Permafrost and climatic change in Mongolia

Jindřich Kynický [1], Martin Brtnický [2], Dušan Vavříček [1], Radka Bartošová [1], Uondon Majigsuren [3]

[1] Department of Geology and Pedology, Mendel University of Agriculture and Forestry, Zemědělská 3, 61300 Brno, Czech Republic, [2]Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Mendel University of Agriculture and Forestry, Zemědělská 1, 61300 Brno, Czech Republic, [3] Mongolian University of Science and Technology, Ulaanbaatal 46, Mongolia

Abstract. The permafrost area range in Mongolia is almost 1 million km^2, and can be easily divided into latitudinal and altitudinal types. The permafrost environment has changed markedly several times in central Asia. The ice wedges and permafrost formed during the Late Pleistocene are still present in central Mongolia. The lower limit of altitudinal permafrost in western Mongolia has elevated only a little (near 300m) since the last glaciation maximum. Compared with that in northern Europe and North America, latitudinal permafrost in northeastern Mongolia is less sensitive to local warming, but altitudinal permafrost, especially permafrost in the Altai and Khangai and partially also in Khentii Mountains, is sensitive to climate warming. Since the middle of the 20th century, significant permafrost degradation has occurred in Mongolia.

Introduction

Sodnom and Losev (1976) summarized the principal characteristics of permafrost in Mongolia. Although no maps have been digitized and included in the GIS-aided databases and models for cryospheric studies in Mongolia till now. During the last 10 years, permafrost studies in Mongolia have started and contributed to environmental protection. Our study has made an approached estimation for change in territorial permafrost distribution in Mongolia at the various scripts of possible change in a current climate. Further, within the 10 years of field works, new information for long-term average annual temperature of air and new borders of permafrost were found out in Mongolia.

Data and methods

Frozen ground was investigated in 2003-2009 period to study the distribution and degradation of permafrost in the selected mountains and basins, located at the northern Mongolia.

The presence of permafrost was examined by electrical and thermal soundings. The obtained data of permafrost distribution fitted to the sounding results was mapped and processed by GIS applications (Houška and Kynický, 2004). Detail temporal variations in thermal and hydrological regimes were also investigated for two years (2004, 2005) at Khentii Mountains by manual observations of air and ground temperatures, precipitation, and near-surface soil moisture and groundwater level.

Results and disscussion

Permafrost distribution

The permafrost area in Mongolia is estimated at about 0,804×10^6 km^2, accounting for 51.4% of the total Mongolian land territory. Permafrost in Mongolia is mainly in the Khubsgul, Orkhon-Selenge, Khentii, Khangai and partially also in Hutag Ull Ord Mountains and can be divided into latitudinal and altitudinal permafrost or into 7 thermal stability types. The development and distribution of permafrost in Mongolia is mainly dependent upon climatic, geographic, geologic, hydrologic and surface cover conditions. The latitude is the second important factor that influences the distribution of the mean annual air temperature (MAAT) and thus, the distribution and development of altitudinal permafrost. With southward increase in the temperature, the lower limit of permafrost ascends 200-240 m in the Khentii, 150-270 m in the Khubsgul area, 260-320 m in the Khangai, 150-210 m in the Hutag Ull Ord Mountains and 240-350m in the Altai.

Permafrost evolution during the Quaternary

Many intensive and persisting glaciation–interglaciation permafrost shifts have set in the Quaternary (Prokopenko et al., 2007). In the Early Pleistocene, permafrost developed only in high mountains (Marchenko et al., 2007). The second glacial maximum during the Quaternary occurred between 0.8 and 0.6 Ma, with a MAAT in range from −12 to −4°C, and permafrost was extensively developed, especially in the northern Mongolia. Ice-wedges, formed during the coldest stage of the Late Pleistocene, were found at several places in the Khubsgul and Khentii (Kynický, 2006).

The interglacial period was warm period, and permafrost almost completely occurred in very high mountains of Altai, probably. During the glacial periods from 330 and 200 ka, permafrost was continuously distributed identified at least four periods of permafrost expansion during the past 150 ka. The permafrost area during the last glacial maximum (16–32 ka) was estimated at 1×10^6 km^2 (Kynický, 2006).

The warm period in the Holocene occurred from 8.8 to 3.4 ka, when the MAATs were about 2–5°C higher, resulting in permafrost degradation. Sand wedges stopped developing about 9 ka, indicating the start of warming. During 8–3 ka, the climate was warm and humid, and peat and paleosols were well developed as a result (Kynický, 2006). The warmest period in central Asia was about the 8.5–5.2 ka, when the MAATs were about 3–5°C higher; the megathermal occurred at about 6–4.5 ka (Marchenko et al., 2007). Therefore, the permafrost in Mongolia is relict and has been degrading since the last glaciation. With the climatic fluctuations, the lower limits of permafrost moved up and down several times simultaneously, going down their present positions. During the Early Holocene warming, intensive and frequent flooding resulted in widely distributed gravel strata with thicknesses of 0.5–10 m overlying sediment with polygonal wedges. Permafrost north of the northern Gobi desert thawed completely.

Sensitivity of permafrost in Mongolia to past climatic changes

The southern limits of permafrost distribution in northern Europe have retreated 23–24° northward since the last

glaciation and have shrunk 16–18° northward in North America. However, in Mongolia, there have been only 5–7° retreats. This can be attributed to the combined influence of the strong and persistent inversion layer of the atmosphere up to 1500 m in elevation, controlled by the Siberia-Mongolia low pressures and local geography. In western Mongolia, the lower limits of altitudinal permafrost have risen several hundred m (Sodnom, Losev, 1976). In other words, the periglacial environment in Mongolia has been less sensitive to climate changes.

Recent permafrost degradation

As a result of climate warming about 0.4–0.5°C during the last 50 years, based on permafrost monitoring and characteristic of winter warming, extensive permafrost degradation has been interpreted and is expected in the future.

Monitoring along the transect through the Khubsgul and Khentii indicates an increasing of the MAGTs of about 0.4–0.5°C in seasonally frozen ground, taliks, and island permafrost zones, and about 0.2–0.3°C in the continuous permafrost zones. In the unstable permafrost zone, with a MAGT of −0.5–0°C, permafrost warms quickly. The secular warming during the last 35 years was estimated at least 1.0°C in the Khentii Mountains, and the southern limit of Eurasian permafrost has retreated 20–30 km northward there. It is predicted that the northward shrinkage of the permafrost will be about 80–200 km and the MAGT will rise correspondingly, if the air temperature increases 1°C within the next 50 years.

Recent climate humidization versus aridization events

Episodes of dry/warm and cool/humid are distinctive for overall Upper Holocene. But they are of no important significance for quarternary climate history. Alternations of warm/wet optima and cool/dry pesims are more important. Occurrence of unusually strong summer monsoons brings floods into Mongolia too (Bajer et al., 2008). In contrast, following winter could be affected by heavy dry spell during El-Niňo event. Flood events in Asia do not correspond with warming cycles. That is why permafrost melting could not be attended acompanished with by the central Asia climate humidization. After permafrost melting, the huge runoff or desiccation with desertification could come. No long-term relation between humid periods and stronger Asian summer monsoons alternations was evidenced (Prokopenko et al., 2007). Permafrost degradation does not indicate other spreading of niches for vegetation. Probably for this reason a biome borders in Eastern Siberia and Mongolia still have been occurring in the same ranges since the Late glacial through strong climate changes run (Tarasov et al., 2000). Landscape of the Mongolia is still predisposed to desertification (Houška and Kynický, 2004; Samec et al., 2006; Bajer et al., 2008).

Conclusions

The area of permafrost in Mongolia has experienced recent shifts, and may have disappeared in central Mongolia, except on very high mountains, during next decades. Accelerating fluctuations of climate and permafrost have been identified during the Holocene, and most areas of permafrost in Mongolia now are relicts of cold climates and have been in degradation, especially during the past 50 years. The climate has been warming since the last glaciation, significant warming and flood events have been observed since the 1970s and 2000s, and the same trend is expected in the future.

The most important impact of permafrost degradation is on water resources. Protection of cold regions and water resources will be a key issue for the human and environment in Mongolia (Kynický, 2006; Novotná, 2008; Rukavičková, 2008).

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