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## DETERMINATION OF THE GALINDEZ ISLAND ICE CAP THICKNESS BY THE VERTICAL ELECTRIC- RESONANCE SOUNDING METHOD

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**Abstract.** During the seasonal works in the 9-th Ukrainian Antarctic Expedition the thickness of the ice cap near the Academic Vernadsky station on the Galindez Island was measured using the vertical electric-resonance sounding method (ERS-method) based on studying the processes of the natural polarization of environment and spectral features of natural electric field under investigation objects. The method permits to define the location depths of the stratigraphic cross-section complexes and separate anomalous objects. Results of these works were used to set up: a) a sketch-map and 3-D diagram of the ice cap thickness on Galindez Island; b) vertical sections of the glacier mass along five profiles; c) sketch-map and 3-D diagrams of the Galindez Island surface both with the ice cap and without it. It was shown that the vertical electric-resonance sounding method can be effectively used for studying the ice cap structures of the West Antarctic region.

**Key words:** West Antarctic region, vertical electric-resonance sounding method, glaciology, ice caps.

**Визначення товщини льодовика о. Галіндез методом вертикального електрорезонансного зондування.** С.П. Левашов, М.А. Якимчук, В.П. Усенко, І.М. Корчагін, В.Д. Соловйов, Ю.М. Пішчаний

**Реферат.** Наводяться результати геоелектричних досліджень льодового покриву о. Галіндез, отриманих при проведенні сезонних робіт 9 Української антарктичної експедиції. Головна задача досліджень – визначення потужності льодовика – вирішена за допомогою методу вертикального електрорезонансного зондування (ВЕРЗ), який базується на вивченні процесів природної поляризації середовища та спектральних характеристик природного електричного поля над об'єктами, що досліджуються. Метод ВЕРЗ дозволяє визначити глибини розміщення стратиграфічних комплексів розрізу та окремих аномальних об'єктів. На діаграмах зондування впевнено фіксується також контакт між льодовою товщею та корінними породами. Проведені дослідження засвідчили високу ефективність методу електрорезонансного зондування та можливість його практичного застосування при дослідженнях льодових покривів.

**Определение толщины ледника о. Галиндез методом вертикального электрорезонансного зондирования.** С.П. Левашов, Н.А. Якимчук, В.П. Усенко, И.Н. Корчагин, В.Д. Соловьев, Ю.М. Пишчаний

**Реферат.** Приводятся результаты геоэлектрических исследований ледникового покрытия о. Галиндез, полученных во время сезонных работ 9 Украинской антарктической экспедиции. Главная задача исследований – определение мощности ледника – решена при помощи метода вертикального электрорезонансного зондирования (ВЭРЗ), основанного на изучении процессов природной поляризации среды и спектральных характеристик природного электрического поля под исследуемыми объектами. Метод ВЭРЗ позволяет определять глубины размещения стратиграфических комплексов разрезов и отдельных аномальных объектов. На диаграммах зондирования уверенно фиксируется также контакт между ледниковой толщей и коренными породами. Проведенные исследования показали высокую эффективность метода электрорезонансного зондирования, возможность его практического применения при исследовании ледниковых покровов.

### 1.Introduction

To estimate the present global effect of the Antarctic region on the formation of the regional climate change, it is necessary to study the relief's dynamics and thickness change of some glaciers and ice caps on the Antarctic Peninsula and isles of the West Antarctic region.

Such studies were widely performed at different points of this region in the frame of the project "Glaciology of the Antarctic Peninsula". Their main goal was to study the regularities of the glaciations, ice field dynamics, stratigraphic features, formation history and glaciers and ice caps evolution in the West Antarctic region.

The diversity of the method applied in studying the causes of growing warm Antarctic region climate allowed concluding that it was largely due to the change in the large-scale atmospheric circulation in the Southern Ocean – atmosphere system interaction in this region.

The existence of the warming periods in the remote past with some glacier thawed was confirmed by the studying of rock samples taken on the continental shelf under the presently existing shelf glaciers.

These results doubt the hypothesis of the predominant effect of the present human activity on the climate warming process (BAS, 2000-2001).

It should be noted that a notable effect on the formation and course of glaciological processes in this region is exerted by the glacial situation at the Antarctic Peninsula. The difficulties of such studies have impoverished our knowledge of many qualitative and quantitative characteristics of local glacial forms. Therefore the studies of the local features of the regimes of some glaciers and ice caps of the West Antarctic region are urgent and relatively accessible.

## 2. The Galindez Island ice cap thickness investigations

On the Galindez Island where Akademik Vernadsky is located the observations of the ice cap began more than fifty years ago. On the basis of later observations these investigations allowed stating the general significant diminishing of its sizes (Thomas, 1963; Sadler, 1968).

Similar tendency was revealed for other points of the Argentine Archipelago during geodetic observations of the ice caps in 2002 for the first time performed using photogrammetric method with a highly accurate GPS – referring of the coordinates of the observation points (Glotov, 2003).

The researches aimed studying the dynamics of the ice caps of the Argentine Archipelago with the application of the subaerial phototheodolitic survey began in 2002 enabled to determine the spatial changes of some ice caps and their sizes. The dynamic the glacier's masses is less concerned because the detailed topography of the subglacial relief was unknown in spite of the fact that some ice thickness were determined from the earlier radiolocation researches.

As noted in (Thomas, 1963; Sadler, 1968; BAS, 2000-2001) the ice cap of the Galindez Island like other Argentine's Archipelago islands is a relict of the ordinary shelf glacier, which subsequent evolution needs further studies. The discrete monitoring of the Galindez Island ice cap state shows that the unstable balance of the levels of accumulation and ablation during the last decades tends to the predominant ablation (thawing and evaporation) which yields a negative mass balance of this glacier, diminishing of the ice cap's volume (Thomas, 1963; Sadler, 1968).

If such response to the regional climatic changes is steady for a long time the ice cap of the Galindez Island may disappear completely though in remote future.

### 2.1. The principle of electric-resonance sounding

The ERS method (Levashov, 2003) is based on the effect of polarization of the geological section's geoelectric non-uniformities in the Earth's natural quasi-stationary electric field. In its near-surface part the intensity of the Earth's natural electric field  $E(z)$  reaches as much as 100 V/m.

Geological section's non-uniformities, which distinctive feature is anomalous values of the medium's geoelectric parameters, are polarized in the Earth's natural field, creating a system of electric doublets. If the value of  $E(z)$  changes in a natural way or in an artificial way, the electric doubles radiate electromagnetic oscillation with the wave-length  $l=2H$ , where  $H$  is the depth of the bedding of the polarized body's surface.

On this surface the new electromagnetic field resulting from changes in the natural electric potential can be observed. This field can be presented as a wave packet of the electromagnetic oscillation, half the length of the packet's wave corresponding to the depth of the bedding of the polarized body's upper bound.

Identifying and studying this electro-magnetic oscillation enables us to evaluate the depth range of the anomalous electromagnetic body's bedding. On the observed body's surface, identifying and registering the packet's separate waves, as well as determining their characteristics, can be

conducted either through matching the resonance frequency by means of a generator that produces electromagnetic oscillation or by applying long antennas.

In the first method an electromagnetic oscillation generator with smoothly varying amplitude-frequency characteristic curve is used. In the course of measurements the antenna registers moments, when resonance of natural and generator-produced electromagnetic waves of certain lengths occur.

The other method requires an earthed long line fixed in a sounding point. The wave is 'intercepted' by antenna, thus creating nodes with anomalous values of the intensity of the electric field along the waveguide. Values of the field intensity are registered by a flux-meter – the special device designed for measuring the Earth's electrostatic fields.

The model of medium is developed on a base of sounding results, featuring sections with increased and decreased geoelectric resistance.

As known the main rocks composing the Galindez Island are Mesozoic volcanic complexes of liparites – dacitic composition and their tuffs (Oscar series) with some dykes of microdiorites.

Their formation covered the major part of Mesozoic and lasted more than 100 my. The volcanic rocks of this group widely occur along the Penola Strait and Lemair Channel. Here they are

represented by lavas of andesites, dacites and by pyroclastic rocks with more than 1000m thickness (Shepel, 2002).

According to the studies of the physical properties of samples of volcanogenic complexes taken on the Galindez Island, the values of their parameters (electrical resistance especially) differ by more than three orders from the same value for the ice. This creates physical premises for detailed mapping of the subglacial relief by the ERS – method.

This method was applied during the seasonal works of the 9-th Antarctic Expedition in 2004 for studying the thickness of the ice cap situated in the southern part of the Galindez Island.

In recent years BAS is measuring electrical characteristics of some horizons of glaciers differing in the composition of admixtures which enables setting up the distribution of the measured parameters for a comparative correlation with ice cores of different regions.

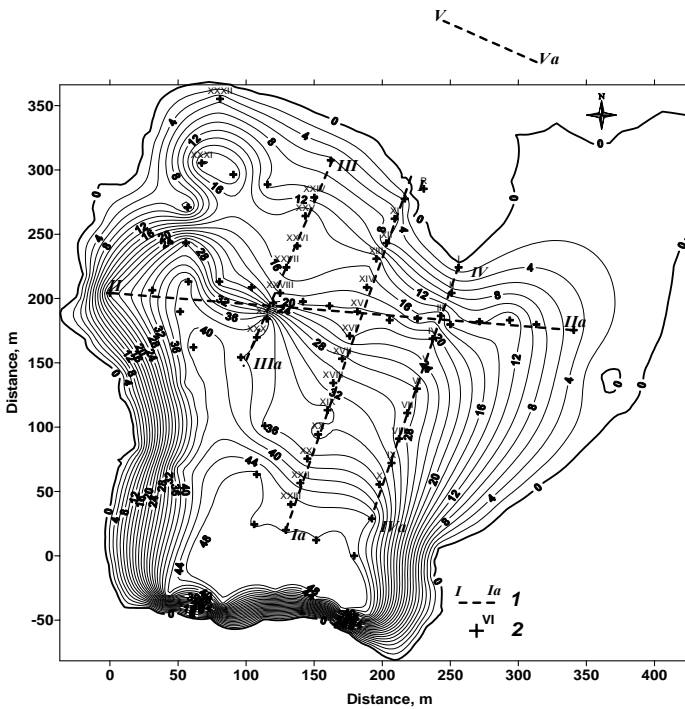


Fig. 1. The sketch-map of the ice cap thickness and profiles and VERS station position. 1 – VERS profiles position; 2 – sounding station position on the ice cap.

The possibilities of the ERS – method in studying the Antarctic Peninsula's glaciers was also notably widened with their using for mapping the dynamics of the behaviour of all ice masses during the marked time span. These data enable to divide into components the total effect of ice thinning due to the superficial compacting and melting processes at its bottom. At present time the glacier thinning can be marked with an accuracy to several millimetres (BAS, 2000-2001).

## 2.2. Results

The ERS – method was used during the seasonal works of the 9-th Antarctic Expedition in 2004 for detailed mapping of the ice cap thickness in the southern Galindez Island.

This dome is elongated, main ice mass is concentrated at the southern end with a steep slope in a form of some cliffs.

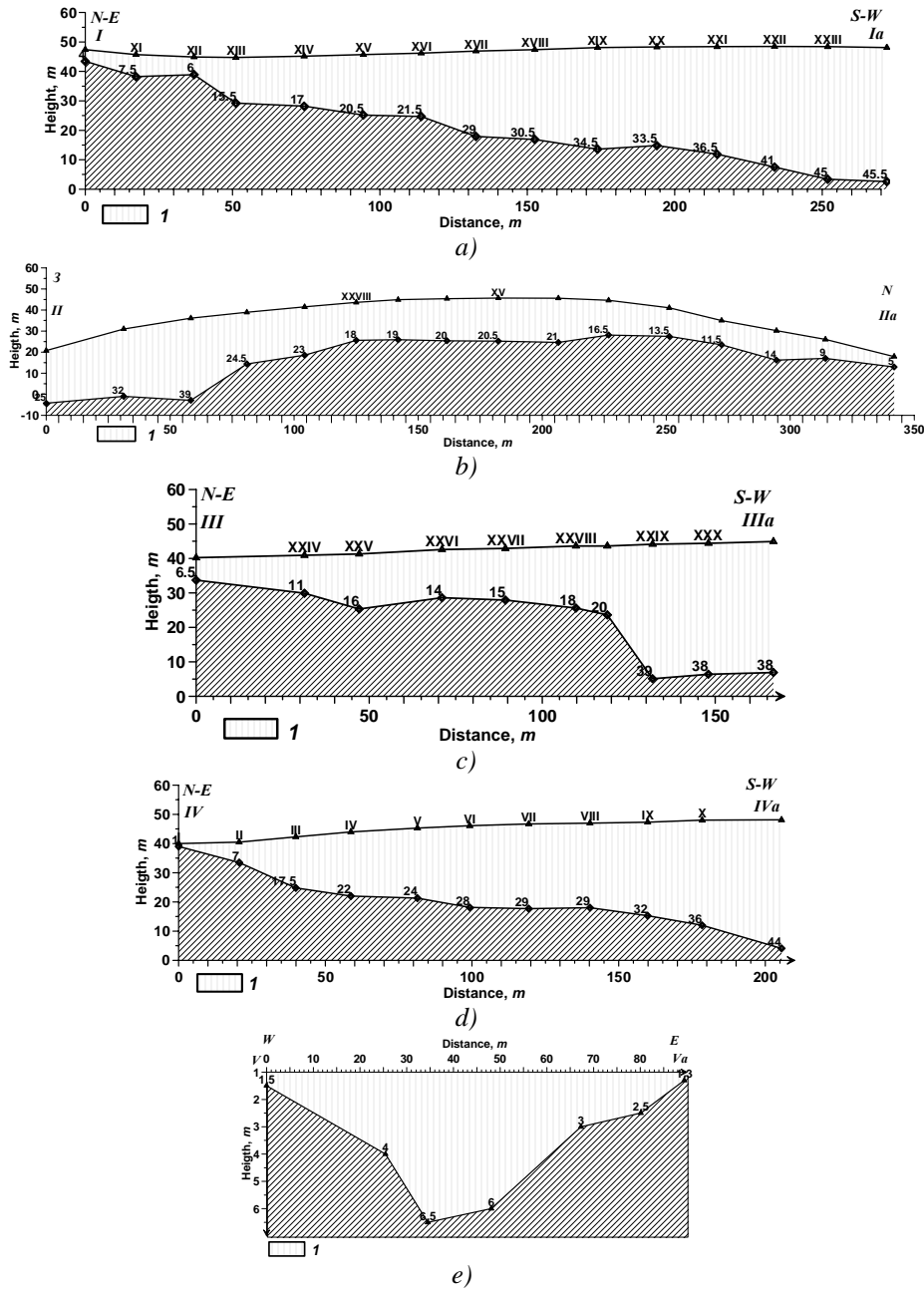


Fig. 2. Vertical cross-section along profiles I – V at the Akademik Vernadsky station (Galindez Island). I – the ice cap thickness.

The measurements show the ice-solid rock boundary reliably distinguished on the ERS-diagrams. The measurements carried out by the vertical ERS – method at 75 points situated on the ice cap along four long and one short profiles. The ice cap contour was mapped by more than 125 points (fig.1).

These data were used to construct vertical sections of the glacier mass that enabled to set up the detailed scheme of the subglacial relief of this part of the island (fig. 2-3).

These results were used to set up: a) a sketch-map and 3-D diagram of the ice cap thickness on Galindez Island; b) vertical sections of the glacier mass along five profiles; c) sketch-map and 3-D diagrams of the Galindez Island surface both with the ice cap and without it.

The ice cover thickness distribution confirms the domal (ice cap) character of this small glacier's formation – there is small ice thickness on its north-, east- and west-margins and thickening cap (up to 30–40 m) in its central part. The thickest ice (up to 45–48 m) is observed in the southern part of this island (fig. 2-3).

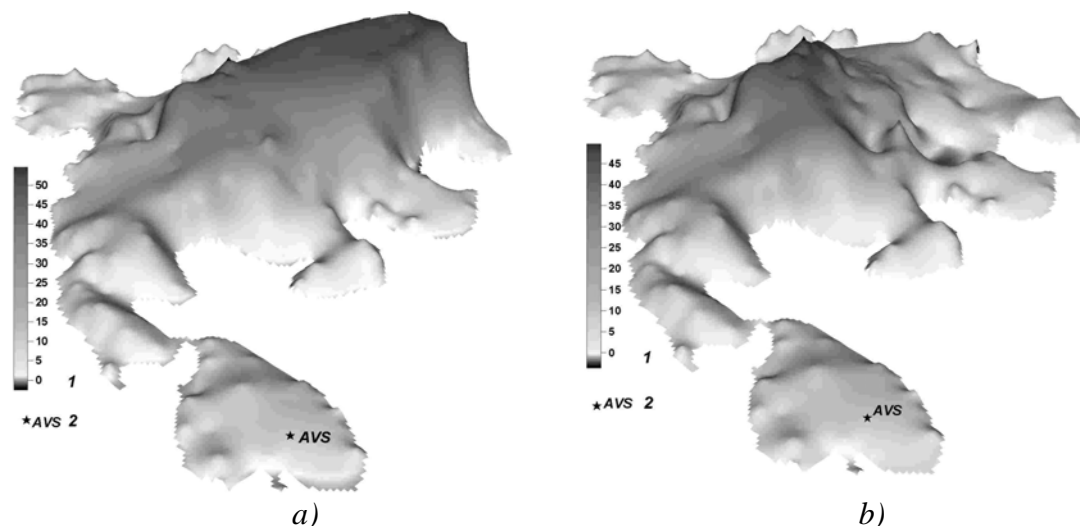


Fig. 3. 3-D model of Galindez Island: a) with ice cap; b) without it. 1 – height scale; 2 – Akademik Vernadsky” station.

The sounding diagrams clearly distinguish the main ice–solid rock border which behaviour confirms the assumption of the relative smoothing of the rocky relief under the prolonged effect of the glacier.

The gentle position of the solid bed gradually smoothing in S–wards changes only at several points where some tectonic disturbances in the central part of this glacier may occur.

### 3. Conclusion

During the seasonal works in the 9-th Ukrainian Antarctic Expedition the thickness of the ice cap situated near the Akademik Vernadsky station on the Galindez Island was measured. This problem was solved by the vertical electric-resonance sounding method that is widely used in solving different ecological, geologic-geophysical and geologic-engineering problems.

The vertical electric-resonance sounding method (ERS method) is based on the effect of the polarization of geoelectrical inhomogeneities of the geological section in the Earth's natural quasi-stationary electric field. This field can be presented as a wave packet of electromagnetic oscillations. Half of the length of the packet's wave is corresponding to the bedding depth of the polarized body upper boundary. Identifying and studying of these electromagnetic oscillations enables to evaluate the depth range of an anomalous electromagnetic body bedding.

During the seasonal works electromagnetic soundings were made at 75 points situated on the ice cap of Galindez Island. The ice cap contour was mapped by more than 125 points.

Results of these works were used to set up: a) a sketch-map and 3-D diagram of the ice cap thickness on Galindez Island; b) vertical sections of the glacier mass along five profiles; c) sketch-map and 3-D diagrams of the Galindez Island surface both with the ice cap and without it.

The researches performed show that the vertical electric-resonance sounding method can be effectively used in studying of the ice cap structures of the western Antarctic.

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