Quaternary Geology of Long and Bear Valleys, West-Central Idaho

GEOLOGICAL SURVEY BULLETIN 1311-A

Prepared on behalf of the U.S. Atomic Energy Commission

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By DWIGHT L. SCHMIDT *and* J. HOOVER MACKIN

CONTRIBUTIONS TO GENERAL GEOLOGY

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Late Cenozoic Basin-and-Range-type faulting and late Quaternary mountain-valley glaciation controlled the origin and distribution of radioactive placer deposits containing monazite and euxenite

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QUATERNARY GEOLOGY OF LONG AND BEAR VALLEYS, WEST-CENTRAL IDAHO

By DWIGHT L. SCHMIDT and J. HOOVER MACKIN [1]

ABSTRACT

Monazite and euxenite were extensively dredged as placer minerals from Quaternary alluvial deposits in Long and Bear Valleys during 1951–59. These and other accessory heavy minerals were released from the rocks of the Idaho batholith by deep weathering during the Tertiary and early Quaternary. Concentration of the heavy minerals in large placers depended on particular sets of circumstances, variously involving block faulting and glacial and periglacial processes.

First-order physiographic features in west-central Idaho are linear north-south ranges and valleys formed by block faulting during the late Tertiary and Quaternary. Tertiary (Miocene) Columbia River Basalt overlies the gneissic and granitic rocks of the west border of the Idaho batholith and is commonly tilted 15°–30° W. Lacustrine deposits, probably as young as early or middle Pleistocene, are tilted as much as 20°, an indication that block faulting was active during the Quaternary. The block faulting deranged the Payette drainage system, and alluvium accumulated in the fault valleys, especially in Long Valley, where gravity measurements indicate as much as 7,000 feet of fill.

Moraines and proglacial outwash of Bull Lake and Pinedale age are the most widespread Quaternary deposits. A few outcrops of ancient till in the Long Valley area probably represents an extensive pre-Bull Lake drift that has been mostly removed by erosion or buried by the younger deposits. Upper- and post-Pleistocene moraines occur above 7,500-foot altitude in several north- and northeast-facing cirques. Periglacial deposits of both Pinedale and Bull Lake age are prevalent in small drainage basins that were not glaciated.

Altiplanation, especially intense in the periglacial environment of Pleistocene time, may be the process that produced the rolling upland surface that is well developed in west-central Idaho and is generally common throughout the high mountains of Idaho. Glacial scour and rapid periglacial slope denudation during the late Pleistocene has practically eliminated deeply weathered bedrock in west-central Idaho. As a consequence, placer deposits are not being formed at the present time.

[1] Deceased Aug. 12, 1968.

INTRODUCTION

This report is a byproduct of a study of placer deposits that contain radioactive heavy minerals in west-central Idaho, principally monazite in the Long Valley area (Mackin, 1952) and euxenite in the Bear Valley area (fig. 1; Mackin and Schmidt, 1953, 1956). The investigation was made on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission. The deposits were drilled concurrently by the U.S. Bureau of Mines; it is a pleasure to acknowledge the cooperation of R. M. Storch and A. F. Robertson, engineers in charge of the drilling (Eilertsen and Lamb, 1956). Paul L. Williams and John F. Kolars assisted ably in the field work. We are indebted to Charles B. Hunt for discussions of field relations, particularly the correlation of glaciations with the Pleistocene succession elsewhere in the Rocky Mountains.

The 15-minute quadrangle maps used as a base for the geologic maps became available after completion of our mapping on 1:20,000 aerial photographs, but transfer of the geology has caused little or no loss of accuracy because most of the geologic units are expressed by the topography or detailed planimetry. Contacts of the Columbia River Basalt on West Mountain are only approximately located. Because the text is mostly an explanation of relations shown on the geologic maps, frequent reference to the maps is required during reading of the text.

GEOLOGIC SETTING

MAJOR ROCK UNITS

The Bear Valley area, underlain by predominantly directionless granitic rocks of the Cretaceous Idaho batholith, is near the center of the batholith (Larsen and Schmidt, 1958; Ross, 1936; Anderson, 1952). The granitic rocks are cut by mid-Tertiary felsic to mafic dikes (Ross, 1934, p. 249). Long Valley lies obliquely across a broad belt in which the directionless granitic rocks of the interior of the batholith grade westward into gneiss and schist of the border of the batholith. The western half and border of the batholith is divided into six rock zones that have been defined on the basis of the variation of major rock-forming minerals (Schmidt, 1958, 1964). Minor accessory minerals vary systematically from zone to zone. Sphene, allanite, epidote, and magnetite, in varying proportions, characterize four foliated border zones, whereas various combinations of ilmenite, magnetite, and monazite typify the directionless granodiorite and quartz-monzonite zones of the interior of the batholith. Apatite and zircon are nearly ubiquitous.

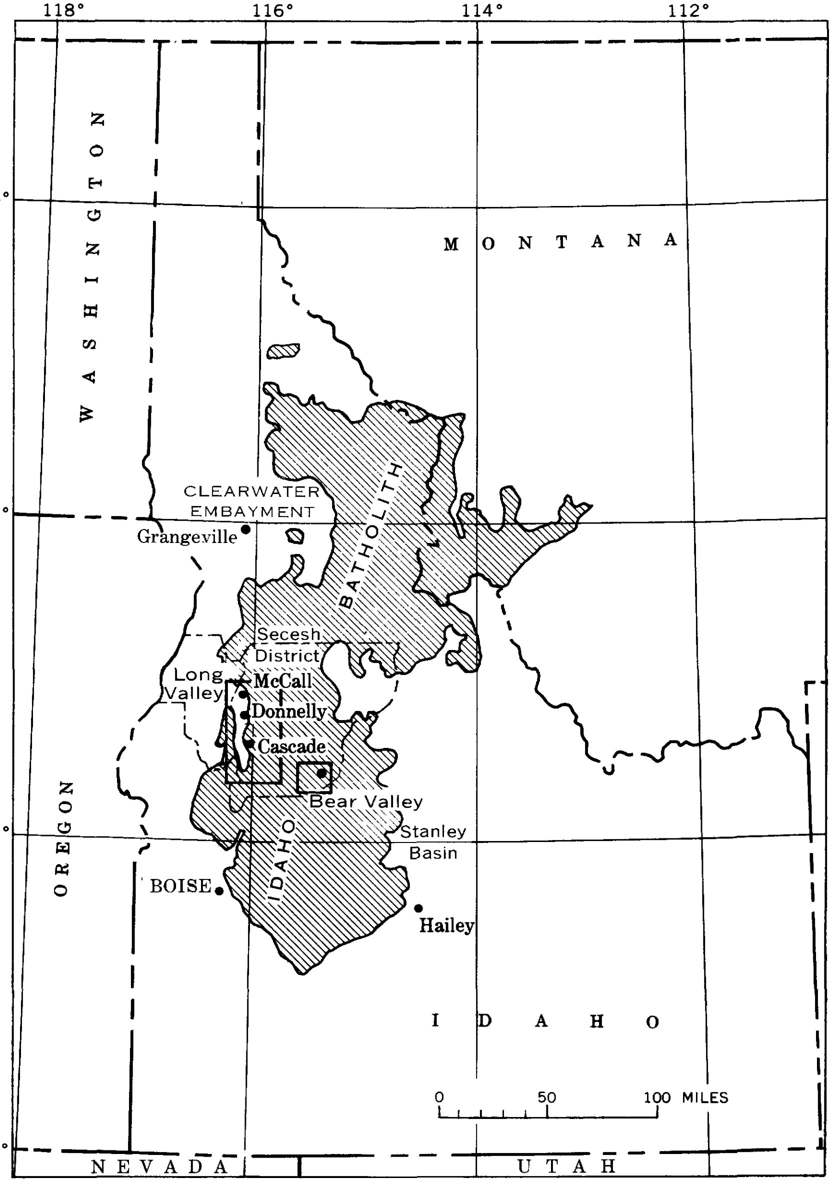

FIGURE 1.—Index map of Idaho outlining the Idaho batholith and the areas of the Long Valley and Bear Valley maps.

Monazite in placer deposits in Long Valley is chiefly derived from the zone of directionless granodiorite east of Long Valley. Euxenite in placer deposits in Bear Valley is derived specifically from narrow granodioritic belts surrounding small areas of quartz diorite within the quartz-monzonite zone.

Long Valley corresponds approximately with the eastern boundary of the Columbia River Basalt. The boundary is irregular in plan because the basalt flows spread from the west into valleys of an erosion surface having as much as 2,000 feet of relief (Lindgren, 1900, p. 96; Bond, 1963). A sedimentary sequence consisting chiefly of lacustrine silt and clay, underlying and interbedded with the basalt, is tentatively correlated with the Latah Formation of the Spokane area on the basis of similar stratigraphic relations (fig. 2) and on the occurrence of pollen grains consistent with the Miocene flora of the region (H. P. Hansen, written commun., 1958).

GEOMORPHIC AND FAULT RELATIONS

Of the several major geomorphic elements of west-central Idaho, the most extensive is a rolling upland surface, commonly 7,000—9,000 feet in altitude, that is trenched in many places by steep-sided valleys. This is the so-called Idaho peneplain, considered by various workers to be Eocene to Pliocene in age. We believe that smooth slopes that characterize the surface were formed by frost-accelerated erosion above the oscillatory timberline of the Pleistocene. This interpretation makes it an altiplanation surface rather than a peneplain and younger rather than older than certain valleys cut below it which are occupied in part by Columbia River Basalt. The long-standing controversy of the peneplain has been reviewed by Fenneman (1931, p. 185–196) and Thornbury (1965, p. 386–387). The arguments advanced by the proponents for peneplanation at any given date during the Tertiary and against peneplanation at other times add up to a strong case against peneplanation at *any* time.

Rising above the general upland surface are north-south ranges having crestlines of from 8,000 to 11,000 feet; at the higher altitudes smooth slopes give way to steep cliffs cut by alpine glaciers. Many of the ranges are asymmetric in cross section and are bordered by wide north-south valleys at altitudes of 5,000–6,000 feet; these ranges and broad valleys were probably formed by block faulting.

As suggested by Anderson (1934) and Capps (1941b), the faulting is a northward continuation of Basin-and-Range structure. It is similar in type of movement and span of age. West-central Idaho, however, differs from the Great Basin in overall altitude and climate; most of the Great Basin is alluviated plains that have internal drainage, whereas in West-Central Idaho only the deepest fault troughs are alluviated and all drainage is to the sea.

The largest and best documented fault in the area marks the break between the 3,000-foot-high West Mountain escarpment and Long Valley. It is part of a system of branching faults described by Anderson (1934, p. 25) and extended by Capps (1941b, p. 7) as a single fault—the Long Valley fault—about 100 miles north to Grangeville and 60 miles south to Boise (fig. 1). Geologic proof of faulting is provided by the Columbia River Basalt, which is relatively uplifted and tilted westward in the West Mountain block and in several smaller fault blocks within and east of Long Valley (fig. 2). A gravity survey by Kinoshita (1962) in 1957 indicated a thickness of 7,000 feet of sediments in Long Valley between the West Mountain scarp and Donnelly; this depth of fill, as well as the height of the scarp, means that the postbasalt throw is about 10,000 feet. The gravity survey also demonstrated the presence of other faults of large throw that are associated with westward-dipping valley-filling sediments; most of the concealed faults are extensions of, or splits from, faults mapped on the basis of geologic relations at the surface.

Most faults in the directionless granitic rocks east of the basalt are inferred on the basis of geomorphic evidence, chiefly stream alinements and linear patterns of relief for which there is no obvious other struc-

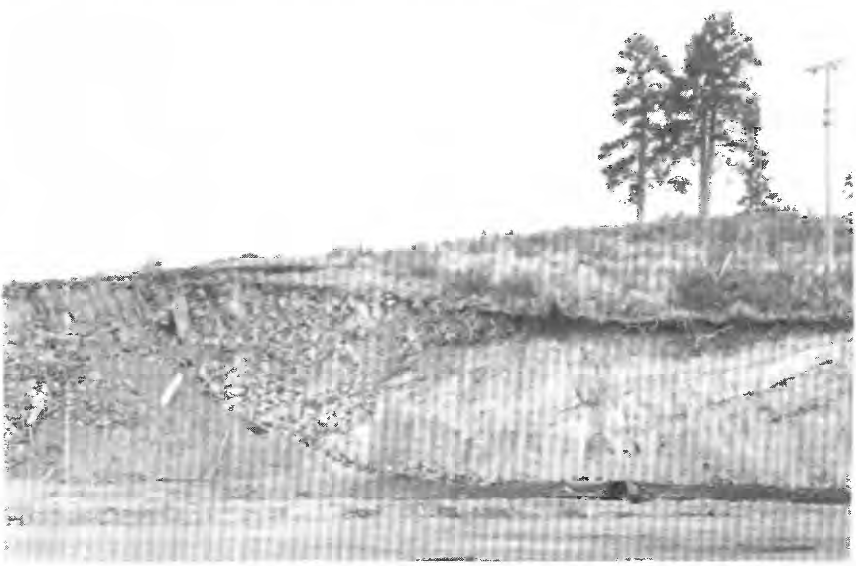

FIGURE 2.—Silt and clay of the Latah (?) Formation and an overlying flow of the Columbia River Basalt, tilted westward on the back slope of the Cascade fault block. Note columnar jointing and platy parting in the basalt. Outcrop is 1 mile northwest of the Cascade Reservoir spillway.

tural or lithologic cause. Of the many inferred faults in the Bear Valley mapped area, there is positive evidence only for the one along Reeves Creek on the upper Deadwood River (sec. 12 T. 13 N., R. 7 E.), where upper Pleistocene moraines are displaced. Stanley Basin, about 15 miles east of Bear Valley near the east border of the batholith, is bounded by faults of large throw (Williams, 1961, p. 4).

The faults trend north, north-northeast, and, less commonly, north-northwest; some segments are curved in plan—concave toward the downthrown side. Such evidence as there is indicates that the faults dip steeply and that the movement is dip-slip and normal. Because of the absence of pre-Miocene stratified rocks, the possibility that the faulting started in the early Tertiary cannot be evaluated; displacement of the Columbia River Basalt proves that major movements on some of the faults were Miocene or later. Anderson (1934, p. 26) and Capps (1961b, p. 6) suggested that the faulting occurred chiefly during the late Pliocene. To the north in the Clearwater Embayment, Bond (1963, p. 65) reported truncated spurs and faulted fans which, like the displaced moraine in the Deadwood area, indicate that faulting continued through the Pleistocene. A strong earthquake having an epicenter near Cascade was recorded in 1937 (Newmann, 1940, p. 11), and about a dozen earthquakes have been recorded in the vicinity of the Idaho batholith in the last 30 years (Wollard, 1958, p. 1142).

The overall relations indicate that the faulting occurred, not in one restricted period, but from time to time and place to place throughout the late Cenozoic. Whereas most linear scarps associated with faults are clearly fault scarps, some are fault-line scarps and some are composite.

The latest displacement along the Long Valley fault zone at the base and on the escarpment of West Mountain may be pre-Bull Lake because Bull Lake deposits are not obviously displaced. However, the complexity of the fault zone and the lack of detailed mapping on the escarpment itself necessarily leave the question of minor displacement open. In the area of massive granite farther east, some presumed fault escarpments are steep and fresh, whereas others are subdued or nearly eliminated by erosion. In some places all or part of the relief is due to the erosion of weak sediments on the downthrown block.

ORIGIN OF DRAINAGE

Gravel deposits in scattered exposures seen in reconnaissance at the base of the West Mountain scarp (mapped as fluvial deposits of Tertiary and Quaternary age opposite the mouth of Gold Fork) and high on the backslope of West Mountain (not mapped) consist dominantly of well-rounded smoky-quartz pebbles, mostly less than an inch in diameter. The associated monazite-bearing heavy-mineral suite was not derived from the basalt or metamorphic rocks of West Mountain but is substantially the same as the suite that characterizes similar monazite- and smoky-quartz-bearing gravel in tributaries that enter Long Valley from the east. This distinctive gravel could not have moved to West Mountain *across* the North Fork of the Payette River, which flows south in Long Valley; it must have been deposited by west-flowing streams before the North Fork was in its present position. Indeed, the occurrence of remnants of the gravel on the backslope of the West Mountain block indicates that it must have been deposited before that block was raised to its present height.

The most obvious hypothesis is that the original west-flowing drainage was defeated by uplift of West Mountain and that the North Fork of the Payette is, in effect, consequent on the floor of the Long Valley fault trough. Part of the river's course is, however, not entirely in accord with this hypothesis. At Cascade, the North Fork turns eastward through the raised part of the Cascade fault block (pl. 1; fig. 3) and then continues south for several miles down the depressed part of the fault block. But instead of continuing in the depressed block into Round Valley, the river abruptly turns west into the southern extension of the West Mountain block and then south into a deep narrow gorge (fig. 4). While anomalous, this erratic behavior does not

FIGURE 3.—View northwestward across Long Valley and Cascade (center) to the steep escarpment of West Mountain in the background. The North Fork of the Payette River is antecedent or superposed across the raised part of the Cascade fault block (the wooded ridge, center) at Cascade. Upstream the river channel is flooded by Cascade Reservoir.

FIGURE 4.—Erratic course of the North Fork of the Payette River at the south end of the Cascade fault-block basin. View is southward to Round Valley (back center). The river, flowing generally southward, does not continue in the valley of the depressed Cascade fault block into Round Valley but turns west and then south in a narrow deep gorge cut in the West Mountain fault block (right of center).

count strongly against the hypothesis; the stream could be consequent in its overall southerly course in the fault zone and locally be antecedent or superposed, or both, on minor blocks within the zone.

There is, however, an alternative possibility: the original west-flowing streams may have been blocked by the Columbia River Basalt, and the North Fork may be consequent in the topographic low between the regional westward slope on the crystalline rocks and the eastward initial slope of the basalt. This is the origin of the course of the Columbia River around the northern and northwestern borders of the same lava field. According to this second hypothesis, the monazite- and smoky-quartz-bearing gravel would be part of the Latah Formation.

The two hypotheses are of course not mutually exclusive; the North Fork could have been consequent along the margin of the basalt and further deranged by postbasalt faulting. The hypotheses have different implications as to whether the exotic gravel is above or below the basalt on West Mountain and could be resolved by mapping.

In the Bear Valley area, and in the interior of the batholith generally, some of the main drainage lines are along faults, but it is not possible to determine whether the streams developed in the fault zones as subsequents or were consequent on the faulted topography. Lag gravel on interfluves in some places marks the position of former transverse streams, but the relation of lag gravel to former drainage lines has not been resolved. An example of glacial diversion in Bear Valley is outlined on page A15; such diversions, at least those of late Pleistocene age, are small-scale features because the late Pleistocene glaciers occupied only parts of the valleys and rarely covered pre-existing divides.

SURFICIAL DEPOSITS

The surficial deposits of the area are divided into two categories on the basis of origin: (1) glacial deposits, chiefly moraine and outwash, and (2) nonglacial deposits, including alluvium and colluvium. They are further subdivided on the basis of age into pre-Bull Lake, Bull Lake, Pinedale, and post-Pinedale deposits. The usage of the names Bull Lake and Pinedale corresponds to that of Blackwelder (1915) and of Holmes and Moss (1955) in the Wind River Range of western Wyoming. Formal subdivisions of the Bull Lake and Pinedale Glaciations have not been made. In order to permit the delineation of the bedrock units as accurately as possible, even where they are partly obscured by drift, only thick morainal and outwash deposits are shown on the geologic map. Glaciated areas where the drift is thin and patchy are shown by patterns overprinted on the bedrock units. Three divisions on the upland are recognized: (1) areas covered by Bull Lake glaciers, (2) areas covered by Pinedale glaciers, and (3) areas not glaciated during the late Pleistocene.

A comprehensive understanding of the origin of placer deposits is dependent on a knowledge of the regional geomorphic history, particularly the effects of glaciation, as clearly demonstrated by Capps (1940) and Reed (1937) in adjoining areas. The basic principles were developed by Jenkins (1935) in a discussion of Sierra Nevada gold placers; they are rephrased briefly here insofar as they apply to placer deposits of radioactive minerals in west-central Idaho.

Monazite and euxenite, the principal radioactive minerals in the west-central Idaho placers, are accessory minerals in some of the granitic rock of the batholith. The first prerequisite for development of stream placer concentrations of these minerals is that they be freed by disintegration of the rock matrix. Ideally, a "first concentration" is effected by selective weathering; chemical decay of the main rock-forming minerals in place and removal of some of the decay products in solution result in accumulation of a residual mantle enriched in the chemically resistant radioactive accessories. A "second concentration" occurs during the transfer of the weathered mantle to the streams by creep and other types of mass movement and by washing. A "third concentration," by stream-channel processes, is chiefly based on density

375-239 O—70——2

and durability to attrition. Because the radioactive minerals are only about twice as heavy as quartz and feldspar and are about one-third as heavy as gold, they do not concentrate in alluvial deposits as well as gold. Monazite is extremely durable, but crystals of euxenite shatter readily and are quickly reduced to silt size in travel with coarse gravel along a streambed (Mackin and Schmidt, 1956, p. 379). For this reason, monazite placers may extend tens of miles downstream from the source area, but optimum concentrations of euxenite are limited to within a few miles of the source.

The most critical geologic factors in the localization and tenor of the Idaho radioactive placers are (1) the presence of the valued minerals in the bedrock and (2) the extent of late Pleistocene glaciation. Gravel in streams draining areas that were not glaciated during the late Pleistocene consists chiefly of vein quartz, feldspar phenocrysts, and various resistant dike-rock types; the granitic rock that underlies more than 99 percent of the drainage basin is represented only by coarse sand. The heavy-mineral concentrate in these nonglacial stream deposits is high, averaging about 30 pounds per cubic yard of alluvium; this concentration is thought to be due to weathering enrichment of a residual mantle prior to the Bull Lake Glaciation and a quickened downslope movement of that mantle under periglacial climatic conditions during the Bull Lake Glaciation. Outwash from Bull Lake glaciers, however, consist dominantly of pebbles of granitic rock and carries only about 20 pounds of heavy-mineral concentrate per cubic yard. The Pinedale glaciers were smaller than the Bull Lake glaciers and hence occupied only areas scoured by Bull Lake ice; as a result, Pinedale outwash averages about 10 pounds of concentrate per cubic yard. There are of course marked local departures from these averages, and the percentage of radioactive minerals in the concentrate varies greatly depending on the occurrence of these minerals in the bedrock, but the 3–2–1 ratio expresses the effect of late Pleistocene glaciation on placer development (Mackin and Schmidt, 1956).

Because all the larger drainage basins include both glaciated and nonglaciated areas, the alluvium of trunk streams usually includes glacial outwash which dilutes potential placer values from nonglacial parts of the basin. Hence favorably situated nonglaciated tributaries commonly carry better values than the mainstreams. It is evident, moreover, that pre-Bull Lake and pre-Pleistocene alluvium may be minable in valleys where younger alluvium yields a poor concentrate; such older alluvium may warrant directed search where it is covered by basalt, moraines, barren outwash, or slopewash from local valley sides.

One additional enrichment factor has greatly contributed to the making of the placer deposits that have been worked to date. Magnetite is destroyed in the wet mountain-meadow environment that is characteristic of the high valleys of west-central Idaho. As magnetite commonly accounts for about half of the heavy-mineral concentrate, the elimination of magnetite means an enrichment factor of about 2. As a given magnetite-bearing gravel is moved slowly through a wet meadow by the meandering trunk stream, the gravel is deposited on the inside of meander bends and eroded from the outside of bends. Between brief intervals of transport the gravel is at rest beneath a layer of meadow vegetation and peat. Meadow ground water, made acid (pH 6.2–5.5) by the peat, descends through the gravel and slowly dissolves the magnetite. The rate of solution is far greater than the average rate of transport of gravel through the meadow, so the elimination of magnetite is commonly complete even in small meadows, perhaps in a few hundred years (Mackin and Schmidt, 1956, p. 380).

PRE-BULL LAKE DEPOSITS

The most extensive of the several types of pre-Bull Lake deposits are fluvial and lacustrine sediments, in places tilted as much as 20°, which underlie the broad valley floors of fault-block basins (fig. 5). These deposits were apparently trapped in these subsiding basins and later deformed by continued faulting. The deposits may range from Pliocene through early Pleistocene. Because they are unconsolidated, easily eroded, and commonly mantled by younger sediments, the fault-basin deposits are rarely exposed; nothing is known of their thickness or structure at depth except as indicated by gravity survey (see p. A5). The deposits are difficult to distinguish from the Latah(?) Formation and (or) from deposits associated with pre-Bull Lake glaciation.

Most deposits mapped as "pre-Bull Lake deposits" contain small amounts of detrital gold, detectable by panning. Attempts to recover gold from these deposits during the late 1800's are abundantly apparent in old diggings throughout the Long Valley area. In several placer workings ¼–1 million cubic yards of gravel was washed, and in many pits 10,000–100,000 cubic yards was worked.

A roadcut near Pearsol Creek, on the east side of the Cascade fault-block basin about 4 miles east of Cascade (fig. 5), consists of till or till-like material overlain by laminated silt and clay that dips about 20° NW. The deposits are deeply weathered and are evidently an erosion remnant of a much more extensive sedimentary unit. The clay contains a pollen assemblage, including pine, fir, and spruce, which differs from the present forest and suggests a cool, damp climate characteristic of

FIGURE 5.—Rolling, maturely dissected topograhy cut on fluvial and lacustrine sediments of pre-Bull Lake age, possibly Pliocene through early Pleistocene. These sediments lie in the fault-block basin east of Cascade and may largely be basin fills that are genetically related to faulting. Associated with the deposits are till or till-like sediments, tilted 20° to the west and resting on granitic rock; they are exposed along the road on the left (north) edge of the photograph. All the deposits contain monazite derived from the granitic rock of the Idaho batholith to the east. Reworking of the deposits locally results in monazite placers downstream. The foreground surface is a periglacial alluvial deposit of Bull Lake age and is moderately dissected.

the glacial or periglacial environment of the Pleistocene (H. P. Hansen, written commun., 1958). If, as seems likely, the deposit is glacial, it indicates (1) pre-Bull Lake glaciation in an area far beyond the limits of the Bull Lake glaciers and (2) a tilting of the fault block that continued into the Pleistocene. The presence of westward-dipping laminated and, possibly, varved clays associated with till-like deposits at several other places along the east side of Long Valley is additional evidence that suggests that tilting of the Long Valley fault blocks continued into the Pleistocene.

A large morainal ridge southeast of Little Payette Lake, along the eastern edge of and outside the conspicuous Bull Lake lateral moraine, is mapped as a pre-Bull Lake moraine. An abandoned placer pit in the morainal material indicates that at least minimal gold values encouraged extensive digging. The workable placer gold, complete disintegration of granitic boulders, oxidation to a depth of 6 inches or more in quartzite boulders, and the advanced degree of topographic modification indicate that this moraine is much older than the adjoining Bull Lake moraine. However, two stades of the Bull Lake Glaciation are recognized elsewhere in the Rocky Mountains (Richmond, 1965); if the moraine mapped as Bull Lake is actually late Bull Lake, the older moraine may be early Bull Lake. Its designation as pre-Bull Lake is therefore arbitrary, and a more specific assignment of this and other deposits must await more detailed study.

Photographs taken by Capps (1941a) in the adjoining Secesh district show striking examples of creep in deeply weathered bouldery detritus, which he regards as lower Pleistocene morainal material. Like those in Long Valley, the deposits have little or no topographic expression; nothing is known as to the extent or directions of movement of the glaciers that may have formed them. The Secesh deposits contain detrital gold, and in some places a blanket a few feet thick has been sufficiently enriched by chemical weathering to form workable eluvial gold placers. This enrichment and the erosional origin of the topography make it necessary to be on guard in west-central Idaho against equating pre-Bull Lake with preglacial.

Lag gravel occurs on interfluves in many places. It ranges from a veneer of resistant rock types underlain by remnants of the original deposit to scattered pebbles and boulders on bedrock. The lag gravel was evidently let down and concentrated by selective erosion. Some of the rock types, such as quartzite and certain dike rocks, are far-traveled and may mark the courses of former streams, but it is usually not possible to determine from the float, in the absence of exposures, whether the original deposit was fluvial or glacial.

An abundance of lag gravel in the foothill belts along the east sides of the westward-tilted fault-block basins, particularly Little, Scott, and Long Valleys, provides a clue to the former height of the basin-fills. The lag-mantled areas in some places grade into erosion surfaces cut on granitic rock; the surfaces are well defined, are sharply trenched by streams, and are far below and not continuous with the rolling upland surface discussed earlier. They are clearly cyclic and may mark one or more pauses in stream downcutting or in the block-fault movement, or both; no attempt has been made to correlate them from valley to valley.

BULL LAKE AND PINEDALE GLACIAL DEPOSITS

In contrast to the little-modified depositional roughness of the Pinedale moraines, Bull Lake moraines are distinguished by a smooth hummocky topography, clearly morainal but subdued by erosion. Closed depressions which characterize Pinedale moraines are generally drained or filled on Bull Lake moraines. Most of the depositional surface on Bull Lake outwash has been destroyed, whereas most of the Pinedale surface remains. The contrast in degree of weathering is conspicuous; for example, in Bull Lake deposits a large percentage of granitic pebbles and boulders disintegrates readily whereas in Pinedale deposits under otherwise comparable conditions a large percentage is fresh. The Bull Lake terminal moraines are commonly downvalley from the Pinedale moraines, the distance between them ranging from less than 1 mile to 4 miles, depending on topographic relations.

No attempt was made in the field to use soil stratigraphic techniques or other current precision methods for distinguishing and mapping Bull Lake and Pinedale deposits. The 3–2–1 ratio of heavy-mineral concentration in different alluvial deposits, mentioned earlier, and a distinct difference in degree of weathering enrichment of heavies in the soil profile provide quantitative criteria directly pertinent to the purpose of the investigation and, incidentally, confirm the concept of multiple glaciation in the late Pleistocene. Our observations of Bull Lake and Pinedale moraines elsewhere in the Rockies, and a field check by Charles B. Hunt, leave little doubt as to the correlation; it therefore seems preferable to use these established terms (Richmond, 1965, 1962, p. 87; Morrison, 1964, p. 113; Hunt and others, 1953, p. 16) rather than coin a new set of local names. Undoubtedly subdivisions of the Bull Lake and the Pinedale occur in the mapped area, but identification of them is uncertain based on our field methods; such subdivisions do not bear directly on the placer geology, and they are not distinguished on the maps.

Bull Lake and Pinedale moraines are ideally displayed at the north end of Long Valley, where patterns of compound piedmont lobes are defined by morainal loops; the Payette Lakes lie within the Pinedale moraines, which in turn are surrounded by outer loops of Bull Lake age. South of the Bull Lake moraines, the dissected Bull Lake outwash plain is partly buried beneath a smooth-surfaced plain of Pinedale outwash (fig. 6). Much of the Pinedale outwash fills broad valleys cut in the Bull Lake outwash during the interglacial interval.

Short steep glaciers from West Mountain barely reached the valley floor. Although morainal forms are not well developed, Bull Lake and Pinedale moraines and outwash are readily distinguished in most places. Both consist mostly of subangular metamorphic rock types and basalt that contrast sharply with the exotic quartz-pebble gravel mentioned earlier.

Big Meadow is a broad north-south segment of the upper part of Bear Valley Creek (pl. 2, T. 11 N., R. 8 E.; fig. 7) and is bordered on the west by a range high enough to have supported Bull Lake and Pinedale glaciers which extended to the valley floor. Big Meadow is bordered on the east by a relatively low ridge that was not glaciated during the late Pleistocene; short tributaries entering the meadow from the east carried no glacial debris. The overall topographic asymmetry is probably due to faulting, but the alluvial fill which underlies the meadow, known from drilling to be as much as 200 feet thick, was probably impounded as a result of glaciation rather than faulting. The river turns from the broad deeply alluviated Big Meadow segment to flow northeast in a narrow youthful valley where rock is still commonly exposed in the channel. It seems likely that Bear Valley Creek formerly took a northerly course through the valley of Bearskin Creek to the Elk Creek drainage until it was diverted by Bull Lake glaciers. If so, the Big Meadow placer deposits may continue under the moraines and outwash that occupy the Bearskin valley; even though such deposits would not be minable under present conditions, they may be a resource for the future (Mackin and Schmidt, 1956).

PERIGLACIAL DEPOSITS

Erosion and deposition in areas not scoured by Bull Lake or Pinedale ice resulted in extensive deposits including the most significant placers. These periglacial deposits were formed under a rigorous glacial climate, during which accelerated slope erosion caused stream aggradation and colluvial accumulation (Bryan, 1949; Smith, 1949; Denny, 1951; Peltier, 1950). That such periglacial deposits formed adjacent to glacial areas in the Northern Rocky Mountains is well demonstrated in the Hailey area of Idaho (Schmidt, 1962, p. 65–69).

Monazite was dredged from tributary stream deposits along the east side of Long Valley southeast of Cascade during 1951–55 (fig. 8). These and similar deposits were formed by streams entering the valley from a broad belt of low upland which was not glaciated during the late Pleistocene except for small ice tongues high in the headwaters 10–15 miles to the east. The degree of dissection and other criteria indicate that most of the deposits are of Bull Lake age (fig. 5). There is reason to believe that they were formed by aggradation caused by accelerated mass movement that resulted from the advent of Bull Lake periglacial climatic conditions. Before the periglacial aggradation a surface mantle had been enriched by selective weathering during a long period of milder climate.

Fluvial deposits of lower Big Creek in Long Valley southeast of Cascade are mapped as Pinedale periglacial deposits, despite the fact that upstream the Pinedale deposits in Scott Valley are mapped as Pinedale outwash. The gravel and heavy-mineral assemblages in the two areas justify the mapping and support a conclusion that glaciation in the headwaters of Big Creek, which occurred entirely above Scott Valley, was not intense enough to appreciably dilute the Pinedale periglacial alluvial contribution at and below Scott Valley.

Euxenite was dredged in the upper part of Big Meadow in Bear Valley during 1955–58 (fig. 9). These deposits were formed largely

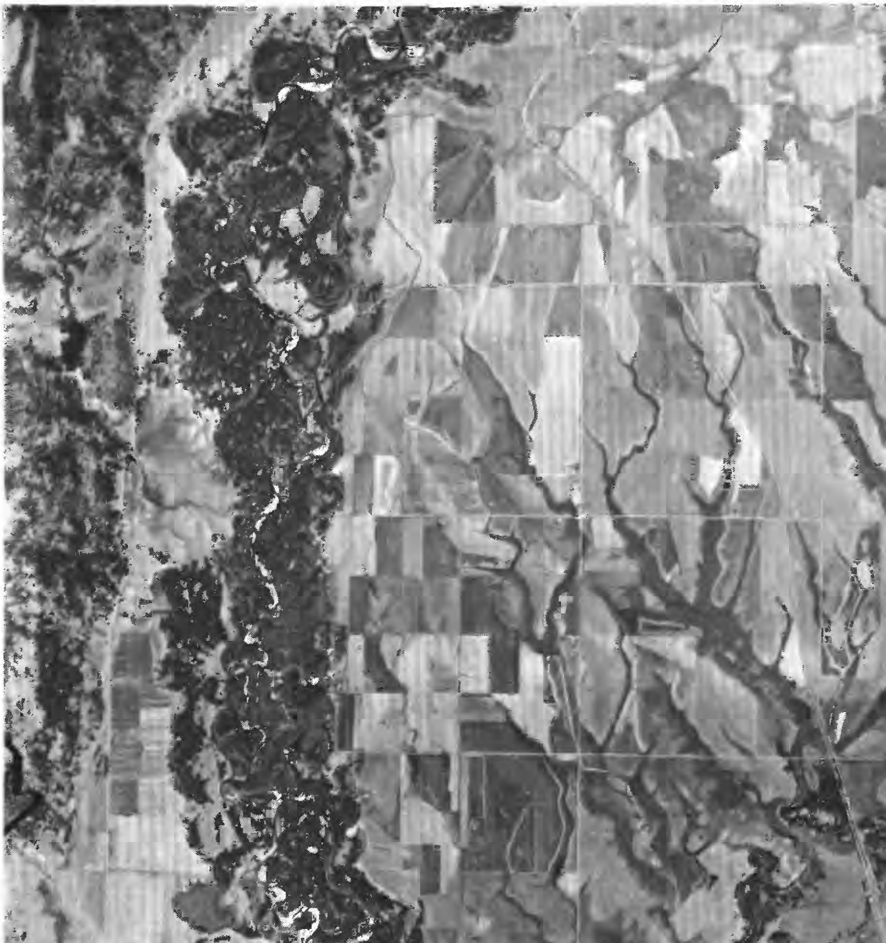

FIGURE 6.—The dissected Bull Lake outwash plain (center and north) in the northern part of Long Valley is partly buried beneath a smooth-surfaced plain of Pinedale outwash (south center) on which a relict braided drainage pattern of Pinedale outwash streams is faintly visible. This braided pattern is sharply contrasted to the sinuous meandering pattern of the modern streams on the wooded flood plains to the left and right of the Pinedale outwash plain. The

irregular topography along the north edge of the photograph is underlain by Bull Lake moraine and is 3 miles south of McCall. Both the North Fork of the Payette River (left) and Lake Fork (right and center) flow southward through the Bull Lake moraine and are entrenched into the Pinedale outwash plain. The North Fork flows at the base of the West Mountain fault escarpment (west edge). Photograph by U.S. Department of Agriculture.

FIGURE 7.—View northward across Big Meadow in Bear Valley. Big Meadow is a shallow basin filled by alluvium chiefly as a result of damming at the north end by Bull Lake glaciers from White Hawk Mountain off the photograph to the west. The ridge east of Big Meadow was not glaciated but contributed alluvium enriched in heavy minerals, largely during glacial times. Euxenite placers occur in the upper part of Big Meadow; the right one-third of the meadow has been dredged since the photograph was taken in 1953.

by small tributary streams that drained the low-relief ridge on the east side of Big Meadow where late Pleistocene glaciers did not exist. Deposits by streams entering the valley from the west are chiefly glacial outwash and are not ore grade. Deposits of the trunk stream are mixtures of east- and west-side alluvium and are minable only downstream from junctions of rich eastern tributaries (Mackin and Schmidt, 1953, fig. 5).

POST-PINEDALE DEPOSITS

A few cirque moraines are present in west-central Idaho. Though active glacier ice is not exposed, some of the unstable moraines may be underlain by relict ice; other unstable debris may be active rock glaciers. The unstable moraines and more abundant older cirque moraines occur only in favorably oriented north or northeasterly cirques at high altitudes where snow accumulation is slightly greater and protection from insolation is better than in cirques of other orientation. The moraines consist of angular blocks of freshly frost-rived rock in

FIGURE 8.—Monazite placer (center) on the lower piedmont slope of the Big Creek drainage southeast of Cascade. View is southwest across the southern part of Long Valley to the 3,000-foot-high escarpment of West Mountain (background). Cirques were cut on the high treeless part of West Mountain during Bull Lake and Pinedale Glaciations. The photograph was taken during August 1953, when two dredges were operated by Baumhoff-Marshall, Inc. and the Idaho-Canadian Dredging Co.; a third dredge operated by the Warren Dredging Co.—had capsized during May 1953.

arcuate ridges having unstable or only slightly stabilized slopes. In the Long Valley area, cirque moraines at altitudes between 7,500 and 8,000 feet are mapped above Louie Lake on Boulder Creek southeast of McCall. Perhaps these correlate with the younger Gannett Peak Stade and older Temple Lake Stade of post-Pinedale age (Richmond, 1965, p. 226). In the Sawtooth Mountains west of Stanley Basin, Williams (1961, p. 11) mapped cirque moraines at altitudes of about 9,000 feet.

Trunk streams developed narrow flood plains during post-Pinedale time, whereas many smaller streams have no flood plain. Many mountain meadows are typical examples of stream-valley segments still choked by locally derived periglacial debris of Pinedale age. It is evident that post-Pinedale erosion has been negligible on all but the valley floors of larger streams and that the present landforms are mostly fossil surfaces, that is, holdovers from the Pleistocene (Büdel, 1953).

FIGURE 9.—Euxenite placer operation in upper Big Meadow of Bear Valley during September 1956. View is westward across Big Meadow to White Hawk Mountain. The moderately well developed cirque on the scantily wooded top of White Hawk Mountain (right) was cut during Bull Lake and Pinedale Glaciations. The left ridge top was glaciated during Bull Lake time. One of two bucket-line dredges operated by the Porter Bros. Corp. is shown. Photograph by P. L. Williams.

GLACIATED BEDROCK

Disintegration of bedrock and the freeing of heavy minerals—essential to placer formation—is now only starting in bedrock areas scoured by late Pleistocene glaciers. Virtually bare, unweathered bedrock is characteristic of areas covered by Pinedale glaciers. Outside the Pinedale glaciated area, in areas scoured by Bull Lake ice, the bedrock is only moderately weathered but is considerably more vegetated than the Pinedale-scoured rock. In periglacial areas outside the glaciated tracts, the soil mantle is thin, commonly only a few inches thick, although the bedrock is mechanically disintegrated for many feet.

The widespread deep and thoroughly weathered mantle that is believed to have covered much of the area before the Bull Lake Glaciation is now only locally preserved. Post-Pinedale placer-making is limited chiefly to reconcentration by streams presently reworking Pleistocene alluvium.

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