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Impact of war on geophysical research in Ukraine: An eyewitness report from the formerly occupied palaeomagnetic lab

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Abstract: In the 8th year of its hybrid war against Ukraine, Russia openly invaded more of Ukraine. This brutal aggression affected millions of Ukrainians and divided their lives into "before" and "after". All aspects of life have suffered irreparable losses, in particular, in scientific fields. This short communication is devoted to a small group of researchers who, despite all the difficulties of the war, continue to work for the progress of fundamental science. Representing the only palaeomagnetic laboratory in Ukraine, we share with the world scientific community our team's research progress before the invasion, reflecting events during the occupation, and after the liberation of some regions.

Key words: geophysical society, palaeomagnetic studies, mineral resources, geological sites, environmental pollution, Russian invasion, research in Ukraine

1. Introduction

Ukraine covers an area of 603,700 sq km (0.4% of the world's land surface) and it hosts numerous geological landmarks. Geological units and rocks of Ukraine were formed over a gigantic time interval of 3.85 billion years, and comprise a stratigraphic record from the Precambrian to present. The extensive distribution of exposures, their stratigraphic completeness, and the enormous progress in their study provide a rare opportunity to investigate the Earth's evolution.

The major geological and metallogenic unit of Ukraine, the Precambrian Ukrainian Shield, occupies more than one third of the country (Fig. 1). It is overlain by a Phanerozoic sedimentary cover of irregular distribution, with thickness up to 120 m. Together with negative structures beyond, the Dnipro-Donets Depression, Black Sea Depression and Volyn-Podilia Plate,

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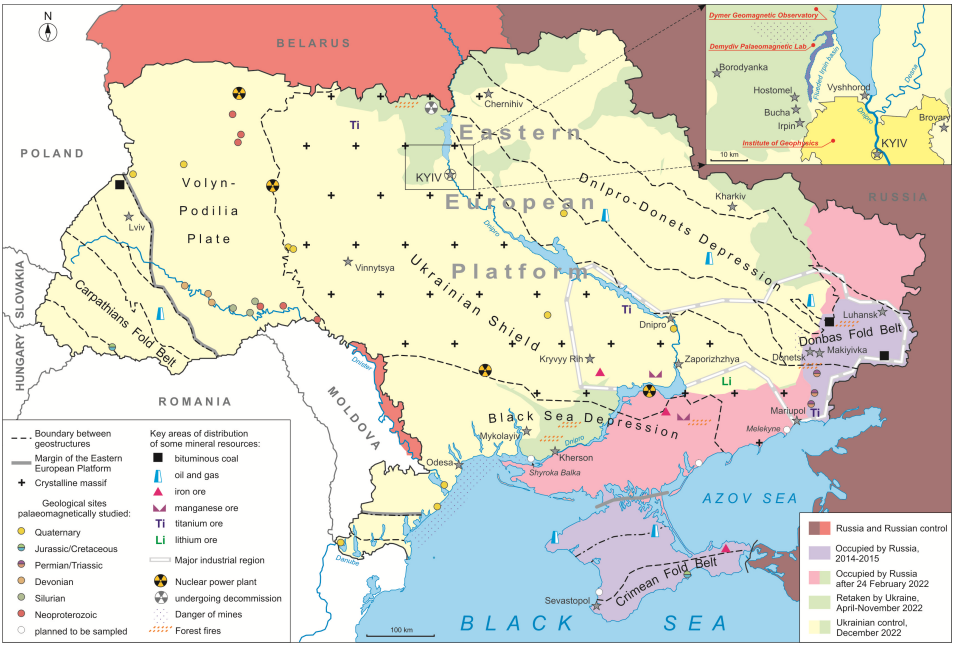

Fig. 1. Simplified map of geostructures of the territory of Ukraine, location of key geological sites studied by our team, distribution of major mineral resources deposits, critical infrastructure, overlain on map indicating territories occupied by Russia and territories liberated by Ukraine's armed forces (modified from Wikimedia Commons). The situation at the front is presented as of December 2022; however, the situation changes radically as Ukrainian forces liberate new territories. The newly retaken areas will not be available for geophysical study for a long time due to shelling and mining.

and the Donbas Fold Belt, it comprises the southwestern margin of the Eastern European Platform, which, in turn, is surrounded by young Alpine units of the Carpathians in the west and Crimea in the south. Ukraine has extremely rich and complementary mineral resources (5% of the world's potential), deposited mainly in the southeastern part of the country. With reserves of some strategic mineral types, Ukraine is the largest source country in the world (*Bezvynniy et al., 2006*).

Geophysical research in Ukraine has been ongoing for the past 100 years. At present, the leading geophysical institution is the S. I. Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine (Kyiv), cre-

ated in 1960 as a result of the unification of various geophysical laboratories and departments from different geological institutions. The main aim of the institute is the study of the deep-seated structure of the Earth's crust and the upper mantle, and the exploration of mineral deposits using geophysical methods.

For the past decade our team, operating at the Department of Rock Magnetism and Marine Geophysics, in collaboration with Ukrainian and international peers, has constantly contributed towards Ukraine's, as well as global geophysical research. The results on palaeomagnetism and rock magnetism of abundant deposits of different ages in large areas of Ukraine and the Antarctic Peninsula, as well as palaeoclimate reconstructions and geomagnetic secular variations, were published in reputable journals (Table 1). Furthermore, a mechanism for a possible connection between the geomagnetic field and climate change, and the investigation of its features in the two Earth's hemispheres and Antarctic regions has been recently presented (Table 1). This analytical research was conducted in the Palaeomagnetic Lab (founded in 1959), located in a picturesque forest area near Demydiv village, 35 km north of Kyiv (Figs. 1 and 2). Our laboratory is the only research facility in Ukraine that possesses palaeomagnetic equipment.

2. Russia attacks Ukraine

On 24 February 2022, Russia suddenly and unjustifiably attacked Ukraine. Tens of millions of peacefully sleeping people in the cities and villages, in the very centre of Europe, awoke to find themselves under fire from missiles, bombs and artillery.

As Russian forces bombarded and sought to encircle the Ukrainian capital of Kyiv, some researchers hunkered down at home, whereas others took refuge with relatives in the countryside near Kyiv or were displaced to central and western Ukraine. We did not expect the sudden attack of Russian troops from Belarus directed at Kyiv. Thus, for 35 days (from February 24 to April 1), the staff of the Palaeomagnetic Lab suffered a terrible occupation, under regular shelling resulting in a humanitarian catastrophe, with no electricity, gas, and telephone connection. Only a few managed to leave, following a green corridor. The members of the staff of the laboratory were alive and healthy, but their homes were damaged.

Table 1. Recent palaeomagnetic and palaeoclimatic research developments in Ukraine (with participation of our team).

Object of research	Methods used	Main result/ Global impact	Reference
Earth			
Geomagnetic field and climate	Geomagnetic models Time series analyses Statistical methods of data processing	New mechanism of relationships between geomagnetic field and climate changes	*Kilifarska et al., 2015; Kilifarska et al., 2017; Kilifarska et al., 2020a,b*
Antarctica			
Cretaceous and Palaeocene plutonic rocks from western Antarctica	Palaeointensity Palaeomagnetism Magnetostratigraphy	New palaeodirections and palaeointensity data from the Antarctic Peninsula	*Bakhmutov and Shpyra, 2011; Shcherbakova et al., 2012*
Crustal studies of the Antarctica	Gravity Magnetic Seismic Petrology	Investigated crustal structure and processes of the northern Antarctic Peninsula	*Yegorova et al., 2011; Yegorova and Bakhmutov, 2013*
Complex magma-gas-fluid system of the western Antarctica	Deep structure Fluids Submarine volcanoes Mobile technology Remote sensing Data processing	Discovery of a complex magma-gas-fluid system of the western Antarctica	*Soloviev et al., 2021*
Ukraine			
Quaternary loess-soil sequences in Ukraine	Rock magnetism Magnetostratigraphy Palaeopedology Sedimentology	New pan-European climato-stratigraphic model of the Pleistocene	*Bakhmutov et al., 2017; Hlavatskyi and Bakhmutov, 2020, 2021; Bakhmutov and Hlavatskyi, 2022*
Permian and Triassic intrusions of Donbas, eastern Ukraine	Palaeomagnetism applied to tectonics	Reconstruction of the palaeoposition of Pangea at 280 Ma	*Yuan et al., 2011*

Table 1. Continued from the previous page.

Jurassic and Cretaceous sedimentary rocks from Crimea (southern Ukraine) and Carpathians (western Ukraine)	Biostratigraphy Magnetostratigraphy Gamma ray spectrometry Carbon isotope stratigraphy Microfacies	New magnetostratigraphic, biostratigraphic and chemostratigraphic evidence of the Jurassic-Cretaceous boundary	*Bakhmutov et al., 2018;* *Grabowski et al., 2019;* *Wimbledon et al., 2020, 2022*
Silurian and Devonian sediments from Podilia, SW Ukraine	Palaeomagnetism applied to tectonics Rock and mineral magnetism	Reconstruction of the palaeoposition of Baltica at 410 Ma	*Jeleńska et al., 2005;* *Jeleńska et al., 2014*
Ediacaran trap formation of Volyn Basalt Province, NW Ukraine	Magnetic field variations Palaeointensity Rock and mineral magnetism	New palaeodirections and palaeointensity data for the Ediacaran	*Shcherbakova et al., 2020;* *Thallner et al., 2022*

On 25 February 2022, the 1960s dam, built to drain the wetlands at the mouth of the River Irpin, was opened to stop Russian troops advancing on Kyiv. This flooded parts of Demydiv and 13,000 hectares of land (*Mundy, 2022*) (Fig. 2). The laboratory was not flooded; the magnetic equipment replaced in the basement had been saved, although it was wetted due to the lack of heating.

During the occupation, Russian troops settled in the laboratory, but caused relatively minor damage (Fig. 2). Nevertheless, they destroyed equipment and stole computers in the geomagnetic observatory in Dymer, another institute facility, located 8 km north of Demydiv (Fig. 1). This observatory (IAGA code KIV), operational since 1958, has been a member of INTERMAGNET since 2011.

The main building of the Institute of Geophysics, sitting on the northwestern edge of Kyiv, was likewise located in the combat zone. From 25 February to 01 April 2022, the institute was only 5 km from the front line (Fig. 1). Only 1 km from the institute, a high-rise apartment building was completely destroyed by a missile. Fortunately, work had been transferred to remote operations.

3. A return to research and new challenges

Those of us who remained in the unoccupied part of Ukraine are actively involved in volunteering, such as Ievgen Poliachenko, while others are making financial donations to the armed forces, urban territorial defence, and hospitals, and are involved in information warfare online. Fortunately, after the defeat and retreat of the Russian troops in the battle of Kyiv, and the liberation of the Demydiv Palaeomagnetic Lab on 1st April 2022, our ability to conduct field work and analytical research has been partially renewed. However, the continual explosions and howl of air-raid sirens are making it increasingly difficult for many scientists to carry on with their research. In particular, a massive rocket attack on Kyiv and Kyiv Oblast on 10 October 2022 stunned us again, when buildings of the major scientific and educational institutions, and energy infrastructure, were targeted. In addition to air alerts, recent power outages slow down our research work.

In addition to the massive civilian casualties, the destruction and the humanitarian crisis caused by the war, Russia's military intervention in Ukraine has interrupted its flourishing scientific research. After 2020, with the support from the newly created National Research Foundation of Ukraine, there has been significant improvement, with stimulation of break-through research and integration into world Scientometrics. Leading and young scientists at universities and research institutes have long worked guided by international canons within interstate projects, and more recently in domestic ones. One such project was the National Research Foundation of Ukraine project 2020.02/0406, whereby our team aimed to study magnetic proxies of palaeoclimate change in the Pleistocene loess-palaeosol sequences of Ukraine. Due to the war, the implementation of projects has been suspended, and all funds have been transferred for the needs of the Armed Forces of Ukraine.

As of December 2022, Russia continued to occupy parts of Donetsk, Luhansk, Kherson and Zaporizhzhia oblasts, as well as the entire territory of the Autonomous Republic of Crimea (Fig. 1). These include 15% of the entire loess distribution area in Ukraine, where many of the most important sections in Quaternary deposits (of continental, estuarine and marine facies) are located. In 2022, expeditions had been planning to study the Pleistocene loess-soil sections of Shyroka Balka (Black Sea Lowland) and Melekyne (Azov Lowland) (Fig. 1). The first was recently on the front line

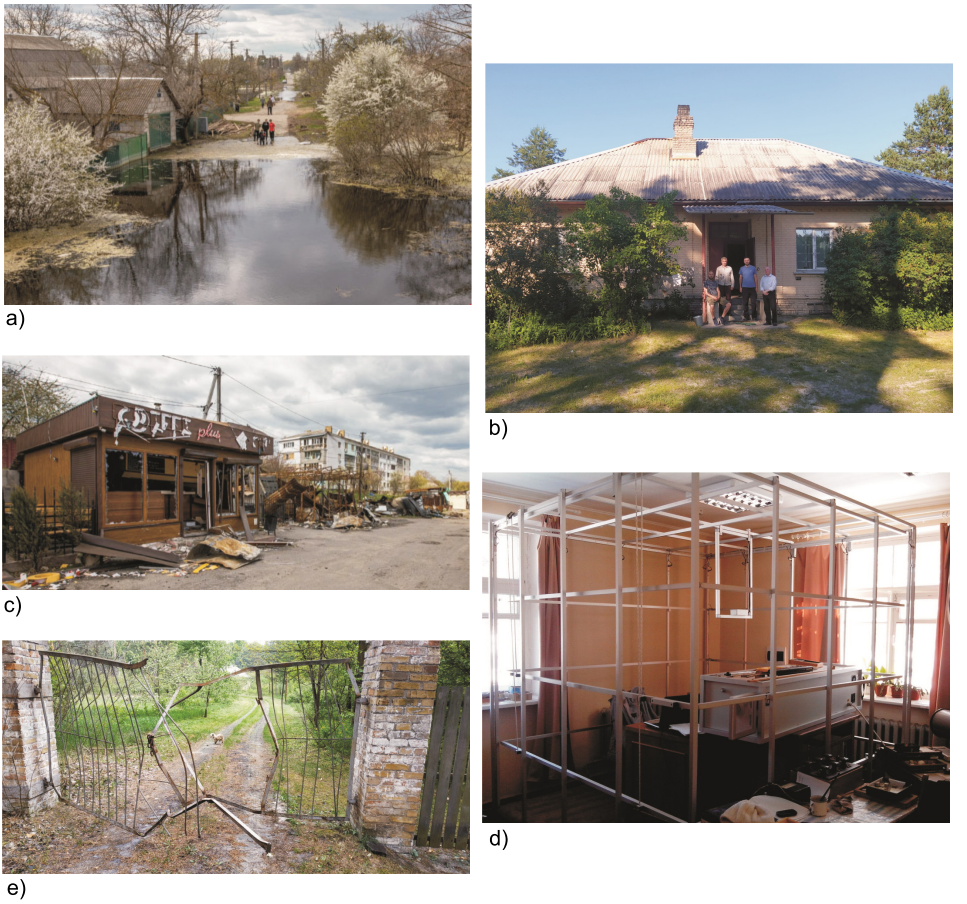

Fig. 2. Aftermath of war in Demydiv and Palaeomagnetic Lab: a) flooded street in Demydiv; b) Palaeomagnetic Lab after the liberation; c) destroyed shops in the centre of Demydiv; d) magnetically shielded room at the laboratory; e) gate destroyed by Russian armored vehicles at the entrance to the territory of the lab.

(liberated on 11 November 2022 together with the city of Kherson); there was heavy fighting, and the villages beyond are largely destroyed. Melekyne is located 10 km southwest of Mariupol, temporarily under Russian occupation.

The unique Mesozoic sections of Crimea and Palaeozoic sections of Donbas, which were actively studied by our group, are also under occupation.

Although a large number of distinctive geological sites, such as the Volyn Ediacaran Traps, the Podilia Neoproterozoic sedimentary deposits, and the Quaternary deposits of Volyn, are located in northern and southwestern parts of Ukraine; their research is potentially unsafe, because of constant long-range missile attacks and ever-present threat of attacks from Belarus and Russian-occupied part of Moldova (Fig. 1).

Russia's forces have occupied the areas in eastern Ukraine that have a significant concentration of mineral deposits, power plants and industry. Fighting at the Zaporizhzhya nuclear power plant and bombardment of the Kharkiv Institute of Physics and Technology's flagship nuclear facility, destruction of mines, chemical plants, oil depots and other industrial and energy infrastructure, and burning of forests, significantly degrades the environmental situation in Ukraine and Eastern Europe. It is obvious that the environmental issues will be most relevant (after the military, medical, and habitation considerations) relative to further research projects in Ukraine. After the end of the war and the liberation of the south-eastern regions of Ukraine, along with the restoration of infrastructure and reconstruction of housing and plants, areas with geological sites will also need careful demining and restoration, which will hamper the study of these areas.

4. Ukraine's urgent needs

As stated by the president of the National Academy of Sciences of Ukraine (*Zagorodny, 2022*), Ukraine now needs widespread humanitarian support and miscellaneous supplies to stop Russia's brutal aggression, to offer safety for our citizens, including researchers. The Ukrainian people face unprecedented aggression, but they also feel unprecedented support from the entire civilised world. Ukrainians defend not only their land; they foster and stand guard over rights, freedoms and progress held dear by all mankind. In particular, Ukrainian scientists will continue with their research, against all odds.

Assistance to the geophysical society in Ukraine might include international projects, remote scholarships, publication fee waivers, and discounts on equipment. Transfer of scientific equipment (even second-hand) would greatly help to improve scientific activity of local research groups. Interested parties are encouraged to contact the authors.

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References

Bakhmutov V., Hlavatskyi D., 2022: On the reliability of a stratigraphic interpretation that overlooks geophysical techniques and results when determining the age of loess-soil deposits – Comment on Łanczont et al. (2022) "A remarkable last glacial loess sedimentation at Roxolany in the Dniester Liman (Southern Ukraine)". Quat. Sci. Rev., **297**, 107668, doi: 10.1016/j.quascirev.2022.107668.

Bakhmutov V., Shpyra V., 2011: Palaeomagnetism of Late Cretaceous-Paleocene igneous rocks from the western part of the Antarctic Peninsula (Argentine Islands Archipelago). Geol. Q., **55**, 4, 285–300.

Bakhmutov V. G., Halásová E., Ivanova D. K., Józsa Š., Reháková D., Wimbledon W. A. P., 2018: Biostratigraphy and magnetostratigraphy of the uppermost Tithonian–lower Berriasian in the Theodosia area of Crimea (Southern Ukraine). Geol. Q., **62**, 2, 197–236, doi: 10.7306/gq.1404.

Bakhmutov V. G., Kazanskii A. Y., Matasova G. G., Glavatskii D. V., 2017: Rock magnetism and magnetostratigraphy of the loess-sol series of Ukraine (Roksolany, Boyanychi, and Korshev sections). Izv. Phys. Solid Earth, **53**, 6, 864–884, doi: 10.1134/S1069351317050020.

Bezvynniy V. P., Biletski S. V., Bobrov O. B. et al., 2006: Geological Landmarks of Ukraine (in 3 volumes); Kalinin V. L., Gurskiy D. S., Antakova I. V. (Eds.), Kyiv, DIA, State Geological Survey of Ukraine, Volume I, 320 p. (in Ukrainian, English).

Grabowski J., Bakhmutov V., Kdýr Š., Krobicki M., Pruner P., Reháková D., Schnabl P., Stoykova K., Wierzbowski H., 2019: Integrated stratigraphy and palaeoenvironmental interpretation of the Upper Kimmeridgian to Lower Berriasian pelagic sequences of the Velykyi Kamianets section (Pieniny Klippen Belt, Ukraine). Palaeogeography, Palaeoclimatology, Palaeoecology, **532**, 109216, doi: 10.1016/j.palaeo.2019.05.038.

Hlavatskyi D. V., Bakhmutov V. G., 2020: Magnetostratigraphy and magnetic susceptibility of the best developed Pleistocene loess-palaeosol sequences of Ukraine: Impli-

cations for correlation and proposed chronostratigraphic models. Geol. Q., **64**, 3, 723–753, doi: 10.7306/gq.1544.

Hlavatskyi D., Bakhmutov V., 2021: Early–Middle Pleistocene magnetostratigraphic and rock magnetic records of the Dolynske section (Lower Danube, Ukraine) and their application to the correlation of loess–palaeosol sequences in eastern and south-eastern Europe. Quat., **4**, 4, doi: 10.3390/quat4040043.

Jeleńska M., Bakhmutov V., Konstantinienko L., 2005: Paleomagnetic and rock magnetic data from the Silurian succession of the Dniester basin, Ukraine. Phys. Earth Planet. Inter., **149**, 3-4, 307–320, doi: 10.1016/j.pepi.2004.10.005.

Jeleńska M., Kadziałko-Hofmokl M., Bakhmutov V., Poliachenko I., Ziółkowski P., 2014: Palaeomagnetic and rock magnetic study of Lower Devonian sediments from Podolia, SW Ukraine: Remagnetization problems. Geophys. J. Int., **200**, 1, 557–573, doi: 10.1093/gji/ggu411.

Kilifarska N. A., Bakhmutov V. G., Mel'nik G. V., 2015: Geomagnetic field and climate: Causal relations with some atmospheric variables. Izv. Phys. Solid Earth, **51**, 5, 768–785, doi: 10.1134/S1069351315050067.

Kilifarska N. A., Bakhmutov V. G., Melnyk G. V., 2017: Galactic cosmic rays and tropical ozone asymmetries. Comptes Rendus de l 'Academie Bulg. des Sci., **70**, 7, 1003–1010.

Kilifarska N. A., Bakhmutov V. G., Melnyk G. V., 2020a: The geomagnetic field's imprint on the twentieth century's climate variability. Geol. Soc. Spec. Publ., London, **497**, 1, 205–227, doi: 10.1144/SP497-2019-38.

Kilifarska N. A., Bakhmutov V. G., Melnyk G. V., 2020b: The hidden link between Earth's magnetic field and climate. Elsevier, doi: 10.1016/C2018-0-01667-9.

Mundy V., 2022: Ukraine's 'hero river' helped save Kyiv. But what now for its newly restored wetlands? The Guardian, 11 May 2022.

Shcherbakova V. V., Bakhmutov V. G., Shcherbakov V. P., Zhidkov G. V., Shpyra V. V., 2012: Palaeointensity and palaeomagnetic study of Cretaceous and Palaeocene rocks from Western Antarctica. Geophys. J. Int., **189**, 1, 204–228, doi: 10.1111/j.1365-246X.2012.05357.x.

Shcherbakova V. V., Bakhmutov V. G., Thallner D., Shcherbakov V. P., Zhidkov G. V., Biggin A. J., 2020: Ultra-low palaeointensities from East European Craton, Ukraine support a globally anomalous palaeomagnetic field in the Ediacaran. Geophys. J. Int., **220**, 3, 1920–1946, doi: 10.1093/gji/ggz566.

Soloviev V., Bakhmutov V., Yakymchuk N., Korchagin I., 2021: Deep structure and new experimental data of the Bransfield Strait volcanoes (West Antarctica). Ukr. Antarct. J., 2021/1, 3–15, doi: 10.33275/1727-7485.1.2021.661.

Thallner D., Shcherbakova V. V., Bakhmutov V. G., Shcherbakov V. P., Zhidkov G. V., Poliachenko I. B., Biggin A. J., 2022: New palaeodirections and palaeointensity data from extensive profiles through the Ediacaran section of the Volyn Basalt Province (NW Ukraine). Geophys. J. Int., **231**, 1, 474–492, doi: 10.1093/gji/ggac186.

Wimbledon W. A. P., Bakhmutov V., Halásová E., Svobodová A., Reháková D., Frau C., Bulot L. G., 2020: Comments on the geology of the Crimean Peninsula and a

reply to a recent publication on the Theodosia area by Arkadiev et al. (2019): "The calcareous nannofossils and magnetostratigraphic results from the Upper Tithonian–Berriasian of Feodosiya region (Eastern Crimea)". Geol. Carpath., **71**, 6, 516–525, doi: 10.31577/GeolCarp.71.6.3.

Wimbledon W. A. P., Svobodova A., Bakhmutov V., Poliachenko I., Hlavatskyi D., 2022: Further observations on the bio- and magnetostratigraphy of the J/K boundary interval in southern Ukraine. Geol. Q., **66**, 1, 66:11, doi: 10.7306/gq.1643.

Yegorova T., Bakhmutov V., Janik T., Grad M., 2011: Joint geophysical and petrological models for the lithosphere structure of the Antarctic Peninsula continental margin. Geophys. J. Int., **184**, 1, 90–110, doi: 10.1111/j.1365-246X.2010.04867.x.

Yegorova T., Bakhmutov V., 2013: Crustal structure of the Antarctic Peninsula sector of the Gondwana margin around Anvers Island from geophysical data. Tectonophysics, **585**, 77–89, doi: 10.1016/j.tecto.2012.09.029.

Yuan K., Van Der Voo R., Bazhenov M. L., Bakhmutov V., Alekhin V., Hendriks B. W. H., 2011: Permian and Triassic palaeolatitudes of the Ukrainian shield with implications for Pangea reconstructions. Geophys. J. Int., **184**, 2, 595–610, doi: 10.1111/j.1365-246X.2010.04889.x.

Zagorodny A., 2022: President of National Academy of Sciences of Ukraine calls for solidarity, Nature, **603**, 7900, 228, doi: 10.1038/d41586-022-00668-5.