Devonian and Mississippian Rocks of Central Arizona

GEOLOGICAL SURVEY PROFESSIONAL PAPER 233-D

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By JOHN W. HUDDLE *and* ERNEST DOBROVOLNY

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 195[illegible]

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Stratigraphic studies, in the central part of the State, as the basis for postulating stratigraphy and petroleum possibilities in northeastern Arizona

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1952

UNITED STATES DEPARTMENT OF THE INTERIOR

Oscar L. Chapman, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 65 cents (paper cover)

CONTENTS

ILLUSTRATIONS

DEVONIAN AND MISSISSIPPIAN ROCKS OF CENTRAL ARIZONA

By John W. Huddle and Ernest Dobrovolny

ABSTRACT

Stratigraphic studies of the late Paleozoic rocks of central Arizona form the basis for postulating the extent and the petroleum-bearing possibilities of Devonian and Mississippian rocks in northeastern Arizona.

The Martin formation of Late Devonian age consists of a lower member of conglomeratic sandstone and dolomitic limestone, a middle member of sandstone and cliff-forming limestone, and an upper member of sandstone, sandy limestone, and shale. The formation, as traced from southeastern Arizona toward the central part of the State, becomes increasingly sandy and in the vicinity of the Mogollon Rim laps against ridges of quartzite of Cambrian and pre-Cambrian age. Between these quartzite ridges, the Martin formation is present in normal thickness and character. It is equivalent, in part, to the Temple Butte limestone of the Grand Canyon area, Merriam's Devils Gate formation of Nevada, Stevenson's Sly Gap formation and the Percha shale of New Mexico, and the Upper Devonian rocks of Colorado and Iowa. The contact with the overlying Redwall limestone of Mississippian age is unconformable.

The thin limestone of Mississippian age in central Arizona is the equivalent of the Redwall limestone of northwestern Arizona and the Escabrosa limestone of southeastern Arizona. The name "Redwall limestone" is extended for use in central Arizona because it is the older of the two names. Typically, the Redwall consists of a lower impure dark-gray limestone, a middle massive cliff-forming limestone, and an upper thin- to medium-bedded cherty limestone. North of the Salt River, however, these subdivisions tend to disappear, the formation there consisting of loose blocks of limestone, surrounded by red sandy mudstone, and a few solid limestone beds. The Redwall is thin in central Arizona; the thinness and fragmentation of the limestone beds were caused by the erosion that occurred before the Pennsylvanian epoch. Principally by solution, the erosion produced a red residual soil containing blocks of undissolved limestone and chert. Caves and sinkholes in the limestone later were filled with rubble breccia by the inwash of residual materials and with limestone blocks derived from collapse of the overlying rocks. The cherty residual soil developed by the erosion was partly reworked to form the basal red sandy mudstone member of the Naco formation. This member of the Naco was formed in the same manner as the Molas formation of Colorado and is correlated with it. The Redwall limestone is early Mississippian in age. The absence of later Mississippian rocks may be due to widespread pre-Pennsylvanian erosion.

That an ancient land mass existed in central Arizona during Devonian time is indicated by the distribution of the sandy facies of the Martin formation and the character of the unconformity between it and the older rocks. This land mass, a part of Mazatzal land, is a residue of northeastward-trending mountains of pre-Cambrian age which extended from central Arizona to the Defiance uplift. The mountains, folded in pre-Cambrian time, were deeply eroded, after which late pre-Cambrian and Cambrian sediments were deposited on their flanks. Near the Mogollon Rim three prominent ridges of quartzite on Mazatzal land formed peninsulas, islands, or rocky reefs in the Devonian and Mississippian seas. A northward extension of the ancient mountain chain is indicated by the granitic ridge encountered in wells drilled near Holbrook and by the northeastward trend of pre-Cambrian rocks in the Defiance uplift. A gap in the land mass immediately north of the Mogollon Rim probably permitted the Devonian and Mississippian seas to extend unbroken from southeastern to northwestern Arizona.

Mazatzal land, the granitic Holbrook ridge, and the Defiance uplift were residual mountain masses rather than rapidly rising sources of sediments like the "ancestral Rockies" in Colorado and New Mexico. The distribution and character of late pre-Cambrian, Cambrian, and Devonian sediments were influenced by Mazatzal land, which also affected Mississippian sedimentation, although to a less extent. By Pennsylvanian time Mazatzal land probably was covered with sediments. The Defiance uplift, however, was not buried until Permian time.

Devonian and Mississipian strata probably are present in the subsurface southeast of the granitic Holbrook ridge and perhaps may be present in the Black Mesa basin to the north. Although this basin owes its shape to Laramide movements, its position may be related to a Paleozoic depositional area. Deposition in the Black Mesa basin during Devonian and Mississippian time is indicated by the Devonian (?) and Mississippian strata found in one of the wells drilled south of Holbrook; by Devonian strata at Elden Mountain, about 4 miles northeast of Flagstaff; by a thick section of Devonian strata at Jerome; and by thick sections of Devonian and Mississippian strata in wells in southeastern Utah. The Black Mesa basin probably had a history similar to that of the San Juan basin in New Mexico, where there are Devonian and Mississippian strata containing oil and gas. Hence Devonian and Mississippian rocks in the Black Mesa basin may also contain some oil and gas.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

The northeastern part of Arizona is the most promising part of the State for oil and gas production. If found there in commercial quantities, the oil and gas will probably come from Paleozoic strata. The authors made stratigraphic studies of the Paleozoic rocks exposed in central Arizona to determine their thickness and character and correlated the rocks with those of the sequence found in wells drilled in northeastern

Arizona and adjacent states. Some results of this study were published in preliminary form (Huddle and Dobrovolny, 1945). The present paper offers supplementary data, which were too detailed to be included in the preliminary report, on the Devonian and Mississippian formations.

LOCATION AND GEOGRAPHY

Devonian and Mississippian strata are present in a belt trending northwestward across Arizona, as shown in figure 8. The area of principal field work was in the east-central part of the State, chiefly in Gila County and the adjacent part of Navajo County (figs. 8, 9). This area lies in the southern part of the Colorado Plateau province and in the adjacent part of the Basin and Range province. The southern boundary of the Colorado Plateau province as drawn by Fenneman (1931, p. 382 and map in pocket) extends along the Mogollon Rim and then eastward through the White Mountain lava plateau. Near the headwaters of the Verde and Tonto Rivers, where the Mogollon Rim is a scarp 1,000 to 2,000 feet high, the boundary between the two provinces is clearly defined. East of Canyon Creek, however, where the Mogollon Rim is less prominent and is buried by lava flows, the boundary is indistinct and arbitrary.

A line extending southward from the Mogollon Rim along Canyon Creek to the Salt River and then southeastward to include the Natanes Plateau delimits a broad area with plateau characteristics which is not included in the Colorado Plateau province. This area is relatively high and is characterized by numerous canyons cut into essentially horizontal rocks. The Coconino sandstone and the younger rocks have been removed by erosion, and the present surface is a badlands area developed in the red beds of the Supai formation. Buttes and mesas are capped by lava flows or the thick limestone member of the Supai formation named by Stoyanow the "Fort Apache limestone member." The rocks and structures of the Mazatzal Mountains and the Sierra Ancha are largely pre-Cambrian in age, and it is probable that these mountains once were buried under late Paleozoic sedimentary rocks and have since been resurrected by the stripping associated with the northward retreat of the plateau scarp. This process is incomplete in the Fort Apache Indian Reservation; its much greater advance in the Mazatzal-Sierra Ancha region is probably due to an uparching of this area in post-Permian time.

FIELD WORK

Field work consisted principally of measuring stratigraphic sections in a belt extending from the Fort Apache Indian Reservation to the East Verde River, as indicated in figure 9. This work was begun in February 1944 and continued through September of that year. Work was concentrated in the area where the outcrops of Paleozoic strata are closest to the wells drilled south of Holbrook. In order to determine the character of lithologic variations from north to south, sections near Roosevelt Lake (localities 15, 16, on fig. 9), Superior (locality 18, fig. 9), Globe (locality 17, fig. 9), and Tornado Peak (locality 19, fig. 9) were studied. Well samples and cores from northeastern Arizona, southeastern Utah, and northwestern New Mexico were examined, and the section exposed on the Animas River north of Durango, Colo., was visited.

ACKNOWLEDGMENTS

The authors are indebted to A. A. Baker, C. M. Gilbert, E. D. McKee, N. P. Peterson, C. B. Read, and J. S. Williams for assistance in the field and to G. A. Cooper for the identification of the Devonian fossils. The Mississippian fossils were identified by J. W. Huddle with the aid of J. S. Williams and Helen Duncan. Well samples and cores were loaned by the Continental Oil Co., the Union Oil Co. of California, the Sinclair Oil Co., the Museum of Northern Arizona, and the Colorado School of Mines.

STRATIGRAPHY

The rocks exposed in east-central Arizona range in age from pre-Cambrian to late Paleozoic. The older rocks crop out in broad areas in the vicinity of the Sierra Ancha and the Mazatzal Mountains (fig. 9), in the Salt River and tributary canyons, and in the mountains near Globe and Superior. The Paleozoic strata are best exposed along the Mogollon Rim and in the Fort Apache Indian Reservation. Pre-Cambrian rocks of both "Archean" and "Algonkian" types are present in the area and are classified by Wilson (1939) as older and younger pre-Cambrian (fig. 10). The older pre-Cambrian rocks include rhyolites, greenstones, metamorphosed sediments, and granitic rocks, and the younger pre-Cambrian rocks include the slightly metamorphosed sedimentary rocks of the Apache group. In the Sierra Ancha and the Mazatzal Mountains and the area to the southeast of these mountains, pre-Cambrian rocks are unconformably overlain by the Cambrian Troy quartzite. In the northwestern part of Gila County, the Tapeats sandstone of Cambrian age overlies the pre-Cambrian rocks. No Ordovician nor Silurian rocks are known in the area, and the Martin formation of Devonian age rests unconformably on the pre-Cambrian and Cambrian formations. Limestones of Mississippian age referred to the Redwall

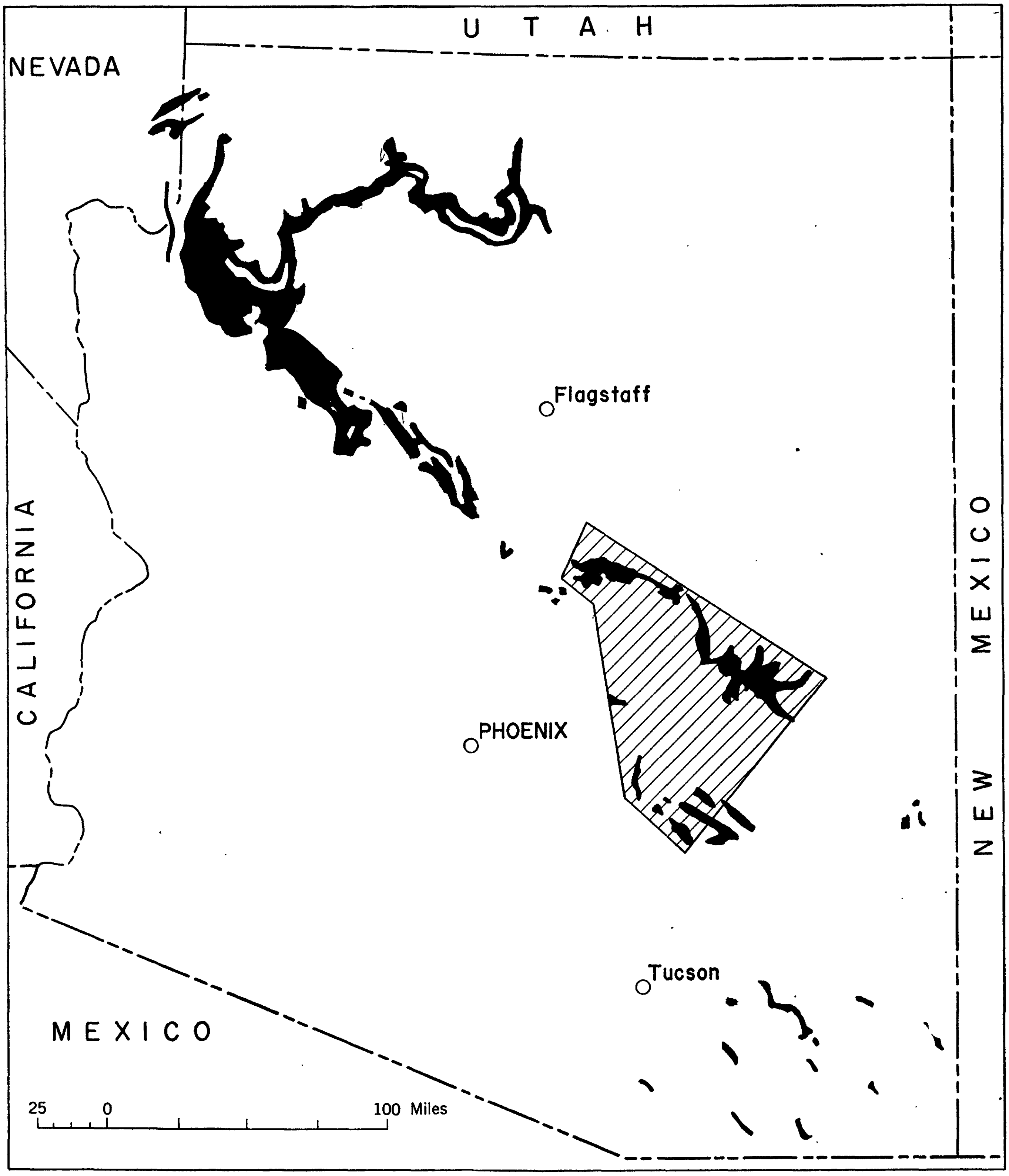
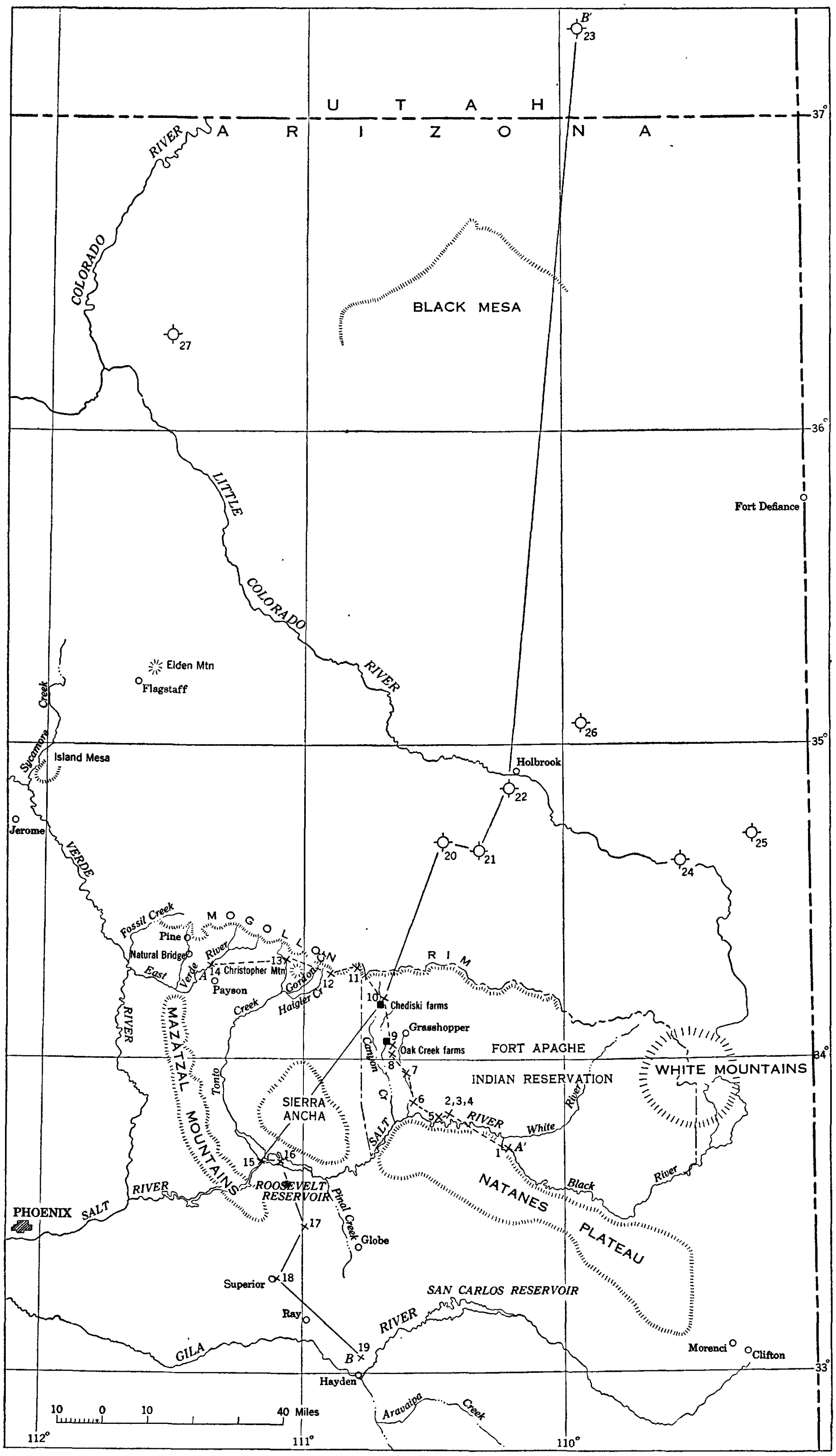


FIGURE 8.—Map showing the distribution of outcrops of Devonian and Mississippian sedimentary rocks in Arizona and the area described in this report.



EXPLANATION

A - - - - A'
Line of columnar sections shown on plate 11

B ——— B'
Line of columnar sections shown on plate 12

×
Location of measured section

Location of drilled well from which data were obtained

LIST OF MEASURED SECTIONS

1 Black River
2 Salt River
3 Flying "V" Canyon
4 Horseshoe Mine Road
5 Prochnow Mines
6 Rockhouse Butte
7 Salt River Draw
8 Cliff House Canyon
9 Oak Creek Farms
10 Spring Canyon
11 O. W. Ranch
12 Colcord Canyon
13 Tonto Creek
14 East Verde River
15 Roosevelt Dam
16 Windy Point, Hill
17 Gold Gulch
18 Superior
19 Tornado Peak

LIST OF DRILLED WELLS

20 Union Oil Co. of California and Continental Oil Co., Aztec Land and Cattle Co. No. 1 well
21 Union Oil Co. of California and Continental Oil Co., New Mexico-Arizona Land Co. No. 1 well
22 Great Basin Oil Co., Taylor-Fuller No. 1 well
23 Utah Southern Oil Co., Noble No. 1 well, Cedar Mesa, Utah
24 Franco-Arizona Oil Co., Government No. 1 well
25 Argo Oil Corp., State No. 2 well
26 General Petroleum Corp., Creager-State No. 14-6 well
27 Collins, XX No. 1 well

FIGURE 9.—Index map of northeastern Arizona showing the location of measured sections, drilled wells from which data were obtained, and lines of sections shown on plates 11 and 12.

limestone immediately overlie the Martin formation. The Supai formation of Pennsylvanian and Permian age rests unconformably on the Redwall limestone. The youngest rocks in the area are the Coconino sandstone and the overlying Kaibab limestone, both of Permian age.

PRE-DEVONIAN ROCKS

PRE-CAMBRIAN

The pre-Devonian rocks of central Arizona were not examined in detail during the course of the field work, but the pre-Cambrian rocks have been described by Wilson (1939). The accompanying table of pre-Devonian rocks (fig. 11), after Wilson, shows the relative ages of the pre-Cambrian rocks, which, in places, are in contact with the Martin formation of Devonian age. Some of the Martin and Redwall sediments were derived from the pre-Cambrian rocks of central Arizona, and the structure of the older rocks had a considerable effect on the deposition of the Martin formation.

CAMBRIAN

The Martin formation lies unconformably on the Troy quartzite or Tapeats sandstone of Cambrian age in most localities. The Troy quartzite is present south and east of Christopher Mountain (fig. 9), and the Tapeats sandstone occurs west of Christopher Mountain.

The Troy quartzite originally was placed in the Apache group by Ransome (1915), who classed the group as Cambrian(?). Darton (1932, p. 319), however, showed that it is pre-Cambrian except for the Troy, which he placed in the Middle and Upper Cambrian on the basis of a few fossils. The formation is absent in places and ranges in thickness from 30 feet along Haigler Creek (Darton, 1925, p. 236) to 900 feet in the Sierra Ancha (Ransome, 1916, p. 154). It is a fine- to coarse-grained siliceous sandstone with included granules and pebbles of quartz. In most localities the cementing material is siliceous and ferruginous, the rocks breaking across the grains and pebbles, but in other places the rock is a relatively weak calcareous or argillaceous sandstone. Much of the formation is cross-bedded. The beds vary from thin shaly laminations to massive layers 25 to 50 feet thick. The Troy quartzite generally is a prominent cliff former.

The Tapeats sandstone in ledges near the Pine-Payson highway bridge over the East Verde River is reddish brown to buff, weathering brown and slabby. It is a cross-bedded, massive conglomeratic sandstone, about 40 feet thick, resting unconformably on granite of pre-Apache age and including pebbles of the granite.

According to Ransome (1916, p. 165), there is little change in the character of the Tapeats sandstone from Payson to Jerome, and the correlation with the Tapeats in the Grand Canyon region is firmly established. Although it seems reasonable to correlate the Troy quartzite with the Tapeats, nevertheless the two formations are different in lithology, inasmuch as the Troy is typically a quartzite and the Tapeats typically a sandstone, although in some outcrops one formation may exhibit the typical lithology of the other. At Cliff House Canyon (detailed sec. 8) the Troy quartzite is a sandstone lithologically similar to the Tapeats sandstone, even to the slabby weathering. The Tapeats sandstone cannot be traced into the Troy quartzite because of the overlap of the late Paleozoic strata near Christopher Mountain, but the two formations may be continuous in the subsurface below the Mogollon Rim.

McKee (1945, p. 36) has shown that the Tapeats sandstone in the Grand Canyon region is progressively younger from west to east and that toward the east the upper part is probably Middle Cambrian. The Tapeats sandstone in the Pine-Payson area may be even younger than Middle Cambrian. The Troy quartzite probably is progressively younger from southeastern Arizona toward Christopher Mountain.

DEVONIAN ROCKS: MARTIN FORMATION

TERMINOLOGY

The oldest name applied to the Devonian rocks of Arizona is the term "Temple Butte limestone," proposed by Walcott (1889, p. 50) for the Devonian sedimentary rocks in the Grand Canyon, but this name has been used only in the northern part of the State. In central and southeastern Arizona, the Devonian strata have been referred to as the "Martin limestone," a name proposed by Ransome (1904, p. 33). In the type section near Bisbee, the formation consists of limestone and calcareous shale. There it rests on the Abrigo limestone (Cambrian) and is overlain by the Escabrosa limestone (Mississippian). According to Ransome, both the upper and lower contacts apparently are comformable, and the upper contact is difficult to recognize.

In the Clifton-Morenci mining district, the Devonian rocks were named "Morenci shale" by Lindgren (1905, pp. 66–69), but the name has not been used outside the type area. The Morenci shale is more nearly similar in lithology to the Percha shale of New Mexico, discussed by Stevenson (1945), than it is to the Martin formation.

Sandstones of Cambrian and Devonian age near Payson were mapped by Lausen and Wilson (1925, pp. 7, 12–13) as the "Sycamore Creek formation," the name being credited to an unpublished manuscript by Stoyanow. Later Stoyanow (1936, p. 499) changed the name to "Sycamore sandstone member of the Jerome

	Age classification	Group	Formation	Character	Thickness in feet
		Disconformity			
Cambrian (Middle)			Sandstone	Red-brown cross-bedded pebbly Troy sandstone in northern Sierra Ancha and southern Mazatzal Mountains area; dark red-brown bedded friable Tapeats sandstone, 75-100 feet thick, in northwestern portion of region.	75-400
Pre-Cambrian	Younger pre-Cambrian	Apache group (in eastern Tonto Basin and southeastern portion of Mazatzal Mountain)	Unconformity		
Pre-Cambrian	Younger pre-Cambrian	Apache group	Basalt	Vesicular, epidotized basalt, present at most places	0-75
Pre-Cambrian	Younger pre-Cambrian	Apache group	Mescal limestone	Thin-bedded cherty dolomitic limestone, intruded by diabase	225-300
Pre-Cambrian	Younger pre-Cambrian	Apache group	Dripping Spring quartzite	Reddish-brown, generally massive, fine-grained arkosic quartzite; intruded by diabase	450-700
Pre-Cambrian	Younger pre-Cambrian	Apache group	Barnes conglomerate	Smooth, rounded pebbles in sandy, arkosic cement; intruded by diabase	5-50
Pre-Cambrian	Younger pre-Cambrian	Apache group	Pioneer shale	Brownish-red hard shale; intruded by diabase	150-250
Pre-Cambrian	Younger pre-Cambrian	Apache group	Scanlan conglomerate	Imperfectly rounded pebbles in sandy arkosic cement; intruded by diabase	0-30
Pre-Cambrian	Older pre-Cambrian	Unconformity	City Creek series	Shale with some interbedded quartzite; stratigraphic position uncertain	2000±?
Pre-Cambrian	Older pre-Cambrian	Mazatzal quartzite		Light-brown to gray vitreous, hard quartzite; intruded by granite	3800
Pre-Cambrian	Older pre-Cambrian	Maverick shale		Gray to maroon shale; appears only in Mazatzal Mountains; intruded by granite	500-800
Pre-Cambrian	Older pre-Cambrian	Deadman quartzite		Light-brown to gray, vitreous hard quartzite, pebbly at base; appears only in Mazatzal Mountains; rests unconformably on Red Rock rhyolite; intruded by granite	90-800
Pre-Cambrian	Older pre-Cambrian	Fault contact	Unconformity Alder series	Shale and grit with some quartzite and conglomerate; locally metamorphosed; intruded by diorite porphyry, porphyritic pyroxenite, granite, and rhyolite porphyry	5000 ±
Pre-Cambrian	Older pre-Cambrian	Yavapai group (previously termed Yavapai schist)	Red Rock rhyolite	Massive rhyolitic flows and agglomerate with minor intrusives; intruded by granite	1000 ±
Pre-Cambrian	Older pre-Cambrian	Yavapai group (previously termed Yavapai schist)	Fault contact Yaeger greenstone	Volcanic rocks of intermediate to mafic composition together with some intercalated sedimentary material; generally affected by low-grade metamorphism; intruded by diorite porphyry, granite, and rhyolite porphyry Base not exposed	2000±

After E. D. Wilson, 1939

FIGURE 10.—Pre-Devonian rocks of central Arizona.

formation" and apparently restricted it to one or more sandstone beds in the lower part of the Devonian. The term "Jerome formation" was proposed by Stoyanow in 1930 (pp. 316–317) for the Devonian rocks in north-central Arizona because he considered the Jerome formation as lithologically distinct, and separated by a land barrier, from the Martin limestone in southeastern Arizona. According to Stoyanow, the sandy beds in the upper part of the Devonian strata exposed on the Verde River about 12 miles northeast of Jerome contain a molluscan fauna. He proposed the name "Island Mesa beds" (1936, p. 500) for these sandy beds 122 feet thick and considered them younger than any in the Devonian section at Jerome. In the same paper, he restricted the Martin limestone and proposed additional names for the Devonian sedimentary rocks in southeastern Arizona (1936, pp. 486–495).

Stoyanow applied the name "Picacho de Calera formation" to the lower part of the Martin limestone in the Picacho de Calera Hills, the Rincon Mountains, and the Whetstone Mountains. In the Santa Catalina Mountains and on Pinal Creek north of Globe, he called the upper part of the Martin limestone the "Lower Ouray formation." Near Superior, Ariz., the lower 253 feet of the Devonian section has been called the "Crook formation" by Harshman (Short and others, 1943, p. 27), the middle 77 feet the "Martin limestone," and the upper 24 feet the "Lower Ouray formation." The term "Santa Rita limestone" was proposed by Stauffer (1928b, pp. 429–434) for a formation thought by him to be Middle Devonian, but it has not been recognized by other geologists (Stoyanow, 1936, pp. 494–495).

In the area studied, the Devonian strata comprise an essentially continuous mappable unit similar in lithology and topographic expression. Because here the formation contains 40 to 50 percent sandstone and shale, the name "Martin formation" is preferred to "Martin limestone." The general character of the formation is shown in figure 11. It will require considerable mapping and stratigraphic and paleontologic work to determine the relationships of the variously named units of Devonian age in Arizona. Several of the names seem to apply to peculiar facies or faunas and may represent merely a grouping of collecting localities and faunal zones. Hence it is not thought advisable to recognize formal subdivisions of the Martin formation in this report.

GENERAL DESCRIPTION

The average local thickness of the Martin formation in central and southeastern Arizona ranges from 300 to 400 feet where the whole formation is present. Near Grasshopper (fig. 9), the formation is thin because its lower part is missing; it ranges from 32 to 100 feet in thickness. The formation consists of a series of limestone, sandstone, and shale beds grading into one another horizontally and vertically. In most places these relatively weak beds form slopes, broken by low cliffs, between high cliffs formed by the underlying quartzites and the overlying Redwall limestone (Mississippian).

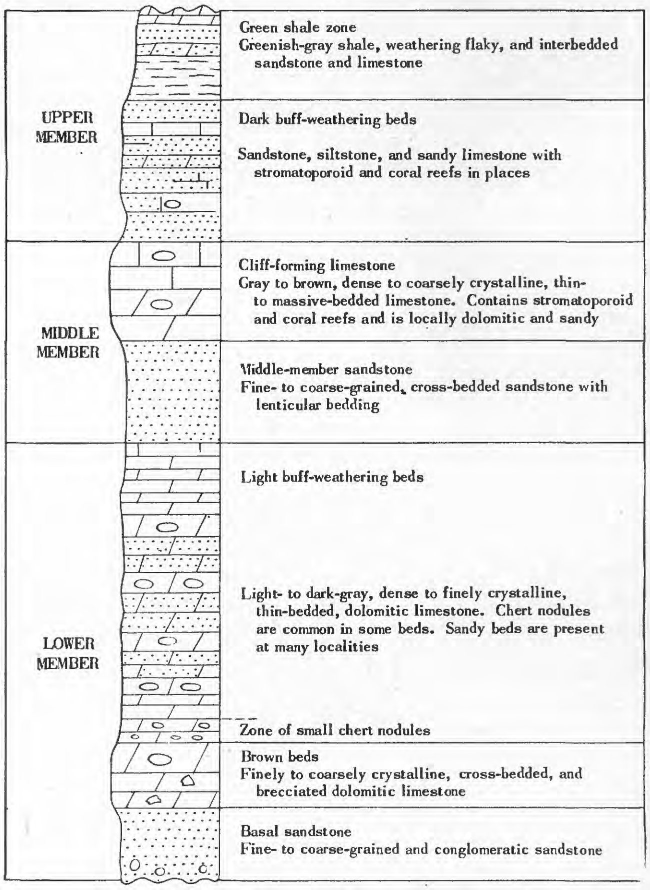


FIGURE 11.—Generalized section of the Martin formation (Devonian) in central Arizona.

Figure 12 shows typical exposures of the formation near the Salt River. As shown in the photograph, many of the beds, traced laterally, appear to wedge out.

DIVISIONS

Even though the rocks of the Martin formation are variable, the formation can be divided into three members: a lower conglomeratic sandstone and dolomitic limestone member; a middle member of sandstone and cliff-forming limestone; and an upper member consisting of calcareous sandstone, limestone, and shale. These three members are shown in the generalized section of the Martin formation (fig. 11 and pls. 11 and 12). They are more or less arbitrary and grade into

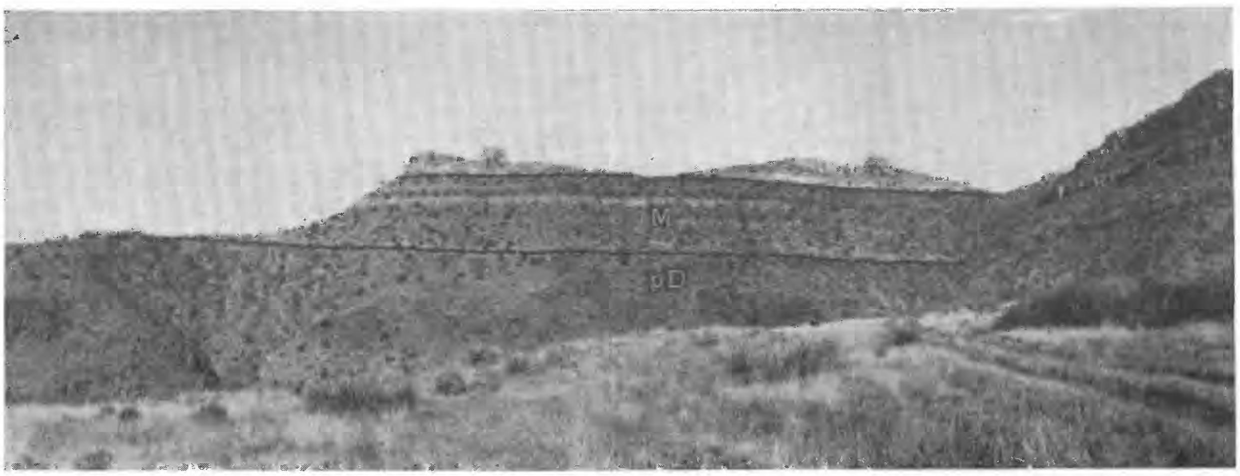


FIGURE 12.—View of the Devonian and Mississippian rocks exposed in the north wall of the Salt River canyon at the Prochnow mines, central Arizona (locality 5, fig. 9). The gray cliffs on the sky line are Redwall limestone (R), of Mississippian age, and the slopes below these cliffs are formed by the Martin formation (M), of Devonian age, which rests unconformably on the pre-Devonian diabase (pD) exposed in the canyon and in the foreground.

one another. The prevailing light-buff color of the dolomite in the upper part of the lower member distinguishes this member, even at some distance from the outcrop, from the dark-buff and gray-weathered middle and upper members. This difference in weathering was noted by Ransome in the Ray-Globe area (1916, p. 141).

LOWER MEMBER

The lower member includes (fig. 11 and pls. 11 and 12) a basal sandstone, brown limestone beds, and light buff-weathered beds. It ranges in thickness from 140 to 175 feet at most localities but thins to 83 feet at Tonto Creek (detailed sec. 13) and 93 feet at Cliff House Canyon (detailed sec. 8). Near Oak Creek village (detailed sec. 9), Spring Canyon (detailed sec. 10), and the O. W. Ranch (detailed sec. 11) the lower member is absent, and at Colcord Canyon (detailed sec. 12), where a detailed section was not measured, it was not recognized. The lower member, as used in this paper, is nearly equivalent to the Crook formation of Harshman (Short and others, 1943, pp. 27–29), but he included the sandstone near the middle of the Martin formation in the Crook formation, whereas the present authors have placed this sandstone in their middle member.

The basal sandstone of the lower member is 10 to 20 feet thick in most localities where the lower member of the Martin formation is present, but it is missing in places near Rockhouse Butte (detailed sec. 6) and Cliff House Canyon (detailed sec. 8). It is 200 feet thick at Gold Gulch (detailed sec. 17), where it fills a pre-Martin valley. The sandstone is greenish gray, weathering to a light yellow brown; it is uneven-grained to conglomeratic and is characterized by granules and pebbles of quartz and quartzite embedded in a fine- to coarse-grained matrix. The smaller grains tend to be clear and angular, but the larger grains and granules generally are frosted and well rounded. The cementing material is mainly argillaceous, although calcareous and quartzose beds may be found at most localities. The bedding is thin to medium, with faintly cross-bedded lenses varying greatly in thickness within short distances. Angular boulders are present in the basal sandstone at localities 13 and 17 (fig. 9) and at Natural Bridge.

The basal sandstone of the lower member grades upward into the overlying brown dolomitic limestones. The transitional beds, about 3 feet thick, consist of dark-gray sandy dolomitic limestone, with interbedded sandstone, and green to black shale in beds 0.01 to 0.1 foot thick. The brown beds of the lower member, where present, range in thickness from 20 to 53 feet and consist of dark-brown or black to light-gray dolomitic limestone which weathers brown and gives off a petroleum odor when freshly fractured. The texture of the rock is mainly finely crystalline, but some beds are medium to coarsely crystalline. The bedding is usually irregular, with lenses and wedges ranging from laminations to thick cross-bedded or brecciated masses in uneven contacts with the overlying limestone. The more massive phases of these brown beds tend to form cliffs. Dark-colored chert nodules and irregular masses are present in most outcrops, and poorly preserved fossils were found in the upper part of the brown beds at the Black River (detailed sec. 1).

The lower member is exposed in a road cut north of the Salt River (locality 2, fig. 9), as shown in figure 13. This is the most easily accessible and the best unweathered exposure of the Martin formation.

The light buff-weathering beds of the lower member include 77 to 138 feet of thin- to medium-bedded dense dolomitic limestone interbedded with very thin layers of green shale, as shown in plate 13. They are absent, or not typically developed, at Oak Creek village (detailed sec. 9), Spring Canyon (detailed sec. 10), and the O. W. Ranch (detailed sec. 11). The limestone varies from light to dark gray and weathers light buff or gray. Many of the limestone beds have rounded and frosted grains of quartz sand scattered through the rock or arranged along the bedding or cross-bedding planes. Calcite-filled cavities and dense gray chert nodules and stringers occur sparingly throughout the light-buff beds, but near the base is a zone 2 to 10 feet thick containing abundant small chert nodules. This is shown on figure 11 and plate 11 as a "chert zone." The nodules are about the size and shape of beans, averaging about 10 millimeters in length, and have dense dark-gray centers and yellow-brown rinds. The zone can be recognized at most localities by its peculiar chert, enclosed in the dense brittle dolomitic limestone, and its position immediately above the brown beds. It was not recognized at Tornado Peak (detailed sec. 19) nor at the localities between Cliff House Canyon (detailed sec. 9) and Tonto Creek (detailed sec. 13), where this part of the Martin formation is missing. Ransome (1916, p. 141) has described this chert zone in the Ray-Globe area, and it seems to be a widely traceable zone in the Martin formation.

MIDDLE MEMBER

The middle member, composed of a cross-bedded sandstone and a cliff-forming limestone, ranges in thickness from 50 to 177 feet. However, it is absent at Oak Creek village (detailed sec. 9), Spring Canyon (detailed sec. 10), and the O. W. Ranch (detailed sec. 11). The thickness of the sandstone ranges from that of a single grain one-sixteenth millimeter in diameter to 90 feet, and its texture varies from that of a very fine grained sandstone to that of a coarse-grained conglomeratic sandstone with its larger grains well rounded and frosted. The cementing material is mainly clay or calcium carbonate, but some silica occurs at most places and the rocks are correspondingly weak or strong depending upon the amount of silica cement. The bedding is generally thin and slabby, with small-scale cross bedding in wedges or lenses when seen in a weathered outcrop. However, on fresh unweathered surfaces the sandstone appears to be massive. It is greenish gray, weathering to buff, reddish brown, or gray. Sandy shale and sandy limestone are interbedded with the sandstone. Fucoidal markings are common on the under sides of the sandstone beds, and there are numerous worm borings. A few poorly preserved spirifers were observed in the calcareous phases of the sandstone.

The cliff-forming limestone in the upper part of the middle member varies from a dense to a medium-crystalline light-gray to brown limestone which is partly dolomitic. It ranges from 38 to 98 feet in thickness. Some thin beds exist, but thick beds are characteristic of the unit; all the beds thicken and thin markedly within relatively short distances. Many of the massive limestone lenses are crowded with corals and stromatoporoids and seem to represent small bioherms. The limestone is sandy and grades laterally into sandstone in places. At Roosevelt Lake (detailed secs. 15, 16) and at the Black River (detailed sec. 1), the entire middle member is especially sandy.

FIGURE 13.—Lower member of the Martin formation as exposed in a road cut on United States Highway No. 60 north of the Salt River, central Arizona (locality 2, fig. 9). The brown beds (B) are in the lower third of the cut. The upper two-thirds of the cut shows the thin-bedded gray dolomitic limestones and shale partings of the light buff-weathering beds.

UPPER MEMBER

The upper member consists mainly of sandstone and sandy limestone and green shale, shaly sandstone, dolomitic limestone, and limestone. It ranges in thickness from 32 to 194 feet. As a whole, the member is more calcareous than the lower and middle members and weathers to a deeper buff.

The dark buff-weathering beds are 26 to 178 feet thick. The detrital sediments include sandstone, siltstone, and green shale. The sandstone is greenish gray to light yellow white on fresh fractures. Most of the beds weather to a dark buff, but some weather to gray, reddish brown, or pink. The sandstone is uneven-grained and has a matrix of very fine sand or silt and scattered coarser grains, granules, or small pebbles. Most of the larger grains are rounded and frosted, but the small ones are subangular to subrounded and lack the frosted surface. Much of the sandstone is cemented with calcareous or argillaceous material, but some silica-cemented beds are present in the more resistant ledges. The sandstone is typically thin-bedded and slabby, although massive cross-bedded sandstone lenses occur in many places.

The dolomitic limestone is dense light gray to brown and weathers to a dark buff or brown. Most of the limestone is silty or sandy, with rounded and frosted quartz grains scattered through the rock or arranged along the planes of bedding or cross bedding. It is very similar to some of the beds in the upper part of the lower member. The limestone is the same color as the dolomitic limestone, but its texture varies from dense to coarsely crystalline and it commonly contains abundant corals and stromatoporoids. The dolomitic limestone is thin- to medium-bedded, but the limestone occurs mainly in thick lenses or bioherms.

Brown, strong-textured chert nodules are common in some of the sandstone and sandy limestone beds, and, in the vicinity of Grasshopper (detailed secs. 8–11), there are beds and nodules of gray to white dense fossiliferous chert. Calcite-lined cavities and geodes with quartz and calcite crystals occur throughout the upper member. Fucoids, worm tubes, corals, brachiopods, crinoid stems, and fish plates occur sporadically, and the fossils in many of the sandstone and sandy limestone beds are being silicified in the present weathering cycle. In most localities, the fossils are poorly preserved, and the faunules collected contain relatively few species even though the individuals of a few species are abundant.

The green shale zone at the top of the upper member is 6 to 75 feet thick, averaging about 45 feet, but it appears to be absent at the O. W. Ranch (detailed sec. 11) and Colcord Canyon (detailed sec. 12) and to be represented by argillites at Tornado Peak (detailed sec. 19). The shale is a fissile clay shale, olive gray on fresh surfaces but weathering to yellow-brown papery flakes or needles. At Gold Gulch (detailed sec. 17) the green shale appears to be lower in the Martin formation than it is in the sections to the north; probably it does not occur in the same stratigraphic position everywhere. The interbedded limestone is brown, weathers dark buff, and is dense to medium-crystalline, dolomitic, and sandy or silty. The sandstone is similar in color, bedding, and grain size to the sandstones in the other members. Some sections of the green shale zone show thick beds of shale, whereas other sections show very thin interbedded shales, sandstones, and limestones, with great variation in lithology within short distances. This unit is concealed in many localities, although it is exposed naturally in some places (fig. 19) and is completely exposed in a road cut on United States Highway No. 60.

RELATIONSHIP TO UNDERLYING FORMATIONS

An angular unconformity separates the Martin formation from the underlying pre-Cambrian and Cambrian rocks in central Arizona. In much of the area, the underlying formation is the Cambrian Troy quartzite or Tapeats sandstone, but in many localities the Cambrian rocks are absent and the Martin formation rests on older rocks. Where the Troy is a true sedimentary quartzite, it is easily distinguished from the sandstone in the base of the Martin formation because the latter is weaker, more calcareous, and lighter in color than the Troy quartzite. At Cliff House Canyon (detailed sec. 8) and in other localities where the Troy is a sandstone, it is difficult to determine the Troy-Martin contact. In the Tonto and East Verde River basins, the Tapeats sandstone, which there underlies the Martin formation, is difficult to distinguish from the sandstone of the Martin. The Tapeats sandstone is more resistant to erosion, darker brown, and more strongly cross-bedded, and it weathers more slabbily than the sandstone generally found in the base of the Martin formation. The sandstone which is included as the basal unit of the Martin formation in the section along Tonto Creek (detailed sec. 13) is not typical of either the Martin formation or the Tapeats sandstone.

If the authors are correct in assigning the basal Paleozoic sandstone at Tonto Creek (detailed sec. 13) to the Devonian Martin formation, the Devonian here rests on granite of pre-Apache age, possibly equivalent in age to the granite found in wells south of Holbrook, Ariz.

Stoyanow, both in 1942 (pp. 1266–1268) and in earlier papers, reported finding Devonian fish plates in sandstone at several localities in the Tonto and East Verde River basins, but the exact stratigraphic position at which he found them is not clearly indicated in his reports. Fish plates are not common at any of the localities the present authors visited in this area, and the specimens they found came from beds well above the base of the Martin formation. No fossils were found in the sandstone assigned to the Tapeats. It will require detailed mapping and careful collection and study of fossils to establish definitely the correlations of the sandstone beds in this area.

Near the O. W. Ranch (detailed sec. 11), the Martin formation is in contact with the beveled edges of the Cambrian Troy quartzite and with formations in the pre-Cambrian Apache group (fig. 25). A similar relationship is shown at Gold Gulch (detailed sec. 17), where the basal sandstone of the Martin averages 20 feet in thickness but locally is 200 feet thick where it fills a pre-Martin valley. The thick conglomerate in the valley fill is composed of angular to well-rounded pebbles and angular boulders up to 3.5 feet in diameter embedded in a matrix of poorly sorted micaceous sand. The round quartz pebbles seem to have come from the Barnes and Scanlan conglomerates, and the angular boulders look like fragments of the Dripping Spring quartzite, the Pioneer shale, and other formations of the Apache group locally in contact with the Martin. The material in the conglomerate must have been derived from a local source. The pre-Martin surface must have had a local relief of at least 180 feet.

At Horse Shoe Bend in Gold Gulch, the Martin formation is intruded by diabase dikes and sills which, in places, follow the contact between the Martin formation and older rocks. At the Salt River (detailed secs. 2, 5), the Martin formation rests on weathered diabase very similar in lithology to the post-Devonian diabase at Gold Gulch, but the diabase at the Salt River is considered to be of pre-Devonian age. In the east wall of Cow Canyon near its junction with the Salt River (opposite Beckers Butte observation shelter on United States Highway No. 60), the Troy quartzite appears to have been downfaulted against the diabase, and the Martin formation rests unconformably on each of them (fig. 14). The basal sandstone of the Martin is either thin or absent where the formation overlies the Troy quartzite, but it is well developed above the diabase.

About a mile north of Cliff House Canyon (detailed sec. 8), the Martin formation abuts against cliffs of the Troy quartzite and thins from 400 to 100 feet (estimated), as shown by figures 15 and 16. The lower and middle members of the Martin formation abruptly pinch out, and only the upper member continues northward over the buried ridge. This buried ridge is here named "Chediski ridge" after the Chediski Indian farms (fig. 17). The basal sandstone of the Martin formation is not especially thick in the vicinity of Chediski ridge but is even thinner and less continuous north of Rockhouse Butte (detailed sec. 6) than it is southeast of this locality. The middle member of the Martin formation becomes sandier and thicker toward Chediski ridge, as is indicated by the thickness of the sandstone (88 feet) and the sandy cliff-forming limestone (89 feet) in the middle member at Cliff House Canyon (detailed sec. 8). Near the cliff there are angular blocks of Troy quartzite in the dolomite of the lower member of the Martin formation, but these are

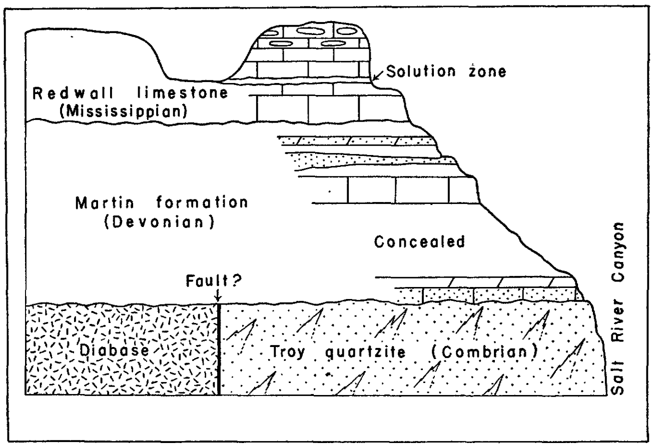


FIGURE 14.—Diagrammatic sketch of the exposures in the east wall of Cow Canyon, central Arizona, opposite United States Highway No. 60 (locality 2, fig. 9), showing the Martin formation (Devonian) resting unconformably on the Troy quartzite (Cambrian) and pre-Devonian diabase. The contact between the Troy quartzite and the diabase is apparently faulted. The sketch is not to scale.

relatively rare and the cliff does not seem to have supplied a great deal of sediment. The upper member of the Martin formation on Chediski ridge, although sandy, includes thick lenses of limestone which in places rest directly on the Troy quartzite. At other places the basal beds of the upper member are sandstones and conglomerates which vary greatly within short distances.

In the vicinity of Gordon and Haigler Creeks, between the Chediski and Christopher Mountain ridges (figs. 17, 25), about 300 feet of Martin formation is present. This thickness was determined by pace-and-compass traverse; no detailed section was measured because the exposures are poor. At Christopher Mountain the Apache group, the Troy quartzite, and the Martin formation abut against cliffs of the pre-Cambrian Mazatzal quartzite. The Apache group and the Troy quartzite are not known west of this mountain, but the Martin formation is probably continuous to the north.

The stratigraphic relations of the rocks at Natural Bridge, first pointed out by Ransome (1916, p. 159), were later discussed by Hinds (1936a, p. 10) and Stoyanow (1942, pp. 1267–1270). Stoyanow regards the

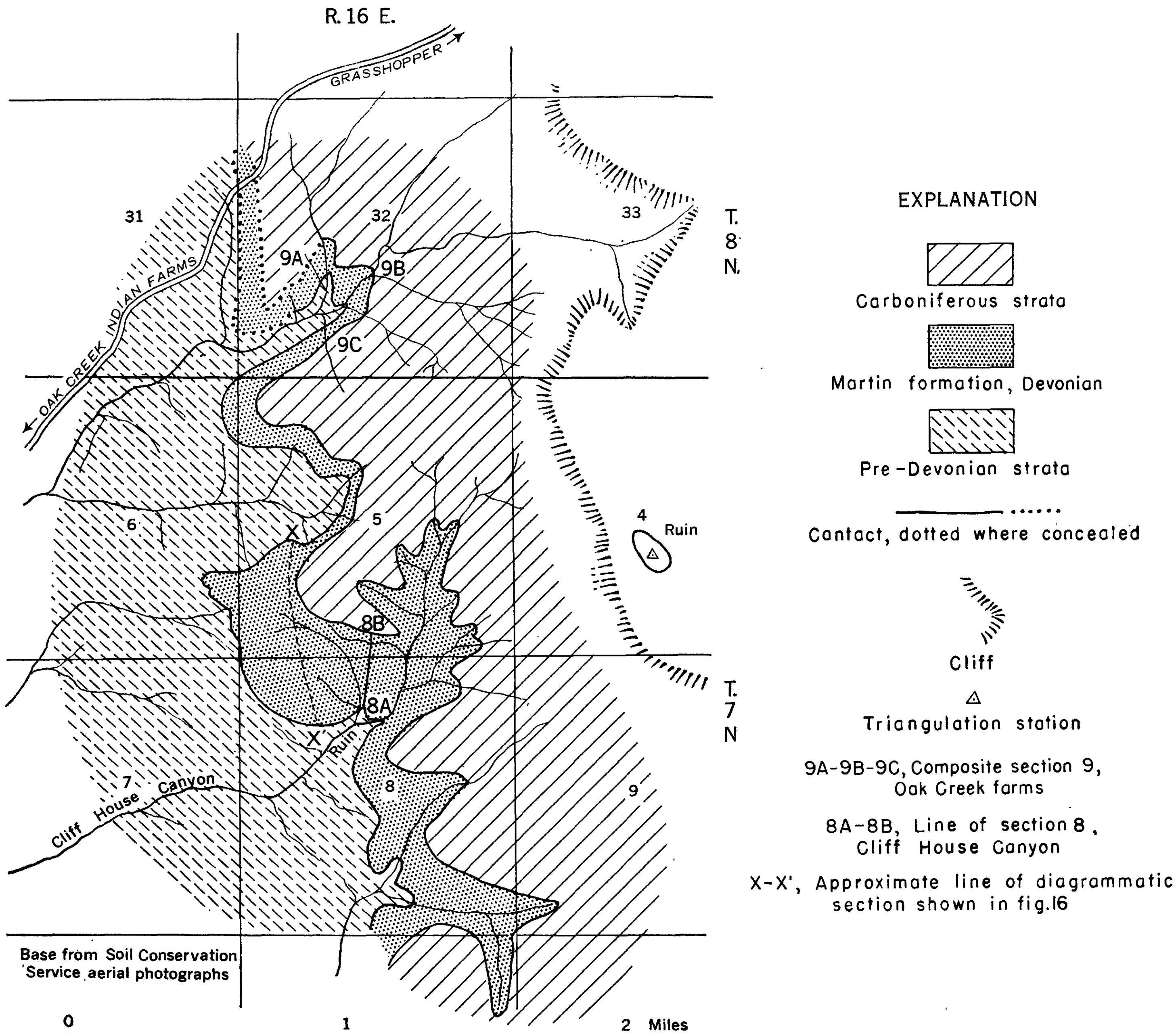


FIGURE 15.—Geologic sketch map of the Cliff House Canyon area, central Arizona, showing the distribution of the Martin formation (Devonian) and the location of the pre-Devonian quartzite cliffs against which it thins, the location of measured sections, and the location of the diagrammatic section shown in figure 16.

basal Paleozoic sandstone at Natural Bridge as the base of the Martin formation, although previously it had been considered Cambrian in age. In the present report his determination has been accepted. Inasmuch as the Paleozoic strata near Natural Bridge are not well exposed, the local structure will be difficult to work out. There are faults in the Paleozoic beds, and in places they dip 30°–45°. It will require careful mapping and considerable time to measure this section accurately. The unconformable contact between the Martin and the underlying Mazatzal quartzite or Red Rock rhyolite of Wilson is exposed in several places in Pine Canyon just above Natural Bridge (fig. 18). The basal sediments of the Martin formation are very conglomeratic and include large angular blocks of quartzite and rhyolite. Undoubtedly the Martin formation and Redwall limestone abut against cliffs of the Mazatzal quartzite at Natural Bridge essentially as Ransome showed them (1916, p. 159, fig. 14). This ancient land area was a northeastward-trending spur of Mazatzal land and is here called "Pine ridge" (figs. 17, 25).

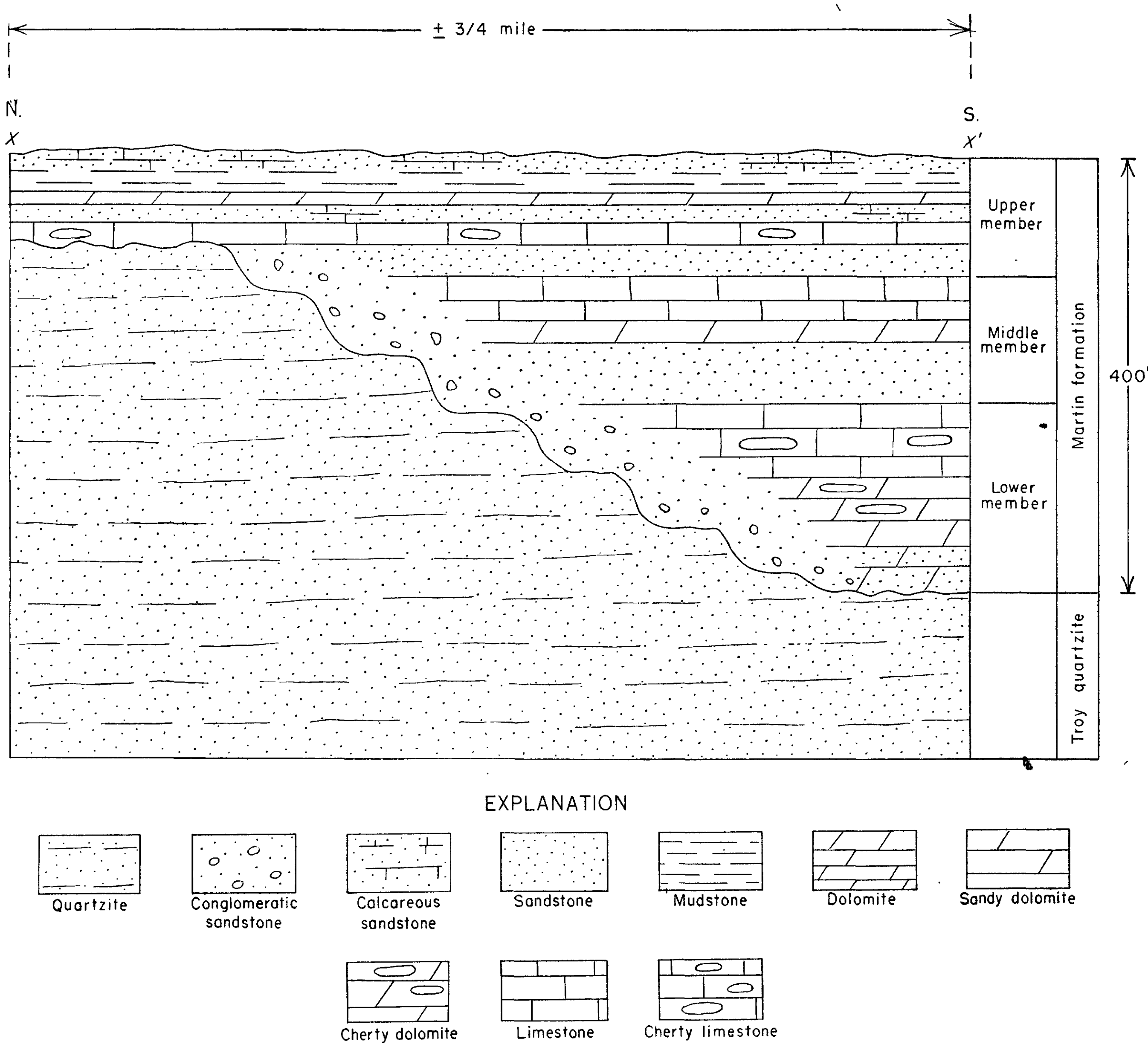


FIGURE 16.—Diagrammatic section of the Martin formation, abutting against cliffs of the Troy quartzite near Cliff House Canyon, central Arizona. (See fig. 15 for the location of the section.)

Conglomerate, sandstone, and sandy granular limestone of the Martin formation rest unconformably on the Mazatzal quartzite on the southeast flank of Pine

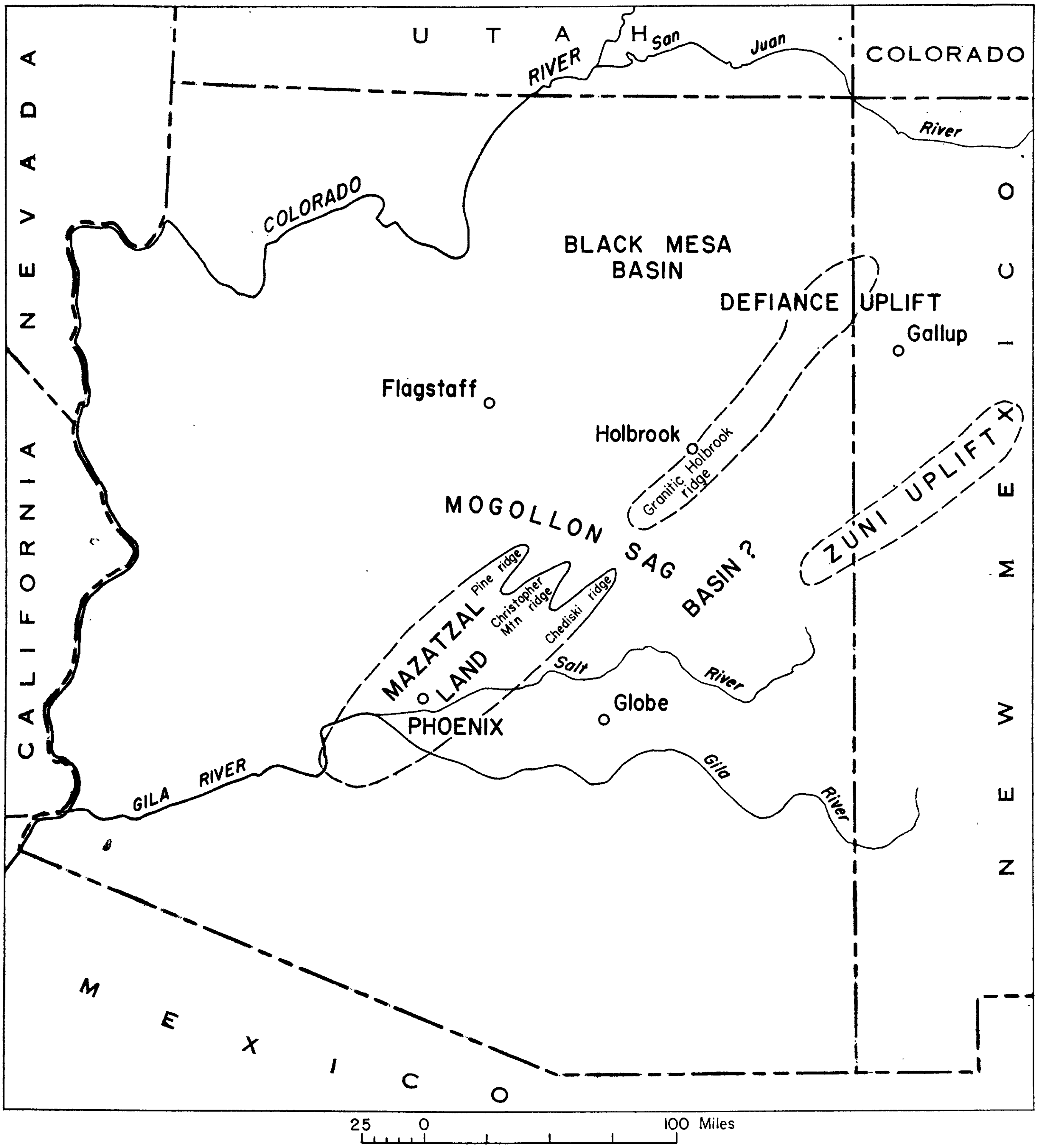


FIGURE 17.—Map showing the distribution of Late Devonian paleogeographic elements in Arizona.

ridge at the north end of Buckhead Mesa, along the Pine-Payson highway just south of bench mark 5735, Pine quadrangle. At the north end of Pine ridge, about a mile south of the town of Pine, the contact between the Mazatzal quartzite and the adjacent rocks is concealed. The Redwall limestone and the Naco formation appear to abut against the ridge. The dip of the Redwall limestone and the distance to the nearest outcrop of Mazatzal quartzite indicate that there is little or no Devonian here. Pine ridge probably was completely covered by the Supai formation, but it may have been an island during Pennsylvanian time.

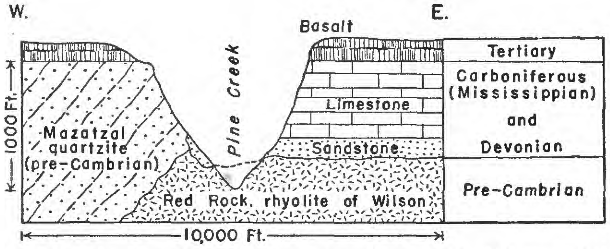


FIGURE 18.—Diagrammatic section across Pine Creek at Natural Bridge, northwest of Payson, Ariz. The Devonian and Mississippian rocks abut against a cliff of pre-Cambrian rocks, and Pine Creek marks the approximate position of the ancient sea cliff. Modified from Darton and Stoyanow.

RELATIONSHIP TO OVERLYING FORMATION

The top of the Martin formation is not easily recognized at all localities, as was pointed out by Ransome in his original description (1904, pp. 34–35). Although the contact appears to be conformable, there was probably a break in deposition between the Martin formation and the Redwall limestone. As the thickness of the Martin is relatively uniform over large areas where the whole formation is present, probably little was removed during a prolonged period of erosion. The green shale that forms the top of the Martin at some places is not resistant to erosion, and it would have been removed during a prolonged period of erosion. The contact is usually drawn at the base of the massive Redwall limestone for convenience in mapping (figs. 12, 19). It is possible that some of the limestone at Superior (detailed sec. 18), Gold Gulch (sec. 17), and the Black River (detailed sec. 1) included in the Redwall limestone should have been referred to the Martin formation. At Superior, fossils collected from the limestone, here considered basal Redwall limestone, were tentatively identified by Huddle as Mississippian. The rocks containing the fossils are similar in lithology to the limestone questionably referred to the Redwall at Gold Gulch and the Black River. No identifiable fossils were collected at the latter localities. Gutschick (1943, p. 4) reports reworked red regolith at the base of the Redwall at Sycamore Canyon (Yavapai County). In the Grand Canyon region the Temple Butte limestone was strongly eroded before the deposition of the Redwall limestone.

PALEOGEOGRAPHY

The possibility of a Paleozoic land area in Arizona has long been recognized. Schuchert (1910, pl. 49, opposite p. 464) recognized a Paleozoic positive element in Arizona, California, and Mexico which he called "Ensenada," and a similar positive element was called "Calarizona" by Ver Wiebe (1932, fig. 4, opposite p. 514). Both of these were considered northward-trending land masses lying principally in western Arizona. Ransome (1916, p. 159) described the stratigraphic relations of the Mazatzal quartzite and the Paleozoic rocks near Pine and Natural Bridge. He suggested the existence of a land barrier in the area adjacent to Tonto Basin which probably persisted throughout the Paleozoic and separated a Paleozoic basin in central and southeastern Arizona from a similar basin in the plateau region to the north and west. Stoyanow (1936, p. 462, and 1942) expanded this idea and proposed the name "Mazatzal land" for a positive element in southwestern and central Arizona which he considered to have been persistent throughout the Paleozoic and to have affected Mesozoic paleogeography. He also assumed that there was a land mass in northeastern Arizona during the Paleozoic, but it is not clear whether he considered this a part of Mazatzal land.

Mazatzal land is here regarded as a northeastward-trending land mass in central Arizona, as shown in figure 17. At its north end, near the present Mogollon

FIGURE 19.—Contact between the Martin formation and the Redwall limestone in Flying "V" Canyon, central Arizona (locality 3, fig. 9). The Redwall limestone (R) forms the overhanging ledge at the top of the exposure, and the upper member of the Martin formation is shown in the middle and foreground. There is no obvious unconformity between the Redwall limestone and the green shaly beds (Mg) of the Martin formation.

Rim, Mazatzal land splits into three northeastward-trending spurs, the Chediski, Christopher Mountain, and Pine ridges previously mentioned. Between these ridges there are normal sections (fig. 25) of the Devonian sedimentary rocks, and the Late Devonian seas obviously had access to the interridge basins throughout the time of the deposition of the Martin formation in central Arizona. This access may have been mostly to the northwest, or complete connection between the northwestern and southeastern seas may have extended between Mazatzal land proper and the northeastward continuation, the granitic Holbrook ridge. The authors have postulated a sag, or gap, between the land masses near the Mogollon Rim, which they have called the "Mogollon sag." The presence of the upper part of the Martin formation in the area between Grasshopper and the O. W. Ranch on Chediski ridge shows that the Late Devonian seas spread through a gap between Mazatzal land and the granitic Holbrook ridge during the late phases of Martin deposition, but it does not prove that the gap was a seaway throughout the time of the deposition of the Martin formation. Data now available do not prohibit the contouring of 300 feet of the Martin formation in the Mogollon sag, but the tentative lines of equal thickness (pl. 13) suggest that the Mogollon sag was not a seaway throughout the time of Martin deposition.

The granitic Holbrook ridge is indicated by the absence of Devonian sedimentary rocks above granite in the logs of the Taylor-Fuller No. 1 well (Great Basin Oil Co.) and the New Mexico-Arizona Land Co. No. 1 well (Union Oil Co. of California and Continental Oil Co.). No Devonian strata were recognized in the samples from the Taylor-Fuller well, but the Redwall limestone may be represented by 11 feet of limestone which rests on crystalline rocks. The New Mexico-Arizona Land Co. No. 1 well encountered only 10 feet of limestone, probably Redwall, and entered weathered granite at 3,593 feet. The granitic Holbrook ridge probably continues northeastward to the Defiance uplift, as indicated by the Creager-State No. 14-6 well (General Petroleum Corp.), northeast of Holbrook, which encountered granite at a depth of 3,355 feet.

The Defiance uplift must have been a high area during the Paleozoic, for only in Permian time was it completely buried. The structure of the pre-Cambrian rocks in the Defiance uplift, like that of the pre-Cambrian rocks in central Arizona, trends northeastward. According to Hinds (1936b, p. 101), there may have been a continuous belt of mountains from central Arizona to southwestern Colorado as a result of the Mazatzal revolution during pre-Cambrian time. He considers the quartzite of the Defiance uplift very similar to the Mazatzal quartzite in central Arizona. These quartzites could have persisted throughout the Paleozoic as a chain of ridges because they are extremely resistent to erosion. According to Wilson (1939), who described the Mazatzal revolution in central Arizona, there were no orogenic movements after the Mazatzal revolution in this area until the Tertiary.

Devonian and Mississippian strata are probably present in normal thicknesses in Black Mesa basin to the northwest of the granitic Holbrook ridge. The present shape of Black Mesa basin may be due to Laramide or later movements, but its location was probably predetermined by Paleozoic deposition in the same area. It is much less probable that it was a Paleozoic land area. The presence of middle Paleozoic rocks is indicated by the fact that the Aztec Land and Cattle Co. No. 1 well (Union Oil Co. of California and Continental Oil Co.) penetrated about 45 feet of Redwall limestone and 32 feet of what is probably Martin formation before the well was abandoned. The other well drilled by the same companies 9 miles to the east seems to have been closer to the crest of the granitic Holbrook ridge, inasmuch as it penetrated only 10 feet of what is probably Redwall limestone before entering granite.

The Black Mesa basin of Paleozoic time probably trended northeastward parallel with the granitic Holbrook ridge. The section of the Martin formation at Jerome, about 500 feet thick (Darton, 1925, pp. 57–59), is probably in the southern extension of the basin. The Redwall limestone, though not especially thick at Jerome, is considerably thicker there than near Pine and Payson. Only 120 feet of Devonian strata are exposed on the flank of Elden Mountain (Brady, 1933, p. 303); the base of the formation is not exposed. The northward continuation of Black Mesa basin is suggested by the thick sections of Devonian and Mississippian rocks shown in wells in southeastern Utah (Bass, 1944). The XX No. 1 well (Burrell Collins, Collins), in Coconino County (fig. 9), encountered 180 feet of limestone, probably of Mississippian age, and 320 feet of dolomitic limestone, probably of Devonian age. The samples from this well, loaned by the Sinclair Oil Co., were examined by J. B. Collins. However, they are incomplete and difficult to correlate.

The Black Mesa and San Juan basins are separated by the Defiance uplift. These three structural features may be genetically related, and, if this is correct, the two basins may have had a similar history. Devonian and Mississippian oil- and gas-bearing rocks are known in the San Juan basin, and this occurrence suggests that these rocks may also exist in the Black Mesa basin.

The principal evidence against a Paleozoic Black Mesa basin is the fact that the early Paleozoic formations exposed in the Grand Canyon suggest the approach to a land mass as they are traced toward the east. This has been shown by McKee (1945, pp. 119–120) and earlier writers, but the evidence does not seem to require a continuous rugged land mass in the whole of northeastern Arizona.

Slight indications of a basin to the southeast of the granitic Holbrook ridge are seen in the thickness of the Devonian and Mississippian strata in the Fort Apache Indian Reservation to the south (pl. 13) and in the limestone penetrated just above the basement rocks in the Government No. 1 well (Franco-Arizona Oil Co.). This limestone may be equivalent in age to the lower part of the Supai, but if it is Devonian or Mississippian it would indicate a basin in this area.

A southwestern extension of the Zuni uplift is suggested by the quartzites found in the State No. 2 well (Argo Oil Corp.) at Zuni Creek and the fact that no possible Devonian or Mississippian strata were penetrated by this well. The granitic Holbrook ridge and the Defiance and Zuni uplifts probably formed a continuous land area, at least at times, during the Late Devonian (fig. 26).

DISTRIBUTION OF FACIES AND CONDITIONS OF DEPOSITION

The principal belts of facies in the Martin formation trend toward the northeast in central and southeastern Arizona and are roughly parallel to Mazatzal land. In southeastern Arizona the Martin formation is mainly limestone but also contains some shale, which increases in thickness from Bisbee northward to Tombstone, the Clifton-Morenci district, and Tornado Peak (detailed sec. 19). The sandy facies of the Martin are well represented on the southeast flank of Mazatzal land near the town of Roosevelt and near Oak Creek. A similar facies is present on the northwest side of Mazatzal land.

The percentages of sandstone in each section, shown on plate 13, were computed by totaling the thickness of sandstone and dividing by the formation thickness. Although, thus presented, they give the appearance of accuracy, they are subject to several types of error. To compute percentages from the field data it is necessary to assume that the beds are pure rock types, such as pure sandstone, containing neither limestone nor mud. This obviously is not so. Probably the authors were inconsistent in the field separation of calcareous sandstones and sandy limestones. Moreover, thick concealed units, such as the 50-foot unit in the upper part of the Martin formation at Salt River draw (detailed sec. 7), greatly change the percentages, if assumed to be sandstone. Plate 13 was prepared to show graphically the distribution of the sandy facies and the relationship of the sandy facies to the thickness of the formation. Several types of clastic ratios were computed, such as those used by Read and Wood (1947) and Krumbein (1948), but the percentage of sandstone seemed to be most significant and is shown on plate 13. It approximates most closely a quantitative expression of the increasing sandiness of the Martin formation as Mazatzal land is approached. It is not a true representation of sandiness, however, since the limestones in the sections nearest Mazatzal land contain a larger percentage of sand grains than those in the more distant sections, and this sand is not accounted for in the computations.

The data shown on plate 13 seem to indicate that there is no relationship between thickness and percentage of sandstone. The thickest sections at Roosevelt Lake and one of the thinnest sections, that at Oak Creek, contain about the same percentage of sandstone. The thick sections at Superior and Salt River draw are not especially sandy. Considering its position, the East Verde River section has a surprisingly low percentage of sandstone. The percentage of sandstone is the same at Superior and Gold Gulch, but the significance of this is not clear.

Many of the limestones appear to be clastic in origin, particularly those with quartz sand grains along crossbedding planes. The presence of these clastic limestones may reduce the significance of the percentage of sandstone and the percentage of arenaceous and argillaceous rocks as compared to the percentage of calcareous rocks.

The Martin formation appears to have been deposited in a sea which advanced from a geosyncline in Mexico, spread on both sides of Mazatzal land, and joined again through the Mogollon sag and perhaps around the northeast end of the Defiance uplift. The land surface over which the sea spread was relatively flat in the northwestern and southeastern parts of Arizona, but the flanks of Mazatzal land had a relief of 100 to 300 feet. The total relief of Mazatzal land is unknown. Chediski ridge was completely submerged only very late in the Devonian period; Christopher Mountain ridge, Pine ridge, parts of the granitic Holbrook ridge, and the Defiance uplift seem to have projected as islands above the Devonian sea. Christopher Mountain ridge and Pine ridge may have been peninsulas extending from the main mass of Mazatzal land. No regressive deposits have been recognized in the Martin formation. Sedimentation during the Late Devonian must have been rather slow, because limestone and dolomite were deposited in the vicinity of Mazatzal land throughout the epoch.

A basal sandstone of the Martin formation is found in most of the sections examined in central Arizona (pls. 11, 12), but it varies in thickness and at some localities is absent. It has not been reported from the extreme southeastern part of the State, but Stoyanow (1936, p. 488) reported a yellow sandstone 4 feet thick at the base of the Devonian in the Picacho de Calera Hills, 15 miles northwest of Tucson. The basal sandstone is thin, or absent, near Rockhouse Butte (detailed sec. 6) and in the sections (7, 8) closer to Chediski ridge. This ridge seems to have supplied little of the early sediments to the Martin formation, and the distribution and thickness of the sandstone show no close genetic relationship to Mazatzal land. The conglomerates in the basal sandstone are thickest and best developed where they filled existing valleys, as at Gold Gulch (detailed sec. 17), and near the buried ridges. The sandstone and conglomerates seem to have been spread by waves and currents into bars and lenses filling the low places on the sea floor as the advancing Late Devonian sea reworked the sandy veneer of the old land surface. Such a depositional environment is suggested by the irregular bedding, cross bedding, and uneven grain sizes of the basal sandstone. The common occurrence of rounded frosted grains in the Martin formation in central Arizona suggests that there may have been some wind-blown sands on the old land surface.

The brown beds of the lower member were recognized at all the localities studied where this part of the Martin formation is present. They contain quartz sand grains only in the localities nearest the ridges of Mazatzal land, but this land area apparently supplied little sediment during the time when the brown beds were deposited. The irregular upper surface, cross bedding, and brecciation of the brown beds suggest that periods of deposition alternated with periods of submarine erosion during the time of their accumulation and that the beds must have been laid down in water shallow enough to be subject to strong wave and current action. The strongly cross-bedded portion of the brown beds appears to be a clastic deposit. No older limestone is known in the area which could have supplied calcite or dolomite sand grains, and, as there are relatively few fossils in the brown beds, it is unlikely that organisms supplied such grains. Accordingly, the limestone sand needed to form the clastic portion of the brown beds apparently was supplied by the reworking of slightly older and partly consolidated limy beds followed by dolomitization of the redeposited lime fragments.

The light buff-weathering beds of the lower member of the Martin formation are typically dolomitic limestone. Green shale partings separate the limestone beds in the areas north and west of Tornado Peak (detailed sec. 19). In southeastern Arizona, the dolomitic limestone is replaced by limestone and pink shale, according to Ransome (1904, pp. 34–35). At Tornado Peak the marble above the O'Carroll ore bed (pl. 12) is slightly dolomitic, though not sandy. In all sections north and west of Tornado Peak, some beds of dolomitic limestone contain sand grains, and in many localities there are beds of sandstone or siltstone. The amount of sand in the limestone and the change from limestone to dolomitic limestone seem to be governed by proximity to Mazatzal land. Slow sedimentation in shallow water during the time of deposition of the light-buff beds is indicated by the thin to medium bedding, shale partings, ripple marks, and mud cracks in the limestone in several localities and by the even more common occurrence of cross-bedded streaks of sand grains.

The cross-bedded sandstone and the organic cliff-forming limestone of the middle member of the Martin formation also were deposited in shallow water and are increasingly sandy toward Mazatzal land, as is shown by the very sandy sections at Roosevelt Lake (detailed secs. 15, 16) and Cliff House Canyon (detailed sec. 8). The sandstone in the middle member does not indicate readvance of the sea, for the time of its deposition does not correspond to the spread of sediments over Chediski ridge. This sandstone may have been deposited and the associated bioherms built up in Late Devonian time when this portion of the sea floor was near wave base. Later the sea covered Chediski ridge and sedimentation was resumed.

Bioherms are abundant in the middle and upper members of the Martin formation in central Arizona and have been reported by Stoyanow (1936, p. 487) in the Santa Rita and Santa Catalina Mountains south and north of Tucson. They were built largely by stromatoporoids and corals but in part by other organisms. The bioherms are relatively low mounds a few hundred feet to a few hundred yards in diameter and 10 to 30 feet thick. The interreef areas are filled by sandstones, siltstones, and sandy limestones. Massive cores and flank fingers of brecciated limestone are not present, but there is evidence of wave and current action in the irregular bedding characteristic of the interreef sediments and in the extreme lateral variations in thickness and lithology of the organic limestone and interreef deposits. The variable thicknesses of bioherms caused difficulty in measuring sections on Chediski ridge and in Salt River draw (locality 7, fig. 9), where bioherms are well developed. The areas most favorable to the development of bioherms seem to have been those places where the Late Devonian sea spread over the rocky ledges of Chediski ridge.

The upper member of the Martin formation also demonstrates the increasing sandiness of the formation toward Mazatzal land. As shown in plates 11 and 12, this member includes limestone beds in sections 1, 17, and 18 and at Pinal Creek north of Globe, whereas in sections 2, 4, 5, 6, 7, 8, 15, and 16, which are nearer Mazatzal land, it is predominantly sandstone. The sections overlying Chediski ridge show a mixed sandstone and limestone facies, but there the limestone is mainly organic in origin. An arenaceous facies appears to be present on the northwest side of Mazatzal land, as is indicated by the sandy sections at Jerome and Island Mesa (Stoyanow, 1936, pp. 495–500). The increase in the amount of sand supplied to the sea during the time of the deposition of the upper member was probably due to an advance of the shore line over the sandy soil and dune sands of Mazatzal land. The advance of the sea over these loose sandy deposits provided an easily available source of sand. The quartzites of Mazatzal land probably provided very little sand directly, but some new material may have been produced by marine erosion of the quartzites. The sea must have been relatively shallow and deposition slow to have permitted the growth of bioherms when the upper member was being laid down.

CORRELATION

The fossils collected by Ransome from the Martin formation were regarded by H. S. Williams as Middle Devonian (Ransome, 1904, pp. 35–42), but Kindle (Ransome, 1923, pp. 7–8), restudying these and other collections, concluded that the Martin fauna is Late Devonian in age and that the same fauna occurs from Bisbee to Jerome. Stauffer (1928a, p. 152) agreed with the Late Devonian correlation. Stoyanow (1936, pp. 484–505) accepted the previous correlations of the part of the Martin limestone containing the *Cyrtospirifer* fauna but divided the Martin limestone of Ransome into three formations: the Picacho de Calera formation at the base, the Martin limestone (restricted), and the Lower Ouray formation at the top. He regarded the Martin limestone (restricted), which contains the typical Martin fauna, as equivalent to the Hackberry fauna of Iowa and younger than the fauna of his Picacho de Calera formation. Stoyanow considered the latter a possible correlative of the Cedar Valley limestone fauna of Iowa. The lithology of his Picacho de Calera formation does not seem especially distinctive, nor is the faunal evidence sufficiently compelling at present to justify separating these beds as a formation. He proposed the name "Lower Ouray formation" as a working term to separate the beds containing *Paurorhyncha endlichi* and lying above the beds containing a fauna equivalent to the Hackberry fauna. He reported the presence of this species at Pinal Creek, the Santa Catalina Mountains, and Arivaipi Canyon and suggested that the green shale zone at Roosevelt Lake may belong to his Lower Ouray. Harshman (Short and others, 1943, p. 29) correlated the yellow shale member of the Martin limestone (green shale zone of this paper) at Superior with Stoyanow's Lower Ouray on the basis of lithology and regarded the lower dolomite member (Crook formation) as equivalent to the Cedar Valley limestone of Iowa on the basis of the occurrence of *Platyrachella iowensis* and other fossils in his zone 7.

The fauna of the Ouray limestone of Colorado was described by Kindle (1909, pp. 1–60). At that time this formation was considered Devonian and Mississippian in age. Kindle recognized two faunas, and Kirk (1931) restricted the name "Ouray" to the limestone containing a Devonian fauna in southwestern Colorado. Kindle (1909, p. 31) regarded the Ouray limestone fauna as distinct from the typical fauna of the Martin limestone.

The Devonian sedimentary rocks of New Mexico have been discussed by Stevenson (1945), who proposed the new formational names "Onate" and "Contradero" and divided the Percha shale into the Ready Pay and Box members. The name "Onate formation" was given to beds in the Sacramento and San Andres Mountains, and Stevenson regarded it as late Middle or early Late Devonian, older than his Sly Gap formation or the Percha shale. The possibility that Stevenson's Onate formation represents a facies of his Sly Gap formation or the Percha shale is not completely excluded. Stevenson's Sly Gap is described from the Sierra Caballos and the San Andres, Sacramento, and Mud Springs Mountains. According to Stevenson, the diagnostic fossils in the formation are *Atrypa*, *Productella*, *Nervostrophia*, *Emanuella?*, and *MacGeea*, and he considers the fauna to be slightly older than the Hackberry shale, younger than the Independence shale, slightly older than the Martin limestone, and of the same age as the Devils Gate formation of Merriam. Many genera are common to Stevenson's Sly Gap formation and the Martin formation. Stevenson correlates his upper, or Box, member of the Percha shale with the Ouray limestone of Colorado and Stoyanow's Lower Ouray formation of Arizona. He also suggests that his Sly Gap formation may be a fossiliferous facies of his lower, or Ready Pay, member of the Percha shale and that his Contradero formation, described as occurring in the central part of the San Andres Mountains, may be a lentil of the same formation. This seems to be the best possible interpretation of the known facts.

The fauna of the Percha shale has been studied by Stainbrook (1947), who has reconsidered the age assignment of the Ouray limestone and the Percha shale. He regards these formations as early Mississippian in age and cites as evidence the presence of the productid genera *Avonia*, *Buxtonia*, *Pustula*, *Krotovia*, *Heteralosia*, and *Echinoconchus*. These genera have not been reported from other formations of Devonian age. The species of *Cyrtospirifer* in the Ouray and Percha faunas are regarded by Stainbrook as hold-overs. *Cyrtospirifer* is usually regarded as an index fossil for the Upper Devonian. Some of the species characteristic of the Percha fauna are present, according to Stainbrook, in the upper part of the Martin formation at Mount Martin near Bisbee. However, the evidence is not conclusive, and the stratigraphic occurrence of some genera needs field verification.

The fauna of the Martin formation has not been completely studied. The work of the present authors did not include extensive collecting of fossils from the formation; however, those collected were identified by G. A. Cooper and are listed in the accompanying stratigraphic sections. Accurate correlations of the whole Martin formation and the recognition of faunal zones cannot be made without considerable additional field work. The authors' inadequate collections and observations suggest that the Martin may contain equivalents of some of the faunal zones of the Devils Gate formation of Merriam. The lower member of the Martin formation contains relatively few fossils, but the middle member contains abundant stromatoporoids and corals and it is possible that the lower and middle members of the Martin formation represent part or all of the *Stromatopora* zone of the Devils Gate formation of Merriam. The *Spirifer argentarius* zone of the Devils Gate formation of Merriam has not been recognized in the Martin formation and may be absent, but the *Phillipsastrea* (*Pachyphyllum*) zone is probably present in the upper member of the Martin formation. The fauna regarded as typical of the Martin formation, usually correlated with that of the Hackberry shale of Iowa, occurs in the upper member of the Martin formation. The precise correlation with the Hackberry shale is probably overemphasized, inasmuch as the rocks in the two areas were deposited in different basins and species are not identical. If Stainbrook is correct in his assignment of the Percha shale to the early Mississippian, the uppermost beds of the Martin formation also may be Kinderhook in age, but the available faunal evidence in Arizona indicates a Late Devonian age.

CARBONIFEROUS (MISSISSIPPIAN) ROCKS: REDWALL LIMESTONE

TERMINOLOGY

The limestone of Mississippian age in northern Arizona has been called the Redwall limestone since 1875, when it was named by Gilbert (1875, pp. 162, 177–186, 197). The original definition included rocks older and younger than Mississippian, but the name later was restricted to strata of Mississippian age by Noble (1922, pp. 26, 54). Ransome (1904, pp. 42–44) proposed the name "Escabrosa limestone" for the limestone of Mississippian age in the Bisbee district in 1904, and the name has been used throughout southeastern Arizona. Stoyanow (1936, pp. 505, 517) regarded the Redwall limestone as slightly older than the Escabrosa on the basis of slightly different faunas in the two formations, a difference perhaps due to incomplete collections and poor preservation rather than to any real variation in age. In central Arizona the two formations can be traced into each other, and they represent a single mappable unit. Inasmuch as "Redwall limestone" is the older name, the present authors have used it for the limestone of Mississippian age.

Gutschick (1943, pp. 1–11), after carefully studying the Redwall limestone in north-central Arizona, divided the formation into four members, beginning at the base: (1) a white, crystalline, oolitic limestone member; (2) a fine-grained, cherty, porous limestone member; (3) a massive, coarsely crystalline limestone member; and (4) a gray, micro-oolitic, dense limestone member. He refrained from assigning names to these because his field work was restricted to a small area and he did not know the full areal extent of the members.

Harshman (Short and others, 1943, pp. 29–30) divided the Escabrosa limestone at Superior into four members on the basis of color and tendency to form cliffs: (1) dark-gray limestone; (2) massive, cliff-forming white limestone; (3) thin-bedded dark limestone; and (4) cherty shale and white limestone. His uppermost (fourth) member belongs in the overlying Naco formation. It includes the red mudstone and chert breccia at the base of the Naco and a white limestone, higher in the formation, which contains fossils of Pennsylvanian age, including *Spirifer* of the *Spirifer occidentalis* group.

GENERAL DESCRIPTION

The general description given here applies best to the sections at localities 1, 2, 3, 15, 16, 17, and 18 (pl. 1); it is not entirely applicable to the section at Tornado Peak (detailed sec. 19) nor to the sections close to Mazatzal land. The members distinguished by Gutschick were not recognized in the area studied, but the three lower members described by Harshman are essentially the subdivisions used in this discussion.

The Redwall limestone consists mainly of light-gray to white, dense to coarsely crystalline, thin- to very thick-bedded limestone. The coarsely crystalline character of some beds is due to an abundance of crinoid stems. The dense limestone is generally oolitic, but the number of oolites varies greatly from locality to locality. The lower part of the formation is commonly a gray-brown, medium thick-bedded impure limestone 50 to 70 feet thick. Locally it contains small quartz geodes, and a thin zone of sandy or conglomeratic limestone is present at the base of the formation. The middle part of the Redwall limestone is made up of massive beds of dense, generally oolitic, cliff-forming limestone. When traced along cliffs, this massive layer is seen to grade

FIGURE 20.—Contact between the Redwall limestone (R), of Mississippian age, and the basal member of the Naco formation (N), of Pennsylvanian age, in a road cut on United States Highway No. 60 north of the Salt River, central Arizona (locality 2, fig. 9). The contact shows no sign of faulting and is interpreted as one side of a filled sinkhole.

laterally into a rubble breccia of large, angular to rounded limestone blocks and angular chert blocks separated by thin seams of red sandy mudstone (pl. 20). The limestone blocks are stained green or red near their edges.

The upper part of the formation is a thin- to medium thick-bedded slope-forming limestone and is more cherty than the rest of the formation. Dense nodules of gray to white chert occur in the lower and middle parts, though not abundantly at most localities. Fossils are common in the whole formation but are difficult to collect from the thick limestone beds. Some of the fossils in the upper part of the formation have been silicified, and there are fossils in many of the chert nodules.

THICKNESS

As has been pointed out by Darton (1925, p. 237) and Stoyanow (1936, p. 507), the limestone of Mississippian age is thickest in the northwestern and southeastern parts of Arizona and thins toward Mazatzal land. Ransome (1904, p. 43) reported that the Escabrosa limestone is 600 to 800 feet thick, and Noble (1922, p. 54) reported a similar thickness of limestone of Mississippian age in the Grand Canyon at Bass Trail. In north-central Arizona, Gutschick (1943, p. 4) has measured several sections of the Redwall limestone which average 265 feet in thickness. Sections measured by the present authors near the Mogollon Rim (see pls. 11 and 12 and detailed sections) show that the Redwall limestone is only a few feet thick at the O. W. Ranch (detailed sec. 11), as much as 67 feet thick at the East Verde River (detailed sec. 14), and more than 100 feet thick at Fossil Creek (base not exposed). East of this area, the formation increases to about 300 feet in thickness at the Black River (detailed sec. 1); southward, it increases to about 500 feet at Tornado Peak (detailed sec. 19).

Wells drilled south of Holbrook, Ariz., penetrate a very thin section of Redwall limestone. As previously mentioned, the Redwall is about 45 feet thick in the Aztec Land and Cattle Co. No. 1 well (Union Oil Co. and Continental Oil Co.) and about 10 feet thick in the other well drilled by the same companies (New Mexico-Arizona Land Co. No. 1 well) about 9 miles to the east. The correlation of the limestone in the first-mentioned well with the Redwall limestone is based largely on the presence of a specimen of *Spirifer centronatus* found in a core sample at a depth of 3,810 feet and identified by James Steele Williams. The limestone is dolomitic and quite unlike the Redwall limestone seen at outcrops in central Arizona. The dolomitization may be due to solution and replacement prior to Pennsylvanian time. The 32 feet of rock in the Aztec Land and Cattle Co. No. 1 well referred to the Martin formation is somewhat similar in lithology to the Martin as shown in the sections near the Mogollon Rim (detailed secs. 11–14). This correlation, based on similarity in lithology, is not positive, and the 32-foot section also may be Redwall limestone.

The authors consider that the thinning of the limestone of Mississippian age on Mazatzal land is due largely to erosion prior to Pennsylvanian time, but it may be due partly to overlap, as suggested by Stoyanow (1942, p. 1272). Large horn corals are present in the Redwall limestone near Grasshopper (detailed secs. 7–10), where the formation is 30 to 90 feet thick, and in the upper part of the formation at the Salt River (detailed secs. 2–4), where it is more than 200 feet thick. Gutschick (1943, p. 4) reported large horn corals near the top of the Redwall limestone at Sycamore Canyon (Yavapai County), where the limestone

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is about 260 feet thick. The lower 100 to 150 feet of the Redwall limestone may be missing near Grasshopper, but this interpretation is open to question because the thickness of the limestone there seems to have been reduced by solution prior to Pennsylvanian time and because the local range of the large horn corals is unknown.

EFFECTS OF PRE-PENNSYLVANIAN EROSION

Evidence of karst topography before the Pennsylvanian in central Arizona is very apparent and includes the extremely irregular upper surface of the Redwall limestone, the rubble breccia and associated filled sinkholes and caverns, and the distribution and character of the basal red mudstone and chert breccia in the overlying Naco formation.

The contact between the Redwall limestone and the Naco formation is clearly unconformable at most localities. Local relief of 15 to 30 feet on top of the Redwall is well expressed at Tonto Creek (detailed sec. 13), as shown in figure 21. Near the Salt River (detailed sec. 2) the relief on top of the Redwall in places is at least 30 feet, and somewhat greater relief is shown in the vicinity of localities 7, 8, 9, and 10 (fig. 9) near Grasshopper. Of the three sections measured near the Salt River the thickest (detailed sec. 3) includes a white crystalline limestone 17.5 feet thick at the top of the Redwall. However, it is absent from the other localities (detailed secs. 2, 4) and apparently was removed by erosion prior to Pennsylvanian time.

The relief on the upper surface of the Redwall limestone is probably due to solution prior to the Pennsylvanian, inasmuch as some of the depressions are clearly sinkholes which have been filled with red residual mudstone and chert breccia. The contact between the Naco formation and the Redwall limestone exposed in a cut on Highway 60 (locality 2, fig. 9) is noteworthy in that red residual mudstone of the Naco formation abuts against gently dipping Redwall limestone with a nearly vertical contact. This contact (fig. 20) does not seem to represent a fault and is interpreted as one side of a filled sinkhole.

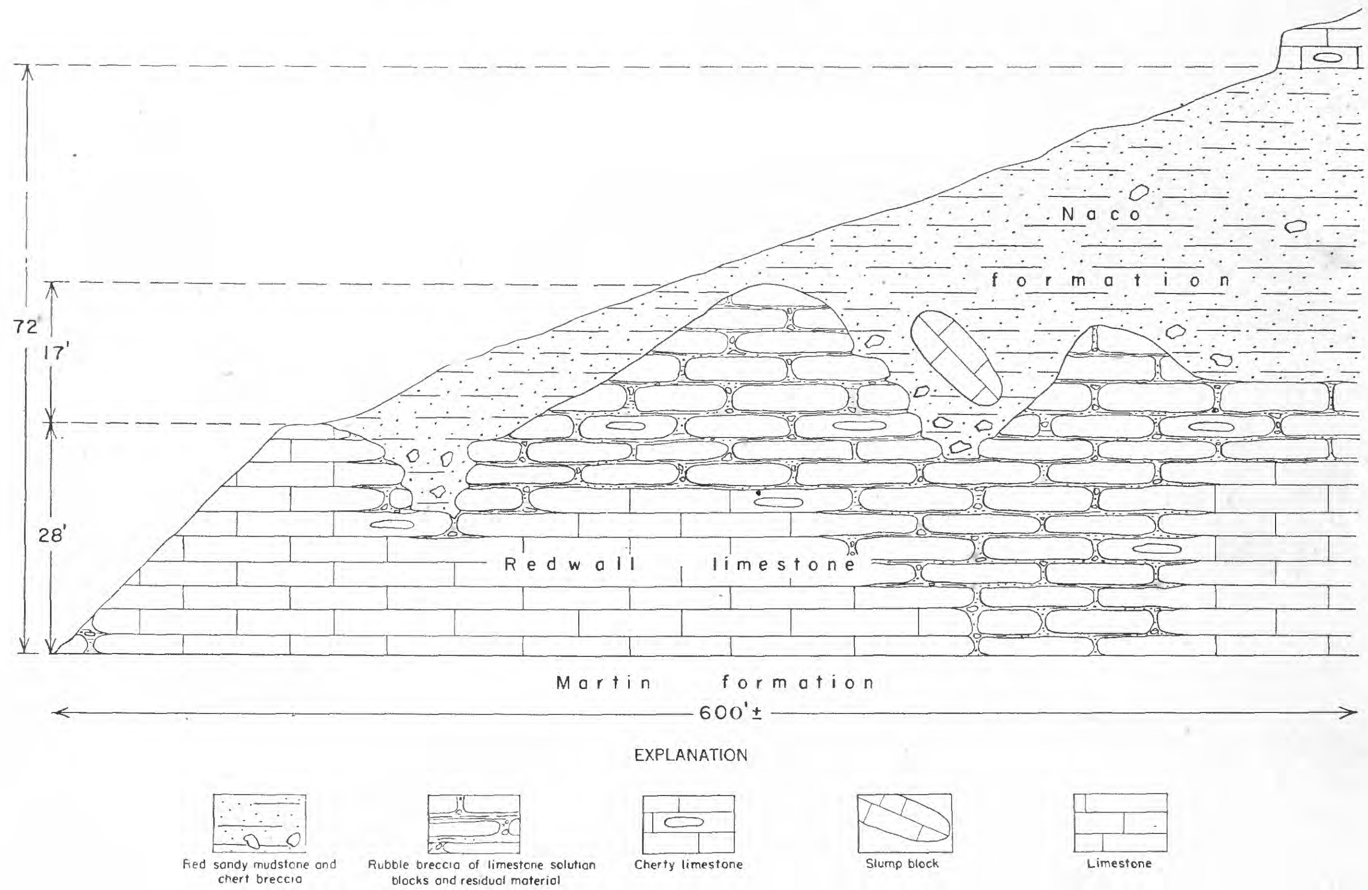

FIGURE 21.—Sketch showing the contact of the Redwall limestone and the Naco formation near the confluence of Horton and Tonto Creeks, Gila County, Ariz. (locality 13, fig. 9).

The rubble breccia and associated cavern fills characteristic of the middle portion of the Redwall limestone are well exposed in the cuts on Highway 60 (detailed sec. 2), as shown in figures 22 and 23. The cavern fill consists of red sandy mudstone, chert breccia, and red and green, dense to coarsely crystalline limestone. The red-, gray-, and green-banded, coarsely crystalline limestone may be altered cave travertine, whereas the dense limestone blocks are stained pieces of the formation from the cave roof. Rubble breccia extends to a depth of 234 feet below the top of the Redwall at the Black River (detailed sec. 1) and to a depth of 180 feet at the Salt River (detailed sec. 2). The exposures of the Redwall limestone are poor in the sections between Salt River draw and the East Verde River (detailed secs. 7–14), where the formation is thin and does not form a cliff. Solid ledges of limestone exist in places, but at most localities the formation is represented by a rubble breccia consisting of loose blocks of limestone embedded in red sandy mudstone and chert breccia. The red residual material has infiltrated to the base of the Redwall at Salt River draw (detailed sec. 7), Cliff House Canyon (detailed sec. 8), and other localities.

The thickness of the Redwall limestone must have been reduced by internal solution prior to the Pennsylvanian, but this reduction is not marked in the limestone cliffs along the Salt River except in the collapsed cavern areas. There may have been relatively little reduction above caverns with roofs strong enough to prevent collapse before the caves were filled with sediments. Considerable reduction in thickness must have occurred in areas where the Redwall limestone consists entirely of rubble breccia, because this breccia must have been formed, partly at least, by cavern collapse. The thinner-bedded, more highly jointed, and more soluble limestone must have been dissolved first, leaving the larger joint blocks and less soluble limestone to form the rubble breccia.

The basal member of the Naco formation in central Arizona consists of reddish- to purplish-brown sandy

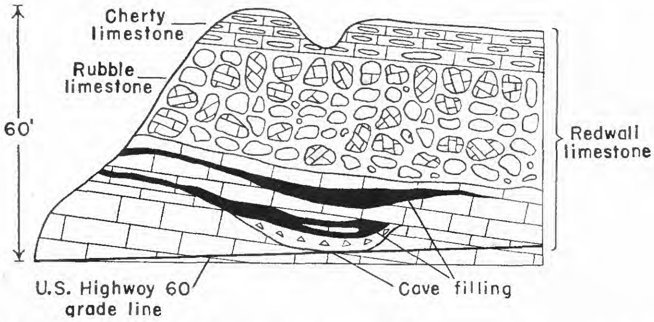

FIGURE 22.—Road cut on United States Highway No. 60 north of the Salt River, central Arizona, showing cave fillings of red sandy mudstone and overlying rubble breccia in the Redwall limestone (Mississippian).

FIGURE 23.—Rubble breccia in the massive member of the Redwall limestone exposed in a road cut on United States Highway No. 60, central Arizona (locality 2, fig. 9). The limestone blocks are separated by red sandy mudstone.

mudstone, siltstone, sandstone, conglomerate, and breccia, and the lower part of the member consists mainly of structureless, nonsorted, sandy mudstone. The mudstone shows no signs of bedding but contains suggestions of slumping. Much of the chert breccia occurs as pockets and lenses in the lower part of the member (fig. 24). The chert fragments contain Mississippian fossils and are similar in lithology to the chert in the Redwall limestone. The upper part of the member is more or less bedded and sorted. It includes mudstone and shale, in which there are limestone nodules; beds and lenses of limestone; sandstone; and conglomerate containing well-rounded red chert pebbles. Pennsylvanian fossils have been found in the limestone at some localities. The lack of bedding and sorting and the pockety distribution of the chert breccias suggest that the lower part is undisturbed residual soil formed on the Redwall limestone. The thickest pockets of chert breccia seem to be sinkhole fills. The upper part of the member was reworked by the Pennsylvanian sea, but it is doubtful that the reworking penetrated to the lower part in all localities.

The red residual member is not everywhere present at the base of the Naco formation, probably because the advancing Pennsylvanian sea completely removed the mantle from the higher parts of the submerged land surface. The thickness of the red residual member, though varying greatly within short distances, on the average is no more than 15 to 50 feet at most localities in central Arizona north and east of Globe. At Tornado Peak (detailed sec. 19) a 1-foot bed of chert conglomerate seems to represent this horizon. According to Ransome (1916, p. 147), the sections in southeastern Arizona do not show an unconformity between the Mississippian and the Pennsylvanian series. Certainly the thickness and prominence of the red residual member increase near Mazatzal land, owing probably to a slight uparching of Mazatzal land at the close of the Mississippian, which resulted in subsurface drainage and karst topography in the limestone areas. The solution caused the accumulation of a thicker residual mantle here than in neighboring areas having surface drainage.

FIGURE 24.—Chert breccia in the base of the Naco formation exposed north of the Salt River, central Arizona (locality 4, fig. 9). The stadia rod is 15 feet long.

The red residual member of the Naco formation is similar in lithology and origin to the Molas formation of Colorado. Both were formed by the accumulation of weathering products of Mississippian limestone and were partly reworked by the Pennsylvanian sea. It might be possible to trace the Naco red residual member into the Molas formation in the subsurface if enough wells were drilled in Black Mesa basin, inasmuch as the Molas is present in wells in southeastern Utah (Bass, 1944, chart 7). For the present, however, it is not thought advisable to use the name "Molas" in Arizona, even though there is little doubt about the correlation.

CORRELATION

The Redwall limestone long has been regarded as representing parts of the Kinderhook and Osage groups (Ransome, 1904, p. 46). The authors made no special study of fossils from the Redwall limestone. Some chert nodules found in the base of the Naco contain *Lithostrotionella*, and beds as young as St. Louis limestone may once have been present in central Arizona.

HISTORY OF MAZATZAL LAND

The Mazatzal revolution (Wilson, 1939, p. 1161) produced a chain of mountains extending probably from southwestern Arizona to southwestern Colorado with subparallel folds and thrust faults trending northeastward. The tectonic movements that produced these folds and faults were followed by the intrusion of granite and other plutonic rocks parallel with the structural features. The orogeny and associated intrusions took place after the Mazatzal quartzite was deposited. The mountains subsequently were well worn down by erosion, but the very resistant Mazatzal quartzite formed ridges along the core of the old mountain chain. The ridges served to separate the basins in which the rocks of the Apache and Unkar groups were deposited. Although the correlation of these two groups is not certain, some sediments in both were derived from the core of Mazatzal land, and the groups may be contemporaneous (Hinds, 1936b, pp. 99, 132). The Apache group abuts against the barrier of Mazatzal quartzite in Gordon and Haigler Canyons (Darton, 1925, p. 235).

Both the Apache and Unkar groups were considerably eroded before the Troy quartzite and Tapeats sandstone of Cambrian age were deposited, as has been shown by Darton (1925, p. 256), Hinds (1936b, pp. 33, 34), and McKee and others (McKee, 1945, pp. 111–122, figs. 7, 8, 10). After the deposition of the Cambrian sandstones, Mazatzal land probably was uparched slightly and eroded, because the Martin formation in central Arizona rests on a surface of some relief. There are neither Ordovician nor Silurian rocks in central Arizona, and probably there never have been any. Cambrian rocks may have extended through the Mogollon sag, and a considerable thickness of them may have been removed from Mazatzal land during the long erosional interval between the retreat of the Late Cambrian seas and the spread of the Late Devonian seas. The gradual burial of the mountains and Mazatzal land before Pennsylvanian time is summarized diagrammatically in figure 25. Because the later movements, and the Zuni uplift has a similar history. The Uncompahgre-San Luis highland, the Front Range highland, and their extensions into New Mexico differ markedly from Mazatzal land and related features in that they were rising land masses which supplied large quantities of sediments during the late Paleozoic. The absence of lower Upper Devonian strata in Colorado suggests a land area of low relief that was not completely submerged until very late in the Devonian.

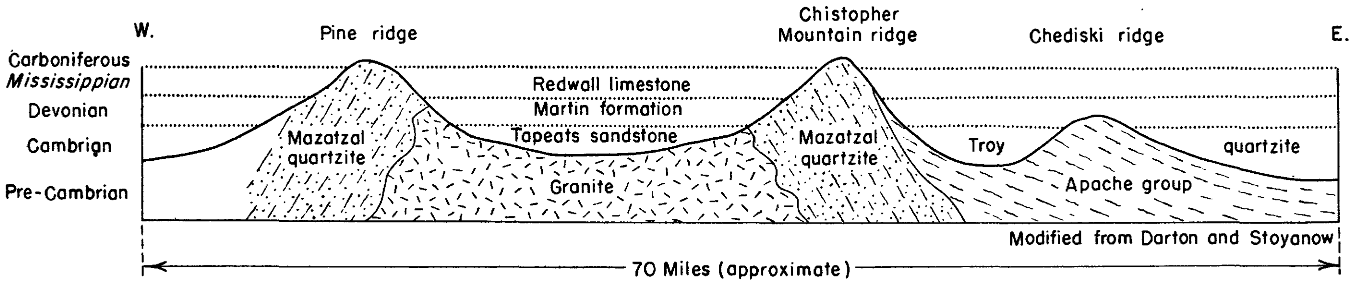

FIGURE 25.—Restored section across the northern part of Mazatzal land at the end of Mississippian deposition, modified from Darton and Stoyanow.

Martin formation was not deeply eroded prior to the deposition of the Redwall limestone, probably no diastrophic disturbances of Mazatzal land occurred at the close of the Devonian. After the Mississippian limestone was laid down, however, Mazatzal land again was uparched, as shown by the great erosional reduction of the Redwall limestone on Mazatzal land and the related increase in the thickness of the red residual member of the Naco formation nearby. The effects of the erosional interval after Mississippian time were widespread in the western United States and may have removed late Mississippian strata from wide areas.

During Pennsylvanian and Permian time, Mazatzal land north of the Mogollon Rim was deeply buried by sediments which probably extended a considerable distance southward into central Arizona. Some time after the Permian, Mazatzal land again was slightly uparched, as indicated on Darton's map of the plateau region in Arizona (1925, p. 146). This arch seems to account for the stripping of the Paleozoic rocks from Mazatzal land in the Tonto Basin area, although they are still present in the Fort Apache Indian Reservation to the east.

Mazatzal land was not an actively rising source of sediments during the Paleozoic, but served rather as a "submarine barrier," as originally described by Ransome (fig. 26). Its persistence is due to slight arching and to the fact that quartzites in the core of the ancient mountains resisted erosion. The granitic Holbrook ridge and the Defiance uplift are northeastward extensions of Mazatzal land which have been modified by

The Devonian and Mississippian strata are thickest near the axis of the Cordilleran geosyncline in eastern Nevada. Immediately west of the geosyncline there was a geanticline whose axis was in central Nevada. According to Nolan (1928; 1943, pp. 172–175), this geanticline began to rise in Late Devonian time and continued to rise until the Permian, but without great uplift. The geanticline and the geosyncline trended

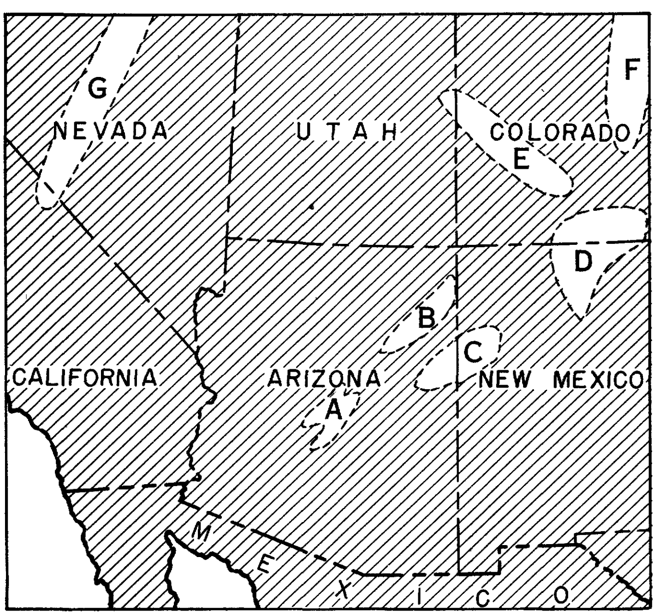

FIGURE 26.—Early Mississippian paleogeography of the southwestern United States. *A*, Mazatzal land; *B*, granitic Holbrook ridge and Defiance uplift; *C*, Zuni uplift; *D*, San Luis highland; *E*, Uncompahgre highland; *F*, Front Range highland; *G*, Manhattan geanticline. Seas ruled.

slightly east of north, and Mazatzal land was roughly parallel with them. The geosynclinal seas may have extended into western Arizona during Devonian and Mississippian time, but most of the State was covered by epicontinental seas during these periods (fig. 26). McKee (1947) reports fossil-bearing pebbles of Devonian and Mississippian age in Cretaceous (?) conglomerate in the New Water Mountains of west-central Arizona. These pebbles had a local source, indicating that Upper Devonian and Lower Mississippian sedimentary rocks formerly were present in this area. According to McKee, the sea in which these rocks were deposited probably was connected to the sea in the western Grand Canyon and may have joined the seas in southern and southeastern Arizona.

In the Harquahala Mountains northeast of the New Water Mountains, in the western part of the State, Devonian and Mississippian strata occur, according to McKee (1947, p. 289). Darton (1925, p. 264) has described Mississippian strata in the Vekol Mountains in south-central Arizona, and Gilluly (1946, p. 38) has reported boulders of Devonian and Mississippian (?) age in the gravels near Ajo, in the same general area. This evidence suggests that Mazatzal land was limited to a relatively small area in central Arizona. Devonian and Mississippian epicontinental seas are therefore indicated in figure 26 as extending over most of Arizona.

SUMMARY

The paleogeographic map (fig. 26) summarizes the concepts presented in this paper: that a Paleozoic land area was present in central and northeastern Arizona; that this land area was a residue of pre-Cambrian mountains; and that it was gradually covered with sediments during the late Paleozoic. It is thought probable that Devonian and Mississippian sedimentary rocks are present in the subsurface in Black Mesa basin and in the northern part of the Fort Apache Indian Reservation. The fact that Devonian and Mississippian rocks contain oil and gas in the San Juan basin suggests that they may be reservoir rocks in the Black Mesa basin as well, because the two basins probably had a similar history. Black Mesa basin offers the most promise of oil and gas production, although production from the northern part of the Fort Apache Indian Reservation also is possible. Stratigraphic traps quite possibly exist in connection with the buried ridges and bioherms, and structural traps may be present.

DETAILED STRATIGRAPHIC SECTIONS

Section 1, Black River (sec. 11, T. 4 N., R. 20 E.), Gila County, Ariz.*

[Martin formation measured in meander scar on north side of Black River about one-half mile west of San Carlos-Fort Apache road bridge. Redwall limestone measured one-half mile southwest of bridge on south side of River]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Limestone, shale, and sandstone with red sandy mudstone and chert breccia at base.	
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, white, weathering gray; medium-crystalline, thin- to medium-bedded, with dense gray chert nodules which weather white	45
Limestone, light-gray, oolitic, massive, weathering to angular blocks	53
Limestone, gray-brown, dense to medium-crystalline, rubbly, with some angular chert breccia	29
Limestone, gray-white, dense, oolitic, and massive	40
Limestone, gray-green, dense, and rubbly	11
Sandstone, white, consisting of fine to medium rounded quartz grains with calcareous cement; lenticular, grading laterally into limestone	3
Limestone, gray, dense, oolitic, and massive	23
Limestone, mainly white; medium-crystalline and massive, but includes some chert breccia and rubbly limestone	30
Limestone, brown, weathering dark gray; fine-grained, silty, with quartz geodes in lower half; massive, weathering into large spalls in lower 4 feet	29
Limestone, gray-brown, weathering gray with red and yellow stains; fine-grained, silty, with a few white quartz geodes up to 0.7 foot in diameter; bedding thin to thick with maximum of 4 feet; weathers back by vertical spalling to form notch at base of limestone cliff. A few crinoid stems	34
Total Redwall limestone	297
Devonian:	
Martin formation:	
Upper member:	
Green shale zone: Concealed; green shale dug out in lower part of interval	14
Limestone, brown, weathering yellow brown; finely crystalline, shaly, thin-bedded. Fossils from this horizon identified by G. A. Cooper, as follows: *Caractophyllum* sp., *Schizophoria* cf. *iowensis* Hall, *Cranaena* aff. *calvini* (Hall and Whitfield), *Atrypa* cf. *devonica* Webster, *Tenticospirifer* cf. *cyrtinaformis* (Hall and Whitfield), *Gypidula* aff. *cornuta* (Fenton and Fenton), *Douvillina* aff. D. *arcuata* Hall, *Spirifer hungerfordi* (Hall and Whitfield)	20.0
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Limestone, sandy, gray-brown, weathering brown; medium- to coarsely crystalline; crinoidal; scattered coarse, rounded and frosted quartz grains; uneven beds 1 to 2 feet thick; fossiliferous	6.5
Dark buff-weathering beds.	
Sandstone, brown, weathering greenish yellow and slabby; very fine grained, calcareous, and fossiliferous. *Douvillina* sp. (identified by G. A. Cooper)	9.0
Limestone, gray to brown, weathering dark buff to gray; dense to medium-crystalline, sandy in lower part and silty and dolomitic in upper part. Crinoid stems and other fossils	26.0
Sandstone, gray, weathering reddish to yellowish brown; mainly fine-grained, but some coarse rounded and frosted grains present; thin- to thick-bedded, very calcareous, weak and shaly in upper part	34.5
Middle member:	
Limestone, dolomitic, gray-brown, medium-crystalline, with many calcite vugs; beds 1 to 1.5 feet thick	3.5
Limestone, gray, weathering blue gray; dense, nodular	1.7
Sandstone, white to gray, weathering gray; fine-grained below, becoming coarse-grained above; very calcareous, crystalline near top, massive	22.7
Limestone, dark-gray to brown, medium-crystalline, sandy, and dolomitic, grading into underlying sandstone; thin to medium beds	16.0
Sandstone, greenish-gray, weathering yellow brown; fine to coarse, rounded and frosted grains; very calcareous, shaly, and fucoidal	6.6
Lower member:	
Light buff-weathering beds.	
Limestone, dolomitic, gray, weathering light buff; dense, sandy, with larger grains rounded and frosted; large calcite vugs and stringers of dense black chert near top; medium beds, 1.5 to 2.5 feet thick, with green shaly partings between limestone beds	29.0
Siltstone, greenish-gray, weathering buff; calcareous; weak, breaking into irregular blocks; dolomitic limestone bed 1.8 feet thick 7 feet above base	28.0
Limestone, dolomitic, gray, weathering buff and gray; dense, with a conchoidal fracture; small calcite vugs; zone of small elongate chert nodules with brown rind near base	19.0
Siltstone, greenish-gray, massive	2.8
Limestone, dolomitic, gray-white, weathering light yellow brown; dense, with scattered coarse, rounded and frosted quartz grains	8.5

*The Fort Apache Indian Reservation has not been surveyed by the General Land Office. The section numbers given are those plotted on the map of the reservation (1942 edition) issued by the Department of the Interior, Office of Indian Affairs. Editions of the map earlier than that of 1938 were not plotted in the same way.

	Feet
Devonian—Continued	
Martin formation—Continued	
Lower member—Continued	
Limestone, dolomitic, light-gray to pink, weathering light yellow brown; thin-bedded, with mud cracks, contemporaneous breccia, and small chert nodules with brown rind. Base very uneven	9.8
Brown beds.	
Limestone, dolomitic, pink, weathering gray and white; medium-crystalline, massive; some chert. A few poorly preserved fossils	5.0
Limestone, brown to pink, weathering gray; finely crystalline. Crowded with large, poorly preserved Stropheodontas	1.9
Limestone, dolomitic, gray, weathering creamy white; fine to medium-crystalline; lower 3 feet thin-bedded, upper part massive	12.6
Limestone, calcareous at base, becoming dolomitic above; gray to brown, fine to medium-crystalline, massive; upper 12 feet irregularly bedded and brecciated	33.0
Basal sandstone.	
Sandstone and conglomerate, greenish-gray to reddish-brown, with purple spots in lower part; sand grains, granules, and pebbles angular to rounded; pebbles of quartz, quartzite, or chert fragments ranging in size from 4 to 100 millimeters. averaging about 20 millimeters	21.0
Total Martin formation	331.6
Cambrian:	
Troy quartzite: Quartzite, reddish-brown, thin-bedded (about 75 feet exposed).	

Section 2, Salt River, Gila County, Ariz.

[Measured along United States Highway No. 60, at point 3.7 to 11 miles north of bridge over river]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Limestone, shale, and sandstone with basal member of red sandy mudstone and chert breccia	775
Carboniferous (Mississippian):	
Redwall limestone:	
Concealed, except for a few ledges of gray to brown, dense to coarsely crystalline limestone with some white-weathering chert and a few fossils. Surface very uneven. This interval absent in the highway cuts	28.5
Limestone, buff, fine-grained, sugary, argillaceous, and silty, with some chert nodules	10.0
Limestone, light- to greenish-gray, dense, with lenses of coarsely crystalline crinoidal limestone; abundant white-weathering chert nodules. Numerous fossils. Infiltrated by red sandy mudstone	38.0
Carboniferous (Mississippian)—Continued	
Redwall limestone—Continued	
Limestone and chert: Light-gray, dense to coarsely crystalline, very fossiliferous limestone with abundant nodules and beds of gray- and white-banded dense chert, thin-bedded and weak, weathering back to form notch in limestone cliff	10.0
Limestone, gray to brown, finely to coarsely crystalline, crinoidal, in massive beds ranging in thickness from 4.5 to 10 feet, with reeflike wedges and cross bedding; also gray- and white-banded chert. Numerous fossils in chert and limestone	21.5
Mudstone, red and sandy, including fragments and nodules of limestone. Probably a pre-Pennsylvanian solution cavity and fillings	2.0
Limestone, gray-green to light-gray, with streaks of red; dense and oolitic; bedding vague or absent owing to formation of solution rubble or breccia with red sandy mudstone surrounding limestone blocks	17.0
Sandstone, granule conglomerate, and limestone, gray to greenish-gray, weathering red: Pockets and lenses of coarse, uneven-grained sandstone of rounded and frosted quartz grains and granules and large rounded limestone "pebbles"; limestone lenses and beds, dense, greenish-gray, cut by pockets and stringers of sandstone. Contacts irregular; seems to be a solution cavity filling	5.0
Limestone, greenish-gray, dense	8.0
Limestone, gray, medium-grained, sugary, with gray chert in upper part, replaced laterally by red and green, dense to coarsely crystalline limestone and red sandy mudstone and chert breccia, similar to basal member of Naco formation. Probably a pre-Pennsylvanian cave filling; red and green limestone may have been travertine	17.0
Limestone, light brownish-gray, oolitic, and fossiliferous	5.0
Limestone, dark-gray, with brown banding, weathering dark gray brown or buff; fine- to medium-grained, sugary, silty or argillaceous; massive beds 4 to 6 feet thick; zone of black to gray chert near middle of unit. Many crinoid stems	27.0
Total Redwall limestone	189.0
Martin formation:	
Upper member:	
Green shale zone.	
Sandstone, brown and gray, weathering greenish buff; fine-grained; mainly calcareous, but with quartzose lenses; thin irregular beds with shaly and silty partings	18.0
Shale, olive-gray: Soft clay shale with red-brown and greenish-gray sandstone and conglomerate lenses near base and top; larger grains in sandstone and conglomerate rounded and frosted. Lower sandstones contain fucoids	24.0

	Feet
Carboniferous (Mississippian)—Continued	
Martin formation—Continued	
Upper member—Continued	
Dark buff-weathering beds.	
Siltstone, gray-green, mottled red brown and weathering buff; calcareous, with calcite-filled cavities; massive in upper part and thin-bedded, with green shale partings, in lower part; basal 3 feet micaceous and sandy, with rounded and frosted quartz grains. Silicified fossils	20.0
Sandstone, red-brown and white, weathering reddish buff; very calcareous; mainly fine and even-grained, but some beds contain coarse, rounded and frosted grains; unit massive; forms ledge but thins laterally	25.0
Shale, green, weathering gray; silty and micaceous	3.3
Sandstone, greenish-gray and brown, weathering dark buff; calcareous, silty, fine-grained, with scattered rounded and frosted coarse grains; friable; grades upward into shale. Large fucoids in base	4.7
Mudstone, silty, greenish-gray	2.0
Siltstone, dark-gray, weathering brown; micaceous and quartzose, with calcite-filled cavities. Worm tubes, fucoids, and poorly preserved brachiopods	6.5
Middle member:	
Cliff-forming limestone.	
Limestone, greenish-gray and brown, weathering buff, with red bands; fine-grained, argillaceous	2.6
Limestone, light gray-brown, dense, sandy in part; thin to medium uneven beds with calcite specks and cavities. Poorly preserved corals and stromatoporoids	10.5
Limestone, dolomitic, reddish-brown to greenish-gray, fine to medium-crystalline, with calcite cavities; medium beds, 1 to 3 feet thick	22.0
Limestone, dolomitic, dark-gray to brown, fine to medium-crystalline, with gray shaly breaks near top	8.5
Sandstone, greenish-gray, fine-grained, silty, with scattered coarse grains; mainly quartzose, breaking across grains, but calcareous in part; thin irregular lenses with shaly breaks; appears massive in fresh cuts	44.4
Lower member:	
Light buff-weathering beds.	
Limestone, mainly light- to dark-gray, buff-weathering; commonly dense and dolomitic in beds 1 to 3 feet thick, but with some argillaceous and sandy beds and partings	34.5
Sandstone and siltstone, gray, weathering reddish brown; silt to medium sand grains of rounded quartz with calcareous or siliceous cement; faintly cross-bedded	12.0

	Feet
Carboniferous (Mississippian)—Continued	
Martin formation—Continued	
Lower member—Continued	
Limestone, dolomitic, mainly light-gray, weathering light buff and gray; dense, partly lithographic, with conchoidal fracture; beds 1 to 3 feet thick with shale partings; occasional light- to dark-gray chert nodules and scattered quartz grains in some beds	81.2
Limestone, dolomitic, light- to medium-gray, dense, with conchoidal fracture, in beds less than 1 foot thick containing small elongate dark-gray dense chert nodules with yellow-brown rind	5.7
Brown beds.	
Limestone, dolomitic, dark-brown to light-gray, fine to medium-crystalline; thin irregular beds with scattered dark-gray to black chert nodules and calcite cavities	26.0
Limestone, dolomitic, dark-gray, dense, thin-bedded, with black shale and greenish-gray sandstone partings	2.5
Basal sandstone.	
Sandstone and conglomerate, greenish-gray, weathering yellow brown; poorly sorted sand, silt, granules, and pebbles; larger grains tend to be rounded and frosted and smaller grains subangular; bedding irregular, with faint cross bedding in thicker beds	13.0
Total Martin formation	366.4
Pre-Devonian diabase, deeply weathered at contact.	

Section 3, Flying "V" Canyon (SW¼ sec. 16, T. 5 N., R. 18 E.), Gila County, Ariz.*

[Measured about one-quarter mile east of United States Highway No. 60]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Limestone, shale, and sandstone, with red sandy mudstone and chert breccia 40 feet thick at base.	
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, white, coarsely crystalline; thin beds, less than 1.5 feet thick. Many large corals and other fossils	17.5
Limestone, light- to dark-gray, finely crystalline, cherty	11.2
Concealed	26.0
Limestone, buff, fine-grained, argillaceous	2.8
Concealed	23.0
Limestone, white, weathering gray; mainly coarsely crystalline; beds 0.5 to 3 feet thick; abundant white-weathering chert. Silicified fossils	28.0

*See note, p. 93.

	Feet
Carboniferous (Mississippian)—Continued	
Redwall limestone—Continued	
Limestone, white to gray, finely crystalline; thin-bedded nodules and beds of gray- and white-banded chert; weak zone forms notch at base of thin-bedded cherty limestone which lies above main massive cliff-forming member. Numerous silicified fossils	7.5
Limestone, mainly light-gray, dense, oolitic, and massive; very little chert, but basal 4 feet is white, coarsely crystalline cherty limestone. Cliff-forming member of the Redwall limestone; grades laterally into rubble limestone	76.5
Limestone, light-gray, stained red and weathering gray; dense, oolitic, and massive	14.0
Limestone, dark- to light-gray, finely crystalline and oolitic near base, with calcite cavities; scattered gray chert nodules; sparingly fossiliferous; medium-bedded	18.0
Total Redwall limestone	224.5
Devonian:	
Martin formation.	

Section 4, Horseshoe Mine Road (sec. 19, T. 5 N., R. 18 E.), Gila County, Ariz.*

[Upper part of Redwall limestone measured in draw west of United States Highway No. 60 and below old road to Horseshoe asbestos mine. Middle and lower parts not measured]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation.	
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, light greenish-gray, coarsely crystalline	2.5
Limestone, light-gray, finely crystalline, in beds 0.3 to 1.5 feet thick, with uneven shale partings; light-gray chert nodules	12.5
Limestone, shaly, and shale, light gray-green, weathering gray and buff; finely crystalline; thin slabby beds with *Spirophyton*-like markings; dense gray chert nodules	12.8
Limestone, dark-gray, fine-grained, massive, with dark-gray chert nodules	10.0
Limestone, dolomitic in upper part, weathering buff; medium-crystalline and massive, with dense white chert nodules and gray crinoidal limestone beds, weathering to form smooth rounded outcrops	25.0±
Limestone, white, finely to coarsely crystalline and crinoidal, thin- to medium-bedded, with fossils and gray chert, weathering white	29.0
Limestone, light-gray, finely crystalline, thin-bedded and weak, forming notch. Base of thin-bedded cherty upper part of Redwall limestone	3.0

*See note, p. 93.

Section 5, Prochnow Mines (sec. 25, T. 5 N., R. 17 E.), Gila County, Ariz.*

[Measured above Prochnow asbestos mines, 2.2 miles northeast of bridge over Salt River on United States Highway No. 60]

	Feet
Carboniferous (Mississippian):	
Redwall limestone.	
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Limestone, dolomitic, brown, sandy, poorly exposed	3.0
Shale, olive-gray, with thin beds of sandstone; mainly concealed	42.0
Sandstone, reddish-brown, medium-grained, friable, irregularly bedded	3.3
Dark buff-weathering beds.	
Limestone, dolomitic, greenish-gray, weathering dark buff; very fine grained, silty; forms prominent ledge. Silicified fossils, including Spirifers and Atrypas	11.5
Sandstone and granule conglomerate: Conglomerate, greenish-yellow, buff-weathering, fine-grained, calcareous, and shaly, thin-bedded, slabby sandstone with fucoids and small quartz geodes; lower 3 feet granule conglomerate with rounded and frosted grains and granules. Weak slope-forming unit	20.0
Sandstone, yellowish-green, fine-grained, and shaly	1.3
Concealed; probably calcareous sandstone	23.5
Sandstone, brown, weathering buff; fine-grained and calcareous	5.6
Middle member:	
Cliff-forming limestone.	
Limestone, gray, red, and brown, weathering gray; medium-crystalline, massive, with thin beds of chert and limestone fragments; forms top of limestone cliff	6.0
Limestone, mottled green, gray, and red, weathering blue gray; dense, with numerous calcite specks; thin- to thick-bedded	10.0
Limestone, dolomitic, gray, weathering green and brown; finely crystalline, with many calcite-filled cavities. One locally traceable bed 10.5 feet above base has numerous tubes apparently formed by solution of ramose corals or Bryozoa	22.0
Limestone, dolomitic, light-pink, dense, with subconchoidal fracture; many calcite-filled cavities; massive, laminated beds	6.0
Limestone, dolomitic, gray, finely crystalline and sandy, with many calcite-filled cavities	2.0

*See note, p. 93.

	Feet
Devonian—Continued	
Martin formation—Continued	
Middle member—Continued	
Sandstone, gray, weathering buff; fine-grained, calcareous, slope forming, with occasional ledges; shaly in part, with interbedded gray and black shale in beds up to 0.5 foot thick. Fucoids and molds of Spirifers in some beds	40.0
Lower member:	
Light buff-weathering beds.	
Limestone, dolomitic, pink, weathering buff; very sandy, with many rounded and frosted quartz grains	2.1
Sandstone, gray, weathering dark buff; fine-grained and massive in upper part, with greenish-gray shale and friable sandstone near base	5.5
Limestone, gray, dense, rubbly, and shaly, with greenish-gray shale 0.1 foot thick at base	3.1
Limestone, dolomitic, pinkish-gray, weathering buff; sandy, with very coarse sand grains; forms massive ledge with greenish-gray shale 0.2 foot thick at base	7.0
Limestone, pinkish-gray, weathering to buff-colored rounded blocks; conglomerate, with quartz sand grains and granules and pebbles of limestone with maximum diameter of 4 millimeters and numerous cavities filled with calcite crystals; greenish-gray shale 0.2 feet thick at base	3.5
Limestone, dolomitic, gray and pink, weathering buff; dense, with many calcite specks; beds mainly 2 to 3 feet thick and sandy near tops, with some rounded and frosted grains and granules; three greenish-gray shales, about 1 foot thick, interbedded with limestone	24.7
Shale and siltstone, purple, red, green, and gray, calcareous, and weak; pink to purple dense limestone beds, 0.8 to 1.8 feet thick, interbedded with shale and siltstone	13.4
Sandstone, greenish-gray and red-brown, fine-grained, glauconitic, micaceous, and shaly, with large calcite crystals in cavities; thin- to medium-bedded; weak, forming slope	8.0
Limestone, white to red, coarsely crystalline, apparently clastic; calcite and dolomite grains with coating of hematite which also penetrates grains along cleavage planes	4.2
Limestone, dolomitic, light-gray, with pink to red staining, weathering buff; dense and sandy near top and bottom	12.1
Limestone, dolomitic and cherty, light-gray, weathering gray; sublithographic; zone 0.5 foot thick of coarse sand grains and chert breccia 8 feet below top; numerous calcite-filled cavities and considerable gray chert	25.0
Shale, greenish-gray, hard	0.3

	Feet
Devonian—Continued	
Martin formation—Continued	
Lower member—Continued	
Limestone, dolomitic, light-gray, weathering gray white; sublithographic, with scattered gray chert nodules and coarse rounded grains of quartz	12.9
Limestone, dolomitic, gray-white, weathering light buff; dense, brittle, with subconchoidal fracture; thin beds of gray chert and zones of pea-size chert nodules with yellow-brown rind; black fissile shale at base 0.1 foot thick	5.9
Limestone, dolomitic, light-gray, weathering white gray; dense, brittle; irregular thin to medium beds; large gray chert nodules and zones of small elongate chert nodules with yellow-brown rind	9.8
Brown beds.	
Limestone, dolomitic, dark-brown, weathering gray brown; dense, with strong petroliferous odor; irregular bed of black chert at top	2.0
Limestone, dolomitic, gray, weathering light gray; dense, massive, containing a few gray chert nodules	11.2
Limestone, brown, weathering dark gray; medium-crystalline, porous; strong petroliferous odor; massive, with irregular wedges of cross bedding and laminations	10.3
Limestone, dolomitic, gray, dense, thin-bedded, with partings of gray and green sandy shale and sandstone; grades from sandstone below to limestone above	3.5
Basal sandstone.	
Sandstone, conglomeratic, greenish-gray, weathering yellow to reddish brown; uneven-grained, fine to coarse, with scattered granules; larger grains rounded and frosted; beds 0.5 to 4 feet thick, with shaly partings between some beds; calcite-filled cavities	15.0
Total Martin formation	375.7
Pre-Devonian:	
Diabase, deeply weathered, red and purple.	

Section 6, Rockhouse Butte (sec. 30, T. 6 N., R. 17 E.), Gila County, Ariz.*

[Measured on southwest flank of Rockhouse Butte, about 1¼ miles north of Seven Star group of asbestos mines (Riedhead mines)]

	Feet
Tertiary:	
Lava; black vesicular basalt capping butte. Barometer thickness	135
Gravel; mainly quartzite pebbles and cobbles. Barometer thickness	160
Total Tertiary beds	295

*See note, p. 93.

	Feet
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, in loose blocks; dense to medium-crystalline, gray to white. Silicified corals. Top taken at highest float of limestone	20.0
Limestone, sandy, weathering gray brown; dense, thin-bedded, and banded with limestone breccia at base; drusy chert on weathered faces	3.5
Mainly concealed, with dense brown limestone exposed near base	5.2
Limestone, light- to dark-brown, dense, thin-bedded	5.0
Concealed	15.0
Limestone, white, weathering gray; medium- to coarsely crystalline, sandy; thin-bedded, with faint cross bedding	9.5
Total Redwall limestone	58.2
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Limestone, weathering yellow and pink; fine-grained, sandy; brecciated near top	5.0
Limestone, dolomitic, medium-gray, fine-grained, argillaceous, silty; massive, weathering blocky; partly concealed	27.5
Limestone, dolomitic, gray, weathering buff; dense and sandy	3.0
Shale, greenish-gray	2.0
Concealed	8.5
Dark buff-weathering beds.	
Sandstone, light yellow-brown, fine-grained, shaly, calcareous, friable, with scattered elongate stony chert nodules	3.7
Concealed	9.0
Sandstone, gray, weathering yellow and pink; very fine grained, calcareous; thin to medium beds, with stony gray-brown chert nodules forming about 25 percent of rock; quartz and calcite geodes; partly concealed near top. Numerous fucoids	23.9
Concealed; slump blocks of quartzose sandstone near top	21.0
Sandstone, gray-brown, weathering buff; very fine grained, calcareous, slabby. Fucoids	4.0
Concealed	7.6
Middle member:	
Cliff-forming limestone.	
Limestone, light-gray, dense, massive, shaly near base. Abundant poorly preserved stromatoporoids and other fossils in upper part	20.5
Limestone, brownish-white, weathering gray; medium-crystalline; massive and sandy in lower part	5.8
Limestone, gray, medium-crystalline, thin- to medium-bedded, sandy in upper part; variation in grain size produces banding on weathered surfaces	9.0
Limestone, dolomitic, brown, fine-grained. Many overcalcified ramose fossils. This bed traceable locally	0.5
Devonian—Continued	
Martin formation—Continued	
Middle member—Continued	
Concealed; probably fine-grained, yellow-brown, calcareous sandstone	7.8
Limestone, brown to gray, medium-grained, and sandy	1.5
Limestone, dolomitic, gray to brown, weathering buff: fine-grained, sandy, with scattered fine to coarse grains	4.5
Sandstone, gray to pink, very fine grained, calcareous, friable, and massive	4.0
Concealed	2.5
Limestone, dolomitic, brown, weathering buff; fine-grained, sandy	2.5
Concealed	2.5
Sandstone, white, weathering buff; mainly fine-grained, with some laminations of coarse grains; calcareous, friable, massive, with shaly breaks in upper part. Fucoids in some beds	22.2
Lower member:	
Light buff-weathering beds.	
Limestone, dolomitic, greenish-gray, weathering buff; dense to fine-grained, very sandy, with layers of coarse sand grains; uneven bedding; calcite-filled cavities	8.6
Shale, reddish-brown	0.4
Limestone, dolomitic, light-gray, stained pink, weathering buff; dense, sandy, with distorted bedding; conglomerate and breccia in lower part	6.5
Limestone, dolomitic, sandy and argillaceous, light- to dark-gray, weak, eroding back under a falls; weathers blocky in part; includes 1-foot bed with red concentric-weathering bands	8.0
Limestone, dolomitic, gray-white, chalky, weathering light gray, with laminations of coarse rounded and frosted sand grains and many calcite specks	9.0
Limestone, dolomitic and silty, very fine grained, weathering blocky and lavender	2.0
Limestone, dolomitic, gray-white, with chalky appearance; brittle, with irregular fracture; massive; scattered sand grains and calcite-filled cavities	16.3
Concealed	8.0
Limestone, dolomitic, gray, weathering light buff; dense, with scattered sand grains and lenses of gray-banded chert weathering brown	5.4
Partly concealed slope with loose blocks and outcrops of light-gray, light buff-weathering dolomitic limestone; partly sandy and cherty	31.3
Limestone, dolomitic, light-gray, weathering white gray; dense, brittle; many small elongate gray chert nodules with brown rind	5.5
Brown beds.	

	Feet
Devonian—Continued	
Martin formation—Continued	
Lower member—Continued	
Limestone, dolomitic, medium-gray, weathering yellow gray; dense, massive, with large masses of gray chert, calcite-filled cavities, and contemporaneous breccia	6.5
Concealed	6.5
Limestone, dolomitic, light-brown to gray, weathering gray brown; fine-grained, sugary; thin uneven beds; petroliferous odor on fresh fractures; limestone and chert breccia in upper 2 feet	9.5
Basal sandstone.	
Sandstone, gray to red; fine to medium, angular to subround grains; calcareous and hematitic	2.0
Concealed	2.6
Total Martin formation	326.6
Cambrian:	
Troy quartzite (?): Sandstone and quartzite, white to red, fine- to coarse-grained and conglomeratic, with hematitic and siliceous cement. Top drawn at highest bed with siliceous cement	30.0

Section 7, Salt River Draw (secs. 1, 12, 13, T. 6 N., R. 16 E.), Gila County, Ariz.*

[Measured along Salt River draw from a point three-fourths mile below junction with East Tin Roof draw to a point 2 miles above junction, between 9 and 12 miles south of Grasshopper]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Red sandy shale and chert breccia (not measured).	
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, white, gray, and brown, dense, oolitic, and medium-crystalline; lower part massive, cliff forming, with a gray and brown chert nodules in zone at top of cliff, 43 feet above base; upper part loose blocks of cherty crinoidal limestone with silicified fossils including corals and brachiopods. Naco red sandy shale infiltrated to base of unit	73.0
Concealed	3.4
Limestone, gray-brown, weathering gray; dense and thick-bedded	8.8
Limestone, light brownish-gray, weathering buff; fine to medium-crystalline, with abundant fine to coarse rounded and frosted quartz grains; thin-bedded	3.8
Total Redwall limestone	89.0
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Limestone, dolomitic, greenish-gray, weathering light yellow; fine-grained, sugary, silty, and massive, with shaly zones	8.0

*See note, p. 93.

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Concealed; greenish-gray shale exposed in a few places	50.0
Upper buff-weathering beds.	
Limestone, gray-brown, weathering red brown; very fine grained, with scattered quartz grains; thin-bedded and banded	9.0
Shale, gray-green, and white to red-brown, cross-bedded, medium-grained, calcareous, slabby sandstone; partly concealed	24.8
Limestone, very sandy, weathering pink, with many calcite-filled cavities. Partly silicified crinoid stems, ramose corals, and brachiopods	5.3
Sandstone, greenish-gray, weathering dark buff; very fine grained, calcareous, slabby, containing stony gray chert nodules and lenses and small quartz geodes; forms cliff	34.0
Sandstone, white, weathering brown; coarse, uneven-grained, quartzose, with *Scolithus*-like tubes; large joint blocks slump to form rock "cities"; bed is lenticular, with average thickness of	3.7
Concealed; yellow, calcareous, slabby sandstone float	19.0
Middle member.	
Cliff-forming limestone.	
Limestone, gray, dense. Many partly silicified stromatoporoids	2.5
Concealed	2.7
Limestone, brown, medium-grained. Crowded corals and stromatoporoids	4.1
Concealed	5.4
Limestone, brown, weathering gray with pink stains; medium-grained, sugary; in beds 0.5 to 1.0 foot thick	3.7
Limestone, gray, dense. Crowded with stromatoporoids and corals	8.4
Limestone, light-brown to light-gray or white, dense to medium-crystalline; fine drusy chert scattered through rock. Contains a few stromatoporoids	29.0
Limestone, dolomitic, greenish-gray, finely crystalline, silty; thin-bedded below, becoming massive above; many calcite-filled cavities. Ramose corals (?)	23.5
Sandstone.	
Sandstone, gray, with red-weathering spots; very fine grained, blocky Mudstone, green and red, sandy and calcareous	1.4
Limestone, brown, weathering pink and gray; sandy and banded, with calcite specks in upper part	1.9
Sandstone, greenish-gray to white, mainly very fine grained, with some medium- to coarse-grained beds; massive, fucoidal, calcareous, weathering blocky in part	17.8
Siltstone, mottled greenish gray and pink; thin-bedded, slabby, with greenish-gray shale partings	7.1

	Feet
Devonian—Continued	
Martin formation—Continued	
Middle member—Continued	
Sandstone, gray, stained pink; very fine grained, calcareous, slabby; cross bedding and lensing	11.9
Lower member:	
Light buff-weathering beds.	
Limestone, dolomitic, gray to brown, with pink staining; fine-grained, sugary; thin to medium beds; shaly and blocky weathering in lower part	11.9
Limestone, dolomitic, light-brown to white, dense to fine-grained, sandy, with scattered well-rounded quartz grains and limestone breccia near top. Many branching calcite-filled cavities which may have been ramose corals originally	12.3
Concealed	14.4
Shale, green and red	0.9
Limestone, dolomitic, brown, fine-grained, and sandy	0.8
Limestone, dolomitic, chalky-white, dense, brittle, massive, with calcite-filled cavities and pink breccia in upper part	14.0
Limestone, dolomitic, light-gray; dense conchoidal fracture in lower part; beds medium to thick; scattered sand grains and calcite veins and filled cavities, some of which contain quartz crystal; gray chert bed, half a foot thick at top	13.0
Limestone, dolomitic, gray-brown, fine-grained, well-jointed, with much gray and white chert	4.0
Limestone, dolomitic, light-gray, weathering to white conchoidal flakes and blocks; dense thin beds 0.1 to 0.9 foot thick; a few chert nodules	8.5
Shale and dolomitic limestone, greenish-gray, interbedded	2.8
Limestone, dolomitic, light gray-white, dense, medium-bedded, silty; conchoidal fracture develops on weathering	6.5
Shale and siltstone, greenish-gray, interbedded	1.5
Limestone, dolomitic, light-gray to brown, dense, with scattered sand grains in some beds; thin- to medium-bedded, with green shale partings	17.0
Limestone, dolomitic, light-gray, dense, brittle, breaking to irregular blocks, with some large gray chert nodules and a relatively few small elongate chert nodules with yellow-brown rind	5.8
Brown beds.	
Limestone, dolomitic, light- to dark-gray, weathering gray and pink; dense, massive, brecciated in part; gray-banded chert nodules with brown rind; thin uneven shaly beds in upper part	8.8
Concealed	3.0
Devonian—Continued	
Martin formation—Continued	
Lower member—Continued	
Limestone, dolomitic, light- to medium-brown, weathering darker brown; fine-grained, sugary; thin, uneven beds, with large masses of drusy gray and white chert; petroliferous odor on fresh fractures	11.0
Basal sandstone.	
Sandstone, white and gray-green, weathering pink and yellow with purple mottling; grains uneven, mainly medium-rounded; calcareous in part; thin to thick beds, partly cross-bedded and ripple-marked	10.2
Total Martin formation (probably too great; best outcrops are thicker parts of limestone lenses; if section could have been measured in smaller area, thickness shown would probably be less than figure given)	422.5
Cambrian:	
Troy quartzite.	

Section 8, Cliff House Canyon (NW¼ sec. 8 and NE¼ 5, T. 7 N., R. 16 E.), Gila County, Ariz.*

[Measured in canyon, beginning just above ruins]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Red sandy shale and chert breccia	13–18
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, in loose blocks; white, gray, and brown, dense to medium-crystalline; brown chert nodules; red sandy shale infiltrated to base. Partly silicified crinoid stems and corals	63.0
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Mainly concealed; exposures of gray, shaly, thin-bedded, fine-grained, blocky-weathering limestone	30.0
Limestone, brown, weathering red brown; medium-crystalline; locally traceable. Abundant silicified fossils	1.0
Dark buff-weathering beds.	
Sandstone, white, stained red; very fine grained, calcareous, friable; very thin bedded	7.2
Limestone, brown, weathering red brown; medium-crystalline, with masses of white chert; locally traceable. Abundant silicified fossils, including Prismatophyllums, Atrypas, Spirifers, and others	3.0

*See note, p. 93.

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Sandstone, yellow, very fine grained, calcareous, thin-bedded, and poddy; considerable stony gray and brown chert and a few geodes	17.0
Chert and limestone. Green and purple chert and red, medium-grained, uneven-bedded limestone. Fossiliferous. Recognizable at localities 9 and 10	1.8
Limestone, gray, weathering red brown; medium-grained, fossiliferous, and very sandy, grading from underlying sandstone	7.0
Sandstone, gray, weathering brown; medium to coarse, mainly rounded and frosted quartz grains, with siliceous cement; strongly cross bedded. A few fish plates	12.4
Limestone, gray and brown, weathering brown; dense to medium-grained, sandy, thin- to thick-bedded. Abundant stromatoporoids and corals	12.0
Sandstone and limestone conglomerate, gray, uneven-grained, massive, calcareous, and weak, with shaly zones. Ramose corals in some beds	15.0
Limestone, gray and red-brown, dense, massive in lower part and medium-bedded above. Abundant corals and stromatoporoids	12.7
Sandstone, white, fine-grained, calcareous, friable, and slabby; lower part concealed	11.5
Middle member.	
Cliff-forming limestones.	
Limestone, gray and pink, fine-grained, very sandy along cross-bedding planes; resistant, forming ledge	7.5
Limestone, brown, medium-grained, sandy, and fossiliferous	9.0
Limestone, dolomitic, brown, weathering gray and red; dense, massive, with many calcite-filled cavities	11.5
Limestone and sandstone: Intergrading, brown to gray, reddish brown-weathering, finely crystalline, sandy limestone and fine- to coarse-grained sandstone with many grains rounded and frosted	39.5
Limestone, gray to brown, weathering gray and rough; medium-crystalline, massive, fossiliferous, sandy and conglomeratic near base	20.0
Sandstone, gray; medium to coarse rounded grains; massive, calcareous, grading upward into sandy limestone with thin beds of sand and limestone pebbles; numerous calcite-filled cavities	22.5
Limestone, dolomitic, gray, weathering yellow and gray; dense and sandy	5.5
Sandstone, white, red, and brown; grains uneven, fine to medium-rounded, and frosted; calcareous, massive, becoming shaly and slabby near top	29.0
Devonian—Continued	
Martin formation—Continued	
Middle member—Continued	
Sandstone and sandy shale: Thin beds of red shale and blocky red sandstone, with interbedded quartzose sandstone lenses 0.5 to 1.0 foot thick	23.0
Sandstone, red-brown, with green mottling; medium-grained sand, mainly quartz with about 10 percent calcite rhombs; massive, blocky, friable, becoming shaly in upper part and grading into overlying unit	7.8
Lower member:	
Light buff-weathering beds.	
Limestone, brown and white, medium-crystalline and sandy	3.3
Limestone, dolomitic; gray below, becoming chalky white above; dense, with many calcite specks; scattered sand grains in basal part	19.0
Limestone, dolomitic, gray, weathering buff; fine-grained, sandy, and cherty; resistant in upper part, forming overhanging lip of falls	9.7
Mudstone, gray and pink, calcareous, blocky-weathering	4.0
Limestone, dolomitic, light-gray to white, dense, with scattered grains of quartz and shale partings	13.0
Limestone, dolomitic, light-gray and pink, weathering buff; dense, sandy, thin- to medium-bedded; blocky in upper part; chert nodules and stringers along joints	24.0
Limestone, dolomitic, light-gray, dense, with blocky fracture; contains small elongate chert nodules with brown rind, large chert nodules, and sand grains near top	3.8
Brown beds.	
Limestone, dolomitic, light-gray, dense, sandy, brecciated	4.5
Limestone, brown, fine-grained, sugary; thin uneven beds; petroleum odor on fresh fractures	16.0
Basal sandstone.	
Not recognized.	
Total Martin formation	403.2
Cambrian:	
Troy quartzite (?): Sandstone, red and white, weathering brown; loosely cemented, calcareous in part, cross-bedded, with granule and pebble conglomerate beds; forms overhanging ledges. Estimated exposed thickness 100 feet.	

Section 9, Oak Creek Indian Farms (sec. 32, T. 8 N., R. 16 E.), Gila County, Ariz.*

[Composite section measured along three creeks tributary to Oak Creek, about 1 mile east of Oak Creek Indian village and about 2.5 miles southwest of Grasshopper]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Chert float covering top of hill	20.0

*See note, p. 93.

	Feet
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, dense, light-gray, in loose blocks. Crinoid stems and large cup corals	19.0
Limestone, greenish-gray, weathering pinkish gray; dense, sugary in upper part; crinoidal	5.0
Limestone, crystalline, dark-gray, dense to fine-grained	3.0
Limestone, red and gray, sandy and conglomeratic, with rounded and frosted quartz grains and red limestone pebbles up to 10 millimeters in diameter	2.5
Total Redwall limestone	29.5
Devonian:	
Martin formation:	
Upper member.	
Green shale zone.	
Concealed	3.5
Shale, gray-green, breaking to thin flakes	2.5
Dark buff-weathering beds.	
Sandstone, gray and brown, weathering buff; fine-grained, thin-bedded, very calcareous, grading laterally into sandy limestone; many small quartz geodes and calcite-filled cavities	7.0
Chert and sandy limestone, red-gray and green, weathering pink to purple; dense, oolitic. Fossiliferous, including crinoid stems and the following, identified by G. A. Cooper: *Prismatophyllum*, *Cyrtospirifer whitneyi* Hall, two species of *Atrypa*, *Spirifer hungerfordi* (Hall and Whitfield), *S. orestes* (Hall and Whitfield), and *Tylothyris?* sp	1.5
Sandstone, gray, with wavy light and dark banding, weathering yellow and pink; fine-grained, calcareous, slabby; thin to medium beds; a few quartzose lenses, fossils, and geodes	13.0
Chert and siliceous limestone, brown and gray, dense. Following fossils identified by G. A. Cooper: *Spirifer hungerfordi*, *S. orestes*, *Schizophoria iowensis*, *Atrypa* sp	0.5
Sandstone, gray, white, and red-brown, weathering pink and buff; uneven-grained, very calcareous, cross-bedded in part; a few small pebbles and fossils	10.0
Limestone, gray-brown, weathering pink and gray; dense, sandy, grading laterally and vertically into sandstone. In places crowded with corals and stromatoporoids, including digitate Favosites, Cladoporas, and Stromatoporas, identified by G. A. Cooper	6.0
Sandstone, gray, weathering pink and yellow; very fine grained, with scattered coarse, rounded grains; calcareous; thin to thick bedding. Traces of fossils	15.0

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Limestone, white and gray, weathering gray, brown, and red; dense to medium-grained, sugary; thin to medium beds; nodular in upper part. Crowded with corals and stromatoporoids in places	15.0
Sandstone, conglomerate, and sandy limestone, gray and brown, fine- to coarse-grained, with quartzite, chert, and limestone pebbles; very unevenly cross-bedded; lensing, with thick beds pinching out in tens of feet	5–30.0
Middle and lower members absent.	
Total Martin formation	80±
Cambrian:	
Troy quartzite.	

Section 10, Spring Canyon (sec. 36, T. 9 N., R. 15½ E.), Gila County, Ariz.*

[Measured in Spring Canyon, near Chediski Indian farms]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation:	
Limestone, gray, dense, nodular. Contains *Chaetetes*	3.0
Shale and chert breccia, red sandy shale, and residual chert breccia; red chert pebble conglomerate 25 feet above base	35.±
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, gray to white, weathering blue gray; fine to medium-crystalline; oolitic in upper part, massive and thin-bedded below	35.0
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Sandstone and green shale, partly concealed; sandstone, fine-grained, uneven-bedded, calcareous, gray, with a few geodes weathering to thin red and yellow slabs. A few poorly preserved fossils	8.0
Dark buff-weathering beds.	
Limestone, red- and yellow-brown, sandy, and chert. Silicified fossils, including *Platyrachella* and *Atrypa* (identified by G. A. Cooper), and crinoid stems	1.5
Sandstone, weathering pink and yellow brown; fine- to coarse-grained, with a few limestone pebbles up to 25 millimeters long; thin slabby beds. Traces of fossils, probably digitate corals and stromatoporoids	11.5

*See note, p. 93.

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Limestone, gray-brown, weathering gray; dense; medium-thick beds in lower part becoming shaly and sandy in upper part with coarse, rounded and frosted quartz grains. Abundant small corals, including *Alveolites ?*, digitate *Favosites*, and *Cladopora* (identified by G. A. Cooper), and stromatoporoids	11.0
Middle and lower members absent.	
Total Martin formation	32.0
Cambrian:	
Troy quartzite.	

Section 11, O. W. Ranch (SW¼ sec. 34, T. 10½ N., R. 15 E.), Gila County, Ariz.

[Measured in east wall of a tributary to Canyon Creek, across the ranch road, about 2 miles south of the ranch buildings. The O. W. Ranch was formerly called the Ramer Ranch]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Limestone; shale; chert breccia. Partly concealed.	
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, gray, dense, and fossiliferous, in loose blocks	2–3
Devonian:	
Martin formation:	
Limestone and sandstone; basal 10 feet conglomeratic, overlain by gray to brown dense dolomitic limestone, medium-bedded and sandy in places; upper 35 feet includes gray, mainly fine-grained sandstone and sandy limestone that weather pink and buff and contain a few poorly preserved fossils. No detailed section measured	110
Pre-Cambrian:	
Mescal limestone (?): Dolomite and quartzite, thin-bedded and ferruginous	40±

Section 12, Colcord Canyon (sec. 34, T. 10½ N., R. 14 E.), Coconino County, Ariz.

[Measured in Colcord Canyon about three-fourths mile southwest of Hunt Ranch (see map of Tonto National Forest, edition of 1941, published by Department of Agriculture, Forest Service]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Limestone and shale. Not measured.	
Shale and chert breccia consisting of red sandy mudstone enclosing blocks of white chert	30.0
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, white, granular, oolitic; thin-bedded near base and loose blocks in upper part. Abundant corals	30–40
Devonian:	
Martin formation:	
Limestone and calcareous sandstone, conglomeratic near base with rounded pebbles of quartz and quartzite, overlain by sandy and granular limestone; thin-bedded in upper part. Poorly preserved corals and stromatoporoids. No detailed section measured; thickness obtained by pace and compass traverse and barometer elevations	300±
Cambrian:	
Troy quartzite (?): Quartzite, pink, medium-grained, massive, and strongly fractured.	

Section 13, Tonto Creek (Promontory Butte quadrangle), Coconino County, Ariz.

[Lower part of Martin formation measured at junction of Tonto and Horton Creeks about 1 mile north of Kohl Ranch; upper part of section measured about half a mile north in east wall of Tonto Creek]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation:	
Limestone, gray, dense, nodular, with red chert. Poorly preserved productids and spirifers	2.0
Siltstone, mudstone, and chert breccia: Mainly red to dark-purple, sandy and pebbly siltstone and mudstone weathering blocky; chert breccia mostly in lower part, especially in depressions in underlying Redwall limestone; apparently filled sinkholes; upper 12 feet mainly concealed	27–44
Carboniferous (Mississippian):	
Redwall limestone: Limestone, dense, weathering yellow and gray; mainly loose blocks separated by infiltrated red siltstone. Poorly preserved cup corals, brachiopods, and gastropods	28–45
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Seventy-five percent concealed; outcrops of thin-bedded, fine-grained calcareous sandstone and sandy limestone weathering yellow and pink. A few poorly preserved fossils	17.5
Dark buff-weathering beds.	
Sandstone, brown, weathering yellow and pink; uneven-grained; mainly coarse, calcareous, and massive	7.0
Limestone, gray, weathering yellow and pink; dense, sandy, with scattered rounded quartz grains; thin-bedded and slabby	12.0
Limestone, gray-brown, weathering yellow, pink, and gray; medium- to coarsely crystalline, with scattered grains of fine sand	5.5
Sandstone, gray, weathering brown and pink; grains uneven, fine to coarse, with larger ones rounded and frosted; calcareous, cross-bedded, massive, becoming slabby on weathering	16.5

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Sandstone and limestone, gray, weathering buff and pink: Thin-bedded, fine- to medium-grained, very calcareous sandstone; dense, very sandy limestone beds less than 1 foot thick	24.0
Sandstone, greenish-gray, weathering buff and pink; grains uneven, medium, mainly subangular to rounded; very calcareous; massive, partly cross-bedded, with bed of white fine-grained quartzose sandstone at top of unit	15.5
Middle member (?):	
Limestone, gray, white, and gray-brown, weathering gray; lower part medium-crystalline, becoming finely crystalline in upper part; massive in places, but upper part becomes sandy and thinner-bedded laterally. Abundant ramose calcite-filled cavities which may be overcalcified corals or bryozoans	26.0
Limestone, dolomitic, gray, stained pink; dense to finely crystalline, sandy, with coarse rounded grains; thin to medium beds 0.05 to 2.0 feet thick; brown and white chert nodules near the base and small hematite nodules near top. Slope former, about 10-percent concealed	72.5
Sandstone, gray, stained pink; uneven-grained, with some coarse grains rounded and frosted; conglomeratic in places, with pebbles 3 to 5 millimeters in diameter; massive, calcareous, cross-bedded; forms falls in Tonto Creek	33.6
Lower member:	
Limestone, white, stained red; coarsely crystalline, weak; forms partly concealed slope	25.0
Limestone, dolomitic, light-gray, dense, with hackly fracture; thin beds and sandy laminations, with rounded and frosted quartz grains and subangular pink grains; thins laterally with loss of lower part	9.0
Sandstone and limestone breccia: Gray, arkosic, calcareous, massive, medium- to coarse-grained sandstone stained pink and changing laterally into limestone breccia	10.0
Limestone, dolomitic, light-gray, dense, thin-bedded, and blocky	3.7
Conglomerate and arkose, red to pink; matrix composed of angular to rounded feldspar, quartz, and green-mineral grains, scattered angular to rounded quartz and quartzite pebbles averaging 20 to 30 millimeters in diameter in upper part and angular boulders of granite and quartzite in lower 4 feet	35.0
Total Martin formation	312.8
Pre-Cambrian:	
Granite; green hornblende phase with large pink feldspars.	

Section 14, East Verde River, Pine quadrangle, Ariz.

[Measured in draw about half a mile east of bridge over East Verde River on Pine-Payson highway and in highway cuts and valleys east of Sycamore Creek and about 1½ miles north of East Verde River bridge. About 6 miles north of Payson. Differs considerably from same section as reported by Stoyanow (1926, pp. 313, and 1936, p. 499). Authors were unable to recognize Stoyanow's units or to understand just what he included in his Sycamore Creek formation or member, even though this is its type section]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Siltstone, shale, and limestone, with basal member of red mudstone and chert breccia.	
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, white and gray, finely to coarsely crystalline, with a few nodules of gray, dense chert; mainly loose blocks with infiltrated red sandy mudstone from overlying Naco formation. Large corals near top	65.0
Limestone, mottled gray and red, dolomitic in lower part; sandy and conglomeratic, with small pebbles less than 10 millimeters in diameter. Worn fragments of Cladoporas	2.0
Total Redwall limestone	67.0
Devonian:	
Martin formation:	
Upper member:	
Siltstone, gray- and green-banded, weathering whitish gray; calcareous; massive in fresh outcrops but thin-bedded and shaly when weathered. Unever contact with overlying Redwall limestone	16.0
Limestone, yellow- and red-brown, finely crystalline, very sandy. Numerous fossils, mainly corals and brachiopods	2.0
Limestone, greenish-gray, very fine grained, calcareous, weathering shaly; cherty and fossiliferous	7.5
Limestone, gray, weathering pink; medium-crystalline, cherty at top. Contains silicified fossils	2.5
About 90-percent concealed; ledges of yellowish-brown calcareous sandstone containing quartz geodes. Silicified fossils	38.0
Limestone, white to gray-brown, weathering buff; fine to medium-crystalline, sandy in part, with thin layers of rounded and frosted quartz grains; thin- to medium-bedded. Silicified Cladoporas near middle. Partly concealed in upper part	33.0
Limestone, dolomitic, light-brown, weathering buff; fine to medium-crystalline, with calcite-lined cavities and small quartz geodes. Fifty-percent concealed	37.0
Limestone, gray, weathering gray brown; fine-grained, sandy and silty, thin-bedded	22.0
Sandstone, gray to pink, with streaks of brown along bedding; fine-grained, very calcareous, massive, forming strong rounded outcrops; numerous calcite-filled cavities	8.0

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper member—Continued	
Limestone, gray to brown, weathering gray to buff; dense to fine-grained, sandy, thin-bedded. About 40-percent concealed	28.0
Middle member (?):	
Limestone, gray-white, mottled red; fine-grained, sandy and silty, with scattered rounded and frosted quartz grains; mainly massive	6.0
Limestone, gray to white, weathering light gray; dense to finely crystalline, sandy, with rounded and frosted quartz grains scattered through rock and concentrated along bedding planes; mainly massive; cliff forming	23.0
Limestone, white, weathering gray; very sandy, with calcareous sandstone and breccia at base; massive	8.8
Sandstone, brown, weathering gray white to brown; mainly medium subangular to subround quartz grains; calcareous, with lenses of quartzose cement; grades upward into limestone	13.5
Lower member:	
Limestone, dolomitic, pink and white, fine-grained, sugary, argillaceous, weathering to rounded blocks	2.6
Fifty-percent concealed; dolomitic limestone, pink and yellow, impure, dense, and brittle, with conchoidal fracture; sandy near top	27.0
Limestone, gray and pink, weathering buff; dense and argillaceous, with scattered calcite crystals	5.0
Limestone, grayish-white, weathering white; dense. About 20-percent concealed	10.5
Limestone, light- to medium-gray, weathering gray and buff; dense, with conchoidal fracture; scattered sand grains; calcite-filled cavities; beds 1 to 2 feet thick, probably separated by thin gray shales. Slope-forming unit; about 25-percent covered	15.0
Limestone, slightly dolomitic, light- to medium-gray, weathering gray and buff; dense, with conchoidal fracture; scattered sand grains in some beds. Ramose calcite-filled cavities, possibly overcalcified corals or Bryozoa	22.0
Limestone, slightly dolomitic, gray to brown, dense, and brittle; small, thin, dense gray chert nodules with brown rind	4.0
Breccia of limestone and chert without bedding; blocks of gray- and red-banded chert with maximum diameter of 1 foot, fragments of small brown chert nodules, and blocks of porous white sandstone and limestone; some of chert blocks broken and offset 3 to 4 inches	2.2
Devonian—Continued	
Martin formation—Continued	
Lower member—Continued	
Limestone, dark-gray to black, weathering brown and gray; fine-grained; bedding lenticular and irregular, with thin beds and laminations within lenses; sandy near base, gray to white chert nodules near top; many calcite-filled cavities; strong petroleum odor throughout. Forms a cliff	20.0
Limestone, dolomitic and cherty, gray and brown, weathering white; dense; very thin, uneven beds with green shale partings	2.5
Sandstone, weathering mottled pink and brown, probably greenish gray when fresh; medium-grained, calcareous, becoming coarse-grained and arkosic near top; weak, forming partly covered slope with occasional cliffs	30.0
Total Martin formation	386.1
Cambrian:	
Tapeats sandstone (?):	
Sandstone, white, arkosic, conglomeratic, with subangular pebbles up to 20 millimeters in diameter. Forms top of cliff	7.0
Sandstone, conglomeratic, red, white, and brown, weathering brown; fine to coarse, subangular to subrounded sand grains of quartz, rotten feldspar, and biotite; pebbles 0.4 to 15 millimeters in diameter, mainly quartz and chert but including some granite fragments near base; massive, cross-bedded, weathering slabby	33.0
Pre-Cambrian:	
Granite, with weathered zone about 3 feet thick at top.	

Section 15, Roosevelt Dam, Roosevelt quadrangle, Ariz.

[Measured on both sides of reservoir (Roosevelt Lake) immediately above dam]

	Feet
Devonian:	
Martin formation:	
Upper and Middle members (section incomplete, faulted at top):	
Sandstone, brown, fine-grained at base, becoming coarse-grained above; calcareous	18.0
Sandstone, brown, fine-grained, calcareous, fucoidal, and thick-bedded	14.0
Siltstone, brown, calcareous. Contains numerous molds of Spirifers and Atrypas	1.5
Sandstone, yellowish-brown, uneven-grained, calcareous, in beds 1 to 3.5 feet thick	33.0
Limestone, brown, medium-crystalline, and sandy, in beds 1 to 4 feet thick	18.0

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper and Middle members—Continued	
Sandstone, yellow-brown, fine- to medium-grained, calcareous, with thin quartzose pods and lenses; massive beds	9.0
Sandstone, yellow and brown, fine-grained and calcareous, with wavy laminations	22.0
Sandstone and siltstone grading into sandy and silty limestone, yellow-brown, thin-bedded. Molds of fenestellids near top	77.0
Sandstone, brown, fine- to medium-grained, quartzose, vitreous on fresh fractures and breaking across grain; lenticular beds	2.5
Sandstone, brown and pink, weathering buff; silt to medium sand grains; calcareous, massive, and cross-bedded. Poorly preserved Spirifers near top	38.0
Sandstone. conglomeratic; lower part brown, upper part greenish gray; subangular to subround medium sand grains with scattered pebbles of quartz up to 6 millimeters in diameter; beds 1 to 3 feet thick, cross-bedded in lower part and becoming slabby and shaly in upper part	12.0
Lower member:	
Light buff-weathering beds.	
Limestone, dolomitic, greenish-gray and purple, argillaceous, weathering blocky	8.0
Limestone, dolomitic, light- to dark-gray and brown, dense, silty in uppermost third; beds 1 foot thick or less, probably separated by thin shales. About 20-percent concealed	78.0
Concealed; dense, medium- to dark-gray dolomitic limestone float similar to limestone above; zone of small dense gray chert nodules with brown rind near base of unit	30.0
Brown beds.	
Limestone, dolomitic, medium-brown, finely crystalline, with a few calcite-filled cavities; bedding irregular, with lenses of laminated limestone	17.0
Limestone, dolomitic, dense, light-brown, interbedded with green shale having rounded fine to coarse sand grains; beds 0.1 foot thick or less	3.3
Basal sandstone.	
Sandstone, light greenish-gray, weathering brown with red streaks; fine-grained calcareous matrix with scattered large rounded and frosted grains; beds thin to medium-thick	15.0
Total Martin formation	16.5
Cambrian:	
Troy quartzite: Sandstone and conglomerate, red and greenish-gray, weathering red brown; fine- to coarse-grained, containing grains ranging from granules to pebbles 60 millimeters in diameter; grains mainly angular to rounded quartz, but angular feldspar grains present in lower part; massive and cross-bedded below, and thin to medium-thick beds with green shale partings in upper part. Similar in lithology to the Tapeats sandstone near Pine and Payson.	

Section 16, Windy Point, Roosevelt quadrangle, Ariz.

[Measured at Windy Point (Windy Hill), on Roosevelt Lake. This section was measured by Stoyanow (1936, p. 493) at a time of low water. He reported 141 feet of limestone at the base, but no limestone was exposed at the time of the authors' visit in August 1944. The authors' section shows a greater thickness of sandstone than reported by Stoyanow. It is not clear whether this is due to a difference in the description of the beds or to a difference in the amount of correction for dip. The authors measured the section with tape, rod, and hand level and used an average dip of 16°]

	Feet
Tertiary:	
Gila conglomerate.	
Carboniferous (Missisippian):	
Redwall limestone:	
Limestone, gray and white, dense to coarsely crystalline, and crinoidal, in beds 3 to 5 feet thick, containing dense white chert nodules. Silicified fossils, including solitary and colonial corals	66.0
Limestone, light- to dark-gray, in beds 2 to 6 feet thick, containing dense gray chert nodules. Silicified corals. About 20-percent concealed	60.0
Limestone, buff to yellow-brown, finely crystalline, in beds 2 to 4 feet thick. Silicified corals	37.0
Limestone, white, coarsely crystalline, and crinoidal; beds 1 to 3 feet thick	12.0
Total Redwall limestone	175.0
Devonian:	
Martin formation:	
Upper and middle members (?):	
Sandstone, reddish-brown and buff, fine-grained, very calcareous, with pods and lenses of quartzose sandstone; cross-bedded	29.0
Sandstone and shale: Purplish-gray, thin-bedded, fine-grained, calcareous, shaly sandstone in lower part, calcareous shale with sandstone lenses in upper part. Partly concealed	37.0
Sandstone, brown and green, medium- to coarse-grained, with scattered quartz granules; weak and crinoidal in lower part, but upper part is massive and cross-bedded and forms cliff	21.0

	Feet
Devonian—Continued	
Martin formation—Continued	
Upper and middle members—Continued	
Sandstone, brown and red, calcareous; mainly fine-grained, but contains rounded and frosted coarse quartz grains and granules; lower 7 feet massive and resistant, upper part weak and slabby	26.0
Sandstone, pink, yellow, and brown, calcareous, mainly fine-grained, with scattered coarse rounded and frosted quartz grains; bedding ranges from laminations to beds 2.5 feet thick, with some cross bedding. A few crinoid stems and suggestions of other fossils in lower part. Resistant, forming cliff	32.0
Sandstone, green, brown, and red, very fine-grained, calcareous, weak, thin-bedded, weathering to rounded blocks 1 to 2 inches in diameter; contains calcite-filled cavities. Molds of brachiopods	83.0
Sandstone, brown; grains uneven, ranging from medium sand grains to granules; calcareous, with quartzose lenses; cross-bedded	15.0
Sandstone, brown, gray, and red, weathering reddish brown; fine-grained, with scattered coarse grains; calcareous; bedding uneven, ranging from thin and slabby to massive and cross-bedded	57.0
Total Martin formation	300.0
Water level of Roosevelt Lake.	

Section 17, Gold Gulch, Globe quadrangle, Ariz.

[Measured near Horseshoe Bend, Gold Gulch, northwest of Castle Dome mine, by John P. Albers and C. M. Gilbert. N. P. Peterson, chief of party]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation: Shale and limestone, partly concealed: Light-gray to white calcareous or chalky shale and mainly dense, light- to medium-gray limestone with red chert nodules; zone of brown limestone and chert nodules 380 to 465 feet above base, red chert conglomerate about 10 feet thick 45–50 feet above base, and 25 to 30 feet of red sandy mudstone and chert breccia at base	465.0
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, light-gray to white, partly oolitic, containing rounded and frosted grains of sand; massive, forming a cliff	295.0
Limestone, light- to medium-gray, stained pink; granular, thin- to medium-bedded, weak, slope forming. Doubtfully referred to Redwall limestone	70.0
Total Redwall limestone	365.0
Devonian:	
Martin formation:	
Upper and middle members:	
Green shale zone.	
Limestone, gray to brown, massive, granular to oolitic. Small and fragmentary fossils	5.0
Limestone, dolomitic, gray, dense, and argillaceous	45.0
Shale, greenish-gray	25.0
Dark buff-weathering beds and cliff-forming limestone.	
Limestone, dolomitic, brown, weathering buff with pink and red stains; fine-grained. Fossiliferous, containing numerous Atrypas	10.0
Limestone, gray and brown, weathering buff and gray; medium to coarsely crystalline; sandy in upper part, with rounded fine grains of quartz scattered through rock and along planes of cross bedding; thin to medium beds. Fossiliferous, containing crinoid stems, fenestellids, Schizophorias, and Atrypas	60–70.0
Sandstone.	
Sandstone and granule conglomerate, gray, weathering brown; mainly calcareous but including lenses of quartzose sandstone up to half a foot thick; grains uneven, ranging from fine sand to granules, many of which are rounded and frosted; locally cross-bedded	25–35.0
Lower member:	
Light buff-weathering beds.	
Limestone, dolomitic, medium-gray, weathering buff and gray; dense to fine-grained, arenaceous, with scattered rounded and frosted sand grains and granules; thin to medium-thick beds with green shale partings and gray chert nodules near base	83.0
Limestone, dolomitic, light-gray, weathering buff; dense; small gray chert nodules with brown rind	2.0
Brown beds.	
Limestone, dark-gray to brown, medium-crystalline; thin laminated beds, partly cross-bedded; slight petroleum odor	36.0
Limestone, dolomitic, dark-gray, dense, very thin bedded, with partings of sandy shale	3.0
Sandstone and conglomerate: Brown, micaceous, coarse-grained, cross-bedded sandstone; conglomerate, composed of rounded and angular boulders of quartz, quartzite, schist, and conglomerate with a maximum diameter of 3.5 feet in a quartz and mica sandstone matrix. Rests unconformably on Troy quartzite and formations of Apache group; boulders in Martin formation appear to have been derived locally from older rocks. Martin formation intruded by diabase at Horseshoe Bend. Basal sandstone ranges in thickness from 10 to 200 feet with average thickness of	20.0
Total Martin formation	334.0

Section 18, Superior, Ariz.

[Measured near Queen Creek mine. (Modified from Harshman, in Short and others, 1943, pp. 28, 30)]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation:	
Conglomerate, red, gray, and brown; matrix consists of angular to round brown sand grains enclosing angular to subround black, white, and red chert pebbles	1.0
Limestone, weathering white; dense; in beds 1 to 2 feet thick	40.0
Mudstone, red, sandy, and massive	18.0
Chert breccia and conglomerate, altered by mineralization; mainly a manganese mineral and brown iron ore	13.0
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, light-gray to white, weathering bluish gray; finely to coarsely crystalline, partly crinoidal; contains considerable dark-gray chert	12.0
Limestone, light- to dark-gray, weathering blue gray; dense to finely crystalline; dense dark-gray chert nodules; geodes; beds 1 to 2 feet thick; forms back slope. Silicified horn corals	67.0
Limestone, light-gray to gray-brown, weathering blue gray and yellow gray; dense and oolitic to medium-crystalline and crinoidal; beds 1 to 4 feet thick, forming cliff and ridge crest. A few large silicified horn corals	51.0
Limestone, light-gray, weathering buff; fine-grained; sandy in upper part, crinoidal in lower part; considerable dense vitreous and stony gray chert which weathers brown; thin-bedded. About 20-percent concealed	31.0
Limestone, medium-gray, weathering yellow gray to brown; finely to coarsely crystalline and crinoidal, with light-brown quartz and calcite geodes 1 to 4 inches in diameter, and scattered dense gray chert nodules; beds 1 to 3.5 feet thick. Silicified fossils, including horn corals, productids, and spirifers	16.0
Limestone, medium-gray, weathering blue gray and yellow brown; fine to medium-crystalline; crinoidal, with gray and white fossiliferous chert nodules the largest of which are 2 inches thick and 18 inches long and elongate parallel to bedding; beds less than 1 foot thick	38.0
Limestone, mainly light-gray and white, weathering light bluish white; oolitic; lithographic to finely crystalline, with a few nodules of gray and white chert; basal 4 feet pink, probably owing to alteration	54.0
Limestone, mainly light-gray, weathering bluish gray; dense and massive, with 1-foot bed of sandy limestone at top; basal zone, about 10 feet thick, has solution cavities, pink and gray fine-grained limestone, and blocks of overlying limestone	46.0
Carboniferous (Mississippian)—Continued	
Redwall limestone—Continued	
Limestone, medium- to dark-gray, weathering yellow gray, dark gray, and brown; dense to fine-grained, with irregular fracture; light-brown quartz geodes 1 to 3 inches long; massive, making dark band on slope beneath white limestone cliffs as seen from distance. Occasional crinoid stems	48.0
Limestone, gray and brown, weathering gray with anastomosing bands of buff; dense and silty, with brownish-white quartz geodes. Silicified brachiopods and corals tentatively identified as Mississippian in age	18.0
Total Redwall formation	381.0
Devonian:	
Martin formation:	
Upper member:	
Green shale zone.	
Shale, weathering red and yellow; fissile, with fine-grained, sandy, buff-weathering limestone beds less than half a foot thick in upper part	32.0
Dark buff-weathering beds.	
Limestone, brown to reddish-brown, weathering buff; fine-grained and sandy; beds less than 1 foot thick. Lenses of crinoidal limestone	28.0
Limestone, gray and red-brown, weathering gray and yellow; dense to medium-crystalline; thin-bedded below and massive above. Sparingly fossiliferous; crinoidal in upper 10 feet	47.0
Limestone, gray and brown, weathering gray; coarsely crystalline, sandy, crinoidal, massive, cross-bedded. Contains a few brachiopods	5.0
Sandstone, red-brown to pink, weathering dark buff; medium- to coarse-grained, calcareous; thin-bedded, with bed 3 feet thick at top	8.0
Sandstone, brownish-red, weathering yellow brown; fine- to medium-grained, with scattered coarse rounded grains; calcareous, cherty; thin slabby bedding; weak and partly concealed. Sparsely fossiliferous	25.0
Middle member:	
Cliff-forming limestone.	
Limestone, dark-gray, fine-grained; thin slabby and nodular beds, sandy in upper 7 feet and grading into overlying sandstone. Contains Atrypas, Spirifers, and crinoid stems	33.0
Limestone, light gray-brown, weathering yellow brown; fine-grained, sandy, in beds less than 1 foot thick	8.0
Sandstone, yellow-brown, medium-grained, with scattered rounded quartz granules in upper part; quartzose and massive	16.0

	Feet
Devonian—Continued	
Martin formation—Continued	
Lower member:	
Light-buff beds.	
Limestone, medium-gray, weathering light buff; dense and sandy, with rounded quartz grains and angular chert grains; beds 0.3 to 1 foot thick	10.0
Concealed; probably shaly limestone	9.0
Limestone and dolomitic limestone, light- to dark-gray, weathering light buff and gray; dense, cherty; beds 1 to 2 feet thick in lower part and 1 to 4 feet thick in upper 30 feet	95.0
Limestone, dolomitic, dark-gray, weathering light gray; dense and brittle; contains small dense-gray chert nodules with a brown rind	10.0
Brown beds.	
Limestone, dolomitic, dark-brown and black, weathering gray brown; dense to fine-grained; irregular laminated and brecciated beds with black and red chert nodules, somewhat mineralized and much fractured, as shown by rough weathered surface	25.0
Limestone, dolomitic, dark-gray, dense, brittle, very thin bedded	1.2
Limestone, yellow, with pink stain; deeply weathered, fine-grained, sandy, thin-bedded, poorly exposed	15.0
Basal sandstone.	
Sandstone, greenish-gray, weathering yellow brown; fine- to coarse-grained, with larger grains rounded and frosted; mainly calcareous, but quartzose beds are present	10.0
Total Martin formation	377.2
Cambrian:	
Troy quartzite.	

Section 19, Tornado Peak, Christmas quadrangle, Ariz.

[Measured near Tornado Peak, about 3 miles north-northeast of Hayden, by N. P. Peterson]

	Feet
Carboniferous (Pennsylvanian):	
Naco formation:	
Limestone, gray to white, dense to coarsely crystalline, thin- to thick-bedded, with a light-gray conglomerate composed of a brown sandy matrix and angular red chert pebbles 3 feet thick at base	385.0
Carboniferous (Mississippian):	
Redwall limestone:	
Limestone, gray, weathering buff; dense to fine-grained, with rusty chert lenses and nodules; basal 4 feet concealed. Doubtfully placed in Redwall limestone	59.0
Limestone, medium-gray, dense to fine-grained. Poorly preserved fossils	50.0
Limestone, white and dark-gray, dense to coarsely crystalline and crinoidal; white and gray chert nodules and beds	57.0
Carboniferous (Mississippian)—Continued	
Redwall limestone—Continued	
Limestone, light-gray, dense, locally crinoidal and massive	10.0
Limestone, white, sugary, and shaly	18.0
Limestone, dark-gray, forming cliff. Many corals	32.0
Porphyry sill or dike and fault.	
Limestone, white and gray, coarsely crystalline, and crinoidal, with large white chert nodules. Large horn corals and poorly preserved Spirifers	48.0
Limestone, dark-gray, massive, with sandy cross bedding; large masses of white chert. Relics of horn corals	40.0
Limestone, white and pink, with sugary texture	12.0
Limestone and dolomitic limestone, light- and dark-gray, dense and massive. Silicified Syringoporas and small horn corals	88.0
Porphyry diorite sill (140 feet thick).	
Limestone, dark-gray	4.0
Garnet, specularite, and quartz	7.0
Limestone, light-gray, dense, crystalline, with white and brown chert nodules	5.0
Marble, dark- to light-gray, massive, with numerous needles of tremolite; gray chert nodules near base	122.0
Total Redwall limestone	552.0
Devonian:	
Martin formation:	
Upper and middle members:	
Limestone, light-gray, finely crystalline, somewhat altered, thin-bedded, shaly. About 50-percent concealed	30.0
Concealed	17.0
Argillite, black, green, and red, weathering rusty brown; siliceous, with scattered garnets; thin-bedded, breaking to small triangular blocks. About 80-percent concealed	66.0
Limestone, somewhat altered, gray to brown, weathering buff; thin-bedded and shaly. About 40-percent concealed	60.0
Lower member(?):	
Marble, slightly dolomitic, white to medium-gray, fine-grained, and cut by porphyry dikes and sills with associated garnets. About 25-percent concealed	120.0
Shale, greenish-gray	0.7
Marble and argillite, with limonite, copper minerals, magnetite, and garnet (O'Carroll ore bed)	25.0
Sandstone, brown and gray, thin-bedded and blocky	13.0
Quartzite, brown, uneven-grained, calcareous in upper part, thin-bedded	6.0
Total Martin formation	337.7
Porphyry sill.	
Cambrian:	
Quartzites and shales.	

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INDEX

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