THE MARGARET WASH SECTION OF THE MOGUL FAULT,
PINAL COUNTY, ARIZONA

by

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A Thesis Submitted to the Faculty of the
DEPARTMENT OF GEOLOGY
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

1961
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ABSTRACT

The Mogul fault is a strand of the Texas lineament. The Margaret Wash section of the fault is 27 air-line miles north-northeast of Tucson near the north end of the Santa Catalina Mountains.

Attitudes were measured on bedding and foliation in a long narrow belt of Pinal schist which has been in part deformed by movements on the Mogul fault. At the east end of the belt the bedding strikes north-east and dips northwest, however, at the west end of the belt bedding and gneissic foliation strike west-northwest and dip south-southwest. The writer interprets the internal structure of the Pinal schist as reflecting left lateral strike slip in a fault zone which includes the west end of the schist belt but lies to the north of the east end. The age and amount of strike slip are unknown. Later normal faulting which is probably Cenozoic cuts obliquely (more northwest) across the strike
slip oriented schist. The normal fault dips steeply to the south and the maximum dip slip is probably a few hundred feet.
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INTRODUCTION

Baker (1934, p. 212) called the Texas lineament, "probably the greatest single structural line of the Western Hemisphere." The Margaret Wash area, Pinal County, Arizona, lies within the belt making up the lineament and contains rocks which were deformed by movement in directions that either coincided with or traversed the belt.

The Margaret Wash area extends from near the center of sec. 13, T. 10 S.; R. 15 E. west-northwestward, through secs. 14, 15, 10, 9, 8, 5, and 6 of the same township, to near the center of the east half of sec. 1, T. 10 S.; R. 14 E. Gila and Salt River Base and Meridian (Pl. 1). The southeast end of the area is near lat 110°46' W.; long 32°34' N. and the northwest end is near lat 110°51' W.; long 32°35'30" N. Margaret Wash is 27 air-line miles north-northeast of Tucson and 3 air-line miles southwest of Oracle (Fig. 1).

The topographic base map used in this study was obtained by enlarging the Winkelman 3 SE., Arizona 1:24,000 advanced sheet (subject to correction) published as part of the Oracle, Arizona, 15-minute quadrangle, United States Geological Survey.
Figure 1. LOCATION MAP
ACKNOWLEDGMENTS

The thesis problem was chosen, the fieldwork done, and this report written under the guidance of Evans B. Mayo. The other members of the faculty of the Department of Geology have also helped and encouraged my graduate study and thesis work. Fellow graduate students have helped, encouraged and discussed problems with me throughout graduate study and while the thesis was in progress. To all of these the writer expresses his thanks.
PREVIOUS WORK

Wallace (1954) studied the structures at the north end of the Santa Catalina Mountains. He pointed out the northeast, nearly north-south, northwest and west-northwest trends that developed in older Precambrian and influenced all later deposition and deformation. Banerjee (1957) studied the Oracle granite. He included the Pinal schist of the Margaret Wash area in his study and the present thesis follows one of his suggestions for further investigation.
PURPOSE

The purpose of this study has been to record field observations on the structure of the Pinal schist in the Margaret Wash area and to use this information to interpret the nature and sequence of movements on a section of the Mogul fault. The fieldwork was done during February, March, April and May and the report written during June and July 1961. The exposures of Pinal schist were excellent in washes but ranged from fair to nil on slopes.
GEOLOGIC SETTING

Rock units in this general area are:

Alluvium ..........................................................} Cenozoic
Conglomerate ..................................................}

Diabase ........................................................... age unknown

Apache group ...................................................... younger Precambrian

Mescal limestone
Dripping Spring quartzite
Barnes conglomerate
Pioneer formation
Scanlan conglomerate

Oracle granite ..................................................} older Precambrian
Pinal schist .....................................................}

Apache group

All sedimentary members of the Apache group (Ransome, 1903, 1916), which is in contact with the Pinal schist on the east and south (Pl. 1), were recognized in the Margaret Wash area. The age of the Apache group is now considered younger Precambrian (Lance, 1959).
Oracle granite

The Oracle granite of older Precambrian age is a coarse-grained porphyritic rock varying in color from light gray to light pinkish gray. It is in contact with the Pinal schist on the north (Pl. 1). The primary structure in the granite is planar with dominant northeast strike and steep dips to the northwest. Banerjee (1957) has discussed the petrology and structure of the Oracle granite in detail.

Pinal schist

The name Pinal schist (Ransome, 1903) is now in general use for all older Precambrian schist in southeast Arizona. It has been assigned to the older Precambrian because of its position beneath the younger Precambrian Apache group (Lance, 1959) and geochemical dating of associated rocks (Damon, 1959) tends to affirm this age. The thickness of the Pinal has not been determined or estimated in most of the areas where it has been studied, because no basal contact was exposed. In the Margaret Wash area, the metamorphic rank is so low that in most places the term schist seems to be a misnomer.

The long narrow belt of Pinal schist, exposed between the Oracle granite and the overlying Apache group in the Margaret Wash area, is divided for ease of description and discussion into an eastern or Cove Wash segment and a western or Copper Hill segment (Pl. 1).
This division is based on structural differences within the schist (p. 11) and is arbitrarily placed normal to the long axis of the schist outcrop near the 1/4 corner centered between secs. 10 and 15. The change from one segment to the other, although not sharp, is rapid enough that a separate discussion of the transition zone is not warranted.

The Cove Wash segment, which is the eastern one, crops out in an area 10,000 feet long and, over most of this length, is approximately 2,000 feet wide. The eastern end of the schist outcrop has a jagged blunt outline in plan and the Scanlan conglomerate rests in depositional contact on the schist. The Cove Wash segment tapers to an outcrop width of 1,000 feet on the west where it joins the Copper Hill segment.

The major rock types in the Cove Wash segment are quartzite, mica schist and a slightly metamorphosed sandstone. The quartzite is a grayish orange (10 YR 7/4) cryptocrystalline rock which occurs as lenses in the sandstone and as a major unit extending across the outcrop. The mica schist is a dark gray (N 3) highly fissile rock which occurs as lenses in the sandstone. The slightly metamorphosed sandstone is a light gray (N 7) moderately fissile rock which makes up the bulk of the exposures in the Cove Wash segment. The sandstone has a squeezed appearance but the nearly spherical outlines of the medium sized sand grains are readily discernible. The rock is thin bedded and has generally a fresh, unweathered aspect.

The Copper Hill segment, which is the western one, crops out
in an area 18,000 feet long and is irregular in width. Its greatest width is 1,500 feet but most of the outcrop is approximately 600 feet wide. The outcrop narrows at the western end because of encroachment of aluvium under which the schist finally disappears.

The major rock types in the Copper Hill segment are mica schist, crinkled siliceous rock, gneiss, and metamorphosed sandstone. The mica schist is medium to dark gray (N 5 to N 3) with often a satiny lustre due to sericite. The rock commonly has a smeared out appearance which indicates deformation within the unit. The crinkled siliceous rock is grayish red to dusky red (10 R 4/2 to 5 R 4/2) and is finely laminated. The laminations are intensely crinkled and a planar attitude is not always obtainable. The gneiss is a transition rock between the granite and the schist and the granite-schist contact is indicated as gradational (Pl. 1). Both the mica schist and the crinkled siliceous rock grade into gneiss at places. The metamorphosed sandstone is a light gray (N 7) granular rock that is more sericitized than the sandstone of the Cove Wash segment. Fault gouge and breccia are common in the Copper Hill segment.

**Texas lineament and Mogul fault**

Ransome (1915, p. 295) in 1913 gave the name Texas lineament to a series of features aligned across the southwestern United States.

Robert T. Hill (1902, p. 173) pointed out this line and described it later
(1928) as, "a narrow belt or zone trending nearly east-west (south of east, north of west)." Moody and Hill (1956, p. 1229) state, "the Texas or Hill lineament... coincides in part with a series of left lateral wrench faults which strike N. 60° W. to N. 70° W." Mayo (1958, p. 1172) terms the Texas lineament the southern border of the tectonic framework of the western United States. He estimates the entire zone in southern Arizona may be more than 150 miles wide and notes that strands within the zone are marked by nearly east-west faults and elongated or aligned intrusions. The Mogul fault is a strand of the Texas lineament. In the Copper Hill segment of the Pinal schist belt (Pl. 1) this fault lies within the schist and it appears to lie immediately to the north of the Cove Wash segment.
STRUCTURE OF PINAL SCHIST

Banerjee (1957, p. 34) noted a change in the pattern of foliation (mostly bedding) between the eastern and western ends of the Pinal schist outcrop. He suggested a more detailed study when a suitable base map was available. With the information provided by the more detailed study the outcrop of Pinal schist can be readily divided, as was done above, into two segments on the basis of general attitude of bedding, intensity of rock deformation, and character of the granite-schist contact (Pl. 1).

In the eastern or Cove Wash segment the bedding of the slightly metamorphosed sandstone strikes generally northeast but curves north and finally northwest as it nears the north or granite contact. The dip of the bedding is to the west except for surface slump features and minor structurally disturbed areas and the average dip is approximately $55^\circ$. The quartzite rib near the middle of the segment strikes N. $20^\circ$ E. and dips $60^\circ$ W. The outcrop width of the rib is approximately 500 feet which gives a calculated stratigraphic thickness of 433 feet. The strike of the rib does not curve as it nears the granite contact; however, there is a small intensely deformed area just south of the granite contact on the west side of the quartzite rib. Gouge occurs
only along the south contact and no breccia occurs in this segment.

The south edge of the Pinal outcrop in the Cove Wash segment is a high-angle normal fault dipping to the south. From near the 1/4 corner centered between secs. 10 and 15 eastward to near Cove Wash the fault is generally marked by gouge. From near Cove Wash eastward for at least 4,000 feet the fault is occupied by diabase. The diabase occasionally leaves the contact and is entirely in either the schist or the sedimentary rocks of the Apache group. The north border of the Cove Wash segment is a fault which marks a sharp break between Oracle granite and Pinal schist. Along this portion of the contact Banerjee (1957, p. 35) observed that there was no transition either in structure or composition from granite to schist. Diabase occupies much of the fault and a major diabase dike diverges from the contact and extends into the granite in the northeast 1/4 of sec. 14.

In the western or Copper Hill segment the bedding and the gneissic foliation strike in general west-northwest parallel to the long axis of the schist outcrop. The dip of the bedding and of the gneissic foliation is consistently southward. Where the outcrop bulges southward the metamorphosed sandstone is exposed but the strike of bedding does not change direction here as does the strike of bedding of the sandstone in the Cove Wash segment. Areas where the bedding or gneissic foliation attitudes were not determined in the Copper Hill segment were soil or alluvium covered patches, some areas of crinkled siliceous rock,
and fault zones.

The south edge of the Pinal outcrop in the Copper Hill segment is marked by gouge and breccia or occurs where the schist is overlain by Apache group, conglomerate, or alluvium. The normal fault that marks much of the south edge of the Cove Wash segment continues to the west and marks the south edge of the Copper Hill segment to near the center of sec. 9. There the fault zone enters the schist, continues through Copper Hill, and probably on to the western end of the Pinal outcrop. The fault dips 70° S. at Irene Wash; 60° S. near the center of sec. 9; and 45° S. at Copper Hill. Striations on slippage planes in gouge and breccia generally indicate dip slip. The north side of the Copper Hill segment is a zone of transition from schist to granite. Banerjee (1957) did petrographic work, petrofabric work and detailed mapping on this zone and pointed out that in this zone the usual north-easterly trending foliation of the Oracle granite, followed southward, turns abruptly eastward to parallel the bedding and gneissic foliation of the schist. He also showed that the transition narrowed and died out to the east. The only lineation observed in the present study occurs in this transition zone and was studied by Banerjee (1957). At the east end of the Copper Hill segment; (1) the strike of bedding begins to swing to the south, (2) mica schist, crinkled siliceous rock and gouge disappear from the Pinal, and (3) the granite-schist transition ceases, and its place is taken by a sharp contact.
DISCUSSION OF STRUCTURE

The present study indicates that two major fault movements affected the Pinal schist in the Margaret Wash area. Wallace (1954) and Banerjee (1957) both pointed out evidence of strike slip and dip slip with the dip slip being the younger.

The writer interprets the internal structure of the schist as reflecting left lateral strike slip in a fault zone which is almost entirely in the granite at the east end of the schist outcrop, joins the granite-schist contact in the northeast 1/4 of sec. 14, runs along the north contact to near the end of the Cove Wash segment, slices into the schist and continues west to the south of the present southernmost exposures of schist. In addition to the deformation of the schist, this course of the fault is indicated by a diabase dike along part of the granite-schist contact with a major extension in the granite, and by a zone of intense deformation which crosses obliquely the schist outcrop (Pl. 1). Thus all of the Copper Hill segment is within the zone of strong left lateral movement but the Cove Wash segment is affected only along the northern edge. The quartzite rib added appreciably to the stability of the Cove Wash segment. The only rocks affected by this strike-slip movement in the Margaret Wash area are Precambrian; therefore the time
of movement cannot be closely determined from local evidence. The amount of strike slip is unknown and how much dip slip, if any, accompanied it is also unknown.

The normal fault which marks much of the south side of the Cove Wash segment and some of the south side of the Copper Hill segment apparently represents a movement definitely later than the strike slip. This is indicated by the continuity of the strike of the normal fault across the zone of strike slip. On the north side of the fault at the extreme southeast corner of the schist outcrop Scanlan conglomerate rests on a mica schist at 4,580 feet elevation. On the south side of the fault in Cove Wash Scanlan rests on metamorphosed sandstone at 4,060 feet. These figures suggest that the maximum dip slip of the normal fault is a few hundred feet with the south side relatively down, although the southern block as a whole is now topographically the higher.

The consolidated Cenozoic conglomerate (DuBois, 1959, p. 220; called post-Cretaceous rock dump material by Wallace, 1954, p. 35) indicates that rapid deposition occurred south of the present normal fault in Cenozoic time. The present alluvium contains pockets of coarse Oracle granite debris south of the normal fault. Either or both the conglomerate and the alluvium may represent times of movement of the normal fault. Much of the gouge along the fault is soft and is therefore suggestive of geologically young movement.
CONCLUSION

Wallace (1954, p. 7-8) first noted evidence of both left lateral strike slip and normal dip slip on shear surfaces in the Pinal schist, but he did not attempt to explain the apparent close association of these two types of displacement. Banerjee (1957, p. 107) suggested that:

At this [Jurassic or Cretaceous] time the western part of the Mogul fault zone functioned as a left-lateral strike slip fault. The southern side of the fault sheared relatively eastward toward and against a resisting buttress of quartz monzonite, so that the Pinal schist was dragged into parallelism with the fault at the west and was only moderately rotated counterclockwise farther east....

Finally, the southern, or mountain block sank with relation to the northern area....

The writer's suggestion, stated above, contains two concepts not previously offered: (1) The older, left lateral strike slip Mogul fault slices through the Copper Hill segment, dragging both schist and adjacent transition, whereas the fault lies north of the Cove Wash segment, which is therefore little dragged. (2) The dip slip took place on a later break oblique to the original Mogul fault. These concepts appear to explain most of the structural observations. The concepts are simple and logical, and they seem to be free from the difficulties inherent in the previously offered explanations.
The writer hopes that his contribution will be a help to others in their study of the area and in the general problem of the Texas lineament.
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STRUCTURE MAP OF PINAL SCHIST in THE MARGARET WASH SECTION OF THE MOGUL FAULT, PINAL COUNTY, ARIZONA.