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RELIEF INTENSITY AS A COEFFICIENT DIVERSIFYING THE FORMS OF THE POMERANIAN YOUNG-GLACIAL LANDSCAPE

key words: relief forms analyses, Poland, Pomerania

INTRODUCTION

The landscape as a system of connected features, phenomena and processes distinguishing an area is simultaneously characterized by changeability. It is the consequence of feedbacks and relationships between its components. One of them is the terrain relief and the morphometric analysis makes possible its quantitative description.

A scale of the area and choice of the appropriate reference surface (basic area) is the main problem of the terrain forms study (Grygorenko, 1973; Mościbroda, 1981; Kozieł, 1990). Applied methods usually were very laborious, for example the hillocks distinguishing and their classification (Richling, 1973). There were also measured the additional parameters such as relative heights, mean slope, number of hollows, length of water-course lines and their number (Ławniczak, 2003). Hence such studies were limited to some small test-areas and results were extrapolated on bigger regions.

The main aim of this study was working out the method of the homogeneous morphometric analysis. It should be useful for any scale of the region and for any size of the basic area (taking into consideration the average size of the young-glacial landscape forms). There was also another important assumption (taken into account), namely the elimination of differences due to a position above sea level and due to forms ages (the forms of any area could be connected with different phases and oscillations of the last glaciation). Each relief component has been evolving and it influences the forms morphometric changes. But it is possible to find a feature which is the most resistant to them. It is the pattern recognition of forms. It is suggested to use a digital terrain model (DTM) for whole big region of the young-glacial

landscape. On the basis of such data it is possible to indicate some morphometric features of forms and present their pattern recognition (as a part of another research trend; Tadeusiewicz, Flasiński, 1991).

STUDY AREA

Pomerania (NW Poland) as the example of a region with the young-glacial landscape was chosen to the morphometric analysis. It is considered here in its historical borders: between lower parts of the Odra and the Vistula rivers (west and east adequately) and between the Baltic Sea (north) and the Noteć – Warta proglacial stream valley (the Toruń – Eberswald proglacial stream valley) south. It consists of two big physical-geographical regions: The South Baltic Coasts and the Pomeranian districts lake (Kondracki, 1994). Its main feature is the trisectional landscape. The main axis is the Pomeranian hump (Galon, 1972) – end moraines ridge, mainly of the Pomeranian phase maximum extension during the Vistula glaciation with the highest point called Wieżyca (329 m n.p.m.). It is also the main watershed between tributaries of the Odra and the Vistula rivers south and the Baltic Sea Coast rivers north. This hump also agrees with the under-Quaternary relief upheaval.

The southern slope of the hump gradually descending towards the Noteć – Warta proglacial stream valley is a wide zone of outwash plains, today drained by the Myśla, Drawa, Gwda, Brda and Wda rivers and their tributaries. They are overgrown by pine and mixed forests. Furthermore, relatively flat or undulated areas of the ground moraine of former phases make up this region. Today they are used agriculturally.

The northern slope following into seaside lowlands descends towards the Baltic Sea. There are the Pomeranian phase forms like areas of the ground moraine, kame terraces and basins with marginal lake sediments. The relief of this part of Pomerania is diversified by rivers valleys: the Rega, Parsęta, Wieprza, Słupia, Łupawa, Łeba and Reda valley (arose in places of former valleys which had formed before glaciations). These valleys are characterized by their stepped course from SE to NW. This region is used agriculturally, here and there overgrown by beech, oak and pine forests.

End depressions of the Odra and the Vistula lobes are the lowest part of the Pomeranian landscape today with the crypto depression of the Miedwie Lake (c. -30 m b.s.l.).

The characteristic feature of the Pomerania region, especially of the Pomeranian District Lakes is huge number of different lakes – the subglacial tunnels-, moraine-, coastal-type and small, melted-type lakes.

METHODS AND SOURCES OF DATA

In this analysis it was used the DTM with the grid node of 1″ x 1″ of an arc (c. 30 x 30 m in the terrain). It was worked out on the basis of topographic maps of scale 1:50 000 and made available by the Wojskowy Ośrodek Geodezji i Teledetekcji (the Military Centre of the Geodesy and the Remote Sensing), 2001. Data was processed by the Surfer software ver. 8.0 (Golden Software). Fig.1 presents stages of the relief intensity factor (RIF) calculation.

The relief intensity coefficient consists of three factors: a) relative height RH – calculated as a difference between maximum and minimum value of the absolute height in a grid; b) neighborhood NH – sum of differences between an absolute height of the selected grid node and values of nodes north, east, south and west of it (and squared); c) form structure STR which consists of the grain composition of terrain forms deposits GC and the shape of the form FS – convex, concave or flat (undulated, light sloping).

Parameters RH and NH were calculated using the DTM. Next it was used the Geological Map of Poland of the scale 1: 200 000 (Mojski, 1974-1981) to determine STR. Each form was digitized (the classification of selected surface deposits was based on the geomorphological criterion what was the help). Moreover, there were used maps explanations as well as a legend to the map edited by Marks et al. (2006) and forms definitions published in geomorphological and geological literature (Embleton and King, 1975; Jaroszewski et al., 1985; Lindner, 1992; Mizerski and Sylwestrzak, 2002; Goudie, 2004).

Ranks from 0 to 4 were assigned to all the three factors according to a proper interval of values. The values ranges of each rank calculated for RH and NH are presented in tab. 1. Each parameter was processed to a three-dimensional matrix with a grid node of 1,8″ 1,8″ of the arc (c. 55 m x 55 m in the terrain what was optimal due to the number of points as well as the computer processor capacity). A sum of three factors ranks in each grid gave the diversity of the relief intensity for the whole of Pomerania in range from 0 to 12 where 0 means a flat area and 12 – the highest area with the most diverse relief.

The presented factor was tested for different basic areas what is shown in fig. 2. There were selected three dimensions for the test area: c. 30 m x 30 m, c. 55 m x 55 m and c. 150 m x 150 m. Calculated statistical parameters indicate that both factor values as well as the pattern recognition change insignificantly.
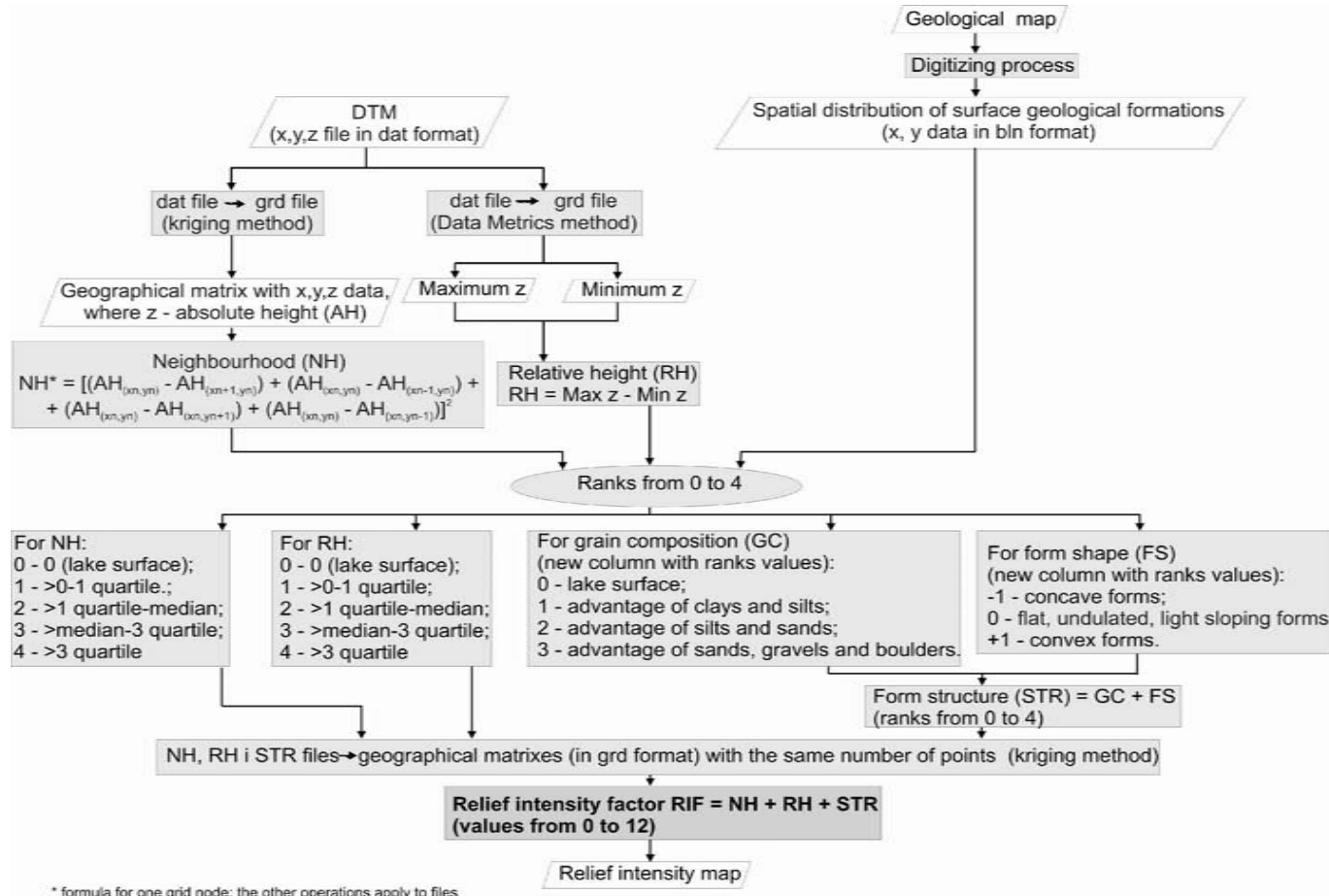
Geological map

Digitizing process

DTM
(x,y,z file in dat format)

Spatial distribution of surface geological formations
(x, y data in bln format)

dat file → grd file
(kriging method)

dat file → grd file
(Data Metrics method)

Geographical matrix with x,y,z data,
where z - absolute height (AH)

Maximum z   Minimum z

Neighbourhood (NH)
$$NH^* = [(AH_{(xn,yn)} - AH_{(xn+1,yn)}) + (AH_{(xn,yn)} - AH_{(xn-1,yn)}) + (AH_{(xn,yn)} - AH_{(xn,yn+1)}) + (AH_{(xn,yn)} - AH_{(xn,yn-1)})]^2$$

Relative height (RH)
RH = Max z - Min z

Ranks from 0 to 4

For NH:
0 - 0 (lake surface);
1 - >0-1 quartile.;
2 - >1 quartile-median;
3 - >median-3 quartile;
4 - >3 quartile

For RH:
0 - 0 (lake surface);
1 - >0-1 quartile;
2 - >1 quartile-median;
3 - >median-3 quartile;
4 - >3 quartile

For grain composition (GC)
(new column with ranks values):
0 - lake surface;
1 - advantage of clays and silts;
2 - advantage of silts and sands;
3 - advantage of sands, gravels and boulders.

For form shape (FS)
(new column with ranks values):
-1 - concave forms;
0 - flat, undulated, light sloping forms;
+1 - convex forms.

Form structure (STR) = GC + FS
(ranks from 0 to 4)

NH, RH i STR files→geographical matrixes (in grd format) with the same number of points (kriging method)

Relief intensity factor RIF = NH + RH + STR
(values from 0 to 12)

Relief intensity map

* formula for one grid node; the other operations apply to files

Fig.1. Stages of the relief intensity factor (RIF) calculation. ***Source:*** *author's compilation.*

Tab. 1. Values ranges of the relative heights RH and the neighborhood NH for each rank, the Pomerania region.

Ranks	Area	Pomerania
Relative heights WW	0	0
	1	>0-3
	2	4-5
	3	6-9
	4	≥10
Neighbourhood SAS	0	0
	1	>0-0.0047
	2	>0.0047-0.0957
	3	>0.0957-0.4979
	4	>0.4979

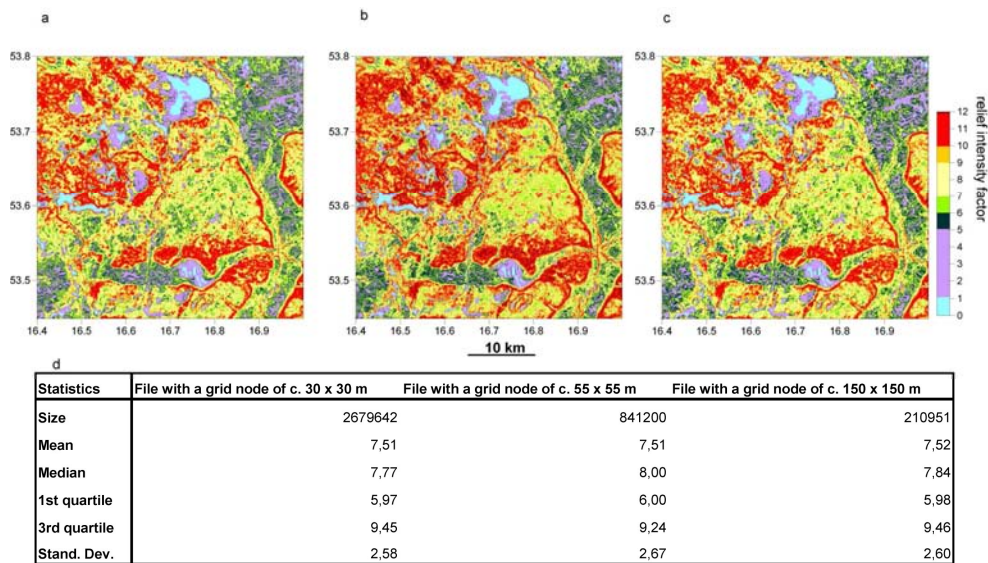*Source: author's compilation on the basis of DTM, Wojskowy Ośrodek Geodezji i Teledetekcji, 2001.*

Statistics	File with a grid node of c. 30 x 30 m	File with a grid node of c. 55 x 55 m	File with a grid node of c. 150 x 150 m
Size	2679642	841200	210951
Mean	7,51	7,51	7,52
Median	7,77	8,00	7,84
1st quartile	5,97	6,00	5,98
3rd quartile	9,45	9,24	9,46
Stand. Dev.	2,58	2,67	2,60

Fig.2. Diversity of the Pomerania relief intensity for the file with the grid node of: a) 1″ x 1″ of an arc (c. 30 x 30 m in the terrain), b) 1,8″ x 1,8″ (c. 55 x 55 m in the terrain), c) 5″ x 5″ (c. 150 x 150 m in the terrain), d) the comparison of the relief intensity factor statistics for different grid node sizes. *Source: author's compilation on the basis of DTM from Wojskowy Ośrodek Geodezji i Teledetekcji, 2001 and maps edited by Mojski, 1974-1981.*

RESULTS

A map of the relief intensity in Pomerania (fig. 3) is a result of the analysis. It was used to cut out each form from the DTM (the Poznań phase and the Pomeranian phase of the Vistulian glaciation were distinguished for the comparison). Basic morphometric parameters were calculated for selected forms (tab. 2).

The carried out procedure of the morphometric analysis makes possible to distinguish some forms of the Pomeranian young-glacial landscape. Its main axis is the central zone of end moraines (A), kames (B) and hummocky marginal zone (according to the map edited by Starkel, 1980) as well as the undulated ground moraine (C) with the relief intensity factor >9. This zone consists of the highest and the most diversifying forms taking into consideration the relief – with the large number of hummockies and hollows what is also presented in the longitudinal profile a (fig. 4).

South of the central axis there is the zone of outwash plains (D) with the factor from 6 to 9 (in a range of 1st-3rd quartile). The same values are characteristic of the flat ground moraine situated north of the Pomeranian end moraines. Their surface is also relatively diversified (fig. 4b) but values of relative heights are lower than it is in case of the central axis. It must be emphasized that outwash plains are forms with the largest range of the relief intensity factor values.

It results from different deposition conditions of fluvioglacial sediments. They are connected with the dynamic state of the glacier and the deglaciation character (as well as the changeability of the deposition conditions; Szafraniec, 2008a, 2008b). Hence outwash plains proximal zones (usually deposited on the buried dead ice blocks) have the diversifying surface with the factor even above 9. Typical outwash fans, e.g. the Barlinek outwash fan, deposited during the maximum glacier extension in mouths of ice-cored moraines gorges have the same morphometric parameters as averages for outwash plains surface (tab. 2). Outwash plains deposited during the extreme glacier floods reveal features typical for the proglacial stream valley with the relief intensity factor below 6 (e.g. the Gwda outwash plain).

Proglacial stream valleys (E) and marginal lake basins (F) with the factor below 6 are the lowest and flattest forms (fig. 4c). Distinct edges usually separate them from other forms.

Subglacial valleys were not distinguished in the table because their inner parts could have different relief intensity factor values. The distinct separation in a form of linear and parallel edges is their feature and it is visible on fig. 3.
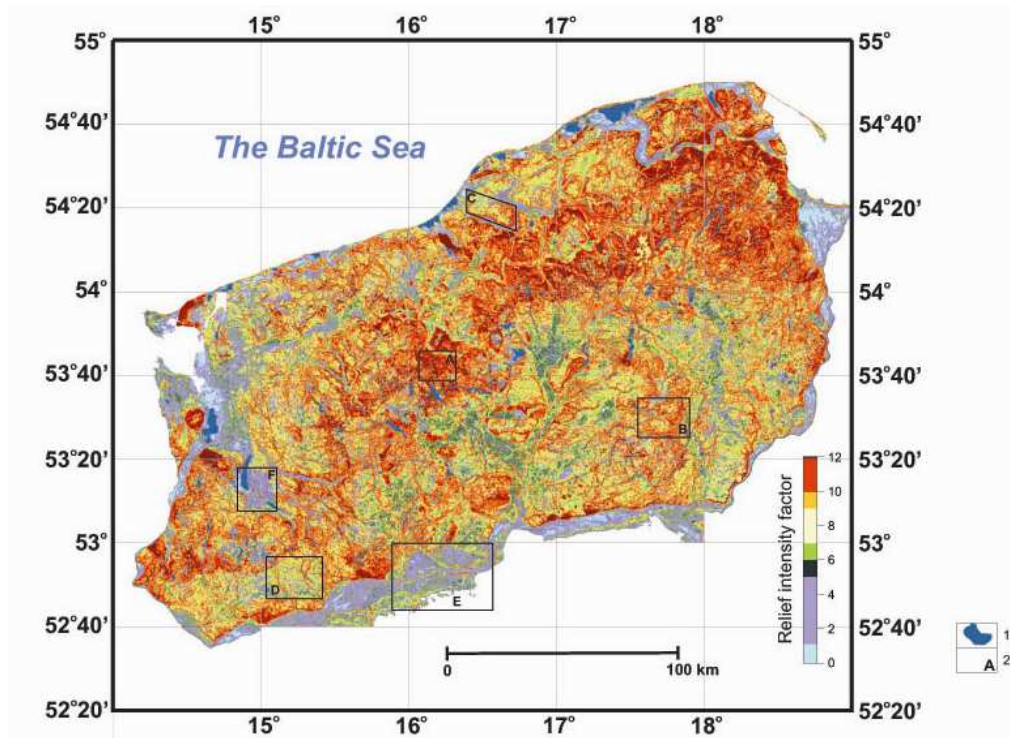
Fig.3. Map of the relief intensity of the Pomerania region : 1- lakes; 2-exam-ples of the pattern recognition of selected young-glacial forms (see also table 2). *Source: author's compilation on the basis of DTM from Wojskowy Ośrodek Geodezji i Teledetekcji, 2001 and maps edited by Mojski, 1974-1981.*
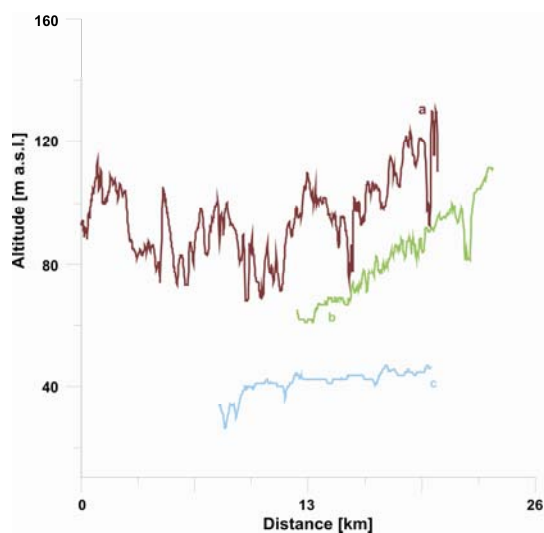

Fig.4. Longitudinal profiles along selected forms of the Pomeranian young-glacial land-scape: a-along end moraines; b-along an out-wash fan; c-along a proglacial stream valley.
Source: author's compilation on the basis of DTM from Wojskowy Ośrodek Geodezji i Teledetekcji, 2001; the vertical axis is 162.5 times outnumbered.

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Tab. 2. Relief intensity factor and relative heights for selected forms of the Pomeranian young-glacial landscape (the Poznań phase and the Pomeranian phase of the Wisła glaciation distinguished.

Form	Grains size	Number of points	Relief intensity factor						Relative heights [m]					
			the Poznań phase			the Pomeranian phase			the Poznań phase			the Pomeranian phase		
			Mean	s.d.	1-3 quart	Mean	s.d.	1-3 quart	Mean	s.d.	1-3 quart	Mean	s.d.	1-3 quart
End moraines (A)	Sands, gravels, tills and boulders	436677	10.33	1.58	9-12	10.52	1.49	10-12	13.20	8.68	7-17	14.35	9.43	8-18
Kames (B)	Gravels, less silts	363278	9.80	1.64	9-11	10.33	1.63	9-12	8.97	5.61	5-12	13.50	8.38	7-18
Ground moraines (C)	Tills (all fractions in different proportions)	7341578	8.72	1.88	8-10	9.20	1.93	8-11	6.34	5.07	3-8	8.48	6.80	4-11
Outwash surfaces (D)	Fluvioglacial sands and gravels	6247202	7.64	1.98	6-9	7.88	2.04	6-9	6.57	6.27	3-8	7.53	6.47	3-10
Proglacial stream valleys (E)	Fluvial sands, gravels and muds	1468949	-	-	-	5.66	1.95	4-7	-	-	-	4.14	4.48	2-5
Marginal lake basins (F)	Ice-dam clays, silts and sands	223360	4.66	2.31	3-7	4.25	1.89	3-6	7.53	9.84	2-10	5.13	4.71	2-7

Source: author's compilation on the basis of DTM from Wojskowy Ośrodek Geodezji i Teledetekcji, 2001 and maps edited by Mojski, 1974-1981).

FINAL REMARKS

The relief intensity factor makes possible to carry out the homogeneous morphometric analysis for the region of any area.

It seems to be a good tool for the preliminary young-glacial forms classification on the basis of DTMs and the analysis of their spatial relations. It also would be the basis for next studies and for the test-areas selection to carry out any other studies (e.g. geological).

The relief intensity factor gives similar results as regards the pattern recognition and the forms morphometry, irrespective of the used model resolution (taking into consideration average forms dimensions). The best model for regions with the area as Pomerania is this one with the grid node of c. 3000-22500 m^2 (from c. 55 x 55 m to c. 150 x 150 m respectively). For areas of detailed studies the 10 x 10 m - 20 x 20 m resolution seems to be more proper (c. 100-400 m^2 of basic area in the terrain; Szafraniec, 2008a, 2008b).

The presented method eliminates differences due to the location above sea level as well as the relief freshness. Hence it is possible to compare analogous young-glacial landscape forms in different latitudes (Szafraniec, 2008a, 2008b).

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SUMMARY

The paper describes a relief intensity factor (RIF) as a method to: 1) recognize main forms of the young-glacial landscape; 2) characterize their morphometry; 3) determine their changes due time and different conditions, as well as 4) compare forms on different altitudes. It consists of three factors: relative height RH and neighborhood NH (counted on the basis of DTM) and also a structure of forms STR – their grain composition GC and the shape FS (relied on geological maps). The model of the Pomeranian relief intensity allows to predict characteristic values for selected postglacial landscape forms. Taking into account the range of the I – III quartile, these values are as follows: for marginal lake basins – 3-6 (mean 4.25); for proglacial stream valleys – 4-7 (5.66); for outwash plains – 6-9 (7.88); for hills consisting of the glacial till (end moraines, ground moraine) and also kames and eskers – 8-12, mean 9.20-10.33 (end moraines 10-12, mean 10.52).