SCIENTIFIC JOURNAL
EARTH'S CRYOSPHERE

Kriosfera Zemli, 2011, vol. XV, No. 4, pp. 56–59 http://www.izdatgeo.ru

PERIGLACIAL EFFECTS AS A RECORD OF HISTORIC AND CLIMATE EVENTS

PERIGLACIAL PHENOMENA IN THE ALTAI MOUNDS, MONGOLIA

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Mound permafrost is common to the mountains of Altai, Kazakhstan, Mongolia, and China. Natural mounds in terrains affected by seasonal and perennial cryogenesis are often hard to tell from manmade burial sites. Mounds in northwestern Mongolia have been found out to lie over ice-rich sediments that differ in color and structure and over standing blocks, a setting typical of ancient tombs. The culturally undisturbed rocks beneath the mounds have lost their natural colors and structures as a consequence of frost heaving and weathering. The high ice contents of cryogenically eroded bedrocks, as well as intense frost shattering and sorting of debris result from local flooding of the active layer under the mound. The periglacial processes appear to have acted for 3000 years after the burial mound had been put up.

Archaeological sites in cold regions of the Earth (Arctic, West and East Siberia, highland Mongolia and China) often lie within past or present permafrost. The international multidisciplinary archaeological expedition of 2006, with permafrost scientists in the team, opened a new page in joint studies of the Earth's history [*Molodin and Parzinger, 2006*]. For archaeologists, who search for cultural objects and traces of human activity, the natural environment is a substrate to act upon while permafrost is a mean of conservation and, besides, something that poses problems to excavation. For cryologists, however, permafrost is an ages-long record of natural and man-caused events that took place during and after the burial. The Mongolia-2006 joint team faced the challenge of identifying whether cryogenic structures in the vicinity of mounds were of natural or cultural origin.

The northern highlands of Mongolia, including the southern slope of the Sailyugem Range, belong to an area of dry continental climate and to a zone of permafrost [*Melnikov, 1974*] subject to related seasonal thawing and frost shattering, heaving, and sorting of rock debris. Polygonal patterns with soil wedges, flat pentagonal mounds, dome-shaped heaves, rings and bands of debris, and standing stones resemble manmade structures by their geometry. The Sailyugem Range is known to be a place where several Bronze and Iron Age burial sites with flat or underground graves (4–0.1 kyr BC) were found [*Polosmak, 2001*].

Geophysical surveys [*Epov et al., 2006*] detected an ice lens and geometrical objects similar to burial chambers at depth to 2.5 m underneath Ulan-Daba-1 mound (Fig. 1). The objectives of the project included looking into the ice formation mechanism and checking the hypotheses of natural or manmade origin of geological heterogeneity, bearing in mind that there were cases of stepped multiple tombs.

The mound of the Ulan-Daba Pass is located in the right-hand side of the Shetk-Oigor-Gol valley at the elevation 2577 m and rests upon an alluvial fan overlying the exarated surface of jointed schists. The fan (subaerial delta of a side tributary) apparently formed after glacier retreat in the second half of the Holocene, possibly, in a cold and dry climate [*Dorofenyuk, 2008*]. Undisturbed rocks near Ulan-Daba-1 mound comprise (Fig. 2, trench 1) (i) black modern and brown fossil stony soils, with relic holes of lemmings and mice; (ii) stratified talus and alluvial reddish-brown debris with sand and clay matrix and carbonate or iron-hydroxide coats. The sediments have low water contents (7.2–9.7 %). They were deposited in a subaerial environment, the deposition being accompanied by shattering, debris sorting, soil formation, and repeated freezing of the active layer. The present active layer in the mound vicinity (southern side of a narrow valley) is 1.8–2.0 m thick and lies over permafrost with the water content 9.2 % (Fig. 2).

Prior to the excavations, Ulan-Daba-1 mound was a flat hill 15 m in diameter, rising 0.5 m above the ground surface, buried under modern soil with tilted schist blocks exposed at the center. The mound structure consisted of (i) a cover of clean small (under 0.2 m) plate-like schist pebbles and angular stones; (ii) a fence and an armor of clay-cemented round

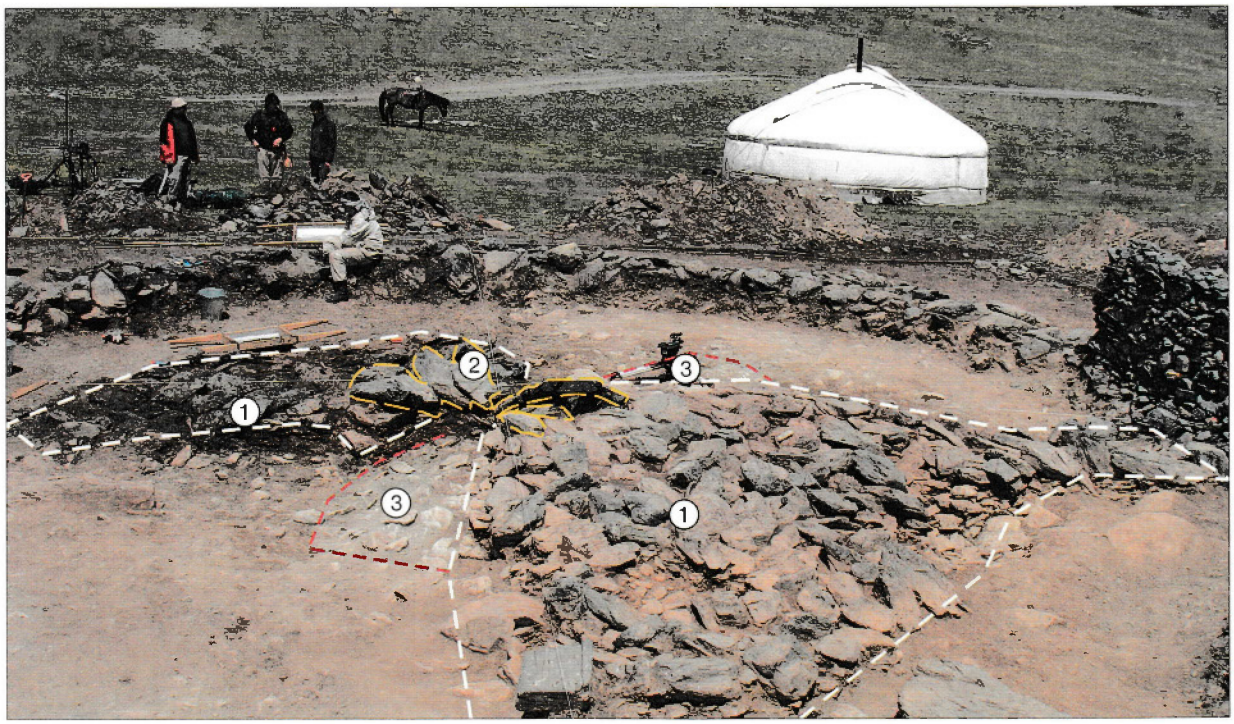

Fig. 1. Excavation at Ulan-Daba-1 mound:

① – fragments of dismounted stone armor (white dash line); ② – schist blocks, tomb remnants (yellow dash line); ③ – quadrangular contour of the false grave under the mound filled with whitish rocks (red dash line).

boulders; (iii) a bank and large (0.5–1.1 m) elongate blocks which are fragments of a stone burial chamber at the center. The burial chamber collapsed and the depression became filled with schist pebbles. The exposed tops of the blocks looked eroded by wind and thaw water while the lower parts were fixed with brown debris-bearing loamy sand, debris, and modern soil. Underneath there were pieces of human bones with a ^{14}C age of (2982 + 23) yr BP (KIA31153)[1]. The bank in the form of a flat hummock was composed of loose debris with thin schist plates. Judging by abraded carbonate crusts on the debris, the bank was built with the use of reddish soil and rocks picked inside the fence. The bank material showed higher water contents (16.5–29.0 %) than the rocks around the mound (Fig. 2).

Below the armor and the bank, there was a rectangular outcrop of unconsolidated light gray rocks including *in situ* debris and colorless schist plates. The rocks had no analogs among the local reddish-brown deposits and were encircled with large standing schist blocks, which made them looking like a filled grave. The excavation section displayed a rectangular 1.5–1.7 m wide pit that crosscut stratified reddish-brown sediments and holes of soil-dwelling animals to a depth of 1.7 m (Fig. 2). That was the active layer with a depthward increase in water content from 5.5 to 15.5 %, containing more sand and less coarse deposits relative to the surrounding ground (Fig. 2). The pit floor was bounded from below by frozen coarse rocks. The pit was called a "false grave" as no burial was found on the floor.

Further down the section (to the depth 2 m) there followed coarse frozen ground composed of flat schist blocks positioned tile-like one upon another and cemented with reddish sand and debris-bearing loamy sand with thin lens-type and reticulate cryostructures (water content 16.8 %). Note that tile patterns are also typical of cultural structures.

At the depth 2.0–2.5 m there appeared the geometric objects predicted by geophysical surveys: standing flat schist blocks with their juxtaposed narrow sides making up two adjacent angular-oval chambers (1.0 × 1.5 m) within the excavated area. The space inside and between the blocks was filled with ice-bearing debris loam and sand upon a fractured basal layer, with water content 30–61 % (Fig. 2). Glassy ice formed up to 10 cm thick crusts around the blocks

[1] Dated at Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian Albrecht University, Kiel, Germany.

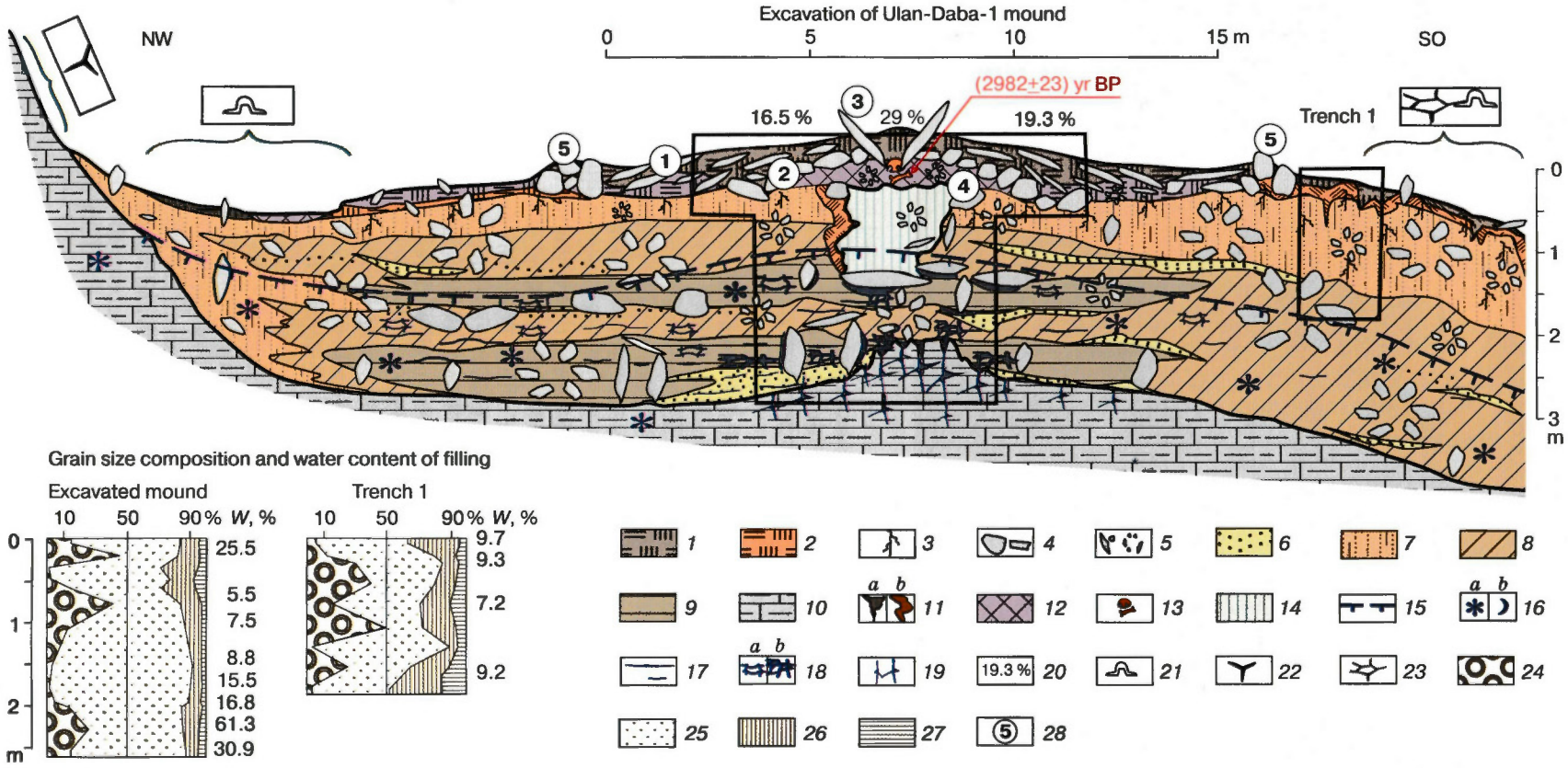

Fig. 2. Cross section of Ulan-Daba-1 mound and alluvium in Shetk-Oigor-Gol valley, Sailyugem Range.

Natural environment: *1* – modern black soil; *2* – fossil brown soil; *3* – plant roots buried *in situ*; *4* – boulders, blocks, plates; *5* – rock debris and annular structures; *6* – sand, gravel; *7* – sandy loamy sand; *8* – loamy sand; *9* – sandy loam; *10* – bedrock (schist, siltstone, sandstone); *11* – soil wedges (*a*), burrow holes (*b*); *12* – made ground; *13* – human bones. Cryogenic features: *14* – false grave, zone of frost weathering; *15* – permafrost boundary; *16–20* – cryostructure: *16* – massive (*a*), crust-like (*b*), *17* – lens-type, *18* – reticulate (*a*), basal (*b*), *19* – blocky, *20* – water content (wt. %); *21* – surface signature of frost heaving; *22* – surface signature of frost shattering; *23* – surface remnant polygon; *24–27* – grain size composition: *24* – 20.0–2.0 mm, *25* – 2.0–0.05 mm, *26* – 0.05–0.005 mm, *27* – less than 0.005 mm. Numerals in circles mark manmade structures (mound elements): ① – stone cover; ② – stone armor; ③ – depression made by collapsed tomb stones; ④ – bank; ⑤ – fence.

and enclosed thin layers of the host loam. The ice was found out to have nitrate-calcium-sodic major-element chemistry with high contents of sulfates (21 mg/l) and magnesium (14.5 mg/l), and a trace-element composition with V, Ti, Mo, W, B, Se, and Sr higher than in snow and ice fields, etc.[2]

The coarse deposits were underlain by a shattered surface of schists with eluvium (ice-filled vertical cracks more than 0.5 m high and up to 0.05 m wide).

The reported data indicate that the pit and the structure underneath the mound were not manmade, and the talus and fan deposits did not undergo later cultural perturbation. The schist blocks collapsed after the tomb had been looted and have survived till today making a depression which can retain snow. The light-gray rocks of the false grave were deposited in a subaerial delta and experienced post-depositional frost weathering and heaving in the active layer after the burial mound had been put up.

The water content pattern, high ice percentage, and the anomalous chemistry of ice and eluvium imply percolation of water enriched in organic and bronze particles, as well as local flooding of the active layer beneath the mound. The geometric structure of standing blocks was produced by sorting and emergence during deposition and seasonal and syngenetic ground freezing. Snow retention upon the mound provided additional moisture supply to the permafrost surface and the formation of an ice-rich zone in alluvial fan deposits and in cryogenic eluvium.

The structure of the culturally undisturbed and naturally altered rocks beneath Ulan-Daba-1 mound records the following sequence of events for the past 12 kyr after the retreat of the Pleistocene ice sheet in that part of the Sailyugem Range:

1. Frost weathering and formation of eluvium in the uppermost gray schist;

2. Burial of eluvium on the side of the Shetk-Oigor-Gol valley under subaerial alluvium of a tributary delta, about 8–4 kyr BP, at a high stand of moraine damlakes. The alluvium deposition was attendant with seasonal and syngenetic freezing and formation of circular systems of standing stones similar to burial structures in their shapes and sizes;

3. A stone armor, a bank, and a surface burial chamber were built about 3 kyr BP; the collapse of the burial chamber caused snow retention in the depression and ensuing local wetting of the active layer under Ulan-Daba-1 mound. That event was responsible for the formation, in the upper permafrost, of segregated ice with its chemistry and high content unusual for the arid climate of the area;

4. A discolored local rectangular zone formed for the past 3 kyr after the burial as a result of erosion and intense frost shattering of original dark deposits. Abundant sand particles and a relatively low content of silt at the site indicates incomplete frost weathering [*Konishchev et al., 2005*].

Therefore, new evidence has been obtained that rocks within geometric zones beneath burial mounds can loose their natural properties as a result of local frost weathering. Thus, till nowadays, the works of ancient people influence natural periglacial processes and upper permafrost.

The study was carried out as part of Basic Research Programs of the Presidium of the Russian Academy of Sciences (20.7) and the RAS Earth Science Department (11.4).

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Received
7 February 2011

[2] Analyzed at Limnological Institute, Irkutsk, by Prof. T.V. Khodzher and Dr. L.P. Golobokova.