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PERMIAN SEDIMENTARY ROCKS OF THE BLACK MESA BASIN AREA

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GENERAL STATEMENT

Information regarding Permian sedimentary rocks of the Black Mesa structural basin must be gathered from a few drill holes and disconnected outcrops on the fringes of the basin. From the center of the Black Mesa physiographic feature it is approximately 80, 72, 60, and 40 miles south, west, north, and east respectively to the Mogollon Plateau, Grand Canyon, Monument Valley, and the Defiance Plateau where Permian sedimentary rocks crop out. As drill hole data are limited over most of the basin area, projected trends through the basin are highly speculative.

PERMIAN BOUNDARIES

Previous workers have emphasized the difficulty of drawing a precise boundary between Pennsylvanian and Permian sedimentary rocks in northern Arizona. That the Supai, lowermost of the Permian formations, crosses the Pennsylvanian-Permian boundary seems well established by studies that have been made in parts of the Grand Canyon and Mogollon Plateau regions—Noble (1922), Hughes (1950), Jackson (1951), Huddle and Dobrovolny (1945), and Winters (1950). In western Grand Canyon and along portions of the Mogollon Rim the red sedimentary rocks of the Supai formation are interbedded with marine limestones near the base in a manner that would seem to be analogous to the Rico "transition interval" described by Bailey (1955) in the Four Corners region.

In eastern Grand Canyon and at Jerome the Supai formation rests on the Mississippian Redwall limestone. Details of the configuration and extent of the latter type of contact are not known but undoubtedly it trends towards the western margins of the Black Mesa basin. On the Defiance Plateau as well as near St. Johns, Permian sedimentary rocks are in depositional contact with granite and quartzite of probable Precambrian age (fig. 1). Permian sedimentary rocks are overlain by Triassic formations in the Black Mesa basin but are truncated by upper Cretaceous sandstones along parts of the Mogollon Rim to the south.

SOME ASPECTS OF PERMIAN STRATIGRAPHY

Supai-Hermit formations

The term "Supai" is currently used over all of northern Arizona except in the Four Corners area. As used it refers to a multiple lithologic sequence dominated by reddish clastics with varying modifications, but in large part sandy. Although the formation contains some limestone, only the prominent Ft. Apache limestone unit of the Mogollon Rim area has been given a formal name. Evaporitic material as well as evaporites seem to be concentrated in the Holbrook to St. Johns region where the Supai formation attains its greatest known thickness of approximately 2600 feet (figs. 1 and 2).

The Hermit formation disconformably overlies the Supai formation in the Grand Canyon region and areas to the north. Evidently the Hermit merges laterally with the Supai southward towards Oak Creek Canyon as at this locality the Coconino sandstone, which overlies the Hermit in the Grand Canyon, is in gradational contact with sedimentary rocks of Supai lithology. The Hermit formation, as in the Grand Canyon area, is not known to extend into the Black Mesa basin.

Figure No. 2 is an attempt to show the thickness distribution of the Supai formation in northeastern Arizona. In the area just south of the San Juan River all of the Cutler formation below the DeChelly sandstone has been considered Supai for all practical purposes. The figure demonstrates the basining around the Holbrook area which contrasts with the formational thinning onto the Defiance and Mogollon Rim areas to the east and south respectively. The configuration of the zone of significant evaporite accumulation is not known to the north along the flank of the Defiance. Recent mapping in the Mogollon Rim to the south has disclosed only minor beds of gypsum occurring near the top of the formation.

The control point just southeast of Kaibito in the north-central part of the area (fig. 2) is based on a log of a test hole drilled by the Sinclair Oil Company in 1952. The log suggests that the interval between the top of the Rico formation and the bottom of the DeChelly is only 580 feet thick. This is the thinnest Supai (Organ Rock tongue of the Cutler fm.) in the area and creates the need for representing a northwest-southeast zone of thinned Supai that trends toward the Black Mesa basin.

Evidently the paleogeographic framework that controlled the Supai formation was initiated during the Pennsylvanian and continued into the Permian period. The floor of the deepening Pennsylvanian-Permian Supai basin must have been sinking more rapidly than the previously existing Defiance positive area and the area along the present Mogollon Rim.

Cutler formation

As indicated in the legend of figures 1-4, the Cutler formation of the Monument Valley area is composed of five members. Although Baker and Reeside (1929) believe that the Permian section in Monument Valley contrasts markedly with the Grand Canyon section, the writer suggests that except for the absence of the Kaibab formation and the insertion by them of the Hoskininni tongue at the top of the section, the stratigraphic sequences of the two disconnected provices have much in common (fig. 1). The Cedar Mesa sandstone member of the Cutler formation passes laterally into red beds to the southeast, south, and probably southwest as this sandstone was not recognized in the Sinclair test hole previously mentioned. The Organ Rock and Halgaito red bed tongues thus coalesce to form a sedimentary sequence that cannot be readily differentiated from the Supai formation of the Black Mesa basin area. Baker and Reeside (1929) as well as Baker (1936) and Baker and Williams (1940) all picture the Cedar Mesa and DeChelly sandstones as merging westward to form the Coconino sandstone. McKee (1933) is not in agreement with this concept and the present writer is in agreement with McKee's views. It seems highly unlikely that the 57 feet of Coconino sandstone near Lee's Ferry represents the 1300 feet of section from the top of the DeChelly sandstone to the bottom of the Cedar Mesa sandstone as shown in the Texas Company Hoskininni Mesa oil test in western Monument Valley (fig. 1).

Coconino-DeChelly sandstones

The Coconino sandstone of the Grand Canyon-Mogollon Plateau regions and the DeChelly sandstone of the Defiance Plateau and Monument Valley areas everywhere

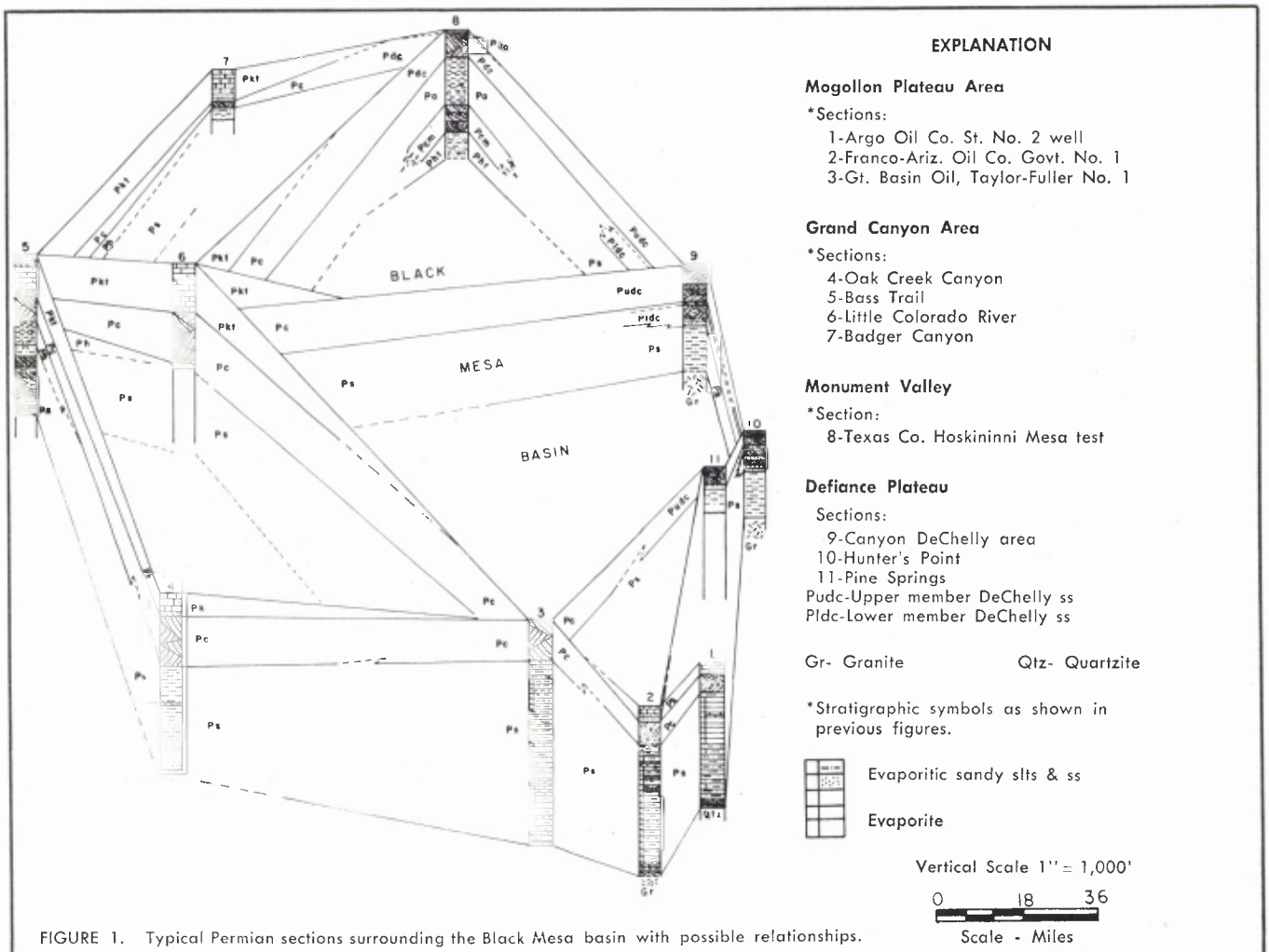

FIGURE 1. Typical Permian sections surrounding the Black Mesa basin with possible relationships.

overlie, so far as is known, red sedimentary rocks. The Coconino has been studied over a wide area by McKee (1933). McKee (1934) spent a few days working on the DeChelly sandstone of part of the Defiance Plateau, particularly at the type section in Canyon DeChelly. Geologists who have worked in the areas of outcrop of these sandstones have expressed differing opinions as to the relationship between them. Gregory (1917) named the DeChelly but did not attempt to make a correlation to the west. Darton (1925) mapped the sandstones on the Defiance Plateau as Coconino and in his text he states:

> "The sandstone (Coconino) is uplifted and exposed over a considerable area extending from near Winslow to Holbrook and into the Defiance uplift in the central and northern part of Apache County where there cannot be the slightest doubt as to its identity."

Baker and Reeside (1929) refer this sandstone back to the DeChelly suggesting that correlation with the Grand Canyon Coconino could not be definitely established. McKee (1934) expressed the view that both a DeChelly and a Coconino sandstone were recognizable and that the Coconino sandstone graded laterally northward into the upper part of the DeChelly sandstone. Read (1951) suggested that the sandstones exposed on the south and east portion of the Defiance Plateau might well be called the Glorieta sandstone of the San Andres formation as seen in the Zuni area of New Mexico.

Unequivocal solutions to problems of this sort are difficult to establish when stratigraphic relationships cannot be traced and key beds such as the Kaibab-San Andres limestone are absent in all known exposed outcrops in the Defiance area. Correlation in such cases must be based on relative stratigraphic sequence, lithologic details, and in this case particularly, the characteristics that may or may not reflect similarities in environments of deposition.

A critical analysis of these features has not been published for all of the DeChelly sandstone as it is presently defined in the Defiance Plateau and Monument Valley areas. The writer is not aware of a detailed analysis of the Glorieta sandstone that compares with the studies that have been made of the Coconino sandstone. Until some of the details are obtained correlation will largely be made from red-bed to red-bed and from sandstone to sandstone.

The writer has had the opportunity to visit many of the outcrops of DeChelly sandstone in both the Defiance Plateau and Monument Valley regions. Regarding the DeChelly sandstone it can be said that: (1) the sandstone pinches out northward near the San Juan River in Utah and that, in the opinion of the writer, pinch out is due largely to non-deposition and erosion in contrast to lateral gradation into red beds, (2) that the interval of the Defiance Plateau now called DeChelly sandstone is made up of units deposited in differing environments, (3) that the DeChelly thins to the south from near 800 feet at the

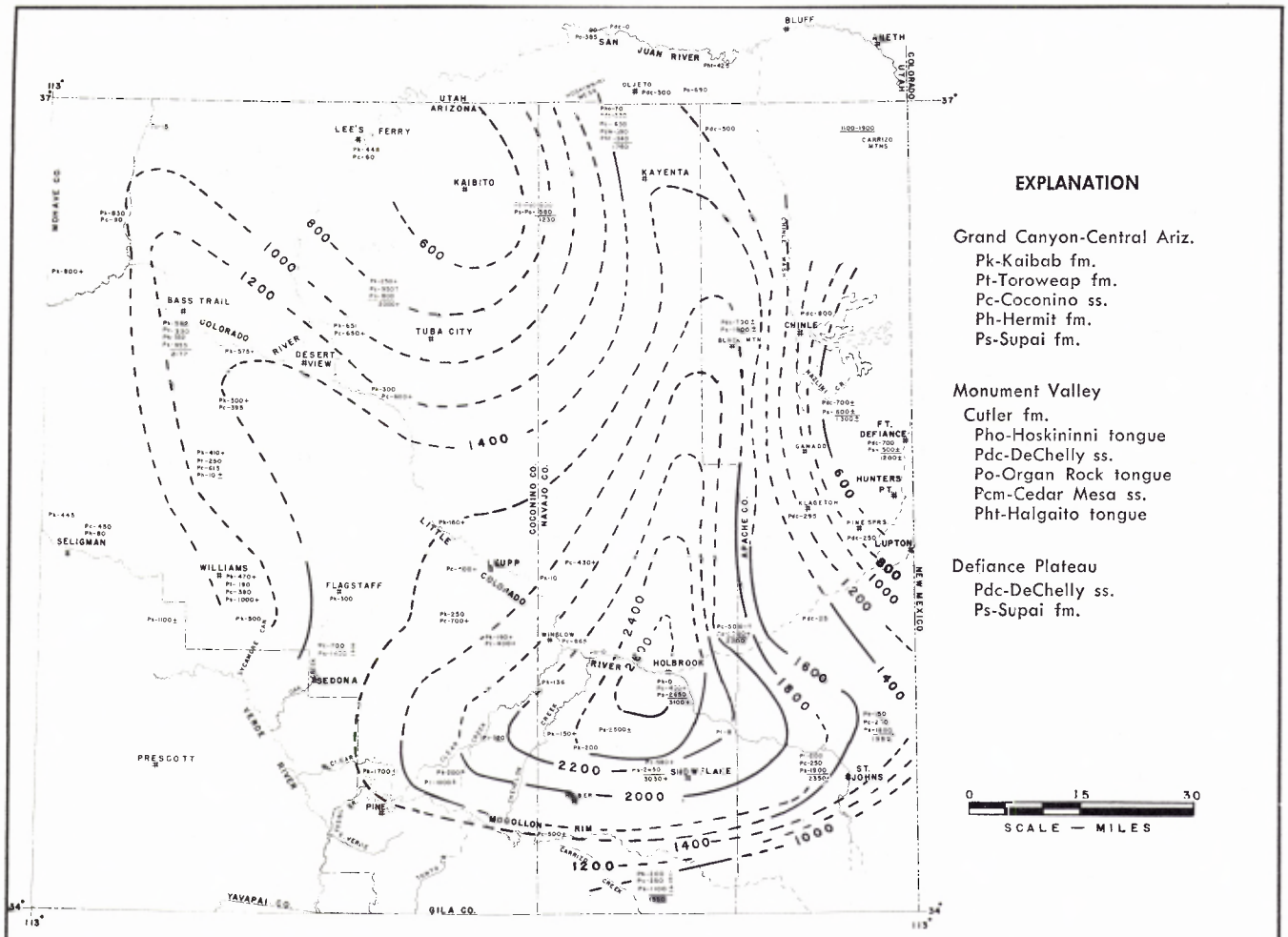

FIGURE 2. Thickness distribution of the Supai formation.

type section in Canyon DeChelly to near 300 feet at Pine Springs with reason to suspect further thinning to the south, (4) that this thinning is due (a) to a loss of the lower member by rapid lateral change to Supai lithology a few miles south of Hunters' Point between Oak Springs and Black Creek Canyon, and (b) to thinning of the upper member from near 500 feet at Canyon DeChelly to near 300 feet in the Pine Springs area. The manner of the thinning of the upper member is not clear and is complicated by the fact that the lithologic and sedimentary structural characteristics over much of the east flank of the Defiance is not a replica of the upper member characteristics as seen in Canyon DeChelly. The conspicuous difference is the decided increase in the number and thickness of horizontally bedded sandstones and silty sandstones seen in sections on the eastern and southern sections of the Defiance Plateau. This is in contrast with an almost homogeneous development of large-scale cross-stratification as seen at Canyon DeChelly and at Nazlini Canyon south of Canyon DeChelly on the west flank of the Defiance uplift.

Four possibilities can be mentioned to account for the changing aspect in the upper member of the DeChelly sandstone: (1) that the large scale cross-stratified sandstones are intertonguing laterally with the Supai or equivalents, (2) that the large-scale cross-stratified sandstones are intertonguing laterally with some phase of the San Andres formation, (3) that the changed aspect is totally different from environments of deposition seen in the type section and might be altogether a phase of the San Andres formation, and (4) that the changing aspect is not related to either the Supai or San Andres formations but represents a changing environment laterally gradational into type section DeChelly sandstone.

The writer cannot readily choose between these possibilities. Of considerable potential significance is a lithologic log and samples from a water well on file at the Museum of Northern Arizona at Flagstaff. These data indicate that there is a few feet of limestone between the Moenkopi formation and the DeChelly sandstone at St. Michaels near the east flank of the Defiance uplift. The writer has looked at these samples and there is no doubt about the existence of limestone in the samples. It is gray, very dense and similar in general appearance to some of the limestones in the San Andres formation in the Zuni area in New Mexico and to one phase of the Kaibab limestone that is exposed south of Showlow. A limestone in this position has not been recorded elsewhere in the Defiance area. It seems likely that many of the peculiarities in the stratigraphy on the east flank of the Definance uplift may be related to the San Andres formation as partially suggested by Read (1951) when he considered some of the sandstones (Black Creek section) to be of Glorieta type. If the San Andres is represented then it

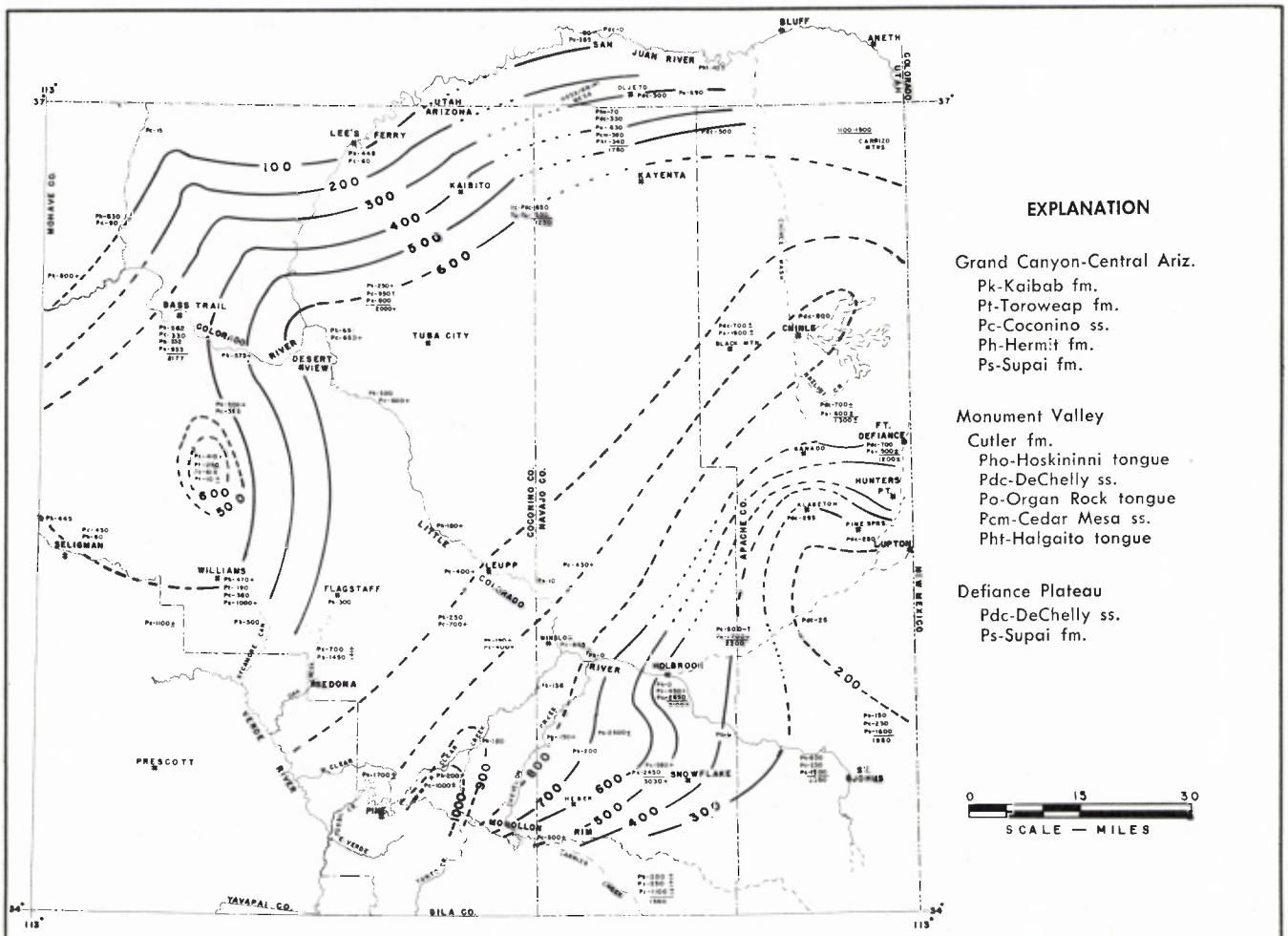

FIGURE 3. Thickness distribution of the Coconino-DeChelly sandstones.

overlies the DeChelly sandstone with unclear lateral relationship.

McKee (1934) suggested that the Coconino sandstone overlies the DeChelly sandstone on the western flank of the Defiance uplift and that it grades laterally into the DeChelly northward. The writer recognizes that this might be the case at some places but is not secure in the belief that it happens in outcrop on any part of the Defiance area. This problem involves many details the significance of which are hard to evaluate.

Figure 3 is an attempt to represent the thickness distribution of the Coconino and DeChelly sandstones. Significant features include: (1) north to northwest thinning of both sandstones, (2) southwestward thinning of both formations, and (3) a suggested belt of maximum sandstone development that trends northeast-southwest through the Black Mesa basin. The overall form is suggestive of a basin of deposition plunging to the southwest. The thickness trends in the northern part of the area on either side of the dotted zone strongly indicate an intimate relationship between the DeChelly sandstone of the Monument Valley area and the Coconino sandstone of the Grand Canyon province. Such a relationship is not so easily indicated in the southeastern part of the region. It is in the latter locality that the problems concerning the Coconino-DeChelly-Glorieta sandstones become most critical. Data to be used in unraveling the picture must be supplied through study of well samples coupled with a knowledge of outcrop characteristics in Arizona and New Mexico.

Kaibab-Toroweap formations

The name Kaibab limestone, as officially recognized today, was designated by Darton (1910). As this sequence of rocks contains a considerable proportion of fine grained sandstone and siltstone, it is suggested that the name Kaibab formation would be appropriate. In the discussion that follows, the Kaibab-Toroweap interval will be referred to only as Kaibab formation. The Kaibab-Toroweap formations have been thoroughly reviewed by McKee (1938). Although the Kaibab formation is probably not an important unit in the Black Mesa basin proper, it is included here for the sake of completeness.

Figure 4 represents the thickness distribution of the Kaibab formation. The suggested pinch out trend is oriented in a north-south direction until it changes to east-west near Holbrook, and heads towards New Mexico. Although workers have correlated the Kaibab formation and the limestone of the San Andres formation on a faunal basis, the actual connection is not traceable in outcrop. The Kaibab of the Mogollon Rim region contains much sandstone interbedded with limestone of varying degrees of purity as well as more or less sandstone at the base overlying the Coconino sandstone. Samples of Kaibab and

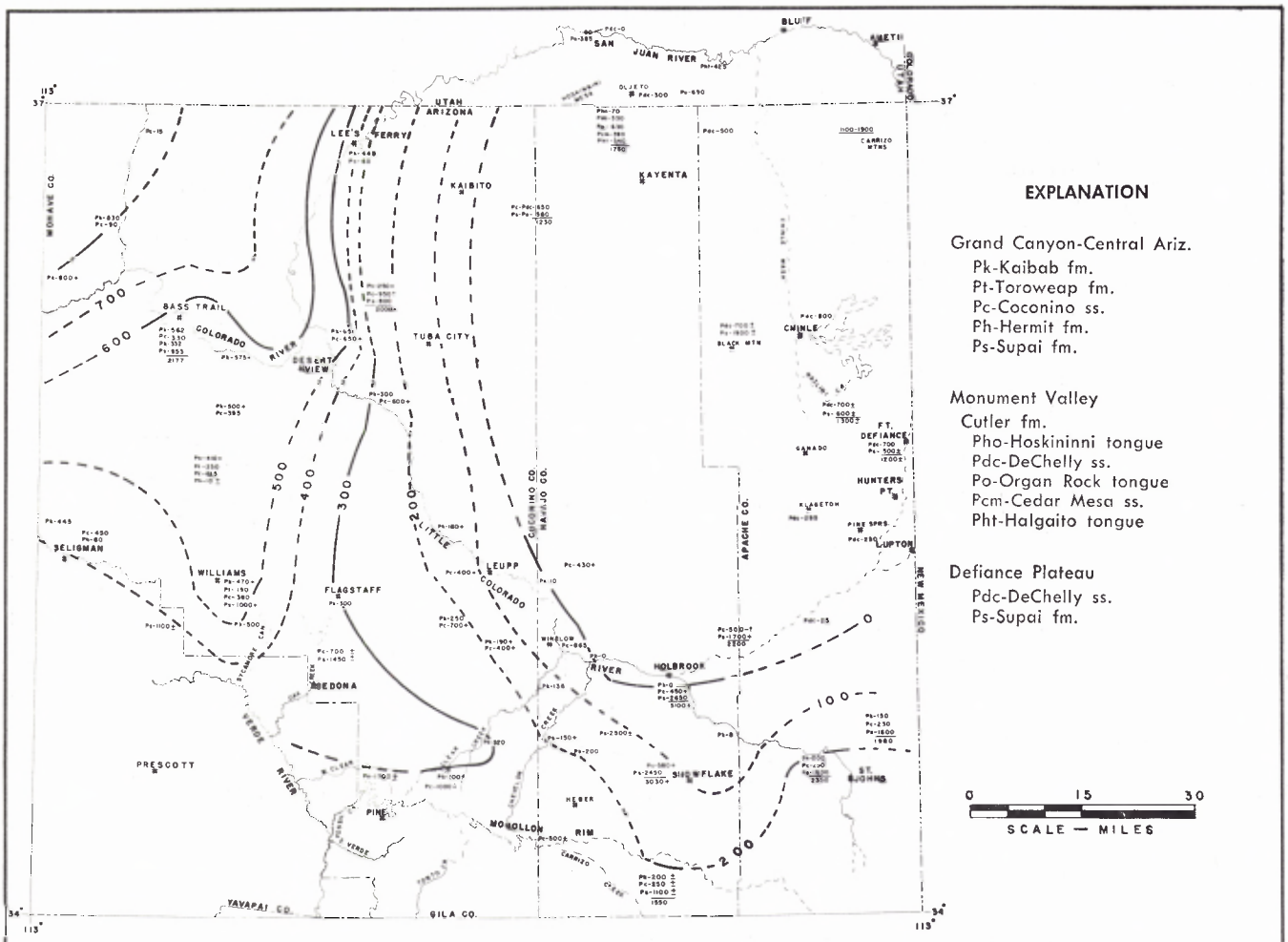

FIGURE 4. Thickness distribution of the Kaibab-Toroweap formations.

Coconino sandstone are alike in hand specimen and in drill cuttings. Sandstone belonging to the basal Kaibab formation encountered in drill holes is likely to be considered as Coconino sandstone. The situation is unavoidable but should be recognized. The development of sandstone in the San Andres formation of the Zuni area might be similar to the development in the Kaibab formation. A reasonable question might be whether or not any of the sandstones in the southern and eastern portions of the Defiance Plateau are marine sandstones without the diagnostic interbedded marine limestones. Such a possibility is tenable, and, if such were the case, then the pinch out line representing the maximum advance of the Kaibab sea would encroach upon the Defiance area. Read (1951) suggests that the Glorieta sandstone in the Defiance area represents migrating beaches and bars, which supports the idea that the Permian seas may have more or less covered the Defiance area. The possibility increases when it is remembered that erosion has removed some of the Permian strata below the Triassic formations.

Total Permian

Figure 5 is a summary of the thickness distribution of Permian sedimentary rocks in northeastern Arizona. It is not strictly a representation of only the Permian because Permian type lithology evidently extends into the Pennsylvanian period. Available statistics are based largely on lithology, not time. As known total Permian thicknesses are sparsely distributed, much of the control was used from a summation of the previous figures representing the individual Permian formations. Such a procedure is not desirable but seemed necessary in this instance.

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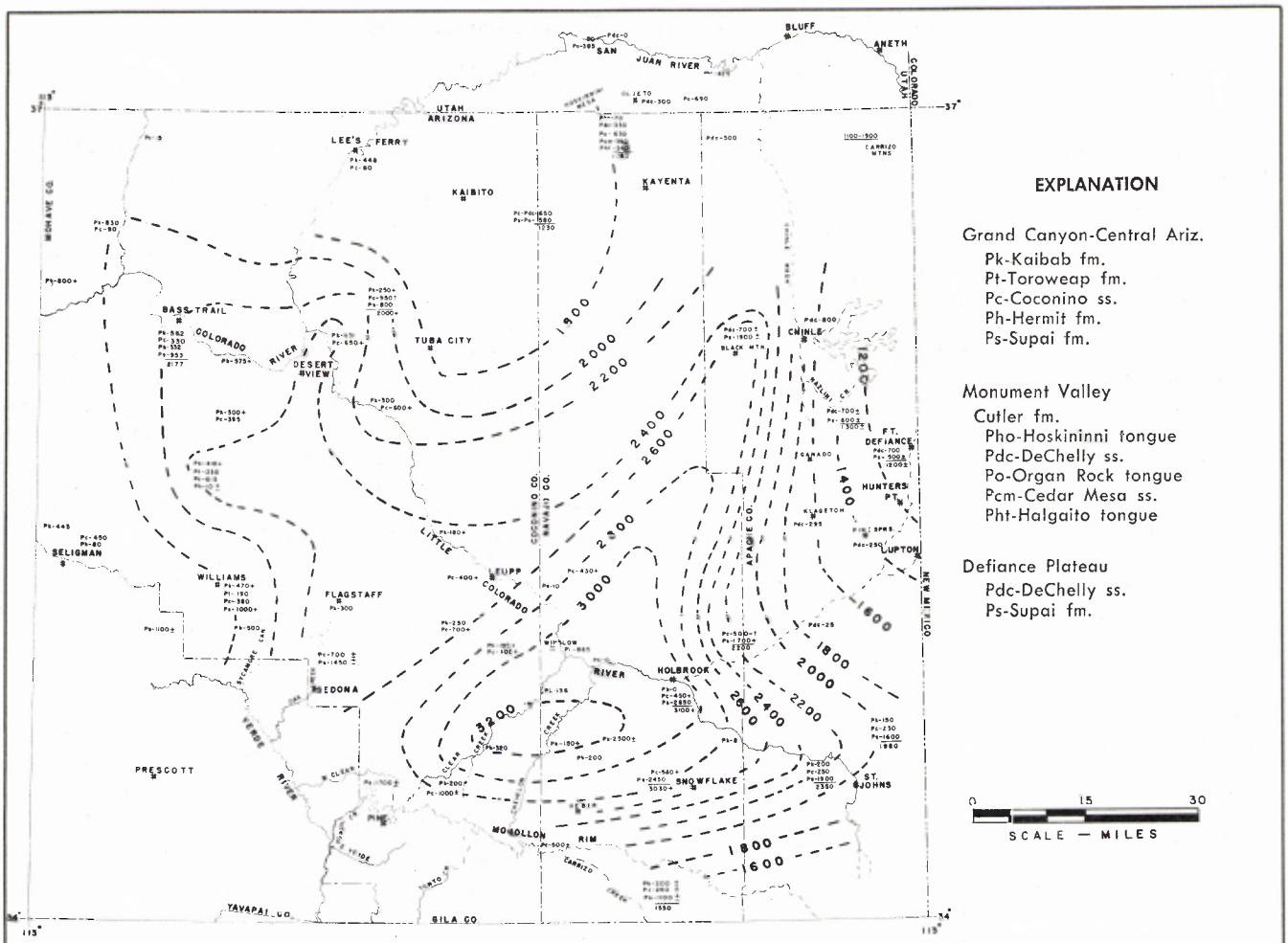

FIGURE 5. Thickness distribution of Permian sedimentary rocks.

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