INTEGRATED GEODATABASE FOR THE COASTAL ZONE BETWEEN SOZOPOL AND TSAREVO (SOUTH BULGARIAN BLACK SEA COAST)

Bogdan Prodanov[1], Lyubomir Dimitrov[1], Valentina Doncheva[1], Todor Lambev[1]

[1]Institute of Oceanology "Fridtjof Nansen", Bulgarian Academy of Sciences, 9000 Varna, bprodanov@io-bas.bg

ABSTRACT. For a complex study and interpretation of the geological conditions in the southern Bulgarian coastal zone between towns of Sozopol and Tsarevo, it was necessary to combine a wide spectrum of data. The creation of an integrated GIS database was the initial stage preceding a complex analysis of the coastal zone. For the purpose seabed data was used, collected by innovative remote sensing methods as multi-beam echo-sounding, mapping by SeaBat 7111 Multibeam Echosounder System (MBES) with 100% coverage of the surveyed area, side-scan imaging, LiDAR and autonomous unmanned system for 3D mapping. Primary sedimentological analyses of 625 sedimentary samples were presented as well as the lithology of the bottom sediments which was brought into a unified classification system (Folk 7 classes). A contemporary shoreline was digitized at a scale 1: 5 000 from airborne orthophoto images with accuracy 0.5 m. Digital models of the seabed and terrestrial relief were generated with an optimal horizontal resolution of 3 m and 30 m respectively. All sedimentary samples, sonar mosaics, terrain models and orthophoto mosaics were analyzed in GIS environment and combined into an integrated database. The information was divided into three main types of data: vector type data, raster elements and digital terrain models (DTM). Combining data of the shelf from contemporary surveys with modern technology and archival material from the Science Fund of the Institute of Oceanology "Fridtjof Nansen" into integral geodatabase allowed us to make a comprehensive study of the geomorphological setting and lithology of the seabed in the coastal zone between towns of Sozopol and Tsarevo.

Keywords: Bulgarian Black Sea, coastal zone, seabed substrate, Multibeam Echosounder System, GIS

ИНТЕГРАЛНА ГЕО-БАЗА ДАННИ ЗА БРЕГОВАТА ЗОНА МЕЖДУ СОЗОПОЛ И ЦАРЕВО (ЮЖНО БЪЛГАРСКО ЧЕРНОМОРИЕ)

Богдан Проданов, Любомир Димитров, Валентина Дончева, Тодор Ламбев

Институт по океанология "Фритьоф Нансен", Българска академия на науките, 9000 Варна, bprodanov@io-bas.bg

РЕЗЮМЕ. За комплексното изучаване и интерпретация на геолого-геоморфоложките условия в брегова зона в южнобългарската брегова зона между гр.Созопол и гр.Царево е нужно комбинирането на широк спектър от данни. Създаването на интегрална ГИС-база данни бе първоначалният етап, предшестващ комплексния анализ на брегова зона. Използвани са данни за морското дъно от иновативни дистанционни методи на изследване: картиране с многолъчева сонарна система (МСС) Seabat'7111 с 100% покритие, заснемане с локатор за страничен обзор, LiDAR и автономна безпилотна система за 3D картиране, както и данни от еднолъчево ехолотиране. За 625 седиментни станции, са представени първичните седиментоложки анализи, както и литоложкото описание на дънните седименти, която е приведена в единна класификационна система по Фолк 7класа. Дигитализирана е съвременна водна линия в М 1:5 000 от ортофото изображения с точност 0,5 m. Генерирани са цифрови модели на релефа за морското дъно и сушата с оптимална хоризонтална резолюция от 3 m и 30m съответно. Всички седиментни проби, сонарни мозайки, теренни модели и ортофото мозайки са анализирани в ГИС среда и са обединени в интегрална база данни. Информацията е поделена на три основни типа данни: векторни, растерни и теренни модели. Съчетаването на данни за шелфа от съвременни изследвания с модерни технологии и фактически материали от научния фонд на Института по океанология „Фритьоф Нансен" в интегрална гео-база данни ни позволи детайлно изследване на дънния седимент и геоморфоложките условия в бреговата зона между гр.Созопол и гр. Царево.

Ключови думи: Българско Черноморие, брегова зона, субстрат, многолъчева сонарна система, географска информационни системи

Introduction

The European Habitats Directive, Water Framework Directive and Marine Strategy Framework Directive require complex mapping of the terrestrial and marine areas of each European country. In order to facilitate the integrated management of marine environment and to optimize maritime spatial planning it is necessary to improve our knowledge of the seabed. A major drawback is the lack of systematic survey and comprehensive study of the Bulgarian Black Sea sector of the Black Sea. The unprecedented levels of human impact on the environment, in particular on the seabed, should automatically raise geological and geomorphologic mapping to a task of national importance. To study the modern geological processes and genetic interpretation of the basic geomorphological units, spatial distribution of benthic flora and fauna, as well as planning and management of biological and mineral resources and different types of seabed engineering activities, it is necessary to apply innovative research methods with the possibility for a large-scale presentation of available information.

The relief forms in the coastal zone often exhibit highly dynamic character as a result of the surrounding environment and natural processes. The impact of waves, tides, river inflow, sea level rise, climate and coastal geology shape their different morphology and spatial distribution. The specific character of the transition between the land and marine environment supposes a complex analysis of the land processes affecting the marine area. The integration of a large amount of different types of data from a multi- and single-beam sonar system, side scan sonar, orthophoto imaging and sampling from the surface

sediment layer allow the creation of an interdisciplinary geo-database. Its development is the initial step in the implementation of the project "Seabed mapping of the southern Bulgarian Black Sea coastal zone for habitat classification", funded by the Bulgarian Academy of Sciences (BAS) within the frame of a Program for Supporting the Young Scientists at BAS, Project № 17-103/28.07.2017. As the project is not completed, the report will focus on the initial layout of the available data and start-up results.

Survey Area

The survey area embraces the coastal zone between the ports of Sozopol and Tsarevo. Geographically, the region is a part of the southern Bulgarian Black Sea coast, whereas in geomorphological terms the region falls entirely in front of the Medni Rid-Strandzha coast (Попов, Мишев, 1984). The western boundary is the contemporary shoreline with a length of approximately 90 km. For the correctness of the study, a terrestrial part which has a significant impact on the coastal zone is also analysed. More specific is a determination of the coastal zone – open sea boundary. Based on the title, we accepted provisionally the 25-meter isobath for delimitation. According to the Water Framework Directive, the surveyed marine area falls into the water bodies of BG2BS000C011 and BG2BS000C012 with wave exposure of the coast ranging from Exposed, Very Exposed to Extremely Exposed (Valchev et al., 2014). The area of the plots is approximately 1000 km^2 (Fig.1).

Data and methods

In 2012 – 2018 the area between Sozopol and Tsarevo was studied predominantly by the Institute of Oceanology – BAS and the Centre of Underwater Archaeology – Ministry of Culture of the Republic of Bulgaria (CUA) for different purposes: engineering, archeological hydrographic, environmental monitoring of the bottom, habitat mapping, etc (Fig.1, 2) Data used in the present study are acquired during hydrographic surveys performed by Multibeam Sonar System „SeaBat7111“ , multibeam echosounder „MB1 Teledyne Odom Hydrographic“, Side Scan Sonars “StarFish 450H“ and „Klein-3000”, as well as single beam echosounder „Hydro Star 4300“, as well as sediment samples taken by Van Veen grab (Assessment Report of Marine Environmental Status, 2013; Todorova et al., 2015). A high-resolution sonar mosaic in a 16-Bit rusty colour scheme of the shallowest area south of the town of Kiten (provided by the CUA) was also used and combined with the other data (Fig.1, 3). For the verification and assigning a lithological substrate type to each area with similar backscatter characteristics, sediment samples taken by Van Veen grab were analysed (Fig.3).

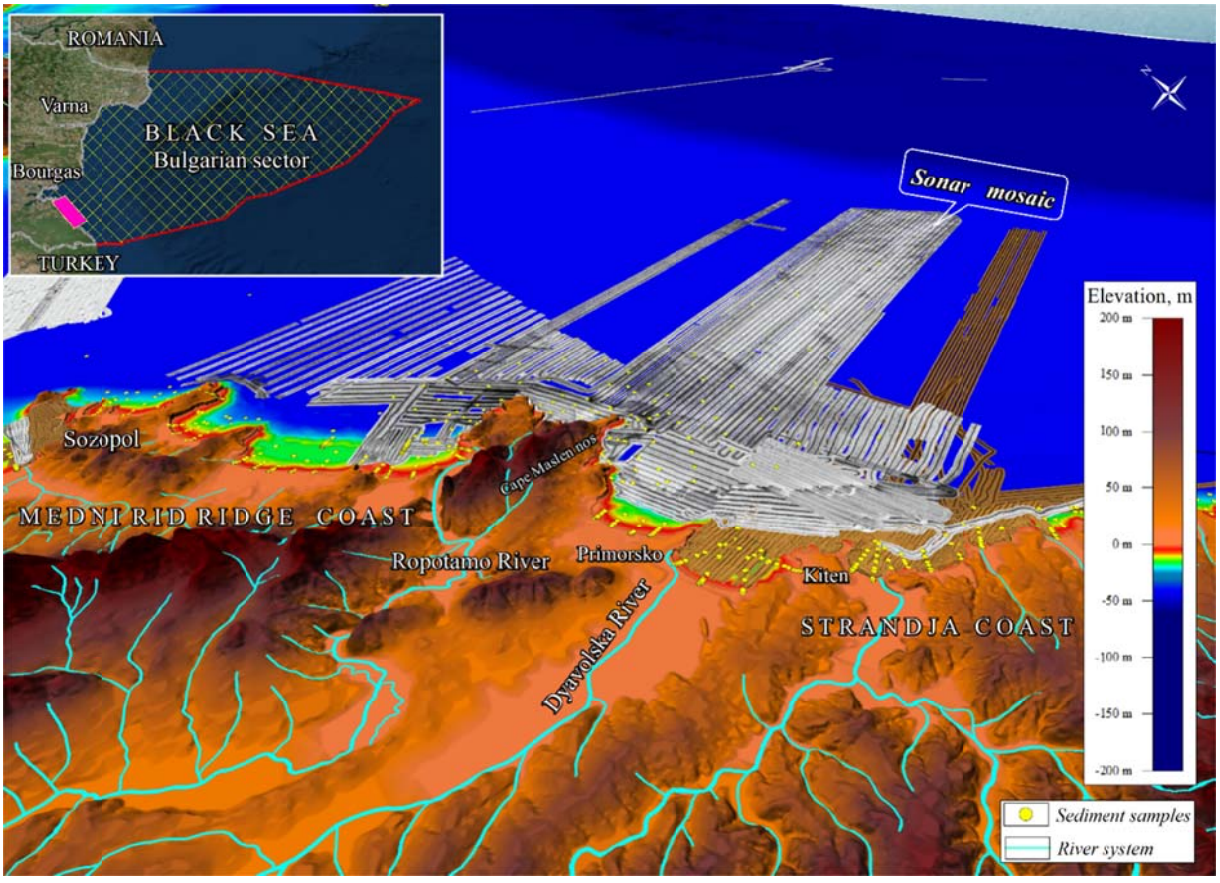

Fig. 1. 3D visualisation of the integrated geodatabase (DTM, sediment sampling and sonar mosaics) along Southern Bulgarian Black Sea coast

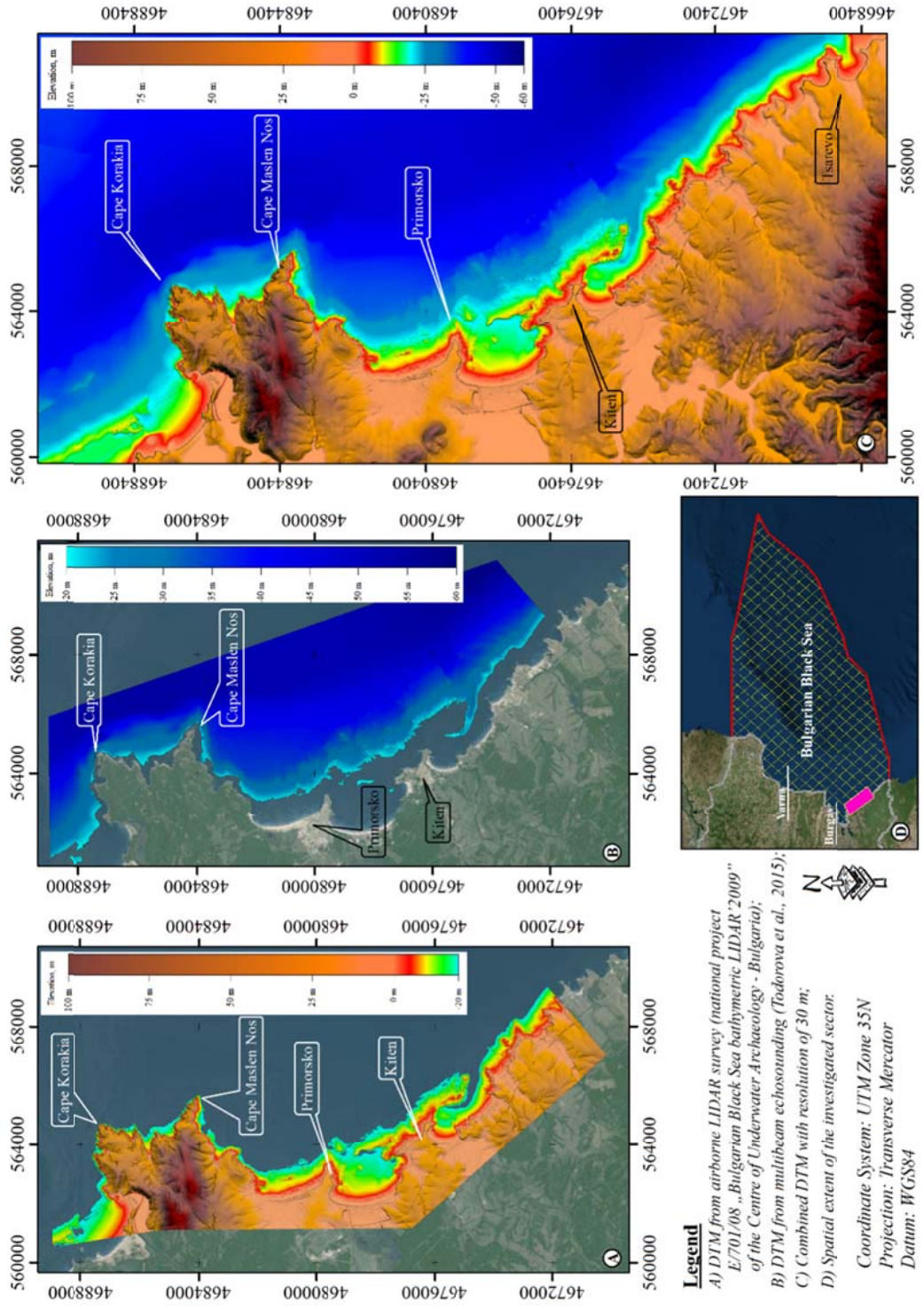

Fig. 2. Digital terrain models of the coastal zone

The integrated geodatabase is a set of data for the seabed of the southern Bulgarian coastal zone in front of the Medni Rid-Strandzha Coast. The data is divided into three basic types: raster, vector and digital terrain models (DTM).

The raster elements were selected with priority for marine research. They are a compilation of past studies done before the year 2000 and retrieved from the archives of the Institute of Oceanology and they include:

- sonar mosaics of the seabed with high resolution (Assessment Report of Marine Environmental Status, 2013; Todorova et al., 2015), some of them kindly provided by the Center for Underwater Archeology in Sozopol;
- 41 satellite images from Google Earth covering the land between ports of Sozopol and Tsarevo; high-resolution air

born orthophoto mosaics captured by an autonomous unmanned system (Scientific Fund of the Institute of Oceanology);
- 1: 5000 topographic maps of the area compiled in the eighties of the twentieth century (Scientific Fund of the Institute of Oceanology);
- different kind of maps of the coastal zone: morpholitho-stratigraphic; geological and tectonic; geological and morphological; bathymetric; morphological and lithological (Petrova et al., 1992a, b; Kenderova et al., 1999; Kozhuharov et al., 2010; Вълчев, 2015, Scientific fund of the Institute of Oceanology);
- in addition, some thematic photographic material of geological formations, phenomena and others were incorporated in the database for more complex interpretation of coastal geology and morphology (Желев и др., 2012, Желев, Вълчев, 2013, 2015, Желев, 2014, Вълчев, 2015).

The vector type data include point, line and polygon which were produced by processing of DTMs, digitization of the available raster materials and geological sampling:
- for detailed tracking of coastal formations, a shoreline in scale 1: 5000 was digitalized;
- from the map material, various elements of the geological base were digitalized: geological, morpho-lithostratigraphic, geological-tectonic, geomorphological, morphological and lithological units;
- from the sonar mosaics, the varieties according to physical characteristics of the seabed were outlined.

An essential part belonged to the large number of sediment sampling stations. 625 samples were unified according to different globally accepted classification systems of marine sediments (Assessment Report of Marine Environmental Status, 2013). The present-day practice of sediment study shows that depending on the needs (geoengineering, environmental or habitat mapping), in addition to Bulgarian state standard (БДС) 2761-86 (БДС, 1987), the sediment has to be unified according to the globally accepted classifications of Folk 15 classes (Folk, 1954), Folk 16 classes (Kaskela et al., 2015) and Wentworth (1922). Using the Gradistat software (Blott and Pye, 2001) all data were classified in all above-mentioned class schemes and organized in the database in such a way to display the preferable class according to the needs.

Digital terrain models. Based on data from topographic and bathymetric surveys, three digital terrain models were created:
- the first model covers the coastal zone between the mouth of Ropotamo River and Lozenets. The data were kindly provided by the Center for Underwater Archeology (Project E/701/08 Bulgarian Black Sea bathymetric LiDAR, 2009);

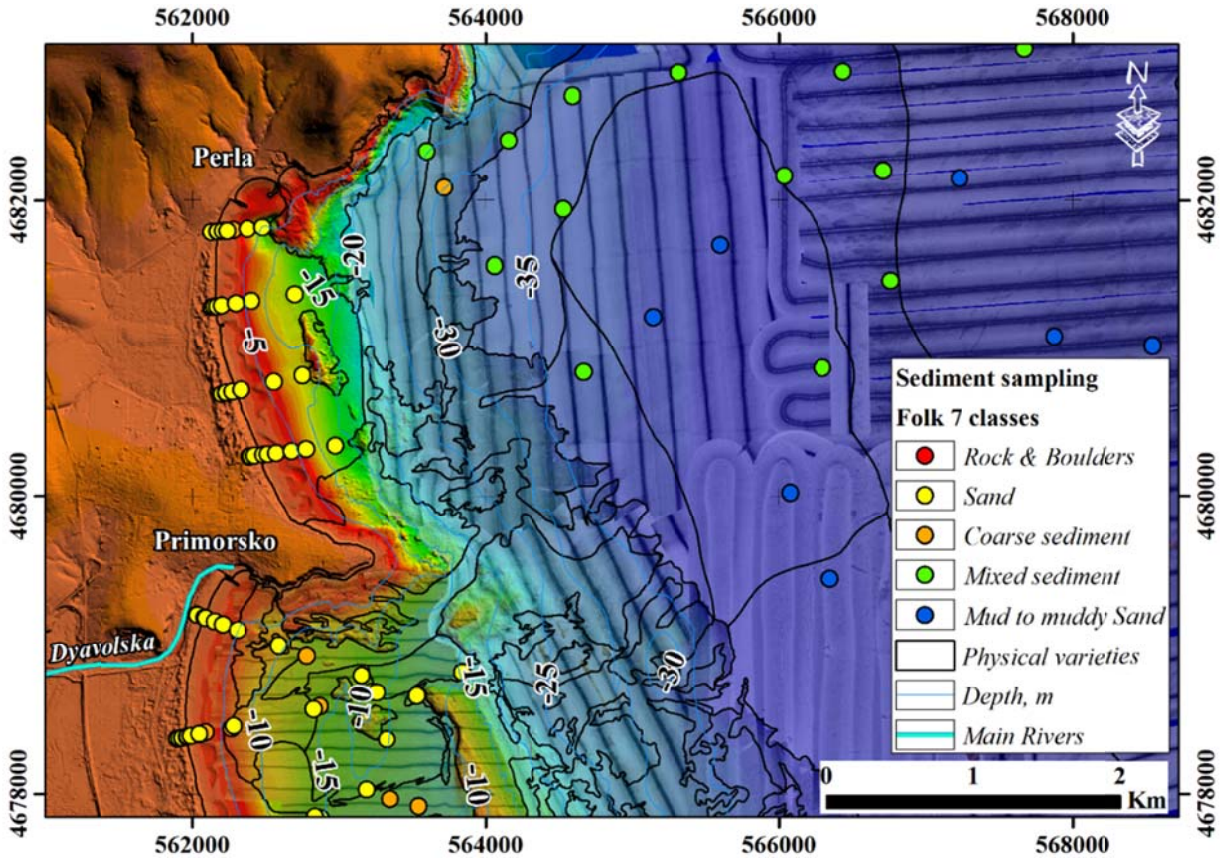

Fig.3. Integrating different types of data sets (digital terrain model, sonar mosaic, physical varieties and sediment samples) for seabed sediment classification

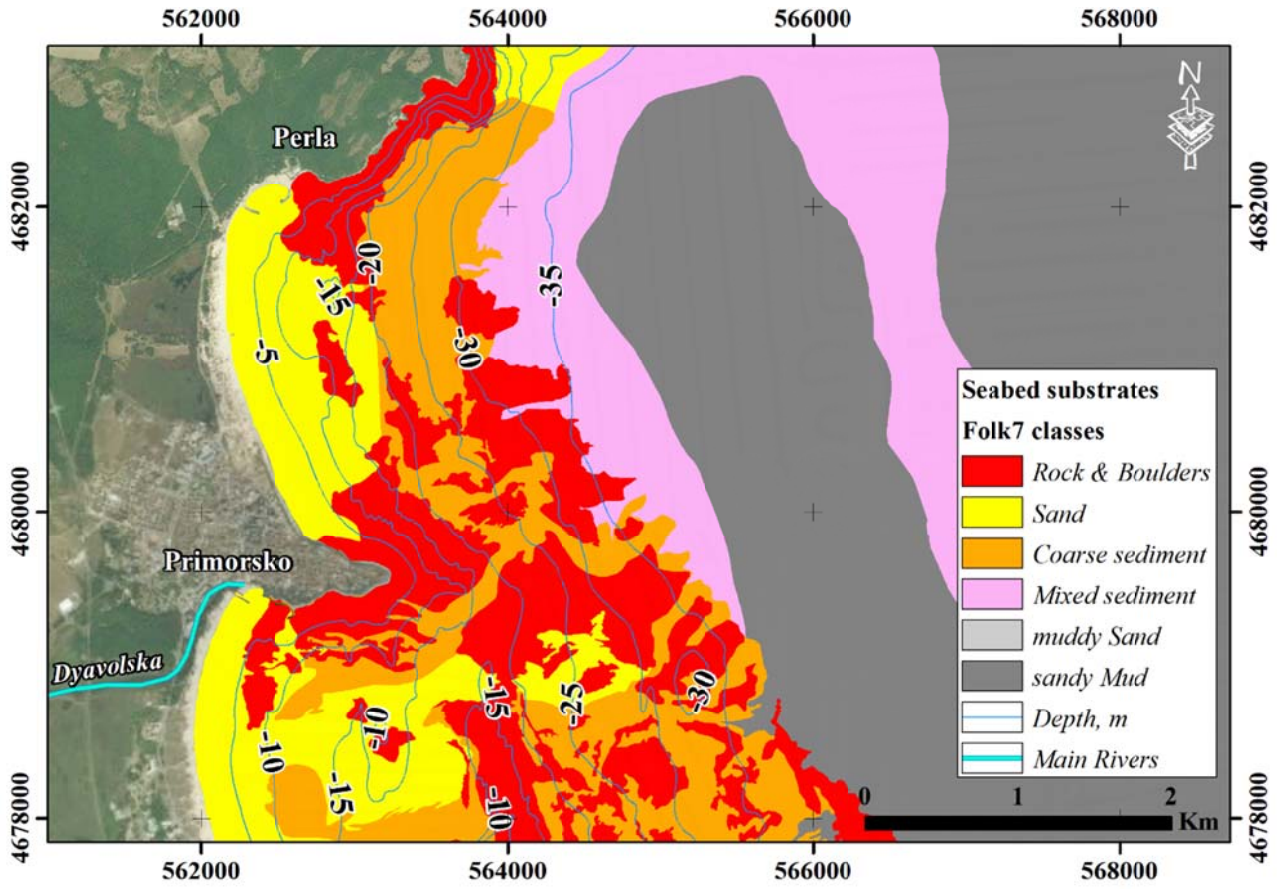

Fig. 4. Seabed substrate map (Folk 7 classes) of Primorsko coastal zone, South Bulgarian coast

- bathymetric terrain models have also been generated at depths between 7 m and 30 m and between 30 m and 55 m with a resolution of 3 m (Todorova et al., 2015);
- by combining topography maps of 1: 5000 scale and 3 ASTER GDEM, bathymetric contours with depth interval of one meter, a digital terrain model with a resolution of 30 m was created for both terrestrial and marine parts of the coastal zone where no sounding data exist.

Initial results

Initially available data about seabed substrate were classified after Wentworth size class scheme (Wentworth, 1922), Folk 16 classes (Folk, 1954), Blott and Pye (2001) and БДС 676 (БДС, 1987) sediment grain size classifications, which enforced a comparison analysis. Discrepancies in grain size classes were established which led to a unification of the sediment data in the above-mentioned classifications. Figure 3 shows the application of the integrated database in the layout of the substrate map. The DTM allowed extraction of bathymetric contours at every 0.5 m for high accuracy bathymetric maps of the coastal zone. The sonar mosaics which represent the intensity of bottom sediments reflectivity were used to identify and outline seabed physical varieties. The lithology of these varieties was determined by means of verification using sedimentological data (Fig.3, 4).

Using a combination of different database layers a map of interest can be produced on a scale up to 1:5000. An example is given on Figure 4 - seabed substrate map which can be used for additional habitat characterization.

Conclusions and challenges

The initial results of the integration of the database completely follow the concept set up in the project *"Seabed mapping of the southern Bulgarian Black Sea coastal zone for habitat classification"*. The research demonstrates the effectiveness of multidisciplinary approaches to mapping and studying seabed morphology and geospatial distribution of the seabed substrate. The combination of high-resolution geophysical mapping of the seabed by multi-beam echo-sounder and side-scan sonar, supported by sediment sampling and video recording allowed drawing of precise large-scale sediment maps of the coastal zone of Primorsko. As a result of the conducted research the following results were achieved:

1. A digital terrain model was developed for the coastal zone between Sozopol and Tsarevo with a horizontal resolution of 30 m;
2. Using the Gradistat software (Blott and Pye, 2001), 625 geological stations were unified according to globally accepted classification systems Folk (Folk, 1954) and Wentworth (Wentworth, 1922);;
3. An initial substrate map of the seabed of Primorsko coastal zone was made using Folk 7 classes.

The main goal, also outlined in the title of the project, is to map the seabed substrate (Folk. 16 classes) as a geological

basis for determination of submarine habitats by integrating data from remote, geological and sedimentological surveys. It will be achieved through achieving the following objectives: creating an initial database of archive data in GIS environment that will be complemented by up-to-date geospatial data on coastal relief, underwater slope and new sediment data; based on the already summarized geospatial information the boundaries of the main lithological types in the studied area will be established and geomorphological and lithological maps of the coastal zone will be produced, which will be a basis for subsequent extraction of information about the natural habitats.

The results, apart from the benefit for the geological study of the Bulgarian continental shelf and the mapping of habitats, present a geodatabase which would be useful in solving future engineering, geological and geophysical tasks and implementing management plans for the Bulgarian Black Sea sector. The realization of such an interdisciplinary project will be a significant contribution to the activity of the Bulgarian Academy of Sciences which main goal is a gradual comprehensive study of the whole Bulgarian Black Sea sector.

Acknowledgements: *The present study was developed under the research project „Seabed mapping of the southern Bulgarian Black Sea coastal zone for habitat classification" funded by Bulgarian Academy of Sciences in the frame of "Program to support young scientists at BAS", Project № 17-103/28.07.2017.*

References

Вълчев, Б. Пясъчни дюни по Българското черноморско крайбрежие южно от гр. Бургас – състояние и геоконсервационно значение. – Сп. Бълг. геол. д-во, 76, 1, 2015. - 35-57. (Valchev, B. Pyasachni dyuni po Balgarskoto chernomorsko kraybrezhie yuzhno ot gr. Burgas – sastoyanie i geokonservatsionno znachenie. – Sp. Balg. geol. d-vo, 76, 1, 2015. - 35-57)

Желев, В. Колокита. –Геология и мин. ресурси, 3, 2014. 21-29. (Zhelev, V. Kolokita. –Geologia i min. resursi, 3, 2014. 21-29)

Желев, В., Б. Вълчев, К. Кършева, Д. Съчков. Геотопите "Устието на река Велека" и "Силистар" – основа на един естествен геопарк по палеовулканология. – Год. МГУ, 55, 1, 2012. - 21-29. (Zhelev, V., B. Valchev, K. Karsheva, D. Sachkov. Geotopite "Ustieto na reka Veleka" i "Silistar" – osnova na edin estestven geopark po paleovulkanologia. – God. MGU, 55, 1, 2012. - 21-29)

Желев, В., Б. Вълчев. Геоложки феномени в района на резервата "Ропотамо", Бургаска област. – Год. МГУ, 56, 1, 2013, -109-118. (Zhelev, V., B. Valchev. Geolozhki fenomeni v rayona na rezervata "Ropotamo", Burgaska oblast. – God. MGU, 56, 1, 2013, -109-118)

Желев, В., Б. Вълчев. Геотоп „Нос Кюприя", гр. Приморско, Бургаска област – Год. МГУ, 57, св. I, 2015. - 39-46. (Zhelev, V., B. Valchev. Geotop „Nos Kyupria", gr. Primorsko, Burgaska oblast – God. MGU, 57, sv. I, 2015. - 39-46)

Попов, Вл., Мишев, К. Геоморфология на Българското Черноморско крайбрежие и шелф, Изд. на Българска Академия на Науките, София, 1974. - 267 с. (Popov, Vl., Mishev, K. Geomorfologia na Balgarskoto Chernomorsko kraybrezhie i shelf, Izd. na Balgarska Akademia na Naukite, Sofia, 1974. - 267 s.)

Blott, S., K. Pye. Technical communication: GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. – In: Earth Surface Processes and Landforms, 26, 2001. - 1237-1248.

Folk, R. The Distinction between Grain Size and Mineral Composition in Sedimentary-Rock Nomenclature. – In: Journal of Geology, 62, 1954. - 344–359.

Kenderova, R., E. Tcherkezova, A. Saraffov. Geomorphological research of the coastal strip wetween the cape Humana and the cape Kaja. - In: Annual of Sofia University "St. Kliment Ohridski", Sofia, 89, Book 2, 1999. -57-69.

Kaskela, A., Kotilainen, A., Alanen, U., Stevenson, A., and EMODNET-Geology partnesr. Seabed substrates anad sedimentation rates of the European Seas - EMODnet-Geology, Geologycal Survey of Finland, 2015 (www.gtk.fi)

Todorova, V., L., Dimitrov, V., Doncheva, E., Trifonova, B., Prodanov. Benthic Habitat Mapping in the Bulgarian Black Sea. - In: Proceedings of 12th International Conference on the Mediterranean Coastal Environment (MEDCOAST 2015), 1, Varna, 97-605-85652-4-1, 2015. - 251-262.

Valchev, N., Andreeva, N., Prodanov, B. Study on wave exposure of Bulgarian Black Sea coast. -In: Proc. 12th Int. Conference on Marine Science and Technology „Black Sea" 2014, Varna, 2014, - 175-182, ISSN 1314-0957

Wentworth, C. A scale of grade and class terms for clastic sediments. –Journal of Geology, 30, 1922. - 377–392.

National Geofund Reports

БДС 2761-86. Строителни почви, физически свойства, определения и означения. Комитет по качество към Министерския съвет, София, 1987. - 9 с. (BDS 2761-86. Stroitelni pochvi, fizicheski svoystva, opredelenia i oznachenia. Komitet po kachestvo kam Ministerskia savet, Sofia, 1987. - 9 s.)

Assessment Report of Marine Environmental Status Contract № 0-33-18 from 06.12.2013 between Ministry of Environment and Water and the Institute of Oceanology - BAS, Varna for implementation of obligations under the monitoring of the Black Sea, on the grounds of Article 171, paragraph 2, item 3 of the Water Act, Scientific fund of Institute of Oceanology, Varna – Bulgarian Academy of Sciences, 2013. - 370 p.

Kozhuharov, E., Dimitrov, L., Hristova, R., Doncheva, V.Geologic map of the Bulgarian Black Sea sector, 2010. Scientific fund of Institute of Oceanology, Varna – Bulgarian Academy of Sciences.

Petrova, A., Ch. Dabovski, S. Savov, G. Chatalov. Geological Map of Bulgaria on Scale 1:100 000. Tsarevo, 111 Silistar, Malko Tarnovo, Rezovo map sheets. Geology and Mineral Resources Committee, Enterprise of Geophysical Survey and Geological Mapping. 1992a..

Petrova, A., L. Mihailova, V. Vasileva. Geological Map of Bulgaria on Scale 1:100 000. Pomorie map sheet. Geology and Mineral Resources Committee, Enterprise of Geophysical Survey and Geological Mapping. 1992b.