

MEMBER COUNTRY: Russia
National Report to SCAR for: 2008-09

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A BRIEF SUMMARY OF SCIENTIFIC HIGHLIGHTS:

RUSSIAN GEOSCIENCE ACTIVITIES IN 2008

ORGANIZATIONS INVOLVED:

Federal Research Institute for Geology and Mineral Resources of the World Ocean (Ministry of Natural Resources and Ecology), VNIIOkeangeologia;

Polar Marine Geosurvey Expedition, PMGE (Ministry of Natural Resources and Ecology).

1. FIELD ACTIVITIES (53rd Russian Antarctic Expedition)

Marine geophysics (PMGE).

Marine geophysical studies were conducted on the eastern Wilkes Land and Terra Adelie (EWL-TA) margin and adjacent Australian-Antarctic basin (between 128E and 142E). About 4200 km of MCS, magnetic and gravity data as well as 10 sonobuoys (along the dip MCS line) were acquired during 2007/2008 season. MCS data were recorded with a 352-channels digital streamer and airgun array of 2860 cub. in. in total volume. Preliminary analysis of geophysical data showed that the EWL-TA margin developed as a result of extreme crustal extension and syn-tectonic unroofing of the upper mantle to form the marginal rift of up to 300 km wide. During this process syn-rift sediments were intensively deformed. Oceanic crust of the study region is characterized by sea-floor spreading lineations from 33 to 20. The total thickness of sediments ranges from 2,5 to 10,0 km. Break-up and glacial-onset unconformities are confidently identified in the sedimentary cover and are correlated with those recognized earlier to the east of the studied area.

Onland airborne geophysics (PMGE)

Airborne survey including magnetic and radio-echo sounding (RES) measurements has been conducted in north-western Prince Charles Mts. (between 62E and 64.3E and between 69.3S and 71.3S) over the area of about 15 000 km² with use of short-range airplane (AN-2). Flight lines were oriented north-south and spaced 5 km apart. The RES studies were carried out using a 60-MHz MPI-60 radio-echo sounder with a dynamic range of 180 dB and a pulse width of 750 ns. Totally about 5 000 km of profiles have been acquired. Compiled magnetic anomaly map shows E-W oriented high-amplitude anomalies in the southern part of survey area and generally quiet magnetic field in its northern part.

Onland ground-based geophysics (PMGE)

About 500 km of over-snow radio-echo sounding profiles and 30 reflection seismic soundings have been carried out in the northern part of Lake Vostok. Seismic studies showed that lake depths range between 700 and 1250 m below sea level.

Onland geology (PMGRE, VNIIOkeangeologia)

Geological studies were carried out at the Mount Willing which is part of volcano-plutonic province of the central Prince Charles Mts. According to field geological mapping Mount Willing composed of four rock complexes: 1) metamorphic (predominantly plagiogneisses); 2) metaintrusive (gabbro-diorite-plagiogranite assemblage); 3) intrusive (layered gabbro); and 4) vein (granodiorites, diorites, dolerites, pegmatites). Two stage of metamorphism are identified in the rock complexes. First (main) stage (amphibolitic facies) is dated by 1020–1000 Ma and second stage (low-grade) is dated by 810 Ma. The age of the layered gabbro intrusion is estimated to be 1250 Ma.

INDOOR ACTIVITY

Tectonic Map of Antarctica (VNIIOkeangeologia)

A new tectonic map of the Antarctic at 1:10 M scale is produced as part of a CGMW project that was also endorsed as an IPY activity. In contrast to previous Russian compilation published almost 30 years ago, this project was executed internationally, though the bulk of preparatory activities was concentrated at VNIIOkeangeologia. Prominent earth scientists from different Antarctic nations were invited to join the compilation team, and those who agreed were continuously consulted during elaboration of the legend and concerning the areas of their specific knowledge. At all stages the compilation procedures were closely supervised by the CGMW leadership and the CGMW Sub-commission for tectonic maps. The new map for the first time shows the tectonic structure not only of the Antarctic continent but also of its submarine margin and the surrounding deep water seabed. Another important distinction from earlier compilations is the separation of the legend into three main blocks defined in the first place by geodynamic settings rather than by a priori assignment to continental, oceanic and/or transitional crustal types which only appear in the legend as additional subdivisions in each of the three major geodynamic settings. The main map is accompanied by supplementary smaller-scale graphics imaging a generalized view of Antarctic tectonic provinces, potential field data, crustal profiles across the continent-ocean transition zone, and sketches of location of different datasets used in the course of compilation. The first draft of the Tectonic Map is planned to be finished in February 2010.

Geochemical and isotopic studies in the Prince Charles Mountains and Amery Ice Shelf fringe (VNIIOkeangeologia, PMGE)

New ion-microprobe U–Pb SHRIMP and LA zircon data were obtained to confirm major tectonomagmatic events at *ca.* 3150 Ma, 2800 Ma, and 2500 Ma in the southern Prince Charles Mountains (PCM) and *ca.* 1150 Ma and 500 Ma in the northern PCM and Amery Ice Shelf fringe. New Sm–Nd data

were obtained for about 30 orthogneiss and granite samples throughout the area, which contributes to much better understanding of the isotopic structure of the region. Initial separation of the continental crust in the southern PCM from the mantle basically occurred between *ca.* 3400–3100 Ma, and two mantle reservoir which correspond to (1) depleted to slightly enriched, and (2) ultra depleted mantle may be discerned. Some material could have been derived from somewhat enriched mantle at *ca.* 2700–3000 Ma. In the northern PCM much younger protoliths occur with crystal residence time basically between 2400–1400 Ma. The Sm–Nd data are available at www.vniio.ru/projects/rfbr. Extensive geochemical studies of metavolcanic and plutonic rocks from the central PCM (Fisher Massif, Willing Massif, Shaw Massif) are under way. The isotopic data allow outlining the geological history of the different tectonic provinces in the PCM, and to constrain a comprehensive correlation of their geological history and geodynamic environments to other parts of East Antarctica and other Gondwanaland blocks.

Subglacial Environments (VNIIOkeangeologia)

Thirteen small (0.7 – 4 mm across) rock clasts represented by sandstone and siltstones were extracted from ice cores of Vostok Drill Hole from the depth 3608 m. These clasts were studied using electron microscopy and QEMSCAN system to identify mineral composition. 11 detrital zircon and 10 monazite grains from 9 clasts (10 – 30 μ m in size) were identified. These U-bearing minerals will be analyzed by SHRIMP to determine their age and to speculate about tectonic setting of the provenance.

Antarctic Digital Magnetic Anomaly Map (ADMAP Project, VNIIOkeangeologia and ADMAP consortium)

VNIIOkeangeologia is responsible for compilation and upgrade of the Antarctic magnetic anomaly map within the ADMAP Project. In 2008, this work was routinely continued and mostly new Russian marine (about 6 000 km) and German (AWI/BGR) airborne (closely spaced) magnetic data (about 8 000 km) collected during IPY project in the area of the southern Kerguelen Plateau have been processed and added to the ADMAP data base. As a result a new magnetic map for the area between 65E and 85E and between 61S and 70S has been compiled.

Antarctic Bedrock Topography and Ice Sheet (ABRIS Project; PMGE and VNIIOkeangeologia in co-operation with Institute of Geography, RAS)

A bedrock topography map of the central (hinterland) part of East Antarctica compiled in 2007 has been developed. The bedrock topography of Enderby Land and Lambert Glacial area has been added. See <http://abris.pmge.ru> for more information about the ABRIS Project.

Selected publications

Leitchenkov G., Guseva J., Gandyukhin V., Grikurov G., Kristoffersen Y., Sand M., Golynsky A., Aleshkova N. 2008 Crustal structure and tectonic provinces of the Riiser-Larsen Sea area (East Antarctica): results of geophysical studies. *Mar. Geoph. Res.* Vol. 29. pp. 135-158.

Mikhalsky E.V. 2008. Age of the Earth's Crust and the Nd Isotopic Composition of the Mantle Sources of East Antarctic Complexes. *Geochemistry International*. Vol. 46, No 2, pp. 168–174.

Mikhalsky E.V. 2008. Sm–Nd crustal provinces in Antarctica. *Doklady Earth Sciences*. Vol. 419A, No 3, pp. 388–391.

Mikhalsky E.V. 2008. The major episodes and geodynamic environments of formation of the East Antarctic continental crust in the Proterozoic □ Early Palaeozoic. *Geotectonics*. □ 6, pp 1–23.

Whittaker J. M., Müller R. D., Leitchenkov G., Stagg H., Sdrolias M., Gaina C., Goncharov A. 2008. Response to Comment on “Major Australian–Antarctic Plate Reorganization at Hawaiian–Emperor Bend Time”. *Science*. Vol. 321. □ 5888, p. 490

□ Cooper A. G. Brancolini, C. Escutia, Y. Kristoffersen, R. Larter, G. Leitchenkov, P. O'Brien, W. Jokat. 2008. Cenozoic climate history from seismic-reflection and drilling studies on the Antarctic continental margin, In M. Siebert and F. Florindo (eds). *Antarctic Climate Evolution*, Elsevier. In: Florindo, F. and Siebert, M. (eds), *Antarctic Climate Evolution, Developments in Earth & Environmental Science*. Vol. 8, Elsevier, pp. 115–228.

Mikhalskii E.V., Belyatskii B.V., Sergeev S.A. 2009. New data on the age of rocks in the Mirnyi Station area, East Antarctica. *Doklady Earth Sciences*. Vol. 426, No 4, pp. 527–531.

Sushchevskaya N.M., Belyatsky B.V., Leichenkov G.L., Laiba A.A. 2009. Evolution of the Karoo–Maud Mantle Plume in Antarctica and Its Influence on the Magmatism of the Early Stages of Indian Ocean Opening. *Geochemistry International*. Vol. 47, No. 1, pp. 1–17

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An obvious character of the climate change that took place at the planet in the 20th century determines the need for a quantitative study of variability of parameters of the Earth's climatic system for creating justified scenarios of the future climate changes. The South polar area being a unique component of the Earth's climatic system produces a significant influence on the formation of global climate and serves as an indicator of current climate changes.

The global climate models predict in what way the Antarctic climate can change during the current centennial, differing in details from model-to-model. The results of most climate models point to a comparatively moderate air temperature increase in the Antarctic during the next decades. However, many processes occurring in the Antarctic region are not quite fully represented in the climate models, and the studies of current and future state of the climatic system require developing the numerical models based on reliable evidence of the current state of climatic conditions. An unsatisfactory description of the Antarctic atmosphere in modern climatic archives can be attributed not only to a sparse network of stations, but also to inaccessibility for investigation of reliable historical archives of meteorological measurement data. Since the duration of regular meteorological measurements exceeds 50 years only at some stations, the answer to the question whether the air temperature changes in the Antarctic reflect the global climate change remains open. For most Antarctic stations the temperature trends are small and as a rule statistically insignificant. The values of the trends depend to a great extent on the interannual variability and the period of data analysis. Therefore it cannot be definitely said at present what is typical of Antarctica in general: warming or cooling.

A database on climate of the Antarctic atmosphere was created at the Arctic and Antarctic Research Institute (St. Petersburg, Russia) based on the information of Russian and foreign Antarctic stations, including the results of surface and upper-level measurements with assessment of completeness of initial data, data quality control and taking into account the changes of parameters of the measurement complexes. For construction of this database the results of observations of main meteorological elements at standard synoptic hours at the stations of all countries conducting studies in the Antarctic, were collected for the period of instrumental measurements including data of 44 meteorological, 46 automatic and 20 upper-air stations. The support of the Scientific Committee on Antarctic Research (SCAR) in the framework of the READER (Reference Antarctic Data for Environmental Research) Project provided for the first time an access to the national meteorological data archives of countries-operators in the Antarctic and unification of the methodology of primary processing of synoptic information. This work is carried out in the cluster project COMPASS IPY 2007/08. One of the Antarctic regions where significant changes both in the surface layer and in the free atmosphere were observed in recent years is the central and southern parts of the west coast of the Antarctic Peninsula. The length of climatic series for this region is more than 50 years, and the mean annual temperature has increased here for this period almost by 3 °C, which is much higher than in the other regions of the Southern Hemisphere. A probabilistic analysis of the time series of key elements of the Earth's climatic system of the Antarctic performed for determining the tendencies of multiyear changes and characteristics of their interannual variability given the modulation of annual variations within the interannual and seasonal variations of synoptic scale variability showed that a possible cause of regional warming is intensification of synoptic and mesoscale vortex activity. In the data of Russian Antarctic stations the average annual trends of surface air temperature for the entire period of instrumental observations were $+0.03 \pm 0.02$ °C year⁻¹ for Bellingshausen station (1969-2007), $+0.01 \pm 0.02$ °C year⁻¹ for Mirny Observatory (1956-2007), $+0.02 \pm 0.01$ °C year⁻¹ for Novolazarevskaya station (1962-2007) and $+0.01 \pm 0.02$ °C years⁻¹ for Vostok station. Only the climatic trends for Bellingshausen and Novolazarevskaya stations are statistically significant.

During the last decade of the 20th century the average air temperature in the lower stratosphere (at the level of 150–100 hPa) over the Antarctic Peninsula has decreased by 4-5 °C in the summer-autumn period compared to the conditions in the 1970s-1980s. For the average annual conditions the statistically insignificant air temperature trend during the period 1956-2002 was -0.06 ± 0.08 °C year⁻¹. In summer, a negative temperature trend (-0.07 ± 0.07 °C year⁻¹) is statistically significant and approximately twice as large as the corresponding values for the winter season (-0.03 ± 0.04 °C year⁻¹).

Pronounced cooling in the lower stratosphere is probably connected with the change of radiation forcing due to a decreased ozone concentration and increased carbon dioxide concentration. In the vicinity of King George Island, warming in the troposphere comprises the largest values in the Southern hemisphere, which is explained by variability of the cloud cover, prevailing large-scale advection of air masses and increased activity of extra-tropical cyclones.

The climatic changes of the lower cloud boundary in the 0-2 km, 2-6 km, 6-10 km and 0-10 km layers for different amounts of clouds - 0-20 %, 0-60 %, 0-80 % and 0-100 % of the sky are estimated for all seasons and for average annual conditions. It was determined that the lower boundary of cloudiness covering 0-100 % of the sky in the 0-2 km and 0-10 km layers at Bellingshausen station has decreased by -35 m/decade and -66 m/decade, respectively. The maximum increase of recurrence of low clouds (11.8 %/decade) was recorded for June. The increase of recurrence of cloudiness in the atmospheric layers of 0-6 km \square 0-10 km is observed in June and comprises 7 %/decade and 2.2 %/decade, respectively. The maximum seasonal increase of recurrence of low clouds (7.4 %/decade) and cloudiness in the 0-6 km layer (3 %/decade) is recorded in winter of the Southern Hemisphere. An increase of low clouds and cloudiness in the 0-6 km layer for average annual conditions is 4.0 %/decade and 1.4 %/decade, respectively. During the winter season the lower boundary of clouds covering 80-100% of the sky in the atmospheric layer of 0-2 km rises by 20 m/decade for July and decreases by -18 m/decade in August.

Current meteorology, actinometry, ozone and upper air dataset of Russian Antarctic Circumpolar network has been completed based on 2009 observation results for all standard measurement programs. Detailed statistical analysis of surface synoptic observation results was provided for Russian Bellingshausen station located at sub-Antarctic King George Island. These results indicate the importance of large-scale processes for strong regional warming event formation because positive annual temperature trend ($+0.03 \pm 0.02$ °C/year for 1969-2008 period) corresponds to negative tendency of intra-monthly temperature dispersion. During first decade of XXI century atmospheric warming over Antarctic Peninsula increased, for instance, maximal monthly temperature trend reveals for August $+0.07 \pm 0.06$ °C/year for 1968-2008 period. Near the tropopause (250-300 hPa isobaric layer) there was registered the strongest warming in the Earth over North part of Antarctic Peninsula.

In the framework of IPY COMPASS project two new Russian automatic weather stations were established at meteorological places of Leningradskaya and Russkaya seasonal bases.

An assessment of the variability of total ozone concentration during the period of the Antarctic ozone anomaly in 2004 - 2007 was made. A complex of equipment for measurements of the \square_2 , \square_2 , \square_4 , \square and N_2 concentrations in the atmosphere at Novolazarevskaya station was prepared. An assimilation model of gas composition of the Antarctic atmosphere was updated taking into account the processes of formation and evolution of polar stratospheric clouds. The database of ground and satellite measurements of ozone and other greenhouse gases in the Antarctic atmosphere was set up.

Archives of the hourly sums of total radiation and spectral aerosol thicknesses of the atmosphere in Antarctica from 1983 up to present were prepared. Data of measurements of semi-spherical and zonal spectral density distributions of the energy brightness of the atmosphere and cloudiness at the range of 0.35-2.9 μ m under different meteorological conditions at Novolazarevskaya station were processed. The radiation models of the state of the

atmosphere and cloudiness at the range intervals of 3-13 μm from data of measurements in the Antarctic were developed. A data archive of solar radiation measurements at the Russian Antarctic stations for the entire observation period 1956 to 2006 was established

Oceanography

More than two hundred CTD stations were made from r/v «Akademik Fedorov» in the continental shelf and slope area near Prydz Bay in 1997 - 2008. Main objective of cruises was to investigate the structure and water masses modification at the Antarctic Slope Front. During the last four years the processes at the continental slope were investigated in the region to the west of Prydz Bay. CTD soundings were made with the spatial resolution around 3 miles at the meridional sections. Sections begin on the shelf near the shelf break, cross the continental slope and reach the deep ocean area. Data show Ice Shelf Water goes to the north along western border of Amery Depression and then flows down the continental slope in the region to the west of Prydz Channel ($\sim 72^\circ$ E). Sinking of dense water plumes along continental slope was not found in the region to the east of 72° E. Descending water in the region to the west of Prydz Channel results in deep water ventilation and bottom water formation. Prydz Bay Bottom Water (PBBW) with the potential temperature -0.3 -1.6°C and salinity 34.54‰ $- 34.62\text{‰}$ is found between 64° E and 72° E at the depth 1300 – 2000 m. PBBW is colder and less saline than Antarctic Bottom Water observed in this region. Studies of the last year are integrated in IPY research project SASSI.

In the frames of IPY CLICOPEN Project at the vicinity of Bellingshausen station there were continued regular all year hydrology observations. Annual course of sea water temperature, salinity, sea level and zooplankton community activities was obtained and compared with available previous observation results.

Paleoclimate and Vostok studies

The Russian ITASE program has focused on the vicinity of Vostok Station. Lake Vostok drilling program was continued. Data of the new ice core studies of the subglacial Lake Vostok, data of geophysical observations in the borehole 5G-1 and data of radio-echo sounding, seismic and glaciological studies in the northern part of Lake Vostok were analyzed. A layout of the updated chart of ice sheet thickness of Lake Vostok at the scale of 1:1 000 000 was created. Estimates of glaciation parameters of the key regions of the marginal zone of East Antarctica during the last glacial maximum were derived. A method of decontamination of the ice samples for biological studies was developed.

Glaciology

Quantitative characteristics of the modern continental ice discharge and estimates of accumulation within the ice catchment basins were derived. The variability of Antarctica coastline was estimated and scenarios of the evolution of glaciers of the marginal zone of Antarctica and Sub-Antarctica were developed. Estimates of the dynamics of mass balance of the Antarctic ice sheet during the second part of the 20th century were performed.

In the frames of IPY ANTPAS cluster activities three geocryology polygon measurements of permafrost active layer parameters distribution are obtained near Bellingshausen, Novolazarevskaya and Progress stations. During 2009 summer season extreme value of permafrost melting layer is 135 cm at King George Island . Russian Antarctic geocryology data are presented at international circumpolar Internet resources <http://www.udel.edu/Geography/calm/data/south.htm> .

Biology

New data on the species composition of some groups of animals and plants, marine and terrestrial ecosystems, including the taxonomic lists by individual groups of biota by the Antarctic regions were analyzed. The descriptions of the new species for science from different groups of flora and fauna and an analysis of the structure of benthic pelagic community of the Weddell Sea were given. A quantitative analysis of zooplankton in Ardley Bay (in the vicinity of Bellingshausen station) was performed from the materials of full-scale year-round investigations. Data of monitoring of a colony of emperor penguins of Haswell Island were processed. Data of molecular-genetic and biochemical studies of Antarctic lichens were analyzed. A dependence of micro-biota on the character and manifestation of natural and anthropogenic loads was investigated. The information-retrieval system and a database on the Antarctic biota were set up.

In the framework of IPY CLICOPEN project the investigations of the zooplankton of the Ardly Bay demonstrated annual and inter-annual variations of krill community. Special study of climate warming input to marine, coastal and terrestrial ecosystems development over Antarctic Peninsula area is provided. King George Island fresh water lakes plankton parameters are studied and described.

The new data about the lichenoflora composition and distribution over Filds Peninsula of King George Island and the Antarctic Peninsula have been found; where 150 species of 52 genera and 25 families were sampled. Systematic description of available Antarctic circumpolar lichen collection was made.

Sea bottom fauna study at Progress station presents several new sea floor animal forms.

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Solar wind influence on atmospheric processes in winter Antarctica

The experimental results demonstrating the strong influence of the interplanetary electric field on atmospheric processes in the central Antarctica have generalized. The unique feature of the Antarctic atmosphere during the winter seasons is the large-scale system of vertical circulation. The influence of the interplanetary electric field is realized through acceleration of the air masses, descending into the lower atmosphere from troposphere, and formation of cloudiness above the Antarctic Ridge, where the descending air masses income into the surface layer. The acceleration is followed by sharp increase of the atmospheric pressure in the near-pole region, which gives rise to the katabatic wind strengthening above the entire Antarctica. The cloudiness formation is resulted in the sudden warmings in the surface atmosphere, since the cloud layer efficiently backscatters the long wavelength radiation going from the ice sheet, but does not affect the adiabatic warming process of the descending tropospheric air masses. When drainage flow strengthening the circumpolar vortex about the periphery of the Antarctic continent decays, the surface easterlies typical of the coast stations during the winter season are replaced by southerlies and the cold Antarctic air masses flow out to the Southern ocean. (AARI, St.Petersburg, Russia)

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