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FENNOSCANDIAN ERRATICS IN GLACIAL DEPOSITS OF THE POLISH LOWLAND – METHODICAL ASPECTS

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Abstract

In the glacial deposits of the Polish Lowland, there are erratic boulders drifted with the last continental ice sheet. Their outcrops are situated in the Baltic Shield area as well as south of it, in the bottom of the central and southern Baltic Sea. Indicator erratics, statistical erratics and the others can be distinguished in coarse-gravels associations. The studies on identification of the indicator erratics are designed for specification of the Scandinavian and Baltic alimentation centres of glacial tills of different age and their fluvioglacial counterparts; they are also aimed at determining the direction of the distant transport as well as the ice-sheet and its streams' transgression routes to the deposition places. Effectiveness of the analysis depends to a large extent on the correct classification of erratics, and this ability happens in turn to be burdened with a subjective evaluation of the clearly visible features of an erratic. In the present paper, an attention is paid to advantages and disadvantages of the analysis on the indicator boulders of the glacial deposits.

Key words: indicator and statistical erratics, glacial deposits, Polish Lowland, Vistulian

INTRODUCTION

The term "erratic" in the Quaternary geology characterizes a boulder dragged by an ice-sheet or a glacier, deposited in the glacial till and the fluvioglacial deposits at a certain distance from the place of its origins. The Scandinavian Peninsula, Finland, the Baltic Sea basin and the Baltic countries are the mother areas for the erratics found in Poland.

Not all erratics have the same indicative meaning of an ice-sheet transgression direction. There are so called indicator erratics (German *das Leitgeschiebe*; Korn 1927, Lüttig 1958) as well as statistical erratics (erratics with limited indicative meaning) (German *das statistische Leitgeschiebe*; Smed 1989) among them. The other erratics are not useful for defining the ice-sheet transgression direction.

"Indicator erratic" is a rock of precisely localized, with defined longtitude and latitude, the only outcrop known today, basing on which a source of a boulder origin can be determined unambiguously and beyond any doubt. Its identification thanks to its clearly visible features cannot create any greater difficulties (*e.g.* Bredvad porphyry, Växjö granite or Tessini sandstone; Fig. 1A).

"Statistical erratic" (erratic with limited indicative meaning) is a rock unambiguously determinable, differring from the indicator counterpart by the fact that it has more than one mother region or/and this region occupies relatively large area. Such erratics are *e.g.* Lower Palaeozoic limestones, Jotnian sandstones, Palaeoporella limestones (Fig. 1B).

Studies of indicator erratics (*e.g.* Dyke, Morris 1988, Stokes, Clark 1999, 2001, Górska 2000, 2002a, b, 2003a, b, Czubla 2001, Gałązka 2002, 2004, Kjćr *et al.* 2003, Woźniak 2004) are applied in order to: a) specify the Fennoscandian and Baltic alimentation centres of different age tills and their chronostratigraphical counterparts – fluvioglacial sediments, deposited in the Polish Lowland (Fig. 2); b) determine direction of the distant transport as well as the transgression route of the ice-sheet and its individualized streams; c) complete the data concerning the dynamics and the icefoot thermal conditions.

The results of analysis of indicator erratics may be presented in tables, where number and type of the indicator erratics originated in particular source regions of Fennoscandia are demonstrated next to each other. The best way of presentation, however, is by drawing a map with circles which centres are in the middle of the mother region and which diameter depends on the number of indicator erratics that are derived from this outcrop (*circle maps* – Smed 1993, 1997, 2000). The circle map is completed with marking the theoretical boulder centre (TBC = *TGZ, das Theoretische GeschiebeZentrum*, Lüttig 1958), with geographical coordinates calculated as averages of the source regions of all indicator erratic rocks, present in the analysed sample. The methods above concern merely 10% of the population of all erratics in the sample, that is why they should not be the only source of interpretation of the distant transport directions of the rock crumbs. In conclusions it is absolutely necessary to take into consideration the information included in the remaining part of the analysed sample (Górska 2003a) as well as to take into account essences connected with the structural and textural features of the glacial deposits (*e.g.* Lüttig 1995, Rühberg 1999, Górska 2000).

THE RECOGNITION SKILL

During identification of the erratic material of the coarse gravels (20–60 mm, pebbles to cobbles, according to Wentworth 1922) some mistakes may appear as a result of the subjective evaluation of clearly visible features of an erratic (Górska *et al.* 2001). The facial diversity of one type rock, observed in the mother region even at a short distance, might crucially influence the different classification of the same erratic, which covered the distance of *e.g.* a few hundred kilometres from its mother region. According to Vinx (1995) the question is not in the difficulty in recognizing one or two erratics. However in case of indicator rocks important is stating the existence of the largest possible number of rocks derived from one mother region (so called series, suite, leading sequence). Such set features are very easily recognizable. As a given alimentation centre is getting better and better represented by the erratics characteristic of it, information about the site of origin of a rock suite and the ice stream transgression route is becoming more convincible than the presence of single erratics derived from anywhere in Fennoscandia.

The fewest classification problems among erratics are caused by rhyolites (called porphyries non-formally) owing to their characteristic legible texture. The indicator sandstones are most difficult to define. The indicator erratics are classified according to the up-to-date knowledge (Vinx 1996, 2002, Geisler 1996). The possibility that a given indicator erratic could originate in some other outcrop, apart from that only one known today, is not taken into account. The attention is rarely paid to that, in the geological past, locations of the alimentation regions were different from the present-day ones and the surfaces of the erratics outcrops were bigger than known today. On the other hand, it is known (Amantov 1995), that the deposits from 25 to 150 m thick have been carried away from the bottom of the Baltic Sea basin. Furthermore there are regions which have been studied only partially and superficially until now and/or the information about their geology is not always well-known to the researchers. The erratics derived from the older glaciations, which change their spectrum when being redeposited into the younger sediments, cannot be categorized at all.

The rocks younger than the Palaeozoic ones, coming mainly from the Jurassic (Gałązka 2004), and the Cretaceous and the Palaeogene periods (including flintstones also) must also be found in the analysed glacial material in Poland. Their outcrops are situated under the Pleistocene rock system to the south of the Baltic Shield, in the area of Denmark, and Rugia (Rügen), in the bottom of the Bay of Gdańsk and in the bed of the Lower Vistula valley as well as in the bottom of the southern Baltic Sea between the coasts of the north-western Poland and Scania (SkÍne) (*e.g.* Pettersson 2002, Górska 2003a, Schulz 2003, Gałązka 2004).

In categorization of indicator erratics the several atlases are helpful (Korn 1927, Hesemann 1975, Smed/Ehlers 1994, 2002, Zandstra 1999, Schulz 2003, Rudolph 2005, Czubla *et al.* 2006). They primarily include crystalline indicator rocks, and sedimentary ones in not a big range. The authors of these atlases do not consider the rocks originated in Lithuania, Latvia or in the vicinities of Kaliningrad, which certainly occur in the glacial deposits of eastern Poland. Labellings of indicator erratics are verified with the model rocks located in the collections of the scientific institutions, among them: in Geological Museum of the Institute of Geological Sciences of the Polish Academy of Sciences – Cracow, in Department of Geology of the University of Łódz, Department of Geomorphology and Quaternary Geology of the University of Gdańsk, Institute of Palaeogeography and Geoecology of the Adam Mickiewicz University – Poznań, Niedersächsisches Landesamt für Bodenforschung – Hannover, Institut für Geologische Wissenschaften Universität Greifswald.

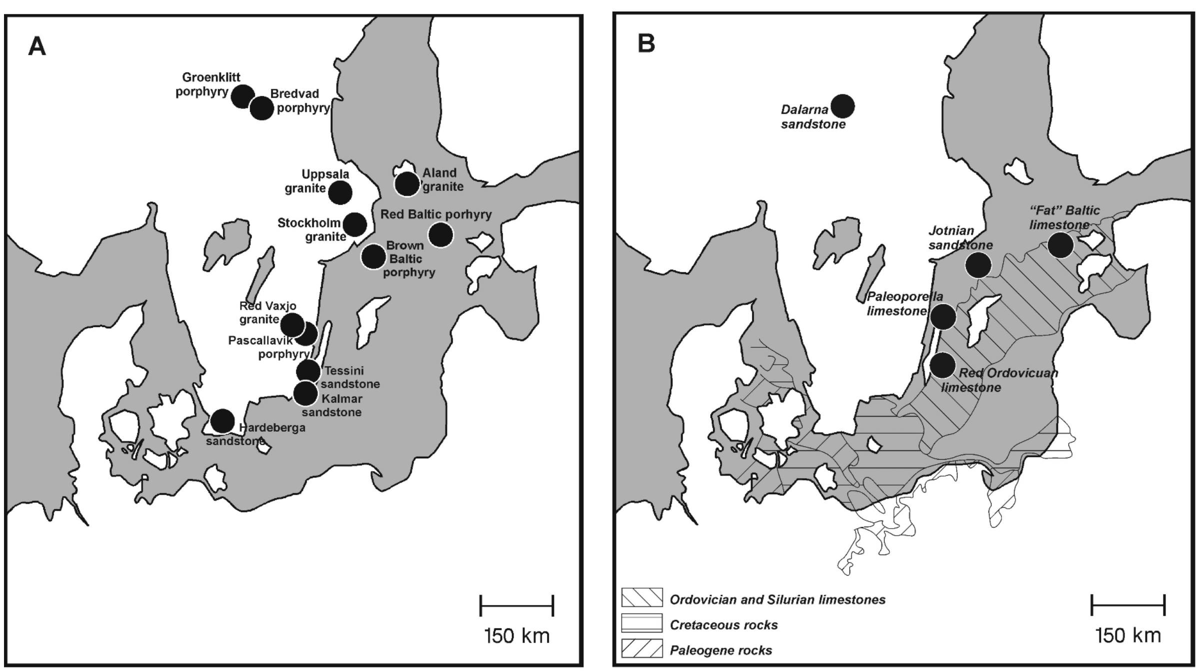

Fig. 1. Location of mother regions of the selected indicator erratics (**A**) and (written in *italics*) the symbolic location of centres of mother regions of the selected statistical erratics (**B**) upon the large outcrops of the statistical erratics.

SAMPLE SIZE AND FACIES CHOICE QUESTION

Correct results of analysis of indicator erratics are achieved on the basis of approximately 50 identified indicator rocks (Smed 1993). Since merely 10% of erratics are indicator ones (Meyer 1983), the sample together with carbonate rocks and flintstones ought to contain not less than 500 specimens, which is undoubtedly a drawback of this method. Obtaining so large population gets still more difficult if the erratics derived from tills are studied. According to Puranen (1990) the best conditions for tracing the erratics origin occur in basal lodgement till. However the latest research (Lüttig 1999, Górska 2002a, b, 2003a, 2005, Rutkowski 2005) suggest that analysis of the glacial till could be substituted by petrographic analysis on rock debris of the fluvioglacial deposits with chronostratigraphic position established to the same age. The differences that appear in the quantitative composition of petrographical types are a result of longer transport of the fluvioglacial deposits than of the glacial till (Lilliesköld 1990) as well as of the additional sorting factor, that is water. Anyway, continuation of petrographical research of the fluvioglacial facies is necessary in order to confirm or reject this hypothesis.

One may try to determine the directions of the ice-sheet advancements on the basis of the smaller population of the indicator erratics if the data are completed with statistical erratics analyses numerous enough (*e.g.* Górska 2003a, b).

ERRATICS IN GLACIAL DEPOSITS – EXAMPLES OF THE TWO EXTREME SITES OF THE POLISH LOWLAND

As an example, the results of studies of erratics found in two extreme field sites in Poland are presented. Associations of indicator and statistical erratics, derived from the stratigraphically diverse beds of glacial till, have been studied there. The Wartanian till in Koczery (Górska 2000b, 2003b) in the Podlasie Lowland and the Pomeranian Phase till of the last glaciation in Nawodna have been sampled. The samples are of similar number both in the indicator erratics group and in the statistical ones. The similarity can be also traced in the representation of three mother regions in both samples, *i.e.* Ĺland Islands, Dalarna and SmĺIand, with the reservation that the percentages of the indicator erratics in both sites are different. The differences between analysed spectra of erratic rocks appear also in the statistical erratics association. Statistical erratics from Nawodna are: Dalarna sandstones and the Cretaceous or Paleogene age flintstones, occurring in the whole southern Baltic Sea bed from Denmark up to the Kaliningrad District (Fig. 1). In Koczery not a single one Dalarna sandstone has been observed, however Devonian dolomites, which are missing in Nawodna (Fig. 2), commonly occur there.

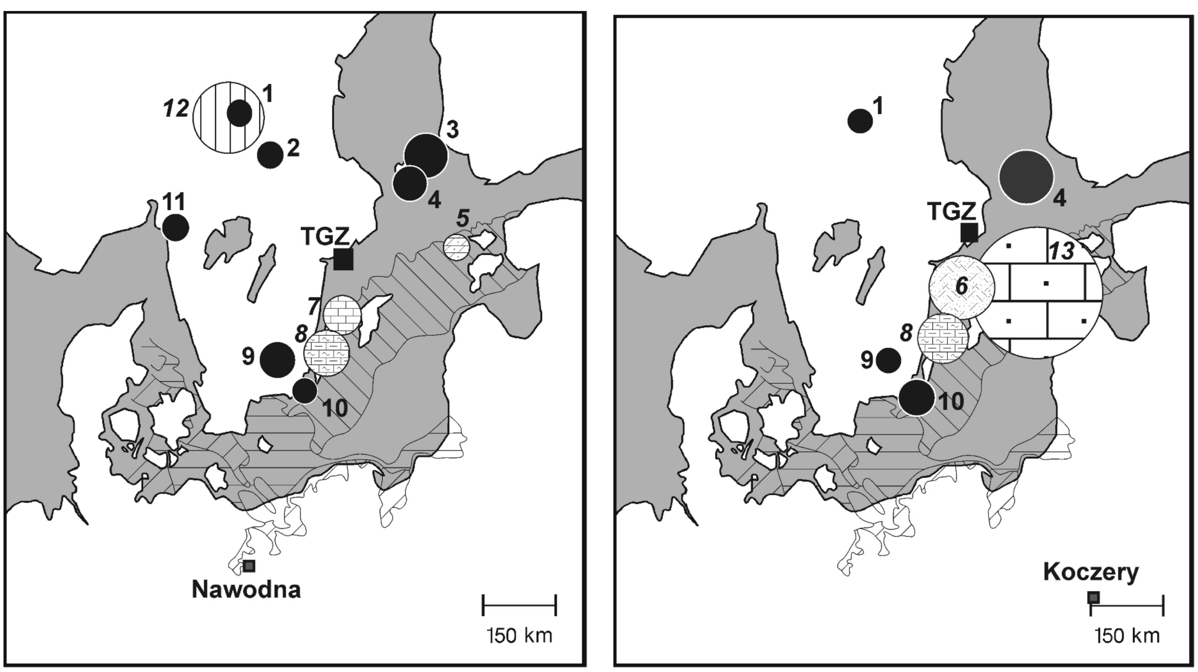

Fig. 2. Mother regions of the indicator erratics (shown by circles) and the symbolic location of the centre of mother regions of the selected statistical erratics (hachure circle) of the Pomeranian Phase till in Nawodna (the Myśliborskie Lakeland) and of the Wartanian till in Koczery (the Podlaska Lowland). Areal hachure – confer the legend in the Fig. 1; numbers stay for erratics: 1 – Bredvad porphyry, 2 – Siljan granite, 3 – Haga granite, 4 – Ĺland granite, 5 – east-Baltic limestone with a distinct “fat” fracture, *6 – Jotnian sandstones, 7 – the Palaeoporella limestone, 8 – red Ordovician limestone,* 9 – PĺIskallavik porphyry, 10 – Kalmar sandstones, 11 – Bohus granite, *12 –Dalarna sandstones, 13 – Devonian dolomites*. Location of the TGZ is shown by squares – (Nawodna): φ 58.7°N λ 17.4°E, TGZ (Koczery): φ 59.0°N λ 18.0°E. Statistical erratics are listed in *italics*.

CONCLUSIONS

The research into Fennoscandian erratics of coarse gravels is an excellent extension of the lithofacial analysis (Kasprzak, Kozarski 1984) and thus presents its great advantage. Analysis of indicator erratics completes the data concerning the dynamics, icefoot thermal conditions, alimentation region and ice-sheet transgression route. It also supports, determined on the basis of stony coefficients, the conclusions about diverse alimentation centres of the glacial tills and, as far as age is concerned, the corresponding fluvioglacial deposits. The research into the erratics confirms the distant transport and defines the ice streams transgression routes.

For example, before the continental ice sheet of the Wartanian stage of the Middle Polish (Riss) glaciation reached the vicinity of Koczery (Fig. 2), it had been plucking and incorporating rocks of Ĺland Islands, Baltic Sea basin, Baltic countries and south-eastern coasts of the present-day Sweden. A single specimen of Bredvad porphyry from Dalarna which turned up within the spectrum of deposits transported during this phase to the Podlasie area, could have originated in the earlier advancements of the Pleistocene ice-sheet or it might have got into the main ice stream together with the sediments of the protorivers draining the central part of Sweden. The theoretical boulder centre calculated for the glacial till indicator erratics in Koczery is located at: φ 59.0°N λ 18.0°E.

The ice stream of the Pomeranian ice sheet must have moved over the outcrops of rocks of Ĺland Islands, eastern part of Smĺland and the adjacent shelf of the Baltic Sea. It eroded and incorporated Haga and Ĺland granites, Pĺskallavik porphyries, Kalmar sandstones, Palaeoporella and red Ordovician limestones. Single indicator erratics coming from Dalarna (Bredvad porphyry, Siljan granite) are associated with statistical erratics (Dalarna sandstones). The theoretical boulder centre calculated for indicator erratics in Nawodna is located at: φ 58.7°N λ 17.4°E. No comparison may be undertaken, because the deposits of the two study sites differ chronostratigraphically.

The researcher who makes an attempt to carry out the petrographical analyses of the glacial deposits needs to take into account many shortages of this method.

1. The choice of lithofacies does exert an influence on the final petrographic composition of the studied glacial deposits. However, the newest results of petrographical research (Górska 2000b, 2002b, 2003b, 2005) in tills and fluvioglacial deposits, their chronostratigraphic counterpart, make up new opportunities in petrografic analyses.

2. The sample population must be statistically representative, *i.e.* it must include at least 500 specimens and the site should be suitably sampled.

3. Determining zones in which the deposits plucking of an ice-sheet proceeded depends on the correct categorization of an erratic and relating it to the mother region of Fennoscandia. The researcher ought to master proficiently the art of distinguishing on the basis of clearly visible features at least 50 indicator erratics and be aware of the occurrence of their mother regions.

4. The research is ardous and long-term. Large samples should be analysed in the field only, over the water body, where rinsed on the sieve, they are adequately classified. Constant verification of the selected indicator erratics with the atlases and collections of the referential erratics is necessary. A special attention should also be paid to statistical erratics, because of their additional, supporting role in determining the transgression routes of an ice-sheet/ice-stream (Górska 2003c).

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