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Determining rock surface micro-roughness and search for new method of relative dating of glacial landforms; a case study from Fláajökull (SE Iceland) and Biferten glacier (Swiss Alps) forefields

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Abstract: Micro-roughness was recorded on glacially abraded stones deposited since Little Ice Age by two glaciers: Fláajökull in SE Iceland (basalts) and Biferten glacier in Swiss Alps (limestones) in order to find indices of relative age of the glacial landforms. Micro-roughness of rock surfaces was analysed with use of Handysurf E35-B electronic profilometer which calculates following roughness parameters: Rz, Rzmax, Ra and Rsm. An increase in roughness parameters towards older moraines is observed in both forefields, however the change is more significant on limestone surfaces. Time-dependent surface deterioration is visible only within first decades of weathering of both types of rock, and further weathering does not cause increase in micro-roughness.

Keywords: Micro-roughness, proglacial weathering, Fláajökull, Iceland, Biferten glacier, Swiss Alps

Introduction

Previous measurements of rock surface (micro) roughness in relative dating of glacial landforms were performed on gneiss within Storbreen forefiled (McCarroll 1992) and in Oldedalen (McCarroll & Nesje 1996). In both cases a hand profilometer was used which enabled measurement of relative heights of micro-depressions and micro-elevations with a theoretical precision up to 0.01 mm, and the range of micro-denivelations was usually 0.5–6 mm. Results proved to be useful in roughness differentiation between Little Ice Age (LIA) landforms and those from the onset of Holocene. The Handysurf E35-B electronic profilometer displays roughness parameters with a resolution of 0.01 μm and therefore, a hypothesis was put forward that differentiation within much younger landforms (deposited since the end of LIA) can be recorded (Fig. 1).

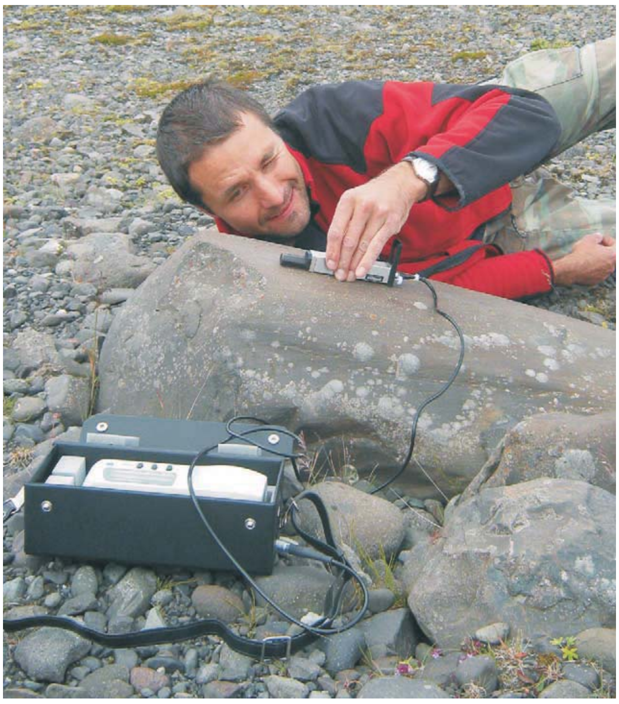

Fig. 1. Use of the Handysurf E35-B electronic profilometer in a field

Study area

Fláajökull flows SE from Vatnajökull ice-cap in Iceland and, since the end of LIA, the glacier developed several moraine ridges on an altitude of 55–80 m a.s.l. (Fig. 2). These were dated by Dąbski (2002, 2007) on the basis of lichenometry as well as historical and carthographical data. However, there is an ongoing discussion about the age of the oldest moraine and the timing of LIA glacier maximum, the age ranging from 1870–1898 AD (Dąbski 2002, 2007, 2010) to 1807–1831 AD (Chenet et al. 2010), as lichenometrical dating is a subject of continuous development (Bradwell 2009).

Biferten glacier flows NE from the Tödi massif in Glarner Alps, Switzerland. It's LIA maximum is marked by the terminal moraine ridge, deposited at 1600 m a.s.l., form the middle of the 19th c. (German et al. 1979). Behind the moraine one can find a large drumlin (Van der Meer 1983) followed by a glacially abraded escarpment (Fig. 2). The snout of the glacier seats directly above it on an altitude of almost 2000 m a.s.l. (Dąbski 2009).

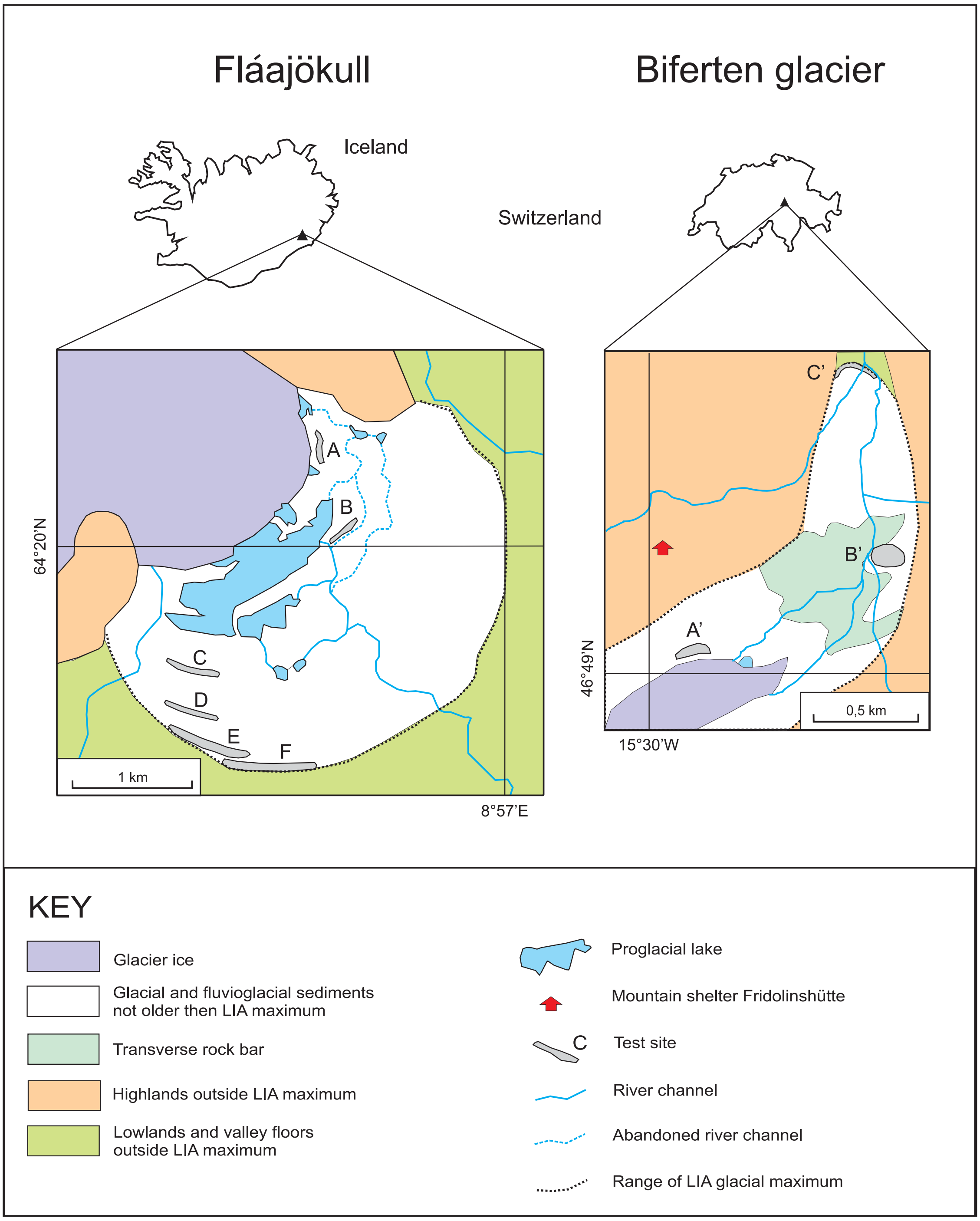

Fig. 2. Location of the study areas

Methods

In the marginal zone of Fláajökull the analysis was performed in 2011 on 90 basaltic boulders ø >30 cm, 15 boulders in each of 6 test sites: from A (youngest) to F (oldest), located on moraines of different age deposited since the end of LIA (Dąbski 2007), Fig. 2. All analyzed boulders were Tertiary grey basalts and the study was performed on glacially abraded surfaces, usually on stoss sides (N, NW) of the boulders. This allowed to infer that weathering has been operating since their release from the glacier ice. Micro-roughness was measured in three smoothest places, free of striation, found on the abraded surface. One measurement produced 4 roughness parameters (Ra, Rz, Rzmax and Rsm), explained below.

In the marginal zone of Biferten glacier the study was performed in 2012. Due to petrographic limitations and difficult terrain, only 3 test sites were chosen (Fig. 2): A' – near the margin of the glacier, B' – in the middle part of the marginal zone within a transverse rock bar, and C' – on the terminal moraine.

The study was performed on glacially abraded dark-grey fine-grained Jurassic limestone surfaces (from pebbles to boulders) exposed towards the glacier (S, SW). Due to scarcity of suitable rock surfaces only 10 stones were selected at each test sites. Micro-roughness was measured in the same way as in case of the Fláajökull moraines.

The Handysurf E35-B electronic profilometer is equipped with a skidded pick-up with a built-in stylus which can register rock surface roughness down to a few micrometer. The diamond stylus tip is pressed against the measured surface with a force of 4 mN or less and run along a demanded profile length, in this study it was set for 4 mm (Fig. 1). Roughness elements are calculated based on the evaluation length of the roughness profile, which consists of five elementary segments (sampling length, referred to as a cut-off value), to produce roughness parameters (Ra, Rz, Rzmax, Rsm). The profilometer is equipped with a micro-processor, LCD display and a light portable printer enabling quick print-outs of magnified surface roughness profiles. Surface roughness is expressed by following parameters:

- Ra – arithmetic mean deviation of roughness profile (integral of the roughness profile function divided by the sampling length),
- Rz – "ten point height of irregularities" (average vertical distance between peaks and valleys),
- Rzmax – maximum height of irregularities;
- Rsm – mean width of the profile elements.

Results

The study revealed that there is a significant diversification of micro-roughness between rock surfaces within a single test site (Fig. 3), which was to be expected considering very high precision of the measurement. Nevertheless, gradual increase in roughness towards older moraines is observed. Mean amplitude of micro-relief (Rz) increases from 21.74 μm (site A) to 28.97 μm (site F), but the actual increase occurs only within young moraines, deposited since 1932 AD (sites A – C, Table 1). Roughness parameters (Ra, Rz i Rzmax) obtained from surfaces of boulders deposited earlier remain on higher, relatively constant level. Only Rsm (mean width of profile elements) decreases between boulders from 1932 AD (site C) and 1907 AD (site site D), which is difficult to explain on contemporary stage of research. Boulders of the oldest moraine ridge, deposited during the LIA

Table 1. Mean values of roughness parameters obtained from Fláajökull and Biferten forefields; the values are expressed in micrometers and accompanied by 95% confidence intervals

Site	Age of release from glacier (AD)	Ra	Rz	Rzmax	Rsm
			Fláajökull forefield		
A	>2000	4.03 ± 0.37	21.74 ± 1.77	30.80 ± 2.79	258.65 ± 19.43
B	1944	4.15 ± 0.27	23.10 ± 1.43	32.80 ± 2.96	281.25 ± 16.99
C	1932	5.27 ± 0.33	28.52 ± 1.58	38.20 ± 2.39	294.80 ± 19.40
D	1907	5.18 ± 0.40	28.04 ± 2.03	39.65 ± 4.08	260.85 ± 18.05
E	1894/98	5.35 ± 0.35	28.77 ± 1.80	37.05 ± 2.65	267.20 ± 17.59
F	1870/94 ?	5.46 ± 0.44	28.97 ± 2.04	39.35 ± 3.21	274.15 ± 19.02
			Biferten glacier forefield		
A'	>2000	3.08 ± 0.42	17.57 ± 2.26	23.58 ± 3.84	170.42 ± 19.37
B'	unknown	8.54 ± 0.88	44.80 ± 3.63	59.16 ± 6.20	255.52 ± 22.49
C'	mid. 19th c.	7.34 ± 0.59	39.69 ± 2.58	53.09 ± 4.22	256.86 ± 22.72

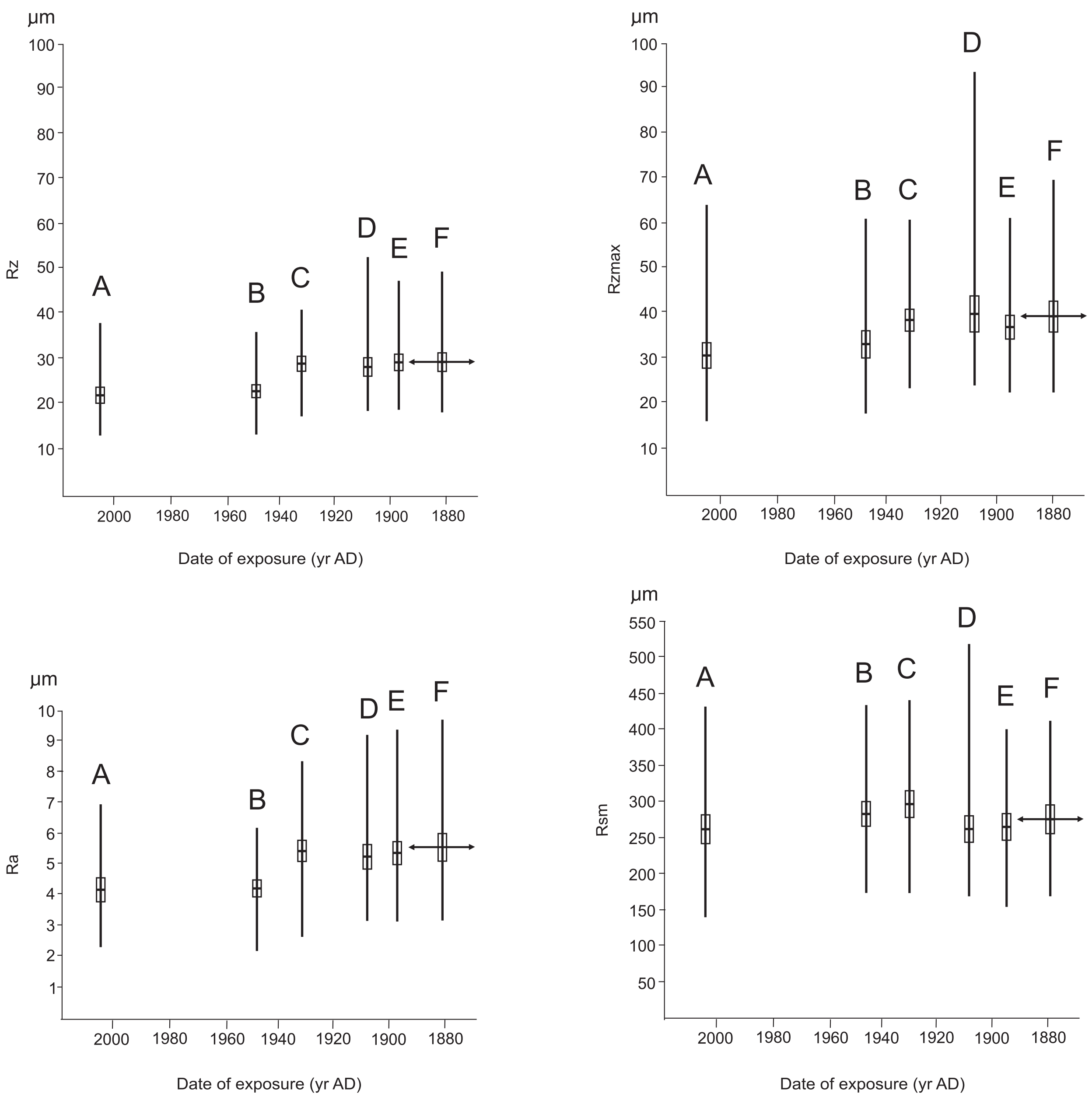

Fig. 3. Roughness parameters obtained from Fláajökull forefields; diagrams indicate minimum, maximum and mean values together with 95% confidence interval; test sites are indicated with capital letters referred to in the main text

glacier maximum, do not exhibit any distinctive roughness, nor R values (Fig. 3, Table 1).

Glacially abraded limestones deposited by Biferten glacier exhibit similar diversification of micro-roughness as Icelandic basalts within a single test site, but as one moves away from the glacier snout (site A') towards the terminal moraine (site C') micro-roughness increases much more significantly (Fig. 4, Table 1). Mean amplitude of micro-relief (Rz) increases from 17.57 μm at the glacier snout (site A') to 39.69 μm on the terminal moraine (site C'). There is also a distinctive difference in Rsm (mean width of profile elements) between test site A' and older sites: B' and C': it increases from 189.78 μm to 279.58 μm (Table 1). Increase in the micro-roughness of studied limestone surfaces occurs only within the younger part of the micro-roughness pattern in the Flaajokull forefield.

Overall, freshly abraded limestone surfaces are slightly smoother in comparison to basaltic ones, but their micro-roughness increases more significantly as one moves towards terminal moraines from LIA maximum.

Conclusions

Previous studies on roughness of glacial landforms proved usefulness of the method elaborated by McCarroll (1992) and McCarroll & Nesje (1996) in diversification between landforms created during LIA and those from the onset of Holocene.

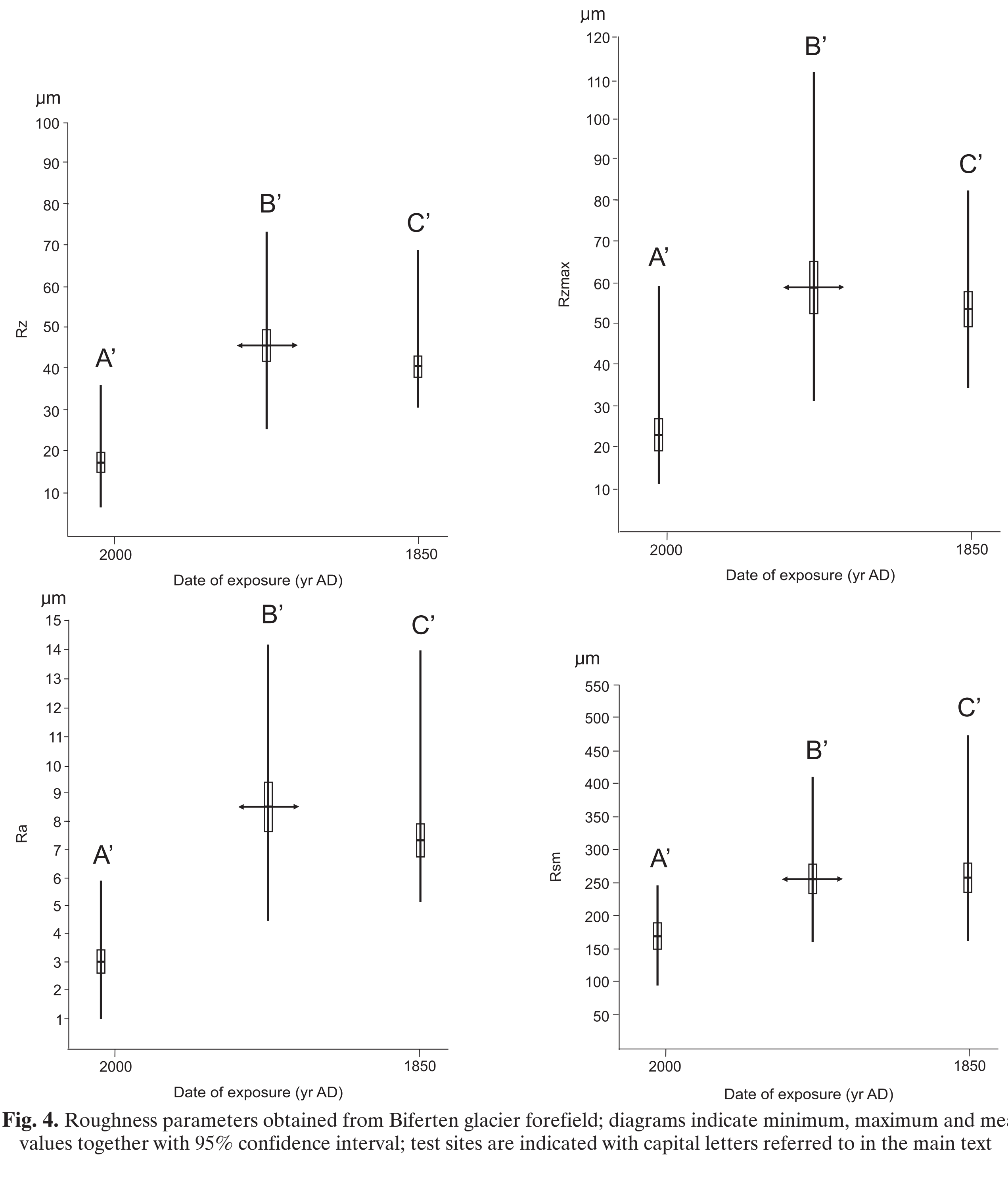

Fig. 4. Roughness parameters obtained from Biferten glacier forefield; diagrams indicate minimum, maximum and mean values together with 95% confidence interval; test sites are indicated with capital letters referred to in the main text

Handysurf E35-B electronic profilometer proved to be useful in detecting initial stages of weathering of basalts and limestones occurring within first decades following glacial deposition. Not only it provides a tool for relative dating of young glacial landforms but also it can be used in studies focusing on effects of glacial polishing.

This study was performed on landforms developed by two different glaciers operating in different environments of Iceland and Swiss Alps, therefore a comparison of abrasion effects of basalts and limestones must be treated with caution. Nevertheless, the results are rather not surprising, as limestones are softer then basalt and much more prone to abrasion. Time-dependant enlargement of micro-depressions on basalts and limestones testifies for chemical weathering acting in proglacial environments. At this stage of research it is difficult to explain micro-roughness levelling-off after first few decades following release from glacier, however exfoliation in case of basalts (Etienne 2002) and case hardening in case of limestones should be considered.

Further studies on different rock types and under different climatic conditions are required.

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References

Bradwell T., 2009. Lichenometric dating: a commentary, in the light of some recent statistical studies. *Geografiska Annaler* 91 A(2): 61–69.

Chenet M., Roussel E., Jomelli V. & Grancher D., 2010. Asynchronous Little Ice Age glacial maximum extent in southest Iceland. *Geomorphology* 114: 253–260.

Dąbski M., 2002. Age of the Fláajökull Moraine Ridges (SE Iceland). Critical Approach to Use of Lichenometry. *Miscellanea Geographica* 10: 67–76.

Dąbski M., 2007. Testing the size-frequency-based lichenometric dating curve on Fláajökull moraines (SE Iceland) and quantifying lichen population dynamics with respect to stone surface aspect. *Jökull* 57: 21–35.

Dąbski M., 2009. Early stages of weathering of glacially-abraded limestone surfaces as determined by various Schmidt hammer tests; Biferten glacier forefield, Glarner Alps (Switzerland). *Landform Analysis* 11: 13–18.

Dąbski M., 2010. A commentary to 'Asynchronous Little Ice Age glacial maximum extent in southeast Iceland' by Chenet et al. (Geomorphology 114 (2010) 253–260); a case of Fláajökull. *Geomorphology* 120: 365–367.

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

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.

McCarroll D., 1992. A new instrument and techniques for the field measurement of rock surface roughness. *Zeischrift für Geomorphologie* 36: 69–79.

McCarroll D. & Nesje A., 1996. Rock surface roughness as an indicator of degree of rock surface weathering. *Earth Surface Processes and Landforms* 21: 963–977.

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 Publishers. Rotterdam: 105–110.