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ROCKS AND WATER IN VERDE VALLEY, ARIZONA*

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ROCKS

Stratigraphic Summary

The age of the rocks exposed in Verde Valley (Figs. 1 and 2) ranges from Precambrian to Recent. The Precambrian rocks and the lower part of the Paleozoic section crop out only in the Black Hills, where the rocks are elevated as a result of the movement in the Verde fault zone — a zone that extends along the entire eastern margin of the Black Hills. The stratigraphic relations of the rocks in the valley are given in Table 1.

System	Series	Formation or rock unit	Thickness (feet)
Quaternary	Recent and Pleistocene	Riverwash and gravel	0-100±
	Pleistocene	Volcanic rocks	0-300±
Quaternary or Tertiary(?)	Pleistocene or Pliocene(?)	Verde Formation	1800+
Tertiary	Pliocene(?) and Miocene(?)	Volcanic rocks	0-3000+
	Miocene(?)	Dry Beaver Creek rocks	0-2000+
Triassic	Middle(?) and Lower Triassic	Moenkopi Formation	300-400
Permian		Kaibab Limestone	300-400
		Toroweap Formation	150-350
		Coconino Sandstone	400-650
Permian and Pennsylvanian		Supai Formation	1500-1600±
Mississippian		Redwall Limestone	250±
Devonian	Upper and Middle(?) Devonian	Martin Limestone	450-500
Cambrian	Middle and Lower Cambrian	Tapeats(?) Sandstone	0-100
Precambrian	Yavapai	Ash Creek Group	20,000±

Precambrian Rocks

Precambrian rocks are exposed throughout the Black Hills. They consist of about 20,000 feet of metamorphosed volcanic flows, agglomerates, and tuffaceous sedimentary rocks of the Ash Creek Group intruded by diorite and quartz porphyry (Anderson and Creasey, 1958, p. 8-45). Metamorphism of some of the rocks is so slight that it is barely perceptible.

Paleozoic Rocks

Tapeats(?) Sandstone

The Tapeats(?) Sandstone is exposed principally in the vicinity of Mingus Mountain and Squaw Peak. The thickness of the formation ranges from 0 to about 100 feet. In general, the Tapeats(?) can be divided into two units, a lower cliff-forming unit of coarse-grained sandstone and conglomerate, and an upper slope-forming unit of siltstone and limy or dolomitic mudstone. The color of the rocks ranges from light gray, very pale orange, and yellowish gray, to grayish red, dusky red, and dark reddish brown. The contact between the Tapeats(?) and the overlying Martin Limestone appears gradational — the upper limy or dolomitic beds of the Tapeats(?) grade imperceptibly into the lowermost dolomitic beds of the Martin. No fossils have been found in the Tapeats(?) in Verde Valley. However, on Tonto Creek near Payson, Arizona, the formation contains plate fragments of arthrodiran fish.

Martin Limestone

The Martin Limestone is exposed in the Mingus Mountain and Squaw Peak areas, and in the downfaulted blocks in the Verde fault zone. The Martin is between 450 and 500 feet thick, and is mostly dolomitic limestone and dolomite that contains nodules of gray chert and some thin beds of limy siltstone, mudstone, and sandstone. It generally forms ledge-and-slope topography. The predominant colors of the rocks are light olive gray, grayish purple, pale red, pinkish gray, and white. Some beds of the formation are very fossiliferous, and several beds in the Mingus Mountain and Squaw Peak areas contain plates of arthrodiran fish.

Redwall Limestone

The best exposures of the Redwall Limestone are in the Mingus Mountain area. There are scattered outcrops of the formation in the southern part of the Black Hills, and there is a small isolated outcrop in the channel of Oak Creek near Sedona. The Redwall is about 250 feet thick, and is primarily a light-gray to yellowish-brown limestone that contains lenses and nodules of chert. It generally forms steep cliffs. Some beds of the formation are very fossiliferous; crinoids are most common, although brachiopods and corals are abundant in some places.

Supai Formation

The Supai Formation, because of its great areal extent, its brilliant red color, and its great thickness, is one of the most prominent rocks in Verde Valley. It is exposed in Mingus Mountain, along the Mogollon Rim, and on the floor of the valley. The thickness of the Supai ranges from about 1,500 to 1,600 feet. The formation is divided into three members — lower, middle, and upper. The lower member, which is 400 to 600 feet thick, is an alternating sequence of sandstone, mudstone, limestone, and dolomite. Typical colors are light brown, moderate orange pink, and grayish red. It generally forms steep ledge-and-slope topography. The middle member is about 275 feet thick, and is composed of reddish-brown and grayish-red dolomitic conglomerate, mudstone, limestone, siltstone, and sandstone that form the gently rolling hills and level flats in the Sedona area. The upper member is 700 to 1,000 feet thick, and is composed of moderate-reddish brown sandstone and silty sandstone that forms very steep or vertical cliffs. Numerous buttes and spires have been

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carved from the upper member in the "red-rock country" around Sedona. About 550 feet above the base of the upper member on the east side of Verde Valley is a 15-foot thick, grayish-red limestone that is known to be fossiliferous at two localities. This limestone pinches out west of Sedona; however, south of Sedona, in the West Clear Creek-Fossil Creek area, there are two limestones with a total thickness of more than 30 feet occupying a similar stratigraphic position. These limestones have been correlated with the Fort Apache Limestone of Stoyanow (1936, p. 533-536) in eastern Arizona.

Coconino Sandstone

The Coconino Sandstone in Verde Valley is exposed only along the Mogollon Rim, where it forms a nearly vertical cliff. The formation is about 400 to 650 feet thick and is a white to very pale-orange, unfossiliferous, crossbedded sandstone. In much of the valley, the contact between the Coconino Sandstone and the lithologically similar Toroweap Formation which overlies it, is marked by a distinct vegetation-covered ledge. South and east of Verde Valley, the Coconino and the overlying Toroweap appear as one massive sandstone.

Toroweap Formation

The areal extent of the Toroweap Formation is about the same as that of the Coconino Sandstone. The Toroweap is about 150 to 350 feet thick and in much of the valley is a very pale orange, unfossiliferous, crossbedded sandstone that forms a vertical cliff. In the area just north of the Black Hills, the formation is composed of very pale-orange and red sandstone, siltstone, and limestone.

Kaibab Limestone

The Kaibab Limestone is well exposed along the Mogollon Rim, and, although it is concealed in many places by younger rocks, the formation is present in much of the Colorado Plateaus province that bounds Verde Valley. The Kaibab is 300 to 400 feet thick, and is mostly limestone or dolomitic limestone containing nodules and thin beds of chert. It forms steep ledge-and-slope topography. The predominant colors of the rocks are very pale orange, yellowish gray, very light gray, and white. The Kaibab is fossiliferous and some beds contain numerous mollusks and brachiopods. A dictyoclostid brachiopod is common, and silicified fragments of this fossil often occur in younger gravel deposits.

Mesozoic Rocks

Moenkopi Formation

The only rocks of known Mesozoic age that occur in the Verde Valley area are those of the Triassic Moenkopi Formation. The Moenkopi is best exposed in the upper reaches of Sycamore Canyon. In this area a cover of Cenozoic rocks has protected the formation from erosion. The Moenkopi is about 300 to 400 feet thick and is composed of moderate-red, pale reddish-brown, and grayish-red siltstone, mudstone, claystone, and sandstone. At the base is a conglomerate about 60 feet thick composed of fragments of quartzite, chert, and jasper (Fig. 3). The mudstone and claystone in the upper part of the exposure contain stringers of gypsum. In this canyon, the Moenkopi is not known to be fossiliferous, although the petrified wood in the overlying Cenozoic gravels may have been derived from the now eroded uppermost beds of the formation.

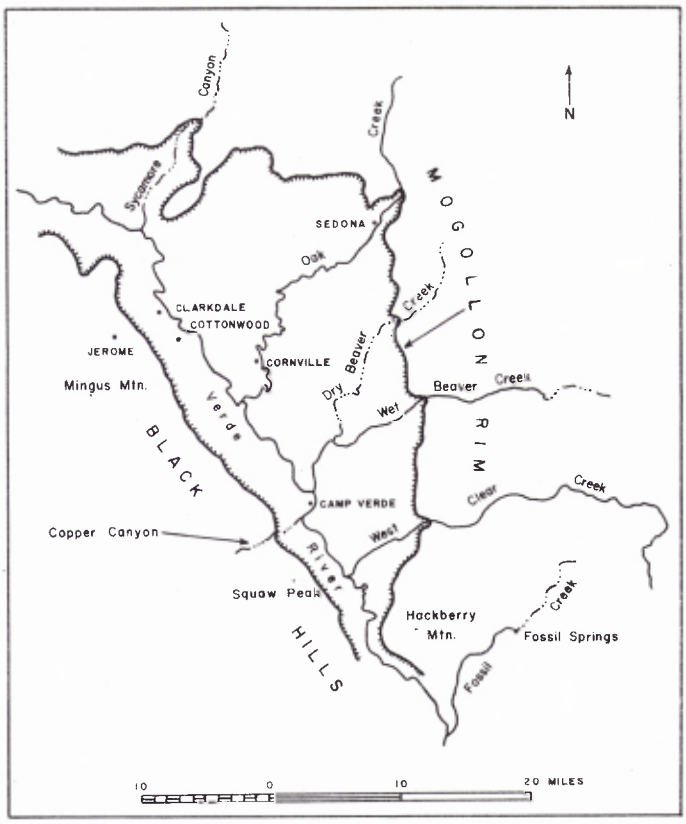

Figure 1. Index map of Verde Valley.

Cenozoic Rocks

Dry Beaver Creek Rocks

The Dry Beaver Creek rocks (Twenter, 1961, p. 153-156) are the oldest known Cenozoic rocks in Verde Valley. The rocks occur as erosional remnants in numerous places, but the best exposures are in the vicinity of Dry Beaver Creek and Copper Canyon (Fig. 1). The rocks are exposed at elevations ranging from about 3,500 to 6,500 feet. The thickness of the Dry Beaver Creek rocks before erosion was more than 2,000 feet, and may have been more than 3,000 feet. The rocks are mostly conglomerate, with lesser amounts of sandstone, mudstone, bentonitic clay, marl, and limestone. Fragments of Precambrian rocks are abundant in the conglomerate, although in some localities, as in the vicinity of Dry Beaver Creek, the nearest Precambrian outcrops are more than 10 miles away. A few gastropods, pelecypods, ostracods, and plant remains occur in the marl and limestone near Dry Beaver Creek, but, as yet, have not been identified. Twenter (1961) concluded that, on the basis of the stratigraphic relation of these rocks to other Cenozoic rocks in central Arizona, ". . . the Dry Beaver Creek rocks are no younger than Miocene . . ."

Tertiary Volcanic Rocks

Tertiary volcanic rocks are present nearly everywhere along the margin of Verde Valley, and locally form the valley floor. Evidence from wells near the center of the valley indicates that the base of the volcanic rocks may be below an elevation of 2,500 feet. Although no average thickness can be assigned to these rocks in Verde Valley, they are 1,000 to 2,000 feet thick at several places. In the Fossil Creek area, they are about 3,000 feet thick.

Figure 2. View of Verde Valley from near Camp Verde. In the foreground is the Verde Formation with its prominent ledge-and bench-forming limestones. The escarpment along the horizon is the Mogollon Rim.

The Tertiary volcanic rocks are primarily basaltic lavas although cinder cones, pyroclastics, agglomerates, and tuffaceous sediments are not uncommon, and in several places are predominant.

The age of the volcanic rocks has not been established by fossils. However, the relation of these rocks to other Cenozoic rocks in central Arizona indicates that they are the result of volcanic activity that probably started in Miocene time.

Verde Formation

The Verde Formation covers much of the floor of Verde Valley (Fig. 2). Information from outcrops and well logs indicates that the formation is more than 1,800 feet thick, and that it may be as much as 3,000 feet thick. The Verde Formation has a diverse lithology. The lower part is chiefly tuffaceous sedimentary rock, agglomerate, conglomerate, claystone, mudstone, and evaporites; its upper part is conglomerate, sandstone, siltstone, claystone, mudstone, marl, and limestone. Several thin basalt flows are intercalated with the formation. In general, the limestone is thickest near the center of the valley and pinches out toward the valley's margin where the predominant rock is conglomerate.

In the southern part of Verde Valley, mudstones that contain evaporites extend over an area of 75 square miles, and are more than 1,200 feet thick. Gypsum and glauberite are the two common evaporite minerals. Blake (1890, p. 43-45) reported the occurrence of thenardite, mirabilite, halite, and glauberite in the salt mine southwest of Camp Verde.

The limestone and marl in the Verde Formation are mostly white, light gray, very light gray, and pinkish gray. The mudstone and claystone are generally yellowish green, pale reddish brown, light gray, pale olive, and yellowish orange. The sandstone and siltstone are usually grayish orange-pink and light brown. The lenses and nodules of chert in some of the limestone and marl are white, light gray, greenish gray, pale blue, and brownish gray.

Fossils occur in many beds in the upper part of the Verde Formation, especially those in the northern part of the valley. The fossils, some of which are well preserved, include gastropods, pelecypods, ostracods, charophyte oogonia, vertebrate teeth and bones, plant seeds or pods, pollen, and plant fragments.

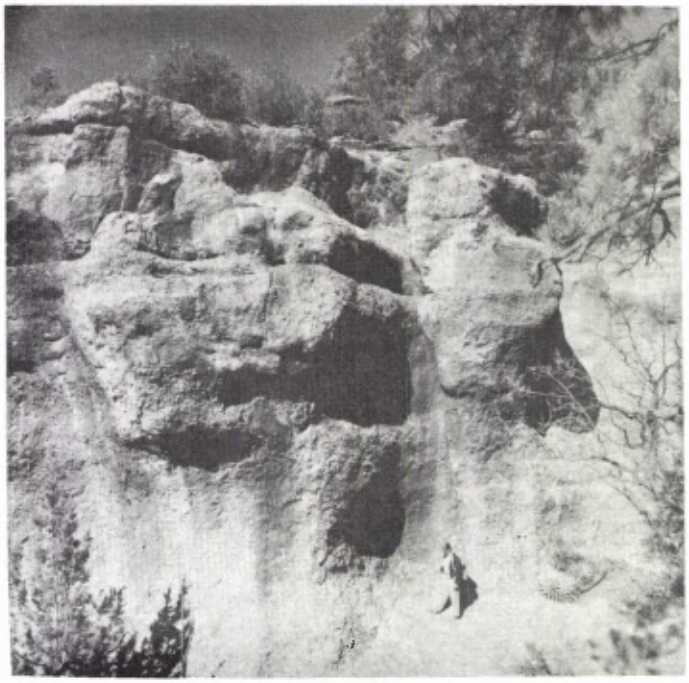

Figure 3. Conglomeratic base of the Moenkopi Formation in Sycamore Canyon.

Quaternary Volcanic Rocks

Quaternary volcanic rocks crop out in a very small area just northeast of Squaw Peak where they rest unconformably on the Verde Formation. Their thickness ranges from a few feet to about 300 feet, and they consist of a volcanic neck, a single flow, and a few tuffaceous sediments. Most of the rocks are rhyolitic.

Quaternary Gravel

Quaternary gravel is exposed in an almost continuous strip 4 to 5 miles wide along the east side of the Black Hills, and in several large areas south of Camp Verde. In general, the gravel ranges from a few feet to about 50 feet thick, and its lithology usually reflects the lithology of the adjacent bedrock from which it was derived. For the most part, the gravel is unfossiliferous. Mastodon remains, in gravel near the mouth of West Clear Creek, may be from this unit.

Riverwash

Most riverwash occurs along the Verde River and its perennial tributary streams. The riverwash is less than a foot to about 30 feet thick, is unconsolidated, and is composed of gravel, sand, silt, and clay derived from the older rocks in the surrounding area.

WATER

Most ground water in Verde Valley moves from the Colorado Plateaus province southwest toward the Verde River and thence southeast along the valley floor. The general direction of ground-water movement is shown on Figure 4.

Springs in Verde Valley provide the perennial flow in the Verde River and its tributaries. On the basis of flow measurements, Twenter and Metzger (in preparation) estimate that the springs in the valley yield water at the rate of about 220 cfs, or about 100,000 gpm.

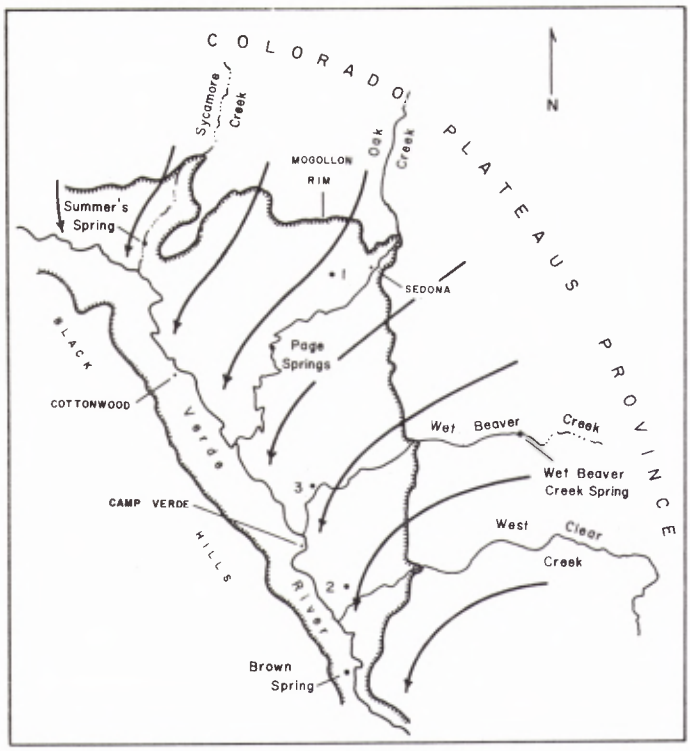

Figure 4. Map showing the general direction (indicated by arrows) of ground-water movement in the Verde Valley area. The numbers refer to the wells listed on Table 2.

In general, the quality of the ground water is good; the dissolved-solids content of most water is about 325 ppm. However, south of Camp Verde, water from some beds of the Verde Formation is very salty. As an indication of the chemical nature of ground water in the valley, the chemical analyses of the water from several wells and springs are given in Table 2.

A summary of the water-bearing characteristics of the rocks in Verde Valley is given below.

Precambrian rocks: Not known to yield water to wells; yields small quantity of water to springs and seeps along east side of Black Hills.

Tapeats Sandstone: Not known to yield water to wells or springs. Because most voids are filled with cement, the rocks are poorly permeable.

Martin Limestone: May yield water to one well in northern part of valley; yields water to one spring in southern part.

Redwall Limestone: Yields water to several springs; is known to yield water to one well and may yield water to several more. From the meager data available, this formation appears to be a good aquifer.

Supai Formation: Yields water to wells and springs. This is the important aquifer in the Sedona area. The depths to water in wells range from about 100 to about 600 feet. Springs from the formation produce much of the perennial flow in Oak Creek.

Coconino Sandstone: Springs from the formation produce the perennial flow in Wet Beaver Creek and West Clear Creek. At most other places in the valley, the formation is topographically high and is drained.

Table 2. Chemical character of the ground water from several wells and springs in Verde Valley. The location of the wells and springs is shown on Figure 2. Dissolved solids in parts per million.

Geologic source	Martin Limestone	Redwall Limestone	Supai Formation	Supai(?) Formation	Coconino Sandstone	Verde Formation	Verde Formation
Location	Brown Spring	Summer's Spring	Well 1 (A-17-5)10bd	Page Springs	Wet Beaver Creek Spr.	Well 2 (A-13-5)15aaa	Well 3 (A-14-5)17aaa
Altitude	2,990	3,700	4,500	3,500	5,025	3,125	3,190
Spring discharge (gpm)	50±	2,300±		10,000±	1,300±		
Well depth			700			132	160
Temperature (°F)	71	67	62	68	60		64
Silica (SiO_2)	54	15	15	18	23	14	25
Calcium (Ca)	58	72	77	42	29	518	49
Magnesium (Mg)	42	27	38	19	10	4,110	35
Sodium and Potassium (Na+K)	36	5.8	.5	8.7	4.8	22,500	20
Carbonate (CO_3)	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	414	341	368	227	147	209	335
Sulfate (SO_4)	29	7.6	7.2	3.7	.2	59,800	9.5
Chloride (Cl)	16	10	28	8	2.5	3,260	17
Fluoride (F)	.2	.2	.2	.0	.2		.2
Nitrate (NO_3)	1.4	1.5	.7	.8	1.1		.3
Dissolved solids (sum)	441	307	346	212	143	90,300	321

Toroweap Formation: Topographically high and is drained; not known to yield water to wells or springs.

Kaibab Limestone: Topographically high and at most localities is drained; water may occur in some beds under perched water-table conditions along the margin of the Colorado Plateaus province.

Moenkopi Formation: Not known to yield water to wells or springs.

Dry Beaver Creek rocks: Not known to yield water to wells or springs. Because of an abundance of clay and silt-size interstitial material and some cement, the rocks are poorly permeable.

Tertiary volcanic rocks: Are topographically high around the valley's margin and generally are drained; locally, however, they yield water to wells and springs. In some areas on the valley floor, these rocks are saturated and may yield moderate quantities of water to wells.

Verde Formation: The numerous joints and solution channels in the limestone and the open voids in some of the clastic rocks enable this formation to store and transmit water readily. More than 100 wells and probably as many as 6 springs obtain water from these rocks. For the most part, the ground water is artesian; in the vicinity of Cottonwood and Page Springs there are several flowing artesian wells. Most water from this formation is of good chemical quality; however, water from the gypsiferous beds has a high dissolved-solids content (Table 2). The depth to water in most wells is less than 200 feet.

Quaternary volcanic rocks: Not water bearing; not suitable for ground-water storage because they are topographically high and are of limited areal extent.

Quaternary gravel: Not known to yield water to wells or springs; not suitable for ground-water storage because they are relatively thin, are topographically high, and are dissected by numerous washes.

Riverwash: Most riverwash in Verde Valley is a good aquifer. The water is under water-table conditions, and the water level occurs at an altitude that approximates that of the water surface in the nearest stream.

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