Proceedings of the Iowa Academy of Science

Volume 66 | Annual Issue

Article 46

1959

The Multiple-Working Hypothesis As Applied to Alaska's Oriented Lakes

Charles E. Carson
Iowa State University

Keith M. Huddey
Iowa State University

Recommended Citation

Carson, Charles E. and Huddey, Keith M. (1959) "The Multiple-Working Hypothesis As Applied to Alaska's Oriented Lakes," *Proceedings of the Iowa Academy of Science*: Vol. 66: No. 1 , Article 46.
Available at: https://scholarworks.uni.edu/pias/vol66/iss1/46

The Multiple-Working Hypothesis As Applied to Alaska's Oriented Lakes

By CHARLES E. CARSON and KEITH M. HUSSEY

Abstract. The problem of the oriented lakes on Alaska's Arctic Coastal Plain provides an excellent opportunity for illustrating the application of the method of multiple-working hypotheses to a geologic problem. Five hypotheses are considered and are deemed to be inconclusive; a composite of these is thought to provide an explanation of the lakes' origin. The hypotheses considered are: (1) that waves, produced by an ancient prevailing wind blowing parallel to the lake elongation, eroded the basins; (2) that the present winds produce wave current systems which preferentially scour the north and south lake shores, thus producing elongation; (3) that the winds produce a preferred distribution of sediment which determines orientation of the lakes by insulating the east and west shores, thus protecting them from erosion; (4) that orientation is developed by thaw produced by maximum insolation during the noon-hours; and (5) that the lakes are developed along north-south trending ice-wedges which formed in the north-south components of a right-angle fracture system. The process of consideration and elimination of these hypotheses leads to a composite hypothesis. This proposes that oriented ice-wedges might develop in the fracture system; that maximum insolation would be more effective in melting the north-south trending wedges than the complementary set; that the oriented depressions so oriented would in effect be perpetuated and enlarged by thaw and wind (wave) oriented sediments on the east-west shores.

A method of investigation which attempts to develop and analyze simultaneously every rational explanation of a phenomenon at hand is certainly a most efficient one. Such a mode of investigation is the method of multiple-working hypotheses set forth by Chamberlin in 1897. This method is very applicable to complex problems in geology, and particularly to some problems in geomorphology. Since the time of Chamberlin's discourse on the subject, geologists have considered this practical approach as being the most productive of satisfactory results of any at their disposal. As the method is followed, component hypotheses are considered, then confirmed, invalidated, or set aside for further review, with the result being a gradual increase in the body of reliable evidence. The end-product is frequently a synthesis consisting of the more acceptable ideas contained in the respective hypotheses.

During the last 30 years, studies of oriented lakes have led to several hypotheses on their origin and, in one instance, the method of multiple-working hypotheses has been used in an attempt to determine which, if any, of the proposed solutions was correct. There are two major areas of oriented lakes in North America: the Carolina "Bays", of the Atlantic coastal plain of southeastern United

States; and, the oriented lakes of the Arctic Coastal Plain of Alaska. In 1944, D. W. Johnson discussed the application of the method of multiple-working hypotheses to a study of the Carolina "Bays", but until now this has not been done with respect to the lakes of northern Alaska. Since 1948, several separate hypotheses have been formulated to explain the origin of the Alaskan oriented lakes, but individually these appear to be inadequate due to lack of substantiating evidence. The purpose of this paper is to discuss these previous ideas, and several new ones, as a sytem of multiple-working hypotheses. It is hoped that such an evaluation will show the merit of applying this method to the problem of oriented lakes in northern Alaska.

Description

The Northern Alaska Lake District lies mostly north of the seventieth parallel in what Payne, *et al.* (1952), called the Arctic Coastal Plain province, an area of some 25,000 square miles in northern Alaska. The province is bounded by the Arctic Foothills province and the Brooks Range on the south, and by the Beaufort and Chukchi Seas of the Arctic Ocean to the northeast and northwest respectively. Near the Canadian border, the Coastal Plain is terminated where the foothills of the Brooks Range extend almost to the ocean.

The Arctic Coastal Plain is a tundra region developed on gently undulating expanses of unconsolidated marine and non-marine sediments, primarily of Quaternary age. The occurrence of recent marine strata at, or close to, the surface over much of the area supports the concept that it is an emergent part of the adjacent continental shelf. Along much of the shoreline, the Coastal Plain merges with the present-day continental shelf.

It is likely that the Coastal Plain reached its maximum extent during the low sea levels of the Pleistocene and is now slowly submerging beneath the advancing sea. The general shoreline configuration gives evidence of a transgressive phase, for there are many lakes which have been incorporated into the sea and now appear as bays and inlets. Ancient beach ridges near the coast are evidence of oscillations during the Pleistocene.

The average annual temperature of the region is about 10 degrees F., and permafrost commonly exists to a depth of 1,000 feet or more. Summer thaw seldom penetrates more than 2 feet below the surface. The upper 15 feet of sediment is estimated to contain, on the average, more than 60 percent ice by volume. This ice is found in the form of large vertical wedges arranged in a polygonal pattern, in lensoid bodies, and diffused throughout the sediment in irregular masses and numerous small grains.

Figure 1. Oblique aerial view of oriented lakes on the Arctic Coastal Plain of Alaska.

Developed on the surface of the Coastal Plain are thousands of lakes, most of which have an elongated shape (Figure 1). The long axes of these lakes are oriented somewhat to the west of north within limits of between 5 and 20 degrees, and for the most part orientation in any one area does not deviate more than 4 degrees. A common axial ratio is 3:1, or 4:1. The lakes vary in size from mere ponds 20 feet long to large lakes 15 to 20 miles in length. Little range in size in any one area is a common characteristic. In general, the small lakes trend more nearly north and occur more in the eastern part of the Coastal Plain; whereas in the Teshekpuk Lake and Barrow vicinities, the lakes are larger, more rounded, and maintain a more westerly orientation. The lakes near the coast are generally quite shallow, with depths ranging from one to six feet. To the south, they are generally deeper and commonly have less oriented shorelines (Figure 2). Many of these lakes have a deeper central basin surrounded by shallow shelves. The shelves are more extensive on the east and west sides than on the north and south sides, and the central basin seems to be oriented in the same manner as the

Figure 2. Oriented lake, showing deeper central basin with shallow shelves on the east and west sides.

lakes farther north. The more dissected southern portion of the Coastal Plain and the adjacent Northern Foothills province is assumed to be older than the area of low relief near the coast. It is believed that the deeper oriented central basins of lakes in this area may represent, in part at least, an original disposition of lakes which have become less oriented with age. Whatever the orienting mechanism, it was, or is now, apparently less effective in this more southerly area.

HYPOTHESES OF ORIGIN

It seems well established that the lakes owe their original inception to summer thaw of the sediment-laden ice, and that they are continuing to form in this manner. Once a body of water is initiated by some means, it tends to grow because there is little evaporation in this cool tundra region, and because low relief inhibits surface runoff while the permafrost restricts underground drainage. Solar radiation often heats the water in shallow pools to as much as 70 degrees F., and they are thus enabled to extend themselves rapidly by thaw of the surrounding permafrost. The temperature of the larger lakes seldom exceeds 45 degrees F.

If the lakes are considered to be originally the products of thaw phenomena, then it is reasonable to assume that they continue to grow by thaw. After the ponds reach an appreciable size, the erosive power of the waves also contributes to the enlargement of lake basins. In this way, the thaw lakes continue to grow until drained by the headward erosion of small streams. Since the lakes possess the ability to grow by virtue of their unique environment, and since they are oriented, they must grow in a preferential manner. In other words, thaw and erosion must proceed in preferred directions. What factors cause preferred loci of thaw and erosion? Since the lakes, large and small, are oriented over a large area, the causal agents must also be operative over the same region. Agents which could cause preferred thaw and erosion of the permafrost are solar radiation and prevailing wind. Another possible causal factor could be the pattern of a fracture system, the special features of which could create oriented sites especially susceptible to thaw. If solar radiation and wind are determined to be effective agencies of preferred thaw and erosion, and the localization of easily thawed areas by a fracture pattern actually does occur, then the exact manner in which these factors operate and the relative effect of each are the essential things to determine. This requires detailed observation, collection of data, and a rigorous analysis of observational and quantitative evidence.

Different interpretations have been made as to the relative importance of each possible cause of orientation, and different concepts of the manner in which each may be effective have been proposed. In general, there are two basic types of hypotheses used to explain the origin of the oriented lakes. One type attributes the dominant cause of orientation to a single agent outside the permafrost regime, such as wind, or solar radiation. The other type considers the essential orienting influence to be some feature effective within the permafrost, such as a fracture system. While both of these concepts have merit, neither type of analysis is clearly substantiated by facts. It seems that a comprehensive approach is necessary. Recent evidence indicates that orientation may be the result of some combination of all known possible agents, each of which may or may not be operating as previously postulated.

The following is a brief account of the evaluations of the various hypotheses. Some have been, or are likely to be, eliminated by recent evidence. Others have been strengthened and may form part of a final compound hypothesis which will adequately account for orientation in all notable lake areas.

The Carolina "Bays" Hypotheses in Reference to the Alaskan Lakes

Before discussing the various hypotheses that have been proposed to account for the oriented lakes in northern Alaska, it is proper to examine briefly the hypotheses proposed to explain the other major group of oriented lakes in North America, the Carolina "Bays"; for it may be that some features are held in common by both groups.

Two major hypotheses which have been proposed to account for the Carolina "Bays" are the meteoric hypothesis and the solution-artesian-lacustrine-aeolian hypothesis. The meteoric hypothesis postulates a meteor shower in the past which struck the earth in the region of the present Carolina "Bays". The "Bays" are supposedly now located in the craters produced by the impact of these meteorites. This hypothesis has been tested by magnetometer and other field investigations, and the results render it suspect. It seems to be even less applicable to the Alaskan lakes, for geophysical investigations have revealed no gravity highs under, or at the ends of, these lakes. The artesian spring hypothesis proposes rising underground water producing broad, shallow basins by solution, which were later modified by wind and wave action. The extensive development of permafrost on the Arctic Coastal Plain likely precludes the possibility of extensive artesian springs, but it is possible, however, that wind and wave action may be important agencies in the development of the Alaskan lakes.

The Hypothesis of Former Prevailing Winds

In 1949, Black and Barksdale postulated that a former prevailing wind blowing parallel to the present long dimension of the lakes was the cause of orientation. To support this contention, they postulated that the east-west prevailing winds of today are re-shaping the lakes in a direction perpendicular to the present trend. As evidence for this, they cited eroded east and west shores. Rosenfeld and Hussey (1958) observe, however, that field and aerial photo evidences indicate that the north-south orientation of the lakes is being maintained under present conditions. Livingstone (1954) also maintains that the lakes are still in very close balance with the processes which originally caused their orientation. The presence of stabilized dunes on the Coastal Plain which were formed by east-west winds is also cited by Rosenfeld and Hussey as evidence that the winds have prevailed in their present manner for a considerable time. If, therefore, the wind determines orientation in the manner postulated by Black and Barksdale, the lakes should show more of an east-west trend than they do.

On the basis of these objections, then, the hypothesis of Black and Barksdale can probably be eliminated as part of a system of multiple-working hypotheses.

The Wind-generated Current System Hypothesis

Livingstone (1954) postulated that the present prevailing winds, which are approximately normal to the long axes of the lakes, produce a horizontal circulation system in the lakes which scours out the ends at a greater rate than the sides. Thus an initially circular lake would become elliptical in shape, with the long dimension perpendicular to the prevailing wind. Rex (1958) postulates essentially the same mechanism as Livingstone. He, however, accounts for the shallow shelves at the sides of the deeper lakes by supposing that the transport competency of the current is effective only at the ends of the lakes and that deposition would take place along the sides.

During the summer of 1958, we undertook to determine the validity of Livingstone's and Rex's arguments. Detailed observations were made on depositional and erosional features around the lakes, measurements of the permafrost table were made, and data on the water movements in a number of lakes were obtained with current meters, dyes, and floats. The work is not yet complete, but enough has been done to indicate that if the current system postulated actually operates in the lakes, it must do so only under certain very special conditions. Instrumental data and close observation revealed that, in the lakes investigated, most of the water movement occurs as the simple oscillation of wave motion with some translatory movement being evident in the form of wave overturn near the shores. Oscillation ripple marks which were observed to parallel the east and west shores tend to confirm this view. These features were observed to endure the most persistent high winds.

It seems that, on the basis of present evidence, the current system hypothesis cannot account for the orientation of the lakes. It would be particularly difficult for such a current system to account for the widespread, numerous, small, oriented ponds. Since it is likely that the larger lakes have grown from smaller ponds, the best that can now be said for the current system hypothesis is that, though it may be responsible for a certain phase of lake development, it cannot wholly explain the oriented lakes. While the current system hypothesis cannot be completely discarded, because it may be valid in certain special cases, it would seem to form only a small part of any system of multiple-working hypotheses used to investigate the lakes.

The Structural Control Hypothesis

Rosenfeld and Hussey (1958) point out that there is evidence for structural control of the orientation of the lakes. The principal evidence for this is a rather well-defined pattern to such drainage as has developed on the Coastal Plain. Many of the smaller streams consist of a series of reaches which pursue courses at right-angles to each other. One set parallels the direction of lake orientation. The frozen sediments are postulated to have responded competently to stresses so that a master fracture pattern has been formed which conceivably could control the maximum development of ice wedges. Later, thaw along these oriented wedges could create oriented lake basins. It is also pointed out that surface thaw during former periods of higher temperature would have lowered the permafrost table enough to have long since destroyed the surface expression of original ice wedges but that, in the subsurface, these may still be present in some areas.

The indication that a fracture system may be present on the Coastal Plain means that such may be considered in any hypothesis that is eventually proposed to account for the lakes. Investigations so far, however, have not indicated the presence of a system of oriented ice bodies. In addition, an examination of air photos and maps shows that the east-west drainage component in the small streams, thought to be structurally controlled, is almost as well developed as the north-south component which is parallel to lake orientation. If structure alone controls orientation, it would seem that there should occur an extensive development of east-west oriented lakes which would reflect the trend of east-west ice-filled fractures. Such is not the case. It may be, however, that a fracture system would control only the early stages of orientation and in a different manner than that previously postulated. A deep fracture might be expressed near the surface as numerous, small, ice-filled fractures along certain trends which, when exposed to certain effects of solar radiation and wind, develop into small oriented ponds which are primarily structurally controlled. Only those fracture trends whose strikes closely approximate the direction of other thaw factors would become sites of initial lakes.

The Solar Radiation Hypothesis

In Arctic latitudes, the maximum angle of the sun above the horizon is very low. The maximum angle reached on the Alaskan Arctic Coastal Plain is only about 44 degrees. The effect of this is that there is a proportionately greater insolation at noon than at any other time. This is because the amount of atmosphere through which the solar rays must pass increases at a much greater rate in the low-angular range from 40 degrees to zero, or horizon position, than it does from a 90 degree maximum to the 44 degree position. At an angle of 45 degrees, the sun's rays pass through approximately ⅛ more atmosphere than they do at a 90 degree position. At the horizon, the solar rays must pass through about ⅝ more atmosphere than they did at the 45 degree position.

On the basis of the above considerations, an hypothesis was formulated that the effect of the solar radiation peculiar to high latitudes may produce oriented thaw trends in the permafrost surface of the Coastal Plain. To test this hypothesis, a recording potentiometer was attached with thermocouples to adjustable copper plates located at the principal points of the compass. The data obtained with this device indicated, as expected, that a much greater amount of insolation occurs btween the eleven and one o'clock positions. From this, it remained to show that geomorphic facets oriented so as to receive the greatest insolation would thaw deeper than facets not so oriented. If this proved to be true, trends of deeper thaw would develop in areas of greater thaw potential. This would reflect the trace on the ground of the noon positions of the sun. Field studies made to determine depth of thaw in different locations revealed that the south-facing slopes thawed two inches deeper, on the average, than the other three possible faces. This supports the hypothesis, but much work remains to be done to establish it on a quantitative basis. More field work and instrumentation are needed to determine such things as the exact effect of water-reflected rays on shorelines, etc. In addition, there are empirical difficulties encountered apart from any field evidence. A major one is that, though lake orientation seems to have a meridional configuration, this is not parallel to the true meridian lines which are also the trends of maximum insolation. The lakes are nearly always oriented slightly to the west of the meridian trend. This might be explained as some kind of thermal lag, but a more obvious explanation is that there are other orienting factors at work. For instance, the perpendiculars to the average wind directions trend just about as much to the west of the meridians as do the lakes.

Another factor which must be considered is that the sun's rays are effectively dispersed by cloud-cover more than half the time during the thaw season on the Coastal Plain. In other words, is there ever enough insolation to be effective? We believe that any differential, however small, could be effective in the Arctic regime—if applied over a period of sufficient duration.

The Sediment Distribution Hypothesis

During the 1958 field season, detailed investigation of lakes in the Point Barrow vicinity produced results which suggested a new hypothesis based on the wind. Data obtained from shoreline, permafrost, and wave-action studies support the view that wind-generated waves distribute sediment in a manner that may partially account for the orientation of the lakes in the area. Perhaps, in conjunction with other hypotheses, it may also account, in part, for the orientation of smaller lakes in other areas.

The sediment distribution hypothesis postulates that the wind *is now* the dominant agent of orientation for the lakes of the Barrow area—but for reasons quite different from those formerly suggested. Many of the lakes in the Point Barrow vicinity are at least a mile long and ¼ to ½ mile wide. On lakes of this size, the prevailing summer winds generate considerable oscillatory wave-action. This preferentially thaws the ice-filled sediments beneath the lakes and in the surrounding areas. It also erodes and re-deposits the thawed sediments. It is believed that the oscillatory waves play a major role in shaping the east and west shorelines, and also the lake basins, for the trends of the depositional strands and the margins of the partially-deposited shelves on each side of the central basins parallel each other. These depositional trends correspond very closely with the average trend of the wave fronts during the thaw season and are thought to be produced by a net shoreward transport of sediment by oscillatory waves. Laboratory and field experiments conducted by the Beach Erosion Board of the Army Engineers confirm this conclusion. Grant (1943) describes these experiments. Some were conducted in a closed tank system, which is essentially what each thaw lake represents. Knowledge of this type of mechanism is not new, for the theoretical basis was demonstrated over 100 years ago by Stokes (1847).

The sediment distribution hypothesis is an attempt to show that ordinary mechanisms of erosion and sedimentation enable the thaw lakes, because of their peculiar environment, to exert an unusual power in determining their basin configuration, aerial outline, and hence, orientation.

Some of the observations which support the sediment distribution hypothesis are as follows: Very large quantities of peat, torn by ice

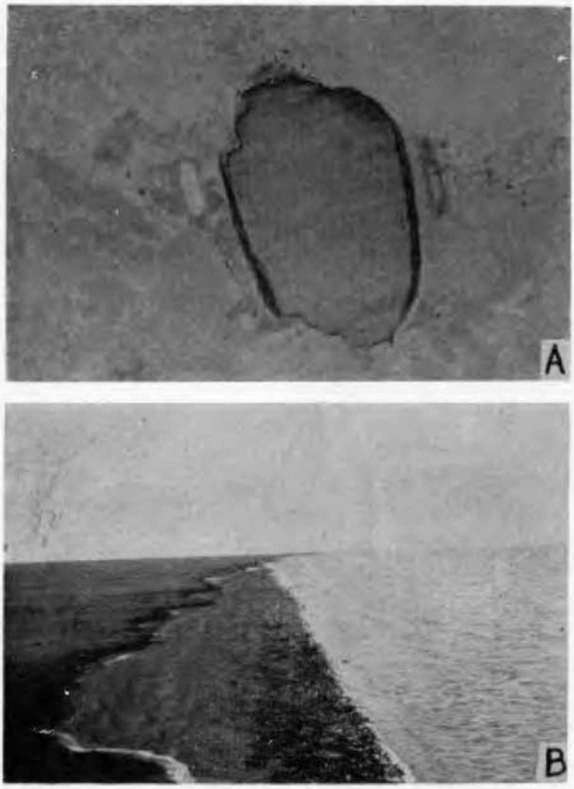

Figure 3. A. Vertical aerial view of a lake with allocthonous peat accumulated on the sides. B. Close-up view of allocthonous peat accumulation on the west shore of the lake diagrammed in Figure 5.

and waves from the surrounding tundra mat, are drifted by wind and wave-action to the shores. This type of material is described as allocthonous peat. Accumulations of peat and fine sediments are found in great strips along the east and west shores (Figure 3). These commonly extend the entire length of the east and west shores, and are sometimes as much as 30 feet wide and three feet deep. The shoreline of these accumulations forms a straight line parallel to the wave fronts which have determined their position. In plan view, the configuration of these strips appears exactly like that of the line of junction between the shallow and deep parts of those lakes which have a central basin (Figure 2).

Profiles of the permafrost table extended from the tundra through the peat accumulations and out into the lake sediments, show that the thick, water-saturated peat and sediment appear to act as an insulator (Figure 4). Depth to permafrost along the sides of the lakes where the peat is present is commonly much less than on the tundra, or in the equivalent near-shore bottoms at either end of the lake where there is no extensive accumulation of peat. The reason for this appears to be that the water trapped in the organic material does not contact the warmer lake waters, and thereby tends to take on the temperature of the permafrost. Once a new accumulation becomes frozen during a winter season, it does not thaw completely during the ensuing summer. In instances where accumulations are thicker than the active layer of the tundra, the permafrost has moved up into it. Where large accumulations occur, the material dries at the surface and its insulating effect is greatly increased.

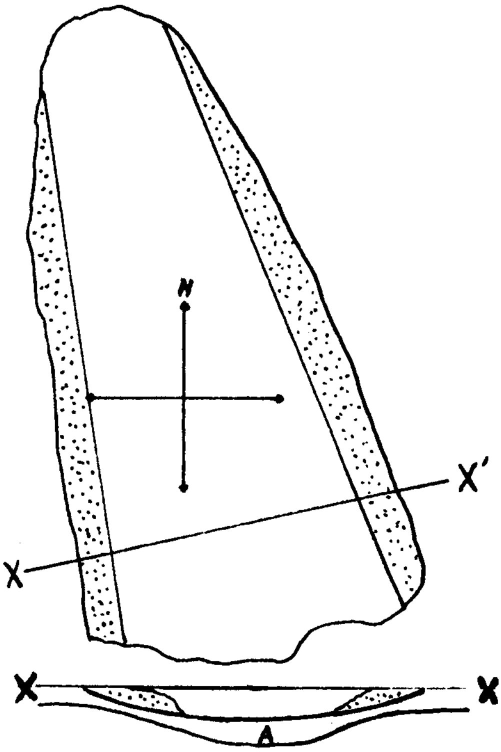

Figure 4. Schematic diagram showing insulating effect of allocthonous peat on the permafrost table (A). Depth to permafrost is much less under the peat bands.

This was well illustrated in a trench dug across an old peat band along the shore of a dry lake bed. The relief on the permafrost table from the tundra, across the peat band, into the dry lake bed was on the order of three feet. Depth to permafrost was only one foot under the peat; and in the adjacent areas it was four feet.

Besides acting as a thermal insulator, the matted peat also acts as a very effective absorbent of wave shock. These two factors—thermal insulation and reduction of wave shock—offer a protection to the east and west shores from exposure to thaw and wave erosion that is not available to the north and south shores. After a sufficient number of thaw seasons have passed, an initially irregular body of water tends to become oriented because the sediment accumulations along the east and west shores retard growth in an east-west direction while growth in a north-south direction can proceed unhindered.

It seems possible that the inorganic sediments accumulated on the east and west shores by the waves also act in a manner similar to that of the peat. The wave-accumulated silts and sands shield the sides against direct contact with the warmer water and, at the same time, act as a shoal which breaks the force of the waves attacking the shore. Like the peat bands, the greatest accumulation of inorganic sediment occurs along the sides, and these accumulations are thought to partially determine the outline of the central basins. Oscillatory wave-motion appears to produce a net translatory movement which scours sediment out of the center areas of the lake and deposits it on the east and west shores. Further investigation may well show that in the over-all picture of lake orientation the inorganic sediments are more important than the allocthonous peat accumulations.

If it is accepted that the shoreline trends of peat and inorganic sediment are deposited by wind-generated waves, it then remains to be shown how these waves correspond to wind direction. Previous wind diagrams have shown only the directions of greatest prevalence and velocity. They have indicated two maxima: the first and major one from the ENE; the second from the WSW. These directions, at least in the Barrow area, do not correspond to the short axes of lake orientation by about 10 degrees. It was believed that a more complete computation might reveal a closer agreement. Accordingly, all possible wind data were gathered from the U. S. Weather Bureau Station at Point Barrow, Alaska. Wind diagrams were constructed. They show by graphic resolution that the cumulative effect of all winds is concentrated in directions almost perpendicular to the respective east and west shoreline trends (Figure 5). In this computation, the winds were assumed to act as simple vectors in effect, if not in actuality.

For the present orientation of lakes in the Barrow area, the sediment distribution hypothesis seems reasonable. The mechanism of shoreward accumulation of sediments appears well established by the work of Grant (1943) and others. Its effect is not yet fully confirmed to be what is postulated, but the evidence so far is strongly in favor of the foregoing hypothesis. There remain, however, some apparent difficulties. In the Barrow area, finely divided organic material (more correctly described as *dy*) was observed to occur in small ponds on a relatively greater scale than the coarser peat in large lakes. A brief reconnaissance in the region of small oriented lakes near the Kuparuk River failed to show the same thing. Aerial photos, however, seem to indicate otherwise. It may be that preferred sedimentation does actually affect these ponds; or, it may be that this mechanism is not active here, and the small lakes and ponds are structural and solar-controlled. Many of these ponds are so small and narrow that their fetch is almost negligible; therefore, it is hard to visualize the sediment distribution mechanism being operative.

A Possible Composite Hypothesis

In the consideration of oriented lakes of all sizes, it may be that

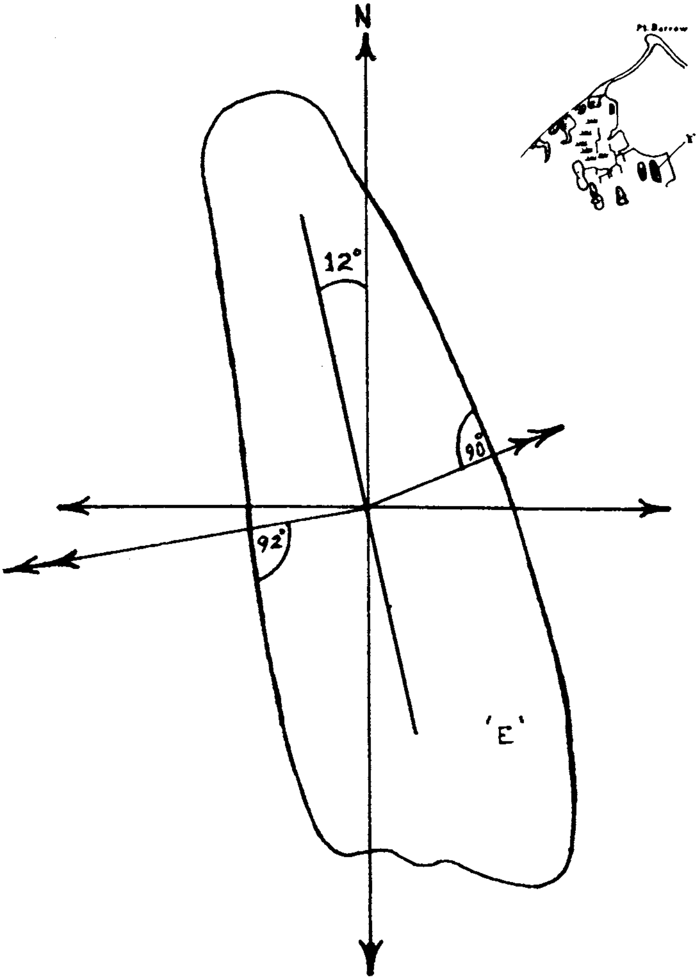

Figure 5. Diagram showing the average directions and relative magnitude of all winds for the months of June through August, 1957. Note the nearly perpendicular directions with respect to both the east and west shorelines.

Figure 6. Oblique aerial view (looking west) of the preferred north-south coalescence of polygonal pools.

a composite explanation is called for; for it seems that our system of multiple-working hypotheses contains several hypotheses and parts of others that are valid only for certain conditions. A composite proposal might be somewhat as follows: Greater ice accumulation could occur along small superficial tension fractures which stem upward from large fractures at depth. The uniformity of this fracture system over a large area could be a reflection of a competent response of the permafrost to regional tectonic stresses. A greater development of approximately north-south, as opposed to east-west, trends and/or the effect of solar radiation would cause only north-south oriented ponds to develop (Figure 6). Later, when the ponds reach the size where fetch becomes effective, sediment distribution could begin to play a decisive part in orientation. One expression of this effect might be the extensive widening of north-south trending reaches, as opposed to east-west reaches of small structurally-controlled streams (Figure 7). At this stage, the dominant factor in orientation of the lakes would be the wind, and some shift in orientation would be expected. It would be extremely coincidental for lakes oriented by fractures and solar radiation to have the same trends as those oriented by another agency, such as the wind. As has been pointed out, variations in orientation seem

Figure 7. Vertical aerial view of a small stream showing structural control and the greater development of north-south reaches, as opposed to east-west. North is to the right.

to be related to differences in size. This relationship certainly conforms in a large measure to the above hypothesis.

CONCLUSION

In the foregoing treatment, we have attempted to consider each of the factors which could conceivably have caused orientation of the thaw lakes of the Arctic Coastal Plain of Alaska. We have tried to point out the strengths and weaknesses of the hypotheses based on different interpretations of these factors. It was pointed out that winds do not seem to produce currents in the lakes which are capable of shaping them. However, the winds do seem to play an important role in the development of waves which, in turn, cause oriented deposits of peat and inorganic sediment. These, in turn, appear to control the shape and development of the lakes. Solar radiation, heretofore not considered as a factor, can conceivably play a role of some importance insofar that the south-facing shores seemingly receive more radiation than other shores. Hence, this shore would retreat most rapidly and an elongate shape would be approached. The weakness of this concept lies in the fact that, even at best, solar radiation is of low value in the Arctic, due to the low angle of incidence and frequent cloud-cover. The possibility that orientation is, to some extent, related to a structural pattern in the permafrost also seems to have some merit. It might well be an explanation of the numerous small oriented ponds of some areas. This concept suffers to some extent, however, from a lack of field evidence of the existence of such a structure pattern.

It is hoped that further investigation utilizing the method of multiple-working hypothesis will finally lead to a convincing explanation of the oriented lakes which will be strongly substantiated by quantitative data.

ACKNOWLEDGMENTS

This entire study is made possible through a grant by contract with the Office of Naval Research, through the Arctic Institute of North America, Contract Number ONR-213. The royalty fee right is hereby granted to the United States Government to reproduce, or disclose, any part, or all, of this paper for Government purposes.

The assistance of members of the staffs of the departments of geology and physics at Iowa State University, Ames, Iowa, is greatly appreciated. The able support and assistance of the Director and staff of the Arctic Research Laboratory, and the benefit of many informative discussions with fellow-investigators, is also acknowledged.

Literature Cited

Black, R. F. and Barksdale, W. L. 1949. Oriented lakes of northern Alaska. Jour. of Geol., vol. 57, pp. 105-118.

Chamberlin, T. C. 1897. The method of multiple working hypotheses. Jour. of Geol., vol. 5, pp. 837-848.

Grant, U. S. 1943. Waves as a sand transporting agent. Amer. Jour. Sci., vol. 241, pp. 117-123.

Johnson, P. W. 1944. Mysterious craters of the Carolina coast. Amer. Sci., vol. 32, pp. 1-22.

Livingstone, D. A. 1954. On the orientation of lake basins. Amer. Jour. Sci., vol. 252, pp. 547-554.

Payne, T. C., *et al.* 1951. Geology of the Arctic slope of Alaska. U.S.G.S. Oil and Gas Jour., Map OM-126.

Rex, R. W. 1958. Orientation of lakes on the northern Alaskan Arctic Coastal Plain. Unpublished manuscript, Scripps Institute of Oceanography, University of California.

Rosenfeld, G. A. and Hussey, K. M. 1958. A consideration of the problem of oriented lakes. Ia. Acad. of Sci. Proc., vol. 65, pp. 279-287.

Stokes, G. G. 1847. On the theory of oscillatory waves. Cambridge Philos. Trans., vol. 8, pp. 441-455.

U. S. Army, Corps of Engineers. 1941. A study of progressive oscillatory waves in water. Beach Erosion Board, Technical Rept. No. 1.

DEPARTMENT OF GEOLOGY
IOWA STATE UNIVERSITY
AMES, IOWA