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LNEK 3-11-40 Tortilla Mts

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A FOLDED OVERTHRUST FAULT AND SEDIMENTS DERIVED FROM THE SCARPS OF OVERTHRUST AND NORMAL FAULTS IN THE TORTILLA MOUNTAINS, ARIZONA

by

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ABSTRACT

On the east flank of the Tortilla Mts., ten miles south of Ray, Arizona, one obtains the casual impression of narrow bands of Paleozoic and older rocks, and giant breccias composed of these rocks, interbedded with steeply east dipping Gila conglomerate. The older rocks have been so emplaced in two manners: (1) On overthrust faults, almost parallel to the bedding whereon the older rocks override the Gila and (2) deposition as interbeds in the Gila of giant breccia derived from the erosion of the advancing overthrust block where it broke through to the then existing surface of the Gila.

Subsequent uplift of the central mass steeply folded the originally flat overthrust and induced considerable tilting of the Gila on the east side of the range. Such uplift was relieved, on the western flank of the mountains, by normal faulting causing, on that side of the range, no appreciable tilting of the Gila sediments. Erosion of this normal fault scarp, during this stage B, in places furnished distinctive horizons conformable with the underlying Gila which, thus, must still have been essentially flat.

Further movement of the central mountain mass in an easterly direction, an underthrust relative to the overlying fault block to the east, further steepened the Gila sediments and the overthrust plates on the east side of the range. Further, the eastern movement of the central block permitted the west block to sag to the east along the normal fault, which sagging produced moderate east dips in the Gila. Hence it is proposed that the steep east dips on the eastern side of the range are due to compression, the more moderate east dips on the west to tension.

Erosion of the footwall of the normal fault, during stage B, permitted deposition of sediments over the fault outcrop, the shore being the erosional scarp. Hence examination of the Gila-basement contact shows no faulting whereas it is believed the significant large relationship between these rocks was caused by normal faulting of considerable magnitude. It is a matter of the youngest Gila capping the fault plane along which older Gila has been displaced.

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Detailed Geological Reconnaissance of the Central Tortilla Mountains, Pinal County, Arizona

Roland J. Schwartz

Thesis

this type of mineralization may be interpreted as indicative of Nevadan mineralization, small discontinuous, northerly trending veins of the same mineralization in the northern part of the eastern range provide added evidence of Nevadan tectonic activity.

Laramide Structures

The Laramide period was one of considerable tectonic and igneous activity and undoubtedly was the time of major mineralization throughout the area. The northerly trending axes of Laramide folds and the easterly strikes of Laramide tensional faulting indicate that the major Laramide structural trend is northerly.

The lack of evidence that diabase intruded along Laramide normal faults as did the later diorite and andesite suggests that such diabase as may be of Laramide age is the earliest of Laramide intrusives. Most of the andesite dikes and sills are believed to be of Laramide age but the andesite flows interbedded with "Cloudburst" conglomerate and such dikes as may have acted as feeders for the flows are certainly post-Laramide. The alteration and mineralization of diorite along Laramide faults indicates a relatively late Laramide age for the mineralization.

Folding. Laramide folding is largely obscured or masked by the subsequent intense post-Laramide deformation. However, the angular unconformity existing between the pre-Laramide strata and the post-Laramide "Cloudburst" or Gila conglomerates and the variations in the angle of divergence between the attitude of pre-Laramide strata and that of the originally low angle intra-Gila thrust indicate considerable pre-Gila folding. The lack of indication of any appreciable deformation between Laramide and Gila time strongly suggests that such folding is the result of Laramide orogeny. The almost constant angle of divergence between the attitudes of pre-Laramide rocks and of post-Laramide conglomerates along northerly strikes suggests that the axes of the Laramide folds are almost coincident with the northerly trending axes of the post-Gila folds.

Faulting. Clear understanding of Laramide faulting is made difficult by the superposition of later faulting during post-Laramide orogeny. Extensive intra-Gila thrusts, so intensely folded as to now have attitudes resembling those of normal faults (Pl. 7C, p. 25), post-Gila normal faults of attitudes nearly identical to those of Laramide faults, and post-Laramide renewed movements along the Laramide faults complicate the pattern of Laramide faulting.

No traces of Laramide thrusts were observed unless missing blocks of Apache, mostly Mescal limestone and invariably associated with an occurrence of diabase, may be construed to be due to dislocation of the missing Apache by low angle Laramide thrusts which were later intruded by the diabase. However, lacking other criteria of thrusting, stoping by diabase sills appears to be a more likely explanation for the missing Apache.

The period of dioritic intrusions appears to have been in part preceded and in part followed by intense tensional faulting with easterly strikes. These normal faults generally have steep southerly dips so that the down-dropped southerly blocks appear displaced to the west in the steep, easterly dipping formations of the eastern range and to the east in the westerly dipping overturned strata of the western range. In places, most noticeable in the western range, diorite intrusives cross these faults without displacement indicating that the faulting preceded the intrusions. In other places, most noticeable in the eastern range, diorite is displaced or sheared along these faults indicating that the faults, or renewed movement along them, were later than the intrusives. The parallelism between the easterly trends of most of the diorite dikes and those of the tensional faults suggests that the diorite may have intruded along planes of weakness provided by the tensional faults and shears. However, some faults cross and shear the diorite and, in such cases, both faults and shears are often mineralized, thus indicating a post-diorite but pre-mineralization age for at least a renewal of movement along the faults, and possibly for the faults themselves.

Northerly striking normal faults are not as common as are those with easterly strikes nor are their ages, except rarely, clearly determinate. Some of the faults which appear to be northerly striking normal faults are probably originally low angle imbricate faults of the intra-Gila thrusts which have been so folded as to now have attitudes approximating those of normal faults. Some of the normal faults have been conjectured as being of Nevadan age, the balance may be either Laramide or post-Gila in age, or both. The age of only those post-Gila normal faults which extend into post-Laramide sediments or displace the trace of known post-Laramide faults is readily determinate. The lack of mineralization, except that suspected of being Nevadan, along these faults indicates that such faults which may be Laramide are of a late post-mineralization age.

Structures of special interest. An allochthonous (not in situ) block of Snyder Hill (?) limestone and overlying Cretaceous (?) volcanic fragmentals, its method of emplacement, and the strong structural trend shown by an encompassing diorite dike are of special interest in understanding the structural geology of the area.

The allochthonous block, encompassed and intimately intruded by diorite, is surrounded by Precambrian granite in secs. 22, 23, 26, and 27, T. 5 S., R. 14 E., Crozier Peak quadrangle (Pl. 1). The Apache rocks a mile to the north on the mutual boundary of secs. 14 and 15 are believed to be significant in understanding the occurrence of the Permian-Cretaceous (?) block at an older Precambrian horizon. Of similar significance may be two small outcrops of Barnes conglomerate, each less than 100 square feet in area and not shown on the map, in the small outcrop of diorite 2200 feet south of the northeast corner of sec. 23.

The relationship of the stratigraphically higher Permian-Cretaceous horizon to the Apache rocks in secs. 14 and 15 indicates a vertical displacement of at least 4000 feet would be required to emplace the migrant block in an older Precambrian horizon. Since the vertical distance is the minimum distance between the two horizons, emplacement by thrusting would require a displacement of such magnitude that further evidence should be apparent in the area. The lack of such evidence of Laramide thrusts strongly suggests that emplacement was by some other means. The narrow width of the block as compared to its displacement precludes serious consideration of simple post-diorite graben faulting.

Two theories to explain the emplacement of this allochthonous block are shown on plate 4. (1) A branching fault (Pl. 5A, B, and C) formed a wedge-shaped block which, as the intruding diorite forced the fault walls apart, sank in the magma. (2) Intruding dioritic magma, stoping its way upward probably, but not necessarily, on fault or shear zones, stoped out a large block which sank in the magma (Pl. 5D). In either case there may or may not have been some lateral migration of the block. The previously mentioned small outcrops of Barnes in diorite occur in the footwall of the northerly striking, westerly dipping faults which bounds both the Apache in secs. 14 and 15 and the Permian-Cretaceous (?) block on the east. This fault is believed to be the footwall branch, possibly offset vertically by a superposed normal fault, of the intra-Gila thrust faults. The movement on this branch fault is thought to be of the order of one mile down to the west in its present folded attitude. Thus the small blocks of Barnes would be about 3000 feet lower in the diorite than the Permian-Cretaceous (?) block -- a distance which approximates their stratigraphic separation. If the diorite encompassing the Barnes is considered as a down-hanging lobe of a larger dioritic mass which previously occurred at higher elevations and of which the diorite intruding the Permian-Cretaceous (?) block was part, then the Barnes could be either the bottommost tip of the block containing the Permian-Cretaceous rocks or part of some similar migrant block which sank about the same distance into the diorite. The diorite shows a sufficient lack of homogeneity to suggest assimilation into its magma of the sediments involved, ranging from quartzite to limestone.

The diorite dike which encompasses the Permian-Cretaceous (?) block marks what appears to be a prominent easterly trending Laramide structure. This dike is traceable from the footwall of the footwall branch of the thrusts westward with little or no lateral displacement into the hangingwall, thence westward into the hangingwall of the hangingwall branch of the thrust with about 1000 feet displacement to the south where it is exposed in the SE¼, sec. 28, T. 5 S., R. 14 E., Crozier Peak quadrangle (Pl. 1). The dike is cut off to the west against Gila by a post-Gila normal fault in the center of sec. 28. Westward across the trough of Gila in the NW¼, sec. 31, diorite is exposed in association with dislocated and rotated blocks of Apache and Troy. The occurrence of diorite and lack of deformation in the Gila indicate that this may be a continuation of the same diorite dike and Laramide structure that was cut off against the normal fault in sec. 28. In this event it appears likely that the dislocated and rotated blocks of Apache and Troy were emplaced in the same manner as was the Permian-Cretaceous (?) block. Eastward into the Winkelman quadrangle this prominent Laramide structural feature appears to have been either diverted in Laramide time or, if ever present, obscured by post-Laramide deformation.

Post-Laramide Structures

Extensive low angle thrusts of considerable magnitudes were formed in intra-Gila time and, together with the Gila conglomerate and older rocks, were intensely folded along northerly trending axes by post-Gila diastrophism. Easterly tilting of large blocks along post-folding, high angle, normal faults of northerly strikes and westerly dips further steepened the attitudes of the strata and thrusts. A high in the axes of folding is shown near the center of the area by the northerly plunge of folding in the northern part of the area and the southerly plunge in the southern part.

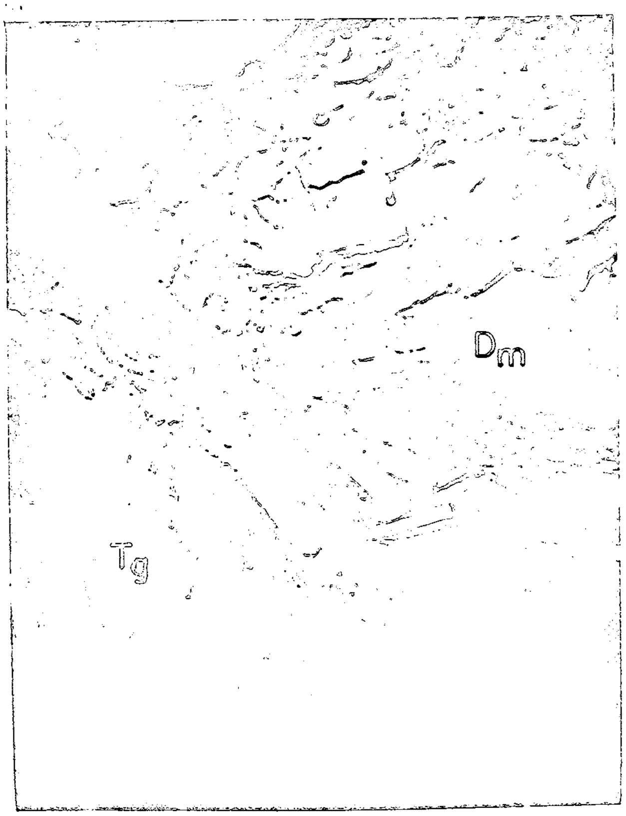
Post-Gila erosion was severe and resulted in the removal of much material from the anticlinal folds and in the beveling of the Gila along the eastern slopes of both ranges. Erosion of the anticlinal folds has exposed an outcrop and structural pattern that resembles a rough, reversed "N" with the western range representing the left leg and the eastern range the right leg of the reversed "N." Since this pattern has resulted from the erosion of northerly plunging folds which include thrusts involving Gila conglomerate in both overthrust and underlying blocks, there can be little doubt that the N-shaped structural pattern is predominantly the result of post-Laramide, therefore post-mineralization, deformation. The intensity of the intra- and post-Gila deformation makes it extremely difficult, if not impossible, to determine whether or not the present structural pattern reflects an earlier Laramide pattern and, if so, how much of the Laramide structure is residual in the present structure.

Comparatively recent lowering of the base level, either by regional upwarp or by downcutting of the Gila River, has incised an intricate drainage pattern in the beveled Gila and its mantle of alluvium.

Thrust faulting. Extensive thrusts were formed in intra-Gila time but it is not evident whether these thrusts represent two or more separate faults or a single fault with branches or imbrications. Movement of the order of about two miles to the west or west-southwest is shown by the displacements of younger Precambrian and Paleozoic strata accomplished by the thrusts (Pl. 4). Thrusts extending through the northern Tortilla Mountains as mapped by Hargraves (1953, Pl. K-1) are northern extensions of these same thrusts, and those described by Benedict (oral communication) in the San Manuel area are believed to be their southern extensions.

Exposures of the thrust faults in either the central or the northern Tortilla Mountains show very little deformation in the footwall block (Pl. 8, p. 52), whereas the hangingwall block is either fractured (Pl. 8A) or brecciated (Pl. 8B). In a drift along Hackberry Wash just north of the northern boundary of Crozier Peak quadrangle, an exposed thrust fault (Pl. 8B, p. 52) shows very little gouge and practically no deformation of the Gila conglomerate in the footwall beyond a few inches from the fault, but does show intense brecciation of the Martin (?) limestone in the hangingwall. The brecciated hangingwalls and relatively undisturbed footwalls of the thrust faults indicate that movement along the faults

A.- Highly fractured Escabrosa limestone (C_e) overthrust on almost undisturbed Gila conglomerate (T_g) in the northern Tortillo Mountains. Looking easterly.



B.- Thrust fault exposed in a prospect drift in Hackberry Wash about one mile north of the area covered in this paper. Hangingwall of Martin (?) limestone (D_m) is intensely brecciated but the footwall of Gila conglomerate (T_g) is relatively undisturbed within a few inches of the fault.

Plate 8.

consisted of westward overthrusting on nearly stationary footwalls.

The structure of the northern part of the eastern range is extremely complicated. Intense folding and later tilting has overturned the thrust planes along the eastern flank of the range, thus, as shown in section A-B-C, plate 4, giving the thrust faults attitudes and indicated directions of movement approximating those expected of normal faults. It appears nearly impossible to determine how much of the repetition of Apache throughout this area is due to folded imbricate thrusts and how much is due to post-folding normal faults. At the northern end of the range erosion has exposed a thrust curving around the nose of the plunging anticline which forms the eastern range. Little, if any, gouge shows along the thrust fault, but the customary stratifaction of the Gila conglomerate in the overriding block has been obliterated for a considerable distance above the fault. The older rocks of the underlying block are intruded by diabase, folded, and intensely faulted on such a small scale as to require a certain amount of generalization in mapping at the scale used.

Around the western limb of this anticline which forms the eastern range, folding has again given the thrust faults the attitudes and appearances of normal faults. The similarity of the Y-shaped rhyolite dike in secs. 26 and 27 to that in secs. 23 and 24, T. 5 S., R. 14 E., Crozier Peak quadrangle

(Pl. 1), suggests that the block containing the former was thrust westerly from above the block containing the latter. The trace of this footwall branch of the thrusts is believed to be concealed or obscured by a superposed normal fault as shown in section A-B-C, plate 4. No definite evidence of this normal fault was observed, but superposed normal faulting appears to be a more likely explanation for the changing dip, inconsistent with the folding, and the lack of parallelism with the hangingwall branch, a parallelism apparent in nearly all other exposures of the thrusts, than does a singular deviation of the footwall branch.

The fault forming the southern contact of the diorite in the SW$\frac{1}{4}$, sec. 28, T. 5 S., R. 14 E., has a steep northerly dip and may or may not represent a curving of the upper or hangingwall branch of the thrusts.

Southward along the eastern range only one thrust is apparent which indicates that either the two branches have merged or the upper branch has extended out into the Gila conglomerate and alluvium where its surface expressions are masked.

The Apache rocks exposed in the Cedar Mountains, sec. 25, T. 6 S., R. 14 E., Winkelman quadrangle (Pl. 2), appear to represent a remnant of an overthrusting block of which the folded thrust plane forms a structural basin (Sec. G-H, Pl. 4). This remnant of the overthrust is cut by many faults of which some are imbricates of the thrust fault and some are late normal faults, but most appear to represent fracturing during thrusting which was accompanied by some rotation of the broken blocks.

Definite field evidence is lacking but the outcrops of Apache and Troy rocks east of Tecolote Ranch, sec. 12, T. 6 S., R. 13 E., Crozier Peak quadrangle (Pl. 1), appear to represent either (1) the plate between the two branches of the thrust with the hangingwall branch curving up through the granite and Gila conglomerate to the north of the outcrops, or (2) the block above both thrust branches which may or may not have merged and which would then be in the granite somewhere to the west and southwest of the outcrops (Sec. D-E-F, Pl. 4).

Folding. Intense folding which probably started during the late stage of thrusting, but which certainly continued after the thrusting had ceased, formed a series of northerly trending anticlines and synclines as shown in sections on plate 4. Across the area from east to west these folds consist of the following:

(1) A large syncline in the low eastern slopes of the eastern range and possibly extending across the Gila and San Pedro Rivers. However, the relatively flat dip of the interbedded andesite flows and "Cloudburst" conglomerate in secs. 6 and 7, T. 6 S., R. 16 E., Winkelman quadrangle (Pl. 2), may indicate the nearness of the axis of the syncline, the plunge of which is likely to the north.

(2) A large anticline, the axis of which nearly coincides with the crest of the eastern range. This anticline has a low northerly plunge throughout the northern two-thirds of the area, but the nose of granite extending into the Pinal schist in secs. 24 and 29, T. 6 S., R. 15 E., Winkelman quadrangle (Pl. 2), indicates that the axis of the anticline has reached a high and is plunging to the south in the southern portion of the area.

(3) A synclinal trough between the two ranges which is composed of two minor synclines and a dividing anticline, all with low northerly plunges. The anticline becomes less and less pronounced to the south as shown in sections A-B-C and D-E-F on plate 4. This anticline appears to be the dying-out southerly expression of a much stronger structure mapped by Hargraves (1953, Pl. K-1) in the northern Tortilla Mountains. In his area the plunge is southerly which indicates a low point in the plunge of the axis somewhere near the north margin of the area shown on plate 1. Gila conglomerate lying between the two branches of the thrust on the crest of this anticline, one branch 2 miles and the other 2½ miles east of point A (Sec. A-B-C, Pl. 4), appears to have been deposited in a manner similar to that of the breccia beds described by Benedict and Hargraves (Appendix I). The Gila conglomerate here differs from that nearby in that it contains subangular pebbles and cobbles consisting almost entirely of rock analogous to that which makes up the

overthrusting block, indicating a derivation from erosion of the advancing overthrust block where it broke through the then-existing surface.

(4) Although not apparent in the granite, it is reasonable to expect another anticline to have its axis in the granite somewhere to the west of the crest of the western range.

The Apache and Troy rocks exposed in the hills east of Tecolote Ranch are in a faulted synclinal structure as shown in section D-E-F, plate 4. The offset of these outcrops to the east from those in the western range to the north and the distorted attitudes of the Mescal and Troy in the NW¼, sec. 31, T. 5 S., R. 14 E., indicate a zone of deformation separating the two exposures. Wash and talus have effectively hidden all traces of the nature of this deformation.

In the southwest corner of the Winkelman quadrangle the S-shaped trace of the granite-schist contact is strongly suggestive of a folded, originally flat-lying surface, and the question presents itself as to whether such a surface may not be a folded, originally low-angle fault. Exposures of the contact are rare and its location was determined largely by juxtaposed outcrops of the granite and Pinal schist. Exposures of the contact are vague, some showing brecciation and others showing little, if any, indication of movement. Mr. Meyer of the Flying UW Ranch, one-time partner in the abandoned Antelope Mine, sec. 19, T. 6 S., R. 15 E., stated that in the mine workings, even though mineralization in the Pinal schist did not extend into the granite, the contact between the two did not appear to be a fault. Lacking good evidence of a thrust, it seems likely that the S-shaped trace is due to a folded, southerly plunging, originally flat-lying intrusive contact as shown in section G-H, plate 4.

Normal faulting. Post-Laramide normal faults are of two major classes: (1) easterly striking tensional faults which occurred while the compressional forces were still operative, and (2) northerly striking "release" faults which occurred as readjustments after the compressional forces had relaxed. Neither type of post-Laramide faults can be distinguished from similar older faults except where post-Laramide strata or structures have been displaced along the faults. Even in such cases diorite intruded along the fault or unequal displacement between pre-Laramide strata and post-Laramide strata or structures, which cannot be accounted for by differences in attitudes, indicate renewed post-Laramide movement on earlier faults.

Many of the easterly striking tensional faults, especially in the eastern range (Pl. 2), show displacement of folded intra-Gila thrusts or of the Gila conglomerate, but in nearly all, if not all, cases post-Laramide renewed movement along faults of Laramide origin is indicated.

The age of such northerly striking faults as do not extend into post-Laramide strata or structures is obscure, and no valid criteria for the age determination of such faults was observed. All or part may be post-Gila "release" faults, but they may equally well be of Laramide or even conceivably Nevadan age. However, some are probably imbrications of the intra-Gila thrusts so folded and overturned as to resemble normal faults.

During the readjustment which followed the intense folding, large blocks were dropped and easterly tilted along extensive northerly to northwesterly striking normal faults of obvious post-Gila age. The easterly tilting of these blocks resulted in a steepening of the attitudes of the folded sediments and thrust faults along the eastern flanks of both ranges. These post-Gila "release" faults are generally of steep westerly dips, of considerable magnitudes, and traceable for long distances along their strikes. Three such faults are evident in the area. (1) The Normal fault presumed to be superposed on the footwall branch of the thrust, secs. 14, 23, and 26, T. 5 S., R. 14 E., Crozier Peak quadrangle (Pl. 1), is believed to continue on to the south but its trace is concealed by the homogeneity of the granite and the alluvial cover. The westerly dipping normal fault displacing the thrust in the Cedar Mountains (Sec. G-H, Pl. 4) is believed to be the possible southern extension of this same fault. (2) Although offset a few places by other faults, an extensive normal fault is traceable down and along Jim Thomas and Eagle Washes from sec. 17, T. 5 S., to sec. 16, T. 6 S., R. 14 E., where its trace is concealed by slope wash and homogeneity of the granite. Hargraves (1953, Pl. K-1) mapped the northward extension of this fault across the northern Tortilla Mountains and down Ripsey Wash. A fault of similar attitude and magnitude mapped by Benedict (1953, Pl. 1) in the San Manuel area is well aligned with this fault across the distances involved and may possibly be its southward extension. (3) The normal fault extending down the length of the western slope of the western range is believed to continue for considerable distances, both to the north and to the south. However, no attempt was made to trace it out of the area to the north and no trace of the fault is evident in the alluvial cover and homogenous granite to the south. This fault brought diabase in contact with granite in sec. 13 and caused some of the repetition of the Apache rocks in secs. 24 and 25, T. 5 S., R. 13 E., Crozier Peak quadrangle (Pl. 1). The isolated Apache rocks in the SE¼, sec. 23, may represent a structural basin in a folded thrust plane as does that in the Cedar Mountains, but the excessive pre-thrust folding required to allow the Apache to be so thrust in its present overturned attitude makes emplacement by normal faulting appear much more plausible. However, the normal fault described above can be responsible for only part of the displacement of the isolated Apache block. Other normal faults of either earlier or later ages are responsible for most of the displacement.

The Apache and Troy outcrops in the hills east of Tecolote Ranch are cut off to the east by an easterly dipping, post-Gila normal fault which forms the western fault of a small graben, as shown in section D-E-F, plate 4. This fault does not appear to continue for any appreciable distances either to the north or to the south.

Relatively recent movement along some of the post-Gila normal faults is indicated by disturbed stratification in the alluvium above some of the faults. This is noticeable in the fault along Eagle wash in sec. 33, in the more southwesterly of the faults in sec. 20, and in the fault through the center of sec. 17, T. 5 S., R. 14 E., Crozier Peak quadrangle (Pl. 1).

Mineralization

There are meager indications of a possible Nevadan mineralization and metallization and some evidence of post-Laramide mineralization in the area. However, by far the major amount of mineralization and metallization appears to be of late Laramide age and to be controlled by easterly striking Laramide tensional faults which apparently acted as channelways for the mineralizing solutions. There appears to be no evidence of mineralization during any of the other periods in the geological history of the region.