An explosive volcanism on the eve of the Cambrian "explosion" (~540 My ago) in the northeast of Siberia

Ivan Chayka[1], Dmitriy Grazhdankin[2,3], Vladimir Rogov[2], and Andrey Izokh[1,3]

[1] *Sobolev Institute of Geology and Mineralogy (IGM SB RAS), Novosibirsk, 630090, Russia,ivanlab211@gmail.com*
[2]*Trofimuk Insitute of Petroleum Geology and Geophysics (IPGG SB RAS), Novosibirsk, 630090, Russia*
[3]*Novosibirsk State University, Novosibirsk, 630090, Russia*

Keywords: volcanic complex, maar, Olenek Uplift, Ediacaran

Terminal Ediacaran and Terreneuvian strata cropping out along the northwestern slope of the Olenek Uplift, NE Siberia provide an exceptionally informative record of the Cambrian "explosion" of metazoan ecological and morphological complexity. The succession hosts laterally discontinuous stratiform tuff breccia and tuffites, occasionally basaltic flows, and is penetrated by numerous diatremes composed of tuff breccia and basalts, which are considered to be feeders for the stratified bodies. A U–Pb zircon date of 543.9 ± 0.24 Ma for a diatrem tuff breccia (Bowring et al., 1993) has long been used to constrain the age of the Ediacaran/Cambrian boundary in Siberia; however, the origin of the zircons remains ambiguous (Kiselev et al., 2016; Rogov et al., 2015; Vishnevskaya et al., 2017) and is in need of revision. A comprehensive field study conducted in 2018 allowed us to re-examine and re-sample a wide range of magmatic and volcanic formations cropping out in the middle reaches of the Khorbusuonka River, Olenek Uplift.

The following main types of magmatic formations have been recognized in the field (Fig.1):

1. Discordant bodies (diatremes) composed of tuff breccia, with variable amounts of tuff, lava-like and lithoclastic compounds, and often cross-cut by dolerite dykes. The bodies are several meters to ~200 m across; however, their exact size was difficult to resolve because of intricate shape and relationships with the host rocks. The diatremes penetrate the Khatyspyt, Turkut and lowermost Syhargalakh formations (Fig. 2A, 2B).
2. Stratiform tuff breccia sheets comprising heavily weathered outcrops as part of the Syhargalakh Formation.
3. Basalt flows interstratified with tuff breccia sheets cropping out on the northern slope of the Tas-Neleger Hill.
4. A volcanic plug composed of basalts and dolerites located in close proximity to the Tas-Neleger basalt flows.
5. Ubiquitous dolerite dykes occurring within large diatremes and as isolated intrusions cross-cutting the Khatyspyt, Turkut and lowermost Syhargalakh formations.
6. Dolerite sills varying in thickness on scale from from tens of cms to tens of meters emplaced in the Khatyspyt Formation.

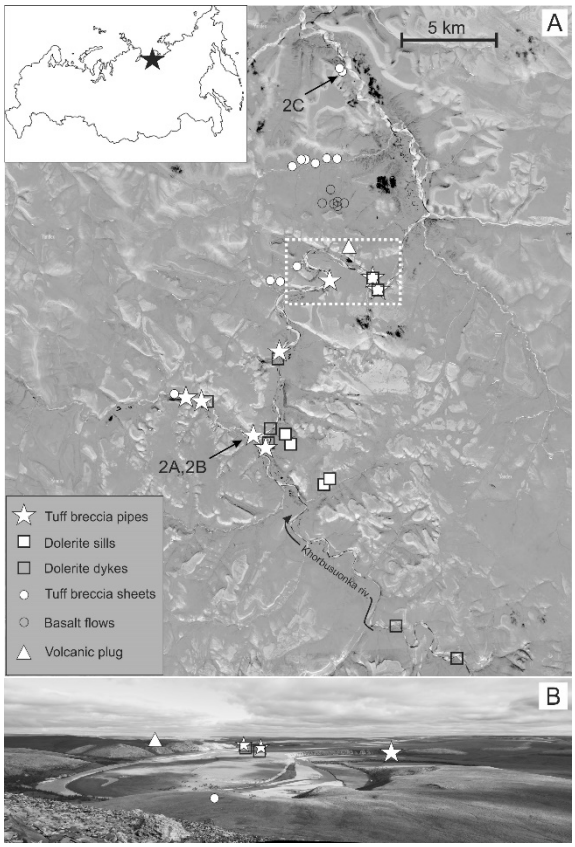

Fig. 1 – (A) The examined outcrops on a satellite photograph. (B) Locations of the outcrops in the landscape of the area outlined on (A).

Based on the field observations and preliminary laboratory examination the following genetic relationships can be inferred:

- Given the apparent textural, geochemical and mineralogical similarity we assume that the basalts, diatreme-hosted dolerite intrusions, and dolerite sills correspond to the same magmatic event. Although the magmatic compound of the breccia has been completely modified precluding chemical comparison with the basalts, the textural evidence and stratigraphic relationships suggest that it is basaltic in composition and the tuff breccia is co-magmatic with the basalts.
- The mingling structure of sandstone xenoliths in the tuff breccia, as well as the "infiltration" of the sandstone xenoliths with tuff matrix (Fig. 2C) provide further evidence that the eruptions are coeval with deposition of the Syhargalakh sandstones.
- Interstratification of the amygdaloidal basalt flows with the tuff breccia sheets in the Tas-

Neleger, along with the intricate relationship between the tuff breccia and the dolerite cross-cutting each other within the large diatremes imply an ambivalent style of eruptions. The basalts are thought to have poured out during "calm" eruptions, whereas the tuff breccia is most likely to have an explosive origin.

- Given that the diatreme-hosting magma contains xenoliths derived exclusively from the Khatyspyt, Turkut and Syhargalakh formations, the diatreme must have exploded at shallow (<200 m) depths, which is a characteristic of phreatomagmatic eruptions (Valentine et al., 2014). Since both surface and underground waters can act as coolant in phreatomagmatic eruptions, it is hard to distinguish whether the eruptions occurred overland or in underwater conditions. However, lithofacial constraints provided by Syhargalakh Formation, favor underwater regime of the eruptions.

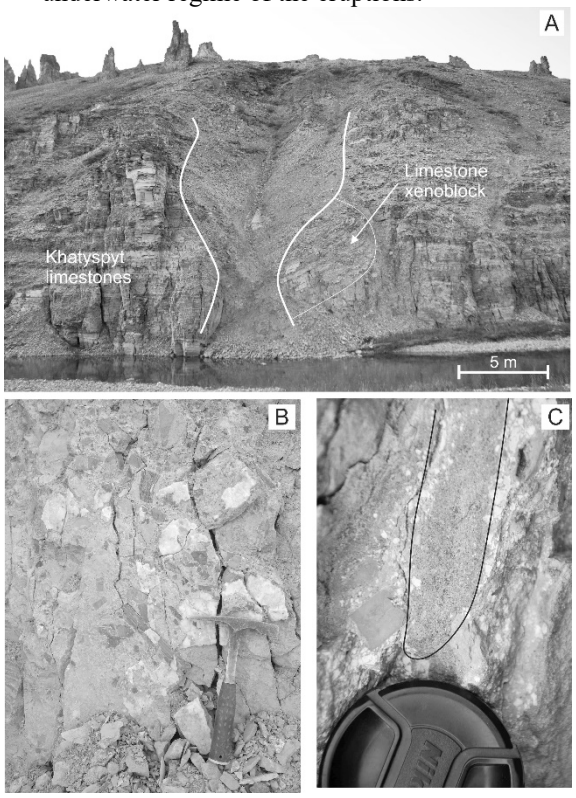

Fig. 2 – (A) Tuff breccia pipe emplaced within Khatyspyt formation. (B) Textures of the breccia within the outcrop. (C) Sandstone mingling (outlined) in the base contact of tuff breccia and Syhargalakh formation (photo rotated 90°).

This study provides a robust field and laboratory evidence for recognizing the Tas-Yuryakh volcano-magmatic complex comprising shallow-level chambers (sills), lava feeders, dome structures, solitary explosion pipes and sheets of basalts and tuff breccia. Insofar as the style of submarine eruptions is thought to be sensitive to water depth (Wohletz and Heiken, 1992), the observed alteration of explosive and effusive eruptions could have resulted from periodic sea-level oscillations in a relatively shallow-water setting, a conclusion that is consistent with lithofacies interpretation for the Syhargalakh Formation. Finally, assuming that the sills are coeval with the volcanic rocks, the U–Pb dating should be performed on baddeleyite from coarse-grained gabbro composing the sills, in order to better constrain the age of Ediacaran/Cambrian boundary in the Siberia.

Acknowledgements

The study was conducted at IGM SB RAS and IPGG SB RAS under Government Contracts and supported by the Russian Foundation for Basic Research grant 18-05-70110.

References

Bowring, S.A., Grotzinger, J.P., Isachsen, C.E., Knoll, A.H., Pelenchaty, S.M., Kolosov P. 1993. Calibrating rates of Early Cambrian evolution. Science 261: 1293-1298

Kiselev, A.I., Kochnev, B.B., Yarmolyuk, V.V., Rogov, V.I and Egorov, K.N. 2016. The Early Paleozoic basite magmatism in the northeastern Siberian Craton. Geodynamics and Tectonophysics 7: 233-250.

Rogov, V.I., Karlova, G.A., Marusin, V.V., Kochnev, B.B., Nagovitsyn, K.E., Grazhdankin, D.V. 2015 Duration of the first biozone in the Siberian hypostratotypepf the Vendian. Russian Geology and Geophysics 56: 573-583.

Valentine, A.G., Graettinger, A.H., Sonder, I. 2014. Explosion depths for phreatomagmatic eruptions. Geophysical Research Letters 41: 3045-3051.

Vishnevskaya, I.A., Letnikova, E.F., Vetrova., N.I., Kochnev, B.B., Drill., S.I., 2017 Chemostratigraphy and detrital zircon geochronology of the Neoproterozoic Khorbusuonka group, Olenek uplift, Notrheastern Siberia. Gondwana Research 51: 255-271

Wohletz, K.H. and Heiken, G. 1992. Volcanology and Geothermal energy. In: Los Alamos Series in Basic and Applied Sciences. Univ. California Press, Berkeley, CA, 432 pp.