphyllum* sp. cf. *P. woodmani* (White), described by Stumm (1948, p. 41) from the Martin Limestone of the western part of the Bisbee quadrangle, no coral species from the Martin Limestone of southeastern Arizona have as yet been identified conclusively from the Jerome Member of the Martin Formation in central Arizona. Additional collecting and further systematic work is needed to determine the degree of relation between the two coral faunas.

Most stromatoporoids and tabulate corals belong to genera whose range is at least Middle to Late Devonian or longer, and because most species have not been identified, they cannot be used for precise correlation.

A selection of representative brachiopods from the upper part of the upper unit of the Jerome Member was studied by P. E. Cloud, Jr., (written commun., 1960) and, with the help of his identifications, I identified other collections. A list of brachiopod species that have so far been identified from the upper unit of the Jerome is given on page 58. Among those of particular importance for age determination and correlation are *Schizophoria iowensis* (Hall), *Atrypa devoniana* var. *bentonensis* Stainbrook, "*A*." *owenensis* Webster, *Spinatrypa* cf. *S. rotunda* Stainbrook, *Platyrachella* cf. *P. mcbridei* (Calvin), *Cyrtospirifer whitneyi* (Hall), and *Theodossia* cf. *T. hungerfordi* (Hall).

According to Cloud (written commun., 1960), the fauna has affinity with that of the Hackberry Shale of Webster (1889) and Independence Shale in Iowa, the High Point Sandstone of Clarke (1885) of Late Devonian age in New York, and the Sly Gap Formation of Stevenson (1941) of New Mexico; the age therefore, is about middle Late Devonian (late Frasnian). This age, of course, is exactly where Cooper (1942) put the Martin and Jerome on the Devonian correlation chart.

Evidence supplied by the conodonts furnishes additional support for this correlation. The only assemblage so far identified—from section 43 (upper Verde River), subunit 26—is listed on page 44. Two of the species allow designation of a restricted age (B. F. Glenister, written commun., 1960): *Polygnathus normalis* Miller and Youngquist is late Frasnian in age, and *Palmatolepis triangularis* Sannemann is restricted to middle and late Frasnian (Iβ/γ and Iδ). *P. triangularis*, according to Glenister, has a worldwide distribution and is a reliable zone marker. This conodont assemblage was obtained in section 43 from the highest observed fossiliferous bed, 93 feet below the top of the Jerome Member.

Umbella Maslov is useful for correlation of the upper unit of the Jerome Member and occurs at many localities, especially in section 31 (Webber Creek), subunit 31, about 115 feet below the top of the Jerome Member. This somewhat enigmatic fossil (see pl. 21 fig. 1) is described on page 103. The same fossils, described by Lombard and Monteyne (1952) as "calcisphire de forme A," are known from rocks of Frasnian age in Belgium. More recently, Bykova and Polenova (1955) described several species of the genus from southeastern European Russia, where they occur in strata ranging from late Givetian to early Famennian in age, but the principal distribution of the genus, including that of the type species *Umbella bella* Maslov, seems to be in the Frasnian.

Paleontological evidence thus indicates a late Frasnian age for the upper part of the upper unit of the Jerome Member. Since the entire upper unit represents one unified stratigraphic and sedimental complex despite its facies differentiation, all its rocks are probably at least Frasnian and possibly late Frasnian in age. No stratigraphically important difference seems to exist between the rich faunas in the upper part of the unit and the poorer faunas in the lower part, except that the poorer faunas comprise fewer species and are generally much less well preserved.

No paleontologic criteria exist for the correlation of the fetid and aphanitic dolomite units of the Jerome Member. The fetid dolomite unit is unfossiliferous except for a few small spherical bodies of doubtful, possibly algal, affinities.

The aphanitic dolomite unit, although patchily fossiliferous, especially where incompletely dolomitized, contains no diagnostic fossils that can be used for exact stratigraphic correlation. Except for calcispheres it has no specific forms in common with the upper unit.

However, the occurrence of *Hypotetragona* sp. near the top of the aphanitic dolomite unit in section 32 (East Verde River) may be significant. The genus has been found by C. A. Sandberg (oral commun., 1960) in the middle part of the lower member of the Jefferson Formation near Livingston, Mont. (Fossil identification was by Jean Berdan in written communication to Sandberg, 1960). According to Sandberg, *Hypotetragona* sp. occurs about 175 feet above the base of the Jefferson Formation, which is early Frasnian in age. Definite identification of the species from these two localities would strongly support the suggestion of a Frasnian age of the aphanitic dolomite unit, but this awaits more detailed paleontological work.

The exact position of the base of the Frasnian in the Jerome Member, therefore, can not be determined. It may be at the base of the aphanitic dolomite unit, or it may possibly be as low as the base of the fetid dolomite unit.

Thus, a determination of whether the entire Jerome Member or only part of it is of Late Devonian age requires additional investigations.

COMPARISON WITH OTHER DEVONIAN STRATA IN THE ROCKY MOUNTAIN PROVINCE

Broadly speaking, the Martin Formation corresponds to the Sly Gap Formation of Stevenson (1941) of New Mexico, to parts of the Devils Gate Limestone of Nevada, and to the Jefferson and Darby Formations of Wyoming and Montana. A detailed correlation, however, is not simply made, and significant differences in the paleontologic features of the formations are apparent. Recent conodont studies by Clark and Becker (1960) have shown that the age of the lowermost part of the Devils Gate Limestone is late Frasnian. This part of the formation is probably that which Merriam (1940, p. 9) named the *Spirifer argentarius* zone and which he then regarded as late Middle Devonian in age. Nolan and others (1956, p. 51) concluded that the boundary of the Middle and Late Devonian is at the base of the *Spirifer argentarius* zone, and this conclusion has been further corroborated by the paleontological studies of Clark and Becker.

Therefore, the upper unit of the Jerome Member of the Martin Formation can probably be correlated with the lower part of the Devils Gate Limestone, but many details remain to be worked out. No species have as yet been discovered that are common to both the Devils Gate Limestone and the Jerome Member.

Little recent detailed information is available on the paleontology of the Devonian rocks of Utah, Colorado, Idaho, Wyoming, and Montana.

Fossils from the Jefferson Formation of Wyoming were first described by Kindle (1908), and since that time few additions to knowledge of the formation have been made (Laird, 1947; Kottlowski, 1950). The fauna listed by Laird (1947, p. 453) from unit Db of the Jefferson of northwestern Montana resembles the fauna from the Martin Formation in general aspect. It is a mixed brachiopod-coral assemblage composed of species of *Disphyllum*, *Tabulophyllum*, *Atrypa*, *Spinatrypa*, *Schizophoria*, and *Cyrtospirifer*, among others; all these genera are common in the Martin Formation although specific resemblances seem to be few. A small conodont fauna described by C. L. Cooper (1945) from the basal part of the Jefferson Formation, Flathead Range, Mont., is middle Frasnian in age. In general, then, the Jerome Member of the Martin apparently correlates at least with the lower part of the Jefferson Formation of Montana.

The Devonian faunas of Alberta have become better known recently and many biostratigraphic zones have been distinguished (Warren, 1949; Warren and Stelck, 1950, 1956), but correlation of individual zones with fossiliferous beds in the Rocky Mountains of the United

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States is difficult. Langenheim (1957) described a Late Devonian fauna from the Swisshelm Mountains of Cochise County, Ariz., that occurred below beds containing corals and brachiopods typical of the Martin Limestone. He correlated this faunal zone with the *Nudirostra athabascensis* zone of McLaren (1954) in Alberta. The upper half of the *N. athabascensis* zone contains *Timanites*, a goniatite characteristic of the earliest Frasnian; if Langenheim's observations are correct, the Martin fauna of Cochise County should be younger than earliest Frasnian. This, of course, agrees with the conclusion presented on page 91 that the upper fauna of the Jerome is later Frasnian in age.

The Martin fauna has fossils in common with three fossil zones defined by Warren and Stelck (1956, p. 6). These zones are, from bottom to top, (1) the zone of *Macgeea proteus*, (2) the zone of *Tenticospirifer cyrtinaformis*, and (3) the zone of *Spirifer strigosus*. These three zones combined correspond to the *Nudirostra albertensis* zone of McLaren (1954). Genera common to both the Alberta and the Arizona faunas are *Tabulophyllum*, *Pachyphyllum*, *Hexagonaria*, *Aulopora*, *Alveolites*, *Thamnopora*, *Nervostrophia*, *Schizophoria*, *Atrypa*, *Spinatrypa*, *Cyrtospirifer*, and *Tenticospirifer*. Closely related or identical species found in the two provinces are *Atrypa devoniana* var. *bentonensis* Stainbrook, *Tenticospirifer cyrtinaformis* (Hall and Whitfield), "*Spirifer*" *strigosus* Meek, and *Schizophoria iowensis* Hall.

Faunistic relationships exist also between the Martin fauna and the next younger zone of *Manticoceras sinuosum* in Alberta (Warren and Stelck, 1956, pls. 23–24), as is indicated by common occurrence of *Cyrtospirifer whitneyi* and of *Theodossia* sp.

Warren and Stelck's succeeding zone is the zone of *Nudirostra walcotti*, which includes the *Nudirostra gibbosa walcotti*—according to McLaren, corresponding to the *Cyrtospirifer* zone of Merriam (1940) in Nevada—and *Nudirostra gibbosa seversoni* zones of McLaren (1954, p. 173).

Thus, the "Martin fauna" as presently though incompletely known from the upper parts of the Martin Limestone and the Jerome Member of the Martin Formation in Arizona is the equivalent of several distinct faunal zones in rocks of Frasnian age in Alberta. No closer comparisons can be made at this time.

The upper part of the Martin Formation is stratigraphically broadly equivalent to the Mount Hawk Formation and the Nisku Formation of central Alberta, and it may include equivalents of part of the Alexo Formation.

Underlying the Nisku is the Ireton Formation (or Ireton Shale Member of the Woodbend Formation), from which Loranger (1954, p. 202) described and illustrated an ostracode under the name of *Kloedenella* sp. This ostracode, according to Jean Berdan (written communication to C. A. Sandberg, 1960), is possibly identical with those identified as *Hypotetragona* sp. from the upper part of the aphanitic dolomite unit of the Jerome Member of the Martin. It may be of some significance that in Alberta as well as in Arizona these ostracodes occur stratigraphically below beds for which general correlation has been determined on the basis of their coral and brachiopod faunas.

More exact correlation of biostratigraphic zones and of rock-stratigraphic units must await a more detailed study of Devonian faunas from all parts of the Rocky Mountain province.

SUMMARY OF FACIES PATTERN AND PALEOGEOGRAPHY

COMMENTS ON SECTIONS

The facies pattern of the Devonian rocks of the area can be read from plates 28–31, on which the numbered stratigraphic columns have been arranged according to nine lettered cross sections. In the following paragraphs, comments are offered on each section; but because the graphical representation of each stratigraphic column conveys in a comprehensible manner information on lithology, bedding, color, grain size of both carbonate and siliceous-detrital rocks, and a detailed analysis of faunal content, the sections are mostly self-explanatory.

SECTION A–A′

Section *A–A′* (pl. 28) presents several interesting features. The Beckers Butte Member varies considerably in thickness owing to intensive channeling in the Canyon Creek area (section 8). Field evidence suggests that from sections 6 through 8 and to Huddle and Dobrovolny's Cliff House Canyon section, the section is along a deep channel of the Beckers Butte Member. Outside the channel the Beckers Butte is a continuous sheet 10–20 feet thick. At the northwest end of the section, in the Spring Creek area, the Beckers Butte Member and the two lower units of the Jerome Member wedge out toward the Defiance uplift.

The fetid dolomite and the aphanitic dolomite units of the Jerome Member are present from the Black River to Cliff House Canyon. The fetid dolomite unit varies little in thickness; the aphanitic dolomite unit thins slightly to the northwest. Generally, throughout the entire area of its distribution, the aphanitic dolomite unit is uniformly composed of thin- to medium-bedded generally light-colored aphanitic dolomite, although lenses of sandstone occur locally. Fossils are scarce and include brachiopods, indeterminable ostracodes, and calcispheres.

The upper unit of the Jerome Member is composed of many facies and has many changes in appearance from one end of the section to the other. In the southeast (Black River, section 2), it is predominantly clastic; it consists of sandstone at the base and is overlain by dolomite that grades upward into dolomitic limestones and fossiliferous calcareous siltstones at the top.

The upper unit thickens toward the northwest. The upper shale-siltstone facies, however, thins in the same direction and becomes unfossiliferous. The middle, dolomitic part thickens and grades into a mixed sandstone-carbonate facies in which limestone increasingly predominates over dolomite to the northwest. This part of the unit is also increasingly fossiliferous northwestward.

The lowermost sandy part of the upper unit of the Jerome is composed of a sandstone-shale facies to the northwest, which wedges out into a moderately pure carbonate—predominantly dolomite—facies; the facies is purest and thickest in section 8. The lower part of the sandstone-shale facies changes to pure sandstone to the northwest near the edge of the Defiance uplift.

In places, a thick biostromal unit separates the lower dolomite facies from the upper mixed sandstone-carbonate facies.

SECTION B–B′

The five measured sections are not fully comparable, because the entire Jerome Member is represented in only two of them (sections 3 and 46). Section *B–B′* (pl. 28), however, is of interest because it illustrates the approximate northerly trends in facies distribution.

The Beckers Butte Member thickens greatly from section 3 to section 5. The sandstone fills a channel and for the most part is very coarse to conglomeratic. This channel is possibly a continuation of the channel shown in sections 6 and 8, and it possibly continues southeastward into the area of section 47. If so, it is continuous for more than 20 miles.

The Jerome Member is considerably attenuated to the south. Section 46, at Sevenmile Creek, has the smallest thickness of Jerome measured anywhere in the area studied. The attenuation affects the aphanitic dolomite unit and the upper unit but not the fetid dolomite unit.

A significant component of terrigenous material—sandstone, siltstone, and shale—is found in all sections; the material occurs in varying proportions and at different stratigraphic levels. The general distribution of these terrigenous sediments suggests a northeastern, eastern, or southeastern source area. Some of these sediments came probably from the Defiance uplift in the northeast; others came from a southeastern source having a yet unknown extent and location. (See also discussion of section *H–H′* on page 95.)

SECTION C–C′

Section *C–C′* (pl. 29) is approximately at right angles to the isopach lines and therefore, is of particular importance. It extends from the area of nondeposition of the fetid and aphanitic dolomite units in the northeast into the edge of the basin where the Jerome Member is thickest.

Sections 10 and 11 are on the edge of the Defiance uplift, where the Beckers Butte Member and the fetid and aphanitic dolomite units of the Jerome Member are missing. The upper unit of the Jerome is thin and contains intercalated sandstone. The carbonate units—here mostly limestone—are richly fossiliferous.

A great change in thickness occurs within a distance of only 4 miles between section 10 and section 12. To emphasize this change, section 45, about 2½ miles north of the line connecting sections 10 and 12, has been projected to the line of section to illustrate the gradual thickening of the upper unit of the Jerome Member west of section 10. Section 45 does not contain any true biostromal facies, although stromatoporoids do occur abundantly at a stratigraphic level approximately equivalent to the levels of the biostromes in sections 10, 11, 12, and 13.

At section 12 both the Beckers Butte and Jerome Members are complete. The Beckers Butte is 83 feet thick here and may have been deposited in the large channel exposed in sections 5, 6, and 8; if so, the channel is 30 miles long.

Both the fetid and the aphanitic dolomite units of the Jerome Member are typically formed at section 12. The aphanitic unit, however, is only 71 feet thick and has a few sandstone interbeds in its lower part, indicating that it was near the wedge edge of deposition.

Not only the fetid and aphanitic dolomite units but also the lower two-thirds or more of the upper unit wedge out between sections 12 and 10. In section 12 the basal part of this unit is composed of sandstone and very sandy dolomite, which indicates that the section is near the onlap of the upper unit over the Precambrian basement.

The sandstone is overlain by dolomite containing rugose corals and *Amphipora*. Two biostromal units (34 and 37) that are still higher in the section are probably the equivalent of the biostromal subunit 2 in section 10. In both sections 10 and 12, they are overlain by sandstone, as in sections 13 and 11. The upper part of the upper unit of the Jerome Member is uniformly fossiliferous from the biostromal subunits upward; brachiopods are abundant in all sections.

Important differences between sections 12 and 13 are the absence of a basal sandstone in the upper unit to the west and the indication of a slightly greater thickness of the aphanitic dolomite unit in the same direction, although the unit is not fully exposed in section 13.

SECTION D–D′

Section *D–D′* (pl. 29) illustrates the units near the wedge edge of the aphanitic dolomite unit of the Jerome

Member. The three sections (14, 15, 16) are arranged approximately at right angles to this edge. Only the lower 25 feet of section 16 probably constitutes the aphanitic dolomite unit, which here has a basal sandstone.

The section also shows the onlap of the upper unit over the Precambrian base just outside the wedge-out line of the fetid and aphanitic dolomite units. Considerable thinning occurs between sections 16 and 14—from 197 feet to 75 feet. At section 16 the upper unit, except for a basal sandstone, consists almost entirely of carbonate rocks. Sections 14 and 15 also have basal sandstones but are considerably more sandy throughout.

The channel at the base of section 14, which is mostly filled with finely to medium-crystalline sandy dolomite rock, is of special interest. Evidently, in this area some relief existed almost to the end of sedimentation in Devonian time, but filling of this particular channel (or depression) took place when, or at a place where, little clastic detrital material was available. Generally, less clastic material was available in this area than in similar stratigraphic positions to the west and to the east. The "channels" in this area were probably shallow, panlike depressions. (See p. 50.)

The uppermost 35 or 40 feet of all three sections are uniformly fossiliferous, although sandiness increases from southwest to northeast.

SECTION E–E′

Section *E–E′* (pl. 29) illustrates the somewhat anomalous slight thickening of the aphanitic dolomite unit from south to north in the direction of the wedge edge. However, correlation of the bottom part of both sections is somewhat arbitrary, as no truly aphanitic rocks but only fine-grained dolomite having a subconchoidal fracture occur.

The upper unit thickens slightly from north to south, away from the wedge edge, and the unit in the more northern section (No. 17) seems to contain more siliceous-detrital material. A true sandstone and silt facies exists only in the uppermost part of section 17 (Colcord Canyon), where the clastic beds are interbedded with limestone. In the southwestern section (No. 18), clastic material is absent from this part of the unit, but one limestone bed remains. In both sections fossils are restricted to this uppermost calcareous and clastic facies.

SECTION F–F′

The important section *F–F′* (pl. 29) traverses Christopher Island and illustrates the general onlap of both the aphanitic dolomite and the upper units of the Jerome Member. The wedging out of the aphanitic dolomite unit at its northwestern end towards the uplift is well illustrated, as is the abrupt northwesterly thickening of the upper unit away from the uplift. The aphanitic dolomite unit contains a significant clastic component.

At the southeastern end of the cross section (section 18, south of Turkey Peak), the entire upper unit is dolomitic. Northwest toward Chistopher Island, an increasing amount of siliceous detrital material was introduced. The aphanitic dolomite unit is missing everywhere along the southwest side of the uplift, and sandstone or dolomite of the upper unit rests directly on Precambrian (mostly Mazatzal) Quartzite.

On the northwest side of the high area, the mixed sandstone carbonate facies persists and here constitutes the uppermost part of the upper unit of the Jerome Member. It is underlain by an abruptly thickening unit composed of pure dolomite, and near the bottom of the unit dolomite is interlayered with clastic sediments.

In the area within about 3 miles of Christopher Island, the rocks are unfossiliferous, but beyond this area normal brachiopod and coral associations, together with other fossils, are present in the higher parts of the sequences.

On the west side of Christopher Island, the aphanitic dolomite unit probably reappears at Kohl Ranch (section 28), where it is composed of sandstone and fine-grained dolomite (subunit 4) totaling 15 feet in thickness. The unit seems to thicken to the north, for in section 27 (junction of Tonto and Horton Creeks) an aphanitic dolomite (subunit 6) underlain by sandstone and conglomerate has possibly a total thickness of 55 feet. Here as elsewhere near the wedge edge, the rocks of the fetid and aphanitic dolomite units change facies and include so much siliceous detrital rock that they are no longer clearly recognizable on the basis of typical lithology. Also, the basal part of the upper unit includes sandstone, and the distinction between sandstone facies of the various units is impossible to make.

Even though some details of correlation of the basal parts of these sections can only be decided arbitrarily, it seems certain that none of the basal clastic rocks belong to the Beckers Butte Member. Apparently, the area shown by the section furnished some of the sedimentary material for the Beckers Butte Member.

SECTION G–G′

Section *G–G′* (pl. 30) illustrates the lithology and the facies changes west and southwest from Christopher Island. At Kohl Ranch (section 28) and Thompson Wash (section 29), the fetid dolomite unit of the Jerome Member and the Beckers Butte Member are missing, and the aphanitic dolomite unit of the Jerome is entirely composed of a sandy facies that becomes more silty in its upper part with increasing distance from the high area. At Thompson Wash the sandstones are in part hard, massive, very crossbedded, and replete with fragmental fish plates.

Further west the typical aphanitic dolomite facies reappears, although the general composition of the unit is still somewhat inhomogeneous. In addition to typical aphanitic dolomite, intercalated sandstone beds and some beds of limestone and slightly dolomitic limestone occur.

The upper unit of the Jerome Member has the same thickness, but details of the lithology of the member near the East Verde River are not yet sufficiently well understood, mostly because exposures are unsatisfactory. However, a lower carbonate (largely dolomitic) facies that is unfossiliferous can probably be distinguished from an upper mixed clastics and carbonate facies that consists of erratically distributed sandstone, siltstone, shale, limestone, and dolomite, some of which are richly fossiliferous.

SECTION H–H′

Section *H–H′* (pl. 30) traverses an area of very complex lithology, the complexities of which cannot be accurately portrayed. It crosses Pine Island, on which no Devonian rocks were deposited and where the Redwall Limestone rests on Dripping Spring Quartzite. However, within a distance of as little as 1½ miles east of Pine Island (at section 33), both the Beckers Butte and the Jerome Members are typically formed; the three units of the Jerome have normal thickness.

The Beckers Butte Member in this area has the characteristic intercalations of sandy dolomite in the upper part.

The fetid dolomite unit of the Jerome is thin east of Pine Island and absent at Tonto Natural Bridge, where the Beckers Butte also is missing.

The aphanitic dolomite unit is present in all sections; however, except for the section at Limestone Hills, 15 miles to the southwest, the unit is much less homogeneous than elsewhere. Some of the dolomite of the aphanitic unit shown in the section is more calcitic than is common for these rocks; at Tonto Natural Bridge intercalations of sandstone and a conglomeratic base are found, indicating that this member here transgresses an irregular Precambrian basement. Tonto Natural Bridge is also one of the few places where fossils (calcispheres and ostracodes) are found in the aphanitic dolomite unit. They occur only in calcareous or slightly dolomitic beds, and their presence indicates that the unit here is near the south side of Pine Island, where normal marine sedimentation existed.

The upper unit of the Jerome has a significant clastic component near Pine Ridge that, however, diminishes and disappears toward the southwest. Sandstone characterizes the middle part, or beds somewhat above the middle, of the unit. The remainder is a fairly pure carbonate facies in which the limestone-dolomite ratio generally shifts towards predominating dolomite from northeast to southwest, and at Limestone Hills (section 38) the upper unit is almost entirely dolomitic.

Fossiliferous horizons are scattered through the upper unit, but most faunas are small and poor.

SECTION I–I′

Section *I–I′* (pl. 31) extends for more than 150 miles. Its greater part, from Pinal Creek (section 35) to the Verde River at Sycamore Creek (section 43), extends northwestward in an almost straight line. Between Theodore Roosevelt Dam (section 36) and Limestone Hills (section 38), it crosses the hypothetical Mazatzal Land and roughly parallels the southwestern edge of the Defiance uplift.

The facies pattern along this entire section is rather uniform. The Beckers Butte occurs as thick channel fill both at Theodore Roosevelt Dam and at Limestone Hills. Along the southeastern part of the section, the Beckers Butte is not exposed. Northwest of the Limestone Hills, the Beckers Butte is still clearly present at Chasm Creek and Squaw Peak; whereas, sandstones in an equivalent stratigraphic position in the Jerome area compose the Cambrian Tapeats Sandstone rather than the Beckers Butte. (See discussion on p. 26–27.)

The fetid dolomite unit of the Jerome Member is uniform in lithology from the Roosevelt area as far as Jerome and is generally uniform in thickness, having only a local thickening to 40 feet at Chasm Creek (section 39).

The aphanitic dolomite unit thickens somewhat from the Roosevelt area to the Limestone Hills. From here westward it seems to have a consistent thickness of slightly less than 150 feet. It is noteworthy that in the entire distance illustrated by the section, siliceous detrital rocks are subordinate in this unit. In the Jerome area only the "red marker bed" of Anderson and Creasey (1958) occurs, which is a highly dolomitic quartz sandstone, and is 2 feet thick; a similar bed is found in the Windy Hill section (37). The aphanitic dolomite unit, then, is remarkably uniform along the entire area and is composed almost entirely of typical aphanitic dolomites and thin shaly interbeds, which are found especially in the lower part.

Similarly the upper unit is rather uniform in facies pattern. At Theodore Roosevelt Lake the unit has a significant siliceous detrital component and has a mixed dolomite-sandstone facies except for the upper 60 feet, which has a sandstone-shale facies. This upper facies thickens considerably southeastward and is 110 feet thick at Pinal Creek (section 35, subunits 20–26), where it also is much more fossiliferous. Brachiopod faunas (atrypids and *Devonoproductus*) are dominant.

A comparison of the section at Theodore Roosevelt Dam (No. 36) with that at Windy Hill (No. 37) indicates that the distribution and lateral extent of individual rock subunits of the mixed dolomite-sandstone facies are apparently very irregular. Although only 4½ miles apart these two sections are not closely similar in the order of succession of carbonate and sandstone subunits. However, in both localities a marked concentration of fossiliferous beds occurs in the middle part of the facies.

The mixed dolomite-sandstone facies thins towards the southeast. At Pinal Creek it is only 96 feet thick and consists of about half dolomite and half siliceous detrital clastics (which here include siltstone). All carbonate subunits and some sandstones are highly fossiliferous.

In the northwestern part of the area, the upper unit is less complex and in fact is composed of an almost pure dolomite facies, most of which is poorly fossiliferous. Obviously this area was far from the sources of terrigenous material. The great variety of dolomitic rocks that characterize this area is described on pages 42 and 43. The unit thickens to the northwest from 218 feet at Limestone Hills (section 38) to 307 feet at Jerome (section 41). In section 43 (Verde River at Sycamore Creek) one shale subunit (24) occurs above the middle of the unit, and a thin sandstone subunit is found at the top. Fossil horizons are few and widely separated although rich assemblages occur locally.

The isolated Elden Mountains section (No. 44) is included in the section in order to show its close lithologic relation with the upper unit of the Jerome Member in the Jerome area.

PALEOGEOGRAPHY

Much evidence derived from the study of facies distribution and the isopach pattern of the rocks of the Martin Formation in central Arizona indicates that the Martin was deposited first on land (Beckers Butte) and then in gradually deepening water on a slowly subsiding, broad shelf to the southwest and west of the Defiance uplift; the evidence also indicates the absence of any ancient landmass in the area. These conclusions are based on (1) the areal distribution of the Beckers Butte, (2) the distribution and facies character of the fetid and aphanitic dolomite units of the Jerome Member, (3) the lateral distribution of terrigenous siliceous detrital material in the upper unit, and (4) the distribution and composition of fossil faunas in the upper part of the upper unit.

The rocks of the fetid and aphanitic units were formed by rather special combinations of sedimentational and diagenetic processes. The uniform thickness and lithologic character of these rocks and their wide distribution southwest and west of the Defiance uplift—from the Jerome area in the northwest as far as Globe and the Black River area in the southeast—indicate that conditions of sedimentation across this very large area were uniform.

Separation of the sea located in the present area of Jerome and the Upper Verde River from that located in the present upper Salt River area by a land barrier, as envisaged by Stoyanow (1942, pl. 5, fig. f), or even the existence of a substantial landmass in the general area would be reflected by facies differentiation that should be decipherable from the present rock record despite widely spaced outcrops. More especially, a significant siliceous-detrital component might be expected in the two lower units of the Jerome Member at Limestone Hills and at Theodore Roosevelt Dam because these localities are close to or possibly within the former shorelines on opposite sides of the supposed land, as shown by some authors. Instead, the sections (Nos. 36, 38) at both localities are very much alike and the fetid and aphanitic dolomite units lack significant amounts of terrigenous detrital material. The fetid dolomite unit is very similar in lithology and in thickness—20 feet at Theodore Roosevelt Dam, 21 feet at Limestone Hills—at both localities.

The aphanitic dolomite unit is 102 feet thick at Theodore Roosevelt Dam and 155 feet at Limestone Hills, but the general lithology is the same. At Theodore Roosevelt Dam the unit consists entirely of aphanitic and subaphanitic dolomite that contains no more detrital quartz than is found in the normal facies of this unit. (See description of subunits 11 and 12 of section 36.) Four and a half miles farther east at Windy Hill (section 37), a 4-foot sandstone bed occurs 15 feet below the top of the aphanitic dolomite unit. This occurrence, too, is not unusual, and the stratigraphic position of this sandstone unit corresponds approximately to that of a similar sandstone bed in the Jerome section (section 41, subunit 13).

At Limestone Hills (section 38) as much of the aphanitic dolomite unit, as is exposed consists entirely of dolomite rock and only scattered detrital quartz. Notwithstanding the 48-foot covered interval, it is unlikely that a sizable sandstone subunit is hidden here, because no sandstone was noted in the talus and because the entire section at Limestone Hills, including the upper unit, consists of a rather pure carbonate facies.

Not only does the facies distribution in the fetid and aphanitic dolomite units seem to be irreconcilable with the assumption of a Mazatzal landmass in Devonian time, but also the distribution of terrigenous siliceous detrital material in the upper unit of the Jerome

Member opposes such an assumption. Both at Theodore Roosevelt Dam and at Windy Hill, the upper unit has a significant component of sandstone. The ratio of sandstone and shale to carbonate rocks at Theodore Roosevelt Dam is 12:13; at Windy Hill, 16:14. Total thickness of sandstone and shale in the upper unit is 123 feet at Theodore Roosevelt Dam and 163 feet at Windy Hill. The general impression that these clastics came from an eastern or southeastern (rather than western) source is also supported by the complete absence of sandstone in the upper unit at Limestone Hills (section 38), although many dolomite and limestone subunits contain appreciable amounts of detrital quartz.

Stoyanow (1942, pl. 5, map f) showed occurrence of widespread arenaceous facies northwest of the postulated northwestern shore of Mazatzal Land and north as far as Jerome and Elden Mountains. Such a sandy facies has been shown to be nonexistent.

The general picture of facies distribution in the upper unit illustrated by section *I–I′* (pl. 31) suggests an area of uniform deposition in which the supply of clastic terrigenous material lessened from southeast to northwest and ceased to be significant at some unknown distance northwest of the Roosevelt area. Published reports (Huddle and Dobrovolny, 1952; Peterson, 1954) indicate that terrigenous rocks are significant also south of the Roosevelt area. Thus, at Superior the ratio of clastics to carbonate rocks is 2:3, and at Gold Gulch, northwest of Castle Dome mine, it is about 1:2. Peterson reported a middle quartzite unit from the Globe quadrangle 10–35 feet thick that seems to correspond to the lower part of the upper unit as defined in this report. The upper shale zone is reported also from the Globe quadrangle.

The Devonian rocks in the area east and south of Globe have not yet been studied in sufficient detail to allow paleogeographical conclusions. In the Globe quadrangle, the thickness of Devonian rocks, according to Peterson (1954), ranges from 150 to 350 feet. At Sevenmile Creek (section 46) the entire Jerome is only 252 feet thick, and the considerably attenuated upper unit contains a significant terrigenous component. The distribution of terrigenous material in the upper unit in the area east of Theodore Roosevelt Dam suggests the presence of a source area to the east rather than to the west.

Along the north and northeast shores of Mazatzal Land drawn on maps, the amount of terrigenous clastics is observed to have decreased with increasing thicknesses of deposits from southward or southwestward. Facies and isopach patterns of the member agree well with these observations. Sections *C–C′*, *D–D′*, *E–E′*, and *G–G′* should be noted especially, as all show that siliceous-detrital material in the upper member decreases southward or southwestward.

Finally, the uniform distribution and composition of marine invertebrate faunas in the upper part of the upper unit indicates ecologic conditions were uniform in the area southwest of the Defiance uplift. The well-preserved thanatocoenotic associations and little-transported brachiopod coquinas indicate nonturbulent conditions during the closing stages of the deposition of the Martin Formation, rather than nearness of rocky shores.

All facts thus point toward the conclusion that the sea covered the area between the Salt and Verde Rivers now occupied by the Mazatzal Mountains and the Sierra Ancha at all times during the deposition of the Jerome Member (fig. 37). Conflicting views regarding the paleogeography of central Arizona in Devonian time have thus been resolved, and the paleogeographic picture that was drawn on the basis of broad generalizations by Eardley (1951) and by McKee (1951) is, in its essential outlines, supported by detailed facies and isopach studies.

The absolute duration of the Late Devonian Epoch has been determined to be about 20 million years. If one considers the fact that the Jerome Member is most probably equivalent to only one of the six Upper Devonian goniatite zones, the total time required for the deposition of the Jerome should have been 3 or 4 million years. This is a time span equivalent to the duration of one-third or one-fourth of the Pliocene. The value is reasonable and allows for the time required for the accumulation of the sediments in the presence of slight negative epeirogenetic movements.

MICROFOSSILS OF THE JEROME MEMBER

Whereas the megafauna of the Jerome Member consists of relatively well known genera, many assemblages of microfossils from the Jerome have not been previously reported; these microfossils are important in the microfacies of the Devonian rocks in the Rocky Mountain province. The microfossils are described and illustrated here in order to call attention to their existence and to stimulate search for them elsewhere.

TINTINNINA(?)

Until recently no tintinnids older than Late Jurassic were known (Campbell, 1954), but Cuvillier (1957) reported the presence of representatives of the group in limestones of Late Devonian age in the Sahara (Algiers) and southern France (Languedoc). These forms have not yet been described in detail. In view of this discovery attention should be called to possible occurrence of tintinnids in the Jerome Member of Arizona.

Small thin-walled shells that resemble tintinnids occur in limestone in upper Colcord Canyon (section

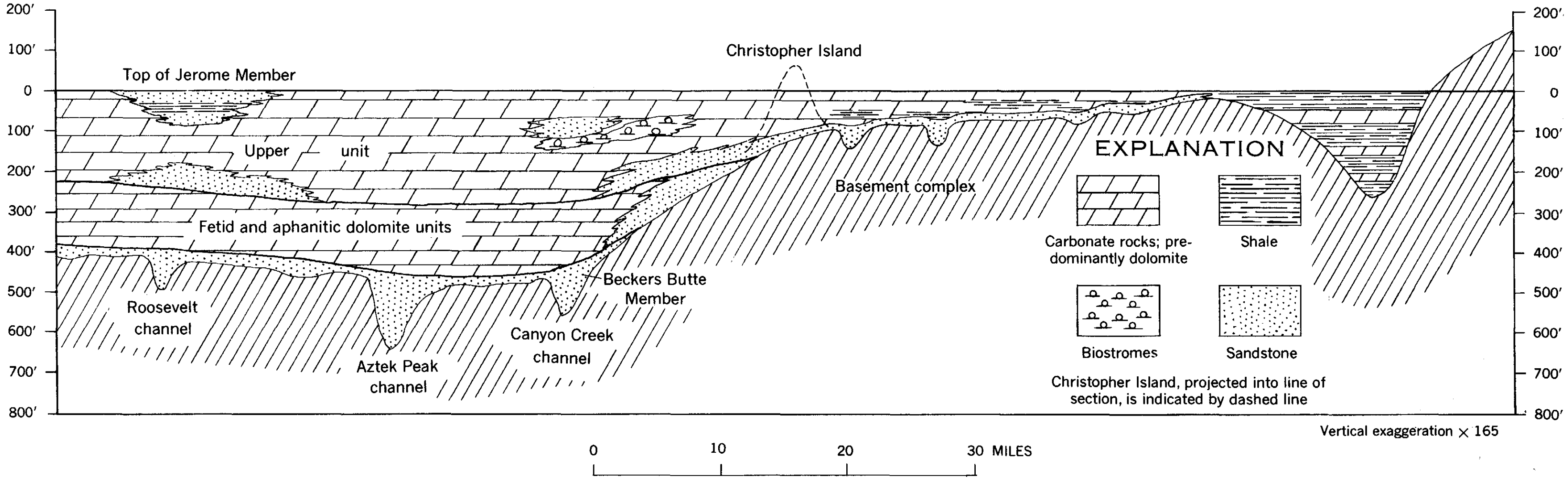

FIGURE 37.—Section from near Holbrook to near Theodore Roosevelt Lake, showing stratigraphic relations at the time of the close of deposition of the Martin Formation.

17) at 177 feet above the base of the Jerome. The limestone is made up of extremely fine grained biogenic material.

These forms (pl. 16, fig. 2) are thin walled and cup shaped and have a rounded bottom and a slightly flaring aperture. They are about 0.6 mm long, 0.45 mm in maximum width, and about 0.35 mm across at the aperture. In shape they resemble somewhat the genus *Tintinnopsella*, known from the Late Jurassic and Early Cretaceous of Europe (Campbell, 1954, p. D173), which, however, is considerably smaller.

Another form was found in a limestone 245 feet above the base of the Jerome in Salt River Draw (section 6). It is bell shaped and has a pointed base; the entire skeleton is 0.5 mm long and 0.35 mm wide in the middle. The aperture is slightly constricted (pl. 16, fig. 1). The form resembles some members of the family Ptychocyclididae. (See Campbell, 1954, p. D175.)

Mesozoic tintinnids do not generally exceed about 0.3 mm in length and most of them are smaller (Colom, 1948). The forms described above are about twice the size of the larger Mesozoic forms. More data are needed before they can be classified with greater confidence.

CALCISPHERES

Many limestones contain abundant hollow spheres that have calcitic shells and range in size generally from less than 0.1 mm to 0.5 mm. Several different morphological types can be distinguished.

Williamson (1881) was apparently the first to describe fossils of this kind, to which he gave the formal generic name *Calcisphaera*. He distinguished several morphologically distinct forms as different species, which with one exception came from marine limestones of Early Carboniferous age in North Wales. The exception was a comparatively large form from marine limestone of Middle Devonian age from Ohio, to which Williamson gave the name *Calcisphaera robusta*. Miller (1889) designated this species as the type of *Calcisphaera*, but Andrews (1955, p. 123), Horn af Rantzien (1956, p. 245), and Konishi (1958, p. 103) believed that this choice was erroneous; Andrews and Konishi suggested that *Calcisphaera laevis* Williamson should serve as the type species. This species had been made the type of a new genus *Granulosphaera* by Derville (1931, p. 132), who later recognized, however, that *Granulosphaera* and *Calcisphaera* should be considered synonyms (Derville, 1941). *Calcisphaera laevis*, occurs in limestone of Carboniferous age in North Wales and is reported by Derville (1931) from marine limestone of the same age in France. *Calcisphaera robusta* was shown by Karpinsky (1906) to be a charophyte, a classification that has been confirmed by later investigators (Hacquaert, 1932; Peck, 1934).

After publication of Williamson's paper, microscopic calcitic spheres were found in many Paleozoic rocks, chiefly those of Devonian and Carboniferous age. The morphological variety of the spheres is considerable, as is shown by the large number of separate genera that authors have attempted to separate from the original genus *Calcisphaera*. Among these are *Granulosphaera*, *Cytosphaera*, *Diplosphaera*, and *Polyderma* of Derville (1931, 1950), *Bisphaera* and *Praechara* Birina (1948), and *Radiosphaera*, *Asterosphaera*, *Radiina*, and *Sphaerella* of Reitlinger (1957), though some of these genera may be Foraminifera.

Because of considerable uncertainty as to the taxonomic affinities of these objects, many authors refer to them informally as calcispheres (French calcisphères; German, Calcisphären). This usage seems preferable to establishment of a formal family (such as Calcisphaeridae Miller, 1889) or higher taxon, and the term is here used for all primarily hollow, more or less spherical calcitic bodies of microscopic size. These bodies vary mainly in size and in thickness and structure of their encasing wall. Konishi (1958, p. 108) demonstrated that the appearance of this wall may vary considerably owing to diagenetic changes.

Calcispheres of Devonian age from the following regions have been mentioned or described: Germany (Chapman, 1921), Belgium (Lombard and Monteyne, 1952), France (Milon, 1923, 1928; Le Maître, 1930), Alberta (Beales, 1956, 1958; Konishi, 1958), the Volga-Ural region (Bykova and Polenova, 1955), the Russian Platform (Birina, 1948; Rakhmanova, 1956; Reitlinger, 1957), and northwestern Australia (Veevers, 1959, p. 18). Calcispheres of Carboniferous (mostly Early Carboniferous) age from marine rocks in the following regions have been described: England (Reynolds, 1921; Wolfenden, 1958; and others), Germany (Paul, 1937), France (Derville, 1931, 1950, 1952; Lapparent, 1923), the Donetz Basin (Botvinkina and others, 1956), Japan (Konishi, 1956), and more recently the United States (Baxter, 1960).

Tiny spherical fossils, resembling the Paleozoic calcispheres, are also known from rocks of Mesozoic age. Among these are the following: *Fibrosphaera* from Cretaceous rocks, described by Lapparent (1924; see also Colom, 1931); *Cadosina* and *Stomiosphaera*, which were first described from Jurassic rocks of Indonesia by Wanner (1940) and since recognized in the Bavarian Alps (Hagn, 1955) and in Morocco (Colom, 1955) and which have a fibrous wall structure as demonstrated by Leischner (1959, p. 870); and *Calcisphaerula*, which was described by Bonet (1956, p. 44) from the Cretaceous of Mexico, Texas and from the Mediterranean area and which cannot be distinguished from the Paleozoic *Calcisphaera*, according to Bonet. Finally, from the Pierre Shale of Late Cretaceous of Colorado, LeRoy and Schieltz (1958, p. 2453) described "microspheres" having the same general appearance.

Attempts to separate morphological groups of calcispheres according to wall structure have been made by Derville (1941) and Reitlinger (1957). Konishi (1958, p. 103) pointed out that apparently objects belonging to three different groups of organisms had been referred to as calcispheres: (1) certain trochilisks, such as "*Calcisphaera robusta*"; (2) organisms of the type described as "calcisphères de forme A" by Lombard and Monteyne (1952, p. 14–16); and (3) the "typical calcispheres" of unknown biologic affinities. To group 1 belong the "calcisphères de forme C" of Lombard and Monteyne (1952, p. 16–17), who apparently did not recognize the charophyte affinities of the form. Group 3 is identical with Lombard and Monteyne's "calcisphères de forme B."

Group 1 is not discussed here because no representatives were found in Devonian rocks of Arizona. The organisms constituting group 2 belong to the genus *Umbella* Maslov, which occurs sparingly in the Jerome Member. The "typical" calcispheres, group 3, are abundant in Arizona Devonian rocks and are discussed first.

The group 3 calcispheres that occur in the Jerome may be divided into thin-walled and thick-walled types. The walls of the thick-walled type may be secondarily thinned during diagenesis, but the two types of shells are also distinguished by size—the primarily thin-walled forms are smaller than the thick-walled ones.

THIN-WALLED CALCISPHERES

Several limestone beds of the upper unit contain large numbers of tiny calcareous spheres that are of two sizes. A representative rock is shown in plate 17, figure 2; the slide contains very many sections of very tiny spheres and a few of distinctly larger ones.

The very small sections are very generally circular, or nearly so, and their diameter does not exceed 100 microns. They, therefore, represent almost perfectly spherical bodies having a maximum diameter of about 100 microns. About half of the tiny spheres are filled with aphanitic limestone matrix, and half are filled with crystalline calcite. The shell of the hollow spheres is 3–5 microns thick.

In another rock (pl. 18, fig. 1) the same kind of sphere is abundant, but the spheres are associated with *Amphipora*. In another rock type the spheres are mixed with a large amount of very fine fossil debris—pteropods, ostracodes, and unidentified material (pl. 17, fig. 1)—but many of them can be clearly distinguished.

THICK-WALLED CALCISPHERES

Thick-walled calcispheres are larger spherical or near-spherical objects having diameters greater than 200 microns and comparatively thick shells that have a recognizable fibrous texture where well preserved. Spheres of this category are of two types: one in which the shell encloses a perfect hollow sphere and another in which the internal hollow space is elliptical. The outside of the shell of both types is more or less irregular.

Type 1 includes all those forms that are closely similar to *Calcisphaera fimbriata* and *C. hexagonata* Williamson (1880, p. 521–522) and to the "*fimbriata* type" of Konishi (1958).

Very typical specimens of this kind make up a large proportion of some originally aphanitic but highly recrystallized limestones in the upper unit of the Jerome Member (pl. 19).

The rock illustrated in plate 19, figure 1 superficially appears "pelletal." The "pellets" of aphanitic limestone, however, which vary greatly in size, are obviously parts of the rock that have escaped recrystallization. That the clear crystalline "cement" originated through grain growth from finer grained probably aphanitic limestone is shown by the fact that it entirely surrounds many calcispheres.

The calcispheres have external diameters as much as and perhaps slightly exceeding 200 microns and internal diameters as much as about 150 microns. Most spheres are embedded in the crystalline cement, and nearly all shells are affected by recrystallization. Where recrystallization has been extreme, the shell is completely replaced by crystalline calcite and is no longer recognizable (pl. 19, fig. 1). All transitions in replacement occur: from shells in which recrystallization has been extreme to shells whose outlines are still well preserved and that have retained the original fibrous texture. Most commonly, only part of the shell was absorbed by the calcite, and the remnants of shell merge into the surrounding calcite along a fuzzy margin (pl. 19, fig. 1*B*), but some specimens apparently retain their original outline (pl. 19*C*, fig. 1).

The inside of the fibrous shell is lined with a dark film. Although the lining has been observed by many authors, especially in calcispheres having fibrous shells, its mineralogical nature has not been determined.

All spheres are filled with clear crystalline calcite that probably resulted from diagenetic infiltration.

As grain growth proceeded in the rock, the greater part of the rock came to consist of crystalline calcite as shown on plate 19, figure 2. Throughout the slide, calcispheres are seen in all stages of "dissolution."

Many lost their identity and are recognizable only as dim "ghosts" in the calcite. Most of these do not show up well in the illustration.

Calcispheres of the spherical thick-walled type also occur in dolomites, both in the upper unit (pl. 8, fig. 3) and in the aphanitic dolomite unit (pl. 6, fig. 4). In these rocks they are everywhere dolomitized, and their detailed structure has been destroyed.

Thick-walled calcispheres of type 2 have a hollow interior that is ellipsoidal rather than spherical; they occur also in limestones of both the aphanitic dolomite and the upper units of the Jerome Member. They are very abundant in some beds and are at places associated with thin-walled calcispheres, but they are less commonly associated with thick-walled calcispheres of type 1. The type 2 calcispheres, furthermore, have more irregular outer surfaces (fig. 38).

A typical rock in which the calcispheres are almost rock-forming is the calcitic dolomite illustrated on plate 20, figure 1. Measurements of three well-preserved calcispheres, marked on the plate, are as follows:

TABLE 7.—*Measurements, in microns, of calcispheres illustrated in plate 20, figure 1*

Specimen	Dimensions: Outer	Dimensions: Inner	Thickness of shell
A [1]	370×250	250×190	20–55
B	370×320	200×150	20–110
C	300×250	225×190	15–45

[1] In specimen A and some others, traces of fibrous texture of the shell are preserved; in others, much recrystallization has occurred.

The inside of each shell has a dark lining that is generally only a film, but in specimen B (pl. 20, fig. 1) and some others, it is as much as 18 microns thick. The outside of the shells is very irregular, as is better seen in drawings made from photographs (fig. 38, *a–l*). This irregularity seems to be an original feature of these shells and not one caused by diagenetic alterations.

Somewhat more regular is another very large calcisphere from the same rock (pl. 15, fig. 5) that has outer dimensions of 640 × 480 microns, inner dimensions of 400 × 275 microns, and a shell thickness of 25–100 microns. The shell is entirely recrystallized. (See also fig. 38, *f*.) A peculiar radiate calcite body that

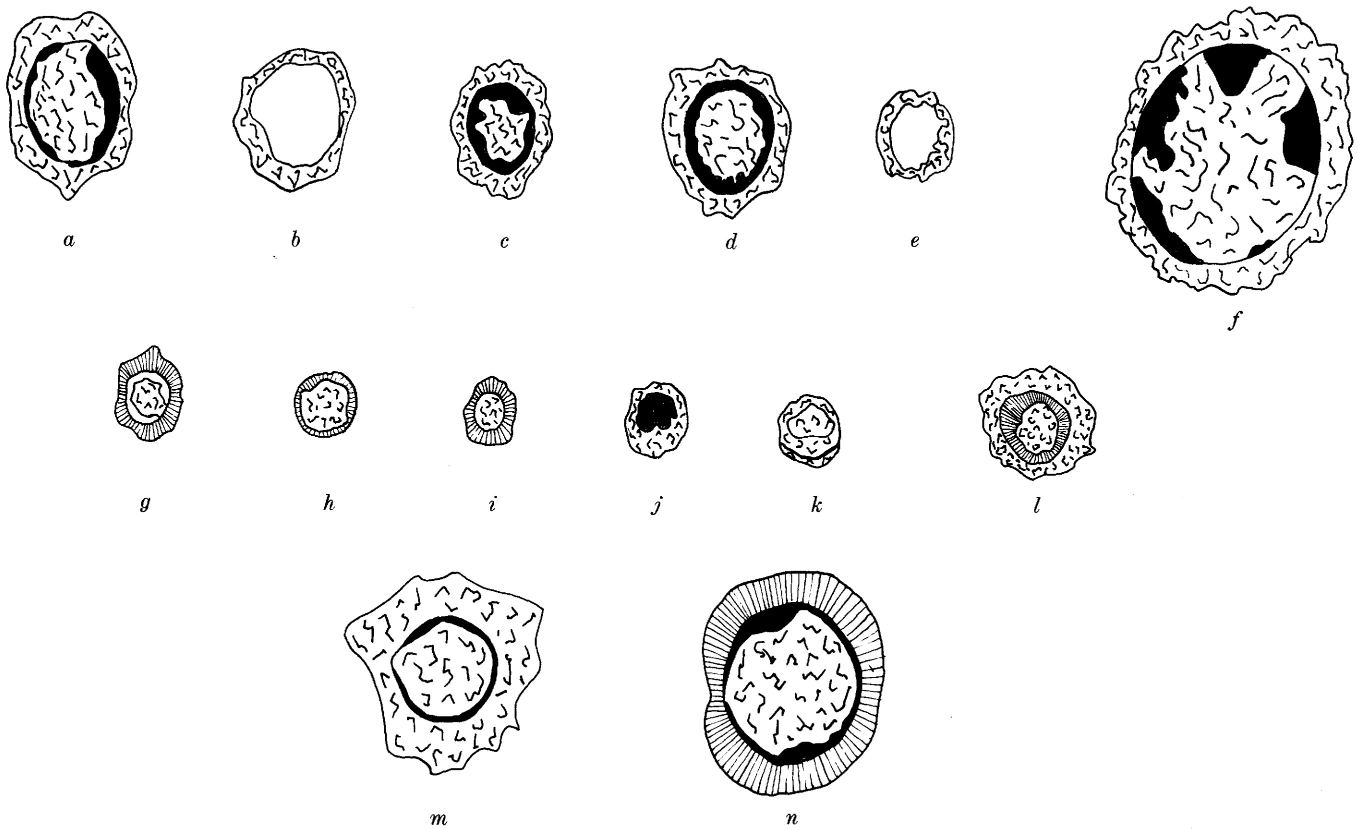

FIGURE 38.—Sections of calcispheres. ×75. Radial lines, fibrous calcite; black, dark inner layer; irregular lines, recrystallized calcite. *a–f*, from calcitic dolomite in aphanitic dolomite unit of Jerome Member, section 6, Salt River Draw, subunit 10; *g–k*, from limestone, upper unit of Jerome Member, section 4, Salt River, subunit 18; *l*, from limestone, upper unit of Jerome Member, section 34, Tonto Natural Bridge, subunit 8; *m*, from limestone, Martin Limestone, Mount Martin, near Bisbee, Ariz.; *n*, from sandstone, upper unit of Jerome Member, section 27, Tonto and Horton Creeks, subunit 8.

may be adventitious is lodged in the interior. It may, however, be organic because a calcisphere containing a rather similar radiate body was described from the Devonian of Silesia by Chapman (1924, pl. 8, fig. 6).

The rock illustrated on plate 20 figure 1, also contains many thin-walled small calcispheres having diameters of about 100 microns; many of these may be detected by close scrutiny of the photograph. The rock is probably almost entirely organogenic.

Many of the thin-walled small spheres are filled with calcite; many spheres of both kinds are engulfed by recrystallized calcite and are themselves partly recrystallized.

Thick-walled calcispheres of type 2 also occur in fine-grained partly recrystallized rocks of the Martin Limestone at the type locality—Mount Martin near Bisbee (pl. 15, fig. 3; pl. 16, fig. 3). Their wall structure has been completely altered.

A somewhat similar, though more regular, type is represented by two well-preserved calcispheres found in fine-grained sandstones (pl. 9, fig. 6; pl. 15, fig. 6). One of these (pl. 15, fig. 6) has outside dimensions of about 500 × 400 microns, inside dimensions of 350 × 300 microns, and a wall thickness of 40–85 microns. The wall in both specimens has a well-preserved fibrous texture; the characteristic dark zone is on the inside. The outside of the shells is smooth, and these forms are therefore transitional in their features to the genus *Umbella* Maslov, to which they may belong.

AFFINITIES

As has been shown, "typical" calcispheres are of various morphological types, some of which are not necessarily closely related. However, all have been classified as calcispheres by observers in the past, although to my knowledge never have as many varieties been described from one stratigraphic formation as have been described from the Martin Formation. Classification and biologic affinities of these fossils are very much in doubt, and little progress can be made in their classification as long as they are lumped together as they have been in the past or as long as only one or the other type is being considered by an author.

Williamson (1881) believed that the calcispheres are some form of extinct Protozoa—though not Radiolaria. Cayeux (1929) regarded them as algae and believed that all calcispheres originally had perforate walls, although the wall structure of many had been changed. Derville (1931) and Wanner (1940, p. 91) regarded them as Foraminifera; Kaisin (1926) believed that they are Protozoa—probably Foraminifera. Lombard and Monteyne (1952, p. 21) believed that they are most likely algal spores. Beales (1958) suggested that they might be hystrichosphaerids, and Thomas (1932) and Pia (1937) thought that they were gas bubbles. Among those who simply admit that their systematic position is unknown are Deflandre (1949) Reitlinger (1957), and Konishi (1958).

Thin-walled calcispheres seem to be very widespread geographically and stratigraphically, but they have rarely been well described or illustrated. Glover (1955, p. 6, fig. 9) described what appear to be thin-walled calcispheres from aphanitic limestone of Middle Devonian age in northwestern Australia as "minute recrystallized ooliths." The description of Cretaceous forms by Bonet (1956, p. 441), who named them *Calcisphaerula*, is one of the best. These forms are calcareous spheres that are 35–160 microns in diameter and have walls 5–10 microns thick. Bonet stated that they are widely distributed in Cretaceous rocks of Texas, Mexico, and Spain and the Alps, Carpathians, and Caucasus. Their presence in the Georgetown Limestone of Late Cretaceous age of Texas had attracted attention before—for example, Thomas (1932) suggested they might be gas bubbles. This interpretation is, however, contradicted by the fact that the spheres of the Georgetown Limestone have very distinctly recognizable shells. Thomas called attention to the wide distribution of similar spheres and mentioned in particular the chalk of England, the Permian of Texas, Carboniferous limestones of England, and the Ordovician of Keisley and Westmoreland. Downie (1957, p. 429) mentioned similar spheres from the Kimmeridge clay of England.

Earlier, Reis (1923, p. 107) described identical spheres occurring in swarms in Tertiary fresh-water deposits of algal origin in the Palatinate of Germany. He named the objects *Chlorellopsis*, because of their supposed affinities to the living green alga *Chlorella*. Hacquaert (1932) called attention to this observation by Reis and reported similar objects in Devonian and Carboniferous rocks of Belgium.

Bradley (1929, p. 207) recognized the presence of *Chlorellopsis* in algal reefs in the Green River Formation (Colorado) of Eocene age. He convincingly pointed out that *Chlorellopsis* Reis is related to the modern genus *Chlorococcum* rather than to *Chlorella*. The habitat of Recent species of *Chlorococcum* is either subaerial or fresh water. *Chlorellopsis* is a fresh-water form, whereas almost all Paleozoic and Mesozoic forms discussed here are marine. No close biological affinities, therefore, are implied by these comparisons.

These observations apparently indicate that the study of calcispheres of the *Calcisphaera-Chlorellopsis* type has been much neglected, although the widespread occurrence of the calcispheres in rocks of all ages is apparent from the published record.

The affinities of the thick-walled forms—the "*fimbriata*-type" as well as the more oblong types having irregular surfaces—continue to remain enigmatic. The present study has made no substantial contribution to this problem.

UMBELLA MASLOV (IN BYKOVA AND POLENOVA, 1955; NON D'ORBIGNY, 1841)

Certain limestones and calcareous sandstones contain abundant remains of ovoid calcitic bodies that differ from typical calcispheres in size and shape and probably also in their mode of growth; they are therefore described separately (fig. 39, pl. 20; fig. 2, pl. 21).

Typical specimens have an ovoid or ellipsoidal shape; they have a long diameter of as much as 450 microns and a short diameter of as much as 400 microns. Whereas many specimens have uniformly and smoothly rounded outlines, some especially larger ones tend to be flattened at one or both ends (pl. 20, fig. 2). The specimens consist of a shell composed of minute radially oriented calcite fibers; the shell encloses a hollow perfectly spherical space that is situated rather eccentrically within the ovoid. The shell, therefore, is thin on one end of the specimen and thick on the other; it ranges in thickness generally from 10 to 150 microns.

The inner sphere is lined with a thin somewhat ill-defined dark layer that is never more than 15 microns thick; the layer is commonly thinner and in some is present only as traces.

In addition to the shells just described which constitute most of those present, the rocks contain many incomplete shells. The incomplete shells have an opening or aperture of varying width. Characteristically, the interior of all shells having such an opening is filled with limestone matrix, whereas the interior of almost all the complete shells is filled with crystalline calcite. Very few shells appear in thin section that are both complete and are filled with matrix; these shells undoubtedly have openings that were not cut by the section. The edges of the shell are smoothly rounded around the openings and show no evidence of breakage. I believe, therefore, that shells having openings represent immature stages of the species and that the shells became closed only during later growth stages (fig. 40). Additional support for this belief is the fact that in the largest specimens (more than 0.375 mm in diameter) the shell is entire and that most smaller specimens have open shells. Since both open and entire shells have identical structures, there is little likelihood that they represent different biologic forms. The sections shown in figure 39, therefore, probably illustrate ontogenetic stages of one species only.

TABLE 8.—*Measurements of sections of specimens of* Umbella *Maslov in sample T56–521*

[Measurements in microns]

Specimen	Diameter		Diameter of inner sphere	Shell thickness		Filling of inner sphere	Remarks
	Long	Short		Minimum	Maximum		
1	225	225	112	22	75	Calcite	Shell entire.
2	280	245	106	--------	94	Matrix	Shell open.
3	280	262	115	--------	65	do	Do.
4	300	280	245	--------	65	do	Do.
5	300	280	253	--------	56	do	Do.
6	300	262	188	28	94	Calcite	Shell entire.
7	300	280	188	19	75	do	Do.
8	300	253	197	9	76	do	Do.
9	300	245	169	11	112	do	Do.
10	320	300	225	--------	112	Matrix	Shell open.
11	328	280	188	19	112	Calcite	Shell entire.
12	338	320	--------	--------	--------	--------	Shell completely fibrous.
13	338	253	168	28	131	Calcite	Shell entire.
14	375	320	262	--------	141	Matrix	Shell open.
15	385	320	106	56	131	Calcite	Shell entire.
16	412	330	245	38	150	do	Do.
17	450	300	202	75	112	do	Do.
18	450	395	290	38	112	do	Do.

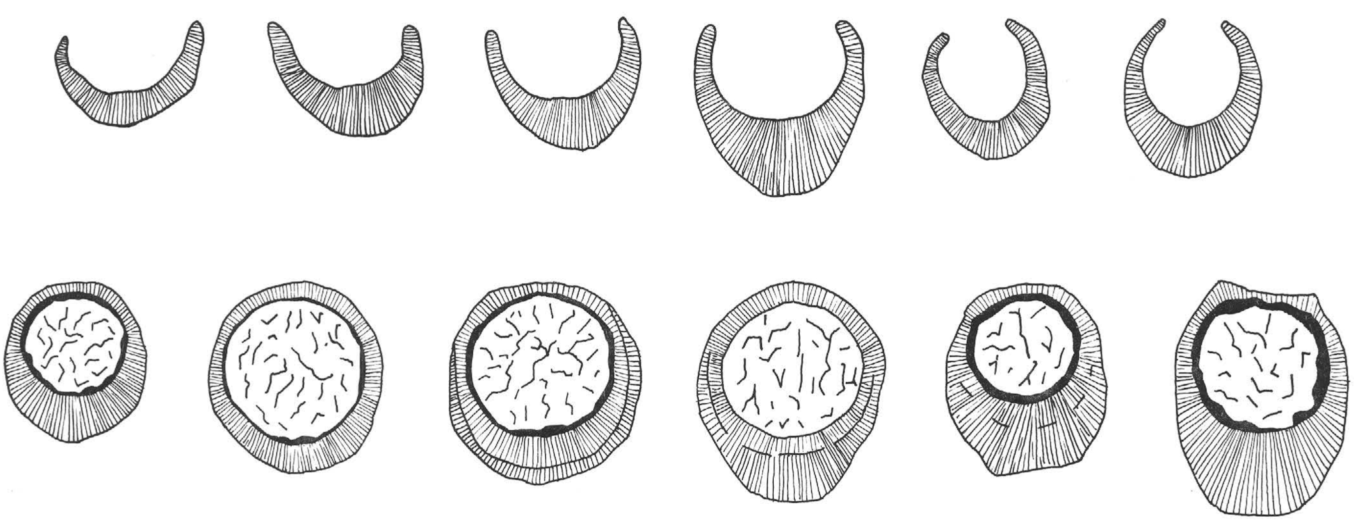

FIGURE 39.—Specimens of *Umbella* sp. × 88x. Radial lines, fibrous calcite; black, dark inner layer; irregular lines, coarsely crystalline calcite. Limestone, upper unit of Jerome Member, section 31, Webber Creek, subunit 31.

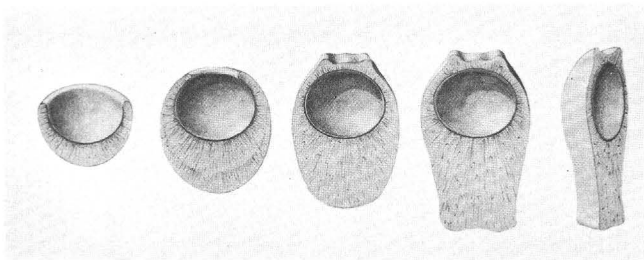

FIGURE 40.—Reconstruction of suggested successive growth stages of *Umbella*, showing one half of shells sectioned longitudinally. × 75.

DISTRIBUTION

In central Arizona the best-preserved specimens were found in aphanitic limestone in section 31, Webber Creek, 317 feet above the base of the Jerome Member; they were more rarely found in section 8, Canyon Creek and possibly in the Martin Limestone at Mount Martin, near Bisbee, Ariz.

I also recognized the species in aphanitic limestone in the Elbert Formation of Late Devonian age in Florida Valley, southwestern Colorado. Konishi (1958, p. 103–104) described a representative of probably the same species from the Cooking Lake Formation in Alberta. He did not name it, but compared it with somewhat similar forms which Lombard and Monteyne (1952) described as "calcisphère de forme A."

Outside North America forms which undoubtedly belong to the same genus were first described by Lombard and Monteyne (1952, p. 14–16). Their "calcisphère de forme A" occurs in the Frasnian of southern Belgium, where they are associated with trochilisks (probably *Sycidium*=Lombard and Monteyne's "calcisphère de forme C") and typical calcispheres.

In 1955, Bykova and Polenova described the same organisms from rocks ranging in age from late Givetian to early Famennian, from many localities in the middle Devonian Field of the Russian platform, and from the Urals, Bashkiria, and elsewhere. They gave these forms the name *Umbella*, which was credited to Maslov in manuscript. The affinities of *Umbella* were sought with the foraminiferal family Lagenidae. Bykova and Polenova described a total of 10 named and 1 unnamed species. The species most similar to the Arizona form is *Umbella baschkirica* Bykova and Polenova (1955, p. 38), which is late Givetian in age.

Fossils that seem to belong to the same genus were illustrated as "Foraminifera with aragonitic shell" by Polonskaya (1956, pl. 6, fig. 40); they occurred in aphanitic limestone of early Famennian age in the Kuibyshev area.

NOMENCLATURE

The name *Umbella* was first used by d'Orbigny (1841) for a molluscan genus (*fide* Neave, 1940, p. 609). If *Umbella* Maslov is a foraminifer, as Bykova and Polenova believe, the name would be preoccupied and the organism would have to be renamed. However, the affinities of *Umbella* Maslov seem to be far from certain, and if the genus is an alga, the name would stand, because, as far as I am aware, this name has not been previously given to a genus of plants. [After this manuscript was completed, Loeblich and Tappan (1961, p. 284) proposed the name *Umbellina* to replace *Umbella* Maslov, and they accepted the genus as a foraminifer. However, they based their conception of the genus on the complete etched specimens of *Umbella bella*, figured by Bykova and Polenova, and the generic description of *Umbellina* is not easily applicable to the sections seen in thin sections illustrated by these and other authors, including those of the present report. Subsequently, the foraminiferal nature of *Umbella* (*Umbellina*) in the sense of Loeblich and Tappan has been accepted by Ozonkowa (1962, p. 107). On the other hand, Mikluk-ho-Maklaj (1961, p. 655) treats *Umbella* Maslov as an alga (Characeae?). It seems possible that the freely etched specimens described by Bykova and Polenova which served as types for *Umbellina* Loeblich and Tappan (1961) are not congeneric with the specimens shown as sections in aphanitic limestone by Bykova and Polenova (1955), Lombard and Monteyne (1952), Konishi (1958), and in this report. We may have to do here with two different kinds of organisms—one foraminifer (*Umbellina* Loeblich and Tappan) and one of uncertain affinities for which the name *Umbella* Maslov may be provisionally retained.]

AFFINITIES

The taxonomic position of *Umbella* Maslov cannot be decided on the base of available evidence. No organic remains that are very similar to it are known from either the animal or the plant kingdom or from among the Protista. (See Moore, 1954.) The closest resemblance is with certain calcispheres having a fibrous shell. These calcispheres, however, are always much smaller, and their shell is spherical or irregularly spherical rather than ovoid or ellipsoidal as in *Umbella* Maslov. Lombard and Monteyne (1952) seemed to regard these organisms as algae or algal spores. Bykova and Polenova (1955) believed that the shells are cupshaped and are closed by a lid. (See especially their pls. 14 and 15.)

There is, however, no convincing evidence that any of the specimens shown in thin sections possessed such a lid (except in pl. 8, fig. 3, where a lid may possibly be adventitious); there is also no intrinsic evidence that the small capsules with lids figured by Bykova and Polenova are the same organisms as those shown in the thin sections. No other Foraminifera are known in which the aperture is closed by a lid. In fact, Bykova and Polenova referred to the brachiopod *Richthofenia* and the pelecypod *Hippurites* as analogies to this structure.

Bykova, Dain, and Fursenko (1959) established within the family Lagenidae the new subfamily Umbellinae for *Umbella* and two additional early Paleozoic genera, *Cochleatina* Bykova and *Illigata* Bykova. The illustrations of *Umbella* given are only those of entire, apparently etched out shells, reproduced from Bykova and Polenova (1955). Since these bodies are not fully comparable with the limestone specimens studied in thin section, the systematic position of the limestone specimens continues to remain in doubt.

The cup-shaped organisms having lids that Bykova and Polenova assign to *Umbella* are somewhat reminiscent of the Jurassic genus *Schizophaerella* Deflandre and Dangeard (1939), which, however, is only 12–30 microns in size. The affinities of *Schizosphaerella* are likewise unknown. That these organisms are Foraminifera seems extremely doubtful, because as far as I am aware, lidlike structures closing the aperture are unknown in true Foraminifera.

At present, *Umbella* Maslov is best regarded as an organism of uncertain taxonomic position that may represent either a new group of Protista or may have algal affinities.

STRATIGRAPHIC SECTIONS OF THE MARTIN FORMATION

EXPLANATION

The figure and letter combinations at the end of each subunit description are sample numbers—for example, T56–282.

The total thickness of the Martin Formation is the first figure for cumulative thickness given for the upper unit of the Jerome Member.

Unless otherwise stated the Martin Formation is always overlain by Mississippian Redwall Limestone and underlain by undifferentiated Precambrian rocks.

With the exception of many of the *Thamnopora* and all of the *Amphipora*, all identifications of corals and stromatoporoids are by W. A. Oliver, Jr.

The identification numbers of the aerial photographs on which the locations of the measured sections appear are given for each section. The photographs are Army Map Service photographs, scale 1 : 50,000.

The locations of the measured sections are shown in plate 32.

SECTION 1.—*Sawmill Road*

[About 7½ miles by way of road east of U.S. Highway 60, on road through San Carlos Indian Reservation that branches eastward from U.S. Highway 60, 6 miles south of bridge over Salt River (San Carlos Indian Reservation, sec. 26, T. 4 N., R. 18 E., unsurveyed). Photograph lots AK 1988, 1989. Measured by Curt Teichert, 1953 and 1956]

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
8. Limestone, dolomitic, mottled light-brown (5*YR* 6/4) and pale-red (5*R* 6/2), very fine grained, argillaceous; richly fossiliferous, containing crinoid ossicles, *Thamnopora* sp., *Striatopora* sp., *Atrypa clarkei* Warren, *A. borealis* Warren, and *Gruenewaldtia americana* Stainbrook; thin bedded to flaggy; weathers light brown to pale brown. (TP–49, T56–282)	16	159
7. Sandstone, light-brown, fine-grained, flaggy; poorly exposed in part; becomes calcareous toward top	18	143
6. Limestone, light olive-gray (5*Y* 6/1), coarse-grained, medium-bedded; contains some crinoid ossicles; weathers brownish gray	11	125
5. Sandstone, grayish orange-pink (5*YR* 7/2), very fine grained, well-sorted; contains much calcareous matrix; abundant invertebrate tracks on bedding planes; thick-bedded; weathers light brown	13	114
4. Limestone, biostromal, very light gray to light-gray; consists entirely of stromatoporoids (*Actinostroma*? sp. and *Stictostroma* sp.) and of large colonies of *Pachyphyllum*. (TP 48, T56–283)	18	101
3. Sandstone, light-brown, coarse-grained; contains quartz granules as much as 5 mm in diameter	12	83
2. Sandstone, light-brown (5*YR* 6/4), very fine grained, well-sorted, porous— probably due to leaching of calcareous cement; invertebrate tracks on bedding plains; thin- to medium-bedded, partly soft and poorly exposed; weathers light brown, with pitted surface. (T206)	20	71
1. Limestone, mottled light-brown (5*YR* 6/4) and grayish orange-pink (5*YR* 7/2), very fine grained; upper part, medium grained; some calcispheres, abundant crinoid ossicles and some colonies of *Aulopora* sp. in lower part of subunit; crinoidal; contains chert bands consisting of irregularly fused flat nodules 1–2 in. thick; medium bedded; weathers light brown. (T205)	51	51

Fault contact at base of section.

SECTION 2.—*Black River*

[About 1½ miles south of junction of White and Black Rivers (Fort Apache Indian Reservation, SW¼ sec. 2, T. 4 N., R. 20 E., unsurveyed). Photograph lots AK 1992, 1993. Measured by Curt Teichert, 1953, and by Teichert and R. L. Harbour, 1956]

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
22. Siltstone, mostly covered; contains some marly limestone and shale; very fossiliferous	35	271.5
21. Limestone, mottled light brownish-gray (5*YR* 6/1) and moderate red (5*R* 5/4); medium- to coarse-crystalline; thoroughly mixed rock consisting of pellets, calcite crystals, detrital quartz, and bioclastic material, including very small calcispheres and crinoid stems; quartz grains as much as 0.3 mm in diameter, mostly angular to subangular; subunit increasingly sandy toward top; medium bedded. (H56–7)	3	236.5
20. Siltstone, yellowish-gray (5*Y* 7/2), calcareous; contains fossil fragments	3	233.5
19. Limestone, yellowish-gray (5*Y* 8/1), coarsely crystalline; friable on weathered surface; contains crinoid and brachiopod fragments; scattered detrital quartz grains, subrounded, as much as 1 mm in diameter, all highly shattered; medium-bedded (beds 1 ft. thick). (H56–6)	6	230.5
18. Siltstone, calcareous, olive-gray (*Y*5); fissile; contains poorly preserved brachiopods; poorly exposed; slope-forming	14	224.5
17. Dolomitic limestone, very sandy, mottled light brownish-gray (5*YR* 6/1) and pale-red (10*R* 6/2); fragmental, mixed detrital carbonate and bioclastic material, brachiopod(?) and ostracode remains; coarse-grained; detrital quartz grains present throughout unit, more abundant in certain layers and in top 6 in.; individual quartz grains as much as 0.5 mm in diameter, mostly angular, containing small admixture of subrounded grains; medium-bedded. (H56–5)	1.5	210.5
16. Dolomitic limestone, pale-red (5*R* 6/2), very fine-grained, argillaceous, thick-bedded (beds 3 ft. thick); weathers pale red. (H56–4)	6	209
15. Sandstone, pale reddish-brown (10*R* 5/4), coarse-grained; contains calcareous cement; grains subrounded to subangular; friable; medium-bedded. (H56–3)	2	203
14. Dolomite, pinkish-gray (5*YR* 8/1) to light brownish-gray (5*YR* 6/1); finely crystalline; contains dark calcite vugs as much as 2 cm long;		

SECTION 2.—*Black River*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
14. Dolomite, etc.—Continued irregularly spaced laminae containing abundant quartz grains as much as 1.2 mm in diameter that are mostly subrounded to rounded, most grains having etched surface; medium-bedded. (H56–2)	5	201
13. Dolomite, light olive-gray (5*YR* 6/1); very fine grained, crystalline; individual crystals as much as about 0.1 mm in diameter; subconchoidal fracture; scattered small detrital quartz grains ranging from silt size to 1 mm in diameter; weathers light to dark gray; medium-bedded. (H56–1)	4	196
12. Shale, gray, poorly exposed	1	192
11. Dolomite, light brownish-gray (5*YR* 6/1), fine-grained, very thick bedded to massive; cliff-forming; contains many calcite stringers; weathers light brown, with pitted surface. (T56–265)	10	191
10. Dolomite, pale-red (5*R* 6/2) mottled with darker red, fine-grained, very sandy, thick-bedded to massive, cliff-forming; lower half shows lamination on weathered surfaces, upper part has brecciated appearance; weathers light brown. (T56–263)	8	181
9. Dolomite, pale-red (5*R* 6/2), and some purplish-red streaks, very fine grained, thin-bedded (4–6 in. beds thick); contains a few vugs as much as 1 cm in diameter that are filled with brown calcite; in places, brecciation is indicated; weathers yellowish brown. (T56–263)	4	173
8. Sandstone, pale-pink (5 *RP* 8/2), contains pale-red (5*R* 6/2) laminae; fine-grained, contains quartz grains about 0.1 mm in diameter; thinly crossbedded; weathers light brown. (T56–262)	12	169
7. Sandstone, light-gray (*N*7), coarse-grained contains subrounded quartz grains 0.3–1 mm in diameter; soft, flaggy; weathers light brown to gray. (T56–261)	10	157
Aphanitic dolomite unit:		
6. Dolomite, grayish orange-pink (5*YR* 7/2 to 5*YR* 8/2) to light olive-gray (5*YR* 6/1), very fine grained, has subconchoidal fracture; scattered quartz grains mostly 0.1–0.2 mm in diameter, but some are as much as 0.5 mm in diameter; grains have varying degrees of roundness; in places grains occur in thin more densely packed layers; weathers light brown. (T56–260, 259, 258)	22	147

SECTION 2.—*Black River*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
5. Dolomite, very light gray (*N* 8) to pale-red (5 *R* 6/2); very fine grained and irregular fracture in lower part, aphanitic and conchoidal fracture in upper part; thick-bedded, bedding planes irregular; aphanitic-rock type contains very small quartz grains not larger than 0.1 mm and fragments of fine-grained dolomite 0.3–3 mm in diameter; weathers grayish orange to grayish orange pink. (T56–256, 255)	12	125
4. Dolomite, has 3-inch brecciated hematitic zone at base; pale red (10*R* 6/2) in lower part, light brownish gray (5*YR* 6/1) in upper; aphanitic and conchoidal fracture in lower part; subaphanitic to very fine grained and subconchoidal to very smooth fracture in upper part; generally thin bedded (beds 6–12 in. thick), but becomes more thick bedded in uppermost 8–10 ft; weathers to various shades of light gray and brown; at 3–4 ft zone of flat brown rind chert pebbles as much as ⅜ in. thick and 1 in. long occurs; at 15 ft a zone of larger chert nodules as much as 2 ft long occurs; calcite veins and vugs present throughout entire subunit. (T56–254, 253, 252, 251, 250)	51	113
3. Dolomite, pale-red (5*R* 6/2) to grayish-red (5*R* 4/2), medium-grained, very homogeneous; has irregular fracture; medium bedded (beds 1–2 ft thick), has irregular bedding planes; weathers light olive gray; contains a few silicified brachiopods (possibly *Atrypa*) 7 ft above base. (T56–249)	10	62
Fetid dolomite unit:		
2. Dolomite, light brownish- to light olive-gray (5*Y* 6/1) to medium gray (*N* 5) in upper part; medium bedded (beds 1–2 ft thick); laminated throughout, though less markedly in upper half, 5–6 laminae per inch; very fine grained to almost aphanitic in upper part, where rock fracture is subconchoidal; generally fetid odor, weaker in upper part; weathers various shades of light brown. (T56–248, 247, 246, 245)	34	52

SECTION 2.—*Black River*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Beckers Butte Member:		
1. Conglomerate grading into sandstone. At places where measured, this subunit can be subdivided as follows (T56–244):		
C. Sandstone, medium-gray (*N* 5), medium- to coarse-grained; consists of tightly packed quartz grains 0.3–1.5 mm in diameter that are generally not well rounded (roundness 0.5–0.6); very little cement, slightly calcareous; weathers brown. Thickness, 10 ft. (T56–243.)		
B. Sandstone, light-gray (*N* 7) to brownish-gray (5*YR* 4/1), has irregular brown mottling, medium-grained; poorly sorted, grains mostly 0.1–1 mm in diameter; generally medium- to well-rounded (0.5–0.7); slightly calcareous cement; weathers brown. Thickness 1–2 ft. (T56–242.)		
A. Conglomerate, greenish- to brownish-gray (5*YR* 4/1); poorly sorted, grains and pebbles range from 0.2 mm to several centimeters in diameter; grains less than 1 mm in diameter are generally well rounded; larger grains and pebbles generally contain calcareous cement; pebbles mostly quartzite, but some larger feldspar fragments present; toward the top 2 ft, this subunit changes into sandstone, which is medium to coarse-grained and poorly sorted and which is a mixture of poorly and well rounded grains; weathers gray to light brown. Thickness, 6 ft. (T56–241.)		
The entire member is cliff forming	18	18
Precambrian: Troy Quartzite (T56–240).		

SECTION 3.—*Flying V Canyon*

[Near mouth of Flying V Canyon, on slope above intersection of U.S. Highway 60 and base of Jerome Member (Fort Apache Indian Reservation, SW¼SW¼ sec. 29, T. 5 N., R. 18 E., unsurveyed). Photograph lots AK 2010, 2011. Measured by R. L. Harbour, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
35. Sandstone, light-brown (5*YR* 6/4), medium fairly evenly grained; quartz grains subrounded; calcareous cement; thin-bedded; weathers light brown. (H56–60)	20	359

SECTION 3.—*Flying V Canyon*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
34. Shale, dark-gray; weathers greenish gray	28	339
33. Dolomite, light olive-gray (5*Y* 6/1), sandy to silty, finely crystalline; contains detrital quartz grains as much as 0.2 mm in diameter; medium-bedded; scattered silicified brachiopod fragments (*Schizophoria* sp.). (H 56–59)	30	311
32. Sandstone, light olive-gray (5*Y* 6/1) to greenish-gray (5*GY* 6/1), irregularly laminated, fine-grained; quartz grains subrounded to subangular, embedded in finely crystalline dolomitic cement, which makes up as much as 50 percent of the rock; weathers pinkish gray. (H56–58)	6	281
31. Siltstone alternating with shale; yellowish-gray (*Y* 6); poorly exposed; slope-forming	20	275
30. Dolomite, medium-gray (*N* 5); thin-bedded; poorly exposed	10	255
29. Dolomite, light brownish-gray (5*YR* 6/1), medium-grained; crops out in three beds separated by siltstone layers; medium-bedded; weathers light olive gray	4	245
28. Dolomite, medium-gray (*N* 5), finely crystalline, finely laminated; cliff-forming; thick-bedded; weathers light olive gray. (H56–57, 56)	23	241
27. Siltstone, poorly exposed	7	218
26. Dolomite, medium light-gray (*N* 6), medium-crystalline; crops out in two resistant finely laminated beds; thick-bedded; weathers light olive gray. (H56–55)	5	211
25. Siltstone, light olive-gray (5*Y* 6/1), fissile; contains numerous invertebrate trails on bedding planes. (56–54)	30	206
24. Sandstone, medium-gray (*N* 5), very fine grained, dolomitic; crops out in three beds separated by sandy clay bands; thick-bedded	7	176
23. Siltstone, medium-gray (*N* 5); slope-forming; poorly exposed	12	169
Aphanitic dolomite unit:		
22. Dolomite, light-gray (*N* 7), fine-grained; detrital quartz grains at base, angular dolomite fragments at top	1	157
21. Dolomite, yellowish-gray (5*Y* 8/1), cliff-forming, medium-bedded; contains thin layers of gray shale, very finely crystalline; abundant detrital quartz grains ranging from silt size to about 0.5 mm in diameter; in uppermost foot, subrounded grains as much as 5 mm in diameter; weathers yellowish gray. (H56–53, 52)	13	156
20. Dolomite, slightly calcitic, light-gray (*N* 7); microbreccia containing angular fragments of aphanitic dolomite as much as 1.5 mm in diameter embedded in very fine grained dolomite matrix; thin-bedded dolomite beds average 6 in. in thickness and are separated by claystone layers as much as 3 in. thick; dolomite weathers yellowish gray. (H56–51)	11	143
19. Covered	14	132
18. Dolomite, light-gray (*N* 7) to medium light-gray (*N* 6); finely laminated, medium crystalline; weathers light olive gray. (H56–50)	2	118
17. Sandstone, brownish-gray (5*YR* 5/1), quartzitic, fine- to medium-grained, crossbedded; base slightly channeled into underlying dolomite, contains fragments of dolomite and subangular granules of milky quartz; forms resistant brown cap to underlying cliff-forming dolomite. (H56–49)	2	116
16. Dolomite, light-gray (*N* 7), very fine grained; size of dolomite crystals generally less than 0.07 mm; subconchoidal fracture; cliff forming; beds 2–3 ft thick; weathers yellowish gray. (H56–48)	9	114
15. Covered	4	105
14. Dolomite, very light gray (*N* 8), aphanitic; conchoidal fracture; pelletal and clastic texture; contains small amount of crystalline cement; rich in detrital quartz grains ranging from silt size to 0.5 mm in diameter; grains partly highly etched; outcrops in two beds; thick-bedded; weathers yellowish gray. (H56–47)	3	101
13. Covered interval; siltstone fragments on slope	2	98
12. Dolomite, light-gray (*N* 7), aphanitic; one bed	3	96
11. Shale and dolomite, poorly exposed	1	93
10. Dolomite, light-gray (*N* 7), aphanitic; conchoidal fracture; very fine pelletal texture; thick-bedded (beds are 4 ft thick); dark-gray chert in lenses and reticulating veins; weathers brown; dolomite weathers yellowish gray. (H56–29, 28)	16	92
9. Marl and shale, poorly exposed	2	76
8. Dolomite, light olive-gray (5*Y* 6/1), subaphanitic; subconchoidal fracture; extremely fine pelletal texture; scattered very small calcite vugs; evenly bedded, individual beds about 2 ft thick separated by shale partings and scattered lenses of gray chert; scattered quartz grains near base; has some "ghosts" of calcispheres; weathers yellowish gray. (H56–27, 26)	16	74
7. Dolomite, medium-gray (*N* 6), subaphanitic; small irregular dark chert nodules having brown rinds; one poorly laminated bed is distinguished by an extensive system of coalescing lenses of mottled medium- and light-gray chert nodules as much as 1 ft thick	4	58

SECTION 3.—*Flying V Canyon*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
6. Dolomite, medium light-gray (*N* 6) to medium-gray (*N* 5), aphanitic; conchoidal fracture; very small calcite vugs; dark-gray chert pebbles having brown rinds; thin bedded (beds are 6 in. thick); upper part contains scattered detrital quartz grains, angular, as much as 1 mm in diameter; interbedded with scattered layers of gray shale; medium bedded; weathers yellow gray. (H56–24)	10	54
Fetid dolomite unit:		
5. Dolomite, medium light-gray (*N* 6); alternating very fine grained and aphanitic beds; some dark chert nodules near base; medium-bedded (beds are 1 ft thick); weathers light gray. (H56–23, 22)	12	44
4. Dolomite, light brownish-gray (5*YR* 6/1) to light olive-gray (5*Y* 6/1); very finely and uniformly crystalline; strong fetid odor; finely laminated; lamination caused by finely distributed organic matter; scattered shale partings and mottled white and dark-gray chert in small lenses; cliff-forming; thick-bedded; weathers medium light gray. (H56–21)	17	32
Beckers Butte Member:		
3. Shale, dark- to medium-gray (*N* 5), dolomitic; interbedded with yellowish-gray argillaceous dolomite layers. Some of the shale beds contain abundant remains of a rich psilophyte flora (Teichert and Schopf, 1958). (H56–20)	2	15
2. Sandstone, light brownish-gray (5*YR* 6/1) to light olive-gray (5*Y* 6/1), coarse grained, well-cemented, poorly sorted, containing many medium to fine grains; medium-bedded (beds about 1½ ft thick); beds separated by thinner layers of green-tinted sandy shale; weathers grayish orange. (H56–18)	12	13
1. Conglomerate, dark yellowish-orange (10 *YR* 6/6) to dusky yellow (5*Y* 6/4), brecciated, poorly sorted; contains quartz grains ranging from silt size to coarse; contains weathered fragments of diabase; iron stained; friable; contains calcareous cement; variable thickness averaging about	1	1
Precambrian: Diabase sill.		

SECTION 4.—*Salt River Asbestos Mine*

[Above abandoned asbestos mine, on north bank of Salt River, about 8 miles due east of road bridge of U.S. Highway 60 (Fort Apache Indian Reservation, NE¼ sec. 30, T. 5 N., R. 19 E., unsurveyed). Photograph lots AK 2008, 2009. Measured by Curt Teichert and R. L. Harbour, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
22. Covered with talus of Redwall Limestone; possibly underlain by green shale	15	280
21. Shale, weathers grayish green; outcrops poor	15	265
20. Dolomite, grayish-orange (10*YR* 7/4), fine-grained, silty, medium-bedded to flaggy (beds as much as 18 in. thick), hard; at 7½–8½ ft, olive-gray layers densely packed with nonsilicified *Atrypa* shells; weathers grayish orange. (T56–312–311)	18	250
19. Sandstone, light-brown (5*YR* 6/4) to grayish-orange (10*YR* 7/4), medium-grained; contains many larger grains as much as 1 mm in diameter; grains subangular to angular, clear; in places quartz grains densely packed, in places embedded in abundant calcareous cement; weathered specimens tend to be porous due to leaching of carbonate cement; thick bedded, massive, crossbedded; cliff-forming; weathers dark yellowish brown. (T56–310)	21	232
18. Dolomite, grades into limestone; medium light-gray (*N* 6) to light-gray (*N* 7); thick-bedded (beds are 1–3 in. thick), hard, cliff-forming; subunit begins with fine-grained medium light-gray dolomite, which is overlain by medium light-gray to light-gray limestones that generally contain a scattering of idiomorphic dolomite crystals; limestone is generally granular and contains abundant calcispheres; at 17 ft, a bed containing *Amphipora* occurs; weathers generally yellowish brown. (T56–309, 308, 307)	27	211
17. Sandstone, medium-gray; thick-bedded (beds are 1–3 in. thick); fine-grained, having a scattering of grains in the medium range, as much as 0.5 mm in diameter; much carbonate cement, which seems to consist of a slightly calcitic dolomite; crossbedded; cliff-forming; some beds are penetrated by vertical tubes ⅛–⅜ in. wide, 2–3 in. long; weathers light brown. (T56–306)	11	184
16. Dolomite, medium-gray (*N* 5), very fine grained, hard; medium-bedded (beds are 1 ft thick); weathers brownish gray. (T56–305)	2	173

SECTION 4.—*Salt River Asbestos Mine*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
15. Sandstone, yellowish-gray (5*Y* 8/1), coarse- to very coarse grained; quartzose, having a very small amount of calcitic cement; quartz grains generally frosted, poorly sorted, ranging in size from 0.2 to 3.0 mm, mostly well rounded to subrounded; thin bedded (beds are 2–4 in. thick); upper two-thirds of subunit generally finer grained, laminated and slightly crossbedded; uppermost foot is a gray silty sandstone; weathers grayish orange. (T56–304)	16	171
14. Dolomite, medium-gray (*N* 5) to medium dark-gray (*N* 4), very fine grained; subconchoidal fracture; medium bedded (beds are about 18 in. thick); upper 3 ft contains large (1 in.) calcite-lined vugs and scattered quartz grains as much as 2 mm in diameter; cliff-forming; weathers yellowish brown. (T56–302)	10	155
13. Dolomite, light olive-gray (5*Y* 6/1), fine-grained; tends to fracture along uneven surfaces, forming sharp angles; contains scattered very small vugs filled with yellowish calcite; medium- to thick-bedded (beds are 1–3 ft thick); cliff-forming; at top of subunit, layer contains brachiopod fragments, probably stropheodontids; weathers orange gray. (T56–301)	5	145
12. Dolomite, light-gray (*N* 7) to yellowish-gray (5*Y* 8/1), fine-grained; rough fracture surfaces; silty to fine sandy; thin-bedded (beds are 1–4 in. thick); weathers yellowish brown; at top of subunit, 2-in. layer of distinctly laminated gray chert. (T56–300)	5	140
11. Dolomite, yellowish-gray (5*Y* 8/1), subaphanitic; subconchoidal fracture; very thick bedded (beds are 1–5 ft thick); apparently at least partly laminated, although laminae visible only on some weathered surfaces; contains very few quartz grains; irregularly penetrated by vugs of various sizes, larger ones as much as 15 mm long, filled with clear or brown calcite; smaller vugs generally filled with brown calcite; weathers yellowish orange. (T56–299)	8	135
Aphanitic dolomite unit:		
10. Dolomite, various shades of pink, red, and gray, varying from medium gray (*N* 5) to pale red (5*R* 6/2), very fine grained to aphanitic; subconchoidal to conchoidal fracture; very pure carbonate; little or no porosity; thin-bedded (beds are 3–5 in. thick); weathers grayish orange. (T56–298–297)	21	127

SECTION 4.—*Salt River Asbestos Mine*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
9. Sandstone, pinkish-gray (5*YR* 8/1), medium-grained; contains quartz grains subrounded to subangular; very small amount of slightly calcareous cement; thick-bedded (beds as much as 3 ft thick); crossbedded, foreset beds generally dipping south to southeast; hard; cliff-forming; weathers yellowish orange. (T56–296, 295)	15	106
8. Dolomite, medium light-gray (*N* 6), aphanitic; conchoidal fracture; uppermost bed fine grained, dense; thick-bedded; highly jointed; contains abundant chert nodules and chert impregnations; nodules as much as 4 in. long and 2 in. thick; under microscope, showing "clouds" and interpenetration texture; uppermost bed has slight vuggy porosity. The rock here is very slightly calcitic; weathers light orange gray. (T56–294, 293)	22	91
7. Dolomite, medium light-gray (*N* 6), very fine grained to aphanitic; subconchoidal fracture; medium-bedded (beds are 6–18 in. thick); fine clastic appearance under the microscope; lower 2 ft rich in angular to subangular quartz grains as much as 1.5 mm in diameter; chert pebbles abundant, partly on bedding planes, partly oriented in layers between bedding planes; most are slightly larger than those in unit 6 and have irregular shape as much as 2½ in. long and ¼ in. thick. The dense dolomite has calcite vugs and stringers oriented vertical to bedding planes; weathers yellowish gray. (T56–292, 291)	20	69
6. Dolomite, medium-gray (*N* 5), aphanitic; conchoidal fracture; thin-bedded (beds are 4–12 in. thick); finely laminated with many layers of brown-rind chert pebbles; generally ½–1 inch long and ⅛–¼ inch thick; scattered calcite vugs; traversed by microscopic joints similar to those in rocks of subunit 4; weathers light olive gray. (T56–290)	8	49
5. Dolomite, medium light-gray (*N* 6), fine-grained, thick-bedded; some beds have a very vuggy porosity; vugs are elongated in general direction of bedding and as much as 10 mm long; weathers various shades of orange gray. The first five subunits are cliff forming. (T56–289)	4	41

SECTION 4.—*Salt River Asbestos Mine*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
4. Dolomite, medium dark-gray (*N* 4), very fine grained; subconchoidal fracture; flaggy to thin bedded (beds are as much as 10 in. thick); contains scattered calcitic vugs and calcite veins; penetrated by microscopic joints (generally less than 0.1 mm thick), which are filled with slightly calcitic material; weathers light gray. (T56–288)	5	37
Fetid dolomite unit:		
3. Dolomite, medium-gray (*N* 5) to light brownish-gray (5*YR* 6/1), fine-grained, thin- to medium-bedded, (beds are 2 in. to 1½ ft thick) although has a more massive appearance in outcrop; lamination visible on weathered surface, probably laminated throughout; generally similar to subunit 2, but without characteristic fetid odor; weathers yellowish brown. (T56–287)	9	32
2. Dolomite, medium-gray (*N* 5), fine-grained; thin- to medium-bedded; very finely laminated, laminations 0.5–1 mm thick; slight fetid odor; weathers dark gray. At 8–9 ft intercalation of hard lighter gray very finely saccharoidal dolomite, containing calcitic matrix along the interfaces between dolomite grains; contains lumps of chert. (T56–286, 285)	15	23
Beckers Butte Member:		
1. Sandstone, mottled light-gray (*N* 7) to brownish-gray (5*YR* 4/1); thick-bedded (beds are 1–3 ft thick); medium- to fine-grained; generally quartzose, but contains a small amount of calcareous cement; contain a few angular pebbles as much as ½ inch in diameter; crossbedded; cliff-forming; weathers in various hues of gray and orange. (T56–284)	8	8

SECTION 5.—*South of Salt River Bridge*

[East of U.S. Highway 60, about 1½ miles south of road bridge over Salt River (San Carlos Indian Reservation, SW¼ sec. 36, T. 5 N., R. 17 E., unsurveyed). Photograph lots AK 1933, 1934. Measured by R. L. Harbour, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Fetid dolomite unit (top eroded):		
8. Dolomite, light brownish-gray (5*YR* 6/1), medium-crystalline, laminated; some laminae finely crystalline; fetid ordor; contains white and yellow-tinted chert in lenticular and irregular bodies; thin- to medium-bedded; weathers moderate brown. (H56–17)	3+	122+
Beckers Butte Member:		
7. Covered, probably underlain by sandstone or shale	5	119+

SECTION 5.—*South of Salt River Bridge*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Beckers Butte Member—Continued		
6. Conglomerate, grayish-orange (10*YR* 7/4), pale-pink (5*RP* 8/2), and other colors; partly silica-cemented; well-rounded granules of quartz and quartzite; contains pebbles as much as 1 in. in diameter; lenticular beds of reddish sandy shale less than 6 in. thick; very thick bedded (beds as much as 9 ft thick); cliff-forming. (H56–16, 15)	61	114+
5. Sandstone, arkosic, grayish-red (10*R* 4/2); generally fine grained; poorly sorted and contains large angular to subangular quartz grains as much as 2 mm in diameter; also contains mica, feldspar, and dark minerals; interbedded with some silty layers; soft, niche-forming; weathers grayish-red. (H56–14)	5	53+
4. Conglomerate, grayish-red; contains thin beds of dark-red sandy clay; granules and pebbles are as much as 15 mm in diameter and compose about two-thirds of the rock	10	48+
3. Siltstone and sandstone, grayish-red; alternating in layers 6 in. thick; siltstone is fissile, argillaceous, and micaceous; sandstone beds crossbedded, becoming fine grained in upper part	10	38+
2. Sandstone and conglomerate, pale-red (5*R* 6/2) to pale red-purple (5*RP* 6/2); sandstone, very coarse grained, contains pebbles as much as 5 mm in diameter and much calcareous cement; conglomerate beds, contain rounded cobbles as much as 3 in. in diameter; thick-bedded (beds are 3 ft thick); crossbedded. (H56–13)	24	28+
1. Sandstone, arkosic, grayish-red (5*R* 4/2); coarse- to very coarse grained, poorly sorted; contains some quartz grains as much as 2.5 mm in diameter; larger grains rounded to subrounded; all grains coated with limonite; scattered pebbles as much as 25 mm in diameter. Rock is soft and poorly exposed; weathers grayish red. (H56–12)	4	4+

Base covered.

SECTION 6.—*Salt River Draw* (*south section*)

[4 miles from junction of Salt River Draw and Salt River (SE¼NE¼ sec. 25, T. 6 N., R. 16 E., unsurveyed). Photograph lots AK 2067, 2068. Measured by Curt Teichert, 1953]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
37. Covered, probably underlain by upper continuation of subunit 36	11	480
36. Shale, weathers yellowish gray	4	469
35. Covered, possibly overlain by lower continuation of subunit 36	6.5	465
34. Limestone, grayish-orange, very argillaceous; poor outcrops	3	458.5

SECTION 6.—*Salt River Draw (south section)*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
33. Covered	25	455.5
32. Limestone, streaky grayish-orange (10*YR* 7/4) and light-brown (5*YR* 6/4), very finely crystalline, very argillaceous; scattered detrital quartz grains, as much as 1 percent, mostly fine; contains poorly preserved spiriferids; thin bedded; weathers light brown. (T145)	3	430.5
31. Covered, probably underlain by limestone similar to subunit 28, but unfossiliferous (T144)	23	427.5
30. Chert, lenticular; contains poorly preserved spiriferids. (T143)	1	404.5
29. Covered; slope strewn with rubble of argillaceous limestone	13	403.5
28. Limestone, dolomitic, mottled light-brown (5*YR* 6/4) and pale yellowish-brown (10*YR* 6/2), very argillaceous, coarsely crystalline; contains large numbers of small dolomite rhombohedra; richly fossiliferous, containing crinoid stems, brachiopods (*Atrypa clarkei* Warren, *Theodossia* sp.), large poorly preserved gastropods; thin-bedded; weathers light brown. (T142)	8.5	390.5
27. Silicified rock, yellowish-gray (5*Y* 8/1); consists of amorphous or cryptocrystalline groundmass of silica and contains abundant fine detrital quartz, and numerous dolomite rhombohedra, averaging 0.07 mm in diameter; small amounts of calcite, filling small irregular cavities; scattered small chert nodules, 4–5 mm in diameter; thin-bedded; weathers light olive gray. (T141)	22.5	382
26. Sandstone, yellowish-gray (5*Y* 8/1), coarse-grained, poorly sorted; larger grains rounded to subrounded; medium-bedded; some crossbedding; weathers light olive gray. (T140)	14.5	359.5
25. Covered; slope strewn with sandstone rubble	17	345
24. Sandstone, grayish-orange (10*YR* 7/4); generally medium-grained; poorly sorted, containing grains 0.3 mm in diameter and larger, generally subrounded; grains tightly packed and impressed on each other; little carbonate (calcitic dolomite) matrix; some of the more calcareous and less sandy layers contain crinoid stems and fragments of fish plates (coccosteans?); thin-bedded; abundant invertebrate tracks on bedding planes; weathers light brown; entire subunit poorly exposed. (T149)	34	328

[Subunits 20 to 36 form a prominent cliff about 20 ft. high]

SECTION 6.—*Salt River Draw (south section)*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
23. Limestone, light-gray, very finely crystalline, unfossiliferous, thick-bedded	6.5	294
22. Limestone, light olive-gray (5*Y* 6/1), very finely crystalline, pelletal; contains *Amphipora* abundant small calcispheres as much as 0.3 mm diameter, and abundant corals (*Thamnopora?* and other genera); medium bedded in lower 3 feet; remainder thick-bedded (beds are 2½ ft thick); weathers light brown. (T137)	10.5	287.5
21. Limestone, biostromal, light-gray; composed of stromatoporoids. (T108)	1.5	277
20. Limestone, light-gray (*N* 7), very finely crystalline, pelletal; contains *Amphipora* and small calcispheres as much as 0.15 mm in diameter; thick-bedded. (T107)	12	275.5
19. Dolomite, light olive-gray (5*Y* 6/1), finely crystalline, saccharoidal; contains vugs and stringers of white and brown calcite; thick-bedded; weathers light brown. (T106)	10	263.5
18. Limestone, dolomitic, light-gray (*N* 7), finely crystalline, contains large numbers of idiomorphic dolomite rhombohedra averaging 0.2 mm in size; some ostracode tintinnids and abundant calcispheres 0.07–0.2 mm in diameter; massive; weathers light gray. (T105)	10	253.5
17. Dolomite, slightly calcitic, yellowish-gray (5*Y* 8/1), very finely crystalline; saccharoidal; contains some interstitial calcite; calcite stringers and some irregular small chert nodules; hard, massive; weathers yellowish gray. (T105, 103)	17	243.5
16. Sandstone and siltstone, calcareous, streaky yellowish-gray (5*Y* 8/1) and pinkish-gray (5*YR* 8/1). In places there is so much calcareous and argillaceous matrix that rock assumes character of calcareous fissile to platy mudstone; weathers yellowish gray. (T102)	17.5	226.5
15. Sandstone, yellowish-gray (5*Y* 8/1), medium- to coarse-grained, poorly sorted; most grains angular to subangular, a few grains are rounded; considerable overgrowth and contact etching of grains; thin-bedded; bedding planes contain invertebrate trails as much as 1 in. wide; weathers light brown. (T101)	18	209

SECTION 6.—*Salt River Draw (south section)*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
14. Sandstone, mottled grayish orange-pink (5*YR* 7/2) and pinkish-gray (5*YR* 8/1), very fine grained; contains numerous rounded quartz grains 0.3–0.5 mm in diameter; matrix, calcitic dolomite; thick-bedded; slightly laminated; weathers yellowish gray. (T100)	2.5	191
Aphanitic dolomite unit:		
13. Dolomite, light-gray, aphanitic; conchoidal fracture; medium- to thick-bedded (beds are 6–20 in. thick)	3.5	188.5
12. Sandstone, light-gray (*N* 7), very fine grained, well-sorted; small amount of carbonate matrix (calcitic dolomite); platy; has invertebrate trails on bedding planes; weathers light brown. (T99)	4.5	185
11. Dolomite, light-gray, aphanitic; conchoidal fracture; many calcite stringers	2	180.5
10. Dolomite, calcitic, medium-gray (*N* 5), very finely crystalline; has pelletal or micro-arenitic structure; calcite occurs in small to microscopic vugs; contains ostracode shells and shell fragments, and calcispheres of different types from 0.1–0.7 mm in diameted. (T98)	2	178.5
9. Dolomite, very slightly calcitic; yellowish-gray (5*Y* 8/1), aphanitic; conchoidal fracture; scattering of detrital quartz grains as much as 1 mm in diameter; larger grains subrounded; shattered; thin-bedded; weathers yellowish gray. (T97)	29	176.5
8. Dolomite breccia, light-gray	2	147.5
7. Dolomite, very slightly calcitic, pinkish-gray (5*YR* 8/1), aphanitic; conchoidal fracture; varying but generally small amounts of detrital quartz grains; scattered chert bands; thin-bedded; weathers pinkish gray. (T98)	50.5	145.5
6. Dolomite, light brownish-gray (5*YR* 6/1); aphanitic; conchoidal fracture; many small rounded chert nodules and some larger chert lenses; scattered detrital quartz of silt size; upper part has irregular small calcite stringers; thin-bedded; weathers yellowish gray. (T95, 96)	24	95
5. Dolomite, very slightly calcitic, light brownish-gray (5*YR* 6/1), very finely crystalline; elongated, rounded chert nodules as much as 1 in. long; thin-bedded (beds are 4–6 in. thick). (T92)	12.5	71

SECTION 6.—*Salt River Draw (south section)*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Fetid dolomite unit:		
4. Dolomite, pale-red, finely crystalline; thinly laminated in part; continuous layer of gray chert lenses at top, 3 in. thick; thin-bedded (beds are 4–6 in. thick)	16.5	58.5
Beckers Butte Member:		
3. Sandstone, pinkish-gray (5*YR* 8/1) to pale red-purple (5*RP* 6/2), very coarsegrained, thick-bedded, crossbedded; weathers pale brown. (T91)	14	42
2. Sandstone, conglomeratic; contains pebbles as much as 4 in. in diameter; larger pebbles are quartzite, smaller ones are composed of quartz and chert; cliff-forming	2	28
1. Sandstone, medium-gray (*N* 5) to grayish red-purple (5*RP* 4/2), very coarse-grained; has basal conglomerate of quartz pebbles as much as 15 mm in diameter; poorly sorted subangular to subrounded quartz grains having considerable overgrowth; medium-bedded, some crossbedding. (T90)	26	26
Precambrian: Dripping Spring Quartzite, light gray, cross-bedded, thin-bedded.		

SECTION 7.—*Salt River Draw (north section)*

[East side of Salt River Draw, about 7 miles upstream from its junction with the Salt River (Fort Apache Indian Reservation, sec. 1, T. 6 N., R. 16 E., unsurveyed). Photograph lots AK 2067, 2068. Measured by Curt Teichert, 1953]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
5. Limestone, not studied in detail, gray, thick-bedded; contains *Tabellaephyllum peculiaris*. (T206)	32	140+
4. Limestone, light olive-gray, finely crystalline; contains abundant detrital quartz grains as much as 2 mm in diameter, rounded to subrounded; contains crinoid stems, *Syringopora* sp. (and *Schizophoria* sp. (TP205); thin- to medium-bedded	38	108+
3. Dolomite, calcitic, light-brown (5*YR* 6/4), very finely crystalline, saccharoidal, argillaceous; rich in corals, abundant colonies of *Hexagonaria* sp., *Thamnopora* sp., and *Alveolites* sp. (T203, T204)	7	70+
2. Sandstone, calcareous, light-brown, well-sorted, very fine-grained; to fine-grained; layer containing *Atrypa*, at 14 ft. (T203)	33	63+
1. Limestone, biostromal, medium light-gray; consists of stromatoporoids and *Thamnopora* colonies; layer containing *Atrypa* at top; very thick bedded	30+	30+

Lower part of section not exposed.

SECTION 8.—*East side of Canyon Creek*

[Upper part of escarpment on eastern side of Canyon Creek, about 7 miles upstream from its junction with the Salt River (Fort Apache Indian Reservation, east of center sec. 9, T. 6 N., R. 16 E., unsurveyed). Photograph lots AK 2066, 2067. Measured by Curt Teichert and R. L. Harbour, 1956; additional observations by Teichert, 1957]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
29. Dolomitic limestone and dolomite, various shades of light gray and grayish pink, fine-grained to very fine grained, probably thin bedded to flaggy throughout; some layers contain scattered small quartz grains; weathers light brown; very poorly exposed under rubble from overlying Redwall Limestone. (T56–281, 280, 279, 278)	70	516
28. Sandstone, light brownish-gray (5*YR* 6/1), medium-grained; contains a few scattered coarser grains; quartz grains tightly packed, smaller grains subangular, larger grains subrounded; some calcareous cement; thin- to medium-bedded (beds are 2–6 in. thick); weathers light brown; poorly exposed. (T56–277)	6	446
27. Dolomite, medium-gray, finely crystalline, thin-bedded (beds are 6–9 in. thick); contains traces of *Thamnopora*	6	440
26. Dolomitic limestone, pinkish-gray; one massive bed of *Theodossia* coquina, containing an admixture of crinoid stems, compound and single rugose corals (*Hexagonana occidens* Stumm, *Alveolites*? sp.) in upper 6 in. Position of about 80 percent of shells convex upward, except in uppermost layer, where positions vary. (T56–276)	2.5	434
25. Limestone, magnesian, light brownish-gray (5*YR* 6/1), coarse-grained, medium-bedded (beds are 4–6 in. thick), very homogeneous; weathers medium gray, with slightly pitted surface. (T56–275)	5	431.5
24. Dolomite, pinkish-gray (5*YR* 8/1) to pale-red (5*R* 6/2), very fine grained; finely and irregularly laminated, some layers contain small pebbles (2–10 mm) of light gray dolomite; thin bedded (beds are 3–4 in. thick); very poorly exposed; weathers light brownish gray to light gray. (T56–274, 273)	16.5	426.5

SECTION 8.—*East side of Canyon Creek*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
23. Sandstone, grayish-orange (10*YR* 7/4), coarse-grained, thick-bedded (beds are 1–2 ft thick), bedding irregular; quartz grains tightly packed, subrounded to subangular. Penetrated by open tubes about 2 mm wide, many of which are perpendicular to bedding plane; others parallel or at various angles; cliff-forming; weathers yellowish brown, with pitted surface. (T56–272)	15	410
22. Limestone, mostly biostromal:		
c. Poorly exposed, probably medium-bedded, gray, fine-grained; 4–5 ft. (T56–271.)		
b. Biostrome of stromatoporoids (*Actinostroma* sp.), *Hexagonaria* sp., *Pachyphyllum* cf. *P. woodmanni* about (White), *Alveolites* sp., and favositoid colars; about 7 ft. (T56–271.)		
a. Limestone replete with *Thamnopora* sp. and brachiopods, chiefly *Atrypa*; 6 in	12	395
21. Sandstone, light-brown (5*YR* 6/4), coarse- to medium-grained; tightly packed quartz grains subrounded; medium bedded; weathers moderate brown. (T56–270)	3	383
20. Limestone, dolomitic, medium light-gray (*N* 6), very fine grained, thick-bedded; very few vugs, filled with white calcite; stromatoporoid biostrome (*Idiostroma*? sp., *Gerronostroma* sp., and *Pachyphyllum* sp.), organic structures very largely destroyed through partial dolomitization; weathers medium light gray. (T57–443, T56–269)	6	380
19. Dolomite, light-gray, very fine grained, thin-bedded; weathers light gray; lower 6 ft very poorly exposed	8	374
18. Dolomite, light brownish-gray (5*YR* 6/1) to grayish-pink, fine-grained, thick-bedded (beds are 8–10 in. thick); few large vugs, as much as 1 cm in diameter, filled with clear or pink calcite; weathers light brown. (T56–268)	9	266

SECTION 8.—*East side of Canyon Creek*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
17. Dolomite, grayish orange-pink (5*YR* 7/2), medium-grained, almost saccharoidal, hard, massive; little visible bedding. Considerable vuggy porosity, much of it in the form of tubular cavities about 2–3 mm wide and oriented approximately vertical to bedding planes; possibly of organic origin; lined with brown crystalline calcite. Entire unit crossed by many closely spaced vertical joints along many of which slickensides are apparent; weathers medium light gray. (T56–267)	11	357
16. Dolomite, grayish orange-pink (5*YR* 7/2), medium-grained, saccharoidal; partly calcite-filled vugs as much as 1 cm in size irregularly scattered throughout rock; cliff-forming; weathers light brown. (T56–266)	11	346
15. Dolomite, pale-red (5*R* 6/2), finely crystalline, thick-bedded (beds are 3 ft thick); cliff-forming; weathers grayish red. (H56–46)	12	335
14. Dolomite, pale-red (5*R* 6/2), finely crystalline, porous; some pores filled with solid calcite crystals as much as 2 mm in diameter; thin-bedded; weathers pinkish gray. (T57–438)	20	323
13. Sandstone, pinkish-gray (5*YR* 8/1), very fine grained, laminated; tightly packed angular quartz grains, and a very small amount of calcareous matrix; thin-bedded, resistant; invertebrate trails; weathers yellowish gray. (T57–437)	3	303
12. Covered	6	300
11. Dolomite, light brownish-gray (5*YR* 6/1), finely crystalline, laminated, porous; in part very sandy; contains detrital quartz grains ranging from silt size to 1 mm in diameter; larger grains subrounded and mostly highly etched on surface; forming one resistant bed. (H56–45)	2	294
10. Siltstone, poorly exposed	3	292
9. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline, slightly porous, medium- to thick-bedded (beds as much as 5 ft thick); weathers yellowish gray. (H56–44)	11	289
8. Covered	1	278
Aphanitic dolomite unit:		
7. Dolomite, pinkish-gray (5*YR* 8/1), very finely crystalline to subaphanitic; contains varying amounts of detrital quartz grains ranging from silt size to about 2 mm in diameter, larger grains subrounded; upper part contains angular fragments of preexisting dolomite; thick-bedded (beds are 3 ft thick); weathers yellowish gray. (H56–43, MP–96)	21	277
6. Covered interval; reddish-brown shale fragments on slope. (H56–42)	25	256
5. Dolomite, only partly exposed unit, very light gray (*N* 8) to medium light-gray (*N* 6), aphanitic to very fine grained, thin- to medium-bedded; small chert pebbles having brown rinds in basal part; some beds have abundant detrital quartz, generally subangular grains with peripheral etching; some beds contain detrital dolomite fragments, also small calcispheres and ostracodes; other beds are finely laminated, and laminae showing evidence of microslumping. (H56–41–40, MP–105; H56–39, 38, 37, 36)	70	231
Fetid dolomite unit:		
4. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline to subaphanitic; finely laminated by finely distributed organic matter; emits strong fetid odor; thin-bedded to medium-bedded; weathers light olive gray. (H56–35, 34)	15	161
Beckers Butte Member:		
3. Sandstone, grayish- orange (10*YR* 7/4) to very pale orange (10*YR* 8/2), generally coarse grained, partly conglomeratic, poorly sorted, partly arkosic; pebble beds, having individual pebbles as much as 20 mm in diameter and concentrated in pockets; outcrops in cliff-forming beds, which are as much as 20 ft thick and show large-scale oblique bedding having southward dips; weathers light brown. (H56–33, 32, T57–43, 46, 45, H56–31)	124	146
2. Conglomerate, sandstone, and siltstone, poorly exposed, crossbedded. (T57–434)	6–21	22
1. Sandstone, grayish orange-pink (10*R* 8/2), poorly sorted, very coarse grained to coarse-grained; contains pebbles as much as 7 mm in diameter; weathers a dark shade of grayish orange pink. (H56–30)	0–1	1

Precambrian: Mazatzal Quartzite: Quartzite, light-gray, fine-grained, finely crosslaminated. (T57–433.)

SECTION 9.—*Oak Creek Farm Road*

[Road from Grasshopper to Oak Creek Farm, 3 miles southwest of Grasshopper, Navajo County (Fort Apache Indian Reservation, east of center sec. 32, T. 8 N., R. 16 E., unsurveyed). Photograph lots AK 2134. Measured by Curt Teichert, 1953; additional observations by Teichert, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
26. Limestone, medium-gray (*N* 5), subaphanitic; scattering of detrital quartz, in places concentrated in small lenses; grains ranging from 0.1 to 0.5 mm in diameter, all badly shattered; weathers medium light gray. (T198)	3	142
25. Chert and silicified limestone, light-gray to light brownish-gray; highly fossiliferous, containing spiriferids and large fauna of rugose corals, including *Hexagonaria occidens* Stumm; weathers into large angular blocks; corals weathering out singly. (T197)	6	139
24. Sandstone, grayish orange-pink (5*YR* 7/2), very fine grained to silty, well-sorted, thin-bedded, laminated; weathers grayish brown. (T196)	16	133
23. Chert and silicified limestone, light-gray (*N* 7) to light brownish-gray (5*YR* 6/1); highly fossiliferous; contains specimens mostly of *Atrypa*. (T195)	1	117
22. Covered	5	116
21. Limestone, pale-red, medium-crystalline; contains *Atrypa* fragments; weathers in rounded outcrops	4	111
20. Limestone, very light gray, very fine grained; contains fragments of *Atrypa*, *Spinatrypa*, and spiriferids; thin-bedded; weathers into angular plates. (T194)	11	107
19. Sandstone, pinkish-gray (5*YR* 8/1), very poorly sorted; smaller grains subangular, larger grains (as much as 2.5 mm) subangular to subrounded; much calcitic, sparry cement, constituting locally more than 50 percent of rock; most larger quartz grains have peripheral etching; contains poor brachiopod fragments; crossbedded; disintegrates easily on weathering. (T193)	4	96
18. Limestone, mottled gray; has abundant stromatoporoids (*Actinostroma*, *Anostylostroma*, *Stictostroma*); massive; weathers medium gray. (T191)	2	92
17. Sandstone, very pale orange (10*YR* 8/2); medium-grained laminae; calcareous matrix; thin-bedded; weathers grayish orange pink. (T192)	4.25	89.75

SECTION 9.—*Oak Creek Farm Road*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
16. Sandstone, calcareous, pinkish-gray; contains some poor gastropod remains	4	85.50
15. Covered, possibly underlain by platy pale-red sandy limestone	4	81.50
14. Dolomite, calcitic, pale-red (5*R* 6/2), very fine grained; contains abundant large calcite vugs and much interstituial calcite; poorly preserved impressions of gastropods (*Arizonella*?) as much as 2 cm in diameter; medium-bedded; weathers pale red. (T190)	5	77.50
13. Sandstone, pinkish-gray (5*YR* 8/1), coarse-grained, poorly sorted; contains subrounded grains as much as 4 mm in diameter, also contains scattered limestone pebbles as much as 4 cm in diameter; much calcareous matrix; very fossiliferous, containing ?*Favosites* sp., *Cyrtospirifer* cf. *C. whitney* Hall and unidentified brachipods; thick-bedded; weathers light brown. (T188)	4	72.50
12. Limestone, mottled yellowish-gray (5*Y* 8/1) and very light gray (*N* 8), very fine grained to aphanitic; contains *Amphipora*, *Styliolina* (?), abundant ostracode fragments and calcispheres, as in subunits 8 and 10; near top, one bed contains abundant specimens of *Thamnopora* sp. and some stromatoporoids; medium-bedded bed (A–6 in. thick); weathers grayish orange. (T187)	17	68.50
11. Limestone, light-gray; aphanitic; conchoidal fracture; contains some unidentifiable gastropods near top; thick-bedded	4.50	51.75
10. Limestone, light brownish-gray (5*YR* 6/1); some pale-red (5*R* 6/2) beds near base; very fine grained to aphanitic; conchoidal and subconchoidal fracture; pelletal structure; lower pale-red beds penetrated by many vermicular calcite vugs; some ostracode fragments and abundant calcispheres, 0.1–0.2 mm in diameter; some poor gastropod fragments weathered out on slope; medium-bedded; weathers light brown. (T185, 186)	6.75	47.25

SECTION 9.—*Oak Creek Farm Road*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
9. Limestone, mottled light brownish-gray (5*YR* 6/1) and grayish-red (5*R* 4/2); subaphanitic; subconchoidal fracture; pelletal or finely clastic structure; scattered detrital quartz; subangular grains as much as 0.5 mm in diameter; medium-bedded; weathers light gray. (T184)	8.50	40.50
8. Limestone, light brownish-gray (5*YR* 6/1), very finely crystalline to aphanitic; pelletal structure; abundant calcispheres, 0.1–0.2 mm in diameter; bryozoan fragments; thin-bedded; weathers medium light gray. (T183)	5.50	32
7. Mostly covered; very poor outcrops of fine-grained crossbedded light-brown sandstone	11	26.50
6. Sandstone, yellowish-gray (5*Y* 8/1) with pale-red spots, hard, quartzitic, medium-grained; contains a few grains as large as 1 mm; grains generally rounded to subrounded; almost all grains have considerable overgrowth; weathers medium light gray. (T182)	4.50	15.50
5. Covered, probably underlain by brown platy sandstone	3	11
4. Limestone; like subunit 2	1	8
3. Sandstone; like subunit 1	2	7
2. Limestone, medium light-gray and pale-red mottling, very fine grained to aphanitic; penetrated by numerous more or less vertical calcitic tubes, 2 mm wide and 100 mm or more long, which are probably burrows	2	5
1. Sandstone, mottled pinkish-gray (5*YR* 8/1) and grayish-red (5*R* 4/2), fine- to medium-grained; some larger rounded grains are as much as 1 mm in diameter; smaller grains tightly packed, angular to subangular; weather pale brown. (T180)	3	3
Precambrian: Mazatzal, Quartzite, mottled light-gray and pale-red.		

SECTION 10.—*Spring Canyon*

[0.5 mile east of junction of Spring and Canyon Creeks at Chediski, Navajo County (Fort Apache Indian Reservation, SW¼NW¼ sec. 36, T. 9 N., R. 15½ E., unsurveyed). Photograph lots AK 3255, 3256. Measured by Curt Teichert, 1953]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
4. Dolomite, pale-red (5*R* 6/2), finely crystalline; irregularly distributed, poorly sorted detrital quartz (as much as 15 percent of rock) ranging from silt size to grains as much as 1 mm in diameter; larger grains rounded to subrounded; weathers grayish orange pink. (T158, 157)	12	36
3. Sandstone, grayish orange-pink (10*R* 8/2), fine-grained, well-sorted; maximum of 20 percent calcareous matrix; grains as small as 0.1 mm in diameter subrounded; channeling into surface of biostromal limestone, subunit 2; friable. (T156)	8.5–16	24
2. Limestone, biostromal, very light gray (*N* 8); consisting predominantly of stromatoporoids (*Gerronostroma*, *Idiostroma*) and favositids and admixture of rugose corals (*Thamnopora*, *Alveolites*, *Disphyllum*?, *Tabulophyllum*). (T155)	0–7.5	8–15.5
1. Limestone, very light gray (*N* 8), very finely crystalline; upper 2 ft richly fossiliferous, containing *Thamnopora* sp. and *Atrypa* cf. *A. clarkei* Warren; thick-bedded; weathers light gray. (T154)	8	8
Precambrian: Mazatzal Quartzite, platy, crossbedded.		

SECTION 11.—*Spring Canyon*

[About 1 mile southeast of junction of Spring and Canyon Creeks near Chediski, Navajo County (Fort Apache Indian Reservation, SE¼ SW¼ sec. 36, T. 9 N., R. 15½ E., unsurveyed). Photograph lots AK 3255, 3256. Measured by Curt Teichert, 1953]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
18. Chert and silicified limestone, light-gray; rich in calcispheres, crinoid stems, and specimens of *Spinatrypa* sp. and *Schizophoria* sp., at least in basal part; weathers brownish gray; poorly exposed. (T178, 177)	8	75
17. Sandstone, mottled pale-red and pinkish-gray, poorly sorted, fine- to medium-grained, grains rounded to subrounded; very crossbedded; thick-bedded; cliff-forming. (T176)	16	67
16. Limestone, biostromal, light-gray; consists mostly of stromatoporoids and accessory favositids and *Thamnopora*; base of subunit undulating, having relief of about 3 ft; top irregular, having relief of about 1 ft; uppermost 6–12 in. contains limestone boulders as much as 10 in. in diameter; evidence of penecontemporaneous weathering at top of subunit; massive; average thickness	6	51

SECTION 11.—*Spring Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
15. Limestone, light-gray, aphanitic to very finely crystalline; pockets of *Thamnopora* colonies near base; thick-bedded. (T175)	3	45
14. Limestone, dolomitic, pinkish-gray, finely crystalline, saccharoidal; medium-bedded, laminated. (T175)	3.5	42
13. Covered	2.75	38.5
12. Limestone, light brownish-gray (5*YR* 6/1), finely crystalline; pelletal matrix containing calcispheres; considerable amount of detrital quartz, subrounded to rounded grains as much as 0.7 mm in diameter; thin-platy, laminated; weathers medium light gray. (T173)	.5	35.75
11. Covered	2	35.25
10. Limestone, light-gray (*N* 7), aphanitic; irregular fracture; large amounts of scattered detrital quartz grains, subrounded to rounded, as much as 0.7 mm in diameter; medium-bedded (beds are 8–10 in. thick); weathers light brownish gray. (T172)	5.75	33.25
9. Covered	2.75	27.5
8. Limestone, light-gray, platy	.5	24.75
7. Covered	5	24.25
6. Limestone, light brownish-gray (5*YR* 6/2), aphanitic; conchoidal fracture; contains calcispheres and crinoid fragments; contains scattered detrital quartz in rounded to subrounded grains as much as 0.4 mm in diameter; weathers medium gray. (T171)	1	19.25
5. Sandstone, mottled pinkish-gray (5*YR* 8/1) and grayish-red (5R 4/2), medium-grained; has calcareous matrix and calcite vugs; grains rounded; thin-bedded (beds are 4–10 in. thick), laminated; weathers mottled reddish-gray and gray. (T170)	10	18.25
4. Sandstone, finely mottled pinkish-gray (5*YR* 8/1) and pale-red (5*YR* 6/2), fine-grained, well-sorted; contains much calcareous matrix, which in lower part is recrystallized in large units having uniform crystalline orientation ("Fontainebleau structure"); weathers pale brown. (T167)	5.5	8.25
3. Limestone, light-gray (*N* 7), fine-grained, pelletal; contains brachiopod and crinoid fragments and calcispheres; weathers medium light gray. (T166)	.5	2.75
2. Sandstone, mottled pale-brown (5*YR* 5/2) and grayish orange-pink (10*R* 8/2), medium-grained, well-sorted; grains rounded to subrounded; some calcareous matrix; laminated. (T165)	.75	2.25
1. Sandstone, pale-red (5*R* 6/2 to 10*R* 6/2), some pinkish-gray patches, fine-grained, well-sorted; grains subrounded; calcareous matrix; at base, pebbles and boulders of underlying quartzite are as much as 2 ft in diameter; thin-bedded; weathers pale red. (T164)	1.5	1.5

Precambrian: Mazatzal Quartzite.

SECTION 12.—*Lost Tank Canyon*

[North side of Lost Tank Canyon, 1–2½ miles upstream from junction of Lost Tank Canyon and Canyon Creek (Fort Apache Indian Reservation; section lies somewhat obliquely through central parts of secs. 1 and 2 T. 9 N., R. 15 E.). Photograph lots AK 3256, 3257. Measured by Curt Teichert and R. L. Harbour, 1956]

Martin Formation: Jerome Member: Upper unit:	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
46. Sandstone, pale reddish-brown (10*R* 5/4), fine- to medium-grained; contains detrital subangular to subrounded quartz grains; color due to limonitic staining; very porous, porosity ranging from about 5 to 10 percent; porosity may be due to leaching of original calcareous cement; poorly exposed. (T56–389, TP56–403)	2	386
45. Dolomite, calcitic (or dolomitic limestone), pale-red (5*R* 6/2); very fine grained to aphanitic; contains a few silt-sized particles of detrital quartz (these, however, are possibly silicified fossil fragments); microstylolitic, stylolitic sutures spaced as closely as 1 mm, some stylolitic sutures visible with naked eye; lower part contains silicified *Atrypa* shells and shell fragments; 6-in. brachiopod coquina occurs at 8 ft; part above the coquina is almost unfossiliferous; thin bedded to flaggy; weathers light brown. (TP56–402, 388)	20	384
44. Dolomite, calcitic (or dolomitic limestone), pale-red (5*R* 6/2), very fine grained; contains large number of silicified specimens of *Theodossia*, in places acquires aspect of a brachiopod coquina; thick-bedded (beds are 1–2 in. thick); weathers pale red. (TP56–387)	3	364

SECTION 12.—*Lost Tank Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
43. Dolomitic limestone, pale-red (5*R* 6/2), very fine grained; contains very scattered silt-sized detrital quartz particles and scattered small cavities, as much as 2.5 mm in diameter, filled with calcite; scattered crinoid ossicles; thin-bedded to flaggy; weathers light brown. (TP56–386)	8	361
42. Dolomite, calcitic, grayish-red (5*R* 4/2) fine- to medium-grained; contains very few detrital quartz grains, as much as 1.2 mm in size; scattered cavities, 0.5–0.7 mm in diameter, filled with calcite; in places, lamination brought out by weathering; thick-bedded; weathers olive gray. (TP56–385)	4	353
41. Dolomite, silty (or dolomitic siltstone?), pale-red (5*R* 6/2); matrix is a dense slightly calcitic dolomite, which is mixed in about equal portion with siltsized quartz particles, mostly about 0.06 mm in diameter; laminations result from tighter packing of silt in thin layers, which are 3–6 mm apart; thin-bedded to flaggy; weathers pale red. (TP56–401, 384)	4	349
40. Sandstone, pale-red (5R 6/2), fine- to medium-grained; consists of tightly interlocking mosaic of quartz grains that are generally subangular to subrounded and very little deformed; thick-bedded (beds are ½–3 in. thick), distinctly laminated and very highly crossbedded; weathers reddish brown. (TP56–383)	6	345
39. Sandstone, pale-red (10*R* 6/2), very fine grained, most grains about silt size (0.06mm); contains large amount of carbonate cement, which seems to be a calcitic dolomite; thin-bedded to flaggy; weathers grayish red. (TP56–382)	10	339
38. Sandstone, white (*N* 9) to pinkish-gray (5*YR* 8/1), medium-grained; consists of rather tightly interlocking mosaic of detrital quartz grains, many of which are somewhat deformed, and small quantity of calcareous cement; roundness varies from subangular to well rounded, although original shape is deformed in many places; thick-bedded (beds are ½–3 in. thick); massive; ledge-forming; weathers medium gray. (TP56–400)	7	329
37. Limestone, light olive-gray (5*YR* 6/1), dense; subconchoidal fracture; brecciated and in part biostromal, containing stromatoporoid colonies; thick-bedded; weathers gray to brown. (TP56–399)	5	322
36. Limestone, light brownish-gray (5*YR* 6/1); fine-grained; calcarenitic, consisting principally of more or less rounded limestone grains as much as 1 mm in diameter; matrix between these grains mostly recrystallized, giving rock a finely vuggy appearance; thick-bedded; weathers yellowish gray. (TP56–398)	1	317
35. Dolomitic limestone, light brownish-gray (5*YR* 6/1), sandy; limestone matrix aphanitic, apparently originally calcarenitic; contains many idiomorphic dolomite crystals, which possibly make up as much as 20–25 percent of the rock; irregularly scattered quartz grains, mostly very fine to fine, and scattered grains as much as 0.75 mm in diameter; grains more than 0.3 mm in diameter are well rounded, those less than 0.3 mm are mostly angular; thick-bedded (beds are 10 in. to 2 ft thick); subconchoidal fracture; weathers light olive gray. (TP56–397)	4	316
34. Limestone, biostromal, yellowish-gray (5*Y* 8/1); lower part brecciated, somewhat laminated, contains many stromatoporoid fragments (*Gerronostroma* sp., *Idiostroma* sp.) and scattered *Favosites* colonies; upper 3 ft contains dense packing of large spherical stromatoporoid colonies as much as 2 ft in diameter; thick-bedded, massive. (TP–56, 396, 395)	7	312
33. Dolomite, pale-red, very fine grained; rich in recrystallized *Thamnopora* skeletons, particularly in uppermost 6 in.; thick-bedded; very similar in appearance to subunit 31	2	305
32. Dolomite, grayish-pink (5*R* 8/2), slightly calcitic, very fine grained; contains scattered, poorly recrystallized *Thamnopora* skeletons; thick-bedded (beds are 1½–2 in. thick); weathers pinkish gray. (TP56–394)	5	303
31. Dolomite, pale-red (5*R* 6/2), very fine grained; contains about 10 percent silt-sized quartz particles; medium-bedded (beds are 6–8 in. thick); weathers grayish red. (TP56–393)	8	298
30. Dolomite, pale-red (5*R* 6/2), very fine grained; contains many very highly recrystallized *Thamnopora* skeletons; thick-bedded; weathers reddish gray. TP56–392)	3	290
29. Dolomite, yellowish-gray, fine-grained, thin-bedded; poorly exposed	2	287

SECTION 12.—*Lost Tank Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
28. Dolomite, yellowish-gray (5*Y* 8/1), slightly calcitic, very fine to fine-grained; contains clouds of very fine grained dolomite surrounded by somewhat coarser grained material; contains very many highly recrystallized *Amphipora* skeletons, most of which have lost their structure; very few scattered quartz grains as much as 0.3 mm in diameter, subrounded; thick-bedded; weathers light gray. (TP56–391)	2	285
27. Dolomite, pale-red (5*R* 6/2), fine- to medium-grained, saccharoidal, thick-bedded; at 5–7 ft, large, calcite-filled vugs as much as 4 inches in diameter occur; weathers grayish red. (TP56–381, 390)	11	283
26. Covered interval	4	272
25. Dolomite, pale-red (5*R* 6/2), fine- to medium-grained, saccharoidal; contains a few scattered quartz grains as much as 0.3 mm in diameter, angular to sub angular; thin-bedded to flaggy; weathers pale red. (TP56–380)	5	268
24. Covered interval; slope covered with rubble of fine-grained light-gray thin- to medium-bedded dolomite	25	263
23. Dolomite, pale-red (5*R* 6/2), coarsely crystalline; contains a few idiomorphic dolomite crystals; thick-bedded; weathers pale red with pitted surface. (TP56–379)	5	238
22. Covered interval; probably mostly light-gray fine-grained dolomite and some coarser pinkish-gray dolomite	15	233
21. Dolomite, pinkish-gray (5*YR* 8/1), calcitic, very sandy; grades into sandy dolomite; thick-bedded; quartz grains, very fine to fine; grains as much as 0.3 mm, angular to subangular, large or grains rounded to subrounded. Quartz grains make up 10 percent or more of the rock; in places, they are concentrated so they are tightly packed to form sandy layers several millimeters thick; scattered vugs of varying sizes as much as 10 mm in diameter, filled with pinkish to white calcite; weathers light gray. (TP56–378)	3	218
20. Sandstone, pinkish-gray (5*YR* 8/1), medium- to coarse-grained; quartz grains mostly angular to subangular, some of the larger grains subrounded; grains are tightly interlocked; rock contains practically no matrix; very thick bedded (beds as much as 7 ft thick); conspicuous		

SECTION 12.—*Lost Tank Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
20. Sandstone, etc.—Continued cliffs; weathers light brown. (H56–133, 200)	27	215
19. Covered	2	188
18. Dolomite, light gray, very finely crystalline, silty and sandy; weathers into rounded ledges	7	186
17. Sandstone, pale-red (5*R* 6/2) to pale red-purple (5*P* 6/2), medium- to coarse-grained, well-sorted, quartz grains subrounded to subangular, embedded in opaque matrix (possibly clay); friable; weathers olive gray. (H56–131)	5	179
16. Dolomite, pale red-purple (5*P* 6/2) to grayish-pink (5*R* 8/2); aphanitic; good conchoidal fracture; very uniform matrix with insignificant amounts of silt-sized detrital quartz grains and a few very small (less than 1 mm) calcite vugs; crops out in two thinly laminated cliff-forming beds; weathers yellowish gray. (H56–130, 129)	22	174
15. Dolomite, pinkish-gray (5*YR* 8/1) aphanitic; conchoidal to subconchoidal fracture; scattered detrital quartz grains, mostly silt size to fine, and a few subrounded grains as much as 0.3 mm in diameter; medium- to thick-bedded (beds are 2–3 ft thick); weathers grayish pink. (H56–128)	14	152
14. Dolomite, grayish orange-pink (5*YR* 7/2), subaphanitic; subconchoidal fracture; matrix in places breccious, containing clasts of aphanitic dolomite as much as 15 mm in diameter; abundant detrital quartz grains, ranging from silt size to about 1 mm in diameter, either scattered diffusely throughout the rock or concentrated in thin lenses or laminae; large grains subrounded; medium-bedded (beds are 1–2 ft thick); weathers yellowish gray. (H56–127)	13	138
13. Sandstone, pale-red, dolomitic; similar to subunit 9	2	125
12. Dolomite, medium-gray, aphanitic	2	123
11. Sandstone, pale-red, poorly sorted (like subunit 9); fills fine cracks in underlying dolomite to depth of 1 ft	0.5	121
10. Dolomite, medium-gray, aphanitic, thinly laminated	1	120.5
9. Sandstone, pale-red (R*R* 6/2), poorly sorted, fine- to coarse-grained; larger quartz grains subrounded, smaller grains subangular to angular; small amount of dolomitic matrix. (H56–126)	0.5	119.5

SECTION 12.—*Lost Tank Canyon*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
8. Dolomite, banded grayish orange-pink (5*YR* 7/2) and light brownish-gray (5*YR* 6/1), subaphanitic; contains vugs as much as 5 mm long filled with red-tinted calcite; laminated, lamination caused mainly by thin layers of detrital quartz grains, which ars subrounded to subangular and range from silt size to about 1 mm in diameter; matrix contains aphanitic dolomite clasts as much as several millimeters in diameter. (H56–125)	2	119
7. Sandstone, light-gray, poorly sorted, fine- to coarse-grained; well-rounded coarse-grained clasts embedded in very fine matrix	1	117
6. Dolomite, pale-red (5R 6/2), subaphanitic; subconchoidal fracture; contains as much as 3 percent detrital quartz grains, which are angular to subangular and as much as 0.7 mm in diameter; medium-bedded, hard; weathers grayish pink. (H56–124)	13	116
Fetid dolomite unit:		
5. Dolomite, medium-gray, finely saccharoidal, thinly laminated	3	103
4. Dolomite, grayish-red (10*R* 4/2), very finely crystalline; small amount (1 percent or less) of detrital quartz grains as much as 0.1 mm in diameter; very thin bedded to fissile; weathers pale reddish brown. (H56–123)	3	100
3. Dolomite, pale-red (5*R* 6/2), very finely crystalline, thinly laminated; insignificant amount of silt-sized detrital quartz grains; slightly fetid odor; weathers pale red. (H56–122)	13	97
Beckers Butte Member:		
2. Dolomite and shale, interbedded, grayish-red, lenticular	1	84
1. Sandstone, grayish-purple (5*P* 4/2) to pale reddish-brown (10*R* 5/4); mostly medium grained, but contains many pockets of coarser material; generally thick bedded, although in places, irregularly bedded to flaggy; massive, cliff-forming; crossbedded	83	83
Precambrian: Mazatzal Quartzite.		

SECTION 13.—*Southwest Branch of Lost Tank Canyon*

[East of Heber-Young Highway, 0.8 mile south of turnoff to Lost Tank Canyon (Fort Apache Indian Reservation, NW¼ sec. 3, T. 9 N., R. 15 E.). Photograph lots AK 3257, 3258. Measured by Curt Teichert, 1953; additional observations by Teichert, 1957]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
24. Dolomite, slightly calcitic, grayish-pink (5*R* 8/2), very finely crystalline; contains small calcite vugs; argillaceous; richly fossiliferous; in part, coquina of silicified brachiopods (*Theodossia* sp.); medium-bedded; weathers grayish pink. (T56–403)	32	303
23. Dolomite, slightly calcitic, pale-red (5*R* 6/2), very finely crystalline, argillaceous; contains rich silicified fauna (*Cyrtospirifer* cf. *C. whitneyi*, *Schizophoria iowensis*, *Theodossia* cf. *T. hungerfordi*, *Atrypa* cf. *A. devonica*, *Spinatrypa planosulcata*); medium-bedded (beds are 8–10 in. thick); weathers into large very pale orange slabs. (T56–402)	26	271
22. Dolomite, calcitic, mottled pale-red (5*R* 6/2) and grayish orange-pink (5*YR* 7/2), finely crystalline; few small calcite vugs; pin-point porosity; medium-bedded (beds are as much as 8 in. thick); weathers pale red	3	245
21. Dolomite, slightly calcitic, mottled pale-red (10*R* 6/2) and grayish orange-pink (5*YR* 7/2), finely crystalline; contains small amount of detrital quartz grains in sizes 0.5 mm and less; larger grains rounded; very fossiliferous, containing abundant silicified branchiopods, mostly *Theodossia* cf. *T. hungerfordi*; medium-bedded; weathers yellowish gray. (T56–401)	5	242
20. Dolomite, grayish-purple, coarsely crystalline, thin-bedded, poorly exposed	2	237
19. Dolomite, calcitic, pale-red (5*R* 6/2), very fine grained, argillaceous, finely crystalline; fossiliferous, contains *Aulocystis* sp. or *Syringopora* sp., *Platyrachella* cf. *P. mcbridei*, *Cyrtospirifer* sp., *Spinatrypa planosulcata*; thin-bedded; weathers pale red. (T280)	2	235
18. Sandstone, light-brown, fine-grained, becomes coarser toward top; invertebrate tracks on bedding planes; thin-bedded; poorly exposed, except top 3 feet, which is cliff forming	36	233

SECTION 13.—*Southwest Branch of Lost Tank Canyon*—Con.

Martin Formation—Continued / Jerome Member—Continued / Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
17. Limestone, biostromal, massive; consists of colonies of spherical and branching stromatoporoids (including ?*Amphipora* sp. and *Idiostroma*) and *Alveolites* sp.; scattered small calcispheres; comparatively little interstitial limestone matrix; at top of subunit, 2 ft. of brecciated limestone containing stromatoporoid fragments. (T257)	11	197
16. Limestone, light-gray, very finely crystalline, thick-bedded; grades into subunit 17	4	186
15. Sandstone, pinkish-gray, medium-grained, medium-bedded	9	182
14. Sandstone, yellowish-gray (5*Y* 8/1), very fine grained, well-sorted, thin-bedded; weathers light olive gray. (T256)	4	173
13. Covered	10	169
12. Sandstone, pinkish-gray (5*YR* 8/1), very fine grained, well-sorted; fucoidal structures; thick-bedded; weathers brownish gray. (T255)	2.5	159
11. Dolomite, very finely crystalline, thin-bedded (beds are 4–6 in. thick); weathers medium gray	2.5	156.5
10. Dolomite, pale-red, very finely crystalline, thin-bedded; weathers pale red	3	154
9. Covered	10.5	151
8. Dolomite, grayish-red (5*R* 4/2), very finely crystalline; contains abundant *Amphipora* sp. and *Thamnopora* sp.; thick-bedded; weathers pale red. (T254)	14.5	140.5
7. Dolomite, grayish red-purple (5*RP* 4/2), very finely crystalline, subconchoidal fracture; thin-bedded; weathers light olive gray. (T253)	18.5	126
6. Dolomite, very slightly calcitic, mottled pale-red (5*R* 6/2) and grayish-pink (5*R* 8/2), coarsely crystalline; contains hypidiomorphic dolomite crystals and little interstitial calcite; lower half thin-bedded (beds are 4–6 in. thick), upper half, medium bedded (beds are as much as 1 ft thick); weathers pale red; poorly exposed. (T252)	32	107.5
Aphanitic dolomite unit:		
5. Dolomite, light-gray (*N* 7), aphanitic; scattered detrital quartz grains, rounded, as much as 1 mm in diameter; thin-bedded; weathers yellowish gray. (T251)	16.5	75.5
4. Dolomite, pinkish-gray (5*YR* 8/1), very finely crystalline; abundant detrital quartz, as much as 1 mm in diameter, poorly sorted; grais rounded to subrounded; thin-bedded; weathers yellowish gray. (T250)	4	59

SECTION 13.—*Southwest Branch of Lost Tank Canyon*—Con.

Martin Formation—Continued / Jerome Member—Continued / Aphanitic dolomite unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
3. Covered, surface strewn with sandstone and dolomite boulders	35	55
2. Dolomite, light-gray (*N* 8), very finely crystalline; contains abundant detrital quartz, poorly sorted, as much as 1 mm in diameter; grains subrounded to rounded. (T249)	10	20
1. Dolomite, light-gray, aphanitic; scattered detrital quartz; bedding not well exposed; weathers medium gray	10	10

NOTE.—Below subunit 1, the slope is covered with talus composed of light-gray aphanitic dolomite for 45 ft. Farther down, the talus consists of brown sandstone. No outcrops occur in this sandstone subunit, and its base is not exposed.

SECTION 14.—*West bank of Canyon Creek*

[2 miles south of O. W. Ranch (Tonto National Forest, NE¼SW¼ sec. 15, T. 10½ N. R. 15 E.). Photograph lots AK 3166, 3167. Measured by R. L. Harbour, 1956]

Martin Formation: / Jerome Member: / Upper unit:	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
27. Dolomite, pale-red (5*R* 6/2), very finely and uniformly crystalline; contains a little detrital quartz, ranging mostly from silt to fine in grain size a few grains of which are as much as 0.3 mm in diameter; contains fragments of *Atrypa* sp. and *Platyrachella* cf. *P. mcbridei*. (H56–119)	5	143
26. Covered	7	138
25. Dolomite, light-gray (*N* 7), very finely crystalline; contains abundant detrital quartz grains ranging from silt to very fine in grain size; laminated; slope-forming. (H56–118)	5	131
24. Dolomite, grayish orange-pink (10*R* 8/2), very finely crystalline; contains abundant detrital quartz ranging in size from silt to about 0.7 mm in diameter; larger grains rounded to subrounded; comparatively little etching of grains; detrital quartz constitutes as much as 25 percent of the rock; lower half of subunit flaggy, upper half is one undivided bed; weathers pale orange. (H56–117)	7	126
23. Limestone, medium light-gray (*N* 6), aphanitic; contains aboundant individual crystals and small clusters of calcite and abundant detrital quartz grains, ranging from silt to about 2 mm in diameter in grain size, whose surface more or less heavily etched; contains few calcispheres; crops out in two laminated resistant beds; weathers light gray. (H56–116)	4	119
22. Dolomite, pinkish-gray (5*YR* 8/1), finely crystalline, very sandy; in part grades into sandy dolomite; detrital quartz grains abundant in all size grades ranging from silt to 1 mm in		

SECTION 14.—*West bank of Canyon Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
22. Dolomite, etc.—Continued diameter; all grains about 0.5 mm are well rounded, outer surfaces slightly etched; very thin bedded; slope-forming; weathers light brownish gray. (H56–115)	7	115
21. Dolomite, pinkish-gray, finely and evenly crystalline; subunit and underlying subunit form cliffs	2	108
20. Siltstone, gray, dolomitic, resistant	1	106
19. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline to aphanitic; contains very small amount of silt sized quartz grains; medium-bedded beds about 1 ft thick separated by shale bands as much as 3 in. thick; slope-forming; weathers pale brown. (H59–114)	10	105
18. Covered	2	95
17. Siltstone, gray, dolomitic; contains medium-sized quartz grains near base; contains one slightly laminated bed	4	93
16. Dolomite, pale-red, saccharoidal; contains one resistant somewhat laminated bed	4	89
15. Sandstone, gray, medium-grained, dolomitic, friable	3	85
14. Siltstone, grayish-red, dolomitic, resistant	2	82
13. Dolomite, pale-red (5*R* 6/2), very finely and uniformly crystalline; forms one bed; weathers grayish red. (H56–133)	4	80
12. Dolomite, pinkish-gray (5*YR* 8/1), very finely and uniformly crystalline; contains very small amount of silt sized detrital quartz grains; scattered calcite vugs as much as 15 mm in diameter; medium-bedded (beds are 1 ft thick); slope-forming; weathers pale yellowish brown. (H56–112)	8	76
11. Dolomite, pale-red (5*R* 6/2), fine- to medium-crystalline, saccharoidal; consists of aggregate of idiomorphic and hypidiomorphic dolomite crystals; thick-bedded (maximum thickness of beds, 5 ft); weathers pale red. (H56–111)	12	68
10. Dolomite, grayish orange-pink (5*YR* 7/2), very finely crystalline to aphanitic; matrix contains irregularly disseminated clusters and veinlets of crystalline calcite; subunit contains small lenses and laminae of detrital angular quartz grains ranging in size from silt to about 0.4 mm in diameter; indistinctly laminated but has no well-defined bedding; weathers light brown. (H56–110)	7	56

SECTION 14.—*West bank of Canyon Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
9. Dolomite, pale-red (5*R* 6/2), very finely and uniformly crystalline; contains scattered calcite vugs as much as 15 mm in diameter; crops out as one ledge-forming bed. (H56–109)	2	49
8. Dolomite, sandstone, interbedded with shale and sandy dolomite, pale-red (5*R* 6/2), poorly sorted; contains quartz grains ranging in size from silt to 1.5 mm in diameter; smaller grains angular to subangular, larger grains rounded to subrounded; shaly layers, brownish-red; thin-bedded (beds are as much as 4 in. thick); weathers grayish pink. (H56–108)	2	47
7. Dolomite, pale-red (5*R* 6/2), coarsely crystalline, saccharoidal; consists of idiomorphic and hypidiomorphic dolomite crystals as much as 1 mm in diameter; contains as much as about 3 percent detrital quartz grains ranging in size from silt to about 1 mm in diameter; contains larger grains that are generally subangular; medium-bedded (beds are 1–2 ft thick); weathers pale red. (H56–107)	13	45
6. Sandstone, gray-tinted, poorly sorted, fine- to coarse-grained; contains red-tinted clay partings	3	32
5. Sandstone, pinkish-gray (5*YR* 8/1) to pink (5*RP* 8/2), medium-grained, poorly sorted; contains quartz grains ranging in size from silt to 0.7 mm in diameter; as much as 20 percent dolomitic matrix; contains a resistant bed; weathers pale brown. (H56–105)	1	29
4. Dolomite, calcitic, pale-red (5*R* 6/2), very silty and sandy; contains detrital quartz grains, ranging in size from silt to 1 mm in diameter, and making up 5–10 percent of rock; larger grains well rounded to subrounded; matrix of medium- to coarse-grained dolomite crystals and interstitial calcite; massive, slope forming. (H56–105, 104, 103)	24	28
3. Covered; probably mudstone	0.5	4
2. Sandstone, pale-red (5*R* 6/2), poorly sorted, medium- to coarse-grained; somewhat laminated; larger quartz grains subrounded to rounded; smaller grains subangular to angular, tightly packed, and interlocking. (H56–102)	3	3.5
1. Mudstone, red-tinted, poorly exposed	0.5	0.5

Precambrian: Dripping Spring Quartzite.

Section 15.—*East side of Canyon Creek*

[1 mile south of O. W. Ranch (Tonto National Forest, SE¼NW¼ sec. 10, T. 10½ N., R. 15 E.). Photograph lots AK 3166, 3167. Measured by Curt Teichert, 1956]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
24. Limestone, grayish-red (5*R* 4/2), dolomitic, medium-grained, slightly sandy; scattered quartz grains make up 1–2 percent of rock and grade in size from very fine to fine; grains larger than 0.2 mm generally well rounded; medium-bedded (beds are 6–12 in. thick); weathers grayish red. (T56–371)	6	133
23. Limestone, pinkish-gray (5*YR* 8/1) to yellowish-gray (5*Y* 8/1), very fine grained, very sandy; quartz grains make up 10–30 percent of rock, mostly in size grades ranging from very fine to medium; a few grains are coarse; small grains are angular to subrounded; large grains tend to be well rounded; calcareous matrix, calcarenitic, consisting of well-rounded grains of very fine grained limestone cement containing fine-grained calcareous material; contains a very few brachiopod remains; thick-bedded, weathers pinkish gray. (T56–370)	3.5	127
22. Sandstone, pale-red (5*R* 6/2), medium- to coarse-grained; has irregular lamination indicating a rough separation of the medium and coarse fraction; cement, clayey to silty, somewhat limonitic; grains as much as about 0.3 mm in diameter are angular to subangular; larger grains tend to be better rounded; thin-bedded; weathers pale red. (T56–369)	2	123.5
21. Limestone, light brownish-gray (5*YR* 6/1), speckled medium-gray, fine-grained, very sandy, thick-bedded (beds are 2 ft thick), laminated; quartz grains range in size from very fine to medium; smaller grains angular; larger grains subrounded to rounded; quartz grains make up 10–30 percent of rock; weathers light gray. (T56–368)	4	121.5
20. Limestone, light olive-gray (5*Y* 6/1), very fine grained; contains scattered euhedral dolomite crystals and irregularly distributed quartz grains ranging in size from very fine to medium; larger quartz grains frosted; well-rounded; locally, the quartz grains may make up 10 percent of the rock but are generally rarer; weathers light gray. (T56–367)	1	117.5

Section 15.—*East side of Canyon Creek*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
19. Sandstone, grayish-pink (5*R* 8/2), medium- to coarse-grained; contains much calcitic matrix; quartz grains range from 0.05–0.5 mm in diameter, some are larger; small grains subangular; larger grains subrounded to rounded, most are rounded; some grains show slight calcite replacement; matrix entirely calcitic; weathers light gray. (T56-366)	6	116.5
18. Limestone breccia, light-gray (*N* 7), biostromal, unbedded, nodular appearance; contains angular limestone fragments as much as 3 in. in diameter; contains stromatoporoid colonies in place (*Actinostroma* sp.) as much as 12 in. in diameter; contains much organic fragmental material, including *Thamnopora;* weathers light gray. (T56–365)	6	110.5
17. Covered interval	8	104.5
16. Limestone, yellowish-gray (5*Y* 8/1), very fine grained, sandy; contains 5–20 percent very fine quartz grains; matrix predominantly calcitic, containing scattered euhedral dolomite crystals; thin- to medium-bedded (beds are 2–12 in. thick); weathers light brown to gray. (T56–364)	10	96.5
15. Dolomite, pale-red (5*R* 6/2), slightly mottled yellow, medium-grained, saccharoidal, calcitic; calcium-rich material found along boundaries of irregularly shaped and interlocking dolomite crystals; thick-bedded; weathers reddish brown. (T56–363)	5	86.5
14. Dolomite, pinkish-gray (5*YR* 8/1), medium-grained, calcitic, very sandy; quartz grains range in size from very fine to fine; contains a scattering of coarser grains as much as 1 mm in diameter; smaller grains, angular to subangular; larger grains, subrounded to rounded; quartz grains make up 20–25 percent of the rock; most larger grains have slight marginal replacement by dolomite; thin- to medium-bedded; weathers pale red. (T56–362)	16	81.5
13. Dolomite, pale-red (5*R* 6/2), fine- to medium-grained, saccharoidal, very sandy; much of the rock is an intimate mixture of fine-grained dolomite and small quartz grains, both about 0.05 mm in diameter; larger quartz grains scattered through the rock are as much as 1.0 mm in diameter and have marginal dolomite replacement;		

SECTION 15.—*East side of Canyon Creek*—Continued

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
13. Dolomite, etc.—Continued quartz grains make up 20–50 percent of the rock. Vugs having irregular shape and size are common; they are lined with yellow calcite but are mostly hollow; weathers pale red. (T56–361)	12	65.5
12. Dolomite, grayish orange-pink (10*R* 8/2), fine-grained, finely porous—pores generally less than 0.3 mm in diameter, rarely larger—flaggy; weathers pale red	7	53.5
11. Dolomite, grayish orange-pink (10*R* 8/2), fine-grained, sandy, grades into dolomitic sandstone; quartz grains making up 20–60 percent of the rock in different parts; graded bedding in about 1-in. layers indicated. Dolomite is much finer grained than that in subunits 3, 5, 7, and 9; quartz grains have similar appearance and were subjected to dolomite replacement. Medium-bedded, laminated; contains some small-scale slump structures; weathers light brown	7.0	46.5
10. Dolomitic shale, grayish-red	0.5	39.5
9. Dolomite, pale-red (5*R* 6/2), coarse-grained saccharoidal, very sandy; quartz grains make up 40–50 percent of rock. Except for larger percentage of sand, this rock is similar in appearance to that of subunits 3, 5, and 7. (T56–358)	4.5	39
8. Sandstone, pinkish-gray (5*YR* 8/1), very fine to fine-grained, laminated; has a general alteration of very fine grained and fine-grained laminae, each of which is about 2.5–3.5 mm thick; smaller grains, angular to subangular; large grains tend to be subrounded; no cement; weathers very light brown. (T56–357)	3	34.5
7. Dolomite, pale-red (5*R* 6/2), coarse-grained, saccharoidal; consists in part of idiomorphic dolomite crystals; megascopic appearance similar to that of subunits 3 and 5. (T56–356)	2.5	31.5
6. Sandstone, pinkish-gray (5*YR* 8/1); identical with subunit 4. (T56–355)	1.5	29
5. Dolomite, pale-red (5*R* 6/2), coarse-grained, saccharoidal, very sandy; megascopic and microscopic appearance identical with that of subunit 3. (T56–354)	1	27.5
4. Sandstone, pinkish-gray (5*YR* 8/1), generally fine grained; contains sprinkling of larger grains as much as 1.5 mm in diameter; small grains, angular to subangular, tightly packed, containing very little dolomitic cement; larger grains subrounded; thin-bedded to platy; weathers pinkish gray. (T56–353)	2	26.5
3. Dolomite, pale-red (5*R* 6/2), coarse-grained, saccharoidal, very sandy. Quartz grains make up 10–15 percent of rock and were originally angular to subangular but are in process of being replaced by dolomite; hence, most quartz grains are now quite irregular in shape; their size ranges from very small to about 1.5 mm in diameter. Thick-bedded; weathers pale red. (T56–352)	2.5	24.5
2. Sandstone, pinkish-gray (5*YR* 8/1), mottled light-brown (5*YR* 6/4); poorly sorted in the fine- to coarse-grain range; quartz grains tightly packed, mostly angular to subangular, some subrounded; rock contains practically no cement; thin-bedded, softer than subunit 1; has porous bands; weathers brownish gray. (T56–351)	16	22
1. Sandstone, pale-purple (5*P* 6/2), medium-grained quartzose; grains angular to subangular; tightly packed; rock contains practically no cement; thick-bedded, hard; has slight indications of crossbedding; weathers dark gray. Rests unconformably on Dripping Spring Quartzite; contact irregular and thickness of subunit ranges from 1 to 6 ft. (T56–350)	6	6

SECTION 16.—*Naeglin Rim*

[Gila County (Tonto National Forest, NE¼ sec. 23, T. 10 N., R. 14 E.). Measured by Curt Teichert and R. L. Harbour, 1956]

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
20. Limestone, grayish orange-pink (5*YR* 7/2) to grayish-orange (10*YR* 7/4); has irregularly distributed dark spots; dense; conchoidal fracture; small amount of silt-sized quartz particles scattered throughout the rock; few silicified brachiopods (spiriferids); flaggy; weathers light brown; generally similar to subunit 18. (T56–422)	8	197

SECTION 16.—*Naeglin Rim*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
19. Covered interval	7	189
18. Limestone, dolomitic, pale-red (10*R* 6/2); fine grained, contains very few detrital quartz grains as large as 1 mm; flaggy; weathers light brown. (T56–421)	11	182
17. Sandstone, white, medium-grained, quartzose, poorly exposed	1	171
16. Limestone, slightly dolomitic, moderate reddish-orange (10*R* 6/6); very fine grained; subconchoidal fracture; contains an abundance of silicified shells of *Theodossia;* thick bedded; weathers grayish pink. (T56–420)	14	170
15. Limestone, light-gray (*N* 7) to medium light-gray (*N* 6); dense; subconchoidal to conchoidal fracture; laminated, in places slightly brecciated; contains a small amount of idiomorphic dolomite crystals; microstylolites are well formed but poorly exposed. (T56–419)	4	156
14. Covered interval	12	152
13. Sandstone, white to pinkish-gray (5*YR* 8/1), fine grained; composed of a mosaic of tightly interlocking detrital quartz grains, which are angular to subrounded; almost no cement; medium-bedded; weathers pinkish brown; poorly exposed. (T56–418)	5	140
12. Dolomite, pale-red, fine grained, saccharoidal; flaggy; contains small calcite-filled vugs and calcite stringers; weathers light gray	3	135
11. Covered interval	6	132
10. Dolomite, pale-red (5*R* 6/2), dense to very fine grained, very homogeneous; subconchoidal fracture; thin-bedded (beds are 4–8 in. thick); weathers yellowish brown. (T56–417, 416)	14	126
9. Dolomite, light-gray (*N* 7), very fine grained, sandy; contains detrital quartz grains ranging in size from silt to as much as 1.5 mm in diameter; detrital quartz makes up as much as 10 percent of rock; grains mostly subangular to subrounded, some grains well rounded; most grains were peripherally attacked by dolomite although generally not to the extent as in subunit 8; thin- to medium-bedded; lower 1 ft has a vuggy porosity, some of the larger vugs are filled with brown calcite; uppermost 3 ft more sandy than the rest and has a brecciated dolomite matrix; weathers orange gray; generally poorly exposed. (T56–415)	15	112
8. Dolomite, light olive-gray (5*Y* 6/1), very fine to fine-grained, very sandy; quartz grains as much as 3 mm in diameter, most are about 0.5 mm in size; original shape of most grains subrounded, but nearly		

SECTION 16.—*Naeglin Rim*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
8. Dolomite, etc.—Continued all are peripherally replaced by dolomite and their margins appears angular and jagged; detrital quartz may make up as much as 25–30 percent of the rock; matrix generally a dolomite breccia containing penecontemporaneous pebbles as much as 1½ inches in diameter; upper 5 ft has a few calcite vugs; thick-bedded (beds are 1½ ft thick), in part laminated; weathers orange gray. (T56–414, 413)	14	97
7. Dolomite, mottled light brownish-gray (5*YR* 6/1) and light olive-gray (5*Y* 6/1); very fine to fine-grained; contains very few scattered detrital fine quartz grains; some beds contain small penecontemporaneous dolomite pebbles; upper part has large calcite vugs as much as 1½ in. long and ½ in. wide; generally thin bedded; some flagginess formed in the upper half; at 36–38 ft, highly recrystallized tube- or rodlike structural features are found that are probably dolomitized skeletons of *Amphipora;* entire unit is remarkably uniform in lithology and appearance; weathers grayish orange to yellowish gray. (T56–412, 411, 410)	43	83
6. Dolomite, mottled very light gray (*N* 8) to light-gray (*N* 7) to grayish-pink (5*R* 8/2); on the whole, very fine grained, but in most parts highly brecciated; consists of rolled dolomite fragments varying in size to as much as several inches in diameter; some smaller fragments have concentric layering suggesting ooids; matrix between fragments, largely recrystallized, composed mostly of calcite, but shows some later dolomitization; general sprinkling of quartz grains, most less than 0.5 mm in diameter, subangular to rounded; many quartz grains have slight marginal replacement by dolomite; in places, detrital quartz grains form sandy layers and pockets; in outcrops, the rock has a thick-bedded appearance, although it lacks clearly defined bedding planes; it weathers as large rounded knolls resembling biohermal structures, but no organic constituents are in evidence; weathers medium light gray to pinkish gray. (T56–409)	12	40
5. Dolomite, pinkish-gray (5*YR* 8/1), very fine grained, saccharoidal, thick-bedded; weathers reddish brown; poorly exposed	3	28

SECTION 16.—*Naeglin Rim*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
4. Dolomite, grayish orange-pink (10*R* 8/2), dense, but has irregularly angular fracture; highly and closely jointed; detrital quartz grains present, generally fine, but locally medium in pockets and layers; scattered pebbles as much as 1 in. in diameter; some vugs as much as 10 mm in diameter filled with clear calcite; thin-bedded, except uppermost 2 ft, which is medium bedded (beds are 10 in. thick); weathers brownish gray. (T56–408, 407)	7	25
3. Covered interval	5	18
2. Dolomite, grayish-pink (5*R* 8/2) to grayish orange-pink (10*R* 8/2), very fine grained to fine-grained—the fine-grained portion is saccharoidal—scattered detrital quartz particles, generally of silt size but as much as 0.4 mm in diameter, subangular to rounded; appearance nodular; has no distinct bedding; weathers light brown. (T56–406)	5	13
1. Sandstone, yellowish-gray (5*Y* 8/1), medium- to fine-grained; is a mosaic of tightly interlocking detrital quartz grains, which are slightly deformed and generally subangular to angular; thin-bedded (beds are about 6 in. thick); weathers yellowish brown. (T56–405)	8	8

Precambrian: Dripping Spring Quartzite.

SECTION 17.—*Upper Colcord Canyon*

[Tonto National Forest, NW¼NE¼ sec. 15, T. 10½ N., R. 14 E.). Photograph lots AK 3168, 3169. Measured by Curt Teichert, 1953; with revisions, 1956]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
21. Limestone, dolomitic, yellowish-gray (5*Y* 7/2), fine grained; contains silicified crinoid stems and fragments of *Platyrachella* at about 4 ft; contains scattered large vugs as much as 2 cm in diameter filled with white calcite; medium-bedded; weathers yellowish gray. (T56–446)	11.5	222
20. Sandstone, grayish orange-pink (5*R* 7/2), fine-grained to silty; large percentage of matrix is slightly calcitic dolomite. The bulk of the detrital quartz is of silt to very fine grain size; the grains are angular; scattered among them are larger grains, commonly as much as 0.5 mm in diameter, exceptionally as much as 1 mm; large grains more rounded, some of the larger grains have slightly corroded edges as seen in cross section. Thin-bedded to flaggy; weathers light brown. (T56–445)	9	210.5

SECTION 17.—*Upper Colcord Canyon*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
19. Dolomite, slightly calcitic, pale-red (5*R* 6/2), medium-grained; contains many *Amphipora* colonies, whose skeletons are completely replaced by crystalline calcite and dolomite; the material replacing the *Amphipora* skeletons is light in color value and the rock appears mottled, beds generally appear thick-bedded but break into thinner beds where highly weathered; weathers pale red. (T–302)	9	201.5
18. Siltstone, contains dolomitic limestone matrix; very light gray (*N* 8); carbonate matrix very fine grained to dense. Silt particles are in places tightly packed; in other places, the particles make up less than 50 percent of the rock; this unit is thus on borderline between a calcareous siltstone and an argillaceous limestone. Beds contain brachiopod fragments; thin-bedded beds (4–8 in. thick); weathers light brown. (T56–444)	3.5	192.5
17. Limestone, light brownish-gray (5*R* 6/1); very fine grained; subconchoidal fracture; rich in tintinnids (?), calcispheres and ostracodes; thin-bedded; weathers moderate brown. (T56–443)	2	189
16. Siltstone, mixed with dolomitic limestone matrix, pale-red (10*R* 6/2); carbonate matrix, very fine grained and in places makes up as much as 50 percent of the rock; detrital quartz predominantly silt size, but beds contain scattered well-rounded grains about 0.2-mm in diameter; thick-bedded; massive; weathers pale red. (T56–442)	5.5	187
15. Covered interval	1.5	181.5
14. Limestone, probably slightly dolomitic, very sandy, mottled orange-pink (5*YR* 8/4) and grayish-pink (5*YR* 8/2); very fine grained carbonate matrix containing abundant very poorly sorted detrital quartz grains; the grains range in size from silt to about 1 mm in diameter; larger grains are subrounded to well rounded; very little carbonate replacement or etching of the quartz; because of the high content of quartz grains, the megascopic appearance of rock is like sandstone, although detrital quartz probably rarely exceeds 30 percent of rock; thin-bedded; weathers orange pink. (T56–441)	2	180

SECTION 17.—*Upper Colcord Canyon*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
13. Dolomite, very slightly calcitic, pale-red (5*R* 6/2); very fine grained; contains abundant detrital quartz grains ranging in size from silt to about 0.5 mm in diameter; larger grains subrounded to well rounded; detrital quartz tends to be concentrated in layers, giving the rock a slightly laminated appearance; the quartz generally does not exceed 3–4 percent of the rock, although it is more highly concentrated in scattered thin layers of dolomite sandstone; thin-bedded to platy; weathers pale red. (T56–440)	11	178
12. Dolomite, pinkish-gray (5*YR* 8/1); very fine grained, irregularly laminated; consists of a ground mass of dense dolomite containing large numbers of idiomorphic or hypidiomorphic dolomite rhombs as much as 0.05 mm in diameter; a few silt-sized detrital quartz particles probably make up 1–2 percent of the rock; thick-bedded; weathers yellowish gray. (T56–439)	22.5	167
11. Dolomite, calcitic in spots, pale-red (5*R* 6/2) to 10*R* 6/2), fine grained; no detrital quartz; thick-bedded, massive, hard; weathers pale red. (T56–438)	22	144.5
10. Covered interval	11	122.5
9. Dolomite, pale-red (5*R* 6/2), very fine grained; contains a few silt-sized detrital quartz particles, which are fairly evenly distributed and make up about 3–4 percent of the rock; thin-bedded; weathers pale red. (T56–437)	11	111.5
8. Covered interval	5.5	100.5
7. Dolomite, very slightly calcitic, mottled pale-red (5*R* 6/2) and pinkish-gray (5*YR* 8/1), fine-grained; contains no detrital quartz; upper part contains calcite stringers; medium-bedded. (T56–436)	10.5	95
6. Dolomite, grayish-pink (5*R* 8/2) to pale-red (5*R* 6/2); fine grained; tends to be saccharoidal in upper part; contains no detrital quartz particles; medium- to thick-bedded (beds are 6 in. to 2 ft thick); weathers pale red. (T56–435)	21.5	84.5
5. Dolomite, pale red-purple (5*RP* 6/2), very fine grained; subconchoidal fracture; contains very scattered detrital quartz, mostly of silt size, and scattered grains as much as 0.5 mm in diameter, generally subangular; detrital quartz composes not more than 1 percent of rock; medium-bedded; weathers pale orange. (T56–434)	16	63
4. Dolomite, slightly calcitic, pinkish-gray (5*YR* 8/1), very fine grained, contains some scattered detrital fine quartz grains; matrix dense; quartz grains, angular to subrounded, making up 1–2 percent of the rock mass; contains abundant calcite stringers parallel to bedding as much as ⅛-in. thick; medium-bedded; weathers pinkish-gray. (T56–433)	6	47
3. Covered interval	24	41
2. Dolomite, very slightly calcitic, grayish orange-pink (5*YR* 7/2), very fine grained; subconchoidal fracture; contains scattered grains of detrital quartz ranging in size from silt to medium; smaller grains angular, larger grains subrounded to well rounded; detrital quartz may make up as much as 5 percent of rock; medium-bedded; weathers grayish orange. (T56–432)	9	17
1. Sandstone, grayish-pink (5*R* 8/2), fine grained; matrix contains scattered pebbles as much as 15 mm in diameter, especially in lowermost 12 in., which appears to be a breccia composed of angular quartzite fragments; contains a small amount of slightly calcitic dolomite as cement; medium quartz grains are generally well rounded to subrounded, larger and smaller grains tend to be angular to subangular; medium-bedded, weathers brown. (T56–431)	8	8

Precambrian: Dripping Spring Quartzite.

SECTION 18.—*Two miles south of Turkey Peak*

[Gila County (Tonto National Forest, NW¼ sec, 5, T. 10 N., R. 14 E.). Photograph lots AK 3168, 3169. Measured by R. L. Harbour, 1956]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
22. Covered	5	199
21. Limestone, pale-red (5*R* 6/2), very fine grained; contains vugs as much as 1 cm in diameter filled with brown calcite; contains abundant silicified fossils (*Thamnopora* sp., *Atrypa* sp., *Schizophoria* sp.). (H56–150)	2	194
20. Covered	11	192
19. Dolomite, calcitic, moderate orange-pink (5*YR* 8/4), very finely crystalline; densely spotted by small iron stains; small amount of silt; scattered crinoid stems as much as 12 mm in diameter; fissile; weathers grayish orange. (H56–149)	1	181
18. Covered	32	180

SECTION 18.—*Two miles south of Turkey Peak*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
17. Dolomite, pale-red (10*R* 6/2), saccharoidal; lower part of unit consists of dolomite crystals which fall into two clearly distinct size groups: (1) idiomorphic and hypidiomorphic crystals 0.5–1.0 mm in diameter and (2) clusters of idiomorphic and hypidiomorphic crystals about 0.07–0.1 mm in diameter; upper part of subunit is uniformly fine crystalline and contains a considerable admixture of very fine sand. Medium-bedded (beds are 1 ft thick). (H56–148, 147)	15	148
16. Sandstone grayish-pink (5*R* 8/2); contains much dolomitic finely crystalline matrix; quartz grains poorly sorted and range in size from silt to about 0.7 mm in diameter; larger grains generally well rounded to subrounded and etched around margin; crops out as one resistant bed. (H56–146)	2	133
15. Dolomite grayish-pink saccharoidal very sandy; contains quartz grains as much as 1 mm in diameter; laminated; has a few vugs as wide as 7 mm filled with coarse-crystalline calcitic dolomite	5	131
14. Dolomite grayish-pink (5*R* 8/2) finely crystalline; contains pockets and layers of mostly fine grained detrital quartz; contains some larger grains, which are subrounded and as much as 0.5 mm in diameter; crops out as one bed; weathers yellowish gray. (H56–145)	5	126
13. Dolomite, grayish-pink (5*R* 8/2), very fine grained, hard, resistant, medium-bedded (beds are 1½ ft thick); weathers yellowish gray. (H56–144)	10	121
12. Covered	5	111
11. Sandstone, pinkish-gray (5*YR* 8/1); contains much matrix composed of calcitic dolomite; beds are poorly sorted; grains range in size from silt to 1 mm in diameter; larger grains are generally subrounded, and most have highly etched surfaces; laminated; weathers grayish orange pink. (H56–143)	1	106
10. Covered	2	105
9. Dolomite, similar to subunit 7	3	103
8. Covered	4	100
7. Dolomite, light-gray (*N* 7), very finely to finely crystalline; contains some detrital quartz, mostly silt, and very few subangular larger grains as large as 0.2 mm; crops out as three resistant beds; weathers light gray (H56–142)	4	96
6. Dolomite, light-gray, finely crystalline, silty; poorly exposed	17	92
5. Dolomite, mottled light brownish-gray (5*YR* 6/1) and brownish-gray (5*YR* 4/1), finely crystalline, saccharoidal; contains a small amount of detrital quartz grains as much as 0.3 mm in diameter; has a few calcite vugs, as much 1 cm in diameter; contains some gray chert nodules as much as 1.5 cm in diameter; weathers light olive gray. (H56–141)	1	75
4. Dolomite, pale-red, saccharoidal	1	74
3. Dolomite breccia, medium-gray; composed of angular dolomite fragments; thin-bedded; poorly exposed	12	73
2. Dolomite, grayish-pink (5*R* 8/2), pale-red (5*R* 6/2), and light brownish-gray (5*YR* 6/1); lower half, medium to coarse crystalline, becomes fine crystalline in upper part; basal 5 ft, very sandy, containing detrital quartz grains as much as 0.5 mm in diameter, generally subrounded; many grains are shattered; medium-bedded (beds are 1 ft thick) weathers brownish-gray (H56–140, 139, 138, 137)	37	61
Aphanitic dolomite unit:		
1. Dolomite, grayish-pink (5*R* 8/2) to pale-red (5*R* 6/2); very finely crystalline; rich in detrital quartz grains, which diminish in size from bottom to top of the subunit; bottom layer, 1–2 ft thick, contains well-rounded quartz grains as much as 1 mm in diameter; smaller grains generally subangular; this layer also contains angular to subrounded pebbles of underlying rock as large as several centimeters in diameter; the dolomitic matrix is microbreccial; upper part of unit contains calcite veinlets and vugs as much as 1 cm in diameter. Medium-bedded (beds are about 2 ft thick); weathers grayish-orange-pink. (H56–136, 135; T56–538)	24	24

Precambrian: Mazatzal (?) Quartzite. Fine-grained quartzite and chert. (H56–134).

SECTION 19.—*Christopher Mountain Ridge*

[Gila County (Tonto National Forest, NW¼ sec. 12, T. 10½ N., R. 13 E. unsurveyed). Photograph lots AK 3123. Measured by Curt Teichert, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
18. Dolomite, calcitic; $CaCO_3$ content varies greatly; motled in varying shades of pale red (5*R* 6/2), fine- to medium-grained; upper 2 ft finer grained and sandy, containing layers of detrital quartz grains ranging in size from silt to about 1 mm in diameter, poorly sorted; large grains subrounded to well rounded; medium-bedded; weathers pale red. (T56–460, 459)	12	144

SECTION 19.—*Christopher Mountain Ridge*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
17. Covered interval	8	132
16. Dolomite, slightly calcitic, pale-red (5*R* 6/2), fine- to medium-grained; contains pebbles of very fine grained slightly darker red dolomite; contains completely recrystallized *Amphipora* skeletons; thick bedded; weathers pale red. (T56–458)	9	124
15. Limestone, light-gray (*N* 7); dense-calcilutite; contains sparsely scattered silt-sized detrital quartz, nowhere composing more than 1 percent of the rock; lower 6 in. contains abundant brachiopod and gastropod fragments and calcispheres; medium-bedded; weathers light gray. (T56–457)	3	115
14. Dolomite, pale-red, medium-grained, saccharoidal, soft; poorly exposed	3	112
13. Dolomite, calcitic, mottled pinkish-gray (5*YR* 8/1) and grayish-pink (5*R* 8/2), fine- to medium-grained; contains large (as much as 1 ft) colonies of fossils, which are completely recrystallized and no trace of detailed skeletal structures is preserved; thick-bedded; weathers light gray to yellowish gray. (T56–456)	3	109
12. Dolomite, light brownish-gray (5*YR* 6/1); medium-grained, saccharoidal, the bulk of rock is an aggregate of hypidiomorphic dolomite crystals about 0.5 mm. in diameter; between the crystals is a "matrix" of small idiomorphic dolomite crystals about 0.05 mm.; many angular silt-sized quartz fragments occur throughout, most of which are embedded in the large dolomite crystals; also, larger detrital quartz grains as much as 1 mm. in diameter, many of which are somewhat corroded and replaced by dolomite. Thick-bedded; weathers pale red. (T56–455)	5	106
11. Covered; probably thin-bedded dolomite	7	101
10. Dolomite, slightly calcitic, irregularly mottled pinkish-gray (5*YR* 8/1) and pale-red (5*R* 6/2); very fine grained; contains a negligible quantity of silt-sized detrital quartz; thick-bedded, massive; weathers light gray. (T56–454)	4	94
9. Dolomite, slightly calcitic, mottled grayish-pink (5*R* 8/2) and pale-red (5*R* 6/2), very fine grained; rich in detrital quartz particles of silt size, which make up as much as 10 percent of rock; has irregularly laminated appearance due to alternation of pink and pale-red color that is not caused by mineralogical changes; thin- to medium-bedded; poorly exposed; weathers pale red. (T56–453)	16	90
8. Dolomite, slightly calcitic, very light gray (*N* 8); fine- to medium-grained, saccharoidal; composed mostly of hypidiomorphic crystals averaging 0.2–0.3 mm. in diameter; thick-bedded (beds are 1½ ft thick); weathers light gray. (T56–452)	3	74
7. Covered interval	7	71
6. Dolomite, slightly calcitic, mottled light brownish-gray (5*YR* 6/1) and pale-red (5*R* 6/2), very fine grained; contains scattered vugs as much as 1½ inches in diameter, filled with clear calcite and dolomite; medium- to thick-bedded; weathers medium light gray. (T56–451)	8	64
5. Dolomite, light brownish-gray (5*YR* 6/1), very fine grained; contains scattered silicified fragments of stromatoporoids and *Thamnopora;* fossils very unevenly distributed along strike; thick-bedded; weathers yellowish brown. (T56–450)	5	56
4. Dolomite, mottled yellowish-gray (5*YR* 8/1) and pale-red (5*R* 6/2), fine-grained, stylolitic, thick-bedded (beds are about 2 ft thick); weathers medium gray. This subunit is poorly exposed and includes some more uniformly light gray as well as more uniformly pale-red beds of same texture. (T56–449)	21	51
3. No outcrops; slope covered with dolomite talus	9	30
2. Dolomite, slightly calcitic, medium light-gray (*N* 6), very fine grained; contains numerous very small vugs filled with pink to clear calcite and dolomite; in part saccharoidal; thick-bedded; weathers light gray. Outcrops poor in lower half, good in upper half. (T56–448)	13	21
1. Sandstone, light-brown, medium-grained; weathers dark brown. No outcrops, but loose slabs cover ground for a distance equivalent to an approximate thickness of	8	8

Base not exposed.

SECTION 20.—*Hunter and Sharp Creeks*

[Upstream from point near junction of Sharp Creek. On the map of Tonto National Forest the creek named Hunter Creek on the Promontory Butte quadrangle is called Sharp Creek. This, however, is the name of the tributary which flows into Hunter Creek from the north about 2 miles from the latter's junction wih Christopher Creek. (Tonto National Forest, NW¼ sec. 32 T. 11 N., R. 13 E.). Photograph lots AK 3122, 3123. Measured by Curt Teichert, 1953; additional observations, 1957]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
22. Dolomite, pale-red (10*R* 6/2), very fine grained; contains abundant detrital quartz grains as much as 0.5 mm in diameter, rounded to subrounded, and in places tightly packed; rich silicified coral fauna (*Disphyllum*? sp., *Stringophyllum*? sp). (T-301, 300)	9	174
21. Dolomite, pale-red, finely crystalline, hard, massive	1	165
20. Dolomite, yellowish-gray, coarsely crystalline (similar to subunit 3)	11	164
19. Covered	5	153
18. Dolomite, pale-red, very finely crystalline, thin bedded (beds are 4–6 in. thick)	3	148
17. Poor exposures; probably a continuation of subunit 16, but contains a certain amount of detrital quartz grains	22	145
16. Dolomite, light-gray, fine- to medium-crystalline; thick-bedded (beds are as much as 3½ ft thick)	15.5	123
15. Covered; probably continuation of subunit 14	5.5	107.5
14. Dolomite, very light gray (*N* 8), very finely crystalline, argillaceous; contains scattered detrital quartz grains, rounded to subrounded and as much as 0.5 mm in diameter; thin-bedded (beds are 3–6 in. thick); weathers pinkish gray. (T299)	8.5	102
13. Covered	2	93.5
12. Dolomite, light-gray, coarsely crystalline, thin-bedded (beds are 1–3 in. thick)	5.5	91.5
11. Dolomite, light-gray (*N* 7), very finely crystalline, argillaceous; contains with spherical calcite vugs as much as 1 cm in diameter; thin-bedded; weathers light olive gray. (T298)	3.5	86
10. Dolomite, light-gray, coarsely crystalline, thick-bedded; weathers gray	7.5	82.5
9. Dolomite, pale-red (5*R* 6/2), very finely crystalline, thin-bedded (beds are 1–2 in. thick); weathers pale red. (T297)	5	75
8. Dolomite, light brownish-gray to pale-red, finely crystalline; contains scattered detrital quartz in a few layers; the quartz is more abundant in upper part; at top of subunit, the grains are 5 mm in diameter; generally thin- to medium-bedded; weathers pale red	27	70
7. Covered	3	43

SECTION 20.—*Hunter and Sharp Creeks*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
6. Dolomite, slightly calcitic, light brownish-gray (5*YR* 6/1), finely crystalline, massive; weathers light olive gray. (T296)	2	40
5. Dolomite, pale-red; similar to subunit 3, but thinner bedded	5.5	38
4. Sandstone, light brownish-gray (5*YR* 6/1), poorly sorted, medium- to coarse-grained; grains generally subrounded; medium-bedded (beds are 6–15 in. thick); crossbedded; weathers medium gray. (T295)	9	32.5
3. Dolomite, calcitic, pale-red (10*R* 6/2), medium-crystalline, argillaceous; contains large white calcite veins as much as 1 cm wide; thick-bedded (beds are 2–3 ft thick); weathers pale red. (T294)	16	23.5
2. Sandstone, mottled pale-red and light-gray, medium-grained; several layers contain angular quartzite clasts as much as 10 in. in diameter; breccia bed on top of subunit; thick-bedded (beds are 2–3 ft thick), but thinner bedding (beds are 2–3 in. thick) is produced by weathering	4	7.5
1. Sandstone, yellowish-gray, well-sorted, medium-grained; contains a basal breccia (6 in. thick) containing angular quartzite pebbles as much as 4 in. in diameter; weathers grayish red	3.5	3.5
Precambrian: Mazatzal Quartzite; quartzite, grayish-red, fine-grained, thin-bedded.		

SECTION 21.—*Hunter Creek*

[0.6 mile east of junction of Hunter and Christopher Creeks (Promontory Butte quadrangle, W½SE¼ sec. 30, T. 11 N., R. 13 E.). Photograph lots AK 3121, 3122. Measured by Curt Teichert, 1953; additional observations, 1957]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
17. Limestone, yellowish-gray (5*Y* 8/1), medium- to very coarsely crystalline, saccharoidal; contains less than 1 percent detrital quartz, mostly silt sized, and scattered grains as much as 1 mm in diameter; weathers brownish gray. (L–165)	5	117
16. Limestone, pale red-purple (5*RP* 6/2) with pale greenish-yellow (10*Y* 8/2) patches; very finely crystalline; weathers medium light gray. (L–164)	4.5	112
15. Limestone, pale-red (5*R* 6/2) with light-gray streaks, very finely to finely crystalline; contains less than 1 percent detrital quartz ranging in size from silt to very fine; weathers pale red. (L–163)	4.5	107.5

SECTION 21.—*Hunter Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
14. Dolomite, calcitic, grayish orange-pink (5*YR* 7/2), medium crystalline, saccharoidal; contains interstitial calcite; weathers grayish orange pink. (L–162)	2	103
13. Dolomite, calcitic, grayish-orange (10 *YR* 7/4), coarsely crystalline; contains much interstitial calcite; weathers medium light gray. (L161)	3.5	101
12. Covered; underlain by dolomite or limestone	11.5	97.5
11. Limestone, highly dolomitic, pale reddish-brown (10*R* 5/4) to pale-orange (10*YR* 8/2); intimate mixture of medium crystalline calcite and dolomite; contains as much as 3 percent detrital quartz, ranging in size from silt to 0.7 mm in diameter; weathers light brown. (L160, 159)	8	86
10. Sandstone, pale-red (10*R* 6/2), poorly sorted; contains subrounded grains as much as 0.8 mm in diameter; contains much carbonate matrix consisting of calcitic dolomite. (L158)	4	78
9. Covered; probably underlain by sandstone	13	74
8. Sandstone, very pale orange (10*YR* 8/2) to grayish orange-pink (5*YR* 7/2), poorly sorted; contains grains reaching a maximum of about 1 mm in diameter; the grains that are larger than about 0.2 mm are generally rounded to subrounded; contains a considerable amount (as much as 50 percent) of carbonate matrix consisting of coarsely to very coarsely crystalline dolomite and much interstitial calcite; weathers light brown. (T56–464—L157)	4	61
7. Dolomite, calcitic, mottled pale red and light-gray, saccharoidal; contains some scattered detrital quartz grains as much as 4 mm in diameter	11.5	57
6. Covered; probably underlain by dolomite	10.5	45.5
5. Dolomite, calcitic, grayish orange-pink (5*YR* 7/2), very coarsely crystalline, saccharoidal, thin-bedded; weathers medium light gray and light brown	10.5	35
4. Dolomite, grayish orange-pink (5*YR* 7/2), finely crystalline; contains scattered detrital quartz grains, subangular, as much as 1.5 mm in diameter; contains a few vugs filled with brown calcite; thin-bedded; weathers pale brown	6	24.5
3. Covered; probably sandstone	4.5	18.5
2. Dolomite, calcitic, grayish orange-pink (5*YR* 7/2), coarsely to very coarsely crystalline, saccharoidal; contains much interstitial calcite between dolomite crystals; composed of idiomorphic dolomite crystals subrounded by calcite linings; contains very little (less than 1 percent) detrital fine quartz grains	2	14
1. Sandstone and conglomerate, pinkish-gray; sandstone generally medium grained, composed of subangular grains and considerable overgrowth; poorly exposed	12	12

Unconformity.

Cambrian(?): Sandstone, moderate orange-pink, poorly sorted, medium-grained.

SECTION 22.—*Four-tenths mile west of Christopher Ranch*

[Promontory Butte quadrangle, about center of NW¼ sec. 30 T. 11 N., R. 13 E. Photograph lots AK 3121, 3122. Measured by Curt Teichert, 1953 and 1957]

Martin Formation: Jerome Member: Upper unit:	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
9. Sandstone, calcareous, grayish-orange (10 *YR* 7/4), poorly sorted, medium- to coarse-grained; larger grains, rounded to subrounded, etched; contains much calcareous cement; very poorly exposed. (T57–383, 382)	5	110
8. Dolomite, calcite, grayish-orange (10*YR* 7/4), coarsely crystalline; contains interstitial calcite; contains a considerable amount of detrital quartz increasing in amount from bottom to top of the subunit; the uppermost 6 ft is composed of as much as 20 percent quartz grains, which are as much as 0.5 mm in diameter and poorly sorted; larger grains, rounded; also contains many small rounded pebbles of Mazatzal Quartzite; medium-bedded; very poorly exposed; weathers light brown. (T57–381; T293)	40	105
7. Sandstone, poor outcrops	6	65
6. Sandstone, grayish orange-pink (10*YR* 8/2), poorly sorted, medium- to coarse-grained; contains lenses of fine-grained quartz and scattered granules of quartz more than 2 mm in diameter; tightly packed within matrix; large grains, subrounded to rounded; medium-bedded; friable; weathers light gray. (T57–380; T292?)	12	59
5. Covered	11	47

SECTION 22.—*Four-tenths mile west of Christopher Ranch*—Con.

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
4. Dolomite, calcitic, grayish-orange (10*YR* 7/4), coarsely crystalline, saccharoidal; contains interstitial calcite; contains much detrital quartz grains (as much as 20 percent), which are subangular to rounded and as much as 1 mm in diameter; medium-bedded (beds are 8–12 in. thick); friable; weathers pale yellowish-brown. (T57–379; T290)	6	36
3. Covered	8	30
2. Dolomite, very pale orange (10*YR* 8/2), coarsely to very coarsely crystalline; contains a very small amount of silt (less than 1 percent); thick-bedded; weathers grayish orange pink. T57–378; T291?)	6	22
1. Sandstone, pale-red (5*R* 6/2), laminated medium and coarse grained; contains quartz grains, angular to subangular, and a scattering of large rounded quartz granules as much as 3 mm. in diameter; conglomeratic layer, 2 ft thick, at base; thick-bedded (beds are 1–3 ft thick); slightly crossbedded; weathers pale purple	16	16

Angular unconformity. (T57–377, 376.)
Precambrian: Mazatzal Quartzite.

SECTION 23.—*Christopher Creek*

[Small canyon 0.4 mile east of Christopher Creek Camping Area (Promontory Butte quadrangle, on border of NE¼ sec. 25 T. 11 N., R 12 E., and NW¼ sec. 30, T. 11 N., R. 13 E.). Photograph lots AK 3121, 3122. Measured by Curt Teichert, 1953]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
2. No well-defined outcrops, but ground strewn with irregularly weathering slabs of brown fine- to medium-grained sandstone	about 30	about 100
1. Covered; lithology unknown	about 70	about 70

Precambrian: Mazatzal(?) Quartzite; grayish-red, very fine grained; in part schistose.

SECTION 24.—*Christopher Creek Camping Area*

[Promontory Butte quadrangle, just south of center NE¼ sec. 25, T. 11 N., R. 12 E. Photograph lots AK 3121, 3122. Measured by Curt Teichert, 1953]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper(?) unit:		
1. Sandstone, medium dark-gray (*N* 4), poorly sorted; grains range in size from silt to about 1 mm in diameter; most grains 0.1 mm and larger are rounded to subrounded; also, some small flat pebbles of underlying quartzite as much as 2 cm in diameter are scattered through subunit; thin-bedded; weathers brownish gray and yellowish gray	0–15	0–15

Precambrian: Mazatzal(?) Quartzite; quartzite, grayish-red, thick-bedded.

SECTION 25.—*Boy Scout Ranch No. 1*

[North bank of Christopher Creek, near stables (Promontory Butte quadrangle, N½SE¼ sec. 26, T. 11 N., R. 12 E.). Photograph lots AK 3121, 3122. Measured by Curt Teichert, 1953]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
7. Sandstone and conglomerate, medium light-gray, mottled pale-red and olive-gray; calcareous matrix; poorly sorted; smaller quartz grains—0.7 mm and less—rounded to subrounded; larger pebbles of quartz and quartzites are as much as 1 cm in diameter and are angular to subangular; weathers medium gray	5	39+
6. Dolomite, slightly calcitic, light-gray (*N* 7) to medium light-gray (*N* 6), finely crystalline; weathers medium light gray to light brownish gray. (L–189)	1	34+
5. Covered; probably underlain by dolomite	3	33+
4. Dolomite, calcitic, grayish orange-pink (5*YR* 7/2), coarsely crystalline, thick-bedded; weathers light brown. (L–188, 187)	6	30+
3. Covered; probably underlain by sandstone	6	24+
2. Sandstone, yellowish-gray, calcareous, thin-bedded, poorly exposed	2	18+
1. Sandstone, mottled pale-brown and yellowish-gray, medium-grained, thick-bedded, poorly exposed	16+	16+

Base of Devonian not exposed; thickness of missing section unknown.
Precambrian: Mazatzal Quartzite; quartzite, grayish-red, thick-bedded.

SECTION 26.—*Doubtful Creek*

[1.2 miles east of Kohl Ranch, in canyon below road (Promontory Butte quadrangle, south of center sec. 22, T. 11 N., R. 12 E.). Photograph lots AK 3120, 3121. Measured by R. L. Harbour, 1956]

Martin Formation:
Jerome Member:
Upper unit:
17. Limestone, yellowish-gray (5*Y* 7/2) to grayish-orange (10*YR* 7/4); very sandy, contains 46 percent poorly sorted detrital quartz; grains range in size from silt to 0.5 mm in diameter; larger grains, subrounded; some of the larger grains

SECTION 26.—*Doubtful Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
17. Limestone, etc.—Continued have a narrow peripheral shattered zone; in upper part of subunit, most grains are more badly shattered; limestone matrix, fine grained to medium grained; lower part of subunit grades into sandstone; thick-bedded; cliff-forming, as three massive beds. (H56–165, 166)	10	175
16. Dolomite, grayish orange-pink (5*YR* 7/2), subaphanitic; contains much detrital quartz ranging in size from silt to 1 mm in diameter; large grains, rounded and etched; all quartz grains, badly shattered. (H56–167)	2	165
15. Sandstone, light-gray, very dolomitic; lower half contains much calcareous matrix; upper half contains angular fragments of chert and dolomite, and rounded quartzite pebbles as much as 12 mm in diameter; contains poorly preserved brachiopod fragments (spiriferids?); two beds	2	163
14. Dolomite, grayish-orange (10*YR* 7/4), very fine grained; contains as much as 30 percent detrital quartz, poorly sorted, ranging in size from silt to 1.5 mm; larger grains, rounded to subrounded and have slight marginal etching; one easily weathered bed; weathers pale brown. (H56–168)	3	161
13. Sandstone, pale-red (10*R* 6/2), poorly sorted, fine- to coarse-grained; contains much fine-grained calcareous cement; larger quartz grains tend to occur in small clusters and slightly interlocked; lowermost foot, argillaceous; remainder of subunit, one bed. (H56–169)	11	158
12. Dolomite, grayish orange-pink (5*YR* 6/4), very finely crystalline to subaphanitic; contains varying amounts of silt and very fine grained sand, the amount increasing to about 10 percent in upper part of subunit, which also contains *Spinatrypa* cf. *S. rotunda* Stainbrook; upper 5 ft contains coarse quartz pebbles; bedding variable from thin to thick (6 in. to 6 ft); weathers lightbrown. (LP–136; H56–170)	24	147
11. Dolomite, light-gray, finely crystalline; fissile, containing clay partings; at base, about 3 in. of coarse to fine sandstone occurs, which forms niche below prominent cliff	4	123

SECTION 26.—Doubtful Creek—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
10. Dolomite, light-gray (*N* 7), very finely to finely crystalline; contains as much as about 3 percent detrital quartz, very poorly sorted, ranging in size from silt to about 1 mm in diameter; grains have varying degrees of roundness; thin-bedded; weathers light olive gray. (H56–172)	12	119
9. Dolomite, light-gray (*N* 7), very finely to finely crystalline, hard; detrital matter mostly silt size and smaller; contains a few subangular quartz grains as much as 0.3 mm in diameter; medium-bedded (beds are 1 ft thick); weathers light gray. (H56–173)	10	107
8. Dolomite, grayish-pink, very fine grained, argillaceous; fills channels in underlying subunit 7	0–4	97
7. Dolomite, pinkish-gray (5*YR* 8/1) and grayish-pink (5*R* 8/2); light olive gray (5 *Y* 6/1) in upper part; very finely crystalline; contains a small amount of silt-sized to very fine grained detrital quartz; thin-bedded (beds are 4 in. thick); basal layers contain small lenses of red-tinted clay. (H56–180–181, 182)	41–45	93–97
6. Dolomite, mottled grayish-pink (5*R* 8/2) and grayish orange-pink 10*R* 8/2), very finely crystalline; lower 2–3 ft, very sandy; detrital material consists of poorly sorted subangular to angular quartz grains as much as 1 mm in diameter and of chert fragments as much as 2 mm in diameter; also contains dolomite clasts as much as 12 cm in diameter; higher up, the subunit becomes finely to very finely crystalline, and the detrital component is very fine grained to silt size; poorly bedded and resistant. (H56–183, 184)	18	52
5. Dolomite, pale-red (5*R* 6/2), coarsely crystalline; about 1 percent detrital quartz is silt size and very fine grain size; contains a few large subrounded grains as much as 0.3 mm in in diameter; more sandy near bottom of subunit; basal 3 ft contains angular dolomite clasts; poorly bedded and resistant; weathers brownish gray. (H186–185)	15	34
4. Claystone, pale-red, and saccharoidal dolomite containing angular fragments of dolomite; poorly exposed	3	19

SECTION 26.—*Doubtful Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
3. Dolomite, mottled grayish-pink (5*R* 8/2), pale-red (5*R* 6/2), and pinkish-gray (5*YR* 8-1); coarsely crystalline, saccharoidal; contains about 1 percent very fine detrital quartz; angular dolomite pebbles occur at base of subunit; rests in places directly on Precambrian rocks; cliff-forming. (H56-186)	8	16
2. Conglomerate, pale-red (5*R* 6/2); composed mainly of angular to subangular dolomite pebbles as much as 2 cm in diameter embedded in a clayey, silty, and sandy matrix that also contains some small pebbles derived from the Precambrian fills channels beneath subunit 3 and locally cuts out underlying subunit 1 along erosional unconformity. (H56-187)	0-3	8
1. Dolomite, pale red-purple (5*RP* 6/2; contains some red- and green-tinted mottling; medium crystalline; contains about 1-2 percent evenly distributed detrital quartz, mostly silt size to very fine grain size, and a few rounded grains as much as 0.4 mm in diameter; poorly bedded. (H56-188)	8-0	0-8

Precambrian: volcanic rocks.

SECTION 27.—*Tonto and Horton Creeks*

[Ridge between Tonto and Horton Creeks near their junction, 1-1.3 miles north of Kohl Ranch (Promontory Butte quadrangle, NW¼ sec. 16, T. 11 N., R. 12 E.). Photograph lots AK 3120, 3121. Measured by Curt Teichert, 1953 and 1956]

Martin Formation: Jerome Member: Upper unit:	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
20. Limestone, dolomitic, pale-red (10*R* 6/2), very fine grained; laminated by zones of idiomorphic dolomite crystals that are as much as 0.15 mm in diameter; thin-bedded; poorly exposed; weathers yellowish gray. (T57-372, 370)	12	321
19. Limestone, dolomitic, mottled pale reddish-brown (10*R* 5/4) and grayish-orange (10*YR* 7/4), medium crystalline, argillaceous, medium-bedded, richly fossiliferous; contains abundant silicified colonies of *Disphyllum* spp., *Hexagonaria* sp., and "*Aulopora*" spp.; weathers pale red. (T57-371, 369, LP 75)	13	309

SECTION 27.—*Tonto and Horton Creeks*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
18. Sandstone, pinkish-gray (5*YR* 8/1) to yellowish-gray (5*Y* 8/1); not further subdivided; this unit contains very fine grained to coarse-grained rocks; bedding ranges from thin to thick; in coarse-grained parts; the larger grains are rounded to subrounded; contains varying amount of dolomitic matrix that is locally slightly calcitic; weathers generally medium light gray to light brown. (T57-368, 367, 366)	75	296
17. Dolomite, medium light-gray (*N* 6), finely crystalline; contains numerous large and small calcite vugs as much as 35 mm in diameter; no detrital quartz; lower two-thirds, irregularly platy to thick-bedded; upper third, thin-bedded (beds are 6-10 in. thick); weathers light olive gray. (T57-365)	16	221
16. Dolomite, calcitic, yellowish-gray (5*Y* 8/1), coarsely crystalline, saccharoidal; contains much interstitial calcite between dolomite crystals; thick-bedded (beds are 2-3 ft thick); cliff-forming; weathers medium light gray. (L67; T57-364)	20	205
15. Dolomite, light-gray (*N* 7), finely crystalline; evenly scattered silt-sized quartz particles make up 2-3 percent of rock; very finely laminated by thin laminae composed of argillaceous matter; thin-bedded; poorly exposed; weathers light gray. (T57-363)	15	185
14. Dolomite, light brownish-gray (5*YR* 6/1), very finely to medium-crystalline; contains almost no detrital quartz; irregularly thin-bedded; weathers light brown. (T57-362)	17	170
13. Dolomite, light-gray (*N* 8), finely crystalline; finely laminated by scattered layers of more concentrated argillaceous matter and silt; contains scattered very fine quartz grains and a few subrounded grains as much as 0.3 mm in diameter; thin-bedded; weathers light olive gray. (T57-361)	30	153
12. Dolomite, pale-red (5*R* 6/2), finely crystalline, saccharoidal, lowermost 1-2 feet sandy; thin-bedded; poorly exposed; weathers pale yellowish brown. (T57-360)	18	123

SECTION 27.—*Tonto and Horton Creeks*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
11. Sandstone, pale-red (10*R* 6/2), coarse-grained; grains rounded to subrounded; maximum of 30 percent calcareous ground mass; thick-bedded; cliff-forming; weathers pale red (T57–359)	17	105
10. Dolomite, pale-red (5*R* 6/2), very finely crystalline; contains about 2 percent scattered detrital quartz; grains are as much as 0.5 mm in diameter; larger grains, rounded to subrounded. (T57–358)	1	88
9. Covered; probably underlain by sandstone. (T57–357)	16	87
8. Sandstone, grayish orange-pink (5*R* 8/2) to pale-red (5*R* 6/2); contains poorly sorted subangular to rounded quartz grains as much as 2 mm in diameter; contains varying amounts (maximum, 40 percent) of dolomitic very finely crystalline matrix; has a few specimens of *Umbella* sp.; medium-bedded (beds are 6–12 in. thick); indistinctly crossbedded; weathers brownish gray. (T57–356)	5	71
7. Dolomite, pale-red (5*R* 6/2), medium-crystalline; contains varying amounts (maximum, 50 percent) of detrital quartz grains, ranging in size mostly from silt to very fine; contain a few rounded to subrounded large grains as much as 1 mm in diameter; some grains have etched surfaces and overgrowth; medium-bedded; weathers light brown	11	66
6. Dolomite, pale-red (5*R* 6/2), aphanitic; conchoidal fracture; contains layers of angular to subangular dolomite clasts as much as 0.5 mm in diameter; contains scattered detrital quartz, angular to subrounded, as much as 0.4 mm in diameter; medium-bedded (beds are 6–18 in. thick); weathers grayish orange pink. (T57–354)	9	55
5. Dolomite, mottled grayish-pink (5*R* 8/2) and pale-red (5*R* 6/2), medium- to coarsely crystalline; contains scattered poorly sorted detrital quartz grains, angular to rounded and as much as 0.5 mm in diameter; contains small scattered patches of authigenic chert; thick-bedded; weathers light brownish gray. (T57–353)	6	46
4. Conglomerate, containing boulders as much as 3 feet in diameter; mostly quartzite and some dolomite pebbles and boulders; lower surface channels into underlying subunit	9–15	40
3. Graywacke, dolomitic, contains conglomeratic bands; grayish-orange (10*YR* 7/4); contains angular to subangular poorly sorted chert and quartz fragments embedded in up to 50 percent dolomitic groundmass; medium- to thick-bedded; poorly exposed; weathers light brown. (T57–551)	10–16	25–31
2. Covered; almost certainly underlain by sandstone similar to subunit 3	10	15
1. Covered	5	5

Precambrian: Weathered igneous rock.

SECTION 28.—*Kohl Ranch*

[East bank of Tonto Creek, 0.7–0.5 mile southeast of Kohl Ranch (Promontory Butte quadrangle, SE¼ sec. 21, T. 11 N., R. 12 E.). Photograph lots AK 3120, 3121. Measured by R. L. Harbour, 1956]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
32. Limestone, light-gray, argillaceous to sandy, medium-bedded; contains ?*Tabulophyllum* sp., *Atrypa clarkei* Warren, *Spinatrypa* cf. *S. rotunda* Stainbrook ?*Platyrachella* sp., spiriferid (genus indet.)	17	292
31. Dolomite, grayish orange-pink (5*YR* 7/2), very finely crystalline; crops out as two beds. (H56–179)	1	275
30. Covered, probably underlain by pale-red to light-brown medium-crystalline limestone or dolomite	18	274
29. Dolomite, grayish-pink, saccharoidal; one bed	1	256
28. Limestone, light-gray (*N* 7), subaphanitic, clotty texture; contains small amount of detrital quartz grains, very fine to silt size; laminated; platy, having ripple marks on bedding planes; weathers light brownish gray. (H56–178)	2	255
27. Sandstone, pale-red (10*R* 6/2). Similar to subunit 26, but dolomitic matrix is coarsely crystalline and contains interstitial calcite between dolomite crystals; detrital component coarser in lower part. Grains are as much as 1 mm in diameter; upper part is free from detrital material, and the matrix is even more coarsely crystalline than lower part; thin-bedded. (H56–177, 176)	15	253

SECTION 28.—*Kohl Ranch*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
26. Sandstone, moderate orange-pink (5*YR* 8/4) to grayish orange-pink (5*YR* 7/2); composed of about equal parts of detrital quartz and dolomitic matrix; detrital component poorly sorted, grains ranging in size from silt to 0.5 mm in diameter; larger grains, rounded to subrounded, surfaces etched; overgrowths present on many of the larger grains; dolomitic matrix finely crystalline; thin-bedded; cliff-forming; weathers medium dark gray. (H56–175)	10	238
25. Dolomite, lightgray, subaphanitic; detrital quartz grains concentrated in parallel laminae	5	228
24. Dolomite, grayish-pink, silty to sandy, poorly exposed	5	223
23. Dolomite, irregularly laminated very pale orange (10*YR* 8/2) and pinkish-gray (5*YR* 8/1), subaphanitic; contains abundant detrital quartz, which tends to be finer grained and more evenly distributed in the pale-orange bands and medium grained and more abundant in the pinkish-gray bands; quartz grains are poorly sorted and range in size from silt to about 0.5 mm in diameter; weathers light brown. (H56–174)	1	218
22. Dolomite, yellowish-gray, finely crystalline; contains much detrital quartz	3	217
21. Covered	18	214
20. Dolomite, grayish orange-pink (5*YR* 7/2) and fine pale-red (5*R* 6/2) mottling; very finely to finely crystalline; contains a scattering of detrital quartz grains as much as about 1 mm in diameter; all grains have etched surfaces—some grains possibly entirely changed to dolomite—contains some poorly preserved brachiopod fragments; crops out as one bed; slightly crossbedded; weathers pale yellowish brown. (H56–163)	3	196
19. Covered	4	193
18. Dolomite, light brownish-gray (5*YR* 6/1) and fine pale-red (5*R* 6/2) mottling, very finely to finely crystalline; contains a small amount (less than 1 percent) of silt-sized to very fine grained detrital material and scattered well-rounded larger quartz grains as much as 0.5 mm in diameter; contains poorly preserved silicified coral and brachiopod fragments; weathers light brownish gray. (H56-162)	10	189
17. Dolomite, light brownish-gray (5*YR* 6/2), coarsely crystalline, saccharoidal; contains a few idiomorphic, mostly hypidiomorphic dolomite crystals and a very small amount (less than 1 percent) of silt-sized detrital quartz; medium-bedded (beds are 1 ft thick); weathers medium light gray	14	179
16. Dolomite, light brownish-gray (5*YR* 6/2), very finely crystalline; subconchoidal fracture; contains about 2–3 percent silt-sized detrital quartz dispersed evenly throughout rock; thin-bedded; weathers grayish orange. (H56–169–159)	27	165
15. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline to subaphanitic; subconchoidal fracture; detrital material scarce; grains are not larger than very fine sand size; poorly exposed. (H56–158)	5	138
14. Dolomite, grayish-pink (5*R* 8/2), finely to medium-crystalline. Lower part contains an abundance of detrital quartz grains, mostly medium to coarse, well rounded, and highly shattered; the amount of detrital quartz decreases upward and is not found in upper part of the subunit. Poorly bedded; weathers light brownish gray. H56–157–156)	25	133
13. Dolomite, grayish-pink (5*R* 8/2); subaphanitic; pelletal structure; contains calcite veinlets and vugs as much as 1.5 mm wide; has abundant detrital quartz grains and some chert fragments; quartz grains, poorly sorted, are in all sizes to maximum of 1 mm in diameter; almost all grains are highly shattered; almost all larger grains are covered by a thin rind of dolomite, probably resulting from etching of grains; larger grains, well-rounded to subrounded; crops out as one bed; weathers light olive gray. (H56–155)	4	108
12. Sandstone, pale-red (5*R* 6/2); contains much matrix composed of calcitic dolomite; very poorly sorted; quartz grains varying in size to a maximum of 1.5 mm in diameter; larger grains, generally well rounded, many of them shattered; almost all show peripheral etching; contains an appreciable admixture of detrital chert fragments as much as 10 mm in diameter. (H56–154)	4	104

SECTION 28.—*Kohl Ranch*—Continued

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
11. Covered	45	100
10. Sandstone, grayish-red, coarse, conglomeratic; contains angular clasts as much as 12 mm in diameter; quartzitic at base	15	55
9. Dolomite, mottled grayish-pink (5*R* 8/2) and pale-red (5*R* 6/2), medium to coarsely crystalline; contains varying amounts of detrital quartz, as much as 3 percent, poorly sorted, varying in size from silt to 0.5 mm in diameter; weathers grayish red. (H56–153)	1	40
8. Conglomerate, grayish-red, soft; has an argillaceous matrix and contains angular quartz pebbles as much as 12 mm in diameter	3	39
7. Dolomite, pale-red, saccharoidal; poorly exposed	2	36
6. Covered	5	34
5. Sandstone, grayish-pink (5*R* 8/2), coarse- to very coarse grained; grains composed mostly of quartz and chert, poorly sorted; also contains fragments of limestone and quartzite as much as 25 mm in diameter; thin-bedded; weathers light brown. (H56–152)	14	29
Aphanitic dolomite unit:		
4. Dolomite, pale-red (5*R* 6/2), very fine grained, argillaceous and silty; contains a very few quartz grains as much as 0.2 mm in diameter; thin-bedded; weathers grayish red. (H56–151)	7	15
3. Sandstone, medium light-gray, very arkosic; quartz grains are poorly sorted, rounded to subangular, as much as 3 mm in diameter	3	8
2. Sandstone, medium light-gray, arkosic, conglomeratic; has a slightly calcareous matrix; quartz grains are subangular, poorly sorted, range in size from 0.2 to 3.0 mm; contains scattered pebbles as much as 6 mm in diameter; weathers dark gray	3	5
1. Sandstone, light-gray, medium-grained, somewhat arkosic; quartz grains subrounded to subangular, mostly between 0.2 and 0.4 mm in diameter; contains scattered grains as much as 2 mm in diameter	2	2
Covered interval, in which the base of the Jerome Member is situated	5	
Precambrian: Granite.		

SECTION 29.—*Thompson Wash*

[1.5 miles southwest of Kohl Ranch, north and south of highway bridge over Thompson Wash (Promontory Butte quadrangle, sec. 29, T. 11 N., R. 12 E.). Photograph lots AK 3119, 3120. Measured by Curt Teichert, 1953 and 1957]

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation		
Jerome Member:		
Upper unit:		
24. Limestone, dolomitic, pinkish-gray (5 *YR* 8/1), medium-crystalline; contains brachiopod remains (*Atrypa*?) and *Thamnopora* sp.; weathers medium gray. (LP214)	4	282+
23. Limestone, pale-red (5*R* 6/2), subaphanitic; subconchoidal fracture; argillaceous; very fossiliferous, containing *Atrypa* cf. *A. devoniana* Webster "*Atrypa*" *owenensis* Webster, *Platyrachella*? sp., spiriferid (genus undet.); medium-bedded; weathers grayish pink. (LP 213; T57-398)	7	278+
22. Dolomite, calcitic, grayish-pink (5*R* 8/2), finely crystalline; contains much detrital quartz (as much as 15 percent) ranging from very fine to silt in grain size; rich in brachiopods (spiriferids, *Cranaena*? sp.); thin-bedded, platy; weathers medium gray. (T57-397; LP 212)	14	271+
21. Chert, very light gray (*N* 8) to pinkish-gray (5*YR* 8/1); composed almost wholly of silicified limestone; consists of fine- to coarse-grained aggregate of hypidiomorphic to allotriomorphic crystalline quartz; contains small patches of remnant finely crystalline, turgid calcite; all calcite patches have a habit like that of single crystals; highly fossiliferous, almost coquinalike, containing brachiopods, tabulate corals, and calcispheres(?); thin-bedded; weathers pale brown. (T57-396)	4	257+
20. Dolomite, calcitic, grayish-pink (5*R* 8/2) to pale-red (5*R* 6/2), finely to medium crystalline, very sandy; contains detrital quartz grains of all sizes (maximum, 1 mm), generally rounded to subrounded; contains *Thamnopora*(?) sp.; medium-bedded; weathers light brown. (LP 215; T57-395)	14	253+
19. Dolomite, calcitic, light-gray (*N* 7), very fine grained, very sandy; contains poorly sorted detrital quartz making up as much as 50 percent of rock; grains are of all sizes (maximum, 1 mm in diameter); smaller grains, generally rounded to subrounded; contains *Aulopora* sp. and rugose corals; weathers light brown. (T57-393)	5	239+

SECTION 29.—*Thompson Wash*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	Sub-unit thickness (feet)	Cumulative thickness (feet)
18. Dolomite, slightly calcitic, grayish orange-pink (5*YR* 7/2); medium- to coarse-crystalline; contains interstitial calcite between hypidiomorphic dolomite crystals; very sandy; contains detrital quartz grains ranging in size from silt to about 1 mm in diameter, and making up as much as 50 percent of rock; contains gastropod fragments; weathers light brownish gray. (T57–394)	2	234+
17. Covered	10	232+
16. Dolomite, slightly calcitic, pinkish-gray (5*YR* 8/1) and grayish-pink (5*R* 8/2) mottling, very fine grained to subaphanitic; contains abundant detrital quartz (as much as 50 percent) ranging in grain size from silt to very fine; contains stromatoporoids, *Alveolites* sp., *Syringopora*? sp., partly silicified; weathers light olive gray. (T57–392)	2	222+
15. Sandstone, grayish-pink (5*R* 8/2), poorly sorted, medium- to coarse-grained; consists of tightly packed quartz grains ranging from 0.05 to 1 mm in diameter; most grains are larger than 0.2 mm and are rounded to subrounded; thin-bedded; poorly exposed; weathers pale brown. (T57–391)	7	220+
14. Dolomite, light olive-gray (5*Y* 6/1) with light brownish-gray (5*YR* 6/1) streaks, very finely crystalline; contains large calcite drusen as much as 2 in. in diameter; thick-bedded; weathers pale yellowish brown. (T57–390)	9	213+
13. Limestone and calcitic dolomite, mottled grayish-red (5*R* 4/2) and light brownish-gray (5*YR* 6/2), finely crystalline, argillaceous; contains silicified fragments of *Thamnopora*? sp. and crinoid ossicles; scattered large calcite druses (as much as 2 in. in diameter); thick-bedded; weathers pale brown. (T57–389)	12	204+
12. Dolomite, grayish-pink (5*R* 8/2, very finely crystalline; contains a very small amount of silt-sized detrital quartz; middle part of subunit is thick bedded; lower and upper parts are thin bedded; stylolitic near top; weathers yellowish gray. (T57–388)	22	192+
11. Poorly exposed interval; contains at least one bed of dolomitic sandstone, pinkish-gray (5*YR* 8/1); medium- to coarse-grained; contains rounded to subrounded quartz grains embedded in much dolomitic matrix, which is finely crystalline; quartz grains have little or no surficial etching; weathers grayish brown. (T57–387)	10	170+
10. Covered; probably underlain by finely saccharoidal dolomite	20	160+
9. Dolomite, pale-red (5*R* 6/2), very finely crystalline; contains scattered small calcite vugs and veins; medium-bedded; weathers light brown. (T57–386)	15	140+
8. Dolomite, mottled pale-red 5*R* 6/2) and pinkish-gray (5*YR* 8/1), very finely to finely crystalline; contains a small amount (1 percent) of silt and a few very fine detrital quartz grains; thin-bedded; weathers light brown. (T57–385)	5	125+
7. Covered; probably dolomite similar to subunit 6	10	120+
6. Dolomite, light brownish-gray (5*YR* 6/1), finely crystalline, medium-bedded, poorly exposed; weathers light brown. (T57–384)	10	110+
Aphanitic dolomite unit (sandstone facies):		
5. Shale, fissile siltstone, and hard sandstone beds ½–1 ft thick and 4–5 ft apart; sandstone, pale red-purple 5*RP* 6/2) to yellowish gray (5*Y* 7/2); coarse-grained, poorly sorted; contains angular to subrounded quartz grains as much as 1 mm in diameter; contains abundant chert and quartzite granules and pebbles as much as 5 mm in diameter. (T57–401, 404, 405)	25	100+
4. Dolomite, pinkish-gray (5*YR* 8/1), interbedded with silty sandstone; argillaceous; contains abundant detrital quartz grains and chert fragments, unsorted, angular to rounded, as much as 1 mm in diameter; thin-bedded (beds are 6 in.–1 ft thick); weathers light brown. (T57–403)	10	75+
3. Sandstone, yellowish-gray (5*Y* 8/1), in part laminated and mottled pale red (10*R* 6/2), medium- to coarse-grained composed generally of pure quartz sandstone having subangular to subrounded grains; interbedded layers containing detrital chert fragments occur 10 feet above base horizon and have abundant unidentified arthrodiran plates preserved as casts; thick-bedded; highly crossbedded; weathers pale brown. (T57–400, 399, 402)	25+	65+

SECTION 29.—*Thompson Wash*—Continued

Martin Formation—Continued Jerome Member—Continued Aphanitic dolomite unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
2. Sandstone, very coarse, arkosic, grayish-orange (10*YR* 7/4) to grayish orange-pink (5*YR* 7/2); contains poorly sorted angular to subangular grains of quartz and feldspar and a minor amount of chert fragments as large as 15 mm in diameter; grades upward into medium-grained sandstone; medium- to thick-bedded; weathers light brown. (T57–406)	30	40
1. Conglomerate, consists of densely packed pebbles composed of quartzite and of igneous rocks	10	10

Precambrian: Granite.

SECTION 30.—*Diamond Point*

[Escarpment below Diamond Rim, 0.5 mile northwest of Diamond Point (Promontory Butte quadrangle, Gila County, NW¼ sec. 23, T. 11 N., R. 11 E.). Photograph lots AK 3118, 3119. Measured by R. L. Harbour, 1956; additional observations by Curt Teichert, 1957]

Martin Formation: Jerome Member: Upper unit (top of section eroded; subunit 46 is probably near top of upper unit):	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
46. Limestone, dolomitic, pale-red (10*R* 6/2), finely to medium crystalline; very fossiliferous, crinoidal, containing stromatoporoids, large *Syringopora* colonies; *Disphyllum* sp. *Breviphyllum*? sp., and silicified brachiopods (*Atrypa* sp.); thin-bedded; weathers pale red. (T56–523)	6	448
45. Covered	4	442
44. Dolomite, pale-red, finely crystalline; contains silicified brachiopod fragments and small crinoid stems; thin-bedded. (T56–525)	5	438
43. Shale, pale red-purple; poorly exposed	13	433
42. Dolomite, breccious, grayish-pink. finely crystalline; contains brachiopod fragments and large crinoid stems, which were converted to chert; thin-bedded. (T56–524)	5.5	420
41. Covered	8	414.5
40. Sandstone, medium light-gray, very fine grained, fissile	0.5	406.5
39. Dolomite, mottled pale-red (10*R* 6/2) and pale red-purple (5*R* 6/2), finely to medium crystalline; contains stromatoporoids, bryozoan (*Fenestella*), and brachiopod fragments. (T56–524–218)	4	406
38. Covered	8	402
37. Dolomite, pale-red, saccharoidal, laminated, resistant	3	394
36. Limestone, medium light-gray, aphanitic; contains clusters of *Aulopora*	1	391
35. Dolomite, pale-red, saccharoidal, very thinly and irregularly bedded	2	390

SECTION 30.—*Diamond Point*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
34. Dolomite, pale-red (10*R* 6/2) to grayish orange-pink (5*YR* 7/2), finely to medium crystalline; contains as much as 10 percent detrital quartz grains, poorly sorted, ranging in size from silt to 0.5 mm in diameter; larger grains, well rounded and shattered; weathers light brown. (T56–217)	2	388
33. Dolomite, mottled medium-gray and pale-red, finely crystalline, sandy, thin-bedded, poorly exposed	13	386
32. Dolomite, pale-red, saccharoidal; contains a few angular fragments of fine-grained dolomite; two resistant beds	3	373
31. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline; contains a very small amount of detrital quartz grains (less than 1 percent), angular, which are as much as 0.15 mm in diameter except in uppermost foot, where rounded quartz grains as much as 1 mm in diameter are present; thin-bedded (beds are 6 in. thick); weathers light brown. (H56–216)	12	370
30. Limestone, medium-gray, fine-grained, very thinly bedded, poorly exposed	3	358
29. Dolomite, grayish orange-pink (5*YR* 7/2), very sandy; contains much finely crystalline dolomitic cement; quartz grains poorly sorted and as much as 1 mm in diameter; grains 0.3 mm and larger are generally well rounded; contain scattered fragments of dolomite as much as 2 in. in diameter; forms one resistant bed having well-formed current bedding. (H56–215)	6	355
28. Dolomite, light brownish-gray (5*YR* 6/1), upper part mottled yellowish-gray and pale-red, very finely crystalline; contains a very small amount of silt-sized detrital quartz; thin-bedded (beds are less than 1 ft thick); weathers light brownish gray to yellowish gray. (H56–214, 213)	22	349
27. Dolomite, pale red-purple (5*RP* 6/2); very finely crystalline. Lower part contains very scattered detrital angular quartz grains as much as 0.1 mm in diameter; upward in subunit, detrital component increases to as much as 2 percent, and subunit contains subrounded grains as much as 0.5 mm in diameter; upper 3 ft constitute one bed; weathers grayish pink. (H56–212, 211)	21	327
26. Dolomite, grayish-pink, very finely crystalline, thick-bedded	4	306

SECTION 30.—*Diamond Point*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
25. Limestone, dolomitic, grayish orange-pink (5*YR* 7/2); subaphanitic limestone matrix; contains a large amount (as much as 50 percent) of small idiomorphic dolomite crystals about 0.1 mm in diameter; crops out as two beds. (H56–210)	5	302
24. Limestone breccia, mottled various shades of gray; contains fragmental brachiopods and crinoids; crops out as two beds	5	297
23. Limestone, dolomitic, grayish orange-pink (5*YR* 7/2) and yellowish-gray (5*Y* 7/2), very finely crystalline, very sandy; grades upward into very fine grained dolomitic sandstone; matrix, finely to medium crystalline; detrital quartz grains are generally less than 0.1 mm in diameter, angular; laminated; contains scattered large calcite drusen. (H56–209, 208)	20	292
22. Siltstone, light-gray, fissile, argillaceous, poorly exposed	4	272
Aphanitic dolomite unit:		
21. Limestone, medium-gray, aphanitic, laminated	1	268
20. Dolomite, pale-red, very finely crystalline, thin-bedded (beds are 3 in. thick)	2	267
19. Limestone, medium-gray (*N* 5), subaphanitic; contains scattered dolomite rhombohedra as much as 0.05 mm in diameter; contains fragments of ostracode shells and a few small calcispheres less than 1 mm in diameter; thin- to medium-bedded (beds are 6 in. to 2 ft thick); weathers light olive gray. (H56–207)	8	265
18. Dolomite, grayish-pink (5*R* 8/2), subaphanitic; subconchoidal fracture; contains a very few quartz grains 0.07 mm and less in diameter; a few grains are as much as 0.3 mm; medium-bedded (beds are 2 ft thick); weathers light gray. (H56–206)	8	257
17. Dolomite, pinkish-gray (5*YR* 8/1), subaphanitic, very sandy; contains detrital quartz grains as much as 1 mm in diameter, which are abundant throughout subunit and are concentrated in lenses and layers so as to form dolomitic sandstone; most large grains are rounded to subrounded; thin-bedded; weathers brownish gray. (H56–205)	10	249
16. Sandstone, pale-red (10*R* 6/2), poorly sorted, medium- to coarse-grained; contains tightly packed quartz grains, which are subangular to subrounded and badly shattered; medium-bedded (beds are 2 ft thick); forms prominent cliffs; weathers pale red. (H56–204)	26	239
15. Dolomite, mottled pinkish-gray (5*YR* 8/1), light brownish-gray (5*YR* 6/1), pale-red (5*R* 6/2), and grayish-red (5*R* 4/2); middle part grayish pink (5*R* 8/2); mottling results from irregular staining by iron oxide; very fine grained to subaphanitic; in places subconchoidal fracture; silty; middle part of subunit contains scattered angular to subangular quartz grains as much as 0.15 mm in diameter; thin- to thick-bedded (beds are 6 in. to 3 ft thick); contains shale layers as much as 6 in. thick separating major beds; weathers generally yellowish gray to brownish gray. (H56–203–202, 201)	44	213
14. Dolomite, mottled pale-red (5*R* 6/2) to grayish-red (5*R* 4/2), very fine grained, silty; mottling results from irregular staining by iron oxide. (H56–200)	4	169
13. Limestone, dolomitic, pale red-purple (5*RP* 6/2), very fine grained; subconchoidal fracture; contains scattered dolomite rhombohedra as much as 0.05 mm in diameter; silty, containing very little fine grained detrital quartz; somewhat microbreccious texture; contains scattered small ostracode shell fragments; thin-bedded; weathers pinkish gray. (H56–199)	6	165
12. Covered	3	159
11. Dolomite, light brownish-gray (5*YR* 6/1) and light-gray (*N* 7) with pale-red mottles, subaphanitic to very fine grained; subconchoidal fracture; practically free from detrital quartz except in uppermost part, where very scattered angular quartz grains as much as 0.3 mm in diameter are present; medium-bedded (beds are 1 ft thick), beds are separated by thin shaly layers; weathers pinkish to yellowish gray. (H56–198, 197, 196)	36	156
10. Dolomite, medium light-gray (*N* 6), aphanitic; conchoidal fracture; contains small chert pebbles having brown rinds; contains a very small amount of silt and very fine sand scattered throughout rock except in upper 2 ft which is more sandy; thin bedded—layers less than 6 in. thick, separated by shale layers less than 1 in. thick; weathers yellowish gray. (H56–195)	10	120

SECTION 30.—*Diamond Point*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Fetid dolomite unit:		
9. Dolomite, pale yellowish-brown (10*YR* 6/2) to grayish orange-pink (5*YR* 7/2), fine- to medium-crystalline, finely laminated; fetid odor; somewhat porous; contains calcite vugs; contains light-gray chert lenses as much as 1½ ft. in diameter; thin- to thick-bedded (beds are 3 in. to 3 ft thick); weathers pale yellowish brown. (H56–194, 193)	20	110
Beckers Butte Member:		
8. Sandstone, pale-red (5*R* 6/2), fine- to medium-grained; has a calcareous matrix; contains poorly sorted clusters of tightly packed angular to subangular and a few subrounded quartz grains; friable; medium-bedded (beds are 1 ft thick); weathers pale red. (H56–192)	15	90
7. Sandstone, mottled pale-red and light-brown, poorly sorted, fine-grained to conglomeratic; contains pebbles as much as 8 mm in diameter; crops out as one bed	5	75
6. Dolomite, light-brown (5*YR* 6/4) with grayish-red (10*R* 4/2) mottling, very fine grained, calcitic, argillaceous; contains scattered angular quartz grains as much as 0.5 mm in diameter; thin-bedded; weathers light brown. (H56–191; T57–349)	9	70
5. Sandstone, pale-red (10*R* 6/2), generally fine-grained to silty; contains scattered angular quartz grains as much as 1 mm in diameter; thin-bedded; weathers pale red. (H56–190; T57–348)	5	61
4. Sandstone and siltstone, grayish-red (5*R* 4/2 to 10*R* 4/2); siltstone layers contain angular to subangular fragments of quartz and chert as much as 2 mm in diameter and are interbedded with conglomeratic layers; very crossbedded; poorly exposed. (T57–347)	12	56
3. Sandstone, grayish orange-pink (10*R* 8/2) and yellowish-gray (5*Y* 8/1), very coarse-grained; contains angular pebbles of quartz and quartzite as much as 10 mm in diameter; very crossbedded; thick-bedded (beds are generally 2–3 ft thick; basal bed is 5 ft thick). (T57–346)	18	44
2. Sandstone, grayish-red (5*R* 4/2), coarse-grained, arkosic, slightly crossbedded; contains pebbles of quartz and quartzite as much as 5 mm in diameter; soft and nonresistant; bedding obscure. (T57–345)	14	26
1. Sandstone, pale-red, coarse and conglomeratic; contains angular quartz pebbles as much as 8 cm in diameter; very poorly exposed	12	12

Precambrian: Granite.

SECTION 31.—*Webber Creek*

[Bed and west bank of Webber Creek, 0.2–1.4 miles south of crossing of road from Pine to Kohl Ranch (Pine quadrangle, sec. 5, T. 11½ N., R. 10 E., unsurveyed). Photograph lots AK 3083, 3084. Measured by Curt Teichert, 1953; additional observations, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
37. Dolomite, calcite, medium light-gray (*N* 6) to light olive-gray (5*Y* 6/1), very fine grained; in upper 25 ft. interbedded with dolomitic shale; lower part contains some fine- to medium-grained saccharoidal beds; 23–33 ft above base, silicified brachiopods occur, most of which are unidentifiable but including a large species of *Atrypa;* weathers yellowish gray. (This subunit could probably be further subdivided but is too poorly exposed.) (T56–517; TP–366)	57	437
36. Sandstone, light-gray, fine-grained, thin-bedded; has large ripple marks crests 1–1½ in. apart)	6.5	380
35. Dolomite, pale-red, medium-grained, saccharoidal, thin-bedded	5	373.5
34. Dolomite, pale-red (10 *R* 6/2) and light-gray (*N* 7), very fine grained to dense; contains abundant detrital quartz grains, unsorted, ranging in size from silt to about 0.75 mm in diameter; grains greater than 0.2 mm in size are generally well rounded to subrounded; smaller grains are angular to subangular; many grains show peripheral replacement by dolomite; contains large globular stromatoporoids; medium-bedded (beds are 4–10 in. thick); weathers medium gray. (T56–519)	7.5	368.5
33. Sandstone, calcareous, medium light-gray, medium grained becoming increasingly more fine grained towards top; contains a few well-rounded large quartz grains in a very fine groundmass	25	361
32. Dolomite, mottled grayish-pink (5*R* 8/2), light-gray, and medium light-gray (*N* 6–7); gray parts very fine grained; pink parts somewhat coarser grained; contains large calcite drusen as much as 10 in. in diameter; medium-bedded; weathers light brown. (T56–522)	14	336
31. Limestone, light olive-gray (5*Y* 6/1), dense; contains some scattered dolomite rhombs 0.05–0.2 mm in diameter; has many microfossils (*Umbella*, ostracode shells, and tiny gastropod shells); medium-bedded; weathers grayish brown. (T56–521)	5	322

SECTION 31.—*Webber Creek*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
30. Dolomite, calcitic, yellowish-gray (5*Y* 8/1) to pinkish-gray (5*YR* 8/1), very fine grained; rather intimate mixture of crystalline dolomite and calcite; contains large ramifying calcitic structures as much as 4 in. in diameter simulating fossils; 2 ft below top is 10-in. layer containing silicified stromatoporoids and large *Thamnopora* fragments; thick-bedded; weathers yellowish gray. (T56–520)	11.5	317
29. Dolomite, light-gray, fine-grained, medium-bedded	10.5	305.5
28. Dolomite, light gray, very fine grained, thin-bedded; upper part liminated	7.5	295
27. Dolomite, medium light-gray, finely brecciated	0.5	287.5
26. Dolomite, medium light-gray, dense; conchoidal fracture; massive; weathers light gray	7.5	287
25. Dolomite, mottled pale-red and light-gray, very fine grained, hard, very finely laminated; contains some slump structures and some calcite vugs; top layer brecciated	3	279.5
24. Covered interval; probably fine-grained gray dolomite	10.5	276.5
23. Sandstone, medium light-gray, evenly medium-grained; contains calcareous cement; generally thick-bedded, becoming more medium bedded toward top; "worm tracks" seen on some bedding planes	35	266
22. Limestone, slightly dolomitic, light-gray (*N* 7) to grayish orange-pink (5*YR* 7/2), very fine grained; the light-gray beds tend to be laminated and have thin layers of fine grained detrital quartz; the amount of detrital quartz increases in upper 8 ft. or so. Thick-bedded mudcracks on bedding planes seen in fallen blocks. Weathers light brown (T56–516)	38	231
21. Shale, sandy, red-tinted	4	193
20. Dolomite, fine-grained, silty, mottled grayish-pink and pale-red (10R 6/2); matrix consists of a uniform mixture of idiomorphic and hypidiomorphic dolomite crystals; contains abundant detrital quartz of silt size, only very few grains are as much as 0.3 mm in diameter; contains large fragmentary bone plates in the uppermost beds; thick-bedded; weathers pale red to light brown (TP 335; T56–514, 515)	17	189
19. Sandstone, poorly exposed	4	172
Aphanitic dolomite unit:		
18. Dolomite, calcitic, pale-red (5*R* 6/2), very fine grained, argillaceous; has irregular pattern of darker red vugs and veinlets; contains some veinlets		

SECTION 31.—*Webber Creek*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
18. Dolomite, etc.—Continued of white calcite; thick-bedded; weathers pale red. Outcrops are disconnected. (T334)	10	168
17. Covered interval	9	158
16. Limestone, dolomitic; pinkish-gray (5*YR* 8/1), generally aphanitic, subconchoidal fracture; contains some bands of fine-grained limestone; contains many vugs as much as 2 cm in diameter filled with calcite and chert; thick-bedded (beds as 1–3 ft thick); weathers medium gray. (T56–513)	16.5	149
Fetid dolomite unit:		
15. Limestone, medium-gray (*N* 5) to medium dark-gray (N 4), very fine grained to dense, laminated; lamination caused by very thin wavy dark-brown layers, probably consisting of some organic material; thin, platy; emits strong fetid odor when struck with hammer; weathers medium dark gray. (T56–512)	7.5	132.5
14. Dolomite breccia, light, gray	1	125
13. Dolomite, calcitic, laminated light-brown (5*R* 6/4), light brownish-gray (5*YR* 6/1), and light-olive-gray (5*Y* 6/1); very fine grained; contains local concentrations of idiomorphic dolomite crystals; lower part has many calcite vugs and one bed containing ovoid bodies of brecciated chert about 8–10 inches long; appearance in outcrop is thick bedded, but on weathering, rock breaks up into thin plates; faint ripple marks occur in places on bedding planes; emits slightly fetid odor when struck with hammer; weathers pale yellowish brown. (T56–511)	10	124
Beckers Butte Member:		
12. Covered interval	14.5	114
11. Limestone, yellowish-gray (5*Y* 8/1), very fine grained; groups of grains lie in identical optical orientation, forming reflecting planes on fresh surfaces (luster mottling); laminated, thin-bedded; weathers olive gray. (T56–510)	3	99.5
10. Sandstone, mottled light-brown, pale-red, and orange medium-grained	4	96.5
9. Dolomite, grayish-pink (5*R* 8/2), alternating with calcareous shale, grayish yellow-green (5*GY* 7/2). Dolomite beds are very fine grained to dense and contain scattered silt-size detrital quartz particles, which constitute as much as 10 percent of the rock. The dolomite weathers pale red; the shale weathers light brown to reddish brown. (T56–508, 509)	8.5	92.5

SECTION 31.—*Webber Creek*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Beckers Butte Member—Continued		
8. Dolomite, slightly calcitic, very sandy, grayish-pink (5*R* 8/2); matrix dense; contains abundant detrital quartz and other mineral grains that are unsorted, range in size from silt to about 0.5 mm in diameter, are angular to subrounded, and make up as much as 15 percent of the rock mass; flaggy to shaly; weathers light brown. (T56–507)	2	84
7. Sandstone, grayish-red (5*R* 4/2), fine- to coarse-grained, conglomeratic in part, very poorly sorted, arkosic; contains grains of all sizes that are angular to subangular; medium-bedded (beds are 8–10 in. thick); weathers light brown. (T56–506)	6	82
6. Sandstone, pale-red, alternating with sandy shale, gray; lithologic types like subunits 4 and 5	7.5	76
5. Shale, gray, sandy	1	68.5
4. Sandstone, mottled pale-red (5*R* 6/2) and moderate-pink (5*R* 7/4), mostly fine grained; has a slightly calcareous cement; contains detrital quartz grains generally about 0.1 mm in diameter and a few as large as 0.5 mm; flaggy; weathers light brown. (TL 333)	2	67.5
3. Sandstone, yellowish-gray, coarse to very coarse; very cross-bedded; contains conglomeratic layers that have pebbles 2–3 cm in diameter; thick-bedded (beds are 1–5 ft thick); weathers brown	54.5	65.5
2. Sandstone, yellowish-gray, somewhat arkosic, thin-bedded to platy	7.5	11
1. Sandstone and breccia, grayish-red (10*R* 4/2)—except basal layer, which is yellowish gray (5*Y* 7/2)—generally coarse grained to very coarse grained; contains some fine grained layers; contains angular fragments of red-tinted chert and quartz as much as 4 in. in diameter; thick-bedded; weathers light brown to grayish red	3.5	3.5

Precambrian: Granite, deeply weathered.

SECTION 32.—*East Verde River*

[On north side of East Verde River, about half a mile east of Payson-Pine Road bridge and about 1 mile north of same bridge along east side of Sycamore Creek (Pine quadrangle, NW¼ sec. 17 and SW¼ sec. 8, T. 11 N., R. 10 E., unsurveyed). Photograph lots AK 3115, 3116. Partly measured by Curt Teichert, 1953. Upper unit adapted from Huddle and Dobrovolny, 1952, p. 104–105. Brackets surrounding rock names indicate that the lithology of the rock has not been checked; some of the "limestones" are dolomites or calcitic dolomites]

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
35. Siltstone, banded gray and greenish-gray, calcareous; massive in fresh outcrops, but thin bedded and shaly where weathered; weathers light gray	16	437
34. [Limestone] yellowish- and reddish-brown, finely crystalline, very sandy; fossiliferous, containing corals (*Pachyphyllum* sp., *Hexagonaria* sp., *Thamnopora* sp.) and brachiopods. (T–321 and 324)	2	421
33. [Limestone] greenish-gray, very fine-grained, cherty, fossiliferous; con-a few shaly partings	7.5	419
32. [Limestone] gray, medium-crystalline; cherty at top; contains silicified fossils	2.5	411.5
31. Mostly concealed; forms ledges of yellowish-brown calcareous sandstone containing quartz geodes; fossiliferous	38	409
30. [Limestone] white to grayish-brown, finely to medium-crystalline, sandy in part; has layers of rounded frosted quartz grains; thin- to medium-bedded; contains silicified tabulate corals (*Pachyphyllum* sp.) near middle; upper part partly concealed; weathers buff	33	371
29. [Limestone, dolomitic] light-brown, finely to medium-crystalline; has calcite-lined cavities and small quartz geodes; 50 percent concealed; weathers buff	37	338
28. [Limestone] gray, fine-grained, sandy and silty, thin-bedded; weathers grayish brown	22	301
27. Sandstone, gray to pink, with streaks of brown along bedding; fine-grained; very calcareous; massive; forms prominent rounded outcrops; contains numerous calcite-filled cavities	8	279
26. [Limestone] gray to brown, dense to fine-grained, sandy, thin-bedded; about 40 percent concealed; weathers gray to buff	28	271
25. [Limestone] grayish-white, mottled red, fine-grained, sandy, silty; contains scattered rounded frosted quartz grains; mostly massive	6	243
Aphanitic dolomite unit:		
24. Limestone, light-gray, aphanitic; contains a few scattered very small quartz grains	2	237
23. Limestone, slightly dolomitic, pinkish-gray (5*YR* 8/1) with brownish stains, very fine grained, thin-bedded. (T–318)	2	235
22. Limestone, medium dark-gray (*N* 4), aphanitic; conchoidal fracture; contains abundant ostracodes (*Hypotetragona* sp.), places forming a micro-coquina; thick-bedded; weathers yellowish gray. (T–317)	8	233

SECTION 32.—*East Verde River*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
21. Limestone, dolomitic, pinkish-gray (5*YR* 8/1), subaphanitic; subconchoidal fracture; contains a few well-rounded quartz grains at bottom, increasing in quantity toward top; thin-bedded (beds are 4–8 in. thick)	4	225
20. Limestone, medium-gray, aphanitic; conchoidal fracture; mudcracks occur on one bedding plane near base of subunit; thin-bedded (beds are 4–8 in. thick)	6	221
19. Limestone, pinkish-gray, finely crystalline; contains abundant detrital quartz	1	215
18. Sandstone, medium-gray, hard, calcareous	1	214
17. Covered	5.5	213
16. Dolomite, medium-gray, aphanitic	1.5	207.5
15. Sandstone, light-gray to pale-pink; contains calcareous matrix; lower two-thirds thin bedded (beds are as much as 1 ft thick)	7	206
14. Siltstone, pale-purple	3	199
13. Sandstone, pinkish-gray (5*YR* 8/1), well-sorted, very fine grained; contains scattered grains as much as 0.5 mm in diameter; grains subangular to subrounded; weathers light brown. (T-316)	16	196
12. Dolomite, light-gray, subaphanitic, medium- to thick-bedded; weathers into small angular chips	10	180
11. Dolomite, medium-gray, aphanitic, conchoidal fracture; contains abundant detrital quartz in lower 5 ft; medium-bedded	16	170
10. Limestone, mottled grayish-red (5*R* 4/2) and light olive-gray (5*Y* 6/1), subaphanitic; contains abundant small dolomite rhombohedra. In part the subunit is a microcoquina composed of ostracode shells and small calcispheres. Contains a few specimens of *Umbella*?. (T-313)	12	154
9. Dolomite, medium light-gray, aphanitic; conchoidal fracture; thin-bedded; weathers light gray	23	142
8. Dolomite, light olive-gray (5*Y* 6/1), subaphanitic; several beds contain calcite vugs and stringers; medium-bedded; weathers yellowish gray	18.5	119
7. Dolomite, light-gray, aphanitic, flaggy	3.5	100.5
6. Sandstone, light brownish-gray (5*YR* 6/1), poorly sorted; grains are subrounded to subangular and are as much as 0.3 mm in diameter; contains much carbonate (calcitic dolomite) matrix; thick-bedded; hard; weathers light brown. (T-312)	1.5	97
5. Dolomite, light brownish-gray (5*YR* 6/1), subaphanitic; subconchoidal fracture; contains many chert concretions as much as 6 in. in diameter; thin-bedded, breaks up into small flakes; weathers yellowish brown. (T-311)	8.5	95.5
Fetid dolomite unit:		
4. Dolomite, pale yellowish-brown (10*YR* 6/2) to grayish orange-pink (5*YR* 7/2), very finely crystalline, laminated; some beds contain abundant calcite vugs as much as 6 mm in diameter; fetid odor; generally thin bedded but contains a few thicker beds; weathers pale yellowish brown. (T-307, 308, 310)	19	87
Beckers Butte Member:		
3. Sandstone, calcareous, mottled very pale orange (10*YR* 8/2) and grayish red-purple (5*RP* 4/2); the basal and the uppermost part of subunit are more uniformly light gray; fine-grained, well-sorted; partly laminated; thin-bedded; weathers grayish orange pink (T-306)	16	68
2. Sandstone, arkosic, mottled light-brown (5*YR* 6/4) and grayish orange-pink (5*YR* 7/2); basal part conglomeratic and contains granules generally 4–5 mm in diameter and scattered pebbles as much as 1 cm; becomes gradually more fine grained from bottom to top; upper part of subunit well sorted; fine-grained; thin-bedded; generally poorly exposed. (T-304, 305)	11	52
1. Sandstone, grayish-red (5*R* 4/2), arkosic, very coarse grained to conglomeratic; poorly sorted; contains subangular grains as much as 2.5 mm in diameter; contains many quartz and quartzite granules as much as 5 mm and some pebbles as much as 1 cm in diameter; medium- to thick-bedded; crossbedded; weathers grayish red. (T303)	41	41
Precambrian: Granite		

SECTION 33.—*Upper Sycamore Canyon*

[1.2–1.9 miles downstream from road to Pine-Kohl Ranch, about 1 mile east of Pine-Payson Road (Pine quadrangle, sec. 14, T. 11½ N., R. 9 E., unsurveyed). Photograph lots AK 3084, 3085. Measured by Curt Teichert and R. L. Harbour, 1956]

Martin Formation:

Jerome Member:

Upper unit:

41. Limestone, dolomitic, mottled light-gray (*N* 7), pinkish-gray (5*YR* 8/1), and light brownish-gray (5*YR* 6/1); very fine grained; contains a small amount (less than 1 percent) of silt-sized

SECTION 33.—*Upper Sycamore Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
41. Limestone, etc.—Continued detrital quartz; contains some sandier layers; irregularly thick bedded; weathers pinkish gray to light brownish gray. (T56–536)	6	467
40. Dolomite, strongly calcitic, streaky pale-red (5*R* 6/2), very fine grained; subconchoidal fracture; contains much silt-sized detrital quartz particles, making up 1–2 percent of rock; slightly laminated appearance; medium-bedded; weathers pinkish gray. (T56–535)	15	461
39. Dolomite, pale-red (10*R* 6/2); composed of a fine-grained mosaic of tightly interlocking allomorphic dolomite crystals and a little interstitial calcite; contains a small amount of detrital quartz grains ranging in grain size from silt to fine, mostly subangular to subrounded, composing not more than 1 percent of rock mass; contains a few unidentified silicified brachiopod fragments; medium-size vugs; thin- to medium-bedded; weathers light brown. (T56–534)	7	446
38. Limestone, somewhat dolomitic; pale-red-purple (5*RP* 6/2), very fine grained; contains scattered fine-grained laminae; subconchoidal fracture; has a few calcite vugs; thin- to medium-bedded; weathers light brown	9	439
37. Dolomite, mottled grayish-pink (5*R* 8/2) and pale-red (5*R* 6/2), very fine grained; contains sandy layers as much as 3 or 4 mm thick composed of detrital quartz grains ranging in size from silt to more than 1 mm in diameter; larger grains are well rounded and have frosted surfaces; peripheral replacement of silica by dolomite is common; rich in silicified brachiopod shells (*Theodossia* and others); medium- to thick-bedded and locally cliff-forming; weathers yellowish gray. (T56–532)	3	430
36. Dolomite, mottled grayish-brown and light purple; the lower part is thin bedded, upper part is medium bedded; poorly exposed	5	427
35. Dolomite, medium light-gray, dense, flaggy; weathers light gray. (T56–531)	10	422
34. Dolomite, grayish-pink (5*R* 8/2) to pale-red (5*R* 6/2), fine- to medium-grained; composed mostly of hypidiomorphic dolomite crystals and very little interstitial calcite; contains a small amount of detrital quartz ranging in grain size from silt to very fine that constitutes no more than 1 percent of rock mass; contains microstylolites; thin-bedded; weathers very pale orange; poorly exposed. (T56–531)	2	412
33. Dolomite, yellowish-gray, coarse-grained, very sandy, medium-bedded (bed are 10 in. thick)	2	410
32. Dolomite, slightly calcitic, yellowish-gray (5*Y* 8/1), with small reddish-gray spots; medium- to coarse-grained, saccharoidal; composed of hypidiomorphic dolomite crystals; contains no detrital quartz; thin bedded; poorly exposed; weathers yellowish gray. (T56–529)	5	408
31. Dolomite, calcitic, mottled and banded light brownish-gray (5*YR* 6/1) and yellowish-gray (5*Y* 8/1), coarse grained; consists mostly of hypidiomorphic dolomite crystals 0.5–1.0 mm in diameter; contains much interstitial calcite and no detrital quartz; medium-bedded; weathers yellowish gray (T56–528)	6	403
30. Dolomite, pale red-purple (5*RP* 6/2); very fine grained; contains a very small amount of silt-size quartz detritus; contains numerous calcite-filled vugs as much as ¾ in. in diameter; medium-bedded; weathers pinkish gray. (T56–527)	5	397
29. Sandstone, dolomitic, yellowish-gray (5*Y* 8/1), coarse grained; matrix composed of calcitic dolomite, which consists of idiomorphic to hypidiomorphic dolomite crystals from 0.05 to 0.75 mm in diameter, containing calcitic cement between crystals; contains unsorted detrital quartz grains ranging in size from silt to about 1 mm in diameter; grains larger than 0.25 mm are subrounded to well rounded; larger grains have frosted surfaces; some peripheral replacement of silica by dolomite or calcite occurs, although not on a large scale; thick-bedded; massive, ledge-forming; weathers light brown. (T56-526; H56–244)	20	392
28. Dolomite, grayish orange-pink (5*YR* 7/2), saccharoidal; composed of a medium-crystalline aggregate of idiomorphic and hypidiomorphic dolomite crystals; contains an insignificant amount of silt-size detrital quartz and very few rounded grains as much as 0.5 mm in diameter; forms one resist-		

SECTION 33.—*Upper Sycamore Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
28. Dolomite, etc.—Continued ant bed; weathers yellowish gray. (H56–243)	6	372
27. Dolomite, mottled pinkish-gray (5*YR* 8/1) and yellowish-gray (5*Y* 8/1); consists of a subaphanitic ground mass containing angular and rounded grains of aphanitic dolomite as much as 1 mm in diameter; contains abundant detrital quartz (as much as 15 percent), poorly sorted; contains rounded grains as much as 0.5 mm in diameter; medium-bedded (beds are less than 1 ft thick); weathers light light olive gray. (H56–242)	6	366
26. Covered	6	360
25. Dolomite, light-gray (*N* 7) to pinkish-gray (5*YR* 8/1); weathers into large rounded nodules that are concentrically laminated by pale-red Liesegang rings; very finely crystalline; contains less than 1 percent of silt-size detrital quartz particles; has scattered cavities as much as 5 cm in diameter filled with white calcite; forms one massive bed; weathers light brown. (H56–241)	7	354
24. Dolomite, light-gray (*N* 7), very finely crystalline; contains an insignificant amount of detrital quartz grains ranging in size from silt to very fine; medium-bedded (beds are 1 ft thick); weathers yellowish gray. (H56–240)	7	347
23. Dolomite, pale-red (5R 6/2) in lower part, light gray (*N* 7) in upper part, saccharoidal; consists of a medium- to coarse-grained mixture of idiomorphic and hypidiomorphic dolomite crystals and a small amount of interstitial calcite; contains scattered mostly very fine detrital quartz grains (about 1–2 percent), and a few angular grains as much as 0.3 mm in diameter; thick-bedded; weathers yellowish brown to grayish orange pink. (H56–239, 238)	29	340
22. Dolomite, slightly calcitic—especially in lower part—mottled light-gray (*N* 7) and light brownish-gray (5*YR*-6/1), more uniformly light gray in upper part, very fine grained to subaphanitic; contains varying amounts (as much as 10 percent) of detrital quartz grains of all sizes (as large as 0.5 mm in diameter); all grains are angular to subangular; medium-bedded (beds are 1 ft thick); weathers grayish orange pink to light brown. (H56–237, 236; H57–235)	34	311
21. Dolomite, pale-red, saccharoidal, sandy, poorly bedded	5	277

SECTION 33.—*Upper Sycamore Canyon*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
20. Covered	10	272
19. Limestone, medium light-gray (*N* 6), subaphanitic; has a pelletal texture containing sparry calcite between pellets; contains a very small amount of detrital quartz, as much as 0.3 mm in diameter, angular; one bed weathers nodular; weathers light gray. (H56–234)	5	262
18. Dolomite, grayish-pink (5*R* 8/2) to pale-red (10R 6/2); greater part is finely crystalline, becoming medium-crystalline toward top; near base contains angular pebbles of reddish-gray quartzite; lower part is rich in detrital quartz grains of all sizes 0.8 mm and less; larger grains rounded; detrital quartz diminishes in amount toward the top of subunit; very thick bedded (beds are 5 ft thick); weathers light brownish gray to light olive gray. (H56–233, 232, 231)	38	257
17. Sandstone, light-gray and grayish-pink, medium-grained, very dolomitic and resistant, irregularly bedded	5.5	219
16. Dolomite, calcitic; mottled grayish-pink (5*R* 8/2), pale-red (5*R* 6/2), and light-gray (*N* 7), very fine grained; contains a scattering of detrital angular quartz grains as much as 0.15 mm in diameter; weathers grayish orange pink. (H56–230)	12	213.5
15. Sandstone, pale-red (5*R* 6/2, poorly sorted, fine- to medium-grained; grains are as much as 0.5 mm in diameter; larger grains, rounded to subrounded; irregularly bedded. (H56–229)	1.5	201.5
14. Dolomite, mottled light-gray and grayish-pink, very fine grained; one bed	3	200
13. Covered	15	197
Aphanitic dolomite unit:		
12. Dolomite, slightly calcitic, light-gray (*N* 7), subaphanitic to very fine grained; contains tiny veinlets and vugs filled with crystalline dolomite; contains sparsely scattered detrital quartz grains, angular; mostly grains are smaller than 0.3 mm in diameter; medium-bedded; weathers light gray. (H56–228)	5	182
11. Covered	32	177
10. Dolomite, calcitic, mottled grayish-pink (5*R* 8/2) and pale-red (5*R* 6/2); consists mostly of idiomorphic very fine to fine dolomite crystals; contains scattered clusters of medium-sized dolomite crystals and much interstitial calcite. (H56–227)	15	145
9. Covered	17	130

SECTION 33.—*Upper Sycamore Canyon*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
8. Limestone, dolomitic, pinkish-gray (5*YR* 8/1); lower part very fine grained; very silty and sandy; contains detrital quartz grains as large as 1 mm in diameter; all larger grains are subrounded and highly shattered; grades upward into aphanitic dolomite containing irregularly scattered detrital quartz grains as much as 0.5 mm in diameter; larger grains are angular; contains irregular layers of dark-gray chert and small spherical chert pebbles having brown rinds; thin-bedded (beds are as much as 1 ft thick); weathers pinkish gray. (H56–226, 225)	26	113
7. Dolomite, light brownish-gray (5*YR* 6/1), aphanitic; conchoidal fracture; contains scattered clasts of slightly darker and denser aphanitic dolomite, and contains sparsely scattered detrital quartz grains as much as 0.07 mm in diameter; weathers grayish orange. (H56–224)	13	87
6. Sandstone, quartzitic, very light gray (*N* 8) to medium light gray (*N* 6), very fine grained to medium-grained; consists of tightly packed angular quartz grains and contains no cement; contains some angular pebbles composed of aphanitic dolomite; slightly variable in thickness; weathers light to pale brown. (H56–223)	1	74
Fetid dolomite unit:		
5. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline, finely laminated, somewhat porous; fetid odor; contains lenses of gray chert throughout subunit, as much as 1 ft in length, weathers yellowish gray. (H56–222)	8	73
Beckers Butte Member:		
4. Sandstone, pale-red, poorly sorted, fine- to coarse-grained; thin-bedded; contains red-tinted sandy shale partings; slope-forming	12	65
3. Sandstone, pale-red (5*R* 6/2), poorly sorted, generally fine- to medium-grained; contains a few coarse grains; smaller grains are angular to subangular; large grains are generally subangular; consists of 20 percent calcitic cement; scattered quartzite cobbles; crops out as one massive bed; weathers pale brown. (H56–221)	5	53
2. Conglomerate consisting of rounded cobbles of red-weathering quartzite averaging 4 in. in length (maximum of 8 in.); poorly cemented by red-tinted sandy clay matrix; very soft, channeled into the underlying subunit	8	48

SECTION 33.—*Upper Sycamore Canyon*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Beckers Butte Member—Continued		
1. Sandstone, yellowish-gray (5*Y* 8/1) to light brownish-gray (5*YR* 6/1) to grayish-red (5*R* 4/2) in upper part, coarse-grained; contains quartz grains, which are angular and tightly packed and interlocked; becomes very coarse grained in upper part; most quartz grains are shattered; very thickbedded (beds are 3–6 ft thick); subunit shows much current bedding; contains scattered quartz and quartzite pebbles, which are rounded and as much as 10 mm in diameter throughout subunit. (H56–220, 219)	40	40

Base of section not exposed.

SECTION 34.—*Tonto Natural Bridge*

[Narrow canyon rising directly southeast of Natural Bridge (Pine quadrangle, NW¼NE¼ sec. 8, T. 11 N., R. 9 E.). Photograph lots AK 3113, 3114. Measured by Curt Teichert, 1956]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation		
Jerome Member:		
Upper unit (top eroded):		
43. Dolomite, slightly calcitic, very sandy, light brownish-gray (5*YR* 6/1) to light olive-gray (5*Y* 6/1); consists of a fine-grained crystal aggregate containing some interstitial calcium carbonate; contains detrital quartz grains ranging in size from silt to more than 0.75 mm in diameter, making up not more than 5 percent of the rock; larger grains are well rounded; 3 ft below top, calcitic crinoid stems occur in pockets; medium- to thick-bedded; weathers moderate brown. (T56–502, 501)	22	389
4. Dolomite, slightly calcitic, pale-red (5*R* 6/2), very fine grained, thinly laminated; contains a small amount of detrital quartz grains ranging in size from silt to about 1 mm in diameter; quartz grains are peripherally replaced by calcium carbonate, some are highly replaced; thin-bedded; weathers light brown. (T56–500)	25	367
41. Dolomite, calcitic, grayish orange-pink (5*YR* 7/2), medium- to coarse-grained, saccharoidal; consists of a tightly packed aggregate of idiomorphic and hypidiomorphic dolomite crystals and some interstitial calcitic matter; contains scattered detrital quartz grains of silt and fine-sand size constituting less than 1 percent of rock; microstylolites present; medium-bedded; weathers medium light gray. (T56–499)	7	342
40. Sandstone, dolomitic, similar to subunit 38	5	335

SECTION 34.—*Tonto Natural Bridge*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
39. Limestone, medium light-gray (*N* 6), very fine grained, microscopic calcarenitic texture; contains a few indistinct fragments of microfossils; contains much detrital quartz, unsorted, ranging in grain size from silt to almost 1 mm in diameter, which makes up as much as 20 percent of rock mass; fine grains and larger are subrounded to rounded; weathers light brown. (T56–498)	2	330
38. Sandstone, dolomitic, grayish orange-pink (5*R* 8/2); consists of an unsorted aggregate of detrital quartz grains ranging in size from silt to about 0.5 mm in diameter; larger grains are generally subrounded to rounded; grains are embedded in carbonate matrix that seems to be a slightly calcitic dolomite; it is very fine grained; bedding is irregularly thin to thick; contains some crossbedding. (T56–497)	14	328
37. Dolomite, slightly calcitic, grayish orange-pink (5*YR* 7/2); consists of a coarse grained aggregate composed mostly of idiomorphic dolomite crystals and some interstitial calcitic matter; crystals are concentrically laminated; contains scattered detrital quartz grains, generally of silt size, totaling less than 1 percent of rock mass; upper 3 ft contains large (3 in.) spherical cavities filled with white calcite; thick-bedded; weathers medium gray to medium dark gray	24	314
36. Covered interval. (T56–496)	7	290
35. Dolomite, pinkish-gray, very fine grained, laminated, poorly exposed	3	283
34. Dolomite, calcitic, pinkish-gray (5*YR* 8/1); consists of a fine grained matrix having a calcarenitic texture in places; contains abundant detrital quartz grains ranging in size from silt to about 0.5 mm in diameter; larger grains are generally subrounded to rounded; grains make up as much as about 7 percent of rock; small calcite vugs are abundant; subunit is medium-bedded. (T56–495)	10.5	280
33. Sandstone, light-gray, medium-grained, quartzose, thin bedded, very weathered and poorly exposed	2	269.5
32. Dolomite, slightly calcitic, sandy, pale-red (5*R* 6/2); groundmass is a medium- to coarse-grained aggregate composed of idiomorphic to hypidiomorphic dolomite crystals and some interstitial calcitic material; contains varying amounts of detrital quartz grains ranging in size from silt to about 0.5 mm in diameter; grains mostly angular to subangular, but some of the larger grains are well rounded; detrital quartz constitutes as much as 5 percent of the rock; unbedded; weathers pale gray. (T56–494)	2	267.5
31. Sandstone, pinkish-gray (5*YR* 8/1), fine- to medium-grained; consists of a tightly packed aggregate of subangular quartz grains ranging in size from silt to about 0.6 mm in diameter; contains very little calcareous cement; crossbedded; thick-bedded; weathers light brown. (T56–493)	4.5	265.5
30. Dolomite, slightly calcitic, pale red-purple (5*RP* 6/2) to grayish-red (10*R* 4/2), fine-grained; lowermost 1 ft is very sandy and contains detrital quartz grains ranging in size from silt to about 0.5 mm in diameter; the grains are subangular to subrounded and make up as much as 20 percent of the rock mass; upper part darker and finer grained containing a small amount of silt-size quartz detritus only; has a massive appearance and no well-formed beds; weathers yellowish gray. (T56–492)	5	261
29. Dolomite, pale red-purple (5*RP* 6/2), fine- to medium-grained, saccharoidal; consists of an aggregate of idiomorphic and hypidiomorphic dolomite crystals and some interstitial calcium carbonate; contains no detrital quartz; thick-bedded; weathers light brownish gray to yellowish brown. (T56–491)	2	256
28. Sandstone, grayish orange-pink (5*YR* 7/2), poorly sorted; medium- to coarse-grained, but contains many quartz particles as small as silt; all grains, even most of larger ones, are angular to subangular; in places, grains are tightly packed, in others, much calcareous cement occurs; many grains are peripherally replaced by calcite; thin-bedded; weathers light brown. (T56–490)	5	254
27. Covered interval	15	249
26. Dolomite, pale-red, medium-grained, saccharoidal; appears to be thick-bedded with many interspersed thinner beds (beds are 2 in. to 2 ft thick); weathers purplish gray	12	234

SECTION 34.—*Tonto Natural Bridge*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
25. Dolomite, very slightly calcitic, pale-red (5*R* 6/2), very fine to fine-grained, saccharoidal; contains a considerable amount of detrital quartz grains—mostly silt size, some grains as much as 0.25 mm in diameter—all grains are angular; total detrital quartz constitutes less than 5 percent of the rock; medium-bedded; poorly exposed; weathers light brown. (T56–489)	7	222
24. Covered interval	10	215
23. Dolomite, medium light-gray, very fine grained, medium-bedded; weathers light gray	8	205
22. Dolomite, slightly calcitic, grayish-pink (5*R* 8/2), very fine grained; contains abundant detrital quartz, mostly of silt size, but some grains are very fine; detrital quartz makes up as much as 10–15 percent of the rock; thick-bedded; weathers light brown. (T56–488)	5.5	197
21. Limestone, medium light-gray (*N* 6), mottled grayish-pink (5*R* 8/2); consists of a dense calcareous matrix containing many small idiomorphic dolomite crystals, abundant authigenic doubly terminated quartz crystals, and calcispheres and ostracode shells; mottling caused by veins and stringers of coarsely crystalline pink calcite; generally thick bedded (beds are 1½–2 ft thick; some beds are thinner), weathers light brown. (T56–487)	14.5	191.5
20. Dolomite, calcitic, pale-red (5*R* 6/2), fine-grained, saccharoidal; contains very little very fine detrital quartz grains; thin-bedded; weathers pale red. (T56–486)	9	177
19. Limestone, dolomitic; mottled pinkish-gray (5*YR* 8/1) to grayish-pink (5*R* 8/2) to pale-red (5*R* 6/2), more moderately pink (5*R* 7/4) in upper part, fine-grained and silty to sandy in lower part, medium-grained and more sandy in upper part; detrital quartz grains in lower part range in size from silt to about 0.3 mm in diameter; grains are angular and make up no more than 10 percent of rock; in upper part quartz grains are 0.5 mm and less and are mixed angular to well rounded; many grains are peripherally replaced by limestone or dolomite and make up as much as 25 percent of rock; lower part laminated; thick-bedded throughout (beds are 2–4 ft thick); weathers yellowish gray. (T56–485, 484)	23	168
18. Sandstone, grayish orange-pink (5*YR* 7/2), very fine to fine-grained; consists of detrital quartz grains ranging in size from silt to about 0.3 mm in diameter; forms a tightly interlocking mosaic containing a small amount of dolomitic limestone cement; thin-bedded to flaggy; weathers grayish orange. (T56–482)	6	145
17. Dolomite, calcitic, mottled grayish-pink (5*R* 8/2) and light-gray (*N* 7), very fine grained to aphanitic; seems to be generally laminated, although laminations are not seen everywhere; thick-bedded; weathers light brown. (T56–481)	9	139
16. Dolomite, mottled grayish-pink (5*R* 8/2) and pale-red (5*R* 6/2), very fine to fine-grained; contains no detrital material; irregularly bedded; weathers pale red. (T56–480)	7	130
15. Limestone, mottled light-gray (*N* 7) and pinkish-gray (5*YR* 8/1), aphanitic; subconchoidal fracture; calcarenitic texture; contains rounded limestone pebbles generally less than 1 mm in diameter; slightly laminated; thick-bedded; weathers light gray. (T56–479)	2	123
14. Dolomite, grayish-pink (5*R* 8/2), very fine grained; consists of an aggregate of dolomite crystals generally less than 0.05 mm in size and a few angular detrital quartz grains as much as 0.25 mm in diameter; thick-bedded (beds are 1–3 ft thick); weathers grayish pink. (T56–478)	4	121
13. Dolomite, pale-red (5*R* 6/2), very fine grained, sandy; matrix consists of a very fine aggregate of dolomite crystals less than 0.1 mm in diameter; contains abundant detrital quartz grains ranging in size from silt to 0.5 mm in diameter; contains scattered pebbles as much as 2 mm in diameter, making up as much as percent of the rock; all quartz grains are angular to subangular, the largest grains also are poorly rounded; massive, unbedded; weathers pale red. (T56–477)	7	117
12. Dolomite breccia, composed mostly of boulder-sized fragments of two types of dolomite: (1) pale-red, medium- to coarse-grained, saccharoidal; and (2) light-gray to medium light-gray, fine-grained to dense dolomite	9	110
11. Dolomite, pale-red, fine-grained, saccharoidal, thin-bedded, poorly exposed	6.5	101

SECTION 34.—*Tonto Natural Bridge*—Continued

Martin Formation—Continued Jerome Member—Continued Aphanitic dolomite unit:	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
10. Limestone, light brownish-gray 5*YR* 6/1); mottled pale-olive (10*Y* 6/2); matrix aphanitic, containing scattered idiomorphic dolomite crystals and very few detrital quartz grains of silt size that account for much less than 1 percent of the rock; contains a very fine debris composed of ostracode fragments; has many small calcite vugs and stringers; thick-bedded (beds are 1–1½ ft thick); weathers grayish orange. (T56–476)	2.5	94.5
9. Limestone, pale-red (5*R* 6/2); matrix dense, containing a few small idiomorphic dolomite crystals not more than 0.2 mm in diameter and much detrital quartz, most from silt size to about 0.5 mm in diameter but some grains as much as 2 mm; all except the largest grains are angular to subangular; the distribution of quartz grains is very uneven; the grains tend to accumulate in sandy layers where they make up 30–40 percent of the rock. The limestone matrix contains numerous ostracode shells and fragments; length of the shells is generally less than 0.5 mm; they are not identifiable as to genus or species. Thin-bedded to flaggy; some layers tend to be shaly; weathers olive gray. (T56–475)	5	92
8. Limestone, mottled grayish orange-pink (5*YR* 7/2) and grayish-pink (5*R* 8/2); matrix composed of dense limestone, numerous idiomorphic dolomite crystals, as much as 0.25 mm in diameter, and many small calcite stringers randomly orientated; contains abundant detrital quartz grains ranging in size from silt to about 1 mm in diameter and making up as much as 10 percent of the rocks; individual grains are angular to subangular, except for the largest, which may be subrounded; contains a few scattered calcispheres; medium-bedded (beds are 8–10 in. thick); weathers light brown. (T56–474)	2	87
7. Limestone, slightly dolomitic, pale-red (5*R* 6/2 to 10*R* 6/2), medium grained, very sandy; matrix formed of crystalline aggregate; detrital quartz abundant, making up as much as 25 percent of rock; individual quartz grains range in size from fine to medium, and are generally angular to subangular; lower 3 ft contains quartzite pebbles as much as 1 in. in diameter; thick-bedded (beds are 2–4 ft thick);		

SECTION 34.—*Tonto Natural Bridge*—Continued

Martin Formation—Continued Jerome Member—Continued Aphanitic dolomite unit—Continued	*Subunit thickness (feet)*	*Cumulative thickness (feet)*
7. Limestone, etc.—Continued weathers yellowish to purplish gray. (T56–473)	11	85
6. Sandstone, yellowish-gray (5*Y* 8/1), fine- to medium-grained; mosaic composed of tightly packed detrital quartz grains, which are angular to subangular—rarely subrounded—and range from 0.05 to 0.5 mm in diameter; contains a small amount of calcareous matrix; very thick bedded (beds are 2–3 ft thick); weathers pale to light brown. (T56–472)	20	74
5. Dolomite, pale-red (5*R* 6/2), in places mottled grayish-orange (10*YR* 7/4), dense, very sandy; detrital quartz grains very unevenly distributed, in places constituting as much as 20 percent of the rock; grains very unsorted and range in size from silt to 1.5 mm in diameter; all except the largest grains are angular and even the largest grains are poorly rounded; upper 1–1½ ft contains quartzite boulders as much as 5 in. long and 2 in. thick and stringers of quartz sandstone; grades abruptly into subunit 6; thick-bedded (beds are about 2 ft thick); weathers pale red to light brown. (T56–471)	8	54
4. Sandstone, pale-red (10*R* 6/2), fine-grained appearance; dolomitic matrix in places constitutes as much as 40 percent of the rock; contains detrital quartz grains, which are unsorted, angular to subangular, and range in size from silt to fine; some grains are as much as 0.5 mm, and even the larger grains are poorly rounded; lamination seen on weathered surfaces; above 5 ft. patches of angular pebbles of medium- to olive-gray fine-grained to dense dolomite occur, forming pockets of intraformational conglomerate; top 3 ft is conglomeratic and contains quartzite pebbles as much as 2 in. in diameter; in places poorly defined bedding planes 4–6 in. apart occur; the subunit is generally massive; weathers brownish gray. (T56–470, 469)	15	46
3. Dolomite, pale-red (10*R* 6/2), very fine grained, laminated; contains a few angular silty to fine quartz grains that at no place constitute as much as 1 percent of the rock; somewhat porous, the pores are rarely larger than 1 mm and are arranged along certain laminae; the subunit is characterized by many intraformational		

SECTION 34.—*Tonto Natural Bridge*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
3. Dolomite, etc.—Continued disconformities resulting in lateral gradation from thin-bedded (bed are ½ in. thick) to very massive rock; weathers grayish orange. (T56–468)	18	31
2. Dolomite, varying shades of pale red (5*R* 6/2 to 10*R* 6/2); consists of an aphanitic ground mass containing irregularly scattered detrital quartz grains ranging in size from silt to 0.5 mm in diameter, which are generally angular to subangular and more rarely subrounded; part of the rock is free from quartz detritus, in other parts, it may constitute as much as 3 percent of rock; vugs are as much as 10 mm in diameter and are lined with crystalline dolomite and filled with calcite; also contains some large calcite drusen; in parts, laminated with alternating red- and gray-tinted bands; contains closely spaced microstylolites; in lower part, some pockets of more sandy dolomite, intraformational conglomerate, and small dolomite pebbles occur; medium-bedded; weathers reddish to yellowish gray. (T56–467, 466)	9	13
1. Conglomerate, reddish-brown; matrix composed of coarse-grained calcareous sandstone containing large angular to poorly rounded pebbles and boulders of Mazatzal Quartzite as much as 10 in. in diameter and, generally, smaller pebbles of Red Rock Rhyolite as much as 2 in. in diameter; thick-bedded	4	4
Precambrian: Red Rock Rhyolite of Wilson (1939).		

SECTION 35.—*Pinal Creek*

[West bank of Pinal Creek, 3½ miles northwest of Globe (Globe quadrangle, NW¼SE¼ sec. 10, T. 1 N., R. 15 E.). Photograph lots AK 1783, 1784. Measured by Curt Teichert, 1953 and 1956. This section was not sampled lithologically, and the following descriptions are from field notes only]

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
26. Siltstone, dolomitic, yellowish-brown	18	262
25. Shale, light-brown to yellowish-brown, poorly exposed	31	244
24. Siltstone, dolomitic, partly sandy, massive; rich in *Atrypa*, *Theodossia*, and other brachiopods. Mostly of the Atrypas are bivalved and lie parallel to the bedding, but some are at right angles to bedding planes. Subspherical quartz concretions occur locally	17	213

SECTION 34.—*Tonto Natural Bridge*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
23. Siltstone, dolomitic, fissile, light-brown contains a fossiliferous chert band, 2 in. thick, at 9 ft.; in upper part, elongated chert lenses, 4–5 in. thick, occur, some fusing into continuous layers	15	196
22. Alternating limestone and dolomitic siltstone in beds about 1 ft. thick. Limestone: dark, full of brachiopod fragments. Siltstone; light brown	6	181
21. Siltstone, dolomitic, grading into silty dolomite, light-gray to light-brown; fissility formed by weathering; richly fossiliferous at 15–16 ft. and contains one 4-in. calcarenite band	19	175
20. Siltstone, dolomitic; has interbeds of shaly siltstone containing brachiopods	4	156
19. Dolomite, light, brownish-gray, finely crystalline; contains silicified corals and brachiopods	8	152
18. Limestone, medium- to dark-gray, medium-crystalline, sandy, thick-bedded (beds are as much as 3 ft. thick); silicified brachiopods occur in lower 3 ft; remainder of subunit is rich in fossil fragments	8	144
17. Sandstone, very fine grained, thin-bedded to flaggy; contains small-scale crossbedding; lower 1–2 ft quartzitic	4	136
16. Mostly covered interval; some shaly siltstone in upper 8 ft	21	132
15. Sandstone, very fine grained	1	111
14. Dolomite, brownish-gray, very finely crystalline	1	110
13. Limestone, medium-gray, medium- crystalline to coarsely crystalline, generally crinoidal; contains some brachiopod fragments	4	109
12. Sandstone, light grayish-brown, medium-bedded, fine-grained, laminated, crossbedded	2	105
11. Shale, silty, dolomitic, light-brown; contains some light-brown to gray dolomitic siltstone	12	103
10. Dolomite, very silty, medium-gray, medium-crystalline to finely crystalline; nodular; contains partings of siltstone; cliff-forming	16	91
9. Dolomitic, medium-gray, finely crystalline, laminated; the uppermost 6-in. layer has a very irregular lower bedding plane	2	75
8. Sandstone, silty, dolomitic, light-gray, medium-bedded, crossbedded	3	73
7. Siltstone, argillaceous, soft	1	70
6. Sandstone, calcareous, brown, thick-bedded; contains invertebrate fossils on bedding planes	10	69

SECTION 35.—*Pinal Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit:	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
5. Dolomite, gray, finely to medium- crystalline, mottled	3	59
4. Dolomite, yellowish-gray, very finely crystalline, slightly calcitic, arenaceous	16	56
3. Dolomite, light-gray, aphanitic, thick-bedded; lower 2 ft is platy	14	40
2. Dolomite, generally light-gray to yellowish-gray, aphanitic, thick- to medium-bedded; contains some layers of sandy dolomite	19.5	26
1. Dolomite, gray, aphanitic, thick-bedded	6.5	6.5

Base of section not exposed.

SECTION 36.—*Theodore Roosevelt Dam*

[East of Theodore Roosevelt Dam (Roosevelt quadrangle, sec. 29, T. 4 N., R. 12 E.). Photograph lots AK 2811, 2812. Measured by R. L. Harbour, 1956]

Martin Formation: Jerome Member: Upper unit:	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
41. Sandstone, brownish-gray (5*YR* 5/1), fine-grained, hard; grains angular to subangular; contains an appreciable amount of calcareous cement; invertebrate tracks abundant throughout; uppermost 5 ft. coarser grained and contains gray limestone fragments; thin-bedded; weathers light olive gray. (H56–99)	25	486
40. Shale, gray with greenish tint; very poorly exposed	35	461
39. Dolomite, mottled pale-red (10*R* 6/2), grayish-orange (10*YR* 7/4), and pale-brown (5*YR* 5/2), very finely crystalline; contains a considerable amount (as much as 10 percent) of very fine grained detrital quartz; has one resistant bed; weathers light brown. (H56–98)	5	426
38. Sandstone, light-brown, well-sorted, coarse-grained, thin-bedded; forms dark resistant cap to underlying light-colored cliff-forming subunit	5	421
37. Sandstone, grayish orange-pink (10*R* 8/2), very fine grained; contains much calcareous cement and silt and some larger angular to subangular grains as much as 0.3 mm diameter, laminated; cliff-forming; weathers pinkish gray. (H56–97)	4	416
36. Dolomite, medium-gray, thin-bedded, poorly exposed	4	412
35. Sandstone, gray, conglomeratic, consists of well-sorted rounded grains containing scattered granules as much as 3 mm in diameter	4	408
34. Dolomite, light-gray, medium-crystalline; consists of abundant coarse sand grains near base; crinoidal; crops out in two resistant beds separated by 3 in. of gray argillaceous dolomite	3	404

SECTION 36.—*Theodore Roosevelt Dam*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thick-ness (feet)*	*Cumu-lative thick-ness (feet)*
33. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline; subconchoidal fracture; contains less than 1 percent silt-size to very fine-grained detrital quartz; in basal 1 ft., quartz grains as much as 1 mm in diameter occur; contains scattered calcite vugs; thickbedded (beds are 2½ ft. thick); highly jointed and forms slopes; weathers light brown. (H56–96)	10	401
32. Dolomite, calcitic, pale red-purple (5*RP* 6/2), finely crystalline; contains small vugs as much as 5 mm in diameter filled with baryte(?) and a small amount of silt-size and very fine grained detrital quartz; has a few large sand grains and, in places, abundant nonsilicified crinoid stems; forms not more than two beds; weathers grayish orange pink. (H56–95)	7	391
31. Dolomite, very sandy, pale-red (10*R* 6/2), finely crystalline; contains much silt- and fine-sand sized detrital quartz; grades locally into dolomitic sandstone; crops out in two thick beds, which are finely crossbedded; contains scattered impressions of fish plates on bedding surface; weathers light brown. (H56–94)	10	384
30. Dolomite, very slightly calcitic, grayish orange-pink (5*YR* 7/2), very finely to finely crystalline; contains scattered detrital quartz grains which compose as much as about 3 percent of the rock and are as much as 0.5 mm in diameter and subrounded; some brachiopods occur near base of unit; forms one massive bed (the subunit is the most prominent cliff former in entire section); weathers dark yellowish orange. (H56–91, 92, 93)	17	374
29. Dolomite, light gray, finely crystalline; sandy; contains abundant partially silicified brachiopods; crops out in three beds	6	357
28. Sandstone, very dolomitic, grayish orange-pink (5*YR* 7/2); has a very finely crystalline carbonate matrix which is slightly calcitic and contains detrital quartz grains ranging in size from silt to very fine; grades into sandy dolomite in places; very thinly laminated, crossbedded; weathers grayish orange. (H56–90)	2	351
27. Dolomite, light-gray, saccharoidal, medium-bedded (beds are 1 ft. thick)	5	349
26. Dolomite, yellowish-gray (5*Y* 7/2), very finely crystalline; contains abundant silicified brachiopods	2	344

SECTION 36.—*Theodore Roosevelt Dam*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
25. Dolomite, pale yellowish-brown (10*YR* 6/2) with small pale-red patches, very finely to finely crystalline; contains a small amount (less than 1 percent) of detrital quartz grains ranging in size from silt to very fine; thin-bedded (beds are less than 18 in. thick); weathers pale yellowish brown. (H56–89)	5	342
24. Dolomite, pale yellowish-brown (10*YR* 6/2), medium-crystalline; contains calcite-filled cavities as much as 1.5 cm in diameter; contains poorly preserved silicified brachiopod fragments. (H56–88)	1	337
23. Dolomite, medium-gray, very finely to medium crystalline; contains brachiopod and crinoid fragments (not silicified); thin-bedded	2	336
22. Dolomite, slightly calcitic, pale yellowish-brown (10*YR* 6/2), finely to medium-crystalline; evenly distributed silt-size detrital quartz constituting as much as 3 percent of the rock; thin-bedded; beds are interlayered by gray shale; basal dolomite beds contain crinoid columnals as much as 12 mm in diameter; slope-forming; weathers pale yellowish brown. (H56–87)	19	334
21. Dolomite, slightly calcitic, light olive-gray (5*Y* 6/1) to yellowish-gray (5*Y* 7/2), very fine grained, very thin bedded (thickest bed is 6 in.); interbedded with grayish-brown and light-brown shale; slope-forming. (H56–85, 86)	24	315
20. Sandstone, light-brown, fine- to coarse-grained; contains much dolomitic cement and many calcite-filled solution cavities; cliff-forming; weathers yellowish brown	5	291
19. Sandstone, very pale-orange (10*YR* 8/2) to grayish-orange (10YR 7/4); consists of a poorly sorted aggregate of angular to subangular detrital coarse to very coarse quartz grains and some pebbles as much as 5 mm in diameter; crops out as two beds of equal thickness; weathers grayish orange. (H56–84)	6	286
18. Dolomite, pale yellowish-brown (10*YR* 6/2), very uniformly and finely crystalline; contains an insignificant amount of silt-size detrital quartz; thin-bedded and contains interbedded shaly layers; slope-forming. (H56–83)	11	280
17. Dolomite, pale yellowish-brown (10*YR* 6/2); consists of a subaphanitic dolomitic matrix containing abundant idiomorphic dolomite crystals about 0.1 mm in diameter and some rounded fragments of denser dolomite as much as 0.8 mm in diameter; contains as much as 10 percent mostly very fine detrital quartz grains, and some subrounded grains as much as 0.5 mm in diameter; contains one cliff-forming crossbedded bed; weathers grayish orange. (H56–82)	4	269
16. Covered	1	265
15. Sandstone, grayish orange-pink (5*YR* 7/2) and grayish-orange (10*YR* 7/4), poorly sorted, very fine to medium-grained, consists of as much as 50 percent dolomitic matrix; larger quartz grains are generally subrounded; matrix is subaphanitic; crops out in two conspicuously crossbedded beds; cliff-forming; weathers grayish orange. (H56–80, 81)	18	264
14. Covered	4	246
13. Sandstone, yellowish-gray (5*Y* 8/1) to light brown (5*YR* 6/4), has limonitic stains; medium to coarse grained, poorly sorted; grains are angular to subrounded, tightly packed; quartzitic texture; contains a small quantity of chert fragments, no matrix; medium-bedded beds are 2 ft thick; contains interbedded layers of grayish-green shale; current-bedded; poorly exposed. (H56–79)	19	242
Aphanitic dolomite unit:		
12. Dolomite, mostly light brownish-gray (5*YR* 6/1) to light olive-gray (5*Y* 6/1); some beds are medium dark gray (*N* 4), generally aphanitic, grades into very finely crystalline dolomite in about the uppermost 20 ft; basal 20 ft contains detrital quartz becoming less abundant upward from a maximum of about 10 percent near base; quartz grains are poorly sorted, generally angular to subangular, in sizes as large as 0.5 mm; also, restricted to basal 15 ft is an admixture of small angular fragments of dolomite as much as 0.3 mm in diameter and of scattered feldspar crystals, some of which are larger than 2 mm in diameter; subunit is regularly thin bedded, (beds average somewhat less than 1 ft in thickness) separated by grayish-green shale layers containing many invertebrate trails; weathers in various shades of orange and yellowish brown. (H56–71–78)	88	223
11. Dolomite, medium light-gray (*N* 6) to medium-gray (*N* 5), subaphanitic; in lower part, matrix consists of irregularly convoluted layers and fragments of more or less transparent dolomite (visible in thin section) and grades upward into almost aphanitic dolomite containing very scattered silt-size detrital quartz grains; medium- and light-gray chert		

SECTION 36.—*Theodore Roosevelt Dam*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
11. Dolomite, etc.—Continued occurs in lenses and small nodules having brown rinds; medium-bedded; weathers light olive gray. (H56–69)	14	135
Fetid dolomite unit:		
10. Dolomite, pale-brown (5*YR* 5/2) to pale yellowish-brown (10*YR* 6/2), finely crystalline, laminated; emits a very weak fetid odor; lower part contains numerous small calcite-filled cavities; throughout subunit, mottled dark-gray and white chert lenses as long as 1 ft. and fine distributed chert occur. (H56–67, 68)	20	121
Beckers Butte Member:		
9. Dolomite and shale, interbedded in 1-in. thick beds. Shale, medium gray. Dolomite, reddish-gray, very fine grained	3	101
8. Sandstone and shale, thinly interbedded. Sandstone: light-gray, clean, and composed of a mixture of coarse and very fine quartz sand. Shale: sandy, micaceous, grayish-red to grayish-olive	8	98
[Subunits 1–7 fill a steep-walled channel in Troy Quartzite and Mescal Limestone]		
7. Sandstone, mottled light brownish-gray (5*Y* 8/1), very arkosic, poorly sorted—fine to very coarse grained—contains individual quartz and feldspar grains as much as 8 mm in diameter; all quartz grains are badly shattered and broken and angular to subangular; forms smoothly rounded cliff having conspicuous crossbedding; weathers brownish gray. (H56–66)	10	90
6. Sandstone, yellowish-gray (5Y 8/1), very arkosic; contains feldspar grains as much as 3.5 mm in diameter; quartz grains are tightly interlocked, subangular to angular, and fine- to coarse-grained; contains some pebbles as large as 10 mm; contains scattered angular black chert fragments as much as 7 mm in diameter; contains thick, crossbedded layers separated by thin layers of greenish micaceous shale; cliff-forming. (H56–64, 65)	20	80
5. Shale, grayish-green, sandy, micaceous; poorly exposed	1	60
4. Sandstone, pinkish-gray (5*YR* 8/1) to yellow-gray (5*Y* 8/1), poorly sorted, fine- to coarse-grained; contains scattered quartz grains as much as 5 mm in diameter, generally ranging from angular to subrounded, and having a considerable amount of overgrowth and some etching; medium-bedded (beds are 1½ ft thick); current-bedded; invertebrate trails occur on top of subunit; weathers yellowish gray. (H56–63)	13	59
3. Sandstone, medium-gray with pale-red streaks, finely laminated; generally fine grained, but contains quartz pebbles as much as 6 mm in diameter	6	46

SECTION 36.—*Theodore Roosevelt Dam*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Beckers Butte Member—Continued		
2. Conglomerate, medium-gray, current-bedded; contains rounded quartz pebbles as much as 1 in. in diameter; one bed	5	40
1. Sandstone, pale red-purple (5*RP* 6/2) to grayish red-purple (5*RP* 4/2); fine-grained, laminated, crossbedded; consists of angular to subangular quartz grains which are tightly packed; basal 10 ft contains weathered boulders of siltstone and limestone; medium-bedded. (H56–62)	35	35
Precambrian: Troy Quartzite and Mescal Limestone.		

SECTION 37.—*Windy Hill*

[East and southeast slope of Windy Hill, a promontory on the south side of Roosevelt Reservoir (Roosevelt quadrangle, sec. 24, T. 4 N., R. 12 E.). Photograph lots AK 2812, 2813. Measured by R. L. Harbour, 1956; additional observations by Curt Teichert, 1957]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
27. Dolomite, pale-red, very fine grained, resistant, unbedded	5	382+
26. Dolomite, pale-red, fine-grained, silty, slope-forming; weathers into nodules	7	377+
25. Sandstone, medium light-gray, fine-grained, quartzitic, thin-bedded (beds are 1–6 in. thick)	16	370+
24. Shale, bluish-gray, poorly exposed; contains laminated medium gray chert lenses and layers as much as 3 in. thick, some of which contain brachiopod fragments. (H56–361)	36	354+
23. Dolomite, mottled pale-red (10*R* 6/2) and grayish-red (5*R* 4/2), calcitic, fine-grained; contains abundant detrital quartz grains ranging in size from silt to 0.3 mm in diameter; contains brachiopod remains and, more rarely, fish plates. (H56–360)	2	318+
22. Dolomite, mottled pale-red (10*R* 6/2) and light-brown (5*YR* 6/4), very calcitic, fine- to medium-crystalline; contains abundant detrital quartz, patchily distributed, that forms 10–50 percent of the rock; containing dolomite clasts of granule size and crinoid stem fragments as much as 1.5 mm in diameter; lower 2 ft poorly bedded, resistant; bulk of subunit shows crossbedding and is cliff forming; upper 3 ft finer grained, fissile; weathers grayish orange pink. (H56–359)	25	316+
21. Dolomite, grayish orange-pink (5*YR* 7/2), fine- to medium-crystalline; contains abundant (as much as 15 percent) detrital quartz in silt and very fine sand size and scattered rounded larger grains as much as		

SECTION 37.—*Windy Hill*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
21. Dolomite, etc.—Continued 0.5 mm in diameter; lower half easily eroded, upper half more resistant; indistinctly bedded; weathers light brown. (H56–358)	16	291+
20. Dolomite, broadly mottled pale-red (10*R* 6/2) and grayish-orange (10*YR* 7/4) speckled with dark gray (*N* 3), fine- to medium-crystalline; contains abundant (as much as 15 percent) poorly sorted detrital quartz ranging in grain size from silt to rounded as much as 1 mm in diameter; most larger grains are superficially etched; weathers pale red. (H56–357)	13	275+
19. Sandstone, medium light-gray, fine-grained, finely cross-laminated	5	262+
18. Dolomite, pale-red (10*R* 6/2), medium- to coarse-crystalline, finely laminated; contains scattered detrital quartz of silt size and a few rounded grains as much as 1 mm in diameter; contains very small crinoid plates and fragments of fish plates; weathers pale red. (H56–356)	18	257+
17. Sandstone, pinkish-gray (5*YR* 8/1), very fine grained to silty; cement is composed of slightly calcitic dolomite; most quartz grains are about 0.06 mm in diameter, angular; cliff forming; weathers yellowish gray. (H56–355)	10	239+
16. Dolomite, mottled medium light-gray and pale-red, thin-bedded	5	229+
15. Dolomite, mottled medium light-gray and pale-red; contains partially silicified brachiopod fragments; has one laminated resistant bed	5	224+
14. Dolomite, medium light-gray, very finely crystalline, thin-bedded	3	219+
13. Dolomite, medium light-gray, very finely crystalline; contains crinoid stems and brachiopod remains; medium-bedded (beds are 1 ft. thick). (H56–354)	3	216+
12. Dolomite, light olive-gray (5*Y* 6/1); lower half finely crystalline; upper half medium crystalline, containing an admixture of detrital quartz (as much as 10 percent) in silt and very fine sand size; thin-bedded, containing shaly partings; slope-forming; weathers yellowish gray. (H56–352, 353)	39	213+
11. Sandstone, very pale orange (10*YR* 8/2); has much dolomitic cement. Evidence of lamination occurs on weathered surface. Contains quartz grains ranging in size from silt to fine sand, angular to subangular; grades		

SECTION 37.—*Windy Hill*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
11. Sandstone, etc.—Continued upward into very sandy medium-grained saccharoidal dolomite, finely laminated; thin-bedded, containing partings of green-tinted shale and many invertebrate trails on bedding planes; weathers yellowish gray. (H56–350, 351)	30	174+
10. Sandstone, medium light-gray, coarse-grained, crossbedded; grains subrounded, having etched surfaces; has dolomitic matrix; basal 3 ft is cliff forming	14	144+
9. Sandstone, grayish-pink (5*R* 8/2), very fine to medium-grained, has as much much as 50 percent dolomitic matrix; quartz grains range in size from silt to 0.5 mm in diameter and are angular to subangular, rarely subrounded; thin-bedded, contains shaly partings near base; upper half finely cross-bedded; weathers grayish orange pink. (H56–349)	26	130+
8. Sandstone, light-brown (5*YR* 6/4) to grayish orange-pink (5*YR* 7/2), indistinctly laminated, fine- to medium-grained; similar to subunit 5 but has less well sorted aggregate of fine to medium quartz grains, subangular to subrounded, containing moderate proportion of dark minerals (hornblende and others); weathers pale yellowish brown. (H56–348)	26	104+
Aphanitic dolomite unit:		
7. Dolomite, mottled pale-red (10*R* 6/2) and light brownish-gray (5*YR* 6/1), aphanitic; conchoidal fracture; groundmass pelletal to finely clastic; medium-bedded (beds are less than 1 ft thick) having shaly partings between dolomite beds; weathers light brown. (H56–347)	10	78+
6. Covered	5	68+
5. Sandstone, grayish orange-pink (10*R* 8/2) to yellowish-gray (5*Y* 8/1), fine-grained, indistinctly laminated; composed of an aggregate of tightly interlocked subangular quartz grains; contains sprinkling of glauconite grains; weathers light yellowish brown. (H56–346)	4	63+
4. Dolomite, pale-red (5*R* 6/2) with grayish-red stains, aphanitic; conchoidal fracture; contains aphanitic dolomite clasts as much as 0.7 mm in diameter and small calcite vugs (as much as 1 mm in diameter) having irregular outlines; weathers grayish orange. (H56–345)	24	59+

SECTION 37.—*Windy Hill*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
3. Dolomite, medium-gray (*N* 5) to medium light-gray (*N* 6), aphanitic; conchoidal fracture; laminated. In upper part of subunit, rock contains angular clasts of aphanitic dolomite in an aphanitic groundmass and angular to subangular detrital quartz grains, some having etched surfaces as much as 0.5 mm in diameter. Subunit contains dolomite beds approximately 1-ft thick separated by 3-in. beds of gray shale and lenses of gray chert; weathers light brown. (H56–343, 344)	25	35+
2. Dolomite, medium-gray, slightly mottled and laminated; contains flat chert nodules as much as 10 in. long and 4 in. thick	8	10+
1. Dolomite, pale-red (5*R* 6/2) to grayish-red (10*R* 4/2) and medium-gray (*N* 5), aphanitic, very finely laminated; contains scattered detrital quartz grains, in places, in thin layers and lenses; grains are angular, as much as 0.3 mm in diameter; contains scattered small and flat chert pebbles having brown rinds; weathers yellowish gray. (T57–444)	2+	2+

Base not exposed.

SECTION 38.—*Limestone Hills*

[Upper part of escarpment facing East Verde River about 2 miles southeast of junction of Verde and East Verde Rivers (Turret Peak quadrangle, sec. 28, T. 11 N., R. 7 E., unsurveyed). Photograph lots AK 3109, 3110. Measured by Curt Teichert and R. L. Harbour, 1956]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit (top of section not exposed):		
34. Dolomite, light-gray (*N* 7), finely crystalline; contains a large number of silicified brachiopods (*Camarotoechia* sp., *Cranaena*? sp.) and some corals (*Breviphyllum* sp., *Hexagonaria* sp.) occurring in loose rocks; contains very little rounded detrital quartz grains as much as 0.3 mm in diameter; weathers yellowish gray. (H56–341)	9	480
33. Covered (possibly underlain by thin-bedded dolomite)	32	471
32. Dolomite, pale-red, finely crystalline; constitutes one resistant bed; weathers into rounded blocks	2	439
31. Dolomite, medium-gray, finely crystalline; constitutes one resistant bed	3	437
30. Dolomite, medium-gray, finely crystalline, thin-bedded, slope-forming	2	434

SECTION 38.—*Limestone Hills*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
29. Dolomite, grayish-pink (5*R* 8/2), finely crystalline; contains much detrital quartz (as much as 50 percent) locally concentrated in thin beds. (H56–340)	3	432
28. Dolomite, light brownish-gray (5*YR* 6/1), very finely to finely crystalline; contains a large amount (as much as 50 percent) of detrital quartz, generally unsorted, ranging in grain size from silt to well-rounded, grains have peripheral etching; at 32–33 ft is a breccia bed; medium- to thick-bedded (maximum bed thickness, 4 ft); weathers light brown. (H56–338, 339, 339A)	46	429
27. Dolomite, light-gray (*N* 7) with pale-red streaks, very fine grained; contains a large amount of detrital quartz (as much as 50 percent), unsorted, ranging in grain size from silt to well-rounded as much as 0.5 mm in diameter; larger grains have some peripheral etching; thin-bedded; weathers grayish orange pink. (H56–337)	7	383
26. Dolomite, light-gray (*N* 7), uniformly very fine grained; constitutes one cliff-forming bed. (H56–336)	10	376
25. Dolomite, light brownish-gray (5*YR* 6/1); has a very fine grained ground mass containing streaks of aphanitic dolomite; contains much detrital quartz, unsorted, ranging in grain size from silt to 0.5 mm in diameter; larger grains, rounded to subrounded; thin-bedded; weathers yellowish gray. (H56–335)	6	366
24. Dolomite, pale-red, saccharoidal; constitutes one cliff-forming bed containing ?*Thamnopora* and stromatoporoids	9	360
23. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline; contains scattered detrital quartz sand, ranging in grain size mostly from silt to very fine, containing a few rounded grains as much as 0.6 mm in diameter; basal 4 ft form one bed; remainder of subunit, thin bedded; weathers pale brown. (H56–334)	9	351
22. Dolomite, slightly calcitic, pale-red (10*R* 6/2) to pinkish-gray (5*YR* 8/1), finely to very finely crystalline; contains varying amounts (as much as 50 percent) of detrital quartz sand ranging in grain size from silt to very fine laminated; thin-bedded; weathers grayish orange pink. (H56–332, 333)	28	342

SECTION 38.—*Limestone Hills*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
21. Limestone, dolomitic, light brownish-gray (5*YR* 6/1); fine crystalline; rock divided into areas 1 cm or more in diameter in which all crystals have identical or similar optical orientation; contains large amounts (as much as 10 percent) of detrital generally angular quartz grains 0.2 mm or less in diameter; contains a few fish plates near base of unit; slightly laminated; thin-bedded; weathers pale yellowish brown. (H56–331)	9	314
20. Dolomite, medium-gray, sandy; contains some calcareous brachiopod fragments at base	1	305
19. Siltstone, yellowish-gray, fissile, slope-forming	6.5	304
18. Limestone, medium light-gray (*N* 6) to light brownish-gray (5*YR* 6/1); has aphanitic matrix; contains some small idiomorphic dolomite crystals and small amount of detrital quartz; contains coquinalike assemblage of brachiopods (spiriferid?, *Atrypa*?); contains also echinoid fragments and ostracodes; weathers light brown. (H56–330)	0.5	297.5
17. Siltstone, yellowish-gray, fissile	1	297
16. Covered (some thin-bedded saccharoidal dolomite found on slope)	34	296
Aphanitic dolomite unit:		
15. Dolomite, light-gray, aphanitic	3	262
14. Dolomite, medium-gray (*N* 5), very finely crystalline, slightly calcitic, laminated; has very weak fetid odor; contains some light- to medium-gray chert 1 ft above base of subunit. (H56–329)	9	259
13. Dolomite, light brownish-gray (5*YR* 6/1), aphanitic; conchoidal fracture; contains scattered detrital quartz sand, mostly silt size to very fine; contains a few rounded to subrounded grains as much as 0.7 mm in diameter and also clasts of darker aphanitic dolomite that are well-rounded and as much as 0.6 mm in diameter; contains scattered small spherical chert pebbles; weathers yellowish gray. (H56–328)	12	250
12. Dolomite, pinkish-gray (5*YR* 8/1) and light olive-gray (5*Y* 6/1), aphanitic; conchoidal fracture; lower part contains 1–2 percent detrital quartz of silt size; upper part contains no detrital quartz and very small calcite vugs; faintly pelletal or clotty texture of dolomite recognizable in upper part; medium bedded (beds are 1–2 ft thick); weathers yellowish gray. (H56–326, 327)	19	238

SECTION 38.—*Limestone Hills*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
11. Covered	48	219
10. Dolomite, light-gray (*N* 7), medium light-gray (*N* 6), and light brownish-gray (5*YR* 6/1), aphanitic; conchoidal fracture; contains varying amounts (as much as 1 percent) of detrital quartz grains as much as 1 mm in diameter, although most are smaller; grains more than 0.3 mm are generally well rounded to subrounded; medium-bedded (beds are 2 ft thick); weathers yellowish gray. (H56–322, 323, 324, 325)	52	171
9. Dolomite, banded pale red purple (5*RP* 6/2) and grayish red (5*R* 4/2), aphanitic, finely laminated; contains a scattering of detrital quartz grains as much as 0.2 mm in diameter; thin-bedded (beds are 6 in. thick) and contain partings of greenish-gray shale less than 1 in. thick between dolomite beds; contains lenses of gray chert that distort the lamination; weathers grayish pink. (H56–318)	12	119
Fetid dolomite unit:		
8. Dolomite, medium-gray (*N* 5), very finely crystalline; contains layers of reworked chert granules and pebbles and some detrital quartz grains as much as 0.2 mm in diameter; weathers light olive gray. (H56–317)	2	107
7. Dolomite, light brownish-gray (5*YR* 6/1); fetid odor; finely crystalline; contains large numbers of idiomorphic dolomite crystals ranging in size from 0.05 to 0.15 mm; finely laminated, lamination caused by finely dispersed organic matter; has considerable megascopic and microscopic porosity, amounting in places to over 10 percent; upper 3 ft contains lenses of banded orange to very light gray and light-gray chert; weathers grayish orange pink. (H56–320, 321)	19	105
Beckers Butte Member:		
6. Covered	8	86
5. Sandstone, mottled pale-red (5*R* 6/2) and grayish orange-pink (5*YR* 7/2), very poorly sorted; contains grains as much as 2 mm in diameter; smaller grains generally angular; grains 1 mm and more in diameter subrounded to angular; contains small amounts of cement composed of slightly calcitic dolomite; thin-bedded; contains partings of red-tinted shale. (H56–319)	14	78
4. Covered	4	64
3. Sandstone, light-brown to pale-brown, coarse-grained; contains conglomeratic layers; thick-bedded; crossbedded; top of subunit poorly exposed	45	60

SECTION 38.—*Limestone Hills*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Beckers Butte Member—Continued		
2. Conglomerate, light-brown; contains pebbles of igneous rock and quartzite as much as 6 in. in diameter; thick-bedded	8	15
1. Conglomerate, mottled light brown (5*YR* 6/4) and pale-brown (5*YR* 5/2); contains pebbles of igneous rocks and quartzite as much as 6 in. in diameter; grades upward into coarse-grained sandstone, poorly sorted; contains angular to subrounded quartz grains and a considerable amount of calcareous cement; thick-bedded; weathers grayish brown	7	7
Precambrian: diabase(?)		

SECTION 39.—*Chasm Creek*

[2.5–3 miles upstream from junction Chasm Creek and Verde River (Turret Peak quadrangle, probably on border of secs. 5 and 8, T. 12 N., R. 5 E., unsurveyed). Photograph lots AK 3012, 3013. Measured by Curt Teichert and R. L. Harbour, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit (top not exposed):		
24. Dolomite, light-gray (*N* 7) to light brownish-gray (5*YR* 6/1), finely crystalline; laminated by layers of detrital quartz grains ranging in size from very fine to fine; thick-bedded (beds are 1–3 ft. thick); weathers yellowish gray; forms vertical cliff of which only the lowermost 8 ft. could be examined. (H56–267)	25	305+
23. Dolomite, mottled grayish orange-pink (5*YR* 7/2) and medium dark-gray (*N* 4), finely crystalline to medium-crystalline, thick-bedded; weathers grayish orange. (H56–266)	7	280+
22. Dolomite, yellowish-gray, finely crystalline; lower half rich in poorly preserved brachiopod fragments; thick-bedded; very hard, cliff-forming; weathers yellowish brown. (H56–269)	15	273+
21. Covered (probably underlain by fossiliferous dolomite)	16	258+
20. Dolomite, light-gray (*N* 7), finely crystalline; contains abundant broken brachiopod shells and some gastropods; medium-bedded; weathers yellowish gray; poorly exposed. (H56–270)	15	242+
19. Dolomite, pale yellowish-brown (10*YR* 6/2), very finely crystalline; subconchoidal fracture; argillaceous, medium-bedded; weathers yellowish gray. (H56–265)	3	227+
18. Dolomite, light brownish-gray (5*YR* 6/1) to light olive-gray (5*Y* 6/1); extremely varied lithology; basal 1 ft. laminated and brecciated; remainder of subunit partly aphanitic, mottled,		

SECTION 39.—*Chasm Creek*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
18. Dolomite, etc.—Continued and laminated, partly finely crystalline, darker in color, and cherty; forms upper part of cliff, base of which is formed by subunit 17; weathers yellowish brown. (H5–263, 264)	9	224+
Aphanitic dolomite unit:		
17. Dolomite, light-gray (*N* 7); variable lithology; aphanitic to finely crystalline; upper 2 ft laminated; some vuggy porosity occurs; contains a few scattered chert fragments in uppermost foot; scattered detrital quartz grains ranging in size from silt to very fine; thick-bedded; cliff-forming; weathers yellowish gray. (H56–262)	7	215+
16. Covered	12	208+
15. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline to subaphanitic; contain some vuggy porosity; thick-bedded (beds are 2–2½ ft thick); massive, cliff-forming; weathers yellowish gray. (H56–261)	8	196+
14. Dolomite, grayish orange-pink (5*YR* 7/2), aphanitic; conchoidal fracture; has micropelletal structure and dense pattern of small vugs filled with calcite; contains scattered layers having vuggy porosity; has a few chert impregnations and chert fragments; entire subunit massive, having few signs of bedding. (H56–260)	15	188+
13. Covered	8	173+
12. Dolomite, yellowish-gray (5*Y* 7/2), aphanitic; subconchoidal fracture; clastic, consisting mostly of rounded dolomite clasts ranging in size from very small to 2 mm in diameter; contains scattered small chert "clouds"; medium-bedded; weathers yellowish gray. (H56–259)	6	165+
11. Dolomite lithologically like variety 1 of subunit 10	13	159+
10. Dolomite, alternating layers of (1) pale red-purple (5*RP* 6/2) dolomite, which is aphanitic, has a conchoidal fracture, is argillaceous, contains scattered detrital quartz ranging in size from silt to 0.3 mm in diameter, and weathers yellowish gray; and (2) mottled light brownish gray (5*YR* 6/1) and medium gray (*N* 5) dolomite, which is aphanitic, has a conchoidal fracture, contains no detrital quartz, and has small cherty and calcite vugs, the chert in which is probably authigenic. Entire subunit is medium bedded, weathers yellowish gray. (H56–257, 258)	11	146+

SECTION 39.—*Chasm Creek*—Continued

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
9. Dolomite, banded medium gray (*N* 5) and medium light gray (*N* 6), aphanitic; subconchoidal fracture; laminated; contains some thin chert bands at intervals; in some parts, has mircobreccia structures; other parts are sandy, containing poorly sorted detrital quartz making up more than 50 percent of rock; quartz grains are as much as 1 mm in diameter, subangular to subrounded, and have some peripheral etching; medium- to thick-bedded (beds are 4 in. to 2 ft thick); weathers yellowish gray. (H56–255, 256)	37	135+
8. Covered	12	98+
7. Dolomite, medium-gray (*N* 5), aphanitic; conchoidal fracture; has scattered layers containing small chert pebbles having limonitic rinds; lower 3 ft, thin bedded; upper 3 ft, medium- to thick-bedded; weathers light olive gray. (H56–254)	6	86+
Fetid dolomite unit:		
6. Dolomite, medium-gray (*N* 5), very fine grained, very finely laminated; in places small-scale slump structures and brecciation occur; uppermost 3 ft has many thin layers of chert parallel to lamination; medium-bedded (beds are 10 in. to 2 ft thick); weathers pale yellowish brown. (H56–252, 253)	20	80+
5. Dolomite, light brownish-gray (5*YR* 6/1), very fine grained, thinly laminated in places; has faintly fetid odor; locally contains some poorly sorted detrital quartz, of which the rounded shattered grains are as much as 0.8 mm in diameter; thin-bedded to flaggy; weathers light brownish gray. (H56–251)	5	60+
4. Dolomite, lower 3 ft alternating light brownish gray (5*YR* 6/1) and grayish red (5*R* 4/2); remainder of unit light brownish gray with grayish red mottling; very fine grained; argillaceous; scattered detrital quartz (1 percent or less) ranging in grain size from silt; to very fine thin-bedded to flaggy and fissile; near top several layers of mottled gray and grayish-red shale occur; weathers light olive gray. (H56–250)	15	55+
Beckers Butte(?) Member:		
3. Dolomite, grayish-red (10*R* 4/2), very finely crystalline, silty; contains a considerable amount of unsorted detrital quartz ranging in size from silt grains to rounded shattered grains as much as 0.5 mm in diameter; thin-bedded; weathers pale red. (H56–249)	3	40+
2. Sandstone, dolomitic, grayish-red (10*R* 4/2); changes laterally into sandy dolomite; poorly sorted, containing angular grains ranging in size from very fine to medium, and a scattering of rounded highly shattered grains as much as 1 mm in diameter; thick-bedded (beds are about 2 ft thick); weathers yellowish brown. (H56–248)	5	37+
1. Sandstone, yellowish-gray (5*Y* 8/1), mostly medium-grained; composed of tightly packed angular to subangular grains of quartz. Many individual beds are conglomeratic, containing pebbles of red-tinted quartzite and granite as much as ½ inch in diameter; some beds are crossbedded. Medium- to thick-bedded; weathers light olive gray. (H56–245, 246, 247)	32+	32+

Base not exposed.

SECTION 40.—*Squaw Peak mine*

[On northeastern slope of Squaw Peak, above Squaw Peak mine, about 6 miles south of Camp Verde (Turret Peak quadrangle, center sec. 31, T. 13 N., R. 5 E.). Photograph lots AK 3091, 3002. Measured by Curt Teichert, 1953]

	Sub-unit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Aphanitic dolomite unit (top of section eroded):		
7. Dolomite, medium-gray, finely crystalline; contains scattered detrital quartz; has brecciated zone at base; thick-bedded; poorly exposed. (TL–365)	5+	63+
6. Sandstone, light-gray, quartzitic, medium-grained	1	58
5. Dolomite, medium-gray, aphanitic; has brecciated zone at top	2	57
Fetid dolomite unit:		
4. Dolomite, slightly calcitic, medium-gray to light olive-gray (5*Y* 6/1). Lower part finely crystalline, laminated; upper part very finely crystalline, having considerable vuggy porosity. Has slightly fetid odor; thick-bedded; poorly exposed; weathers yellowish gray. (TL–364)	14	55
Beckers Butte(?) Member:		
3. Sandstone, streaky grayish-pink (5*R* 8/2) and grayish orange-pink (10*R* 8/2), medium- to coarse-grained; contains rounded to subrounded quartz grains embedded in a considerable amount of		

SECTION 40.—*Squaw Peak mine*—Continued

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation—Continued		
Beckers Butte (?) Member—Continued		
3. Sandstone, etc.—Continued dolomitic matrix; medium-bedded; weathers light brown. (TL–363)	7	41
2. Sandstone, pale-red (5*R* 6/2), very poorly sorted; contains quartz grains as much as 1.5 mm in diameter, generally subrounded; contains a considerable amount of dolomitic matrix; partly grades into sandy dolomitic rock; weathers light brown. (TL–362)	1	34
1. Sandstone, arkosic, pinkish-gray (5*YR* 8/1) to yellowish-gray (5*Y* 8/1), very coarse grained to conglomeratic. Basal part contains subangular quartz pebbles as much as 1 cm in diameter and angular feldspar pieces as much as 7 mm in diameter. Thick-bedded (beds are 2–3 ft thick); highly crossbedded throughout; weathers light brown. (TL–361)	33	33
Precambrian: Granite.		

SECTION 41.—*Jerome*

[Small canyon in slope 1.1 miles northeast of Jerome and 0.3–0.4 mile southeast of Hopewell (Clarkdale quadrangle, sec. 14, T. 16 N., R. 2 E., unsurveyed). Photograph lots AK 2361, 2362. Measured by Curt Teichert and R. L. Harbour, 1956; additional observations by Teichert, 1957]

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
40. Dolomite, light-gray, aphanitic, thin-bedded, poorly exposed	3	491
39. Limestone, dolomitic, very sandy, pinkish-gray (5*YR* 8/1); has fine-grained carbonate matrix containing unsorted detrital quartz grains ranging in size from silt to 0.7 mm; larger grains are generally subrounded, highly etched; finely porous; medium-bedded; cliff-forming. (T56–550)	4	488
38. Dolomite, pinkish-gray (5*YR* 8/1), medium-grained, saccharoidal; similar to subunits 30, 32, 34, and 36; interbedded with several smaller subunits of almost aphanitic white-weathering dolomite	22	484
37. Dolomite, pinkish-gray (5*YR* 8/1) to light brownish-gray (5*YR* 6/1), very fine grained, laminated, somewhat brecciated; contains scattered chert fragments and quartz grains ranging in size from silt to medium; weathers light gray. (T56–549)	2.5	462
36. Dolomite, slightly calcareous, light brownish-gray (5*YR* 6/1), generally medium-grained, saccharoidal; contains some layers of dense calcareous dolomite containing abundant detrital quartz grains as much as 1 mm in diameter, subrounded to well-rounded. Dolomite replaces some sil-		

SECTION 41.—*Jerome*—Continued

	Sub-unit thick-ness (feet)	Cumu-lative thick-ness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
36. Dolomite, etc.—Continued ica. Similar in outcrop appearance to subunits 30 and 32; weathers light brown. (T56–548)	37	459.5
35. Dolomite, pinkish-gray (5*YR* 8/1), medium-grained; consists of idiomorphic to hypidiomorphic dolomite crystals. Upper part very porous and contains calcite-filled vugs as much as 5 in. in diameter; upper 5 ft contains abundant poorly recrystallized *Amphipora*. Hard, cliff-forming; weathers grayish orange pink. (T56–546, 547)	11	422.5
34. Dolomite, grayish orange-pink (5*YR* 7/2), medium-grained; consists of idiomorphic to hypidiomorphic dolomite crystals; similar to subunit 32 but less porous; contains some small crinoid debris; unbedded; breaks up into small rounded fragments; weathers light brown. (T56–545)	38	411.5
33. Dolomite, pale-red (5*R* 6/2) to pale-red (5*RP* 8/2), very fine grained, hard, bank-forming; contains much fine silicified crinoid debris; weathers yellowish gray. (T56–544)	1.5	373.5
32. Dolomite, pinkish-gray (5*YR* 8/1), fine- to medium-grained; composed of hypidiomorphic to allomorphic dolomite crystals; generally porous, containing some large cavities as much as ½ in. in diameter; thick-bedded; upper 2–3 ft are shaly; weathers dull gray. (T56–543)	7.5	372
31. Dolomite, pale red-purpe (5*RP* 6/2), fine-grained; contains irregular chert "clouds" and irregularly shaped chert particles; rich in silicified corals (?*Tabulophyllum* sp., cyathophylloid and amplexoid corals); hard, cliff-forming, highly jointed; weathers light gray. (T56–542)	1.5	364.5
30. Dolomite, grayish-pink (5*R* 8/2) to pinkish-gray (5*YR* 8/1), very fine grained, silty and argillaceous; contains detrital quartz silt constituting as much as 15 percent of rock; poorly formed bedding; upper 2–3 ft is shaly; weathers pinkish gray. (T56–541)	14	363
29. Dolomite, light-gray (*N* 7) to light brownish-gray (5*YR* 6/1); composed of an aggregate of very fine- to medium-grained hypidiomorphic and allotriomorphic dolomite crystals; contains a sparse sprinkling of rounded detrital generally fine quartz grains; thin-bedded; slope-forming; slightly porous; weathers light olive gray. (H56–316)	21	349

SECTION 41.—*Jerome*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
28. Dolomite, light olive-gray (5*Y* 6/1), medium-grained, saccharoidal; consists of idiomorphic to hypidiomorphic dolomite crystals; thin-bedded; weathers yellowish gray. (H56–315)	4	328
27. Dolomite, grayish-pink (5*R* 8/2), very fine grained to subaphanitic; rich in detrital quartz grains making up as much as 20 percent of rock; grains range is size from silt size to 1 mm in diameter; nearly all grains except smallest ones, are subrounded to rounded and have etched surfaces; thinly laminated, thin-bedded; weathers pinkish gray. (H56–314)	5	324
26. Dolomite, light brownish-gray (5*YR* 6/1) to medium-gray (*N* 5), very fine grained to subaphanitic; contains ghosts of either pellets or microfossils; laminated, thin-bedded (beds are less than 1 ft thick); weathers yellowish gray to light olive gray. (H56–312, 313)	23	319
25. Dolomite, medium-gray, fine-grained, friable	2	296
24. Dolomite, light brownish-gray (5*YR* 6/1) and pinkish-gray (5*YR* 8/1) and yellowish-gray (5*Y* 8/1) mottles, subaphanitic, faintly laminated; contains "clouds" of somewhat darker material (probably clay?); medium-bedded (beds are less than 1 ft thick); weathers yellowish gray. (H56–311)	12	294
23. Covered interval	2	282
22. Dolomite, light-gray (*N* 7), very fine grained, thick-bedded (beds are 2½ ft thick); scattered small fish plates occur in lower part. (H56–309, 310)	12	280
21. Dolomite, medium-gray, mottled light-gray and olive-gray, finely crystalline	7	267
20. Dolomite, medium light-gray (*N* 6) to medium-gray (*N* 5), very fine grained, thinly laminated; contains abundant ghosts of microfossils (ostracodes?, calcispheres?); thin-bedded; weathers yellowish gray (H56–308)	12	260
19. Dolomite, light-gray (*N* 7) with some pale-red stains, very fine grained to subaphanitic, thinly laminated; contains very scattered quartz silt grains; weathers white to yellowish gray. (H56–307)	14	248
18. Dolomite, mottled light brownish-gray 5*YR* 6/1), light olive-gray (5*Y* 6/1), and pale-red (5*R* 6/2), very fine to finely crystalline; contains many idiomorphic dolomite crystals and large calcite vugs as much as 1 in. in diameter; gastropod remains occur in lower 2 ft; thick-bedded (beds are generally 2–3 ft thick). (H56–303, 304, 305, 306)	42	234
17. Dolomite, medium-gray (*N* 5), very slightly calcitic, very fine grained, thick-bedded in finely laminated beds as much as 1½ ft thick separated by partings of sandy shale; contains some calcite-filled brachiopod casts; weathers light olive gray. (H56–287)	9	192
Aphanitic dolomite unit:		
16. Dolomite, medium light-gray, aphanitic; forms one resistant bed; weathers light gray	3	183
15. Dolomite, light brownish-gray (5*YR* 6/1) with pale-red stains, very finely and evenly crystalline, thinly laminated; weathers light brown. (H56–286)	6	180
14. Dolomite, light olive-gray (5*Y* 6/1), aphanitic; conchoidal to subconchoidal fracture; contains scattered spherical bodies that appear to be dolomitized calcispheres; contains scattered gray concentrically banded chert nodules as much as 2 in. in diameter; thin-bedded (beds are 2 in. thick); weathers yellowish gray. (H56–285)	6	174
13. Sandstone, pinkish-gray (5*YR* 8/1), poorly sorted; contains quartz grains ranging in size from silt to about 0.5 mm in diameter; larger grains are subrounded to rounded; smaller grains are subangular; most grains are etched by carbonate replacement; composed at least 20 percent of dolomitic cement; weathers light reddish-brown and forms distinctive low cliff. (H56–284)	2	168
12. Dolomite, light-gray, aphanitic; contains irregular stringers of medium quartz sand composed of well-rounded frosted detrital grains	8	166
11. Covered interval, possibly red-tinted shale	2	158
10. Dolomite, mottled pinkish-gray (5*YR* 8/1) and light brownish-gray (5*YR* 6/1), aphanitic; conchoidal fracture; lower 4 ft. brecciated and cliff forming; has pelletal structure and very small to microscopic dolomite-filled cavities; contains possibly ghost structures of calcispheres; contains a very small amount of very fine grained detrital quartz; weathers pinkish gray. (H56–283)	9	156

SECTION 41.—*Jerome*—Continued

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
9. Dolomite, mottled pale red (5*R* 6/2) to grayish pink (5*R* 8/2), aphanitic; conchoidal fracture; contains very small to microscopic vugs and fissures filled with crystalline dolomite; lower part consists of two beds separated by less than 1 in. of purplish-gray shale; upper part consists of one 3-ft. bed containing some gray chert; weathers light yellowish gray. (H56–282)	7	149
8. Dolomite, light-gray (*N*7) to light brownish-gray (5*YR* 6/1) (some beds mottled pale red), aphanitic, conchoidal fracture; thick-bedded (beds are 2 ft. thick) individual dolomite beds are separated by beds of grayish-purple shale averaging a few inches in thickness; dolomite beds weather light yellowish brown. (H56–280, 281)	22	142
7. Dolomite, pinkish-gray (5*YR* 8/1) light brownish-gray (5*YR* 6/1), and light olive-gray (5*Y* 6/1; medium-bedded (beds are 1–2 ft. thick); dolomite beds are separated by shale partings, which average 2 in. thick; dolomite beds are generally aphanitic and have a conchoidal fracture; parts of rocks are very finely pelletal; pellets are generally 0.1–0.2 mm in diameter, but some are as large as several millimeters. Contains sparsely scattered generally subangular to angular detrital quartz grains ranging in size from very fine to fine; weathers yellowish gray. (H56–277, 278, 279)	30	120
6. Dolomite, medium-gray (*N* 5) to medium dark-gray (*N* 4), thin-bedded (beds are less than 1 ft thick); contains thin shaly partings; aphanitic; conchoidal fracture; very finely laminated; contains two kinds of chert: (1) irregular small nodules of light-gray chert having a limonitic rind within dolomite beds and (2) lenses of dark-gray chert emplaced in shale partings between dolomite beds in such a manner that bedding is slightly disturbed; weathers pale yellowish brown. (H56–274, 275, 276)	27	90
Fetid dolomite unit:		
5. Dolomite, medium light-gray (*N* 6) to light-gray (*N* 7), fine- to medium-grained, saccharoidal, and laminated as subunit 1; in places, brecciated and contorted; weathers yellowish gray. (H56–273)	6	63
4. Dolomite, medium light-gray (*N* 6) to medium-gray (*N* 5), massive, cliff-forming, fine-grained, saccharoidal; contains idiomorphic to hypidiomorphic dolomite crystals; finely laminated, the laminae consisting of dark, probably organic, material; contains small calcite vugs throughout; fetid odor; weathers yellowish gray. (H56–271, 272)	15	57
Tapeats Sandstone:		
3. Dolomite, pale-red (10*R* 6/2), very fine grained, argillaceous; contains stringers of detrital quartz grams ranging in size from silt to very fine; occurs in layers as much as 1 in. thick interbedded with red- and green-tinted shale. (T56–572, T57–343)	6	42
2. Shale, silty, and fissile siltstone, red- and green-tined, poorly exposed	14	36
1. Sandstone, grayish-red (5*R* 4/2), thick-bedded, coarse-grained, very cross-bedded; lower 1½ ft is conglomeratic, containing pebbles as much as 3 in. in diameter. (T57–344)	22	22
Precambrian: Deception Rhyolite.		

SECTION 42.—*Upper Hull Canyon*

[North of Jerome-Prescott Road and west of BM 5910, about 2 miles west-southwest of Jerome (secs. 28 and 29, T. 16 N., R. 2 E., unsurveyed]

This section was measured and sampled in 1953 but not by the standards employed in 1956. No rock samples were available for examination. Reference to this section is made only to state thickness and to fix derivation of some important fossil collections that are discussed.

SECTION 43.—*Verde River at Sycamore Creek*

[North side of Verde River, a quarter of a mile above junction of Sycamore Creek (Clarkdale quadrangle, about center of SE¼ sec. 7, T. 17 N., R. 3 E., unsurveyed). Photograph lots AK 2856, 2857. Measured by Curt Teichert and R. L. Harbour, 1956]

	Subunit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
33. Sandstone, grayish orange-pink (10*R* 8/2), poorly sorted, fine- to coarse-grained; quartz grains more than 0.3 mm in diameter are generally well rounded; those less than 0.3 mm in diameter are angular to subangular; contains some calcareous cement; thin-bedded, friable; contains many broken and wrinkled beds; weathers pale red. (T56–571)	10	367+
32. Dolomite, grayish orange-pink (10*R* 8/2), very finely crystalline; contains scattered detrital quartz, mostly fine grained or smaller, making up as much as 3 percent of rock; some parts are more sandy and contain rounded quartz grains as much as 1 mm in diameter; massive, poorly bedded; weathers pale red. (T56–570)	18	357+

SECTION 43. *Verde River at Sycamore Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
31. Dolomite, grayish-pink (5*R* 8/2), finely crystalline; some beds are laminated and have slump structures in places; thick-bedded to massive; weathers pale red. (T56–569)	6	339+
30. Dolomite, pale-red (5*R* 6/2), very finely crystalline, saccharoidal; weathers into fine powder composed of dolomite crystals; contains scattered detrital quartz grains which are fine or smaller; larger grains are highly shattered; massive, having only indistinct bedding. (T56–568)	14	333+
29. Dolomite, grayish-pink, saccharoidal, unbedded, highly weathered and poorly exposed	10	319+
28. Dolomite, light olive-gray (5*Y* 6/1), finely to coarsely crystalline, saccharoidal; has some vuggy porosity; generally unbedded; weathers light olive gray. (T56–566, 567)	33	309+
27. Dolomite, slightly calcitic, very pale orange (10*YR* 8/2) to grayish-orange (10*YR* 7/4), very finely crystalline; contains many long narrow tubes, partly calcite-filled, oriented parallel to bedding plane; bedding indistinct; weathers pale yellowish brown. (T56–565)	2	276+
26. Dolomite, pinkish-gray (5*YR* 8/1), very finely crystalline, saccharoidal; lower 1–2 ft contains *Congeriomorpha andrusovi* Stoyanow and *Arizonella allecta* Stoyanow; 2 ft above this fauna is a conodont assemblage containing *Palmatolepis triangularis* Sannemann, *Hindeodella* sp., *Synprioniodina* sp., *Spathognathus* sp., and *Falcodus*? sp.; indistinctly bedded; weathers light olive gray. (T56–564)	7	274+
25. Dolomite, grayish orange-pink (5*YR* 7/2), very finely crystalline, saccharoidal, argillaceous; contains scattered detrital quartz silt constituting as much as 5 percent of rock and a few rounded quartz grains as much as 0.6 mm in diameter; thin-bedded; becomes shaly in upper 2 ft; weathers grayish orange. (T56–563)	7	267+
24. Dolomite, grayish-pink (5*R* 8/2), finely crystalline; contains as much as 1–2 percent detrital quartz silt; argillaceous; very fissile, having some flaggy beds 2 in. thick; weathers grayish pink; poorly exposed. (T56–562)	12	260+
23. Dolomite, calcitic, grayish orange-pink (5*YR* 7/2), finely crystalline, saccharoidal, very porous; uppermost foot is abundantly fossiliferous (stromatoporoids, *Aulopora* sp., *Thamnopora* sp., rugose coral, brachiopods); massive, having indistinct bedding; weathers pale yellowish brown. (T56–561)	5	248+
22. Dolomite, brownish-gray (5*YR* 4/1) to light brownish-gray (5*YR* 6/1), finely to medium-crystalline; has vuggy porosity; contains small chert fragments; thick-bedded, cliff-forming; weathers light olive gray. (T56–560)	9	243+
21. Dolomite, light-gray (*N* 7), very finely crystalline; contains much poorly sorted detrital quartz, forming as much as 50 percent of rock; larger grains are rounded to subrounded, are as much as 1.2 mm in diameter, and have slightly etched surfaces; medium-bedded; weathers grayish pink. (T56–559)	5	234+
20. Alternations of light-gray finely crystalline dolomite and grayish-purple shale	15	229+
19. Dolomite, light olive-gray, finely to very finely crystalline; similar in appearance to subunit 18 but porous and softer. (T56–558)	9	214+
18. Dolomite, slightly calcitic, light olive-gray (5*Y* 6/1), coarsely crystalline, saccharoidal; consists of tightly interlocked hypidiomorphic dolomite crystals surrounded by thin calcite films; hence, weathers into a coarse powder composed of dolomite grains; poorly bedded, massive, cliff-forming; weathers light olive gray. (T56–557)	9	205+
17. Dolomite, light-gray, very slightly calcitic, finely crystalline, thin-bedded except for massive 1-ft bed at base. (T56–556)	7	196+
16. Dolomite, light olive-gray (5*Y* 6/1), very finely crystalline, saccharoidal, thick-bedded; weathers into poorly rounded yellowish-gray rubble. (T56–555)	5	189+
15. Dolomite, light- to medium-gray, some pale-red mottling in upper half; finely crystalline. (T56–554)	6	184+
14. Dolomite, grayish orange-pink (5*YR* 7/2), very finely crystalline, saccharoidal, thin- to medium-bedded; weathers light olive gray. (T56–553)	3	178+
13. Dolomite, light-gray, finely crystalline; forms one resistant bed	4	175+
12. Dolomite, light- to medium-gray, some pale-red mottling in upper half; finely crystalline	6	171+

SECTION 43. *Verde River at Sycamore Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Upper unit—Continued	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
11. Dolomite, irregularly laminated pinkish-gray (5*YR* 8/1) and yellowish-gray (5*Y* 8/1), very finely crystalline, saccharoidal; contains scattered small lenses of gray chert; medium-bedded (beds are less than 2 ft thick); weathers pinkish gray. (H56–302)	13	165+
10. Dolomite, grayish-pink, medium-crystalline, saccharoidal; laminated by layers of rounded medium to coarse quartz grains	4	152+
9. Dolomite, pinkish-gray (5*YR* 8/1), very finely crystalline, saccharoidal, thin-bedded; weathers yellowish gray. (H56–301)	6	148+
8. Dolomite, yellowish-gray (5*Y* 8/1) with streaks and laminae of light brownish-gray (5*YR* 6/1), very finely crystalline, saccharoidal; contains a small amount of quartz silt; invertebrate tracks occur on bedding planes; mottling indicates activity of mud-burrowing animals; thick-bedded (beds are as much as 3 ft thick); weathers yellowish gray. (H56–300)	12	142+
7. Dolomite, medium light-gray, finely crystalline, saccharoidal, thin-bedded	4	130+
6. Dolomite, medium light-gray, finely crystalline, saccharoidal, thick-bedded (beds are as much as 3 ft thick)	9	126+
5. Dolomite, mottled shades of pale red (5*R* 6/2 to 10*R* 6/2), very finely crystalline, saccharoidal; weathers into dolomitic powder; slope-forming; weathers pale red. (H56–299)	5	117+
4. Dolomite, grayish orange-pink (5*YR* 7/2), finely crystalline; has irregularly distributed porosity; contains crinoid ossicles and gastropod(?) remains; on weathering tends to disintegrate into dolomitic siltlike powder; weathers pale red. (H56–297, 298)	21	112+
3. Dolomite, pinkish-gray (5YR 8/1), very finely to finely crystalline, saccharoidal, friable; on weathering tends to disintegrate into dolomitic siltlike powder; weathers grayish orange pink. (H56–296)	21	91+
2. Dolomite, pinkish-gray (5YR 8/1), very finely crystalline, laminated; some beds are brecciated; uppermost 2 ft. is very sandy, containing shattered rounded quartz grains as much as 0.7 mm in diameter; thin-bedded; weathers yellowish gray. (H56–294, 295)	12	70+

SECTION 43. *Verde River at Sycamore Creek*—Continued

Martin Formation—Continued Jerome Member—Continued Aphanitic dolomite unit:	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
1. Dolomite, more or less calcitic, pinkish-gray (5*YR* 8/1), very finely crystalline to aphanitic; part has conchoidal fracture; contains very little detrital quartz greater than silt size; thin-bedded; weathers pinkish gray; during weathering rock tends to disintegrate into a fine chalklike dolomitic powder. (H56–288, 289, 290, 291, 292, 293)	58+	58+

Base of section cut off by fault.

SECTION 44.—*Elden Mountains*

[Eastern slope of Elden Mountains (Flagstaff quadrangle, NW¼ sec. 30, T. 22 N., R. 8 E.). Measured by Curt Teichert and R. L. Harbour, 1956]

Martin Formation: Jerome Member: Upper unit:	*Sub-unit thickness (feet)*	*Cumulative thickness (feet)*
16. Covered interval	14	181
15. Dolomite, light brownish-gray (5*YR* 6/1), medium-bedded, very fine grained; porous, perhaps due to leaching of tubular fossil structures(?); weathers brownish gray. (T56–583)	2	167
14. Covered interval	31	165
13. Dolomite, light brownish-gray (5*YR* 6/1), thick-bedded, hard, very porous, very fine grained; weathers brownish gray. (T56–582)	2	134
12. Covered interval	16	132
11. Dolomite, light-gray (*N* 7), thick-bedded, hard, very fine grained, very porous; contains brachiopod fragments; weathers light gray. (T56–581)	9	116
10. Covered interval	9	107
9. Dolomite, yellowish-gray (5*Y* 8/1), medium-bedded, medium-grained; consists of idiomorphic to hypidiomorphic dolomite crystals; very porous due to weathering out of tubular fossil structure (*Amphipora*?). (T56–580)	2	98
8. Dolomite, light-gray, thin-bedded to; flaggy; otherwise similar to subunit 7; weathers very light gray	3	96
7. Dolomite, light-gray (*N* 7), medium-bedded, hard, very porous, very fine grained; contains hypidiomorphic dolomite crystals; contains ghost structures of brachiopod or ostracode shells; contains scattered detrital quartz silt and a few larger grains as much as 0.3 mm in diameter; weathers yellowish brown. (T56–579)	5	93

SECTION 44.—*Elden Mountains*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
6. Dolomite, pale red-purple (5*RP* 6/2), thin-bedded, hard, laminated, very fine to fine-grained, silty; consists of hypidiomorphic dolomite crystals and detrital quartz silt; weathers yellowish brown. (T56–578)	25	88
5. Dolomite, light-gray, thin-bedded to flaggy, fine-grained; weathers light gray	12	63
4. Dolomite, mottled pale-red (5*R* 6/2) and greenish-gray (5 *GY* 6/1), medium-bedded, hard, medium grained; consists of allotriomorphic dolomite crystals having crenulated, interlocking boundaries; contains large open vugs (maximum of 1 in. in diameter) partly filled with calcite; weathers pale brown. (T56–577)	11	51
3. Dolomite, pinkish-gray (5*YR* 8/1) to yellowish-gray (5*Y* 8/1), thin-bedded, hard; consists of a very fine grained crystal aggregate; weathers yellowish gray. (T56–576)	22	40
2. Dolomite, grayish-pink (5*R* 8/2) to light olive-gray (5*Y* 6/1), thick-bedded, fine-grained, saccharoidal; consists of idiomorphic to hypidiomorphic dolomite crystals, which in places are embedded in larger calcite crystals; weathers medium gray to yellowish gray. (T56–575)	3	18
1. Dolomite, grayish orange-pink (5*YR* 7/2) to pinkish-gray (5*YR* 8/1) and some pale-red (5*R* 6/2), medium-bedded, fine grained, saccharoidal; consists of hypidiomorphic dolomite crystals; at least one bed is rich in *Amphipora;* weathers yellowish gray. (T56–573, 574)	15	15

Base of section not exposed.

SECTION 45.—*South of Iron King mine*

[On small eastern tributary of Canyon Creek, about 1½ miles south of abandoned iron mine. (SE¼NE¼ sec. 15, T. 9 N., R. 15½ E., unsurveyed). Photograph lots AK 3235, 3226. Measured by Curt Teichert, 1960]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit:		
16. Covered, but contains grayish-pink fine-grained fossiliferous limestone having abundant silicified specimens of *Cyrtospirifer* sp. and *Atrypa* sp	30	135
15. Dolomite, pale-red (5*R* 6/2) mottled grayish-pink (5*R* 8/2), very fine grained; contains abundant fossil debris (spiriferids, *Atrypa* sp., crinoid remains); weathers grayish red	2	105
14. Covered	10.5	103

SECTION 45.—*South of Iron King mine*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
13. Dolomite, slightly calcitic, light-brown (5*YR* 6/4) with pale-red mottling, medium-crystalline, medium-bedded; weathers pale brown	2	92.5
12. Covered	11.5	90.5
11. Limestone, medium-gray (*N* 5), very fine grained; contains scattered detrital quartz grains as much as 1 mm in diameter; thick-bedded; uppermost 3 ft. is rich in silicified stromatoporoids and *Thamnopora* sp.; weathers medium light gray	7	79
10. Limestone, medium light-gray (*N* 6), flaggy, very fine grained; uppermost 6 in. contains stromatoporoid fragments	2	72
9. Sandstone, grayish-pink (5*R* 8/2), coarse-grained; contains much calcareous cement; contains well-rounded frosted quartz grains; thick-bedded; weathers light brown	6	70
8. Covered	2	64
7. Sandstone, pale-red (5*R* 6/2), coarse-grained; contains large amount of dolomitic cement (probably as much as 50 percent); contains well-rounded frosted quartz grains; medium-bedded; weathers pale brown	2	62
6. Covered	3	60
5. Dolomite, very slightly calcitic, grayish orange-pink (5*YR* 7/2), very fine grained; contains a few small calcite vugs; thick-bedded (beds are as much as 3 ft thick); some beds are laminated; weathers medium gray	8	57
4. Covered interval except for one 6-in. bed of pale-red fine-grained dolomite, 4½–5 ft from base of subunit	11	49
3. Dolomite, pale-red (5*R* 6/2), very fine grained; contains no detrital quartz; thin- to medium-bedded; weathers grayish orange pink	11.5	38
2. Covered, but rock probably similar to subunit 1	5	26.5
1. Dolomite, pale-red (5*R* 6/2), very finely crystalline; contains scattered detrital quartz grains as much as 0.5 mm diameter; medium-bedded (beds are generally 8–18 in. thick, but some are thinner); finely laminated beds occur in middle of subunit; uppermost 1 ft contains large colonies of *Spongophyllum* sp.; weathers generally grayish red to pale red	21.5	21.5

Base not exposed, but spring at base of subunit 1 suggests that base rests on impermeable basement, probably Dripping Spring Quartzite.

SECTION 46.—*Sevenmile Creek*

[On east side of Sevenmile Creek, about 5 miles downstream from crossing of U.S. Highway 60. (SE¼ sec. 8, T. 2 N., R. 17 E., unsurveyed). Photograph lots AK 1892, 1893. Measured by Curt Teichert, 1960]

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation:		
Jerome Member:		
Upper unit:		
26. Shale, olive, poorly exposed ("green shale" zone)	42	258
25. Siltstone, poorly exposed; contains three beds of dolomitic limestone; forming, ledges at 5 and 15 ft above base, one ledge at top of unit. The dolomitic limestone is dark yellowish orange (10*YR* 6/6), to moderate yellowish brown (10*YR* 5/4); very finely crystalline; lowest bed contains fish plates and crinoid ossicles. Limestone beds weather dark yellowish orange. (T60–91, 92)	30	216
24. Dolomite, very slightly calcitic, light-brown (5*YR* 6/4), very finely crystalline; contains large crinoid stems about 15 mm in diameter; contains scattered garnet grains as much as 1 mm in diameter, probably of authigenic origin; weathers dark yellowish orange. (T60–90)	1.5	186
23. Limestone, generally light-gray (*N* 7), coarsely crinoidal; contains fragmental brachiopods; thick-bedded; contains a considerable component of detrital quartz grains as much as 3 mm in diameter; particularly sandy in middle part of subunit, where large, slightly ribbed atrypids occur; weathers light olive gray. (T60–89)	20	184.5
22. Sandstone, pale yellowish-brown (10*YR* 6/2), fine-grained; contains scattered larger quartz grains as much as 1 mm in diameter; contains a large amount of cement composed of calcitic dolomite; thin-bedded, crossbedded; invertebrate parts common on most bedding planes; abundant vertical burrows occur in lower half of subunit; weathers moderate yellow. (T60–88)	5	164.5
21. Dolomite, calcitic, yellowish-gray (5*Y* 7/2), very fine grained, thick-bedded; penetrated by tubular twisting burrow structures about 5 mm in diameter; weathers dusky yellow. (T60–87)	6	159.5

SECTION 46.—*Sevenmile Creek*—Continued

	Subunit thickness (feet)	*Cumulative thickness (feet)*
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
20. Dolomite, calcitic, yellowish-gray (5*Y* 7/2), finely crystalline; contains lenses and layers of undolomotized crinoidal limestone, which are as much as 4 in. thick; thin- to medium-bedded; weathers yellowish gray. (T60–86)	5	153.5
19. Covered	5	148.5
18. Dolomite, very slightly calcitic, grayish orange-pink (5*YR* 7/2), very finely crystalline; thin- to medium-bedded; contains one 3-ft bed 5–8 ft above base of subunit; laminated in parts; probably somewhat silty; lowermost 6 in. rich in crinoidal debris; weathers light brown. (T60–85)	10	143.5
17. Sandstone, mottled pale-brown (5*YR* 5/2) and very pale orange (10*YR* 8/2), fine-grained; has a calcareous cement; medium-bedded, very crossbedded; locally invertebrate tracks occur on bedding planes; weathers light brown. (T60–84)	10	133.5
16. Sandstone, grayish-red (5*R* 4/2), coarse-grained to very coarse grained; contains a considerable amount of calcareous-dolomitic cement and crinoid ossicles as much as ⅝ in. in diameter; medium- to thick-bedded, very crossbedded; cliff-forming; weathers pale brown. (T60–83)	8.5	123.5
Aphanitic dolomite unit:		
15. Dolomite, pale-red (5*R* 6/2), aphanitic; has a very finely clastic texture, in which individual clasts are generally less than 1 mm in diameter; medium-bedded; weathers grayish orange pink. (T60–82)	8.5	115
14. Dolomite, pale-red (10*R* 6/2), aphanitic, generally homogeneous; contains scattered lighter colored aphanitic clasts as much as 2 mm in diameter; contains a few scattered detrital quartz grains as much as 1 mm in diameter; thin-bedded; poorly exposed; weathers yellowish gray. (T60–81)	10.5	106.5
13. Dolomite, pale-red (10*R* 6/2), aphanitic, finely brecciated, thick-bedded, partly vuggy; weathers grayish orange pink. (T60–80)	5	96

SECTION 46.—*Sevenmile Creek*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Aphanitic dolomite unit—Continued		
12. Dolomite, pale-red (*R* 6/2), aphanitic, thin-bedded; contains interbedded shale and siltstone layers; contains abundant detrital quartz grains as much as about 0.5 mm in diameter; poorly exposed; weathers grayish orange. (T60–79)	7	91
11. Dolomite, various shades of pale red and pink (5*R* 6/2 to 10*R* 8/2), brecciated and conglomeratic; consists mostly of angular or rounded fragments of aphanitic dolomite, ranging from a few to about 20 mm in diameter; weathers grayish orange. (T60–78)	5	84
10. Covered (probably thin-bedded aphanitic dolomite). (T60–77)	11	79
9. Dolomite, pinkish-gray (5*YR* 8/1), very fine grained but having some aphanitic parts, medium- to thin-bedded; very vuggy, most pore spaces empty; weathers yellowish gray	3	68
8. Dolomite, grayish orange-pink (10*R* 8/2), aphanitic, medium- to thick-bedded; slightly vuggy, pore spaces either empty or partly filled with light-colored calcite; weathers very pale orange. (T60–76)	5	65
7. Dolomite, light brownish-gray (5*YR* 6/1), aphanitic, medium-bedded, unlaminated; very vuggy, pore spares either empty or filled with only a little brown calcite; weathers yellowish gray with very pitted surface. (T60–75)	11	60
6. Dolomite, light brownish-gray (5*YR* 6/1), aphanitic, thick-bedded, laminated; contains small rounded chert concretions having brown rinds; weathers very pale orange. (T60–74)	7.5	49
5. Dolomite, pale-brown (5*YR* 5/2), subaphanitic, laminated; contains closely spaced small irregular calcite vugs; weathers pale yellowish brown. (T60–73)	3	41.5
Fetid dolomite unit:		
4. Dolomite, pale-red (5*R* 6/2), medium-crystalline, very massive, almost unbedded; contains varying amounts of chert, partly in large concretionary lumps several feet in diameter; rubbly and conglomeratic zone occurs from 6½–8 ft. above base of subunit; some beds emit weak fetid odor; weathers light brown with very cavernous surface. (T60–69, 70, 71)	12	38.5
3. Dolomite, light brownish-gray (5*YR* 6/1), thick-bedded, thinly laminated throughout; generally porous having		

SECTION 46.—*Sevenmile Creek*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Fetid dolomite unit—Continued		
3. Dolomite, etc.—Continued vugs as much as ½ in. in diameter; slightly fetid odor; extensive interstratal solution occurs along some bedding planes; uppermost 5 ft. has scattered chert nodules as much as ½×1½ inches in cross section; weathers light brown	17.5	26.5
2. Dolomite, mottled pale-red (5*R* 6/2) and pale-brown (5*YR* 5/2), coarsely crystalline, slightly porous; weathers pale reddish brown	3	9
Beckers Butte Member:		
1. Sandstone, light-brown (5*YR* 6/), medium- to coarse-grained; rich in green-tinted mineral grains (glauconite?); very weathered and crumbles in outcrops. (T60–67, 68)	6	6
Precambrian: Volcanic rocks.		

SECTION 47.—*Mormon Tank*

[About half a mile southeast of Mormon Tank (Fort Apache Indian Reservation, near center sec. 18,, T. 4 N., R. 19 E., unsurveyed). Photograph lots AK 1989, 1990. Measured by Curt Teichert, 1960]

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation:		
Jerome Member:		
Upper unit (top of section eroded):		
15. Sandstone, light-brown (5*YR* 6/4), fine- to medium-grained, hard; has slightly calcareous matrix; thin- to medium-bedded; abundant narrow invertebrate trails having median furrow occur on most bedding planes; 10 ft above base is one bed containing poorly preserved pelecypods having possibly pteriid affinities; weathers moderate brown. (T60–65, 66)	38+	273+
14. Sandstone, brown, thin-bedded, fine-grained, soft; matrix slightly calcareous; poorly exposed; slope-forming	15	235
13. Dolomite, grayish (orange-pink (5YR 7/2), medium-crystalline, hard, slightly crossbedded; contains *Thamnopora* sp. and silicified brachiopod fragments; weathers light brown. (T60–64)	2	220
12. Dolomite, pale-red, fine-grained, lower 3 ft is sandy; laminated; weathers with pitted surface; poorly exposed	18	218
11. Dolomite, streaky grayish orange-pink (10*R* 8/2) and grayish-pink (5*R* 8/2), very slightly calcite, very fine grained; laminated and in places brecciated; weathers light brown. (T60–63)	4	200
10. Dolomite, light brownish-gray (5*YR* 6/1), very finely crystalline; sandy near base, contains large calcite vugs higher up; medium-bedded (beds 9–12 in. thick); weathers light brown. (T60–62)	12	196

SECTION 47.—*Mormon Tank*—Continued

	Sub-unit thickness (feet)	Cumulative thickness (feet)
Martin Formation—Continued		
Jerome Member—Continued		
Upper unit—Continued		
9. Sandstone, pale-red (5*R* 6/2), fine-grained, quartzitic, thin-bedded, slope-forming; weathers light- to medium-gray. (T60–61)	21	184
Aphanitic dolomite unit:		
[This unit is very poorly exposed; slope is covered with dolomite talus. The following descriptions are generalized and based predominantly on talus material and a few outcropping rock ledges]		
8. Dolomite, aphanitic, pale-red (5*R* 6/2) to 10*R* 6/2) to grayish-pink (5*R* 8/2), generally thick-bedded; some beds contain varying quantities of detrital quartz; some beds are brecciated or contain dolomite clasts. (T60–58, 59, 60)	41	163
7. Covered	16	122
6. Dolomite, pale-red, very fine grained, thick-bedded; contains a few calcite vugs as much as 1 mm in diameter	10	106
5. Dolomite, light brownish-gray (5*YR* 6/1), aphanitic; in part rich in detrital quartz grains, in part very porous, having small cavities either void or lined or filled with brown calcite; weathers generally yellowish gray. (T60–56, 57)	15	96
4. Dolomite, medium light-gray (*N* 6), aphanitic; contains brown rind chert nodules, generally flat, as much as 1 in. long and a fraction of an inch thick	23	81
3. Dolomite, light brownish-gray (5*YR* 6/1) to brownish-gray (5*YR* 4/1), aphanitic; some beds contain scattered detrital quartz grains; some beds are laminated; weathers generally yellowish gray. (T60–54, 55)	27	58
2. Dolomite, pale yellowish-brown (10*YR* 6/2), finely crystalline, thick-bedded, laminated; emits weak fetid odor; uppermost 8 ft cherty and brecciated, the silica occurring in spongy lumps having saccharoidal texture. (T60–53)	28	31
1. Dolomite, pale yellowish-brown (10*YR* 6/2), finely crystalline, homogeneous, hard; emitts weak fetid odor; weathers pale yellowish brown. (T60–52)	3	3

Underlain by undifferentiated Beckers Butte Member having an estimated thickness of more than 100 ft.

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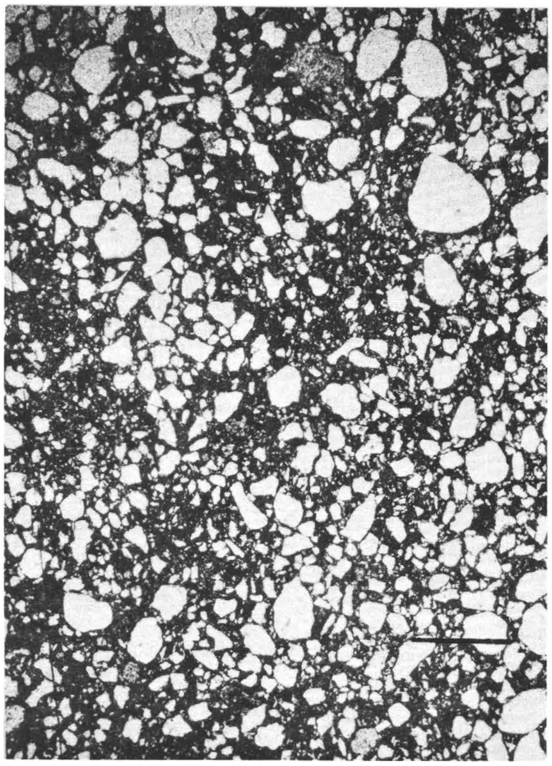
PLATES 1–21

Every individual photograph having an enlargement of × 25 or less is marked by a black or white bar indicating the length of 1 mm in the scale of the illustration. Unless the illustration is described as "unoriented" in the explanation, the photograph is oriented so that the bar lies parallel to the bedding plane and the direction upward from and perpendicular to the bar is also the direction upward in the rock. The number in parentheses at the end of the figure description—for example (T–220)—is the sample number. Points marked by intersection of lines projected from points AA, BB, CC, or DD (for example, fig. 2 of pl. 17) indicate items discussed in the text.

PLATE 1

FIGURE 1. Sandstone containing a considerable amount of calcareous cement. Beckers Butte Member. Section 12, Lost Tank Canyon. × 12.5. (T–220)

2. Sandstone with calcareous cement. Basal part of Beckers Butte Member. Section 2, Black River, subunit 1. × 12.5. (T–54.)
3. Sandstone. Detrital grains are composed mostly of quartz and a small amount of chert and feldspar. The cement is clay. Beckers Butte Member. Section 30, Diamond Point, subunit 5. × 12.5. (H56–190.)
4. Dolomitic microbreccia. Fetid dolomite unit of Jerome Member. Section 2, Black River, subunit 2. × 9. (T56–247.)
5. Very fine grained dolomite having microlamination and intrastratal erosion. Fetid dolomite unit of Jerome Member. Section 39, Chasm Creek, subunit 6. × 15. (H56–252.)



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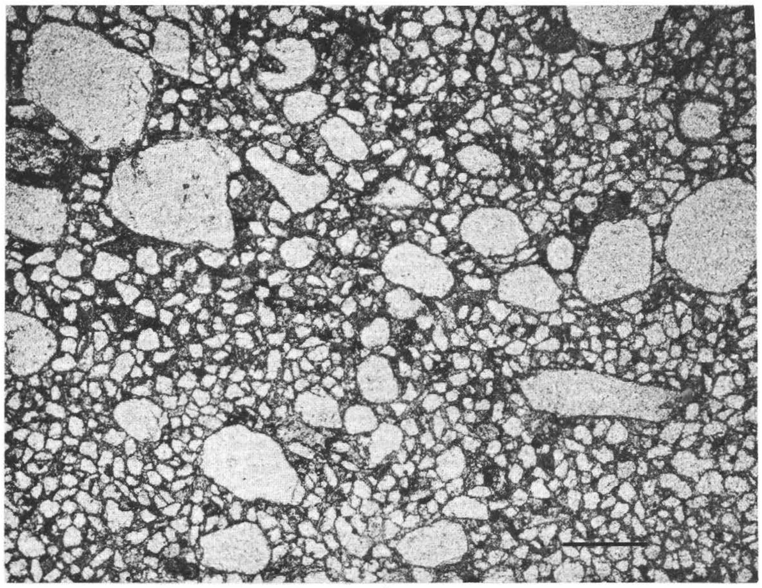

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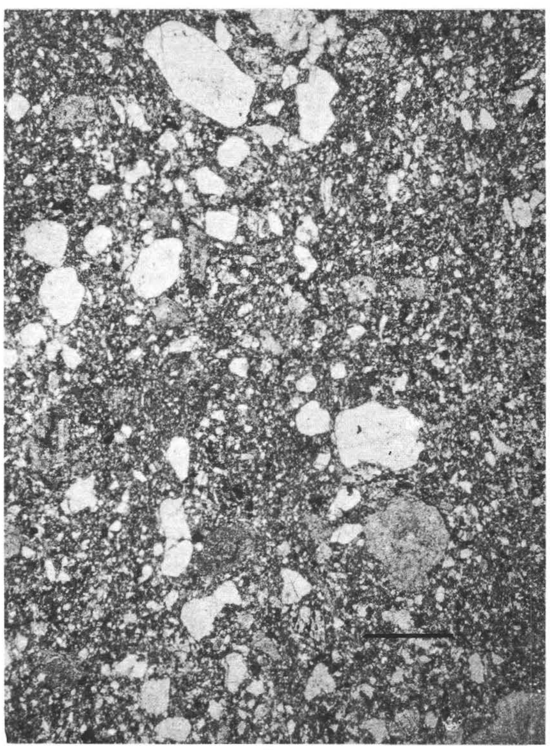

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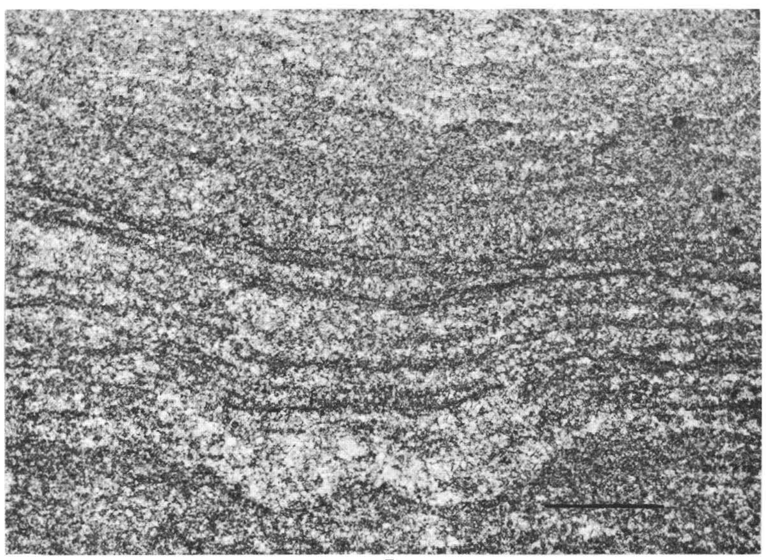

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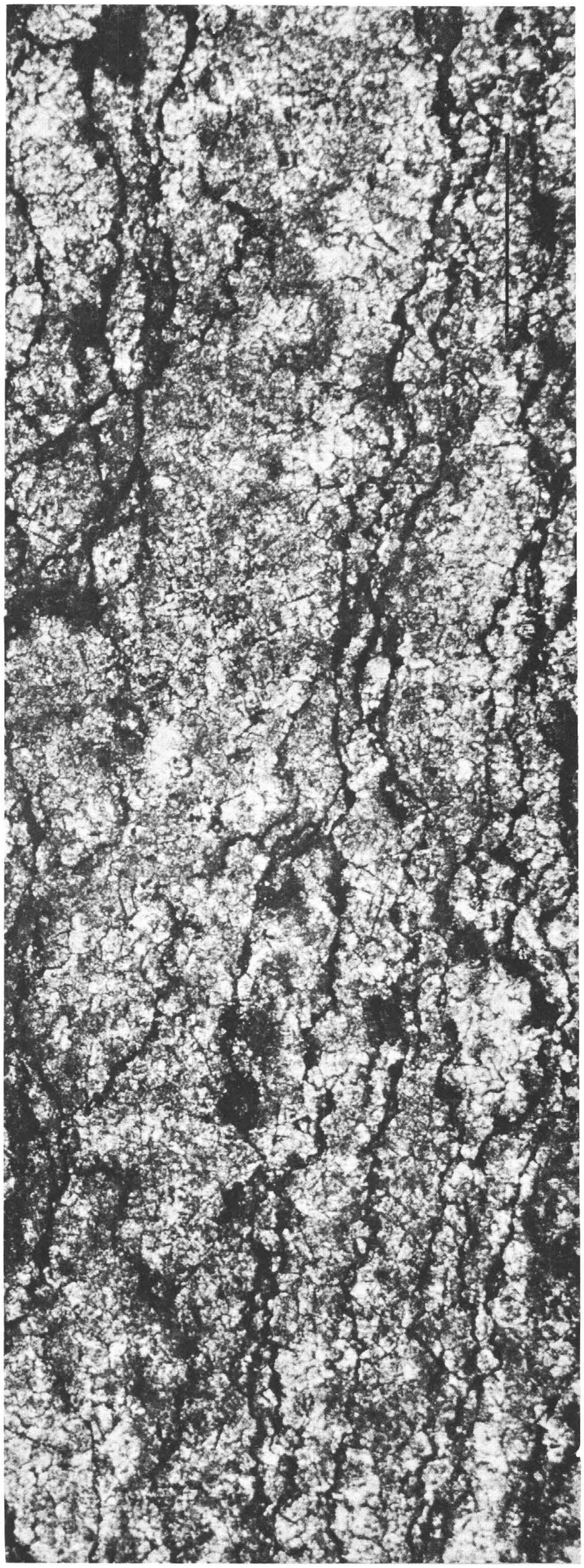
ROCKS OF THE BECKERS BUTTE MEMBER AND THE FETID DOLOMITE UNIT OF JEROME MEMBER

PLATE 2

Figure 1. Very fine grained dolomite having thin opaque laminae. Section 4, Salt River, subunit 2. × 25. (T56–285.)

2. Aphanitic thinly laminated limestone. Section 31, Webber Creek, subunit 15. × 25. (T56–512.)



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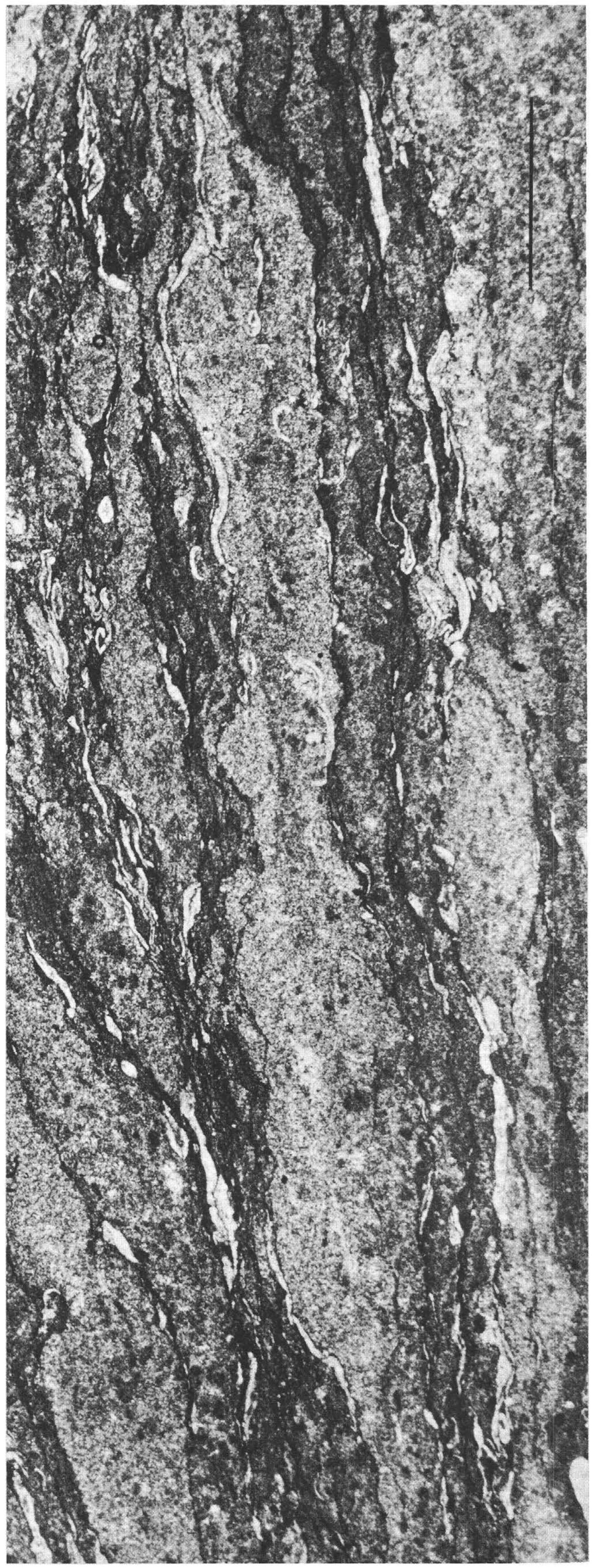

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ROCKS OF THE FETID DOLOMITE UNIT OF THE JEROME MEMBER

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PLATE 3

FIGURE 1. Very fine grained clotty limestone, indistinctly laminated. Same locality and rock subunit as figure 2 of plate 2. × 25. (T56–512.)

1

ROCK OF THE FETID DOLOMITE UNIT OF THE JEROME MEMBER

PLATE 4

FIGURE 1. Very fine grained dolomite and irregular layers of aphanitic dolomite. Section 34, Tonto Natural Bridge, subunit 3. ×15. (T56–468.)

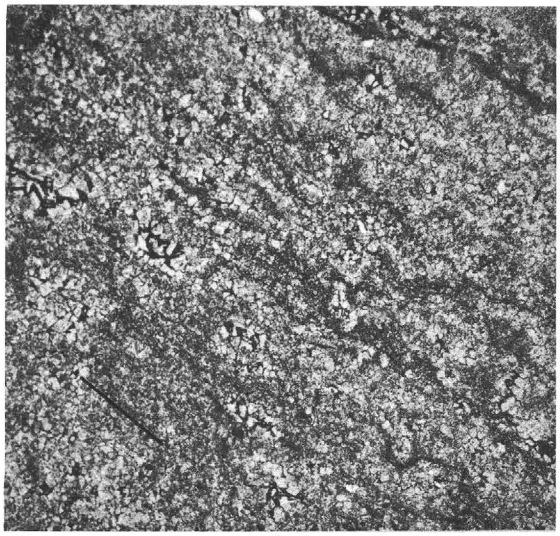
2. Silica-impregnated aphanitic dolomite breccia (for description see p. 39). Section 39, Chasm Creek, subunit 9. ×15. (H56–255a.)

3. Aphanitic dolomite containing two kinds of differently colored intraclasts and having an extensively recrystallized matrix. Section 39, Chasm Creek, subunit 12. ×15. (H56–259.)

4. Intraclastic subaphanitic dolomite. Clasts range 0.05 to 2 mm in diameter and are more finely aphanitic than matrix. Lower part of unit. Section 37, Windy Hill, subunit 3. ×15. (H56–344.)

5. Chert-impregnated fine-grained dolomite. Section 36, Roosevelt, subunit 10. All large and small white areas are chert. ×12.5. (H56–68.)

6. Aphanitic dolomite breccia; fractures are filled with finely crystalline dolomite. Section 3, Flying V Canyon, subunit 20. ×15. (H56–51.)



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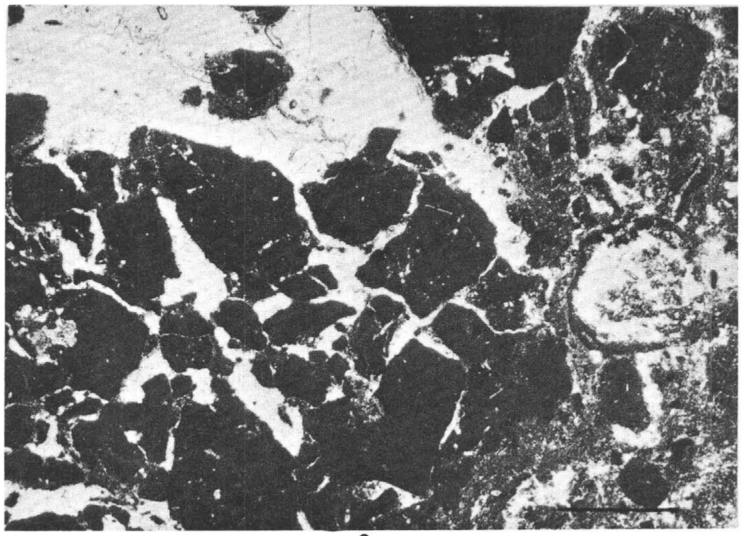

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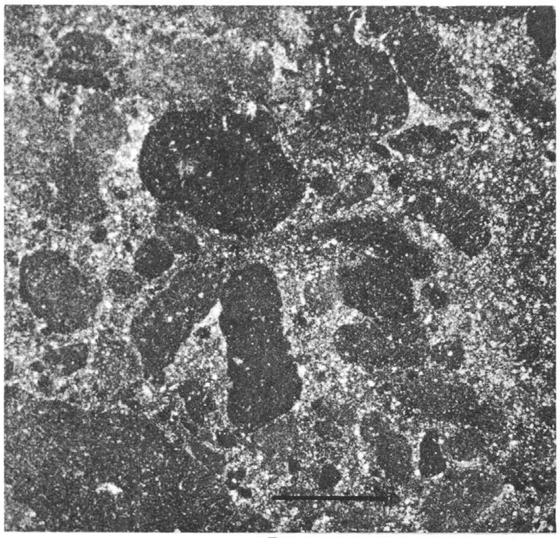

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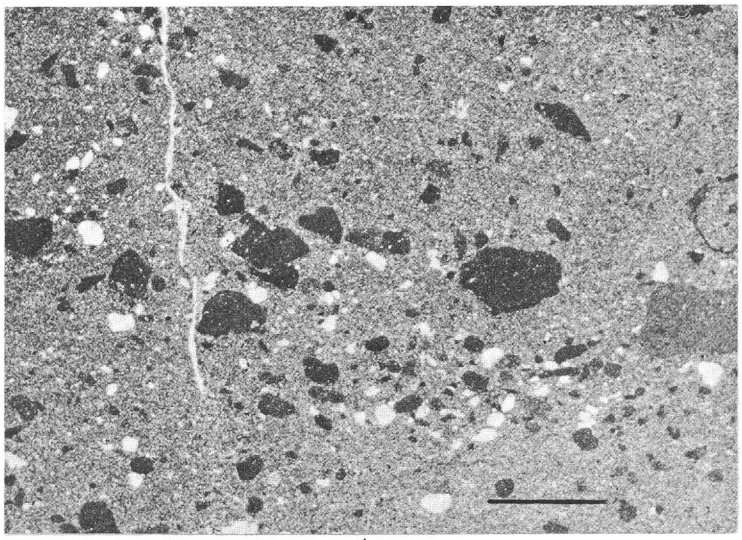

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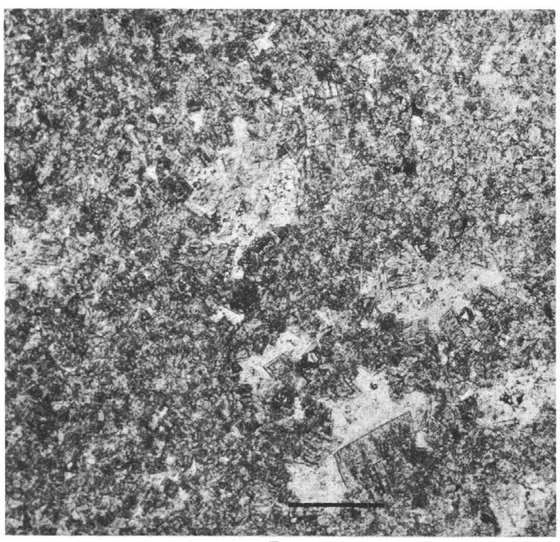

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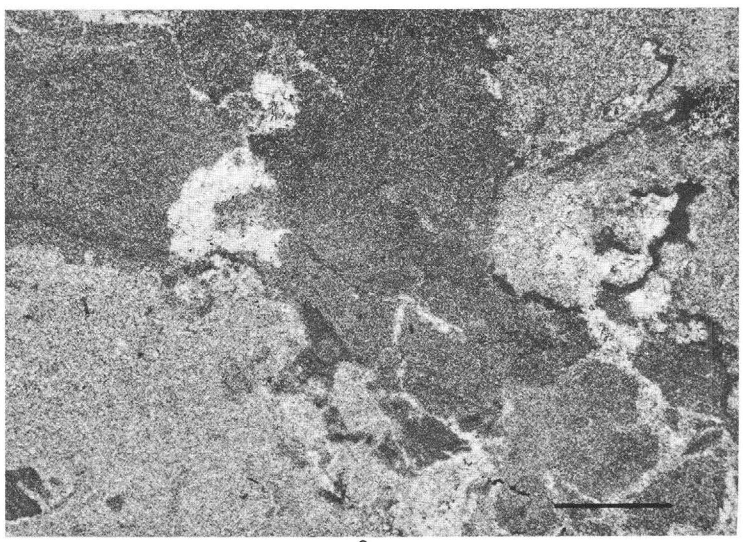

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ROCKS OF THE APHANITIC DOLOMITE UNIT OF THE JEROME MEMBER

PLATE 5

FIGURE 1. Aphanitic limestone, primarily intraclastic, partially recrystallized. Section 34, Tonto Natural Bridge, subunit 15. × 15. (T56–479.)

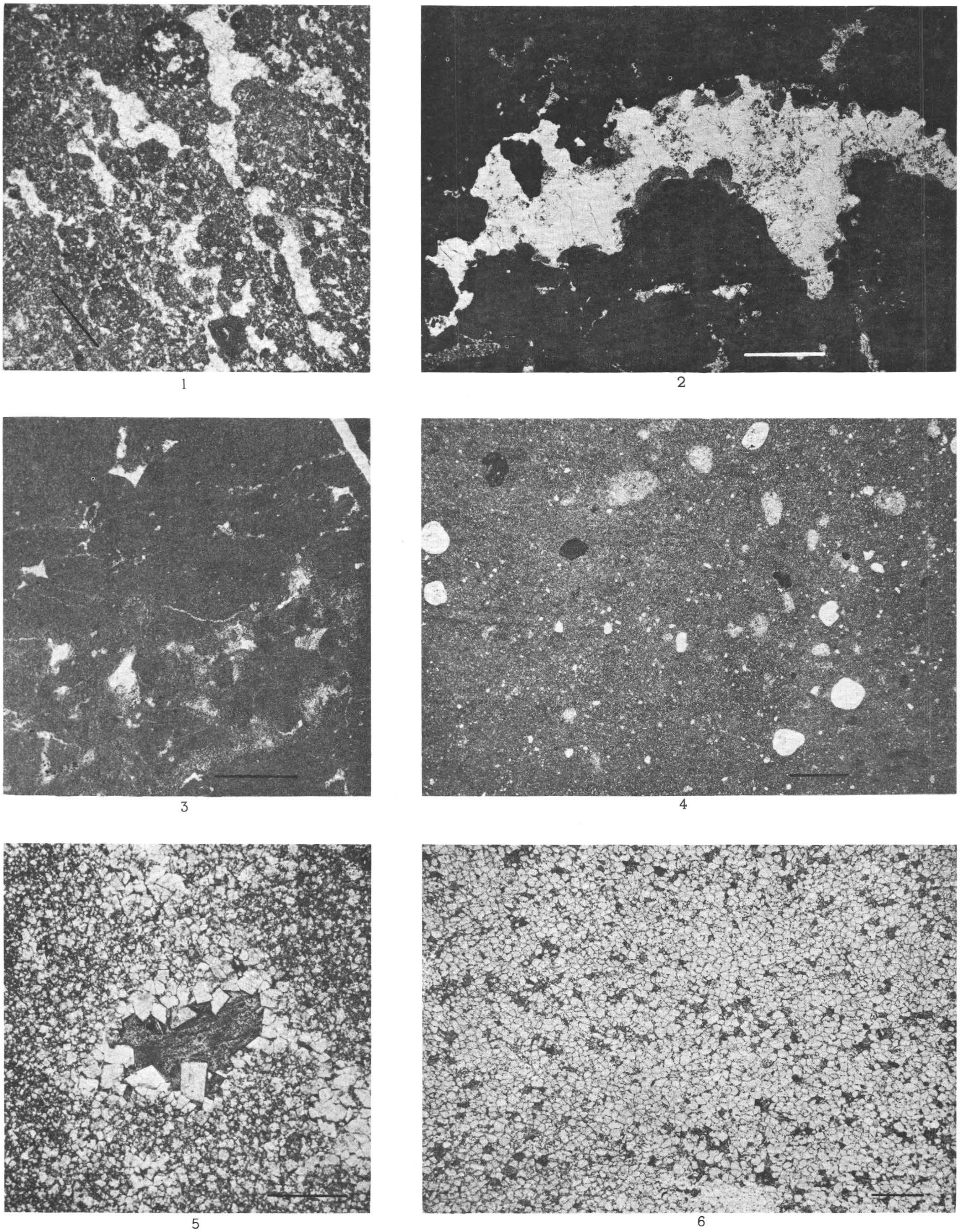
2. Aphanitic dolomite containing a large cavity filled with spherulitic quartz, which is marginally replaced by dolomite. The large white area is spherulitic quartz; the black area surrounding it is aphanitic dolomite; the gray cloudy belts at the margins of the quartz area are aphanitic dolomite, which is more transparent than the original dolomite rock. The smaller irregularly shaped gray areas scattered across the specimen are crystalline dolomite. Section 39, Chasm Creek, subunit 10. × 15. (H56–258.)

3. Aphanitic dolomite having indistinct primary lamination and containing secondary calcite (white patches). Section 37, Windy Hill, subunit 3. × 15. (H56–343.)

4. Aphanitic dolomite containing detrital quartz grains (white), small aphanitic dolomite clasts (dark), and recrystallized dolomite clasts. Section 38, Limestone Hills, subunit 13. × 9. (H56–328.)

5. Fine-grained to very fine grained dolomite containing a calcite vug. The dark area in center is one single calcite crystal (stained). Section 33, Upper Sycamore Canyon, subunit 10. × 15. (H56–227.)

6. Very fine grained sandstone. The dark patches are dolomitic cement. Section 37, Windy Hill, subunit 5. × 9. (H56–346.)



ROCKS OF THE APHANITIC DOLOMITE UNIT OF THE JEROME MEMBER

PLATE 6

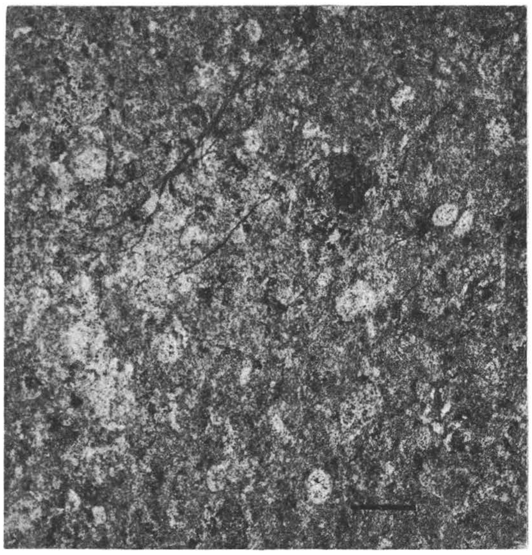
FIGURE 1. Aphanitic dolomite thoroughly impregnated with microcrystalline silica and containing silicified shells of calcispheres. Dark-gray areas are dolomite; light-gray and white areas are silica. Top of unit. Section 4, Salt River, subunit 8. × 9. (T56–293b.)

2. Aphanitic limestone containing ostracodes (*Hypotetragona* sp.). Upper part of unit. Section 32, East Verde River, subunit 22. × 12X. (T–317.)

3. Fossiliferous dolomite. The dark groundmass is aphanitic dolomite; the white areas are crystalline dolomite. Note outlines of small ostracodes in lower right corner and shell fragments scattered throughout most of specimen. Section 8, Canyon Creek, subunit 5. × 30. (H56–40.)

4. Aphanitic dolomite containing thoroughly recrystallized, dolomitic calcispheres. Top of unit. Section 41, Jerome, subunit 14. × 22.5. (H56–285.)

5. Aphanitic dolomite containing authigenic spherulitic quartz. Section 38, Limestone Hills, subunit 8. × 15. Crossed nicols. (H56–317.) Unoriented.



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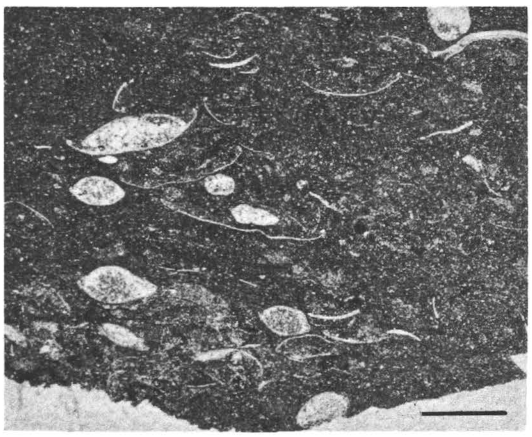

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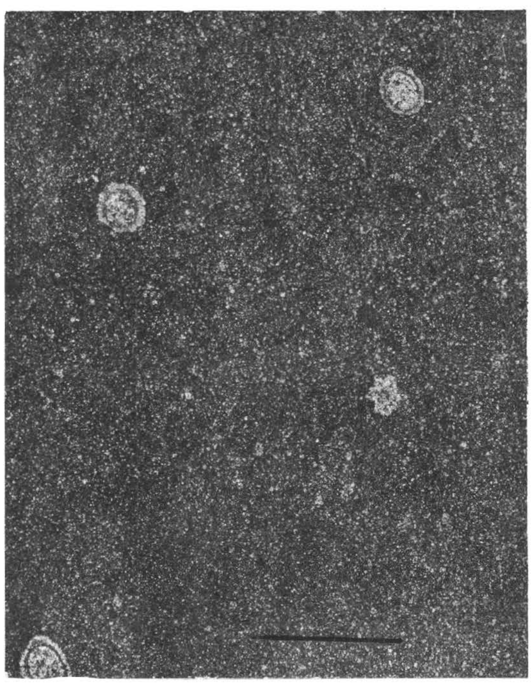

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ROCKS OF THE APHANITIC DOLOMITE UNIT OF THE JEROME MEMBER

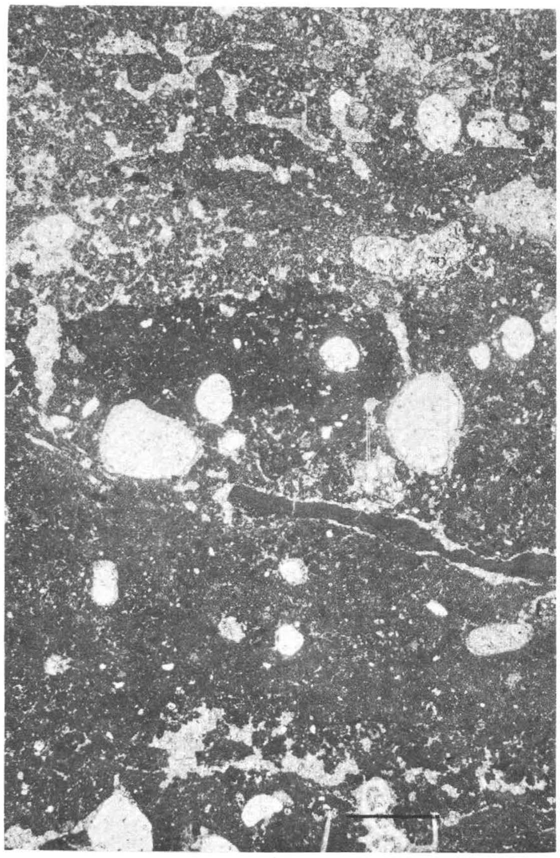
PLATE 7

FIGURE 1. Aphanitic dolomite containing much detrital quartz. Some of the matrix has been recrystallized into crystalline dolomite, and almost all quartz grains have thin rims of very fine grained dolomite. Aphanitic dolomite unit. Section 28, Kohl Ranch, subunit 14. × 9. (H56–156.)

2. Aphanitic limestone containing scattered dolomite rhombohedra, doubly terminated authigenic quartz crystals, thin-walled calcispheres, and unidentified fossil debris. Upper unit. Section 34, Tonto Natural Bridge, subunit 21. × 60. (T56–487.) Same thin section as shown in plate 11, figure 5.

3. Calcitic dolomite, very sandy. Groundmass composed of coarse, anhedral dolomite crystals and abundant detrital quartz. Quartz grains only slightly etched. Upper unit. Section 34, Tonto Natural Bridge, subunit 32. × 12.5. (T56–494.)

4. Dolomite. Light parts consist of crystals 20–50 microns in diameter; dark parts of crystals are less than 20 microns in diameter. Lower part of upper unit. Section 41, Jerome, subunit 24. × 12.5. (H56–311.)



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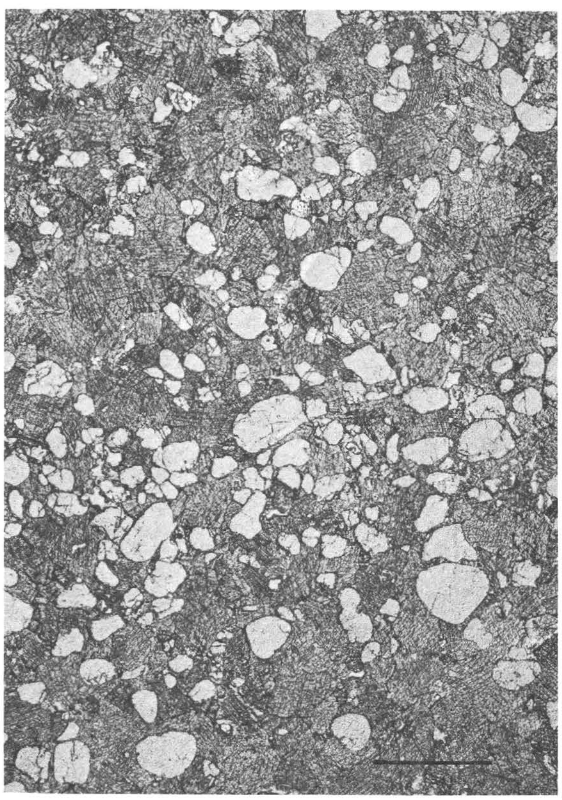

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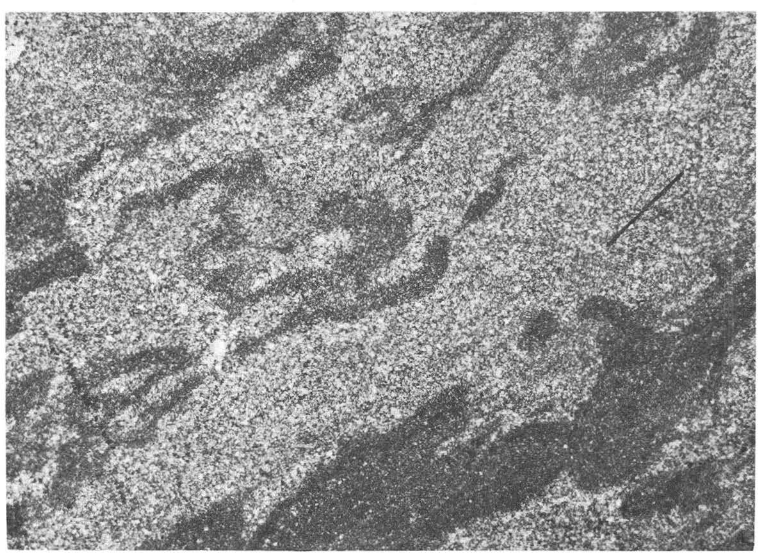

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ROCKS OF THE APHANITIC DOLOMITE UNIT AND THE UPPER UNIT OF THE JEROME MEMBER

PLATE 8

FIGURE 1. Aphanitic limestone containing scattered dolomite rhombohedra, detrital quartz, and organic debris. Cross section of brachiopod spine located just below center; cross sections of echinoid spines occur in upper left and lower left quadrants; several cross sections of shells of punctate brachiopods are shown. Section 38, Limestone Hills, subunit 18. × 22.5 (H56–330.)

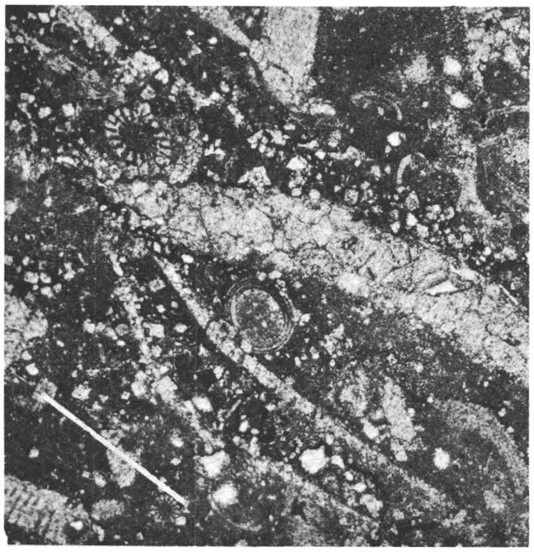
2. Slightly calcitic saccharoidal dolomite and interstitial calcite. White: primary pores. Dark lines between dolomite crystals: calcite (stained). Section 43, Verde River at Sycamore Creek, subunit 18. × 22.5. (T56–557.)

3. Fine-grained dolomite containing "ghosts" of dolomite clasts and microfossils (calcispheres?). Lower part of unit. Section 41, Jerome, subunit 20. × 15. (H56–308.)

4. Calcitic dolomite, very sandy. Dark-gray areas are calcite (stained); each patch has the properties of a single crystal. Section 34, Tonto Natural Bridge, subunit 19. × 15. (T56–485.)

5. Aphanitic limestone and a large area (white to light gray) composed of crystalline calcite (recrystallized), scattered dolomite rhombohedra, doubly terminated authigenic quartz crystals, and fragmental microfossils, including thin-walled calcispheres; cross section of *Amphipora* is shown slightly below the center. Section 34, Tonto Natural Bridge, subunit 21. × 15. (T56–487.) Same thin section as that shown in plate 7, figure 2.

6. Microstylolite in very fine grained dolomite. Section 29, Thompson Wash, subunit 12. × 15. (T57–388.)



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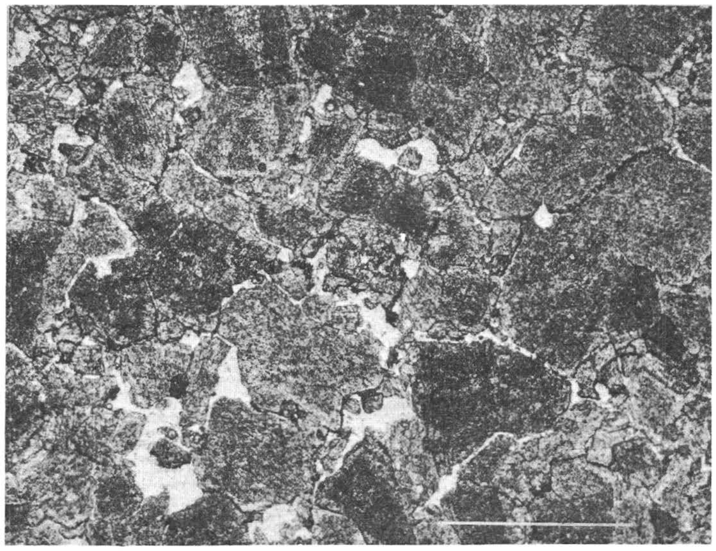

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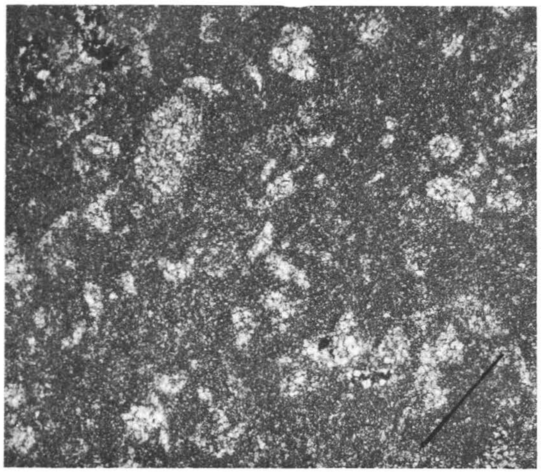

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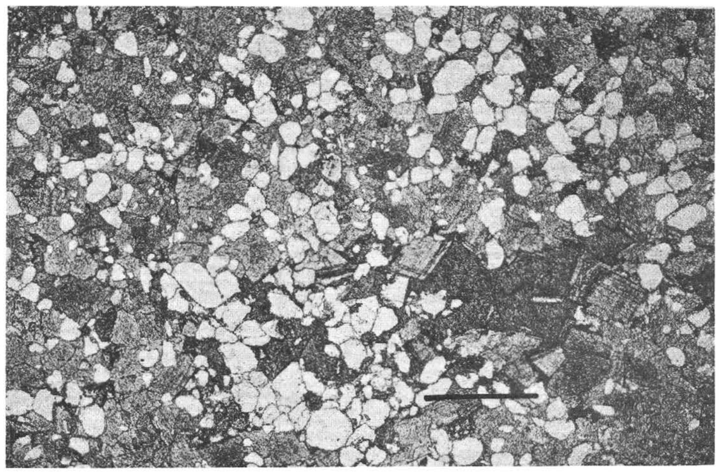

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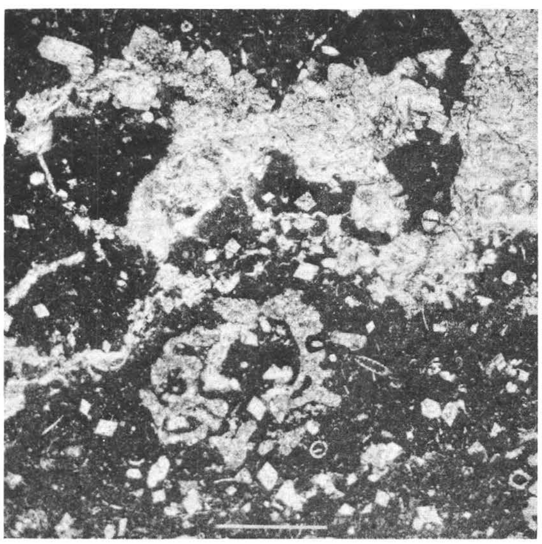

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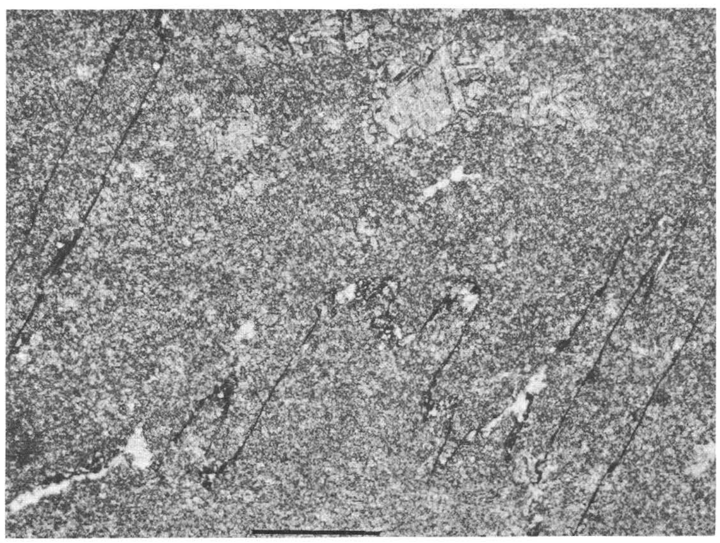

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ROCKS OF THE UPPER UNIT OF THE JEROME MEMBER

PLATE 9

FIGURE 1. Sandy calcitic dolomite. Black: calcite (in extinction position); gray: dolomite rhombohedra, variously oriented; white: detrital quartz. Section 38, Limestone Hills, subunit 31. × 9. Crossed nicols. (H56–331.) Unoriented.

2. Dolomitic limestone. Dark gray: aphanitic limestone matrix; lighter gray: dolomite rhombohedra and quartz silt. Top of unit; section 27, Tonto and Horton Creeks, subunit 20. × 12.5. (T57–370.)

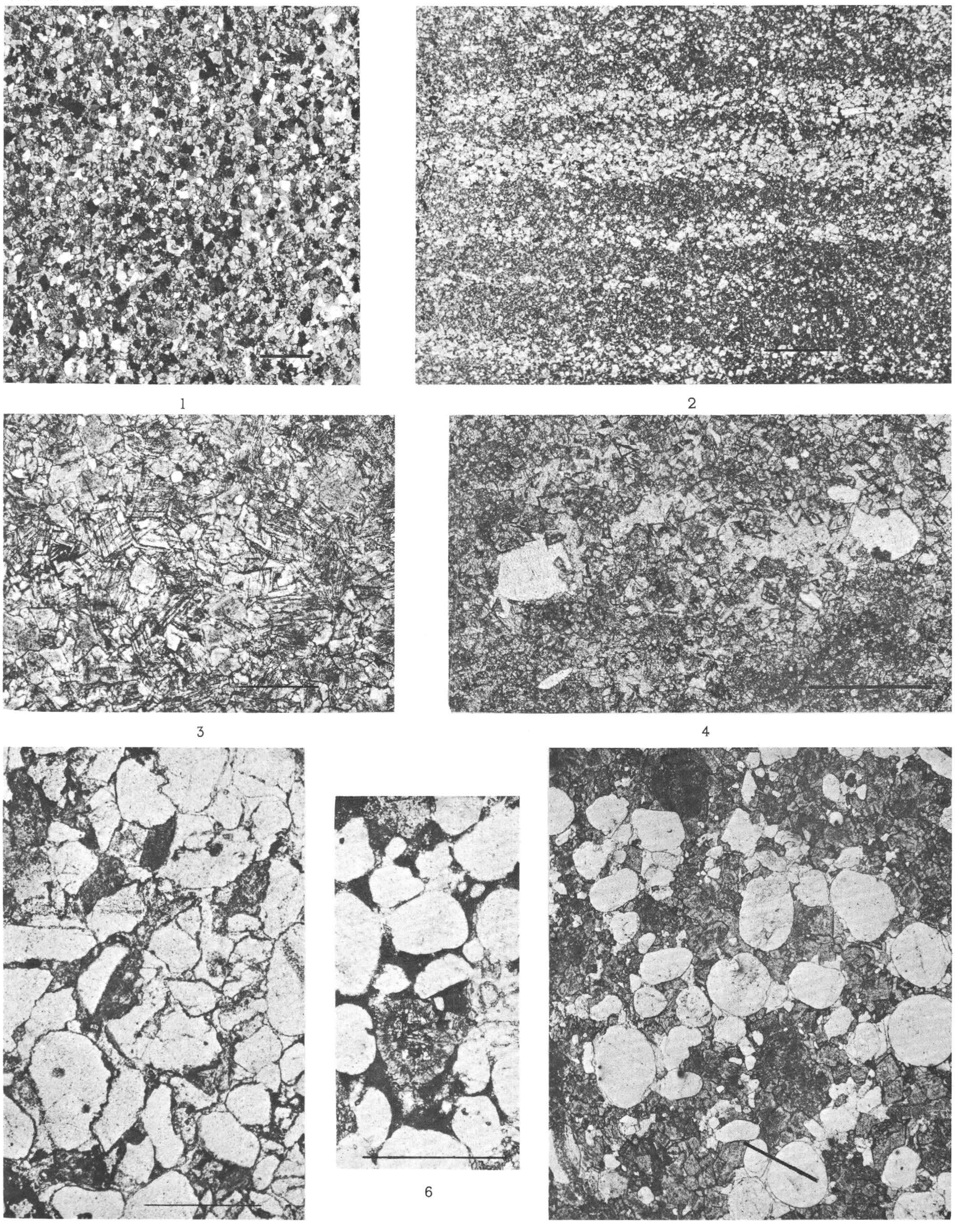
3. Slightly calcitic dolomite: mixture of anhedral and euhedral dolomite crystals, interstitial calcite, and very little detrital quartz. Section 34, Tonto Natural Bridge, subunit 37. × 15. (T56–496.)

4. Slightly calcitic arenaceous dolomite. The two large quartz grains on the left and the right sides of the figure are extensively replaced by dolomite and have entirely lost their original outlines. Section 34, Tonto Natural Bridge, subunit 43. × 22.5. (T56–502.)

5. Sutured grain contacts in thin-bedded sandstone containing invertebrate trails. Near base of unit; section 6, Salt River Draw, subunit 15. × 22.5. (T–101.) Unoriented. (The gray bands cutting across grains in upper left quadrants are pencil marks.)

6. Medium-grained sandstone containing specimen of *Umbella*? sp. near center. Lower part of unit: section 27, Tonto and Horton Creeks, subunit 8. × 22.5. (T57–356.) Unoriented.

7. Dolomitic sandstone having a finely crystalline dolomite matrix in which "ghosts" of pellets or clasts can be recognized. (See especially in upper left quadrant.) Detrital quartz grains have considerable overgrowth and little etching. Section 28, Kohl Ranch, subunit 26. × 15. (H56–175.)



ROCKS OF THE UPPER UNIT OF THE JEROME MEMBER

PLATE 10

FIGURE 1. Calcitic arenaceous dolomite. Interstitial calcite between dolomite crystals, emphasized by staining, and moderate amount of peripheral dolomite replacement of quartz grains are shown. Section 22, west of Christopher Creek Ranch, subunit 4. × 15. (T57–379.)

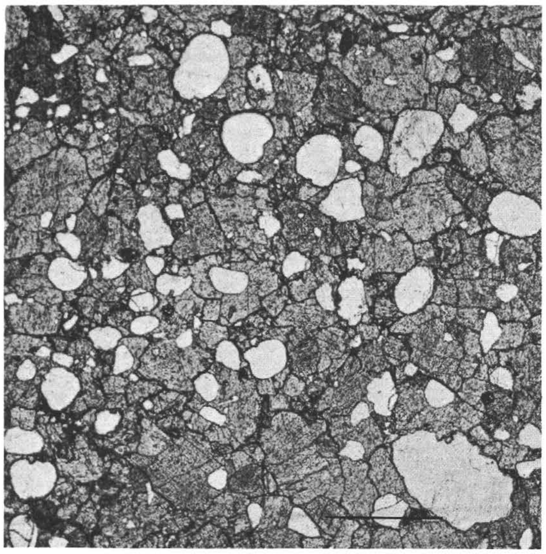
2. Luster mottled dolomite. Partly interpenetrating groups of dolomite crystals having identical optical orientation within each group are shown. Crossed nicols. Section 22, west of Christopher Creek Ranch, subunit 2. × 15. (T57–378.)

3. Dolomite. The aphanitic matrix is recrystallized mostly into finely crystalline aggregate. Calcispheres are preserved in parts of the aphanitic matrix. Section 16, Naeglin Rim, subunit 7. × 8. (T56–412.)

4. Limestone. Dark: aphanitic limestone, granular; translucent: crystalline calcite. White: detrital quartz. Note near absence of quartz grains in areas of crystalline calcite. Section 9, Oak Creek Farm Road, subunit 9. × 15. (T–184.) Unoriented.

5. Medium-grained sandstone. Almost all grain contacts are diagenetic; overgrowth is moderate. Base of unit; section 16, Naeglin Rim, subunit 1. × 12.5. (T56–405.)

6. Saccharoidal dolomite consisting of two distinct size groups of dolomite crystals. Upper part of unit; section 18, south of Turkey Peak, subunit 17. × 15. (H56–147.)



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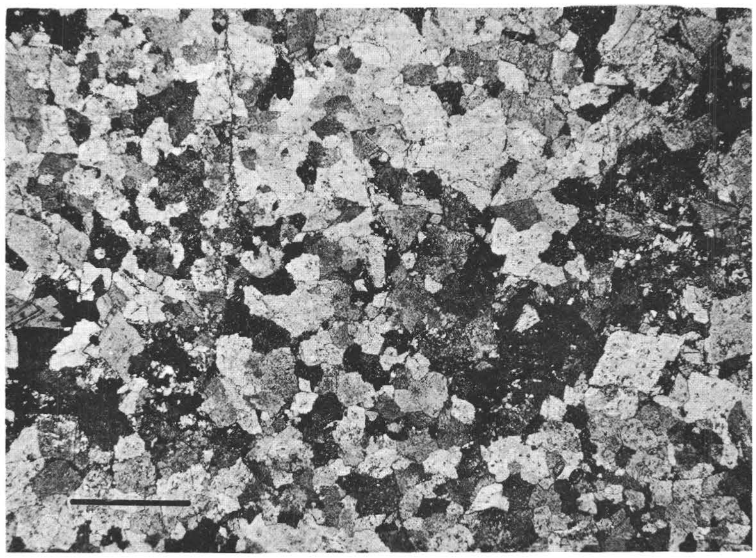

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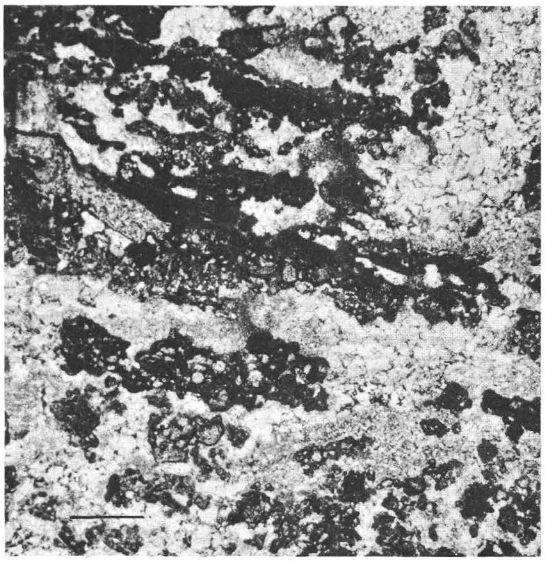

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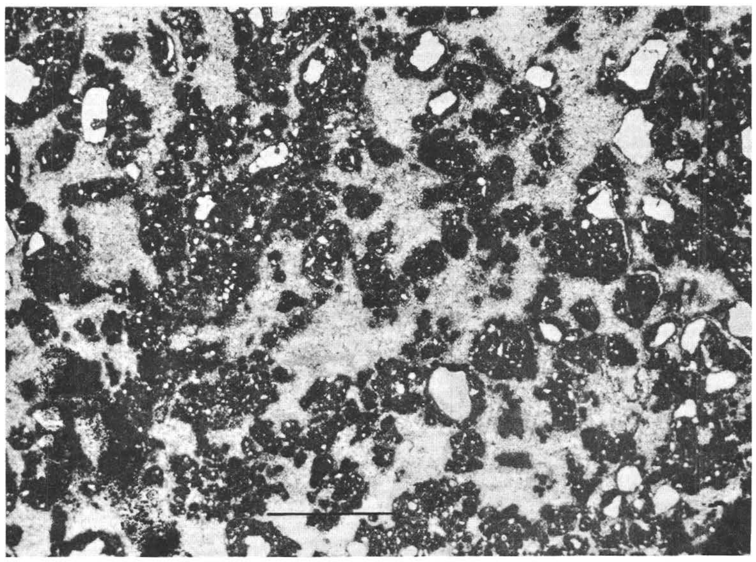

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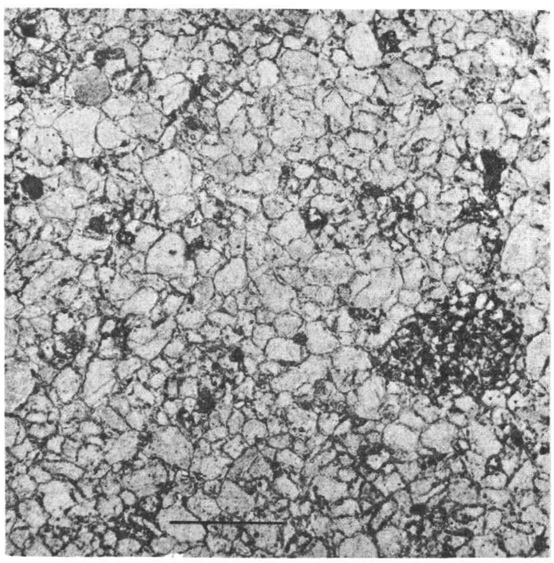

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6

ROCKS OF THE UPPER UNIT OF THE JEROME MEMBER FROM VICINITY OF ONLAP BELT

PLATE 11

FIGURE 1. Dolomite breccia. Some of the minute fissures are calcite-filled; the indistinct ovoid and ellipsoidal shapes in lower left quadrant may be calcispheres. Section 16, Naeglin Rim, subunit 6. × 8. (T56–409.)

2. Arenaceous saccharoidal dolomite. The dolomitic matrix (gray) and detrital quartz (white) are about equal in grain size. Upper part of unit; section 18, south of Turkey Peak, subunit 17. × 22.5. (H56–148.)

3. Very fine grained dolomite containing rounded quartz grains surrounded by halos of slightly more coarsely crystalline translucent dolomite. Section 16, Naeglin Rim, subunit 6. × 8. (T56–409.)

4. Dolomite consisting of aphanitic matrix and (darker) aphanitic clasts and containing much detrital quartz, mostly of silt and fine-sand size. The three largest grains in the picture are quartz (top), chert (lower left), and aphanitic dolomite (lower right). Large grains and some smaller ones are surrounded by halos of finely crystalline dolomite; the dolomite also partly replaces the aphanitic matrix between grains. Lower part of unit; section 18, south of Turkey Peak, subunit 1. × 15. (H56–136.)

5. Arenaceous aphanitic limestone that is very finely intraclastic and contains much detrital quartz. Near top of unit; section 15, 1 mile south of O.W. Ranch, subunit 23. × 12.5. (T56–370.)

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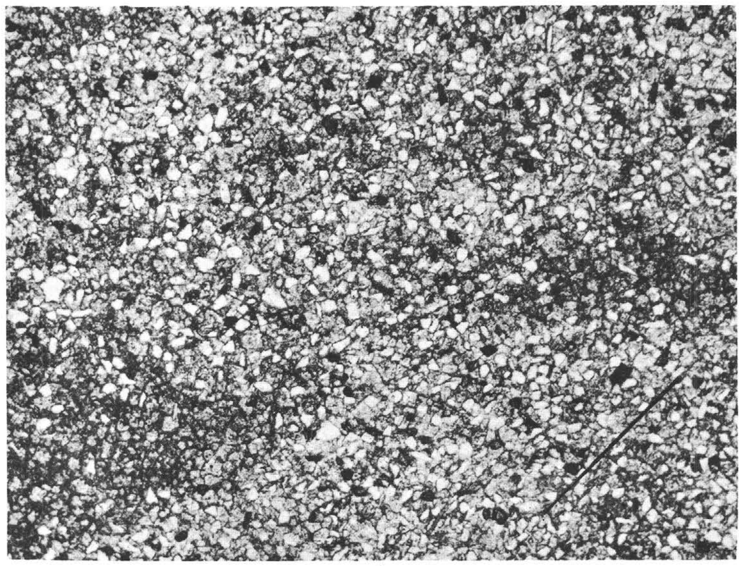

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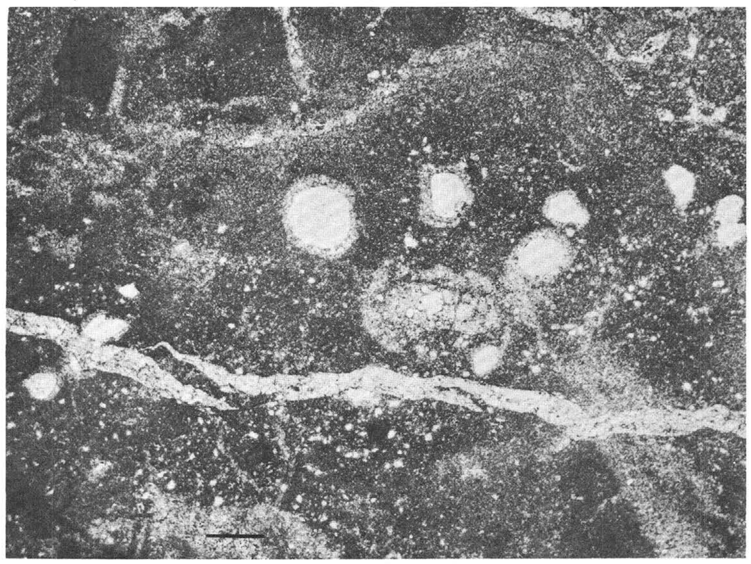

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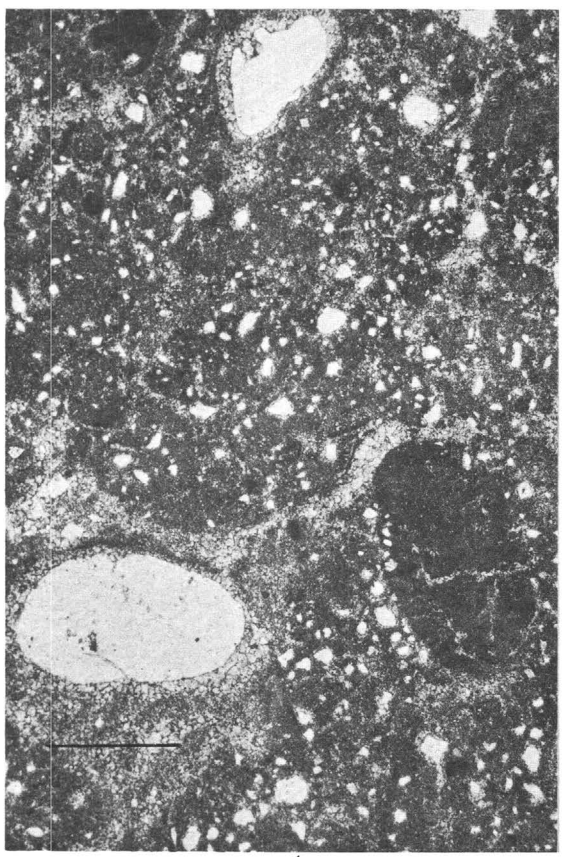

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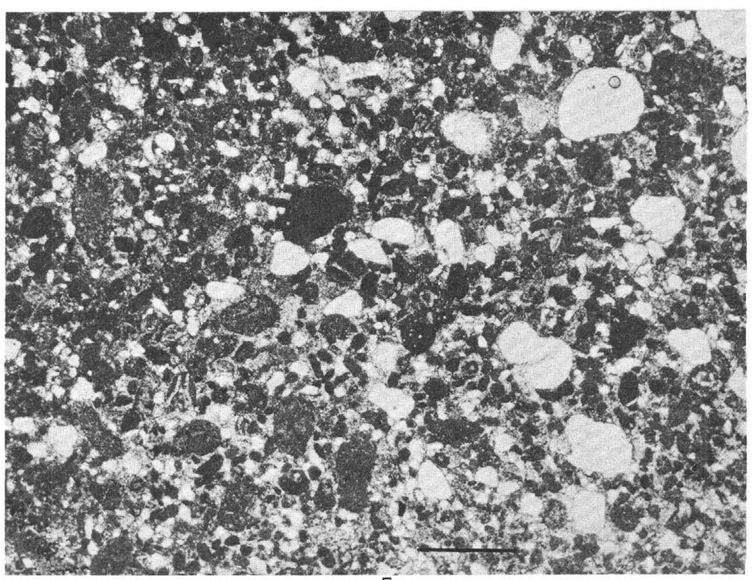


5

ROCKS OF THE UPPER UNIT OF THE JEROME MEMBER FROM VICINITY OF ONLAP BELT

PLATE 12

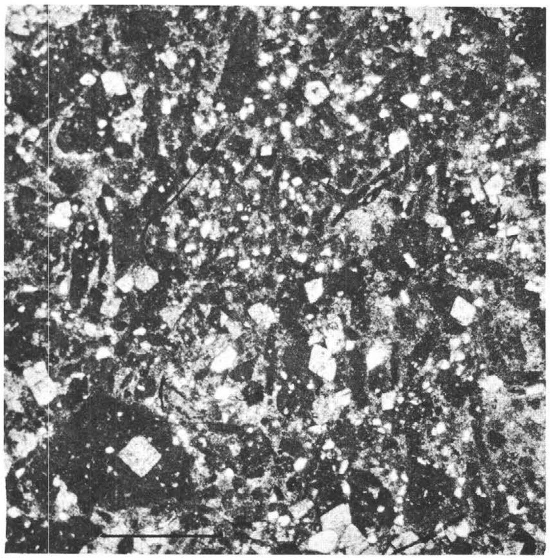
FIGURES 1, 2. Photographs of different parts of one thin section. Figure 1 shows the original nature of the rock which is an aphanitic limestone consisting of a light colored groundmass, dark-colored small intraclasts, some silt-size detrital quartz, and a few dolomite rhombohedra. Figure 2 shows the same rock almost completely replaced by dolomite rhombohedra. Section 12, Lost Tank Canyon, subunit 35. × 15. (T56–397.)

3. Arenaceous calcitic dolomite. A considerable amount of peripheral dolomite replacement of quartz grains is shown. Channel fill; section 14, 2 miles south of O. W. Ranch, subunit 4. × 15. (H56–105.)

4. Calcitic sandstone. This specimen is from a portion of the rock that has more cement than sand grains. The cement is recrystallized into crystal grains several millimeters in diameter. Quartz grains show some peripheral calcite replacement. Section 9, Oak Creek Farm Road, subunit 19. (T–193.) Unoriented.

5. Fine-grained sandstone, many grains of which have considerable overgrowth. The specimen was collected near the onlap belt. Section 9, Oak Creek Farm Road, subunit 6. × 9. (T–182.) Unoriented.

6. Limestone, originally aphanitic, now largely recrystallized. Calcispheres are abundant in both the aphanitic rock and the recrystallized matrix. Upper part of unit near onlap belt; section 4, Salt River, subunit 18. × 15. (T56–308U.)



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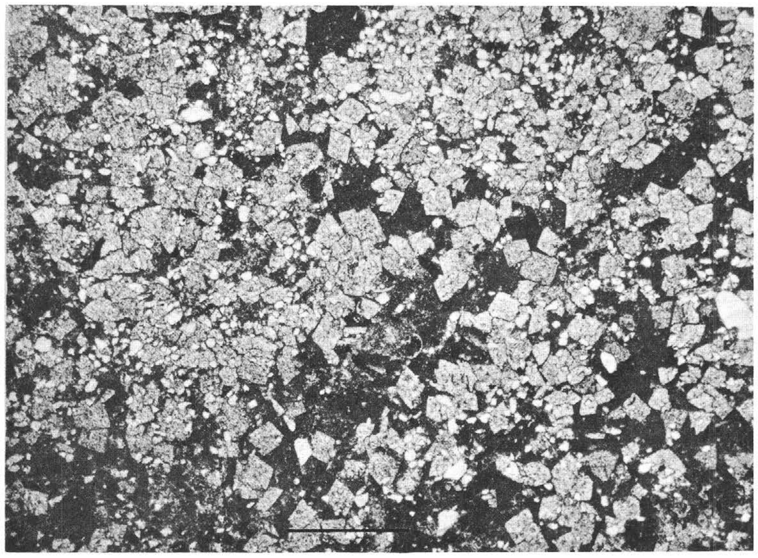

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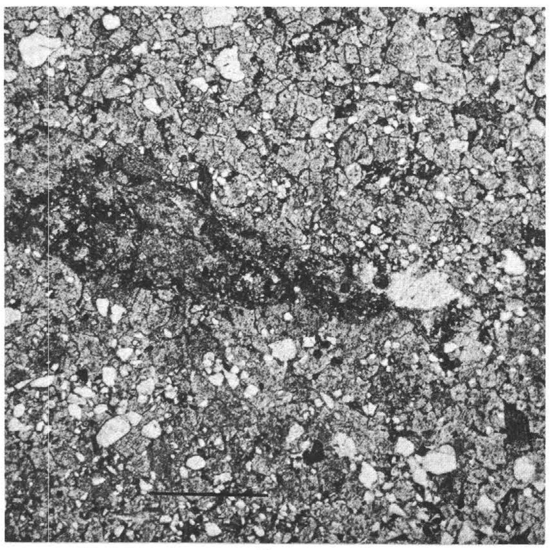

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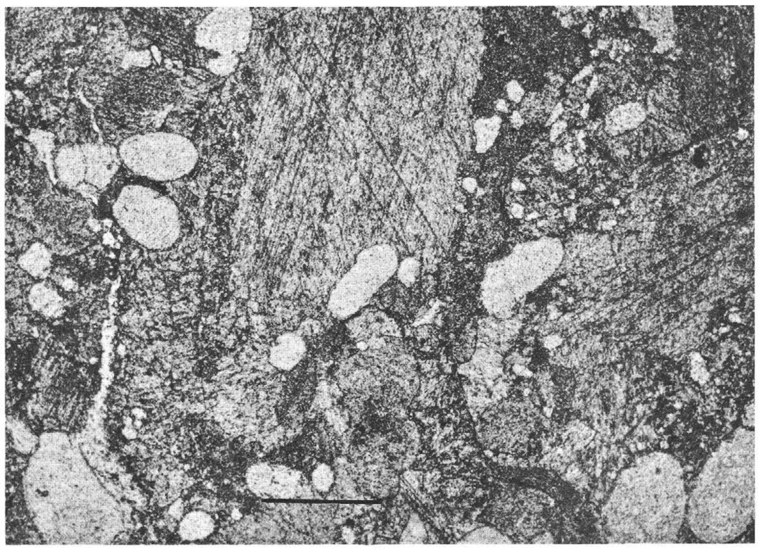

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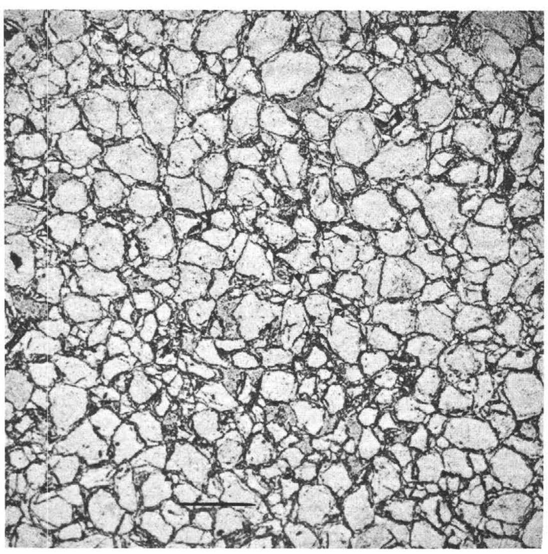

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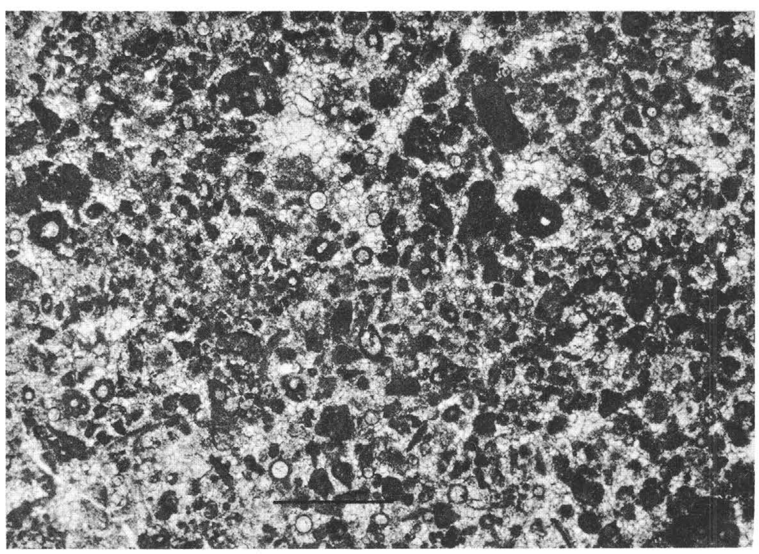


6

ROCKS OF THE UPPER UNIT OF THE JEROME MEMBER

PLATE 13

FIGURE 1. Aphanitic limestone containing pteropods (*Styliolina*?), calcispheres, and unidentified objects. Section 9, Oak Creek Farm Road, subunit 12. × 9. (T–187A.) Unoriented.

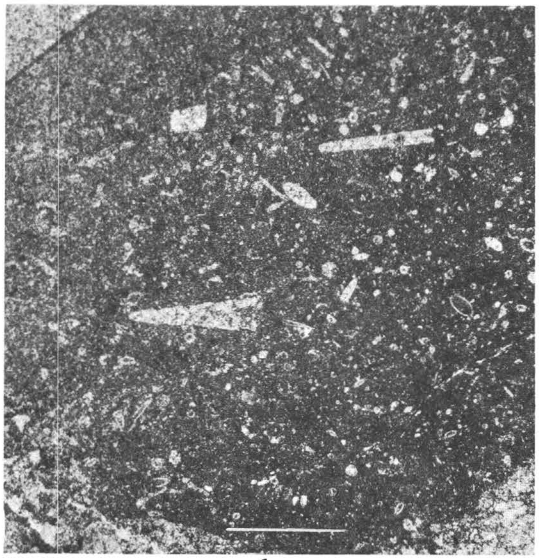
2. Dolomitic limestone. The groundmass is composed of aphanitic limestone and contains abundant calcispheres, tintinnids (?), and unidentified fragmental fossils; about half of the rock is replaced by authigenic dolomite rhombohedra. (See also pl. 16.) Lower part of unit; Section 6, Salt River Draw, subunit 18. × 15. (T–105.) Unoriented.

3. Saccharoidal dolomite, very impure. The matrix consists of a mixture of anhedral and euhedral dolomite crystals having greatly varying sizes; some specimens show good lamellar texture. Much fine-grained detrital quartz and clay is distributed through the dolomite. In the center and lower right of the figure are "ghosts" of sedimentary structures. Section 15, 1 mile south of O.W. Ranch, subunit 3. × 15. (T56–352.)

4. Same rock as illustrated in figure 2, containing fewer dolomite crystals, some large and small thin-walled calcispheres, and other fossil debris. One calcisphere is partly replaced by a dolomite crystal. Section 6, Salt River Draw, subunit 18. × 22.5. (T–105.) Unoriented.

5. Calcareous sandstone, fine grained. Grain contacts are partly sedimentary but mostly diagenetic. Dark areas between grains are calcareous cement. Section 12, Lost Tank Canyon, subunit 38. × 12.5. (T56–400).

6. Fragmental limestone composed mostly of recrystallized calcispheres and aphanitic limestone clasts. The more homogeneous areas shown near the center and lower left of the figure are recrystallized echinoderm fragments. The space between individual clasts or other fragments is filled with crystalline calcite. Section 11, Spring Canyon, subunit 3. × 20. (T–166.) Unoriented.



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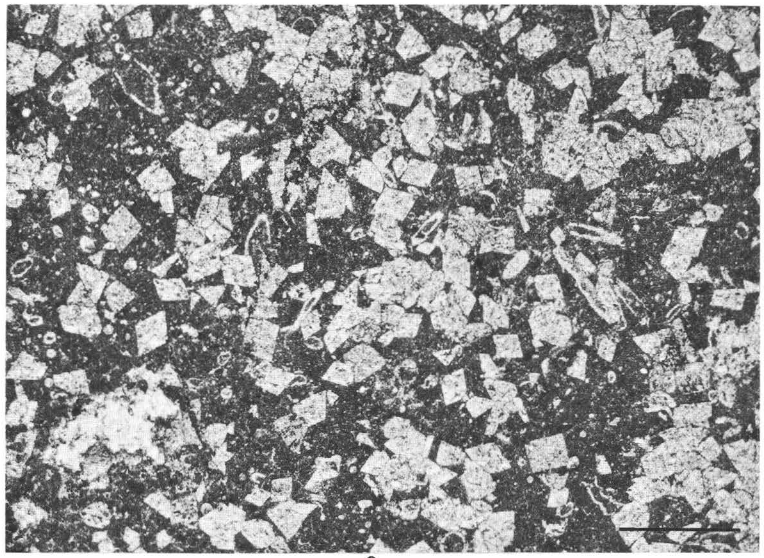

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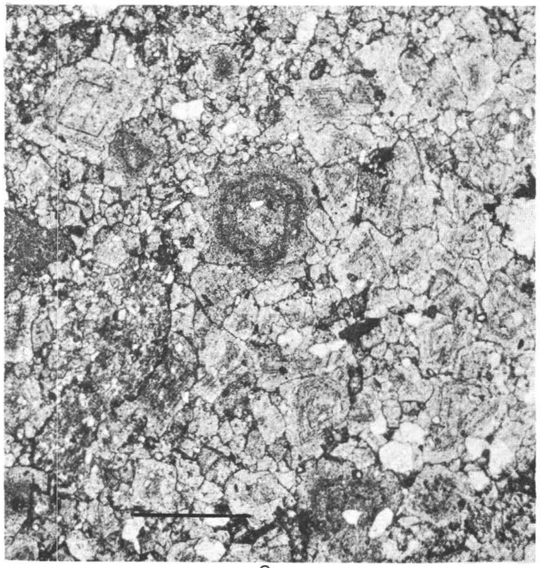

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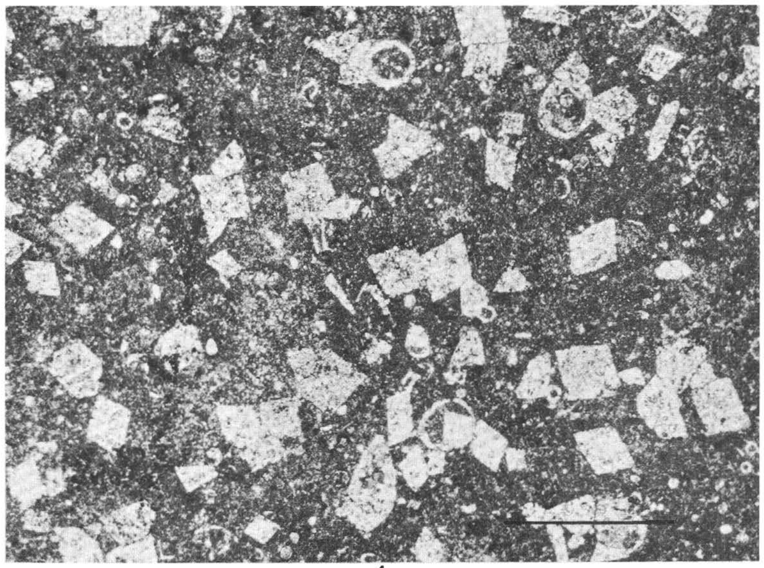

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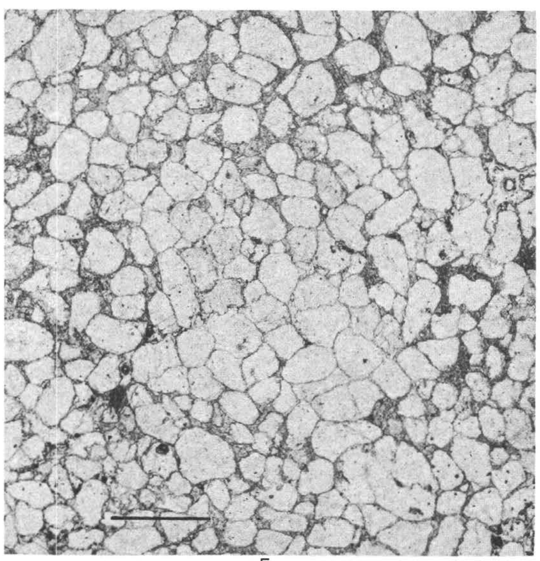

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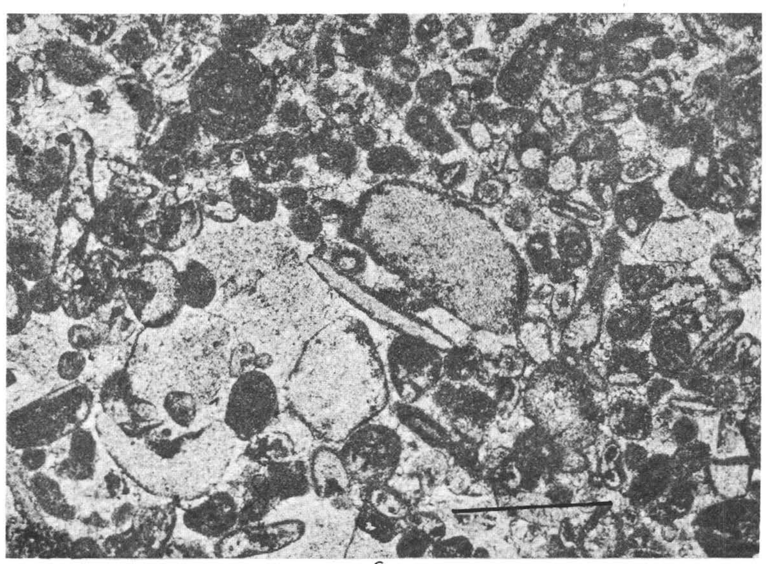

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ROCKS OF THE UPPER UNIT OF THE JEROME MEMBER

PLATE 14

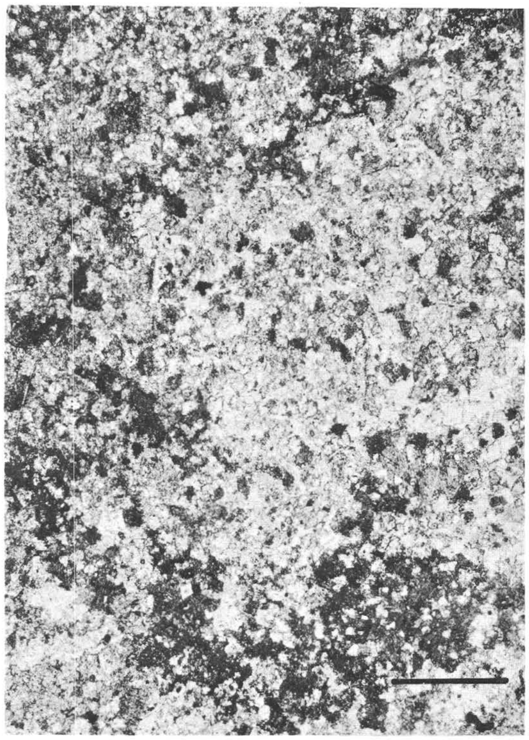
FIGURE 1. Dolomite having luster mottling. Two partly interpenetrating groups of dolomite crystals having parallel optical orientation within each group are shown. Uppermost part of Beckers Butte Member; section 31, Webber Creek, subunit 11. ×15. (T56–510.) Crossed nicols.

2. Cross section of a partly silicified brachiopod shell in limestone. The light-colored rim of the shell is composed of microcrystalline chert; the gray area inside is calcite. Upper unit of Jerome Member; section 6, Salt River Draw, subunit 28. ×12.5. (T–142.)

3. Sandstone, highly calcareous. Matrix consists of fine-grained limestone and numerous small aphanitic limestone clasts (black). Upper unit of Jerome Member; section 36, Roosevelt Dam, subunit 15. ×15. (H56–81.)

4. Saccharoidal, calcitic dolomite. Calcitic matrix is crystallized in areas having a single crystal structure, which are distinguished by different shades of gray; poikilitically enclosed dolomite rhombohedra are in random orientation. Upper unit of Jerome Member; section 44, Elden Mountains, subunit 2. × 9. (T56–575.) Crossed nicols.

5. Fine-grained luster-mottled sandstone. In the right half of the figure, three dark areas of calcareous matrix (extinction position) occur, whereas in the left half of the figure, calcareous matrix forms one light-colored area. Upper unit of Jerome Member; section 11, Spring Creek, subunit 4. × 9. (T–167.) Unoriented. Crossed nicols.



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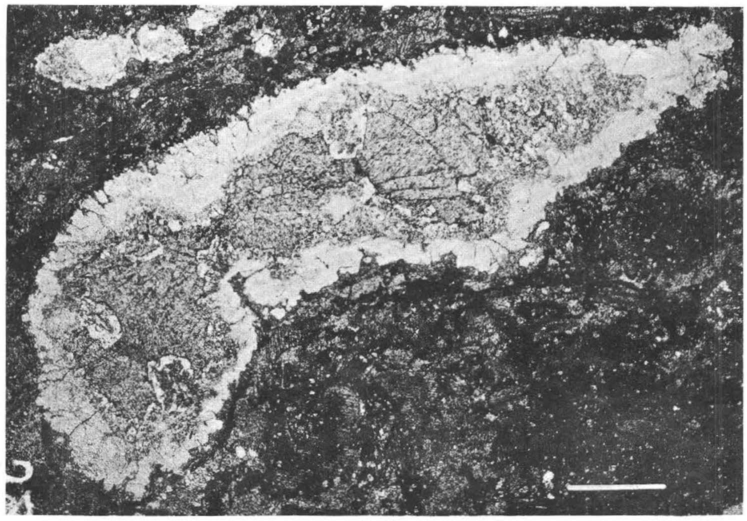

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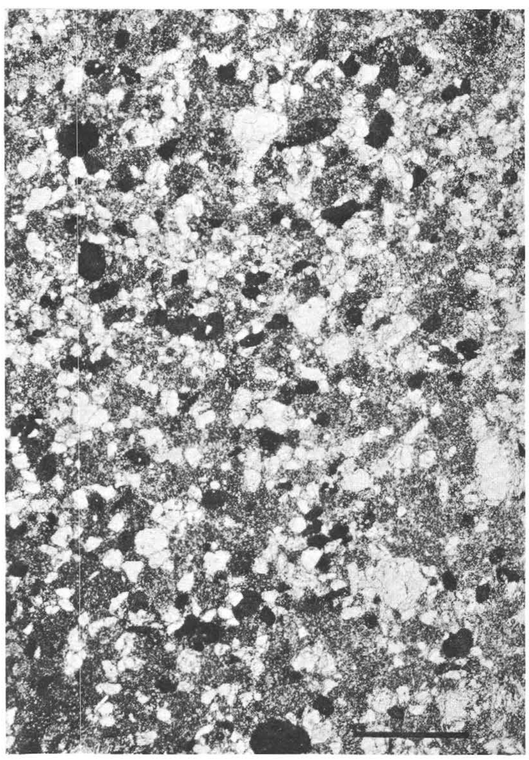

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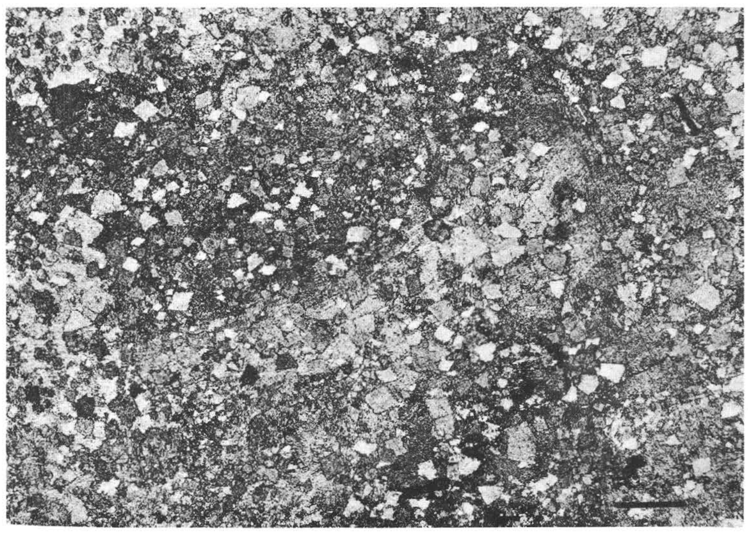

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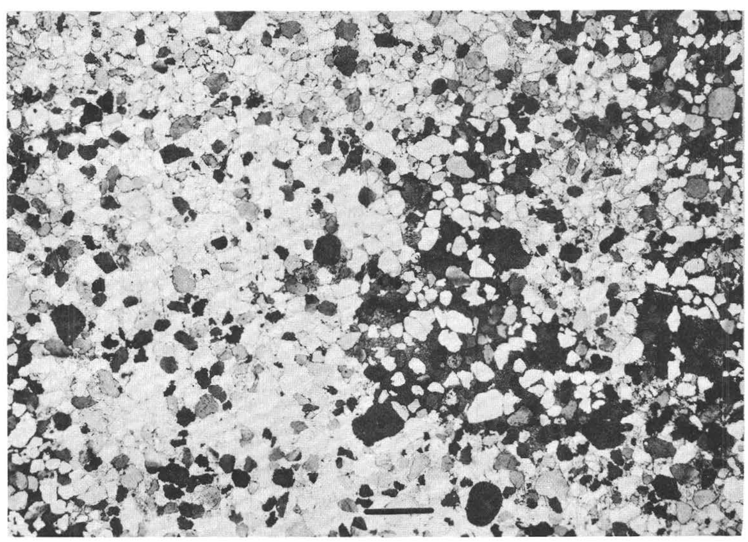


5

LUSTER MOTTLED ROCKS AND SILICIFICATION

745-106 O—64——10

PLATE 15

FIGURE 1. Fine-grained sandstone containing chert granule in center. All grain contacts are diagenetic. Lower part of upper unit of Jerome Member; section 36, Roosevelt Dam, subunit 19. × 12.5. (H56–84.)

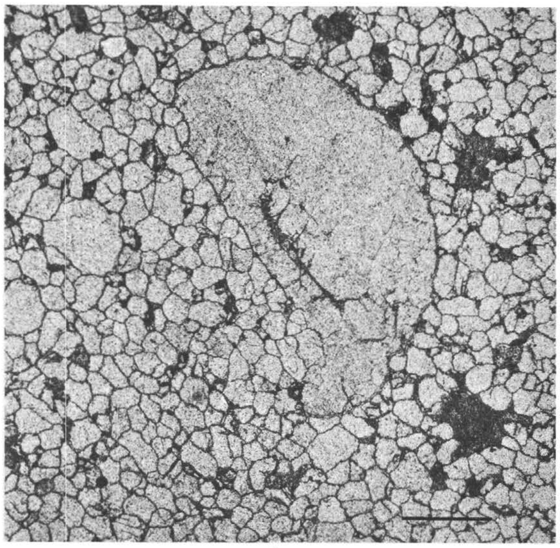
2. Silicified coral in unpolarized light. The septa and dissepiments are clearly shown. Top of upper unit of Jerome Member; section 20, Hunter Creek. × 9. (T–301.)

3. Aphanitic limestone containing a large recrystallized area. In the upper part of the recrystallized area is an outline of a thick-walled calcisphere, possibly *Umbella*. The specimen was collected from the Martin Limestone, about 40 feet above the base. Mount Martin, near Bisbee, Ariz. × 22.5. (T56–319.) Unoriented.

4. Same specimen as shown in figure 2, photographed between crossed nicols to show aggregate of quartz crystals. × 9.

5. Thick-walled calcisphere, possibly having a recrystallized internal structure. Upper part of aphanitic dolomite unit of Jerome Member; section 6, Salt River Draw, subunit 10. × 75. (T–98.)

6. Specimen of *Umbella*(?) in dolomitic sandstone. The wall has a well-preserved fibrous texture. Upper unit of Jerome Member; section 27, Tonto and Horton Creeks, subunit 8. × 45. (T57–356.) Unoriented.



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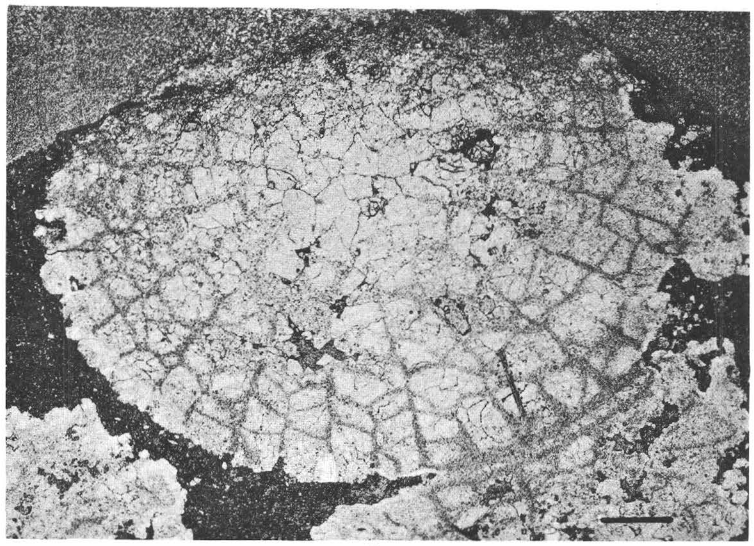

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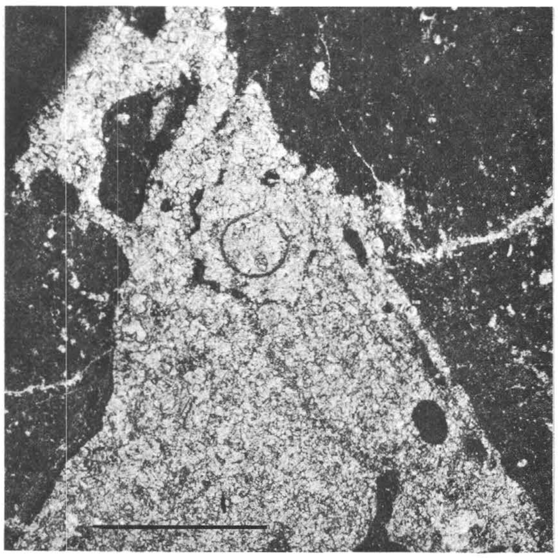

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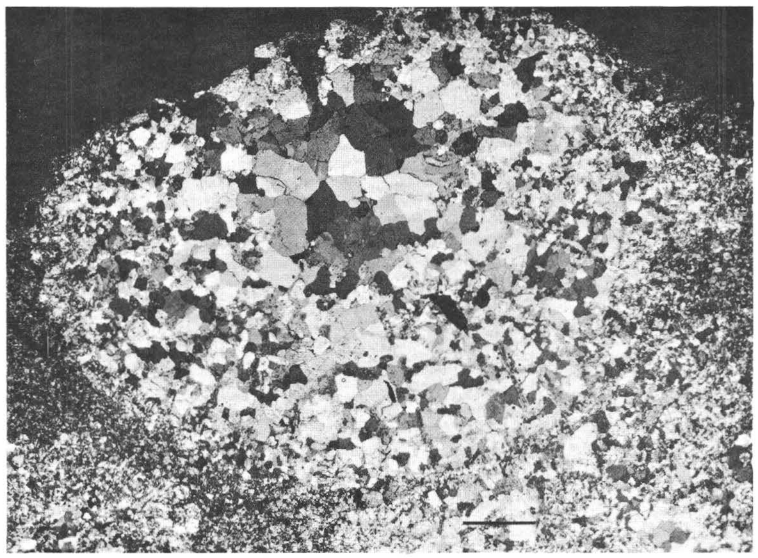

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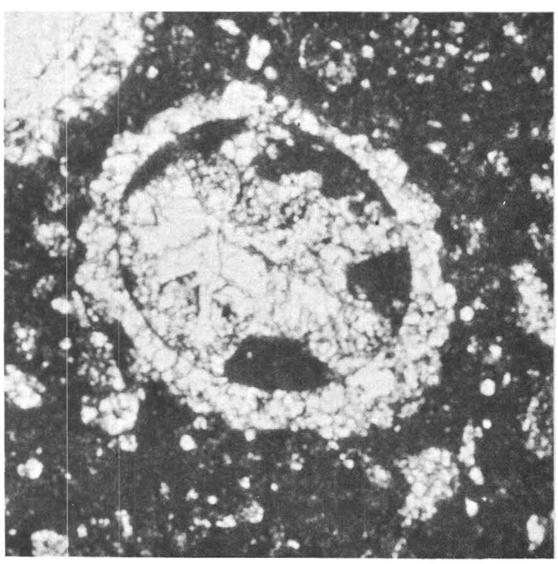

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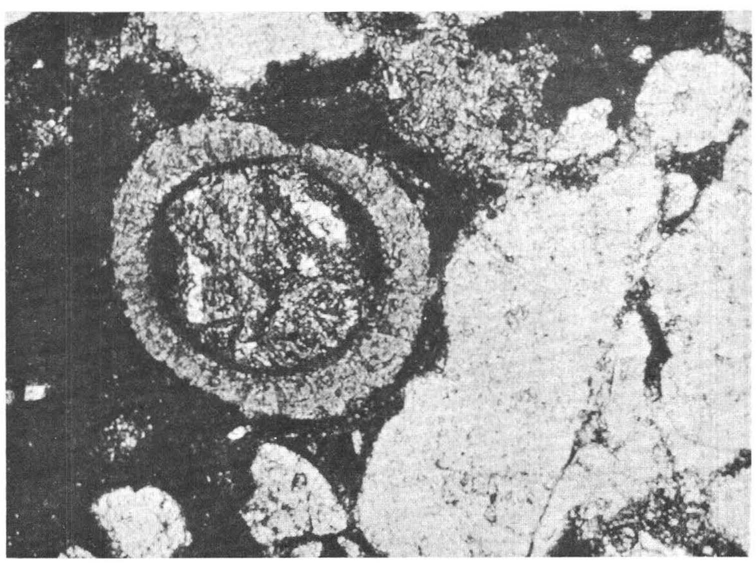


6

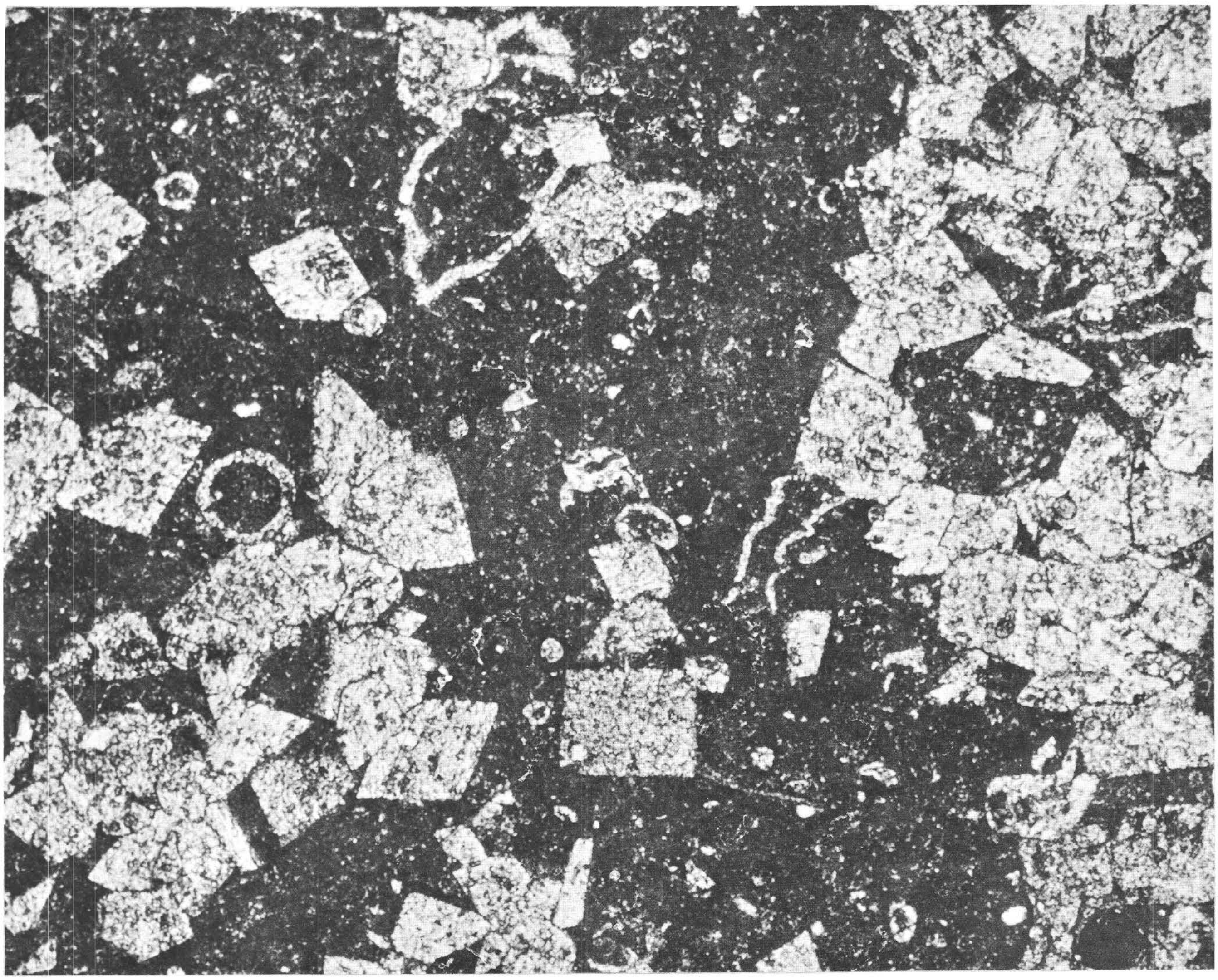
SILICIFICATION, CALCISPHERES, TINTINNIDS(?)

PLATE 16

FIGURE 1. Dolomitic limestone. The groundmass is composed of aphanitic limestone; the rock contains tintinnid(?) (upper part of figure), thin-walled calcispheres, and unidentified objects and debris. Part of the rock is replaced by authigenic dolomite rhombohedra. (See also pl. 13, figs. 2 and 4.) Upper unit of Jerome Member; section 6, Salt River Draw, subunit 18. × 56. (T–105.) Unoriented.

2. Limestone, very finely crystalline, containing possible tintinnids (one longitudinal and one transverse section near center), ostracodes, and unidentified fossil debris. Upper unit of Jerome Member; section 17, Colcord Canyon, subunit 17. × 30. (T56–443.)

3. Aphanitic limestone, partly recrystallized, containing two thick-walled calcispheres, also recrystallized (possibly *Umbella*). Martin Limestone, about 40 feet above the base; Mount Martin, near Bisbee, Ariz. × 30. (T56–319.) Unoriented.



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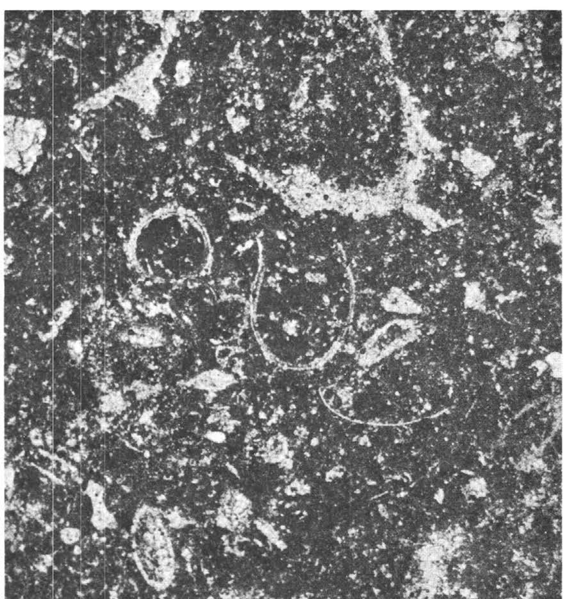

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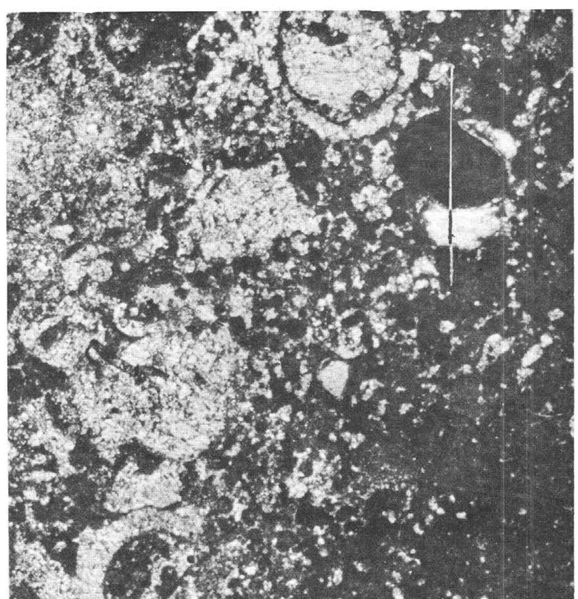

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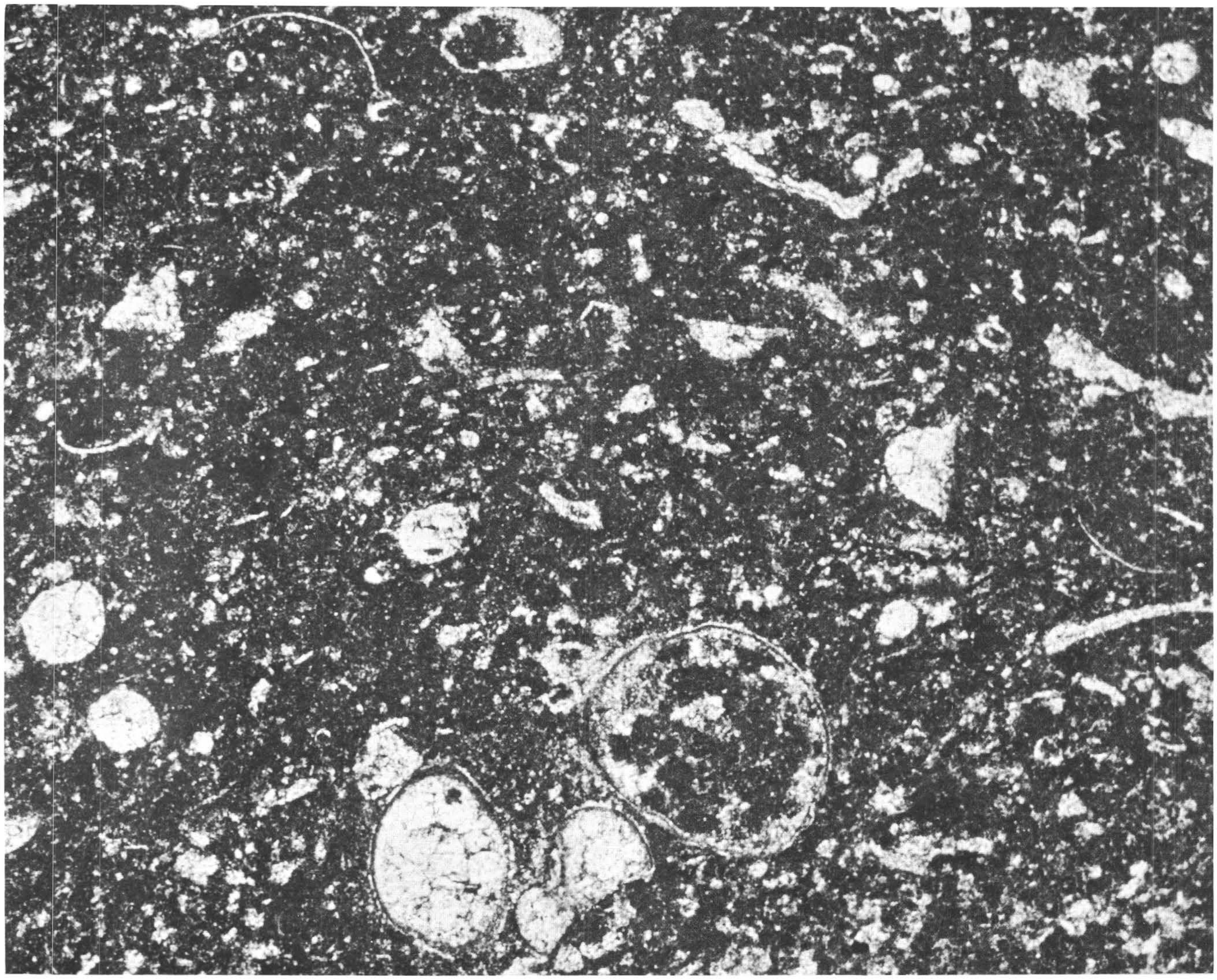
CALCISPHERES, TINTINNIDS(?)

PLATE 17

FIGURE 1. Limestone, very fine grained, containing abundant calcispheres, some unidentified shell fragments—probably ostracodes—and scattered dolomite rhombohedra. Upper unit of Jerome Member; section 9, Oak Creek Farm Road, subunit 10. × 30. (T–185.) Unoriented.

2. Very fine grained limestone containing many thin-walled calcispheres, ostracodes, and unidentified fossil debris. Upper unit of Jerome Member; section 17, Colcord Canyon, subunit 17. × 45. (T56–443.) Unoriented.



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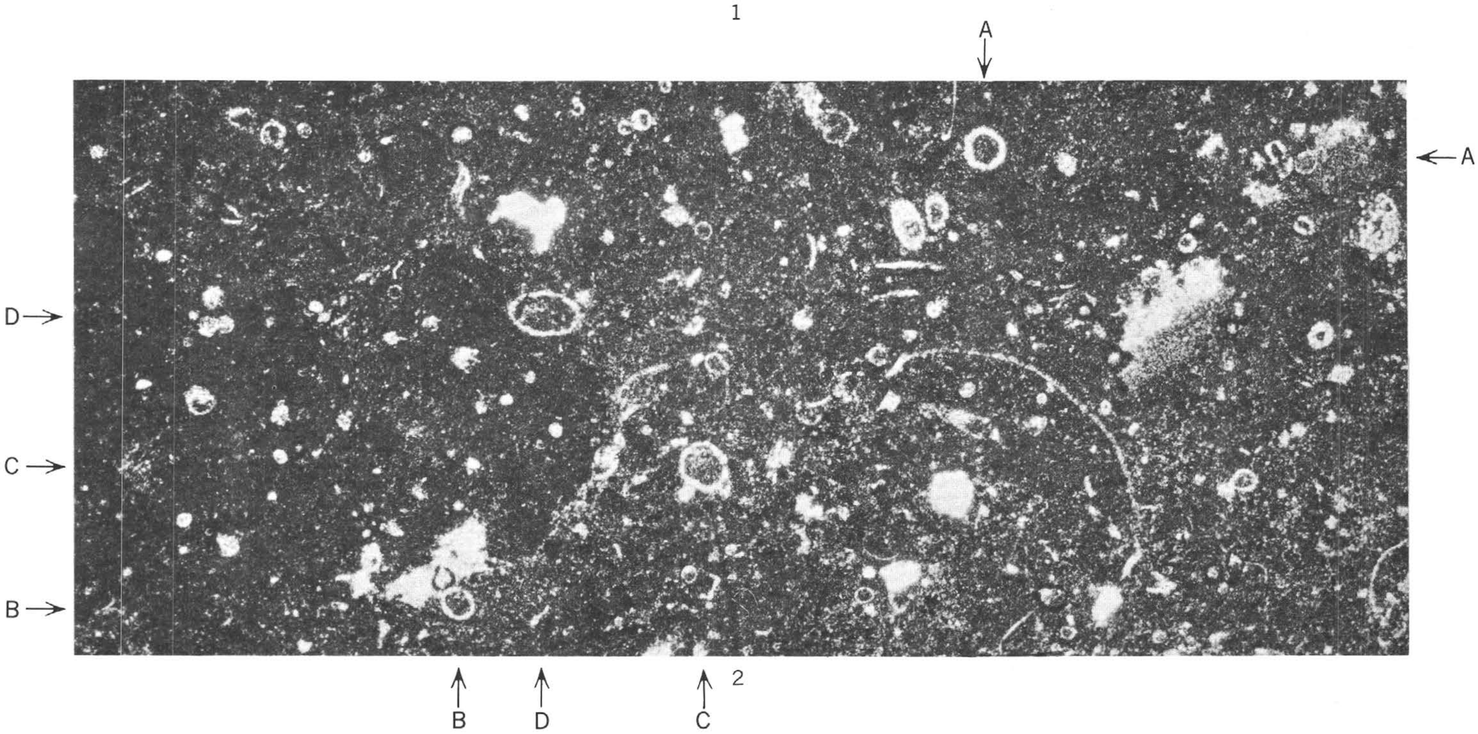

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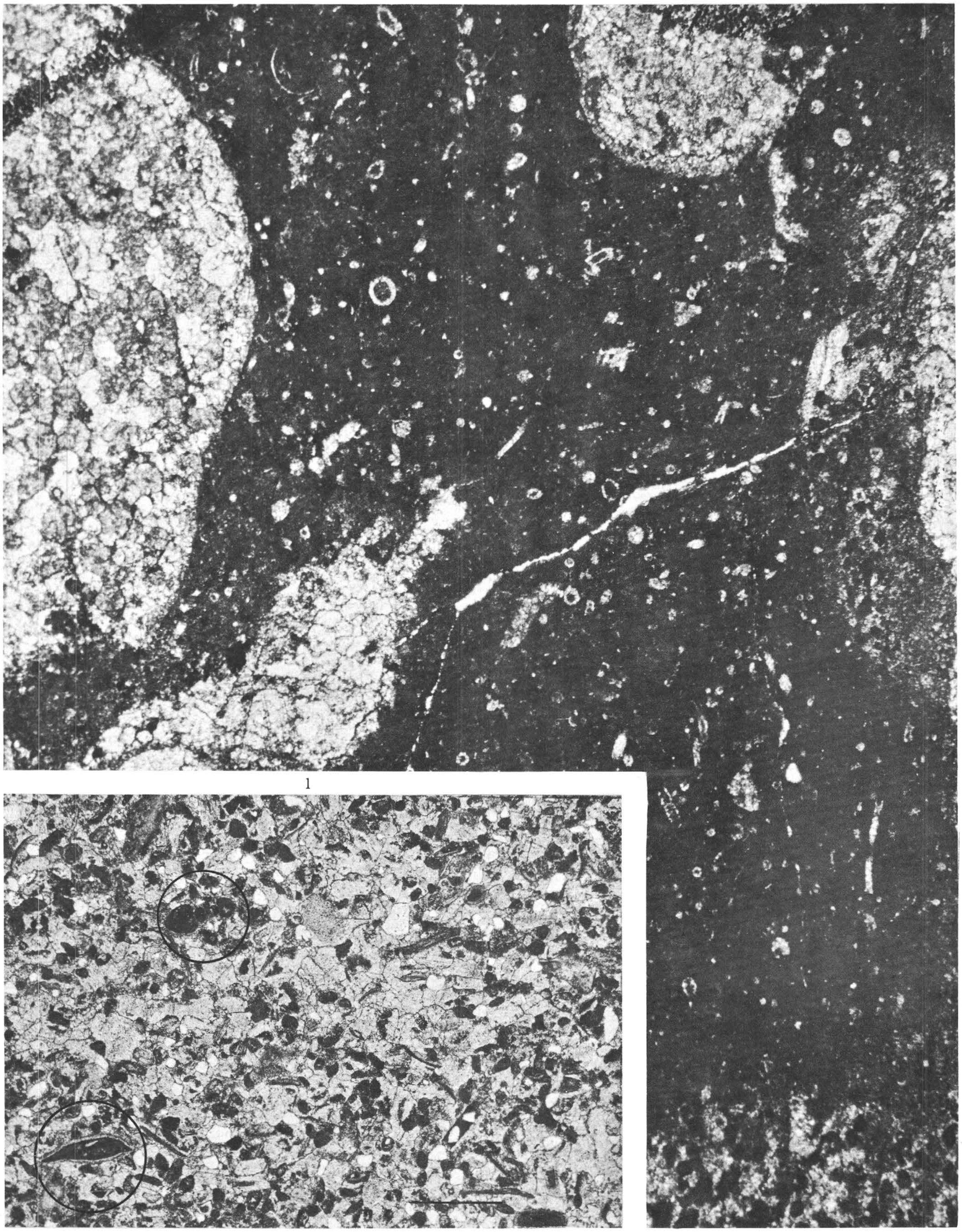
CALCISPHERES, OSTRACODES

PLATE 18

FIGURE 1. Aphanitic limestone containing many thin-walled calcispheres and unidentified fossil fragments. The large recrystallized areas are cross sections of either *Amphipora* or *Thamnopora* colonies. Upper unit of Jerome Member; section 9, Oak Creek Farm Road, subunit 12. × 24. (T–187.) Unoriented.

2. Limestone, very sandy. The rock was primarily aphanitic but is largely recrystallized. It contains calcispheres and other organic remains, such as the whorls of a goniatite (shown in cross section in the upper left quadrant of the figure) and an ostracode shell (shown in the lower left quadrant). Upper unit of Jerome Member; section 2, Black River, subunit 17. × 15. (H56–5.)



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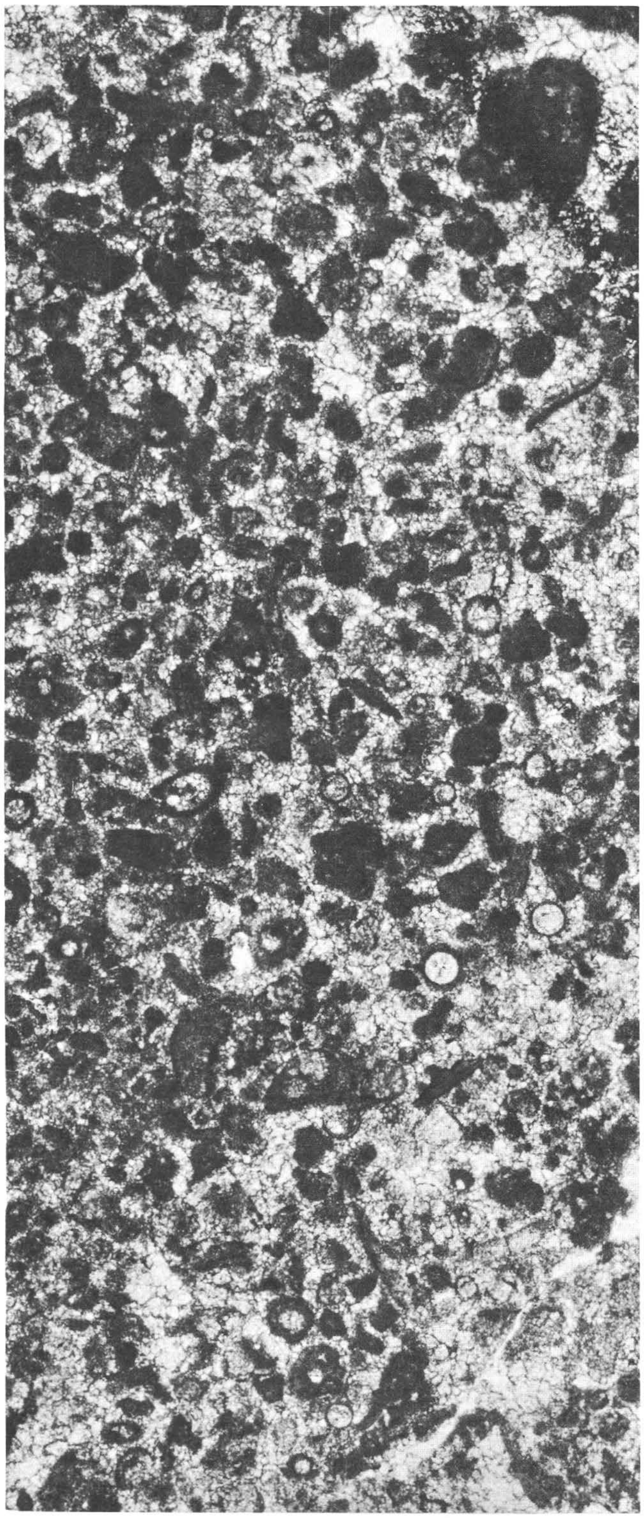
CALCISPHERES

PLATE 19

FIGURE 1. Limestone containing abundant thick-walled calcispheres. The rock has a pseudoclastic texture because of extensive recrystallization of the original aphanitic matrix. Recrystallization has modified the shape of the calcispheres in varying degrees. Upper unit of Jerome Member; section 4, Salt River, subunit 18. × 30. (T56–308U.) Unoriented.

2. Limestone. The rock is primarily aphanitic but highly recrystallized by grain growth; it now presents a pseudoclastic appearance. The abundant thick-walled calcispheres are in various stages of recrystallization. At bottom of the figure, a completely recrystallized *Amphipora* skeleton is shown. Upper unit of Jerome Member; section 6, Salt River Draw, subunit 20. × 30. (T–107.) Unoriented.



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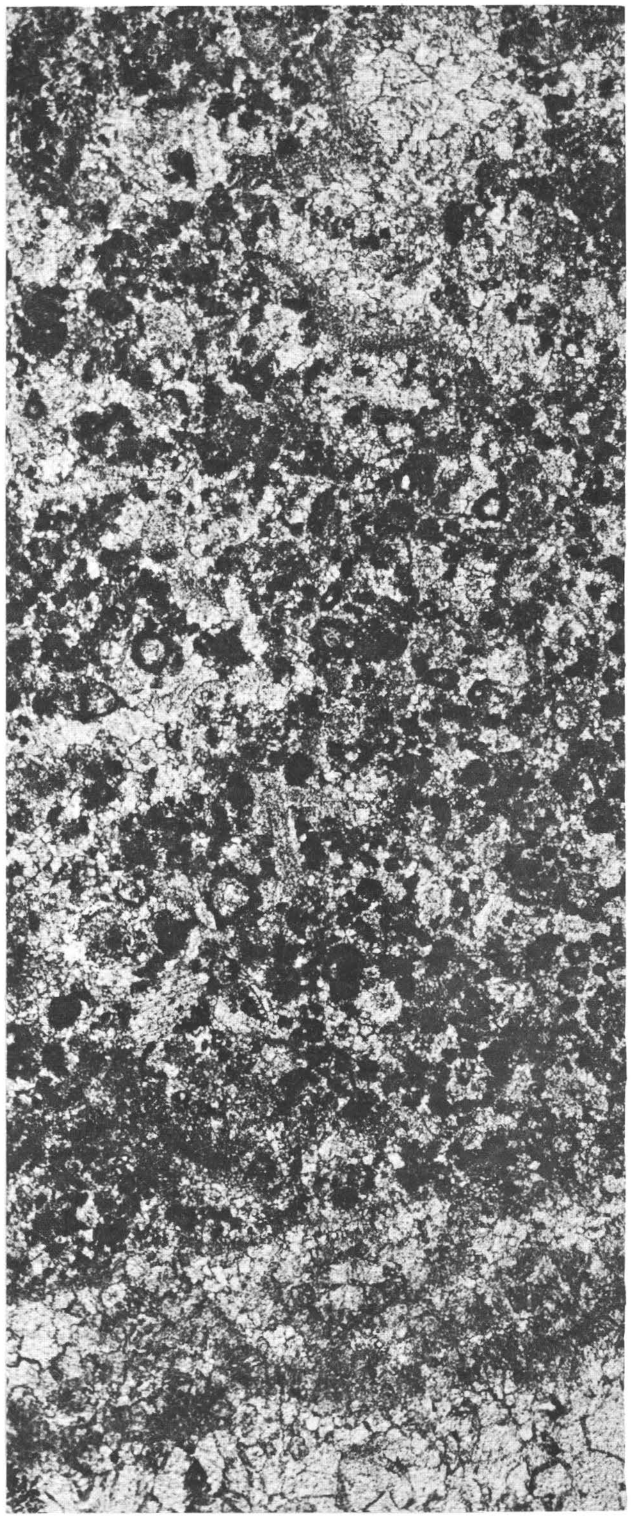
1 ↑A ↑C ↑B



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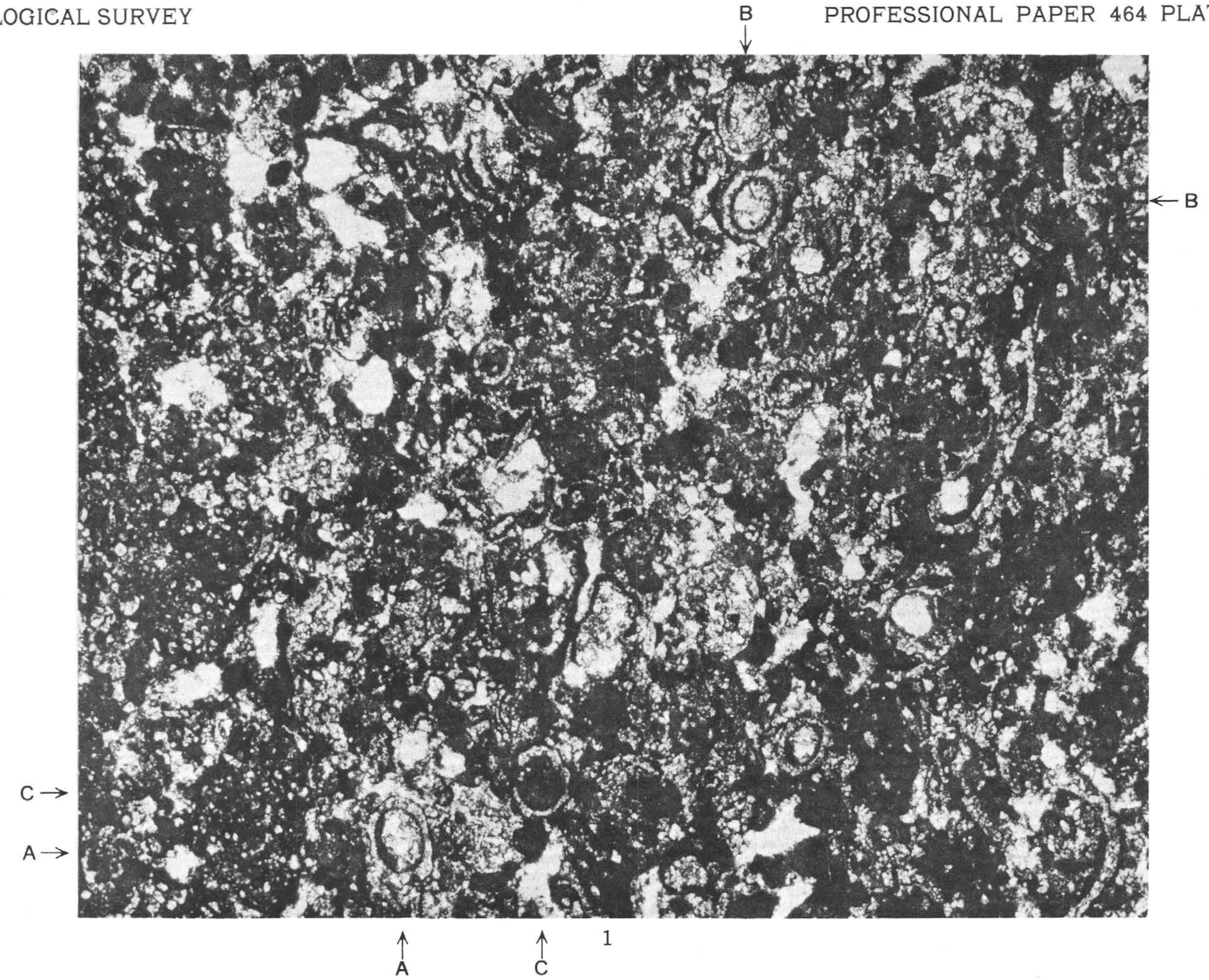
CALCISPHÈRES

PLATE 20

FIGURE 1. Calcitic dolomite. The original aphanitic dolomitic matrix is partly dedolomitized; many of the white crystalline areas are calcite. The rock contains abundant thick-walled calcispheres resembling *Umbella*-types, scattered small quartz grains, and unidentified fossil debris. Upper part of aphanitic dolomite unit of Jerome Member; section 6, Salt River Draw, subunit 10. × 30. (T–98). Unoriented.

2. Aphanitic limestone containing *Umbella* sp., smaller calcispheres, and unidentified fossil debris. Upper unit of Jerome Member; section 31, Webber Creek, subunit 31. × 88. (T56–521.) Unoriented. (See also pl. 21.)



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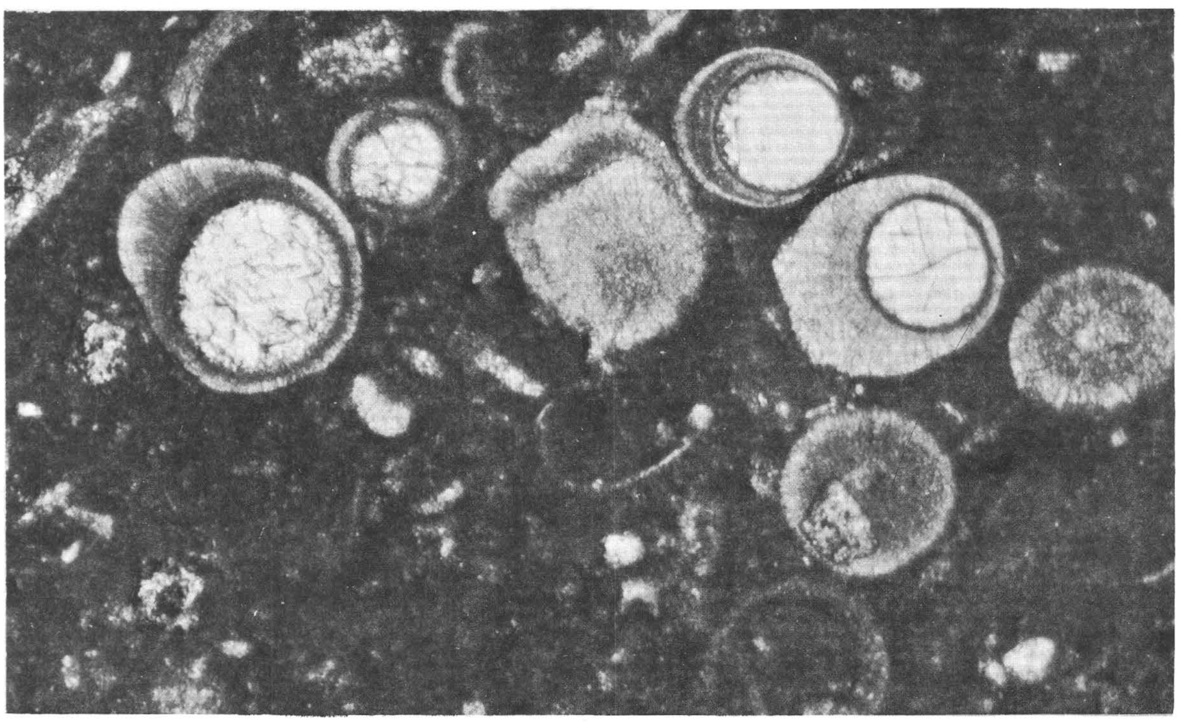

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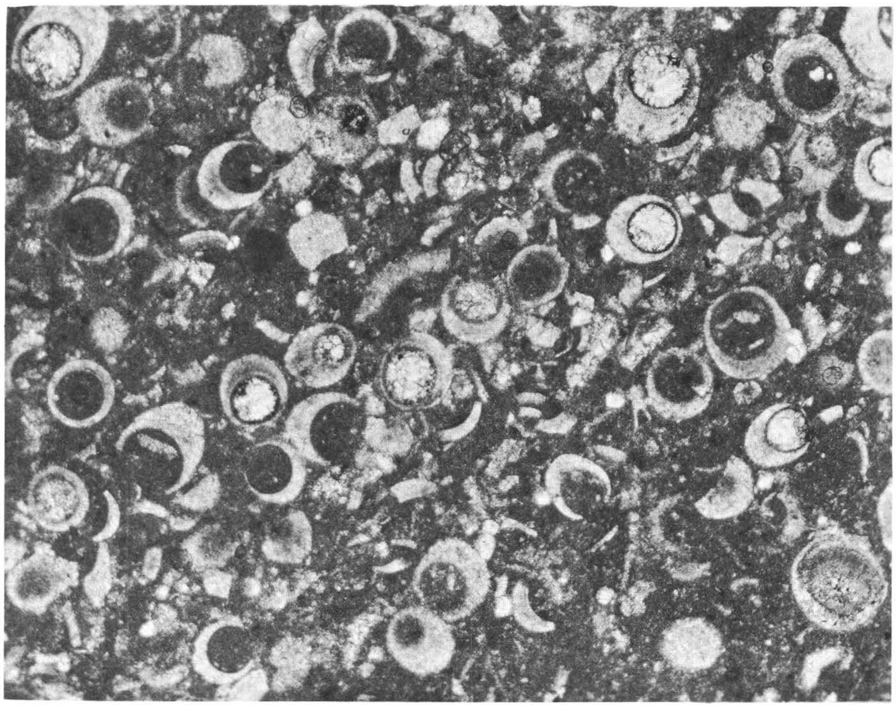
CALCISPHERES, *UMBELLA*

PLATE 21

FIGURE 1. Aphanitic limestone containing abundant *Umbella* sp., smaller calcispheres, and unidentified fossil debris. Upper unit of Jerome Member; section 31, Webber Creek, subunit 31. × 34. (T56–521.) Unoriented.

2. Aphanitic limestone containing *Umbella* sp., smaller calcispheres, and unidentified fossil debris. Upper unit of Jerome Member; section 31, Webber Creek, subunit 31. × 34. (T56–521.) Unoriented.



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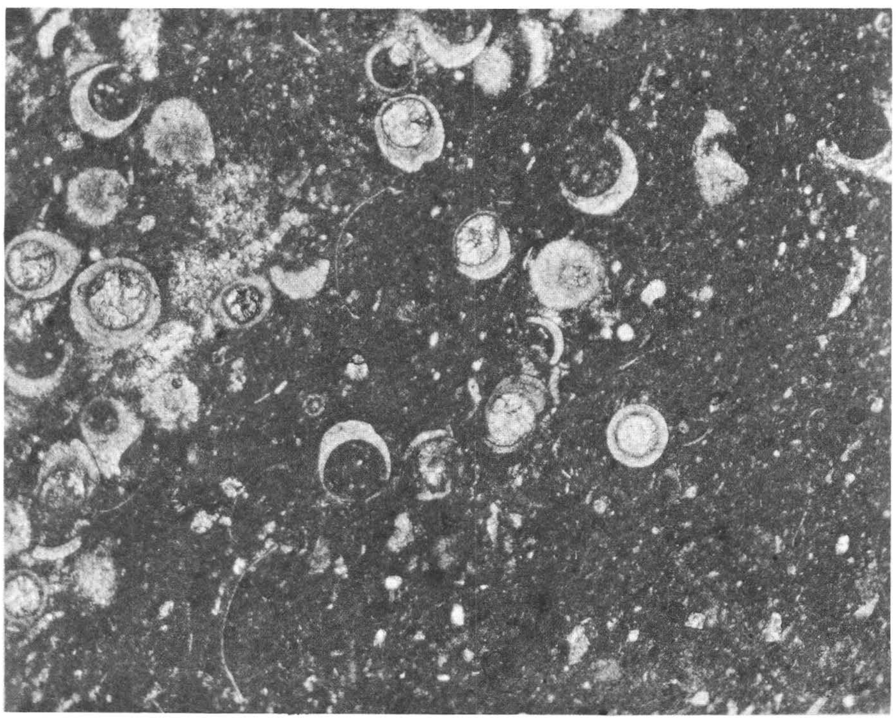

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UMBELLA