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Russian RES and GPR research in Antarctica

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Abstract. Russian (former Soviet Union) investigations of Antarctica by radio-echo sounding (RES) were commenced in 1964. In two years later, ice-penetrating radar has been fixed on board the airplane IL-14 opening the door to future airborne studying of the Antarctic ice sheet and bedrock topography. By present the ground-based profiles and mostly airborne RES flights have covered more than 5.5 mln. sq. km of icy continent. Since 1985 Russian airborne research concentrated to study 60E – 110E sector of East Antarctica carrying out 5-km apart surveys. In the period of 1990s – 2010s ground-based RES research in scientific traverses were concentrated to study Lake Vostok and the Antarctic inland. Systematic Russian ground-penetrating radar (GPR) investigations was commenced in 2010s. Mostly it was a reason to study and revealing of crevasses in the area of logistic traverse route and other safety supply of the logistic operations. As well GPR engineering research used to find a right place to construct a new snow-runway at Mirny Station, also to investigate icy-runway at Novolazarevskaya Station and new snow airfield Zenith, near Progress Station, East Antarctica.

1. The initial stage of systematic geophysical research: 1950s - 1970s

An important old stage of Antarctic research finished with the beginning of the First International Geophysical Year (IGY), which took place in 1957-58. It lasted more than a hundred years, and had a pronounced geographical focus. Despite the fact that a large amount of research was carried out during that time, knowledge about the continent as a whole was fragmentary and descriptive. The most significant achievement of that stage was the determination of the coastline of the icy continent, the mapping of large glaciers and mountain ranges, as well as the creation of a system of geographical names for lands, coasts and seas. New stage which commenced with IGY brought active study of Antarctica, its ice sheet and subglacial relief [1,2]. The importance of the geophysical, glaciological and geological data collected in that time cannot be overestimated for related fields of science and lights are the basis of most constructions. In particular, the maps of ice thickness and subglacial relief are the base for creation of structural-tectonic schemes and geomorphological maps, also for glaciological and climatic reconstructions.

In February 1956, Russia (Soviet Union in that time), opened its first Antarctic station, Mirny, on the Davis Sea coast. This remarkable event opened the doors to study of the icy continent in the 20th century, including the ice sheet and subglacial topography. At that time, only very complex seismic methods were used for this [1,2]. The turning point came in February 1964, when new radio-echo sounding (RES) technique was carried out in the area of Mirny station for the first time in the

history of Russian Antarctic research. The GUYS-1M4 naval radar was used for these first experiments [1,2]. Two years later it was installed on the IL-14 aircraft, and the first aviation tests were carried out. This opened wide prospects for using a new effective mobile geophysical method to study the glaciers and also subglacial relief. In a year later, in 1967, the first special Russian ice-penetrating radar was developed in the Arctic and Antarctic Research Institute (AARI) [1,2]. In February 1968, the first Russian airborne RES survey from IL-14 aircraft was carried out on Enderby Land (East Antarctica) with space between profiles of about 50 km. The GUYS-1M4 radar was used. The total length of the flights was about 11,000 km [1,2]. The location of all RES and seismic research is shown in fig. 1.

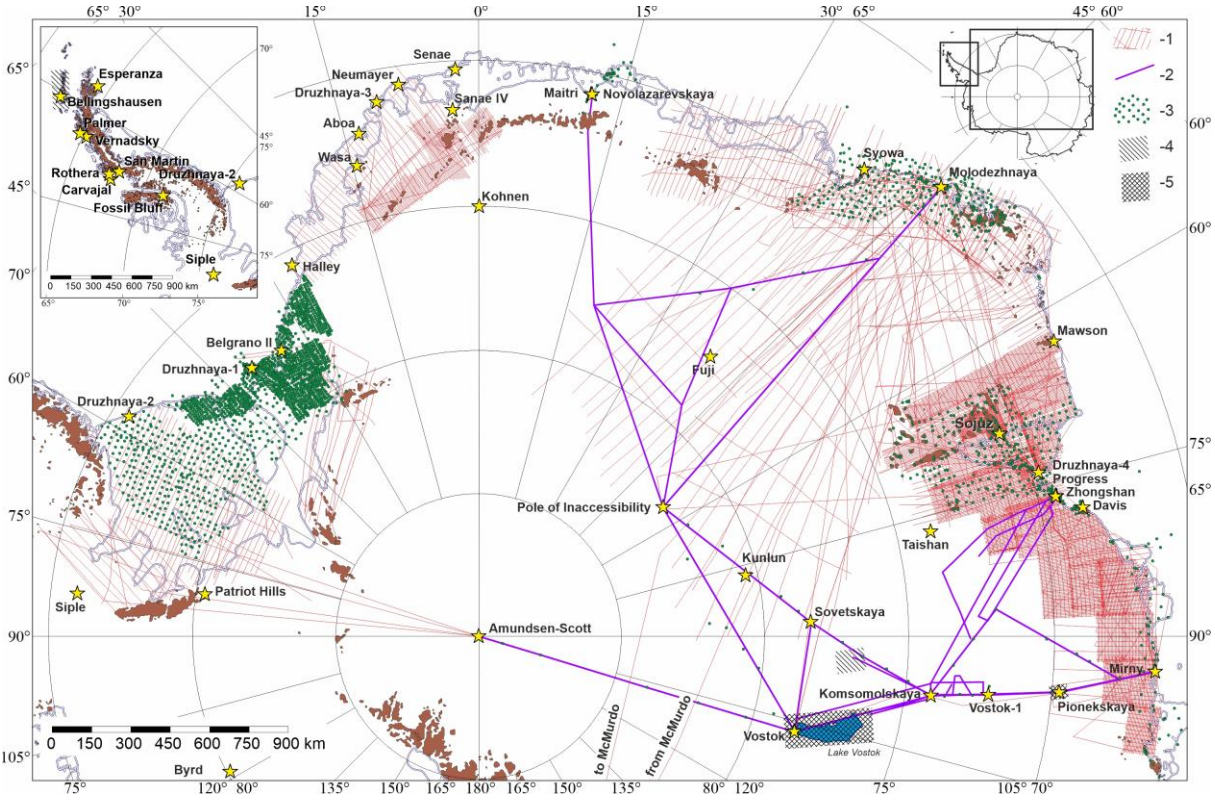

Figure 1. Location of Russian RES and seismic research. 1- airborne RES; 2- ground-based RES; 3- reflection seismic soundings; 4- area of ground-based RES survey; 5- area of ground-based RES and reflection seismic survey.

2. Stage of systematic airborne survey: 1970s – 1990s

The period from the beginning of 1970s to the end of 1980s is a “Golden Age of Russian Geophysics”. Over these two decades, complex airborne geophysical surveys, including RES, covered more than 5 million sq. km of Antarctica [1,2]. Operation “Amery”, which was carried out in 1971-74, can rightfully be considered the widest Russian project of that time which carried out by the Polar Marine Geosurvey Expedition (Polar Geophysical Expedition in that time) in the sector of 60E – 110E (fig. 1). The main tasks of operation "Amery" included a comprehensive study of the area of the Lambert-Amery glacier system and Lambert rift valley. Airborne RES flights were carried out from IL-14 aircraft along a regular network with the space between profiles of about 20 km. Special designed ice-penetrating radar RLS-60-67 with a main frequency of 60 MHz was used. Reflection seismic soundings were also carried out on a network of 30×30 km to measure the sea depths under Amery Ice Shelf (fig. 1) [1,2]. The collected data was taken as the base for subsequent structural and tectonic constructions for this region [3–5]. After a significant interruption, in 1985, geophysical research in

this area was resumed by carrying out systematic airborne RES and magnetic surveys with the space between profiles of 5 km (fig. 1) [1,6].

The next important result of this stage was wide airborne geophysical research in the Antarctic inland. These investigations were carried out over three field seasons of 1987-90 using the flying laboratory based on IL-18D GAL airplane with space between profiles of 50 km [1,2]. One of the main results of these research was the revealing the main features of the subglacial Gamburtsev mountains, the largest mountain country, covered by ice which discovered in 1958 during the scientific traverse of the 3rd Soviet Expedition [7]. The next time the study of this difficult to access region was carried out under umbrella of the international project AGAP only two decades later [8,9].

The main result of this stage was the accumulation of plenty radio-echo and seismic data as Russian as by international expeditions. As following, this was a good opportunity to start ambitious international project Bedmap to compile all the data on the ice thickness and bedrock which collected in Antarctica.

3. Recent RES research: 1990s – 2020s

During the current stage, Russian research is focused on studying the sector of 60E – 110E (fig. 1). At the same time, there was a change in the scientific priorities: the main topic transforms to more deep study of the glacier structure and the subglacial processes including hydrological ones. Airborne investigations were carried out using a flying laboratory based on AN-2 aircraft. See details at [6].

The most grandiose scientific event of the end of the last century was the Lake Vostok revealing [10,11]. Due to the geographical location and logistics capabilities since 1995 Russian researchers began a systematic study of this area using ground-based remote geophysical methods. They included reflection seismic (since 1995) and RES (since 1998) [12]. These investigations were yielded to determine of the lake coast and the ice thickness in the drilling site vicinity. That was extremely important for safe penetration into Lake Vostok. Thise geophysical research was resulted in the area of the water surface of Lake Vostok is 15,790 km², eleven islands have been identified inside the lake, and 56 isolated subglacial reservoirs were also revealed. The total volume of Lake Vostok is estimated about 6100 km³ [12].

In the same time during the field seasons of 2004-13 ground-based RES mostly with glaciology and geodesy were carried out along the “Mirny – Vostok” and “Progress – Vostok” traverse routes (fig. 1). They gave the first new information about glacier structure and bedrock topography of a large gap between Argus Dome and Lake Vostok. In addition, these researches discovered a subglacial lake located in 821-st km from Mirny to Vostok and one more was revealed exactly under Pionerskaya Station [1,2].

4. GPR research

Russian GPR research in Antarctica has been commenced in 2012 for safety supply of transport operations of the Russian Antarctic Expedition mostly [1,2]. Now they include searching right places for airfields, testing airfields, engineering surveys for the construction of new buildings of the Vostok station, choosing a site for unloading ships and others. The most important GPR engineering research was three-year investigations at Mirny station to construct new airfield for ski-chassis airplane. On February 10, 2016 the DC-3T (BT-67) “Turbobasler” airplane by ALCI Company was accepted. Thus, aviation communication with Mirny station, interrupted for two decades, was restored. After that GPR research was carried out at icy runway at Novolazarevskaya Station and new snow runway Zenith at Progress Station to check the internal structure there.

One of the most significant recent fundamental GPR research was the study of a vast depression 183×220 m, with a depth of 20-30 m in the Dålk glacier (Larseman Hills, Princess Elizabeth Land, East Antarctica). It formed after outburst of an interglacial lake [13,14]. Thus, researchers have a real opportunity to see and simulate the processes that occur under a very thick ice and multidisciplinary scientific research, including GPR, made it possible to create a mathematical model which describe this kind of processes [14].

Russian RES and GPR research continue as a systematic investigation to study glacier structure, bedrock, and subglacial processes especially subglacial hydrological processes.

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