The Origin of the Mountain River Dams in Tajikistan

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Abstract

The origin of mountains lakes' dams is the source of much discussion among researchers. The most common interpretation is that gravitational phenomena on valley slopes are the primary source of such dams. Moreover, the biggest dams are interpreted as seismically triggered events, resulting in estimates of very high past seismicity rates for areas where such dams are located. Nevertheless, many big mountain river dams have the glacial origin, although the shape of such dams are the same like gravitational phenomena.

Keywords

Landslide • Glacier • River dam • Moraine • Lake • Mountain

The last glaciation (glacial epoch) in the mountain systems of Pamirs, Hissar-Alay, Turkestan and Zeravshan occurred in the Upper Pleistocene, with the maximum 18,000–20,000 years ago (Lim et al. 1989). The thickness of the ice cover reached 2 km in the valleys. Deglaciation was episodic over long period of time, ending in the Holocene (3,000–4,000 years ago). As a result of the complicated glacial history, glacial ridges and benches were formed on the slopes of mountain valleys, and end moraine complexes of loose deposits collected on valley floors. Most of these deposits are further covered by ablation moraines.

The structure of such glacial deposits is very complicated, and requires detailed investigation. In general two types of glacial deposits can be recognized: properly glacial and those created by melt water. Together, these two groups form complicated glacial complexes with characteristic bedding and soft-sediment deformation from shearing and folding.

When the glacier melts, cirque walls with steep fractured walls are formed, and rock glaciers or talus tails collect on the toe of the slopes. These features are commonly misinterpreted as rock slides because the shape of the glacial niches and a rock slide scarps are very similar, as is the shape of the rock glacier and a slide body. However, near-slope rock glaciers are situated with end-moraine complexes (for instance, Lake Sheva in Afghanistan).

If lateral moraines are thick enough, they form bench like slope discontinuities which fix the stage of glacial melting. The bench shapes are different from alluvial terraces. They have sagging profiles, their surface and riser ages are the same, their surfaces have significant slope, and they end with ridges formed by psephitic rocks. Like rock glaciers, these moraines are often misinterpreted as mass-wasting features, sometimes as paleo-seismodislocations (seismic cracks). A good example of misinterpretation of such forms are the "rock slides" sections on the Lake Sarez in Pamir (Fig. 1). The differences between rock slide forms and glacial forms can be recognized only by investigating the internal structure of such bodies, not by analysis of the shape. Such investigation suggests that several mountain lakes in the Pamir (and some lakes in Southern Tien Shan like Iskanderkul Lake, Marguzor lakes) are associated with glacial activity and glacial deposits. These mountain lakes are located either within the subglacial deposits or behind end-moraine complexes. Where end-moraine complexes are incised by the rivers, but we can still find evidence of moraine dams in the form of upstream lake deposits.

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Fig. 1 Benches in the side moraine on the Vatasaif section, Lake Sare

One good example of a lake dammed by glacial deposits is Lake Yashilkul in Alichur River basin. It is the biggest existing glacial dammed lake in the Pamir. This lake is usually interpreted as a rock slide dammed lake, with the rock slide originating on the left side of the valley (Rajabov et al. 2002). However, sedimentological analyses suggest that this lake was instead formed in the end of Upper Pleistocene by the deposits of multiple glaciers in tributaries of the Alichur River – Big and Little Marjanay, Big Bogjigir and Oktobogjigir 1st and 2nd. The moraine complex consisting of side ridges and end-moraine was formed after deglaciation and dammed the river valley. A few such ridges (3–4) can be recognized on the right side of the Alichur valley near Burgumol pass on the elevation 3,900–4,000 m. After extending for 1.2 km to the west, they sharply decend to the bottom of the valley.

The Lake Yashilkul dam has a isometric shape and extends from east to west over 4 km, with a maximum width of 1.4 km (Fig. 2). Rock fragments of different size (up to 5–6 m long) are located on the dam surface. The rock fragments are unsorted, and the shapes of single fragments may be elongate or isometric and angular. The lithology of the fragments varies, including almost all type of rocks located around the lake. The rock fragments have desert varnish on all surfaces (not just surfaces currently facing upward), and many have drift scratches with the furrow widths up to 2–3 cm. Deposits with rolled and angulated small fragments without varnish also occur, as do exposures of fine fill of pale color in some places under the rock fragments. The content of the fill reaches a maximum of 60 %. The biggest angular rock fragments drape over the underlying strata of moraine

Fig. 2 The Lake Yashilkul's dam

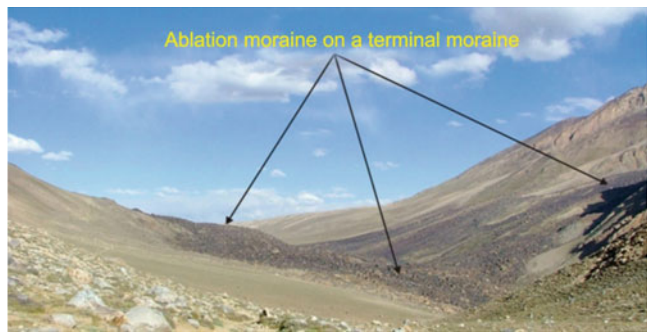

Fig. 3 The cover of ablation moraine on the Lake Yashilkul's dam

deposits. This cover tracks the original moraine surface, so the surface of the dam is hillocky and chaotic. Similar rock fragments also cover the sides and bottom of the valley (Fig. 3).

Such stratigraphy is more typical for glacial deposits than landslides or rock falls. Furthermore, if we assume that this dam is a rock slide than it should contain only biotite granite and gneiss-granite of the Pamir-Shugnan complex based on the proposed source area (according to geological map of this area). Instead, the dam also contains granites and granodiorites of the Alichur complex, plus shist, quartz rocks and marbles of the Ramaif suite of Proterozoic rocks, and phyllite slates of the Nematsdarinskaya suite of Lower Carboniferous. Thus, the lithology, internal structure, and shape of the Lake Yashilkul dam are more consistent with a glacial origin for this dam (Ischuk 2010, 2011).

Next, Lake Dirumkul is located in the Shakhdara River basin. This lake dam is also interpreted as a rock slide by most investigators. Again, detailed analysis of the internal structure and dam shape don't support this opinion. Ablation sediments rest on the end moraine here, with a series of side moraines and older terminal moraine ridges extending downstream.

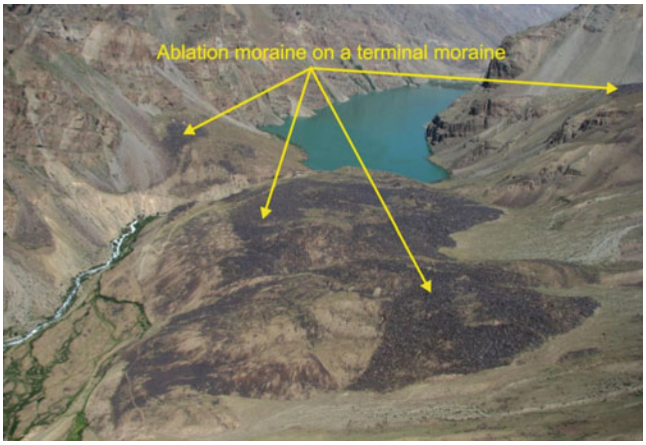

Fig. 4 The cover of ablation moraine on the Lake Dirumkul's dam

Fig. 6 Hillocky-hole surface of the Lake Sheva's dam

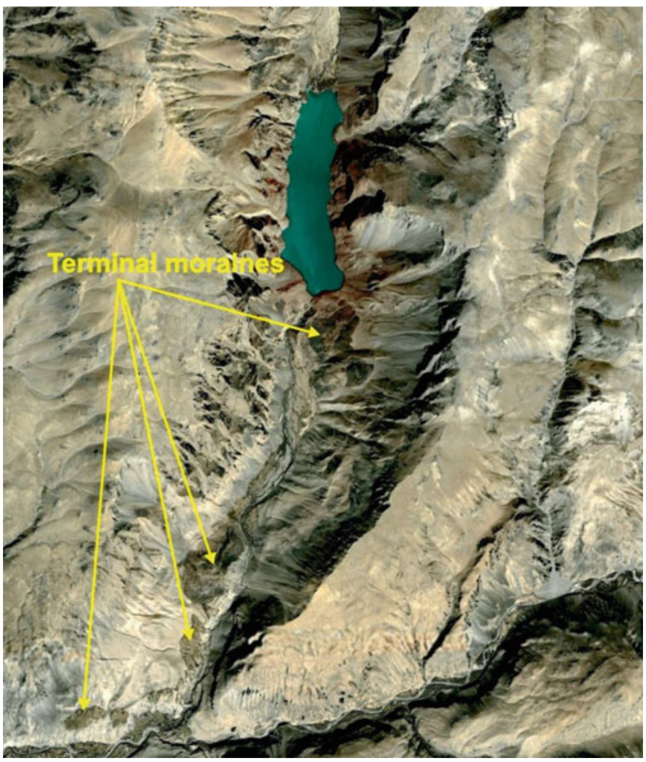

Fig. 5 The end moraines downstream Lake Dirumkul

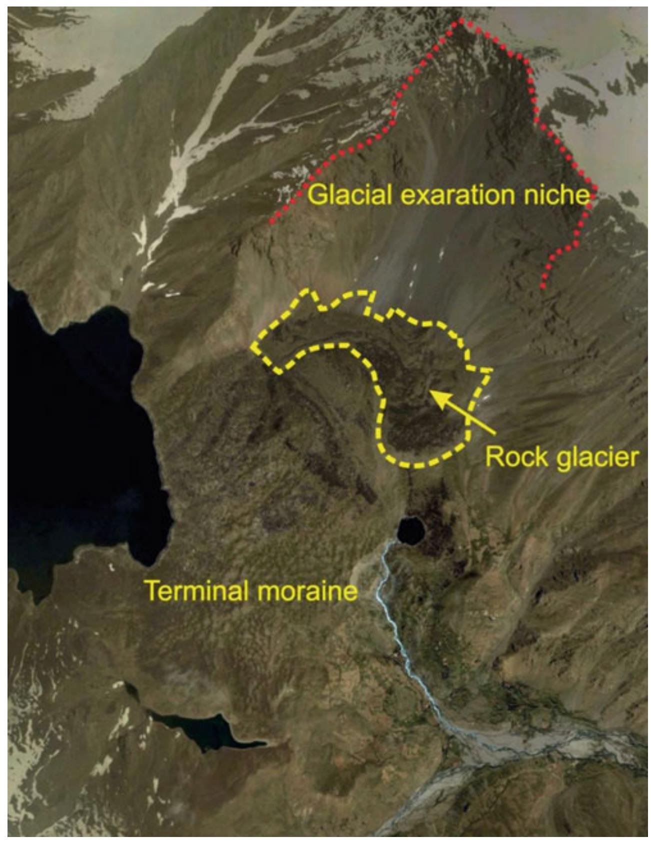

Fig. 7 Exaration-nival niche and near-slope rock glacier on the Lake Sheva's dam

The cross-section of the dam can be seen where the river channel has incised into the dam body, and it displays typical features of an end moraine: coarse layering, orientation of the long-axis rock fragments along the valley, and intact alternating lighter and darker sedimentary strata. The moraine and other glacial features can be mapped both upstream and downstream of the Lake Dirumkul and correlated with end moraines in the adjacent Chandindara and Nimosdara valleys. (Figs. 4 and 5)

Finally, Lake Sheva on the territory of Afghanistan (Fig. 6) also appears to be dammed by a glacial moraine. Indicators of the glacial origin of the dam are hillocky-pit relief, accumulation of rock fragments with desert varnish, a lateral ridges along the valley, and near slope ravines. Moreover, the exaration-nival niche in the upper part of the slope on the left side of the valley is observed, and this niche (so called pseudo-kar) has a clear junction with the end moraine (Fig. 7).

Based on these field analysis and interpretation of the satellite imagery, I identify 1,340 additional candidates for

Table 1 Parameters of some mountain lakes

			Length of lake, м	Volume, million $м^3$	Depth, м		Height of a dam, м
					Maximal	Average	
Name	River basin	The area, $км^2$	L	V	h	h1	H
Hazorchashma	Shing	0.93	2,259	25.10	45	27	290
Marguzor	Shing	1.12	2,706	25.30	46.7	22.6	260
Nofin	Shing	0.50	2,827	4.760	41.3	9.5	90
Gushor	Shing	0.10	1,724	0.730	15	7.3	85.8
Soya	Shing	0.07		1.170	37.2	16.7	
Kyzylkul'-1	Obihingou	0.31	855	7.100	57	23	180
Kyzylkul'-2	Obihingou	0.17	625	0.360	10	4.9	140
Rivakkul'	Rivakdara	1.33	2,666	11.20	16	8.4	190
Dirumkul'	Dirumdara	1.96	2,972	69.00	76	35	218
Yashil'kul'	Gunt	38.0	21,630	525.0	40	13.8	110

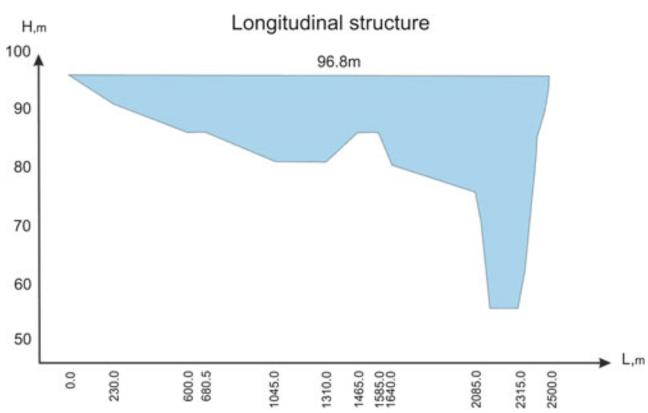

Fig. 8 Profile in elevation of the Lake Nofin (Marguzor lakes)

glacial damming in the Pyanj River basin and other terrene of Tajikistan. Many of these dams are currently interpreted as gravitational landslide dams. Some notable cases are Pasor dam in the Kudara River valley near Pasor village, Shidz dam in the Pyanj River valley near Shidz village, the unnamed river closure near Suchan village in the Gunt River valley, and Kan'yaz dam in Kafirnigan River valley. From the 1,340 cases, end moraines are 60 %, rock glaciers (mostly near slopes) are 35 %, glacial formations from the tributaries that reach the main valley are 4.5 %, and mixed glacial formations (composites of end and lateral moraines and rock glaciers) are 0.5 %. The shapes of all these formations are similar to those expected from mass-wasting induced dams, but the internal structure and content of similar features observed in the field require a glacial origin. Therefore, these dams should not be classified as cases of mass-wasting without field assessment.

Fig. 9 Lake Nofin (Marguzor lakes)

One possible way to differentiate between glacial and mass-wasting dams without field sampling of the dam material is by measuring the relation between the depth of the lakes and the height of the dams. Glacial dams are typically much higher than those from slide events (Table 1). There are also differences between the shapes of the lake beds. Glacial lakes have profiles consistent with glacial erosion, usually with a deeper cupped hole where the main glacial body rested. Irregular location of the ice and rock fragments in the glacier body entail irregular location of the hillocks

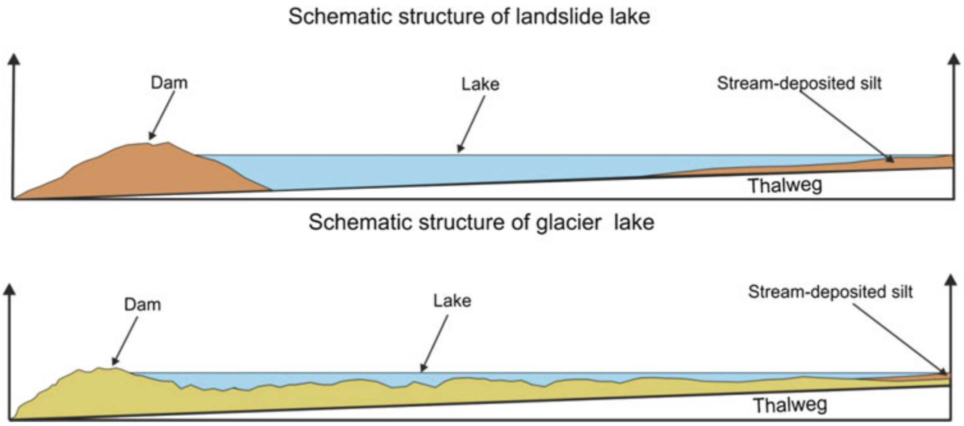

Fig. 10 Layouts of the profile in elevation for the rock slide and glacial dammed lakes

and holes in the lake bed (Figs. 8 and 9). In contrast, rock slide dammed lakes have bed profiles determined by the river bed profile: decreasing of the lake depth from the dam to upstream (Fig. 10).

Visual inspection is not enough in order to correctly determine the origin of a mountain river dam, Rather, one must evaluate the dam's internal structure, lithologic composition and content, and relationship to other landforms in the river valley. Misclassification has important implications. For instance, when scientists consider the big ancient dams in the river valleys to be gravitational forms triggered by strong earthquakes (like Pasor dam in Kudara River valley not far from famous Usoy dam and Lake Sarez (Ischuk 2008)), they infer high rates of seismic activity in the past. If instead these big ancient dams are predominantly glacial, then no conclusions can be drawn about past seismicity.

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