GEOCHRONOMETRIA Vol. 18, pp 35-40, 2000 – *Journal on Methods and Applications of Absolute Chronology*

AGE OF GLACIOTECTONIC STRUCTURES ON THE WOLIN ISLAND IN THE LIGHT OF LITHOSTRATIGRAPHIC DATA AND RADIOCARBON DATING

RYSZARD K. BORÓWKA[1], TOMASZ GOSLAR[2] and ANNA PAZDUR[2]

[1]*Department of Geology and Palaeogeography, Institute of Marine Sciences, Szczecin University, Felczaka 3a, PL-71-412 Szczecin, Poland (e-mail: borowka@univ.szczecin.pl)*
[2] *Department of Radioisotopes, Institute of Physics, Silesian University of Technology, Krzywoustego 2, PL-44-100 Gliwice, Poland (e-mail: pazdur@zeus.polsl.gliwice.pl, goslar@zeus.polsl.gliwice.pl)*

Abstract. On the basis of lithostratigraphic analysis of deposits forming the Wolin End Moraine as well as radiocarbon dating of the intercalations of organic matter found amongst such deposits, the age of glaciotectonic structures existing in the area of morainic hills was determined. It is claimed that both the glaciotectonic deformations and the end moraine itself were formed during regression of the last glaciation.

1. INTRODUCTION

The age determination of glaciotectonic structures can be achieved up to date with either lithostratigraphic or morphostratigraphic method (Rotnicki, 1998). In the first one, marked by a greater universality, the age of glaciotectonic structures is derived indirectly by considering the age of the youngest deposits containing these structures and the age of the oldest deposits covering the perturbed formation. The second one, most commonly applied to young glacial areas, puts in relation the glaciotectonic perturbations with the corresponding marginal zones which mark the ensuing glaciation or deglaciation stages of these areas. The accuracy of such dating methods is usually not high and does not even allow relating the glaciotectonic perturbation zones to given glacial periods. However, the accuracy improves whenever there is a way of absolute dating both the glaciotectonically disturbed deposits and formations covering these deformations (Rotnicki, 1998). Such a situation is characteristic of the Wolin Island, for which as early as in the beginning of this century the rafts of Mesozoic rocks were described and identified amongst the Quartenary deposits together with a number of structures disturbing normal layout of bed exposures in cliffs (Deecke, 1907). These structures classified by C. Heberman (1913), W. Hartnack (1926) and K. Keilhack (1930) as belonging to a group of glaciotectonic deformations were considered in relation with transgression of the last ice sheet (Karczewski, 1968) as well as older glaciations (Krygowska and Krygowski, 1965).

In this work the authors attempted to determine the age of the Wolin End Moraine and the glaciotectonic deformations existing in its area by referring to some new litho- and biostratigraphical observations. These were also confronted with the results of radiocarbon dating obtained for selected intercalations of organic matter found in the sandy and silty-sandy exposures in the northern and central regions of the Wolin hills.

2. GEOMORPHOLOGY

One of the most characteristic relief features of the Wolin Island are the so called Wolin hills (also known as the Wolin End Moraine), reaching the average height of 60 m above sea level with the maximum height of 115 m. They stretch from the environs of Świętouść to the north eastern part of the island, in the direction of Międzyzdroje, to the south western part in the direction of Lubin (**Fig. 1**). Geological structure of these hills is in certain parts perfectly exposed in the cliffs developed in the northern parts of the hills, on the coast of Pommeranian Bay, and in their southern parts towards the Szczecin Transgression. The relief of these hills proves to be particularly interesting. It is composed of more and less elongated and closed depressions having the relative heights of a few tens of metres. The analysis of the Wolin hills relief carried out with a topographical map with scaling of 1:10,000 allowed discovering a clear orientation of these secondary forms (Michalak, 1997). It was also concluded that in the northern part of the island the axes of the forms are oriented along the run directions of principal overthrusts. The Wolin

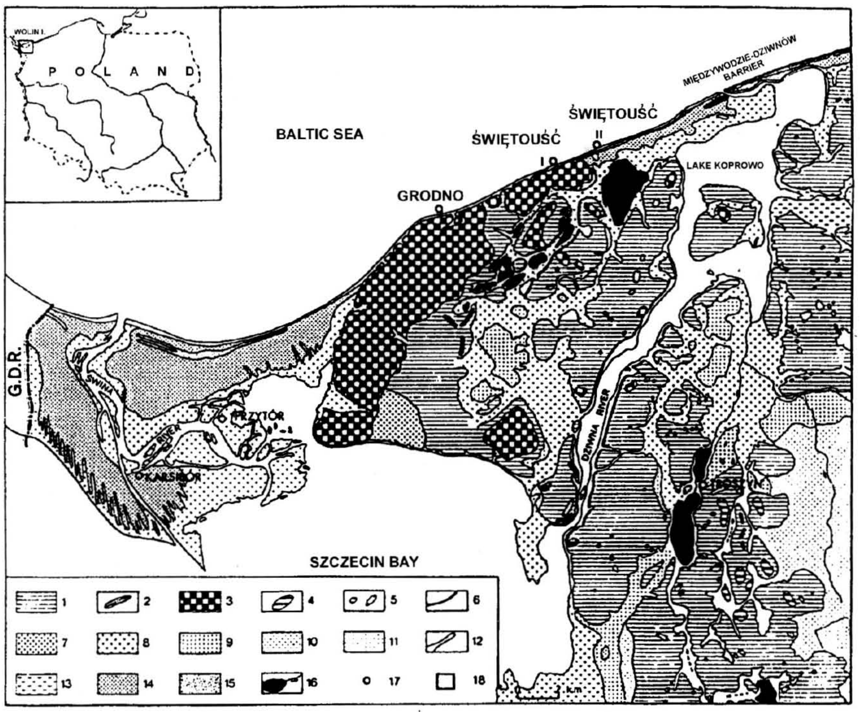


Fig. 1*. Geomorphological map of Wolin Island (after a manuscript by A. Karczewski, 1968):*
1 – morainic plateau, 2 – eskers, 3 – end moraines, 4 – kames, 5 – melt-out depresions, 6 – scarps, 7 – outwash plains; 8, 9, 10, 11 – terraces of Lower Odra Valley, 12 – erosional-denudative valleys, 13 – ice marginal valleys; 14, 15 – inland and coastal dunes, 16 – lakes and streams, 17 – research sites, 18 – location of Wolin Island.

hills together with their numerous glaciotectonic structures constitute one of the youngest marginal zones of the last glaciation period in Poland. They were usually believed to originate from the Wolin-Gardno Phase during which the ice margin is supposed to have run along the contemporary coast line (Galon, 1968; Roszkówna, 1968; Boulton *et al.*, 1985). More recent research of the marginal zones of north western Poland seems to contrast this view (Lagerlund *et al.*, 1995; Kozarski, 1995; Mojski, 1995; Rotnicki and Borówka 1995 a,b). The present view suggests that the marginal zone related to the Wolin hills was formed between 15,500 and 14,200 BP. The lower age limit of this marginal zone is determined by the oldest swampy-lacustrine deposits found at the bottom of the Pommeranian Bay and their radiocarbon dating falls in the range between 14,060±220 and 13,100±300 BP (Kramarska and Jurowska, 1991). The upper age limit of the Wolin marginal zone is harder to determine, however it should not go beyond 16,200 BP, that is the estimated age of the Pommeranian marginal zone (Pommeranian Stadial) which in turn was calculated on the basis of the average rate of deglaciation of the last continental glacier starting from its maximum reach (Kozarski, 1995).

However, the genesis of the Wolin hills is open to question. Some authors consider them as Moraine hills thrust by glaciotectonic process (Hartnack, 1926; Żynda, 1962; Bryl, 1972; Borówka *et al.*, 1982) whereas others share the opinion that only old Pre-Vistulian glaciotectonic structures covered by fluvioglacial deposits, which form the so called kame plateau, exist here (Krygowska and Krygowski, 1965; Krygowski, 1967; Matkowska *et al.*, 1977; Ruszała *et al.*, 1979). The second view is difficult to uphold in the light of recent geological research which shows that sandy series covering the glaciotectonically perturbed deposits is a cover of Late Glacial aeolian sands intercalated by Alleröd fossil soil (Borówka *et al.*, 1982, 1986) and that contradicts the earlier belief which assumed a cover of fluvioglacial kame deposits.

3. LITHOSTRATIGRAPHY

Thanks to the geological research and observations carried out between 1996 on the seaside cliff in the environs of Grodno and Świętouść it was stated that the glaciotectonic exposures include the following deposit series (**Fig. 2** and **3**):

- Cretaceous marls (embedded as glaciotectonic scales and rafts amongst Quaternary formations);
- glacial grey till, in some parts also brown;
- sandy series amongst which appears the marine malacofauna characteristic of Eemian sea (Borówka *et al.*, 1999);
- sandy-silty series which sporadically feature intercalations of organic matter and very rarely the lumps of gravel with sparse boulders.

The glaciotectonically perturbed formations might reach nearly up to the very hilltops, in particular in their elevation zones. In such locations they are often covered by a thin layer of brown glacial till with a thickness of strata up to a few metres. In the underclay numerous structures characteristic of dynamic contact with lower lying deposits are observed.

A series of glaciotectonically perturbed formations and the youngest layer of glacial till are usually significantly eroded (**Fig. 2** and **3**). Above this discontinuity area the following might appear:

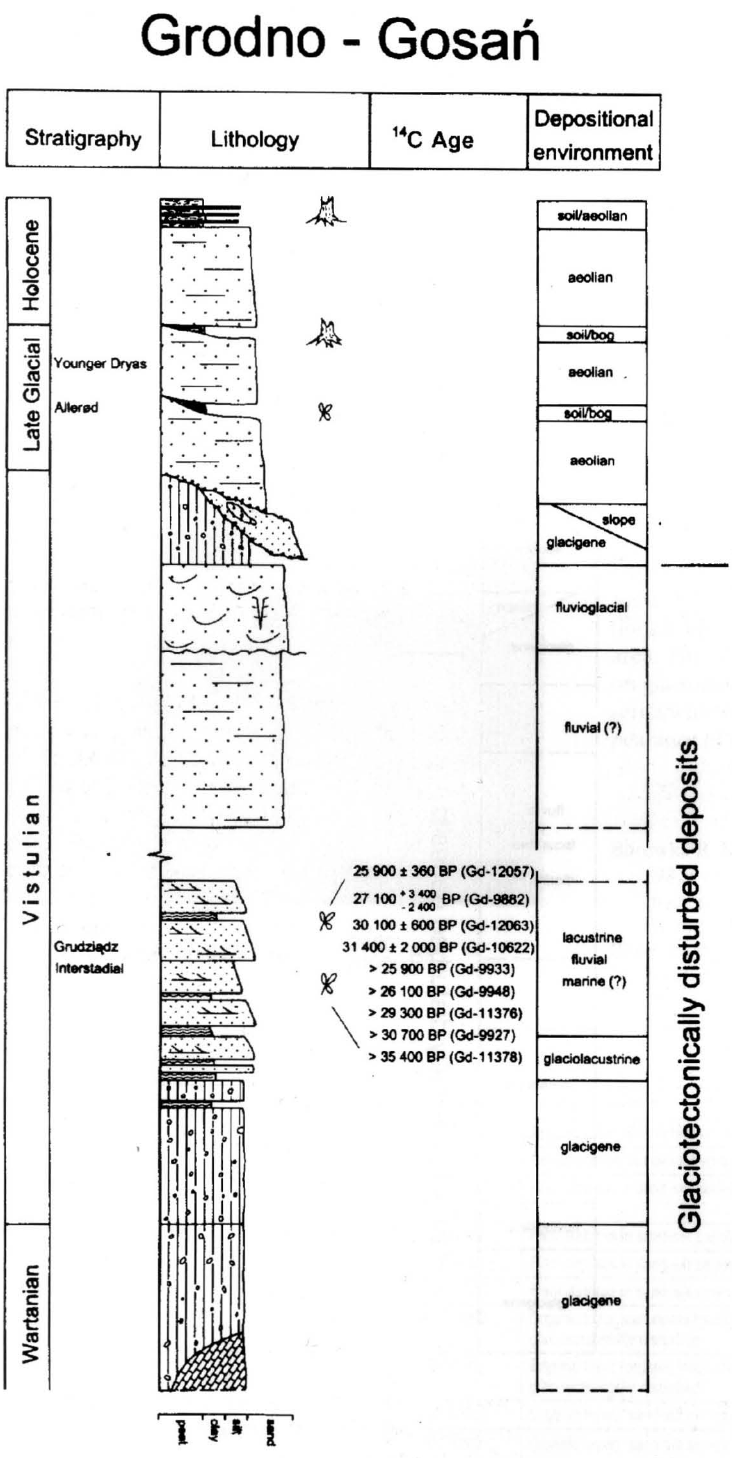


Fig. 2. Generalized lithostratigraphic log from Wolin End Moraine–Grodno Site.

- covers of slope deposits;
- deflational pavement;
- trisectional cover of aeolian sands within which the intercalations of two fossil soils commonly appear; the older one has the features of poorly developed tundra soil of Usselo type and originates from Alleröd period, whereas the younger one was already forming during Holocene period (Borówka *et al.*, 1982). Taking into account the litostratigraphic data it is safe to say that the perturbations described formed between the Eemian Interglacial and the Late Vistulian interglacial. The marine malacofauna found in perturbed sandy series near Świnoujście (Borówka, Makowska and Cedro, 1999) dates from the Eemian Interglacial, whereas the oldest cover of aeolian deposits dates from the Late Glacial and more accurately from the Pre-Alleröd period.

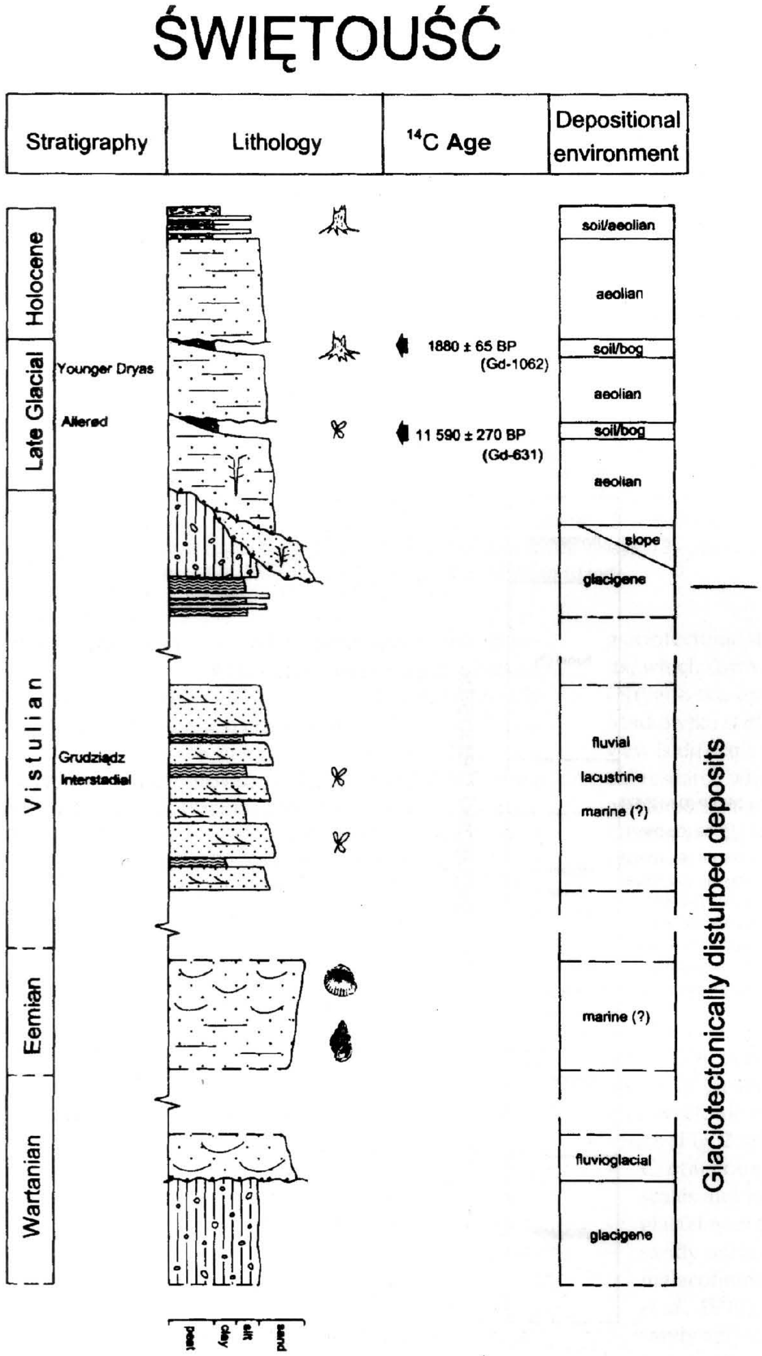


Fig. 3. Generalized lithostratigraphic log from Wolin End Moraine–Świętouść Site.

4. RADIOCARBON CHRONOSTRATIGRAPHY

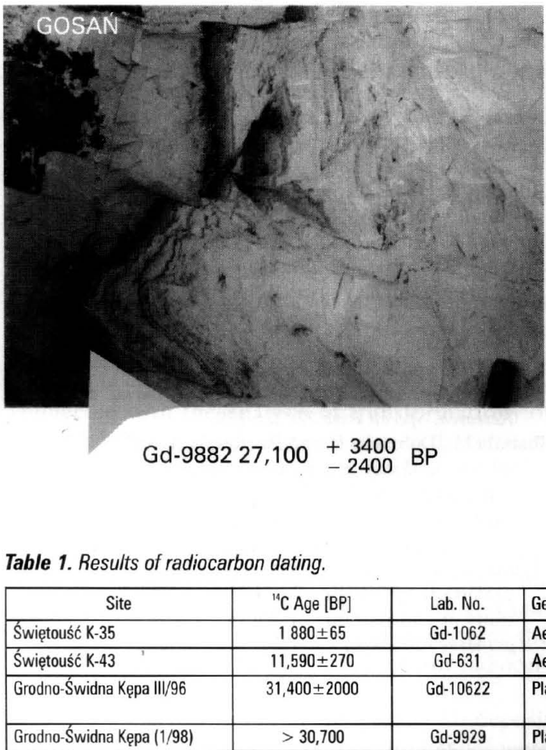
The exposures in the Wolin cliff sometimes contain intercalations of organic matter whose age was determined with the means of radiocarbon dating (**Table 1**). Radiocarbon age of the greatest number of samples was determined at Grodno station where amongst perturbed sandy and silty-sandy deposits numerous intercalations of organic matter were found. These were usually the accumulations of flora debris within the climbing-ripple cross lamination deposits. Also thin organic laminae interlaced with silty layers can be sometimes observed (**Fig.4**).

Four out of nine deposit samples taken from perturbed series yielded definite radiocarbon dates which fell in the interval of 31,140±200 to 25,900±360 BP. However, the youngest date refers to a carbonate fraction. Nevertheless a general conclusion can be drawn that the silty-sandy deposits with intercalations of organic matter were at least partly accumulated during the last glaciation period. A number of geological and geomorphological facts suggest though that the process of glaciotectonic structures formation was rather related to the period of deglaciation of last ice sheet. The most important facts are as follows:

- a clear consistence of orientation of surface elements of end moirane relief (the longer hills axes and depressions with no outflow) with the orientation of main glaciotectonic structures of the last ice sheet;
- continuation of some disjunctive glaciotectonic and relaxation structures within the oldest series of aeolian cover sands for which radiocarbon dating yielded an age beyond the Alleröd period.

The penetration of certain glaciotectonic reverse faults up to the upper lying Pre-Alleröd aeolian sands (compare Borówka *et al.*, 1982) suggests that the early phase of their deposition still occurred during a terminating stress, exerted by ice sheet on its underneath. The Wolin End Moraine seems therefore to have been rather upthrusted during ice sheet retreat (instead of advance) at the end of the last glaciation.

Fig. 4. *Gosań profile. Glaciotectonically disturbed lacustrine silts with a intercalations of organic matter.*



Gd-9882 27,100 $^{+3400}_{-2400}$ BP

5. CONCLUSIONS

The litostratigraphic and chronostratigraphic analyses show that the Wolin End Moraine was formed during the recession of the last glaciation. Perturbed deposits with Eemian malacofauna as well as younger formations from the interplenivistulian period are found in this area. The oldest dated series deposited in unconformity on glaciotectonic structures are the Pre-Alleröd eolian series which were formed yet before the complete disappearance of glaciotectonic tensions.

REFERENCES

Borówka R. K., Gonera P., Kostrzewski A. and Zwoliński Z., 1982: Origin, age and paleogeographic significance of cover sands in the Wolin end moraine area, North-West Poland. *Quaestiones Geographicae* 8: 19-36.

Borówka R. K., Gonera P., Kostrzewski A., Nowaczyk B. and Zwoliński Z., 1986: Stratigraphy of eolian deposits in Wolin Island and the surrounding area, North-West Poland. *Boreas* 15: 301-309.

Table 1. *Results of radiocarbon dating.*

Site	^{14}C Age [BP]	Lab. No.	Geological situation	References
Świętouść K-35	1 880±65	Gd-1062	Aeolian cover, accumulation horizon of younger fossil soil	Borówka *et al.* (1982)
Świętouść K-43	11,590±270	Gd-631	Aeolian cover, accumulation horizon of older fossil soil	Borówka *et al.* (1982)
Grodno-Świdna Kępa III/96	31,400±2000	Gd-10622	Plant detritus in sand-silt series, glacitectonically disturbed	Borówka *et al.* (1998, 1999)
Grodno-Świdna Kępa (1/98)	> 30,700	Gd-9929	Plant detritus in sand-silt series, glacitectonically disturbed	This paper
Grodno-Świdna Kępa 2/98	> 25,900	Gd-9933	Plant detritus in sand-silt series, glacitectonically disturbed	This paper
Grodno-Świdna Kępa 3/98	> 29,300	Gd-11376	Plant detritus in sand-silt series, glacitectonically disturbed	This paper
Grodno-Gosań 0/97	25,900±360	Gd-12057	Organic layer (carbonate fraction) in sand-silt series, glacitectonically disturbed	This paper
Grodno-Gosań 0/98	> 26,100	Gd-9948	Organic layer (organic fraction) in Sand-silt series, glacitectonically disturbed	This paper
Grodno-Gosań 1/98	30,100±600	Gd-12063	Organic layer; sand-silt series, glacitectonically disturbed	This paper
Grodno-Gosań 2/98	27,100 $^{+3\,400}_{-2\,400}$	Gd-9882	Organic layer; sand-silt series, glacitectonically disturbed	Borówka *et al.* (1998, 1999)
Grodno-Gosań 3/98	> 35,400	Gd-11378	Organic layer; sand-silt series, glacitectonically disturbed	This paper

Borówka R. K., Makowska A. and Cedro B., 1999: Ślady interglacjalnych osadów morskich w okolicach Świętouścia na Wolinie (Interglacial marine sediment traces in the area of Świętouść, Wolin Island). In: Borówka R. K, Młynarczyk Z. and Wojciechowski A., eds, *Ewolucja Geosystemów nadmorskich Południowego Bałtyku*. GeoPress, Poznań-Szczecin: 49-54.

Boulton G. S., Smith G. D., Jones A.S. and Newsome J., 1985: Glacial geology and glaciology of the last mid-latitude ice sheets. *Journal of the Geological Society* 142 (3): 447-474.

Bryl A., 1972: Spostrzeżenia nad zaburzeniami w glinie morenowej klifu morskiego w Grodnie na Wolinie (Remarks about disturbances within glacial till building the marine cliff in Grodno, Wolin Island). *Badania Fizjograficzne nad Polską Zachodnią* 25: 61-73.

Deecke W., 1907: *Geologie von Pommern.* Berlin: 1-302

Dobracka E. and Ruszała M., 1988: Charakterystyka geologiczna i geomorfologiczna strefy przymorskiej na odcinku Międzyzdroje-Trzęsacz-Niechorze (Geological and geomorphological characteristics of the coastal zone between Międzyzdroje and Niechorze). *Prace Naukowe Politechniki Szczecińskiej 378, Instytut Inżynierii Wodnej* 27: 9-52.

Galon R., 1968: Ewolucja sieci rzecznej na przedpolu zanikającego lądolodu (Evolution of fluvial system in foreland of retreating ice sheet). *Prace Geograficzne IG PAN* 74: 101-120.

Haberman C., 1913: *Geologisch-morphologischen Wandkarte der Provinz Pommern. 1:200,000.*

Hartnack W., 1926: Die Küste Hinterpommerns unter besonderer Berücksichtigung der Morphologie. *Jahrbuch der Geographischen Gesellschaft Greifswald* 43/44, II Beiheft: 1-324.

Karczewski A., 1968: Wpływ recesji lobu Odry na powstanie i rozwój sieci dolinnej Pojezierza Myśliborskiego i Niziny Szczecińskiej (Influence of the Odra lobe recession upon the origin and development of the valley net of Myślibórz Lakeland and Szczecin Lowland). *Prace Komisji Geograficzno-Geologicznej Poznańskiego Towarzystwa Przyjaciół Nauk* 8 (3): 1-106.

Keilhack K., 1930: *Geologische Karte der Provinz Pommern. 1: 500,000.*

Kozarski S., 1995: Deglacjacja północno-zachodniej Polski: warunki środowiska i transformacja geosystemu (~ 20 ka → 10 ka BP)(Deglaciation of northwestern Poland: environmental conditions and geosystem transformation (~20 ka → 10 ka BP)). *Dokumentacja Geograficzna* 1: 1-82.

Kramarska R. and Jurowska Z., 1991: *Objaśnienia do Mapy Geologicznej Dna Bałtyku 1:200,000, arkusz Dziwnów, Szczecin (Explanation to The Geological Map of the Baltic 1:200,000, sheet Dziwnów, Szczecin).* Państwowy Instytut Geologiczny, Warszawa: 1-40.

Krygowska L. and Krygowski B., 1965: Kilka spostrzeżeń dotyczących struktury klifu w Grodnie na Wolinie (Remarks about geological structure of cliff at Grodno, Wolin Island). *Badania Fizjograficzne nad Polską Zachodnią* 15: 167-170.

Krygowski B., 1967: Ważniejsze problemy plejstocenu Polski Zachodniej (Main problems of West Poland Pleistocene). In: Galon R. and Dylik J., eds, *Czwartorzęd Polski.* PWN, Warszawa: 167-205.

Lagerlund E., Persson K. M., Krzyszkowski D., Johansson P., Dobracka E., Dobracki R. and Panzig W-A., 1995: Unexpected ice flow directions during the Late Weichselian deglaciation of the south Baltic area indicated by a new lithostratigraphy in NW Poland and NE Germany. *Quaternary International* 28: 127-144.

Matkowska Z., Ruszała M. and Wdowiak M., 1977: *Objaśnienia do Szczegółowej Mapy Geologicznej Polski, ark. Świnoujście i Międzyzdroje, 1:50,000 Explanation to the Detailed Geological Map of Poland, sheet Świnoujście and Międzyzdroje).* Państwowy Instytut Geologiczny, Warszawa: 1-56.

Michalak M., 1997: Struktury zaburzeniowe w osadach wolińskiej moreny czołowej na przykładach odsłonięć klifu z okolic Grodna i Świętouścia (Deformational structures within the Wolin End Moraine deposits, Grodno and Świętouść vicinity). *M.Sc. Thesis, University of Szczecin, Department of Geology and Palaeogeography.*

Mojski J. E., 1995: Zanik ostatniego lądolodu plejstoceńskiego (Recession of the Last Pleistocene Glaciation). In: Mojski J. E., ed., *Atlas Geologiczny Południowego Bałtyku.* Państwowy Instytut Geologiczny, Sopot-Warszawa: 36-37.

Roszko L., 1968: Recesja ostatniego lądolodu z terenu Polski (Recession of last inland ice from Poland territory). *Prace Geograficzne IG PAN* 74: 65-100.

Rotnicki K., 1989: Dating bases for glaciotectonic deformations. *Quaestiones Geographicae, Special Issue* 2: 129-136.

Rotnicki K. and Borówka R. K., 1995a: Dating of the Upper Pleni-Vistulian Scandinavian Ice Sheet in the Polish Baltic Middle Coast. In: Mojski J. E., ed., *Proceedings of the Third Marine Geological Conference "The Baltic".* Prace Państwowego Instytutu Geologicznego CXLIX: 84-89

Rotnicki K. and Borówka R. K., 1995b: The last cold period in the Gardno-Łeba Coastal Plain. *Journal of Coastal Research, Special Issue* 22: 225-229.

Ruszała M., Dobracka E. and Piortowski A., 1979: *Objaśnienia do Szczegółowej Mapy Geologicznej Polski, ark. Wolin i Międzywodzie, 1:50,000 (Explanation to the Detailed Geological Map of Poland, sheet Wolin and Międzywodzie).* Państwowy Instytut Geologiczny, Warszawa: 1-89.

Żynda S., 1962: Wyniki wstępnych badań nad moreną czołową wyspy Wolin (Results of preliminary investigations of end moraine of Wolin Island). *Badania Fizjograficzne nad Polską Zachodnią* 9: 159-168.