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Early stages of weathering of glacially-abraded limestone surfaces as determined by various Schmidt hammer tests; Biferten glacier forefield, Glarner Alps (Switzerland)

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Abstract: The Schmidt hammer method was successfully used in determining early stages of weathering of glacially-abraded Jurassic limestone surfaces within the post-LIA forefield of the Biferten glacier (Switzerland). It was shown that the formerly glaciated landforms are differentiated in terms of mean and maximum R-values and when comparing between standard deviation of R-values from polished and non-polished surfaces. It is concluded that the most important factors in R-value differentiation within the young marginal zones are duration of weathering and rock structure. However, the first factor can only be detected on non-polished surfaces.

Key words: Schmidt hammer, stages of weathering, dating of glacial landforms, Biferten glacier

Introduction

The aim of the study was to test the Schmidt hammer as a tool in determining early stages of surface weathering of glacially abraded rocks and thus to infer about the relative age of the landforms developed since the end of the Little Ice Age (LIA). Obtained results are preliminary and should be treated as a continuation of a methodological discussion.

The use of the Schmidt hammer in dating of landforms is based on the following assumptions: 1 – there is a relationship between the age of a landform and a state of its weathering, 2 – surfaces of weathered landforms (relatively old) are weaker comparing to the fresh ones.

Geomorphologists borrowed the Schmidt hammer from engineers working on the strength and quality of concrete (Day & Goudie 1977, Runkiewicz & Brunarski 1977) and use in relative dating of a variety of landforms (moraines, river terraces, talus, rock glaciers) based on their weathering state. The method is also used in studies on structural relief development. Evaluation of the Schmidt hammer method in geomorphology was thoroughly done by Placek & Migoń (2005), Goudie (2006) and Placek (2006).

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Study area

The marginal zone of the Biferten glacier in the Glarner Alps (Switzerland) was chosen for the study. The glacier flows NE from the Tödi massif (3,614 m a.s.l.). Retreat of the glacier front since the end of the LIA exposed a forefield closed by a terminal moraine ridge deposited at an altitude of c. 1,600 m a.s.l. in the middle of the 19th century (German et al. 1979). Behind the moraine there is a distinct drumlin with flutings on its surface (Van der Meer 1983). Further up the valley, there is a rocky step 250 m high and a contemporary glacier front lies immediately behind it, on the flatter area 1,960 m a.s.l. (Fig. 1, 2, 3, 4).

Methods

The tests were conducted on dark-grey fine-grained Jurassic limestone surfaces which showed clear signs of glacier abrasion (polished surfaces with glacier striae) located in different distances from the glacier, representing consecutive stages of weathering *in situ*.

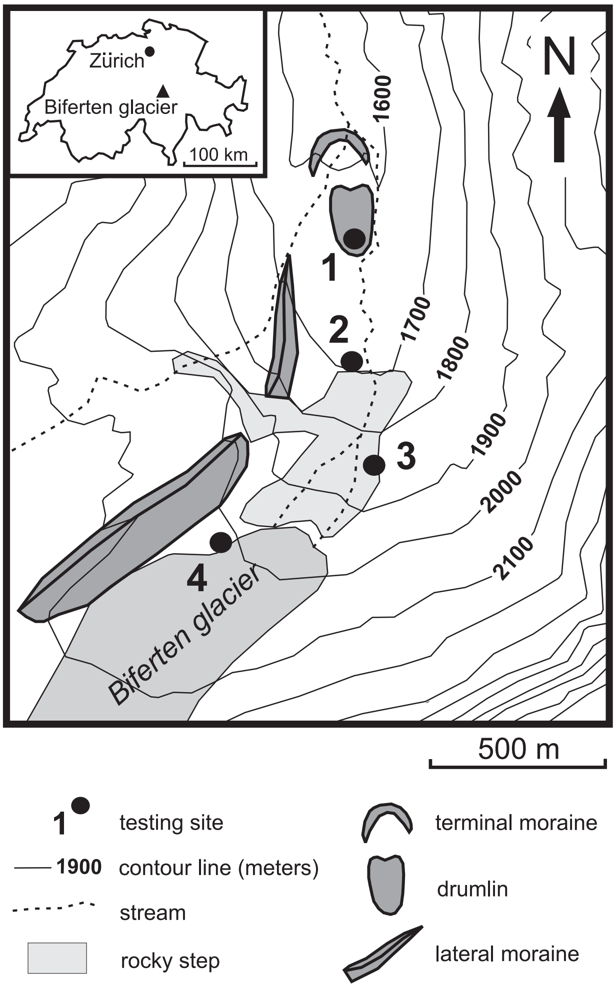

Fig. 1. Location of the study area

The rock exhibited slightly visible lamination with the thickness of layers c. 10 cm. The tested surfaces were parallel or sub-parallel to the lamination. The sites were: 1 – a large lodged boulder (a axis = 2 m) found at the beginning of one on the flutes on the drumlin surface (Fig. 1, 2), 2 – bedrock surface at the base of the rocky step (Fig. 1, 3), 3 – a large boulder found in the middle of the rocky step (a = 1 m) (Fig. 1, 3) and 4 – a large boulder (a = 1 m) found near the glacier front (Fig. 1, 4). In order to check influence of rock structure, two surfaces were tested on the last boulder: 4a – perpendicular and 4b – parallel to the lamination.

Fig. 2. Testing site 1 – large lodged boulder at the beginning of a flute (surface of the drumlin)

Fig. 3. General view on testing sites 2 and 3 – the rocky step

Fig. 4. General view on testing site 4 (in the foreground of the picture) – the front of the Biferten glacier

Only four testing sites were selected due to difficulties in finding rock surfaces which: 1 – were built of the same rock type, 2 – exhibited clear signs of glacial abrasion and 3 – were easily accessible.

Ten impacts of the Schmidt hammer type N were performed on each tested surfaces. Research was performed in dry summer condition to avoid the effect of rock wetting. Edges, calcite veins, uneven places and lichens were omitted and the impacts were 1–2 cm apart. Later, the neighbouring surface was polished with a use of carborundum and the series of 10 impacts was performed on the polished surface.

Rebound values (R-values) were corrected according to an angle of the hammer to reduce to influence of a gravitation force (Runkiewicz & Brunarski 1977). The obtained values are shown on Figure 5.

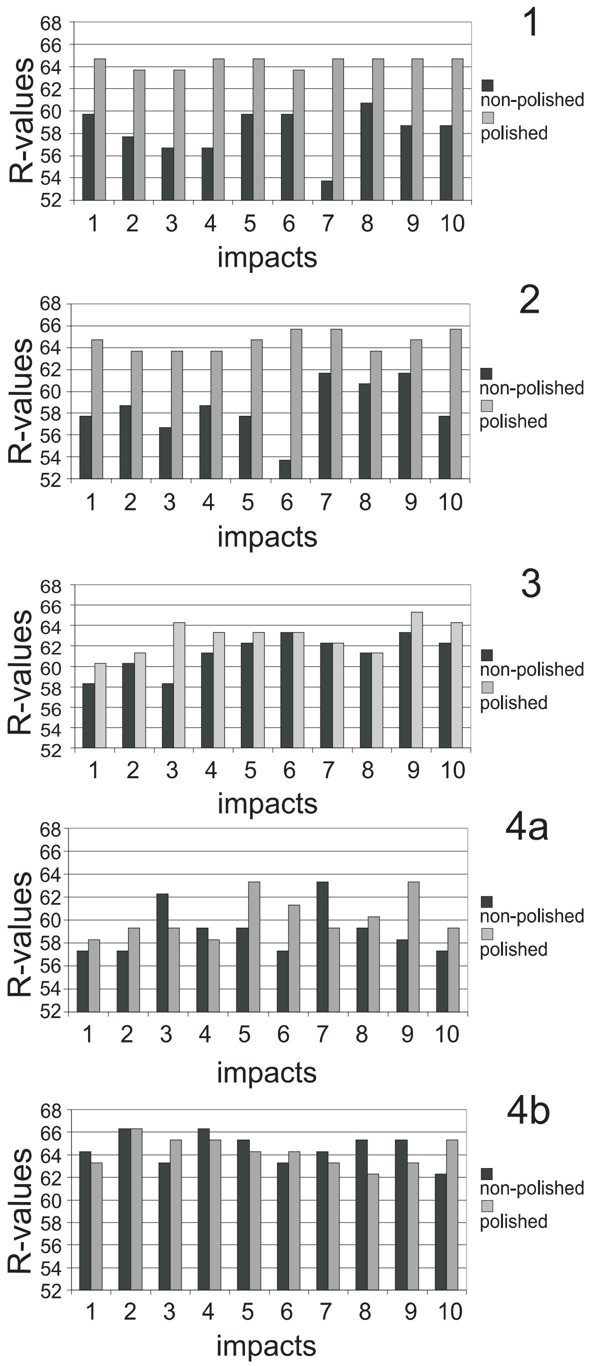

Fig. 5. Impacts and relevant rebound values (R-values) on the testing sites

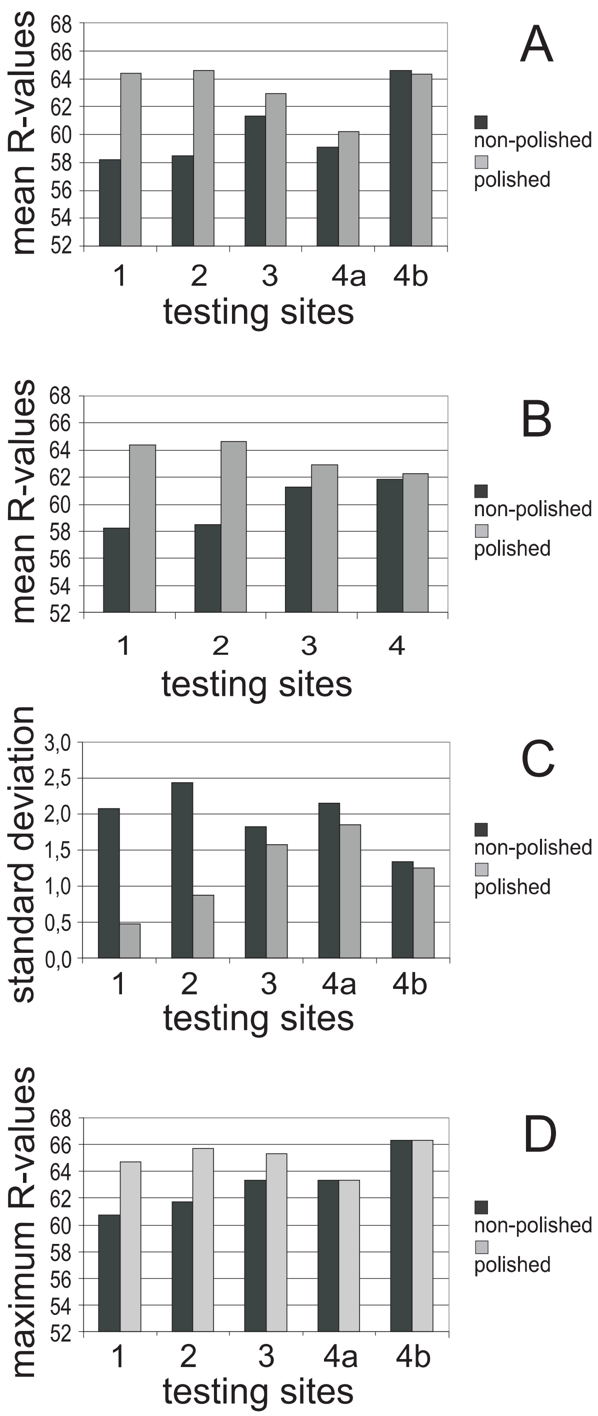

Fig. 6. Mean R-values, standard deviation and maximum R-values on the testing sites; graph B shows averaged results for sites 4a and 4b (description in the text)

Mean values, standard deviation and maximum values for each sites are shown on Figure 6.

The used Schmidt hammer was not worn out and it was recently calibrated, so any instrument errors (McCarroll 1989) can be neglected.

Results

The R-values are bracketed between 53 and 67, therefore the tested limestone appeared to be a hard or a very hard rock (Selby 1980, Goudie 2006). Polishing caused significant increase of surface hardness on sites 1 and 2, located relatively far away from the glacier front (Fig. 5). This allows inferring that the duration of weathering (less than 150 years, probably about 100 years) was sufficient to produce a relatively soft weathering rind which could be easily removed by the carborundum. Differences in hardness between polished and non-polished surfaces on younger sites (3, 4a, 4b) are much smaller or even non-existing (Fig. 5).

The surface perpendicular to the lamination (4a) was significantly weaker in comparison with the parallel surface (4b).

Mean R-values show an increasing trend (in the direction of the glacier) only on non-polished surfaces (Fig. 6, A and B). The trend is clear when comparing between parallel (or sub-parallel) surfaces – 4b is taken into consideration (Fig. 6, B). In this case, the difference between mean R-values on the oldest and the youngest surface is 6.4.

Surface polishing caused significant decrease in standard deviation (by 1.6) on older sites 1 and 2 (Fig 6, C). The closer to the glacier the smaller the influence of polishing upon standard deviation is.

A clear correlation seems to be between maximum R-values of non-polished surfaces and age of the landforms (Fig. 6, D). The closer to the glacier the higher the maximum R-value is. If comparing between only parallel (or sub-parallel surfaces), the difference between the maximum R-values on the oldest and the youngest surface is 7, slightly higher than the difference between mean R-values.

Discussion

Surface polishing demanded in engineering works (Runkiewicz & Brukarski 1977) or in classic geomorphological studies (Day & Goudie 1977) can be important in assessing early stages of rock weathering within young glacial landforms only if non-polished surfaces are also tested and the results are compared.

Averaging R-values appears to work well in assessing early stages of weathering of glacially-abraded limestone within the post-LIA marginal zone of the Biferten glacier. It has been shown previously that the mean R-values can be useful when comparing glacial landforms which differ significantly in age and the ones developed during the whole Holocene, even if lithology of the landforms is diversified (Aa & Sjåstad 2000, Winkler 2000, 2005, Shakesby et al. 2006, Owen et al. 2007). McCarroll (1993) demonstrated that the Schmidt hammer can be useful only for distinguishing between sites glaciated in the LIA and those glaciated in the Late-glacial or early Holocene. According to Kotarba et al. (2002) reasonable results are obtained only if comparing moraines formed in different glaciations in the Tatra Mountains. This can, however, be explained by the coarse character of the granites. In the case of the Biferten glacier forefield, the abraded rock is relatively homogenous, fine grained limestone.

Comparing the maximum R-values of non-polished surfaces appears to be a surprisingly sound method. Similar results were obtained by Evans et al. (1999) for different moraines in SE Iceland (built of basalts) deposited since the end of the LIA. Correlation between the maximum R-values and diameters of largest *Rhizocarpon* lichen thalli, which shows the age of the moraine, occurred to be very strong. On the other hand they found that there is only a small correlation between the age of the moraines and mean of the 5 highest R-values.

Matthews & Owen (2008) conducted an interesting study on moraines of the Storbreen glacier (Norway), deposited in the 20th century and built of gneiss boulders. They proved that on such young landforms, R-values differ between moraines of different age only when hammer impacts are performed on places with visible endolithic lichen thalli of *Lecidea auriculata.* Surface of rocks were significantly and progressively weakened by growth of the lichens already in the first decades after deglaciation.

Apart from the lichens, a variety of litobionts (mycodestructants) can play an important role in a quick weathering of various types of rocks, including limestones (Chlebicki 2007). A fast rate of development of biochemical weathering rind on basaltic boulders from moraines deposited since 1890 AD has been shown by Etienne (2002). The testing surfaces in the marginal zone of the Biferten glacier were from 50 to 150 cm^2, therefore it is probable that some impacts were done in places occupied by invisible litobionts producing smaller R-values.

A significant decrease in standard deviation at sites 1 and 2 (Fig. 6 B) after the polishing can be explained by a partial removal of the weathering rind or decreasing surface roughness which developed due to weathering on older surfaces (McCarroll 1991).

Clear difference between R-values on surfaces 4a and 4b support Selby's findings (1980), who states that planes of weakness in rocks such as fractures or lamination have significant influence on the Schmidt hammer readings. It appears that the surface parallel to the lamination (layers c. 10 cm thick) in the tested limestone is much harder.

Runkiewicz & Brunarski (1977) state that the thickness of the tested concrete should be more that 10 cm (in a case of a plate or a slab) or 12 cm (in a case of poles). This is an important issue to remember in making the Schmidt hammer tests on moraines. Unfortunately, diameters of the tested clasts sometimes are not reported (Evans et al. 1999).

Conclusions

The Schmidt hammer method appeared to be useful in detecting early stages of weathering of glacially-abraded Jurassic limestone surfaces found within the Biferten glacier forefield, exposed to atmospheric conditions since the end of the LIA (mid 19th century). Mean and maximum R-values from non-polished surfaces as well as difference between standard deviation of R-values obtained on polished and non-polished surfaces proved to be robust. However, in order to obtain reasonable results, it is very important to compare rock surfaces of similar internal structure. Any lamination of rock, if carelessly treated, can result in decreased R-values.

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References

Aa A.R. & Sjåstad J.A., 2000. Schmidt hammer age evaluation of the moraine sequence in front of Bøyabreen, western Norway. *Norsk Geologisk Tidskrift* 80: 27–32.

Chlebicki A., 2007. Nielichenizujące grzyby epi- i endolityczne (litobionty). *Wiadomości Botaniczne* 51(1/2): 5–13.

Day M.J. & Goudie A.S., 1977. Field assessment of rock hardness using the Schmidt test hammer. *British Geomorphological Research Group Technical Bulletin* 18: 19–29.

Etienne S., 2002. The role of biological weathering in periglacial areas: a study of weathering rinds in south Iceland. *Geomorphology* 47: 75–86.

Evans D.J.A., Archer S. & Wilson D.J.H., 1999. A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers. *Quaternary Science Reviews* 18: 13–41.

German R., Hantke R. & Mader M., 1979. Der subrezente Drumlin im Zungenbecken des Biferten-Gletschers (Kanton Glarus, Schweiz). *Jahreschefte der Gesellschaft für Naturkunde in Württemberg* 134: 96–103.

Goudie A.S., 2006. The Schmidt Hammer in geomorphological research. *Progress in Physical Geography* 30(6): 703–718.

Kotarba A., Król K. & Rutkowski J., 2002. Zastosowanie młotka Schmidta do badania granitów tatrzańskich. In: *VI Zjazd Geomorfologów Polskich „Środowiska górskie – ewolucja rzeźby”* – streszczenia referatów i posterów (papers and posters' summaries), Jelenia Góra: 79–80.

Matthews J.A. & Owen G., 2008. Endolithic lichens, rapid biological weathering and Schmidt hammer R-values on recently exposed rock surfaces: Storbreen glacier forefield, Jotunheimen, Norway. *Geografiska Annaler* 90A(4): 287–297.

McCarroll D., 1989. Potential and Limitations of the Schmidt Hammer for Relative-Age Dating: Field Tests on Neoglacial Moraines, Jutunheimen, Southern Norway. *Arctic and Alpine Research* 21(3): 268–275.

McCarroll D., 1991. The Schmidt hammer, weathering and rock surface roughness. *Earth Surface Processes and Landforms* 16: 477–480.

McCarroll D., 1993. The vertical extent of ice sheets in Nordfjord, western Norway: measuring degree of rock surface weathering. *Boreas* 22: 255–265.

Owen G., Matthews J.A. & Albert P.G., 2007. Rates of Holocene chemical weathering, “Little Ice Age” glacial erosion and implications for Schmidt-hammer dating at a glacier-foreland boundary, Fåbergstølsbreen, southern Norway. *The Holocene* 17(6): 829–834.

Placek A., 2006. Młotek Schmidta w badaniach geomorfologicznych – ewaluacja i przykłady zastosowania metody. *Czasopismo Geograficzne* 77(3): 182–205.

Placek A. & Migoń P., 2005. Zastosowanie młotka Schmidta w badaniach geomorfologicznych – potencjał, ograniczenia i wstępne wyniki badań w Sudetach. In: A. Kotarba, K. Krzemień & J. Święchowicz (eds.) *Współczesna ewolucja rzeźby Polski*, 19–22 września 2005, Kraków: 367–371.

Runkiewicz L. & Brunarski L., 1977. *Instrukcja stosowania młodków Schmidta do nieniszczącej kontroli jakości betonu w konstrukcji, nr 210.* Instytut Techniki Budowlanej, Warszawa: 44 pp.

Selby M.J., 1980. A rock mass strength classification for geomorphic purposes: with tests from Antarctica and New Zealand. *Zeitschrift für Geomorphologie. N.F.* 24(1): 31–51.

Shakesby A.A., Matthews J.A. & Owen G., 2006. The Schmidt hammer as a relative-age dating tool and its potentioal for calibrated-age dating in Holocoene glaciated environments. *Quaternary Science Reviews* 25: 2846–2867.

Van der Meer J.J.M., 1983. A recent drumlin with fluted surface in the Swiss Alps. In: E.B. Evenson, C. Schlüchter & J. Rabassa (eds.) *Tills and Related Deposits: Genesis, Petrology, Application, Stratigraphy*. A.A. Balkema, Rotterdam: 105–110.

Winkler S., 2000. The “Little Ice Age” maximum in the Southern Alps, New Zealand: preliminary results at Mueller Glacier. *The Holocene* 10(5): 643–647.

Winkler S., 2005. The Schmidt hammer as a relative-age dating technique: potential and limitations of its application on Holocene moraines in Mt Cook National Park, Southern Alps, New Zealand. *New Zealand Journal of Geology & Geophysics* 48: 105–116.