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1962, pp. 123-128. https://doi.org/10.56577/FFC-13.123

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

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GEOLOGY ALONG THE DIAMOND RIM AND ADJOINING AREAS GILA AND NAVAJO COUNTIES, ARIZONA

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INTRODUCTION

The Diamond Rim, a fault scarp that forms a border or step-like morphological feature along the southern edge of the Mogollon Rim, is a major topographic feature located approximately 8 miles northeast of Payson, Gila County, Arizona. This rim is one of a group of lesser escarpments that have been created by faulting that parallels the trend of the Mogollon Rim in Gila and Navajo Counties. Its geological importance lies in the fact that it is the product of a major fault of variable displacement, usually on the order of 1000 feet, that dropped a series of blocks south of the Colorado Plateau and facilitated development of the present topography along a portion of the Mogollon Rim.

The break that separates the Mogollon Rim from the central mountains of Arizona is not everywhere as strikingly developed as along the Diamond Rim. Consequently, studies of the break contribute to interpretations of the origin of the Plateau and its relationship to the Basin and Range Province in Arizona.

ACKNOWLEDGMENTS

Field work upon which this report is based consisted of approximately two weeks of reconnaissance mapping, and an additional week of areal reconnaissance, in the Payson and Christopher Mountain areas during 1961 and 1962. Mr. Charles A. Ratte assisted in the field. A portion of the field work was supported by United Electrodynamics of Pasadena, California whose assistance is gratefully acknowledged.

In the preparation of this paper, the author has drawn freely from other sources of information, particularly the publications of Huddle and Dobrovolny (1952), Shride (1961), Wilson (1939) and the County Geologic Map series of Arizona, published by the Arizona Bureau of Mines. I would also like to acknowledge many helpful discussions on regional geology with Dr. Eldred Wilson, Professor John Lance, and Mr. H. W. Peirce, all of Tucson. They are not to be held responsible, however, for the interpretations and hypotheses which have been presented to account for many of the geologic features in the area.

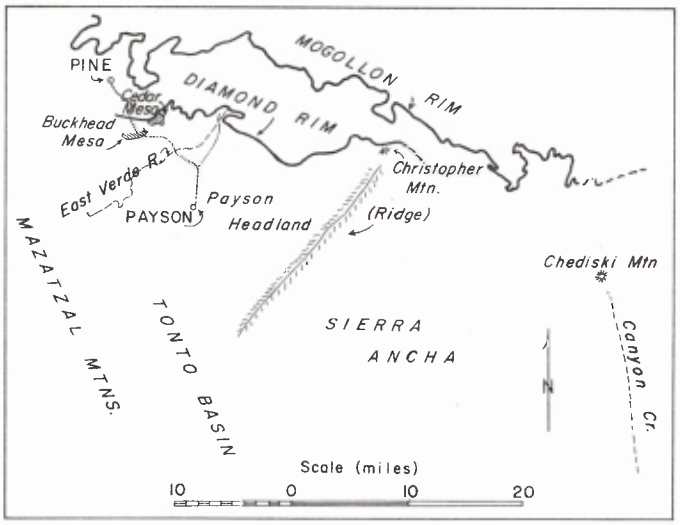

Figure 1.—Index map of geologic and geographic features.

REGIONAL SETTING

The Diamond Rim lies in central Arizona a few miles north of Payson, in what has been termed by Ransome (1923), the Mountain Region of Arizona. This area is transitional in many respects, particularly in topography, elevation, climate, and geology, between the Basin and Range Province to the south, and the Colorado Plateau to the north. Maximum relief in the vicinity of the Diamond Rim is around 1500 feet, with higher elevations in the north and west part of the region. The average relief of the Rim is around 400 feet with relief increasing to the west.

Topography in the area is dominated by the scarp forms of the Diamond and Mogollon Rims, but geomorphology more closely approximates that of the Plateau than that of the basin-and-range forms to the south. South of the Diamond Rim, the land forms are characterized by relatively flat, extensive mesas capped by resistant sandstones or basalt. However, closer to Diamond Rim somewhat more rugged forms have developed locally from tilted fault blocks. The rock units present have been dissected by south-flowing drainage that, in places, has developed relief in excess of 200 feet. North of the Diamond Rim, elevations rise rapidly, some 2000 feet over a distance of seven miles, to the summit of the Mogollon Rim.

Access to most of the area is limited to poor jeep roads and trails, except for the road from Payson to Taylor Ranch, and Washington Park that crosses the fault near the East Verde River. West of the river, the highway from Payson to Pine crosses the western extension of the fault near Buckhead Mesa.

Along the foot of the Diamond Rim, vegetation is heavy and, at places, almost impenetrable. Dominant types are manzanita, scrub oak, cat claw, and juniper. Pinyon and Ponderosa pine are present but not abundant. These floral characteristics persist over much of the length of faulting south of the Mogollon Rim in Gila and Navajo Counties. At higher elevations on the Rim, conifers are predominant.

GEOLOGIC SETTING

The Payson region lies below the Mogollon Rim at the north end of the Tonto Basin and, except for the blocks dropped from the Mogollon Rim, and the valley fill to the south, lies in an area of extensive outcrop of Older Precambrian rocks. To the southeast, the Sierra Ancha contains extensive exposures of relatively flat-lying Younger Precambrian sedimentary rocks. Southwest of Payson,

the Older Precambrian sedimentary and volcanic rocks of the Mazatzal Mountains dominate the west side of Tonto Basin, and are abruptly cut off at their north end, west of Payson, by younger volcanic units. It is in this setting, between the Paleozoic-capped Mogollon Rim to the north and the older basement rocks to the south, that the Diamond Rim and its associated fault blocks is interposed between Plateau and Basin and Range geology and geomorphology.

STRATIGRAPHY OF THE PAYSON AREA

General Statement

Middle Cambrian, Devonian, and Mississippian sedimentary rocks nonconformably overlie Precambrian granite in the area in which the Diamond Rim fault was mapped. This region is herein referred to as the Payson Headland.* Much of this region is covered by a thin veneer of alluvial deposits, most of which are of Recent age, but some of which may be as old as Tertiary. The Apache Group, sedimentary rocks of Younger Precambrian age, is missing near Payson although formations of the Group are extensively exposed in the Sierra Ancha to the south. The reason for this absence may in part be due to Precambrian erosion of the Apache Group, or, as Lance (1958) has indicated, non-deposition of these sediments because of the presence of a positive area in central Arizona. Shride (1961) has noted a lapping out of lower members of the Apache Group north and northwest of the Sierra Ancha, and has also suggested removal of considerable thicknesses of Younger Precambrian rocks by erosion. East of Payson, in the Diamond Butte area, Gastil (1958) has defined a sequence of pre-Apache metasedimentary and volcanic rocks of northeast trend that appear to have influenced the deposition of certain formations of the Apache Group. Shride suggested that the Apache Group was undoubtedly present northwest of this part of the Sierra Ancha — probably near Payson.

The inferred presence of an early Paleozoic positive area, first suggested by Schuchert (1910), and further defined by Stoyanow (1936, 1942), also may have influenced geologic events in central Arizona. The Payson region lies at the northwestern flank of this positive area, known as Mazatzal Land. This spur represents a southward extension of the Holbrook granitic ridge, and is separated from it by what Huddle and Dobrovolny (1952) have termed the Mogollon Sag. Mazatzal Land may have included much of the present Sierra Ancha, and may have been positive during part of Devonian time. The presence of some Devonian(?) sediments at Aztec Peak in the Sierra Ancha, however, and the inferred deposition of Devonian sediments upon the Apache Group in the Sierra Ancha (Shride, 1961), leaves the existence of Mazatzal Land open to question in this area.

A brief description of the rocks present in the Payson area is presented below.

Older Precambrian Granite

The Precambrian granite is predominantly a medium-grained, equigranular rock with typical plutonic igneous rock texture. It is composed of pink orthoclase, feldspar, clear, vitreous quartz, some hornblende, and magnetite. The rock is largely a pinkish color, although many color variations may be observed. Numerous dark green to black diabase dikes cut the granite, but nowhere is there any indication that these dikes, referred here to the Precambrian, cut younger rocks.

Along the Diamond Rim Fault and subsidiary breaks, the granite is commonly altered (probably chloritized) to a dark green sheared rock. Crushed and brecciated quartz veins and stringers are also common in areas of sheared granite.

The granite appears to weather readily to a crumbly mixture of brown sand and pea-sized pebbles of feldspar and quartz. This material is easily eroded and covers the banks and fills the channels of most of the washes over a great portion of the area.

Wilson (1939) suggested correlation of this granite, believed to be of post-Mazatzal pre-Apache age, with the Bradshaw granite of the Bradshaw Mountains, and with the Ruin granite of the Globe district.

Middle Cambrian Tapeats Sandstone

The Tapeats sandstone is the oldest Paleozoic sedimentary formation in the Payson region. Its correlation with similar units at Jerome and at the Grand Canyon has been made on the basis of lithology by Ransome (1916). It was deposited on an old erosion surface on the granite. As a consequence of the present erosion cycle, it forms resistant caps on the lower mesas and the lower cliffs along the Diamond Rim. In the vicinity of Payson, its thickness may range as great as 60 feet, and, near the East Verde River, down to about 40 feet. The unit weathers buff to brown; on fresh surfaces it is reddish brown to buff. In its basal parts, the Tapeats appears to reflect the composition of the underlying granite, and in some locations is difficult to distinguish from the older basement rock. Relief on the granite surface was very slight, and the granite was apparently deeply weathered prior to deposition of the Tapeats. The basal portion is conglomeratic, with pebbles of ¼ to ½ inch diameter predominant. Commonly this basal unit exhibits crude cross-bedding and grades laterally into a coarse arkose.

Above the conglomeratic basal zone, which may range from a few to 10 feet in thickness, the Tapeats retains its cross-bedded nature, but becomes less conglomeratic and more even grained. Beds become increasingly silty upward and, in its upper part, the Tapeats consists of shaly sandstones of maroon, grey, and green hues, all of which exhibit slabby weathering characteristics.

Near Christopher Mountain and Kohl's Ranch, some 12 miles east-northeast of Payson on the Mogollon Rim, the Tapeats Sandstone dies out as a unit. On the other side of Christopher Mountain, that is, to the east, it is missing entirely and the quartzites of the Troy Formation make up the pre-Devonian surface. Inasmuch as Shride (1961) has established the age of the Troy as Younger Precambrian, the suggestion by Huddle and Dobrovolny (1952) that the Troy and Tapeats may be continuous beneath the Paleozoic overlap at Christopher Mountain does not now seem valid.

Upper Devonian Martin Formation

A complete description of the Martin Formation in central Arizona has been outlined by Huddle and Dobrovolny (1952), and the discussion that follows is a summation of the relevant points of their description, supplemented by personal observations.

The lower portion of this formation near Payson is a

*The Payson Headland was defined by Stoyanow (1942, p. 1268) as the basal platform of the Payson area. It is used in the present paper in a geographic sense to include the area lying between Christopher Ridge, the Diamond Rim, and the Tonto Basin.

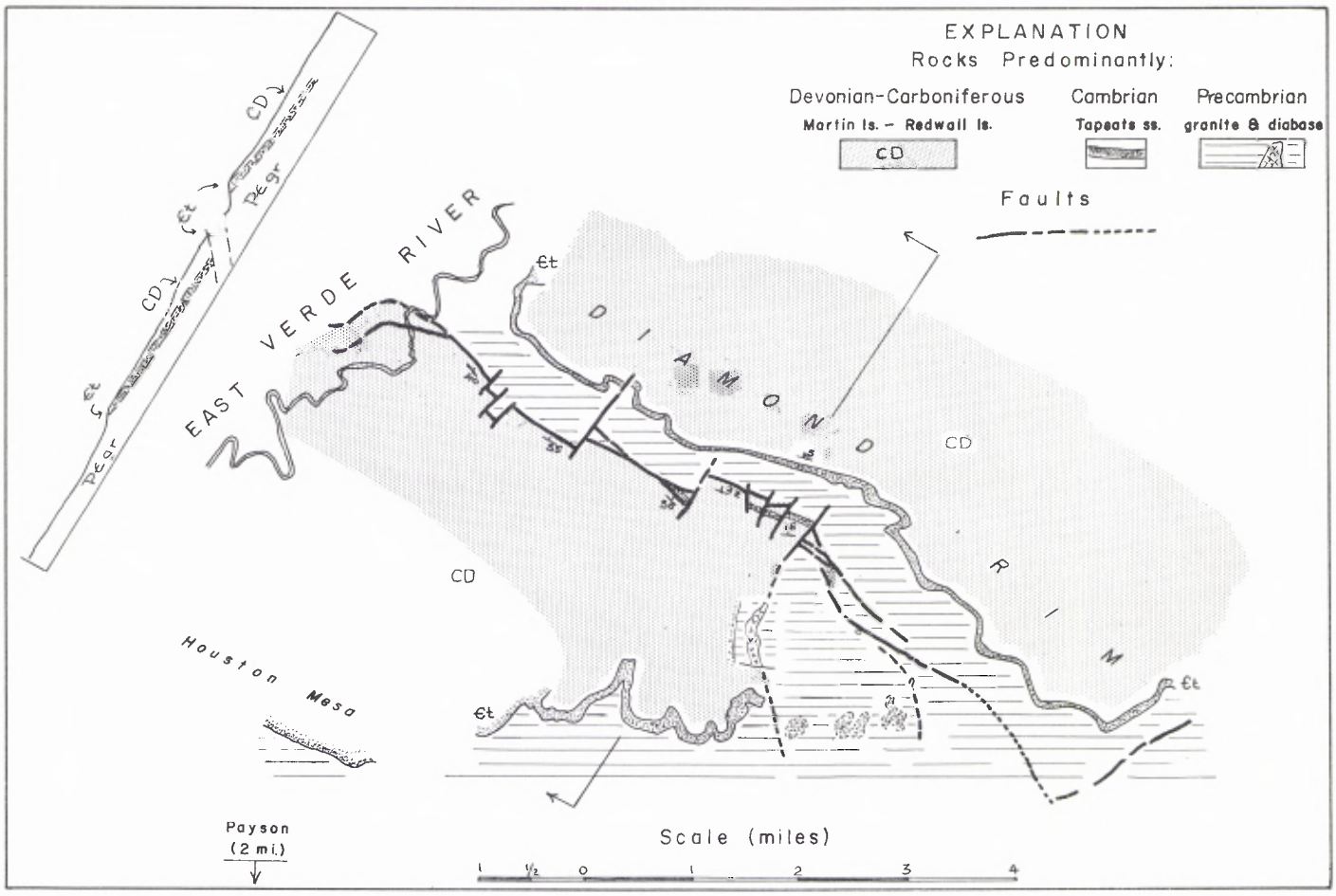

Figure 2. Geologic map along the Diamond Rim Fault, Gila County, Arizona.

grey, thinly-laminated sandy limestone that lies upon the Tapeats sandstone in unconformable contact. Above this sandy limestone is a thick zone of blue-grey limestone containing large nodules and bands of chert, jasper, and agate. The upper part is a grey limestone with lenses and streaks of maroon shaly limestone.

The thickness of the Martin formation in the vicinity of the East Verde River is recorded by Huddle and Dobrovolny (1952) as approximately 380 feet, and by Peirce (1955) as 500 feet. Peirce claims that the section in this area has been shortened by faulting. The thickest exposed section of the Martin formation near Payson probably lies in a small compressed syncline just south of the Diamond Rim Fault.

Lower Mississippian Redwall Limestone

Huddle and Dobrovolny have outlined the characteristics of the Redwall limestone, and the reader is referred to that paper for additional information. Only the middle portion of the Redwall limestone is exposed near the Diamond Rim; its lower portion was faulted below the surface, and its upper parts removed by erosion. However, a complete section can be put together in the Payson region from several exposures. East of the river, exposures are of typically thin (one to two feet thick) beds of maroon shale and sandy shale overlain by maroon, grey, and grey-green mottled limestone. The limestone appears to be brecciated and is pocked with numerous small solution cavities. This portion of the section corresponds very closely to the middle portion of the Redwall limestone described by Huddle and Dobrovolny (1950) as ". . . a rubble breccia of large, angular to rounded limestone blocks and angular chert blocks separated by thin seams of red sandy mudstone (pl. 20). The limestone blocks are stained green or red near their edges."

Thickness of the Redwall limestone at the East Verde River has been given as 67 feet (Huddle and Dobrovolny, 1952), and as 75 feet by Peirce (1955). This thinning, from typical thicknesses on the order of several hundred feet, has been interpreted by Huddle and Dobrovolny as the result of renewed uplift of Mazatzal Land during pre-Pennsylvanian time with subsequent erosion of the Mississippian unit.

Tertiary Sands and Gravels

Moderately consolidated alluvium of possible Tertiary age is present in the banks of some stream cuts, and is exposed along the highway from Payson to Pine and the road from Payson to Taylor's Ranch. The sediments are roughly laminated, coarse sands and gravel conglomerates containing angular to sub-rounded particles of granite, sandstone, and limestone of local derivation. Age of these units is not known, but they predate some of the major movement along faults in the area. Age of Tertiary

units in the Tonto Basin to the south has been considered Lower and Middle Pliocene by Lance (1960), but the lithology of these dated units is completely dissimilar to the conglomerates near Payson.

Recent Sands and Gravels

Most of the hill tops, slopes and stream beds are covered by Recent sands and gravels. These are composed entirely of unconsolidated material, except where they have been strongly cemented by caliche, and usually contain large boulders of sandstone, limestone and chert; granite boulders and pebbles are usually confined to the lower slopes and stream beds. Much of the material is residual soil, or float not far removed from bedrock. The material on the slopes is deeply weathered talus, and varies from a few inches up to at least several tens of feet in thickness.

DIAMOND RIM FAULT

General Statement

The Diamond Rim Fault is a complex structure (Fig. 2). There is a single break along which most of the vertical offset between the Diamond Rim and the lowlands to the south has taken place. In some locations this single break is complemented by closely spaced parallel breaks. Further complicating the structural picture are a series of north- to northeast-trending faults that offset the major fault so that continuity of the trace is broken. The resulting pattern is that of a fault mosaic. While these northerly-trending faults are obvious along the course of the main fault, they are less so to the south where their trace is obscured by the similarity of the Paleozoic carbonate rocks.

Actual exposures of the main fault are few, but its course can be followed closely by the character of the outcrop. East of Payson, around Diamond Point, outcrops of sedimentary rocks are non-existent on the downthrown block but the fault trace can be followed as a zone of shearing in the granite.

Character and Displacement

Generally speaking, the major fault is of normal character. At one locality or another, or at different times, portions of it may have undergone slight reverse movement. As shown on the section of Fig. 2, some Toreva blocks are present. The trace of the fault suggests that it is quite steep or nearly vertical — local steep dips to the south and southeast are indicated. Evidence suggesting gross lateral movement is lacking, although comparisons of rock units on the Diamond Rim with equivalent units in the down-dropped block indicate that there may have been a slight westward component of movement of the south block.

Displacement along the fault is variable, but appears to increase westward. Although it is possible that some hinge movement may account for this, field evidence suggests that increased displacement took place from block to block, each block having moved separately. At the east end of the area shown on Fig. 2, the displacement is on the order of 1000 feet or less, while at the East Verde River, the displacement is about 1500 feet.

Age of Faulting

No evidence of recent movement along the fault zone was observed. It is quite likely that recurrent movement has taken place along the fault zone since the Mogollon Rim structures developed, and Feth (1954) citing the work of Heck suggests, in view of earthquake data, that the area is still active to some degree. In the Cedar Mesa area, along the highway from Payson to Pine, the Diamond Rim Fault cuts Tertiary sediments that are overlain by unbroken Quaternary(?) basalt. A similar relationship can be seen along the highway from Payson to Pine, south of the Cedar Mesa locality above, where Tertiary sediments have been faulted into contact with Martin and Redwall limestones. In view of the block-like nature of the hanging wall, it would seem reasonable to expect local readjustment in separate blocks.

DISCUSSION

Tectonics

The Diamond Rim and the Payson Headland lie in an area that has been a focal point of significant geologic events over a long span of earth history. Many of these aspects have been discussed previously, but in summary it should be noted that the oldest dated event is the intrusion of a granitic pluton during the Mazatzal Revolution. During post-Mazatzal time, the area was apparently high north of the basin which received earliest Apache Group sediments, as indicated by the fact that the basal conglomerate of the Apache Group rises in the section from the Sierra Ancha northward, and that the upper units of the Apache Group are progressively beveled by the unconformity at the base of the Troy Quartzite (Shride, as cited by Lance, 1958). Continued influence of this high is indicated for Cambrian time when the region was apparently a shelf, protected on its eastern end by the Christopher Mountain Ridge and to the southeast by the Sierra Ancha. An alternative possibility is that the Payson Headland area remained a basin while the Christopher Mountain Ridge and the Sierra Ancha were elevated, permitting erosion and removal of the Cambrian sand prior to deposition of Devonian and Mississippian sedimentary units. Darton (1925), citing the work of Ransome and Wilson, noted that the Tapeats abuts older quartzite near Pine, suggesting a basin edge. In view of the eastward thinning of the Tapeats at Grand Canyon (McKee, 1945) and the possibility that the Payson region may have represented a basin edge (Stoyanow, 1942), the hypothesis of subsequent erosion does not seem as likely as the hypothesis of non-deposition. The data are too few, however, to permit definite conclusions at this time.

During later Paleozoic time, deposition of sediments continued to be influenced to some degree by a positive area in central Arizona, although there is some controversy concerning its exact nature. Huddle and Dobrovolny have shown Stoyanow's Mazatzal Land, and noted the relationship of Devonian-Mississippian sedimentation to three resistant prongs in the Pine-Chediski Mountain area. Their interpretation of a Mogollon Sag to explain features of mid-Paleozoic sedimentation again places the region in an area of geological transition and crustal activity. The Diamond Rim Fault nearly parallels a line from Pine to Christopher Mountain, and sedimentation on the Payson Headland lies between the Pine and Christopher Mountain Ridges of Mazatzal Land. Further, the eastward extension of the Diamond Rim Fault nearly parallels a line from Christopher Mountain to Chediski Mountain. Thus, the major fault line not only separates two areas of modern geological contrast, but also marks an ancient boundary between areas of contrasting environment.

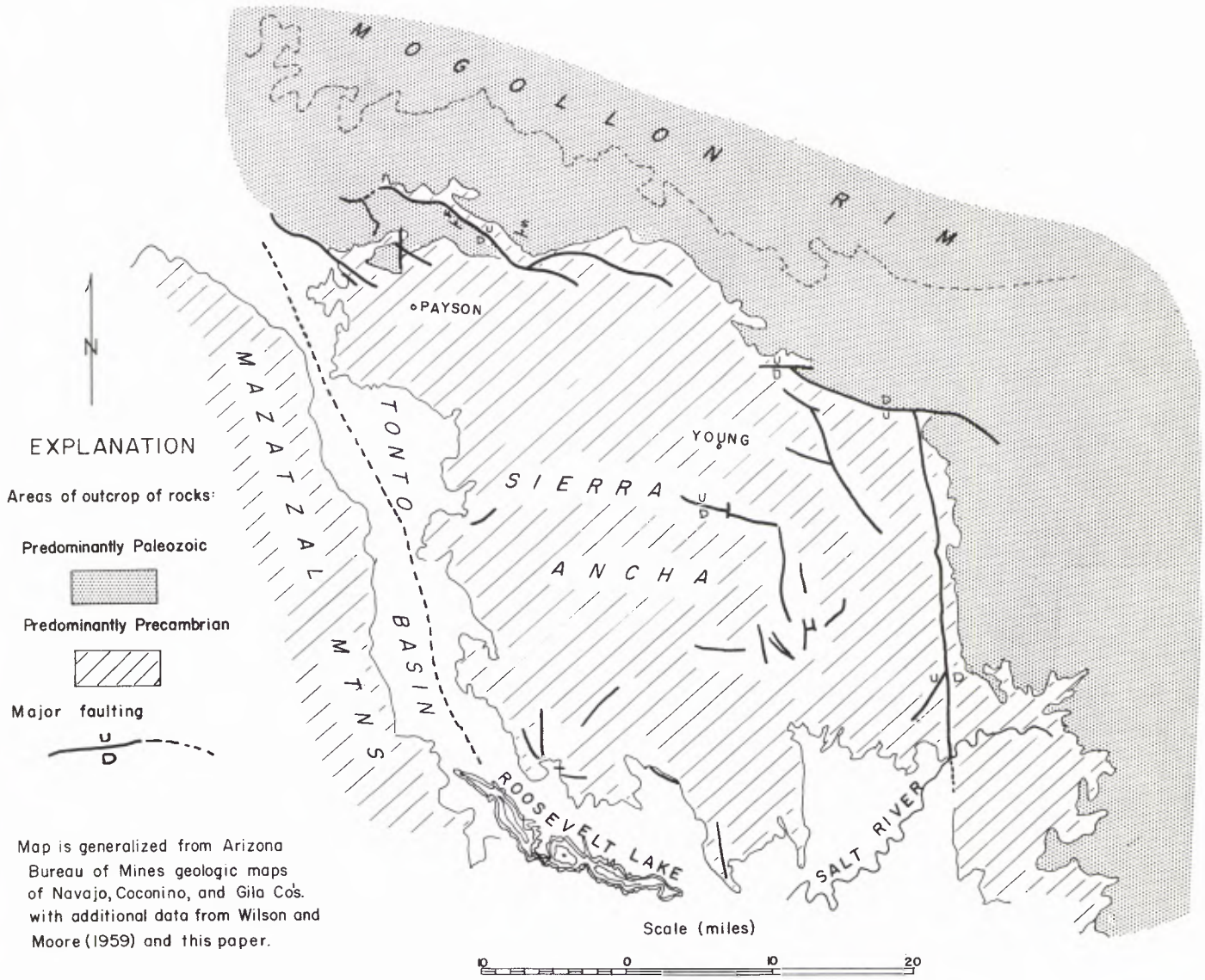

Figure 3. Generalized geologic map of the Mogollon Rim region in the vicinity of Payson and Young, Gila County, Arizona.

Fig. 3 shows the generalized distribution of rock assemblages in east-central Arizona along the Mogollon Rim. It should be noted that the Sierra Ancha form a reentrant in surface rocks that are dominantly Paleozoic to the north and east. Contacts along the reentrant are largely fault contacts that are well exposed north of the Sierra Ancha, and along the eastern border in Canyon Creek. Relative movements of these faults with respect to adjoining blocks, however, does not suggest a simple tectonic framework. The Pine-Payson block is down-dropped with respect to the Plateau, while the Sierra Ancha block stands structurally higher with respect to both the Paleozoic rocks to the east and the Pine-Payson block to the north. Despite the structural elevation of the Sierra Ancha block, it stands topographically lower than the Mogollon Rim.

Several alternatives should be considered in interpretations of faulting along this portion of the Mogollon Rim. The Paleozoic blocks on the down-dropped side of the Diamond Rim Fault have northerly dips considerably greater than corresponding units in place along the rim. Locally this steepening is the result of Toreva-block movement, but movement of this sort is indicated for only a few blocks. Dips are in the wrong direction to have been steepened by drag. A rotational origin would require downward movement of the northern edge of the Sierra Ancha block. Although tilting of the Sierra Ancha block might operate to produce the relative displacements observed, it is difficult to visualize uniform movement of a block of this size without its being further deformed in the process. Bedding on the Sierra Ancha is nearly horizontal, and there is no suggestion of any widespread northward regional dip.

An alternative mode of origin involves separate movement of the Payson block and the Sierra Ancha block. Increasing displacement of the Diamond Rim Fault to the west suggests that this old basin may have undergone renewed subsidence. However, there is no obvious break on the north end of the Sierra Ancha which would separate it from the Payson block. Such a break may be concealed

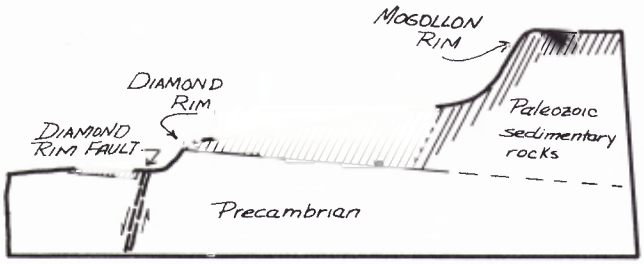

Figure 4.—Diagrammatic section looking west along the Diamond and Mogollon Rims.

in the granite, where recognition would be difficult, or it may flank one edge of Christopher Ridge. Gastil has shown a break along the rhyolite mass forming the ridge that trends northeast on the southeast side of the Payson Headland. He has interpreted it as an older break, but the suggestion is here advanced that this old break may have undergone renewed movement that has influenced the present structural pattern. In this case the Payson Headland is, structurally, a graben.

Which of these alternatives most closely approximates the actual situation is not known, and considerable additional field work will be necessary before the tectonics of the region will be understood.

Regardless of the ultimate solution, however, there is one important factor that deserves final emphasis. The Sierra Ancha block appears to have acted in the role of a solid buttress or rigid framework about which later tectonic events have taken place. The development of this portion of the Mogollon Rim is closely associated with, if not related to, the same major tectonic events that affected the Sierra Ancha and ancient Mazatzal Land. This block was elevated and probably provided a source of material that was transported northward onto the Plateau during Tertiary times. Erosion has been deep, but the more resistant Apache Group sediments have resisted attack.

In his discussion of the Mazatzal Revolution, Wilson (1939, p. 1134) stated that, "The Tertiary block faults, which are parallel to pre-Apache structural features, probably followed breaks or zones of weakness inherited from the Mazatzal Revolution." In view of the profound influences of the Sierra Ancha block and Christopher Ridge upon development of the Mogollon Rim, there is a good basis in this part of Arizona for substantiating such a concept.

Geomorphology

The Mogollon Rim north of Payson is a receding scarp that has developed by erosion back from Diamond Rim Fault. Hunt's (1956) view that faulting in the Basin and Range Province commenced in Oligocene time, and the Plateau developed as a structural unit by early Miocene time, would place a relatively early age on the initiation of faulting along the Diamond Rim. The possibility that the area is still structurally active is supported by relatively recent vulcanism and deformation on the Plateau (Hunt).

It seems reasonable to presume, nonetheless, that the present topography started to develop sometime during the Miocene with erosion along the fault scarp, and that it has been modified intermittently since then by renewed and continuing movement. At the present time, erosion has proceeded rimward from the fault, leaving a resequent fault line scarp along the Diamond Rim and a broad waning slope or pediment on lower Paleozoic rocks. Locally, the waning slope surface is made up of basalt. The slope has a variable width, but probably averages some six or seven miles between the Diamond Rim and the Mogollon Rim.

In their subdivision of the structural and physiographic regions of Arizona, Wilson and Moore (1959) recognized a zone intermediate between the Plateau and Basin and Range Provinces which they designated the Transition Zone. The distinctiveness of this intermediate zone was questioned by Heindl and Lance (1960), and they proposed a simple two-fold physiographic subdivision of Arizona that implies no transition between plateau and basin-and-range characteristics. The Sierra Ancha and Payson Headland were included with the Transition Zone by Wilson and Moore, and with the Colorado Plateau by Heindl and Lance. The results of the present study support the validity of the Transition Zone of Wilson and Moore. The characteristics for inclusion in the Plateau and the characteristics necessary for inclusion in the Basin and Range Province established by Heindl and Lance are both met to a degree in this portion of Arizona. The topography is essentially that of the Plateau in both the Payson Headland and the Sierra Ancha, yet the structure of the region is complex. It is suggested, therefore, that the region is transitional in character, and the need for such a physiographic subdivision, at least locally, is recognized. In this area, the Plateau boundary should be drawn along the Diamond Rim Fault and its extensions, and the southern limit of the Transition Zone should be drawn along the east and north-east sides of the Tonto Basin to include the Sierra Ancha.

REFERENCES CITED

Darton, N. H., 1925, A resume of Arizona geology: Univ. Arizona Bull. 119, Geol. Ser. No. 3.

Feth, J. H., 1954, Preliminary report of investigation of springs in the Mogollon Rim region, Arizona: U. S. Geol. Survey Open File Report.

Gastil, Gordon, 1958, Older Precambrian rocks of the Diamond Butte quadrangle, Gila County, Arizona: Geol. Soc. America Bull., v. 69, p. 1495-1514.

Heindl, L. A., and Lance, J. F., 1958, Topographic, physiographic, and structural subdivisions of Arizona: Arizona Geol. Soc. Digest, v. 3, p. 12-18.

Huddle, J. W., and Dobrovolny, Ernest, 1952, Devonian and Mississippian rocks of central Arizona: U. S. Geol. Survey Prof. Paper 233D.

Hunt, C. B., 1956, Cenozoic geology of the Colorado Plateau: U. S. Geol. Survey Prof. Paper 279.

Lance, J. F., 1958, Precambrian rocks of northern Arizona, in Guidebook of the Black Mesa Basin, northeastern Arizona: New Mexico Geol. Soc., 9th Field Conf., p. 67-70.

....., 1960, Stratigraphic and structural position of Cenozoic fossil localities in Arizona: Arizona Geol. Soc. Digest, v. 3, p. 155-159.

McKee, E. D., 1945, Cambrian history of the Grand Canyon region: Carnegie Inst. of Wash. Pub. 563, p. 3-168.

Peirce, H. W., and Peirce, F. L., 1955, A report on the Paleozoic stratigraphy across central Arizona: unpub. report.

Ransome, F. L., 1904, Description of the Globe quadrangle (Ariz.): U. S. Geol. Survey Geol. Atlas, Folio 111.

....., 1916, Some Paleozoic sections in central Arizona and their correlation: U. S. Geol. Survey Prof. Paper 98-K.

....., 1923, Description of the Ray quadrangle (Ariz.): U. S. Geol. Survey Geol. Atlas, Folio 217.

Schuchert, Charles, 1910, Paleogeography of North America: Geol. Soc. America Bull., v. 20, p. 427-606.

Shride, A. F., 1961, Some aspects of Younger Precambrian geology in southern Arizona: Univ. Arizona, unpub. Ph.D. thesis.

Stoyanow, A. A., 1936, Correlation of Arizona Paleozoic formations: Geol. Soc. America Bull., v. 47, p. 459-540.

....., 1942, Paleozoic Paleogeography of Arizona: Geol. Soc. America Bull., v. 53, p. 1255-1282.

Wilson, E. D., 1939, Precambrian Mazatzal Revolution in central Arizona: Geol. Soc. America Bull., v. 50, p. 1113-1164.

Wilson, E. D., and Moore, R. T., 1959, Structure of Basin and Range Province in Arizona: Arizona Geol. Soc. Guidebook 2, p. 89-105.