FAULTED FANGLOMERATES

AT THE

MOUTH OF PERRY AIKEN CREEK

NORTHERN INYO RANGE, CALIFORNIA-NEVADA

by

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Introduction

In this thesis some phases of the problem of the mechanics of faulting along the margins of what is believed to be a typical basin and range in the Basin and Range Province will be considered. The structure and the later geologic history of a favorably located area at the margin of this typical basin and range will be presented in detail.

What happens to a fault at depth? For that matter, what happens to it at only a short distance below the surface of the ground is sometimes equally as difficult to answer. This problem immediately presents itself when one attempts to establish the margin of a fault block mountain in a desert region. Gravel waste frequently covers much of its slopes and extends far into its reentrant valleys, completely concealing the boundary between the mountain and the valley blocks.

Renewed movement along such a marginal fault in many cases has found expression in displacement of the overlying fanglomerate cover, with the development of a pattern of gravel scarps which roughly parallel the front of the mountain block. Such a series of gravel scarps may be found at the eastern base of the Northern Inyo

Range, California-Nevada, where its gravel fans spread out into Fish Lake Valley.

Study of the scarps and the gravels has disclosed a number of structural and physiographic relationships which can be represented properly only on an accurate and large scale map. At the suggestion of Dr. G. H. Anderson, under whom the work was done, a preliminary map of the gravels of the eastern slopes of the range was supplemented by a detailed plane table map of the geology and topography in the vicinity of the mouth of Perry Aiken Creek, latitude $37^{\circ}40'$, longitude $118^{\circ}6'$. The preliminary mapping was done in company with Mr. M. H. Evans during the first part of

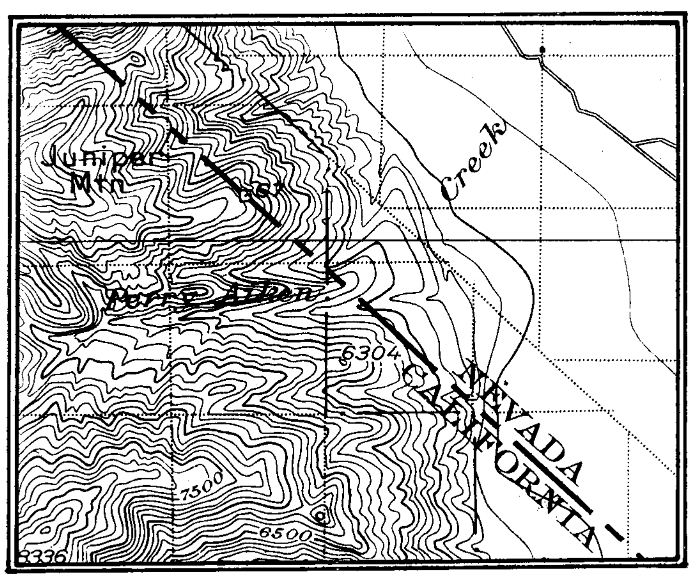


Figure 1. An enlarged section of the White Mountain quadrangle showing the generalized topographic forms represented at this scale, using 100 foot contours, cf. the plane table map made during subsequent work.

the summer field season of 1936, using an enlarged copy of the White Mountain Quadrangle, California-Nevada, as a base. The detailed mapping was done in the spring of 1937 with the assistance of a number of graduate and undergraduate students including Messrs. J. F. Dougherty, W. M. Fielder, L. F. Schombel, M. Sklar and J. C. Wells.

<u>The Fish Lake Valley Block.</u> Fish Lake Valley is a structurally down-dropped block, partially filled by detritus from the Silver Peak Range to the east and the Northern Inyo Range to the west. Fish Lake, the low point in the valley, is opposite a northwesterly extending spur of the Silver Peak Range. The character of the southern

Figure 2. Looking southeastward along the western, faulted margin of the Fish Lake Valley block from the vicinity of the mouth of Perry Aiken Creek on the eastern slopes of the Northern Inyo Range block.

portion of the valley is distinctly different from that to the north of Fish Lake. For approximately twenty miles to the south the valley maintains a width of close to five miles and a trend of S 30° E, while to the north it suddenly broadens as the eastern margin bends around the Silver Peak Range in a northeasterly to easterly direction. The western margin here maintains the trend N 30° W but is modified by the development of extensive fan deposits at the mouths of a group of streams flowing into the valley from the northern end of the Northern Inyo Range.

Figure 3. Looking northeastward across Fish Lake Valley to the Silver Peak Range opposite Fish Lake from the western side of the valley at the mouth of Perry Aiken Creek. Note the enormous size of the alluvial fan which extends far into the range, unbroken by marginal gravel scarps.

This broadened upper portion of Fish Lake Valley is limited less sharply on the north by a group of low hills of Tertiary volcanics, shown by a vertebrate fauna to be in part of uppermost Miocene or lowermost Pliocene age.

The Silver Peak Block. The Silver Peak Range, although apparently of the fault block type, has a large part of its westerly slopes buried by a series of well developed gravel fans which head far up in the valleys of the range while at the same time the ends of the intervening ridges maintain the even fault front with the valley.

The Northern Inyo Block. This block is the northerly continuation of the much more generalized unit designated as the Inyo Range from which it is separated by the structural depression of Deep Springs Valley. From Deep Springs Valley northward for forty miles the Northern Inyo Range trends uniformly north-northwest, decreasing in width from twenty-five miles on the south to ten miles at the northern end. The crest of the range reaches its maximum elevation in White Mountain Peak (14,242 feet), maintaining a general high level from here to its northern end where Montgomery Peak and Boundary Peak stand at elevations of 13,442 feet and 13,145 feet respectively. The westerly slopes of the range are steeper than those to the east, shown by generalized topographic profiles

Figure 4. Looking northward along the crest of the Northern Inyo Range to Montgomery and Boundary Peaks at at its northern end from White Mountain Peak. Note the angle of slope westward from the crest of the range.

Figure 5. The last winter's snow still remains on the crest of the range in the middle of July. Looking south from an elevation of over 13,000 feet with White Mountain Peak in the distance.

Figure 6. Looking northward along the eastern slope of the Northern Inyo Range from the divide between the headwaters of the north fork of the North Fork of Perry Aiken Creek and the cirque basin at the head of Leidy Creek. Note the general angle of slope eastward from the crest of the range. The forested areas in the right middle distance are growing on the old land surface of Cabin Creek.

across the range to be approximately 18° and 10° respectively. Both the western margin with the Owens Valley block and the eastern margin with the Fish Lake Valley block are sharp.

That the Northern Inyo Range is an uplifted fault block appears evident; that it is essentially a tilted as well as uplifted unit seems probable. This is indicated by gently tilted remnants of basaltic lava caps on several of the ridges on the eastern slopes of

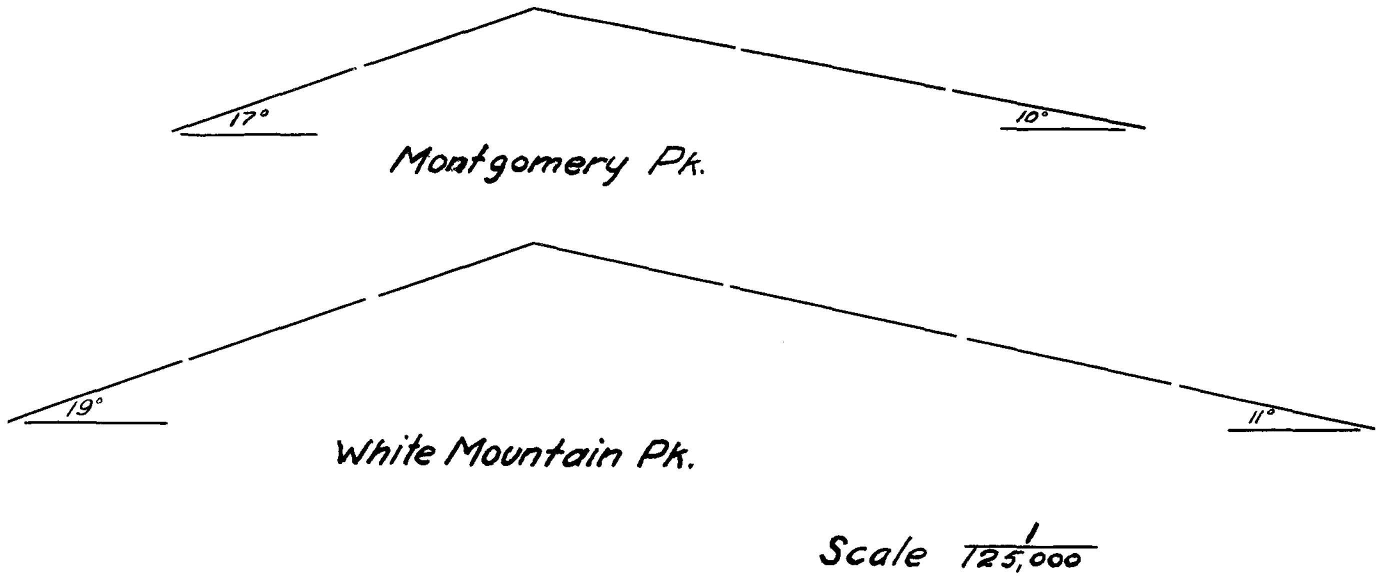


Figure 7. Diagrammatic sketch showing the generalized slopes on the western and eastern sides of the Northern Inyo Range as viewed from the south.

Figure 8. Looking southeastward to late Tertiary (?) basalts of Tres Plumas Flat, on the eastern margin of the crestal upland south of White Mountain Peak. These volcanics rest on an eroded granite surface.

the range and also by the asymmetric profile of the range.

As the rising westerly winds drop most of their moisture on the western slopes, it is here that erosion should be most rapid and the profile should be reduced in elevation most rapidly. However, this is not the result which we now see. That this may be accounted for by a notable difference in rock hardness does not find support in the field. Therefore, the asymmetric profile as well as the gently tilted basaltic lava caps indicate a greater uplift on the western side of the range in relatively recent time.

While the above mentioned features of the range indicate relatively recent eastward tilting of the range block, it is interesting to note that the most recent uplift of the range appears to have resulted in a tilting in the opposite direction. This is shown by the presence of the fresh fault scarps along almost all of its eastern margin and at only a few places along the western side. At one locality on the Owens Valley side, near the mouth of Sacramento Canyon, the scarp faces the range, suggesting that the most recent movement of this part of the range block may have been downward.

As has been indicated, the latest period of faulting has been recorded in the gravels on both margins of the Northern Inyo Range, better shown on the eastern side, and has not been noted at all on the western margin of the Silver Peak Range.

Figure 9. Looking down on the gravel scarp at the western base of the Northern Inyo Range opposite the Sacramento Mine. This scarp slopes toward the Range.

Perry Aiken Creek

The position and importance of marginal faulting in the later geologic history of the region is here recorded in the distribution and character of the gravels. The composite nature of the gravel fan at the mouth of Perry Aiken Creek and also the presence of three or perhaps four distinct terraces within its valley indicate that this later history has been varied within relatively recent time. These terraces are the product of a stream oscillating between aggradation and degradation and correspond in time to the development of the several parts of the fan at its mouth.

Stream Entrenchment

Entrenchment of a stream is the direct result of an increase in its transporting power which, in turn, is controlled by a number of variable factors which may be found discussed in any elementary textbook of geology. Of these the principal factors are velocity, volume and load. Velocity varies with the gradient, shape of channel, and to some extent the load. Volume changes may be caused by climatic variation, stream capture or changes in the porosity of the bedrock. Variation in the load of a stream may be brought about by an increase in velocity, contributions by landslides, glacial activity--quarrying and scour-- and by stripping of hillsides as in a cloudburst. The stream gradient may be increased by stream erosion in time of flood, stream capture, lateral cutting (or filling up) to a divide, or by warping or faulting.

Obviously the most important factor in the entrenchment of the fans at the mouth of Perry Aiken Creek has been the increase in gradient due to faulting. Even more recently the effect of stream erosion during major flood stages and also the movement of the fan portion of the stream to a steeper part of the fan have been important controlling factors.

Geographic Units

Detailed discussion of an area, however small, is materially aided by the use of established place names. Reference to the geologic map will show that the terrace formed by the gravels on the upthrown side of the marginal scarp has been cut into by an intermittent stream to the north of Perry Aiken Creek. A large volume of water swept down its channel during a cloudburst early in August of 1936 and for this reason it will be referred to as Cloudburst Canyon. The gravel terrace between Perry Aiken Creek and Cloudburst Canyon will be known as the central terrace, the one south of Perry Aiken Creek as the southern terrace, and the one north of Cloudburst Canyon as the northern terrace, the latter being separated from its northern end by an entrenched drainage channel, hence the name northern extension for its northern end.

Figure 10. Looking slightly west of south along the main road in Fish Lake Valley to the marginal scarps near the mouth of Perry Aiken Creek. The white streak to the left of the road is fresh gravel spread out at the mouth of Cloudburst Canyon at the time of the cloudburst in 1936. The other geographic units may be seen on either side of this outwash. Note the distinct lack of homogeneity in the porphyritic Boundary Peak granite north of Cloudburst Canyon, brought out by nearly horizontal banding.

The gravel knob immediately south of the sharp bend where Perry Aiken Creek emerges upon the fan was used as the base station for the plane table survey and was assigned an elevation of 5,280 feet. It will be referred to as Base Hill. Later comparison by aneroid barometer with the bench mark near McAfee Ranch showed that this elevation is about fifty feet too great.

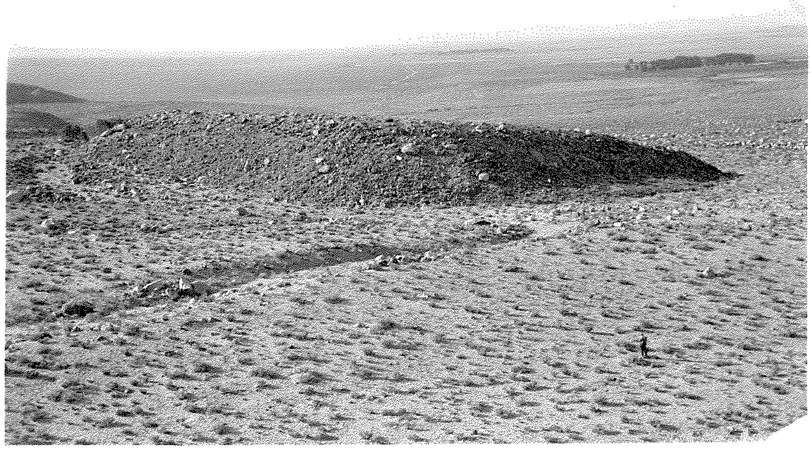


Figure 11. Base Hill with the northern part of Fish Lake Valley and the Tertiary volcanic hills in the distance. The figure in the right foreground furnishes a comparative scale.

Rock Units

In the vicinity of the mouth of Perry Aiken Creek the basement rock is Boundary Peak granite. Opposite the southern terrace this granite is coarse grained in texture and poor in dark minerals but commonly stained brown by weathering. Where it is exposed in the base of the range to the north of Cloudburst Canyon it seems to be characterized by a coarse porphyritic texture and to have associated simple pegmatites. Viewed from a distance, a crude banding is apparent, showing that it is not uniform in composition. Opposite the central terrace the Boundary Peak granite is hidden from view by an overlying cover of gravel of uncertain age, treated in this thesis as a part of the basement complex. Limestone appears at the front of the range north and also south of the limits of the terraces. Gravels of the basement complex again appear at the south end of the southern terrace.

Figure 12. Looking south to the southern edge of the area where the limestone and gravels of the basement complex again appear. The marginal bedrock scarp is just beyond the left margin of the picture.

Fanglomerates

The marginal gravel deposits might well be placed in two groups according to whether they were deposited before or after the latest recognized period of faulting. If this were done, only the Ancient Gravels would fall within the group of pre-faulting gravels. The Enigma, Martinelli and Cottonwood Gravels all were formed subsequent to the fault movement.

Ancient Gravels. The Ancient Gravels, the oldest here considered, were deposited by the ancestral Perry Aiken Creek. That this creek was an extremely powerful transporting agency is shown by the enormous size of many of the boulders and by the wide expanse of its fan deposits which extend far into Fish Lake Valley. Some of the largest boulders, usually of aplitic Boundary Peak granite, exceed 400 cubic feet in volume while many of them reach 25 cubic feet. That these deposits are

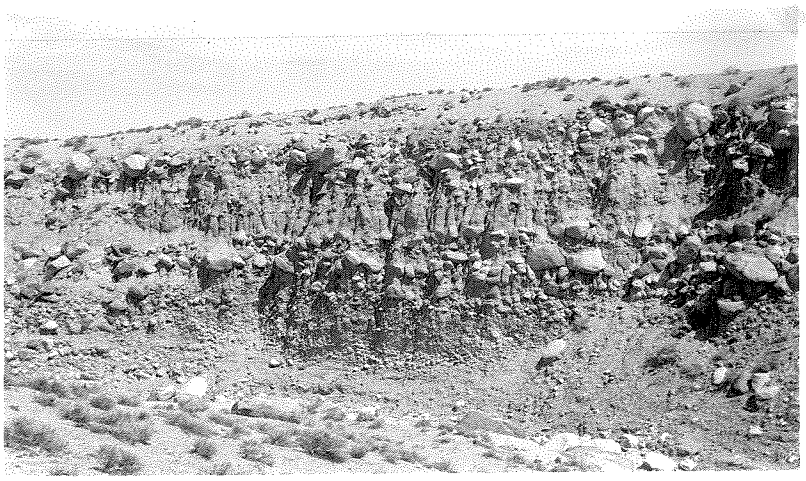


Figure 13. Ancient Gravels exposed in a nearly vertical bank on the south side of Cloudburst Canyon. A number of the boulders in this stratified section have maximum diameters of more than ten feet. Notice the ten foot cover of finer gravel, derived from the nearby Boundary Peak granite.

stratified may be seen in some of the steeper slopes developed as the result of recent undercutting in Perry Aiken and Cloudburst Canyons. Boundary Peak granite is the most common constituent of these boulders. It is usually moderate in grain size and is not porphyritic. Following it in abundance is a rather coarse grained gabbroic rock, while other types less frequently represented include aplitic Boundary Peak granite, quartzite, schist, and gneiss, and basalt(?). Limestone appears in the southern part of the area but may well be a locally derived contaminating element.

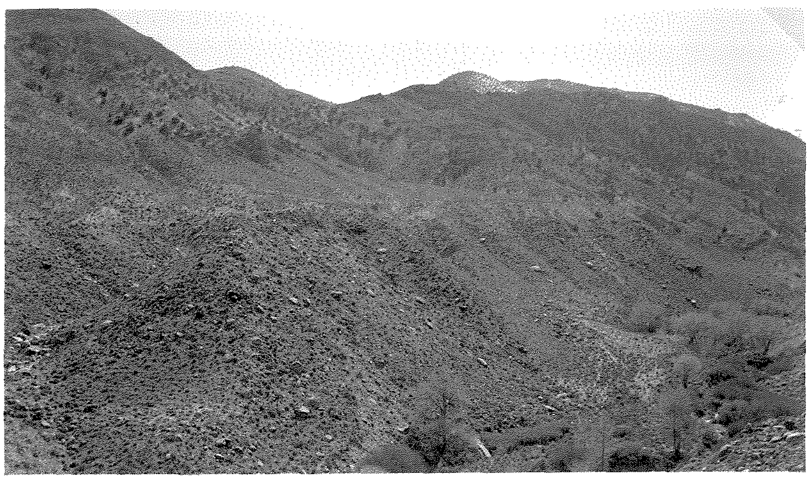


Figure 14. Ancient Gravels on the south side of Perry Aiken Creek, showing the cover of lighter local gravels merging with the Boundary Peak granite slopes of the ridge. At the upstream end of this section the gravel cover is at least forty feet thick.

<u>Enigma Gravels.</u> An enigma may be defined as something which is obscure or baffling. The Enigma Gravels are named with this in mind. They are described from the area immediately southwest of Base Hill. Here a surface of deposition of fine gravel may be followed

Figure 15. Looking southwest from the top of Base Hill and showing recent finer Boundary Peak granite gravels spreading into the graben south of the mouth of Perry Aiken Creek.

continuously for over 700 feet into the valley of Perry Aiken Creek. Subsequent stream erosion has exposed a section approximately thirty feet thick beneath the fine gravel surface and it is seen to be similar to, if not identical with, many of the sections of the Ancient Gravels. This depositional surface continues out over the gravels of the valley side of the marginal scarp where it no longer can be recognized.

Figure 16. Looking west from Base Hill up the valley of Perry Aiken Creek. The Enigma Gravels are in the left middle distance and may be seen continuing up the south side of the valley at the base of the Ancient Gravel scarp. Compare the size of the car with that of the boulder to the left of it. This boulder is at the base of exposed section of the Enigma Gravels and may have been derived from the erosion of nearby Ancient Gravels. The car is parked on the surface of the Martinelli Gravels.

Martinelli Gravels. The Martinelli Gravels form the principal post-faulting gravel unit of the region. Their name was chosen in honor of a character who long will be remembered, Joe Martinelli . These gravels form the surface of the fan north and northeast of Base Hill and may be followed continuously into the valley of Perry Aiken Creek, where they may be traced with certainty for at least a third of a mile. The fan material which was deposited here at this time is in general rather fine. Its boulders are commonly one to two cubic feet or smaller. They are quite fresh and formed largely of quartz diorite and Boundary Peak granite, standing out with a blue-grey color where the finer material later has been stripped away. The finer gravels, where they are exposed on the surface of the undisturbed portion of these deposits, are uniformly fine and have an olive-green color.

Figure 17. Looking slightly west of north from Base Hill. The gravel surface in the foreground is of Martinelli Gravel. The complex marginal scarp pattern north of the mouth of Perry Aiken Creek is shown. The trees in the left foreground are cottonwoods growing on an inner terrace of Cottonwood Gravels.

Both north and south of the limits of the fan at the mouth of Perry Aiken Creek any gravels recognized as being post-faulting in age are considered to be a part of the Martinelli Gravels.

Cottonwood Gravels. Several small sandy terraces now may be seen a few feet above the present creek bottom near the mouth of Perry Aiken Creek. It is on these small terraces, near a permanent supply of water, that the few cottonwood trees are growing. These gravels are important only insofar as they indicate a very brief pause in the general work of degradation by Perry Aiken Creek.

Natural Levees

Natural levees are well developed on the stream terraces of the Martinelli Gravels in Perry Aiken Creek. Immediately northwest of Base Hill terraces of Martinelli Gravels occur on opposite sides of the present stream channel and on the edge of each one is a well developed natural levee. If these levees are developed when a stream overflows its channel, as it does in time of flood, it seems quite likely that the width of the old channel of the stream previous to entrenchment may be measured by the distance between these levees, a distance which is close to a hundred feet.

Later Geologic History

If we consider only the geologic history of the region as indicated by the record of the gravel deposits, the first event to consider is the deposition of the Ancient Gravels. These gravels were deposited as a very extensive fan, spreading from the mouth of the old Perry Aiken Creek. The volume of material and the extremely large size of some of its constituent boulders show that this creek was a powerful transporting agent, much stronger than the present creek appears to be. It

Figure 18. Cirque walls at the head of the north fork of the North Fork of Perry Aiken Creek, cutting into the east face of White Mountain Peak. Note the accumulation of light colored glacial debris to the right of the low bedrock divide with the south fork of the North Fork of Perry Aiken Creek. This is the source of the metamorphic rocks which appear at the mouth of the creek.

may be suggested that the volume of both water and waste material was supplied by contemperaneous glaciers in the headwaters of Perry Aiken Creek.

Figure 19. Looking slightly south of east into the lower part of the North Fork of Perry Aiken Creek. This part of the valley is immediately below the lower limits of the recognized morainal deposits. The broad U-shape and the lack of interfingering ridges strongly suggest that this part of the valley was also modified during a still earlier glacial stage.

This vigorous stream virtually ceased its activity for a period during which the gravels it had deposited were buried beneath a cover of locally derived material. This is shown both by the difference in grain-size and source of of the creek gravels and the local cover. The coarsest portion of its load was deposited by the creek near the top of its fan. These gravels had been transported from the headwaters of the creek. The overlying cover is relatively fine-grained and was deposited by correspondingly less powerful streams. The local source of the material shows that these streams were short, little better than sheet floods from the adjacent ridges. If the old Perry Aiken Creek had maintained its activity, these finer gravels would have been swept along and deposited far out on the fan.

Figure 20. Looking westward from the ridge north of Perry Aiken Creek. The North Fork enters the valley on the right. The broad gravel apron, filling the valley from the ridge on the left, is correlated tentatively with the Ancient Gravels at the creek mouth.

Water sufficient to carry the local gravel cover of the Ancient Gravels from the adjoining bedrock slopes would not have left this thick deposit at the top of a cliff such as was formed by the entrenchment of Perry Aiken Creek following the marginal faulting. Therefore it was deposited previous to this faulting. It was after the entrenchment of the Ancient Gravels that the Enigma Gravels should have begun to be deposited by the old stream as it flowed out into Fish Lake Valley through a channel supplied by the graben block southwest of Base Hill. This period of deposition would have ceased when the aggrading stream overflowed the ridge which until then extended northwest from Base Hill.

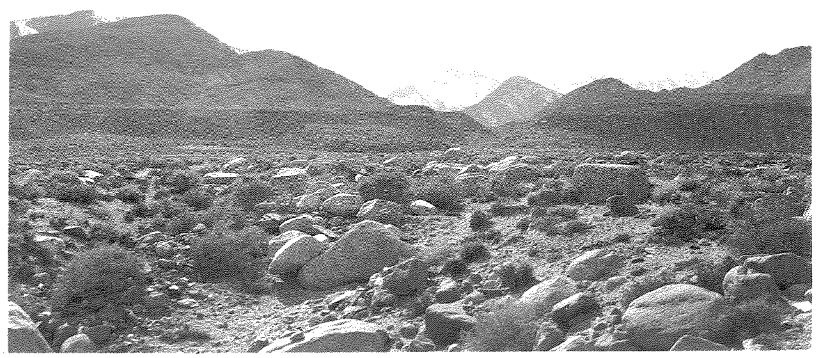


Figure 21. Looking westward from the somewhat dissected Ancient Gravel fan to the mouth of Perry Aiken Creek. The eastern slope of Base Hill, to the left of the creek, apparently was at one time continuous with the gravel slope on the opposite side and at the base of the marginal scarp.

An alternate explanation is that the creek entrenched itself in its general present course and that only occasional flood waters have ever flowed through the graben.

Figure 22. Looking southeastward across the mouth of Perry Aiken Creek to the graben in back of Base Hill. The Enigma Gravels are exposed in the steep slope beyond the car. These darker gravels have been partially covered by lighter gravels from a nearby gully in the Boundary Peak granite. The fine, darker gravel continues up into the creek valley. Note the abandoned channel just to the right of Base Hill.

A third possibility which may be suggested is that the entire unit of these gravels, including the section extending up into the stream valley, may be of Ancient Gravels and was dropped down at one time by faulting.

When the stream deposited the main portion of the Martinelli Gravels it was flowing valleyward along the north side of Base Hill. As Perry Aiken Creek swung farther around to the north side of the fan it began to degrade, stripping away a part of the finer material from the surface of the Martinelli Gravels and finally it entrenched itself in its present course.

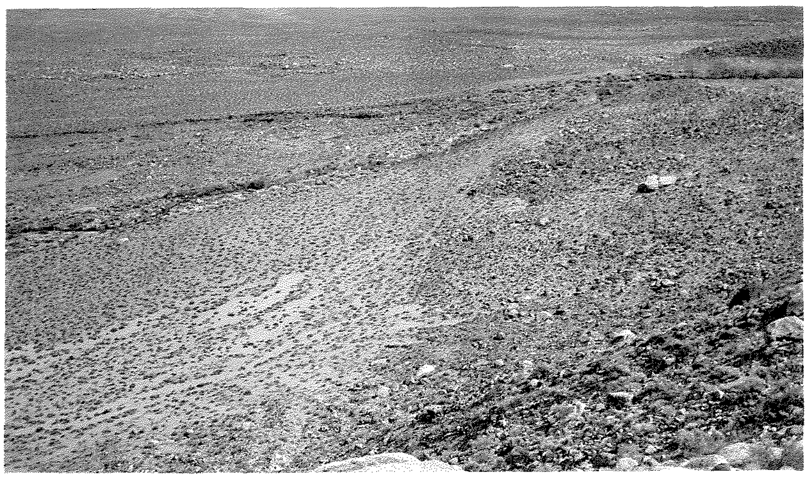


Figure 23. Looking southeastward from the highest part of the marginal scarp north of Perry Aiken Creek. The Martinelli Gravels may be seen spreading out over the northern part of the fan from the creek mouth in the upper right. A number of abandoned channels may be seen beyond the present creek. Three cows slightly right of the center furnish a comparative scale.

Recent Stream Action in Cloudburst Canyon

Relatively few of the streams in the region of the Northern Inyo Range flow as far as the fans at their canyon mouths. Indeed many of them are intermittent throughout their entire lengths. It is only during the infrequent periods of very heavy rain that these streams actually flow out on the marginal fans, carrying with them the accumulated debris from their valley sides and bottoms. Therefore, the actual aggradation or degradation of fans occurs at infrequent intervals and is seldom observed.

Early in August of 1936 a cloudburst sent a flood of water down Cloudburst canyon, scouring its channel and spreading a new layer of gravels over its fan. The head of

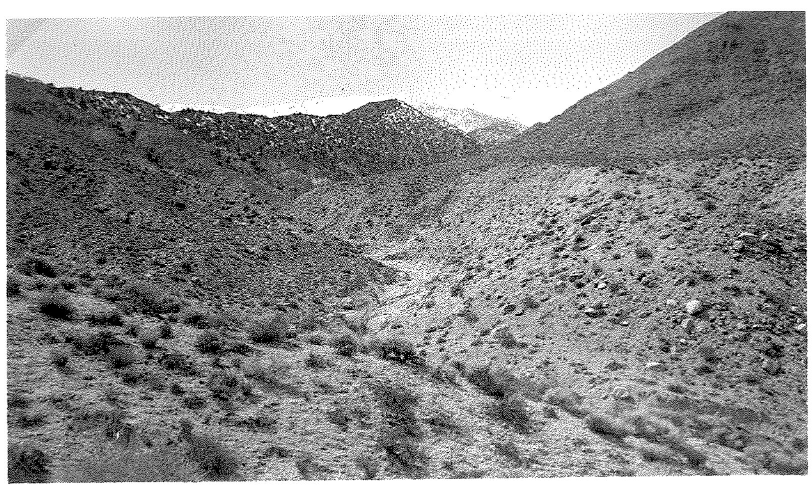


Figure 24. Looking westward into Cloudburst Canyon from the upper edge of the central terrace. The head of this canyon is opposite the hill at the west end of the narrow ridge which lies between this canyon and that of Perry Aiken Creek. The present channel is cut into older gravels, largely of porphyritic Boundary Peak granite.

this canyon is less than two miles above the marginal scarp, limiting the catchment basin for the flood water which nevertheless rose high enough to reach at least fifteen feet above the base of the channel, there leaving a portion of its sand and gravel load. The velocity of the water as it reached the fan is shown by the path it took straight out from the mouth of the canyon although the gradient is less steep on this portion of the fan than it is farther around on either flank. Boulders more than seven feet high now may be seen a quarter of a mile out on the fan, carried there by the flood water and plastered with sand and gravel. The road two miles out in the valley

Figure 25. A natural spillway in Cloudburst Canyon. The marks of the flood water are still plainly preserved here on the downstream side.

Figure 26. These boulders of aplitic Boundary Peak granite now in the bottom of Cloudburst Canyon were lowered to their present position from the Ancient Gravels as the finer materials were carried away. The course of the flood waters which swept over the natural spillway may be seen beyond these boulders. The figure in the main channel is six feet high.

was inundated by sand and silt laden water. It is demonstrated here that such floods do increase the gradient of a stream course and upper portions of its fan by entrenching the fan-head channel. Small volumes of water coming down the channel will deposit their loads of debris in this flood channel, tending to fill it up once more.

Figure 27. Looking northeast on the fan in front of Cloudburst Canyon, showing the path of the flood water. The large boulders of aplitic Boundary Peak granite and of gabbro were derived by reworking of the Ancient Gravels above the marginal gravel scarp. The figure in the middle distance furnishes a comparative scale.

Recognition of Gravel Surfaces

An attempt was made in the field to distinguish between erosional and depositional surfaces of the Ancient Gravels and also between these and the Martinelli Gravels.

It is only natural that none of the Ancient Gravel surfaces should have escaped entirely the erosive action of running water. However, one section of the Ancient Gravels was seen to have suffered considerable erosion. This is the section of gravels which forms the southeastern part of the fan below the marginal scarp. Here a large part of the finer gravels have been carried away, leaving behind jumbled piles of the larger bounders.

In the course of this stripping action channels were developed down fan slopes. It is interesting to note that the drainage thus determined is not along radii of the fan surface but more to the east, showing that this valley block had been tilted valleyward after the original deposition of the Ancient Gravels of the fan surface. This was the period during which the marginal faulting took place.

The boulders of freshly eroded gravel surfaces show little evidence of decomposition. It is only on the uneroded fan surfaces of the Ancient Gravels that the surfaces of the individual boulders tend to be highly granulated and to show a tendency to be reduced to flat surfaces nearly at the level of the fan.

Lateral Weathering

At times intermediate stages may be observed in the development on the mechanically weakened, highly granulated boulders of relatively flat, ground-level boulder surfaces.

The final flat surface of the affected boulders is developed by the gradual inward movement of surfaces which are concave outward, and similar to the progressive retreat of the mountain fronts in a desert region. This is an evolution of boulder surfaces quite distinct from that produced by the generally accepted process of exfoliation.

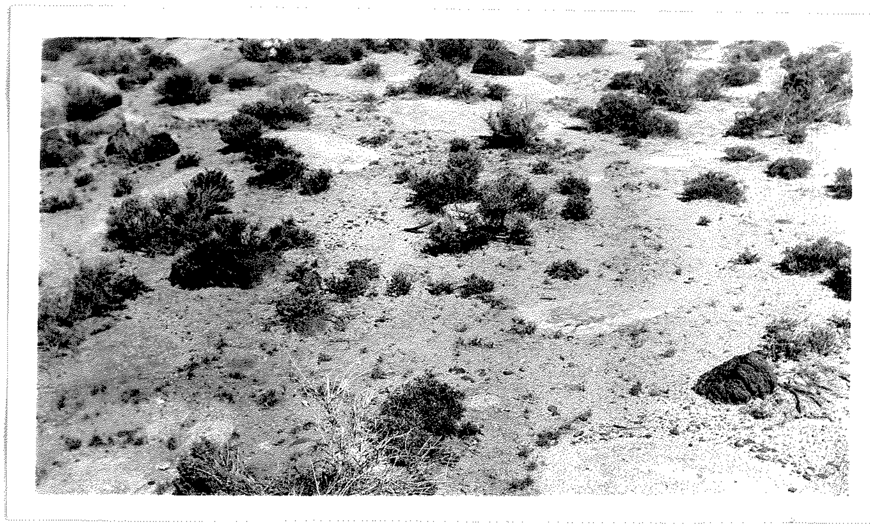


Figure 28. A group of boulders, planed off at the general level of the finer gravels, near the southern edge of the southern terrace. The basic rock in the lower right corner has not been reduced in a similar manner.

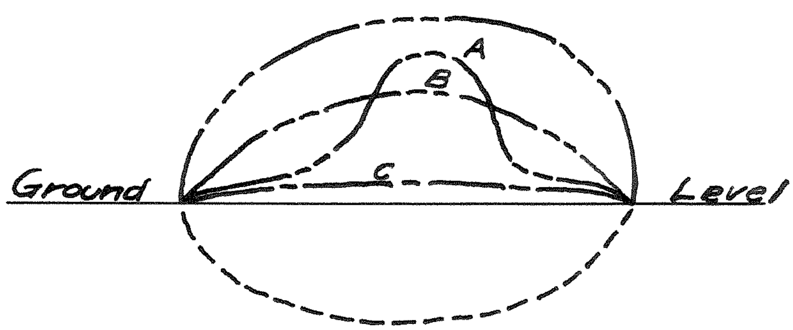


Figure 29. Stages in the destruction of a boulder, showing an intermediate stage in lateral weathering (A), and the corresponding stage in exfoliation (B), both ending with the same form in the final stage (C).

Lateral weathering is particularly important in the case of the moderate to coarse grained, acid Boundary Peak granite. Destruction of boulders of this type has frequently been complete.

The probable process by which this type of weathering proceeds may be recognized within rather narrow limits. In the final stage and also in intermediate stages in the process the close control of the ground surface on the profile produced is evident. Two separate agencies are at work as rock weathering of this type goes on. These are the agencies of decomposition and of transportation. The ground surface may be a controlling factor for either one or both of these agencies.

Mechanical rather than chemical agencies of decomposition are usually considered to be more important in arid regions such as this. The granular surfaces here developed are the result of a mechanical break-down of the boulders. Change in temperature may cause a rock to disintegrate due to different rates of expansion and contraction of the constituent minerals or portions of the rock or it may be due to freezing and thawing of water in minute fractures as between grain units in the rock. Expansion and contraction due to temperature changes at the surface of the ground result in the modification of original surfaces to develop successively new surfaces of

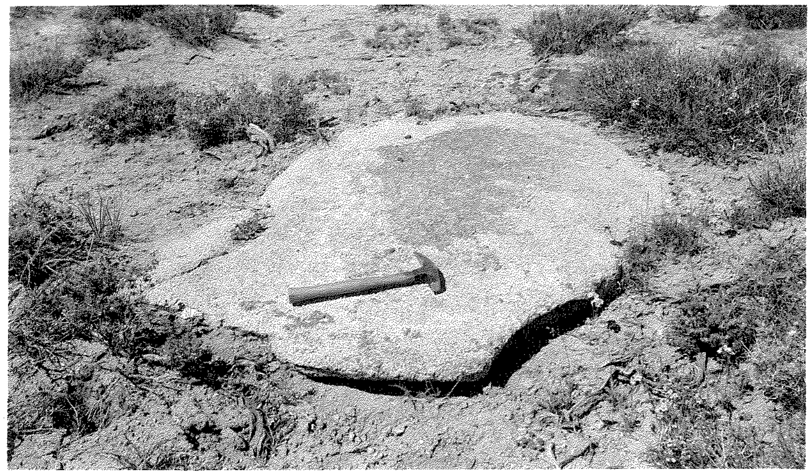


Figure 30. Boulder of coarse grained Boundary Peak granite, planed off at the general level of the gravels which were then partially stripped away by a headward eroding stream on the southern terrace.

Figure 31. Group of boulders of coarse grained Boundary Peak granite, showing the gentle concave profile resulting from deep lateral weathering. These boulders have had their left sides cleaned of gravels by the stream of the channel seen in the background. These boulders are on the upper part of the broad block of Ancient Gravels in front of the gravel scarp of the central terrace.

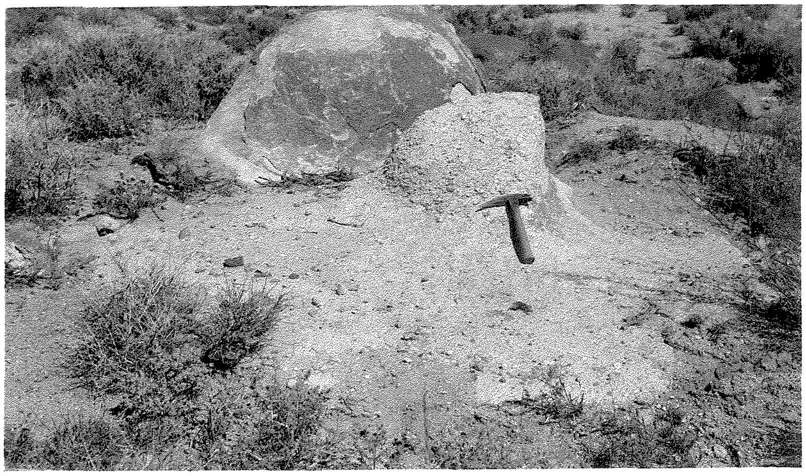


Figure 32. Boulder of porphyritic Boundary Peak granite, showing the strongly concave profile which develops in an intermediate stage in the weathering process. Note the aplitic Boundary Peak boulder in the background, apparently unaffected by the same process. Southern terrace.

Figure 33. An extremely well developed concave profile is shown by this boulder of coarse grained Boundary Peak granite on the southern terrace. The boulders of Figure 32 may be seen in the right background, with several gabbro boulders which do not show the effect of lateral weathering.

greater and greater radii of curvature. This is the case in exfoliation.

Water in the minute fractures of a rock, necessary in the process of freezing and thawing, would also hasten the process of chemical decomposition along these same minute fractures. Would the difference in the rate of evaporation cause water to remain longer in fractures on the sides of boulders and just above the surface of the ground than in fractures at greater heights or on top of the boulder? Probably the answer is yes. If this is the case, the zone of most active lateral weathering corresponds to the zone of longest moisture on the boulder.

The three agencies of transportation, water, wind and ice, all would have for their local base level the gravel surface of the terrace. However, there is no evidence that there has been any stream action on the gravel surfaces during the period of weathering of the boulders. Rain falling directly on the boulder surfaces would be capable of doing no more than wash away loose material. Wind might carry away loose material but it would not carve out these forms on the Boundary Peak boulders without producing similar sand blasted surfaces on other unaffected boulders of different composition found nearby. Also these surfaces are not uniformly opposed to any one direction as of a prevailing wind. Ice as a transporting agent on this small scale could only move material by soil creep produced by frost action.

Therefore, although water, wind and ice may have combined to transport loose material from the boulder surface, their powers of erosion are not demonstrated here to be sufficient to have carved the surfaces of lateral weathering from the solid rock.

The above observations lead one to the conclusion that the surfaces formed by lateral weathering are

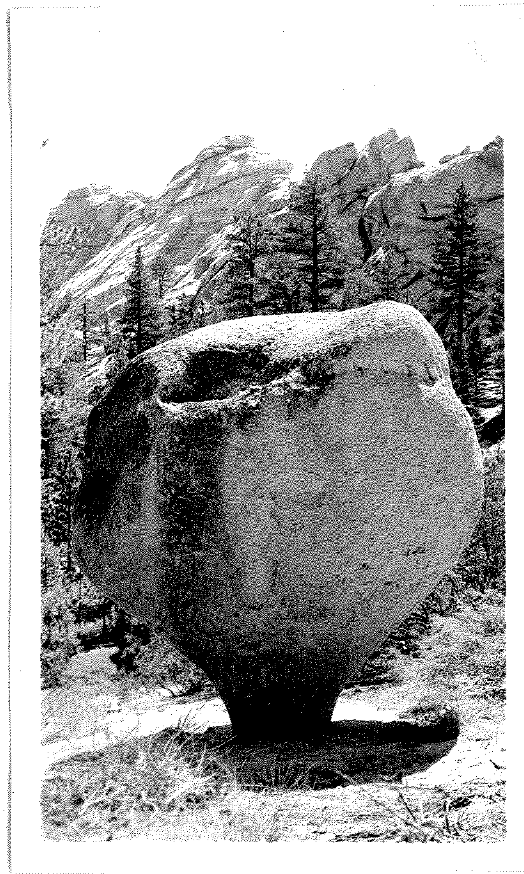


Figure 34. A mushroom-shaped rock of coarse grain size and granitoid texture developed on a gravel-covered ridge in the Dome Land of the north-central Kernville quadrangle in the southern Sierra Nevada. A process similar to lateral weathering has been active in this case also.

produced by chemical and to some extent mechanical decomposition of the surface of a boulder in a zone which remains moist for a maximum length of time, at or slightly above the general level of the gravel surface, and that it is immaterial which agency or agencies of transportation carry away the decomposed surface material.

Water thus proves to be the controlling factor in this type of weathering even in this desert region. A comparison may be made with mushroom rocks found at times in the somewhat more humid region of the southern Sierra Nevada and also with hollows with overhanging lips found on low-lying granite surfaces and attributed to more rapid chemical action in the bottom of water-filled pits.

Comparison of Stream Scarps and Fault Scarps

Stream scarps in the gravels are confined to the vicinity of present drainage channels. In the valley of Perry Aiken Creek these scarps now stand as much as 140 feet above the present stream bottom. Lateral cutting has made some of them quite steep opposite curves in the channel. In these steeper scarps the bedding of the gravels is distinctly shown, dipping toward Fish Lake Valley and very nearly parallel with the surface of the terrace above. Such scarps may reach slopes as great as 70° or 80°. Those portions of the stream scarps which have not recently steepened show gentler slopes which represent the angle of repose of these gravels under the desert conditions which exist in this region. The measured angle of repose is found to be between 30° and 35°.

Figure 35. Looking westward up the valley of Perry Aiken Creek from about a quarter mile above the mouth. The upper surface of the Ancient Gravels is seen to extend far up the valley. Note the angle of repose assumed by the gravels where they have not been affected by recent stream erosion.

The major fault scarps in the gravels are seen to parallel the front of the range, trending approximately north-northwest. These scarps show measured slopes which commonly vary between 30° and 35°--recognized on the stream slopes to be the angle of repose of the gravels. They have a maximum elevation of at least 275 feet and merge abruptly with the surface of the gravel fan at their base. Outcrops of stratified material are lacking on these scarps. The scarps show very little dissection by streams flowing down their slopes and are characterized by their even continuation in the horizontal direction.

Figure 36. Looking northwestward at the simple, little eroded marginal scarps which combine to form the limits of the central terrace.

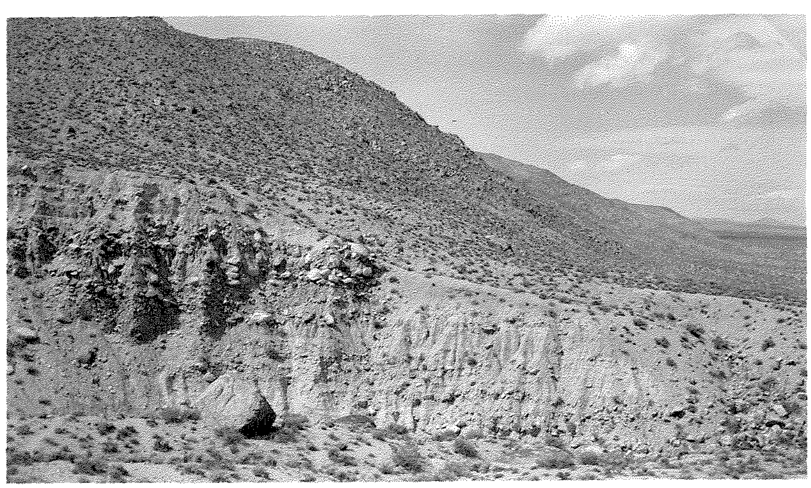


Figure 37. Looking west of north along the eroded basement scarp opposite the northern terrace from the south side of Cloudburst Canyon. The bedrock slopes here are of porphyritic Boundary Peak granite. Examination of the gravels exposed in the canyon wall failed to show the position of the fault at this point.

The surfaces of the bedrock at the upper side of the gravel terraces are still older eroded fault scarps, sloping toward the valley at maximum angles between 35° and 40° (again, the angle of repose of these fractured rocks?).

Marginal Structure

The geologic features discussed thus far form a necessary background for an interpretation of the position which marginal faulting has played in the latest development of the Northern Inyo Range and Fish Lake Valley. The pattern of the fault scarps formed at the mouth of Perry Aiken Creek is adequately shown on the accompanying map and need not be described in any detail. However, there are some features related to the fanglomerate and bedrock structure which demand particular consideration. These are: the broader pattern of faulting along the range front, the significance of master structures within the range, the attitude and direction of movement along these faults, and finally, the relation between the marginal gravel scarps and the marginal basement zone of failure.

Broader pattern of marginal faulting. Inspection of the topographic map of the White Mountain quadrangle shows that the east (and also the west) margin of the Northern Inyo Range, while in general quite regular, consists, in detail, of a series of short straight lines

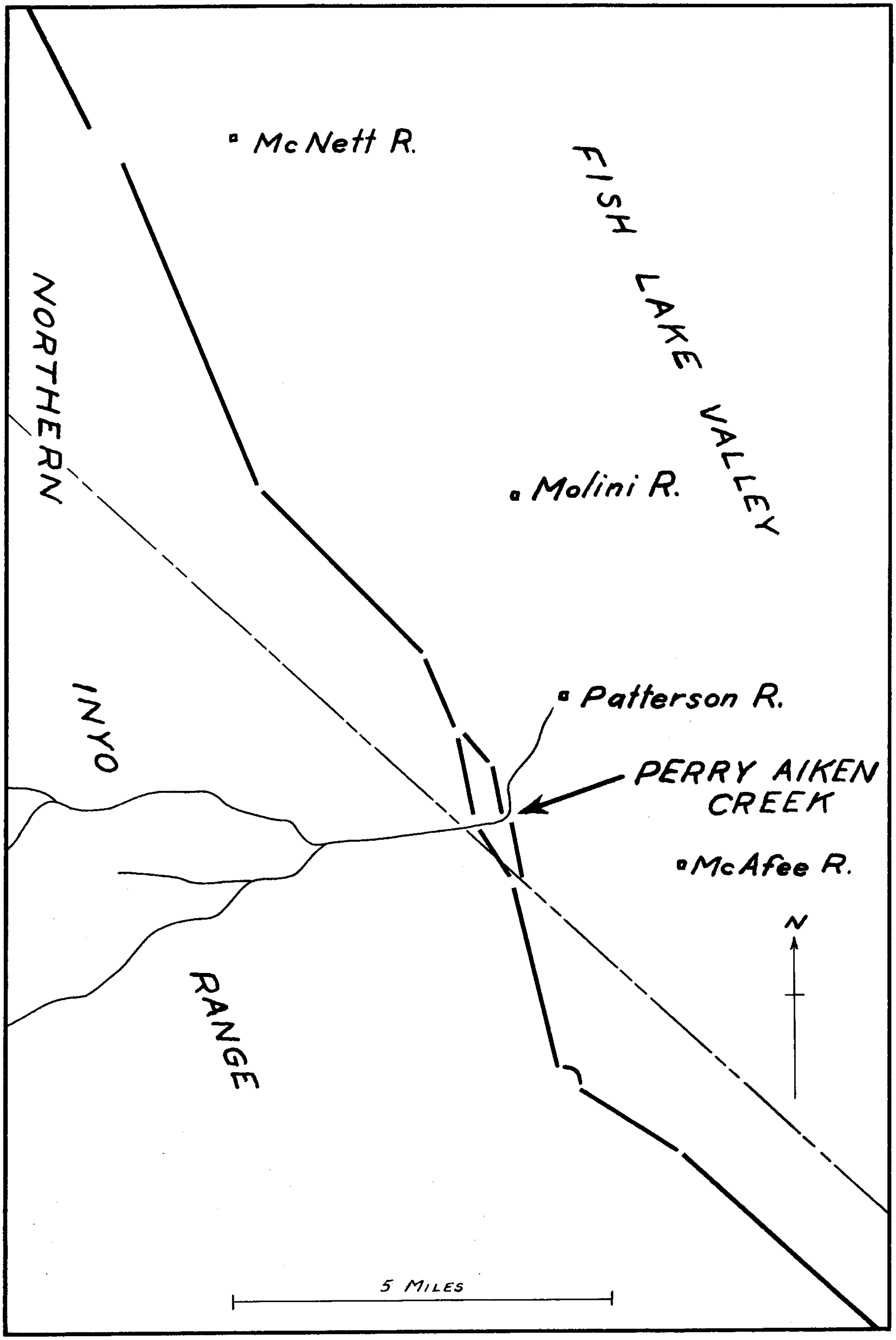


FIGURE 38 - GENERALIZED PATTERN OF MARGINAL FAULTING.

which diverge from parallelism by as much as 45°. Study in the field has shown that the marginal faults in the gravels follow this same zig-zag pattern. Comparison has disclosed that it is at the points where the margin of the range stands farthest out in the valley that the greatest vertical displacement in the gravels occurred during the last period of faulting. This is the case at the mouth of Perry Aiken Creek and also opposite the mouth of Wildhorse Creek, farther to the south.

Figure 39. Looking slightly east of south along the eastern margin of the Northern Inyo Range from the south end of the southern terrace. Note the pronounced change in trend of the range front (from N 15° W to N 60° W) opposite the mouth of Toler Creek and the increased height of the gravel scarp farther south at the mouth of Wildhorse Creek.

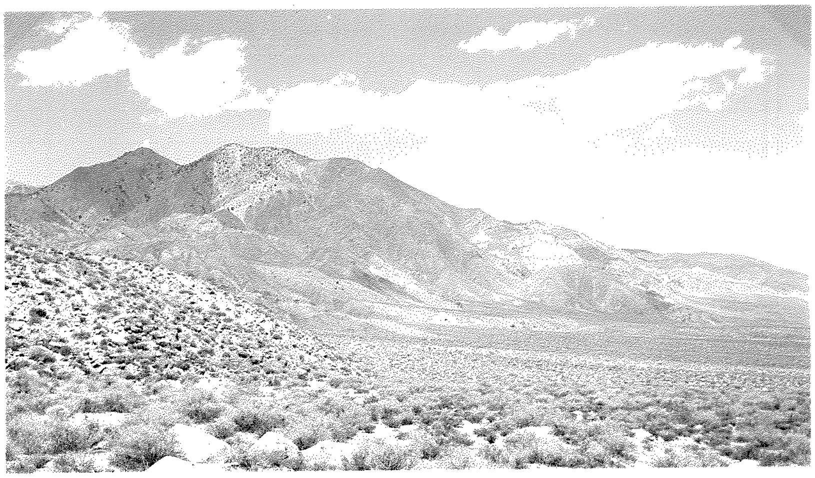


Figure 40. Looking northwestward to the mouth of Toler Creek where the trend of the range margin makes an abrupt change toward the north. Note the complex structure of Red Mountain beyond.

<u>Comparison with bedrock structure.</u> In the bedrock at the mouth of Perry Aiken Creek a zone of shearing is evident parallel to the bedrock-gravel contact at the upper edge of the southern terrace and also the northern terrace. This direction of bedrock structure is indicated on the map in the Boundary Peak granite just south of Perry Aiken Creek. Still farther south along the bedrock-gravel contact a second fault is indicated which is representative of another direction of weakness in the bedrock. The first mentioned direction of weakness is parallel to the majority of the marginal faults in the gravels; the second direction is almost identical with that of the series of diagonally trending scarps which are shown on

the central and perhaps the northern terraces. The drainage channel which lies between the northern terrace and the northern extension follows a zone of minor faults in the gravels close to the bedrock. Comparison of elevations on opposite sides of this channel show the sum of the displacements on these faults to be at least fifty feet. This channel and Cloudburst Canyon as well follow this second, transverse direction of bedrock weakness.

At either end of the marginal scarp of the southern terrace are gravel scarps which strike nearly at right angles to the range front and to the marginal scarp. No zone of weakness in the bedrock can be recognized which has this direction although intermittent streams form a continuation of these scarp directions into the Boundary Peak granite.

Similar parallelism of marginal scarps and bedrock structure has been noted at several other places along the eastern range front.

<u>Attitude of the fault surface in the gravels.</u> Clearly exposed sections showing the dip of the marginal fault surface were not seen. Are they of the normal or the reverse type? Are they high or low angle? They are probably normal faults with dips of about 70°. This is indicated by the attitude of minor associated faults and by the curve of their trace over the topographic high at

Figure 41. A steep,eastward dipping fault in the Ancient Gravels on the north side of Perry Aiken Creek approximately along the line of the principal marginal scarp. The gravels on the right side of the fault dip eastward at an angle of about 14°. This dip probably is duplicated in the gravels of Base Hill and its continuation northwestward to the base of the marginal scarp.

the mouth of Perry Aiken Creek--this curve is slightly concave toward the downthrown side of the fault.

Direction of movement along the marginal fault. The irregular pattern of the marginal faults points strongly to an essentially vertical direction of movement between the upraised Northern Inyo Range block and the depressed Fish Lake Valley block since they were first outlined by the bedrock structures. These irregularities would offer a maximum amount of resistance to horizontal motion, producing alternate zones of tension and compression. Tensional zones should be reflected in the overlying gravels by the presence of graben blocks. These features are seen at several localities but where they can be attributed as logically to normal faulting.

Faults which are known to have a strong strike-slip component, such as the San Andreas and probably the Inglewood faults, show a strong development of associated structures in the overlying, less competent cover which are arranged en echelon to the principal direction of movement in the more competent bedrock below. These characteristics are not recognized along the range front and it is concluded that at least the latest movements of the marginal faults of the bedrock have been vertical.

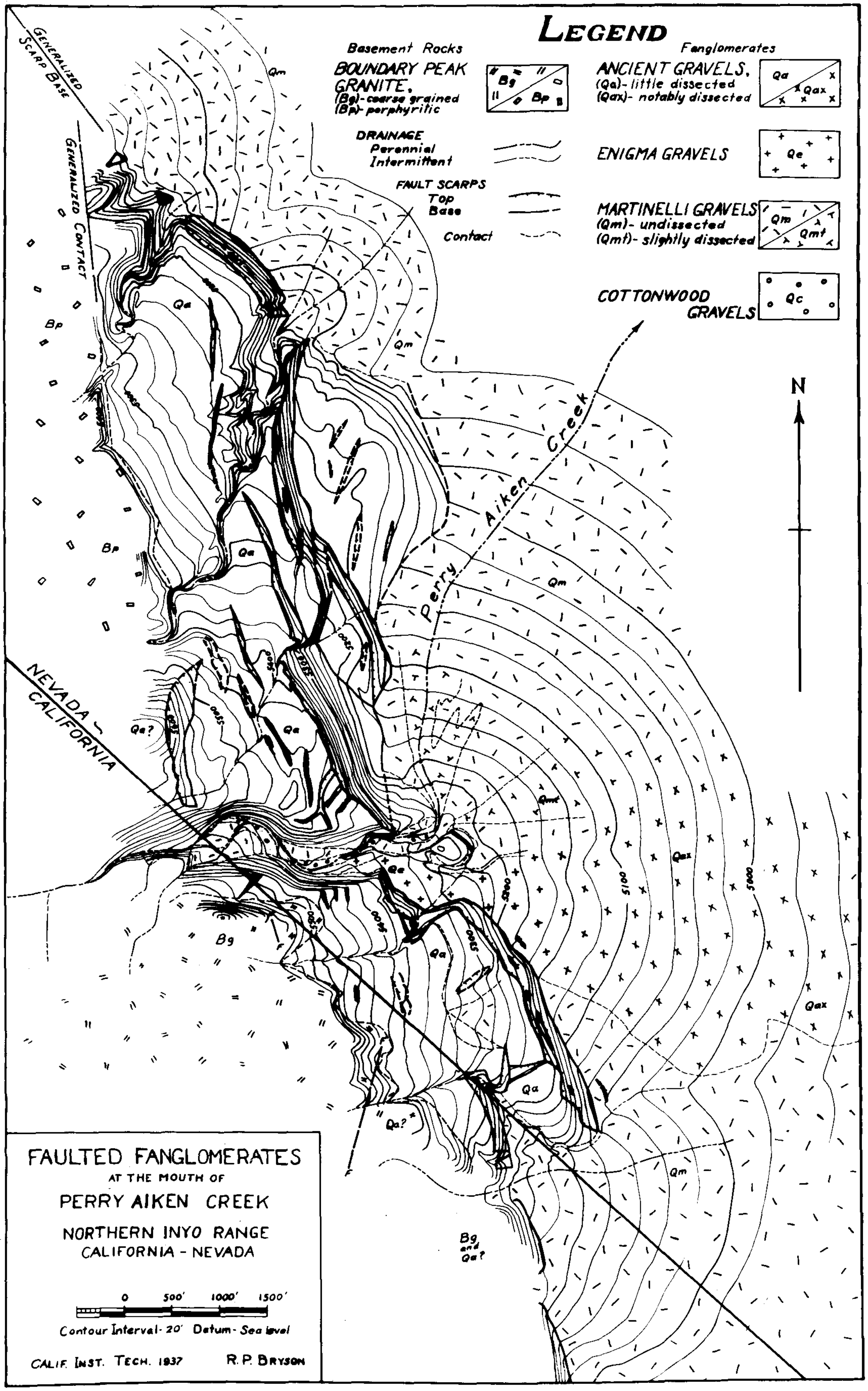
<u>Attitude of the marginal faults in the bedrock.</u> It seems likely that thrust movement of the range block over the valley block would be transmitted as a thrust movement into the overlying gravels and this does not appear to have taken place, as indicated above. A detailed study of the bedrock structure should show that the associated fault structures are of the high-angle normal type, as the marginal faults are believed to be.

<u>Relationship of the gravel scarps to the marginal fault.</u> If shear in a failing rock develops at a smaller angle to a fixed direction of applied stress in a competent

rock than it does in a less competent one, as is illustrated in the change in attitude of a fault surface in passing from a quartzite into an argillite, it is quite probable that the attitude of a similarly developed fault surface would vary in passing from the bedrock into the overlying gravels, assuming a gentler dip as it passed into the gravels provided the direction of applied stress was vertical. In the case with which we are concerned we are not dealing with a single direction of applied stress in the bedrock and in the gravels above. Here the stress in the bedrock is resolved into one effective component which is in the plane of the fault and is determined by the earlier formed bedrock structure. No such resolution of the force of gravity, which is acting on the overlying gravels, takes place. It may be concluded that there need be no fixed relationship between the attitude of the marginal fault in the bedrock and in the gravels above.

No evidence was found in support of the thesis that each scarp in the gravels may be traced down to a separate fault in the bedrock. If a number of faults were active in the bedrock during the last period of faulting, some of them should be traced laterally from the gravel scarps into fresh scarps in the adjacent bedrock--and such cases could not be found.

It seems probable that the latest uplift of the range block has followed an earlier established single line of intersecting faults and that this uplift has resulted in multiple failure of strictly gravity type in the gravel cover above.


LEGEND
Basement Rocks
BOUNDARY PEAK GRANITE.
(Bg)- coarse grained
(Bp)- porphyritic
Fanglomerates
ANCIENT GRAVELS.
(Qa)- little dissected
(Qax)- notably dissected
ENIGMA GRAVELS
MARTINELLI GRAVELS
(Qm)- undissected
(Qmt)- slightly dissected
COTTONWOOD GRAVELS
DRAINAGE
Perennial
Intermittent
FAULT SCARPS
Top
Base
Contact
GENERALIZED SCARP BASE
GENERALIZED CONTACT
Perry Aiken Creek
NEVADA
CALIFORNIA
N
FAULTED FANGLOMERATES
AT THE MOUTH OF
PERRY AIKEN CREEK
NORTHERN INYO RANGE
CALIFORNIA - NEVADA
0 500' 1000' 1500'
Contour Interval- 20' Datum- Sea level
CALIF. INST. TECH. 1937
R. P. BRYSON