EXPLORATION & PROTECTION OF MINERAL RESOURCES

SINCE 1931

BRICS 2024 RUSSIA

SPECIAL ISSUE

http://rion-journal.com

УДК 551.321

G.L. Leitchenkov[1,2], P.G. Talalay[3,4], N. Zhang [3], I.A. Abdrakhmanov[1], D. Gong[3], Y. Liu[3], Y. Li[4], Y. Sun[4], M. Vorobyev[5], B. Li[4]
[1]All-Russian Scientific Research Institute for Geology and Mineral Resources of the Ocean (VNIIOkeangeologia), St. Petersburg, Russia
[2] St. Petersburg State University, St. Petersburg, Russia
[3]Institute of Polar Science and Engineering, College of Construction Engineering, Jilin University, Changchun, China
[4]School of Engineering and Technology, China University of Geosciences, Beijing, China
[5]Institute of Geography, Russian Academy of Sciences, Moscow, Ru**ssia**

FIRST TARGETED GEOLOGICAL SAMPLING BENEATH THE EAST ANTARCTIC ICE SHEET: JOINT RUSSIAN-CHINESE DRILLING PROJECT

Targeted bedrock sampling was carried out on Princess Elizabeth Land by drilling through a 545 m thick ice. The borehole was drilled using cable-suspended Ice and Bedrock Electromechanical Drill (IBED) designed by the Jilin University (China) and under a joint scientific project between VNIIOkeangeologia, Jilin University and China University of Geosciences (Beijing). The drill site is located on the axis of a high-amplitude linear magnetic anomaly that runs parallel to the coast for more than 500 km from Princess Elizabeth Land to Mac.Rosbertson Land. The nature of this anomaly remained unclear, but it is thought to be related to the suture zone between Proterozoic terrains formed during the Neoproterozoic amalgamation of the Rodinia supercontinent. ***Keywords:*** *Antarctica, drilling, bedrock, ice cores, rocks, magnetic anomaly.*

Over the 99 % of Antarctica is covered by ice, and one of the most exciting investigations of our planet concerns the exploration of Antarctic subglacial environments — «enigmatic world» beneath the ice sheet. Subglacial environments have become central to our understanding of the Antarctic ice sheet's formation and to assessments of possible future climate change and sea level rise. Moreover, to date, we have no reliable information at all about the geology of Antarctica beneath the ice. Indirect information about subglacial crustal structure and geology is provided by geophysical surveys (mainly airborne magnetic data), but this requires confirmation by direct sampling (drilling) of the bedrock. Several ambitious projects of this type are currently underway (e.g, USA's Rapid Access Ice Drilling — RAID project, the Chinese drilling expedition's project in the Gamburtsev Mountains; Goodge and Severinghaus, 2016, Talalay et al., 2018), but none of them has been implemented yet, and no targeted geological core sampling of bedrock has ever been carried out in Antarctica, except for sampling of young sediments in subglacial lakes in West Antarctica, coring of bedrock with known geology for paleogeography based on cosmic isotope studies, and test drilling near scientific stations (Talalay et al., 2023).

In the 2023–2024 season, a joint Russian-Chinese drilling project (with cooperation VNIIOkeangeologia, Jilin University and China University of Geosciences, Beijing) was carried out in the north-western part of Princess Elizabeth Land (Fig. 1). Drilling was aimed at establishing the geological nature a high-amplitude linear magnetic anomaly that runs parallel to the coast for more than 500 km from Princess

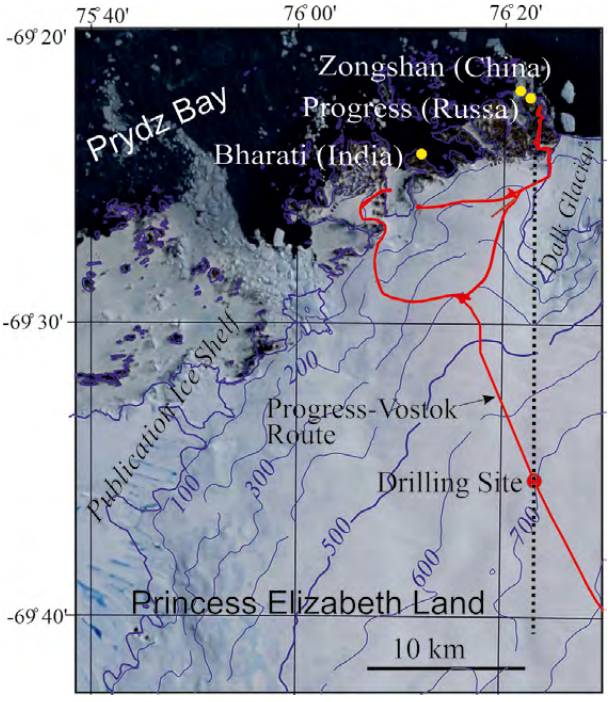

Fig. 1. Position of drilling site in the north-western Princess Elizabeth Land. Dotted line is position of Radio-echo sounding section shown on Fig. 3

Elizabeth Land to Mac.Rosbertson Land, crossing the Lambert Rift Zone, and marks distinct changes in the magnetic field pattern (Golynsky et al., 2018; Fig. 2). The nature of this anomaly remained unclear, but it is thought to be related to the suture zone between Proterozoic terrains formed during the Neoproterozoic amalgamation of the Rodinia supercontinent (Mikhalsy & Leitchenkov, 2018).

The drilling site was selected on the basis of recently derived detailed magnetic and radio-echo sounding data (with 1 km line spacing) and logistical convenience. The optimal place for drilling along the strike of the magnetic anomaly is located at 69.585591S; 76.385165E, on the top of the local bedrock high (Fig. 3) with the ice thickness of 550 +/– 10 m. Ice sheet surface elevation at the drill site is 680 m asl.; ice flow velocity at the drilling site measured by GPS observations is 50–60 meters per year. Radar data suggested a freezing at the base of the ice sheet at the drilling site.

The drilling was carried out using cable-suspended Ice and Bedrock Electromechanical Drill (IBED) designed by the Jilin University. The drilling facilities include movable drilling shelter and workshop (Talalay et al., 2021; Fig. 4). The drilling camp (named «Anomaly»; Fig. 5) was organized from 18 to 24 December 2023 and the drilling itself continued from 25 December 2023 to 26 February 2024. A variety of technologies were used for drilling: auger core set for the snow-firn layer, a cutter drill bit for the meteoric ice, a PDC

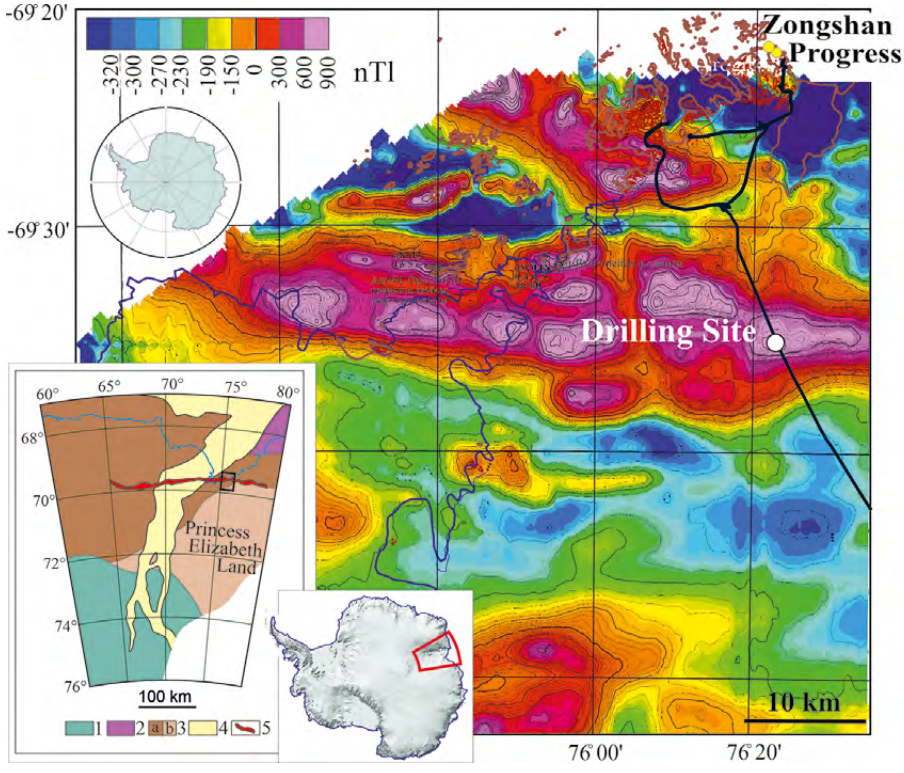

Fig. 2. Magnetic anomaly field of the western Princess Elizabeth Land with position of drilling site. Inset: Tectonic provinces: 1 – Paleoarchean to Paleoproterozoic Ruker Craton; 2 – Neoarchean Vestfold Craton; 3 – Mesoproterozoic to Neoproterozoic Orogen (a – Middle Mesoproterozoic to Early Neoproterozoic Province; b – Late Mesoproterozoic to Early Neoproterozoic Province); 4 – magnetic anomaly; this anomaly is thought to mark changes in crustal composition; orthogneisses dominate south of the anomaly and paragneisses dominate north of the anomaly (Mikhalsky & Leitchenkov, 2018)

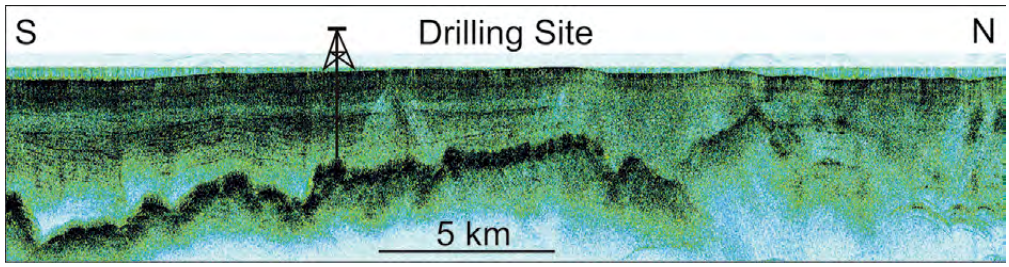

Fig. 3. Radio-echo sounding section showing bedrock morphology and drill site location. See Fig. 1 for line position.

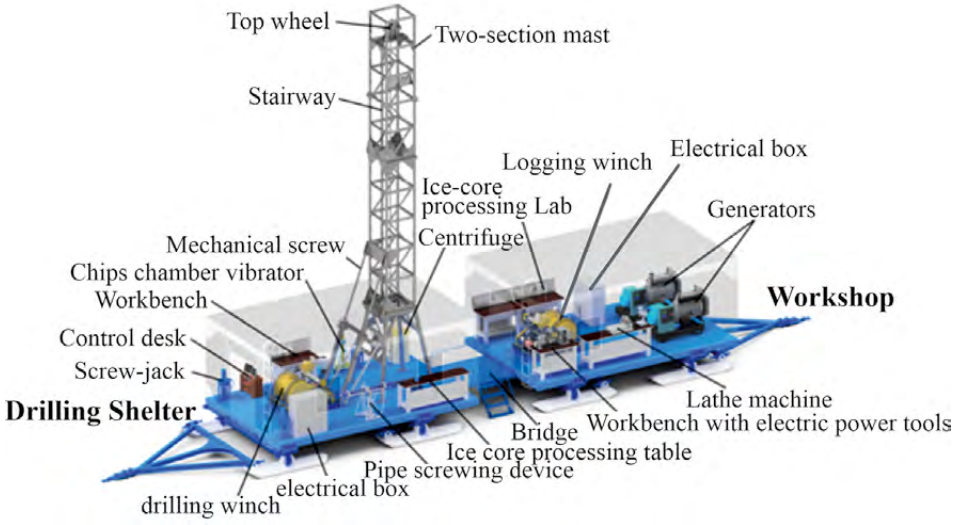

Fig. 4. Three-dimensional scheme of the movable drilling shelter and the workshop connected by the bridge

Fig. 5. Areal view of the field camp «Anomaly» located near the Progress – Vostok logistic route

Fig. 6. Core of basal ice (left) and bedrock (right)

cutter for the basal ice with mineral inclusions and a toothed impregnated diamond drill bit for the bedrock. Jet A-1 fuel was used as the drilling fluid. The average daily drilling rate for meteoric ice was 18–24 m/day with an average core yield of 0.9 m per run. At the bottom of the ice, the measuring system in the drill recorded a temperature of -4.5°C, i.e. well below the pressure-melting point.

A total of 545.5 m was drilled, including about 1.4 m of snow, about 60 m of firn (part of the ice cover where the density reaches 830 g/cm^3), about 485 m of meteoric ice, 17 cm of basal ice with mineral particles, and 48 cm of rocks (Fig. 6). Bedrock core sample was recovered in two runs. Based on visual field identification, the core is presented by mafic crystalline schist. The magnetic susceptibility of the sample is about 0.05 SI and this high value confirms that similar rocks produce a prominent magnetic anomaly. Rock and basal ice cores were sawn in half in Antarctica and divided between Chinese and Russian partners for further laboratory research.

During the next Antarctic season (2024–2025), geophysical borehole logging, including inclinometry, cavernometry and temperature measurements will be carried out to study ice sheet conditions in the marginal part of the ice sheet and to estimate geothermal heat flux. The ice cores have been buried in the snow at Camp Anomaly until next season, when they will be transported to Vostok Station for sawing. Half of the ice cores will be delivered to Chinese specialists, and another half — to the Climate and Environmental Research Laboratory of the Arctic and Antarctic Institute, St. Petersburg, for the paleoclimate research.

Conclusions

The experience of implementing the joint project, integrating technical, logistical, financial and intellectual resources, has once again demonstrated the feasibility and effectiveness of international cooperation in Antarctica. The experience gained will contribute to the improvement of ice-bedrock drilling technologies in Antarctica, and will make it possible to outline new projects with more ambitious tasks in the future. One of them, for example, is drilling in the Gamburtsev Mountains, one of the most mysterious regions of Antarctica, where there are places with relatively thin ice (up to 1000 m) that can be drilled with equipment designed in the Jilin University within 1–2 seasons.

Acknowledgments: The authors thank the Russian and Chinese Antarctic Expeditions and the management of Progress and Zongshan Stations for logistical support of ice drilling. The drilling was carried out within the the Federal Project «Geology. Legend Revival» and the State assignment of the Rosnedra Agency.

REFERENCE

1. Golynsky A.V., Ferraccioli F., Hong J.K., Golynsky D.A., von Frese R.R.B., Young D.A., Blankenship D.D., Holt J.W., Ivanov A.V., Kiselev A.V., Masolov V.N., Eagles G., Gohl K., Jokat W., Damaske D., Finn, C., Aitken A., Bell R.E., Armadillo E., Jordan T.A., Greenbaum J.S., Bozzo E., Caneva G., Forsberg R., Ghidella M., Galindo-Zaldivar J., Bohoyo F., Martos Y.M., Nogi Y., Quartini E., Kim H. R., Roberts J.L. New Magnetic Anomaly Map of the Antarctic // Geophysical Research Letters, –2018. — Vol. 45 — P. 6437–6449.
2. Goodge J.W. Severinghaus J.P. Rapid Access Ice Drill: a new tool for exploration of the deep Antarctic ice sheets and subglacial geology // Journal of Glaciology. — 2016. — P. 1–16.
3. Mikhalsky E.V., Leitchenkov G.L. (Eds.). Geological map of Mac.Robertson Land, Princess Elizabeth Land, and Prydz Bay (East Antarctica) in scale 1:1 000 000 (Map Sheet and Explanatory Notes). St.-Petersburg. VNIIOkeangeologia. –2018.
4. Talalay P., Sun Y., Zhao Y., Li Y., Cao P., Markov A., Xu H., Wang R., Zhang N., Fan X., Yang1 Y., Sysoev M., Liu Y., Liu Y. Drilling project at Gamburtsev Subglacial Mountains,East Antarctica: recent progress and plans for the future / Siegert M. J., Jamieson, S. S. R., White D. A. (Eds). Exploration of Subsurface Antarctica: Uncovering Past Changes and Modern Processes. Geological Society, London, Special Publications, –2018. –Vol. 461. — P. 145–159.
5. Talalay P. Sun Y., Fan X., Zhang N., Cao P., Wang R., Markov F., Li X., Yang Y., Sysoev V., Liu Y., Liu Y., Wu W., Gong D. Antarctic subglacial drilling rig: Part I. General concept and drilling shelter structure // Annals of Glaciology, –2021. Vol. 62(84). — P.1–11. https://doi.org/10.1017/aog.2020.37.
6. Talalay P.G. Deep drilling in Antarctic ice: Methods and perspectives // Earth-science Reviews, 2023. Vol. 243 — 2023. 104471. doi.org/10.1016/j.earscirev

German Leonidovich Leitchenkov // leichenkov@vniio.ru
Pavel Grigorievich Talalay // ptalalay@yandex.ru
Nan Zhang // znan@jlu.edu.cn
Ilnur Albertovich Abdrachmanov // ilnur_01_95@mail.ru
Da Gong // gongda@jlu.edu.cn
Yunchen Liu // lyc041833@126.com
Yazhou Li // yazhouli@cugb.edu.cn
Yuchen Sun // 867781138@qq.com
Mstislav Alekseevich Vorob'ev // mslavavo@gmail.com
Bing Li // bing@cugb.edu.cn