A CRITICAL STUDY OF THE EVIDENCE OF LATE NEOGENE FAULTING AT MCGEE MOUNTAIN, MONO COUNTY, CALIFORNIA

By

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ABSTRACT

Published evidence obtained at McGee Mountain, on the eastern front of the Sierra Nevada, Calif., has been interpreted to indicate 4,000 feet of post-McGee till (Nebraskan) faulting and 9,000 feet of post-basalt (age 2.6 m.y.) faulting. This locality has been re-examined, new evidence has been obtained, and the structural sequence has been reinterpreted.

There is no evidence of either significant post-McGee till or post-basalt faulting. The McGee till was deposited on McGee Mountain as an alb moraine, not a valley moraine. The basalt emanated from a volcano at the crest of the Sierran escarpment and cascaded down that scarp. The volcano has subsequently been dissected, but not obliterated, by erosion. The structural and geomorphic evidence strongly indicates the presence of the McGee Mountain scarp at the time of basalt deposition. There has been only moderate erosion since that time. Late Neogene uplift of the Sierran front at McGee Mountain, therefore, may have been accomplished by warping but was not accomplished by demonstrable faulting.

INTRODUCTION

W. C. Putnam (1962) mapped the classical McGee till of Blackwelder (1931) at McGee Mountain (figs. 1 and 2) and concluded (Putnam, 1962, p. 181) that "this deposit has been elevated approximately 4,000 feet to its present position by faulting and warping since deposition." The basalt underlying the McGee till has undergone faulting, according to Putnam, with a total displacement of 9,000 feet (Putnam, 1962, p. 191). In the vicinity of McGee Mountain, accordingly, the Sierra Nevada would have been uplifted 9,000 feet since deposition of the basalt.

Putnam's excellent geologic map, based on aerial photographs, covers an area of about 25 square miles and shows all the geology necessary for a broad understanding of the problem. My work included 3 days on McGee Mountain assisted by Putnam's map and paper.

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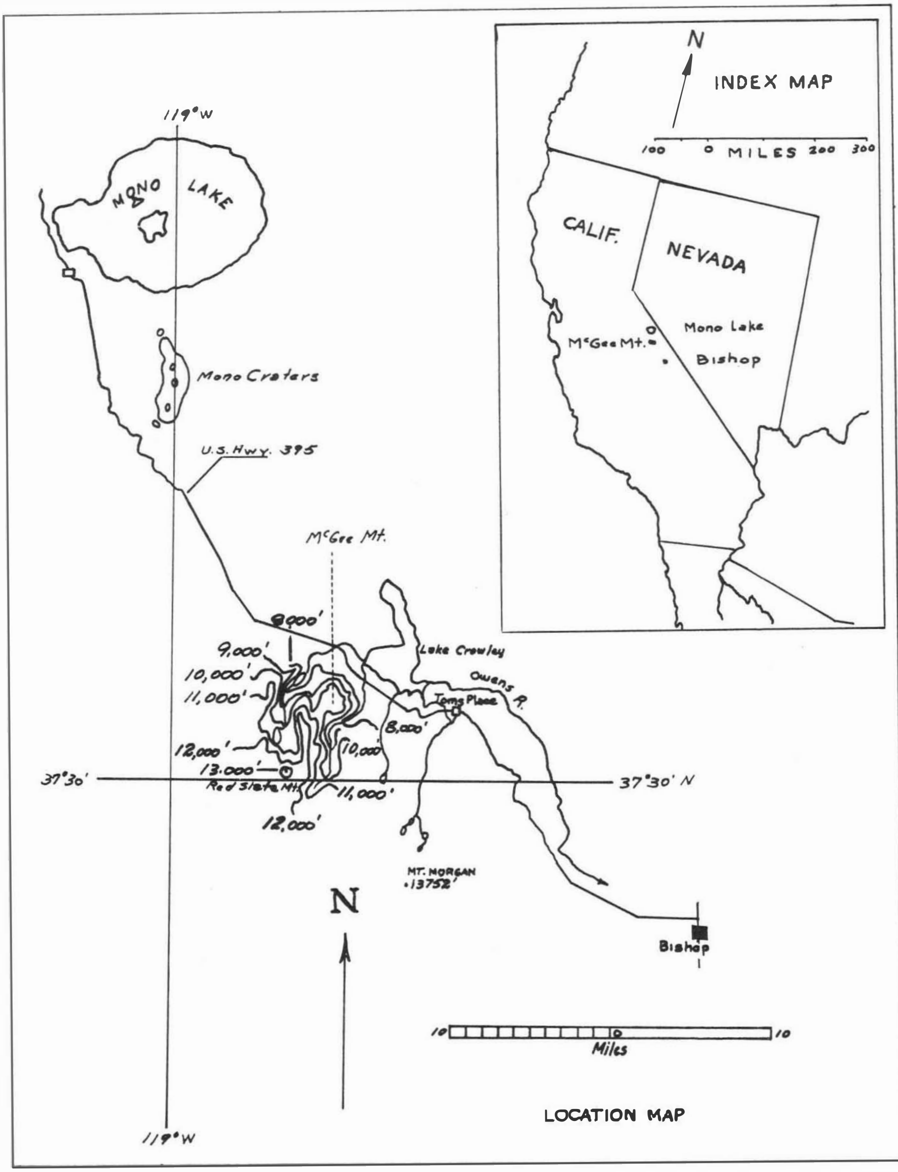

Figure 1. --Index and location maps of McGee Mountain area.

Dr. Evans B. Mayo of the University of Arizona whose close familiarity with the McGee Mountain area, both as an associate of Dr. Blackwelder when he discovered the McGee till and as a long-time student of Sierra Nevada structure, has been of the utmost value in the development of this paper.

INFERRED FAULTING OF THE BASALT

Six statements concerning the basalt require careful evaluation (Putnam, 1962, p. 191).

1. "The basalt has been displaced by faults." On his cross section (Putnam, 1962, map 1) are shown five (or six, if the eastern fault is considered as two) faults cutting the basalt. Putnam inferred that a much larger one (or several with large total displacement) exists to the northeast of the northeasternmost basalt outcrop. Of those that he has shown as obviously cutting the basalt, none have observable displacement. Presumably, they showed as linears on the aerial photographs.

The fourth fault from the southwest end of the basalt, as mapped, shows downthrow to the west (Putnam, 1962, map 1), apparently manifest by basalt on the southwest side and till on the northeast side shown on Putnam's map in fault contact. Downhill creep of the till has resulted in partial or complete covering of the basalt, however; hence, there is no visible structural evidence that this is a fault contact. The fact that the basalt is topographically lower to the southwest than to the northeast can be explained as the result of initial dip on an originally southwestward-sloping surface. This will be discussed more thoroughly in the next two sections.

Since none of the displacements (if they exist) are observable, all the displacement must have occurred along the very front of the mountain itself. This mountain front will be discussed in the consideration of statement No. 5.

2. "Part of it has been moved downslope by landsliding." This particular mass of basalt is shown (Putnam, 1962, map 1) between the 9,120- and 9,440-foot contours north of the main mass of the basalt and as the small northernmost mass of basalt (Tb) in figure 2. Three important features of this mass should be noted.

First, the outcrop is on a topographic nose, rather than in a depression. Normally, a landslide mass would be found in a depression, following the lowest rather than the highest course. Even if it had started on a ridge, it should have slid off to one side after moving 840 feet vertically down a 30° slope.

Second, the material—a hematite-red scoriaceous and agglutinated cindery mass rather than a dense flow—lies on top of granite. This is especially noteworthy because very little of the present slope is underlain by granite bedrock; most of the granite is fractured and weathered so that slopes are generally covered by grus and talus. Yet the basalt lies on bare granite that formed the topographic nose mentioned above. Rapid undermining would remove basalt on a talus or grus slope.

Third, poorly developed flow layers in the cindery material strike N. 45° E. and dip 21° NW.; the present slope strikes N. 40° E. and dips 28° NW.

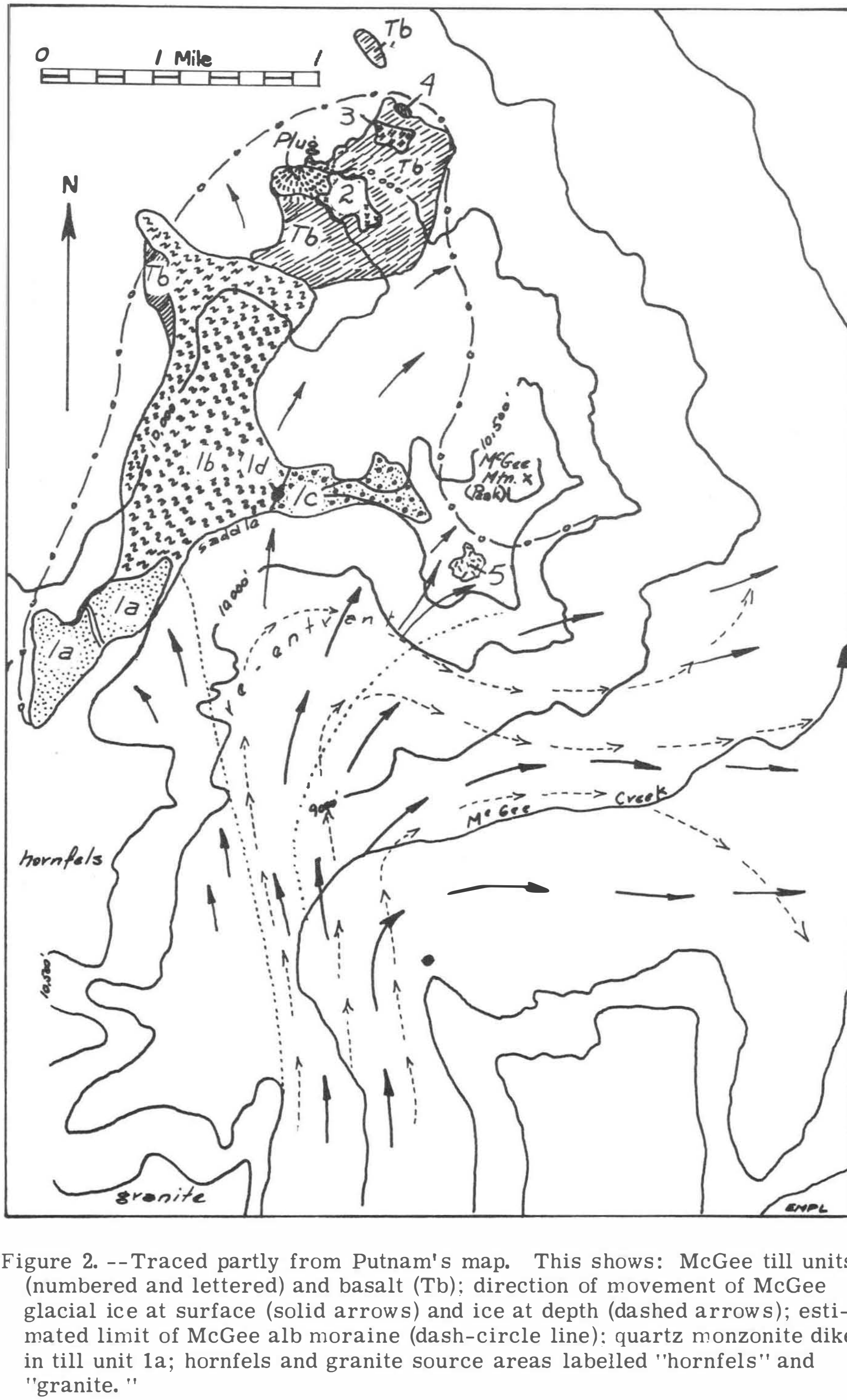

Figure 2. --Traced partly from Putnam's map. This shows: McGee till units (numbered and lettered) and basalt (Tb); direction of movement of McGee glacial ice at surface (solid arrows) and ice at depth (dashed arrows); estimated limit of McGee alb moraine (dash-circle line); quartz monzonite dike in till unit 1a; hornfels and granite source areas labelled "hornfels" and "granite."

This is on the flank of the nose and not parallel to the general northwesterly trend of the northeastern face of McGee Mountain. The flow layers indicate, therefore, deposition of the basalt on a slope essentially parallel to the present one.

The three conditions mentioned strongly indicate that the basalt that Putnam thought to be a landslide mass is part of an original flow. This will become more obvious when the source of the material is described. It appears, then, that the McGee Mountain front existed before the basalt was poured out.

3. "The lava flow appears to have a maximum thickness of about 100 feet." The very northern front of McGee Mountain is the only possible place where this thickness could have been measured (fig. 2). Elsewhere till covers the basalt, and creep has distributed till and basalt talus over a large vertical range, preventing accurate thickness determinations. Even on the northern front of McGee Mountain in but one place does the basalt appear to have a thickness of more than a few tens of feet—its apparent average on the top.

There, the basalt appears to be the eroded heart of a volcanic plug, the magma chamber which underlay the volcanic cone that doubtlessly existed at this site (fig. 3). Along the east side of the lowest exposure of a gypsum outcrop a dike of vesicular basalt is traceable upward hundreds of feet between hornfels and a tectonic breccia zone in the gypsum into a wide zone of massive basalt and cindery material. The cindery material seems to be the continuation of the vesicular basalt dike; the massive basalt may have come from that dike or another one. The cindery material forms a dike that cuts the massive basalt, thus proving the age relationships observed on the surface where the flow materials are overlain by red cinders and bombs. Near the upper part of the magma chamber the material becomes extremely brecciated; the breccia can be traced to the top where volcanic bombs are found on the surface. The size of the bombs decreases away from the core area, also indicating the presence of a volcano at this site.

The vent of the volcano occurs within the 10,000-foot contour (Putnam, 1962, map 1) due west of the three small McGee till outcrops (unit 2, fig. 2); it is labeled "plug" on figure 2. This was the source of all the basalt found on McGee Mountain, including the flow remnant 600 to 900 feet below, which Putnam thought to be a landslide mass. Part of the cinder flow cascaded down the steep escarpment and only that part that was cemented to firm bedrock remains. Other parts of the fluid lava flowed to the east and remain at the crest of the escarpment (fig. 4). Still other parts flowed southwestward down the backslope of the escarpment, over a terrain as smooth and rolling as that of the upland surface of McGee Mountain today (fig. 5).

4. "Indeed a small basalt exposure on McGee Mountain lies in an old valley, later the path of an early glacier which left its moraine on the basalt." This statement from Gilbert (1941) is highly misleading, implying that first the basalt flowed down a valley, and later a glacier followed the same valley. Implicit also is the assumption that this valley is today hanging high on the Sierra front cut off by the frontal faulting.

However, such a valley does not exist. The eroded magma chamber of the volcanic cone may have appeared to Gilbert to be part of a basalt flow in a steep V-shaped canyon, but the structural features of the basalt, especially the steep flow layers in the basalt dike and magma chamber, do not warrant

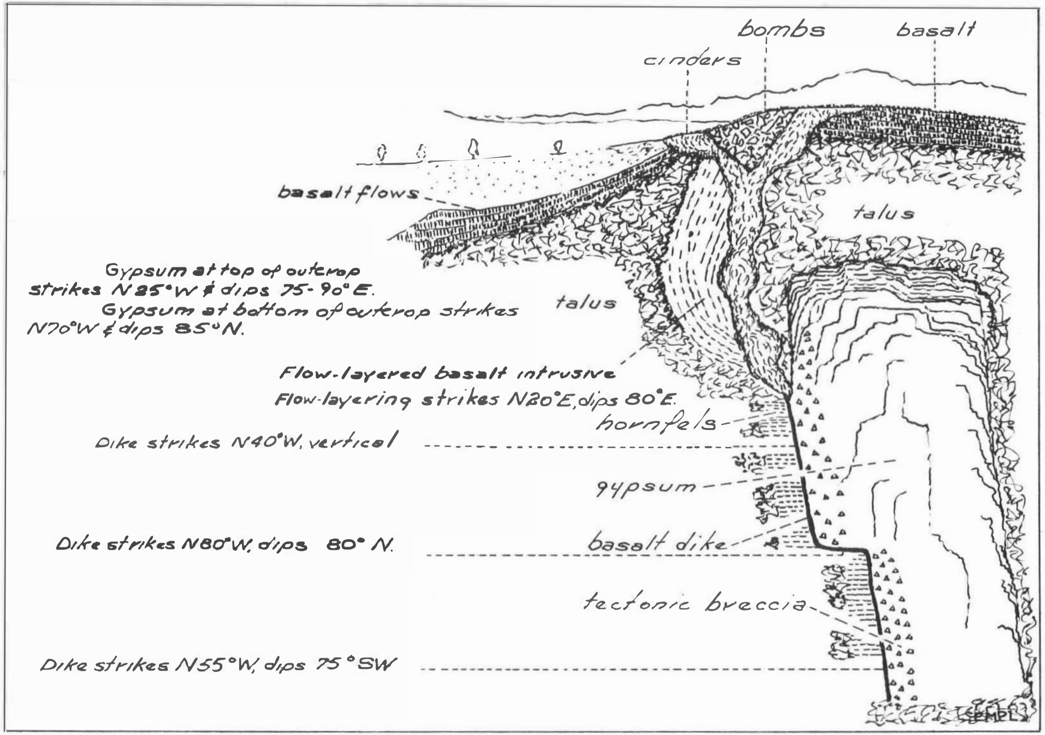

Figure 3. --Schematic cross section of basalt plug on northeast face of McGee Mountain viewed from the northeast. The hillside slopes about 30 degrees toward the observer. The gypsum outcrop is an extremely steep cliff. Talus slopes 35°. Total height from bottom of gypsum to top of basalt is estimated, 600 feet.

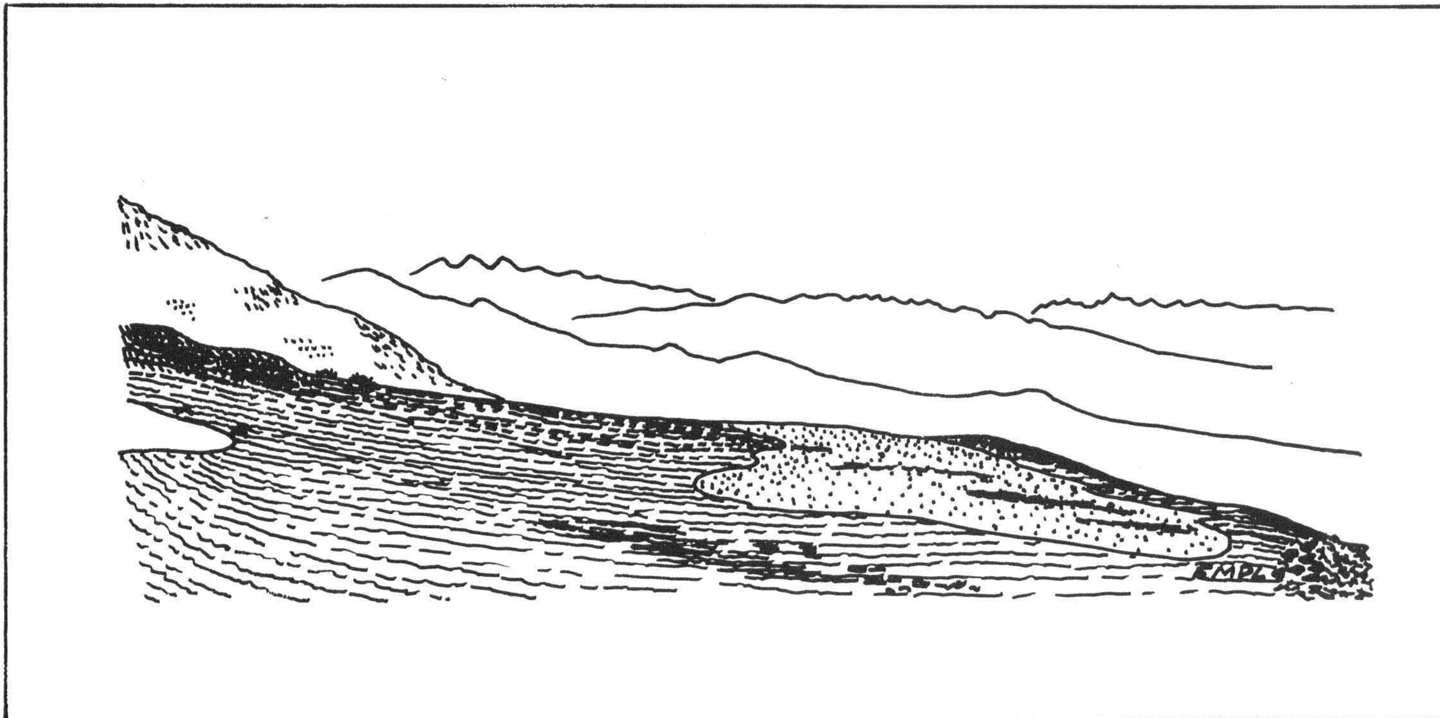

Figure 4. --View toward northwest along the McGee Mountain scarp crest. Unit 3 of the McGee till (light-stippled area) rests on basalt. The basalt plug (dark area beyond snow patch at left edge) and basalt boulders at the eastern edge of the flow (at the very lower right edge of the sketch) stand at the scarp crest.

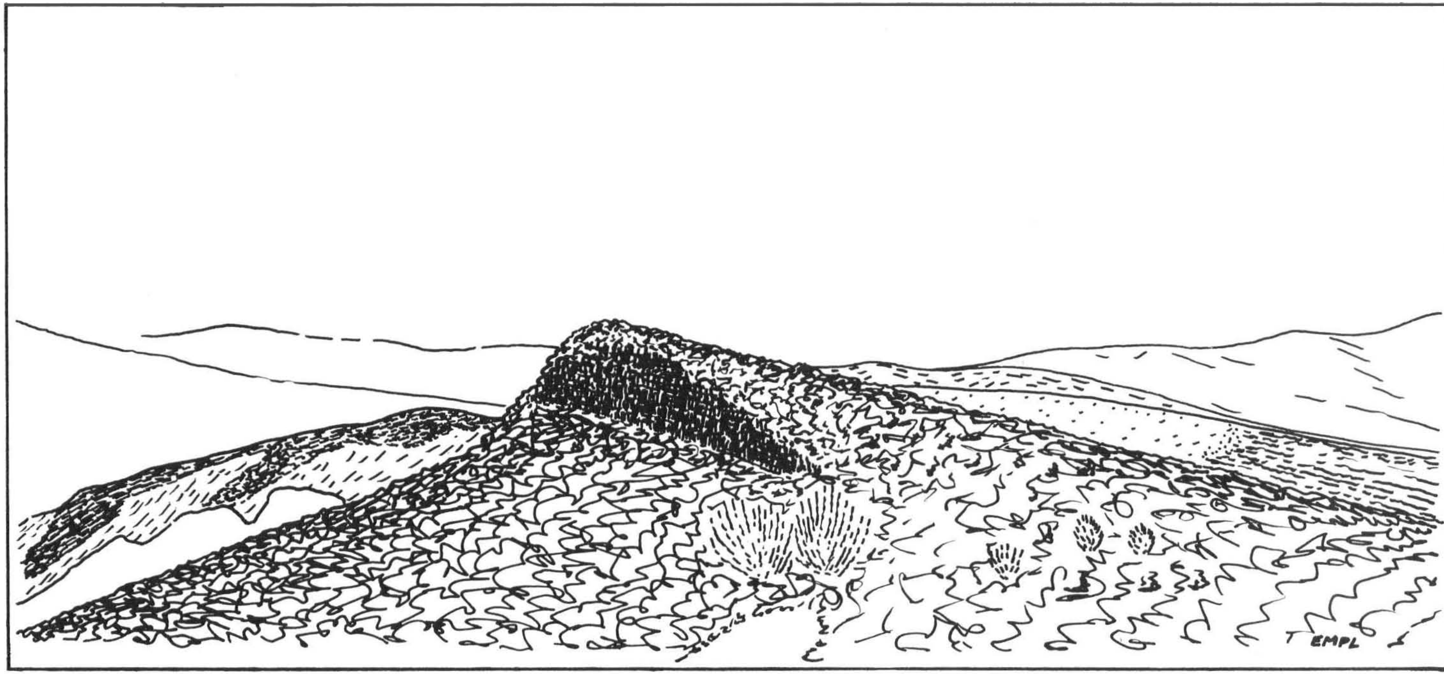

Figure 5. --View eastward along the crest of the escarpment at the northeast edge of McGee Mountain showing southwesterly dip of basalt flows (shown as "basalt" in upper right of fig. 3). Till unit 2 (light-stippled area to right of basalt flows) is about 30 feet thick. Basalt cliff is about 20 feet high. Till units 3 and 4 lie on basalt flows at left. Bare white at left above basalt talus is gypsum outcrop.

that interpretation. That the McGee glacier never followed such a valley will be shown in the discussion on the formation of the till.

5. "The cross-section accompanying the geologic map shows that the basalt terminates abruptly at the escarpment bordering the summit upland of McGee Mountain. This is at an altitude of 9, 840 feet, and a downfaulted possible equivalent exposed in the walls of Owens Gorge, although of variable thickness and much broken by faults, stands at an average altitude of about 6, 500 feet. Allowing a reasonable northward inclination of the bedrock surface upon which the basalt rests, this gives a probable total displacement of 9, 000 feet in the vicinity of McGee Mountain." That the basalt does not terminate abruptly at the escarpment has already been shown. However, instead of assuming the upland surface to be the upwardly displaced datum, Putnam might have used the lowest basalt outcrop, resulting in a displacement of about 720 feet less, or 8, 280 feet, a difference hardly worth mentioning. There is, however, no break in the frontal scarp at this basalt outcrop.

Because the slope continues essentially straight above and below that mass, the history of the slope above and below it must be the same. There is no geomorphic evidence of a two-stage development of the frontal scarp. Again, it appears that the scarp must have existed before the basalt was poured out.

Dalrymple (1963), by means of potassium-argon dating, indicates that the McGee Mountain basalt (2. 6 m. y.) and the Owens Gorge basalt (3. 2 m. y.) are not of the same age. Correlation of the two basalts over a distance of 12 miles with no intervening outcrops was tenuous to begin with. Consequently, the geometry of tilting and even the need for tilting are immaterial.

Unless there is a major error in the above reasoning, one is now obliged to consider seriously whether the frontal scarp of McGee Mountain did not exist about as it now is before the basalt was poured out. If that is so, then there is no evidence of significant post-basalt faulting at this locality[1/].

6. "The question of the age of the basalt is a vital one." Sharp and Birman (1963, p. 1085) believe that the McGee till is of Nebraskan age, as originally thought by Blackwelder (1931). Putnam (1962, p. 195) believes that it is "more likely contemporaneous with the Kansan." The age assignment of Sharp and Birman is based on a larger amount of evidence.

The McGee till rests on a fairly subdued upland surface on McGee Mountain but extends to the very edges of steep (30^{o} and more) slopes. These easily eroded tills have survived the rigorous Alpine climate throughout the Pleistocene. McGee Creek granite boulders in the till lie inches apart on the flat upper parts of the till; hence, weathering cannot have reduced their sizes

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1/ There has been very late Pleistocene or post-Pleistocene movement, amounting to a few tens of feet, on a fault at the northeastern base of McGee Mountain. The displacement is recorded in a basal scarplet that traverses talus fans and the Pleistocene moraines at the mouth of McGee Creek canyon. This slight adjustment, so well documented, cannot be denied. The question is raised, however, whether basal scarplets, aligned springs, even aligned hot springs, etc. can be confidently accepted as evidence of a large amount of Recent or even geologically young fault displacement.

materially. Yet, adjacent to these tills at the top of the steep escarpment the volcanic plug manifests deep erosion of the flows, tens of feet thick, lying on the metamorphic bedrock. Considering these conditions we may conclude that the basalt is considerably older than the till.

This conclusion, independently derived by geological observations, appears to be in accord with Dalrymple's conclusion, mentioned above, of an age of 2.6 m.y. for the McGee basalt.

The conclusions concerning inferred faulting of the basalt are given below.

1. The basalt has not been observably displaced by faulting.

2. The surviving attitudes of the basalt can best be explained as the result of initial outpouring on a steep escarpment as well as on a gentle upland slope.

3. The age of the basalt seems to be significantly greater than that of the McGee till.

INFERRED FAULTING OF THE MCGEE TILL

Putnam's principal statement concerning the McGee till is: "Since the McGee till was deposited, the range of which it is a part has been uplifted a minimum of 3,500 feet—presumably largely by faulting, but with warping playing an indeterminate but possibly significant role. This is a minimum figure because the downfaulted extension of the McGee till and its associated glaciofluviatile deposits, beyond where they are truncated by the Sierran escarpment, are concealed by the alluvium of Long Valley. Assuming a depth of burial of around 500 feet, this would make the post-McGee uplift of this segment of the Sierra Nevada amount to approximately 4,000 feet. Concurrently with this uplift the two canyons of McGee and Convict Creeks were eroded to depths of 2,000 to 3,000 feet below the McGee summit upland."

There is almost a compelling cogency in Putnam's argument at this point. Reasoning by analogy would be:

1. The Sherwin, Tahoe, and Tioga moraines are exposed in the Sierran block.

2. They are also exposed in the Long Valley block.

3. The exposures across the Sierran front are continuous; therefore, there has been no significant faulting of the Sherwin, Tahoe, and Tioga moraines across the Sierran front.

Also:

1. The McGee tills are exposed in the Sierran block.

2. They are not exposed in the Long Valley block but are assumed to exist buried 500 feet beneath later deposits.

3. The exposures of McGee till are not continuous across the Sierran front; therefore, there has been significant faulting of the McGee till across the Sierran front, the displacement being about 4, 000 feet.

However, semantics may be the problem here. Putnam assumes that the McGee, Sherwin, Tahoe, and Tioga tills, as exposed, are all similar; that is, the McGee till was formed geometrically and genetically just as were the later Sherwin, Tahoe, and Tioga moraines. However, if the McGee till is genetically different from the younger deposits and was formed in such a way that the discontinuity across the Sierran front need not imply or prove faulting, then the above analogy is invalid.

Of course, if there has been no significant post-basalt faulting at McGee Mountain, there can have been no faulting amounting to 4, 000 feet since McGee glacial time. Yet, several competent geologists have regarded the nature and position of this old till as evidence of a great post-McGee uplift.

The observation used in support of this supposition has been the existence south of the till, and between it and its inferred source, of the profound canyon of McGee Creek. Had the canyon been present in McGee time, how could the till possibly have reached its present position?

Attempts at alternative explanations have not been lacking. One of these proposes that the "till" is not of glacial origin but represents ancient mud flows from the rising Sierran scarp (unpublished suggestion by A. C. Lawson according to E. B. Mayo, personal communication). This explanation does not solve the problem of transport across McGee Canyon, so it will not be considered further.

Because parts of the till consist almost exclusively of granitic boulders, the suggestion that this material originated in place through the slow disintegration of a granitic stock would seem to have merit. However, none of the granite found on McGee Mountain is like the granite of the boulders.

Furthermore, according to Dr. E. B. Mayo (personal communication), who has spent many years in the study of the region, the granite of the McGee till does correspond exactly with the rock in a large intrusion in the upper part of the valley of McGee Creek (shown as "granite in figs. 2 and 6); this same granite is the source for much of the younger till in McGee Creek canyon. Even more convincing is the degree of plastic deformation undergone by the dark inclusions (Putnam, 1962, pl. 3b) in the granite of the boulders, allowing their source to be located fairly accurately somewhere in the central part of the large intrusion. The deep canyon of McGee Creek now separates that source from the boulders; the problem of transport across this canyon must be solved. To do so requires an examination of the till itself.

Description of the McGee Till

The McGee till is remarkably different from the Sherwin, Tahoe, and Tioga moraines in Convict Creek and McGee Creek canyons (figs. 4, 5, and 7). Putnam did not mention these differences, yet they deserve special description because of their bearing on the origin of this deposit.

For this purpose the deposit must be subdivided geographically. The

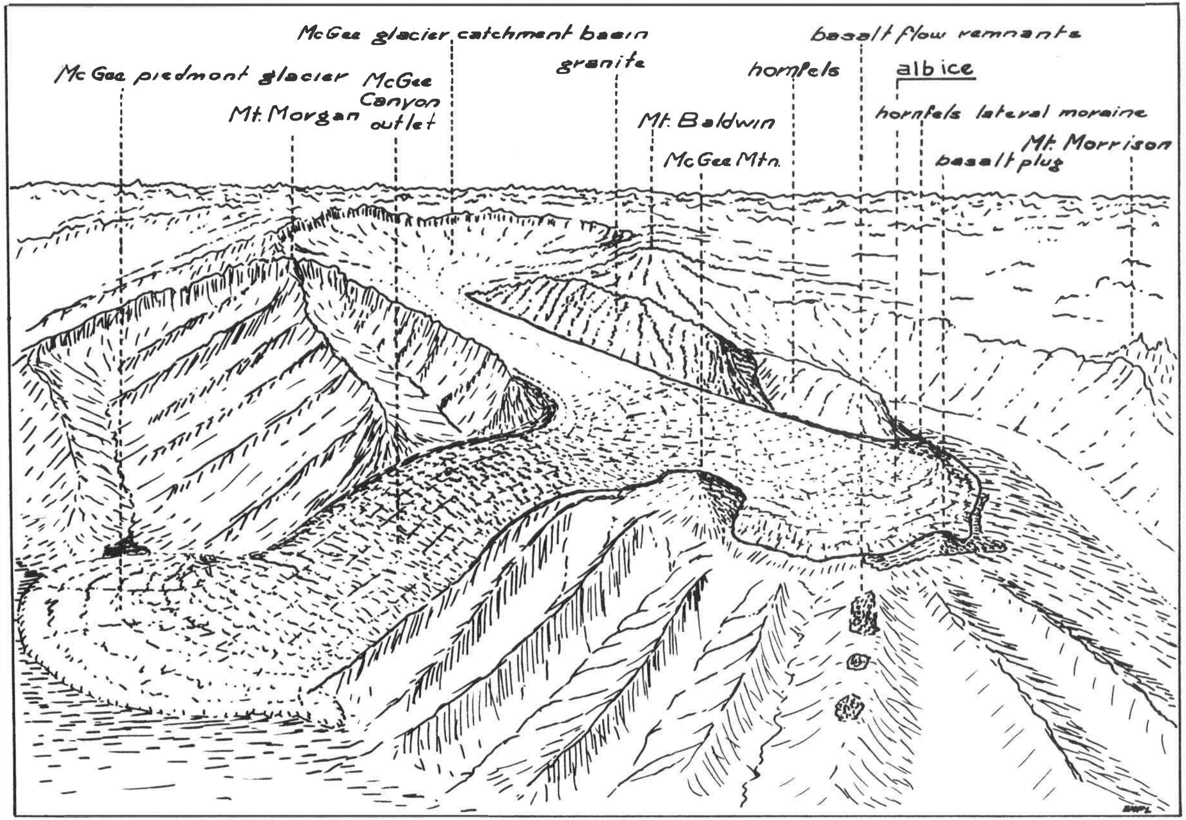

Figure 6. --View toward southwest of McGee Mountain area showing reconstructed McGee glacier at maximum stage of development on McGee Mountain summit upland.

till is exposed in five general units (fig. 2) numbered 1 through 5—the largest being No. 1, the next one north being No. 2, and so on. No. 5 is the small segment of till 0.3 mile south-southwest of McGee Peak. Unit No. 1 is further subdivided into four units—1a, 1b, 1c, and 1d.

Unit 1a (the hornfels lateral moraine shown on figs. 2 and 6) of the McGee till consists of angular fragments of hornfels, generally less than 2 inches long, but boulders as much as 3 feet long are abundant; these consist of nonhornfelsic metamorphics and granitoid rocks (but not the McGee Creek granite). These boulders are quite abundant on the northwest slope extending down into the Convict Creek drainage system (along the skyline to the left of the hornfels ridge shown in fig. 7). The moraine is apparently not more than a few feet thick where it crosses the quartz monzonite dike (fig. 2). The apparently greater thickness, as shown on Putnma's map (1962, map 1), appears to be the result of extensive soil creep down the steep slopes bordering the ridge. The underlying rock type is hornfels similar to that of the till; hence, the till limits are primarily determined by the distribution of the larger round boulders. These tend to roll down the hillside readily; therefore, the till distribution seems much broader than its in situ position.

The contact between unit 1a and unit 1b is sharp with respect to the granite boulders but gradational with respect to the hornfels fragments. This may be the result of original deposition or merely of mixing of till and regolith. The zone of contact is several hundred feet wide, but the granite boulders make an appearance so sudden as to be impressive, for nowhere south of this sharp line are there any McGee Creek granite boulders.

In unit 1b the fine material is grus, derived from the disintegration of the granite boulders. Grus does not occur in unit 1a. There are few small granite boulders in the southern part of unit 1b; the boulders are huge, as Putnam (1962, pls. 3b, 4, and 5, all parts of till unit 1b) pointed out, many of them being more than 15 feet long. In addition to the granite boulders, there are also quartzite boulders, the distribution of which is also noteworthy.

East and south of the saddle (labeled on fig. 2) formed on the ridge 1 mile west of McGee Peak there are no quartzite boulders in unit 1b; the till is composed entirely of granite boulders and fragments. But north and west of that saddle quartzite boulders become common and even abundant with increasing distance north from the saddle. Some of them are as large as the largest granite boulders. Weathering has given them a polish foreign to the weathered surfaces of the granite boulders. Nowhere in the till is there an outcrop of bedrock; the source of the quartzite is unknown, but its distribution indicates that it may not have been transported very far along with the granite boulders and may even have been derived locally. If so, the source of the quartzite may lie beneath the till in the vicinity of the saddle. The origin of the quartzite boulders must also be considered for till units 3 and 4.

On the ridge, in the vicinity of the saddle, the granite boulders are platy as a result of their jointing. They lie with a statistical orientation, the platiness being subhorizontal with a tendency, which may be more apparent than real, toward an easterly dip.

The thickness of unit 1b is greatly variable. At its contact with unit 1a, unit 1b seems very thin, based on the distribution of granite boulders. To the east, the till is only boulder thick near the contact with unit 1c, but north of the saddle the unit seems to thicken. Putnam reported it to be 500 feet thick

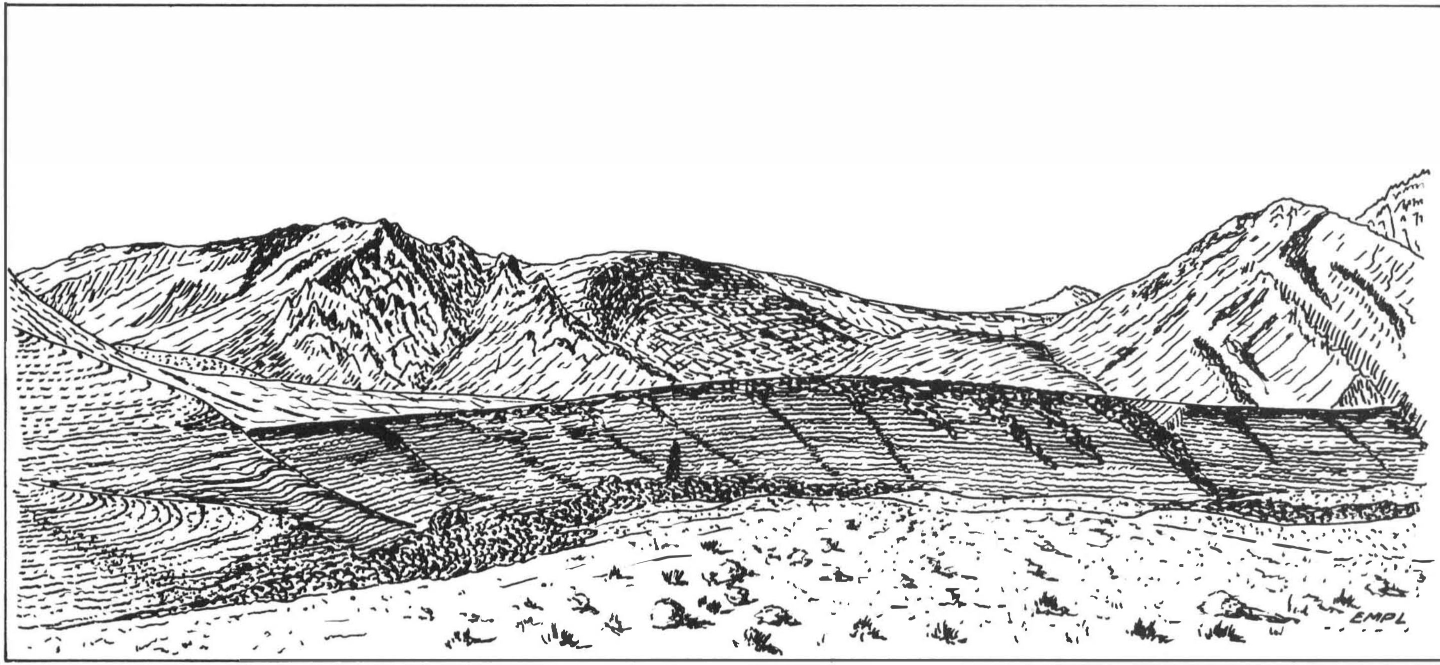

Figure 7.--View toward south from Convict Creek Canyon showing McGee Mountain (jagged mountain at left). The north end of the hornfels ridge (labeled "hornfels" in figs. 2 and 6) barely shows on the skyline in the broad col at the right. McGee till extends along the skyline ridge from that hornfels mass to the basalt plug and flow (dark patches on skyline of McGee Mountain at left). Younger moraines form the long ridge and rounded hills in middle ground and left. Mt. Morrison is at the extreme upper right edge.

(1962, p. 192), but the obviously great amount of soil creep makes a thickness determination difficult if not impossible. Based on estimates made on the northeast side of the ridge, a thickness of more than 200 feet seems improbable, but this estimation is tenuous. Where the till thickness can be determined it is never more than a few tens of feet.

At the northwestern edge of unit 1b the till becomes admixed with basalt boulders, but whether as the result of original mixing or subsequent creep is not known.

Unit 1c is very much like unit 1b, but it is separated from unit 1b by a very small (less than one-third of an acre) area of till remarkably like till unit 1a. This appears to underlie units 1b and 1c, although evidence of this is not convincing. This small bit of unit 1d is important to the subsequent analysis. Unit 1c thins to extinction to the east and is only a few tens of feet thick at the most. Scattered erratics lie on hornfels at its periphery. Minor hornfels fragments occur in the till, but regolith admixture from the hornfels bedrock is probable.

Unit 5, lying southeast of the eastern end of unit 1c, is similar to units 1b and 1c; it is only a few feet thick. There are some scattered hornfels fragments in it, but these seem to emanate from a small acclivity on the hornfels bedrock just north of the till boundary. One striated granite boulder was found in unit 5. The striae were covered with epidote, indicating that they were fault produced. The lack of weathering on that boulder is noteworthy.

Unit 2 resembles the northern end of unit 1b. Granite boulders predominate, and only a few quartzite boulders occur; these are generally fairly small in comparison to the huge quartzite boulders near the central part of the northern end of unit 1b to the south. The thickness of unit 2 is probably about 20 to 30 feet. Grus forms a large proportion of the finer material in the till.

Unit 3 (fig. 4) differs from unit 2, from which it is barely separated, in a most remarkable way. Only two small rounded fragments of greatly weathered granite were found in the unit, and these are at its western end; all other boulders are of quartzite. The smaller fragments consist of hornfels and quartzose metamorphics and scoriaceous basalt fragments, all apparently derived from local bedrock. Boulders are as much as 5 feet long, but smaller fragments, all hornfelsic, from 1 to 2 inches long are abundant. The largest boulders are in the center of the unit. There is no grus in the sand or small fraction of the till. The maximum thickness is about 40 feet; the thickness approaches zero at the edges where scattered erratics lie on the basalt.

Some erratics (or till-derived rock fragments) extend downhill to the east a considerable distance (shown as till in fig. 4). The basalt boulders at the very eastern extremity of the flow (fig. 4) appear to have been slightly disarranged from their original position, but not enough to disorder them greatly, because, first, the flow layers in the various basalt boulders are neither uniformly arranged nor greatly disarranged, and second, none of the boulders seem to be in place. This pile of basalt boulders, therefore, probably represents the very end of the glacial lobe at this point (figs. 2 and 6).

Unit 4 is similar to unit 3 in general appearance, but it is much thinner; no granite is found, for all the boulders are of quartzite. Unit 4 is an outlier of unit 3. Both units are very thin, but unit 4 is nothing more than a veneer of erratics on basalt. In general, the till is only one boulder thick, and the quartzite boulders are separated by basalt outcrop rather than by till fragments. Unit 4 may represent the very edge of glacial deposition also (figs. 2 and 6).

Development of Alb Moraines

The position of the McGee till on the old upland surface of McGee Mountain is strongly reminiscent of the occurrence of ground moraines on alb surfaces (von Engeln, 1948, p. 462), for which we shall here use the term alb moraine. The analogy remains even though the upland surface is not a true alb surface.

The McGee glacier, flowing in a V-shaped canyon considerably shallower than the present one (which has been deepened and widened by four periods of glacial erosion), was forced to execute a nearly right-angled bend before emerging from the mountains (figs. 2 and 6). The steep northward declivity of the southern part of this glacier, plus the necessity to turn so sharply, may have forced the upper layers of the glacier to spill outward on the convex side of the bend. As a result, a thin ice sheet, probably not much more than 200 feet thick, should have been pushed northward over the upland surface toward the edge of the Sierran scarp as alb ice (fig. 6).

The resulting ground moraine should have been relatively thin. It probably never displayed the greatly hummocky surfaces characteristic of the younger moraines today; yet it should have been recognizable as the smoother forms of glacial origin called here alb moraine. Weathering and erosion, mostly soil creep around the periphery, have modified these initial forms to produce the present-day shapeless masses of McGee till or alb moraine.

Development of the McGee Alb Moraine

In order to visualize more clearly the formation of the alb moraine and to explain the peculiar distribution of materials in the McGee alb moraine, a very brief description of the bedrock geology is necessary.

The metamorphics of the region consist of hornfels, limestone, gypsum, and quartzites. Granite crops out on the front of McGee Mountain and also in McGee Creek canyon about 4 miles south of McGee Mountain (figs. 2 and 6). The McGee Creek granite supplied most of the debris for the moraines in McGee Creek canyon and was the source for the granite boulders in the McGee alb moraine, as already pointed out. The geometry of the hornfels and granite outcrops on the west side of McGee Creek canyon was important in the development of the McGee till configuration, as will be shown.

In figure 2 and on the map by Putnam (1962, map 1) the thickest part of the McGee till is shown to lie directly in line with the steep southern segment of McGee Canyon. The momentum of the ice in this northward-trending and north-sloping segment was obviously directed northward, unless the topography of that time was vastly different from that now visualized. In line with this overflow, the McGee till is now extended across the upland, and the isolated patches suggest that the alb ice spilled for some, possibly slight, distance down the northwest slope of the mountain. In line with this "mainstream" of overflow is situated not only the thickest till and the evidence of greatest extension, but nearly all the material now consisting of granitic boulders and grus. Recalling the source of the granitic material, it does not seem possible that the topography of McGee time has been erroneously visualized.

As the McGee glacier advanced down its canyon beyond the granite, the debris on its left side, because of the distribution of the bedrock (fig. 2), should have consisted of metamorphics; so, then, should the left-lateral moraine. As the ice rose and emerged on the upland surface, this early formed left-lateral moraine should have been pressed outward in an ever-widening loop and finally should have been overwhelmed by the uppermost ice layers from the center of the glacier bearing a load of coarse granitic debris.

Using this sequence of events, the distribution of the several lithologic types among the remnants of the alb moraine is easily explained. Area 1d, for example, is a "window" revealing the thin layer of metamorphic debris of that left-lateral moraine on which the spreading alb ice deposited its load of granite boulders. Area 1a, with its metamorphic debris, is likewise a remnant of the old left-lateral moraine unsurmounted by granitic debris.

As the glacier turned to the east in the lower part of the canyon, the deeper portions of the ice (as indicated by the dashed arrows in fig. 2) tended to gouge out the northern wall (the "re-entrant"), the convex side of the turn, thereby developing the large bowl in that part of the canyon. At the same time, the entire lower part of the canyon was being deepened by glaciation. As a result, a stage may have been reached at which the large volume of ice could be accommodated within the canyon, so that the topmost ice was no longer pushed outward on the convex side of the bend to nourish the alb ice. If this happened at some time early in the McGee glacial stage, then the alb ice was short lived. This would account for the very slight mixing of rock types in the McGee till as compared with the thoroughly mixed materials in the valley moraines of the later glacial stages.

In any case, by the end of the McGee glacial stage the canyon deepening and widening must have proceeded so far that no subsequent glacier was able to disturb the McGee alb moraine. On the other hand, so far as known, all evidence of the McGee Valley moraines was subsequently erased from the canyon, and the old McGee terminal moraine must have been destroyed or buried.

CONCLUSIONS

In view of the above observations and inferences, it seems that a reasonable solution has been provided for the problem of transporting the McGee till across the now profound McGee Creek canyon. The canyon was there in McGee time, but it was then much narrower and shallower than at present. The alb ice need not have extended, and probably did not extend, much beyond the northernmost till remnants of today. The perched position of this till, then, cannot be used as evidence of great Pleistocene uplift.

The two phases of this investigation, the study of the basalt and the study of the McGee till, lead to the same conclusion. There has been no great uplift of the Sierra Nevada by faulting at this place since outpouring of the basalt. The geologic evidence cited in support of a late Neogene uplift becomes, after careful scrutiny and critical study, evidence against that same late Neogene uplift.

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