ISSN 0869-2904

EXPERIMENT IN GeoSciences

Mineralogy
Petrology
Geochemistry
Crystallography
Geophysics
Isotopy

2024 Volume 30 Number 1

INSTITUTE of EXPERIMENTAL MINERALOGY
IEM RAS
RUSSIAN ACADEMY OF SCIENCES

EXPERIMENT in GeoSciences

Mineralogy
Petrology
Geochemistry
Crystallography
Geophysics
Isotopy

Founded in **1991** by
INSTITUTE of EXPERIMENTAL MINERALOGY
Russian Academy of Sciences

EXPERIMENT IN GEOSCIENCES is the only journal in English that gives you the latest, most reliable information on advances in experimental mineralogy, petrology, geochemistry, crystallography and geophysics in Russia. The coverage of the journal includes:

- original research and review articles
- abstracts of scientific papers
- proceedings, abstracts and announcements of national and international conferences, symposia and workshop
- information about the leading experimental centers in Russia
- advertisement of new techniques and equipment

Institute of Experimental Mineralogy

Russian Academy of Sciences
142432 Chernogolovka
Academica Osip'yana str, 4,
Moscow region
Russian Federation

http://www.iem.ac.ru

TRANSLATED into ENGLISH by:
the authors

Table 1. Ratios of crater depth (d) to its dtiameter (D)

No	Study areas	Number of craters with D = 150-400 m	Mean d/D value	Standard deviation of d/D value
1	Faustini 1	48	0.114	0.0367
2	Faustini 2	40	0.090	0.0321
3	Shoemaker 1	74	0.073	0.0226
4	Shoemaker 2	60	0.088	0.0289
5	Haworth 1	44	0.118	0.0315
6	Haworth 2	47	0.099	0.0466
7	Lunokhod-2	288	0.082	0.0421
8	Apollo-16	130	0.114	0.0360

So, analysis of the surface morphology within six 4.5 x 6 km Study areas on the permanently shadowed floors of the south-polar lunar craters Faustini, Shoemaker and Haworth showed that it is rather similar to the morphology in the "normally" illuminated by Sun mare and highland plains within the Lunokhod-2 and Apollo-16 sites and it is dominated by populations of impact craters with diameters of tens to hundreds of meters. The ratios of crater depth to diameter of the craters having diameters from 150 to 400 m within the permanently shadowed areas are about the same as within the "normally" illuminated mare and highland plain areas. These conclusions are important for planning, transportation and work of robotic and piloted rovers in the permanently shadowed regions of the Moon. More detailed information on morphology and some other characteristics of the surface will hopefully be obtained from analysis of images with nominal resolution 1.7 m/px taken by the constructed with NASA USA support ShadowCam camera (https://www.shadowcam.asu.edu/) onboard Korea Pathfinder Lunar Orbiter. To obtain images of the permanently shadowed crater floors will be enough solar light reflected from the illuminated tops of the crater rims.

Sources of funding: The work was done under the GEOKHI RAS state assignment (A.T. Basilevsky) and supported by Suzhou Vocational University (Yuan Li).

References

1. Basilevsky A.T. and Li Yuan. Surface morphology inside the PSR area of lunar polar crater Shoemaker in comparison with that of the sunlit areas. Planetary and Space Science. 2024, V. 241. 105839. 10 p.
2. Colaprete A. and 16 coauthors. Detection of water in the LCROSS ejecta plume. Science. 2010. V. 330. 463–468.
3. Hiesinger H., Jaumann R., Neukum G., Head J.W. Ages of mare basalts on the lunar nearside. J. Geophys. Res. 2000. V. 105 (el2), 29,239-29,275.
4. Stoffler D. and Ryder G. Stratigraphy and isotope ages of lunar geologic units: chronological standard for the inner Solar system. Space Sci. Rev. 2001. V. 96, 9–54.
5. Tye A.R., Fassett, C.I., Head, J.W., Mazarico, E., Basilevsky, A.T., Neumann, G.A., Smith, D.E., Zuber, M.T., 2015. The age of lunar south circumpolar craters Haworth, Shoemaker, Faustini, and Shackleton: implications for regional geology, surface processes, and volatile sequestration. Icarus 255, 70–77.

Glazovskaya L.I. [1], Piryazev A.A. [2,3]., Shcherbakov V.D. [1] **Shock transformation of zircon in Logoisk (Belarus) impacties.**

[1]Geological Faculty, Lomonosov Moscow State University, Moscow, Russia, [2] Faculty of Chemistry, Lomonosov Moscow State University, Moscow, Russia ,[3] Institute of Problems of Chemical Physics, Russian Academy of Sciences, Chernogolovka, Russia
Liudmilaglazov@yandex.ru)

Abstract. The transformation of zircon in glasses of suevite of the Logoisk structure has been studied. Various types of its transformation have been revealed: the formation of granular textures both in the rims around the zircon grains and in the inner parts of the grains. Some zircon grains are converted into a fully granular aggregate of crystallites. The transition of zircon to reidite- high-density modification of zircon, the formation of planar fractures and the decomposition of zircon into ZrO_2 and SiO_2 have been established. The rims of the diaplectic and melting glass around the zircon grains were found. The amorphous state of zircon in these rims has been proven by micro Raman spectroscopy. The occurrence of granulated zircon grains with impact melt in the space between its crystallites corresponds to a temperature >2000°C. An assessment of the P-T conditions for the formation of impact glass of suevite according to the conditions of zircon transformation was carried out.

***Keywords**: impactites, zircon, reidite, diplectic and fused glasses of zircon.*

The 17 km diameter, 30 ± 5 Ma old Logoisk structure in Belarus was intensively drilled within the crater area (29 boreholes). The age of the structure was determined by the $^{40}Ar/^{39}Ar$ method. The Logoisk impact structure consists of a two-layer basement: Archean granite gneiss and Late Proterozoic and Middle Devonian horizontally layered sedimentary rocks (the thickness of the sedimentary rocks 200- 300 m). The upper part of the structure comprised of Paleogene–Neogene lacustrine sediments (27–291 m thick) and 102–324 m of thick Quaternary sedimentary rocks. Granite gneiss experienced shock metamorphism to a depth of 150 meters. Currently, the Logoisk impact structure is the most drilled on Earth.

Zircon is the most informative mineral for determining the PT conditions of impactite formation, since its transformation occurs in a wide range of temperatures and pressures from temperatures of 500°C to 2376°C (corresponds to the formation of ZrO2 cubic syngony). The transformation of zircon in Logoisk structure impactites includes the formation of granular textures, the transition of zircon to reidite, a high-density modification of zircon, which is proved by the method of micro-Raman spectroscopy.

The formation of planar fractures in zircon is observed in two directions. The decomposition of zircon into ZrO_2 and SiO_2. may be accompanied by the removal of SiO_2 into the impact melt. The degree of impact can vary from grain to grain.

Methods. Raman spectra were acquired on a Horiba LabRam Evolution Raman spectrometer, equipped with a laser wavelength of 633 nm, using a laser power of 17 mW. The spectrometer is equipped with two diffraction gratings, a high-performance detector cooled by a Peltier element, and a set of neutral gray filters to adjust the radiation power on the sample. The optical microscope has a resolution of 500 nm. The measurements were carried out with a grating of 1800 lines per mm, the laser power was 25% of the maximum, and the objective was ×100. The exposure time was 10 s with two accumulations.

Reidite. Reidite is currently documented in several terrestrial impact structures: Ries, Germany; Haughton, Canada; Xiuyan, China; Chicxulub, Mexico; Woodleigh, Australia; Rock Elm, United States; Chesapeake Bay, United States; Reidite was discovered in shocked zircon from the Stac Fada impactite, Scotland and in the Rochechouart impact structure, France. Reidite has been identified in the HED meteorite NWA 2650 and lunar meteorite SaU 169.

Reidite was proved by micro-Raman spectroscopy in the impact rocks of the Logoisk impact structure (Glazovskaya et al., 2024). The EBSD mapping method made it possible to prove the presence of "former reidite" in the suevite of the Logoisk structure, that is, reidite, which at temperatures exceeding 1100°C passed back into zircon. Zircon can completely transform into reidite or partially. The presence of reidite in the zircon grain suggests a pressure of 17.5 – 53 Gpa (Erickson et al., 2020).

Planar fractures. Planar fractures in two directions are described by us in a thin section of suevite glass, in a thin crack of impact glass in biotite. In the same zircon grain, reidite is present, proven by the method of micro-Raman spectroscopy and the region of decomposition of zircon into ZrO_2 and SiO_2. ZrO_2 is present both in the form of a border around a part of the grain and in the form of the thinnest separations sprayed in the central part of the grain. These areas are diagnosed by the ratio of ZrO_2 and SiO_2 in the zircon structure, which becomes 1.30- 1.34. The presence of planar fractures together with the absence of reidite makes it possible to estimate the pressure as 20-40 GPa. In this grain, the simultaneous presence of planar fractures, reidite (stable up to T -1200 °C), a baddeleyite rim and signs of zircon decomposition into ZrO_2 and SiO_2 (T exceeding 1676 ° C) indicates an uneven distribution of pressure and temperature in this grain on a microscopic scale.

Granular textures. Granular textures in zircon made of glass of the Logoisk impact structure are associated with microscopic inclusions of ZrO_2 formed as a result of dissociation of zircon into ZrO_2 and SiO_2; silica is often carried out into the surrounding melt. Granular textures are installed both in the borders (Fig. 1) around the zircon grains and in the inner parts of the grains. In the inner parts of the grains, in the intervals between the crystallites, there is a zircon-type diplect glass. The presence of ZrO_2 in the granular zircon (Figures 1) of the Logoisk structure suggests an impact pressure of 65–70 GPa and postshock temperatures higher than 1675°C.

The presence of fully granular zircon grains with an impact melt in space between the crystallites in the impactites of the Logoisk structure makes it possible to estimate the temperature of the impact melt as exceeding 2000°C, in accordance with the diagram (Timms et al., 2017).

Zircon amorphization. Zircon amorphization can occur at the solid-phase stage with the formation of a diplectic glass. Previously, diplect glass in zircon was described only in association with reidite (Meteor crater), while its presence was not proven by instrumental methods. Amorphous areas in the zircon grain may also be the result of melting zircon.

We have obtained petrological evidence of the melting of zircon in the suevite of the Logoisk structure. Prior to this, only indirect petrological evidence of zircon melting in natural impactites was known: crystallization of baddeleyite from an impact melt (Boltyshsky crater, Gurov et al., 2015), finding zircon domains that do not correspond in orientation to crystalline zircon and reidite (EBSD mapping method for zircon from impactites of the Vredefort structure, South Africa) (Kovaleva et al., 2021). Zircon amorphization was achieved in experiments at a pressure of 60 GPa to the complete absence of spectral bands of Raman spectroscopy in the peripheral parts and rims (Gucsik et al., 2002).

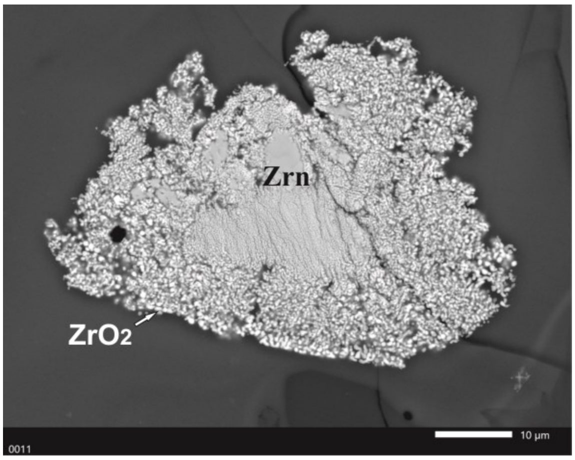

Fig. 1 Rim of granular textures in zircon with dissociation of zircon into ZrO_2 and SiO_2

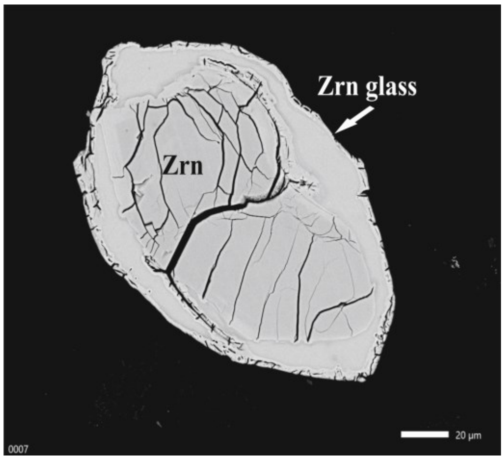

Fig. 2. Rim of fused zircon glass from the suevite of the Logoisk structure

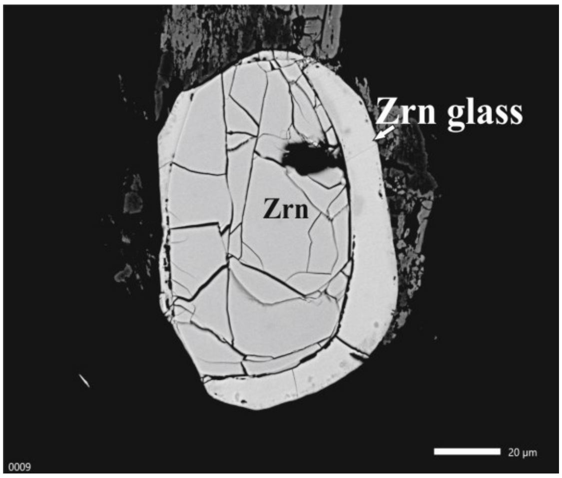

Fig 3. Rim of zircon diaplectic glass from suevite of the Logoisk structure

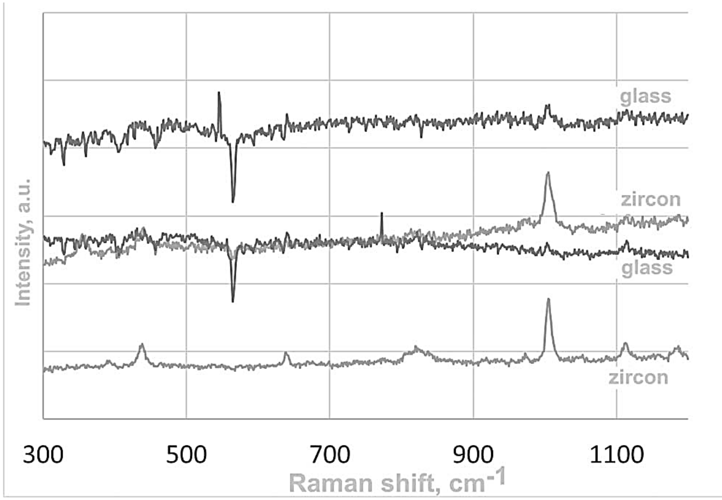

Fig. 4. Raman spectroscopy in zircon (grey lines) and diaplectic glass (dark lines) from Logoisk structure.

Diaplectic and fused glasses in the rims of zircon from the matrix of suevite of the Logoisk impact structure, shown in the figure 2, 3. Their presence was proved by micro-Raman spectroscopy (Fig. 4). The amorphization of zircon in the form of diaplectic glass was also found and confirmed by micro-Raman spectroscopy in impact zircon from the stratified Yarva-Varaka massif (Kola Peninsula) (Kaulina et al., 2017).

Diaplectic glasses are a product of amorphization at the solid-phase stage , the substance is crushed by a shock wave into tiny (<100 Å) fragments (Feldman, Glazovskaya, 2018) that are not identified as a crystalline material by X-ray diffraction.

Diplectic glasses are formed while preserving the boundaries of minerals. In the Logoisk structure, diplectic transformations are also observed for quartz, plagioclase, and kalishpate. When the rims of the diplectic glass are formed, the inner parts of the zircon grains are shielded by the rim and retain their structure.

An amorphous phase of the zircon composition was described in experimental samples at impact pressures of 40 GPa in the form of plates in zircon grains containing planar fractures (PDFs), a partial transformation to reidite was observed in the same grains. While at higher experimental pressure (60 GPa), complete transformation to reidite was observed in experiments.

Conclusion. Upon impact on the target rocks of the Logoisk structure, zircon undergoes transformations (granular textures, transition to reidite - a high-density modification of zircon, formation of planar fractures, decomposition of zircon into ZrO_2 and SiO_2, amorphization at the solid-phase stage with the formation of diplectic and fused glass. The transformations of zircon takes place in the temperature range from the first hundred degrees to temperatures exceeding 2000°C.

References

Glazovskaya, L. I., Parfenova, O. V., and Ilkevich, G. I. 1993. Impactites of Logoisk Astrobleme. Petrology 1: 834–844 (in Russian).

Kaulina T.V., Nerovich L.I., Bocharov V.I., Lyalina L.M., Ilchenko V.L., Kunakkuzin E.L., Kasatkin I.A. 2017. Raman spectroscopy of impact zircon from a layered Yarva-Varak body. (Monchegorsky ore district, Kola Peninsula) Bulletin of the Moscow State Technical University. Vol. 20, No. 1/1. pp. 72-82.

Feldman, V. I., and Glazovskaya, L. I. 2018. Impactgenez KDU, 151 p (in Russian).

Glazovskaya L.I., Shcherbakov V.D., Piryazev A.A. **2024**, Logoisk impact structure, Belarus: Shock transformation of zircon, *Meteoritics and Planetary Science*, v. 59, № 1, p. 88-104

Gucsik A., Koeberl C., Brandsta«tter B, Reimold W.U, Libowitzky E. 2002. Cathodoluminescence, electron microscopy, and Raman spectroscopy of experimentally shock-metamorphosed zircon. Earth and Planetary Science Letters 202. p 495-509.

Gurov, E. P., Shekhunova, S. B., and Permyakov, V. V. 2015. Accessory and Opaque Minerals in Impact Melt Rocks of the Boltysh Structure, Ukraine. Meteoritics & Planetary Science 50: 1139–55.

Erickson, T. M., Cline, C. J., Jakubek, R., Cintala, M. J., and Timms, N. E. 2020. Shock Deformation in Zircon, a Comparison of Results from Shock-Reverberation and Single-Shock Experiments. 51st Lunar and Planetary Science Conference, abstract # 1581.

Kovaleva, E., Kusiak, M. A., Kenny, G. G., Whitehouse, M. J., Habler, C., Schreiber, A., and Wirth, R. 2021. Nano-Scale Investigation of Granular Neoblastic Zircon, Vredefort Impact Structure, South Africa: Evidence for Complete Shock Melting. Earth and Planetary Science Letters 565: 116948.

Masaitis, V. L. 1999. Impact Structures of Northeastern Eurasia: The Territories of Russia and Adjacent Countries. Meteoritics & Planetary Science 34: 691–711.

Timms, N. E., Erickson, T. M., Cavosie, A. J., Reddy, S. M.,Nemchin, A. A., Schmieder, M., Pearce, M. A., Tohver, E., Zanetti, M. R., and Wittmann, A. 2017. A Pressure-Temperature Phase Diagram for Zircon at Extreme Conditions. Earth-Science Reviews 165: 185–202.

Gorbachev P.N., Bezmen N.I. First results of experimental Modeling of the chondritic structure of meteorites. *UDC 550.4*

Korzhinskii Institute of Experimental Mineralogy RAS Chernogolovka, Chernogolovka, Moscow district, Russia: p_gor@mail.ru

Abstract. A chondrites are a type of stony meteorites, characterized by the presence of chondrules - oval-shaped crystallized silicate precipitates in a Fe-sulfide-metallic matrix. The conditions for the formation of chondrules are still the subject of the discussion. The experiments were carried out for modeling the chondrite structure in a high gas pressure equipment at T = 1000ºC and a pressure of 1 kbar using a model composition corresponding to C3 carbonaceous chondrites.

Keywords: *chondrite, experiment, modeling, chondrules, matrix*

Experimental technique. The experiments were run in the the internally heated gas media pressure vessel. As a starting composition, we used a model mixture whose composition corresponded to the anhydrous composition of the Orgail meteorite. The mixture in powder form was pressed into a graphite capsule (15 mm long, 6 mm in diameter). The capsule was placed in a Pt-capsules 60 mm long and Ø 7 mm, then water and paraffin were added. The experiment temperature was 1000ºC, P = 1 kbar, XH_2 = 0.3, duration was 24 hours. After the experiment, a graphite capsule was removed from the Pt-capsules and pressed into place. Fig. 1 shows a quenching sample after the experiment. Then the sample was studied using optical methods and a microprobe.

Results and discussion. The results of the experiment are in table. 1 and in Fig. 2.

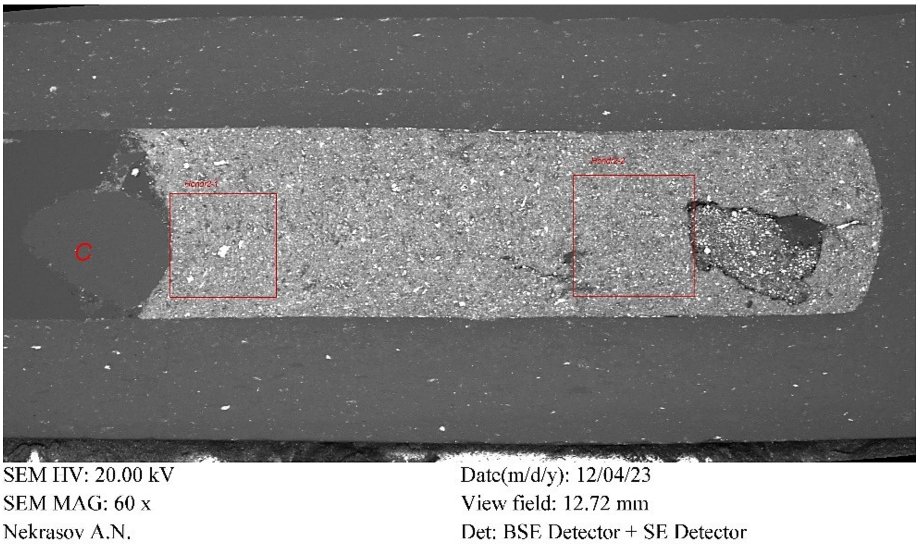

Fig. 1. Quenching sample after the experiment.