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Wojciech Lewandowski, Marek Zgorzelski

WALL-SIDED GLACIERS

Abstract: In the literature devoted to geomorphology and glaciology not much has been written about wall-sided glaciers, thanks to which high mountains have their specific landscape character. It is also difficult to find in the literature of the subject a classification of the wall-sided glacier forms which would take into account the richness and variety of this phenomenon. After many years of experience in almost all highest mountains of Asia, South America and Europe, the authors decided to fill this gap and therefore to provoke a discussion among the geomorphologists.

Keywords: geoecology, high mountains, wall-sided glaciers.

It is surprising how little literature on geomorphology and glaciology is devoted to wall-sided glaciers. It is mainly to these glaciers that alpine landscapes owe their specific and unique character (Fig. 1).

In most monographs and classification systems, glaciers of this type are included only sporadically and usually not much attention is given to them – comp. Ernbelton, King (1975), Word Glacier Inventory (1989) and Benn, Evans (1998). Even if included, these glaciers are usually only mentioned and described in a highly cursory and not always accurate manner. In the literature, it is also difficult to find any sort of classification of ice wall formations, which would take into account the richness and variety of this phenomenon. This is most likely due to many causes, the most important one of which being that relative to the "classic" valley glaciers, these glacial formations are of small size and the morphological role they play is equally small. The most important reason however is that they are located in extreme settings. For this reason, they have incited less interest among the geographers and glaciologists and more among the mountaineers, for whom wall-sided glaciers are, by their very nature, not only an object to be climbed, but also the source of great danger. The walls of ice and firn common in alpine regions, decorated with unearthly cascades of hanging glaciers; ice terraces; tangles of overlapping firn gullies, thin firn and ice flutings as well as other such formations, have a life of their own and are guided by laws which are difficult to observe (Fig. 2). Often and with great regularity, the ice and snow walls "spit" with ice and snow avalanches, which together with the sun and wind, represent the main elements which shape their slopes. These elements give many alpine walls their specific and unique look which can be compared to that of fine lace, or a pipe organ chiseled out of snow and ice or even to that of thin-tube radiators (snow flutings). The most spectacular examples of ice and firn walls are: the northern slopes of Tilcho Peak (7,132 meters above sea level), the eastern and western slopes the neighbor of Everest, Nuptse (7,879 meters above sea level), and the lone ice pyramid of Sinolchu (6,687 meters above sea level), entirely ornamented by impressive ice furrows.

The ice walls, majestic in their raw beauty, sparkle in the mountain sun, enticing one with their remarkable, sharp-edged formations and sheer whiteness, behind which lies extreme danger. Soon after sunrise, heated by the sun's rays, their upper sections "come alive." With a crackle and a roar, the first avalanches, the frequency of which reaches its peak at midday, begin to come down. Earthquakes also often trigger avalanches and the massive breaking off of seraks. Entire hanging glacierets or their sizeable fragments can break off as the result of earthquakes.

The current text is an attempt at synthesizing many years of observations conducted by the authors in the tallest mountains on Earth, done on glaciers which arise surrounded by rock walls and steep slopes.

The most common terminology used in literature dealing with wall-sided glaciers includes: hanging glaciers and hanging ice terraces (Kuhle, 1985), ice aprons and niche glaciers (Groom, 1959), and apron ice fringes (Benn, Evans, 1998).

Some forms of wall-sided glaciers can also be included in the wider category of cascade glaciers and cliff glaciers. In the literature, one can also find the term glacierets, which is meant to signify small glaciers or firn (eternal snow) fields – comp.: Jania (1997).

Within the morphological classification of glaciers presented in the World Glacier Inventory (1989), hanging glaciers are presented as a separate category, within which the ice apron formation is singled out. Hanging glaciers are considered to be active, meaning they advance at a rate greater than 500 meters per year.

In 1959, Groom presented an attempt to classify niche glaciers on Spitsbergen and distinguished five types:

— regular niche glaciers which arise in funnel-like depressions, paired with ice caps;
— niche glaciers similar to the first type – not paired with ice caps;
— funnel-like depressions, seasonally filled with elongated or horseshoe-shaped snow patches;
— bigger, deeper and more developed funnel-like depressions, which illustrate the variation in and heterogeneity of the glacial surface.

It is worth noting however that some of these types are no longer glaciers, but merely their remnants.

Wall-sided glaciers (ice aprons, hanging glaciers) can cover entire faces of rock or mountain slopes (Fig. 3). They have a steep and usually invariable slope and their shape is usually concave or flat, convex only sporadically in

Table 1.

Glacier types in the selected mountains of Asia

Glacier types in the Russian Altai Mountains

	Valley glaciers	Cirque glaciers	Wall-sided glaciers	Cap glaciers
km^2 (%)	641,3 (70,4)	137,6 (15,1)	90,1 (10,1)	41 (4,4)

Glacier types in the Pamir Mountains (not including East Pamir)

	Diffluent glaciers	Valley glaciers	Cirque glaciers	Wall-sided glaciers	Cap glaciers
km^2 (%)	3567,2 (48,1)	2244,5 (30,3)	1292,6 (17,4)	289,1 (3,9)	23,7 (0,3)

Glacier types in the Tien-Shan Mountains (not including Western Tien-Shan)

	Diffluent glaciers	Valley glaciers	Cirque glaciers	Wall-sided glaciers	Cap glaciers
km^2 (%)	1670,4 (23,1)	3927,3 (54,3)	1064,0 (14,7)	358,0 (4,9)	215,2 (3,0)

Glacier types in the Nan-Shan (Qilian-Shan) Mountains

	Valley glaciers	Cirque glaciers	Wall-sided glaciers	Cap glaciers
km^2 (%)	752,1 (33,0)	966,2 (42,4)	388,8 (17,1)	169,4 (7,5)

Data taken from Dolgushin L.D., Osipova G.B. (1989)

their lower section. Rock fragments sliding along the surface of such a glacier create the so-called mound moraine formations at it its lower boundary.

Wall-sided glaciers are a common form of glaciation in alpine regions. Naturally, the most impressive assortment of ice formations of this type can be found primarily in the Karakorum, Himalaya, Pamir, Tien-Shen and Hindu-Kush Mountains, but they are also common in mountains at a much lower altitude, e.g. in the Altai, the Andes and the Alps, as well as in the mountains of Norway and on Spitsbergen.

It is worth noting that the few attempts to sum up the surface area taken up by the various types of glaciers in alpine regions (e.g. Dolgushin, Osipova 1986 – Tab. 1), show that the wall-sided glaciers' share in the overall glacial surface is not at all insignificant, fluctuating between 4 and 17%.

Wall-sided glaciers can originate in four different ways, one of them being the result of the freezing of the water which runs down the rock walls. This results in dripstone formations (ice varnish) which can be found primarily on cold rock faces. Dripstone glaciers are primarily characteristic of the lower ridges. They do not occur at extremely high altitude (Fig. 4).

The second category of origin includes wall-sided flow glaciers. They originate from sections of cap glaciers flowing down the rock face and occur on phandome plains in mountainous locations, usually on ridges. This type of wall-sided glacier is characteristic of older mountains or mountains located in regions with a very high eternal snow line. In Asia, this type of glacier is typical only in the Altai, Tien-Shan and Tibetan Mountains (Fig. 5).

The third category of origin groups glaciers arising as the result of the classic transformation of the snow that gathers between the rock walls (in niches, on shelves, or in gullies) into glacial ice, which then flows down and covers the lower sections of the wall. Usually, within the area of the wall there are many such feeder locations, which cause the entire surface of the wall to become covered with ice. This type of wall-sided glaciation is specific for mountains of the highest altitude, primarily Karakorum and Himalaya.

Hanging glaciers in the form of ice terraces (earlier considered to be snowdrifts) occurring sporadically above 7,000 to 7,200 meters above sea level (above the upper limit of glaciation), constitute the fourth category. Such formations occur for instance on the leeward side of the East Face of Mt. Everest as well as on its North Face – the sizeable terrace in the so-called "Great Couloir" at 7,300 – 7,500 meters above sea level (Khule, 1985;1986; The Digital Image of Everest 2003). The nameless, relatively flat glacieret on the east pillar of K2 in Karakorum, located at about 7,400 meters above sea level, is also an interesting formation. The small number of glaciers of this type owes their existence to favorable topographic conditions (flat surfaces or rock gorges in the wall area). They occur primarily on the leeward side of the summit (the jet effect). This type of wall glaciation can be described as "compacted" glaciers – originating due to high winds.

Incidentally, the fact that even steep walls and summits become entirely covered by firn ice (e.g. Pumori or Baruntse in the Everest region), when exposed to the prolonged effects of strong winds exacerbated by the terrain (the jet effect), testifies to how few conditions need to be met in order for glaciers to form below the 7,000 – 7,200 meters above sea level boundary.

Very often, wall-sided glaciers also feed into firn fields located in glacial kettles, and at times even into valley glacier tongues. In the Himalaya and Karakorum, this currently seems to be the predominant way in which valley glaciers are supplied. Usually however, what links the wall glacial system to the valley glacial system are the avalanche glaciers at the foot of the wall, which originate as the result of the snow mass being swept from under the ice wall in the form of an avalanche, and then being transformed into ice. At certain locations, as is the case in the Altai for instance, the ice cascade is produced by cap glaciers, which become wall covers, and subsequently directly or through avalanche glaciers, link up to basin lakes which the typical firn fields also feed into.

Avalanche-cone glaciers, which are fed from the higher sections of the wall by avalanches, originate at the base of the ice walls (and often even below the eternal snow line). It is worth noting here that the Himalaya is a relatively recent mountain range, where the mountain-building process is still ongoing. Its distinctive feature is the steepness of the lower range of rocks located above the glaciers and measuring about 1,500 meters. Created relatively recently, it has not had time to undergo erosion. As a result, the Himalaya range lacks the firn kettles which are so characteristic of the Alps and which come up all the way up to the ridges, creating reservoirs of snow. Himalayan glaciers are therefore, aside from snowfall, fed by avalanches coming down from the less-steep snow and ice fields located above the lower range of precipitous walls.

Wall-sided glaciers can take on the form of hanging formations. A formation of this type fills the depressions and niches in the rock wall while its head section is suspended above (and often even slung across) the main basin, or the firn field (Fig. 6, 7).

A variety of the wall-sided glacier is the ramp glacier (Fig. 8). Ramp glaciers have the shape of a horizontal or inclined, relatively narrow and elongated ramp or icy slat affixed to the slope. These glaciers originate in places where there is tectonic dislocation or on large ledges (e.g. the great “Ramp” on Kunyang Chhish in the Karakorum).

Ice does not always move along the rock face in a uniform sheet, but in flows of various width and depth and with varying speed. This is mainly dependent upon the exposure and relief of the wall at the given location, as well as upon the manner in which the wall-sided glacier is created. Deep depressions (gullies) make it possible for glacier tongues to emerge. Depressions which are not as deep attract ice flows which move faster along the wall. This leads to the creation of a system of fractures in the ice, which is taken advantage of by the meltwater. The ice flows and glacier tongues moving along the wall usually terminate at its base with branching taluses (Fig. 9). The ice flows work in a way analogous to that of typical glacier tongues and carve out elongated, U-shaped niches in the face of the rock, resembling the glacial gullies encountered in valleys (Fig. 10).

From time to time, one can observe certain inexplicable formations on the ice sheets along the walls, which we propose naming “glacier windows” (Fig. 11, 12, 13, 14). These are concave, but more often convex sections of the rock wall which occur along the ice sheet and which are free from ice. Their emergence is most likely linked to the occurrence of precipices, niches and beehive formations along the wall. It might also be linked to geothermal factors and to the heterogeneity of the geological composition of a given location, as well as to the warming effect of water, which collects in the rock niches beneath the ice. Making the white and uniform landscape of icy precipices more interesting, glacier windows are visually striking. They are perpetually exposed despite the fact that at their upper edges, layers of ice building up from above constantly break off and set off avalanches. It is also notable that glacier windows occur mainly in the ice on those walls which are facing north.

In certain instances in which individual rocks stick out of an ice sheet (icefall), we are no longer dealing with ice windows, but with small wall nunataks.

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