Springs Along the Mogollon Rim in Arizona

J. H. Feth and J. D. Hem

1962, pp. 129-134. https://doi.org/10.56577/FFC-13.129

in:

Mogollon Rim Region (East-Central Arizona), Weber, R. H.; Peirce, H. W.; [eds.], New Mexico Geological Society 13 th Annual Fall Field Conference Guidebook, 175 p. https://doi.org/10.56577/FFC-13

This page is intentionally left blank to maintain order of facing pages.

SPRINGS ALONG THE MOGOLLON RIM IN ARIZONA[1]

J. H. FETH and J. D. HEM

U. S. Geological Survey, Menlo Park, California and Denver, Colorado

INTRODUCTION

Water of the Salt and Gila Rivers is a major factor in the economy of Arizona, especially so in the Salt River Valley area of which Phoenix is the economic center. Therefore, the United States Geological Survey made a brief but systematic study of the springs in the headwaters of those rivers. The results of the study are reported elsewhere (Feth and Hem, 1960), and selected parts of the report are given in this paper.

Attention is centered on the occurrence, control, discharge, and chemical character of the springs and their waters, and on the abundance of travertine at some springs in the region. The geography, stratigraphy, and structural relations of the Mogollon Rim region (see fig. 1) are presented elsewhere in this guidebook. Mention of specific geologic features is made below, where pertinent, but no attempt is made to discuss the geology of the Mogollon Rim region as a whole.

OCCURRENCE

The springs are classified as contact, limestone-conduit, and fault-controlled springs. Basaltic aquifers supply most of the contact springs. They are numerous in eastern Arizona in basaltic terrane that occurs near the Rim, characteristically on the plateau portion but extending down the Rim escarpment in some areas. The Williams Creek Fish Hatchery Spring on a tributary of the White River, (see fig. 2), the spring at the head of Silver Creek about 10 miles northeast of Show Low, and Concho Spring south of the town of the same name, are among the larger in this category. At the three areas named, water emerges at the contact between an impervious layer and the overlying basalt or intercalated gravel. Other contact springs emerge from sedimentary rocks of Paleozoic age in many canyons cut back into the Rim. The controlling contacts in some places are between a permeable sandstone and underlying, relatively impermeable siltstone. A few springs of small discharge apparently are controlled by differing permeabilities in crossbedded layers of the Coconino Sandstone. On the San Carlos Indian Reservation, Cassadore Springs issues from jointed quartzite of Precambrian age at the contact with an underlying diabase sill.

Limestone-conduit springs are relatively few in number but discharge large volumes of water. Alchesay Spring, on the east bank of the White River, north of the town of Whiteriver, discharges about 7,500 gpm (gallons per minute). It is also the site (fig. 1) of a travertine terrace. The spring water rises as a low dome over a visible orifice in rock of the Fort Apache Member of Stoyanow (1936) of the Supai Formation. In Sycamore Canyon north of Jerome, Summers Spring also issues as a low dome of water. Although the orifice is immediately surrounded by soil, the Redwall Limestone is inferred to be the aquifer. The Redwall is highly cavernous where exposed in Sycamore Canyon. As would be expected of a limestone water the water is strongly calcium magnesium bicarbonate in type. Discharge of Summers Spring, measured four times between October 1951 and December 1952, ranged from about 2,300 to 2,700 gpm.

[1]Publication authorized by the Director of the U. S. Geological Survey.

The largest concentration of spring-water discharge in the Mogollon Rim region is from a group of many springs at the head of Fossil Creek, 8 miles northwest of Pine. The discharge on four occasions between June 1946 and July 1952, ranged from 18,600 to 19,200 gpm. The water is strongly calcium bicarbonate in type, and travertine deposition is active at most of the orifices.

Many springs in the region are in areas where faulting is apparent and are inferred to be controlled by the structures. Fault-related springs may be considered in three categories. The first is characterized by occurrence at the intersection of two faults and is illustrated by springs at the head of flow in Oak Creek, between Sedona and Flagstaff. This group, having small but constant discharge, is near the intersection of the Oak Creek fault and a west-trending cross fault. Information obtained from observation and from the records of deep wells drilled at the Navajo Ordnance Depot and for the City of Flagstaff suggests that the Oak Creek headwater springs emerge at or slightly below the elevation of the regional water table.

The second group of fault-related springs occur in a small graben. Springs related to graben structure are found at Natural Bridge, near Pine, and in lower Webber Canyon near its junction with the East Verde River, about 15 miles due west of Payson. In these two, and comparable places in the region, discharge is concentrated in the graben. The nearby structurally higher areas have no known discharge from springs.

In the third category are springs in an area of parallel faulting near Payson. There, during most of the year, flow in Webber Creek, Bray Creek, Chase Creek, and the East Verde River decreases to zero along a lien roughly parallel to and about 3 miles south of the Mogollon Rim. This line apparently coincides with a fault zone that brings the Redwall Limestone to or near the surface. Beginning at a point less than a mile downstream, the East Verde River has perennial flow for several miles. At an undetermined point the flow again decreases to zero, and final permanent flow is not attained until a short distance above the junction of the East Verde River and Webber Creek. The points at which the East Verde River and the other streams become intermittent probably represent outcrops of the Redwall Limestone. Water from the streams percolates downward through this cavernous limestone and reappears lower in the stream course. The repetition of events is apparently controlled by reappearance of the Redwall, repeated by faulting.

Summary of Spring Discharge

The aggregate discharge of springs visited in the study is shown in table 1. The discharge southward, 85,000 gpm, far exceeds the northward flow, which was estimated to be 5,500 gpm. The eastern division (fig. 1) has only about one-sixth of the total discharge, whereas the central and western divisions of the region produce the greater amount of water.

Large northward-flowing springs emerge in the Grand Canyon area, outside the Mogollon Rim region. Some of the water, for example at Blue Spring in the canyon of the Little Colorado River, 13 miles upstream from the mouth, may originate in the Mogollon Rim region. Blue Spring

Table 1. **Summary of maximum aggregate discharge of springs in the Mogollon Rim area visited prior to December 1952**

Area	Discharge (gallons per minute)	Source Rock	Discharge (gallons per minute)
South-flowing springs		Quaternary or Tertiary	
Western division	37,500	Alluvium	5,200
		Volcanic rocks	12,000
Central division	31,400	Verde Formation	17,000
		Permian	
Eastern division	16,000	Kaibab Limestone	20
Total	85,000	Coconino Sandstone	220
		Permian and Pennsylvanian	
North-flowing springs	5,500	Supai Formation	11,300
		Naco Formation	22,000
TOTAL	91,000	Mississippian	
		Redwall Limestone	5,200
		Devonian and Cambrian	6,400
		Precambrian	80
		TOTAL	79,400
		(Flow in Oak Creek from unidentified sources)	11,800
			91,000

discharges about 200 cfs (cubic feet per second) equivalent to 90,000 gpm, or as much as all the springs examined in the Mogollon Rim study. No evidence in hand, however, relates to the recharge areas for Blue Spring.

Relation Between Precipitation and Discharge

The amount of precipitation falling annually in the Mogollon Rim region is imperfectly known. Existing information suggests, however, that an annual average of 16 inches for the region as a whole is a conservative estimate. Assuming that the region has an extent of about 200 by 50 miles, the calculated annual precipitation is 8½ million acre-feet of water. Discharge of the springs is about 150,000 acre-feet per year (from table 1), Thus more than 98 percent of the precipitation leaves the Mogollon Rim region by evapotranspiration, flood runoff, and unidentified subsurface discharge.

CHEMICAL CHARACTER OF THE WATER

Precambrian Rocks

Cassadore Spring on the San Carlos Indian Reservation emerges from quartzite of Precambrian age. The water from this spring contains about 280 ppm (parts per million) of dissolved solids, mostly calcium, magnesium, and bicarbonate. Conversely, at the Salt Banks on Salt River, some 7 miles west by dirt road from the Salt River bridge on U. S. Highway 60, thermal springs discharge highly mineralized water from quartzite of Precambrian age. This water is comparable to sea water in dissolved-solids content and content of chloride. The proportions of other constituents, however, depart from those of sea water. Bicarbonate content is notably higher in the saline springs, equalling or exceeding that of sulfate. In sea water the sulfate content is about 20 times that of bicarbonate. In the springs, calcium and magnesium are present in nearly equivalent amounts, whereas in the ocean, magnesium is more than 30 times as abundant as calcium. The origin of the mineral constituents in the saline spring waters is not known, but they can hardly have been derived from the quartzite.

Near the junction of the Black and White Rivers, on the Whiteriver Apache Indian Reservation, a group of saline springs emerges from rocks of Precambrian age. Concentrations of constituents in water from these sources are proportionally similar to those at the Salt Banks, but the concentrations are only about one-fourth as great as those characteristic of the Salt Banks waters.

Rocks of Paleozoic Age

Water from rocks of Paleozoic age in the region generally is of good chemical quality and reflects in large part the chemical nature of the rocks from which it emerges. Water from limestone, whether in the Martin Formation (Devonian), the Redwall Limestone (Mississippian), the Supai Formation (Permian and Pennsylvanian), or the Kaibab Limestone (Permian) is characterized by moderate dissolved-solids contents. The water is of the calcium magnesium bicarbonate type and characteristically has a silica content of less than 25 ppm. Most of the springs depositing travertine when visited emerge from limestone. Waters

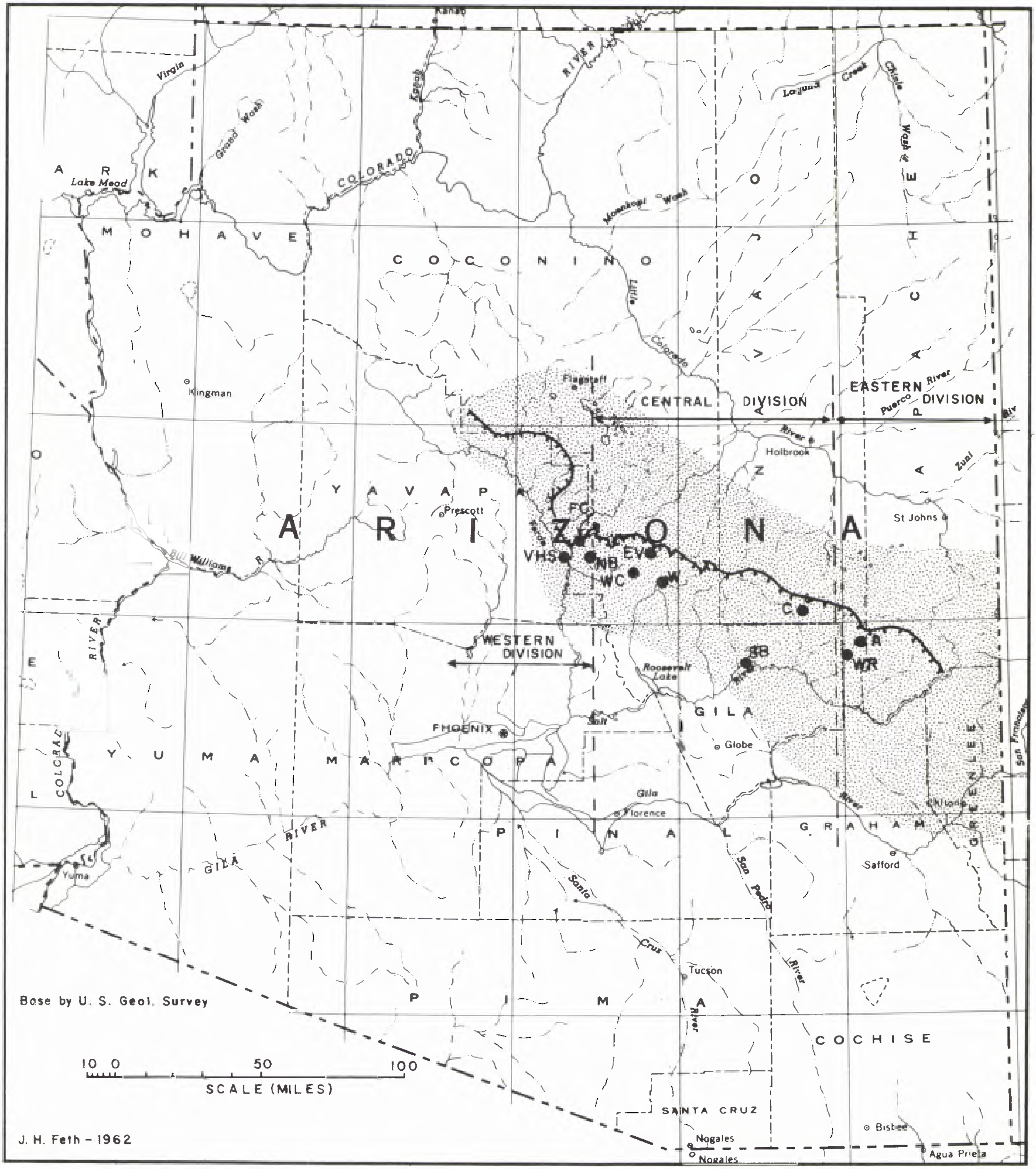

Figure 1. — Map of Arizona showing the Mogollon Rim region (dotted area), approximate location of Mogollon Rim (hachured line, hachures on low side), and locations of travertine terraces mentioned in text. Travertine localities are as follows:

FC—Fossil Creek, sec. 14, T. 12N., R.7E.
VHS—Verde Hot Springs, sec. 3, T.11N., R.6E.
NB—Natural Bridge, sec. 5, T.11N., R.9E.
WC—Wailing Cow Ranch, sec. 9, T.11N., R.10E.
EV—East Verde River, sec. 24, T.11½N., R.10E.
W—Wildcat on Tonto Creek, sec. 13, T.11N., R.11E.
SB—Salt Banks on Salt River, sec. 13, T.5N., R.16E.
C—Corduroy, east side U. S. Highway 60, approximately T.7N., R.20E. (unsurveyed).
WR—White River, west bank White River, approximately sec. 20, T.6N., R.23E. (unsurveyed).
A—Alchesay, east bank White River, approximately sec. 4, T.6N., R.23E. (unsurveyed).

from the Supai, from both limestone and sandstone, contain somewhat more chloride and sodium than those from the other formations named and have a smaller calcium/magnesium ratio.

In areas adjacent to the Mogollon Rim, water from the Coconino Sandstone (Permian) is low in dissolved solids. Calcium, magnesium, and bicarbonate are the dominant ions. Northward from the Rim and downdip, however (Hem, J. D., in Babcock and Snyder, 1947, p. 11-12), water in the Coconino increases in mineral content. Presumably the Coconino has been partially leached of readily dissolved substances near the Rim where circulation of ground water has been active. Saline water appears, however, in the Coconino where wells have been drilled to the formation in areas north of the rim, especially where it is overlain by the Moenkopi Formation (Triassic). As the Moenkopi is known to contain salt, a genetic relationship may exist.

Extrusive Rocks

Various volcanic rocks, ranging in age from Cretaceous(?) to Recent(?), cover extensive areas of the Mogollon Rim region, and supply water to many springs. Among these, springs from basalt discharge the least mineralized of any of the water sampled in the study. The calcium/magnesium ratio is low, approaching unity, and the water commonly contains at least 25 ppm of silica. The basalt is at or near land surface in the region and is fissured. Thus, circulation of ground water is rapid. These factors and the relatively low solubility of the rock combine to cause minimal pick-up of mineral constituents.

Clifton Hot Springs, near Clifton, emerge from alluvium in an area of volcanic rock. The water discharged probably is of deep-seated origin and may contain a small amount of juvenile water. It is largely a solution of sodium and calcium chloride, the contents of bicarbonate, sulfate, and magnesium being appreciably less than those at the thermal springs at Salt Banks or along the White River.

Hem (1950, p. 34-35) has estimated that the discharge of about 1,000 gpm at Clifton Hot Springs, contributes about 50 tons of dissolved solids per day, or 18,000 tons per year, to the San Francisco River which discharges into the Gila River a few miles south of Clifton.

The Verde Hot Springs issue from volcanic rocks near stream level in the canyon of the Verde River, a few miles north of its junction with the East Verde River. These springs discharge small volumes of water that is dominantly sodium bicarbonate in character, although sulfate and chloride contents are also high. The water contains 7.2 ppm of boron.

Neither the Clifton nor the Verde Hot Springs yields water of chemical character that would be considered typical of water from igneous rocks. The increased solvent power of hot water over cold may be the cause of the high mineralization of the water from these sources.

TRAVERTINE TERRACES

Travertine deposits of significant size were seen at 10 localities (fig. 1). Deposition of travertine is continuing at 4 of these, namely Natural Bridge on Pine Creek, Fossil Creek, Salt Banks on Salt River, and Alchesay on the White River. The deposits range widely in size. The smallest is at Verde Hot Springs where travertine clings to the country rock above present spring orifices. The deposit is about 20 feet long and ranges from less than 1 to 5 feet in other dimensions. At Fossil Creek and at an inactive terrace on the White River, each of the deposits is about half as large as the famous Mammoth Springs in Yellowstone Park, Wyo.

At Fossil Creek, the inactive terrace is nearly a mile long and half a mile wide, extends several hundred feet up the slope of the mountain against which it lies, and terminates in a cliff about 100 feet high facing Fossil Creek. At the time of the study, no water was discharging from this terrace. Spring flow, which averages about 19,000 gpm, emerges from many points at or near the level of the stream and about half a mile upstream from the toe of the inactive terrace. The orifices of most of the active springs are in travertine and, according to reports from personnel of the power company that maintains a flume utilizing the flow of the springs, frequently seal over with travertine. The water then finds other adjacent points from which to emerge, and the process repeats.

The terraces at Fossil Creek, Natural Bridge, Wailing Cow, and Corduroy (fig. 1) rest upon 2 to 10 feet of boulders, cobbles, and pebbles that overlie the bedrock and are cemented by the oldest part of the travertine. Where the terraces are cut by gullies, the basal conglomerates are seen to extend continuously beneath the travertine and are, therefore, integral parts of the terrace deposits. Overlying the basal conglomerate, the travertine lies in nearly horizontal beds implying that deposition progressed upwards, reaching in some places to more than 100 feet. Artesian pressures of magnitude sufficient to cause flow at such elevations above the local drainage levels are not in evidence today. In the localities named, the base of the conglomerate now ranges from 5 to at least 150 feet above modern stream channels.

On the East Verde River, near Ellison Creek, travertine is exposed on both the east and west walls of the canyon, overlying granite of probable Precambrian age. The highest occurrence is on the east wall, about 100 feet above the river whence it extends downward on the canyon wall for more than 50 feet. Below the base, granite is exposed to a point about 15 feet above river level where a small patch of travertine lies on a ledge of granite adjacent to a few active seeps. Granite is exposed from below the seeps to river grade. On the west wall, the highest exposure of travertine is about 70 feet above the river and extends from that level to its base about 50 feet above the stream. No water was seen to discharge from the west wall of the canyon. These relationships suggest that initial travertine deposition occurred when the river was at least 50 feet above its present level; hence downcutting has progressed 50 feet since the main mass of travertine was formed at this place. Limestone of Devonian age is exposed a short distance east of the gorge and presumably supplied the calcium carbonate that was deposited as travertine by long-vanished springs in the area.

Two periods of travertine deposition are indicated, relative to late basaltic eruptions along the Mogollon Rim. The inactive terrace on White River rests on basalt that flowed down the canyon of the White River after the canyon already had been well established. This basalt is found some hundreds of feet below the canyon rim. Its base ranges from a few feet to a few tens of feet higher

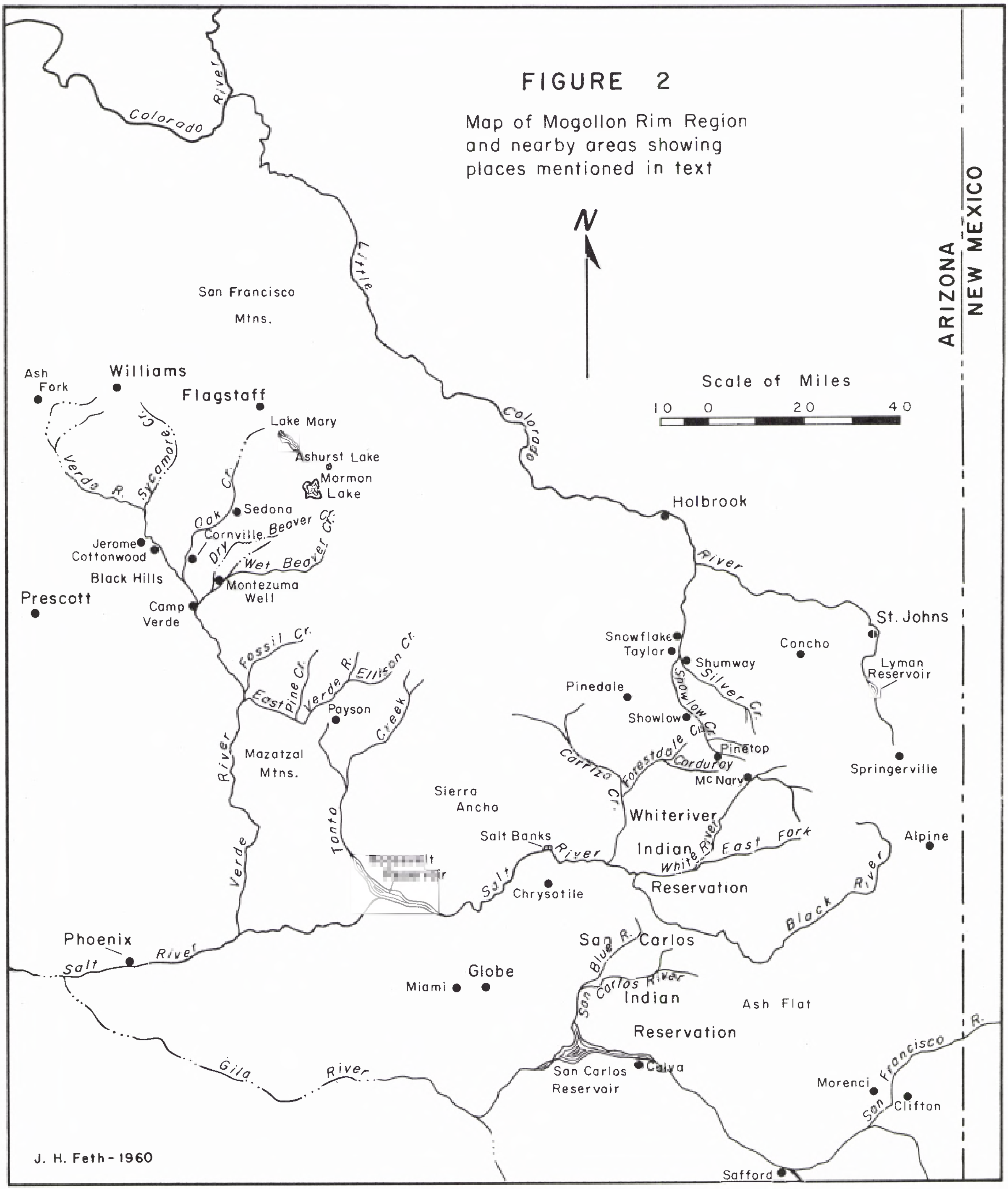

FIGURE 2

Map of Mogollon Rim Region and nearby areas showing places mentioned in text than present river grade. The Corduroy terrace, however, is overlain by a layer of oxidized red soil less than a foot to about 3 feet thick, which in turn is overlain by basalt. If the basalt that caps the Corduroy terrace and the basalt that underlies the White River terrace are of comparable age, then deposition of travertine was contemporaneous with later stages of basaltic activity along the rim in this area.

The relations stated — active deposition of travertine at places near present stream grades, inactive deposits that extend in places hundreds of feet higher than river grade, the bases of travertines exposed tens of feet above modern stream levels, and the relations between travertine and basalt — suggest a long history of travertine deposition in the area. Much of it clearly occurred when ground-water conditions in the region were different from those prevailing today, and before the streams had cut their canyons to present levels. The history remains to be unraveled, and absolute dates need to be ascertained. The potential of the terrace deposits for contributing to knowledge of the geologic history of the region is large.

REFERENCES CITED

Babcock, H. M., and Snyder, C. T., 1947, Ground-water resources of the Holbrook area, Navajo County, Ariz.: with a section on quality of water by J. D. Hem: U. S. Geol. Survey open-file rept., 27 p.

Feth, J. H., and Hem, J. D., 1960, Reconnaissance of headwater springs in the Gila River drainage basin, Ariz.: U. S. Geol. Survey open-file rept. (In preparation as Water-Supply Paper 1619-H).

Hem, J. D., 1950, Quality of water of the Gila River Basin above Coolidge Dam, Ariz.: U. S. Geol. Survey Water-Supply Paper 1104, 230 p.

Stoyanow, A. A., 1936, Correlation of Arizona Paleozoic formations: Geol. Soc. America Bull., v. 47, no. 4, p. 459-540.