

Significance of the Scarcity of Early Pleistocene Glacial Deposits in the Western United States

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A CURIOUS though little remarked fact is that glacial deposits at least tentatively correlative with the four major stages of Pleistocene glaciation are exceedingly rare in the mountainous areas of the western United States. To date, they have been found in only three ranges, despite more than 50 years of investigations.

The common explanation for the scarcity of early Pleistocene glacial deposits in the western mountains is that long and vigorous erosion has removed all traces of such deposits in most localities. Another possible explanation, however, is that early Pleistocene glacial deposits never existed in some western ranges now bearing the impress of glaciation, because these ranges were below glacial snowline early in Pleistocene time and rose into snowline during Pleistocene time. This possibility seems not to have been considered seriously in this country, although a number of glacial geologists in Europe, more impressed than American geologists by the evidence of large amounts of uplift in Pleistocene time, consider it a satisfactory explanation for the slight degree of glaciation evident in some European ranges. Summarizing the European literature, Charlesworth (1957) writes: "Thus Pleistocene earth-movements explain why in the German Mittelgebirge, in the Mediterranean, including the Apennines, Sierra Nevadas, Atlas Mountains, Anatolia and the Balkans . . . only one glacial epoch and that the last is present."

Resume of Mountain Glaciation in the Western United States

The evidence of glaciation in the Rocky Mountain area, as summarized by Flint (1957), consists in general of three elements:

1. Young glacial deposits, showing fresh constructional topography and only slight weathering; referred to the Pinedale glaciation of late Wisconsin time.
2. Older drift, showing constructional forms much blurred by mass wasting and by cover of loess, distinctly weathered and frequently exhibiting a mature soil profile; referred to the Bull Lake glaciation of early Wisconsin time.
3. Patches of deeply weathered drift normally showing no traces of con-

structional forms, in many places lying on erosion surfaces hundreds to more than a thousand feet above present stream levels; originally referred to a Buffalo glaciation, now to one or more pre-Wisconsin stages of glaciation.

Work by Richmond (1957) has demonstrated the evidence of three pre-Wisconsin glaciations in the Wind River Mountains of Wyoming, the mountains of northern Idaho and Wyoming (Glacier National Park area), and the La Sal Mountains of Utah. The evidence consists of sheets of till that are separated by zones of weathering and mature soils. Richmond tentatively correlated the three pre-Wisconsin glaciations with the Nebraskan, Kansan, and Illinoian glaciations of the midcontinent.

A point to be stressed is that the evidence of three pre-Wisconsin glaciations has been found only in three of those mountainous areas that extended far higher into glacial snowline than the majority of the other glaciated areas.

We may examine two types of evidence to test the hypothesis that many ranges showing evidence of glaciation lay below glacial snowline early in Pleistocene time, or not as far above it as they do at present. The first is the heights of glaciated areas above glacial snowline. The second is the probable amount of uplift of the mountainous areas during Pleistocene time.

Heights of Glaciated Areas above Glacial Snowline

The heights that the glaciated ranges of the western United States extended above snowline, at least in Wisconsin time, are considered to equal the differences between summit elevations and the elevations of the lower cirque floors. The assumption that cirque floors and snowline coincide roughly is a fairly strong one that has been argued at length elsewhere (Flint, 1957; Charlesworth, 1957). The elevations of cirque floors accord well in any given range after allowing for expectable differences on opposite sides of ranges and northward decline in elevation (in the northern hemisphere) in long ranges.

Figure 1 shows the differences in elevation between summits and snowline, as shown by cirque floors, in 44 western ranges for which data are available (Flint, 1957). The range in differences in elevation shown for a number of the glaciated mountain areas reflects the differences in elevation of lower cirque floors on opposite side or northern and southern ends of individual mountain ranges.

The figure shows clearly the great differences in the heights of western mountains above snowline of glacial times, from an average of around 5000 feet in the Sierra Nevada to virtually zero on the Aquarius Plateau of Utah. More significantly, the figure shows that the highest summits of nearly half

the glaciated mountain areas extended less than about 2000 feet above snow-line. If these mountainous areas rose as much as 2000 feet during Pleistocene time, about half of the areas that show evidence of glaciation would have

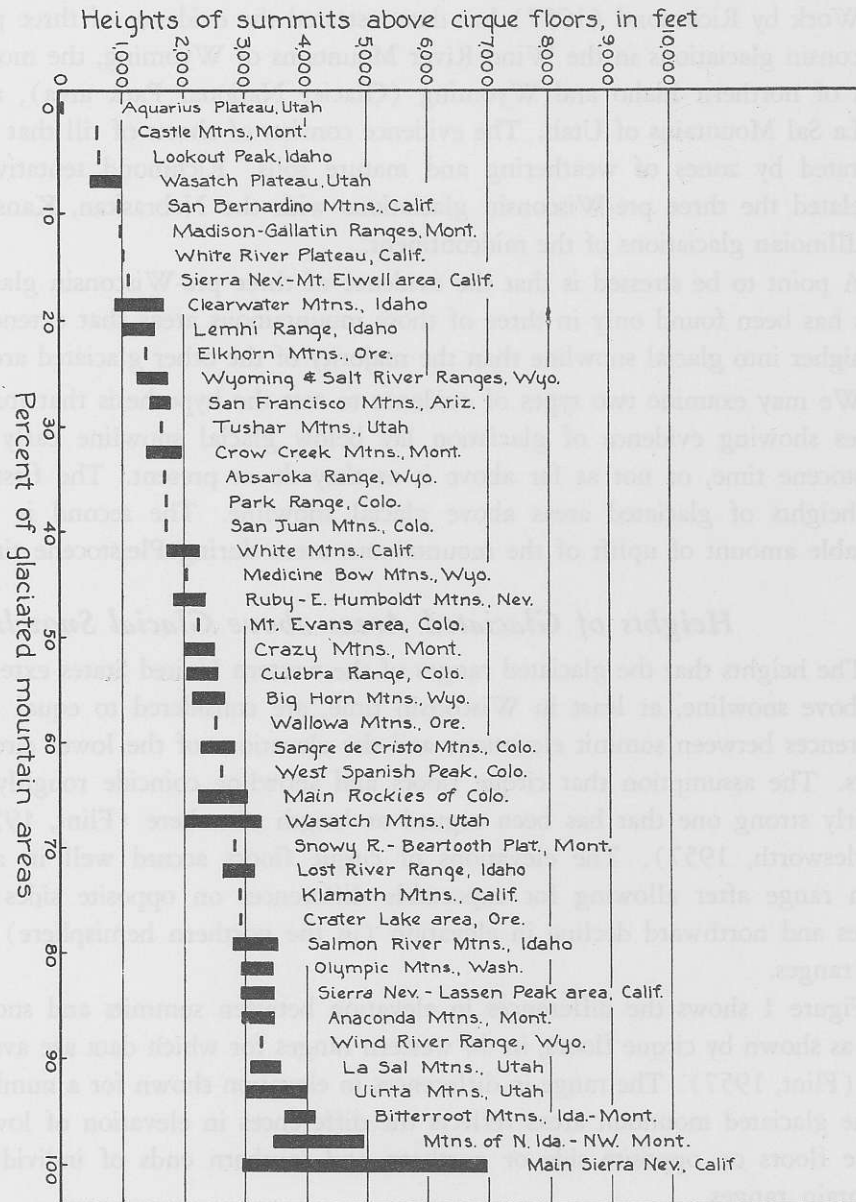


Figure 1. Differences in elevation between summits and snowline of glacial time, as determined from cirque floors, in 44 glaciated mountain areas in the western United States. (Data from Flint, 1957.)

been below snowline early in Pleistocene time, assuming that snowline had about the same elevation above sea level during the early glaciations as during the later glaciations.

Probable Amounts of Uplift during Pleistocene Time

It is now generally agreed that continental areas have risen considerably since Plio-Pleistocene time. According to Flint (1957) post-Pliocene uplift has raised the mean heights of the continents about 1600 feet, from below about 980 feet to around 2600 feet. The reported uplifts since Plio-Pleistocene time in many mountainous areas around the world are larger; they are rarely estimated at less than a few thousand feet (Flint, 1957; Charlesworth, 1957), and in the Himalayas have been estimated at around 13,000 feet by Hagen (1963).

Many ranges of the western United States have risen thousands of feet since late Pliocene time, according to those who have studied them. The Front Range of the Colorado Rockies has risen about 5900 feet (Wahlstrom, 1947); the San Juan Mountains of Colorado 3280 feet (Atwood and Mather, 1932); the mountains of western Montana "several thousand feet" (Pardee, 1950); and the Alaskan Coast Range as much as 5000 feet (Capps, 1931). Although estimates of uplift since late Pliocene time are lacking for most of the other ranges, it seems likely that they have risen at least the 1600 feet that Flint estimates for the continents as a whole, and probably considerably more.

There is a tendency on the part of some geologists to deny that the high surfaces of the western mountains indicate large uplifts. The upland surfaces, the argument runs, are the higher portions of pediments left isolated by erosion of the lower and once very extensive pediment slopes. According to this interpretation, the relief between upland surfaces and the lowlands has been caused by a change in stream regimen, from conditions under which graded streams widened out pediments and spread waste to conditions in which streams cut downward strongly.

Opposed to this concept that the present relief represents a change in process, not uplift, we may set not only the opinions of the many geologists who have reported large uplifts, but also the forcible evidence of uplift in some mountains. The uplift of around 5000 feet of the Alaskan Coast Range that Capps (1931) reports is based on the presence of sediments carrying Pleistocene marine fossils at that height. In California the exhaustive studies of Bull (1964) on segmented alluvial fans show convincingly that the Coastal

Range has risen probably "more than 2000 feet during and since the Coast Range orogeny," which is generally considered to be of middle to late Pleistocene age.

A more important question is: are the present high elevations of continents and mountains due primarily to large-scale uplift in Plio-Pleistocene or early Pleistocene time, or are they due to recurrent uplifting movements that began at those times?

The weight of the present evidence seems to indicate that intermittent uplifts continuing into the present are responsible for a major part of the total uplift of these areas since Plio-Pleistocene time. The surfaces of erosion that one commonly finds between uplands and modern lowlands tell a story of recurrent uplift rather than of one grand uplift early in Pleistocene time. Also, considerable uplift and erosion apparently occurred between such individual glaciations as can be recognized. As Richmond (1957) notes, deposits of pre-Wisconsin till in most places "cap high interstream divided or remnants of broad-valley erosion surfaces along the upper slopes of canyons," and "tend to be dissected from 200 to over 1,000 feet by modern trunk streams."

Here again some geologists may question whether the downcutting between glacial events necessarily signifies uplift. However, most geologists probably will prefer to believe that the cutting of valleys a thousand feet below old erosion surfaces, into strong rocks, signifies uplift rather than a change in stream regimen due to climatic fluctuation, at least until stronger evidence is introduced to support the latter theory.

The belief that present elevations are due to Pleistocene movements is fortified by the accumulating evidence, interestingly summarized by Charlesworth (1957), that all of Pleistocene time has been a revolutionary period, not merely the beginning of it. Although the Rockies and most of the ranges farther west do not show the activity registered in California, where mid-Pleistocene sediments have been folded in the Coast Range orogeny (Bull, 1964) and the San Bernardino Mountains are now rising at a rate of two feet per hundred years (Gilluly, 1949), they certainly are not dead. For example, from tree-ring data Pardee (1950) estimated a movement of 10 to 30 feet along the fault at the foot of the Madison Range in western Montana since 1770.

The available data therefore suggest most strongly that the western ranges in the United States have risen a few to several thousand feet since Plio-Pleistocene time, and that much of this total uplift is due to recurrent movements through Pleistocene time, which are continuing in certain areas even now.

Summary and Conclusions

To the present, evidence of glaciation in all four glacial stages of the Pleistocene has been found in only three of the mountainous areas of the western United States that extend much further above glacial snowline than average. This scarcity of early glacial deposits may very well be interpreted as showing that many mountains bearing the impress of glaciation were uplifted into glacial snowline during the Pleistocene.

In about half of the glaciated areas for which there are data the summits stand from barely above to little more than 2000 feet above glacial snowline as determined from elevations of lower cirque floors. Uplift of the mountains during Pleistocene time probably equalled or exceeded 2000 feet on the average. Therefore mountain areas that extended only a few hundred to 1000 feet or so above glacial snowline during the Wisconsin glaciation almost certainly were below glacial snowline during one or more of the earlier glaciations. To take an actual example, the San Bernardino Mountains of California, which stood slightly less than 1000 feet above snowline in Wisconsin time, are rising two feet per hundred years (Gilluly, 1949) and at this rate would have been 1000 feet lower and below snowline only 50,000 years ago. Other ranges were not so high above glacial snowline in the early Pleistocene—which includes both Kansan and Nebraskan glaciations—as in the late Pleistocene, and consequently were then only lightly glaciated, leaving less evidence to survive the extensive erosion since Kansan time.

If the foregoing hypothesis is true, early glacial deposits should not be expected in a considerable percentage of the glaciated ranges of the western United States because they were below glacial snowline in early Pleistocene time. As a corollary, periglacial deposits such as outwash and loess of early Pleistocene age will also be missing in the vicinity of such ranges, and also the evidence in lake beds of environmental changes accentuated by the waxing and waning of nearby glaciers.

Literature Cited

- Atwood, W. W., and K. F. Mather. 1932. Physiography and Quaternary geology of the San Juan Mountains, Colorado. U.S. Geol. Survey Prof. Paper 166, 176 p.
- Bull, W. B. 1964. Geomorphology of segmented alluvial fans in western Fresno County, California. U.S. Geol. Survey Prof. Paper 352-E, p. 89-128.
- Capps, S. R. 1931. Glaciation in Alaska. U.S. Geol. Survey Prof. Paper 170, p. 1-8.
- Charlesworth, J. K. 1957. The Quaternary era. Edward Arnold, London, 1700 p.
- Flint, R. F. 1957. Glacial and Pleistocene geology. John Wiley and Sons, Inc., New York, 553 p.

Gilluly, J. 1949. Distribution of mountain building in geologic time. *Geol. Soc. Amer. Bull.*, 60:561-590.

Hagen, T., G-O. Dyhrenfurth, C. V. Furer-Haimendorf, and E. Schneider. 1963. Formation, population and exploration of the Everest region. Trans. by E. N. Bowman. Oxford Univ. Press, New York-Toronto.

Pardee, J. T. 1950. Late Cenozoic block faulting in western Montana. *Geol. Soc. Amer. Bull.*, 61:359-406.

Richmond, G. M. 1957. Three pre-Wisconsin glacial stages in the Rocky Mountain region. *Geol. Soc. Amer. Bull.*, 68:239-262.

Wahlstrom, E. E. 1947. Cenozoic history of the Front Range, Colorado. *Geol. Soc. Amer. Bull.*, 58:551-572.

As described from elevations of lower clime facies during Pleistocene time probably equalled or exceeded 2000 feet on the average. The mountain areas that extended only a few hundred to 1000 feet or so above glacial snowline during the Wisconsin glacial stage certainly were below glacial snowline during one or more of the earlier glaciations. To take an actual example, the San Bernardino Mountains of California, which stand slightly less than 1000 feet above snowline in Wisconsin time, are today two feet per hundred years (Gilluly, 1939) and at the rate would have been 1000 feet lower and below snowline only 50,000 years ago. Other ranges were not so high above glacial snowline in the early Pleistocene—which includes both Kansan and Nebraskan glaciations—as in the late Pleistocene, and consequently were then only lightly glaciated, leaving low evidence to survive the extensive erosion since Kansan time.

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Literature Cited

Arnold, W. W. and K. E. Miller. 1931. Physiography and Quaternary geology of the San Bernardino Mountains, California. *US Geol. Survey Prof. Paper* 162, 124 p.

Ball, W. B. 1954. Geomorphology of segmented alluvial fans in western Fresno County, California. *US Geol. Survey Prof. Paper* 322-E, p. 89-118.

Capps, S. J. 1931. Glaciation in Alaska. *US Geol. Survey Prof. Paper* 170, p. 1-8.

Chamberlain, J. K. 1937. The Quaternary of the Grand Strand, South Carolina. *US Geol. Survey Prof. Paper* 170, p. 1-8.

Price, R. E. 1957. Glacial and Pleistocene geology. John Wiley and Sons, Inc., New York, 317 p.