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Origin of Harding Lake in the Interior Alaska

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Abstract

No theory has been established regarding causes of climatic change during the Ice Age and the Interglacial Age, alternating between cold and warm weather and between dry and pluvial weather. In exploration of the causes it is important to gather quantitative paleorecords on precipitation and air temperature through the Postglacial Age starting the Last Ice Age globally, especially in the Arctic Circle directly placed under the arctic air mass, which brings about climatic changes over the northern hemisphere.

In this connection, Harding Lake in the Interior Alaska was subjected to overseas scientific researches on the subject of "the Scientific Research on Climatic Changes through the Postglacial Age in the Arctic Circle" by the members of an expedition headed by Professor Kinshiro Nakao; the researches were conducted three times, August 1977 (preliminary survey), July 1978 and March 1979 (principal surveys). The lake is located on a boundary between low hills of the Yukon-Tanana Upland and the middle Tanana River Valley, which constitutes a lowland of a large tectonic trough.

The basin around the lake is found in the area characterized by discontinuous permafrost and a continental climate with an extreme difference in air temperature between summer and winter, the mean annual air temperature and the annual precipitation being respectively –4°C and 370 mm.

On the basis of the results of the electrical depth sounding and gravimetric survey conducted it is concluded, concerning the origin of Harding Lake, that a trough basin was formed at first by a tectonic movement and then the present lake basin was formed by the damming of tributary.

1. Introduction

Lake Harding, situated in the Interior Alaska at latitude 64°25′N and longitude 146°50′W, is a closed lake. Its morphometric features are: 9.88 km^2 in area, 43 m in maximum depth and 16 m in mean depth, the lake surface being 217 m above sea level.

The lake is located on a boundary between low hills of the Yukon-Tanana Upland and the middle Tanana River Valley, which constitutes a lowland of a large tectonic trough.

As for the origin of this lake, the previous studies (Ager 1975; Schultz, 1965) have led to an inference, considering the Late Quaternary morphological history of the Tanana Valley undergoing climatic changes, that this

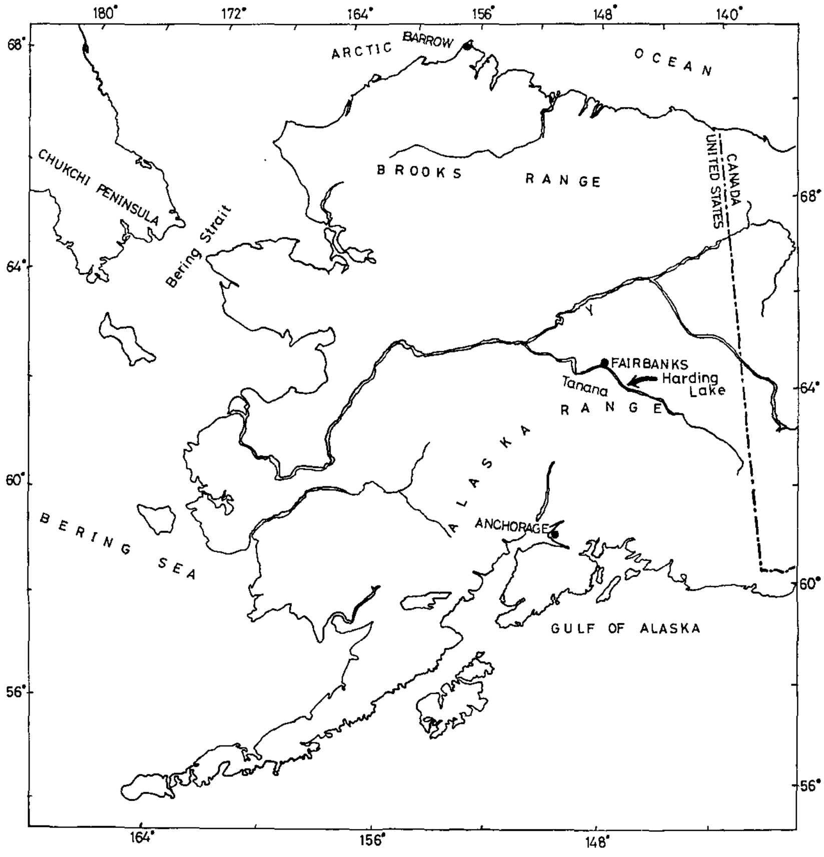

Fig. 1 Location Map of Harding Lake in Alaska

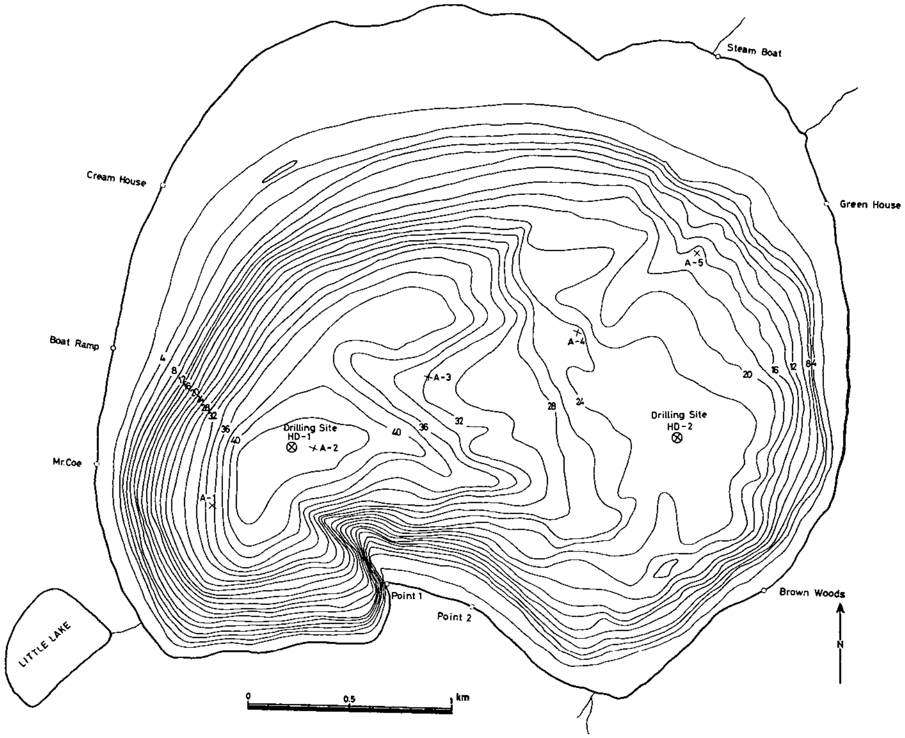

Fig. 2. Bathymetric map of Harding Lake with drilling sites, HD-1, HD-2 and sampling sites indicated. Depth contours denote in meter.

lake was formed by the damming of a tributary which had flowed into the Tanana River out from the upland, as the result of the aggradation of this river in the Illinoian glacial stage, at which time Birch Lake, Quartz Lake and other lakes were also formed in the same manner as this lake.

As to the bathymetric features, however, this lake presents a remarkable difference from other dammed lakes, in that it is greater in depth and irregular in shape, as in Fig. 2; accordingly, it is likely that the tectonic movement had also an effect on the origin of this lake.

Electrical depth soundings were carried out around the lake in August 1977 and July 1978 in an effort to clarify the sedimentary structure and obtain the evidence of damming as to the lake origin. Subsequently in March 1979 a gravity survey was conducted on the ice covering the lake and in the neighborhood of the lake to seek for faults and troughs.

2. Electrical depth sounding

Ground resistivity was measured with a DC-type geohmeter, whose source of power is usually provided by ten 45 volt dry batteries, thus allowing voltage regulations to 450 V.

Minimum readings in measurements are 0.05 mV in voltage and 0.1 mA in current. Electrodes were arranged in the Schlumberger configuration; steel

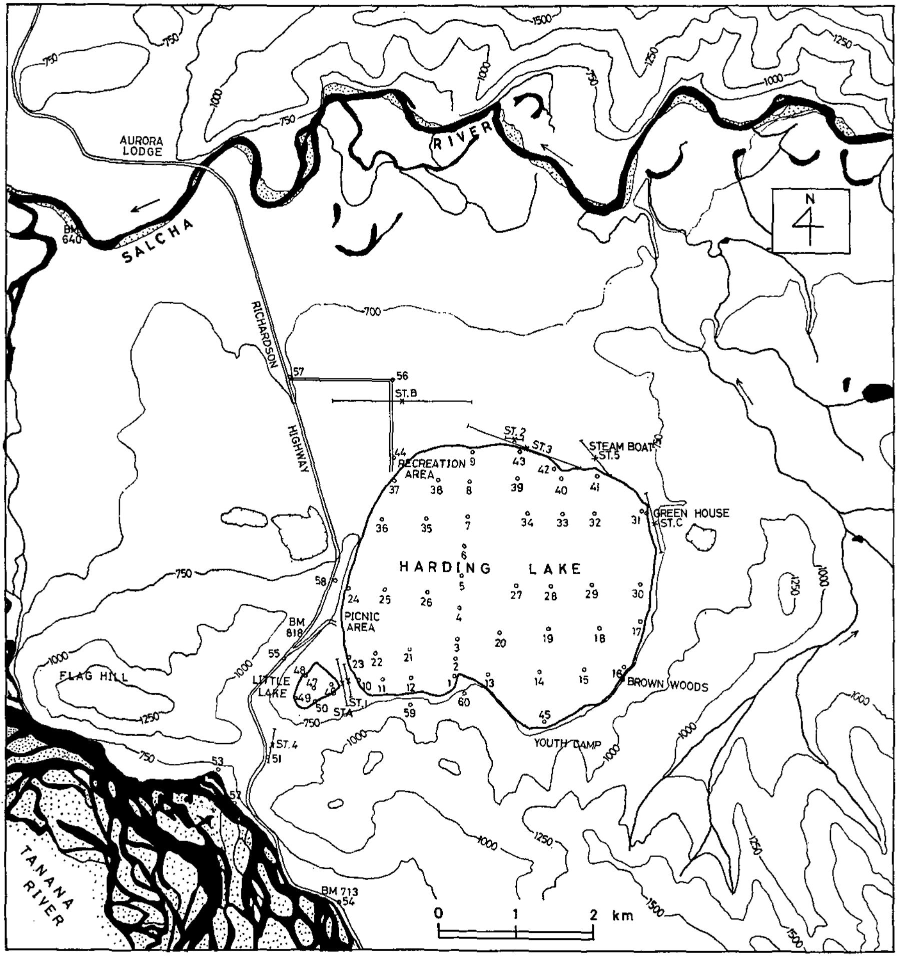

Fig. 3 Topographic features around Harding Lake, indicating location selected for electrical depth soundings and gravimetric surveys. Topographic contours denote in feet.

stakes were used as current electrodes; potential electrodes were copper poles inserted into cloth tubes filled with a saturated solution of copper sulfate.

The current electrodes were extended from the center to a distance of 900 meters in the maximum span of soundings, while the spans of potential electrodes chosen were 0.5, 3, 20, 50 and 100 meters from the center, which increased with increasing distance between the current electrode and the center.

Three locations were selected for electrical depth soundings; namely, site 1 and site A between Harding Lake and Little Lake, site 4 on a low pass formed on a boundary between the lake basin and the Tanana Valley to the southwest of Harding Lake, as shown in Fig. 3.

Field data were analysed by superimposing the field curves obtained on the theoretical curves of Schlumberger, and then underground structures with

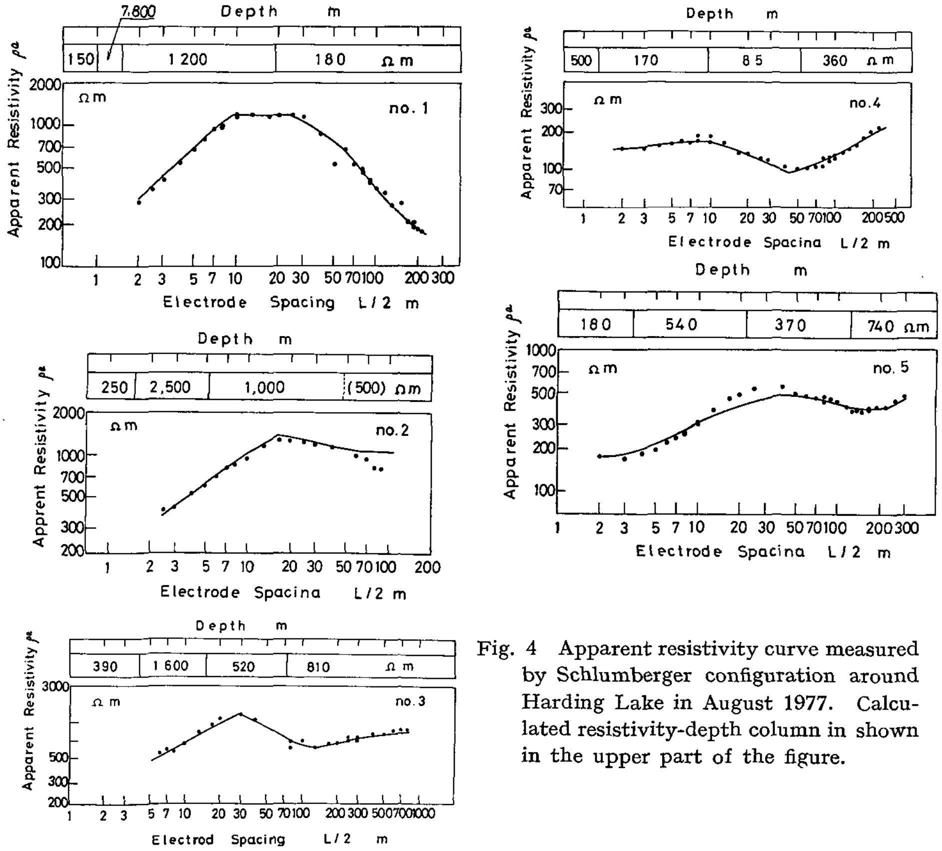

Fig. 4 Apparent resistivity curve measured by Schlumberger configuration around Harding Lake in August 1977. Calculated resistivity-depth column in shown in the upper part of the figure.

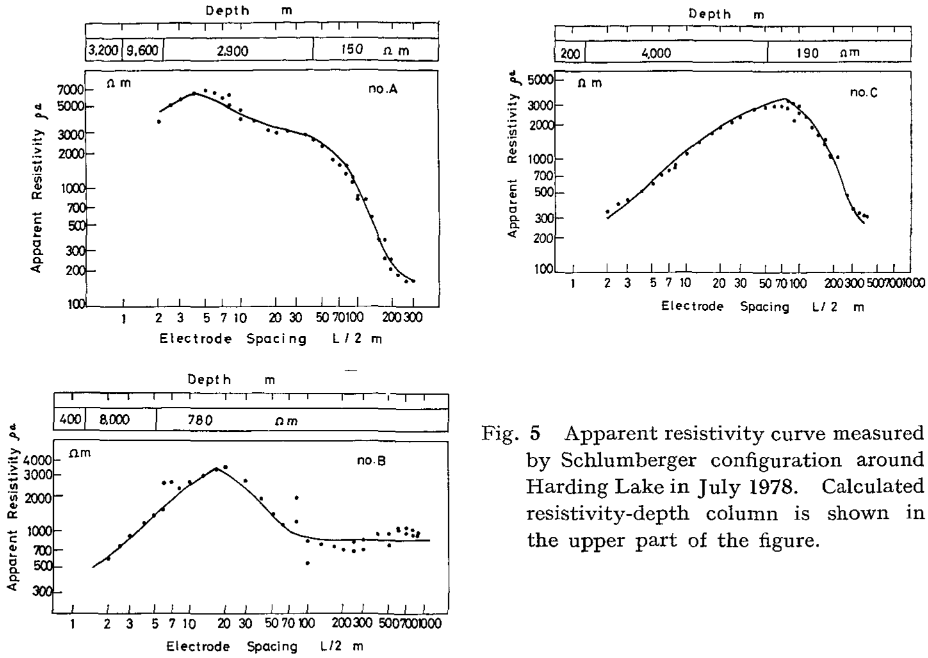

Fig. 5 Apparent resistivity curve measured by Schlumberger configuration around Harding Lake in July 1978. Calculated resistivity-depth column is shown in the upper part of the figure.

multiple strata were analysed, using auxiliary curves, as shown in Figs. 4, 5.

It followed from the interpretation of resistivity on the basis of the previous studies (Ostrem, 1967; McGinnis et al., 1973) that an ice body has resistivities of about 10^4 Ωm and fluvial deposits in permafrost have resistivities of several 10^3 Ωm.

Investigations at sites 1 and A made it clear that a thin ice layer having high resistivities of $9.6 \sim 7.8 \cdot 10^3$ Ωm lies in shallow depths between 1 and 2 m, that the base of permafrost extends to a depth of 20 m from the ground surface at site 1 in bushland and 40 m at site A in a spruce forest, that the underground temperature at a depth of 56 cm from the ground surface at site A was 0°C from measurements by a steel stick inserted with thermister thermometer and further that fluvial deposits extend continuously deeper than the base of permafrost; namely the bedrock lies below a depth of 40 m at this site.

At site 4 on the pass, which is at a height of 25 m above the lake surface, fluvial deposits do not contain ice and permafrost. They show low values in the vertical profile of resistivity, and do not reach the bedrock even a depth of 50 m from the ground surface despite that outcrops of the bedrock composed of a shist are found all over the upland hill.

Photo. 1 Underground ice exposed by cutting a road near Fairbanks.

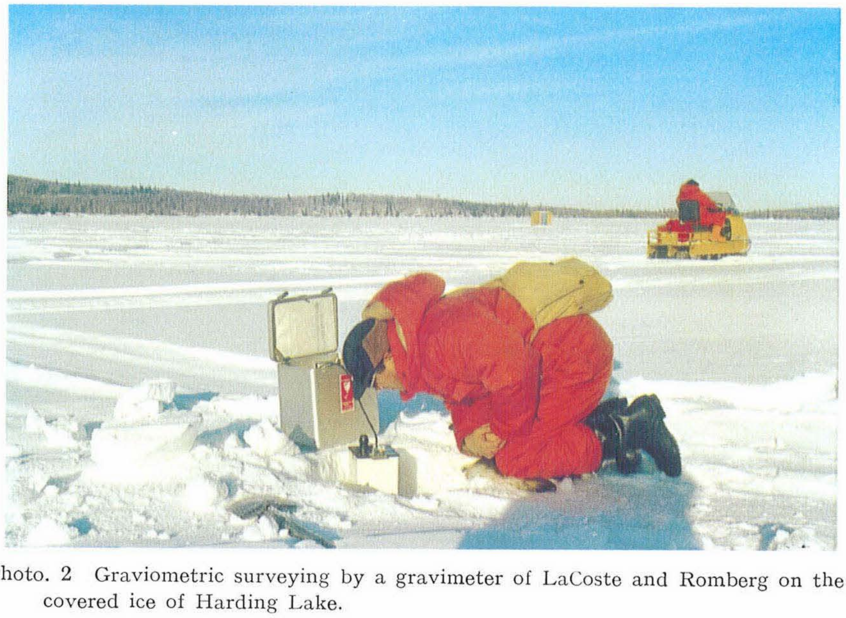

Photo. 2 Graviometric surveying by a gravimeter of LaCoste and Romberg on the covered ice of Harding Lake.

It was the site where the results of soundings indicated a significant fact that deep depression and heavy aggradation had taken place along a line across the pass and Little Lake from the Tanana River to Harding Lake.

Locations of sites 2, 3, 5 were selected near the north shore. It is concluded from the vertical profiles of resistivity that boundarys between the fluvial deposits and the bedrock are present in depths ranging from 70 to 100 m.

An ice layer about 4 m in thickness was found at site B in spruce forest 1 km far from the north shore, which showed resistivities of $8 \cdot 10^3$ Ωm. It was also found that the depth of sediments at site C in the east side of the lake was deeper than 50 m.

It is suggested that the thick fluvial deposits in the area to the north of the lake originated from the aggradation of the Tanana River and the Salcha River.

3. Gravimetric Survey

A gravimetric survey was carried out in March 1979 mainly on the covered ice of Harding Lake by means of a land gravimeter of LaCoste and Romberg (No. 375) and supplementarily at a number of sites on Little Lake in the vicinity of this lake, around this lake and in the Tanana Valley as shown by Fig. 3.

The altitude of the ice surface of Harding Lake is 216 m above sea level, while altitudes of sites around the lake were determined from heights relative to it, using an altimeter of the American Paulin System.

Observed values were standardized by the gravity value, $g=982.2165$ gal, at the Eielson Air Force Base (WA 344) at latitude 64°39.3'N and longitude 147°04.8'W, which is 166 m in altitude above sea level and 32 km far from Harding Lake.

Neglecting topographic corrections, gravity anomalies were estimated as 2.10 gr cm^{-3} for the density of the earth crust in a lowland region and the vertical gradient of gravity as 0.3086 mgal m^{-1}. In latitude 64°25'N at the lake, the normal gravity g was calculated as 982.247, 461 gal.

The results are tabulated in Table 1 and the areal distribution of Bouguer anomalies is shown in Fig. 6, in which all of the values are negative. It is generally characterized that the anomalies increase the negative tendency from the north shore to the south shore of the lake and that they have large negative values along a line from the Tanana Valley via the pass and Little Lake to the southwest shore of Harding Lake as well as in the Tanana Valley, which suggests the presence of a fault valley and trough. As for the origin of

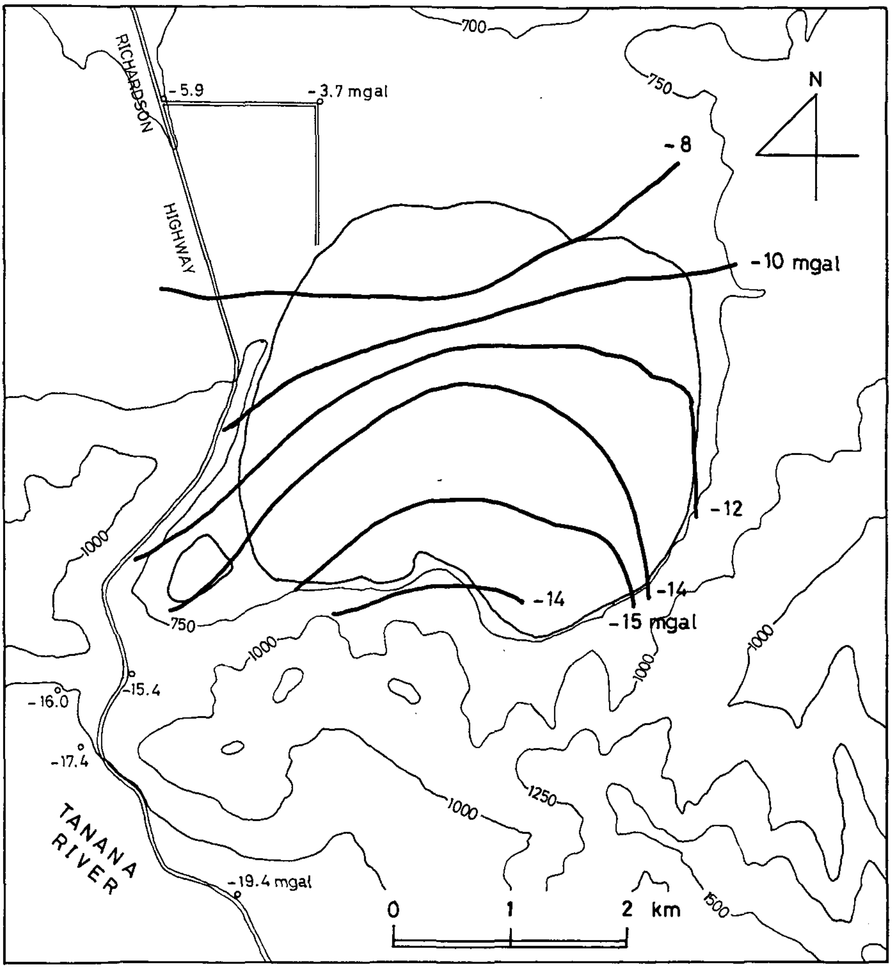

Fig. 6 Distribution of the Bouguer anomalies on and around Harding Lake, in mgal unit. Topographic contours indicate the height in feet.

Harding Lake, it is concluded that a trough basin was formed at first by a tectonic movement and then the present lake basin was formed by the damming of a tributary.

Table 1. Observed values and the anomalies on gravimetric surveys.

Site No.		Altitude (m)	Observed value (mgal) 982,	Free-air anomaly (mgal)	Bouguer anomaly (mgal)
1	On the ice covered the Harding Lake	216	185.17	4.4	−14.6
2		〃	185.10	4.3	−14.7
3	〃	〃	184.35	3.5	−15.5
4	〃	〃	184.50	3.7	−15.3
5	〃	〃	185.08	4.3	−14.7
6	〃	〃	187.29	6.5	−12.5
7	〃	〃	191.55	10.7	− 8.3
8	〃	〃	192.38	11.6	− 7.4
9	〃	〃	192.72	11.9	− 7.1
10	〃	〃	184.88	4.1	−14.9
11	〃	〃	184.98	4.2	−14.8
12	〃	〃	184.74	3.9	−15.1
13	〃	〃	186.30	5.5	−13.5
14	〃	〃	184.20	3.4	−15.6
15	〃	〃	184.73	3.9	−15.1
16	〃	〃	186.64	5.8	−13.2
17	〃	〃	187.70	6.9	−12.1
18	〃	〃	185.95	5.1	−13.9
19	〃	〃	185.35	4.5	−14.5
20	〃	〃	184.68	3.9	−15.1
21	〃	〃	184.11	3.3	−15.7
22	〃	〃	184.32	3.5	−15.5
23	〃	〃	185.48	4.7	−14.3
24	〃	〃	189.14	8.3	−10.7
25	〃	〃	187.38	6.6	−12.4
26	〃	〃	185.09	4.3	−14.7
27	〃	〃	185.25	4.4	−14.6
28	〃	〃	185.71	4.9	−14.1
29	〃	〃	186.56	5.7	−13.3
30	〃	〃	187.88	7.1	−11.9
31	〃	〃	188.78	8.0	−11.0
32	〃	〃	188.37	7.6	−11.4
33	〃	〃	187.94	7.1	−11.9
34	〃	〃	189.06	8.3	−10.8
35	〃	〃	191.18	10.4	− 8.6
36	〃	〃	191.63	10.8	− 8.2
37	〃	〃	192.58	11.8	− 7.2
38	〃	〃	192.54	11.7	− 7.3
39	〃	〃	192.05	11.3	− 7.8
40	〃	〃	191.66	10.9	− 8.2
41	〃	〃	190.65	9.8	− 9.2
42	〃	〃	192.03	11.2	− 7.8
43	〃	〃	192.72	11.9	− 7.1
44	〃	〃	192.73	11.9	− 7.1
45	〃	〃	184.12	3.3	−15.7
46	On the ice covered the Little Lake	226	183.85	6.1	−13.8
47		〃	184.07	6.3	−13.5
48	〃	〃	185.13	7.4	−12.5
49	〃	〃	184.08	6.4	−13.5

Table 1 (Continued)

Site No.		Altiude (m)	Observed value (mgal) 982.	Free-air anomaly (mgal)	Bouguer anomaly (mgal)
50	Little Lake	226	183.73	6.0	−13.9
51	At the pass	241	178.93	5.8	−15.4
52	In the Tanana Valley	202.5	185.42	0.5	−17.4
53	〃	220	182.98	3.4	−16.0
54	〃	218	179.98	−0.2	−19.4
55	Around the lake	249	181.51	10.9	−11.0
56	〃	220.5	195.16	15.7	− 3.7
57	〃	209.5	195.40	12.6	− 5.9
58	〃	240.5	184.95	11.7	− 9.5
59	〃	213	182.29	6.1	−14.2
60	〃	218	185.50	5.3	−13.9

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References

Ager, T.A., 1975. Late Quaternary environmental history of the Tanana Valley, Alaska, Institute of Polar Studies Report No. 54, Ohio State University, 1–117.

McGinnis, L.D., Nakao, K. and C.C. Clark, 1973. Geophysical identification of frozen and unfrozen ground, Antarctica, Proc. Second Internat. Conf. on Permafrost, North American Contribution, Yakutsk, U.S.S.R., 136–146.

Ostrem, G,. 1973. Laboratory measurements of the resistivity of ice, Journal of Glaciology, **6**, 643–650.

Schultz, B. and H.T.U. Smith, 1965. Central and South Central Alaska, Middle Tanana River Valley, VII the INQUA Congress, Guidebooks for Field Conferences, 36–54.