

LICHENOMETRIC - GEOMORPHOLOGICAL INVESTIGATIONS IN THE AREA OF SLAVKOVSKÝ ŠTÍT

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Geomorphological investigations in July 2008 carried out in the area of Slavkovský štít aims to discover the accumulation of a large rockfall or debris flow resulted from extreme hydrometeorological event of 1662 in the Tatras. The discovery of large boulders covered by thalluses of *Rizocarpon geographicum* from this debris flow or rockfall would have created possibilities to prolong backwards the lichenometric curve for the Tatras. The origin of several relief forms (Fig. 1), due to their morphological features, structure and location could be attributed to the event of 1662, but lichenometric data rather exclude their formation during one event. The results of detailed analysis of aerial photographs and authors' geomorphological field investigations do not confirm the fall of such large rock masses, as well as lowering of the Slavkovský štít top by 300 m. The authors assumed such lowering probably had incorrectly classified post-glacial forms.

Key words: lichenometric method; rockfall; debris flow; Tatra Mountains

INTRODUCTION

Lichenometric methods have been used during the last several decades to date relief forms in mountain areas (eg. INNES 1983, 1985, KOTARBA 1989 and 2004, KARLEN and BLACK 2002). Possibilities of dating with the application of this method are limited by the range of the so called lichenometric curve, which is constructed basing on bench marks of a recognised age. The lichenometric curve for the Tatra Mountains was built basing on bench marks not older than 100 years (JONASSON et al. 1991, KOTARBA 2001), however it was applied to date older forms (age of about 200 years). Dating of older forms requires to produce the curve backwards i.e. to find some sites of a recognised age, which originated before 1900. It was expected that one of such sites was a geomorphological record in form of a rockfall cone, debris flow channel and levees, the result of extreme hydrometeorological event (enormous rainfall) which occurred at the beginning of August 1662 in the Tatra Mountains and sub-mountain area at both the Slovak and Polish sides, according to written records in the chronicles of the local towns and villages (NYKA 1962, SIARZEWSKI 2005, PARYSCY 1995).

The records in the chronicles concern the area of Slavkovský štít in the Slovak Tatras. Therefore in July 2008, geomorphological investigations were carried out in the area of Slavkovský štít aiming to discover the accumulation of a large rockfall or debris flow. The

discovery of large boulders covered by thalluses of *Rizocarpon geographicum* from this debris flow or rockfall would have created possibilities to date more precisely several-century old forms of the relief. After studying orthophotomaps and different publications concerning the event which occurred about 350 years ago, it was decided to investigate both the northern (the Veľká Studená dolina valley) and southern (the Velická dolina valley) slopes of the Slavkovský štít ridge (Fig. 1).

RESULTS OF INVESTIGATIONS

The Slavkovský štít elevates to the height of 2,452 m and, despite of the fact that in its neighbourhood there are higher summits (Gerlach 2655 m, Ľomnica 2634 m), for people looking at the Tatra Mountains from the Smokovec's, and not only from Smokovec's, the summit of Slavkovský štít seems to be the highest. Probably this optical illusion was the reason that some former investigators of the Tatra Mountains (eg. David Frölich) recognised that summit as the highest in the Tatras (FRÖLICH, after SZAFLARSKI 1972).

According to the description of Georg Buchholtz, the 17th century's investigator of the Tatras, during an intensive several-day rainfall, possibly accompanied also by an earthquake (BOHUŠ 1983), occurring in the first part of August 1662 in the area of Slavkovský štít, large masses of rock fell down causing that the top of the mountain was lowered by about 300 m (JEITTELES after NYKA

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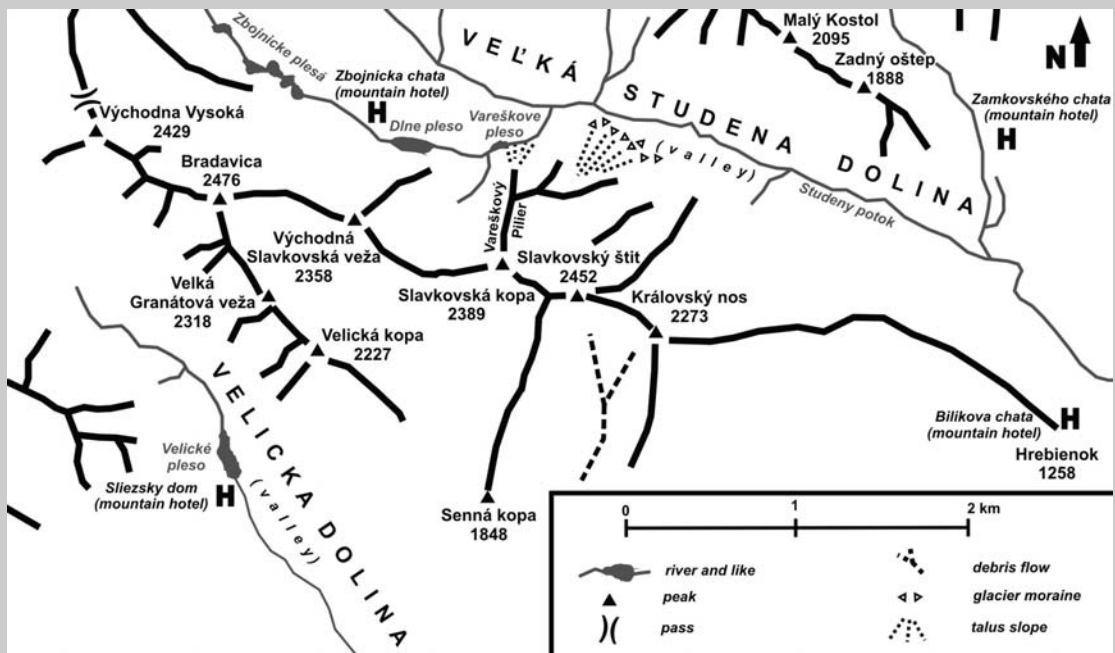


Fig.1 Map of the studied area

1962, KOLÁČEK after NYKA 1962, SIARZEWSKI 2005). Without doubts, such large amount of material in form of a rockfall or debris flow accumulation would still be visible, despite the laps of about 350 years.

The results of detailed analysis of aerial photographs from this area and our geomorphological field investigations indicate that contemporary accumulation forms of the relief in the area of Slavkovský štít do not confirm



Fig. 2 Debris flows on the southern slopes of the Slavkovský štít and the Slavkovský Nos



Fig. 3 View from the bottom of the Veľka Studena dolina valley toward the Vareškovo Pilier ridge and the Slavkovská kopa summit. On first plan the visible large boulders of frontall-lateral moraine, however on second the rockfall-talus cone

the fall of such large rock masses, as well as lowering of the mountain top by 300 m. During geomorphological investigations several relief forms were recognised (**Fig. 1**), the origin of which – due to their morphological features, structure and location - could be attributed to the event of 1662. An indirect confirmation of their attachment to that event would be the size of thalluses present on boulders within these forms, as large as the size of these thalluses determined from the hitherto elongated (without additional older bench marks) lichenometric curve corresponds to the thallus size for 1662.

The first large form which has preserved to the present times and which would possibly be correlated with the one which originated in 1662 is a large debris flow (**Fig. 2**). It is located at the south-west slope of the Slavkovský štít (**Fig. 1**). The flow starts close to the mountain crest between the Královský nos and Slavkovský štít and terminates at the flattening of the slope close to the upper timberline, where, apart from a debris flow gully, clear debris flow levees are visible. The debris flow visible in **Fig. 2** may be that form, which is

mentioned by Georg Buchholtz in his records from his expedition to the Slavkovský štít in 1664 (BUCHHOLTZ after SIARZEWSKI 2005, SZAFLARSKI 1972). Unfortunately, it is not possible to confirm the origin of this flow in 1662 using lichenometric dating. The lower part of the flow is grown by dense vegetation consisting of alpine swards and dwarf pine shrubs. The gully, in the upper part of the debris flow, was probably many times transformed by different slope processes, including debris flows. According to KOTARBA (1994) in the High Tatras, a threshold value for debris flow occurrence is a precipitation of 30 mm/hour. It cannot be also excluded that heavy rainfalls which occurred in 1813 causing one of the largest floods in Europe during the last several centuries, may have had the largest influence on channel transformation, totally changing its size and shape.

Another form, which could be possibly connected with the rockfall of 1662 is a rampart built of rocky boulders and blocks adjacent to the foot of talus-alluvial cone located at the north-eastern slope of Slavkovská kopa, in the

bottom of Veľká Studená dolina valley, at the right side of the stream (**Fig. 1 and Fig. 3**). The origin of this form as a large rockfall is suggested by the presence of large blocks of rock of the longest diameter up to 20 m visible on the surface of this form and also by its location at the cone foot. However, a detailed analysis of the shape of this form and its location suggests rather its glacial origin. The rampart from the river side has a steep slope of the height of 15-20 m. From the slope side it has a partly filled depression. It is therefore a rampart of a frontal-lateral moraine of Veľká Studená dolina glacier. This view is shared by M. LUKNIŠ (1973), who showed this form at his geomorphological map of the High Tatras as a Würm moraine. Also lichenometric dating excludes its origin in 1662. The largest thalluses found in this site (but not the oldest because of large number of decayed old generations of thalluses) of the diameter of 200 mm indicate that the largest blocks were included in this form during at least 500 years.

The results of measurements of the size of lichens thalluses present on large and numerous blocks of rock located on the mentioned above talus-alluvial cone situated above the moraine also did not confirm the presence of a large rockfall from before 350 years ago. Nev-

ertheless, some blocks contained thalluses the age of which could be correlated with 1662, but these blocks are rare and they do not form either a dense cover or any specific form, which might have been connected with one event. The described cone shows large dynamics which is evidenced by large differentiation of the thalluses diameters from several to several hundred millimetres. In the upper part of the cone the material is differentiated in terms of its age with the predominance of fresh material. In the lower part, it is difficult to find places which would have originated in the same or similar time. Almost in each place in the lower part of the cone different boulders, from quite fresh to very old, may be found.

The next form, which origin according to historical descriptions and location may be correlated with the rockfall of 1662 is a cone above the Vareškové pleso lake, located at the eastern slope of Vareškový Pilier ridge, being a lateral arm of the Slavkowská kopa (**Fig. 1 and Fig. 4**). The cone shows clear features of a rockfall cone, which is evidenced by the presence of large boulders and blocks, lack of clear sorting of the material, and presence of well-developed, sometimes fresh rockfall headwalls above the cone. In the lower part of the cone, a large number of boulders is deposited, which



Fig. 4 The rockfall-talus cone under the walls of the Vareškový Pilier ridge. In the right bottom corner the Vareškové pleso lake

are grown by thalluses of a maximum diameter of about 110 mm, which indicates, that these boulders were placed on that cone about 340 years ago. It seems therefore possible, that these boulders come from the rockfall of 1662, providing, that such rockfall really occurred. The size of these boulders and their number do not confirm the proposition that it was a catastrophic event. The results of lichenometric measurements evidence that this cone was not formed during one event, therefore it is difficult to treat it as a bench-mark site for the year 1662, in order to produce a lichenometric curve backwards.

CONCLUSIONS

During intensive rainfalls which occurred in the beginning of August 1662 at Polish and Slovak sides of the Tatra Mountains a large debris flow have the most probably developed between the Královský nos and Slavkovský štít summits. It is possible, that the accompanying earthquake influenced also the activation of the rockfall on the Vareškový Pilier ridge. Probably, if the rockfall really took place, it could partly dammed the outflow from the Vareškové pleso lake and increased the area of the lake. At present, the talus cone located under the Vareškový Pilier ridge drives the Studený potok stream towards the NE making a clear river bend. However, this rockfall, because of its origin (Vareškový Pilier ridge and not Slavkovský štít top) couldn't have influenced the height of the Slavkovský štít. Calculations of some geophysicists assuming that because of a large rockfall the height of Slavkovský štít decreased by about 300 m (JEITTELES after NYKA 1962, KOLÁČEK after NYKA 1962 and SIARZEWSKI 2005) were not confirmed in the field investigations. The reason of these incorrect calculations was improper interpretation of the origin of large block and boulder depositions in the Veľká Studená dolina valley. The authors of these calculations incorrectly classified post-glacial forms as forms derived from a rockfall. In 1982, so after the work by M. LUKNIŠ on post-glacial forms in Slovakian Tatras had been published, Arnold NEMČOK (1982) similarly to other mentioned above geophysicists classified also some moraines as rockfalls, for example the frontal-lateral moraine under the Slavkovská kopa in the Veľká Studená dolina valley.

From all historical data describing this catastrophic event, the most credible seems to be the description by Georg Buchholtz – senior (BUCHHOLTZ after SIARZEWSKI 2005 and SZAFARSKI 1972), who climbed up the summit of Slavkovský štít in 1664. According to him, the only trace of the catastrophic event

from before 2 years was a large landslide below the Královský nos summit. The description of this landslide suggests the existence of a large debris flow (or rather debris flows) between Nos a Slavkovský štít, which has preserved to present times. Possibly, during the Buchholtz's trip only one channel of debris flow existed and the second developed later (eg. in 1813), or Buchholtz did not see or did not remember the other channel. Today, due to the fact that these forms are covered by alpine swards and dwarf pine shrubs, it is difficult to determine their age and even detailed limit. Buchholtz, during his trip to the Slavkovský štít noticed also many large lakes. At present, at the foot of Slavkovský štít, the Dlhé pleso lake is the only larger lake; other lakes like the Vareškové pleso lake or the Slavkovské plieska lakes are quite small and some of them (like two smaller lakes of Slavkovské plieska) are even difficult to notice. Undoubtedly, those large lakes observed by Buchholtz were partly an effect of the event of 1662, what was pointed out by SIARZEWSKI (2005). Several-day intensive precipitation caused that all the surface depressions were filled with water, and the supply of large amounts of fresh material from the slopes may have blocked the water outflow causing the development of shallow but large ponds. It should be also remembered that this event occurred during the so called Little Ice Age, which showed not only climate cooling but also increased humidity (STARKEL and RALSKA-JASIEWICZOWA 1981, LAMB 1984, MARUSZCZAK 1991, KOTARBA 2004, NIEDŹWIEDŹ 2004), which was reflected in the size of the area of some Tatras' lakes.

Therefore, not always even well historically recorded hydrometeorological events are useful in geomorphological investigations. The investigations towards the production of a lichenometric curve for the Tatras backwards need further search of relief forms or buildings of a known age, however most of the buildings have been rebuilt or destroyed losing its geomorphological importance.

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