Report of the Japanese Summer Parties in Dry Valleys, Victoria Land, 1971–1972
XI. Sedimentary Structure near the Saline Lakes in Three Ice-Free Valleys, Victoria Land, Antarctica, inferred from Electrical Depth Sounding

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南極 Victoria Land の Dry Valley 調査報告
XI. 電気探査からみた塩湖周辺の堆積構造

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要旨：南極 Victoria Land の Dry Valley 地域に点在する塩湖を中心に，McMurdo Base および Marble Point などの海岸地域もふくめて総数10カ所で，300 から 600 m におよぶ深層ボーリングが計画されている．これによって，塩湖の成因，変遷と Dry Valley ひいては南極の地史を探ろうとするものである．

Dry Valley Drilling Project の予備調査として，1971年12月より1972年1月にかけて，Taylor Valley, Wright Valley, Victoria Valley の塩湖を中心に人工地震探査，電気探査，地磁気探査が Northern Illinois University (L. D. McGinnis) の調査隊によって行なわれた．筆者らは，この調査隊と行を共にし電気探査を行なった．

Dry Valley 地域には，年平均気温 −20°C 以下の極地としては当然のことながら，いたるところ比抵抗値の高い永久凍土層が存在するが塩湖周辺では，永久凍土層の下に高塩分濃度のため，不凍結水を含んでいると考えられる低い比抵抗値を示す層が見出された．この層の存在は，気候変化に伴う湖の縮少，湖盆の堆積の過程と密接に関係している．

1. Introduction

The three ice-free valleys in which these studies were conducted were the Wright Valley, Taylor Valley and Victoria Valley; all west of McMurdo Sound. As a results of the arid climatic conditions–extremely by low humidity and mini-

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mal precipitation–these valleys are free from snow or ice throughout the year. Furthermore, in these valleys are found several lakes or ponds, all of which have water with abnormally high salinity; are fed only by melt-water from glaciers during the summer, and lose water only through evaporation and sublimation.

This work was carried out as a part of the preliminary work of the DVDP*, and in conjunction with the other concurrent geophysical surveys being conducted by McGINNIS of Northern Illinois University, utilizing seismic refraction methods, and aeromagnetic surveys.

Study locations, as shown in Fig. 1, were chosen at Don Juan Pond (St. 1–9), Don Quixote Pond (St. 10–11), on the western edge of Lake Vanda (St. 27–31), along the lower reaches of the Onyx River in the Wright Valley (St. 32–36), at

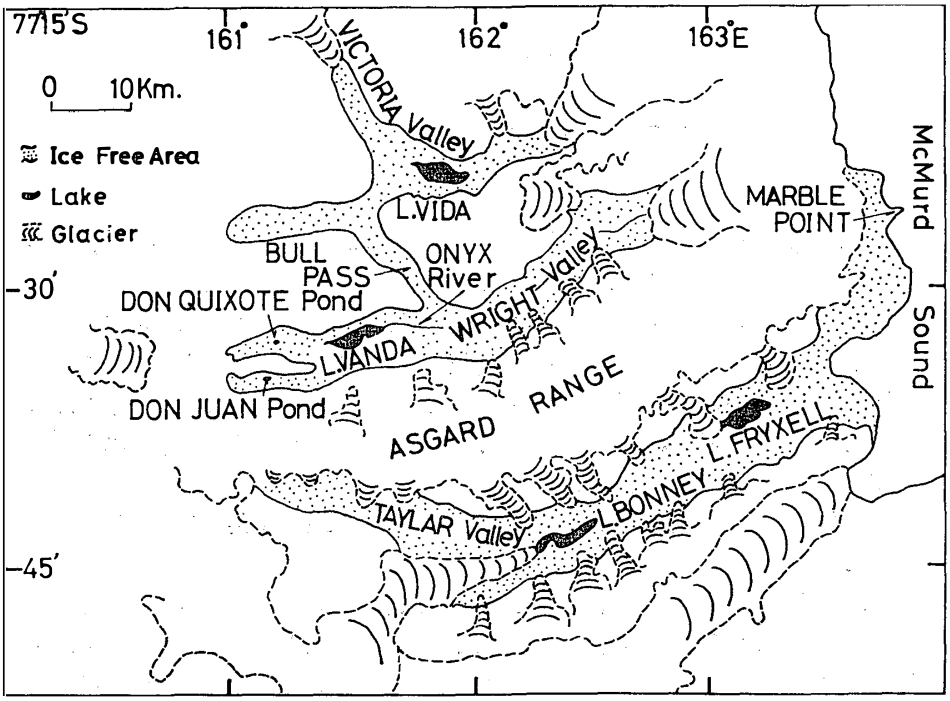

Fig. 1. Field area of electrical depth sounding study in ice-free valleys, Antarctica.

Lake Vida in Victoria Valley (St. 12–17) and at Lake Fryxell in the Taylor Valley (St. 18–26).

Electrical depth soundings in these valleys had been conducted previously by McGINNIS and JENSEN (1971), who reported that unfrozen groundwater existed beneath the confining permafrost.

WILLIAMS (1970) reported that groundwater occurs above, below, and locally within permafrost in Alaska. The present writers also found out by the resistivity method that a stratum of low resistivity seems to exist beneath the confining per-

*Dry Valley Deep Drilling Project

mafrost layer in the area adjoining most of the saline lakes, except the Lake Vida region. It is thought that this stratum contains unfrozen saline water.

2. Equipment and Method of Measurement

The ground resistivity was measured with a DC-type Geohmeter. The usual source of power was ten 45-volt dry cell batteries, except at Don Quixote where fifteen 45-volt dry cells were used. This allowed voltage regulations between 0 and 450 V. Steel stakes were used as current electrodes and the potential electrodes were copper poles inserted into cloth tubes filled with a saturated solution of copper sulfate.

Voltage could be obtained to 0.05 mV and current to 0.1 mA. The electrodes were arranged by the Schlumberger method. The current electrodes were able to be expanded from 2 to 800 meters and the potential electrodes from 0.5 to 100 meters, depending on the distance of the current electrodes from the center. The altitude at the study locations was measured by Paulin's altimeter.

3. Interpretation of the Field Data

The analysis of the field data was made by superimposing the field curves on the theoretical curves of Schlumberger. In addition, the auxiliary curves computed by Ono (1958) were used for the analysis of underground structures with multiple strata. These results are shown in Fig. 2 through 7.

3.1. Don Juan Pond basin

Don Juan Pond is situated near the western end of the South Fork of the Wright Valley and it is some 60 km west of McMurdo Sound. The pond is 400 by 100 m, has a small inflow from the west and no outlet. The maximum depth measured was 24 cm in December 1971.

The pond water has a high concentration of $CaCl_2$–1.38 g/cc in density–and therefore remains unfrozen throughout the year. The beach area around the pond is covered with deposits of $CaCl_2$ and NaCl.

Locations selected for this study were numbered St. 3, 4, 5, 6. They run from the west to the east across the pond. Two other locations – St. 1 and 2 – on the southern shore, were also used.

In the pond basin, as shown in Fig. 8, the ground resistivity of the upper layer is less than 6 Ωm. It is therefore thought that this zone contains an unfrozen liquid with a high saline concentration.

In the deeper layer the value of the resistivity increases to more than 20 Ωm, as seen at a depth of 15 m on the southern shore and at 30 m along the east-west cross section. This layer may be the basement that contains an unfrozen liquid in

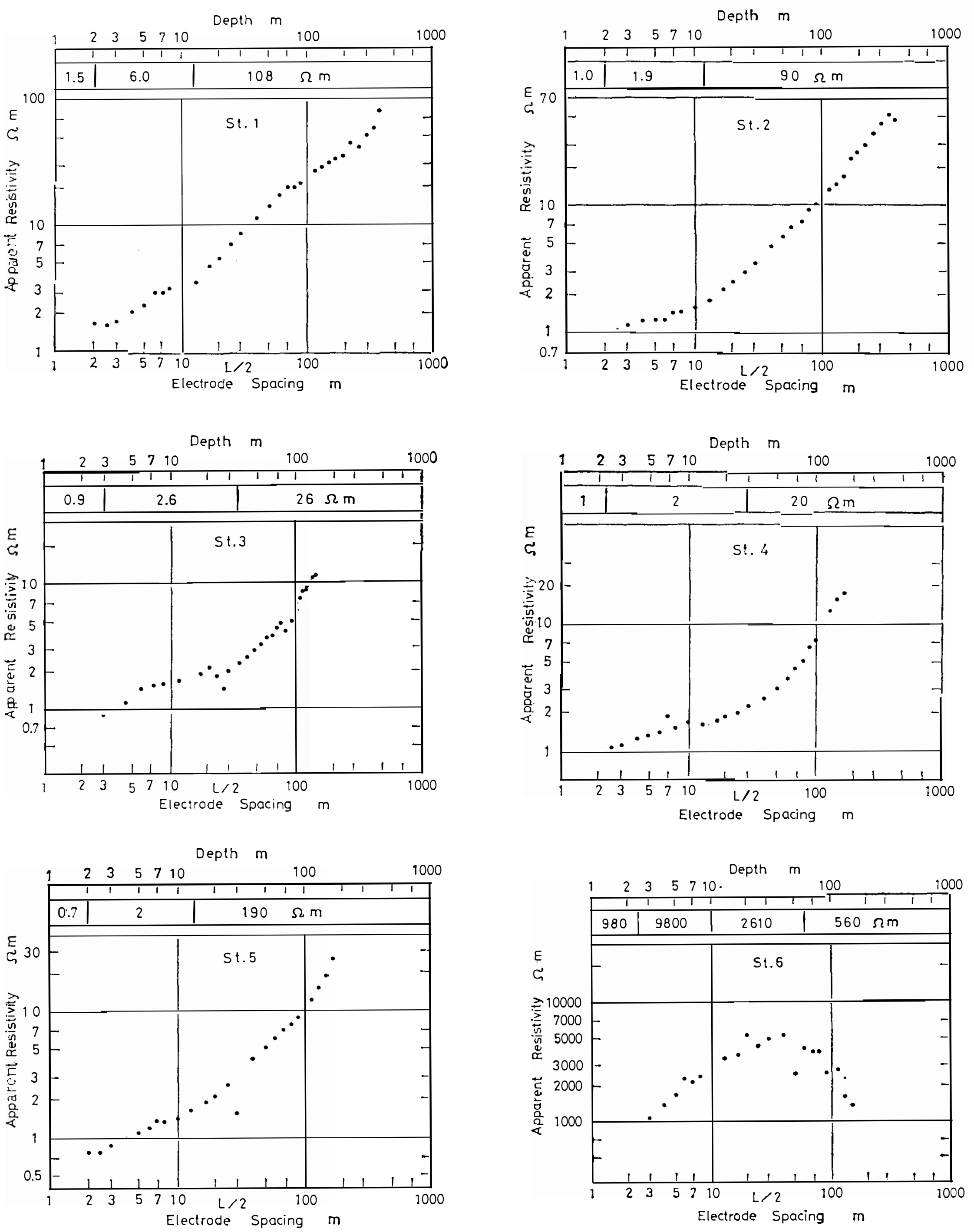

Fig. 2. Apparent resistivity curve by Schlumberger configuration at St. 1–6, Don Juan Pond. Calculated resistivity-depth column is shown in the upper part of the figure.

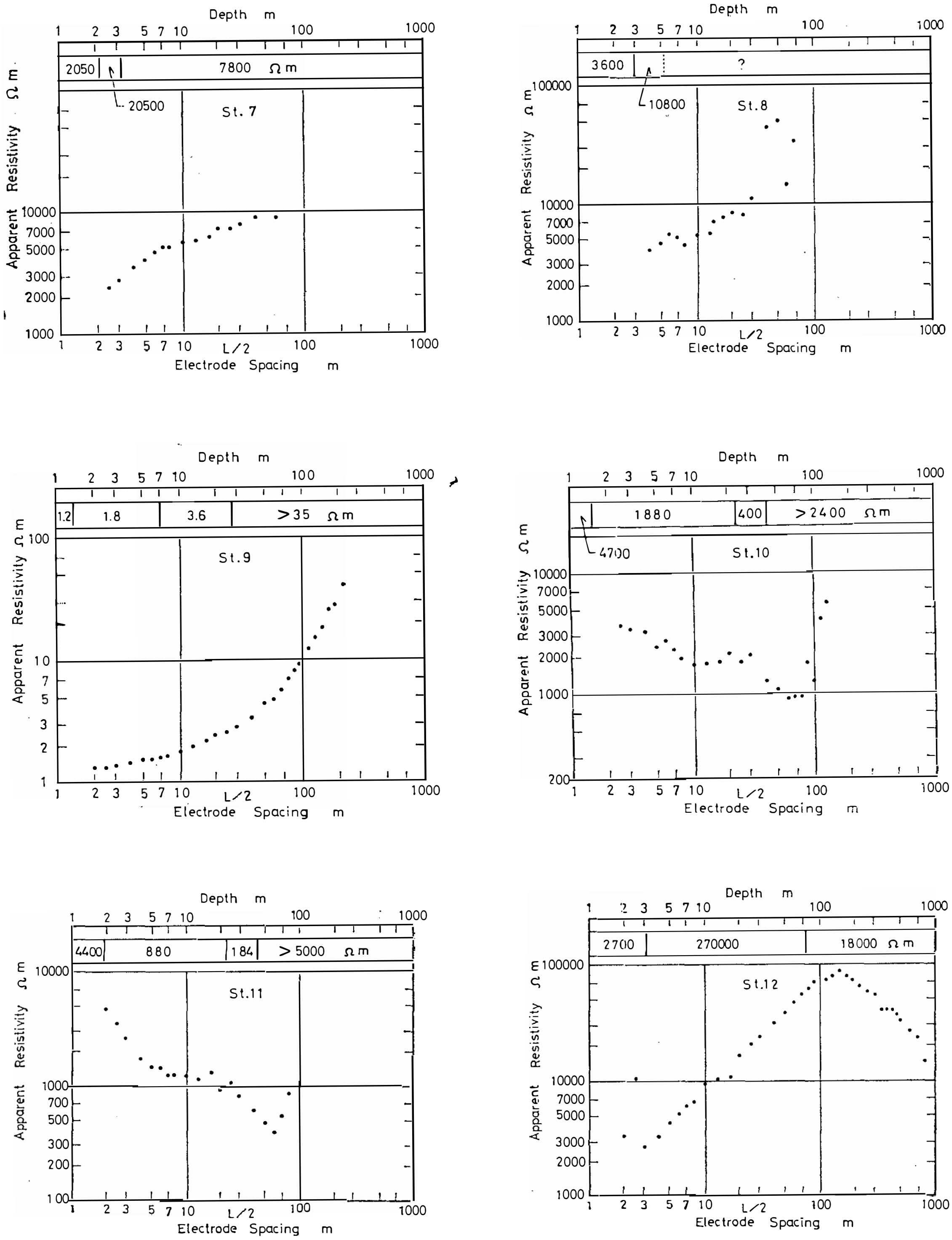

Fig. 3. Apparent resistivity curve by Schlumberger configuration at St. 7–9, Don Juan Pond, St. 10–11, Don Quixote Pond, St. 12, Lake Vida. Calculated resistivity-depth column is shown in the upper part of the figure.

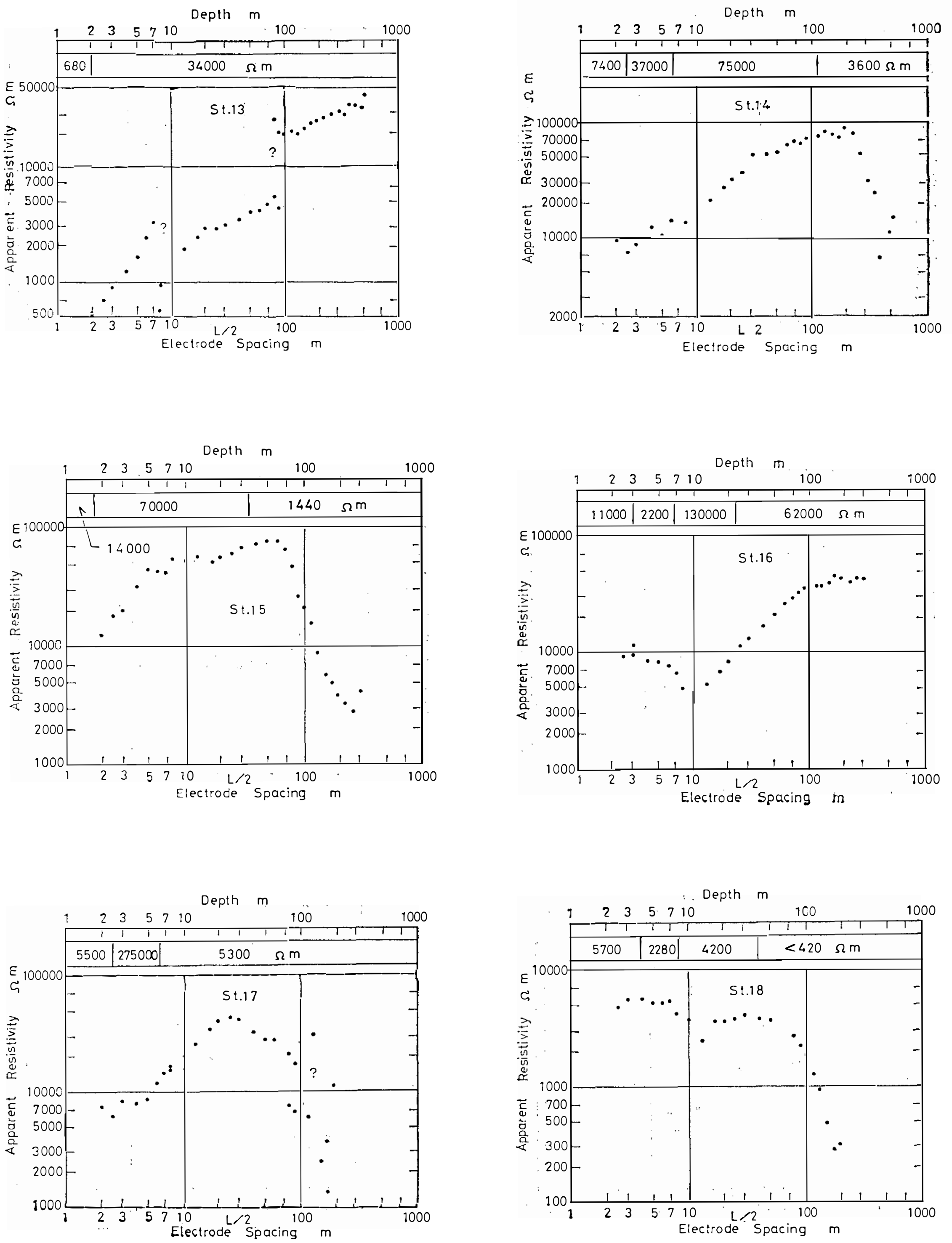

Fig. 4. Apparent resistivity curve by Schlumberger configuration at St. 13–17, Lake Vida, St. 18, Lake Fryxell. Calculated resistivity-depth column is shown in the upper part of the figure.

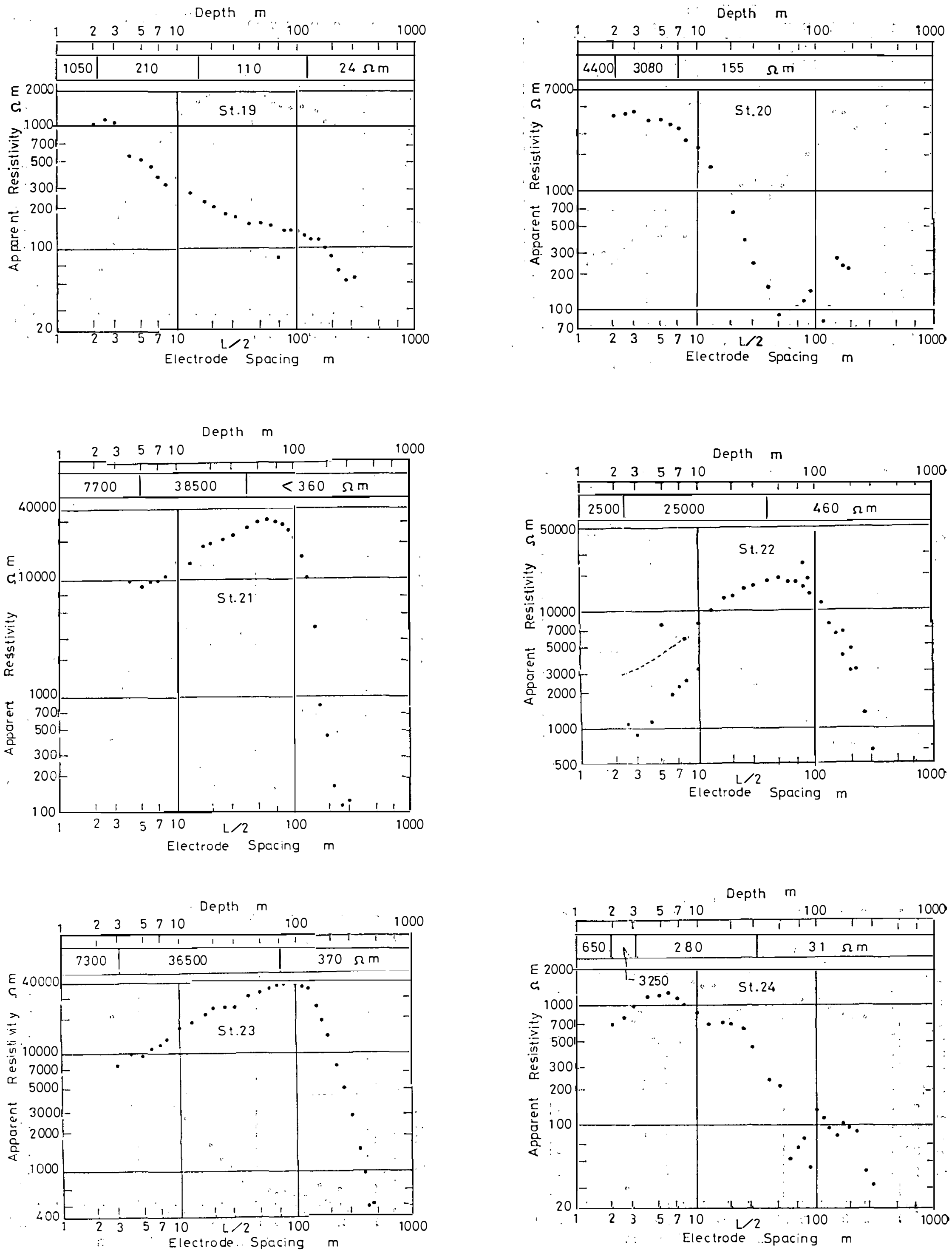

Fig. 5. Apparent resistivity curve by Schlumberger configuration at St. 19–24, Lake Fryxell. Calculated resistivity-depth column is shown in the upper part of the figure.

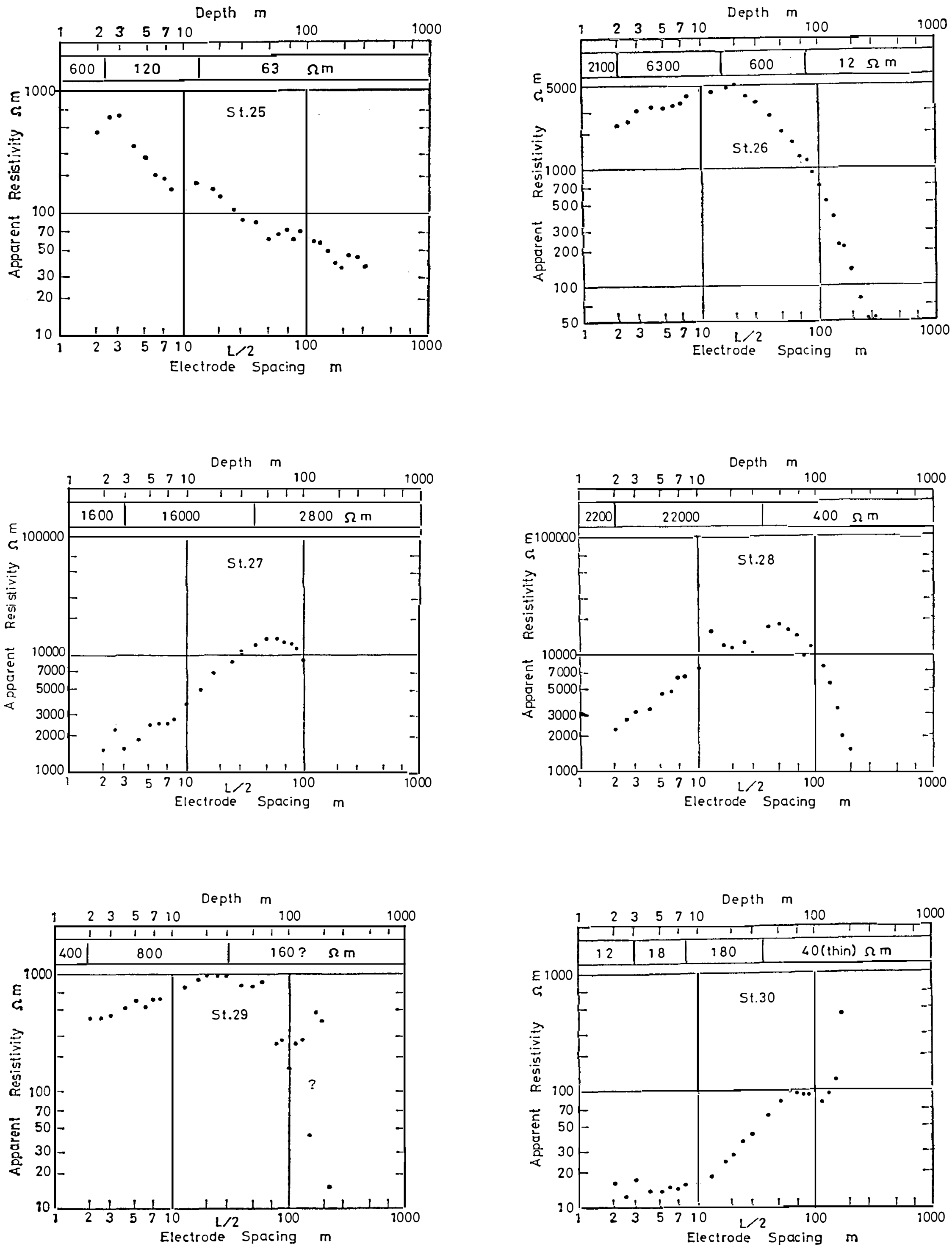

Fig. 6. Apparent resistivity curve by Schlumberger configuration at St. 25–26, Lake Fryxell, St. 27–30, western edge of Lake Vanda. Calculated resistivity-depth column is shown in the upper part of the figure.

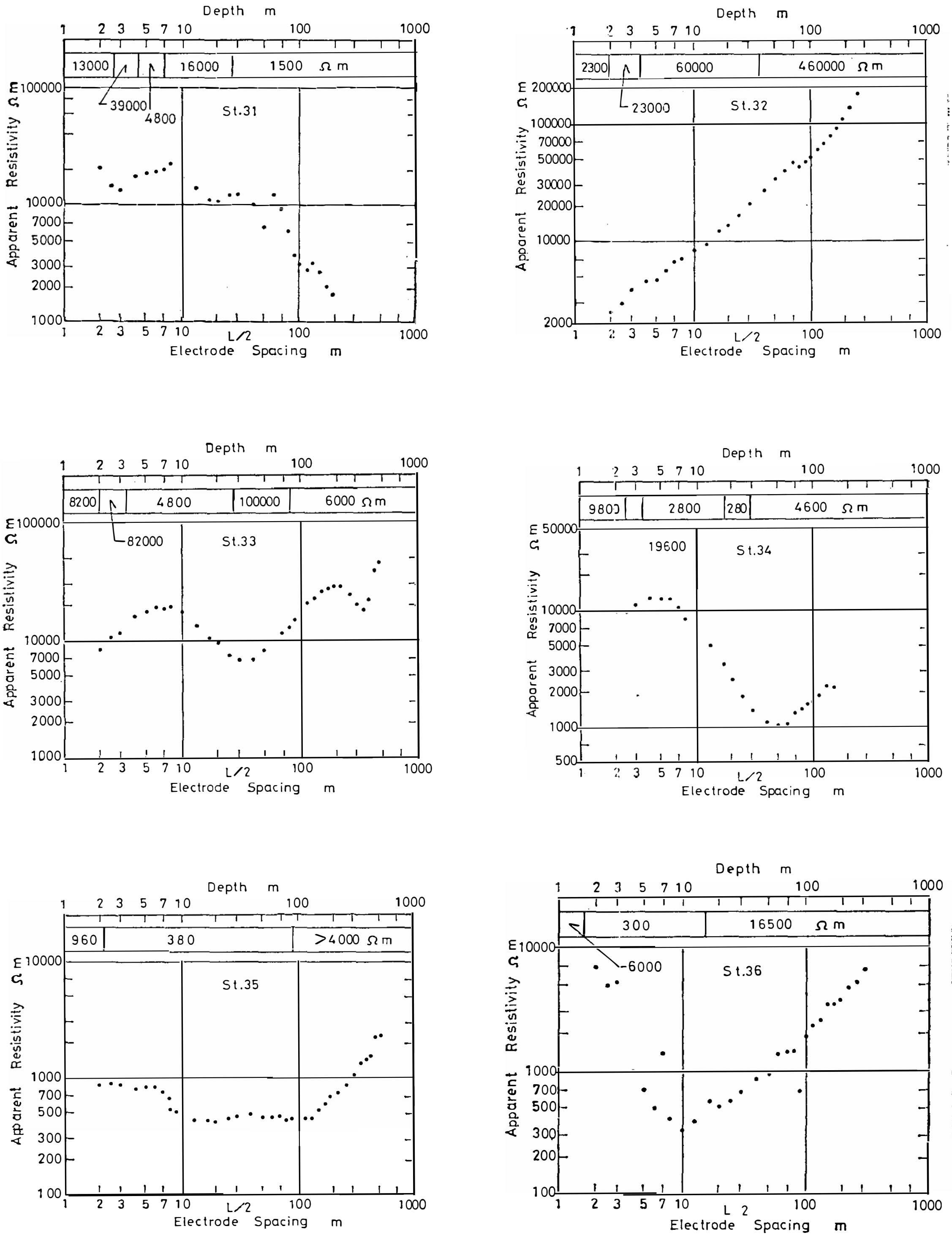

Fig. 7. Apparent resistivity curve by Schlumberger configuration at St. 31, western edge of Lake Vanda, St. 32–36, lower reaches of the Onyx River. Calculated resistivity-depth column is shown in the upper part of the figure.

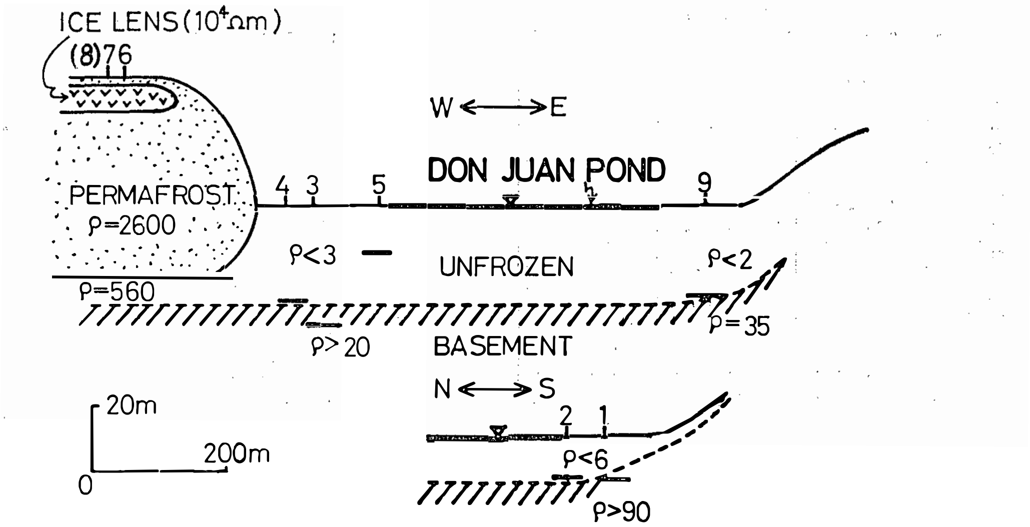

Fig. 8. Sedimentary structure of the Don Juan Pond basin, Wright Valley. "Permafrost" is a confining permafrost. "Unfrozen" is a stratum containing unfrozen liquid. Unit of ρ is ohm-meter.

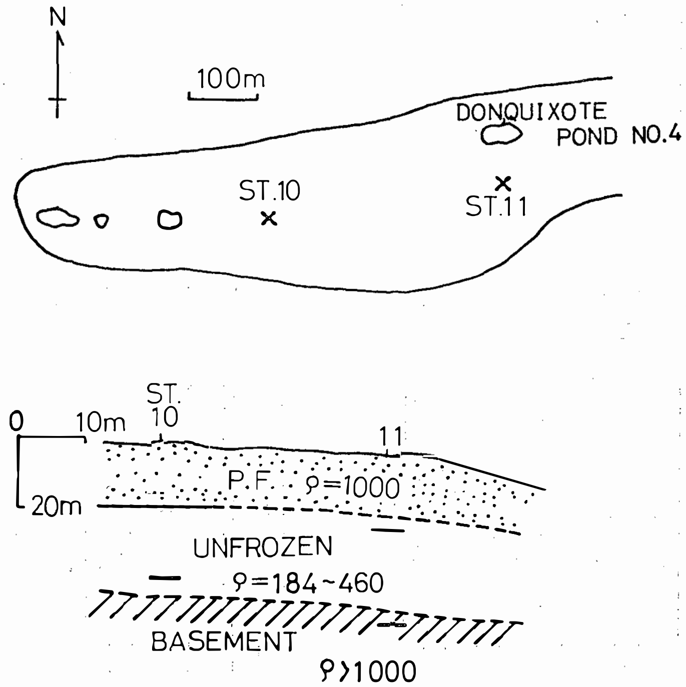

Fig. 9. Sedimentary structure and location of sounding stations in the vicinity of Don Quixote Pond, Wright Valley. "Permafrost" is a confining permafrost. "Unfrozen" is a stratum containing unfrozen liquid. Unit of ρ is ohm-meter.

the fractures.

Locations St. 6, 7 and 8 were selected on the moraine behind the western side of the pond. As is seen in Fig. 3, this moraine is composed mainly of a confining permafrost layer (10^3 Ωm) down to 60 meters below the surface, except for a thin layer of 10^4 Ωm at a depth between 2 and 10 meters. This resembles the ice lens.

3. 2. Don Quixote Pond

Don Quixote Pond is situated at the western end of the North Fork of the Wright Valley. It is a small and shallow saline pond. Locations St. 10 and 11 in this area were used for the study.

The field data seems to indicate that a low resistivity layer exists between the confining permafrost (10^3 Ωm) and the basement ($>10^5$ Ωm). The resistivity of the layer ranged from 184 Ωm to 460 Ωm. This may be attributed to the unfrozen saline liquid. The thickness of the sediments seems to be about 45 m.

3. 3. The western edge of Lake Vanda

Lake Vanda in the Wright Valley is situated approximately 35 km from McMurdo Sound. It is fed by the Onyx River which gathers melt-water from the Lower Wright Glacier during the summer. The lake is 5.6 by 1.4 km, has no outlet and is permanently covered with ice (about 3.5 m thick in summer). The maximum depth measured was 67 m. Its saline density is 1.1 g/cc, and its water temperature is approximately 25°C. The previous chemical and thermal studies have been presented by ANGINO and ARMITAGE (1963), WILSON (1964), RAGOTZKIE and LIKENS (1964), HOARE (1966), JONES and FAURE (1967), TORII *et al.* (1967), YAMAGATA *et al.* (1967), HOARE (1968) and YOSHIDA *et al.* (1971).

Concentration by evaporation and sublimation is the probable source of the salt in Lake Vanda as is the case with some other closed saline lakes which were also produced as a result of the arid climatic conditions (JONES and FAURE, 1967).

Study locations - St. 27, 28, 29, 30 - were selected. They run from the western edge of the lake towards the North Fork (a distance of 1.5 km) as shown in Fig. 10. The ground level at St. 30 was 20 m in the heights below the lake level-in a dry pond basin. Location St. 31 was on the shore of the lake.

It was found that the ground resistivity gradually decreased from a high at St. 27. The lowest value at St. 30 is considered to be a result of the saline water and the silt deposits from the ancient lake.

At a dry pond (St. 30) the moraine and the fluvioglacial deposits were about 50 m in thickness.

The contour lines at about 200 m above sea level approximately coincide with a terrace 52 m above the present lake level - 143 m in altitude, which may indicate the shore line of a ancient lake. (Height of these terraces was measured by K.

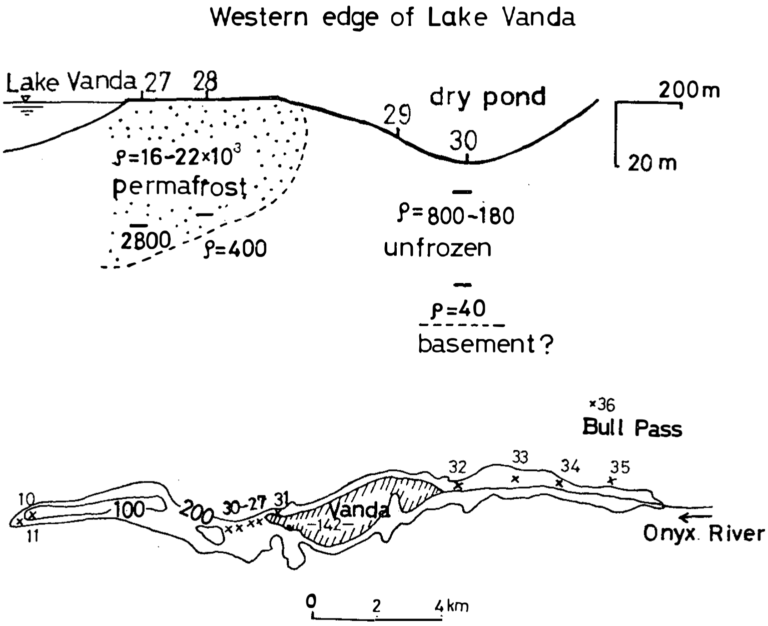

Fig. 10. Sedimentary structure at the western edge of Lake Vanda, and location of sounding stations in the vicinity of Lake Vanda, Wright Valley. "Permafrost" is a stratum containing unfrozen liquid. Unit of ρ is ohm-meter.

NAKAO in November 1971.)

Accordingly, all stations at Don Quixote, western edge of Lake Vanda and the lower reaches of the Onyx River, lie under the water level of the ancient Lake Vanda.

3.4. The lower reaches of the Onyx River

The study sites – St. 32, 33, 34, 35 – are located along the shore of the Onyx River, starting from Lake Vanda and continuing for a distance of approximately 5 km. The elevation of the sites gradually increased from a low at St. 32 (23 m above the Vanda Lake level) to a high of 62 m at St. 35.

The apparent resistivity curve obtained at St. 33 is indicative of the complicated features of fluvioglacial deposits.

Furthermore, the ground resistivity was generally lower along the Onyx River than in the vicinity of Lake Vanda, as pointed out by McGINNIS and JENSEN (1971).

As shown in Fig. 11, the basement seems to lie at a shallow depth of about 2 m near the lake, but the depth increases to 90 m at St. 35.

This depression in the basement seems to indicate an old lake basin filled up by moraine and fluvioglacial deposits.

At. St. 36, on the Bull Pass (380 m in altitude) a layer of low resistivity was found (300 Ωm) at a depth between 1.6 m and 15 m.

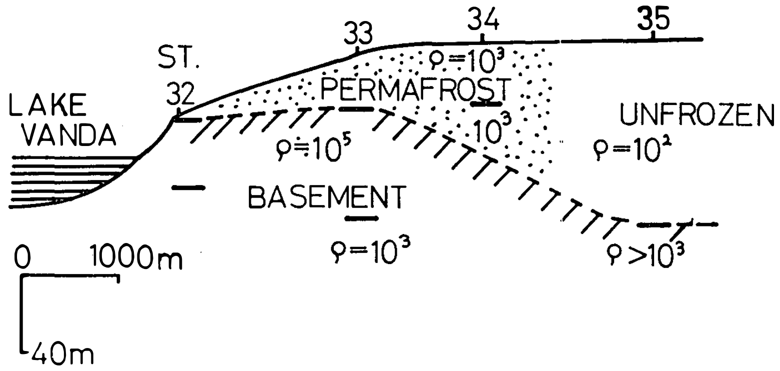

Fig. 11. Sedimentary structure along the Onyx River, Wright Valley. "Permafrost" is a confining permafrost. "Unfrozen" is a stratum containing unfrozen liquid. Unit of ρ is ohm-meter.

3.5. Lake Vida basin

Lake Vida is a closed lake, 3.5 by 1 km, at the east end of the Victoria Valley, and may be completely frozen unlike the other large lakes in these ice-free valleys (CALKIN and BULL, 1967). Its altitude is 390 m.

Study locations were selected near the lake. St. 13 on the southern shore; St. 14 and 15 on the northern shore; St. 12 and 16 near the small inlet on the western side; and St. 17 at the center of the lake.

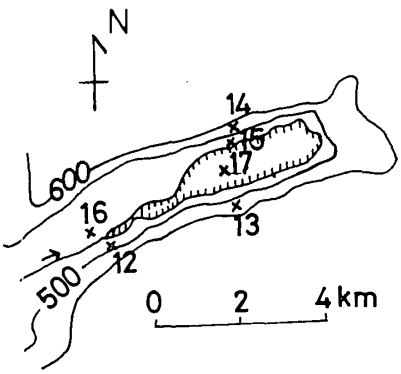

Fig. 12. Stations at Lake Vida basin, Victoria Valley.

The results of the electrical depth soundings seem to indicate that a layer of low resistivity (<10^2 Ωm) does not exist unlike the other regions near the saline lakes. There seems to be only a layer of confining permafrost, which is probably ascribed to the fact that Vida is an ice lake.

At the center of the lake (St. 17), as shown in Fig. 4, the value of resistivity in the first layer – to 2.5 m in depth – (5,500 Ωm) seems to have been influenced by the puddles within the ice, caused by the green house effect. The value of resistivity in the second layer – between 2.5 and 6.3 m – in which there was only clear ice was 2.8×10^5 Ωm.

3.6. The Lake Fryxell basin

Lake Fryxell is situated near the eastern end of the Taylor Valley, about 6.5 km from the coast. The lake, 5 by 1.5 km, is permanently covered with about 4.5 m thick ice.

The lake level is 12 m above the mean sea level, with a maximum water temperature of 2.3°C at a depth of 9 m. The maximum depth measured was 17 m.

Chemical and thermal features of the lake were investigated by ANGINO and ARMITAGE *et al.* (1962), TORII *et al.* (1967) and YAMAGATA *et al.* (1967).

HOARE *et al.* (1965) reported that it is a solar heated lake similar to Lake Bonney. And YAMAGATA *et al.* (1967) pointed out that its chemical composition is not unlike that of sea water – quite unlike the other saline lakes. Therefore, this is perhaps a relic lake of sea water.

Electrical depth soundings were conducted at various locations around the lake. St. 20, 21, 22, 23 are arranged northward from the lake shore as shown in Fig. 13.

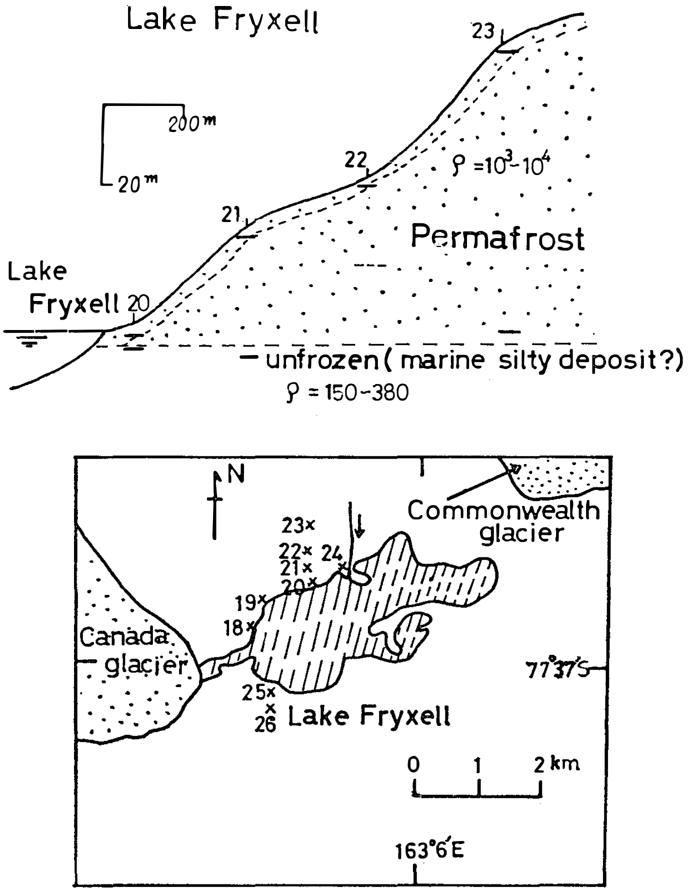

Fig. 13. Sedimentary structure and locations of sounding stations in the Fryxell Lake basin, Taylor Valley. "Permafrost" is a confining permafrost. "Unfrozen" is a stratum containing unfrozen liquid. Unit of ρ is ohm-meter.

The layer of permafrost seems to become thicker as the distance from the lake increases, and the upper edge of the layer of lower resistivity (10^2 Ωm) is horizontally stratified. It resembles an ancient marine deposit covered by moraine. In the immediate vicinity of the lake, the permafrost layer is less than several meters thick.

4. Conclusion

In the greater part of the areas bordering the saline lakes, there seems to exist a low resistivity layer below a layer of confining permafrost. These layers sometimes begin even from the surface of the ground - for example, at Don Juan Pond and in an area approximately 1.5 km from the western edge of Lake Vanda. The value of resistivity was usually less than 10^{-2} Ωm. Resistivity is low in the area surrounding the lakes because that the permafrost contains the saline water which is partially unfrozen in about $-20°$C (annual mean air temperature).

The presence of unfrozen saline water seems to be related to the features of the past and present lake basins themselves and to the salt concentration resulting from the reduction in ancient lake levels.

Acknowledgements

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