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## Organogenic deposits at Zbójno by Przedbórz, western slopes of the Holy Cross Mts, and their bearing on stratigraphy of the Pleistocene of Poland

**ABSTRACT:** Organogenic deposits at Zbójno by Przedbórz, western slopes of the Holy Cross Mts, Central Poland, represent a complete climatic cycle including an optimum phase with large amounts of *Tilia* pollen both preceded and succeeded by a cool phase. The sequence represents a warm interstadial (Zbójno Interstadial) within the anaglacial part of the Odranian (Riss I) Glaciation. The Zbójno Interstadial separated the pre-maximum Krzna Stadial from the preceding Lówiec Stadial during which two upper alluvial series had been accumulated in paleo-valleys developed at the optimum of the Mazovian (Mindel II/Riss I) Interglacial.

### INTRODUCTION

Organogenic deposits have been recorded below the till of the Odranian (Riss I) Glaciation at the depth interval of 2.5 to 4.0 m at the western part of Zbójno village by Przedbórz, western slopes of the Holy Cross Mts, Central Poland (Text-fig. 1). Lithology and palynology of these deposits (see Text-fig. 2) were studied by the present authors; a sample of the underlying silt (depth of 5.5 m) was dated by W. Stańska-Prószyńska and Docent M. Prószyński with use of the thermoluminescence method.

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## GEOLOGIC SETTING

There are abundant geological data from boreholes pierced at the western slopes of the Holy Cross Mts that permit a detailed lithostratigraphic interpretation of the Quaternary deposits in that area (beds 1—26 in Text-fig. 3).

The oldest are here sands intercalated with gravel composed of local but not Scandinavian material (bed 2). According to Jurkiewiczowa (1968), these may be pre-glacial deposits but Lindner (1979, 1980, 1981) attributes them in part to the Podlasiian (Günz/Mindel I) Interglacial. The overlying soliflucted silts with pebbles of local material (bed 3) represent the Nidanian (Mindel II) Glaciation. Higher in the section, there are sands and silts deposited in ice-dammed lakes (bed 4) in front of the ice-sheet of the Sanian (Mindel III) Glaciation. The Sanian Glaciation was clearly bipartite in the Holy Cross Mts, as it is evidenced by two distinct till levels the lower of which represents the pre-maximum phase (bed 5), while the upper one represents the maximum phase (bed 7). The inserted sands and gravels (bed 6) represent an interphase period (Lindner 1971, 1977).

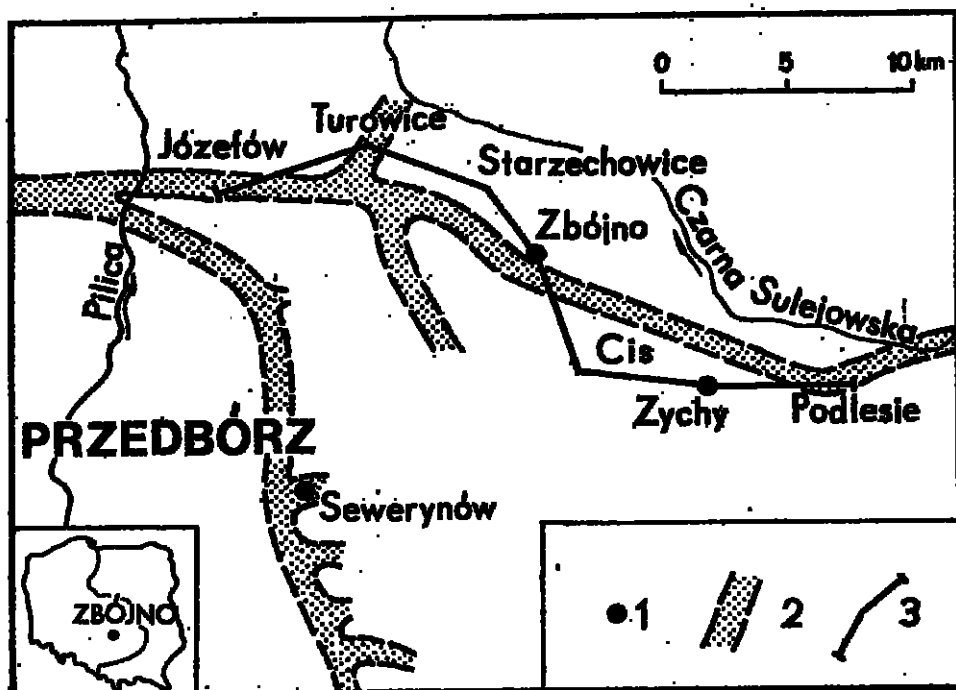


Fig. 1. Location of the investigated sections at Zbójno by Przedbórz; inset shows position of the locality in Poland.

1 floral localities, 2 outline of the paleovalleys developed during the Masovian (Mindel III/Riss I) Interglacial, 3 lines of the geological section shown in Text-fig. 3.

The discussed Quaternary deposits occur at the western slopes of the Holy Cross Mts in form of isolated patches (Lindner 1971, 1978; Grzybowaki 1972). This is due to a considerable erosion during the pre-optimum part of the Mazovian (Mindel II/Riss I) Interglacial effected by the neotectonic movements (Mazovian phase of Barańska 1975), the latter having been expressed mostly in an uplift of the Middle Polish Uplands and Mid-Polish Anticlinorium (Bara-

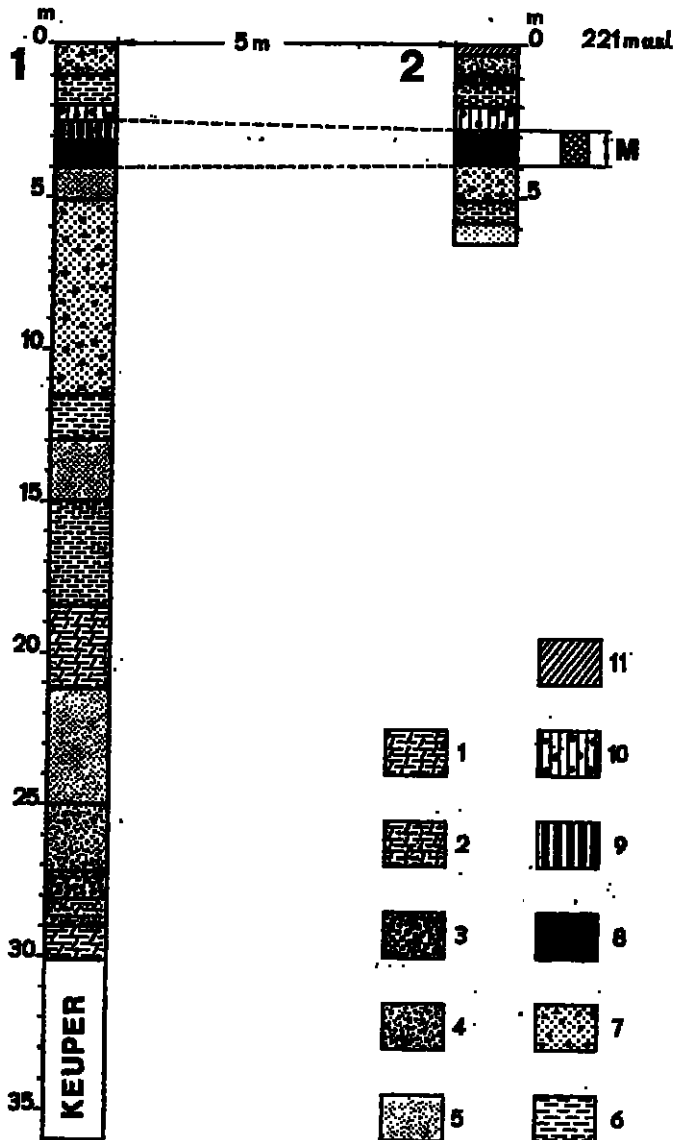


Fig. 2. Lithological section of the boreholes (numbers 1 and 2) at Zbójno

1 gray clay, 2 sandy clay, 3 gravel with Scandinavian material, 4 vari-grained sand, 5 fine-grained sand, 6 light-grey to yellowish-grey clay and silt, 7 medium-grained sand with pebbles, 8 peat with pieces of wood at the top, 9 peaty clay with pieces of wood, 10 till, 11 soil; M core taken for pollen analysis

niecka 1973). This erosion is evidenced in the investigated area by deep paleovalleys the bottom of which lies some 60 to 85 m below the present-day earth surface, i.e. reaching all of them the pre-Quaternary substrate (Text-fig. 3).

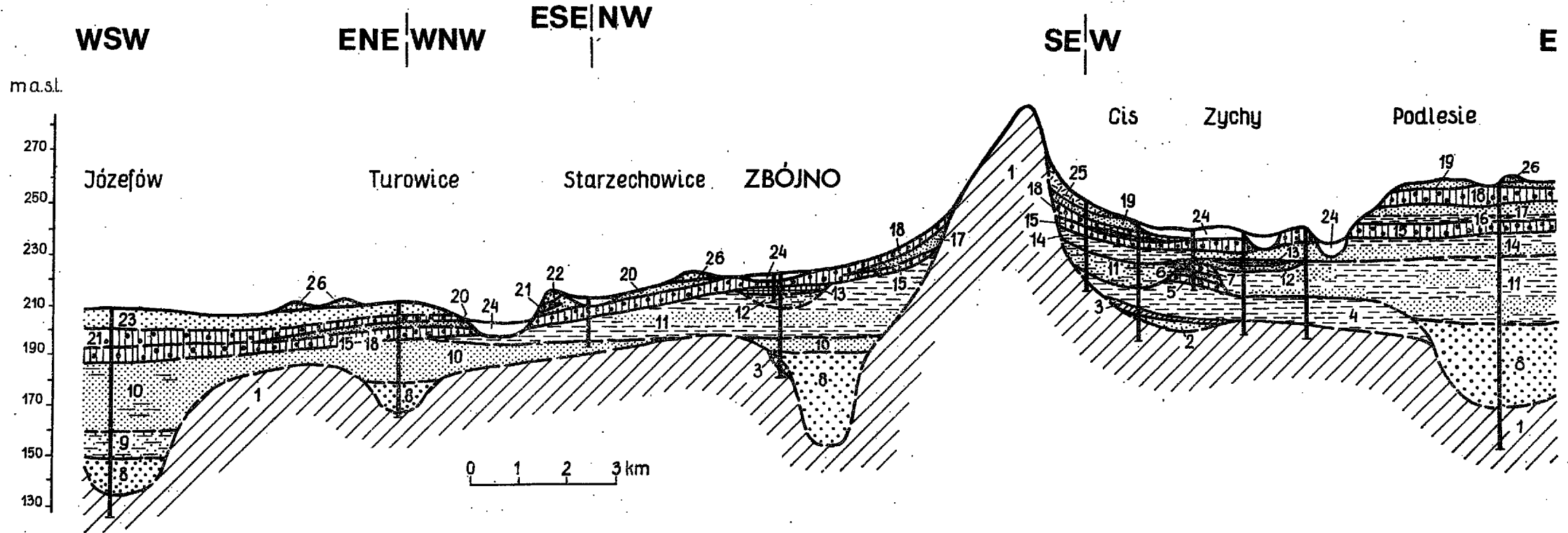
The paleovalleys of Early Mazovian age were filled with alluvial sands and gravels up to 30 m in total thickness (bed 8) during the post-optimum part of the Mazovian Interglacial and at the beginning of the Odranian (Riss I) Glaciation. Organogenic deposits have been preserved in Sewerynow area (cf. Text-fig. 1) in the upper part of this alluvial sequence (Jurkiewiczowa & Mamakowa 1960). Pieces of wood and strongly weathered pebbles of Scandinavian rocks have been recorded in this alluvial sequence at Podlesie by Radoszyce (Czarnecki 1950). Only the upper part of this series has been reached by the borehole Zbójno 1 (see Text-fig. 3).

At the western slopes of the Holy Cross Mts, the alluvial deposits of Late Mazovian to Early Odranian age are overlain by a thick silty-sandy sequence intercalated with varved clays and redeposited loessy material (beds 9—11). These sediments accumulated partly due to a slope displacement and partly in extensive ice-dammed lakes in front of the advancing icesheet of the older pre-maximum, i.e. Liwiec Stadial of the Odranian Glaciation. Presumably, this was the same icesheet that caused the formation of the Lower Pilica Lake (Różycki 1964). This sequence is represented in the section Zbójno 1 by a sandy-silty series with a clay intercalation, ranging in depth from 11.5 to 25.0 m, overlying the interglacial gravels and sands intercalated with gravel.

The sandy-silty series is overlain at Zychy and Zbójno (see Text-figs 1 and 3) by a few meters thick alluvial sands and fine gravels interbedded with silt and gravel (bed 12) and higher in the section, by organogenic deposits ranging up to 2 m in thickness (bed 13). This sequence is in turn overlain by a few meters thick series of sands and silts of fluvio-glacial and ice-dammed lacustrine origin (bed 14) in the area between Cis, Zychy, and Podlesie (see Text-fig. 1). The latter sediments are probably attributable to the Krzna Stadial (Rühle in: Jurkiewiczowa & al. 1973). The till of the Krzna Stadial, interpreted previously as representing a pre-maximum phase of the Radomka Stadial (Lindner 1971), extends all over the investigated area (bed 15). In fact, it overlies directly the above mentioned organogenic deposits at Zbójno. Here and there, fragments of wooden trunks smoothed by the ice occur in this till.

The till of the Krzna Stadial is overlain by silts and varved clays (bed 16) in the eastern part of the investigated area. The latter sediments represent the Podlesie Interstadial documented palynologically at Wyźmierzyce (Mamakowa in: Jurkiewiczowa & al. 1973). The overlying fluvio-glacial sands (bed 17) and till (bed 18) represent the maximum phase of the Radomka Stadial of the Odranian Glaciation (Lindner 1971). Fluvio-glacial deposits preserved at the top of the latter till (beds 19—20) are related in origin to the retreat of the icesheet of the maximum phase. The post-maximum phase is represented by a successive till, transgressive from the west (bed 21), along with the overlying frontal-morainic deposits (bed 22), outwash sediments (bed 23), and ice-dammed lacustrine silts (Laakowska-Wysocka & Nunberg 1961), exposed all of them at Starzechowice (cf. Text-fig. 1).

The further retreat of the icesheet of the Odranian Glaciation and still younger morphogenetic processes are reflected in the investigated area mainly by erosion and subsequent sedimentation in valleys (bed 24), slope displacements (bed 25), and dune formation (bed 26) persistent also during the Holocene.



1 pre-Quaternary rocks; PRE-GLACIAL (PROTOPLEISTOCENE) to PODLASIAN (GÜNZ/MINDEL I) INTERGLACIAL: 2 sands interbedded with gravel of local rocks; NIDANIAN (MINDEL I) GLACIATION: 3 silts with pebbles of local rocks; SANIAN (MINDEL II) GLACIATION: 4 sands and ice-dammed silts, 5 till of pre-maximum phase, 6 interphase (residuum) sands and gravels, 7 till of maximum phase; MAZOVIAN (MINDEL II/RISS I) INTERGLACIAL to ODRANIAN (RISS I) GLACIATION: 8 alluvial sands and gravels  
 ODRANIAN (RISS I) GLACIATION: OLDER PRE-MAXIMUM (LIWIEC) STADIAL: 9 ice-dammed silts and sands, 10 sands and ice-dammed and loess silts, 11 silts and dusty sands interbedded with varved clays and loess delluvia; OLDER (ZBÓJNO) INTERSTADIAL: 12 alluvial sands interbedded with silt and gravel, 13 peats, peaty clays and silts, and humus sands; YOUNGER PRE-MAXIMUM (KRZNA) STADIAL: 14 fluvioglacial and ice-dammed sands and silts, 15 till; YOUNGER (PODLESIE) INTERSTADIAL: 16 silts and varved clays; MAXIMUM (RADOMKA) STADIAL: 17 fluvioglacial sands, 18 till of maximum phase, 19 fluvioglacial sands, 20 fluvioglacial sands and gravels, 21 till of post-maximum phase, 22 end-morainic gravels and sands, 23 fluvioglacial sands  
 EEMIAN (RISS II/WÜRM) INTERGLACIAL to VISTULIAN (WÜRM) GLACIATION and/or HOLOCENE: 24 sands, gravels, and muds; VISTULIAN (WÜRM) GLACIATION to HOLOCENE: 25 soliflucted and delluvial sands, loams, and debris, 26 aeolian sands

## POLLEN ANALYSIS

Nineteen samples were taken every 5 cm from a continuous core including the organogenic deposits recorded at Zbójno 2 at the depth interval of 2.80 to 3.75 m. The samples were prepared with application of the acetolysis method of Erdtmann. Three to five hundred pollen grains of trees and associated herbs have been identified in each sample. The palynological diagram (Text-fig. 4) has been computed relative to the total number of pollen grains exclusive the polypodiacean spores.

The results permit subdivision of the investigated section into three floral phases the middle one of which is bipartite and representative of warm climatic conditions, while the remaining two are indicative of a cooling.

## PHASE I

The spectra are dominated by *Pinus* (84—94%) associated with *Betula* (up to 5%), *Quercus* (3—6%), *Corylus*, and very rarely also *Salix*. This is indicative of predominance of the pine forest with sparse brushwood of *Betula* and *Corylus*. The peat bogs were dominated by the Polypodiaceae.

## PHASE IIa

The contribution of *Pinus* decreases down to at most 13%, while the contribution of thermophilous deciduous trees, especially *Tilia cordata* and *T. platyphyllos*, considerably increases (up to 48%). There are also significant amounts of *Carpinus* (up to 10%), *Alnus* (up to 16%), and *Corylus* (up to 8%), and minor amounts of *Picea* (up to 4%) and *Quercus*. These spectra are indicative of predominance of the linden-hornbeam forest intercalated with *Picea* and *Quercus* and with a brushwood of *Corylus*. The unusually high contribution of *Tilia* is suggestive of the occurrence of a linden wood in a close proximity of the peat bog. The dominance of *Tilia* in the spectra points to warm and wet, optimum climatic conditions.

## PHASE IIb

The contribution of *Tilia* decreases down to at most 20%, whereas the contribution of *Alnus*, *Carpinus*, *Picea* (up to 18% each), *Corylus*, and *Pinus* (up to 7% each) increases. There appear also herbs (up to 3%), while *Quercus* gradually disappears. These spectra are indicative of thermophilous deciduous trees having been replaced by *Picea* associated with *Pinus* and *Alnus*, with *Corylus* persistent in the brushwood; this points to a considerable cooling and a maintenance of wet conditions.

## PHASE III

The contribution of *Pinus* and *Picea* rapidly increases (up to 70 and 38%, respectively) simultaneously with the appearance of *Betula* and *Abies* (the latter up to 23%); whereas *Tilia*, *Carpinus*, and *Corylus* do gradually disappear from the spectra. This is indicative of predominance of the coniferous forest dominated by *Pinus* associated with *Abies* and *Picea*, which points to a further climatic deterioration.

The palynological analysis demonstrates that the organogenic deposits of Zbójno represent a complete climatic cycle including a distinct optimum phase both preceded and succeeded by a cool phase. The optimum phase is unique in unusually large amounts of *Tilia* pollen, the characteristics of which may be of more than only local significance. The order of the recorded climatic changes and the uniqueness of the observed floral succession make unreliable any comparison of the investigated sequence to other interglacial section of Poland.

The organogenic deposits from Marantów near Końin in Central Poland may present the only exception (cf. Borówka-Dużakowa 1967, 1979). Not only an increase in contribution of *Tilia* occurs there at the climatic optimum, but also the successional pattern of *Picea*, *Abies*, *Alnus*, and *Corylus* resembles the investigated section of Zbójno. This is also the case with the successional pattern of *Pinus*, as well as with the occurrence of *Betula* and *Corylus*. It is however to be noted that the organogenic deposits of Marantów were attributed by Borówka-Dużakowa (1967, 1979) to the Brerup Interstadial at the early Vistulian (Wähm) Glaciation.

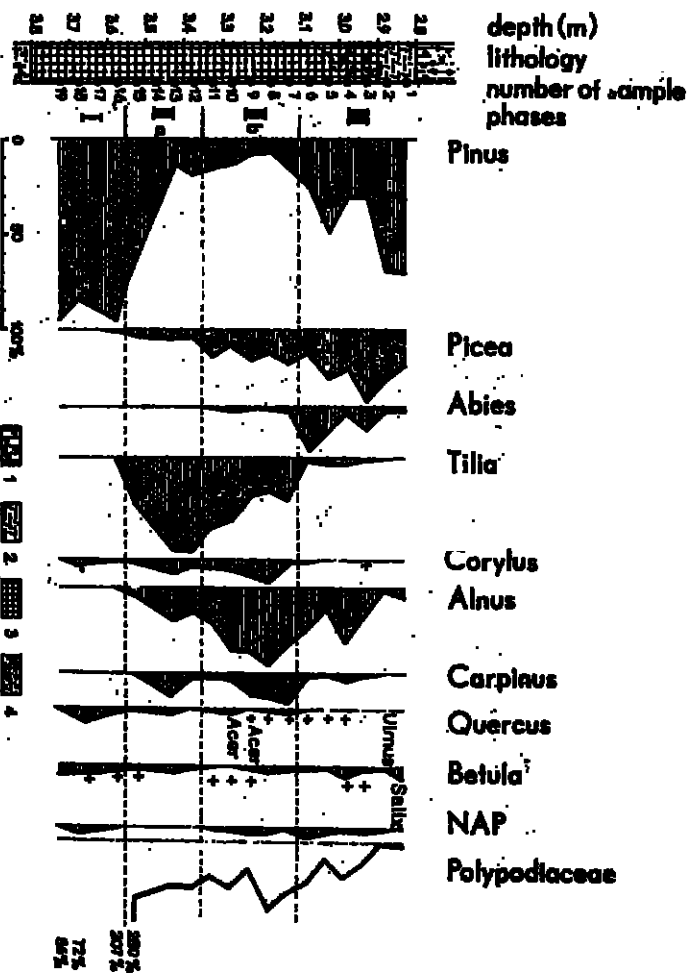


Fig. 4. Palynological diagram of the organogenic deposits of Zbójno (section M in Text-Fig. 3).

1 sil. s dark-brownish peaty clay with pieces of wood, 2 peat with pieces of wood at the topmost part, 3 medium-grained sand with single pebbles

The floral succession at Zbójno may also resemble that one observed by Dr. J. Niklewski in silts underlying the till of the Middle-Polish (Riss) Glaciation at Dąbrowa on Czarna Sulejowska (cf. Grzybowski 1972). The organogenic deposits from Stare Koszary by Kowel (Byelorussian SSR) investigated by Professor J. Bobrowska may also show a similar stratigraphic position and floral succession (cf. Karaszewski & Röhle 1976). Large amounts of *Tilia* pollen, so typical of the sequence of Zbójno, have also been recorded in organogenic deposits supposedly underlying the Middle-Polish till at Mońki in north-eastern Poland (Dr. Z. Janczyk-Kopikowa, *personal communication*).

#### CHRONOSTRATIGRAPHIC POSITION

The geological and palynological data on the organogenic deposits from Zbójno, as well as the thermoluminescence dating of the underlying silts (TL = 388,000 BP) demonstrate that these deposits represent a considerable warming during the anaglacial part of the Odranian Glaciation (Text-fig. 5). This warming was preceded by a cool period responsible for the accumulation of the upper part of the alluvial sediments that fill paleovalleys of Mazovian age. According to Różycki (1972), that cool period is represented by the third and fourth erosion-accumulation cycles observed in the valleys of pre-Vistula and pre-Pilica among others. The organogenic deposits preserved at the top of the third cycle at Barkowice Mokre indicate that the respective warming favored development of mostly coniferous forests (Sobolewska 1952). The nature of the alluvial deposits of the fourth cycle observed at Barkowice Mokre and especially at Witaszyn, where they include at the top some silts with a fossil flora investigated by Professor A. Srodoń and Dr. M. Gołębowa (in: Ciuk & Röhle 1952), demonstrates that there was a cooling or even an icesheet advance north-west of Warsaw (Różycki 1972, Röhle 1973) during the older (bipartite) pre-maximum stadial of the Odranian Glaciation for which the name *Liwiec Stadial* is here proposed (Text-fig. 5). This cooling is represented by the accumulation of sub-till sands dated with use of thermoluminescence method for 352,000 BP in the section at Wąchock on Kamienna river (Lindner & Prószyński 1979).

The earliest part of the Odranian Glaciation may be a time-lithological equivalent of the upper part of the strata designated as the "Likhvin 2 = Lb<sub>2</sub>" (453,000 ± 52,000 to 349,000 ± 45,000 BP) in the interglacial type section at Cherkalin on Oka (Sudakova & Aleshinskaya 1974, Dreimanis & al. 1978, Zubakov 1978), as well as of the strata representative of the *Fuhne-Kaltzeit* in the section at Pritzwalk, East Germany (Cepek 1967; Cepek & al. 1975; Erd 1973, 1978).



The organogenic deposits of Zbójno and the underlying alluvial sands are then to be regarded as representing a later and more distinct warming, supposedly of interstadial rank (Zbójno Interstadial). This warming is represented at Witaszyn by an erosion cutting a dozen meters thick silty set, and accentuated by the sands separating the beds 5 and 7 in that section (Różycki 1972). Those sands are overlain by the till of the younger pre-maximum stadial of the Odranian Glaciation, the Krzna Stadial (Text-fig. 5), the position of which is well established owing to the palynological localities of Podgórze, Romanów, and Podlesie by Wyśmierzyce (Jurkiewiczowa & al. 1973).

Outside Poland, the organogenic deposits from Zbójno may be a time equivalent to the strata designated as the "Likhvin 3 = Lh<sub>3</sub>" (336,000 ± ±41,000 to 318,000 ± 33,000 BP) in the section at Chekalin (Sudakova & Akshinskaya 1974, Dreimanis & al. 1978, Zubakov 1978), and to the sediments of the *Dömnitz-Warmzeit* of Pritzwalk (Cepek & al. 1975; Erd 1973, 1978).

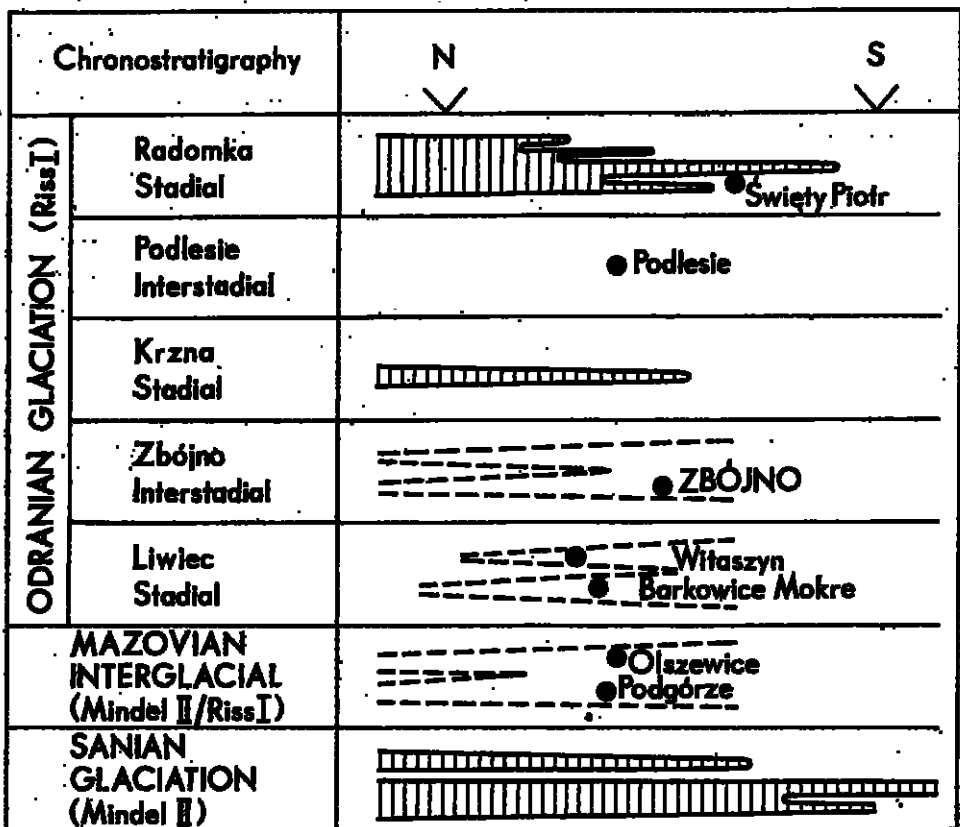


Fig. 5. Chronostratigraphic position of the locality Zbójno relative to other organogenic deposits of the western slopes of the Holy Cross Mts and the extent of tills (hachured)

The Mazovian Interglacial *s.s.* (Text-fig. 5) should then be represented by the erosion at the climatic optimum and the first to second erosion-accumulation cycles (Różycki 1964) along with the post-optimum organogenic deposits, *s.g.* those found at Olszewice (Sobolewska 1956). The organogenic deposits from Podgórze by Wyśmierzyce (Jurkiewiczowa & *al.* 1973) and the floristic-equivalent deposits from Ferdynandów (Janczyk-Kopłkova 1975) are to be attributed to the optimum of the interglacial. This interglacial part of the widely meant interglacial period is then equivalent to the "Likhvin 1 = Lh<sub>1</sub>" (459,000 ± 56,000 BP) of Chekalin (Sudakova & Aleshinskaya 1974, Dreimanis & *al.* 1978, Zubakov 1978) and the Holstein-Warmzeit of Pritzwalk (Cepek 1967; Cepek 1967; Cepek & *al.* 1975; Erd 1973, 1978).

The palynological affinity of the organogenic deposits of Zbójno and Marantów suggests that they are older than it has been accepted by Borówko-Dłużakowa (1979). This is indeed consistent with the opinion of Cepek (1972), Toboński (1979), and others. The Marantów deposits are to be attributed to the Zbójno Interstadial in the anaglacial part of the Odranian Glaciation (Text-fig. 5). This conclusion is also corroborated by the recent dating of the till of Konin area with use of thermoluminescence method (286,000—275,000 BP; W. Stańska-Prószyńska & M. Prószyński, *personal communication*).

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#### OSADY ORGANOGENICZNE W ZBÓJNIE KOŁO PRZEDBORZA I ICH ZNACZENIE DLA STRATYGRAFII PLEJSTOCENU POLSKI

##### (Streszczenie)

Przedmiotem pracy jest analiza osadów organogenicznych napotkanych w Zbójnie koło Przedborza (fig. 1—2) pod gliną zwałową zlodowacenia Odry (fig. 3). Z analizy palinologicznej (fig. 4) wynika, że osady te reprezentują pełny cykl klimatyczny z wyraźnym optimum oraz dwiema fazami chłodnymi, zaznaczonymi na początku i na końcu profilu. Odtworzony obraz sukcesji roślinnej wykazuje daleko idące analogie z profilem Marantowa koło Konina zaliczanym dotychczas do interstadialu Brerup. Osady organogeniczne ze Zbójna reprezentują zapewne okres interstadialny (interstadial Zbójna) oddzielający w obrębie anaglacjalnej części zlodowacenia Odry (fig. 5) przedmaksymalny stadial Krzy od poprzedzającego go ochłodzenia (tj. stadialu Liwca), zaznaczonego akumulacją trzeciego i czwartego cyklu osadów rzecznych w obrębie dolin z optimum interglacjalu mazowieckiego.