

## The radiocarbon age of marine and land deposits in the southern Baltic area

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**Abstract:** Basing on statistical analysis of ca. 150 radiocarbon dates of sediments from different environments an attempt to reconstruct the time framework of main environmental changes during the late Pleistocene and Holocene in the Southern Baltic area was made. The main results are as follow:

- 45 000–22 000 years BP – period of interpleniglacial (Grudziądz Interstadial),
- 22 000–14 500 years BP – period of the last glaciation (lack of dates for this period or uncorrected dates),
- 14 500–8800 years BP – beginning of the last deglaciation and development of the southern Baltic area in land conditions,
- 8800–5000 years BP – period of Mezhohocene (Littorina, Atlantic) transgression of the Southern Baltic with major changes of coastline,
- since ca. 5000 years BP – present shape of the southern Baltic with minor changes of coastline.

**Key words:** radiocarbon dates, Pleistocene, Holocene, Polish coastal zone, Southern Baltic.

### Introduction

The Branch of Marine Geology of the Polish Geological Institute carries out geologic and palaeogeographical investigations of the Polish coast and Southern Baltic since 1968. The Polish Exclusive Economical Zone is a belonging to Poland 30,533 km<sup>2</sup> area of the Southern Baltic. These include a number of basins such as Bornholm Basin (max. depth 95 m), Słupsk Furrow (max. depth 93 m), Gotland Basin (max. depth 120 m) and Gdańsk Basin (max. depth 107 m). The maximum depth given, of course, refer to parts of the basins

occurring within the Polish EEZ. The basins are separated by narrow thresholds with minimum depth of about 60–85 m. In the south, there are shoals between the basins and the coast. These include the Odra Bank, Słupsk Bank and Stilo Bank. Southern Middle Bank occurs to the north of the Słupsk Furrow.

A determination of the chronology of events in this area became possible when absolute age dating of deposits using the  $^{14}\text{C}$  method was introduced in a wide scale. All the available dates were collected in a radiocarbon data bank at the Branch of Marine Geology of the PGI. The most important information stored in this data bank includes: location (geographic co-ordinates, kilometre of coastline according to the kilometre grid of the Maritime Offices, terrain height, water depth, ordinate of sample), BP date, laboratory number of the date, name and symbol of sample, type of dated deposit, bibliography concerning the date.

At present the data bank contains 500 dates from about 250 sites, in that about 150 dates is from the sea bottom and from the coastal lagoons and lakes. Basing on these lasts, an attempt to reconstruct the time framework of environmental changes in the area of the present southern Baltic during the late Pleistocene and Holocene was made. The data set was sufficiently large to allow statistical analysis.

## Material and methods

Basic for the present work were the radiocarbon dates of 150 samples from the Polish coastal zone and Polish Exclusive Economical Zone stored in the radiocarbon data base in Branch of Marine Geology of Polish Geological Institute (Tomczak *et al.* 1998). By far the largest part of the collected dates comes from published sources, only a small part is taken from unpublished archival reports of the PGI Branch of Marine Geology, included into the bank after obtaining permission of the authors. Most of the radiocarbon dates was obtained during investigations carried out by the Branch, significantly intensified in the middle of the 80ties. At that time, deposits from the relatively less known stretches of the coast were dated (Tomczak *et al.* 1989, 1990, 1993; Tomczak 1990a, b, 1992, 1993, 1994, 1995a, b, c), and also – for the first time in the Polish part of the Baltic – deposits forming the sea bottom (Jurowska & Kramarska 1990; Kramarska & Jurowska 1991; Zachowicz & Uściniowicz 1991a, b). The rest of the dates come from publications of authors from other research institutions. It should be mentioned that only these results were used which fulfilled the requirements of the radiocarbon dates bank.

From the sea bottom, material for radiocarbon dating was collected during cartographic works on research vessels, carried out for the needs of the 1:200,000 Geologic Map of Baltic Sea Bottom, and during other investigations. A total of 118 dates from 52 sites was obtained, and the sites were located in the following regions of Southern Baltic: Pomeranian Bay (Jurowska & Kramarska 1990; Kra-

marska & Jurowska 1991), Odra Bank (Kramarska 1993, 1994, 1998), Bornholm Basin (Uścińowicz & Zachowicz 1992, 1993a), Słupsk Bank (Uścińowicz & Zachowicz 1991a, 1991b, 1994b), Gulf of Gdańsk (Uścińowicz & Zachowicz 1993b-d, 1994a), Puck Lagoon (Kramarska *et al.* 1993, 1994, 1995), Vistula Lagoon (Zachowicz & Uścińowicz 1997), the nearshore coastal zone along the stretches Dziwnów–Chłopy and Łeba–Gdynia, including the foreshore of the Hel Peninsula (Geodynamic Map... 1997).

About 30 dates were taken from works published by other authors (e.g. Rotnicki & Borówka 1994a, b, 1995a, b; Wojciechowski 1990, 1995; Zachowicz & Kępińska 1987; Zachowicz *et al.* 1982). The whole set of dates concerning the present bottom of the sea and of coastal lagoons and lakes (defined as lagoons), was statistically analysed, using probability density distributions for various groups of deposits. The set of dates was divided in accordance with a lithologic/genetic criterion (using results of micro- and macrofauna analysis and diatom analysis) into the following subsets:

- fresh water fine grained sediments with various organic matter,
- peat and gyttja,
- marine and lagoon mud with organic matter.

### **Radiocarbon age of deposits from various palaeogeographic environments from the Southern Baltic area**

In the analysed set of dates the span of ages is 45,000 years, which agrees with the range of the method. The presence of older formations is indicated by infinite dates, which are ignored in the statistical analysis. During the 45,000 years, in the area were deposited sediments generated in varying in time and space sedimentation environments. Samples taken from the present sea area represent both marine formations and relics of earlier existing land environments. Radiocarbon dates of these genetically varying deposits determine, with various probability, the time frames of their forming. In connection with the results of other methods of investigation, such as lithostratigraphic, geochemical and especially biostratigraphic (palynological, diatom and macro- and microfauna) analyses it is also allow to trace the history of evolution of the area.

### **Fresh water fine grained sediments with various organic matter**

Fine deposits, i.e. clay, mud and muddy sand with various organic matter, form a not quite uniform group, therefore interpretation of radiocarbon dating requires much caution. This is because the dated organic substance can be

of varying type and age. It may originate from primary production in a sedimentation basin, and then it reflects the real time of deposition. On the other hand, it also may appear in a secondary layer. It may be supplied to the sedimentation basin by surface flow or river transport, or it may come from destroyed older formations. Organic matter from these sources occurs in the deposits quite often, and in varying and different to determine proportions. In such a case the obtained radiocarbon date does not reflect the time of deposition of the sediment, most often it is older. It should be interpreted taking into account the full range of geological information and, if possible, should be verified using relative chronology methods.

For this type of sediments, 39 dates were obtained. Though this set is rather small, three groups of dates can be distinguished, at a small number of dates older than 11,500 years BP. The oldest dates, fitting into the range 37,000–28,000 years BP (not shown on Fig. 1), correspond with the interpleniglacial (Grudziądz Interstadial). These deposits were found in the region of the Odra Bank (Kramarska 1994, 1998), in the Puck Lagoon (Kramarska *et al.* 1995), and in the coastal zone in the coastal regions of the Puck Lagoon (Geodynamic Map... 1997).

A similarly small set of dates falls into the 20,000–14,500 BP interval (also not shown on Fig. 1), which corresponds with the period when the discussed area was covered the ice sheet. From this results an evident discrepancy between the radiocarbon age and the certainly later time of deposition of the sediments. Therefore, most probably, in the dated sample, besides the organic matter formed synchronously with the sediment, there is also an addition of older, redeposited matter. In this situation it must be concluded that the deposit is certainly younger, and that contained in the sample dated organic matter is older than the time of deposition of the sediment.

The largest set of data (26 dates) covers the period younger than 14,500 BP, culminating in the Boreal and Atlantic period. This is connected with the higher production of organic matter, resulting from improved climatic conditions. The lack of dates younger than 5,000 BP is due to the fact that the Southern Baltic area was completely covered by the sea, and that the coastal zone was in about the same position as it is today.

## Peat and gyttja

Peat and gyttja are the most often dated deposits. The dated organic matter is of authogenic character, therefore the samples nearly exclusively represent *in situ* deposits. It results that radiocarbon dates of peat and gyttja are especially geologically credible and useful for palaeogeographic reconstructions. In the area of the present sea, 80 dates of this type of sediments were obtained.

Only one date of peat (not shown on Fig. 1), as also similar dates of fine

sediments with dispersed organic matter described above, documents sedimentation during the Grudziądz Interstadial (Kramarska 1998). The lack of peat, dating from the period 22,000–14,500 BP, indicates the time when the area was under the influence of the last glaciation.

Accumulation of younger gyttja and peat began with the deglaciation of the area at about 14,500 BP. The oldest date of peat (besides the above mentioned one) is  $14,060 \pm 220$  BP (Gd-2928) (Kramarska & Jurowska 1991; Kramarska 1998). The visible periods of more intense accumulation of peat, beginning at the break of the Pleistocene and Holocene and ending at the Atlantic optimum, document changes in climatic conditions. In the sea area, peat formation ended at about 5,000 BP, i.e. when, due to the Atlantic transgression, the sea level reached about its position. The youngest date of peat located below the present day sea level was sampled of the beach of the Puck Lagoon near Rzucewo, and it is  $5,520 \pm 70$  BP (Gd-7698) (Geodynamic Map... 1997).

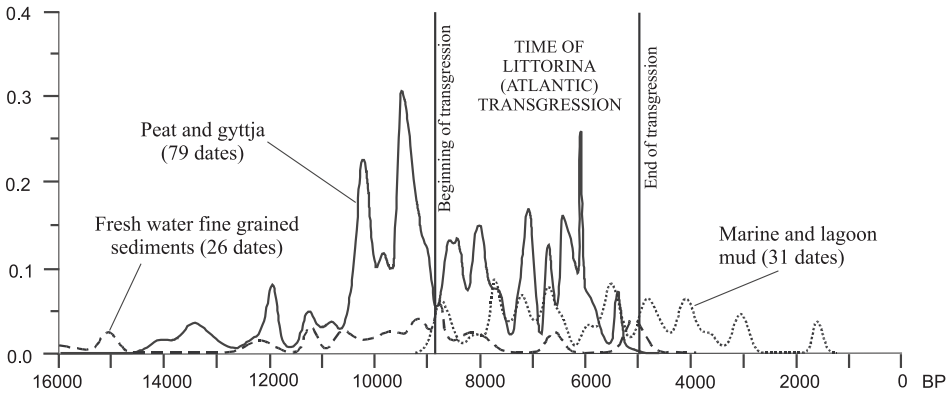
## Marine and lagoon mud with organic matter

This group consists of muddy sediments deposited in marine or brackish environment either in deep-water sedimentation basins or in shallow lagoons or coastal lakes connected directly with the sea and remaining under the influence of the sea. 31 dates of these deposits were collected. Remarks on the origins of the dispersed organic matter in muddy deposits and on the credibility of results, made with respect to the fine grained sediments from inland reservoirs and from rivers, are partly true also in the case of the presently discussed group of deposits, especially with respect to the environment of lagoons and coastal lakes. In case of marine sediments in deepwater sedimentation basins these reservations are less important, since organic matter in them comes mainly from primary production, while possible additions of older, redeposited organic matter become strongly diluted, and have no significant influence on the obtained radiocarbon dates.

The oldest dates of mud with brackish diatoms were found in the Bornholm Basin and Gdańsk Basin. They are  $8,800 \pm 150$ BP (Gd-6324) in the Bornholm Basin (Uściniowicz & Zachowicz 1992) and  $8,750 \pm 170$  BP (Gd-6313) in the Gdańsk Basin (Uściniowicz & Zachowicz 1993d, 1994). These dates mark the moment when the Baltic became connected with the North Sea and the beginning of the Atlantic (Littorina) transgression. Deposition of mud in the deep-water sedimentation basins and in the lagoons is still proceeding. There are no dates younger than 1,500 BP since they were not dated due to their obvious stratigraphic position.

## Conclusions

The results of statistical analysis of subsets of radiocarbon dates well reflect the main environmental changes in the Southern Baltic area during the Upper Pleistocene and Holocene (Fig. 1).



**Fig. 1.** Distribution of probability density functions of the radiocarbon dates subsets and time framework of the environmental changes during Late Glacial and Holocene in the Southern Baltic area.

The time framework of these changes is as follows:

- 45,000–22,000 years BP – period of interpleniglacial (Grudziądz Interstadial),
- 22,000–14,500 years BP – period of the last glaciation (lack of dates for this period or uncorrected dates),
- 14,500–8,800 years BP – beginning of the last deglaciation and development of the southern Baltic area in land conditions,
- 8,800–5,000 years BP – period of Mezoholocene (Littorina, Atlantic) transgression of the Baltic Sea with major changes of coastline,
- since ca. 5,000 years BP – present shape of the southern Baltic with minor changes of coastline.

Reliability and accuracy of time determination of these events depends on the type of dated sediments and their geological position. The best information about the age of sediment, and thus about the sedimentary environment is given by the dates of peat and also gyttja. Less reliable information about the age of deposits is derived from radiocarbon dated organic fine-grained sediments, specially from land environments. Organic matter occurring in the sediments can be older than the real age of final deposition of sediment. More reliable are dates of marine mud from deep water basins where organic matter is mainly from primary production. Radiocarbon dates for organic fine-grained sediments should be supported by palynological and sedimentological analysis of the investigated sites.

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