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Bottom structure of selected basins in the Port of Gdynia

Budowa dna wybranych basenów Portu Gdynia

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Abstract: Bottom structure of the basins in the Port of Gdynia, Poland, was analysed based on the archival materials of the Department of Operational Oceanography of Marine Institute in Gdańsk, particularly seismic profiles and macroscopic descriptions of sediment cores. Seismic profiling and core collection were performed in selected basins and within the fairway. The rich source material was used to draw a detailed bathymetric map of the bottom of the basins, a map of surface sediments, and a synthetic geological cross-section. A considerable variation in bottom depth within the analysed basins was observed. Bedrock sediments comprised Miocene sands and silts covered with glacial and fluvioglacial sediments, which reach the surface of the water, especially in the central part of the fairway. Within the eastern part of the fairway, fluvioglacial sediments are covered with marine sediments related to the Littorina transgression. Within the inner port and in the outport, a series of glacial and fluvioglacial sediments are covered with a thick (about 10 m) series of glaciolacustrine and lacustrine sediments, which in turn is covered with fluvial and deltaic sediments. The surface of the bottom is composed of contemporary, anthropogenically modified sediments. The map of surface sediments of the bottom corresponds to the geological map on the horizon of about 10 meters beneath land surface.

Keywords: SES profiling, vibrocorer, bottom sediments, Gulf of Gdańsk, Poland

Streszczenie: W ramach opracowania budowy dna basenów portowych Portu Gdynia wykorzystano materiały archiwalne Zakładu Oceanografii Operacyjnej Instytutu Morskiego w Gdańsku, tj. profile sejsmiczne oraz opisy makroskopowe rdzeni osadów. Profilowanie sejsmiczne oraz pobór rdzeni wykonano w wybranych basenach oraz w obrębie podejściowego toru wodnego. Bogaty materiał źródłowy posłużył do opracowania szczegółowej mapy batymetrycznej dna basenów, mapy osadów powierzchniowych oraz syntetycznego przekroju geologicznego. Stwierdzono znaczne zróżnicowanie głębokości dna w obrębie analizowanych akwenów. Osady podłoża to piaski i muły mioceńskie, na których zalegają osady lodowcowe oraz wodnolodowcowe wychodzące – zwłaszcza w centralnej części podejściowego toru wodnego – na powierzchnię. W obrębie wschodniej części toru wodnego na osadach wodnolodowcowych zalegają osady morskie związane z transgresją litorynową. Na obszarze portu wewnętrznego oraz w awanporcie seria osadów lodowcowych i wodnolodowcowych przykryta jest miąższą (około 10 m) serią osadów jeziorno-lodowcowych i jeziornych, na których zalegają osady o charakterze rzecznym i deltowym Powierzchnię dna budują osady współczesne, zmienione antropogenicznie. Mapa osadów powierzchniowych dna odpowiada mapie geologicznej na poziomie około -10 m.

Słowa kluczowe: profilowanie sejsmiczne SES, sonda wibracyjna, osady denne, Zatoka Gdańska, Polska

INTRODUCTION

The Port of Gdynia is located in the western part of the Gulf of Gdańsk (Puck Bay). Geomorphologically speaking (Augustowski 1965), the port lies in the end part of the southern Kashubian Ice-Marginal Valley in the Kashubian Strand, between the north-eastern part of the upland within the Kashubian Lake District and isolated morainic plateaus: Redłowo Morainic Plateau to the south and Oksywie Morainic Plateau to the north (Fig. 1).

Typically technogenic coastal sections are present within the port, with breakwaters and waterfronts. The fairway is about 1.5 km long and 300 m wide (*acc. to* Uścinowicz and Zachowicz

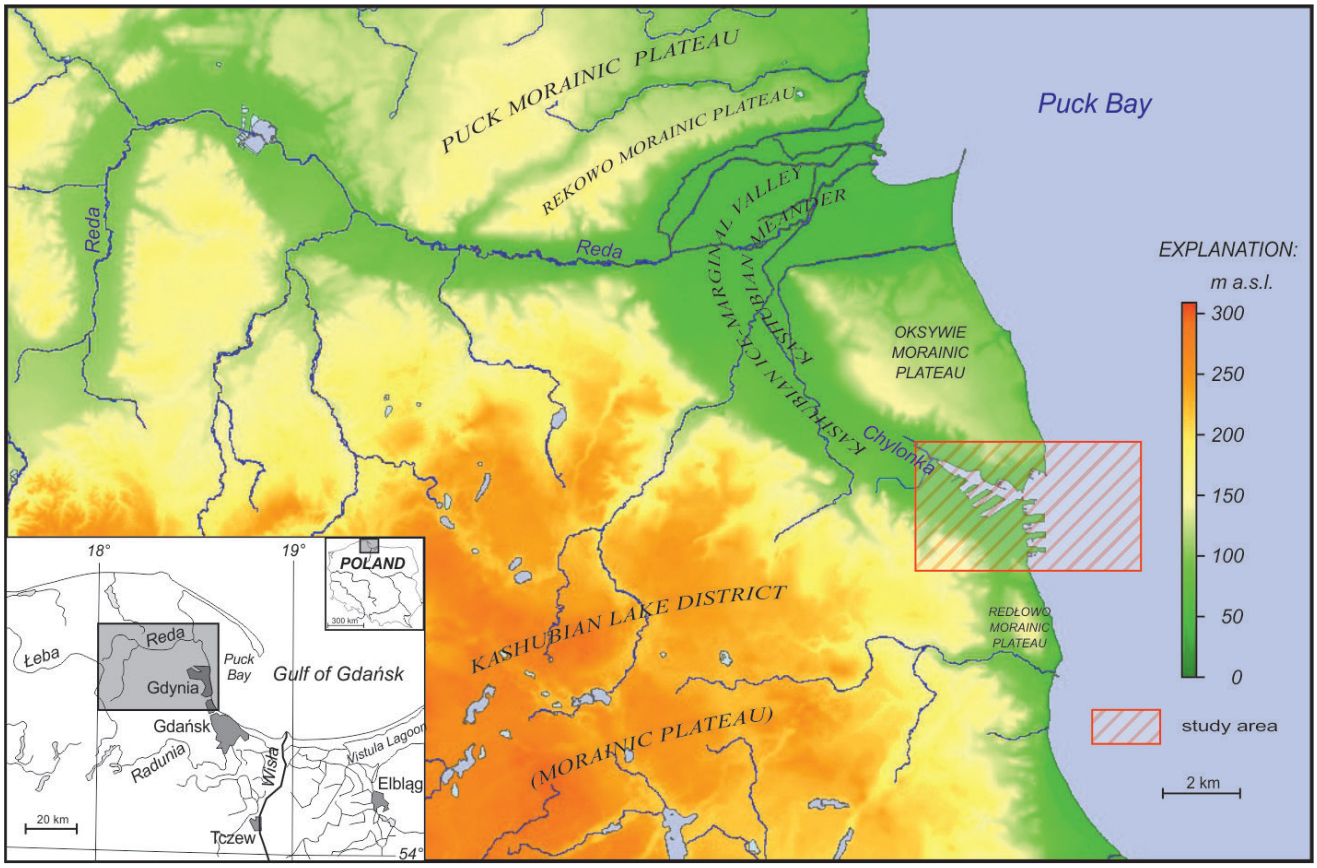

Fig. 1. Location of the research area (acc. to: http://ocean.ug.edu.pl/~oceju/CentrumGIS/dane.html)

1994). The width at the bottom is 150 m (http://www.umgdy.gov.pl/?page_id=1446). The port was constructed between 1920 and 1935 (http://www.port.gdynia.pl/pl/port/historia-portu?showall=&start=1) by cutting off a fragment of the bay with breakwaters and deepening it, after which port basins were dug in the estuary part of the Chylonka Valley.

MATERIALS AND METHODS

The area of the Port of Gdynia was analysed based on the archival materials of the Department of Operational Oceanography of Marine Institute in Gdańsk consisting of 270 sediment cores up to 6 m thick along with their macroscopic descriptions and photographic documentation (Wróblewski 2014, 2015, Cichowska et al. 2015). Detailed data on bottom morphology was also gathered through seismic profiling of selected basins and within the fairway (Fig. 2). The profiling was performed by the Department of Operational Oceanography of Marine Institute in Gdańsk in 2014 and 2015. Sixty-one seismic profiles, about 21 km long in total, were prepared. All works were commissioned by the Executive Board of the Port of Gdynia as part of research on bottom sediments in basins designated as the construction site for the project "Deepen the Fairway and Inner Basins of the Port of Gdynia, Stages I–III" (Sapota et al. 2014, 2015). The seismic profiling of the selected areas was done using a subbottom parametric profiler, an Innomar Technologie GmbH SES-2000. An inertial positioning system ensured precise localisation (to an accuracy better than 0.5 m). The sediment cores were collected using a VKG-6 vibrocorer with an internal diameter of 102 mm. The cores collected from the port were up to 3 m long, and those collected from the fairway were up to 6 m long.

Selected data of some documentation (e.g. Janicka-Morawska 1973, Kamrowska 2006, Pruszkowska and Pruszkowski 1996, Pruszkowski and Pruszkowska 2000) were also helpful in geological interpretation of the seismic recordings.

BOTTOM MORPHOLOGY

The bottom of the following areas was analysed in detail: fairway, the main port canal, the outport, and five basins in the inner port, namely, Węglowy (III), Marszałka Piłsudskiego (IV), Ministra Kwiatkowskiego (V), Basins VIII and Basins IX (Fig. 2).

The rich source material was used to develop a detailed bathymetric map of the bottom of these basins, with an isobath interval of 0.5 m (Fig. 3), based on data on basin depth at the core collection sites and taking into account the bathymetric data from the SES profiles. The depth within the port and the fairway was found to vary considerably (even by several metres), probably

Fig. 2. Documentation map of the research area

Fig. 3. Bathymetric map of selected port basins and the fairway

due to the multiple bottom-deepening works that have been conducted so far. The bottom of the main port canal has been deepened to 13-14 m b.s.l. Basins IV and V are 11-12 m b.s.l. Basin X is the shallowest, its depth reaching no higher than 10 m b.s.l., even in the central part of the basin. The bottom of the basins display the characteristics of a varied and irregular anthropogenic morphology. The depth within the fairway is maintained at 14-15 m b.s.l., reaching more than 19 m b.s.l. in the eastern part. The entire fairway has been deepened by about 2 m beneath bottom level compared to the surrounding abrasion and accumulation plain (Uścinowicz and Zachowicz 1994).

The inclination of the bottom of the basins and the fairway is generally consistent with the inclination of the sea bottom towards east. It should be emphasized that the waterfronts cause significant changes to the depth in their vicinities (Fig. 3), due to the dump of anthropogenic sediments. This is especially apparent in the part of the bottom beyond the entryway to the inner port and in the central part of the port canal. Because the depth is considerably lower near the waterfronts, those parts of the bottom that had an insufficient number of interpolation points, which would have caused an excessive error in interpolation, were excluded from the analysis (Fig. 3).

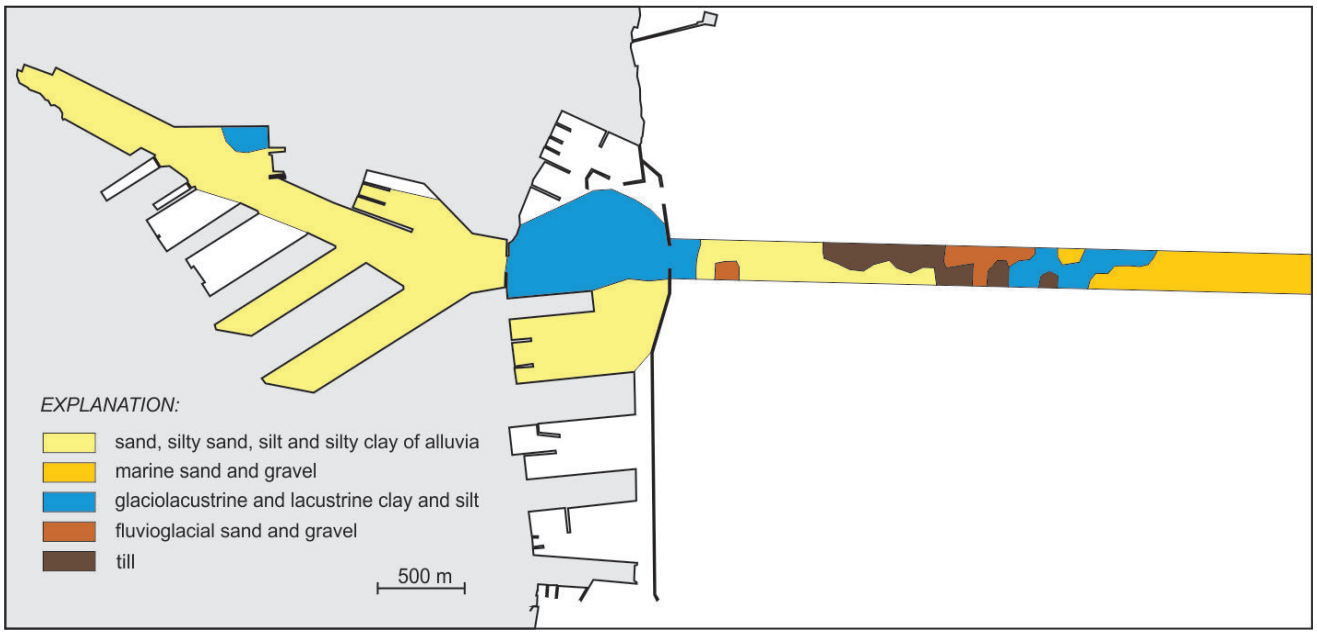

Fig. 4. Map of surface sediments in the bottom of selected port basins and the fairway

SURFACE SEDIMENTS OF THE BASINS' BOTTOM

Surface sediments in the analysed port basins show only slight variation. The dominant sediments (excluding anthropogenic ones in the top layers) are alluvial fine sands, silty sands, silts, silty clays, and glaciolacustrine and glacial mud (Fig. 4). The glaciolacustrine and glacial sediments cover the bottom of the outport and part of the bottom of Basin VIII. The remaining part of the bottom is composed of alluvial sediments (Fig. 4). Sediments within the fairway show much greater variation. In the western part of the fairway, surface sediments are also alluvial. Towards the open Gulf of Gdańsk, the dominant sediments are glacial and fluvioglacial (tills and fluvioglacial sands, gravels, and sandy gravels). The eastern part, at the end of the fairway, has typically marine sediments (marine sands and gravels). Notably, the central part of the fairway contains glaciolacustrine and lacustrine sediments that cover glacial and fluvioglacial diamictons and are themselves partially covered with marine sediments from the east (Fig. 4, 6).

The distribution of each type of sediment within the inner port and the outport does not correlate with the bottom depth in these areas. The south-eastern part of the main canal, which is fairly varied in terms of depth (4-6 m), and Basins IV and V are covered with the same type of alluvial sediment (Fig. 4). Surface sediments show a considerable variation only within the fairway, as has been mentioned. However, their distribution does not correlate with depth, except slightly along the general inclination of the bottom: marine sediments occupy the deepest, eastern part of the bottom.

Surface sediments within many areas, especially in the vicinities of the waterfronts – e.g., along the Polish and Finnish Waterfront in Basin IV (Galer-Tatarowicz et al 2014) – were found to have a large share of pollutants, such as slime containing crude oil derivatives, including those with a high concentration of petroleum hydrocarbons.

BOTTOM STRUCTURE

Seismic units with different types of reflections pattern were distinguished. The seismic units were subsequently interpreted in geological terms (Fig. 5) with respect to core data and knowledge about the research area.

The oldest identified sediments are Miocene sands and silts covered with glacial and fluvioglacial sediments (tills, sandy diamictons, sands and gravels). Till sediments, with outcrops in the central part of the fairway (Fig. 6), have a considerable thickness, exceeding 10 m. Fluvioglacial sediments within the inner port and the outport are covered with glaciolacustrine and lacustrine clays, silts, and fine sands, which are in turn covered with lacustrine and deltaic sediments (sands and silty sands). Within the fairway, fluvioglacial sediments are covered with marine sands and gravels related to the Littorina transgression. These marine sediments are separated by a clear, sharp erosive surface that cuts off the older, lower sediments. Such transgressive marine sands do not occur in the port basins. The surface of the bottom is composed of contemporary, anthropogenically modified sediments, i.e., alluvial sands, slime and, in some areas, dump sediments. All of these form a thin cover with thicknesses ranging from 0.5 m to over 1.0 m (Fig. 6).

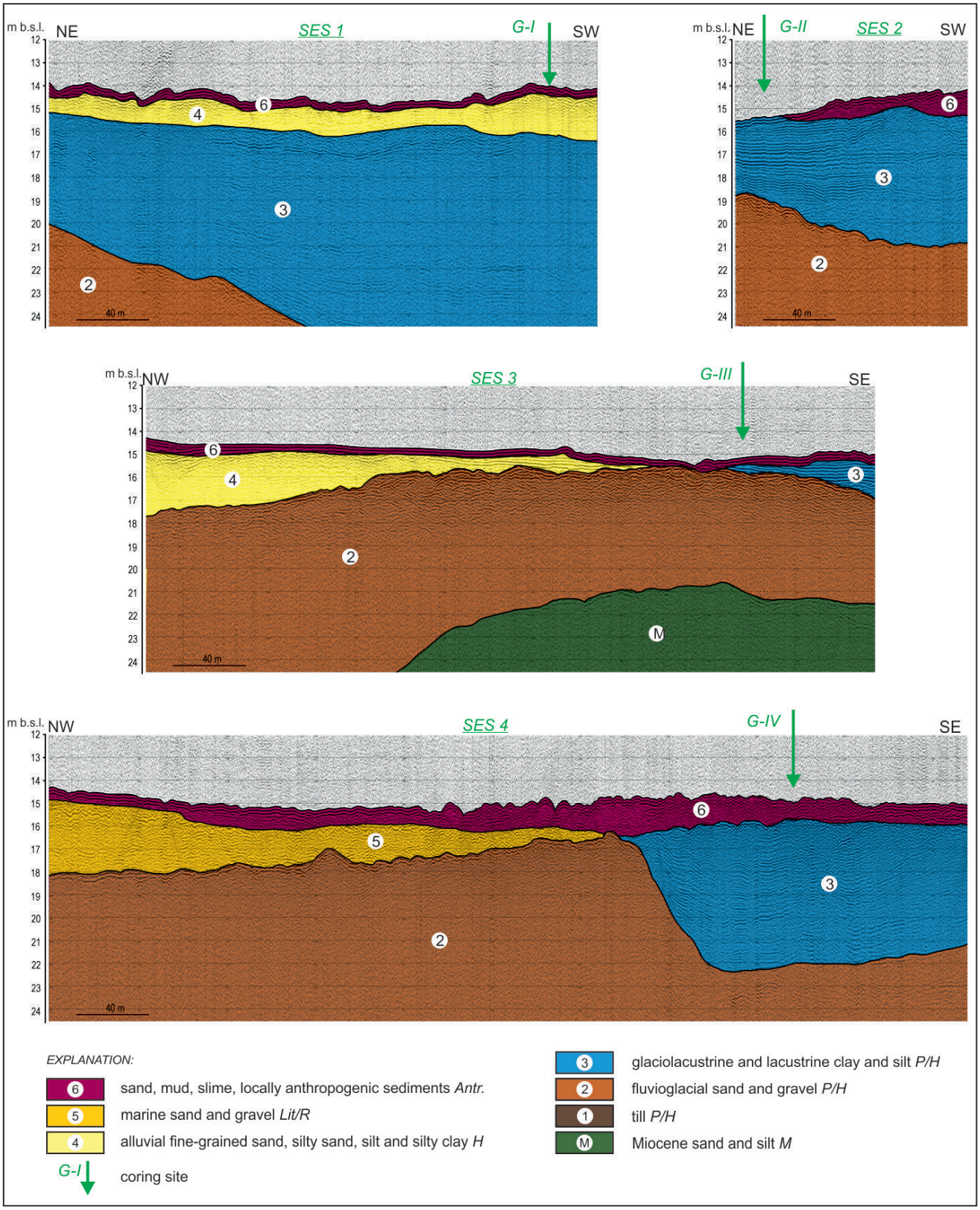

Fig. 5. Selected geological cross-sections

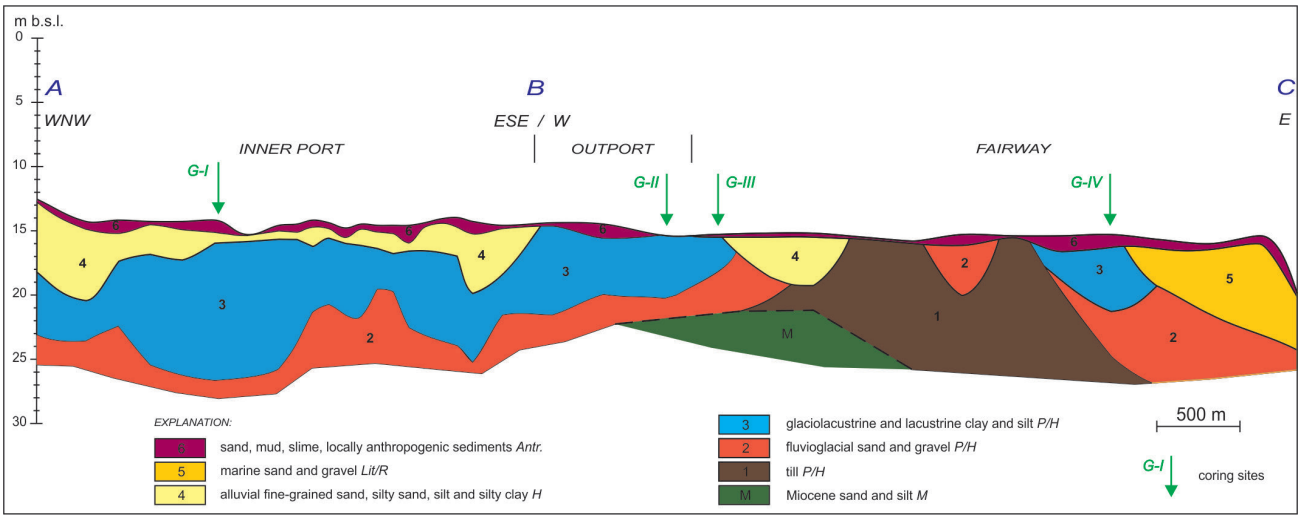

Fig. 6. Geological cross-section within the port basins and the fairway along the ABC line

SUMMARY AND CONCLUSIONS

The results of this study constitute a valuable complement to the knowledge of geological structure of the Port of Gdynia region (down to a depth of about 25-30 metres below bottom level) and concerns the southern part of the so called Kashubian Meander with relation to the morphology of the nearshore bottom within the waterfronts (the fairway area). A uniform draft of bottom structure that provides information of both the bottom and the land is presented. So far, such information has been presented separately: for the sea bottom (on the 1:200 000 Geological Map of the Baltic Sea Bottom, Uścinowicz and Zachowicz 1992) and for the land surface (on the 1:50 000 Detailed Geological Map of Poland, Mojski 1979a, b).

The results (Fig. 4, 6) constitutes an attempt at determining the bedrock structure of the bottom within the port region. The map corresponds to the geological map at the level of about 10 m b.s.l., which is over 10 m deep in relation to the surface of the land. The geological structure of nearly the entire bottom of the port (excluding the fairway) is dominated by sediments that are related to gravitational suspension sedimentation (glaciolacustrine), up to 10 m thick (Fig. 6). These sediments lie directly on the fluvioglacial sediments, which clearly indicates that a body of water was located at the glacier during the most recent deglaciation (*sensu* Marks 2012). The importance of this body of water (its size and range) for the course of deglaciation and the directional discharge of meltwater is a different issue (Marsz 1967, 1994, Sylwestrzak 1973, 1978, Rachocki 1992). In the western part of the research area (Fig. 6), the roof of the glaciolacustrine and lacustrine sediments is indistinct and covered with younger ones, which are interpreted as alluvial sediments. These alluvial sediments have the characteristics of both fluvial ones, related to the flow of water, and deltaic ones. An attempt at determining the character and age (Littorina or post-Littorina?) of these sediments (marginal and alluvial) is very advisable. This could be achieved by performing deep, geologically accurate drilling in the bottom of the valley (the southern part of the Kashubian Meander) that would drill through the postglacial sediments, which reach the depth of about 30 metres below the level of the terrain (*cf.* Mojski 1979b).

The drilling would have to be deep in order to clarify the doubts concerning the bottom sediments (Miocene sands and silts?). A series of sediments that show characteristics similar to Miocene sediments (reflections pattern, which indicates hard, packed sediments) has only been observed in the western part of the fairway (near the main entryway to the port). In the remaining areas, the Miocene layer is weakly marked, with a fairly uneven roof (*cf.* Mojski 1979b).

The obtained results are of significant importance to any future analyses, not only those conducted as part of works related to the operation of the port, but also those concerning the geological structure, morphological development, and current state of the area between two isolated morainic plateaus: Redłowo Morainic Plateau and Oksywie Morainic Plateau, especially in terms of determining the water discharge system during the most recent glaciation (Marsz 1967, 1994, Sylwestrzak 1973, 1978, Rachocki 1992, Jurys 2000, 2002).

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