Short communication

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Lakes of Eurasian interior, which significantly raised their levels in the recent past

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ABSTRACT. The paper presents geomorphological evidences of former appearances of huge lakes in Mongolia and in the south of Siberia visible on satellite images. Most of lakes in Mongolia and transboundary Russia are terminal basins collecting waters from catchments of large rivers draining the Altai, Khangai and Khentey Mountains, while in the south of Siberia such lakes had no sizeable sources for water input. The discussing reasons for these rises are obviously climatic with possible high influence of deglaciation processes in the surrounding mountains.

Keywords: geomorphology, remote sensing, paleolakes, terminal basins, lake level changes, Mongolia, Russia, Central Asia

1. Introduction

There are three regions of Mongolia, where lakes of this type occur: 1) the Great Lakes Depression in its north-west; 2) the Valley of Lakes (sometimes called the Valley of Gobi Lakes) in the south-west; and 3) the north-eastern part of the country (Fig.). All they are parts of the Central Asian Internal Drainage Basin; this means that the lakes under consideration (most of them) are terminal (endorheic), and collect waters from the surrounding mountain ranges. The bounding ranges of the Great Lakes Depression are Tannu-Ola (West and East) in the north, Mongolian Altai in the west and south-west, and Khangai in the east. The Valley of Lakes extends between the Gobi Altai and Khangai Mountains. The north-eastern region has no distinct orographic boundaries and locates eastward, south-eastward of the Khentey (Khentii in Mongolian) or Yablonoy (Yablonoviy in Russian) ranges. The regions consist of a number of separate terminal basins, which include one or two terminal lakes (lake systems) or, in case of the Khyargas Nuur, a system of intermediate lakes.

2. Materials and methods

For the geomorphological analysis of the lake basins presented in this paper, we used the following data sources: general topography from the Russian army map, the Google Earth Pro Earth visualization software with its embedded NASA SRTM DEM topographic data, and the Wikipedia public domain data about the lakes and their basins. The data refer elevations based on different vertical datum; therefore the elevations may differ due to this factor. Additionally, the lake levels may vary with a time, which is also reflected in the elevation marks in the used topographic sources.

3. Results

Brief description of lakes

Uvs Nuur. This is the largest lake of Mongolia by its area - 3350 km^2 (Fig.). With maximum depth 20 m and average 10.1 m, its volume is 35.7 km^3. The lake has map altitude of 759 m a.s.l. The shorelines rising 10 m above the lake are better seen in its northern and south-eastern banks. The upper shorelines obviously cut the previously formed piedmont fan systems; however, without any erosional scarp. The area of the lake at its highest stand seemingly did not rise considerably, whereas the volume increased more than two times and could reach 90 km^3.

Uureg Nuur occupies a small depression inside the Mongolian Altai westward of the Uvs Nuur (Fig.). The lake area is 239 km^2 and volume is 6.4 km^3; maximum depth. 42 m and average depth 26.9 m. The basin lies at the altitude of 1425 m a.s.l. The banks of the lakes have a stair of shorelines rising 55 m above its modern water surface. This means three times increase of the volume of the lake which could reach 20 km^3.

Khyargas Nuur and ***Airag Nuur*** located in the central part of the Great Lakes Depression form a largest terminal basin of Mongolia by its capacity to store water (Fig.). Modern levels of the lakes are 1028

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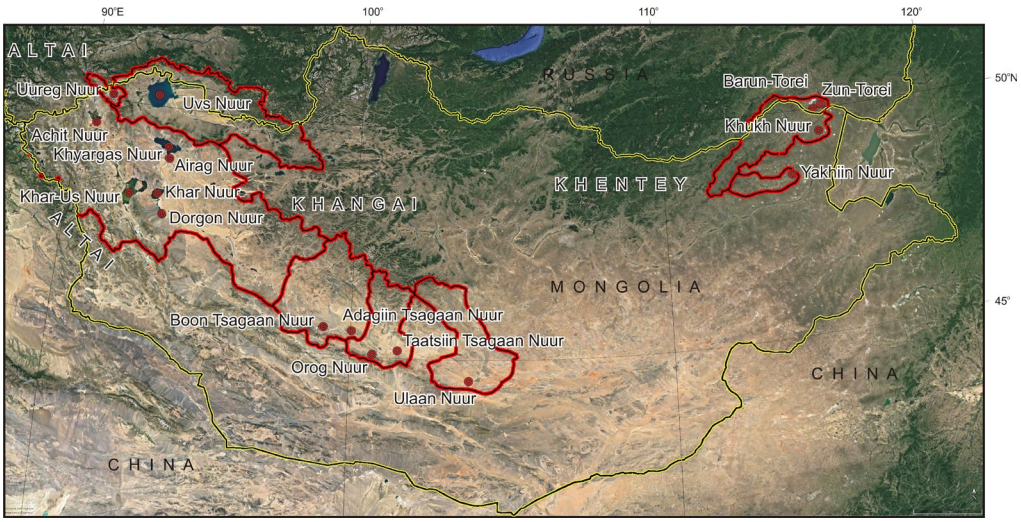

Fig. Google Earth based map of Mongolia and transboundary Russia showing location of the investigated lakes and largest mountain ranges. Yellow line – country boundaries. Red line – boundaries of the lake catchments (Krivonogov et al., 2020).

and 1030 m a.s.l., respectively. The terminal Khyargas Nuur is deep-water with maximum depth of 80 m. Its average depth is unclear; different sources give it in the range from 31 to 50.7 m. Correspondingly, the area estimates vary from 1468 to 1481 km^2 and volume from 66 to 75 km^3. The intermediate Airag Nuur is located to the south of the Khyargas Nuur and is connected with it by a narrow river-like Nuuryn-Kholoi channel. It accepts the major rivers flowing to the basin and annually transfers 1.2 km^3 of the water to the main basin. The area of the lake is 143 km^2. The maximum and average depths are 10.5 and 5.7 m, respectively.

Lakes Khyargas and Airag are surrounded by the shorelines rising 115 m above their current level. They represent a huge lake approximately three times larger in area and many times larger in volume than the modern one, with the maximum depth of 195 m. This rise suggests a huge amount of water delivered from the catchments. The catchment of the Khyargas Basin is very large, about 180,000 km^2. It comprises the Zavkhan Gol valley and valleys of its tributaries, the largest of which is Khovd Gol. If the Zavkhan Gol flows directly into the Airag and Khyargas lakes, the Khovd Gol ends by a delta in the Khar-Us Nuur. From this lake, the waters arrive to the Khar Nuur by the short Chono-Kharaikhyn Gol and farther to the Zavkhan Gol by the Teeliin Gol. These lakes and their linked Dorgon Nuur, form a system of intermediate lakes, where the waters of the Khovd Gol diminish by evaporation.

Boon Tsagaan Nuur – Adagiin Tsagaan Nuur system. This is a terminal basin for the Baidragin Gol (295 km long, catchment about 28300 km^2) (Fig.). The whole depression is rather flat and the river delta serves as a topographic divide between its western and eastern parts, where the lakes locate. Altitudes of the lakes are: the Boon Tsagaan Nuur 1313.4 m a.s.l. and the Adagiin Tsagaan Nuur 1283.8 m. The western shores show the stair of shorelines up to 1317 m a.s.l. and rare bars up to 1321 m a.s.l. The eastern bank of the Adagiin Tsagaan Nuur has a distinct stair of shorelines ascending up to 1341 m a.s.l. which is 49 m higher than the former stable level of the Adagiin Tsagaan Nuur and 29 m higher than the surface of the Boon Tsagaan Nuur. This means that a single lake as large as 2026 km^2 and about 90 km^3 formed at this level.

Orog Nuur – Taatsiin Tsagaan Nuur system. The Orog Nuur and Taatsiin Tsagaan Nuur are terminal basins for the Tuin Gol and Taatsiin Gol, respectively, with total catchment about 21800 km^2 (Fig.). The Orog Nuur has altitude 1221 m a.s.l., area 140 km^2, and volume 0.42 km^3. Its maximum depth is 5 m and average depth 3 m. The lake is surrounded by a stairs of shore bars rising up to 1274 m. a.s.l. The 1266 m a.s.l. level of the Orog Nuur is controlled by a spillway to the Taatsiin Tsagaan Nuur basin. The lake is a dry salty silty plain in our days. The dry bottom on Google Earth is 1236 m a.s.l. In the western edge of the basin, the spillway from the Orog Nuur opens to the plain at 1255 m a.s.l. In the northern edge of the Taatsiin Tsagaan Nuur shorelines are seen at 1243, max. 1245 m a.s.l.

The Torei lake system. The Zun-Torei and Barun-Torei lakes occupy the Torei Basin, a tectonic depression inside low mountainous Siberian and Mongolian Transbaikalia (Fig.). The lakes considerably change their level and form a single lake, two separate ones or even dry out depending on water supply. The lake is fed by the larger Uldza River (425 km long, catchment 26,900 km^2) and smaller Imalka River (156 km long, catchment 1480 km^2). The Barun-Torei Lake at higher water level of 598 m a.s.l. has maximal depth 6 m, area 580 km^2, and volume 1.38 km^3. The terminal Zun-Torei Lake at the water level of 600 m a.s.l. has average depth 1.5-1.6 m and maximum 6.7 m; the area reaches 302 km^2 and volume 1.62 km^3. Shorelines show ancient rises of the Torei lakes; the merged lake reached 616 m a.s.l., i.e. 20 m above the modern (596 m) level. At this level, the lake waters overflowed the basin watershed and discharged southward to the Khukh Nuur lake system via the Teliin Gol River.

Khukh Nuur occupies a terminal basin in the Onon-Kerulen rivers interfluve (Fig.), which is the most lowland territory of Mongolia. It is the lowest place of Mongolia, altitude 560 m a.s.l. The lake surface is 566 m a.s.l., the area is about 67 km^2. Google Earth shows multiple shorelines around the Khukh Nuur rising to about 603 m a.s.l. At this level, the waters should cover

the adjacent lake basins eastward of the Khukh Nuur; there are spillway channels between the lakes and poorly seen shorelines. Watering of the basin is linked to the evolution of the Torei lake system.

Yakhiin Nuur locates in the south of the Eastern (Dornod) Province of Mongolia. The lake is a terminal basin in the southern part of the Onon-Kerulen interfluve (Fig.). Modern lake level is 660 m a.s.l., Mongolian Wikipedia reports area 97 km^2 and volume 0.223 km^3 at the level 670 m a.s.l., maximum depth 4 m and average depth 2.3 m. The lake is fed by the Galiin Gol River; total area of the lake catchment is about 7000 km^2. Shorelines around the Yakhiin Nuur rise to about 705 m a.s.l. This means the lake level increased 47 m above the modern one.

4. Discussion

Several publications reveal histories of the described basins in Western Mongolia, e.g. Lehmkuhl et al. (2018). A limited number of published OSL and ^{14}C dates infers rises of the lakes during the Holocene; however, detailed timing of the described high stands of the lakes is still unclear. Another problem is water sources. Researchers link the rises with moisture evolution (Wang and Feng, 2013), fluvial catastrophes (Agatova and Nepop, 2019) or deglaciation of the surrounding mountains (Krivonogov et al., 2020).

5. Conclusions

The presented remote sensing data on the lakes and age constraints available for the lakes give us ground to declare this problem as unsolved in part of timing, lake catchment history, and general understanding of climatic processes in northern Central Asia.

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Conflict of interest

The author declares no conflict of interest.

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