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ELECTRICAL RESISTIVITY OF ICE FROM THE ANTARCTIC PENINSULA, ANTARCTICA

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ABSTRACT. Georesistivity soundings have been carried out at four sites in the Antarctic Peninsula. The objective of the work was to investigate the electrical behaviour of ice from an area where substantial melting occurs in summer and from contrasting thermal regimes. Electrical measurements made at three sites along a flow line within George VI Ice Shelf reveal that:
(a) the resistivity of deep ice is similar to that of other Antarctic ice shelves,
(b) the resistivity of the ice-shelf surface, which is affected by the percolation and refreezing of melt water, is similar to that of deep ice and hence the ice is polar in character.

A compilation of published resistivities of deep ice from polar regions shows that the range of resistivities is very narrow (0.4–2.0) × 10^5 Ω m between −2 and −29°C, irrespective of the physical setting and history of the ice. Typically, resistivity is within a factor of two of 80 kΩ m at −20°C with an activation energy of 0.22 eV. In contrast, the resistivity of surface ice at Wormald Ice Piedmont, where the ice is at 0°C throughout, is two orders of magnitude higher and falls at the lower end of the range of resistivities for temperate ice.

RÉSUMÉ. *Résistivité électrique de la glace d l'Antarctic Peninsula, Antarctique.* Des sondages de résistivité ont été effectués en quatre sites de l'Antarctic Peninsula. L'objectif de ce travail était de déterminer le comportement électrique de la glace dans une zone où existe une fonte estivale substantielle ainsi que des régimes thermiques contrastés. Des mesures électriques effectuées en trois sites le long d'une ligne de courant sur le George VI Ice Shelf montrent que:
(a) la résistivité de la glace en profondeur est semblable à celle des autres shelfs antarctiques,
(b) la résistivité de la glace à la surface de la glace du shelf, qui est soumise à la percolation et au regel de l'eau de fusion, est semblable à celle de la glace en profondeur et donc la glace a un caractère polaire.

Une compilation des résistivités publiées pour la glace profonde des régions polaires montre que le domaine des résistivités est très réduit (0,4−2,0) × 10^5 Ω m entre −2 et −29°C, quelles que soient la situation physique et l'histoire de la glace. Particulièrement, la résistivité est proche à un facteur deux près de 80 kΩ m à −20°C avec une énergie d'activation de 0,22 eV. Par contre, la résistivité de la glace de surface sur le Wormald Ice Piedmont, où la glace est à 0°C partout, est de deux ordres de grandeur plus élevée et se situe à la limite inférieure du domaine des résistivités de la glace tempérée.

ZUSAMMENFASSUNG. *Elektrischer Widerstand von Eis der Antarctic Peninsula, Antarktika.* An vier Stellen auf der Antarctic Peninsula wurden elektrische Widerstandssondierungen vorgenommen. Das Ziel dieser Arbeit war die Untersuchung des elektrischen Verhaltens von Eis aus einem Gebiet, wo im Sommer wesentliche Abschmelzung auftritt, und aus Bereichen mit unterschiedlichen Wärmehaushalten. Elektrische Messungen an drei Stellen längs einer Stromlinie innerhalb des George VI Ice Shelf ziegen, dass
(a) der Widerstand tiefen Eises ähnlich dem auf anderen antarktischen Schelfeisen ist,
(b) der Widerstand der Schelfeisoberfläche, auf der sich Sickervorgänge und Wiedergefrieren von Schmelzwasser auswirken, ähnlich dem des tiefen Eises ist und folglich das Eis dort polaren Charakter besitzt.

Eine Zusammenstellung veröffentlichter Widerstandswerte für tiefes Eis aus Polargebieten zeigt, dass sich die Widerstände sehr nahe an den Bereich von (0,4−2,0) × 10^5 Ω m zwischen −2 und −29°C halten, unabhängig vom Setzungszustand und von der Vorgeschichte des Eises. Typisch für den Widerstand ist eine Schwankung von 80 kΩ m bei −20°C und einer Aktivationsenergie von 0,22 eV mit dem Faktor 2. Im Gegensatz dazu ist der Widerstand von Oberflächeneis im Wormald Ice Piedmont, wo die Eistemperatur durchwegs 0°C beträgt, um zwei Grössenordnungen höher; er liegt damit an der unteren Grenze des Widerstandsbereiches für temperiertes Eis.

OBJECTIVES, INSTRUMENTATION, AND ANALYSIS

The objective of the work was to investigate the electrical structure of an ice shelf along a flow line in an area where substantial surface melting occurs in summer. Apparent resistivity profiles were obtained at three sites along a flow line of Goodenough Glacier which crosses George VI Ice Shelf at lat. 72°S. (Fig. 1). The area is a percolation/soaked zone with a 10 m ice temperature of -10°C (Reynolds, 1981[a]). To provide a comparison with the ice shelf, a profile was obtained at an airstrip 5 km west of Rothera station, Adelaide Island (lat. 67°34'S., long. 68°08'W.), a flat site at the head of the accumulation area of Wormald Ice Piedmont, where the ice is close to its melting point. All resistivity measurements were carried out in summer with surface conditions given in Table I.

A standard Schlumberger four-electrode configuration was used. Current was provided by a bank of up to six 90 V dry cells. The electrodes were stainless steel tubes 1 m long and 19 mm in outside diameter. The potential and current were monitored by Keithley 602B electrometers and output to a Minigor 520 XY-Yt chart recorder to display the mutual decay of voltage and current. The decay is linear in agreement with Ohm's law and determines a resistance R from which an apparent resistivity ρ_a of the medium can be computed. The well-known relationship for the Schlumberger array is

$$\rho_a = \frac{\pi a^2}{b}\left(1 - \frac{b^2}{4a^2}\right)R$$

where 2a and b are the separations of the current and voltage electrodes respectively. Full details of the data reduction and analysis are given by Reynolds (1982).

The apparent-resistivity profiles have been interpreted using a computer program based on Ghosh's convolution method (Ghosh, 1971). The program synthesizes an apparent-resistivity profile for an n-layered model in which the variables are layer thickness and resistivity. Model profiles were compared with the field data and the variables adjusted by trial and error to obtain an acceptable match.

RESISTIVITY OF GEORGE VI ICE SHELF

Values of apparent resistivity are listed in Table II and illustrated in Figure 2. For each profile the data are shown with standard deviations. Superimposed are the synthesized curves which fit the data well. At the foot of each figure are the layer models used to generate the appropriate curves. In each model, the bottom layer is chosen to represent cold water of oceanic salinity and resistivity 0.3 Ω m.

Profiles for RJ and RK shown in Figure 2a and b have been published previously and discussed in detail by Reynolds (1982). The small variation of resistivity found with depth is due to the ice shelf

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