Ca, Mo and U isotopes suggest Neoproterozoic-like ocean conditions during the Late Permian Mass Extinction

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The most catastrophic extinction event in the history of animal life occurred at the end of the Permian Period, ca. 252 Mya. Ocean acidification and global oceanic euxinia have each been proposed as causes of this biotic crisis, but the magnitude and timing of change in global ocean chemistry remains poorly constrained.

Here we use Ca, Mo and U isotopes applied to globally distributed, well dated late Permian- early Triassic sedimentary sections to better constrain the magnitude and timing of change in ocean chemistry through this interval. All the investigated carbonate successions (Turkey, Italy and China) exhibit decreasing $\delta^{44/40}$Ca compositions, paralleling a major decrease in δ^{13}C values. These findings support an episode of ocean acidification coincident with the major biotic crisis. The Mo and U isotope records exhibit significant rapid negative anomalies at the onset of the main extinction interval, suggesting rapid expansion of anoxic and euxinic marine bottom waters during the extinction interval. The rapidity of the isotope excursions in Mo and U suggests substantially reduced residence times of these elements in seawater relative to the modern, consistent with expectations for a time of widespread anoxia. The large C-isotope variability during the early Triassic, which is similar to that of the early-middle Cambrian, suggests imply largely biogenetically controlled perturbations of the oceanic carbon cycle. These findings strengthen the evidence for a global ocean acidification event coupled with rapid expansion of anoxic zones as drivers of end-Permian extinction in the oceans.

Shiveluch volcano: Mineralogical records of geodynamic complexity

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Shiveluch is the most north active andesite volcano on Kamchatka. Several types of magmas mix and interact in Shiveluch magmatic system. There are only two centres of the basaltic eruptions on Shiveluch. Olivine-plagioclase basalts form dyke complex of the NW orientation on the northern edge of caldera. Second centre was found recently on the western slope of volcano. Complex structure of the magma localization in the thick crust of Northern Kamchatka is revealed by the seismic tomography (Lees *et al*., 2007). Contrasted low Vp zones are traced at the depths 5-7, 13-17, 25-30 km with horizontal dimensions up to 100 km larger than typical intervolcano distances. Results of the magmatic amphibole barometry (new barometer-Simakin *et al*.,2012a) also clustered around three observed geophysically levels. Detailed mineralogical study of two types of Shiveluch basalts demonstrates heterogeneity of the whole rock and even individual crystals. Oxygen fugacity estimates with clinopyroxen geo-oxobarometer (Simakin *et al*., 2012b) yield bi-modal distributions with fO_2 around NNO+1(0.5) and NNO+1.6(2.5). Second maximum is close to the high fO_2 estimates (c.a. NNO+2) typical for the high pressure (up to 10-11 kbar) amphiboles.

Compositions of Holocene volcanites around Shiveluch on SiO_2-Ba diagram are separated into several evolutionary series with different initial Ba content. The upper SiO_2-Ba set (Sedanka volcanic centre with several Shiveluch compositions) on the Th/Yb – Nb/Yb diagram adjoins decompressional mantle partial melts array. These magmas presumably originate at the mantle upgoing flow near the subducting plate edge. Low Ba basalts (Baidarnaya centre) belong to the Bezymianny-Klyuchevskoy volcanoes compositions set forming on the Nb/Yb – Th/Yb diagram vertical array between normal IAB and N-MORB compositions. Effective melting of the underpated thick continental crust near the Moho depth produces oxidized siliceous amphibole-bearing magmas of adacite affinities. These three components mix and undergo crystallization differentiation before being erupted on Shiveluch.

[1] Lees *et al*., Geoph. Monograph Series 172, 2007. [2] Simakin A. *et al*., Earth Science Res., 1(2), 2012a. [3] Simakin A. *et al*., Petrology, 20(7), 2012b.

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