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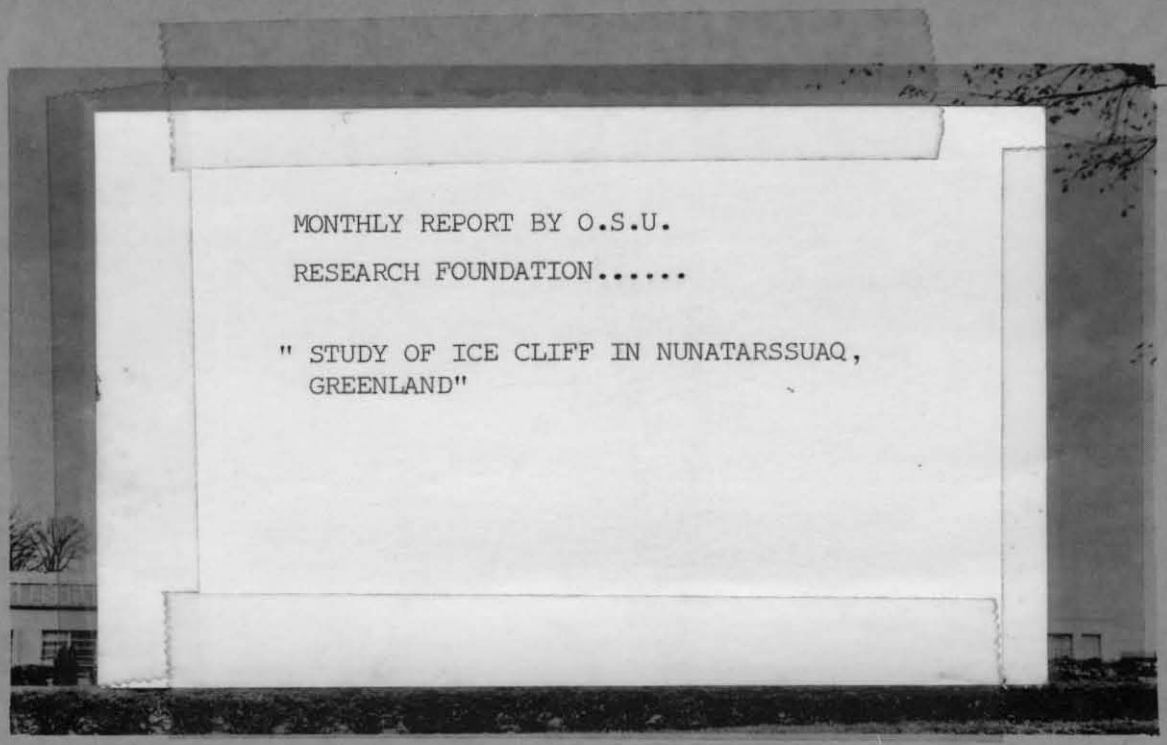

RESEARCH FOUNDATION

Columbus 10, Ohio

Report 636-15
11 October 1956
Richard P. Goldthwait

Corps of Engineers, U. S. Army
Contract DA-11-190-ENG-19

INSTITUTE OF POLAR STUDIES
125 SOUTH OVAL DRIVE
THE OHIO STATE UNIVERSITY

RF Project 636
Report No. 15

MONTHLY

R E P O R T

by

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION

Columbus 10, Ohio

To: CORPS OF ENGINEERS, U. S. ARMY
Snow Ice and Permafrost Research Establishment
Contract DA-11-190-ENG-19

On: STUDY OF ICE CLIFF IN NUNATARSSUAQ GREENLAND

For the period: 1 June 1956 - 31 August 1956

Submitted by: Richard P. Goldthwait
Department of Geology

Date: 11 October 1956

GLACIOLOGY OF GREENLAND ICE CAP AREA

1. INTRODUCTION

This report is rewritten and amplified from the Field Report prepared by Mr. Robert E. Hilty for the period of field study 1 June to 30 August, 1956, and submitted 23 August, 1956, to the 1st Engineer Arctic Task Force. There was no employment or active work on the project in September, 1956.

2. PERSONNEL

2.1 Civilians. Five men were employed under the terms of the contract to complete the field work of project 24.1 at Red Rock Lake Camp:

Dr. Richard P. Goldthwait, Supervisor and Project Leader, 5 to 29 June to direct early operations and conduct study of ice calving and the glacier load.

Dr. William M. Merrill, Assistant Project Leader and Glaciologist, 20 June to 27 July to direct the activities of Red Rock Lake Camp during July and to map ice structures and study ice petrofabrics.

Mr. Robert E. Hilty, Assistant Project Leader and Glaciologist, 5 June to 30 August, to direct the operation of Red Rock Lake Camp during August and to make all studies concerned with the physics of the ice and instrumentation of the ice tunnel.

Mr. Weston Blake, Jr., Research Assistant, 5 June to 30 August, to conduct motion studies of the ice cliff.

Mr. Russell E. Mase, Research Assistant, 5 June to 30 August, to collect data on the ablation of the glacier, the runoff of meltwater, and the related weather conditions.

2.2 Military. To this civilian party was added a total of nine military persons during part or all of the period to assist in scientific work and to perform the various camp functions:

Sp-3 John Sater, 4 June to 30 August, to conduct a photogrammetric survey of the ice cliff and to check the baseline and level stakes.

Sp-3 John C. Gylland, 4 June to 30 August, to maintain radio contact with the base station of 1st Engineer Arctic Task Force and to assist in scientific instrumentation.

Sp-2 James L. Storey, 4 June to 30 August, to render medical aid and to assist in scientific instrumentation.

Sp-2 Cosimo J. Fedele, 4 June to 13 August, to prepare meals, manage ration supplies, and serve as camp manager.

Sgt. Adolph Schulz, 25 June to 1 August, to supervise the tunnel excavation.

Pfc. Robert Williams, 25 June to 1 August, to work on tunnel excavation.

Pvt. Wayne Hoyd, 25 June to 1 August, to work on tunnel excavation.

Pvt. Stanley Robinson, 4 June to 13 June, in charge of supply and camp inventory.

Pvt. Donald Weathers, 25 June to 1 August, to handle supply and assist in tunnel excavation and scientific instrumentation.

2.3 Other Projects. Stationed at Red Rock Lake Camp for varying periods were three individuals working primarily on another field project (24.2) under a separate contract between Northwestern University and the Snow Ice and Permafrost Research Establishment:

Dr. Laurence H. Nobles, Supervisor, 6 to 24 July.

Mr. Alfred T. Anderson, 20 June to 28 August.

Mr. Paul T. Walker, 6 July to 13 August.

In conjunction with Project 28 under Air Force Cambridge Research Center, the following were assigned to Red Rock Lake for a short period:

Mr. David F. Barnes, from 13 to 28 August, directing geophysical team and making gravity measurements.

Mr. Charles R. Bentley, from 13 to 18 August, directing seismic work.

Mr. Ned Ostenso from 13 to 18 August to assist in seismic work.

Mr. Hugh Bennett from 13 to 28 August to assist in seismic work.

3. OBJECTIVES

3.1 Continuing Measurements. The primary function of the 1956 field program was to continue the observations on instruments emplaced in 1955. This would afford record of ice activity during the intervening winter and would allow comparison of the two summer seasons:

a) To maintain three weather stations with recording instruments and continue the ablation studies on 110 stakes and the ablatograph.

b) To measure the runoff from Red Rock Lake during the melt season 1956.

c) To continue measurements of motion on 36 stakes emplaced in the ice cliff with the addition of new stakes as old ones disappear.

d) To continue movement and closure measurements in the old ice tunnel.

e) To continue the occasional measurement of englacial temperatures by thermocouples already established.

f) To continue the photogrammetric study of the exact position of the ice cliff face.

g) To check the spacing and elevation of baseline markers and level stakes.

h) To repeat the photographic study of the condition of the ice cliff at Red Rock and for 3 kilometers southwestward.

3.2 New Measurements. Certain studies were to be extended or initiated during 1956:

a) To make a new tunnel from the old entrance down a dirty shear plane and along the floor of the glacier in order to study ice structure and sample the bottom.

b) To set up a mechanical strain gage with grid of pegs near the bottom of the glacier in the old tunnel in order to study basal ice flow.

c) To increase operating cryokinegraphs to 3 for the summer 1956 and eliminate variables in order to obtain accurate motion curves for ice at 3 levels on the ice cliff.

d) To extend the ice structure study to a careful mapping of the cliff face and further sampling of ice sections for petrofabrics.

e) To extend the seismic survey in a cross-profile toward the higher part of the North Ice Cap and to make detailed observations by gravimeter at each stake location in order to map the rock floor beneath the glacier.

f) To make trial studies of ice hummocks by using insulated fixed plats on the ice.

g) To have flown a new set of vertical aerial photographs.

4. WORK ACCOMPLISHED

4.1 Base Camp. Virtually all of the scientific objectives were achieved. This was made possible through the maintenance of a camp,

Red Rock Lake, from 4 June to 30 August. It consisted of three Jamesway huts, with eating and sleeping accommodations for from 6 to 16 residents, a tarpaulin-covered storage area, and an outhouse. Fuel oil, automotive gasoline, and aviation gasoline were provided to operate two 5-kw generators and one 1-1/2-kw generator, an SCR-188 radio, 3 tent stoves, and 2 cook stoves. The opening and closing operations, together with preparation of reports, handling of supplies, maintenance of radio schedules, and construction of facilities required 65-1/2 man-days, or 9-1/2% of the total effort. The daily cooking, performed by Sgt. Fedele for most of the summer, involved 71-1/2 man-days, or 10% of the effort. Sick call reduced the work effort by only 10 man-days, which is less than 1-1/2% of the total effort. Altogether the maintenance of this camp and unavoidable losses due to minor injury absorbed 21% of the effort.

4.2 Ablation Studies. A total of 123-1/4 man-days or 17-1/2% of the effort was devoted to studies of ablation, runoff and the nature of the disappearance of the glacial ice in the vicinity of the ice cliff. Most of this work was under Mr. Mase.

a) Half of this time (61 man-days, 8-1/2%) was devoted to readings of ablation and maintenance of weather stations. Thermographs were maintained in shelters at the base of the ice cliff, at the upper edge of the ice cliff, and 2.2 kilometers up the glacier from the cliff. An anemometer, an actinograph, and a microbarograph were maintained at or near the lowest shelter. These records plus observations on wind direction and estimates of cloud cover embraced the period from 7 June to 29 August.

   In conjunction with servicing the upper weather stations, 52 bamboo albation stakes were read 15 times at 6-day intervals. In addition, some 20 ablation stakes drilled into the face of the ice cliff were read with field glasses 30 times at 3-day intervals. Ablation from snow areas on the ice ridge east of Red Rock and on the drifts south of the ice cliff was estimated from 39 stakes read 15 times at 6-day intervals.

b) Ten man-days (1-1/2%) were devoted to the maintenance of an ablatograph and the making of ablation plats by the use of insulated blocks. Ten detailed profiles of the ablation changes were studied at the selected locality at 6-day intervals. The ablatograph provided nearly continuous record of the rate of ablation as it changed from hour to hour.

c) Three man-days (1/2%) were devoted by Dr. Goldthwait to the rephotographing of the ice cliff for three kilometers along its face and the plotting of observed falls of ice mass from the face in order to calculate ice losses from this source.

d) Three and one-half man-days (1/2%) were devoted to plotting snow drifts at 15 day intervals and digging an occasional snow pit in order to evaluate the area of snow cover and its density.

e) Forty-one man-days (6% of the effort) were devoted to measuring stream velocity in the outlet of Red Rock Lake 25 different times. This includes 15 man-days required for the blasting and digging of the outlet before overflow.

f) With these flow data, runoff may be calculated from continuous record of water level in Red Rock Lake made in a stilling well near the outlet at a cost of 5 man-days (1/2%).

4.3 Motion Studies. A total of 197-1/2 man-days or 28% of the total time was directed toward studies of ice motion:

a) Under Mr. Blake the positions of 44 stakes were determined at 6 different intervals of 10 to 15 days between 6 June and 24 August. This required 76-1/2 man-days (11% of work time).

b) The establishment of three new continuous-recording instruments (cryokinegraphs) to indicate ice motion at different portions of the ice cliff, required 35 man-days (5%). Records were obtained between 9 July and 26 August by Mr. Blake.

c) Nineteen man-days (2-1/2% of time) were devoted to resurveying the baseline to insure the accuracy of motion measurements. Five 1955 stakes on the glacier surface back from the ice cliff were re-leveled on 28 and 29 July to determine vertical motion, if any. Pegs on the floor of the tunnel at the base of the glacier were leveled on 5 July and 17 August to detect motion during the season. This work was under the direction of Sp-3 Sater.

d) At a cost of 67 man-hours (9-1/2% of the time) a straingage grid of 2 rows of 8 pegs each was measured with a Berry-type strain gage, 8 times at 10-day intervals. Eleven sets of horizontal pegs were read 9 times at 10-day intervals and closure between 6 sets of vertical pegs was read two times. Two other sets of six pegs each were measured for relative change of position in a side room and at the base of a vertical pit to the bottom. Mr. Hilty directed this work.

4.4 Structural Studies. The effort to find out the exact nature of the ice involved 190-1/2 man-days or 27% of the total work effort.

a) Most of this time was devoted to the actual finding, opening, draining, and excavating of tunnel passages; 149 man-days (21%). Sgt. Adolph Schulz supervised this work.

b) Studies of the faults, shear planes, foliation, and other structures by Dr. Merrill during July took 16-1/2 man-days (2%).

c) Under Dr. Merrill also, 18 man-days (2-1/2%) were spent in the collection of more than 20 ice samples, the petrofabric study of a limited number of these samples in the field, and the shipment of the remaining samples to the United States for petrographic study at Wilmette, Illinois.

d) In 7 man-days (1%) between 15 June and 29 August, 4 thermocouple cables were read six times at approximately 15-day intervals by Mr. Hilty.

4.5 Mapping Activities. At the very minor cost of 46 man-days (6-1/2% of work time) to this project both aerial and geophysical efforts were used to obtain materials useful to each of the above areas of study:

a) Most of this time (34-1/2 man-days, 5%) was spent in performing 2 photogrammetric surveys of the ice cliff, on 26 June and 26 August. At both of these times photographs were taken with a T-30 phototheodolite from each of 6 positions on the baseline. When reduced and plotted by Kelch plotter at Columbus, Ohio, during the autumn, 1956, these will afford precise maps comparable to those made in 1955 for each period indicated. This work is under Sp-3 Sater.

b) At the cost of a few man-days (1/2%) for putting out identification panel markers a series of vertical air photographs on the scale of 1:10,000 was flown over this area. These were arranged by SIPRE and flown by the U.S. Air Force.

c) Additional seismic work was accomplished at a cost of 4-1/2 man-days (1/2%) to regular Red Rock Camp personnel. Under field project 28, Mr. Bentley made one long cross-profile from the upper ablation stakes up onto the dome of North Ice Cap.

d) A new gravity survey by Mr. Barnes to provide the depth of ice at each ablation stake was run by field project 28 at a cost of 3 man-days (1/2%) to this project. Calculations to be completed in November, 1956, will afford depth of ice to the rock bottom at each of 57 stake points north of the ice cliff and at various points along the ice ridge and areas to the east of Red Rock Lake.

5. TENTATIVE FIELD CONCLUSIONS

5.1 The 1956 project was eminently successful in that it more than doubled the amount of data accumulated in 1955 for somewhat less effort and money. By doubling the melt season data, the conclusions drawn will be much stronger. Such additions as vertical aerial photography and the performing of gravity measurements, important omissions in the 1955 program, will greatly increase the value of deductions which may be made from motion, structural, and ablation observations.

5.2 Visual analyses of summer air temperatures indicate a higher hourly average in temperature in 1956 than was experienced in 1955. A temperature of 51°F was recorded on 20 June and of 8°F on 12 June. Measured ablation on all ice surfaces in 1956 exceeds that of 1955 by nearly 2 to 1. Near the ice cliff ablation amounted to 1.85 m, on the ice cliff it was 2.1 (average), and 2.7 km north at higher elevation it was 0.56 m. The relative values for exposure and elevation are the same as in 1955. No analysis of runoff is available yet, but it would appear to exceed that of 1955 by a very measureable amount.

5.3 Motions of the ice cliff as indicated by the cryokinegraph are on the same order as those measured in 1955 with the top moving more than twice as fast as the lower (dirty) ice. Theodolite

triangulation was only partially calculated in the field. It is noted, however, that the cryokinegraph indicated erratic motion of the ice cliff throughout the average day with no apparent diurnal cycles such as those noted in the shorter periods of 1955 record. The 1956 instruments utilized Invar wire with practically no thermal expansion, whereas the 1955 measurements were made with steel piano wire.

Average horizontal tunnel closure was approximately 25% greater in the summer 1956 as compared to the summer 1955: 0.8 cm. per 10 days. Motion along the rock floor at the base of the glacier in the 1955 ice pit is extremely slow and increases rapidly upward, following a parabolic flow curve. Diagonals of 8-inch squares parallel with flow changed by 0.2 to 0.4 cm in 10 days.

5.4 It was not possible to trace a dirty shear plane to the source area of ice excavation beneath the glacier. The dirty shear plane selected, ended in a dirt-free shear zone before reaching the bottom of the ice. Large excavations across the rock floor revealed a boulder pavement with lichen cover and mosses once growing between the boulders similar to that seen in 1955. Samples were collected for carbon-14 age analysis. Internal ice temperatures appeared to follow the seasonal changes as exhibited in 1955, except that the zero isotherm may have penetrated somewhat more deeply at the height of the melt season, 1956. Petrofabric analyses support the results given in the preliminary report of 1955 in which the structural mapping indicates greater detail in the fairly simple dipping shear structures at the base of the ice cliff.

5.5 Results of the air photography, photogrammetry, the seismic and gravity work will not be known until proper calculations are completed. Inspection of the data suggests that all efforts in these respects were successful.

6. PROBLEMS ENCOUNTERED

6.1 Deep Snow. During the period between winter observations in March, 1956, and arrival of personnel in the first week of June, 1956, the cover of winter snow had approximately doubled, making the camp difficult to reach and subject to flooding by slush during the period of heavy melt, the last 10 days of June. The same deep snow drifting before the face of the ice cliff made placing of the cryokinegraphs difficult and cut out visibility for motion measurements along the base of the cliff. The deep snow further threatened to raise the level of Red Rock Lake to a point which would inundate the camp and completely submerge the water level gauging station. Much time and effort was consumed in relieving these situations.

6.2 Cliff Avalanches. Calving of large blocks from the cliff occurred on a large scale; this had not been encountered in 1955 or 1954. For two weeks after arrival in early June it was unsafe to put in stakes on the ice cliff and certain narrow areas both above and below the ice cliff were unworkable. Emplacement of stakes for motion measurements and photogrammetry was thus delayed. A heavy snow cornice overhanging the cliff was blasted away on 15 June. The great volume of ice which fell from the ice cliff on 19-20 June effectively blocked the drainage between the high snow drift and the cliff itself. This deepened the ponds of meltwater trapped by ice and from 22 to 26 June threatened to flood the old tunnel. This threat was removed by blasting and digging a deep outlet trench.

6.3 Air Delivery Delays. Because of inclement weather on occasion and owing to repairs required on the available helicopters, delivery of scientific equipment and regular camp supplies was somewhat irregular throughout the season. This delayed delivery of some of the scientific boxes in the early part of June and lack of a few critical items reduced the period of observation of some weather elements, ice temperatures, and snow densities and postponed the setting of new ablation and motion stakes.

7. RECOMMENDATIONS

In August, 1956 it was decided to instrument the new large tunnel openings under North Ice Cap. Eighty-seven pegs were surveyed with the T-2 theodolite. It is proposed, then, that for maximum benefit from the two-year occupation of the Red Rock Lake Camp, a third and brief (two weeks) expedition be made to this site in the summer of 1957 to remeasure all available markers. This might provide as follows:

a) Longer term readings would give better detail of ice flow in the basal zone of the glacier. This information might have wide application to situations where similar relations are sought, but where tunneling is not feasible.

b) Study of the approximately 15 square meters of boulder floor exposed in the 1956 tunnel section indicating the stability of a rock surface which recently has been relieved of the overlying ice load.

c) Motion observations of all cliff stakes still intact to add to the 14 months of observations now on record, thus making the motion observations more statistically sound (24 months).

d) With little effort and time the position of snow and ice against the ablation stakes could be read and would produce a third summer's reading of the net increase or loss at the ice surface for one more year period.

e) Photogrammetry of the ice cliff face in order to add one year to the figures for the counterbalancing effect of ice motion and net ice losses.

f) Since equipment delays prevented the measurement of deep ice temperatures on the thermocouple cables early in the season, 1956, it might be possible to supplement 1956 measurements by an early observation in 1957.

The law of diminishing returns would indicate that continuous weather observations throughout the 1957 ablation season and ablation observations, or runoff calculations, or repeated ice motion measurements throughout the short season, would not justify the expense of another full season of operation.

It is suggested that at least one person familiar with the 1956 ice tunnel and the ablation and motion stakes of the Red Rock Lake area be included as a member of the 1957 concluding party.

Investigator _____ Date _____

Supervisor Richard [illegible] Date 10/23/56

For The Ohio State University Research Foundation

Executive Director Oram C. Woolpert BOP Date 10/24/56