GLACIAL GEOLOGY OF STANLEY BASIN, IDAHO

by

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ABSTRACT

Extensive glacial deposits and evidence of glacial erosion indicate two major glaciations in the mountains surrounding Stanley Basin during late Pleistocene time. The older of these, correlated with the Bull Lake advance of western Wyoming and probably of early Wisconsin age, appears to have consisted of two distinct ice advances. The younger of the major glaciations is correlated with the Pinedale of western Wyoming and is almost certainly of late Wisconsin age. There is evidence of pre-Wisconsin glaciation, and small cirque moraines in some of the higher peaks represent a minor glacial advance of very recent date.

The greater intensity of glaciation in the Sawtooth Range ~~east~~ west of the basin compared with that in the range east of the basin is shown by great differences in amount of glacial erosion and volume of deposits. This is primarily because the Sawtooth Range is higher than the east range, but differences in insolation, and differential effects of late Pleistocene meteorological conditions on the two ranges, are probably also important factors.

Large glaciers from the Sawtooth Range forced the Salmon River eastward. The glaciation also caused aggradation of the valley floor of the Salmon. The present profile of the river consists of graded and non-graded segments, depending on the caliber of material in the Pinedale fill. In the graded seg-

ments the river is able to rework the relatively fine-grained fill, hence the profile is one of transportation. In the non-graded segments large boulders that cannot be transported pose a problem of erosion to the stream.

The Wisconsin glacial advances indirectly caused the accumulation of potential placer deposits in some of the non-glaciated sidestreams east of the Salmon River. The placer minerals, which are accessories in the quartz monzonite of the Idaho Batholith, occur in the bedrock in two distinct suites.

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INTRODUCTION

Multiple Pleistocene glaciation has been recognized in many mountain ranges in western United States. Most of the localities are in the Central and Southern Rocky Mountains; with few exceptions descriptions of glaciation in the Northern Rockies are brief, and are presented as incidental information in reports dealing principally with the bedrock and economic geology.

Stanley Basin is well suited to the study of multiple mountain glaciation because of the high altitudes of the surrounding mountains, which permitted the growth of large glaciers during the Pleistocene. Deeply weathered deposits that may be related to early or middle Pleistocene glaciation occur as small erosional remnants. Two major ice advances, probably of Wisconsin age, are indicated by extensive moraine and outwash deposits. Moraines of a very minor post-Wisconsin advance were found in cirques on the north sides of some of the higher peaks.

This paper deals with the periods of glaciation, their probable correlatives elsewhere in the Cordilleran region, and the factors contributing to the greater intensity of glaciation on the west side of the Basin. The effects of the glaciation on the Salmon River and on the accumulation of placer deposits are also described.

Field work was undertaken during a total of four weeks in the summers of 1954, 1955, and 1956. Mapping was aided by the use of aerial photographs with a scale of 1:40,000. Data was transferred to planimetric maps obtained from the U. S. Forest Service with a scale of 1:31,680.

Acknowledgements

The writer is indebted to Professor J. Hoover Mackin under whose direction the project was carried on. Dwight L. Schmidt made many helpful suggestions during the study and critically read the manuscript. Mr. Ed Oswald of Hailey generously permitted the writer to make use of his cabin in Stanley during the major part of the field investigation.

Location and Access

The area discussed in this paper lies in the southernmost part of the Northern Rocky Mountains (Fig. 1, index map).

Stanley Basin is accessible by U. S. Highway 93. Aside from the main highway and the road which extends northwestward from the town of Stanley to Bear Valley, the roads are rather poor. The Sawtooth mountains west of the Basin are accessible by means of well-kept Forest Service trails which extend up most of the tributary valleys entering the Basin from the west.

The town of Stanley, with a population of about 50, is situated at the northern extremity of the Basin. A post office is maintained there and at Obsidian, 15 miles south of Stanley

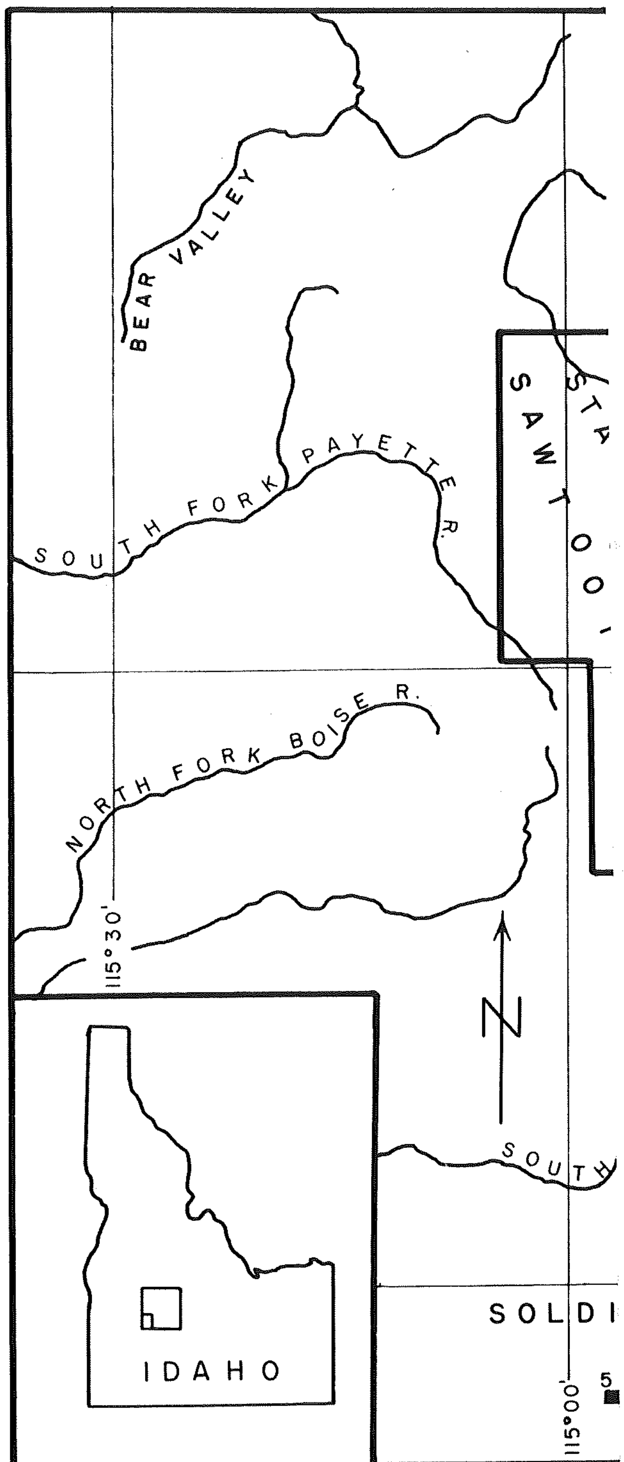

BEAR VALLEY
SOUTH FORK PAYETTE R.
SAWTOO
STA
NORTH FORK BOISE R.
115°30'
IDAHO
SOUTH
SOLDI
115°00'
5

FIG. I: I

along Highway 93. The principal industries are mining and stock-raising.

Topographic Setting

Stanley Basin is an elongate intermontane valley in the headwaters of the Salmon River. The river heads in the Boulder Mountains and flows north-northwest along the axis of the basin to its north end, where it turns abruptly eastward and enters a steep-walled gorge.

The basin is flanked on the west by the Sawtooth Mountains, one of the highest ranges in south-central Idaho. There are a number of peaks above 10,500 feet. The topography of the range is extremely rugged, a result of the intense late Pleistocene glaciation which affected nearly all parts of the range. The range east of the basin is slightly lower in altitude, especially at the northern end. Notable exceptions are the Whitecloud peaks (drainage from which does not enter Stanley Basin) and the peaks immediately to the south, the westerly slopes of which are the headwater areas of Champion and Four of July Creeks. The higher peaks in these two areas, like those in the Sawtooth Mountains, rise above 10,500 feet, and were intensely glaciated. The Boulder mountains south of the basin are slightly lower, although a few peaks exceed 10,000 feet. As the floor of the basin is from 6,200 to 7,000 feet above sea level, relief in the area is about 4,500 feet.

Climate and Vegetation

The climate of south-central Idaho is characterized by severe winter weather with considerable of the precipitation falling as snow, and by dry summers with temperatures that may reach 100 degrees F. (Henry, 1906). U. S. Weather Bureau records for Obsidian indicate a mean annual precipitation of 16.1 inches. This is probably somewhat less than the amount of precipitation in the ranges flanking the basin.

The vegetation varies in amount and kind with the altitude, the nature of the material underlying the surface, and with the direction of exposure. Sage with some grass is dominant on alluvial flats. Groves of aspen are interspersed with lodgepole pine in the lower parts of the range east of the basin, while the pine is dominant at the higher elevations. In the Sawtooth Mountains lodgepole pine is dominant, although sparse above 8,000 feet. Throughout the uplands the stands of pine are most dense on north-and east-facing slopes; slopes that face to the south and west are often barren of trees and are covered with sage and grass. The piedmont morainal belt of the Sawtooths is, for the most part, thickly covered with lodgepole pine; windfalls are locally so numerous as to impede travel.

In contrast to the densely forested moraines, alluvial deposits throughout Stanley Basin are notably free of trees (Fig. 4). A similar situation was noted by Fryxell in Jackson Hole, Wyoming (Fryxell, 1930, p. 87):

"The preference of pines for moraine and sage for outwash flats is an interesting feature of the region. In most cases the contact between the two types of vegetation is a formation contact as well, and it is almost possible to map the moraines and the outwash from the distribution of vegetation."

Previous Work

Many investigators have described Pleistocene glaciation in the Rocky Mountains, for the most part in the Central and Southern Rockies (Chapter 4). The regional pattern shows, in general, evidence of two important late Pleistocene advances, both referred by Blackwelder (1915) to the Wisconsin stage. Thoroughly weathered erosional remnants of till-like material in some areas are ascribed to glaciation earlier in the Pleistocene. In some localities small post-Wisconsin moraines are found.

In the Northern Rockies within the United States, deposits of Pleistocene mountain glaciers were first described by Weed and Pirsson (1896) in the Castle Mountain mining district of western Montana. Two successive advances were recognized, the second of lesser intensity than the first. Alden (1912) recognized pre-Wisconsin drift in Glacier Park, Montana. Hershey (1912) described deposits of two ice advances in the North Fork of the Coeur d'Alene River. Three glaciations were recognized by Capps (1940) in Secesh Basin, Idaho. Anderson (1956) has described deposits of early and late Pleistocene age in Lemhi County, Idaho.

Mackin and Schmidt (in manuscript) in Bear Valley and Long Valley, to the west of Stanley Basin, recognized the two major late Pleistocene advances and have demonstrated the close relationship between the glaciation and the accumulation of placer deposits. Their work has served as a guide in the present study.

Bedrock Geology

For purposes of this report, the bedrock geology (Fig.2) is important for two reasons: (1) Paleozoic sedimentary rocks are restricted to the south and east sides of the basin, permitting distinction of glacial deposits from the Sawtooths from deposits of the Salmon River and the east side tributaries, by the absence or presence of quartzite pebbles and cobbles in the deposits, and (2) placer minerals are restricted to a single rock type, quartz monzonite.

Only a small part of the Sawtooth range was mapped by Ross. Exposures seen in the course of mapping the glacial deposits are chiefly leucocratic crystalline rocks, including quartz monzonite, faintly banded gneisses, and alaskites containing almost no mafic minerals. West of Stanley the moraines contain boulders of dark colored gneiss, with some schist and amphibolite. Generally speaking, the rocks of the Sawtooth range, where visited by the writer, have a metamorphic aspect.

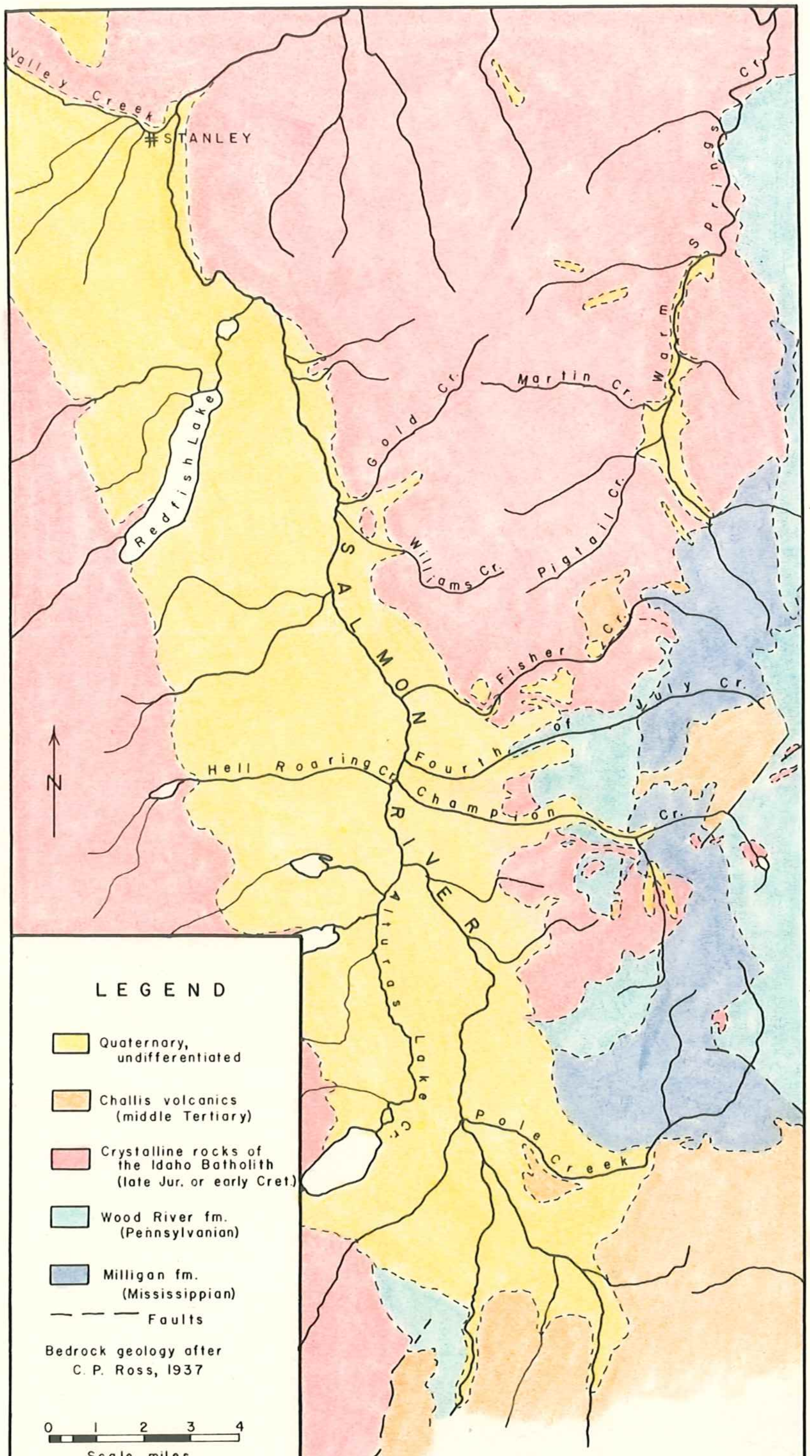


FIG. 2: BEDROCK GEOLOGY

According to Ross, the granitic rocks in the mountains east of the basin consist for the most part of quartz monzonite. In many places the rock is porphyritic, containing insets of microcline up to three inches in length. The quartz monzonite is considered by Ross to have intruded the Paleozoic sedimentary rocks which, in the area of this study, consist of the Milligen formation of Mississippian age, a carbonaceous argillite with some quartzite and dolomite, and the Wood River formation, an argillaceous and calcareous quartzite that has been dated as Pennsylvanian in the Wood River region (Umpleby et al., 1930, p. 32-34) but that has later been demonstrated to be in part Permian (Bostwick, 1955, p. 944). The sedimentary rocks are highly deformed; Ross felt that the intrusion of the quartz monzonite and the deformation of the sedimentary rocks occurred simultaneously, during the widespread diastrophism of the late Mesozoic.

Part of the area east and south of the basin is underlain by latite and andesite flows of the Challis volcanic sequence, a formation widespread in south-central Idaho, which has been dated as late Oligocene to early Miocene (Ross, 1937, p.65-67). The flows were extruded following a long period of erosion of the underlying Paleozoic sedimentary rocks and the granitic rocks, and in many parts of the Bayhorse district, according to Ross, the pre-Challis surface was one of great local relief.

The origin of Stanley Basin cannot be stated with any certainty. The steep east flank of the Sawtooth range suggested to Umpleby and Livingston (1920, p. 13) that the basin resulted in part from a high-angle fault along the range front. Ross, however, felt that the depression that is now Stanley Basin may have been a topographic low prior to Challis time, or may have resulted from less volcanic material having been deposited along the axis. In any event, Stanley Basin, according to Ross, was a topographic low at the close of Challis time.

The writer tends to favor the postulate of a high angle range-front fault first proposed by Umpleby and Livingston, although positive evidence of such a fault is lacking. Block faulting to produce a range and valley topography has been described in the west side of the Idaho Batholith (Mackin and Schmidt, 1956). In that area displacement of later Tertiary and early Pleistocene deposits dated the faulting as very late Tertiary or early Pleistocene. Tertiary deposits that would indicate a similar history in Stanley Basin were sought, but none were found; if present, they are concealed under the thick mantle of moraine. There is no evidence of recent faulting - no faults cut the glacial deposits. Lacking such evidence, the range front fault can be inferred only from the steep mountain front of the Sawtooths and the differences in rock types on opposite sides of the basin.

GLACIAL DEPOSITS

At least two major glaciations and one minor glaciation are recorded in Stanley Basin by moraine and outwash deposits. Similar deposits are present in Bear Valley, and upper Long Valley, Idaho (Mackin and Schmidt, 1956) and in the Secesh Basin, Idaho (Capps, 1940), indicating that the stages are well represented in central Idaho. On the basis of discussion during a field conference in the Long Valley area with Mr. Charles Hunt of the U. S. Geological Survey, these stages are designated Bull Lake and Pinedale, after Blackwelder's (1915) pioneer work in western Wyoming.

The criteria found to be most useful in distinguishing drift of one advance from that of another are those generally employed by students of multiple mountain glaciation. They are (1) topographic and stratigraphic position (2) degree of erosional modification and (3) degree of weathering of the drift. (See especially Blackwelder, 1931, p. 870-880, and Holmes and Moss, 1955, p. 645).

Possible Pre-Bull Lake Glaciation

Ross (1937, p. 70-72; 93-95), has described early Pleistocene deposits from several localities to the east of the area of the present study. He referred them tentatively to the Nebraskan stage. The deposits are said to occur as thick, little-weathered masses of gravel ranging in size from large boulders to sand, crowning several ridges near the crest of the range east of Stanley Basin. The writer did not visit the localities where these deposits are best developed; in the one locality within the present area where the deposits were mapped by Ross, on the ridge just west of the Meadows, it appeared likely that the boulder gravels were deposited as lateral moraine by glaciers of Wisconsin age that occupied the valley of Warm Springs Creek. It is possible that the more extensive deposits east of this locality are actually early Pleistocene in age; if so, the slight weathering described by Ross needs explanation, for in other localities early Pleistocene deposits display an extreme degree of weathering. (For a recent summary of pre-Wisconsin Rocky Mountain glaciation see Richmond, 1957.)

On the divide between Stanley and Kelley Creeks, just north of the map area, deposits of thoroughly weathered, non-sorted gravels are exposed in old placer workings. The gravels have yielded small amounts of gold over a period of many years. The locality is also known as the source from which brannerite, a rare radioactive mineral was first described.

The surface of the deposit is wholly erosional; only the lack of sorting suggests that it is of glacial origin. What were formerly cobbles and boulders of granitic rocks have been reduced by weathering to an incoherent sand preserving only the faint outline of the original rock; the term "ghost pebble" used by some writers is quite appropriate. Only boulders of vein and pegmatite quartz remain intact. The largest of these exceed one foot in diameter; the average size is about six inches.

It is not possible to date the deposits accurately, except to state that, on the basis of their thorough weathering, they resemble the Buffalo drift of western Wyoming (Blackwelder, 1915), and the Kennedy drift of the Rocky Mountains in Canada and Montana (Willis, 1902, and Horberg, 1954). But it cannot be stated with certainty whether or not they are of glacial origin, or whether they are Pleistocene or possibly older.

The Bull Lake Substage

General

The Bull Lake substage was defined by Blackwelder (1915, p. 325), on the basis of large but erosionally modified moraines in the vicinity of Bull Lake on the northern flank of the Wind River range in western Wyoming. Because of morphological similarities to those in the type area, the deposits related to the earlier of the major glaciations in Stanley Basin are referred to the Bull Lake advance.

The Bull Lake moraines form massive embankments on the piedmont zone east of the Sawtooths, from Stanley Lake to Hell Roaring Creek (Plate I, Fig. 3). They are more extensive than the younger Pinedale moraines, which occur principally in the major stream valleys. Morainal deposits formed by glaciers in tributaries on the east side of the basin are scanty.

Alluvial deposits of Bull Lake age, consisting for the most part of glacial outwash, are best developed near Fourth of July Creek and south of Champion Creek (Fig. 4). Terrace

Fig. 3: Piedmont morainal belt east of the Sawtooth range. Pinedale alluvial surfaces of Williams Creek and the Salmon River in the middle ground.

remnants along the Salmon River north and east of Redfish Lake represent aggradation of the main stream during the Bull Lake glaciation.

Morainal Deposits

In most places the Bull Lake moraines on the west side of the basin can be readily distinguished from the Pinedale moraines on the basis of their greater degree of erosional modification. Although the morainal ridges are prominent topographic features, the ridge summits are broad and the ridge flanks are not nearly as steep as in the Pinedale moraines. Subdued "knob and sink" topography is present in the Bull Lake moraines east of Redfish Lake, but there are no closed depressions or swampy areas, and the swales between the several recessional ridges are integrated in an orderly drainage pattern.

The material comprising the Bull Lake moraines is considerably more weathered than in the Pinedale moraines, but it nowhere reaches the state of complete decay of the Buffalo (?) morainal material on Kelley Creek. Boulders of resistant types of granitic rocks are abundant on the ridge crests, but they are more rounded by weathering than similar boulders on the Pinedale moraines and are fewer in number. Near-surface pebbles of most crystalline rocks shatter readily under the impact of a light hammer blow.

The soil at a depth of two to three feet on the ridge crests, as exposed in craters formed by uprooted lodgepole pine, is light brown in contrast to the pale yellow soil on the Pinedale moraines. The darker color appears to be the result of a greater degree of iron staining due to oxidation in the post-Bull Lake interval. Microscopic examination of the sand fraction from the soil shows that most of the feldspar grains and some of the quartz grains are stained yellowish- to red-brown.

In most areas in the Cordilleran region where Early and Late Wisconsin moraines occur in the same valley the greater intensity of the earlier advance is expressed by the fact that the older moraines are found farther down valley than the younger moraines. In Stanley Basin, however, moraines of both Bull Lake and Pinedale advances occur at a common front. The greater intensity of the Bull Lake advance is expressed by the nearly continuous piedmont belt of coalescent moraines, in contrast to the unconnected Pinedale moraines, which are restricted to the stream valleys.

Topographic conditions at the time of each advance probably controlled the down valley extent of the ice. The Bull Lake glaciers spread laterally in a broad piedmont lowland, and hence were shorter than they would have been had they been confined to narrow valleys. The Pinedale glaciers were nearly as long as the much more extensive Bull Lake glaciers because they were restricted to valleys across the piedmont moraine belt.

Alluvial Deposits

Alluvial deposits of Bull Lake age can be distinguished from younger deposits by their largely erosional topography. Benches and fans are well dissected by numerous streams and dry washes. (Fig. 4). All depositional features, such as the sinuous channel markings left by the depositing streams, have been destroyed, but the flat areas between the dissecting washes probably approximates the original depositional surface.

Gravels in the Bull Lake deposits are notably more weathered than those in the younger deposits. Granitic pebbles near the surface are partially decayed (Fig. 5). Near the tops of deposits in artificial exposures the gravels are stained dark brown. On upper surfaces only resistant rock types, notably quartzite of the Carboniferous formations, are conspicuous. The surfaces of the blue quartzite pebbles are stained dark brown.

Most characteristic of the Bull Lake alluvial deposits is their position high above the modern streams. Post-Bull Lake erosion has produced high scarps in the older deposits in many localities, and on Fourth of July Creek the highest part of the outwash fan stands 300 feet above the creek.

Sidestream deposits are for the most part glacial outwash, but some tributary valleys that appear to have escaped glacial action contain alluvial deposits the accumulation of which probably resulted from periglacial aggradation and aggradation caused by upbuilding of the valley floor of the main stream. Terrace remnants along the Salmon east and north of Redfish Lake, consisting largely of boulders carried by glaciers from the west side of the basin, indicate aggradation of the main stream during Bull Lake time.

Fig. 5: Outwash gravels of Bull Lake age exposed in a road cut on Valley Creek. Cobbles of some granitic rock types are well decayed; aplite, pegmatite, vein quartz and porphyry dike rocks are quite fresh.

Two-Fold Bull Lake Advance

Glaciofluvial terrace relationships and patterns of morainal ridges suggest that the Bull Lake substage was compound, consisting of two major advances separated by a recessional stage, probably of short duration.

Southwest of Stanley, outwash from a Bull Lake glacier in the Redfish Lake trough was deposited in part in valleys cut in a bench composed of boulder gravels deposited by the Salmon River (Plate I). Gravels in the Redfish outwash fan and the mainstream bench display the weathering characteristics of Bull Lake deposits; they are not separable in age on the basis of weathering. The evidence suggests that the deposits are related to two ice advances of nearly the same age separated by a recessional stage, during which valleys were eroded in the gravel bench. It is possible, however, that extensive regrading during a single advance could bring about similar relationships between the Redfish outwash fan and the bench gravels.

East of Redfish Lake, where the Bull Lake moraines are well preserved as a result of having escaped the destructive action of Pinedale ice and meltwater, they can be separated into two groups on the basis of trends of the morainal ridges. (Fig. 6). The ridges in the northerly of the two masses are truncated by the ridges of the southerly mass in the same manner that the Pinedale lateral embankment truncates the ridges of the southerly mass. The two masses are designated as Bull Lake I and II on the map and Fig. 6.

<u>Fig. 6</u>: Aerial photograph of area east of Redfish Lake, showing morainal deposits of both Wisconsin advances.

<u>R</u>	Modern floodplain alluvium
<u>Pm</u>	Pinedale moraine
<u>Pam</u>	Pinedale alluvium, main stream
<u>Pas</u>	Pinedale alluvium, side stream
<u>BL-IIm</u>	Bull Lake II moraine
<u>BL-Im</u>	Bull Lake I moraine
<u>BL-u</u>	Bull Lake moraine, undifferentiated
<u>BL-a</u>	Bull Lake alluvium, mostly Salmon River
<u>sw</u>	Slopewash, Bull Lake and younger

<u>A</u>	Williams Creek placer
<u>B</u>	Club Canyon placer
<u>C</u>	"Hourglass" constriction in Salmon River floodplain.

The two morainal masses display similar degrees of weathering and erosion. The moraine designated as Bull Lake II appears to have a slightly fresher morainal topography than the Bull Lake I moraine, and in some of the soil samples the feldspar grains appeared to be less iron stained. Generally speaking, however, the differences are not sufficient to merit assignment of separate stadial rank.

The Pinedale Substage

General

Blackwelder (1915) described fresh bouldery moraines, representing an advance of lesser magnitude than the Bull Lake glaciation, surrounding large lakes in the Wind River range. Blackwelder's descriptions of these moraines fit the young lake-damming moraines in Stanley Basin so closely that Blackwelder's term, Pinedale, is applied to the moraines and their associated outwash.

The valleys of major tributaries west of the Salmon River contained long ice tongues during Pinedale time that built large terminal and lateral morainal embankments (Fig. 7). Smaller stream between the major tributaries contains small glaciers which built irregular, less well defined morainal embankments, none of which dam large lakes (Fig. 8). There is little outwash associated with the moraines on the west side of the basin.

Glaciers descending the three largest tributary valleys on the east side of the basin (Fourth of July, Champion, and

Fig. 7: Pinedale moraine on Hell Roaring Creek. Looking west from Fourth of July Creek.

Fig. 8: Bull Lake alluvial surfaces near the north end of the basin. Bull Lake I mainstream terrace in left and right foreground; building stands on Bull Lake II outwash terrace. Pinedale moraines and Sawtooths in background.

Pole Creeks) built relatively small moraines but gave rise to extensive outwash fans (Fig. 4). Smaller streams on the east side of the basin, such as Rough Creek and Fisher Creek, contain small irregular moraines. Such a minor moraine blocked the valley of Warm Springs Creek, causing aggradation to form the broad alluvial flat known as The Meadows.

Morainal Deposits

The moraines of Pinedale age on the west side of the basin display typical "knob and sink" topography that has scarcely been modified by erosion (Figs. 4 and 6). Closed depressions, some containing small lakes, are common on the terminal moraines. Lateral morainal ridges are steep-sided and sharp, and are virtually undissected. The streams crossing the terminal moraines have thus far cut only small notches; eventually incision by the streams will drain the large lakes impounded by the moraines.

Boulders on the moraine surfaces display only slight weathering. Quartzite boulders are totally unweathered. Granitic boulders have a thin outer layer of grains that can be scraped off with a pick, but the feldspars are fresh and most of the boulders are sound. On the moraines on the west side of the basin surficial boulders are exceedingly abundant, (Fig. 9), and original angularities and those produced by forest fires and frost splitting are not modified by rounding. The scarcity of surficial boulders on the east side moraines (Fig. 10) is not the result of weathering but may be due to meltwater action.

Fig. 9: Boulder-strewn recessional morainal ridge om the Hell Roaring Creek moraine. Typical of Pinedale moraines on the west side of the basin.

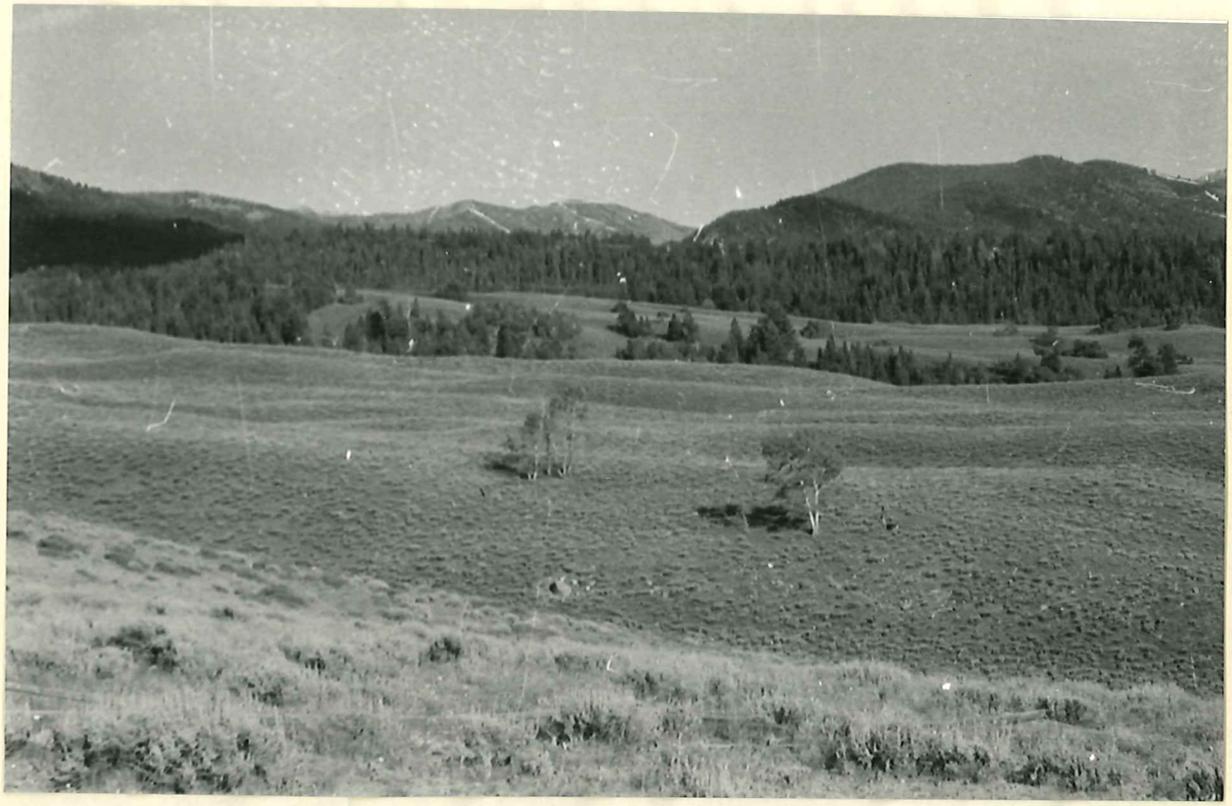


Fig. 10: Pinedale moraine on Fourth of July Creek. Note gentle depositional topography and scarcity of surface boulders.

Only the major streams have opened floodplains in the Pinedale fill. The smaller tributaries have merely entrenched the fill a few feet. In marked contrast to the high scarps at the edges of the Bull Lake remnants, the alluvial surfaces are only a few feet above the modern streams.

Post-Pinedale Glaciation

At the present time there are no active glaciers in the mountains surrounding Stanley Basin. On a few north-facing cirque headwalls in the highest parts of the Sawtooth range perennial snow patches exist, but these are not in motion and could scarcely be termed glaciers.

Near the crest of the Sawtooths above 9000 feet are a number of small cirque moraines, situated on the floors of cirques carved during the Pinedale substage. The fact that they occur only in cirques that open to the north and northeast indicate that the glaciers that deposited these moraines could exist only in areas well protected from the sun. The largest of the moraines, in a cirque overlooking Toxaway Lake is only a third of a mile long.

The angular blocks and slabs of granitic rock of which the moraines are composed are unweathered, but many have been shattered in place by frost action. Virtually no soil is present. Fine particles have been washed downward from the top few feet and are exposed only in slump scarps. The surfaces of the moraines are exceedingly irregular and humpy, and slopes are steep and unstable, suggesting that ice is

Fig. 11: Post-Wisconsin moraine in Pinedale cirque above Toxaway Lake. The steep, unstable scarps facing the observer suggest slumping caused by melting of ice beneath the moraine.

present beneath the moraines and is actively melting, producing a slump topography (Fig. 11).

CORRELATION WITH OTHER AREAS

Because glaciated areas in the Cordilleran region are geographically separated, correlations must be based on such criteria as morphology, weathering, and relative position of deposits. The impossibility of physical tracing of deposits from area to area has resulted in the use of a large number of local names, although a fairly consistent sequence has been established throughout the Cordillera.

The sequence contains several distinct elements (Holmes and Moss, 1955; Flint, 1957, p. 328) These are: (1) very old, thoroughly weathered drift, lacking any constructional topography, and usually occurring as isolated remnants of formerly extensive deposits; (2) extensive drift deposits with subdued depositional topography, moderately weathered, locally representing two ice advances; (3) less extensive, slightly weathered deposits with pronounced depositional topography and (4) very young, fresh drift consisting of upper valley moraines, cirque moraines, protalus ramparts, and rock glaciers.

These elements comprise the basis of classification in Table 1, which is adapted largely from the correlation chart of Holmes and Moss (1955).

Correlation within the Rocky Mountains

Although preceded by a number of workers, Blackwelder was the first to apply formal names to mountain drift resulting from multiple glaciation in the Rocky Mountains (Blackwelder, 1915). His stages (in order of decreasing age, Buffalo, Bull Lake and Pinedale) have been applied widely in the Middle Rocky Mountains by subsequent investigators (Table 1). Although Blackwelder's terms have not been applied as such in the Southern Rockies, Eschman (1952) correlated his glacial deposits in the Never Summer Range of northern Colorado with the Buffalo, Bull Lake, and Pinedale on the basis of similar degrees of weathering, topographic form, and position and number of moraines.

Correlation of the glacial deposits in Stanley Basin with the Buffalo, Bull Lake, and Pinedale deposits, based largely on published descriptions, was confirmed by Mr. Charles Hunt after field examination of deposits, similar to those in Stanley Basin, studied by Mackin and Schmidt in Long Valley, Idaho.

The deposits on Kelley Creek, if of glacial origin, could be correlated with the well-weathered Buffalo till. The deposits described by Ross east of the present area are probably of Buffalo age, if Buffalo is used as a general term for pre-Wisconsin glacial deposits.

The deposits in Stanley Basin termed Bull Lake are strikingly similar to those in the type area. The moraines in both areas are massive but the morainal topography is subdued, and the deposits are more extensive than those of the younger advance. Most striking of all is the strong evidence of two advances within a fairly short period of time; similar evidence has been reported in the Bull Lake type area (Holmes and Moss, 1955) and in other areas (Atwood, 1909 and Fryxell, 1930).

Descriptions of deposits related to the Pinedale advance in western Wyoming apply equally well to the deposits of the last major advance in Stanley Basin - moraines and outwash are virtually unchanged by weathering and erosion. Contemporaneity of ice advance in the two areas seems almost a certainty.

Exact correlation of the cirque moraines in the Sawtooth mountains with similar post-Wisconsin deposits elsewhere is complicated by the fact that climatic conditions permitting such minor ice advances may vary in time and from place to place. Holmes and Moss (1955) found post-Wisconsin moraines of two ages in the southwestern Wind River range; small "upper valley" moraines 10 to 20 miles upstream from the Pinedale terminal moraines, which they referred to the Temple Lake advance of Howard and Hack (1943), and the younger cirque moraines which they referred to the Little Ice Age of Matthes (1933). There is no reason to believe that the small moraines in the Sawtooths were precisely contemporaneous with either of these advances; but the suggestion of the presence of wasting ice beneath the moraine above Toxaway Lake implies that the cirque moraines in the Sawtooths are closer in age to the very young deposits which Holmes and Moss dated as Little Ice Age.

Correlation with Areas West of the Rocky Mountains

Because of the distances involved, changing elevations resulting from tectonic activity, and the possibility of different climatic conditions in various parts of the Cordilleran region during the Pleistocene, correlations of deposits in the Rocky Mountains with those in the Great Basin and Sierra-Cascade provinces are subject to considerable error. Even so, there are striking similarities in descriptions of deposits of different ages from one part of the Cordillera to the other. In Table 1 are listed several areas west of the Rocky Mountains where investigators' descriptions of glacial deposits resemble descriptions of drift in the Rocky Mountains. The Stuart drift of the Cascades (Page, 1939), the Angel Lake of the Ruby - East Humboldt range (Sharp, 1938), and the Tioga of the Sierra Nevada (Blackwelder, 1931) are all described as fresh, unweathered deposits resulting from a strong glacial advance, the ice of which sculptured the rugged alpine topography in the upper parts of the ranges. Similarly the Leavenworth, Lamoille, and Tahoe substages are represented by extensive deposits that are noticably more weathered but that still retain subdued depositional topography. Probably all drift resulting from glaciations preceding the Wisconsin should be grouped together because extensive destruction of the deposits by weathering and erosion removes most of the criteria of correlation; the deposits in different areas have only their thoroughly weathered character in common.

The inclusion of areas west of the Rocky Mountains in Table 1 does not mean that the writer thinks that correlation among these areas, and between them and the Rockies are as firm as correlations within the Rockies; rather they are included because of the similarities in descriptions by different workers throughout the Cordilleran region. Perhaps climates of a severity sufficient to produce glaciations of such magnitude need not be Cordillera-wide; but similarities of deposits from area to area suggests that deposits exhibiting many similar erosional features could not vary greatly in age, especially in the case of the Wisconsin advances.

Correlation with the Midcontinent

Exact correlation of Rocky Mountain glacial deposits with deposits of the Continental ice sheets of the Midwest and East are tentative, and must take into account the fact that continental and mountain glaciation are not always contemporaneous (Bretz, 1913).

Blackwelder (1915) compared the Bull Lake drift of western Wyoming with the early Wisconsin drift of Illinois, but did not specifically propose time correlation.

Subsequent workers in the Rocky Mountains and elsewhere in the Cordilleran region have used criteria of degree of weathering and erosion for tentative correlation with the Midwest stages. In the Waterton region in Alberta, Horberg (1954) described "early mountain drift", similar to the Bull Lake deposits of Western Wyoming, on which were developed soil profiles very similar to the Iowan-Tazewell profiles of the Midwest. He also described "late mountain drift", which he correlated with the Pinedale, overlain by continental drift of Cary age. The two young drifts, mountain and continental, display nearly identical soil profiles, and these profiles compare favorably with those developed on Cary drift in the Midwest. Hence a Cary age for the Pinedale advance seems fairly well established. The greatest significance of this correlation is that the Mankato substage is not represented in the Cordilleran region, unless the small cirque moraines found throughout the Rocky Mountains are of Mankato age. This is probably not the case; most investigators consider the cirque moraines have been formed since the Climatic Optimum.

Pre-Wisconsin deposits in western North America have been variously assigned to the Nebraskan, Kansan, and Illinoian stages. In the Sierra Nevada two pre-Wisconsin drifts have been described (Blackwelder, 1931). The older McGee "tilloid" was tentatively referred by Blackwelder to the Nebraskan; the younger Sherwin drift he placed in the Illinoian, and in part possibly in the Kansan.

Richmond (1957) described three pre-Wisconsin tills in the LaSal mountains, Utah, and Glacier National Park, Montana. He considers correlation with the Nebraskan, Kansan, and Illinoian stages plausible, but as yet unproved (p. 259).

CONTRAST IN GLACIATION OF THE EAST AND WEST SIDES OF STANLEY BASIN

The contrast in intensity of glacial erosion and in amount of deposits on the two sides of Stanley Basin is one of the outstanding features of the glacial geology. Consideration of a number of factors leads to the conclusion that the contrast is partly the result of difference in altitude of the two ranges, and partly due to meteorological contrasts which are more or less independent of altitude.

Contrasts in Erosion and Deposition

It is evident that the Sawtooth range was more intensely glaciated than was the range east of the basin. The whole of the Sawtooth range shows evidence of glacial sculpture; stream valleys are typically U-shaped, and terminate upstream in large cirque amphitheatres. Interstream ridges are narrow, serrate aretes, and the peaks can truly be termed matterhorns (Figs. 3, 7 and 8).

In the east range, such alpine landforms are found only in the high peaks in the central part of the range. The lower parts may be described as having a "biscuit-board" topography; cirques, best developed on the east side of the range, indent the gently sloping summits.

The intensity of glaciation in the two ranges is reflected in the glacial deposits. The total volume of deposits on the west side is many times that of the deposits related to the east side glaciers.

Further contrast is indicated by the difference in type of deposits on the two sides of the basin. As shown in Plate 1, nearly all the deposits on the west side are moraines; outwash is very minor. On the east side, moraines are small and relatively inconspicuous in contrast to large outwash deposits of both Bull Lake and Pinedale ages.

Contrasts can be extended to the surface morphology of the moraines on opposite sides of the basin (Fig. 4). The large west side moraines of Pinedale age display very irregular, hummocky topography with many closed depressions, and are littered with large angular boulders (Fig. 9). Ridges on Pinedale moraines on the east side have a smooth, "streamlined" appearance, and surficial boulders are scarce. (Fig. 10).

The Topographic Factor and the Late Pleistocene Snowline

Taken as a whole, the altitude of the Sawtooth range is greater than that of the range to the east of the basin. Only in the central portion of the east range, in the headwaters of Fourth of July and Champion Creeks, do peaks rise to the same altitude as the crest of the Sawtooths.

Evidence strongly suggests that the Pinedale snowline was definitely lower in the Sawtooths than in the range to the east (Fig. 12). As determined by averaging the

elevations of a number of cirque floors (Sharp, 1938, p. 311), it was found to be 8500 feet on the east flank of the Sawtooths, and 9000 feet on the west flank of the east range. Although the cirque-elevation method of determining snowline is inexact, it is sufficient to indicate that the snowline was definitely lower in the Sawtooths than in the east range. The snowline thus determined applies specifically to the Pinedale advance; it is probable that during the Bull Lake advance the snowline was somewhat lower in both ranges.

Meteorologic Factors

Factors such as amount of precipitation, wind drifting of snow, and solar exposure affect the position of the snowline, which in turn determines the amount of glacial ice that forms and hence the intensity of glaciation.

It is generally held that the prevailing winds of the late Pleistocene moved from west to east (Sharp, 1938 p. 313 and Flint, 1947). Westerly winds would precipitate more snow on the Sawtooths, the first high range of its latitude east of the Oregon Cascades, than on the ranges to the east in its lee.

Westerly winds would, furthermore, drift fallen snow in an easterly direction. This would remove snow from the west side of the Sawtooths to the east (Stanley Basin) side, at the same time removing snow from the east side of the basin, further depleting the amount of snow available for glacial ice on the east side. (Sharp, 1938, p. 313; Lobeck, 1939, p. 265).

Westerly facing slopes such as the east side of Stanley Basin are exposed to solar radiation during the afternoon hours when the sun's heat is most effective for the melting of snow. At the same time of day the east-facing slopes are in partial or total shadow. (Lobeck, 1939 p. 265). The effect of the greater solar exposure on west-facing valley sides is to increase melting, thereby raising the altitude of the local snowline.

Summary

The greater intensity of glaciation in the Sawtooths, as expressed by the greater development of Alpine topography and the much larger glacial deposits is primarily due to the greater altitude of the range.

Although the highest peaks of the east range are as high as the crest of the Sawtooths, the glaciers that originated in the peaks and advanced westward toward Stanley Basin were smaller than their westside counterparts and built smaller moraines. This is attributed to the higher snowline in the east range, which permitted less glacial ice to form. The higher snowline in the east range than in the Sawtooths is the result of (1) less precipitation

EFFECTS OF GLACIATION ON THE SALMON RIVER

The Salmon River was affected in two distinctly different ways by the intense Wisconsin glaciation in the ranges bordering Stanley basin: (1) the advance of the large west side glaciers forced the course of the river eastward and (2) influx of large quantities of outwash caused aggradation of the valley floor throughout the basin.

Changes in the Course of the Salmon River

It is likely that through most of Stanley Basin the pre-glacial course of the river lay to the west of the present course. The present course is largely determined by the position of the ice front of the west side glaciers.

The influence of the ice on the course of the river is most impressive in the segment of the stream opposite the Redfish moraine complex. During Pinedale time, the stream was forced eastward against the bedrock valley side in a short segment near the mouth of Redfish Creek. During the Bull Lake advance the river was forced eastward throughout a segment extending from Gold Creek at least as far downstream as the mouth of Redfish Creek. How far the river course was shifted by the advancing ice is indeterminable; the position of the former course is concealed by the thick morainal deposits.

Changes in the Longitudinal Profile

Throughout its course in Stanley Basin the Salmon River flows on an alluvial fill that accumulated during the Pinedale glaciation. The glaciation caused aggradation in two ways: (1) loading of the stream with glacial outwash and (2) partial blocking of the stream at the Redfish moraine.

With the retreat of the Pinedale ice, the river began to adjust its profile to the changing conditions by incision into the fill. The modern profile is not smooth, but consists of a number of reaches of varying gradient that reflect the resistance to erosion of material encountered by the degrading stream.

The Glacial Profile

The Pinedale profile is shown diagrammatically in Fig.13. From the headwater segment to Gold Creek in the Decker Flat segment the surface of Pinedale outwash is from 10 to 40 feet above the main valley floor. From Gold Creek downstream the height of the surface above the modern stream increases, reaching a maximum of about 100 feet near the mouth of Redfish Creek. Downstream from this point the height decreases steadily, and at the lower end of the Redfish segment the stream flows on the Pinedale surface.

Except in the Redfish segment and the lower few miles of the Decker Flat segment, the Pinedale fill accumulated as the result of increase in the load-discharge ratio, by influx of large quantities of outwash. Although the pre-Pinedale profile cannot be reconstructed, it is probable that it was less steep than the glacial profile; during Pinedale time the increase in load relative to discharge must have caused steepening of the gradient to approach the slope at which the load could be transported.

In the Redfish segment, the Redfish glacier formed a partial obstruction in the stream valley, and caused aggradation for a certain distance upstream by locally raising the base level. Whether the obstruction consisted of ice and moraine, or was merely the result of addition of large morainal boulders that the stream could not transport, is not known; in either event, the effect is the same. Downstream from the obstruction a steep fan was constructed by the river from much of the morainal debris; this fan was regraded, presumably during retreat of the Pinedale ice.

How far upstream from the Redfish segment the effects of the baselevel rise were important in causing aggradation cannot be determined. It is probable that the effects were not dominant much above Gold Creek, and that from Gold Creek to the headwaters the upstream loading with outwash dominated the filling.

A rise of base level such as that caused by the Redfish glacier suggests the possibility of formation of a lake behind the obstruction. No lake silts or clays were found in the Pinedale fill in the Decker Flat segment; moreover, quartzite cobbles, which could have been carried only by the Salmon, are found on and within the fill in the Redfish segment.

These could not have been brought into place had there been a lake, and not alluvium, behind the obstruction. This is taken to mean that the glacial Salmon River was so heavily charged with outwash that filling occurred behind the obstruction as fast as it rose.

The Modern Profile

Since the disappearance of Pinedale ice, the Salmon River has adjusted to the decrease in the load-discharge ratio by incising the fill through much of Stanley basin. The presence or absence of a floodplain appears to be controlled by the erosional resistance of material in the Pinedale fill. Floodplains are well developed in segments where the fill is relatively fine-grained; in such segments boulders seldom exceed one foot in diameter, and the river can rework the fill with relative ease. Where the fill contains large boulders, no floodplain is present; the boulders prevent reworking by the modern stream.

Segments with floodplains, in which the caliber of the fill permits reworking by the modern stream, are considered to be graded; that is, their gradient is determined by the load and discharge entering the segments from upstream (Mackin, 1948). Conversely, segments without floodplains, where the fill contains many large boulders, are non-graded. They are, in effect, rapids, in which the gradient of the stream is determined by the resistance to stream erosion of the boulders flooring the channel, and not by factors of load and discharge. The boulders present to the river a problem of erosion, not of transportation.

The Decker Flat segment is considered to be approximately at grade, and will serve as an example of the graded segments. Throughout this segment the river, in the post-Pinedale interval, has carved a floodplain the width of which equals or exceeds the meander-belt width of the stream (Figs. 4 and 6). The valley floor is from 15 to 40 feet below the surface of the Pinedale fill. The stream flows in a well defined, meandering channel, at a gradient of approximately 20 feet per mile. The bed load consists of coarse gravel containing boulders as large as 12 inches.

A floodplain exists in this segment because post-glacial conditions of load and discharge are such that the Salmon River can rework the fill at a gradient equal to or less than that of the surface of the fill.

The Redfish segment is the most striking example of a non-graded segment. The segment is a white-water rapids; the huge boulders in the fill and on the channel floor and the steep gradient (about 45 feet per mile) are in marked contrast to the much finer caliber of material and the gentle gradient of the Decker Flat segment. Since the boulders far exceed the transporting power of the stream even at flood, the river will achieve grade on this segment only by slow corrasion, as it would in a rapids developed on resistant bedrock.

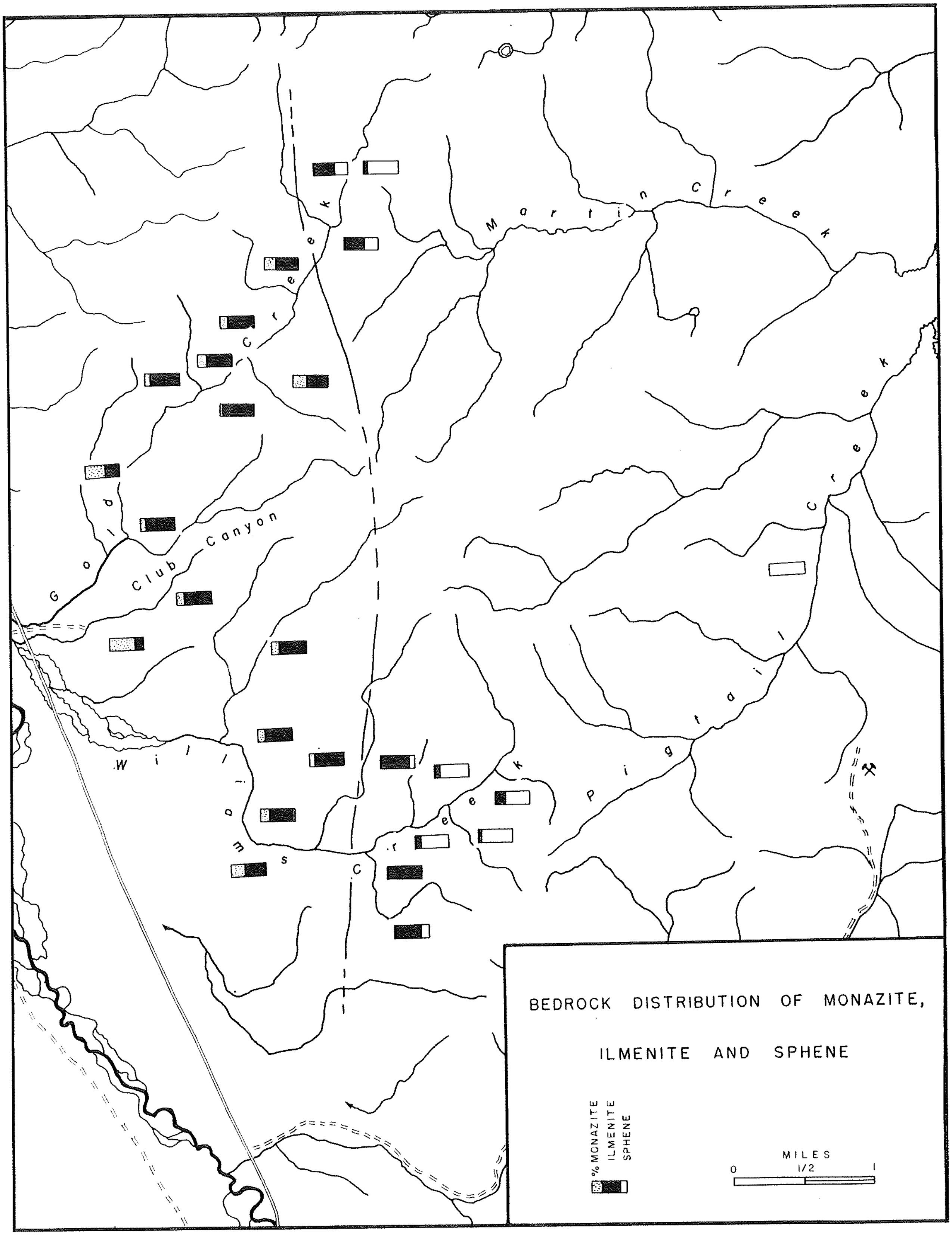
PLACER DEPOSITS IN THE STANLEY BASIN AREA

Placer deposits containing uranium-, thorium-, columbium-tantalum-, titanium-, and rare earth-bearing minerals occur in tributary valleys in the east central part of the area (Plate I). The placer minerals, uranothorite, monazite, sphene, ilmenite and rutile, occur as minor accessories in quartz monzonite of the Idaho Batholith; hence the placer deposits are restricted to areas underlain by that rock type (Fig. 2).

In addition to a source rock containing minerals of economic value, the formation of a placer requires (1) concentration of the minerals by eluvial and stream processes and (2) accumulation in a body of alluvial material of sufficient volume to warrant large-scale recovery operations. In the placers discussed in this paper, these two factors are controlled largely by the Wisconsin glaciation.

None of the placers described in this paper has been developed economically, but the deposits on Williams Creek and Club Canyon were explored by the U. S. Bureau of Mines by churn drilling in 1954. Although no further development work is planned as far as is now known, the total volume of the deposits and the concentrations of valuable minerals are of sufficient magnitude to warrant classification of the deposits as potential placers.

The writer determined the distribution of the placer minerals by microscopic examination of about 60 heavy mineral pan concentrates of soil, streams and alluvial deposits.


Martin Creek
Gold Creek
Club Canyon
Williams Creek
Pigtail Creek
BEDROCK DISTRIBUTION OF MONAZITE, ILMENITE AND SPHENE
% MONAZITE
ILMENITE
SPHENE
MILES
0
1/2
1

Bedrock Occurrence of Placer Minerals

The placer minerals occur in the bedrock in two distinct suites. In the drainages of Pigtail and Martin Creeks, and the head-waters of Gold and Williams Creeks, the quartz monzonite contains rare-earth bearing sphene and uranothorite. In the lower part of the drainages of Gold and Williams Creeks the above minerals are absent on the quartz monzonite, and monazite; ilmenite and rutile occur. These two assemblages are never mixed; the dividing line between them was not precisely located, but appears to be marked by a narrow zone characterized by large amounts of ilmenite and lacking both monazite and sphene, the "index" minerals of the two assemblages (Fig. 14).

The symbols in Fig. 14 do not indicate the precise distribution of the heavy minerals in the quartz monzonite because they are based, for the most part, on pan concentrates from short streams and dry washes. Near the transition zone the minerals of the two assemblages occur together in the stream deposits; in the bedrock, however, sphene never occurs with either monazite or ilmenite.

In general, the sphene-bearing rock is distinctive for containing ten to fifteen percent of insets of microcline. These are rare in the monazite-bearing rock except near the zone of transition between the two assemblages, where the insets comprise five to ten percent of the rock.

The placer minerals occur in varying concentrations in the bedrock; ilmenite and sphene may run as high as one pound per cubic yard, while monazite occurs in small fractions of a pound and uranothorite in trace quantities.

Effects of Glaciation on the Concentration of Placer Minerals

The effects of glaciation on the supply of placer minerals have been thoroughly described by Mackin and Schmidt (1956) east of the present area in Bear Valley. The following is taken largely from their findings.

Processes of weathering in interstream areas tend to produce a surface mantle enriched in the heavier mineral constituents, principally by removal of decomposition products of the feldspars and mafic minerals. The enriched mantle is slowly supplied to the streams which under normal conditions are adjusted to transport the bad to the trunk streams at approximately the rate that it is supplied. In the rigorous peri-glacial climate accompanying a glacial advance, down-slope movement of the mantle is accelerated, chiefly by solifluction and frost-heaving, increasing the rate of supply to the streams and tending to cause aggradation.

Glaciation in a drainage basin has a profound effect on the concentration of the heavy minerals. Scouring by glacial ice removes not only the enriched mantle but decomposed and fresh bedrock as well, so that a considerable period of time is required for the making of an eluvial mantle following a period of glaciation. Hence a drainage area that was glaciated during the Wisconsin age is unlikely to produce an economic placer because of the short time lapse since the glaciation.

Glacial outwash ordinarily does not constitute an economic placer deposit because outwash consists mostly of material that was plucked and abraded from solid bedrock by glacial ice. This material, from which the heavy minerals have not been freed by the weathering processes, greatly dilutes any material derived from erosion of the eluvial mantle present on the bedrock prior to glaciation. In addition, outwash fans are rapidly aggrading deposits from which finer and lighter material is not winnowed out by repeated reworking, as in the deposits of graded streams; part of the load of an aggrading stream is "permanently" deposited, and therefore is not subject to reworking.

In general, if there are equal quantities of placer minerals in the parent bedrock, deposits consisting primarily of periglacially derived alluvium from an essentially non-glaciated drainage offer the best prospects for economic placers, while glacial outwash is, in most cases, the poorest prospect.

Club Canyon Placer

Club Canyon is a valley about two miles long and a half a mile wide, between Gold and Williams Creeks (Fig. 6). The floor of the canyon is occupied in part by an alluvial fill consisting of sand and gravel. The Club Canyon drainage is almost entirely in the monazite-bearing quartz monzonite.

(Table 2, samples SB-17, 26, 27).

The deposit is well dissected, and exposures in artificial cuts display the weathering characteristics of Bull Lake deposits. The surface of the fill is higher and steeper than the Pinedale surface of Gold Creek and is separated from it by an abrupt slope.

There are no moraines or other evidence of glaciation in Club Canyon, and it is likely that the head of the canyon, at an elevation of 8700 feet, was below the Bull Lake snow-line. It is thought that the fill accumulated as the result of periglacial action, coupled with the backwater effect caused by aggradation of the Salmon River, raising the base-level of the stream draining Club Canyon.

Williams Creek Placer

A small area near the mouth of Williams Creek was found by the Bureau of Mines to contain appreciable concentrations of monazite (Fig. 6). The deposit consists in part of slopewash, very local stream material, and Williams Creek alluvial material of Pinedale age. The detailed distribution of monazite values in the three types of material is not known; unfortunately, the writer did not sample the deposit to determine the distribution.

The deposit accumulated largely as a back fill resulting from the aggradation of Williams Creek, which was in turn caused by the aggradation of the Salmon River, during the Pinedale glaciation.

Pigtail and Martin Creek Placer

Concentrations of sphene, ilmenite and uranothorite occur in sand and fine gravel deposits of Pinedale age at the mouths of Pigtail and Martin Creeks (Plate 1). Panning indicates that the minerals occur in high concentrations only along the narrow floodplains where the gravels have been reworked by the streams in post-Pinedale time (Table 2, samples WS-6 and 7).

The fans at the mouths of Pigtail and Martin Creeks were built in response to the filling of the valley of Warm Springs Creek with outwash from a glacier of Pinedale age in the upper valley of Warm Springs Creek (Fig. 15). The outwash would probably not have accumulated to form the Meadows but would have been carried to the Salmon River, had not a glacier from a small east tributary of Warm Springs Creek formed an obstruction in the larger stream valley (Plate I).

Only the gravels of Pigtail and Martin Creeks, which comprise a fraction of the Meadows fill, are of potential value as placer deposits. The remainder of the fill, as shown by panning (Table 2, samples WS4 and WS-8) contains amounts of minerals that are probably far too low to warrant large-scale recovery operations. The low values are the result of (1) the fact that this major part of the Meadows fill consists of glacial outwash and (2) much of the drainage basin of Warm Springs Creek is underlain by Carboniferous

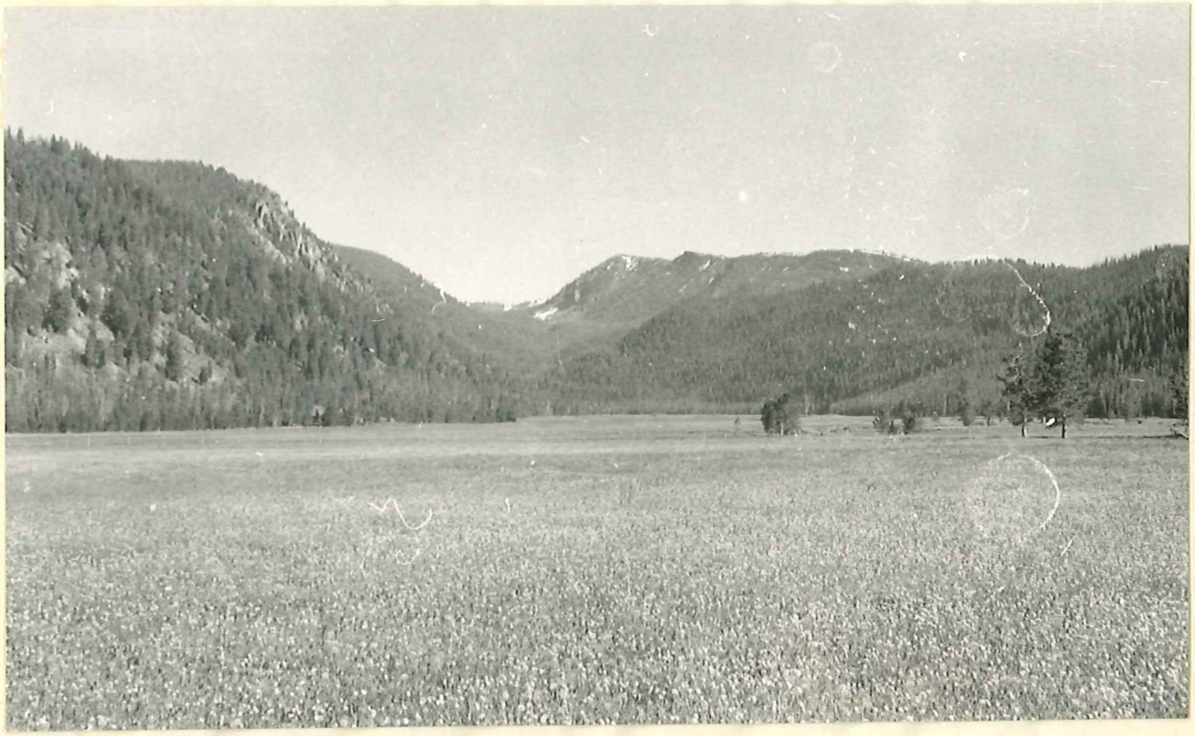


Fig. 15: The Meadows of Warm Springs Creek, a fill consisting of Pinedale outwash. View is looking south up the glaciated valley of Warm Springs Creek.

sedimentary rocks and Challis volcanics, neither of which yields placer minerals and whose presence serves only to dilute the concentration of placer minerals derived from the quartz monzonite.

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TABLE 2 - HEAVY MINERALS

SAMPLE NUMBER	LOCALITY	TOTAL HEAVIES, LBS/CU. YARD	PERCENT MINERAL																			
			MAGNETITE	ILMENITE	Garnet	Hornblende	Allanite	Epidote	SPHENE	MONAZITE	Radio-Blacks	Zircon	Rutile	Anatase	Apatite	Diopside	Olivine	Scheelite	Leucoxene	Pseudopyrite	Tourmaline	URANOTHORITE
STANLEY BASIN 1954																						
SB-11a	Champion Creek	21.	4		T	8			x			T					81					
SB-12	Fisher Creek	4	41	4	T	9	xx		37	T		xx			7		1			1		T
SB-13b	Bull Lake I bench	3	69	10	T	T			XX	xx		xx	T				xx	T		4		
SB-14	Boundary Creek	11	62	29	xx		xx	x		1		xx			3				3			
SB-15	Boundary Creek	54	54	35	xx	T	1	T	xx	5		xx	xx		2				xx			T
SB-16	Cleveland Creek	61	68	24	x	x	xx	x	xx	1		xx	T		1				2	xx		
SB-17	Club Canyon fill	44	75	12	T			T		9			1		xx					2		
SB-18	Dry wash, Club Can.	13	44	12	x			T		40		xx	2		xx				xx			
SB-19	Club Canyon fill	6	40	37	x			xx		19		xx	1		T				1	1		
SB-20	Slopewash, Wms. Cr.	10	79	13				xx	xx	5			1		T				xx	2		
SB-22	Williams Creek	38	39	41	x	T	xx	xx	2	12	T		xx		2				xx	xx		
SB-23	N. Fk. Williams Cr.	17	62	27			xx	1	x	6		x	xx		1				1	xx		
SB-24a	Mid. Fk. Wms. Creek	7	5	69		xx	1	xx		19	T	x	xx		4				xx			
SB-24b	Slopewash, Wms. Cr.	5	33	50	x			1	T	8		x	1		5				1	xx		
SB-25a	S. Fk. Williams Cr.	26	43	38	x	x	1	xx	13	3			xx		2				1	x		
SB-25b	Slopewash, Wms. Cr.	4	67	23	T	T		xx	x	7		x	xx		1				xx	xx		
SB-26	Club Canyon Creek	42	39	44	T			xx	T	13	T	x	2		xx				xx	1		
SB-27	Club Canyon fill	18	81	12	T			xx		3	T	xx	xx		xx					2		
SB-28	N. Fk. Gold Creek	10	20	29	xx	xx	xx	xx		46		x	xx		2				xx	T		
SB-29	Soil, near Gold Cr.	4	85	5		x	x	T		2		x			2					1		
SB-30	Gold Creek	35	72	18	x	2	xx	xx	3	3	T	xx	x		1				xx	xx		
SB-31	Soil, near Gold Cr.	4	66	23	x	xx		xx		9		x	xx		xx				xx			
WARM SPRINGS AREA, 1956																						
WS-1	Pigtail Creek	15	89	x	x	2	T	xx	8	T		xx								xx	xx	xx
WS-2	Pigtail Creek	2	1	xx	T	11	T	5	72	x		1			10				xx		xx	x
WS-3	Slopewash, Pigt. Cr.	6	69			5	T	xx	19			xx	T		6				T	xx	T	xx
WS-4	Warm Springs Creek	2	25	9	T	9	T	xx	11	x		xx			1	5	9		xx	xx	T	T
WS-6	Pigtail Cr.	16	75	1	T	1	xx	xx	19	x	T	xx	T		3	xx	xx			xx	x	xx
WS-7	Martin Creek	51	59	22	T	1	xx	xx	14	xx	T	xx	x		2					x		xx
WS-8	Warm Springs fill	6	62	8	T	2	xx	x	20	xx		xx	T		5	x	1		x		T	xx
WS-10	Pigtail Cr. fan	4	43	xx		5	xx	1	41	T		xx	T		7		xx		x	xx		xx
GOLD CREEK AREA, 1956																						
G-1a	Pinedale gravels	8	56	25	T	3	xx	xx	4	3		xx	xx	T	2							xx
G-1b	Pinedale gravels	8	31	30	x	3	xx	1	1	4		xx	xx		4							
G-2	Slopewash	6	73	6	x	6	xx	6	xx	xx		xx	xx		2	1				xx		
G-4	Gully	3	14	67	xx		xx	1	x	12	xx	xx	xx	T	5							
G-6a	Small stream	10	66	24	xx		xx	xx		6		xx	xx	T	2					xx		
G-6b	Decayed bedrock	5	68	25		xx	xx	xx		xx		xx	x		4					T		
G-7	Dry wash	2	80	14	T	xx		xx	T	1		xx	xx		1					1		
G-8	Small stream	11	53	34	T		xx	xx		10		xx	xx		2					xx		
G-9	Small stream	8	85	5	T			xx		4		xx	1		1					2		
G-9b	Decayed bedrock	2	72	14			4	xx		xx		xx	xx		1					1		
G-9c	Gold Creek	48	78	13		2	xx	xx	2	1		xx	xx		1					xx		
G-10a	North trib.	19	72	16	T		xx	xx	T	8	T	xx	xx		1					1		
G-11a	Gold Creek	38	77	12	T	4	xx	xx	5	xx		x	T		1					xx		
G-11b	Decayed bedrock	4	79	7		x	1	T	x			x			10					T		
G-12	South trib.	75	90	4	T	xx	xx	xx	3			T	T		1					xx		T
G-13	Gold Creek	70	88	1	T	21	xx	xx	7			x			xx					xx		x
WILLIAMS CREEK AREA, 1956																						
W-9	Slopewash	6	81	9		T	xx	xx	T	2	T	x	xx		5					xx		
W-10	Slopewash	13	79	11			xx	xx	T	1	T	xx	xx		3					1		
W-11	Slopewash	6	82	14			xx	xx		xx		xx	x		2					xx		xx
W-13	Williams Creek	85	65	25		xx	1	xx	5	xx		xx	x		1					xx		xx
W-16	Slopewash	16	83	xx		xx	x	x	13	xx		xx	T		3					xx		xx
W-17a	Trib. stream	3	77	2		xx	x	xx	17			x			3					x		xx
W-18	Slopewash	22	82				xx		13	T		xx	T		3					xx		xx
W-19a	Slopewash	14	74			xx	xx		17			T			7					xx		xx
W-19b	Williams Creek	25	80	3		x	xx	x	10			x	T		2					4		xx
W-19c	South trib.	3	69	xx	T	x	x	x	24			x			6					x		xx
W-20a	South trib.	21	71	1	T	xx	xx	x	23			x	T		4					T		xx
W-20b	North trib.	26	57	2		xx	xx	x	31		x	xx	T		7					xx		1
W-21	South trib.	12	76	3		xx	xx	x	15			xx	T		3	xx				1		xx
W-22	Dry wash	6	71	22	T	xx	xx	xx	xx	T					3							
W-23	Dry wash	11	80	10	T		xx	xx	1	T		xx	T		3					xx		xx
W-24	South trib.	3	19	54			1	xx	19	xx		xx	x		7							x
W-25	Slopewash	10	55	13					x	2		xx	xx		4					2		
W-26	Stream	1/4	xx	44		4			T	36		xx	4		12							
W-27	Dry wash	2	65	23		1		xx	1	7		xx	xx		3					xx		
W-28	South trib.	90	78	7	T				xx	9		xx	xx		xx					2		T

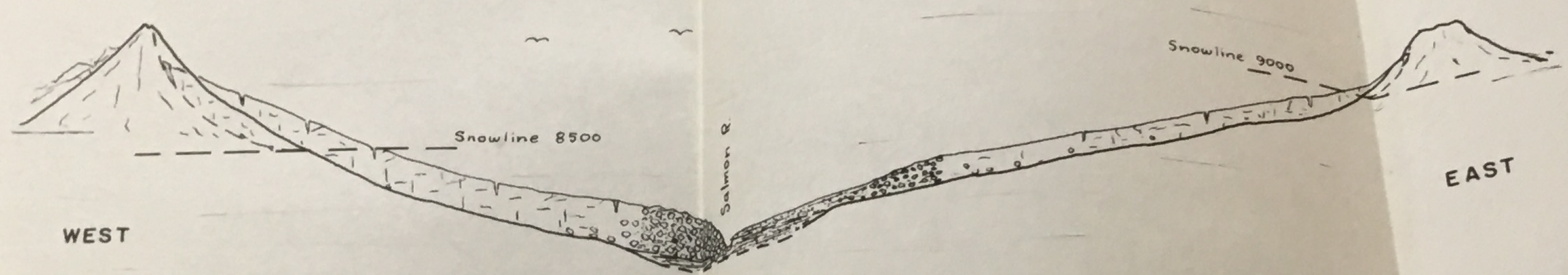
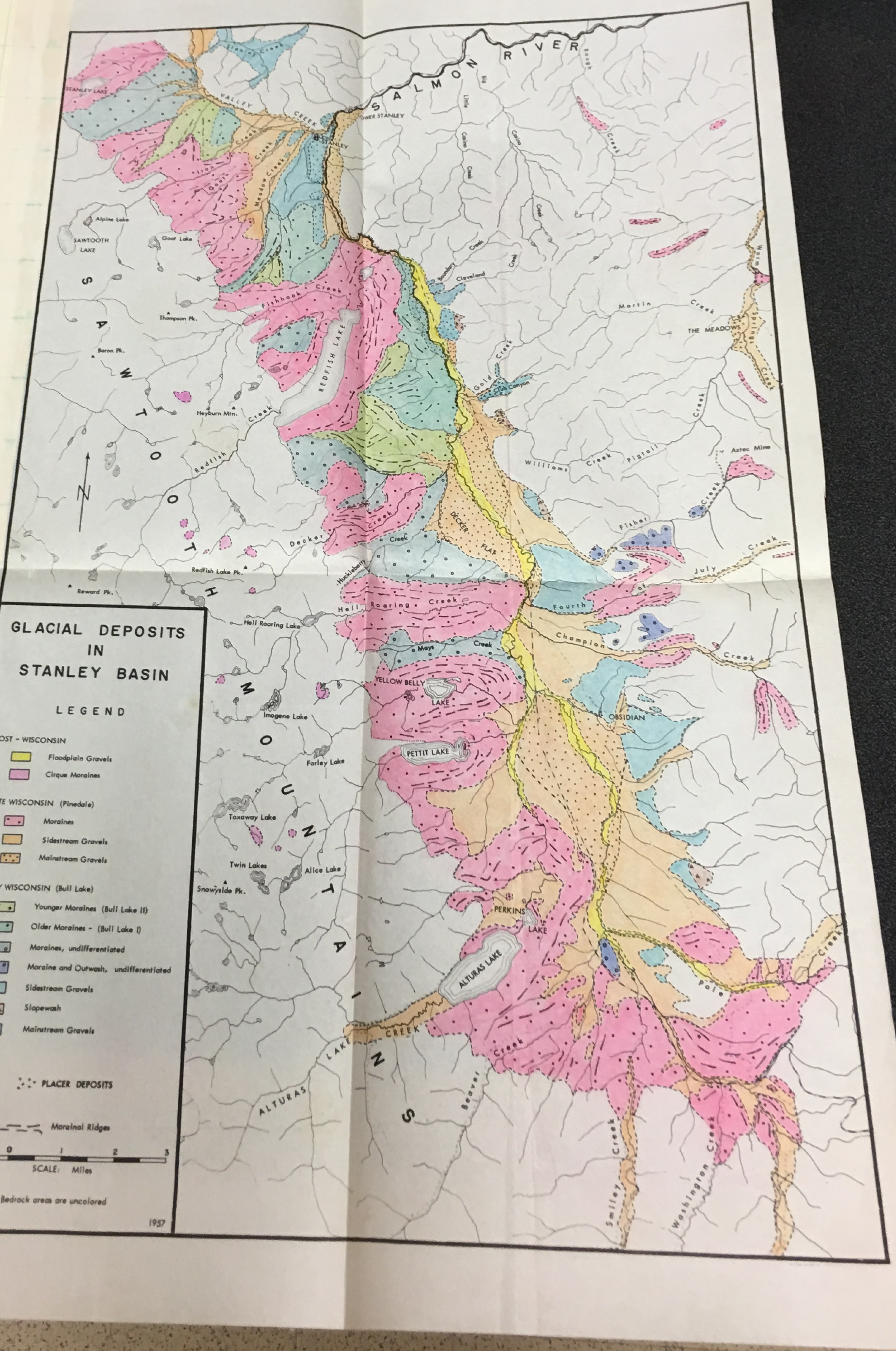
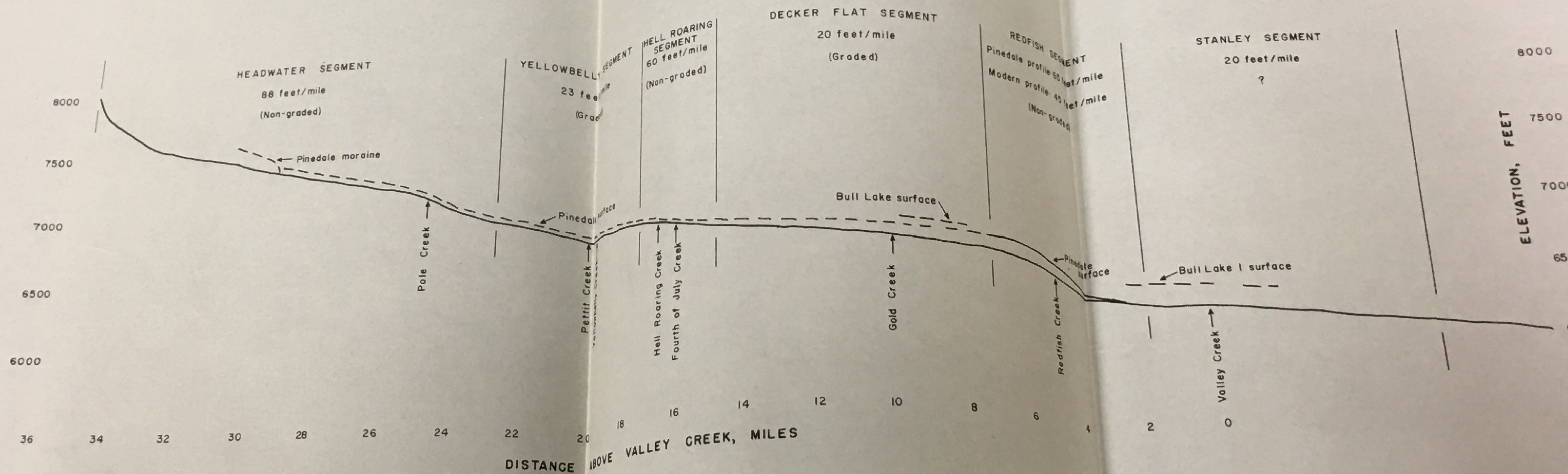


FIG. 12: DIAGRAMMATIC CROSS-SECTION OF STANLEY BASIN



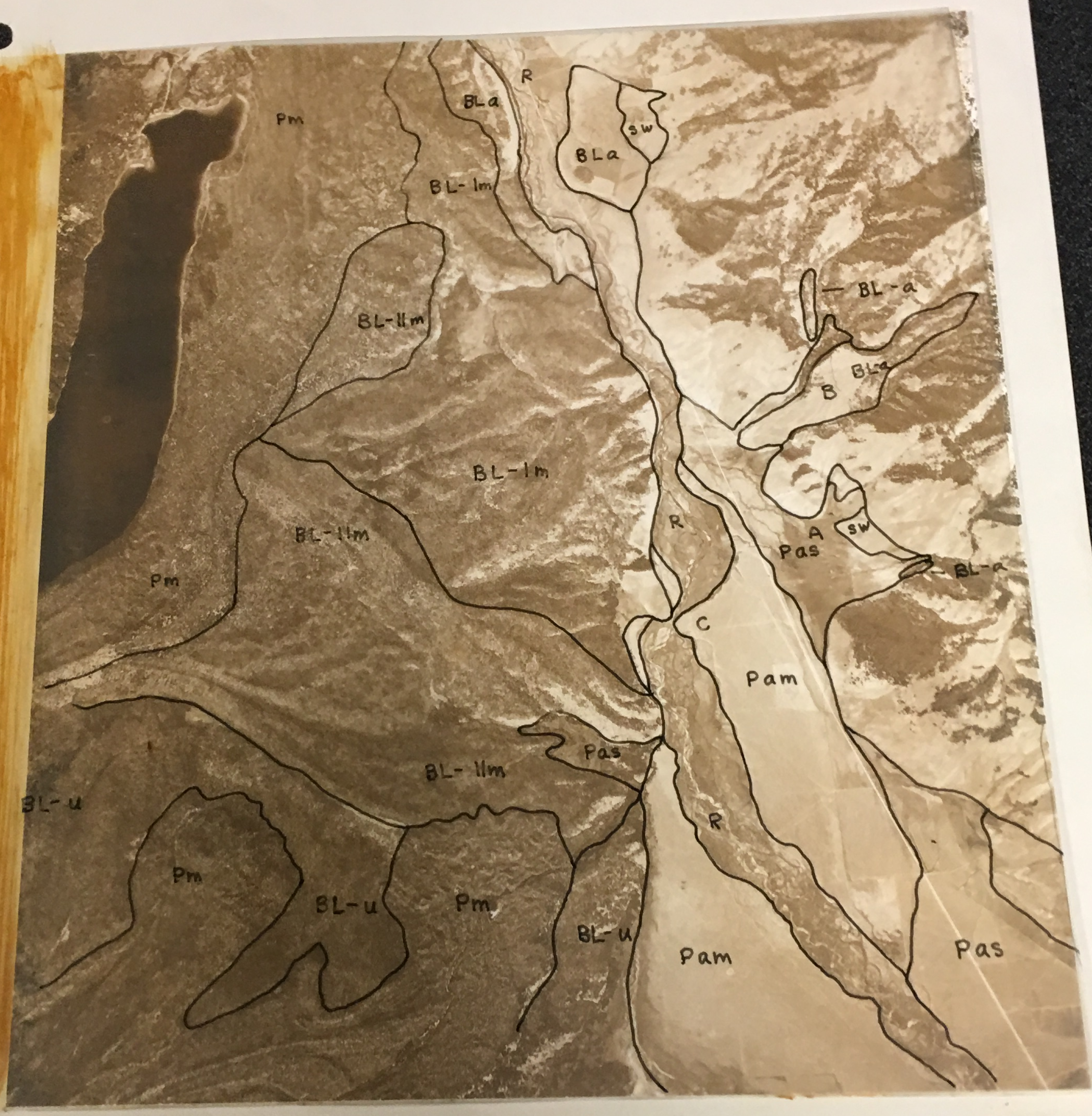
GLACIAL DEPOSITS IN STANLEY BASIN
LEGEND
POST - WISCONSIN
Floodplain Gravels
Cirque Moraines
LATE WISCONSIN (Pinedale)
Moraines
Sidestream Gravels
Mainstream Gravels
EARLY WISCONSIN (Bull Lake)
Younger Moraines (Bull Lake II)
Older Moraines - (Bull Lake I)
Moraines, undifferentiated
Moraine and Outwash, undifferentiated
Sidestream Gravels
Slopewash
Mainstream Gravels
PLACER DEPOSITS
Morainal Ridges
1 0 1 2 3
SCALE: Miles
Bedrock areas are uncolored
PLW
1957
SALMON RIVER
SAWTOOTH MOUNTAINS
STANLEY LAKE
VALLEY CREEK
LOWER STANLEY
Alpine Lake
SAWTOOTH LAKE
Goat Lake
Thompson Pk.
Baron Pk.
Fishhook Creek
REDFISH LAKE
Heyburn Mtn.
Redfish Creek
Decker Creek
Redfish Lake Pk.
Reward Pk.
DECKER FLAT
Huckleberry
Hell Roaring Creek
Hell Roaring Lake
Mays Creek
YELLOW BELLY LAKE
Imogene Lake
PETTIT LAKE
Farley Lake
Toxaway Lake
Twin Lakes
Alice Lake
Snowyside Pk.
PERKINS LAKE
ALTURAS LAKE
ALTURAS LAKE CREEK
Beaver Creek
Smiley Creek
Washington Creek
Pole Creek
OBSIDIAN
Champion Creek
Fourth of July Creek
Fisher Creek
Williams Creek
Pigtail Creek
Aztec Mine
Gold Creek
Cleveland Creek
Martin Creek
THE MEADOWS
Little Casino Creek
Big Casino Creek
Rough Creek



PROFILE OF THE SALMON RIVER IN STANLEY BASIN

CORRELATION OF MOUNTAIN GLACIAL STAGES IN THE CORDILLERAN REGION

	NORTHERN ROCKY MOUNTAINS				MIDDLE ROCKY MOUNTAINS						SOUTHERN ROCKIES		GRT. BASIN	SIERRA NEV	CASCADES
AREA	Secesh Basin, Idaho	Bear Valley & Long Valley, Idaho	Waterton, Alberta	Stanley Basin, Idaho	Western Wyoming	Jackson Hole Wyoming	Wasatch Range Utah	Yellowstone Valley, Wyo.	Uinta Mts., Utah	Southwest Wind River Mts., Wyoming	North Park, Colorado	San Juan Range, Colo.	Ruby-East Humboldt Ra., Nevada	Sierra Nevada California	Leavenworth Area, Wash
AUTHORITY	Capps, 1940	Mackin and Schmidt, unpublished	Horberg, 1954	This paper	Blackwelder, 1915	Fryxell, 1930	Atwood, 1909	Horberg, 1940	Bradley, 1936	Holmes & Moss, 1955	Eschman, 1952	Atwood and Mather, 1932 Richmond, 1954	Sharp, 1938	Blackwelder, 1931	Page, 1939
Very young deposits			Cirque moraine	Cirque moraines		Cirque moraines				Little Ice Age Temple Lake	Cirque moraines American Lakes	Rock glaciers Young moraines			
Slightly weathered deposits with fresh constructional topography	Wisconsin	Wisconsin	Late Wisconsin (Cary)	Pinedale	Pinedale	Pinedale	Inner, fresh moraines	Pinedale	Smith Fork	Pinedale	Silver Creek	Wisconsin II Wisconsin I	Angel Lake	Tioga	Stuart
Massive, weathered deposits with subdued constructional topography	"Intermediate"	Illinoian?	Early Wisconsin (Iowan-Tazewell)	Bull Lake II Bull Lake I	Bull Lake	Bull Lake (possibly two advances)	Outer, eroded moraines	Bull Lake	Blacks Fork	Bull Lake II Bull Lake I	Gould	Durango II Durango I	Lamoille	Tahoe	Leavenworth
Thoroughly weathered, formless drift	"Earliest"	Early Pleistocene	Kennedy	Buffalo (?)	Buffalo	Buffalo		Buffalo	Little Dry	Buffalo	Owl Mountain	Cerro		Sherwin McGee	Peshastin


Pm
R
BLa
sw
BLa
BL-1m
BL-a
BL-IIm
BLa
B
BL-1m
R
A
sw
Pas
BL-a
BL-IIm
Pm
C
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Pas
BL-IIm
BL-u
R
Pm
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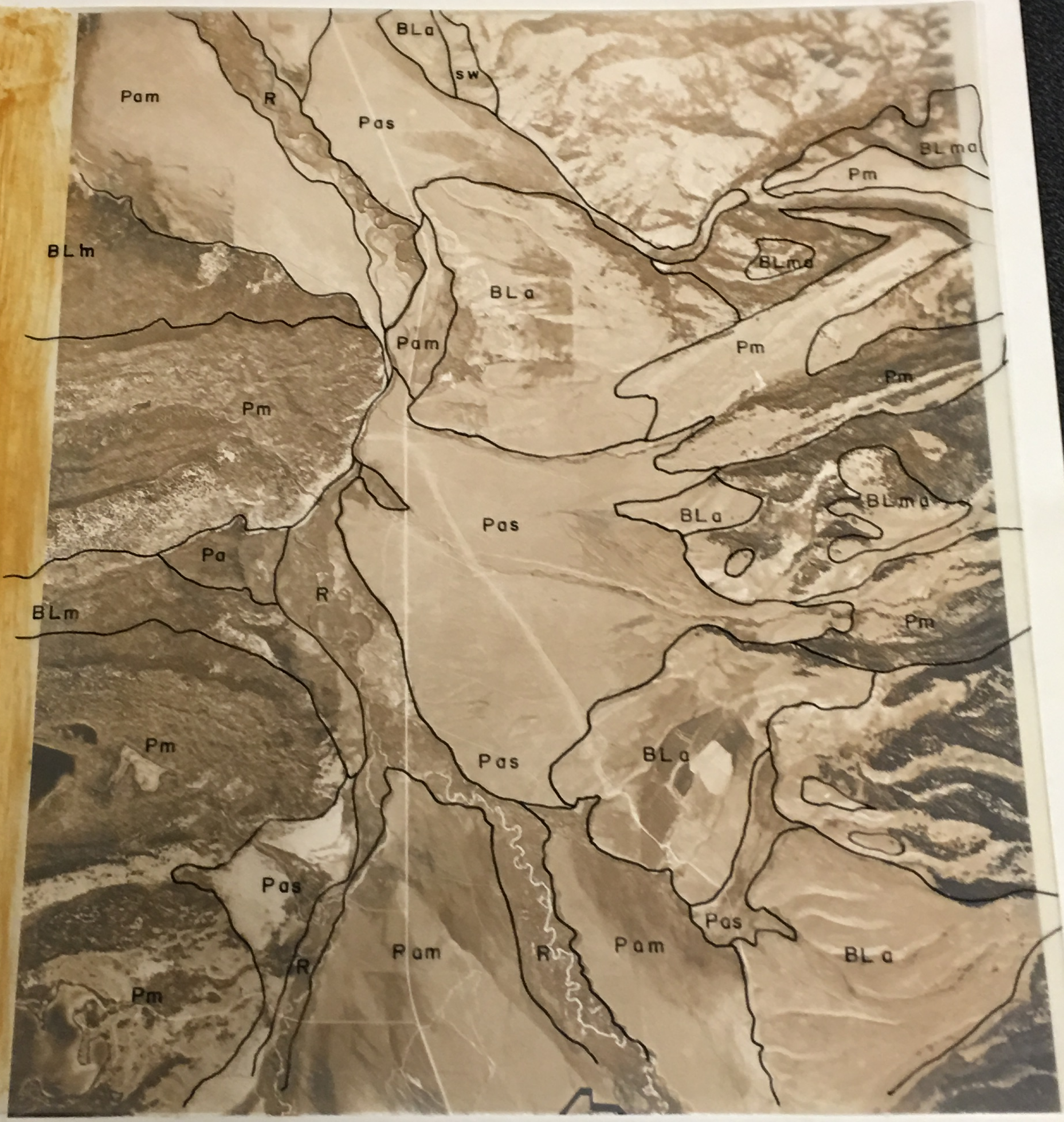
Pam
Pas


BLa
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