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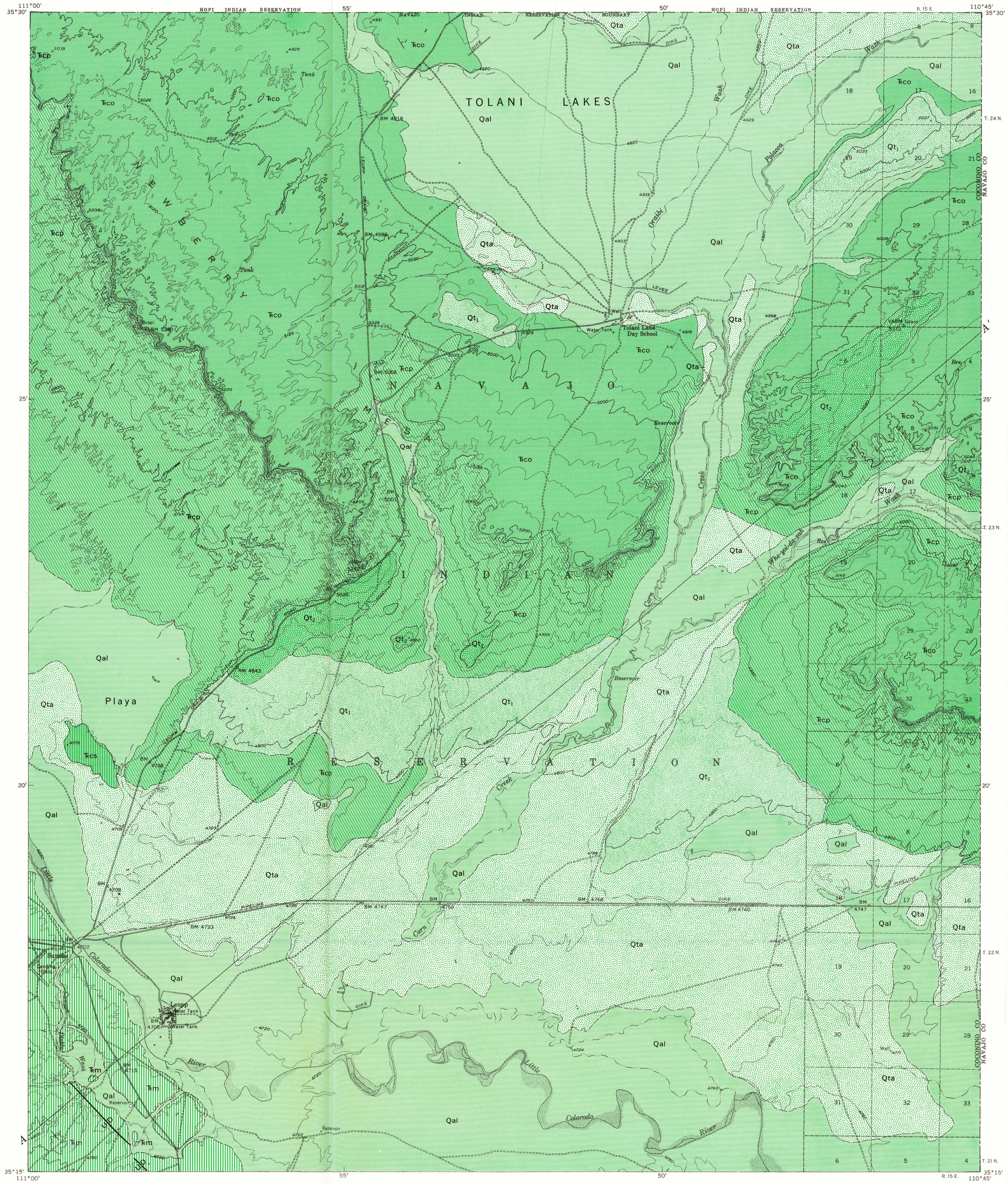


Base map by Topographic Division
U.S. Geological Survey, 1955

TRUE NORTH
MAGNETIC NORTH
14°
APPROXIMATE MEAN DECLINATION, 1962

SCALE 1:62 500

1 ½ 0 1 2 3 MILES

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

Geology by J. H. Irwin, P. R. Stevens, and R. L. Jackson, 1953; J. P. Akers and N. E. McClymonds, 1959; M. E. Cooley, 1960

EXPLANATION

QUATERNARY

Recent — Qal — Alluvium

Pleistocene and Recent — Qta — Alluvial terrace deposits

Pleistocene — Qt_1, Qt_2 — Terrace deposits

TRIASSIC

Upper Triassic — Chinle formation:

Ꞧco — Owl Rock member

Ꞧcp — Petrified Forest member

Ꞧcs — Shinarump member

Lower and Middle(?) Triassic — Ꞧm — Moenkopi formation

PERMIAN

Lower Permian — Pk — Kaibab limestone
Shown on section only

Pc — Coconino sandstone
Shown on section only

PRECAMBRIAN AND PALEOZOIC

Pz — Rocks of pre-Coconino age, undivided
Shown on section only

Contact
Dashed where approximately located

Fault
U, *upthrown side;* D, *downthrown side*

Strike and dip of beds

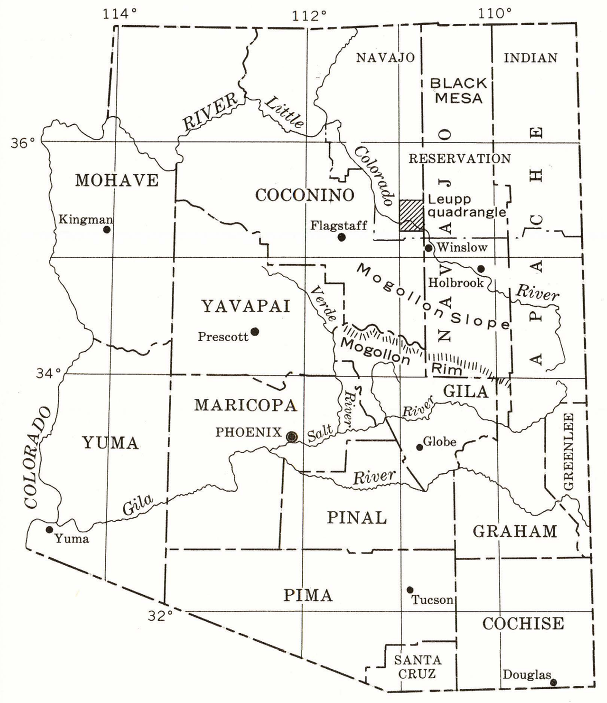
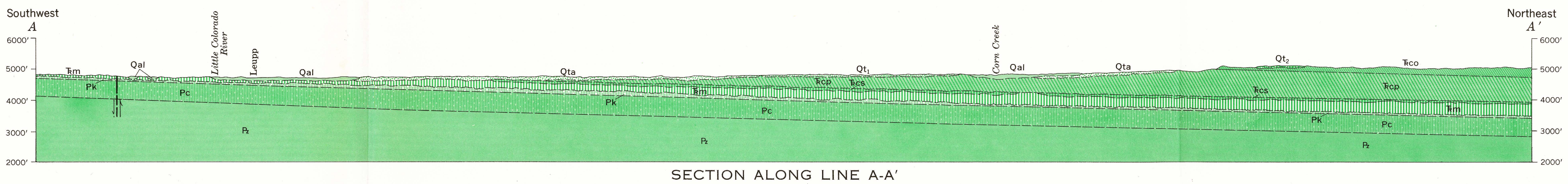


FIGURE 1. MAP SHOWING LOCATION OF THE LEUPP QUADRANGLE, ARIZONA



SECTION ALONG LINE A-A'
VERTICAL EXAGGERATION x 2

INTRODUCTION

The Leupp quadrangle is in the Navajo Indian Reservation about 20 miles northwest of Winslow, Ariz. (fig. 1). Leupp, where the Bureau of Indian Affairs maintains a few offices, and the Tolani Lake Day School are the only settlements in the quadrangle. Two trading posts, one at Leupp and one at Sunrise, 2 miles northwest of Leupp, serve the area.

The high desert country receives only a small amount of rainfall, about 7 inches annually, and thus produces an upper Sonoran or semiarid type of vegetation and poor grazing lands. Much of the area is devoid of soil and vegetation. The few Navajo Indians who live there must move from place to place to obtain adequate forage and water supplies for their sheep.

Several geologists had previously mapped the geology of the Leupp quadrangle, among whom are H. E. Geogory (1917) and N. H. Darton (1924). Their maps, however, are generalized and have been published at small scales.

TOPOGRAPHY AND DRAINAGE

The Leupp quadrangle is within the broad subsequent valley eroded by the Little Colorado River between the highlands of Black Mesa and the Mogollon slope. Within the quadrangle the Little Colorado River, the trunk stream, is intermittent and all its tributaries are ephemeral.

The southern half of the quadrangle, for the most part, is a rather featureless plain sloping toward the Little Colorado River and is carved on alluvial sediments and on soft shale and sandstone of Triassic age. North of the river, the plain slopes gently toward the southwest, at about 25 to 40 feet per mile, from the base of a cuesta formed by resistant limestone beds in the Owl Rock member of the Chinle formation. South of the river, the plain slopes northeastward at a slightly steeper gradient, and ledgy slopes eroded from the Moenkopi formation are exposed. In the extreme southwest corner of the quadrangle, the terrain is rough and is characterized by small canyons. Canyon Diablo Wash drains this area and joins the Little Colorado River near Sunrise.

The cuesta, named Newberry Mesa, is the dominating feature in the north half of the quadrangle and has a a maximum relief of about 300 feet. Its steeper slope is a prominent southward-facing escarpment which rises about 200 feet above the plain. Its backslope extends northeastward at about 65 feet per mile. Corn Creek and its tributary, Whe-yol-da-sah Wash, have breached the cuesta, and together they have cut a recession about 3 miles wide southeast of Tolani Lake Day School. Elsewhere, the crest of the escarpment forms a drainage divide. Washes south of it flow directly into the Little Colorado River, or disappear on the alluvial plain, whereas washes north of it flow first into the Tolani Lakes area and thence into Corn Creek, which empties into the Little Colorado River. Oraibi and Polacca Washes have established courses through the eastern and southeastern parts of the lakes area, and at a point 2 miles east-southeast of Tolani Lake Day School they join to become Corn Creek. There is also an outlet from the lakes area to the northwest through the headwaters of a nameless tributary to Dinnebito Wash, which joins the Little Colorado River about 20 miles downstream from Leupp. This diversion was effected about 1930, when a ditch was dug to carry excess water westward away from Tolani Lakes (William Young, Sr., oral communication, 1960). This junction is 250 feet lower than the junction of Corn Creek and the Little Colorado River, so that continued headward cutting from this lower base level will ultimately result in piracy of Oraibi and Polacca Washes. At the present time, when precipitation is heavy the lake area floods, and some overflow drains through both outlets.

STRATIGRAPHY

Except for Quaternary deposits, the only rocks that crop out in the Leupp quadrangle are the Moenkopi and Chinle formations which are considered to be of Early and Middle(?) Triassic and Late Triassic age, respectively. The Coconino sandstone and Kaibab limestone of Early Permian age lie in the subsurface and are described because of their importance as aquifers in this area.

COCONINO SANDSTONE

The Coconino sandstone extends through a large part of northern Arizona; it is present in the subsurface throughout the Leupp quadrangle. The lithology of the Coconino is relatively uniform wherever it is exposed. Where examined in exposures or in well cutting, it is typically a pale-orange to almost white very fine to fine-grained sandstone, composed principally of rounded quartz grains cemented usually with siliceous, but in places with calcareous, cement. The sandstone is prominently crossbedded and many of the crossbeds extend laterally for more than 200 feet.

The Coconino sandstone in this area is estimated to be about 600 feet thick. In the southwest corner of the quadrangle the Coconino is about 150 feet below the surface, but downdip in the northeast corner it is about 1,600 or 1,700 feet below the surface.

KAIBAB LIMESTONE

The Kaibab limestone is not exposed in the area, but it overlies the Coconino sandstone and underlies the Moenkopi formation in the subsurface. The formation is relatively thin and pinches out near the northeast corner of the quadrangle. Pre-Moenkopi erosion may have removed a considerable part of the Kaibab limestone.

Where seen in exposures southwest of the Little Colorado River, the Kaibab consists of interbedded yellowish-gray to light-gray, very fine to medium-grained sandstone and yellowish-gray to light-olive-gray limestone or sandy limestone; chert beds are common in many places.

The Kaibab is 120 feet thick in a well near Leupp but thins rapidly eastward. About 15 miles east-southeast of Leupp it is only 10 feet thick, and about 30 miles southeast it is not present. In the southwest corner of the quadrangle it is less than 50 feet below the surface, and in the northeast corner it lies at depths of about 1,500 to 1,600 feet.

MOENKOPI FORMATION

The Moenkopi formation lies unconformably on the Kaibab limestone. In this area it is divided, from oldest to youngest, into the Wupatki, the Moqui, and the Holbrook members (McKee, 1954). However, in the Leupp quadrangle only the Wupatki member and the lowermost part of the Moqui member are well exposed. The upper part of the Moqui and the Holbrook member are covered largely by alluvium, soil, and dunes or have been eroded away. The entire formation is present in the subsurface northeast of Leupp and is about 260 feet thick.

Evaporite deposits, vertebrate remains found in the Moenkopi formation outside the quadrangle, original structures, and the fine-grained character of the sediments suggest that the formation represents flood-plain, tidal-flat, and channel deposits.

Wupatki member.—The Wupatki member is exposed in the southwest corner of the quadrangle near Sunrise. It comprises a lower slope-forming shaly mudstone and siltstone unit and an upper ledge-forming sandstone unit. The lower unit is composed of thin-bedded reddish-brown siltstone, sandy siltstone, and silty sandstone. Ripple marks, swash marks, and a few casts of salt crystals are typical of the silty sandstone beds. The upper unit, informally called the "lower massive" sandstone of the Moenkopi formation (McKee, 1954), is composed of poorly to fairly sorted silty, very fine to fine-grained cream to brown sandstone, which is bonded by a calcareous cement. Prominent jointing and rounded cavernous weathered surfaces are typical of this unit. In the lower part it is commonly crossbedded with low-angle small- to medium-scale crossbeds of the trough type. The basal contact is sharp and has a relief of 1 or 2 feet; in places the lower massive sandstone fills small channels cut into the lower unit.

In this area the lower shaly unit is usually less than 10 feet thick; its thickness varies slightly because the contact of the Moenkopi formation and the underlying Kaibab limestone has a relief of 1 or 2 feet. The upper unit averages about 40 feet in thickness.

Moqui member.—In the valley of the Little Colorado River, the Moqui member of the Moenkopi formation is noted for its gypsiferous beds. However, the few feet of basal beds exposed in the Leupp quadrangle do not contain evaporite beds. The member is composed of siltstone and mudstone similar to the lower unit of the Wupatki member.

Typically, the Moqui member is a lighter shade of red than the other members and contains numerous beds and nodules of gypsum. The bedding is broadly lenticular. Some of the lenses are channel deposits, which display medium- and large-scale trough crossbedding at a low angle. The member is about 150 feet thick in the subsurface northeast of the Little Colorado River.

Holbrook member.—The Holbrook member, present in the subsurface northeast of the Little Colorado River, is composed of about 60 feet of gray to red intercalated shale and sandstone beds. The member includes numerous lenses of limestone or mud-pellet conglomerate and a few thin, lenticular beds of limestone. It has trough-type crossbedding and probably is a stream-laid deposit.

MOENKOPI-CHINLE CONTACT

The contact between the Moenkopi and Chinle formations is unconformable. On most of the Colorado Plateaus this unconformity is conspicuous, although in the Leupp area the contact is obscured by surficial deposits. In areas bordering the Leupp quadrangle, channels more than 20 feet deep cut into the top of the Moenkopi formation have been filled with sandstone, conglomerate, and some carbonaceous material of the Shinarump member of the Chinle formation. Many of these channel deposits show radioactive anomalies, and some uranium ore has been produced from them.

CHINLE FORMATION

The Chinle formation within the Leupp quadrangle is divided into three members totaling about 1,400 feet in thickness. The Shinarump member at the base grades upward into the Petrified Forest member, which in turn is gradational with the overlying Owl Rock member.

Shinarump member.—The Shinarump member is poorly exposed in the Leupp quadrangle, being covered by surficial materials except in a small area 6 miles north-northwest of Leupp. It is composed of weakly cemented yellowish-gray conglomeratic sandstone and conglomerate which contains lenses of mudstone and lumps and pellets of mudstone probably derived from the underlying Moenkopi formation. The sandstone consists of poorly sorted, subrounded to subangular, fine to coarse quartz grains. The conglomerate, occurring as stringers or in lenses, is composed of quartz, quartzite, and jasper pebbles and petrified wood fragments imbedded in a sandstone matrix. In most places the Shinarump member displays low- to high-angle, medium- to large-scale crossbeds of the trough type. Ripple marks, mud cracks, and current lineation indicate that the Shinarump member is a fluvial deposit. In this area the thickness of the member ranges from 0 to 40 feet. In some areas sandstone and conglomerate typical of the Shinarump member are not present, and the basal beds of the Chinle are sandy siltstone, mudstone, and silty fine-grained sandstone that are similar in lithology to sediments of the Petrified Forest member.

Petrified Forest member.—The Petrified Forest member crops out between the Little Colorado River and Newberry Mesa. In the area west of the Leupp-Oraibi road near Newberry Mesa, it weathers into spectacular badlands, but east of the road it forms an almost featureless gently sloping, mostly covered surface. The member consists of a thick- and very thick-bedded series of weakly cemented lenticular beds of marl, claystone, mudstone, siltstone, some fine- to coarse-grained sandstone, and conglomerate. Many of the beds "appear and disappear" within a few feet, but a few layers can be traced more than a mile. Numerous intraformational unconformities record temporary interruptions in deposition. The sandstone and siltstone units, where clearly exposed, show large-scale, low-angle crossbeds of the trough type. It is common for one set of crossbeds to be truncated by those of another set, suggesting sedimentation by meandering streams.

The Petrified Forest member is noted for its spectacular colors and "petrified forests" of silicified logs, and it is this member that forms the famous "painted deserts" of the Colorado Plateaus. Colors include shades of gray, yellow, pink, red, purple, and blue. In this area, three zones can be recognized according to color and slight lithologic differences (Akers, Cooley, and Repenning, 1958). These are, in ascending order (1) a bluish-gray mudstone unit about 200 feet thick, (2) a gray and grayish-red mudstone and sandy siltstone unit about 400 feet thick, and (3) a banded gray and pale-reddish-purple mudstone unit about 250 feet thick.

Owl Rock member.—The Owl Rock member of the Chinle formation in the Leupp area consists of an interbedded limestone and calcareous siltstone sequence and is generally regarded as a lacustrine deposit. This member is present in the northern half of the quadrangle, where it forms the cap rock of Newberry Mesa. The limestone is mottled very pale blue and grayish pink, and it contains abundant chert nodules and mud pellets. Locally, the limestone is silty and made up of concretionary nodules. The siltstone is grayish pink to light red. Bedding within the siltstone units is irregular. The individual limestone beds are 1 to 10 feet thick, and some have been traced along continuous exposures as far as 20 miles. In this area the Owl Rock member is about 300 feet thick.

QUATERNARY DEPOSITS

Deposits of Quaternary age are extensive in the Leupp quadrangle and consist of terrace, alluvial, and eolian deposits. A more detailed discussion of the terrace and alluvial deposits and their relationships is given under "Physiography" in this text. The terrace deposits and Recent alluvium are shown on the map. The extensive thin cover of windblown deposits is not shown, in order to avoid obscuring bedrock and terrace relationships.

Terrace deposits.—Several terrace deposits composed of gravel, sand, and silt have been preserved in the Leupp quadrangle. These terrace deposits are shown on the map as Qt_2, Qt_1, and Qta. The older terrace deposits, Qt_2 and Qt_1, are related to the Wupatki surfaces of Childs (1948), which represent a stage in the development of the Little Colorado River valley during Pleistocene time. Qta is a younger alluvial terrace, which has resulted from the damming of the Little Colorado River by a lava flow west of the Leupp quadrangle.

Alluvial deposits.—Extensive deposits of alluvium of late Pleistocene and Recent age are present in the Tolani Lakes area and along the Little Colorado River. Logs of wells drilled in the lakes area show the alluvium to be at least 90 feet thick. Here the deposits are composed of thin- to thick-bedded layers of clay, mud, silt, and sand. Along the river near Leupp, drilled wells have penetrated more 100 feet of alluvium composed of mud, sand, and gravel. More than 90 feet of fine material was deposited in the playa 6 miles north of Leupp.

Eolian deposits.—Nearly 50 percent of the Leupp quadrangle is covered by a thin mantle of dunes and blow-sand deposits. The eolian material is derived locally from sand in the alluvium, terrace deposits, and the bed of the Little Colorado River. The dunes form a hummocky topography which retards runoff. Small patches of alluvium have accumulated in interdune areas. Longitudinal dunes occur in extensive areas south of Tolani Lakes on Newberry Mesa and on the terraces and bedrock east of Polacca Wash and Corn Creek. These dunes, formed by the prevailing southwesterly winds, trend to the northeast in a series of parallel lines, and some are more than a mile long. Climbing dunes, which are well developed on the southwest-facing slope of Newberry Mesa, form perhaps the thickest eolian deposits in the quadrangle. A large dune on the side of the mesa a mile west of Corn Creek is more than 100 feet thick. Barchan dunes are much less common but are present in one small area at the southern boundary of the quadrangle along the north side of the Little Colorado River.

STRUCTURE

The Leupp quadrangle is on the southern flank of the Black Mesa basin, and the strata are inclined about 1° to 2° to the northeast, corresponding to the regional dip of formations lying between the Mogollon Rim and Black Mesa (fig. 1). The rocks southwest of the Little Colorado River dip slightly more than those northeast of the river, reflecting a northwest-trending anticline just off the southwest corner of the quadrangle. No anticlines or synclines are within the boundaries of the quadrangle, and the general structure is a large homocline. The strata in the extreme southwest corner of the quadrangle are offset by two small faults, which trend northwestward parallel to the regional structure of Black Mesa basin. Displacement along these faults does not exceed 20 feet.

PHYSIOGRAPHY

The developmental stages of the valley of the Little Colorado River throughout the Pleistcoene epoch are recorded by terrace remnants on the Black Point surface and the Wupatki surface (Gregory, 1917; Childs, 1948). Each of these surfaces is represented by multiple levels representing repeated cycles of planation and deposition. The levels of the Black Point surface were formed at elevations more than 400 feet above the Little Colorado River, and those of the Wupatki surface occur in an inner valley cut below this level. Physiographic and meager paleontological evidence obtained outside the quadrangle indicate that the deposits on the Black Point surface are of late Pliocene to early Pleistocene age and those on the Wupatki surface are of middle to late Pleistocene.

Projection of the levels of the Black Point surface across the Leupp quadrangle indicates that they are between 5,200 and 5,800 feet above sea level. Post-Black Point erosion has outlined Newberry Mesa and the other higher mesas and cuestas. The summits of these features approximate the level of the late Black Point surface. Deposits on the Black Point surface are not extensive in the quadrangle, but some lag gravel derived from deposition on this surface is on the summit of Newberry Mesa.

Terrace deposits, Qt_1 and Qt_2, overlying the Wupatki surface have altitudes of 4,775 to 5,150 feet and are present on slopes flanking Newberry Mesa, on mesa summits east of Tolani Lakes, and along the Leupp-Oraibi road. These deposits have been traced into the alluvial Jeddito formation of Hack (1942) in the upper part of Jeddito Valley northeast of the quadrangle (Cooley, 1958).

The older Wupatki terrace deposit (Qt_2) east of Corn Creek consists of less than 20 feet of sand, silty sand, and gravelly sand overlying a fairly flat erosion surface which slopes to the southwest about 27 feet per mile. The material is weakly bonded by calcareous cement and has a protective cap of caliche 1 to 2 feet thick. Along the Leupp-Oraibi road, the material is coarser, containing pebble- to boulder-sized gravel eroded from the Owl Rock member of the Chinle formation. Most of the gravel constituting terrace remnants in the northeastern part of the quadrangle is composed of sandstone eroded from Upper Cretaceous rocks on Black Mesa and of limestone and chert pebbles from lenticular limestone beds in Jurassic rocks.

The younger Wupatki terrace, Qt_1, is exposed on both sides of Corn Creek. It has no appreciable gradient in a distance of about 12 miles parallel to the Little Colorado River, but northward along Corn Creek and Polacca Wash the gradient is slightly less than 20 feet per mile. The younger Wupatki terrace probably is a local feature developed as a result of a lava dam across the former channel of the Little Colorado River 12 miles west of Leupp. The material is composed chiefly of mixtures of sand and silt, and contains very little gravel except on the outcrop crossed by the Leupp-Oraibi road. It contains streaks of caliche and east of Polacca Wash is capped by a thin bed of caliche. About 50 feet of terrace material is exposed east of Corn Creek, and logs of nearby wells indicate that this deposit may be as much as 150 feet thick.

Remnants of the lowest terrace, Qta, can be traced to the lava barrier that caused the formation of Grand Falls (Robinson, 1913; Gregory, 1917) 18 miles downstream from Leupp. This terrace level rises only 40 feet across the southern part of the quadrangle in a distance of 20 miles parallel to the river. The gradient is about 10 feet per mile from near the mouth of Corn Creek to the northern boundary of the quadrangle east of Tolani Lakes. Field relationships established downstream from the Leupp quadrangle indicate that this deposit filled an inner valley cut below the youngest Wupatki terrace (Cooley, manuscript in preparation). The youngest Wupatki terrace probably is correlative with the youngest glacial stage (Late Wisconsin Glacial Stage of Sharp, 1942) of the San Francisco Mountain. The late Recent alluvium, Qal, overlaps the sides of the terrace, and the present flood plain of the Little Colorado River is below the top of it. Thus, material of the lowest terrace appears to have been laid down after the formation of the late Pleistocene youngest Wupatki terrace and before the deposition of the late Recent alluvium. East of Leupp, this terrace consists of thin to very thick lenticular layers of silt and silty sand. The units are crossbedded; the crossbeds are mainly low-angle, medium- to large-scale, trough and planar types that are characteristic of flood-plain sediments. The sand is composed of very fine to very coarse grained and granule sized, angular to subangular clear quartz.

The late Recent alluvium, Qal, is composed of flood-plain sediments, similar to the material of the lowest terrace, Qta, and fine-grained playa deposits. Clay, mud, and silt-sized particles are the main constituents of the playa deposits. Thin layers of sand are scattered throughout the clay and silt.

Most of the late Recent alluvium is correlative with the alluvial Tsegi formation (Hack, 1942), which accumulated before A.D. 1200. The alluvial Naha formation of Hack, deposited roughly between A.D. 1300 and 1580, is represented principally by a soil zone in much of the area near the Little Colorado River. In places, alluvial sediments associated with the present period of arroyo cutting overlie the soil zone. As a result of the arroyo cutting the Little Colorado River occupies a channel about 10 feet deep near Leupp, but along the southern border of the quadrangle the river has not been entrenched.

GROUND WATER

Ground water in the Leupp quadrangle is withdrawn from shallow dug wells in the alluvium and from deeper wells drilled into the alluvium and terrace deposits, the Kaibab limestone, and the Coconino sandstone. Small amounts may be obtained locally from the Moenkopi formation.

Water in the alluvium in the Tolani Lakes area is of marginal quality for domestic use. It contains 2,090 ppm (parts per million) dissolved solids, of which 1,090 ppm is sulfate. Hardness of the water, expressed as calcium carbonate, is 826 ppm, and noncarbonate hardness calculated as calcium carbonate is 690 ppm. The well in use at Tolani Lake Day School is in this alluvium. It penetrated 38 feet of alluvium, and it yields 12 gpm (gallons per minute) of water with a drawdown of 23 feet from a static water level of 15 feet.

Several drilled wells yield water from alluvium along the Little Colorado River near Leupp. Records show that these wells penetrated about 100 feet of alluvium and that they yield from 30 to 50 gpm of water. The water contains 1,500 ppm dissolved solids, of which 560 ppm is chloride. It has a hardness of 384 ppm as calcium carbonate. The shallow dug wells may contain as much as 1,000 ppm chloride and 2,400 ppm dissovled solids.

The well at Sunrise withdraws a sufficient amount of ground water from the Kaibab limestone to supply the trading post. It has a static water level of 85 feet. Dissolved solids are 1,060 ppm, of which 308 ppm is chloride. Because the Kaibab wedges out to the northeast, it is probably water bearing only in the southwestern part of the quadrangle.

Water in the Coconino sandstone north of the Little Colorado River has a very high content of chloride, making it unfit for domestic use and marginal or unfit for stock use. However, south of the river, within the quadrangle, water in the Coconino is of usable quality. Two wells recently drilled (1958) near Sunrise have static water levels of about 135 feet and are capable of yielding about 400 gpm each with a drawdown of less than 50 feet. Dissolved solids of water from these wells total about 1,000 ppm. The chemical constituents are within limits recommended by the U.S. Public Health Service for domestic use (U.S. Public Health Service, 1946).

Water in the Coconino sandstone occurs under unconfined (water-table) conditions in the southern part of the quadrangle and under confined (artesian) conditions in the central and northern parts. It lies at depths between 150 and 200 feet in the southwest corner and between 1,600 and 1,700 feet in the northeast corner of the quadrangle.

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INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—62001

GEOLOGY OF THE LEUPP QUADRANGLE, ARIZONA

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James H. Irwin, J. P. Akers, and Maurice E. Cooley

1962

For sale by U. S. Geological Survey, price 50 cents