CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the Doug K. Martin Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

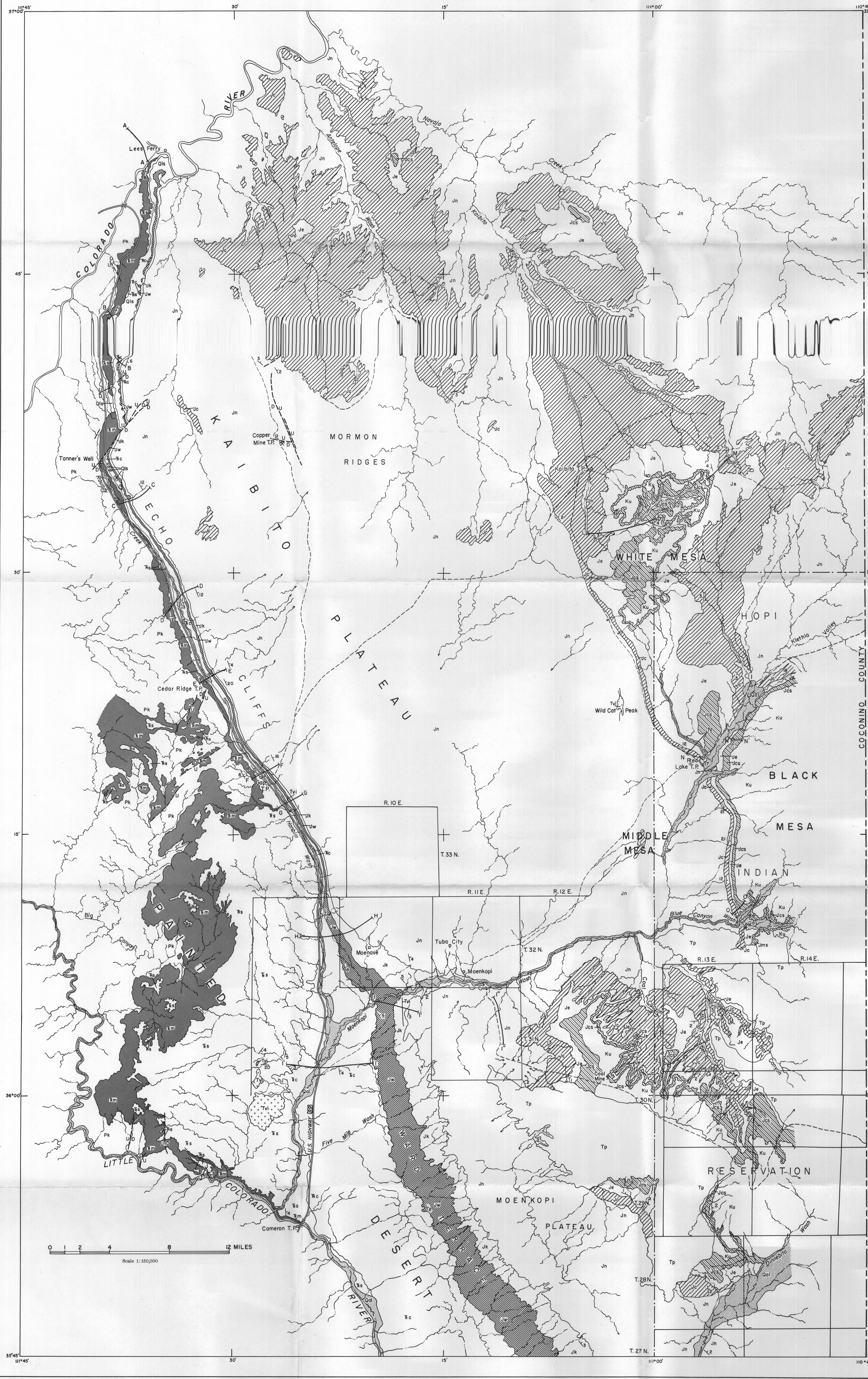
CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.



GEOLOGY OF THE KAIBITO AND MOENKOPI PLATEAUS AND PARTS OF THE PAINTED DESERT, COCONINO COUNTY, ARIZONA

By A. A. Wanek and J. G. Stephens

INTRODUCTION

During the field season of 1950 the writers made a reconnaissance study of the geology of the Kaibito and Moenkopi Plateaus and adjacent parts of the Painted Desert in Coconino County, Arizona. In addition, they made more detailed studies of the Mesozoic rocks that are well exposed in those areas. The purposes of the investigation were to develop a general structural picture of the area and to obtain information on the outcropping rocks in order to aid development of mineral-fuels and ground-water resources in the northwestern part of the Navajo Reservation. The study was made at the request of, and in cooperation with, the Water Resources Division of the Geological Survey as a part of a cooperative program of the Bureau of Indian Affairs and the Geological Survey.

GEOLOGIC STRUCTURE

The area studied is entirely within the plateau province of southwestern United States. The geologic structure is relatively simple and is characterized by gentle dips except in narrow belts along structural terraces. The Echo Cliffs, along the western margin of the area, are a striking example of this terracing. Southward from Lees Ferry, on the Colorado River, easterly dips in the strata comprising these vividly colored cliffs, which form the western margin of the Kaibito Plateau, gradually steepen. Folding is the dominant structure along the monocline that is developed as a result of this local steepening of dips, but there is local faulting. South of Moenave, easterly dips are gentler, and the Mesozoic strata that are compressed into a narrow belt to the north are exposed over a broad belt of cliffs and badlands.

The great areas of the Kaibito and Moenkopi Plateaus east of the Echo Cliffs are high tablelands in which faulting and similar structural complications are rare. However, bodies of intrusive rocks crop out on Wild Cat Peak and a few other places.

In the eastern part of the Kaibito Plateau, the strata dip steeply eastward in a narrow belt from Blue Canyon Wash northward along the western margin of White Mesa. Locally the strata are overturned. Farther south, dips are gentler where the older Mesozoic rocks pass under the Black Mesa structural basin.

IGNEOUS ROCKS

Igneous rocks occur in flows, dikes, and necks. The relations of these bodies to the regional structure are uncertain.

A lava flow megascopically identified as basalt, caps several mesas west of U. S. Highway 89 and north of the canyon of the Little Colorado River. This flow rests on the Shinarump conglomerate.

Four miles southwest of Moenkopi, the Kayenta formation is intruded by a basic dike that is nearly 2 miles long and 3 to 7 feet wide. Adjacent strata appear to be altered and are more resistant to erosion than the dike.

A dike intrudes the Chinle formation and Wingate sandstone about 2 miles south of Gap Trading Post. The dike is several feet wide, porphyritic, and basic in composition. North of Moenave on the Kaibito Plateau, several dikes, ranging in width from a few inches to a foot, intrude the Navajo sandstone. These dikes are dark, dense, and basic in composition and contain scattered xenoliths derived from the Navajo sandstone.

Wild Cat Peak rises as a prominent landmark above the Kaibito Plateau about 6 miles northwest of Red Lake Trading Post. It is thought to be a volcanic neck (Gregory, 1917, p. 103) sheathed by agglomerate; it intrudes the Navajo sandstone. The intrusive rock is phaneric and is basic in composition. Several narrow north-trending, fine-grained melilite basalt dikes (Gregory, 1917, p. 103) radiate from the neck.

Lava flows megascopically similar to basalt appear to occupy ancient stream channels in the canyon of the Little Colorado River. They probably were extruded in late Tertiary or early Quaternary time. By contrast, the volcanic necks such as Wild Cat Peak and the dikes that occur near Moenave and elsewhere probably were emplaced during an earlier period of igneous activity.

SEDIMENTARY ROCKS

Permian rocks are exposed in the canyons of the Colorado and Little Colorado Rivers and their tributaries as well as in the Painted Desert. The oldest strata that are exposed in the area are beds of limestone that are assigned to the Kaibab formation of Permian age. These crop out in the western part of the mapped area but were not studied in detail during the course of the investigation.

Triassic rocks crop out in the Painted Desert and in Ward Terrace. The Lower Triassic strata consist of interbedded, gypsiferous, evenly stratified, thin to thick beds of light-orange to medium-brown siltstone and fine-grained sandstone. East of this belt of Lower Triassic rocks, Upper Triassic strata are exposed. They are thick lenticular beds of cross-stratified, coarse-grained sandstone and conglomerate, overlain by alternating thick, irregular, and lenticular beds of variegated sandstone and siltstone.

Jurassic rocks crop out in the Echo Cliffs, in White Mesa, and in the cliffs of Black Mesa and are at the surface over most of the Kaibito and Moenkopi Plateaus. They include thick intervals of very fine to coarse-grained sandstone and thinner intervals of siltstone. Variations in lithology and in thicknesses of the Mesozoic formations in the Echo Cliffs area are summarized below and in the lines of graphic sections.

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY — Recent
- Qal — Alluvium
- Qls — Landslides

TERTIARY
- Tp — Pediment gravels

CRETACEOUS — Upper Cretaceous
- Ku — Cretaceous rocks (undifferentiated)

Unconformity

JURASSIC — Upper Jurassic — San Rafael group
- Jcs — Cow Springs sandstone
- Je — Entrada sandstone and Summerville formation undifferentiated
- Jc — Carmel formation

Unconformity

JURASSIC(?) — Glen Canyon group
- Jn — Navajo sandstone
- Jk — Kayenta formation
- Jw — Wingate sandstone

TRIASSIC — Upper Triassic
- ℞c — Chinle formation
- ℞s — Shinarump conglomerate

Unconformity

TRIASSIC — Lower Triassic
- ℞m — Moenkopi formation

Unconformity

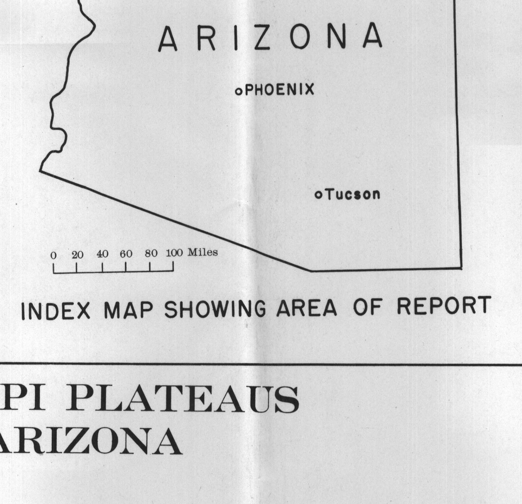
PERMIAN
- Pk — Kaibab limestone

IGNEOUS ROCKS

TERTIARY
- Tvi — Volcanic and intrusive rocks

Miscellaneous Symbols

- Strike and dip of beds
- Fault (U, upthrown side; D, downthrown side)
- A—A Measured section
- Mine or prospect
- Main road
- Secondary road



INDEX MAP SHOWING AREA OF REPORT

TRIASSIC SYSTEM

The Triassic system includes all strata between the Permian Kaibab limestone and the Jurassic(?) Wingate sandstone. Both the upper and lower limits of these Triassic strata are readily traceable. Triassic strata have been subdivided on both faunal and lithologic bases into the Moenkopi formation, the Shinarump conglomerate, and the Chinle formation (Gregory and Moore, 1931, p. 36, 59-95).

Moenkopi formation (Lower Triassic).—The base of the Mesozoic sequence is the erosion surface that underlies the Moenkopi formation. This surface bevels beds of the Kaibab limestone of Permian age and although the disconformity is a surface of slight relief, shallow depressions are locally filled by conglomerate and breccia beds of the Moenkopi formation that contain angular fragments and boulders of Kaibab limestone. The limestone beds are deeply weathered, and it is possible that a regolith developed on them.

The Moenkopi commonly weathers into ledged slopes or into ledges and cliffs capped by the Shinarump conglomerate. The Moenkopi crops out at the base of the Echo Cliffs from Lees Ferry to a point near Gap Trading Post and in the mesas and benches of the Painted Desert.

The basal strata of the Moenkopi are grayish-brown, silty, partly silicified conglomerate beds of variable thicknesses that contain pebbles and cobbles of Kaibab limestone and chert. Above these basal strata the lower part of the formation contains mottled, evenly stratified thin to thick layers of light- to reddish-brown gypsiferous and calcareous siltstone with interbeds of brownish-gray ripple-marked fine-grained sandstone. The sandstone beds are well jointed and weather into rectangular blocks. The sequence contains many thin beds of gypsum. The thickness of the lower part of the formation ranges from about 95 feet at the type locality of the formation, west of Cameron Trading Post, to about 400 feet at Lees Ferry.

In comparison, the upper part of the Moenkopi formation ranges in thickness from about 300 feet at the type locality to about 50 feet at Lees Ferry. The upper part consists mostly of evenly stratified, medium- to thick-bedded, grayish-orange to grayish-red fine-grained sandstone alternating with thick intervals of orange-pink to reddish-brown siltstone. The sandstone beds are in some places cross-stratified, range from 1 to 6 feet in thickness, and contain occasional lenses of mud-pellet conglomerate. The sandstone commonly weathers into cliffs, and the siltstone intervals into slopes. Yellowish-green mottling and horizontal color banding are common in the sequence.

The Moenkopi formation forms a great eastward-tapering wedge that extends across northern Arizona and southern Utah. The thickness of the Moenkopi formation is about 395 feet near Cameron Trading Post, 220 feet at Gap Trading Post, and about 450 feet at Lees Ferry. These variations probably are caused by both depositional thinning and a regional unconformity that bevels the upper beds of the formation. The occurrence of thin beds of gypsum and the presence of ripple marks and mud cracks in the even-bedded strata suggest deposition in alternating subaqueous and subaerial environments. The Moenkopi probably was deposited in part under marine conditions and in part on floodplains or deltas marginal to the sea.

The Moenkopi formation is overlain disconformably by the Shinarump conglomerate. Relief on the contact ranges from a few inches to many feet, and channels in the Moenkopi formation are filled with Shinarump strata. Ferruginous encrustations and lenses are common along the disconformity. The disconformity is very conspicuous near Lees Ferry where channels in the Moenkopi, ranging from 50 to 70 feet in depth, are filled by the Shinarump conglomerate, which contains angular fragments and blocks eroded from the underlying formation. Such features are observed elsewhere in northeastern Arizona, and they suggest a period of widespread erosion after deposition of the Moenkopi.

Shinarump conglomerate (Upper Triassic).—The Shinarump conglomerate forms conspicuous cliffs near Lees Ferry. Southward it crops out almost continuously along the base of the Echo Cliffs and caps benches and mesas in the Painted Desert. The Shinarump conglomerate consists largely of light-gray and grayish-red conglomeratic sandstone and conglomerate beds that are lenticular, medium- to thick-bedded, and cross-stratified. These strata are interbedded with thin to thick beds of even-bedded pale-brown and grayish-red siltstone. The coarse-grained rocks are poorly sorted; subrounded granules and pebbles of black, red, and white chert and quartzite are present as stringers and lenses. Abundant petrified wood fragments and logs that reach a maximum of 30 feet in length and 2 feet in diameter are characteristic of the Shinarump.

Locally, a yellowish- to light-gray conglomerate rests disconformably on the Moenkopi formation. The conglomerate is lenticular, massive, and irregularly cross-stratified. Chert and quartzite pebbles, from half an inch to 3 inches in diameter, are common. The bed is friable and is generally cemented by calcium carbonate and ferruginous material. The Shinarump conglomerate grades laterally from massive conglomerate to interbedded conglomerate, conglomeratic sandstone, and siltstone.

The upper beds of the Shinarump conglomerate appear to grade into and intertongue with the overlying Chinle formation. The contact is therefore arbitrarily placed at the top of the uppermost resistant sandstone bed. Such stratigraphic relations suggest that the Shinarump is the basal phase of deposition in the Chinle formation.

The thickness of the Shinarump conglomerate along the Echo Cliffs is 100 feet at Lees Ferry, 32 feet in the area north of Cedar Ridge Trading Post, 235 feet 12 miles south of Lees Ferry, and about 173 feet near the Little Colorado River. These variations in thickness are commonly the result of lensing of individual beds and of gradation of the upper beds into the Chinle formation. The Shinarump conglomerate, although variable in some aspects, is a blanketlike deposit that probably accumulated on floodplains as the basal phase of Chinle sedimentation. The sources of the materials in the Shinarump are unknown.

Chinle formation.—The Chinle formation crops out in steep and irregular slopes at the base of the Echo Cliffs from Lees Ferry to Moenave. Farther south, in the Painted Desert, it is broadly exposed in badlands.

The Chinle formation rests conformably upon and locally intertongues with the Shinarump conglomerate and is overlain disconformably by the Wingate sandstone. At the type locality, Chinle Valley, Arizona, the Chinle formation is about 1,000 feet thick. It has been divided into four members—A, B, C, and D—by Gregory (1917, p. 42-48). Along the Echo Cliffs the equivalents of the members B and C are recognized in the Chinle formation; the other members, although probably present, are not readily distinguished and probably have merged into or cannot be distinguished from the Wingate and the lower Chinle.

The lower part of the Chinle formation is a succession of fine-grained friable sandstone and siltstone beds that are evenly stratified, thin- to thick-bedded, and parallel- or cross-laminated. Graded lamination is common. The siltstone intervals are argillaceous and bentonitic and contain thin irregular interbeds of calcareous sandstone and conglomerate. Calcareous concretions and fragments of petrified wood occur commonly in the fine-textured rocks. In general, the color banding from the base upward is light bluish gray, dark gray, pale and olive green, moderate brown, and grayish red. The lower part of the Chinle formation becomes more arenaceous southward as the formation thickens from about 650 feet at Lees Ferry to about 850 feet at Tuba City.

The upper part of the Chinle formation thickens from about 150 feet at Lees Ferry to about 270 feet at Cedar Ridge Trading Post. This variation may be the result of a disconformity at the top of the Chinle. Throughout the area the upper Chinle is eroded into benches or buttes and consists of thick intervals of thin- to thick-bedded calcareous siltstone and mudstone that grade upward into a sequence of irregularly stratified calcareous mudstone and siliceous limestone. The colors range from grayish purple to reddish brown, pale red, and orange pink.

The infrequent limestone beds in the Chinle are siliceous, aphanitic, and crystalloblastic; dark-gray and black chert nodules are abundant. The beds contain silty partings and locally grade from dense siliceous limestone to mottled nodular and calcareous mudstone.

A minor disconformity is conspicuous below the lowest limestone bed at Gap Trading Post and Moenave. Irregular apophyses of the limestone bed fill mudcracks and borings in the underlying mudstone.

The Chinle formation thickens and becomes relatively arenaceous southward: the thickness is about 650 feet at Lees Ferry, 500 feet at Tanner's Well, and 850 feet in Ward Terrace near Tuba City.

Along the Echo Cliffs the Chinle formation occurs as the last phase of Late Triassic sedimentation. The sediments were probably deposited in subaqueous and subaerial environments in the earlier stages of the Chinle cycle. Continued erosion of the source areas appears to have resulted in a trend toward deposition of finer materials so that in the later stages fine sediments and limestone accumulated in the depositional basin. Bentonitic materials in lower Chinle strata suggest volcanic activity in the sedimentary source areas.

The position of the contact of the Chinle and Wingate formations in the Echo Cliffs has been uncertain according to the opinions of past workers (Baker et al., 1936, p. 4). For purposes of this report the contact is placed at or near the top of the highest limestone bed of the Chinle formation. This approximate contact may be a disconformity, but if so, it is not everywhere clearly apparent. Locally the limestone is overlain by a thin conglomeratic sandstone bed, the base of which possibly marks the precise position of the contact. The variable thickness of the upper part of the Chinle and the absence of some of the upper limestone beds in several localities suggest a period of erosion prior to deposition of the Wingate.

JURASSIC(?) SYSTEM

Glen Canyon Group

The Glen Canyon group as defined by Gregory and Moore (1931, p. 64) includes the Wingate, the Kayenta (then Todilto), and the Navajo formations. Baker, Dane, and Reeside (1936, p. 4) accepted this nomenclature for eastern Utah and adjacent areas and placed the group in the Jurassic(?). The three formations are present along the Echo Cliffs.

Wingate sandstone.—The Wingate sandstone, the oldest formation in the Glen Canyon group, was deposited in a basin lying chiefly in southeastern Utah, northeastern Arizona, and northern New Mexico. It rests disconformably on the Chinle formation and is conformably overlain by the Kayenta formation. It crops out in a series of massive reddish-brown ledges between Lees Ferry and Tanner's Well. Southward toward Dinnebito Wash, the formation is eroded into reddish-brown or orange-red cliffs and rounded benches. Near Lees Ferry the Wingate is difficult to separate from overlying strata because of the general similarity of the sediments in the Glen Canyon group.

The beds in the lower part of the Wingate are thin and erode into slopes and ledges. These beds are overlain conformably by massive beds of sandstone. Intertonguing and gradational relations between the upper and lower facies are common. Locally, the basal bed of the Wingate is a thin, orange-pink or light-gray conglomeratic sandstone that rests disconformably on the Chinle formation. It is irregularly bedded and contains pebbles of black and red chert as well as fragments of siltstone and limestone. This conglomeratic sandstone is overlain by thin- to medium-bedded orange-pink and reddish-brown cross-laminated fine-grained sandstone and thick beds of mottled, reddish-brown siltstone. The lower part of the Wingate varies in thickness from 125 feet north of Cedar Ridge Trading Post to 245 feet at Gap Trading Post.

The upper part of the formation is generally eroded into steep-jointed cliffs that are streaked with bluish-black desert varnish. It includes massive beds of conspicuously cross-stratified pale-red to reddish-orange fine-grained sandstone. Well-rounded quartz grains are common. The cross-stratification is large in scale. Thin lenses of limy, clay-pellet conglomerate are intercalated in the sandstone beds in many places. The base of the Wingate Cliff is commonly streaked by yellow iron oxide, and the upper beds contain ferruginous sandy concretions that weather to conspicuous masses. The average thickness of the upper part of the Wingate is about 150 feet, whereas the average thickness of the formation is about 300 feet. Along the Echo Cliffs the thickness of the Wingate ranges from about 260 feet to nearly 400 feet.

Near Lees Ferry, the separation of the Wingate from the overlying Kayenta formation is difficult because of the general similarity of the strata, but southward the Wingate is relatively distinct, and the position of the contact can be determined accurately.

The Wingate strata appear to have been deposited in subaqueous and subaerial environments. Thus the formation may represent a transition from fluviatile deposition in its lower part characteristic of the Chinle to deposition dominantly eolian in type in its upper part. Prevailing climatic conditions may have been semiarid. The lithologic similarity of all the strata in the Glen Canyon group near Lees Ferry suggests that sources of the material were to the west and southwest.

Kayenta formation.—The Kayenta formation forms a broad lens-shaped deposit nearly coextensive with the Wingate sandstone. Along the Echo Cliffs the Kayenta conformably overlies the Wingate and is overlain conformably by the Navajo sandstone. It crops out in steep slopes and irregular ledges between the massive cliffs of the Wingate and Navajo.

The formation is about 170 feet thick at Lees Ferry, where it crops out in ledges of light-brown to reddish-brown medium- to thick-bedded cross-stratified argillaceous sandstone. Near Moenave the Kayenta thickens to about 700 feet, and at this point the lower part of the formation, about 360 feet thick, consists of medium- to thick-bedded light-brown siltstone interbedded with medium-bedded light-gray cross-stratified ripple-marked fine-grained sandstone. It is eroded into benches and terraces. The siltstone layers are even-bedded, and the exposed surfaces show many concentric light grayish-green spots. Large well-rounded quartz grains and many lenses of coarse-grained sandstone are common in the sandstone beds. The upper part of the formation, which is about 340 feet thick near Moenave, consists of thick grayish-red mudstone beds interbedded with thin beds of pale-red fine-grained sandstone. These beds grade vertically into massive and evenly stratified mudstone and siltstone beds. Near the top, lenticular beds of pinkish-orange cross-stratified sandstone intertongue with mudstone and siltstone beds. The upper beds of the Kayenta formation grade into and intertongue with the lower part of the Navajo sandstone.

Between Moenave and Dinnebito Wash the Kayenta formation changes gradually from interbedded mudstone, siltstone, and sandstone to irregularly bedded and cross-stratified medium-grained sandstone. Local disconformities and channel deposits are common. The strata are friable and weather into alcoved cliffs and small pinnacles. Southward from Moenave the upper strata of the Kayenta appear to be transitional with the Navajo sandstone. Dinosaur tracks were observed in sandstone beds in the upper part of the formation at Moenkopi Wash.

Along Dinnebito Wash the Kayenta is about 440 feet thick. The sandstone beds are medium- to coarse-grained, irregularly bedded, cross-stratified, and light gray to pale red. Thick interbeds of reddish-brown siltstone are present locally. Color mottling and banding along the planes of cross-stratification are common in this area.

The thickness of the formation near Moenave suggests that the axis of the depositional basin lay near the central part of the Echo Cliffs, whereas the lithologic changes in the Kayenta indicate that materials were contributed from source areas lying west or northwest, as well as south of the basin. The deposits appear to have accumulated on floodplains in the center of the basin. They grade northward into rocks having the lithologic characteristics of the Navajo sandstone. The Kayenta formation thins to the north, and it loses its identity possibly west of the Echo Cliffs in the Wingate and Navajo sandstones.

Navajo sandstone.—The Navajo sandstone, the uppermost unit of the Glen Canyon group, forms a great wedge extending across southern Utah, northern Arizona, and eastern Nevada. The Navajo lies conformably on the Kayenta formation and is at the surface over most of the Kaibito and Moenkopi Plateaus, where it commonly weathers into rounded bosses or domes. The Navajo forms mesas and benches where it is capped by the Carmel formation.

Over most of the Kaibito Plateau, the exposed Navajo strata are massive beds of cross-stratified fine- to medium-grained sandstone. The sweeps of cross-lamination range from 20 to 50 feet in length and are most commonly inclined to the southeast, south, or southwest. In the northern and central parts of the Echo Cliffs area the Navajo sandstone is reddish orange, reddish brown, or pale red with subordinate light-gray mottling and banding. Southward it changes to yellowish gray, light greenish gray, or light gray with some reddish-brown mottling.

The Navajo sandstone grades laterally from sandstone at Lees Ferry to interbedded sandstone, limestone, and siltstone along Dinnebito Wash. Between Lees Ferry and Gap Trading Post the formation consists of massive beds of cross-stratified reddish-brown medium-grained sandstone. Small quantities of chert and ferromagnesian minerals are present. Large well-rounded quartz grains are scattered throughout the sandstone, and lenses of coarse sandstone grains occur along the bedding planes. The joint planes are commonly coated with ferruginous encrustations.

Limestone beds in the lower strata near Moenave increase markedly in number southward along the Echo Cliffs. Along Moenkopi Wash the lower strata of the Navajo sandstone are thick tabular beds of cross-stratified fine-grained sandstone interbedded with thin- and medium-bedded gray siliceous limestone. These beds are overlain by massive beds of friable cross-stratified sandstone with occasional cherty limestone and siltstone layers. A massive yellowish-gray very fine grained sandstone at the top of the formation weathers to abundant ferruginous concretions, which range from a few inches to several feet in diameter.

The Navajo sandstone along Dinnebito Wash is a sequence of alternating beds of massive fine-grained sandstone, thin- to medium-bedded limestone, and siltstone. The sandstone is very fine grained, cross-stratified, yellowish gray to light greenish gray, and very friable. The limestone beds are evenly stratified, thin- to medium-bedded, and laminated. They are pale yellowish brown, siliceous, and either aphanitic or crystalline in texture. The beds contain lenses and nodules of pale-brown chert. Thin layers of pale-red and yellowish-gray calcareous siltstone are interbedded with the limestone beds. Contorted laminae commonly occur in the lower beds of the Navajo.

Dinosaur tracks were observed in the upper part of the Navajo sandstone just west of the Copper Mine Trading Post on the Kaibito Plateau.

The Navajo sandstone thins toward the south: the thickness of the formation is about 1,340 feet near Lees Ferry, about 700 feet near Tuba City, and about 310 feet in Dinnebito Wash.

The sedimentary structures and facies changes in the formation suggest that the Navajo sandstone was deposited in both subaqueous and subaerial environments. The Navajo thickens toward the northwest—toward the possible center of the basin of deposition. The southern margin of the depositional basin probably lay near the southern part of the Echo Cliffs. The source of materials in the Navajo seems to have been in the west or northwest.

JURASSIC SYSTEM

The nomenclature used for the Jurassic formations is that of Baker, Dane, and Reeside (1936, p. 6-10) with some modifications. The massive sandstone that overlies the Entrada sandstone was named the Cow Springs sandstone by Harshbarger, Repenning, and Jackson (1951, p. 97-98). However, it may contain some strata that are equivalent to the upper part of the San Rafael group as well as to the lower part of the Morrison formation.

The San Rafael group includes the strata between the Navajo sandstone and the Cow Springs sandstone. Although the San Rafael group is divided into the Carmel formation, the Entrada sandstone, and the Summerville formation in adjacent areas, accurate separation of the Entrada and Summerville in this area does not appear to be practicable.

The San Rafael group rests disconformably on the Navajo sandstone. Along the Kaibito and Moenkopi Plateaus the contact is an even or wavy erosion surface that bevels the upper beds of the Navajo. Although widespread, this disconformity does not clearly represent an important hiatus.

Carmel formation.—The Carmel formation rests disconformably on the Navajo sandstone in White Mesa, in Black Mesa, and in mesas on the Kaibito Plateau between the Copper Mine Trading Post and the Navajo Canyon. Ferruginous plates and calcareous encrustations are common below this unconformity, and shallow depressions in the upper beds of the Navajo are filled with siltstone and sandstone beds of the Carmel. Carmel strata commonly weather as mesas and benches, but where immediately overlain by the Entrada sandstone they crop out in ledges and cliffs.

The formation consists of thick beds of evenly or cross-stratified pale-red sandstone that are interbedded with thick intervals of even-bedded dark reddish-brown siltstone. These strata grade vertically into thick beds of evenly or cross-stratified fine-grained sandstone. The siltstone intervals contain thin, hard beds of fine-grained calcareous ripple-marked sandstone. Locally these layers grade laterally into thick-bedded cross-stratified friable sandstone.

Along White Mesa, the Carmel is pale red and dark reddish brown with light greenish- and yellowish-gray horizontal banding. In Blue Canyon Wash, it is light greenish and yellowish gray with dark reddish-brown horizontal banding.

A massive cross-stratified very fine grained friable sandstone bed of the Entrada sandstone rests conformably on the Carmel formation. The upper beds of the Carmel appear to grade into the lower part of the Entrada.

The thickness of the Carmel is reasonably consistent and ranges from 210 feet in the upper part of Kaibito Wash to about 230 feet in Ba-ho-no-geh Canyon. The formation thins along Dinnebito Wash.

The Carmel strata were deposited on coastal plains and in shallow seas, and by inference they represent a transition from a continental sand facies in the south to a marine facies in the north. The facies change in the Carmel reflects the uplift of southern highlands during Glen Canyon deposition.

Entrada sandstone and Summerville formation undifferentiated.—The Entrada sandstone and Summerville formation undifferentiated rests conformably on the Carmel formation in White Mesa, in Black Mesa, and in buttes in the northern part of the Kaibito Plateau. The strata crop out in massive, rounded, irregular cliffs, or in vertical cliffs in the canyon walls.

The Entrada sandstone and the Summerville formation undifferentiated consists of massive, even beds of cross-stratified fine to very fine grained calcareous sandstone. The strata in the lower part of the sequence contain occasional lenticular thin- or medium-bedded laminated siltstone. Near the top the sandstone is silty and gypsiferous and includes numerous thin interbeds of siltstone. The cross-stratification is large in scale, and the dominant types in the beds are continuous inclined laminae and concave and diagonal laminae. Parallel stratification is subordinate in the sandstone. The sand grains are subrounded quartz and are cemented by calcium carbonate. Large well-rounded quartz grains lie scattered in a matrix of fine sand grains.

These formations in White Mesa are reddish orange and reddish brown with yellow-gray mottling and banding. Southward along Black Mesa, they are yellow gray with reddish-brown banding. The sandstone is increasingly argillaceous and friable and is more thinly stratified toward the south.

The Entrada sandstone cannot be readily distinguished from the Summerville formation because of the similarities of the strata in the sequence. In adjacent areas the Summerville is a red siltstone sequence that grades and intertongues with the Entrada and Cow Springs sandstones. The upper contact of the combined unit is arbitrary and lies at the top of a crinkly bedded siltstone that forms a recess just below the base of the cliff-forming Cow Springs sandstone. The bed may not be at the same stratigraphic horizon everywhere, since the upper beds of the Entrada sandstone and Summerville formation undifferentiated appear to grade into the lower part of the Cow Springs sandstone.

The Entrada sandstone and Summerville formation undifferentiated thins toward the east and south. The thickness of the unit is about 520 feet in Kaibito Wash, 350 feet in upper Navajo Creek, 290 feet at Red Lake Trading Post, and 210 feet in Ba-ho-no-geh Canyon.

The Entrada sandstone was probably deposited on coastal plains and may be eolian and fluviatile in origin.

Cow Springs sandstone.—The Cow Springs sandstone rests conformably on the Entrada sandstone and the Summerville formation undifferentiated and is disconformably overlain by the Dakota sandstone of Cretaceous age. It crops out in sheer cliffs in White Mesa, in isolated buttes in the northern part of the Kaibito Plateau, and in rounded benches and cliffs along Black Mesa. The cliffs are recessed along joint planes, resulting in many spectacular monuments.

The Cow Springs is composed of massive well-cemented quartzose sandstone. The beds are tabular, conspicuously cross-stratified, fine or very fine grained, and yellowish or greenish gray. The sandstone contains many thin laminae of siltstone. The lower strata are argillaceous and calcareous and include thin, lensing beds of reddish-brown siltstone. Near the top of the formation, thick beds of light-gray well-sorted calcareous sandstone are commonly stained dark gray by material derived from coaly shale in the overlying Dakota sandstone. Along White Mesa, thick beds of friable cross-stratified siltstone grade and interfinger laterally and vertically with the sandstone.

The cross-stratification in the Cow Springs sandstone is large-scale, and contains concave and diagonal laminae or continuous-inclined laminae. Beds with parallel, or small-scale, continuously inclined cross-stratification appear locally in the sandstone, and their number increases toward the south.

At Cow Springs, Arizona, the type locality, the formation is 342 feet thick. It thins westward to about 230 feet in White Mesa, and southward to about 215 feet in the upper part of Kaibito Wash, 160 feet in Blue Canyon Wash, and about 150 feet along Ba-ho-no-geh Canyon. The thinning of the member may be due in part to deposition, as well as pre-Dakota erosion.

The Cow Springs is believed to be mostly fluviatile in origin but is in part eolian. Northward the Cow Springs sandstone grades and intertongues with strata of the upper part of the San Rafael group and the lower part of the Morrison formation.

The Dakota sandstone rests disconformably on the Cow Springs sandstone. The contact is an erosion surface of moderate relief that bevels the upper beds of the Cow Springs sandstone just below the disconformity. The strata are commonly discolored and contain many ferruginous or siliceous encrustations. The disconformity is particularly conspicuous along Ba-ho-no-geh Canyon, where irregular depressions in the top of the Cow Springs sandstone are filled with lenticular beds of the Dakota sandstone.

The Cow Springs sandstone and the Dakota sandstone appear to be generally parallel in the area. However, the absence of upper Morrison strata that are present farther north and east suggests that the disconformity is of considerable extent.

CONCLUSIONS

The Moenkopi formation of Early Triassic age is a blanket deposit in the area. It rests on the eroded but generally parallel Kaibab limestone of Permian age. The Moenkopi is believed to have been deposited in marine and floodplain environments.

The Shinarump conglomerate of Late Triassic age is the basal coarse phase of the Upper Triassic. It rests on the eroded Moenkopi formation and appears to have been deposited in a continental area.

The Chinle formation of Late Triassic age is the upper phase of the sedimentary cycle. It was probably deposited in continental areas; in its lower part it grades and interfingers into the Shinarump conglomerate. The Chinle contains bentonite that has been interpreted as altered volcanic ash transported by air or water from unknown sources.

The Wingate sandstone of Jurassic(?) age rests disconformably on the Chinle formation. It is continental and was deposited in both subaqueous and subaerial environments. The Wingate thickens toward the south and east and interfingers with the Kayenta formation toward the west. Source areas for materials in the Wingate lay to the west and northwest.

The Kayenta formation of Jurassic(?) age rests conformably on the Wingate sandstone. It is fluviatile and interfingers with the Wingate and Navajo sandstones. The Kayenta grades into rocks of Navajo lithology toward the north. The materials of the Kayenta apparently came from source areas in the west and south.

The Navajo sandstone of Jurassic(?) age rests conformably on and interfingers with the Kayenta formation. It is continental and appears to have been both wind- and water-laid. The sandstone is homogeneous and thick in the northwest but thins and becomes silty and calcareous toward the south and southeast. The Echo Cliffs may be a marginal area of the depositional basin; one source area appears to have been to the west or northwest.

The Carmel formation of Jurassic age rests disconformably on the Navajo sandstone. It is even-bedded and silty in the north but becomes arenaceous and transitional with the Entrada sandstone southward. The Carmel, by inference, may be marine. The source areas of materials probably lay to the south.

The Entrada sandstone and Summerville formation undifferentiated, of Jurassic age, rests conformably on the Carmel formation. It is continental and, by inference, partly marine. The unit is silty and calcareous, probably water-laid, and may be an old beach deposit. It interfingers with and grades into the Carmel formation and the Cow Springs sandstone. It is thickest in the northwest and thins to the south and east. The materials came from source areas in the south.

It seems likely that sedimentation was continuous through the deposition of the San Rafael group and Cow Springs sandstone and that the materials were derived from source areas in the south.

The Cow Springs sandstone is believed to be a product of subaqueous and subaerial deposition. The top of the Cow Springs is an erosional unconformity that lies at the base of the Dakota sandstone.

REFERENCES

Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., 1936, Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, 66 p.
Gregory, H. E., 1917, The geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, 161 p.
Gregory, H. E., and Moore, R. C., 1931, The Kaiparowitz region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U. S. Geol. Survey Prof. Paper 164, 161 p.
Harrell, M. A., and Eckel, E. B., 1939, Ground-water resources of the Holbrook region, Arizona: U. S. Geol. Survey Water-Supply Paper 836-b, p. 19-105.
Harshbarger, J. W., Repenning, C. A., Jackson, R. L., 1951, Jurassic stratigraphy of the Navajo country: New Mexico Geological Society Guidebook of the south and west sides of the San Juan Basin, New Mexico and Arizona, p. 95-98.

Base and geologic map compiled from aerial mosaics

OIL AND GAS INVESTIGATIONS
MAP OM 145, SHEET 1 OF 2

S. C. BROWN
P. O. BOX 1266
SCOTTSDALE, ARIZONA

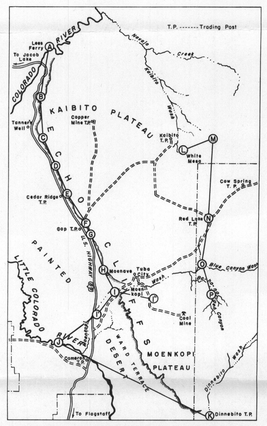
Kaibito Plateau

RECONNAISANCE GEOLOGIC MAP OF THE KAIBITO AND MOENKOPI PLATEAUS AND PARTS OF THE PAINTED DESERT, COCONINO COUNTY, ARIZONA

By A. A. Wanek and J. G. Stephens

1953

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.
Geology by A. A. Wanek and J. G. Stephens
Set of two maps for sale by U. S. Geological Survey, price 50 cents



INDEX MAP SHOWING LOCATIONS AND LINES OF MEASURED SECTIONS

10 0 10 20 Miles

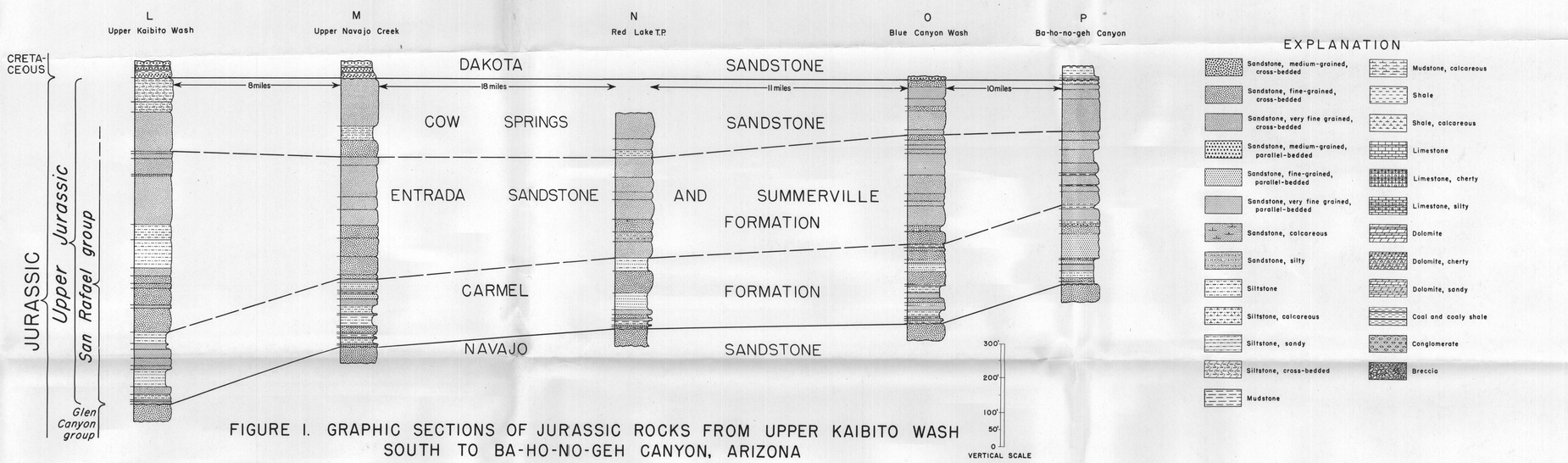


FIGURE 1. GRAPHIC SECTIONS OF JURASSIC ROCKS FROM UPPER KAIBITO WASH SOUTH TO BA-HO-NO-GEH CANYON, ARIZONA

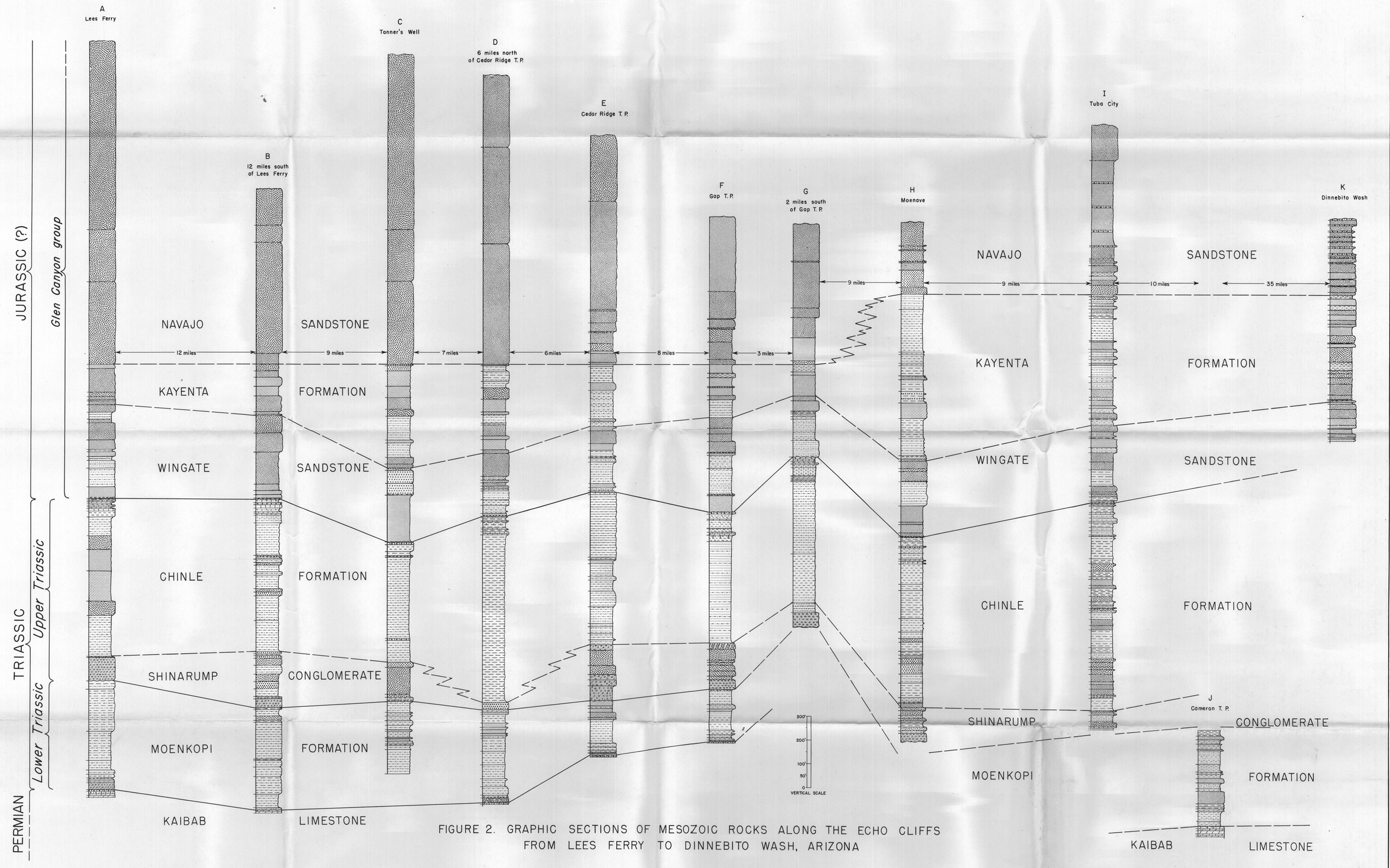


FIGURE 2. GRAPHIC SECTIONS OF MESOZOIC ROCKS ALONG THE ECHO CLIFFS FROM LEES FERRY TO DINNEBITO WASH, ARIZONA

RECONNAISANCE GEOLOGIC MAP OF THE KAIBITO AND MOENKOPI PLATEAUS AND PARTS OF THE PAINTED DESERT, COCONINO COUNTY, ARIZONA

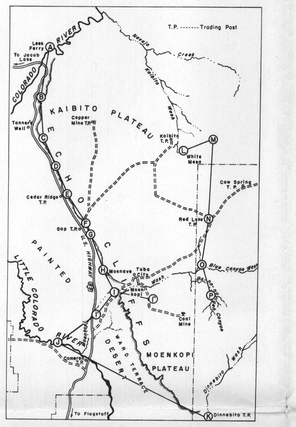
By A. A. Wanek and J. G. Stephens

1953

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.
Geology by A. A. Wanek and J. G. Stephens
Set of two maps for sale by U. S. Geological Survey, price 50 cents

S. C. BROWN
P. O. BOX 1268
SCOTTSDALE, ARIZONA

Kaibito Plateau
X-sections



INDEX MAP SHOWING LOCATIONS AND LINES OF MEASURED SECTIONS

10 0 10 20 Miles

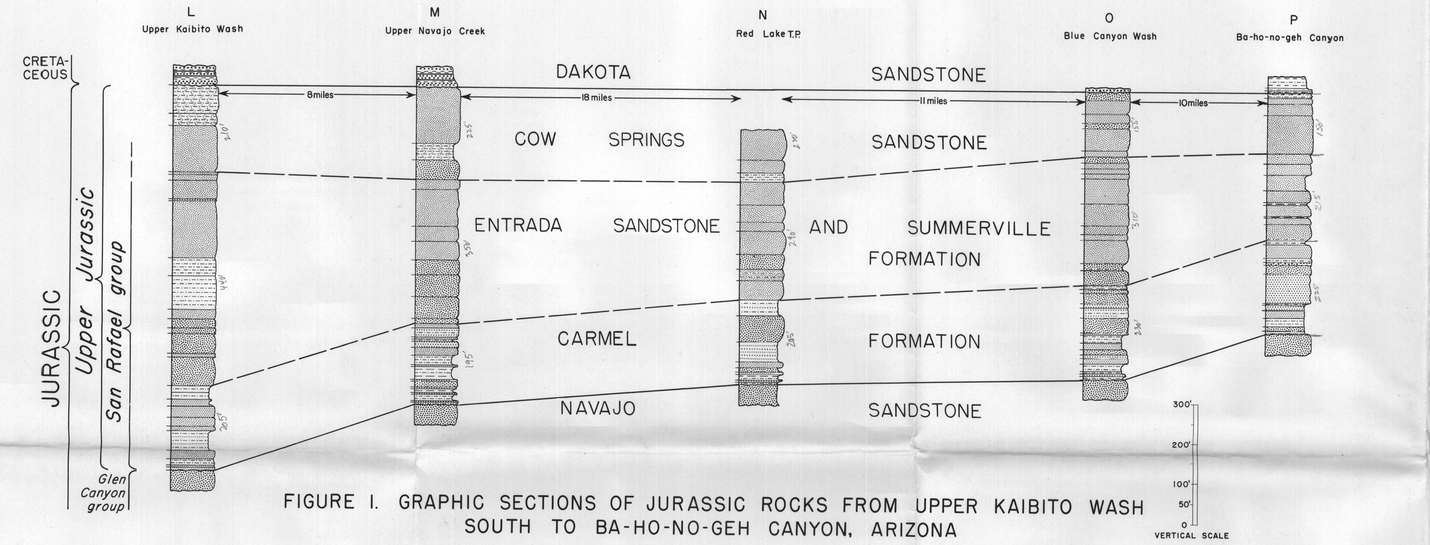


FIGURE 1. GRAPHIC SECTIONS OF JURASSIC ROCKS FROM UPPER KAIBITO WASH SOUTH TO BA-HO-NO-GEH CANYON, ARIZONA

EXPLANATION

- Sandstone, medium-grained, cross-bedded
- Sandstone, fine-grained, cross-bedded
- Sandstone, very fine grained, cross-bedded
- Sandstone, medium-grained, parallel-bedded
- Sandstone, fine-grained, parallel-bedded
- Sandstone, very fine grained, parallel-bedded
- Sandstone, calcareous
- Sandstone, silty
- Siltstone
- Siltstone, calcareous
- Siltstone, sandy
- Siltstone, cross-bedded
- Mudstone
- Mudstone, calcareous
- Shale
- Shale, calcareous
- Limestone
- Limestone, cherty
- Limestone, silty
- Dolomite
- Dolomite, cherty
- Dolomite, sandy
- Coal and coaly shale
- Conglomerate
- Breccia

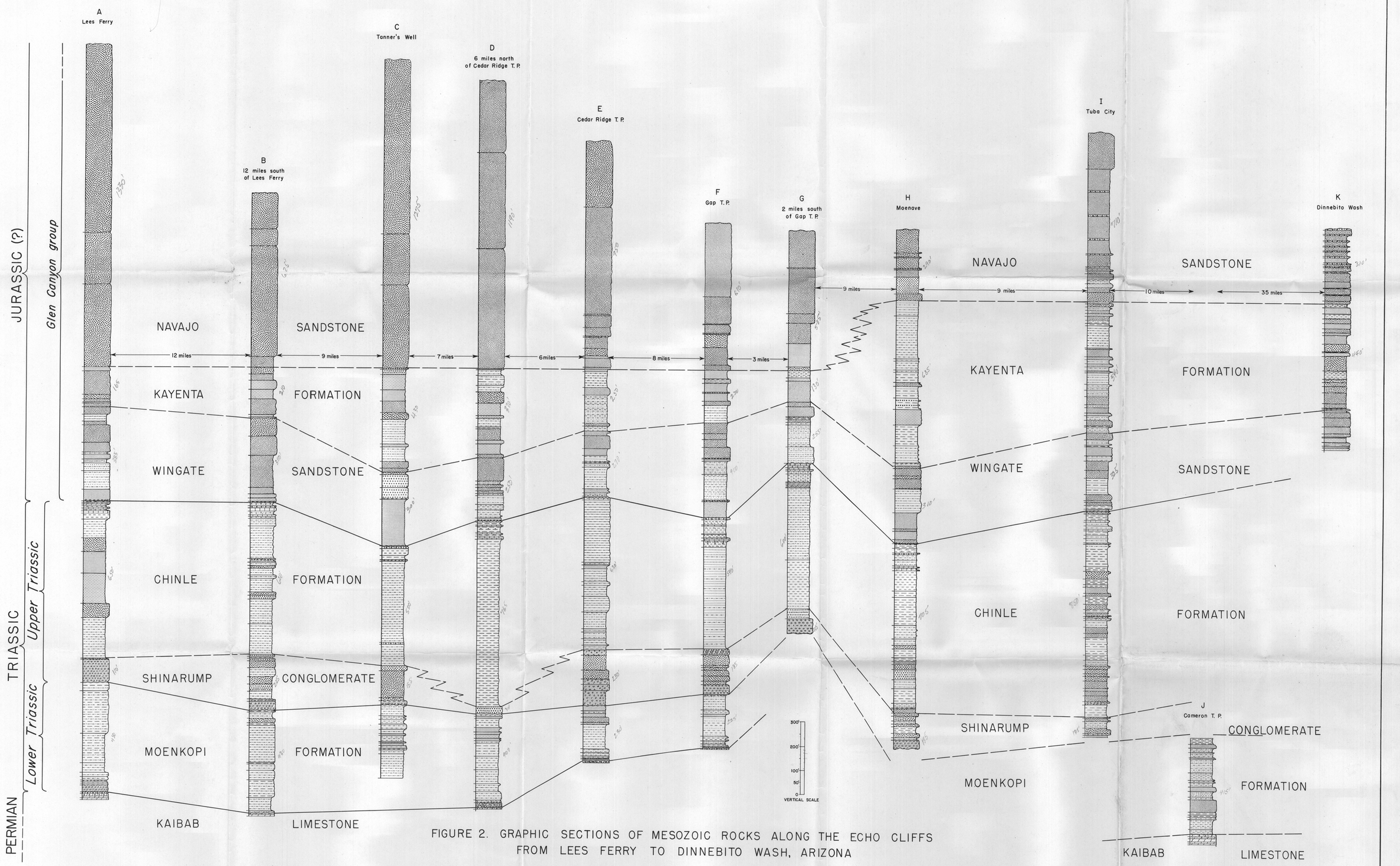


FIGURE 2. GRAPHIC SECTIONS OF MESOZOIC ROCKS ALONG THE ECHO CLIFFS FROM LEES FERRY TO DINNEBITO WASH, ARIZONA

OIL AND GAS INVESTIGATIONS
MAP OM 145, SHEET 2 OF 2

RECONNAISANCE GEOLOGIC MAP OF THE KAIBITO AND MOENKOPI PLATEAUS AND PARTS OF THE PAINTED DESERT, COCONINO COUNTY, ARIZONA

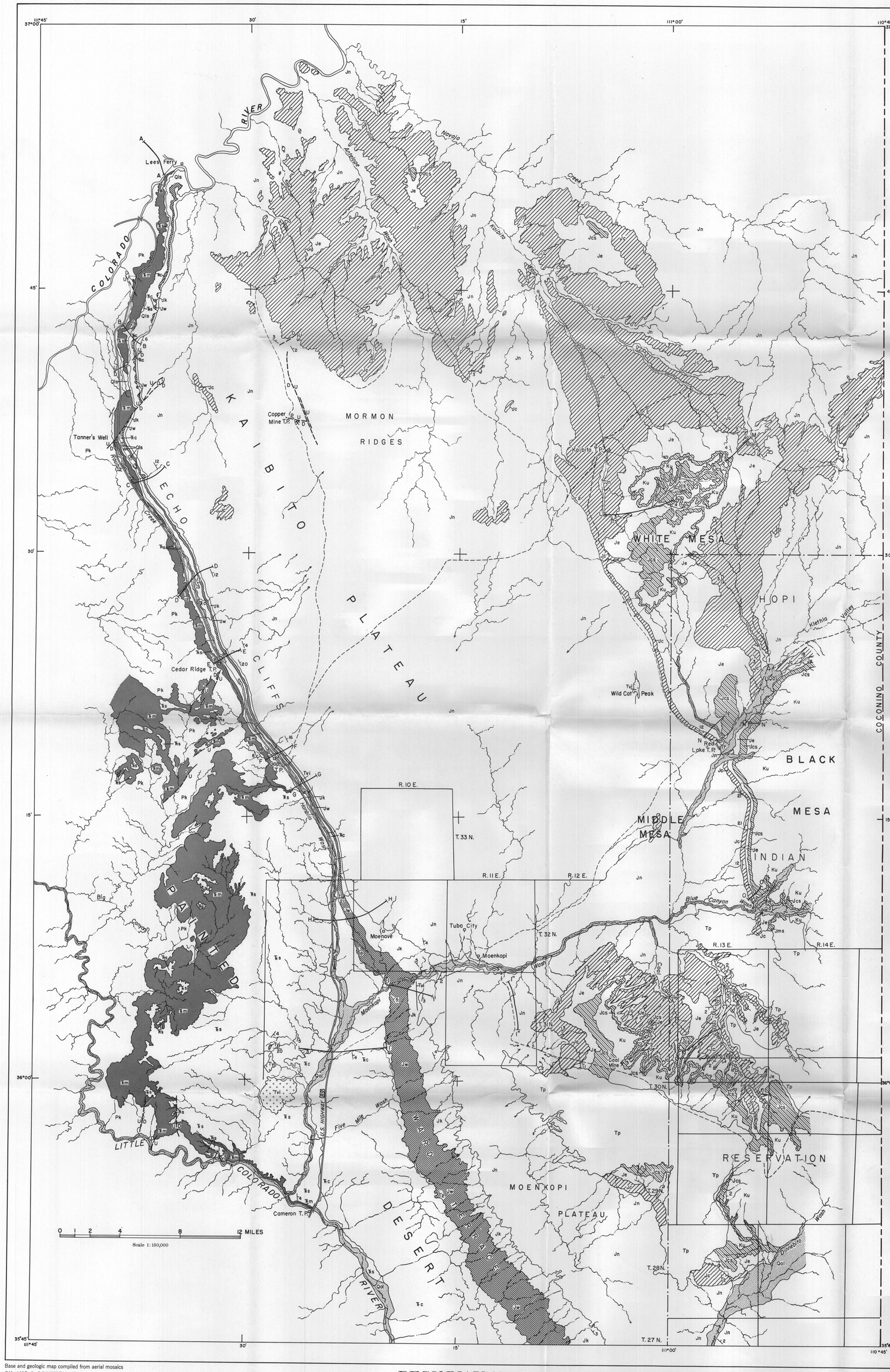
By A. A. Wanek and J. G. Stephens

1953

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.
Geology by A. A. Wanek and J. G. Stephens
Set of two maps for sale by U. S. Geological Survey, price 50 cents

Kaibito & Moenkopi Plateaus & Painted Desert Area
Coconino Co. Arizona

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
W. E. WRATHER, DIRECTOR



Base and geologic map compiled from aerial mosaics

OIL AND GAS INVESTIGATIONS
MAP OM 140, SHEET 1 OF 2

GEOLOGY OF THE KAIBITO AND MOENKOPI PLATEAUS AND PARTS OF THE PAINTED DESERT, COCONINO COUNTY, ARIZONA

By A. A. Wanek and J. G. Stephens

INTRODUCTION

During the field season of 1950 the writers made a reconnaissance study of the geology of the Kaibito and Moenkopi Plateaus and adjacent parts of the Painted Desert in Coconino County, Arizona. In addition, they made more detailed studies of the Mesozoic rocks that are well exposed in those areas. The purposes of the investigation were to develop a general structural picture of the area and to obtain information on the outcropping rocks in order to aid development of mineral-fuels and ground-water resources in the northwestern part of the Navajo Reservation. The study was made at the request of, and in cooperation with, the Water Resources Division of the Geological Survey as a part of a cooperative program of the Bureau of Indian Affairs and the Geological Survey.

GEOLOGIC STRUCTURE

The area studied is entirely within the plateau province of southwestern United States. The geologic structure is relatively simple and is characterized by gentle dips except in narrow belts along structural terraces. The Echo Cliffs, along the western margin of the area, are a striking example of this terracing. Southward from Lees Ferry, on the Colorado River, easterly dips in the strata comprising these vividly colored cliffs, which form the western margin of the Kaibito Plateau, gradually steepen. Folding is the dominant structure along the monocline that is developed as a result of this local steepening of dips, but there is local faulting. South of Moenave, easterly dips are gentler, and the Mesozoic strata that are compressed into a narrow belt to the north are exposed over a broad belt of cliffs and badlands.

The great areas of the Kaibito and Moenkopi Plateaus east of the Echo Cliffs are high tablelands in which faulting and similar structural complications are rare. However, bodies of intrusive rocks crop out on Wild Cat Peak and a few other places.

In the eastern part of the Kaibito Plateau, the strata dip steeply eastward in a narrow belt from Blue Canyon Wash northward along the western margin of White Mesa. Locally the strata are overturned. Farther south, dips are gentler where the older Mesozoic rocks pass under the Black Mesa structural basin.

IGNEOUS ROCKS

Igneous rocks occur in flows, dikes, and necks. The relations of these bodies to the regional structure are uncertain.

A lava flow megascopically identified as basalt, caps several mesas west of U. S. Highway 89 and north of the canyon of the Little Colorado River. This flow rests on the Shinarump conglomerate.

Four miles southwest of Moenkopi, the Kayenta formation is intruded by a basic dike that is nearly 2 miles long and 3 to 7 feet wide. Adjacent strata appear to be altered and are more resistant to erosion than the dike.

A dike intrudes the Chinle formation and Wingate sandstone about 2 miles south of Gap Trading Post. The dike is several feet wide, porphyritic, and basic in composition. North of Moenave on the Kaibito Plateau, several dikes, ranging in width from a few inches to a foot, intrude the Navajo sandstone. These dikes are dark, dense, and basic in composition and contain scattered xenoliths derived from the Navajo sandstone.

Wild Cat Peak rises as a prominent landmark above the Kaibito Plateau about 6 miles northwest of Red Lake Trading Post. It is thought to be a volcanic neck (Gregory, 1917, p. 103) sheathed by agglomerate; it intrudes the Navajo sandstone. The intrusive rock is phaneritic and is basic in composition. Several narrow north-trending, fine-grained mellilite basalt dikes (Gregory, 1917, p. 103) radiate from the neck.

Lava flows megascopically similar to basalt appear to occupy ancient stream channels in the canyon of the Little Colorado River. They probably were extruded in late Tertiary or early Quaternary time. By contrast, the volcanic necks such as Wild Cat Peak and the dikes that occur near Moenave and elsewhere probably were emplaced during an earlier period of igneous activity.

SEDIMENTARY ROCKS

Permian rocks are exposed in the canyons of the Colorado and Little Colorado Rivers and their tributaries as well as in the Painted Desert. The oldest strata that are exposed in the area are beds of limestone that are assigned to the Kaibab formation of Permian age. These crop out in the western part of the mapped area but were not studied in detail during the course of the investigation.

Triassic rocks crop out in the Painted Desert and in Ward Terrace. The Lower Triassic strata consist of interbedded, gypsiferous, evenly stratified, thin to thick beds of light-orange to medium-brown siltstone and fine-grained sandstone. East of this belt of Lower Triassic rocks, Upper Triassic strata are exposed. They are thick lenticular beds of cross-stratified, coarse-grained sandstone and conglomerate, overlain by alternating thick, irregular, and lenticular beds of variegated sandstone and siltstone.

Jurassic rocks crop out in the Echo Cliffs, in White Mesa, and in the cliffs of Black Mesa and are at the surface over most of the Kaibito and Moenkopi Plateaus. They include thick intervals of very fine to coarse-grained sandstone and thinner intervals of siltstone. Variations in lithology and in thicknesses of the Mesozoic formations in the Echo Cliffs area are summarized below and in the lines of graphic sections.

TRIASSIC SYSTEM

The Triassic system includes all strata between the Permian Kaibab limestone and the Jurassic(?) Wingate sandstone. Both the upper and lower limits of these Triassic strata are readily traceable. Triassic strata have been subdivided on both faunal and lithologic bases into the Moenkopi formation, the Shinarump conglomerate, and the Chinle formation (Gregory and Moore, 1931, p. 36, 59-95).

Moenkopi formation (Lower Triassic).—The base of the Mesozoic sequence is the erosion surface that underlies the Moenkopi formation. This surface bevels beds of the Kaibab limestone of Permian age and although the disconformity is a surface of slight relief, shallow depressions are locally filled by conglomerate and breccia beds of the Moenkopi formation that contain angular fragments and boulders of Kaibab limestone. The limestone beds are deeply weathered, and it is possible that a regolith developed on them.

The Moenkopi commonly weathers into ledged slopes or into ledges and cliffs capped by the Shinarump conglomerate. The Moenkopi crops out at the base of the Echo Cliffs from Lees Ferry to a point near Gap Trading Post and in the mesas and benches of the Painted Desert.

The basal strata of the Moenkopi are grayish-brown, silty, partly silicified conglomerate beds of variable thicknesses that contain pebbles and cobbles of Kaibab limestone and chert. Above these basal strata the lower part of the formation contains mottled, evenly stratified thin to thick layers of light- to reddish-brown gypsiferous and calcareous siltstone with intervals of brownish-gray ripple-marked fine-grained sandstone. The sandstone beds are well jointed and weather into rectangular blocks. The sequence contains many thin beds of gypsum. The thickness of the lower part of the formation ranges from about 95 feet at the type locality of the formation, west of Cameron Trading Post, to about 400 feet at Lees Ferry.

In comparison, the upper part of the Moenkopi formation ranges in thickness from about 300 feet at the type locality to about 50 feet at Lees Ferry. The upper part consists mostly of evenly stratified, medium- to thick-bedded, grayish-orange to grayish-red fine-grained sandstone alternating with thick intervals of orange-pink to reddish-brown siltstone. The sandstone beds are in some places cross-stratified, range from 1 to 6 feet in thickness, and contain occasional lenses of mud-pellet conglomerate. The sandstone commonly weathers into cliffs, and the siltstone intervals into slopes. Yellowish-green mottling and horizontal color banding are common in the sequence.

The Moenkopi formation forms a great eastward-tapering wedge that extends across northern Arizona and southern Utah. The thickness of the Moenkopi formation is about 595 feet near Cameron Trading Post, 220 feet at Gap Trading Post, and about 450 feet at Lees Ferry. These variations probably are caused by both depositional thinning and a regional unconformity that bevels the upper beds of the formation. The occurrence of thin beds of gypsum and the presence of ripple marks and mud cracks in the even-bedded strata suggest deposition in alternating subaqueous and subaerial environments. The Moenkopi probably was deposited in part under marine conditions and in part on floodplains or deltas marginal to the sea.

The Moenkopi formation is overlain disconformably by the Shinarump conglomerate. Relief on the contact ranges from a few inches to many feet, and channels in the Moenkopi formation are filled with Shinarump strata. Ferruginous encrustations and lenses are common along the disconformity. The disconformity is very conspicuous near Lees Ferry where channels in the Moenkopi, ranging from 50 to 70 feet in depth, are filled by the Shinarump conglomerate, which contains angular fragments and blocks eroded from the underlying formation. Such features are observed elsewhere in northeastern Arizona, and they suggest a period of widespread erosion after deposition of the Moenkopi.

Shinarump conglomerate (Upper Triassic).—The Shinarump conglomerate forms conspicuous cliffs near Lees Ferry. Southward it crops out almost continuously along the base of the Echo Cliffs and caps benches and mesas in the Painted Desert. The Shinarump conglomerate consists largely of light-gray and grayish-red conglomeratic sandstone and conglomerate beds that are lenticular, medium- to thick-bedded, and cross-stratified. These strata are interbedded with thin to thick beds of even-bedded pale-brown and grayish-red siltstone. The coarse-grained rocks are poorly sorted; subrounded granules and pebbles of black, red, and white chert and quartzite are present as stringers and lenses. Abundant petrified wood fragments and logs that reach a maximum of 30 feet in length and 2 feet in diameter are characteristic of the Shinarump. Locally, a yellowish- to light-gray conglomerate rests disconformably on the Moenkopi formation. The conglomerate is lenticular, massive, and irregularly cross-stratified. Chert and quartzite pebbles, from half an inch to 3 inches in diameter, are common. The bed is friable and is generally cemented by calcium carbonate and ferruginous material. The Shinarump conglomerate grades laterally from massive conglomerate to interbedded conglomerate, conglomeratic sandstone, and siltstone.

The upper beds of the Shinarump conglomerate appear to grade into and intertongue with the overlying Chinle formation. The contact is therefore arbitrarily placed at the top of the uppermost resistant sandstone bed. Such stratigraphic relations suggest that the Shinarump is the basal phase of deposition in the Chinle formation.

The thickness of the Shinarump conglomerate along the Echo Cliffs is 100 feet at Lees Ferry, 32 feet in the area north of Cedar Ridge Trading Post, 235 feet 12 miles south of Lees Ferry, and about 175 feet near the Little Colorado River. These variations in thickness are commonly the result of lensing of individual beds and of gradation of the upper beds into the Chinle formation. The Shinarump conglomerate, although variable in some aspects, is a blanketlike deposit that probably accumulated on floodplains as the basal phase Chinle sedimentation. The sources of the materials in the Shinarump are unknown.

Chinle formation.—The Chinle formation crops out in steep and irregular slopes at the base of the Echo Cliffs from Lees Ferry to Moenave. Farther south, in the Painted Desert, it is broadly exposed in badlands.

The Chinle formation rests conformably upon and locally interfingers with the Shinarump conglomerate and is overlain disconformably by the Wingate sandstone. At the type locality, Chinle Valley, Arizona, the Chinle formation is about 1,000 feet thick. It has been divided into four members—A, B, C, and D—by Gregory (1917, p. 42-48). Along the Echo Cliffs the equivalents of the members B and C are recognized in the Chinle formation; the other members, although probably present, are not readily distinguished and probably have merged into or cannot be distinguished from the Wingate and the lower Chinle.

The lower part of the Chinle formation is a succession of fine-grained friable sandstone and siltstone beds that are evenly stratified, thin- to thick-bedded, and parallel- or cross-laminated. Graded lamination is common. The siltstone intervals are argillaceous and bentonitic and contain thin irregular interbeds of calcareous sandstone and conglomerate. Calcareous concretions and fragments of petrified wood occur commonly in the fine-textured rocks. In general, the color banding from the base upward is light bluish gray, dark gray, pale and olive green, moderate brown, and grayish red. The lower part of the Chinle formation becomes more arenaceous southward as the formation thickens from about 650 feet at Lees Ferry to about 850 feet at Tuba City.

The upper part of the Chinle formation thickens from about 150 feet at Lees Ferry to about 270 feet at Cedar Ridge Trading Post. This variation may be the result of a disconformity at the top of the Chinle. Throughout the area the upper Chinle is eroded into benches or buttes and consists of thick intervals of thin- to thick-bedded calcareous siltstone and mudstone that grade upward into a sequence of irregularly stratified calcareous mudstone and siliceous limestone. The colors range from grayish purple to reddish brown, pale red, and orange pink.

The infrequent limestone beds in the Chinle are siliceous, aphanitic, and crystalloblastic; dark-gray and black chert nodules are abundant. The beds contain silty pellings and locally grade from dense siliceous limestone to nonfed nodules and calcareous mudstone.

A minor disconformity is conspicuous below the lowest limestone bed at Gap Trading Post and Moenave. Irregular apophyses of the limestone bed fill mudcracks and beings in the underlying mudstone.

The Chinle formation thickens and becomes relatively arenaceous southward: the thickness is about 650 feet at Lees Ferry, 500 feet at Tanner's Well, and 850 feet in Ward Terrace near Tuba City.

Along the Echo Cliffs the Chinle formation occurs as the last phase of Late Triassic sedimentation. The sediments were probably deposited in subaqueous and subaerial environments in the earlier stages of the Chinle cycle. Continued erosion of the source areas appears to have resulted in a trend toward deposition of finer materials so that in the later stages fine sediments and limestone accumulated in the depositional basin. Bentonitic materials in lower Chinle strata suggest volcanic activity in the sedimentary source areas.

The position of the contact of the Chinle and Wingate formations in the Echo Cliffs has been uncertain according to the opinions of past workers (Baker et al., 1936, p. 4). For purposes of this report the contact is placed at or near the top of the highest limestone bed of the Chinle formation. This approximate contact may be a disconformity, but if so, it is not everywhere clearly apparent. Locally the limestone is overlain by a thin conglomeratic sandstone bed, the base of which possibly marks the precise position of the contact. The variable thickness of the upper part of the Chinle and the absence of some of the upper limestone beds in several localities suggest a period of erosion prior to deposition of the Wingate.

JURASSIC(?) SYSTEM

Glen Canyon Group

The Glen Canyon group is defined by Gregory and Moore (1931, p. 64) includes the Wingate, the Kayenta (then Todilto), and the Navajo formations. Baker, Dane, and Reeside (1936, p. 4) accepted this nomenclature for eastern Utah and adjacent areas and placed the group in the Jurassic(?). The three formations are present along the Echo Cliffs.

Wingate sandstone.—The Wingate sandstone, the oldest formation in the Glen Canyon group, was deposited in a basin lying chiefly in southeastern Utah, northeastern Arizona, and northern New Mexico. It rests disconformably on the Chinle formation and is conformably overlain by the Kayenta formation. It crops out in a series of massive reddish-brown ledges between Lees Ferry and Tanner's Well. Southward toward Dinnebito Wash, the formation is eroded into reddish-brown or orange-red cliffs and rounded benches. Near Lees Ferry the Wingate is difficult to separate from overlying strata because of the general similarity of the sediments in the Glen Canyon group.

The beds in the lower part of the Wingate are thin and erode into slopes and ledges. These beds are overlain conformably by massive beds of sandstone. Intertonguing and gradational relations between the upper and lower facies are common. Locally, the basal bed of the Wingate is a thin, orange-pink or light-gray conglomeratic sandstone that rests disconformably on the Chinle formation. It is irregularly bedded and contains pebbles of black and red chert as well as fragments of siltstone and limestone. This conglomeratic sandstone is overlain by thin- to medium-bedded orange-pink and reddish-brown cross-laminated fine-grained sandstone and thick beds of mottled, reddish-brown siltstone. The lower part of the Wingate varies in thickness from 125 feet north of Cedar Ridge Trading Post to 245 feet at Gap Trading Post.

The upper part of the formation is generally eroded into steep-jointed cliffs that are streaked with bluish-black desert varnish. It includes massive beds of conspicuously cross-stratified pale-red to reddish-orange fine-grained sandstone. Well-rounded quartz grains are common. The cross-stratification is large in scale. Thin lenses of limy, clay-pellet conglomerate are interbedded in the sandstone beds in many places. The base of the Wingate Cliff is commonly streaked by yellow iron oxide, and the upper beds contain ferruginous sandy concretions that weather to conspicuous masses. The average thickness of the upper part of the Wingate is about 150 feet, whereas the average thickness of the formation is about 300 feet. Along the Echo Cliffs the thickness of the Wingate ranges from about 260 feet to nearly 400 feet.

Near Lees Ferry, the separation of the Wingate from the overlying Kayenta formation is difficult because of the general similarity of the strata, but southward the Wingate is relatively distinct, and the position of the contact can be determined accurately.

The Wingate strata appear to have been deposited in subaqueous and subaerial environments. This the formation may represent a transition from fluviatile deposition in its lower part characteristic of the Chinle to deposition dominantly eolian in type in its upper part. Prevailing climatic conditions may have been semiarid. The lithologic similarity of all the strata in the Glen Canyon group near Lees Ferry suggests that sources of the material were to the west and southwest.

Kayenta formation.—The Kayenta formation forms a broad lens-shaped deposit nearly coextensive with the Wingate sandstone. Along the Echo Cliffs the Kayenta conformably overlies the Wingate and is overlain conformably by the Navajo sandstone. It crops out in steep slopes and irregular ledges between the massive cliffs of the Wingate and Navajo.

The formation is about 170 feet thick at Lees Ferry, where it crops out in ledges of light-brown to reddish-brown medium- to thick-bedded cross-stratified argillaceous sandstone. Near Moenave the Kayenta thickens to about 700 feet, and at this point the lower part of the formation, about 360 feet thick, consists of medium- to thick-bedded light-brown siltstone interbedded with medium-bedded light-gray cross-stratified ripple-marked fine-grained sandstone. It is eroded into benches and terraces. The siltstone layers are even-bedded, and the exposed surfaces show many concentric light grayish-green spots. Large well-rounded quartz grains and many lenses of coarse-grained sandstone are common in the sandstone beds. The upper part of the formation, which is about 340 feet thick near Moenave, consists of thick grayish-red mudstone beds interbedded with thin beds of pale-red fine-grained sandstone. These beds grade vertically into massive and evenly stratified mudstone and siltstone beds. Near the top, lenticular beds of pinkish-orange cross-stratified sandstone intertongue with mudstone and siltstone beds. The upper beds of the Kayenta formation grade into and intertongue with the lower part of the Navajo sandstone.

Between Moenave and Dinehito Wash the Kayenta formation changes gradually from interbedded mudstone, siltstone, and sandstone to irregularly bedded and cross-stratified medium-grained sandstone. Local disconformities and channel deposits are common. The strata are friable and weather into alcoved cliffs and small pinnacles. Southward from Moenave the upper strata of the Kayenta appear to be transitional with the Navajo sandstone. Dinosaur tracks were observed in sandstone beds in the upper part of the formation at Moenkopi Wash.

Along Dinehito Wash the Kayenta is about 440 feet thick. The sandstone beds are medium- to coarse-grained, irregularly bedded, cross-stratified, and light gray to pale red. Thick interbeds of reddish-brown siltstone are present locally. Color mottling and banding along the planes of cross-stratification are common in this area.

The thickness of the formation near Moenave suggests that the axis of the depositional basin lay near the central part of the Echo Cliffs, whereas the lithologic changes in the Kayenta indicate that materials were contributed from source areas lying west or northwest, as well as south of the basin. The deposits appear to have accumulated on floodplains in the center of the basin. They grade northward into rocks having the lithologic characteristics of the Navajo sandstone. The Kayenta formation thins to the north, and it loses its identity possibly west of the Echo Cliffs in the Wingate and Navajo sandstones.

Navajo sandstone.—The Navajo sandstone, the uppermost unit of the Glen Canyon group, forms a great wedge extending across southern Utah, northern Arizona, and eastern Nevada. The Navajo lies conformably on the Kayenta formation and is at the surface over most of the Kaibito and Moenkopi Plateaus, where it commonly weathers into rounded bosses or domes. The Navajo forms mesas and benches where it is capped by the Carmel formation.

Over most of the Kaibito Plateau, the exposed Navajo strata are massive beds of cross-stratified fine- to medium-grained sandstone. The sweeps of cross-lamination range from 20 to 50 feet in length and are most commonly inclined to the southeast, south, or southwest. In the northern and central parts of the Echo Cliffs area the Navajo sandstone is reddish orange, reddish brown, or pale red with subordinate light-gray mottling and banding. Southward it changes to yellowish gray, light greenish gray, or light gray with some reddish-brown mottling.

The Navajo sandstone grades laterally from sandstone at Lees Ferry to interbedded sandstone, limestone, and siltstone along Dinehito Wash. Between Lees Ferry and Gap Trading Post the formation consists of massive beds of cross-stratified reddish-brown medium-grained sandstone. Small quantities of chert and ferromagnesian minerals are present. Large well-rounded quartz grains are scattered throughout the sandstone, and lenses of coarse sandstone grains occur along the bedding planes. The joint planes are commonly coated with ferruginous encrustations.

Limestone beds in the lower strata near Moenave increase markedly in number southward along the Echo Cliffs. Along Moenkopi Wash the lower strata of the Navajo sandstone are thick tabular beds of cross-stratified fine-grained sandstone interbedded with thin- and medium-bedded gray siliceous limestone. These beds are overlain by massive beds of friable cross-stratified sandstone with occasional cherty limestone and siltstone layers. A massive yellowish-gray very fine grained sandstone at the top of the formation weathers to abundant ferruginous concretions, which range from a few inches to several feet in diameter.

The Navajo sandstone along Dinehito Wash is a sequence of alternating beds of massive fine-grained sandstone, thin- to medium-bedded limestone, and siltstone. The sandstone is very fine grained, cross-stratified, yellowish gray to light greenish gray, and very friable. The limestone beds are evenly stratified, thin- to medium-bedded, and laminated. They are pale yellowish brown, siliceous, and either aphanitic or crystalline in texture. The beds contain lenses and nodules of pale-brown chert. Thin layers of pale-red and yellowish-gray calcareous siltstone are interbedded with the limestone beds. Contorted laminae commonly occur in the lower beds of the Navajo.

Dinosaur tracks were observed in the upper part of the Navajo sandstone just west of the Copper Mine Trading Post on the Kaibito Plateau.

The Navajo sandstone thins toward the south: the thickness of the formation is about 1,340 feet near Lees Ferry, about 700 feet near Tuba City, and about 310 feet in Dinnebito Wash.

The sedimentary structures and facies changes in the formation suggest that the Navajo sandstone was deposited in both subaqueous and subaerial environments. The Navajo thickens toward the northwest—toward the possible center of the basin of deposition. The southern margin of the depositional basin probably lay near the southern part of the Echo Cliffs. The source of materials in the Navajo seems to have been in the west or northwest.

JURASSIC SYSTEM

The nomenclature used for the Jurassic formations is that of Baker, Dane, and Reeside (1936, p. 6-10) with some modifications. The massive sandstone that overlies the Entrada sandstone was named the Cow Springs sandstone by Harshbarger, Repenning, and Jackson (1951, p. 77, 98). However, it may contain some strata that are equivalent to the upper part of the San Rafael group as well as to the lower part of the Morrison formation.

The San Rafael group includes the strata between the Navajo sandstone and the Cow Springs sandstone. Although the San Rafael group is divided into the Carmel formation, the Entrada sandstone, and the Summerville formation in adjacent areas, accurate separation of the Entrada and Summerville in this area does not appear to be practicable.

The San Rafael group rests disconformably on the Navajo sandstone. Along the Kaibito and Moenkopi Plateaus the contact is an even or wavy erosion surface that bevels the upper beds of the Navajo. Although widespread, this disconformity does not clearly represent an important hiatus.

Carmel formation.—The Carmel formation rests disconformably on the Navajo sandstone in White Mesa, in Black Mesa, and in mesas on the Kaibito Plateau between the Copper Mine Trading Post and the Navajo Canyon. Ferruginous plates and calcareous encrustations are common below this unconformity, and shallow depressions in the upper beds of the Navajo are filled with siltstone and sandstone beds of the Carmel. Carmel strata commonly weather as mesas and benches, but where immediately overlain by the Entrada sandstone they crop out in ledges and cliffs.

The formation consists of thick beds of evenly or cross-stratified pale-red sandstone that are interbedded with thick intervals of even-bedded dark reddish-brown siltstone. These strata grade vertically into thick beds of evenly or cross-stratified fine-grained sandstone. The siltstone intervals contain thin, hard beds of fine-grained calcareous ripple-marked sandstone. Locally these layers grade laterally into thick-bedded cross-stratified friable sandstone.

Along White Mesa, the Carmel is pale red and dark reddish brown with light greenish- and yellowish-gray horizontal banding. In Blue Canyon Wash, it is light greenish and yellowish gray with dark reddish-brown horizontal banding.

A massive cross-stratified very fine grained friable sandstone bed of the Entrada sandstone rests conformably on the Carmel formation. The upper beds of the Carmel appear to grade into the lower part of the Entrada.

The thickness of the Carmel is reasonably consistent and ranges from 210 feet in the upper part of Kaibito Wash to about 230 feet in Ba-ho-no-geh Canyon. The formation thins along Dinnebito Wash.

The Carmel strata were deposited on coastal plains and in shallow seas, and by inference they represent a transition from a continental sand facies in the south to a marine facies in the north. The facies change in the Carmel reflects the uplift of southern highlands during Glen Canyon deposition.

Entrada sandstone and Summerville formation undifferentiated.—The Entrada sandstone and Summerville formation undifferentiated rests conformably on the Carmel formation in White Mesa, in Black Mesa, and in buttes in the northern part of the Kaibito Plateau. The strata crop out in massive, rounded, irregular cliffs, or in vertical cliffs in the canyon walls.

The Entrada sandstone and the Summerville formation undifferentiated consists of massive, even beds of cross-stratified fine to very fine grained calcareous sandstone. The strata in the lower part of the sequence contain occasional lenticular thin- or medium-bedded laminated siltstone. Near the top the sandstone is silty and gypsiferous and includes numerous thin interbeds of siltstone. The cross-stratification is large in scale, and the dominant types in the beds are continuous inclined laminae and concave and diagonal laminae. Parallel stratification is subordinate in the sandstone. The sand grains are subrounded quartz and are cemented by calcium carbonate. Large well-rounded grains lie scattered in a matrix of fine sand grains.

These formations in White Mesa are reddish orange and reddish brown with yellow-gray mottling and banding. Southward along Black Mesa, they are yellow gray with reddish-brown banding. The sandstone is increasingly argillaceous and friable and is more thinly stratified toward the south.

The Entrada sandstone cannot be readily distinguished from the Summerville formation because of the similarities of the strata in the sequence. In adjacent areas the Summerville is a red siltstone sequence that grades and intertongues with the Entrada and Cow Springs sandstones. The upper contact of the combined unit is arbitrary and lies at the top of a crinkly bedded siltstone that forms a recess just below the base of the cliff-forming Cow Springs sandstone. The bed may not be at the same stratigraphic horizon everywhere, since the upper beds of the Entrada sandstone and Summerville formation undifferentiated appear to grade into the lower part of the Cow Springs sandstone.

The Entrada sandstone and Summerville formation undifferentiated thins toward the east and south. The thickness of the unit is about 520 feet in Kaibito Wash, 350 feet in upper Navajo Creek, 290 feet at Red Lake Trading Post, and 210 feet in Ba-ho-no-geh Canyon.

The Entrada sandstone was probably deposited on coastal plains and may be eolian and fluviatile in origin.

Cow Springs sandstone.—The Cow Springs sandstone rests conformably on the Entrada sandstone and the Summerville formation undifferentiated and is disconformably overlain by the Dakota sandstone of Cretaceous age. It crops out in sheer cliffs in White Mesa, in isolated buttes in the northern part of the Kaibito Plateau, and in rounded benches and cliffs along Black Mesa. The cliffs are recessed along joint planes, resulting in many spectacular monuments.

The Cow Springs is composed of massive well-cemented quartzose sandstone. The beds are tabular, conspicuously cross-stratified, fine or very fine grained, and yellowish or greenish gray. The sandstone contains many thin laminae of siltstone. The lower strata are argillaceous and calcareous and include thin, lensing beds of reddish-brown siltstone. Near the top of the formation, thick beds of light-gray well-sorted calcareous sandstone are commonly stained dark gray by material derived from coaly shale in the overlying Dakota sandstone. Along White Mesa, thick beds of friable cross-stratified siltstone grade and interfinger laterally and vertically with the sandstone.

The cross-stratification in the Cow Springs sandstone is large-scale, and contains concave and diagonal laminae or continuous-inclined laminae. Beds with parallel, or small-scale, continuously inclined cross-stratification appear locally in the sandstone, and their number increases toward the south.

At Cow Springs, Arizona, the type locality, the formation is 342 feet thick. It thins westward to about 230 feet in White Mesa, and southward to about 215 feet in the upper part of Kaibito Wash, 160 feet in Blue Canyon Wash, and about 150 feet along Ba-ho-no-geh Canyon. The thinning of the member may be due in part to deposition, as well as pre-Dakota erosion.

The Cow Springs is believed to be mostly fluviatile in origin but in part eolian. Northward the Cow Springs sandstone grades and intertongues with strata of the upper part of the San Rafael group and the lower part of the Morrison formation.

The Dakota sandstone rests disconformably on the Cow Springs sandstone. The contact is an erosion surface of moderate relief that bevels the upper beds of the Cow Springs sandstone just below the disconformity. The strata are commonly discolored and contain many ferruginous or siliceous encrustations. The disconformity is particularly conspicuous along Ba-ho-no-geh Canyon, where irregular depressions in the top of the Cow Springs sandstone are filled with lenticular beds of the Dakota sandstone.

The Cow Springs sandstone and the Dakota sandstone appear to be generally parallel in the area. However, the absence of upper Morrison strata that are present farther north and east suggests that the disconformity is of considerable extent.

CONCLUSIONS

The Moenkopi formation of Early Triassic age is a blanket deposit in the area. It rests on the eroded but generally parallel Kaibab limestone of Permian age. The Moenkopi is believed to have been deposited in marine and floodplain environments.

The Shinarump conglomerate of Late Triassic age is the basal coarse phase of the Upper Triassic. It rests on the eroded Moenkopi formation and appears to have been deposited in a continental area.

The Chinle formation of Late Triassic age is the upper phase of the sedimentary cycle. It was probably deposited in continental areas; in its lower part it grades and interfingers into the Shinarump conglomerate. The Chinle contains bentonite that has been interpreted as altered volcanic ash transported by air or water from unknown sources.

The Wingate sandstone of Jurassic(?) age rests disconformably on the Chinle formation. It is continental and was deposited in both subaqueous and subaerial environments. The Wingate thickens toward the south and east and interfingers with the Kayenta formation toward the west. Source areas for materials in the Wingate lay to the west and northwest.

The Kayenta formation of Jurassic(?) age rests conformably on the Wingate sandstone. It is fluviatile and interfingers with the Wingate and Navajo sandstones. The Kayenta grades into rocks of Navajo lithology toward the north. The materials of the Kayenta apparently came from source areas in the west and south.

The Navajo sandstone of Jurassic(?) age rests conformably on and interfingers with the Kayenta formation. It is continental and appears to have been both wind- and water-laid. The sandstone is homogeneous and thick in the northwest but thins and becomes silty and calcareous toward the south and southeast. The Echo Cliffs may be a marginal area of the depositional basin; one source area appears to have been to the west or northwest.

The Carmel formation of Jurassic age rests disconformably on the Navajo sandstone. It is even-bedded and silty in the north but becomes arenaceous and transitional with the Entrada sandstone southward. The Carmel, by inference, may be marine. The source areas of materials probably lay to the south.

The Entrada sandstone and Summerville formation undifferentiated, of Jurassic age, rests conformably on the Carmel formation. It is continental and, by inference, partly marine. The unit is silty and calcareous, probably water-laid, and may be an old beach deposit. It interfingers with and grades into the Carmel formation and the Cow Springs sandstone. It is thickest in the northwest and thins to the south and east. The materials came from source areas in the south.

It seems likely that sedimentation was continuous through the deposition of the San Rafael group and Cow Springs sandstone and that the materials were derived from source areas in the south.

The Cow Springs sandstone is believed to be a product of subaqueous and subaerial deposition. The top of the Cow Springs is an erosional unconformity that lies at the base of the Dakota sandstone.

REFERENCES

Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., 1936, Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, 66 p.

Gregory, H. E., 1917, The geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, 161 p.

Gregory, H. E., and Moore, R. C., 1931, The Kaiparowits region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U. S. Geol. Survey Prof. Paper 164, 161 p.

Hastell, M. A., and Eckel, E. B., 1939, Ground-water resources of the Holbrook region, Arizona: U. S. Geol. Survey Water-Supply Paper 856-b, p. 19-105.

Harshbarger, J. W., Repenning, C. A., Jackson, R. L., 1951, Jurassic stratigraphy of the Navajo country: New Mexico Geological Society Guidebook of the south and west sides of the San Juan Basin, New Mexico and Arizona, p. 75-98.

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY — Recent
- Qal — Alluvium
- Qls — Landslides

TERTIARY
- Tp — Pediment gravels

CRETACEOUS
- Ku — Cretaceous rocks (undifferentiated)

Unconformity

JURASSIC — Upper Jurassic — San Rafael group
- Jcs — Cow Springs sandstone
- Je — Entrada sandstone and Summerville formation undifferentiated

JURASSIC(?) — Glen Canyon group
- Jc — Carmel formation

Unconformity

- Jn — Navajo sandstone
- Jk — Kayenta formation

TRIASSIC — Upper Triassic
- Tw — Wingate sandstone
- Tc — Chinle formation
- Ts — Shinarump conglomerate

Unconformity

TRIASSIC — Lower Triassic
- ℓm — Moenkopi formation

Unconformity

PERMIAN
- Pk — Kaibab limestone

IGNEOUS ROCKS
- Tvi — Volcanic and intrusive rocks

Miscellaneous Symbols
- Strike and dip of beds
- Fault — U, upthrown side; D, downthrown side
- A — A — Measured section
- Mine or prospect
- Main road
- Secondary road

INDEX MAP SHOWING AREA OF REPORT

RECONNAISANCE GEOLOGIC MAP OF THE KAIBITO AND MOENKOPI PLATEAUS AND PARTS OF THE PAINTED DESERT, COCONINO COUNTY, ARIZONA

By A. A. Wanek and J. G. Stephens
1953

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.
Geology by A. A. Wanek and J. G. Stephens
Set of two maps for sale by U. S. Geological Survey, price 50 cents

Kaibito & Moenkopi Plateaus
Coconino Co., Arizona
1 of 2 parts