Plinian eruptions of Zavaritsky caldera complex (Simushir Island, Central Kurules) as a source for ultradistal tephras found in deep-sea sediments of Okhotsk Sea.

Dirksen[a] O.V., Rybin[b] A.V., Pletchov[c] P.Yu.
[a] – Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky, dirksen@kscnet.ru
[b] – Institute of Marine geology and Geophysics FEB RAS, Yuzhno-Sakhalinsk.
[c] – Fersman Mineralogical Museum RAS, Moscow

Recent tephrochronological investigations of Quaternary sediments in the deep-sea cores obtained in the NW Pacific revealed the large amount of tephra layers deposited over the Far East Seas (Derkachev et al., 2016a, 2016b, Ponomareva et al., 2018). However, the attempts to correlate those ashes with known terrestrial volcanic eruptions displayed the significant lack of knowledge on the chronology of strong volcanic events occurred within the surrounding areas as well as chemical characteristics of the erupted products. Whereas the chronology of the Holocene powerful eruptions within Kamchatka and geochemical characteristics of their products were established rather scrupulously, the eruptive histories of many Kurile Islands volcanoes are still unstudied. As a result, even for the Holocene (the best studied time interval) marine deposits, only three tephra layers were identified, of them just one tephra of Kurile lake caldera eruption (Southern Kamchatka) was detected with a large confidence. The cluster of volcanic centers in Simushir Island (Central Kuriles) is one of the most enigmatic. Our investigations aimed to cover, in part, this gap and obtained new information on the chronology of eruptions as well as geochemical fingerprints of erupted products. The appearance of local volcanoes implies very complicated eruptive histories of these centers, including several caldera-forming eruptions. Simushir Island presents a narrow belt of five coalesced volcanic edifices of different ages, 57 km long and up to 9 km wide. The most detail publication on the volcanoes of this island occurred in 1967 AD (Gorshkov, 1967). Some data on paleoenvironmental events in Simushir was published by Razzhigaeva et al. (2013). Detail regional tephrochronological research along the whole Kurile Island arc were carried out by Japanise scientists (Nakagawa et al., 2008) and their results helped us to significantly improve our investigations.

Our field work covered an area around Nakatomari bay, from the southern foot of Pik Prevo volcano to the northern outer slope of Zavaritsky caldera complex. We described more than 20 soil-pyroclastic sections and sampled about 150 tephra layers for future geochemical investigations. The major-element compositions of volcanic glasses were determined at the Moscow State University for 70 samples using a JEOL JSM-6480 electron microprobe. The field trips, site-by-site correlation of described sections and the results of geochemical investigations allowed us to reconstruct, in some degree, the eruptive history of Zavaritsky caldera complex for the last 10000 yrs and detect several plinian and sub-plinian eruptions which ashes could be distributed over a large area and found in deep-sea cores in Okhotsk Sea and Western Pacific.

The caldera complex consists of two merged calderas with a large shield-like volcano inside. At the final stage of its evolution, this volcano seems to experience several strong eruptions which destroyed its SE part and formed a big crater (caldera III, according to (Gorshkov, 1967)).The most spectacular site (#201118) was found at the gully of small creek at 2.5 km north of the caldera rim. At the outcrop we detected more than 130 tephra layers, Probably Holocene in age, intercalated with poor volcanic sandyloams. The most of the tephras represent the gray, dark gray scoriaceous lapilli and sand of different thickness. All the tephras of Zavaritsky caldera have a very distinctive feature: they have very low potassium content. While SiO_2 ranges from 55 to 67 wt.%, K_2O varies from 0.36 to 0.9 wt.%. The more alkaline samples represent the tephras of Pik Prevo volcano.

At the base of the outcrop we found two thick pyroclastic deposits which significantly differ from other tephras of Zavaritsky caldera. The lower unit is poorly sorted, matrix supported, non-stratified not-welded lapilli tuff. The main part of the lapilli and gravel population mainly consist of dark yellow highly porous pumice, up to 5 cm in size. The minor part is represented by dark gray clasts of dense slightly porous rocks and hydrothermally altered rocks of different colors. We suggest this unit represent the pyroclastis flow deposits formed during the last caldera forming eruption at the very beginning of the Holocene. We labeled this eruption as Z_H-1 for further using. At other sites this unit is represented by ash fall deposits with a stratified surge-like deposits ontop. We found Z_H-1 deposits in many sections within the island, it is also found in many sections in Central and Northern Kurile Islands what suggest the ash fall dispersed to the North of the eruptive center. Glasses of the pumice of this eruption are the most silisic ones among the other Holocene tephras. SiO_2 content ranges from 71 – 73 wt.%, K_2O – varies in very low range from 0.9 to 1.0 wt.%.

Fig. 1. Soil-pyroclastic section 201118

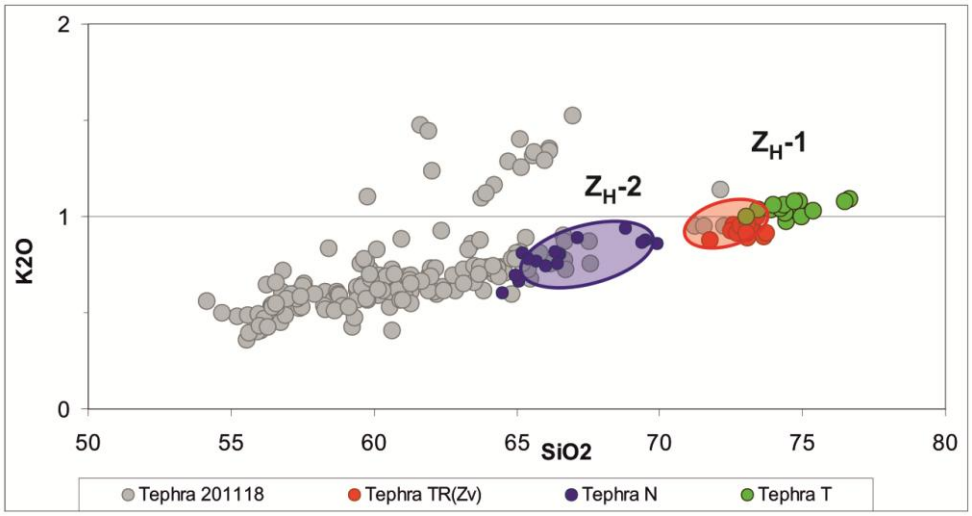

Fig. 2. SiO_2 – K_2O diagram of glass composition for the tephras of 201118 section and tephras from Okhotsk Sea. Tephra labels TR(Zv), N and T – according to (Derkachev et al., 2016a). Red and blue areas outline the composition of Z_H-1 and Z_H-2 tephras, respectively.

The upper unit consists of clast supported well sorted stratified reverse graded pumice lupilli tuff brownish–yellow in color, formed as a result of heavy ash fall. Within the lower 20 cm pumice is 0.5 – 4 cm in size, yellow in color, pumice of the upper 50 cm is gray, yellow in color, many banded clasts occur. The pumice size varies from 1.0 to 6 cm. At the very bottom of the unit we found a fine grained brightly grey sandy ash, 2 – 3 cm thick. SiO_2 and K_2O content in pumice covers wider range: 65 – 72 and 0.7 – 1.1 wt.%, respectively. We labeled this eruption as Z_H-2. We found this unit up to the northernmost tip of the island, where it is 20 cm thick and did not observed south of caldera what suggest the tephra of Z_H-2 eruption also travelled to northern directions.

The characteristic features of Z_H-1 and Z_H-2 units allowed us to easily recognize both units in the sections described in (Nakagawa et al., 2008). Radiocarbon dates published in this paper suggest the ages of eruptions are ca. 8000 ^{14}C yrs BP for Z_H-1 and ca. 6800 ^{14}C yrs BP Z_H-1, respectively.

Distinctive geochemical fingerprints of Z_H-1 and Z_H-2 helped to identify these tephras among the ashes of deep-sea cores obtained in the different parts of Okhotsk Sea (Derkachev et al., 2016a, 2016b). We consider the Z_H-1 corresponds to tephra TR(ZV), found 200 km NW of the island and support the origin TR(ZV) tephra from Zavaritsky caldera. Tephra Z_H-2 corresponds to N tephra, found ca. 900 km NW of the island (Derkachev et al., 2016a), associated by authors with Gamchen volcano (Northern Kamchatka).

At the marine sediments of the southern part of Okhotsk Sea the authors described one more tephra with age of ca. 30 – 35 ^{14}C kyr BP, labeled tephra T, which has rhyolite glass with very low K_2O content (Derkachev et al., 2016a). They associate this tephra with one of the eruptions of Mashu caldera in Hokkaido, Japan. Indeed the geochemistry of Mashu eruptives (Hasegawa et al., 2012) is rather similar to T tephra characteristics. However, the analyzes of published data on this caldera shows that most of powerful eruptions took place during the caldera stage which started ca. 12 ^{14}C kyr BP (Katsui et al., 1975, Yamamoto et al., 2010) and their tephras (labeled Ma-j to Ma-a) were distributed mainly to the East (Hasegawa et al., 2009) but not to the North, the directions to deep-see cores where tephra T was discovered. The earlier eruption were rather weak, their tephras did not dispersed far from the center. From the other hand, the geochemical characteristics of T tephra are very similar to silisic products of Zavaritsky caldera complex. We do not know much about the pre-Holocene eruptive of this center but the older caldera of this center should be formed during the Late Pleistocene. Considering the similar geochemical characteristics and possible Late Pleistocene age of the powerful caldera-forming eruption we favor the idea that tephra T were deposited during the first caldera-forming eruption of Zavaritsky caldera complex which occurred at the Late Pleistocene. However this question requires additional investigation.

This research was carried out as a part of the science investigation theme № 0282-2016-0003.

References:

Derkachev A.N., Nikolaeva N.A., Gorbarenko S.A., et al. Tephra layers in the Quaternary deposits of the Sea of Okhotsk: Distribution, composition, age and volcanic sources // Quaternary International. 2016a. V. 425. pp. 248-272.

Derkachev A.N., Nikolaeva N. A., Portnyagin M. V. Mineral Composition of Tephra Layers in the Quaternary Deposits of the Sea of Okhotsk: Heavy Minerals Associations and Their Geochemistry // Geochemistry International, 2016b, Vol. 54, No. 2, pp. 167–196.

Gorshkov G.S. Volcanisn of the Kurile Islans arc. Moscow, Nauka. 1967. 288 p.

Hasegawa, T., Kishimoto, H., Nakagawa, M., et al. Eruptive history of post-caldera volcanoes of Kutcharo caldera, eastern Hokkaido, Japan, as inferred from tephrostratigraphy in the Konsen and Shari areas for the period 35-12 ka // Journal of Geological Society of Japan. 2009. V.115(8). pp. 369-390.

Hasegawa, T., Nakagawa, M., Kishimoto, H. The eruption history and silicic magma systems of caldera-forming eruptions in Eastern Hokkaido, Japan. Journal of Mineralogical and Petrological Sciences. 2012. V. 107. pp. 39-43.

Katsui, Y., Ando Sh., Inaba K. Formation and Magmatic Evolution of Mashu Volcano, East Hokkaido, Japan. Journal of the Faculty of Science, Hokkaido University. Series 4, Geology and Mineralogy. 1975. V. 16(4). Pp. 533-552.

Nakagawa, M., Ishizuka, Y., Hasegawa, T., et al. Preliminary Report on Volcanological Research of KBP 2007-08 Cruise by Japanese Volcanology group. Hokkaido University, Sapporo, Japan. 2008.

Ponomareva V., Polyak L., Portnyagin M., et al. Holocene tephra from the Chukchi-Alaskan margin, Arctic Ocean: Implications for sediment chronostratigraphy and volcanic history // Quaternary Geochronology. 2018. V. 45. pp. 85-97.

Razzhigaeva N., Ganzei L., Belyanina N., Grebennikova T., Arslanov Kh., Pshenichnikova N., Rybin A. Role of climatic and volcanogenic factors in the formation of organogenic sediments and the development of landscapes on Simushir Island (Central Kurile Islands) in the middle-late Holocene. Russian Journal of Pacific Geology, 2013, V. 7, I. 3, pp. 199–211.

Yamamoto T., Itho J., Nakagawa M., et al. ^{14}C ages for the ejecta from Kutcharo and Mashu calderas, eastern Hokkaido, Japan. Bulletin of Geological Survey of Japan. 2010. V. 61(5/6). pp. 161-170.