

THE GEOLOGY OF THE CENTRAL PART
OF APACHE COUNTY, ARIZONA
(A Preliminary Report)

By

J. P. Akers

U. S. Geological Survey, Tucson, Arizona

INTRODUCTION

The central part of Apache County is bordered on the north by the Navajo Indian Reservation, on the south by U. S. Highway 60, on the east by the Arizona-New Mexico State line, and on the west by the county line (Fig. 1). The area encompassed is about 3,300 square miles. Altitudes range from about 5,200 to more than 7,800 feet.

The report is based on an investigation of the geology and ground water of the area made by the Ground Water Branch of the U. S. Geological Survey in cooperation with the Arizona State Land Department.

PHYSIOGRAPHY

The central part of Apache County is in parts of the Navajo and Datil sections of the Colorado Plateaus physiographic province (Fenneman, 1931). It is part of the structural subdivision, called the "Mogollon slope" (Kelley, 1955), which is a broad homocline that extends from the Mogollon Rim on the south to Black Mesa basin and the Defiance uplift on the north (Fig. 2). The southern part of the area is characterized by an irregular topography formed by lava-capped mesas, cinder cones, and deep canyons; the middle and northwestern parts are formed of badlands, broad valleys, retreating escarpments, and extensive, flat, mesalike highlands; the northeastern part, between the Rio Puerco and Zuni River, is a broad, relatively flat plain lying generally above an altitude of 6,500 feet.

GEOLOGY

The exposed rocks range from Permian to Quaternary in age. Sedimentary rocks older than Late Cretaceous were tilted slightly to the north and beveled so that Late Cretaceous rocks, in general, overlie progressively older rocks toward the south. All the rocks of Jurassic and Early Cretaceous age, if ever deposited, were removed by erosion before the deposition of the Upper Cretaceous rocks. Rocks younger than Cretaceous cover more than two-thirds of the area. Basaltic lava flows of middle Tertiary to Quaternary age cover extensive areas in the southern part of the area.

STRATIGRAPHY

The sedimentary rocks in the central part of Apache County are underlain at depths generally ranging from 2,600 to 4,500 feet by coarsely crystalline pink granite and diabase presumed to be of Precambrian age. The combined thickness of all the sedimentary rocks is about 6,000 feet, but nowhere are all the sedimentary rocks present in one place. A generalized section of the sedimentary rocks in the central part of Apache County is given in Figure 3.

Pennsylvanian Rocks

About 1,000 feet of siltstone, sandstone, and limestone, reported to be of Pennsylvanian age, was logged in a well near Concho. Huddle and Dobrovolsky (1945) state that the Supai formation in central and northeastern Arizona ranges in age from Des Moines (Middle Pennsylvanian) to Leonard (Early Permian). The Pennsylvanian rocks in the well near Concho probably belong to the Supai formation, although the Naco formation, not shown in Figure 3, may underlie the Supai in part of Apache County.

Permian Rocks

The Supai formation, containing the basal Permian beds, occurs only in the subsurface in central Apache County. It consists of interbedded red and brown sandstone, siltstone, and mudstone, and evaporite beds containing white to greenish-gray anhydrite, gypsum, and crystalline salts. The evaporite beds in the upper 1,000 to 1,500 feet of the formation are probably equivalent to the Yeso formation, and the underlying red beds to the Abo formation in western New Mexico. The Supai formation is about 1,600 feet thick in the area near the Arizona-New Mexico State line, but it thickens westward to more than 2,600 feet in a well 14 miles south-southwest of Holbrook.

The Coconino sandstone, here also only in the subsurface, is between 200 and 250 feet thick. It consists of gray to light-yellow, well-sorted, sub-angular to rounded, clear and frosted, fine to medium, quartz grains bonded with firm to weak calcareous or siliceous cement. The Coconino thickens westward to about 600 feet near Snowflake and seems to be continuous in the subsurface to the east with the Glorieta sandstone and to the north with the De Chelly sandstone.

The Kaibab limestone is exposed in several isolated places at the crests of small anticlines. It consists of yellowish-gray to dark-gray, thin to thick beds of magnesian limestone containing abundant marine fossils. The upper part usually contains numerous chert nodules. In this area the Kaibab characteristically contains beds of sandstone, individually from 10 to 95 feet thick, that closely resemble the Coconino sandstone. These beds often are referred to in drillers' logs as "Coconino" sandstone. The Kaibab is 300 to 350 feet thick in the southern part of the area and thins northward and northwestward until it disappears near Taylor and about 30 miles north of St. Johns. It probably is correlative with the San Andres limestone of New Mexico.

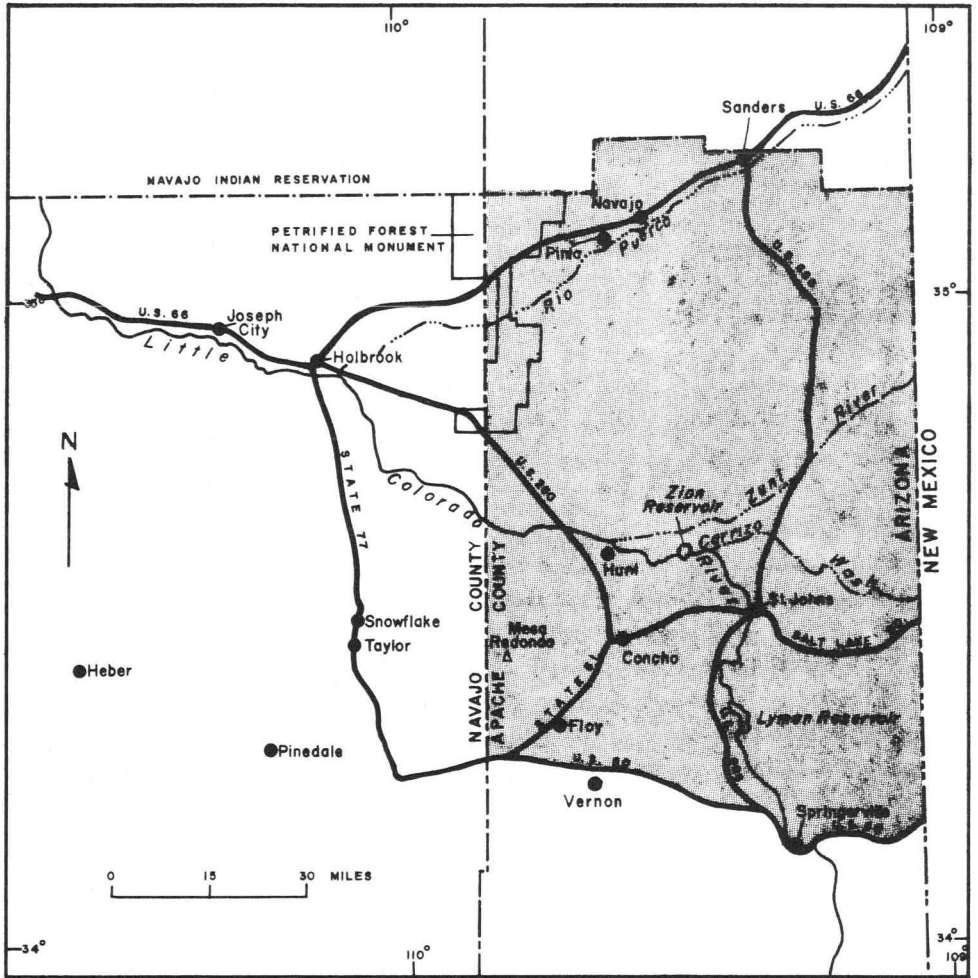


Figure 1. -- Map showing places mentioned in this report and central Apache County (shaded).

Triassic Rocks

The Moenkopi formation of Early to Middle(?) Triassic age unconformably overlies the Kaibab limestone. It is exposed mostly in the valley of the Little Colorado River. The Moenkopi is composed of reddish-brown to gray mudstone, and crossbedded sandstone and conglomeratic sandstone. The beds in Apache County represent only the upper part of the Moenkopi in northwestern Arizona and southwestern Utah. The thickness varies considerably, because erosional unconformities are at the top and bottom of the formation. The formation is from 35 to 50 feet thick near the Arizona-New Mexico State line and, in general, it thickens westward to more than 100 feet near the Navajo-Apache County line.

The overlying Chinle formation of Late Triassic age has four members: (1) the basal Shinarump member consisting of 10 to 80 feet of yellowish-gray, lenticular beds of conglomerate and conglomeratic sandstone containing rounded pebbles composed of quartzite and having diameters of 1/2 to 8 inches and a few lenticular beds of siltstone; (2) the 90- to 125-foot thick Mesa Redondo member of Cooley (1958) which is similar to the Shinarump member, but is purplish red and contains more silty material; (3) the 1,300-foot thick Petrified Forest member which forms the famous "painted deserts" and consists of two brilliantly colored, lenticularly bedded sequences of mudstone, siltstone, and some sandstone, separated by a prominent gray conglomeratic sandstone interval named the Sonsela sandstone bed; and (4) the Owl Rock member composed of 0 to 200 feet of greenish-pink, cherty limestone and calcareous siltstone. The Owl Rock member is present only in the extreme northeastern corner of the area studied. The Chinle formation is extensively exposed in the valleys of the Little Colorado River, Zuni River, and Rio Puerco.

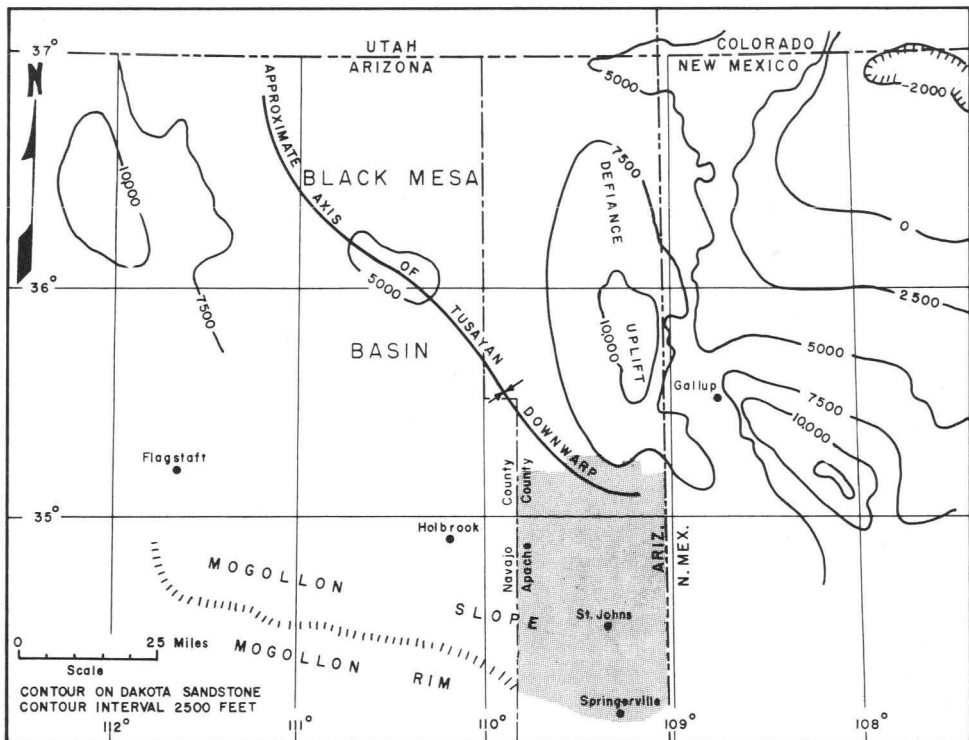
The Wingate sandstone of Late Triassic age has been removed by erosion in all but the extreme northeastern part of the area where 250 feet is present. It overlies the Chinle formation with local unconformity, and consists of intercalated, thin to thick beds of reddish-brown siltstone and fine-grained sandstone. The Wingate, in most of northeastern Arizona, is divided into two members, but in central Apache County only the Rock Point member is preserved.

Upper Cretaceous Rocks

An angular unconformity separates Triassic rocks from the overlying Cretaceous rocks in the central part of Apache County. The Cretaceous rocks are, in ascending order, the Dakota sandstone, Mancos shale, and Mesaverde group; they crop out along the Zuni River near the Arizona-New Mexico State line and in isolated exposures across the southern part of the area. All these strata are of Late Cretaceous age.

The Dakota sandstone consists of three units, all of which may or may not be present at a given place. The upper and lower units are composed of gray, medium- to fine-grained, crossbedded sandstone containing angular to rounded pebbles predominantly composed of chert and quartzite. The middle unit is black to grayish-brown carbonaceous siltstone interbedded with some sandstone and low-grade coal. The Dakota ranges in thickness from 50 to 115 feet.

The Dakota grades upward into the Mancos shale which consists of



Modified from Kelley (1955, p. 24)

Figure 2.--Synoptic structure contour map of northeastern Arizona and northwestern New Mexico. Central part of Apache County is shown by shading.

about 150 to 400 feet of interbedded carboniferous siltstone and claystone with minor amounts of sandstone. Colors of the Mancos are dark gray to yellowish green. The Mancos becomes sandier and thins toward the southwest, and is not recognizable near Pinedale in Navajo County where all Upper Cretaceous rocks consist of interbedded sandstone, mudstone, and coal.

The entire thickness of the Mesaverde group is not present at any one place in the central part of Apache County, but almost 200 feet was logged in a well near Floy. The Mesaverde consists of yellow to gray sandstone interbedded with dark-gray to yellowish-green siltstone.

Tertiary Rocks

Tertiary rocks crop out extensively in central Apache County. The oldest of these is a sequence of nonvolcanic sediments which appears, at least locally, to conformably overlie the Mesaverde group. The sediments are composed of purplish-red to reddish-brown conglomerate, sandstone, and siltstone. The conglomerate consists of well-rounded boulders, cobbles, and pebbles of quartzite, jasper, quartz, and, rarely, limestone, coarse-grained pink granite, and schistose and gneissic material imbedded in a matrix of silt to coarse sand. Some of the limestone is fossiliferous, containing shell fragments, crinoid stems, and fusulinids. The rock types in these sediments are similar to the Paleozoic and Precambrian rocks which crop out in central Arizona. The nonvolcanic sediments crop out only in the extreme southeastern part of the report area where they are about 300 feet thick. These rocks are probably correlative to the Baca formation of New Mexico of probable Eocene age (Wilpolt and Wanek, 1951).

The Datil formation of Tertiary age apparently conformably overlies the nonvolcanic sediments and is composed of sediments derived mostly from rhyolitic, latitic, or andesitic volcanic rocks, and, in the upper part, andesite and basaltic andesite with rhyolitic tuff. The sediments are loosely to firmly consolidated and would be classed as sandstone and pebble conglomerate. The color is olive gray and grayish red. The only outcrop is in the extreme southeastern corner of the report area; elsewhere the formation has been eroded away. However, south of Springerville it is exposed extensively and is more than 1,000 feet thick.

The Bidahochi formation, of Pliocene age, unconformably overlying older rocks, is exposed in the high tablelands in most of the area between the Rio Puerco and the Zuni River and it forms the Chalk Buttes east of St. Johns. The Bidahochi consists of three members: (1) a lower lacustrine member composed of flat beds of grayish-brown sandstone and grayish-green and reddish-brown mudstone and claystone; (2) a middle member composed of basaltic lava and agglomerate; and (3) an upper member composed predominantly of light-gray fluvial and eolian sandstone, and subordinately of yellowish-gray travertine and light-brown to light-green siltstone. The lower member was deposited only in the northern part of the area; the middle member is present only in two small outcrops in the northwestern part near the Petrified Forest National Monument; and, the upper member is widely exposed in most of the eastern half of the area. The thickest known section of the Bidahochi in central Apache County was logged in a well about 20 miles southeast of Sanders where more than 800 feet was penetrated.

System	Series	Group or formation	Thickness (in feet)	Lithologic character
Quaternary	Recent and Pleistocene		0-500	Alluvium, sand, gravel overlying river terraces, travertine, and cinders.
Tertiary	Pliocene	Unconformity		
		Bidahochi formation	0-800	White to light-brown sandstone with minor beds of siltstone and white ash, and light-brown to greenish-gray claystone, mudstone, and siltstone with a few beds of bentonite. Includes lava in the northern part of the area.
		Datil formation	800+	Greenish-gray and reddish-gray mudstone, siltstone, sandstone, and conglomerate composed largely of volcanic fragments.
	Eocene(?)	Nonvolcanic sediments	800±	Light-brown to medium-red conglomerate, sandstone, and siltstone. Contains numerous pebbles and cobbles of quartzite, jasper, granite, gneiss, schist, and limestone.
Cretaceous	Upper	Unconformity(?)		
		Mesaverde group	200+	Yellow, light-green, and reddish-brown siltstone, sandstone, and conglomerate interbedded with gray siltstone and coal.
		Mancos shale	150+	Yellowish to dark-gray siltstone with minor thin beds of yellow to light-brown fine- to medium-grained sandstone.
		Dakota sandstone	50-115	Yellowish-gray to light-brown sandstone with lenticular beds of conglomerate, carbonaceous siltstone and coal.
		Unconformity		
Triassic	Upper	Wingate sandstone	250	Reddish-brown intercalated siltstone and sandstone beds.
		Unconformity		
	Chinle formation	1,500	Variegated, multicolored claystone, mudstone, siltstone, sandstone, conglomerate, and limestone.	
	Middle(?) and Lower	Moenkopi formation	35-250	Brownish-red intercalated siltstone, sandstone, and conglomerate.
Permian	Lower	Unconformity		
		Kaibab limestone	0-350	Yellowish-gray to dark-gray cherty and silty fossiliferous limestone with a few beds of fine-grained sandstone beds.
		Coconino sandstone	200-400	Light-gray to white, fine- to medium-grained sandstone.
		Supai formation	1,000 to 2,000	Red and brown mudstone, siltstone, sandstone, and limestone interbedded with evaporites.
Pennsylvanian		Unconformity		
Precambrian		Basement rocks		Pink coarsely crystalline granite and diabase.

Figure 3.--Generalized section of sedimentary rocks in the central part of Apache County, Ariz.

Quaternary Deposits

Quaternary deposits are widespread in the central part of Apache County and cover about 65 percent of the area. They occur as terrace deposits related to the Little Colorado River and its tributaries, deposits of gravel underlying lava, travertine deposits capping numerous small buttes, alluvium in drainages, dune sand on broad plains, and as landslide deposits at the base of cliffs. Some of the deposits are rather well consolidated, but others will not stand in a bank. The terrace deposits and gravels underlying lava consist of lenticular beds of sand containing abundant gravel composed in order of abundance of quartzite, chert, lava, sandstone, limestone, granite, petrified wood, gneiss, and schist. The travertine deposits occur at numerous places between Hunt and Springerville and at various altitudes in the valley of the Little Colorado River. Several large warm springs near St. Johns are depositing travertine presently.

Quaternary-Tertiary Lava

Extensive lava flows dotted with cinder cones cover the southern part of the area. The lavas are black, massive to vesicular olivine basalts with local breccia and scoria. The thickest section of lava logged within the area is near Vernon, where more than 500 feet was penetrated. At least four periods of eruption are represented by the lava and cinders, and physiographic evidence indicates that the eruptions took place during Miocene through Pleistocene time.

STRUCTURE

The central part of Apache County is mostly within the structural division named the "Mogollon slope" (Fig. 2). The main characteristic of the Mogollon slope is a broad, gentle dip to the northeast. The slope is modified in several places by small folds that generally trend northwest. Anticlines are the most obvious of the small folds. Most are asymmetrical, dipping more steeply to the southwest. Commonly, their axes plunge more steeply to the northwest, toward the Tusayan downwarp, than to the southeast. The Tusayan downwarp is a broad structural trough which, in the northern part of central Apache County, lies between the Defiance uplift, a large anticlinal structure which trends north, and the Mogollon slope. The downwarp trends northwest and extends almost to the Arizona-Utah State line.

There are no large faults in the area and very few small ones. Most faults can be traced no farther than 3 miles and the displacement is less than 150 feet. One fault has offset a lava flow near Concho.

The regional warping of strata in Apache County took place during the Late Cretaceous and early Tertiary orogeny and the small folds had nearly their present form by the end of the Tertiary. The early Tertiary nonvolcanic sediments have been folded, as have the Late Cretaceous and older strata, but the Tertiary formations show little indication of folding. However, some late Cenozoic movement is indicated by the tilting of beds in the upper member of the Bidahochi formation in one area south of Sanders. The movement probably occurred near the end of the Pliocene because the overlying Quaternary sediments were not involved in this folding.

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