A DISTRIBUTION STUDY OF ABANDONED CIRQUES IN THE ALASKA-CANADA BOUNDARY RANGE

MAYNARD M. MILLER

Reprinted from *Geology of the Arctic* (University of Toronto Press, 1961)

A Distribution Study of Abandoned Cirques in the Alaska-Canada Boundary Range

MAYNARD M. MILLER

ABSTRACT

The distribution, orientation, and frequency patterns of 218 cirques in the northern Boundary Range, Alaska-Canada, are analysed. The mean elevation of the lowest ice-filled basins is 3500 feet. In the valleys not formerly glaciated by trunk glaciers from the Wisconsinan Cordilleran ice-sheet, abandoned cirques occur in a repeated five-fold sequence. The mean elevations of these cirques, or cirque-like basins, are: 350, 1100, 1750, 2450, and 3150 feet. The standard deviation in each system is small and the effect of orientation appears to be random. There is no apparent evidence of regional control by lithology, bedrock structure, or pre-Glacial topography. The frequency distribution, therefore, suggests that the cirque levels relate to former névé lines. An apparent correlation of cirque pattern with a sequence of other erosional forms in the main valleys of the range strengthens the inference of relation to Wisconsinan glacial stages. The study suggests that, during the late Pleistocene, glaciers in this maritime region were uniquely sensitive to climatic change.

WITH THE CERTAINTY of increased strategic and commercial activity in the far northern regions over the next several decades, it is natural that there is a corresponding interest developing in the various branches of arctic geology. One of the most important of these disciplines is that of polar and alpine geomorphology. As a knowledge of the nature and morphogenesis of arctic landforms and surface materials can yield information indispensable to operations in these regions, a full comprehension of arctic Pleistocene events and related processes in glaciers, sea ice, and permafrost is a pertinent and practical goal. In outlining the nature of former glacial ages, the classical approach has been to extrapolate from the evidence of relict depositional and erosional features, while regarding the régime and effects of modern ice masses as phenomena of post-Thermal Maximum time, essentially disconnected from the chronology of the Ice Age.

In this paper the problem is approached in the opposite way. Through selected locations of a specific landform, an attempt is made to work directly and sequentially into the past from the present position and activity of existing glaciers. The study bridges the last major glacial age, or Wisconsin Cordilleran glaciation, in the Alaska-Canada Coast Range. The region considered lies in the northern Boundary Range (Bostock, 1948, pp. 83-8), and particularly refers to that portion of the range inland from Lynn Canal in the vicinity of sixtieth parallel (Figure 1).

The field work for the present study was carried out in connection with a more comprehensive investigation of Alaskan and Canadian coastal glaciers in which the writer has been engaged over a number of years. The part of this programme discussed in the present paper was supported by a grant from the Resa Fund of

Reprinted from *Geology of the Arctic* (University of Toronto Press, 1961) the Society of Sigma Xi and by the Expeditionary Research Fund of the Explorers' Club. The work is also related to the systematic regional studies of the Juneau Icefield Research Program, under the aegis of the foundation for Glacier Research, Inc. For assistance in the field, the writer is indebted to Dr. T. R. Haley, Mr. W. W. Miller, and Mr. Barry Prather. Appreciation is also extended to Mr. Hunt Gruening of Alaska Coastal Airlines and Mr. Kenneth Loken, Juneau Air Taxi Service, for competent and cheerful co-operation during the extensive flights made to observe many of the geomorphological features here discussed.

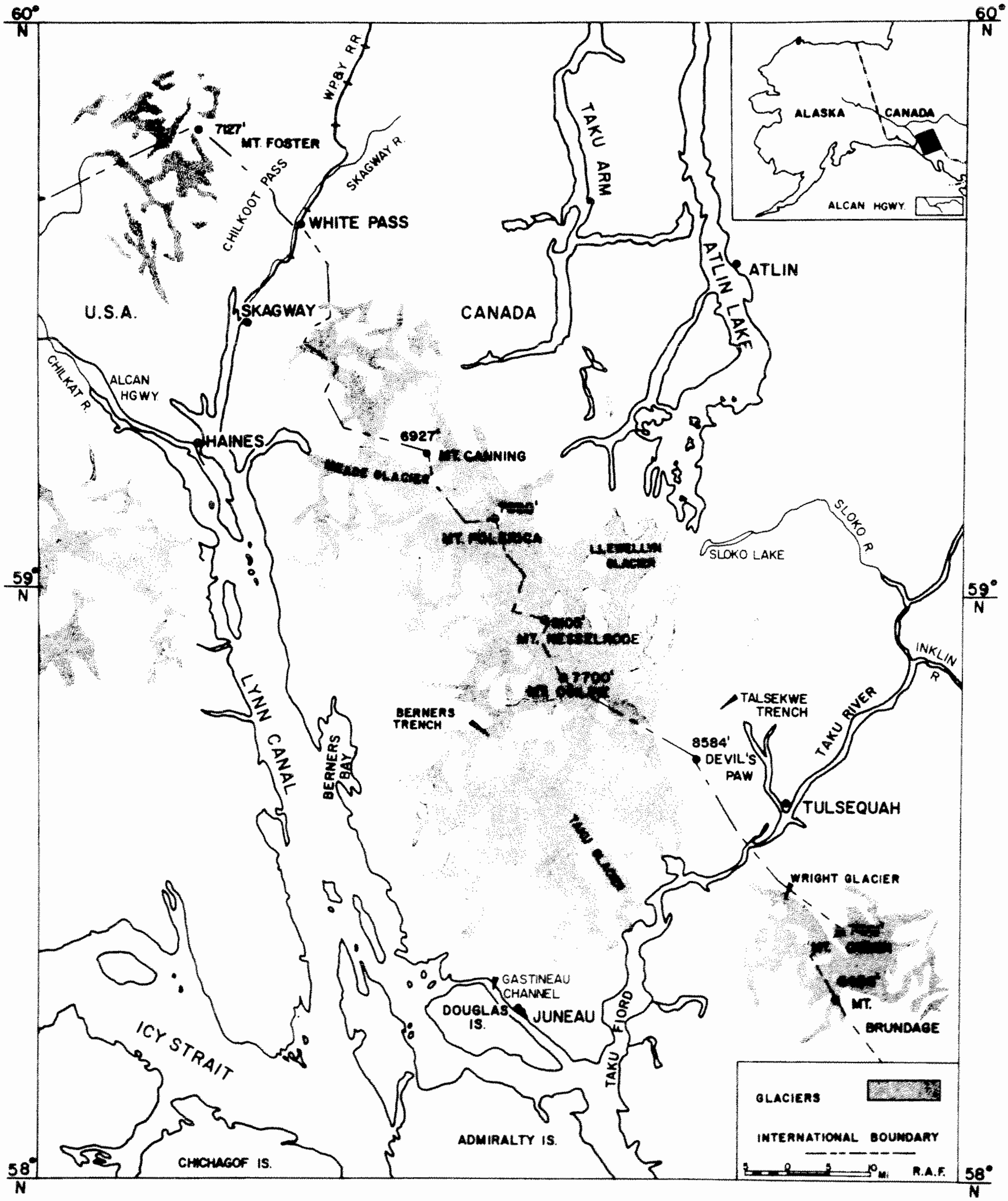

FIGURE 1. General map of the northern Boundary Range. Alaska-Canada.

Lower Glacial Limits from the Position of Abandoned Cirques

The general levels of forest-covered cirques in present non-glaciated valleys of the maritime flanks of the northern Boundary Range provide some useful information on the depression of the Cordilleran ice cover during the Pleistocene. The position of cirques has been used by Ljungner (1948, p. 36) to show the lower limit of ancient glaciation in Scandinavia. Flint (1947, pp. 95 and 230) has also considered the elevation of old cirques as representing excavation during the maximum of glacial ages in the western United States. He suggests that, as the same cirques could be occupied by ice from successive glaciations, it may be difficult to assign a set of cirques to a particular age, but that "future refinements of study may show that some correlation is possible."

In this paper, such a refinement is attempted in an effort to understand a regional pattern of cirque development and to aid in the interpretation of related geomorphic features. From this, a working hypothesis is evolved which is in accord with available evidence and which can be tested by further, more detailed, research. The fundamental assumption is that the elevation of the cirque floors gives a rough estimate of the former regional snowline. As will be discussed, they more likely approximate to the level of former permanent névé lines, a proposition originally suggested by Hann (1903, p. 310).

Also to be considered is the possibility that the distribution and character of these cirques may have economic significance. The main area of the present study lies in the Taku district, within a radius of sixty miles of Juneau, Alaska's capital city. About 60 per cent of the cirques investigated are carved into bedrock areas on the maritime margin of the Juneau ice-field. The other 40 per cent are on the slopes of ridges above the main westerly-trending river valleys and on island massifs near Taku and Gastineau fjords (Figure 1).

A Fivefold Tandem Sequence

In the northern Boundary Range, 218 distinct cirques were studied. In these, there are five noteworthy cirque systems, one of which is distinctly old. These cirques are numerous and well displayed everywhere around the edge of the present ice-fields. To illustrate their relation, a listing of cirques found on the flanks of the main valleys and slopes on the southern and western sides of the Juneau ice-field is given in Table I. Although many are composite and multiple, their forms are usually well defined and, as will be shown, the elevations of the different sets are unexpectedly accordant.

To simplify the discussion, reference is made to five groups of moderate-sized cirques in small, separated valleys leading from ridges not directly connected with the main ice-field area. As indicated in Table I, their elevations appear to be representative. By selecting these smaller valleys, the erosional effects of large through glaciers which have modified many other cirque systems in the region are of less concern. The valleys of Nugget Creek, Salmon Creek, and Gold Creek drain into Gastineau Channel from the area north and east of Juneau; they are noted within the rectangles labelled A, B, and C on the Juneau quadrangle map of Figure 2. The other two valleys are tributary to the inner end of Taku Fjord; the cirques in them are marked by smaller rectangles in the map of Figure 3.

TABLE I

ELEVATION OF CIRQUE FLOORS FROM THE TAKU VALLEY TO BERNER'S BAY

Location and map quadrangle	Elevation in feet and orientation of cirque, as noted					
Taku River, B6						
Mouth of Taku R.:						
E. Side	550NW	950NW	1550W	2300N	3100W*	—
	—	—	1700NW	2700NW	—	—
Johnson Cr.	—	—	1700NW	2150NE	3100N*	3600NW*
Davidson Cr.	—	1250N	1600NW	2400SW	—	—
	—	1200NW	—	2200NW*	—	—
	—	1200N	—	2300N	—	—
	—	1200NE	—	2450N	—	—
	—	—	—	2300N	—	—
	—	—	—	2250NW	—	—
	—	—	—	2350NW	—	—
Turner Lake Area	350N	1150NW	1550N	2300N*	3300NW*	3600W*
	—	900W	1600N	2200NW	3100SW	3600NW
	—	—	1450W	2200W	—	—
	—	—	1800NW	2550W	—	—
	—	—	—	2200W*	—	—
	—	—	—	2200NW	—	—
	—	—	—	2300SW	—	—
	—	—	—	2200E	—	—
Juneau, B1						
Norris Peak:						
N. Side	—	—	—	2600W	3200N	—
S. Side	—	1100S	—	—	—	—
S.W. Br. Norris	—	—	1600SE	2700S	3000E*	—
Taku Inlet:						
Scow Cove	—	—	1500E	—	—	—
W. of Flat Point	—	1150S	1500SE	—	—	—
Annex Cr. valley	—	900SE	1600SE	2250W	—	—
Carlson Creek:						
Sunny Cove	300SE	1050E	—	—	—	—
Salmon and Gold forks	—	1200NE	1600NE	2800SE	3200N	3500E*
Sheep Fork	450NE	900NE	1800NE	2300NE	3300E*	3600NE*
	—	—	1800NE	—	—	—
Hawthorne Peak	300NE	900NE	1800E	2300SE	3100NW*	3600N*
N.E. valley	—	1150SE	1700E	2500SE*	—	—
Rhine Cr.	—	—	1800SE	2500SE	—	—
	—	—	—	2400E	—	—
Thane Area	—	1000SW	1500W	—	—	—
Sheep Cr.	550SW	900W	1500NW	—	3100NW*	—

*These containing ice at present.

TABLE I—*continued*

Location and map quadrangle	Elevation in feet and orientation of cirque, as noted					
Juneau, B2						
Lemon Cr. valley	300W	800W	1900N	2350W	—	—
	—	—	—	2450W	—	—
	—	—	—	2600SW	—	—
	—	—	—	2600N	3000N	3400N*
Mendenhall valley:						
Steep Cr. Sector	—	1300N	2000NW	2650N	—	—
McGinnis Cr.	350SW	1150W	1850S	2700S	3200SW*	—
Douglas Island						
N. Side	—	1200NE	1550NE	—	—	—
Fish Cr.	450N	1000N	1650N	2300NE	—	—
W. Side	—	1150W	1750W	2550NS	—	—
Juneau, B3						
Auke Bay area:						
Peterson Cr.	350N	900N	—	—	—	—
Montana Cr.	—	—	1850W	—	—	—
Juneau, C3						
Herbert R. valley	—	—	1650N	2350N	—	—
Husky Cr.	—	—	—	2600NW	—	—
Eagle R. valley	300SW	1200W	1850NW	2350NE	—	—
	—	—	—	2300SE	3100E*	3500NE
Cowee Cr. area:						
Yankee Cove	450W	1200W	1850NW	2300NW	—	—
Canyon Cr.	—	1300N	1850W	2350W	—	—
Cowee Cr. (main)	300SW	1000SW	1600SW	2400SW*	—	—
Davies Cr.	350S	1200W*	1600S	2200S	—	—
Berner's Bay:						
Sawmill Cr.	—	—	1600N	2500N	—	—
	350W	1150SW	1700SW	2700W	—	—
Juneau, D3						
N.E. Side of Bay	—	1250W	1800W	2200W	3200W	—
S. Br. Antler R.:						
S. Side	300NW	1250N	—	2350S	3000N*	3400N*
	—	1000N	1900N	2500N	—	—
N. Side	—	—	1750S	2200N	—	—
	—	—	1900S	2600S	—	—
Antler R. valley	—	—	—	2200N	3100NW	—
S. Side	—	1400S	1850NW	2750N	—	3500N*
N. Side	250SE	—	1750SW	2800W*	3200S	—
	—	—	1800S	2850SE	—	—
Lace R. valley	—	1250W	—	2200N	3000W	3500N*
	—	1200W	—	2300W	2900W	3450N
	—	1100N	—	2650N	3100W	—
	—	1000S	1800SE	2750S	3200W*	—
	—	1200SE	—	2550W	—	—
	—	—	—	2600W	—	—
	—	—	—	2350SW	—	—
Mean elevation of the major cirque systems (to nearest 50 feet):	350	1100	1750	2450	3150	3500

*These containing ice at present.

Some of the cirques with the lowest elevation have been so altered by headward erosion and valley fill that they are more in the form of elongated basins and, in some instances, where mining operations have taken place, have been formally designated on maps as basins. For convenience, the different sets of cirques are

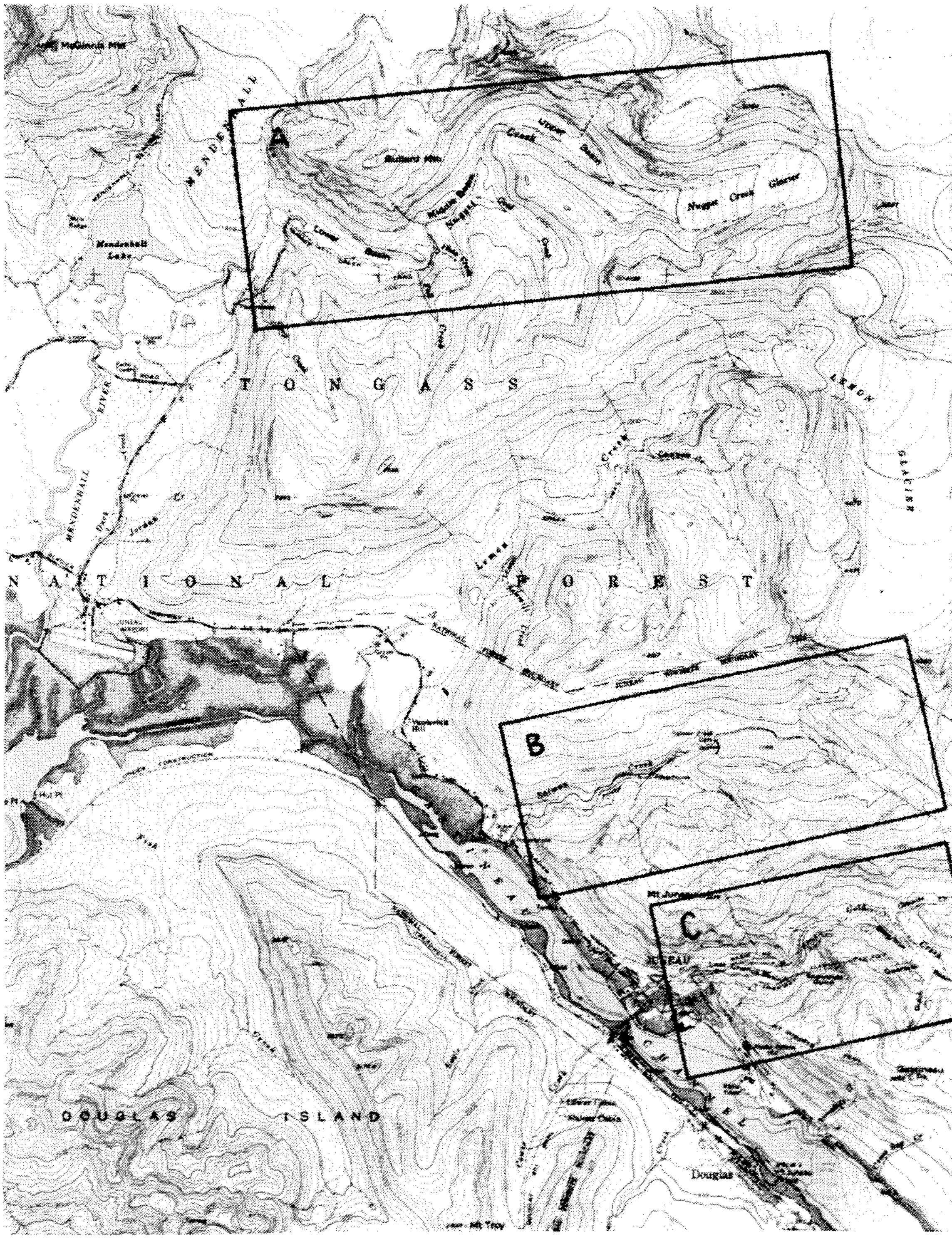

FIGURE 2. Portion of Juneau B-2 quadrangle showing topographic configuration of tandem cirques in selected valleys of the Juneau area. Scale: length of Juneau Airport runway, 1 mile.

referred to in Table II as C1 to C5, beginning with the lowest and oldest and grading upward to the highest cirque at present containing remnant bodies of ice.

In view of the great diversity of rock types in which they occur, grading from low-grade metamorphics to granodiorites in different parts of the area, the general conformity of level indicated by cirques in each system is particularly striking. To demonstrate this statistically, an elevation-frequency diagram has been prepared in

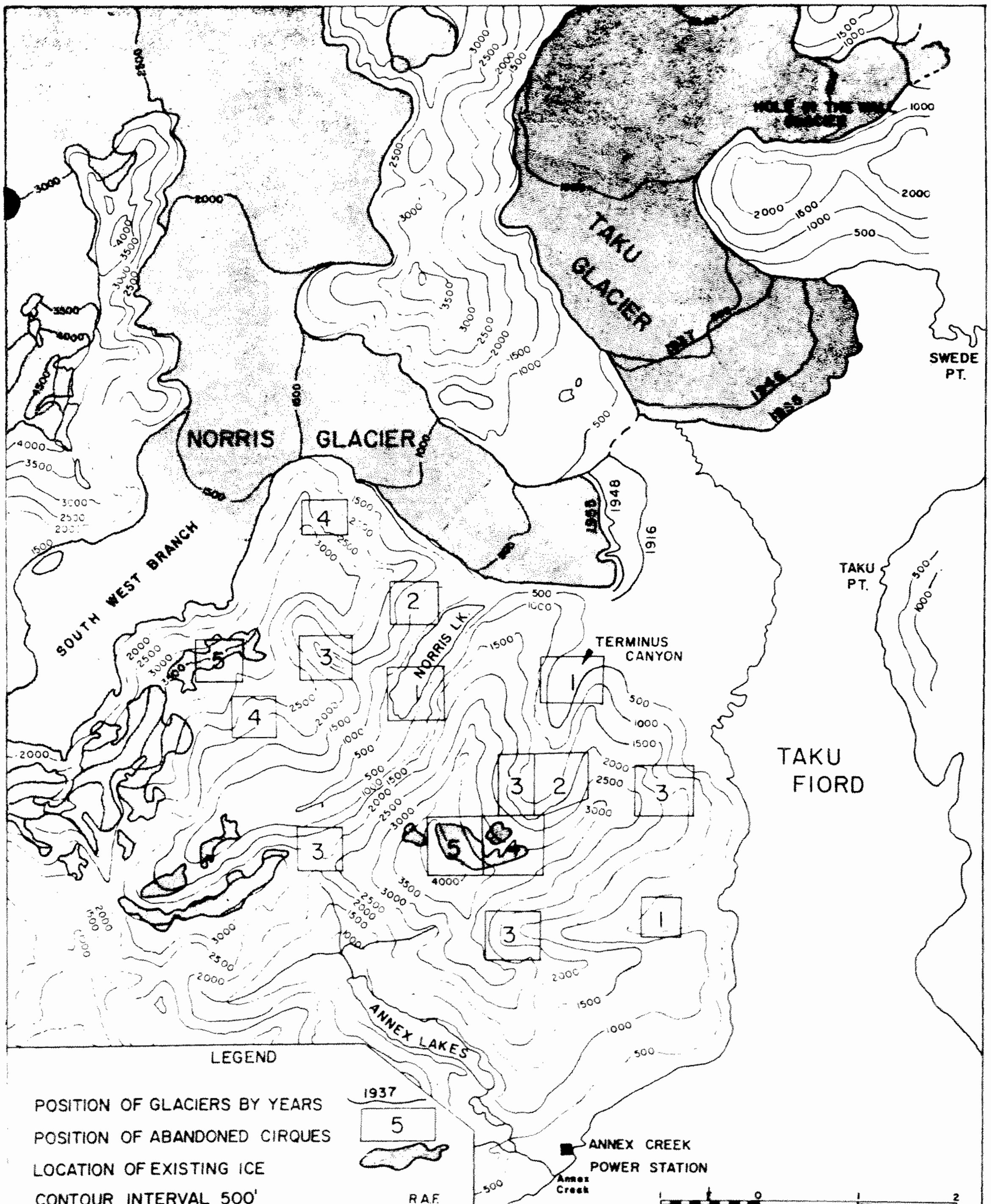

FIGURE 3. Section of inner Taku Fjord showing terminal positions of existing valley glaciers and fivefold pattern of abandoned cirques in the Norris Lake sector.

Figure 4. The diagram embraces the data in both of the table listings. The position of each of the 218 cirques is indicated.

These are not random samples, but are the result of systematic consideration of all cirques in every valley between Taku Fjord and Berners Bay (Figure 1). The elevations of the cirque floors are as inferred from the contours of the Juneau B1, B2, C3, and D3 sheets and of the Taku River B6 sheet of the 1:63,360 series of the topographical maps recently produced from aerial photographs by multiplex methods (United States Geological Survey, 1951-5). From field comparisons made on some of the cirques with aneroid elevations, these maps are believed to permit assessments to an accuracy of twice the contour interval, that is, ± 100 feet. The elevations of cirques in the Juneau area are the most certain, because they are also taken from available large-scale maps prepared for development purposes and mineral exploration.

In row A of Figure 4, the combined positions of all cirques in the district survey are noted, covering a zone some eighty miles in length around the southern and western edges of the ice-field. Although the fivefold distribution pattern may not be as clearly evident in the combined presentation, it is well shown in rows B, C, and D of the figure. Row B reveals the more local distribution pattern in the Lynn Canal sector (Herbert River to Lace River); row C, the Juneau-Gastineau Channel sector; and row D, inner Taku Fjord. Where there is divergence of the pattern locally, it may be ascribed to orientation[1] and orographical differences, and on the regional basis it may be explained as due to positional influences.

The significant fact, therefore, is not that there is a mean level of cirques representing separate systems — the orographical differences and directions of exposure

[1]The orientation of each cirque is noted in the listing in Table I.

TABLE II

FLOOR ELEVATIONS OF ABANDONED AND PARTIALLY ABANDONED CIRQUES
(in feet above msl)

Reference designation	Nugget Glacier valley (Rect. A, Fig. 2)	Salmon Creek valley (Rect. B, Fig. 2)	Gold Creek Canyon, Juneau (Rect. C, Fig. 2)	Valley at delta, Norris Glacier (Fig. 3)	Norris Lake Canyon (Fig. 3)
C1	500 (Lower Basin)	250 (Flume Pond)	300 (Last Chance Basin)	300	300 (Norris Lake)
C2	1300 (Middle Basin)	1000 (Salmon Creek Reservoir)	1050 (Silverbow Basin)	1100*	900
C3	1800 (Upper Basin)	1900	1800 (Granite Creek Basin)	1600*	1700 (Tarn Lake)
C4	2300† (Nugget Glacier tongue)	2600	2300	2600	2100
C5	3100 (Main Nugget Glacier)	3200 (Ptarmigan Glacier)	3100 (Mount Olds Glacier)	3300 (unnamed glacier)	3200 (unnamed glacier)

*Composite cirque with two levels as noted.
†Incised into headwall of C3 (Figure 2)

partly obscure this correlation — but rather that in local sectors and in almost any valley in particular there is a complete sequence of five abandoned cirques. This is also demonstrated in the breakdown of localities noted in Table I and is specifically illustrated by the type distribution pattern at Gold Creek near Juneau (row E of the frequency diagram). As in this typical case, the cirques in each sequence are usually tandem in arrangement. It is suggested that the pattern is developed in distinct régime stages, or sets of similar stages, for each level. Thus different névé lines are probably represented. As has been shown elsewhere (Miller, 1956, chapter VI) even over a period as short as ten years there is a great variation in névé-line positions — as much as 1200 feet vertically in such an interval. If the suggested relation does pertain, each level must concern the mean limiting position over very considerable lengths of time, that is, upwards of some thousands of years.

Improbability of Relationship to Former Marine Levels

An alternative consideration might be that this conformity is a reflection of former marine surfaces related to pre-Pleistocene landscape with a eustatic relation considerably different than today. This appears unlikely, however, if we assume, as Johnson (1917), Antevs (1932), and others have, that cirque formation is the

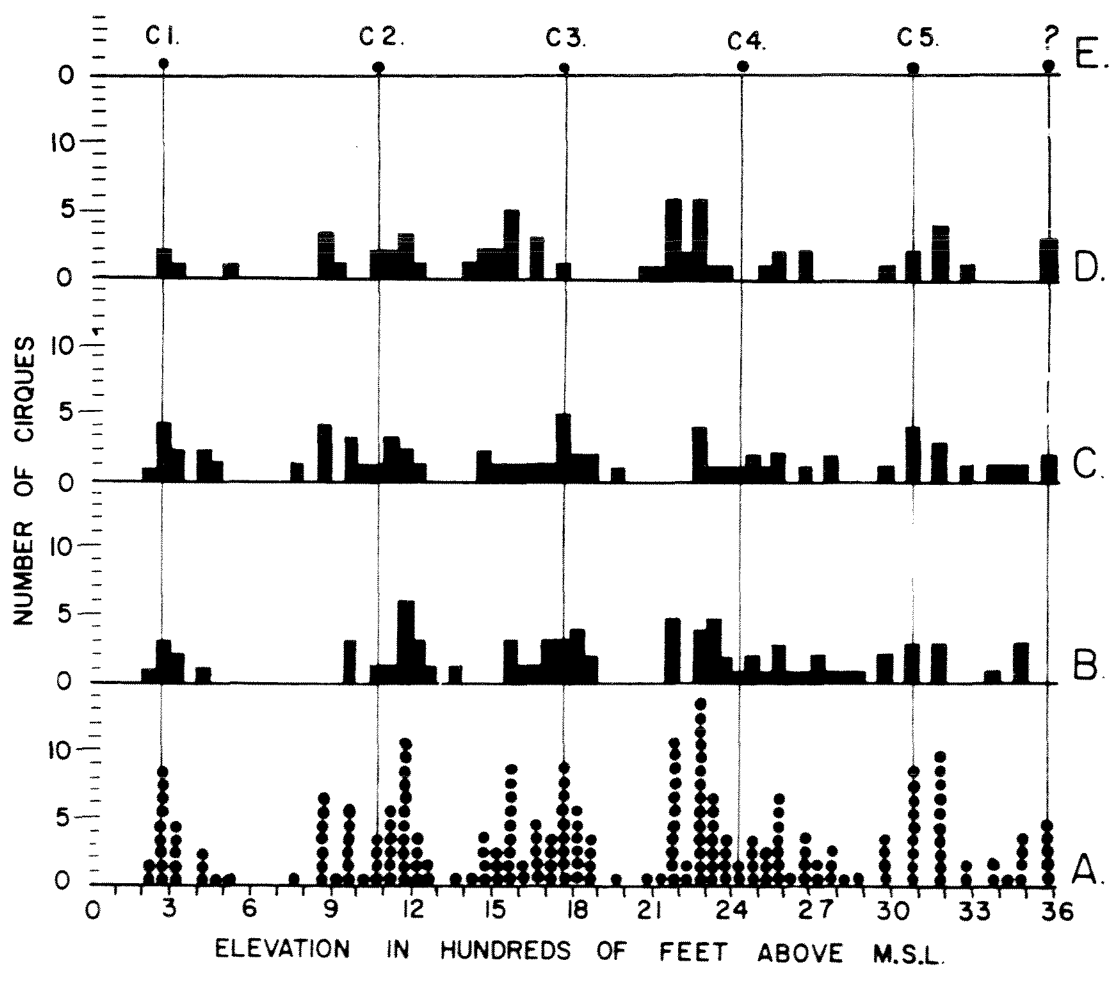

FIGURE 4. Frequency distribution of abandoned cirques as a function of elevation in the maritime sectors of the northern Boundary Range.

last phase of glacial history in a mountain region. Beyond this theoretical assumption, there are the following evidences against the possibility: (1) that a patterned sequence of cirques, with definitely three levels and possibly up to five, is also found at somewhat higher positions on the flanks of the deep valleys on the interior side of the range where, as has been indicated by other studies (Miller, 1956, chapter III) no Tertiary marine deposits occur (also V. Kerr, 1948, p. 53); and (2) that similar cirque systems occur on the ice-carved slopes of large U-shaped valleys which trend towards the coast from positions well inside the Boundary Range. To all appearances, these valleys were incised by the maximum mountain ice-sheet of the Wisconsin age and, in some cases, by continental ice prior to the initiation of the cirques. Examples of these are Berner's Trench, the valley of Gilkey Glacier in Figure 1, and the Taku River valley sector typified by the view in Figure 5.

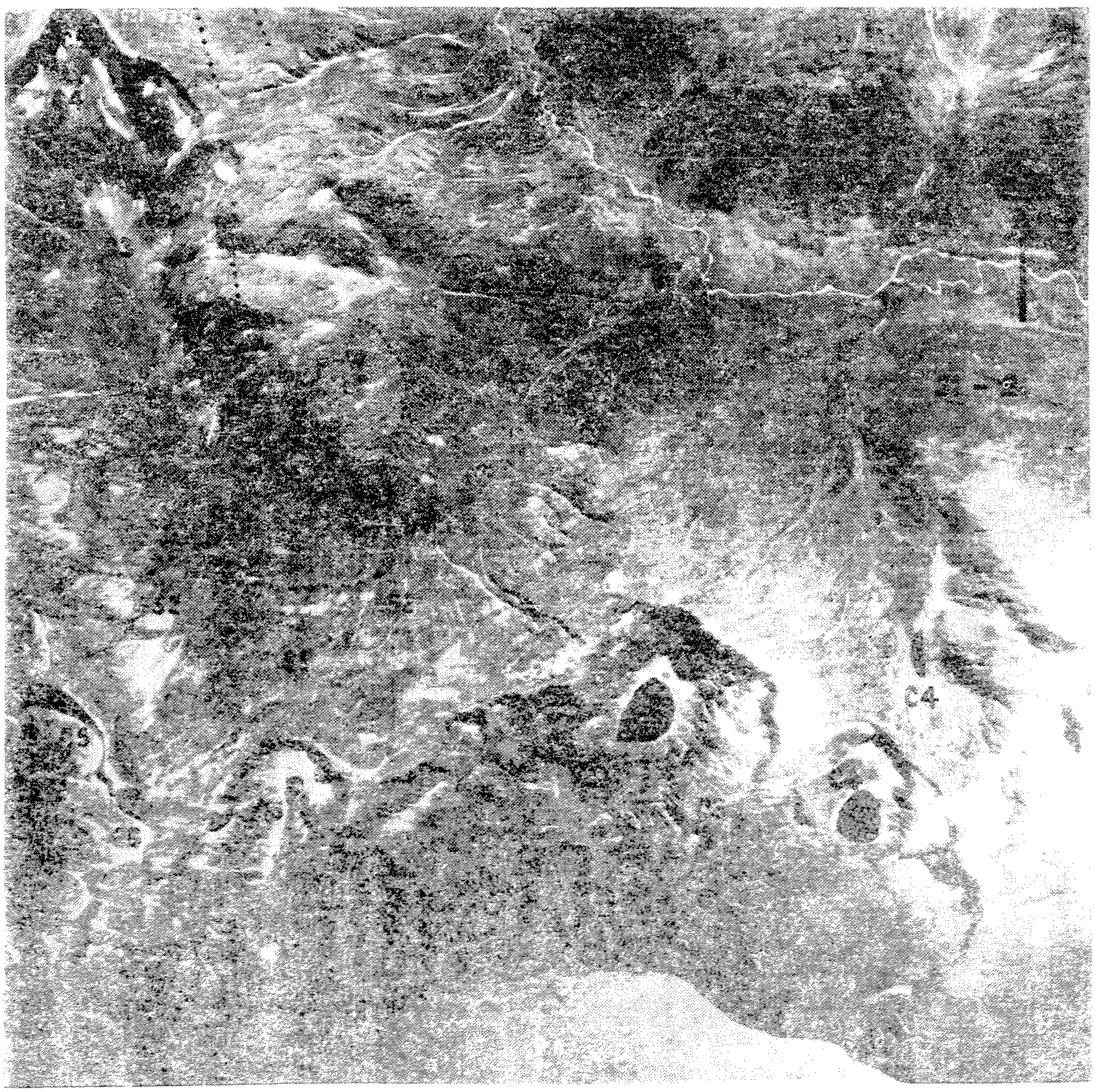

FIGURE 5. Vertical aerial photograph showing development of tandem and composite cirques with associated tarn lakes and glacial valleys south of the Juneau ice-field. The bedrock is massive granodiorite. A portion of Taku River shows at bottom of the photograph.

Further to this, the constricted and protected nature of the narrow fjords and smaller valleys leading off the Juneau ice-field suggests that even if these had been inlets in pre-Pleistocene time they were so confined that wave sculpturing and other marine erosion processes would have been at a minimum. This suggestion is also borne out by the lack of strand flats, wave-cut benches, or sea cliffs, and the absence of marine deposits at elevations greater than 500 feet. Additionally, range upon range of lesser mountains up to 5000 feet high occur on the closely-spaced islands which extend for 80 to 100 miles west of the main Boundary Range, indicating that the open coast even in pre-Pleistocene time, was far removed from the Taku district.[2]

Relative Differences of Alluviation and Form

The lowest basins at 200 to 500 feet elevation are large, although not as well defined as the others. This is due not only to the longer period of erosion and alluviation to which they have been subjected, but to certain other modifying circumstances, noted below. They have also been made more indistinct by the relatively heavier afforestation near sea-level.

They are considered probably to be old cirques on the basis of the following criteria: (1) the semi-enclosed form and the arcuate nature of adjacent slopes; (2) the presence of a tarn lake, or of a downvalley projection of bedrock presumably representing a remnant threshold; and (3) the presence of cyclopean stairs above the basin area, and in most cases also a steep slope below it. Many have been subjected to late-Glacial marine sedimentation and others have received considerable deposits of outwash gravel so that the initial topography has been buried.

Most of the lower cirque-like depressions have also been modified at their outlets by ice passing over them laterally. This is illustrated in the case of both C1 and C2 cirques in the lower part of the photograph of Figure 5 (the dark line in the figure represents the trace of such an ice limit at the base of a truncated spur). And in some cases, glaciers have even pushed upslope into the cirques during stages when the trunk valleys to which they are tributary were channels for ice from other sources. This could only have occurred at times of raised névé limit when the lowest amphitheatres were no longer catchment areas. The faceting and rounding-off of the bases of their confining spurs supports this view and suggests that their present embayment form was developed during a separate later glacial stage, or in a retrogressive cycle of the same glaciation which produced the cirques. This would require the interesting circumstance of local glaciers in disconnected valleys being in a receded condition at the time of maximum advance of ice in the fjords. Such a situation has been described in Washington State (Mackin, 1941) where, during the Wisconsin maximum, the great lowland ice tongue of the Puget Glacier pushed up into the Cascade Mountains and filled some of the lower basins which had previously been occupied by local valley glaciers. The observation begs the fundamental question which has been brought to attention by the present vigorous

[2]On the western shore of the Alexander Archipelago and northward to Cape St. Elias, broad strand flats do occur at low and intermediate levels (D. J. Miller, 1953). These are quite in contrast to what is found in the Boundary Range, further suggesting that marine processes were not effective in this interior coastal area.

advance of the Taku Glacier in its sea-level channel at a time when local glaciers in the side valleys and at higher elevations are in a state of excessive retreat.

The cirques at the second level (C2) are the best defined and usually the deepest. They are also the most elongated, suggesting a considerable period of development with strong headward glacial erosion. They are heavily forested and would appear to represent a distinct stage in the valley development.

The cirques at the third and fourth levels (C3 and C4) are also well formed but usually not as long, suggesting a shorter period of development. They are mantled with successively less alluvial material and soil, and much less vegetation, a fact which is in part due to their elevation above the timber-line. The sharply delineated character of the fourth level of cirques indicates that they have largely resulted from the retrogressive phase(s) of the last major glaciation. An example of the C3 and C4 systems is seen in Figure 6, showing part of the sequence of tandem cirques in Salmon Creek valley. Cirques in the fifth system (C5), however, are usually shallow and are either barren or only partially filled with ice. From the assessment of the total number shown in the frequency diagram, the mean elevation of each key horizon on the west side of the range is taken as 350, 1100, 1750, 2450, and 3150 feet. The average position of another and higher system of broad basins filled with ice is approximately 3500 feet. The highest system (referred to below as C6) is morphologically not a true cirque system. Although its general elevation is close to the present mean névé line on the western side of the Juneau ice-field, the existence of these uppermost basins should not be considered in the same way — that is, as representative of higher snow lines — since they connect with the broad and presently-glaciated highland and hence have been more continuously affected by successive stages down through post-Wisconsin time.

Implications of the Pattern

It is reiterated that the cirques represented in this study are those which were not occupied by glaciers in post-Glacial time, in spite of their positions relatively close to the present ice-field complex. The statistics in the tables reveal that the standard deviation of the floor elevations, especially of the higher cirques, is remarkably small with respect to the mean level for each system. Furthermore, the effect of geographical orientation on the elevation pattern appears to be random and so probably not significant. Added to this is the fact that on the maritime side of the northern Boundary Range a full fivefold sequence of cirques is found along the walls of each of the major deglaciated valleys. From these observations and the apparent lack of lithologic or structural control, the distribution pattern suggests regional significance. As no evidence has been found of control by pre-Glacial topography, there is the exciting implication that the levels represent former mean positions of the regional névé line which has raised and lowered cyclically during the glacial ages. On the basis of this interpretation, the frequency distribution would have major climatological significance.

A possible correlation may exist with other ice-carved forms on the valley walls and on flanks of nunataks in the interior of the range which is glaciated at present. A striking example is provided by a sequence of distinct rock shoulders on exposed bedrock separating surfaces of former erosion on the bordering ridges of the Taku Glacier. Such surfaces are also well displayed on the walls of bordering ice-free

FIGURE 6. Abandoned cirques at the 1900- and 2600-foot levels at the head of Salmon Creek valley (Rectangle B, Figure 2).

valleys, as illustrated by the designations S1 to S3 in Figure 5.[3] There is a continuous array of such berms, with intervening erosion surfaces, elsewhere in the range, adding weight to the interpretation suggested (Miller, 1956, pp. 116-22).

[3]The highest ridge crests in this sector may contain remnants of a pre-Wisconsin surface (p-W). The upper ice limit of major Wisconsin glaciation is interpreted from the highest berm. The trace of this berm is indicated in Figure 5 by dotted line.

The writer considers well that any attempt at broad correlation of ice-eroded features in a heavily-glaciated region must, by its very nature, be most cautious. This is particularly true in a region which may have been subjected to differential crustal warping during the Pleistocene. It is nevertheless of interest that four very prominent and one minor rock bench are found in sequence on rock exposures above the present glacier level in the maritime sector of this range. Geophysical measurements of depth transects in ice also reveal a lesser berm beneath the Taku Glacier in its lower-valley sector (Poulter, 1949, Figure 4). This lesser subglacial bench by position becomes sixth in the sequence. It may not correlate technically with the upper basin, or C6 "cirque" level at 3500 feet in the sequence of Table I, as the latter involves much more continuous glaciation. But at least it represents activity of a recent stage of very much retracted highland ice and hence provides one of the forms bridging the past to the present. As all the larger (older) berms appear to represent significant glacier-carved remnants of former valley floors, it is difficult to resist considering that they may have been sculptured in the same successive stages of glaciation which are suggested as responsible for the pattern of abandoned cirques in the peripheral zones. At least the striking similarity of sequence is tantalizing.

If the concordance of patterns in these two types of erosional features is verified elsewhere in the Boundary Range and if they can be shown to have a traceable relation to sequence of depositional forms in the peripheral lowlands, the inference of a causal relationship to Wisconsin glacial stages will be greatly strengthened. In a search for such corroboration, the study is currently being extended into the valleys and flanks of the adjacent middle and southern Boundary Range, particularly in the Stikine district. Although these other data are not yet available for processing, information to date suggests that the ice masses in the entire Boundary Range during the last major glaciation were unusually sensitive to climatic change. Possibly this seeming sensitivity is related to the unique position of the range, situated as it is in a climatologically-sensitive interaction zone between the cyclonic cellular circulation of air masses over the Gulf of Alaska and anti-cyclonic polar air masses of the continent. A discussion of this aspect is treated elsewhere, particularly with respect to the glacial fluctuations of the "Little Ice Age" (Miller, 1958, 1961).

Abandoned Cirques as Loci of Placer Gravels

As some of the lowest cirques have received considerable deposits of marine and terrestrial sediments, part or all of their initial floor topography has been buried. This, of course, must be considered in attaching any significance to the apparent conformity of level in the lowest system. By assuming the degree of marine sedimentation as comparable in each of the key lower cirques described, and by considering the spur remnants as bedrock thresholds, one at least has a clue to the bedrock positions. Behind the outlet thresholds of the C1 and C2 depressions, glacio-fluvatile materials have been trapped. This is particularly true in those valleys which serve as drainage from existing glaciers. Since the valleys have been cut into the metamorphic zone along the edge of the axial crystalline core of the range, the associated basins have been carved mainly out of lode-injected schists.

These basins are, therefore, loci of gold-bearing gravel. Clays deposited by marine transgressions form the base upon which most of these auriferous gravels have been laid down (Knopf, 1912, p. 33). This probably explains the slightly higher than average elevation of the floor in the Lower basin of the Nugget valley (Table II), and of the outlet basin at Sheep Creek in the Thane area (Table I).

It is of interest that the first discovery of "colours" in the Juneau gold belt was in the outlet streams below the thresholds of several of these abandoned cirque valleys. These findings led to the first rush of gold seekers to Alaska in the 1870's, a quarter of a century before the Klondike strike. This resulted also in the founding of the city of Juneau. On the United States Geological Survey map (Figure 2), it may be seen that in the canyons east of Juneau two of the lowest amphitheatres have been given the descriptive names Last Chance basin and Silverbow basin. Other such terms used locally are Perserverance basin, Flume basin, Lower basin, Middle basin, Upper basin, and Nugget basin. There is, of course, the possibility that a detailed knowledge of the sequence, distribution, and morphology of abandoned cirques, and a recognition of their regional pattern, could serve as criteria in the search for new ore veins. It is possible that such knowledge could also prove to be useful in evaluating the potential of placer operations in zones of auriferous gravels impounded behind the lips of some of the lower cirques.

REFERENCES

ANTEVS, E. 1932. The alpine zone of Mt. Washington; Auburn, Maine.

BOSTOCK, H. S. 1948. Physiography of the Canadian ~~Cordillera~~, with special reference to the area north of the fifty-fifth parallel; Geol. Surv., Mem. 247, Canada Department of Mines and Resources.

FLINT, R. F. 1947. Glacial geology and the Pleistocene epoch; John Wiley and Sons, Inc.

HANN, J. 1903. *In* R. and DEC. WARD, eds., MacMillan Co.; Handbook of climatology.

JOHNSON, D. 1917. Date of local glaciation in the White, Adirondack, and Catskill Mountains; Bul. Geol. Soc. Amer., vol. 28, pp. 543-52.

KERR, F. A. 1948. Taku River map area, British Columbia, Canada; Geol. Surv., Mem. 248, Department of Mines and Resources, pp. 1-84.

KNOPF, A. 1912. The Eagle River region, southeastern Alaska; Bull. 502, U.S. Geol. Surv.

LJUNGNER, E. 1948. East-west balance of the Quaternary ice caps, in Patagonia and Scandinavia; Bull. Geol. Inst. Upsala, vol. XXXIII, pp. 12-96.

MACKIN, J. HOOVER. 1941. Glacial geology of the Snoqualmie-Cedar area, Washington; J. Geol., vol. XLIX, no. 5, July-August, pp. 449-81.

MILLER, D. J. 1953. Late Cenozoic marine glacial sediment and marine terraces of Middleton Island, Alaska; J. Geol., vol. 61, no. 1, pp. 17-40.

MILLER, M. M. 1956. The glaciology of the Juneau icefield, S. E. Alaska: Office of Naval Research, Final Report, Task Order 83001, 2 vols., 800 pp.

——— 1958. Glaciers on the rampage; Science World, vol. 3, no. 8, pp. 4-7.

——— 1961. Casual factors in the fluctuation of Arctic glaciers and sea ice; Trans. New York Acad. Sci. (in press, report of paper delivered before the Society, May, 1958).

POULTER, R. C., ALLEN, C. F., and MILLER, S. W. 1949. Seismic measurements on the Taku Glacier; Stanford Research Institute, Stanford, California.

UNITED STATES GEOLOGICAL SURVEY (1951-5). Alaska Topographic Map Series, at scale of 1:63,360.