Evaporite Deposits of the Permian Holbrook Basin, Arizona

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ABSTRACT

The northwest-southeast trending Holbrook Basin embraces an area of thickened Permian sedimentary rocks located in east-central Arizona near the south margin of the Colorado Plateau. The Basin lies between two positive tending regions, the Mogollon Rim to the southwest and the Defiance region to the northeast. Evaporite deposits of principal interest occur in the "upper" Supai Formation between the Fort Apache Member of the Supai Formation and the Coconino Sandstone. The "upper" Supai ranges from 450 to 1300 feet in thickness and in its thicker portions contains an aggregate thickness of evaporite, largely halite, of up to 485 feet. Subsurface halite occurs over an area of about 2300 square miles. Exploration drilling has verified the existence of a sylvite-bearing zone that occurs high in the evaporite series. Details of this zone are not available.

Evaporites of the "upper" Supai Formation resulted from the evaporation of sea water that periodically transgressed north to northwestward across an active tectonic zone at least partially coincident with the trend and position of the present Mogollon Rim. Clastic influx from northerly directions eventually completed the filling of the Permian Holbrook Basin.

INTRODUCTION

Permian subsurface evaporite deposits in the vicinity of Holbrook, Arizona, have been known for over 40 years, but little information about them has been published.

For years inquiries have come to the Arizona Bureau of Mines from those interested in inventorying possible waste disposal sites, and more recently, recognition of the presence of potash salts has prompted requests for basic data. Within the past three years attempts have been made to determine the extent to which salt solutioning and associated collapse might have modified surface structure and topography; a very practical consideration for those actively engaged in both the extension of Arizona's helium resources and exploration for petroleum products in the area of the Permian Holbrook Basin. Interest in these evaporites, therefore, has become both direct and indirect over a relatively short period of time.

Subsurface information was obtained from exploratory gas, oil, and helium tests. Because these wells were drilled without regard for evaporite trends, their utility for this study is somewhat limited. It is our intention to present only the broader aspects of evaporite distribution and conditions that attended evaporite deposition.

Location

The Permian Holbrook Basin is situated at the southern margin of the Colorado Plateau in southern Coconino, Navajo, and Apache counties in east-central Arizona (Fig. 1). The southern margin of the plateau province in Arizona is marked by a prominent escarpment called the

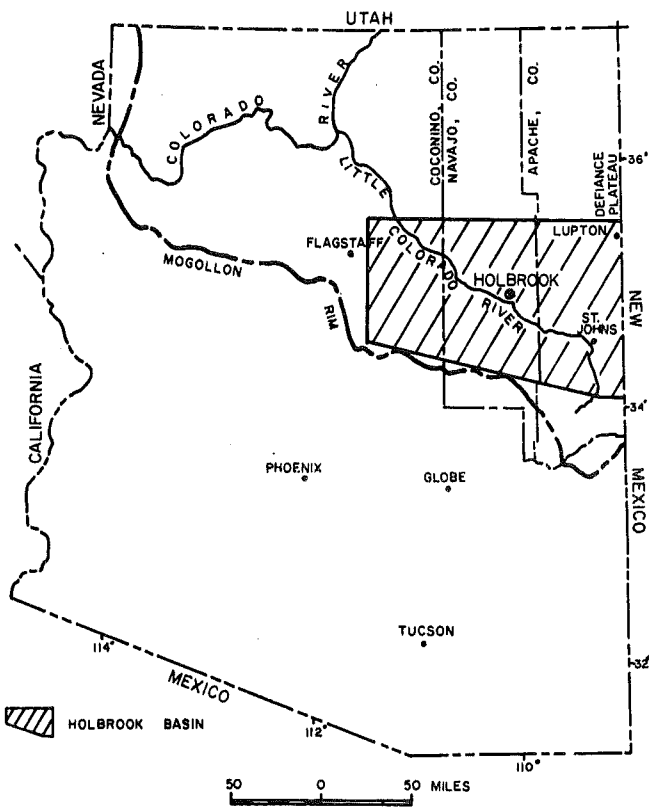

Figure 1. Index map showing location of Permian Holbrook Basin, Arizona.

Mogollon Rim. Paleozoic strata exposed along the Rim dip to the north and northeast at low angles forming a near-dip slope that is commonly called the Mogollon Slope. Table I summarizes the surface and subsurface control used in this study.

GENERAL GEOLOGIC SETTING

The present parallelism that exists between structure and topography is shown in Fig. 2. The dotted lines are structure contours drawn on top of the Permian Coconino Sandstone; the solid lines show the present topography. There are two structurally and topographically high areas, one at about 7500 feet along the Mogollon Rim, and the other at a similar elevation on the Defiance Plateau to the northeast. In the intervening lower land the Little Colorado River flows northwesterly and is at an elevation of 5000 feet near the town of Holbrook.

Figure 3 is a diagrammatic northeast-southwest general geologic section that shows the Mogollon Rim escarpment, the northerly dip that forms the Mogollon Slope, and the Defiance Plateau to the northeast. The absence of Paleozoic sedimentary rocks older than Permian and the thinning of Permian strata onto the Defiance Plateau suggest that the area was active through much of Paleozoic time. The absence of Triassic and Jurassic strata below Cretaceous sandstones and the thinning of Permian rocks in the vicinity of the Mogollon Rim to the southwest indicate a positive tendency of the Rim region in late Paleozoic and early Mesozoic time. Evaporites of the Permian Supai Formation were deposited in the Holbrook Basin situated between the Defiance and Rim positive tending regions.

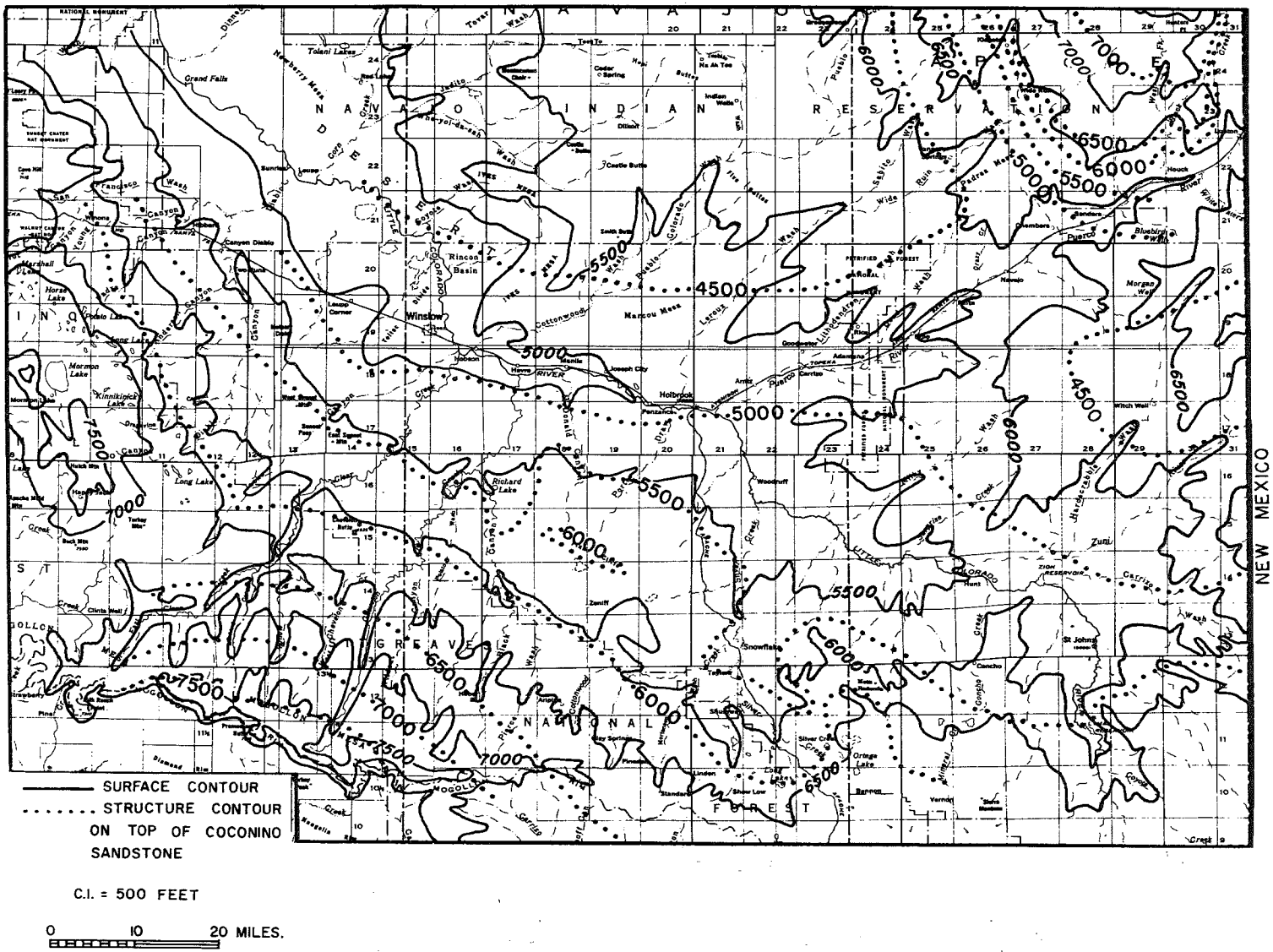

Figure 2. Map showing structural control of modern topography in east-central Arizona.

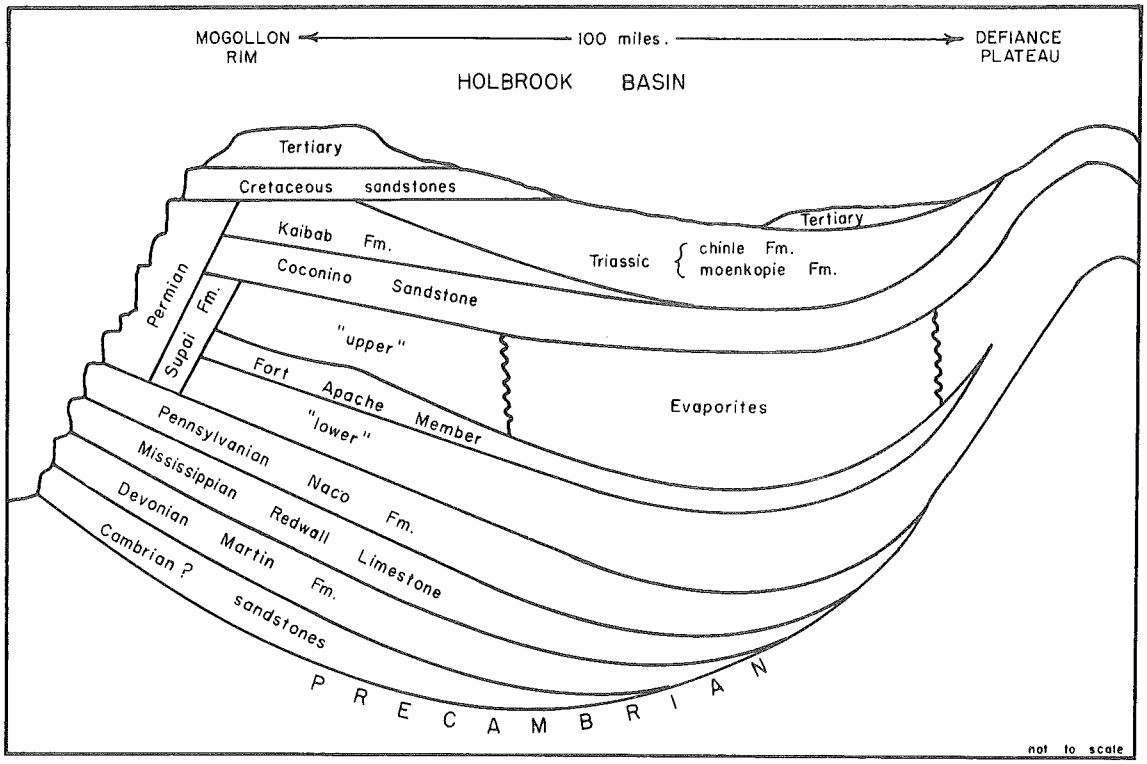

Figure 3. Diagrammatic geologic section along SW-NE direction from Mogollon Rim to Defiance Plateau.

STRATIGRAPHY

Supai Formation

McKee (1951) has pointed out that the Permian sequence in Arizona attains maximum thickness in the subsurface of the Holbrook Basin area. This thickening is due largely to an expanded section of the Supai Formation, and isopachs show that in Supai time, the Holbrook Basin, although of limited areal extent, was a true depositional basin (Peirce, 1958, p. 84). Huddle and Dobrovolny (1945) observed that the Supai Formation thickens northward from the Mogollon Rim and becomes increasingly evaporitic in the upper part.

Supai strata or equivalents are continuous throughout the plateau portion of northern Arizona. They consist principally of red beds but locally are interbedded with limestone, dolomite, and evaporite. The thickness of the formation ranges from 3200 feet in the subsurface near Holbrook to about 1200 feet at the Grand Canyon. Stratigraphic terminology applied to subdivisions of the formation varies as a result of local studies conducted by individual workers. For operational purposes, we have subdivided the Supai Formation in the subsurface of the Holbrook Basin into three parts, a "lower" and an "upper" Supai separated by the Fort Apache Member, a marine fossiliferous unit, consisting of dolomite, limestone, and some evaporite, and ranging up to about 130 feet thick. Although some evaporite occurs below the Fort Apache Member, the thickest accumulation is in the "upper" Supai between the Fort Apache Member and the Permian Coconino Sandstone.

"upper" Supai

The "upper" Supai is defined as that sequence of strata bounded on the top by the contact of the Supai Formation and Coconino Sandstone, and at the base by the Fort Apache Member of the Supai Formation. Although the Supai-Coconino contact seems to be transitional, a consistent operational boundary was established on the basis of a number of different, but easily recognizable, physical characteristics. Correlation of the carbonates of the Fort Apache Member in

surface exposures with strata in the subsurface is more difficult and has been recently attempted by Baars (1962). In this instance efforts resulted in correlating the Fort Apache Member of the Rim with non-equivalent strata in the subsurface. Wengerd (1962) designated various subsurface carbonate horizons as Fort Apache A, B, and C, thus indicating difficulty in making a precise correlation with the outcropping Fort Apache Member.

Gerrard (1964a and b) reviewed the entire problem of surface to subsurface correlation in a study of the Fort Apache Member. Utilizing many available stratigraphic controls, both in outcrop and subsurface, a sound correlation of the Fort Apache Member was established throughout the Holbrook Basin and the unit was then used as the operational lower limit of the "upper" Supai sequence.

The "upper" Supai strata in the Holbrook Basin consist of varying proportions of orange, red-brown, and gray siliceous clastic rocks and interbedded limestone, dolomite, and evaporite. Halite, anhydrite and gypsum are the principal mineral constituents in the evaporite strata; however, recent investigations have established the presence of rather widely distributed sylvite. Additional study would undoubtedly extend the number of mineral species that occur in the evaporite assemblage.

The thickness of the "upper" Supai ranges from about 450 feet at locality 20 along the Rim to about 1300 feet in well 4 near the approximate center of the Basin (Fig. 4). Estimates based on available subsurface data suggest that the aggregate thickness of evaporite deposits in the Basin ranges from 0 to nearly 485 feet. High halite/sulfate ratios coincide with areas of maximum evaporite accumulation. The depositional margin of halite is indicated by the dotted line (Fig. 4) and circumscribes an area of about 2300 square miles.

Isopachous mapping discloses the salient structural elements of the area about the Holbrook Basin in "upper" Supai time. It is noteworthy that this framework is reflected to some extent in the present structural setting of the region. The long axis of the Permian Holbrook Basin nearly parallels the existing Mogollon Rim and the "upper" Supai sediments thin to the south and southwest suggesting the existence of a paleo-Mogollon Slope in Early Permian time. To the northeast the "upper" Supai sediments thin against the Defiance Positive that occupied the site, at least in part, of the present Defiance Plateau.

Figure 5 illustrates the general distribution of lithologic types comprising the "upper" Supai in the Holbrook Basin along stratigraphic section traverse A-B. The position of this traverse is shown in Fig. 4. On the basis of laterally persistent carbonate and sulfate units the "upper" Supai is divisible into four zones numbered I through IV, from bottom to top. The clastics and halite within these zones exhibit considerable lensing and suggest frequent shifting of the evaporite environment in time and space.

Interest has focused on zone III halite because it contains the sylvite of current interest. Potash was first suspected as occurring in well section 5, drilled by Kerr-McGee in 1958 in search of hydrocarbons and helium. Subsequent log analysis of this hole indicated a possible potash occurrence approximately 210 feet below the Supai-Coconino contact in the upper part of the zone III halite. However, active potash exploration did not begin until about 1963. New data obtained from recent exploratory drilling indicate the presence of potash deposits elsewhere in the Holbrook Basin that appear to be stratigraphically equivalent to the suspected occurrence in well 5. Therefore, the distribution of zone III halite is of considerable interest and practical importance.

Halite is absent in zone III of well section 4, 35 miles west-southwest of well section 5. Northeast of the discovery well, in well section 6, halite is present in zones I, II, and III. The absence of halite in well 7 delimits, in a general way, the northeast margin of halite deposition. However, it is possible that zone III salt extends north of section 6, but the "upper" Supai section in that area has not yet been tested. Evaporites of zone III are overlain by clastic rocks of zone IV.

Figure 6 is a northwest-southeast stratigraphic section (C-D) nearly parallel to the axis of the Basin. To the northwest in well section 8 clastic sediments, principally orange to reddish silty sandstones, constitute the entire "upper" Supai. Although the northwestern depositional margin of evaporite is located west of well 9, (bedded) halite is confined to a belt less than

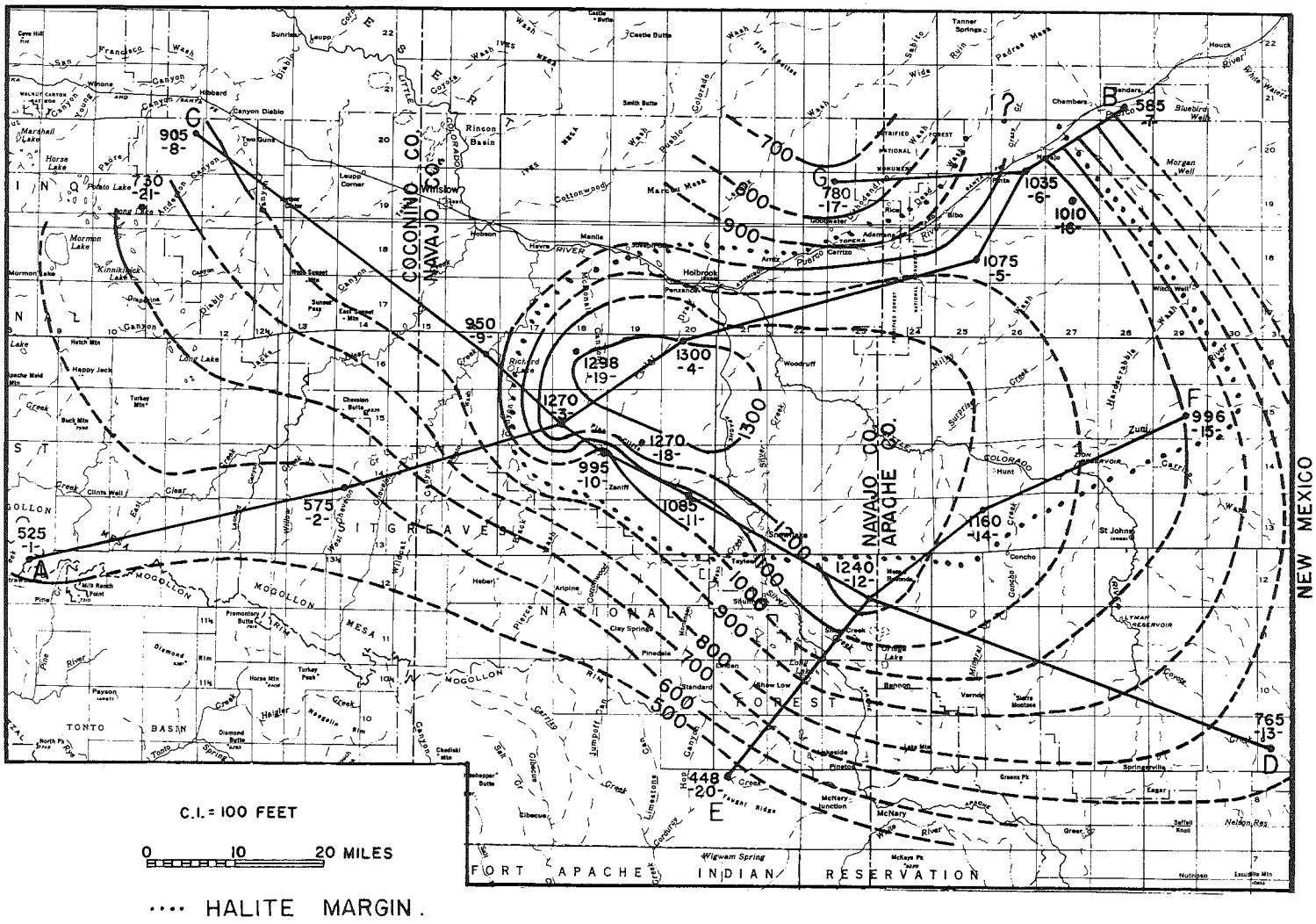

Figure 4. Isopach map of "upper" Supai Formation with index to stratigraphic sections.

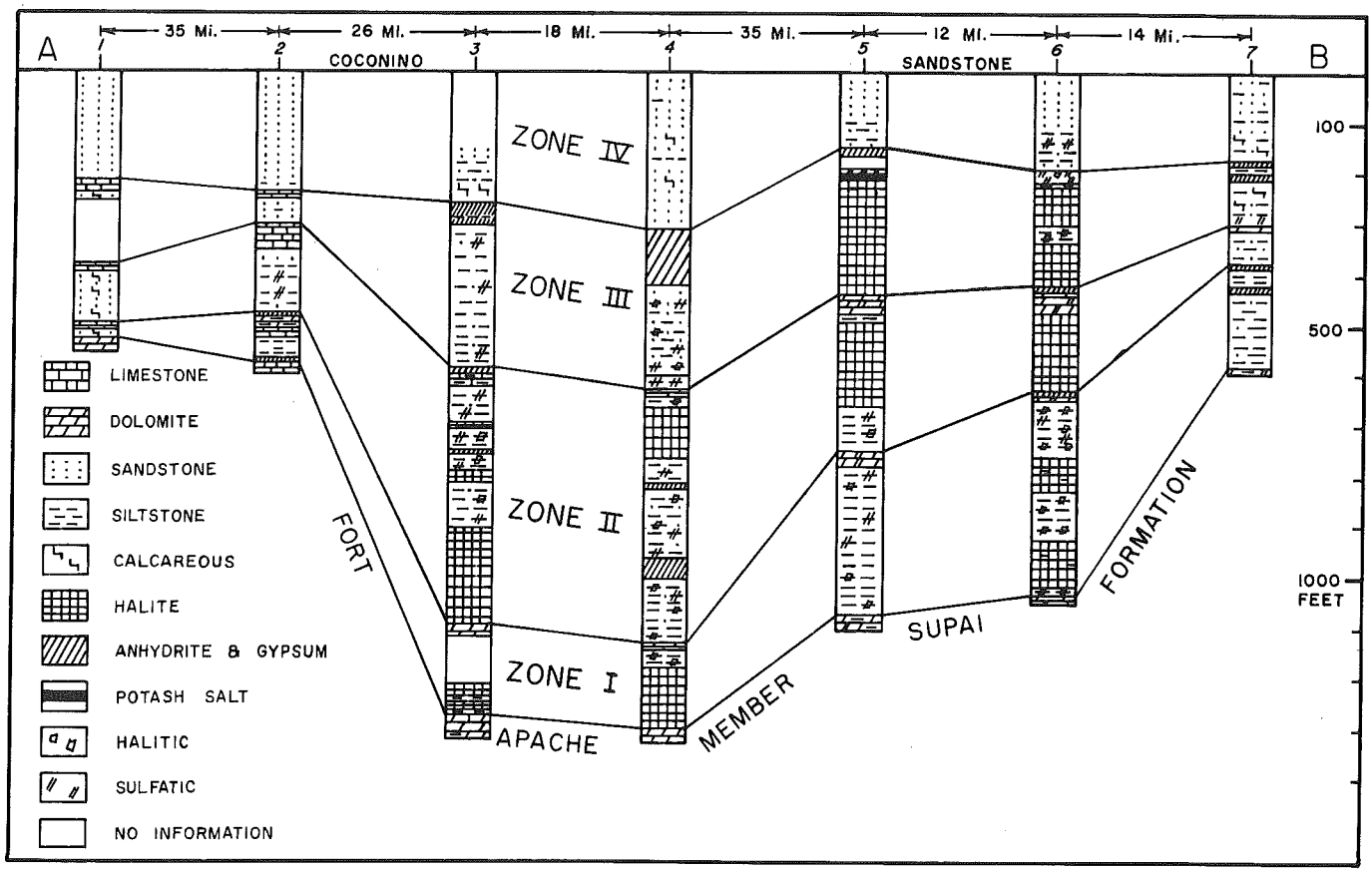

Figure 5. Stratigraphy of the "upper" Supai Formation along line of section A-B.

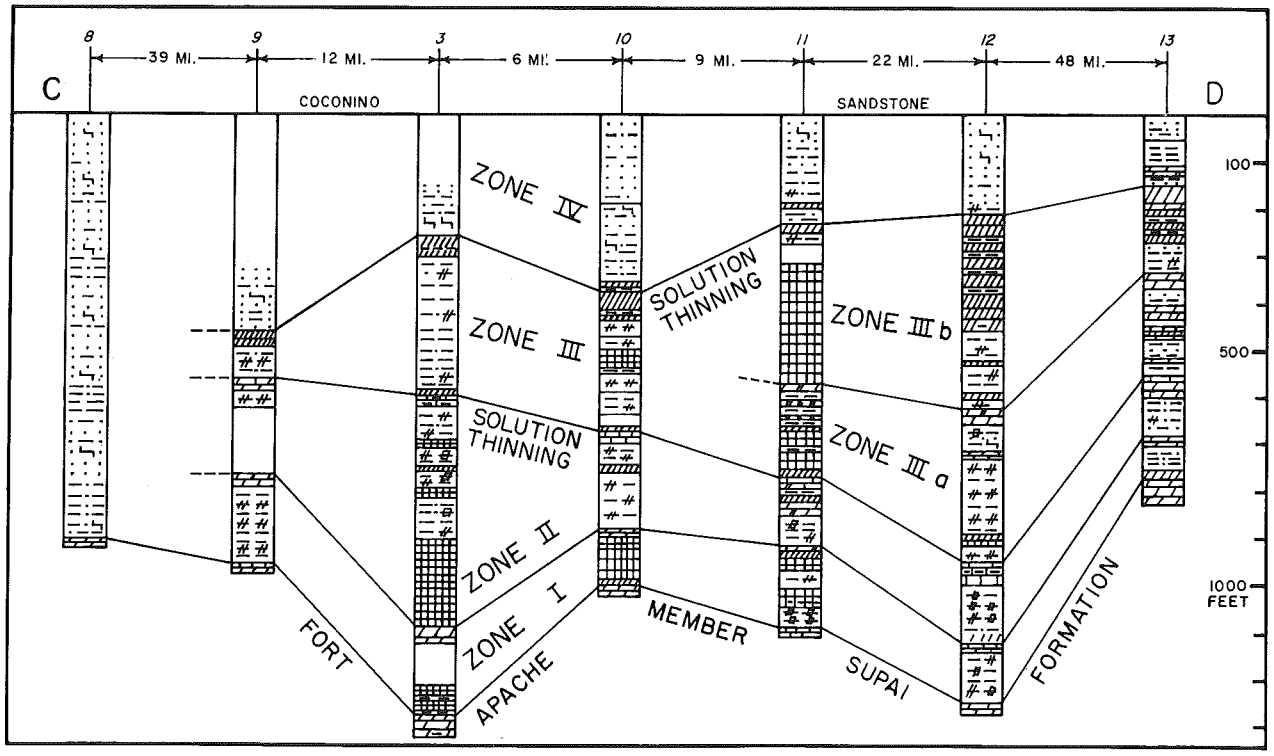

Figure 6. Stratigraphy of the "upper" Supai Formation along line of section C-D.

50 miles wide extending between well sections 9 and 12. The thickest zone III halite accumulation along section C-D occurs in well 11. The abrupt thinning of zone III halite 9 miles to the northwest in well section 10 is attributed, at least partially, to salt solutioning (Bahr-1962).

The thick zone III halite in well sections 11 and 5 suggests continuity of the accumulation along a northeast-southwest trend for a distance of almost 50 miles. The completely clastic "upper" Supai section in well 17 and the thick salt occurrence in well 6 indicate a marked depositional pinchout of evaporites to the north. To the southeast, in well sections 12, 13, and 14, there is a substantial decrease in halite and an increase in the number and thickness of carbonate and bedded sulfate units. The sulfate strata in these wells are confined mainly to zone III b, and are presumably interbedded with halite a short distance to the north.

Stratigraphic section E-F (Fig. 7) is along a southwest-northeast traverse across the southeastern portion of the Holbrook Basin, and demonstrates (1) the continuity of carbonate units between the thinned "upper" Supai along the Mogollon Rim and the thickened sequence in the

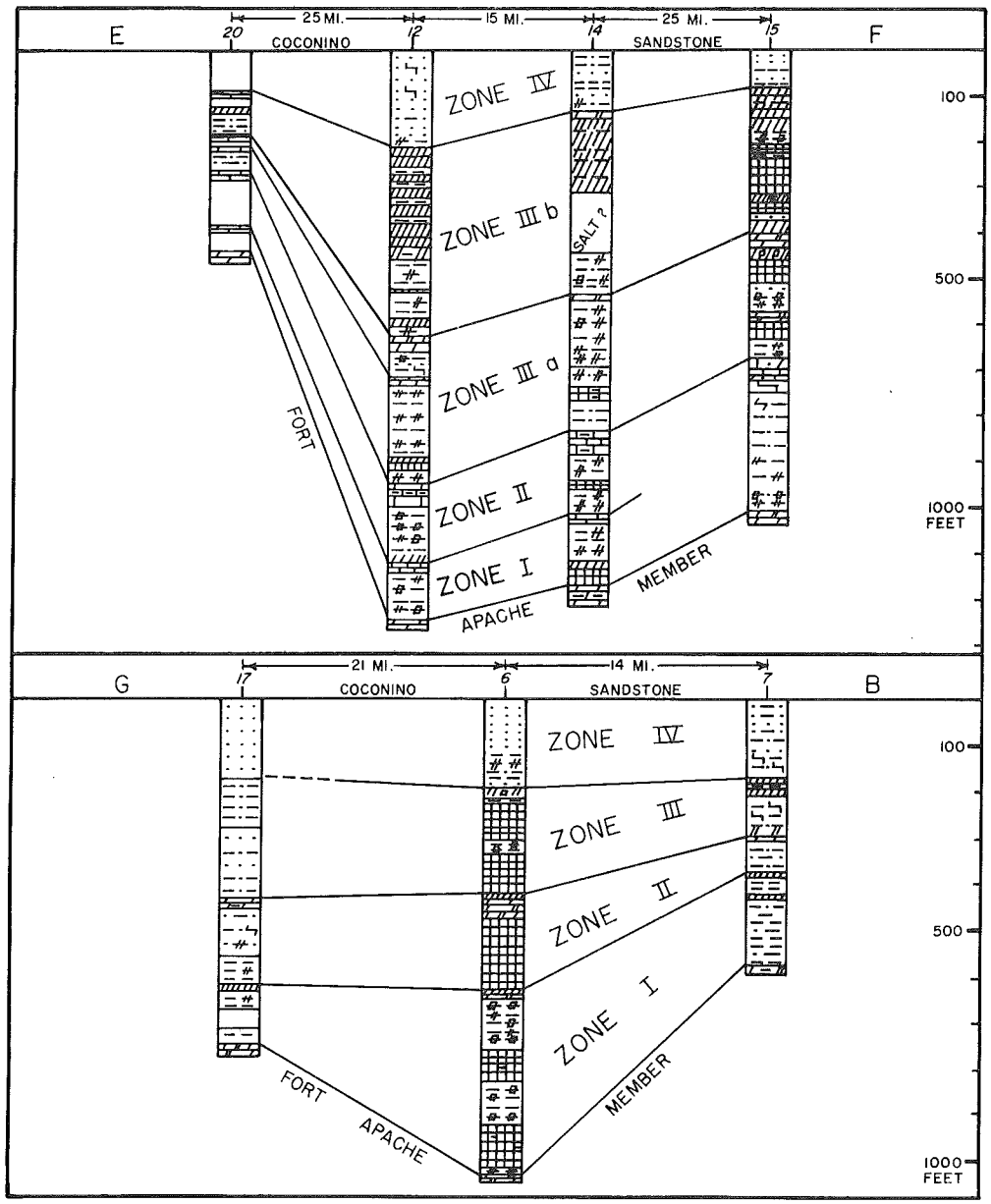

Figure 7. Stratigraphy of the "upper" Supai Formation along lines of sections E-F and G-B.

subsurface to the north, and (2) the occurrence of thick (bedded) halite in zones III a and b in well section 15. The presence of thick halite in well 15 and near absence in wells 12, 13, and 14 establish the margin of thick salt accumulation to the south.

Stratigraphic section G-B (Fig. 7) extends across the northern embayment area, and shows the very abrupt loss of evaporites and very marked thinning of the entire "upper" Supai sequence onto the western margin of the Defiance Positive at well 7. Lithologic changes between wells 6 and 17 are much the same; however, thinning is more gradual.

SUMMARY AND CONCLUSIONS

Available subsurface data indicate that the "upper" Supai of the Holbrook Basin consists of three distinct lithofacies. A clastic facies nearly circumscribes the Basin, dominating the sequence to the north and northwest as well as along the Mogollon Rim to the south. The halite-rich evaporite facies occupies the central part of the Basin along a belt approximately 30 to 40 miles wide, exhibiting a northeast-southwest trend. Strata of the sulfate-carbonate facies are confined mainly to the southeastern margin of the Basin and are interbedded with clastics along the Rim but with strongly halitic sediments toward the Basin center.

Stratigraphic relations suggest that in "upper" Supai time marine waters located to the south or southeast periodically gained access to the subsiding Holbrook Basin by inundating an active structural zone believed to be coincident, at least in part, with the southeastern extension of the present Mogollon Rim. Evaporite deposition resulted from intermittent restriction of accessways. Increasing influx of clastics from the north-northeast and northwest gradually displaced the evaporite environment to the southeast, and ultimately filled the Basin with clastics of zone IV.

The most vertically continuous halite accumulation occurs in zone III of the potash discovery section, well 5. Sulvite occurs near the top of the halite sequence and is what might be expected if the potassium salt originated as a precipitate from a final bittern phase of an evaporite environment. The extent to which post-depositional processes have modified the mineralogy and distribution of the evaporite deposits must await more detailed investigation.

It is our hope that the brief, foregoing discussion will provide the foundation for an improved understanding of the evaporite stratigraphy of the Permian Holbrook Basin. Undoubtedly, the details presented herein will be refined as new and more complete data become available.

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TABLE I

STRATIGRAPHIC CONTROL POINTS

Section No.	Type	Name	Location
1	Outcrop	Fossil Creek	
2	Well	Monsanto Chem. Co. -- No. 1 Cabin Wash	sec. 30 T. 14 N. R. 20 E.
3	Well	Union-Continental -- Aztec No. 1	sec. 19 T. 15 N. R. 19 E.
4	Well	Pan American Pet. Corp. -- Aztec Land & Cattle Co. A-1	sec. 5 T. 16 N. R. 20 E.
5	Well	Kerr-McGee Oil Ind., Inc. -- Hortenstein No. 1	sec. 23 T. 18 N. R. 25 E.
6	Well	Kerr-McGee Oil Inc., Inc. -- State No. 2	sec. 34 T. 20 N. R. 26 E.
7	Well	James G. Brown and Assoc. -- Chambers-Sanders No. 2 Fee	sec. 27 T. 21 N. R. 28 E.
8	Well	Roy Owen & Co. -- No. 12-1 Diablo Amarillo	sec. 12 T. 20 N. R. 11 E.
9	Well	T. C. Eisele -- McCauley No. 1	sec. 11 T. 16 N. R. 16 E.
10	Well	California Oil Co. -- State No. 2519	sec. 12 T. 14 N. R. 18 E.
11	Well	Lydia Johnson, Trustee -- No. 1 Aztec (Land A)	sec. 33 T. 14 N. R. 20 E.
12	Well	Pan American Pet. Corp. -- New Mexico-Arizona Land & Cattle Co. B-1	sec. 25 T. 12 N. R. 23 E.
13	Well	Mae Belcher, Trustee -- State No. 1	sec. 20 T. 9 N. R. 21 E.
14	Well	Pan American Pet. Corp. -- New Mexico-Arizona Land & Cattle Co. A-1	sec. 12 T. 13 N. R. 25 E.
15	Well	Argo Oil Co. -- State No. 1	sec. 22 T. 15 N. R. 29 E.
16	Well	Eastern Pet. Co. -- No. 3 Santa Fe	sec. 9 T. 19 N. R. 27 E.
17	Well	General Petroleum Corp. -- Creager-State No. 14-6	sec. 6 T. 19 N. R. 23 E.
18	Well	Union-Continental -- New Mexico and Arizona No. 1	sec. 34 T. 15 N. R. 19 E.
19	Well	Pan American Pet. Corp. -- Aztec Land & Cattle Co. B-1	sec. 9 T. 16 N. R. 18 E.
20	Outcrop	Corduroy Creek	
21	Well	Western Oil and Minerals Inc. -- No. 1 Walters	sec. 24 T. 19 N. R. 11 E.