Common and specific elements of the microfabrics of vesicular soil horizons and desert varnish in the Mojave (USA) and Trans-Altai Gobi (Mongolia) Deserts

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The desert varnish and the vesicular crust horizon are distinctive morphological features of desert landscapes and, at the same time, generally recognized features of desert soil formation, being commonly referred to as the yermic (Aye) horizons in different sub-groups within reference groups of desert soils (WRB, 2014).

The objects of the present study were the surface horizons of vesicular crust and desert pavement in extremely arid soils of the Mojave (USA) and Trans-Altai Gobi (Mongolia) Deserts. The Mojave Desert objects included volcanic rock fragments with desert varnish from soils of the three most ancient (Early and Middle Pleistocene) piedmont plains without higher vegetation: in the Providence Mountains (age 53–65 kyr), on the volcanic Cima Plato (where the last eruption happened about 80 kyr BP) and within the Panamint Valley (age 75–85 kyr) (McDonald, 2014). In the Gobi Desert, an extremely arid soil on proluvial sediment containing red-coloured Cretaceous and Paleogene saline rocks at the northern slope of the Gobi Tien Shan Mountains was studied.

The study methods included micromorphological analyses of thin sections prepared in V.V. Dokuchaev Soil Science Institute (using an Olympus BX51 polarizing microscope) and submicromorphological analyses (using a JEOL JSM-6610LV scanning electron microscope with an INCA Energy X-Ray analyser). Additionally, we mapped the patterns of element distributions in the loci with morphologically pronounced cross-sections of desert varnish in the cut rock faces.

Our research on the surface horizons of extremely arid soils developed within the ancient piedmont plains has revealed a large complex of similar elements of microfabrics. The vesicular crusts are enriched in silt and clay particles due to aeolian transport and accumulation of such particles under rock fragments of desert pavement and, allegedly, also physical weathering of proluvial sediments under alternating conditions of heating-cooling and wetness-dryness, which cause these sediments to become increasingly silty, calcareous (due to secondary calcium carbonate accumulation) and sometimes saline. These factors favour the development of vesicular porosity. A change in calcium hydrocarbonate balance leads to the replacement of soil air that was adsorbed on mineral surface by condensational moisture and rainwater of rare summer showers.

The microchemical composition of the darkest and thickest varnish from deserts of different continents is similar and does not depend on the bedrock composition. Thin varnish films have deferent composition depending on the microrelief of rock fragment surface. The exposed surfaces of rock fragments of desert pavements are covered mostly by silicate-ferruginous films, while micro-cavities in those rocks usually bear two-layered films: the lower layer with the prevalence of manganese and increased concentration of barium and the upper layer with the prevalence of iron and accumulation of titanium. The proportions of these elements in samples from different deserts are very similar and interconnected. Combining the data of micromorphological and microchemical analyses of numerous samples has allowed us to suggest that desert varnish development is a polygenetic and polychronic process with dual nature: (1) accretionary-microbiological and (2) hydrophysical-biochemical. While the accretionary-microbiological hypothesis of desert varnish formation has already been substantiated (Dorn, Oberlander, 1981), the hydrophysical-biochemical hypothesis is only recently been suggested (Golovanov et al., 2016). Minerals of the coarse fraction from the Mojave Desert are more corroded and stronger fissured than those from the Gobi Desert. Rock fragments of the desert pavement and inside the vesicular crusts in the Mojave Desert are characterized by more developed and more complex pseudomorphs.

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