Project description

Problems. The aim of the present research proposal is to examine the sedimentation pattern (rates and spatial dispersal) within the Danube Delta and in front of it, over the continental shelf based on radiometric methods: ^{210}Pb, ^{137}Cs, ^{226}Ra. Alternatively, the performance of each of these methods and their suitability for such purpose will be tested. Besides the two radiometric techniques, the luminescence method will provide an extension of the dating period back to the formation of the youngest deltaic lobes (approximately 2000yrs).

The general objective of this project is promoted in the context of the international research preoccupation dealing with the relationship between the human society and the natural environment changes. In other countries starting with the end of the 70's research have been made about the sedimentation of the delta rivers (Nittrouer et al., 1979, Michels, 1998). These investigations are still in progress (Jweda and Baskaran, 2011, Humphries, 2010). The ongoing studies have extended from the recently deposited sediment to the maritime shelves in the screening of the antropic factors (Xu et. al. 2008, Canuel et. al., 2009).

Evaluations of sedimentation rates in fine-grained deposits from deltaic systems, coastal zones and shelves are important because of the association with such deposits of chemical pollutants, their impact on biological processes, and their relationship to stratigraphic considerations, including changes in sedimentary environments (Lesueur et al., 2001). Most of the recently published papers on shelf muds have focused on the large dispersal systems associated with subaqueous-deltas, i.e. Amazon, Ganges–Brahmaputra, Changjiang–Huanghe, Fly River (Kuehl et al., 1982, 1986; DeMaster et al., 1985; Alexander et al., 1991; Harris et al., 1993).

River deltas are primarily the product of the fluvial sediment supply and reworking by waves and currents whose relative importance varies in time and space. The sedimentation processes and the associated morphological changes within the Danube delta and along the deltaic coast are complex and less understood. The rates of the sedimentation processes are continuously changing at different time-scales (e.g. macro-scale changes related to climate and sea level changes, meso-scale related to changes of the solid discharge, hydrodynamic characteristic or physical conditions of the river bed) due to both natural and anthropogenic factors. Insights into the spatial and temporal sedimentation rates dynamics within the Danube delta and on front of it, over the continental shelf during the last two centuries represent a major challenge for the better understanding the phenomenology of the Danube delta development. The detailed reconstruction of the sedimentation rates by means of high resolution radiometric methods during the last two centuries will help to isolate and quantify the impact of the human interventions. Understanding the feed-back between the sedimentation processes and the morphological changes within the Danube

delta and deltaic shoreline is a crucial step in predicting how the sedimentary system (Danube delta) will evolve in the near future and in assessing its vulnerability to the extreme events (i.e. sea level rise, storms, floods, droughts) related to the widely acknowledged climate changes. Major human interventions (i.e. dams, hydroenergetic power plants, meanders cut offs, artificial channels cuttings, protection walls) have been performed within the Danube basin within the last century. Of all the anthropogenic interventions the Iron Gate hydroelectric power plant (1972) produces the major effect on the sediment quantity which arrives in Danube delta. While between 1971 and 1980 the Danube River solid discharge was of 1308 kg/s, between 1981 and 1990 this value decreased of 926 kg/s. The maximal value was recorded in 1941 (192×10^6 tons/year) and the minimal in 1921 (19,8 millions of tons per year). The average transported sediment quantity per year shows a decreasing tendency (Coman, C. 2002).

Human interventions both far field constructed dams and embankments within the Danube basin and those performed within the Danube delta (meanders cut off, desiccation works, Sulina-Sfantu Gheorghe dike construction parallel with the shoreline, jetties construction at Sulina arm mouth) lead to fluvial discharge variation between the three distributaries of the Danube and most important to dramatic shoreline changes. From the total length of the Danube delta Biosphere Reserve coastline, 57% is erosive, 36% is prograding and 7% shows a relative stability. Recent investigations yielded rates of up to 20 m/year of shoreline erosion in some sectors of the interdistributary Sulina-Sf. Gheorghe coast (Vespremeanu-Stroe et al., 2007, Stanica et al., 2011). Recent estimation shows that between 1962 and 1992 the surface of the Danube delta decreased with 22 km^2. In the last 35 years the shoreline has retreated with 180 to 300 meters and 80 ha/year of the beach has been lost (Coman, C. 2002).

The deposition of sediment transported by the river plume determines the initial seaward growth of deltas. The Danube delta shoreline dynamics is mainly controlled by the changing sedimentary input The computed longshore sediment transport along the deltaic coast shows considerable amplitudes, ranging from a deficit of -300×10^3 m^3/ yr at 4 km downdrift of Sulina jettey's to 1100×10^3 m^3/ yr updrift of the Sfantu Gheorghe arm mouth (Dan et al., 2009). Determination of the sedimentation rates both within the Danube delta and over the deltaic shelf is a major request in assessing the spatial – temporal pattern of the Danubian sediment dispersal. Sfantu Gheorghe arm mouth is not affected by any anthropogenic interventions such as jetties or other hydrotechnical work, its morphology being the expression entirely of the natural processes. This is why it is an ideal place to investigate the characteristics (rates and spatial distribution) of the river born sediment dispersal into the sea.

The difficulty of the problem is in the interpretation of the data which represents the sedimentation rates in the points where the samples were collected. The sedimentation rates from

the delta can be influenced by two different modifications. The first change which leads to modification in the sedimentation rate is the shortening of the channels (St.Gheorghe from 109 to 69,7 km). As a consequence the water debits changes and leads to modifications in the transported sediment. The second change is due to the barrages built on the Danube. The two changes can be dissociated by choosing correctly the coring points.

The human impact on the sedimentation processes from the Danube Delta has been previously approached by means of some geographic and geomorphologic methods such as historical bathymetric maps comparison (Constantinescu et. al., 2010) or hydrodynamic modeling of extreme events (e.g. floods) behavior (Nistoran-Gogoase et al., 2008). The main drawback of such methods resides in the lack of the temporal detail which is crucial for distinguishing the nature of the sedimentation events. Several rough and spatially scarce estimations of the sedimentation rates in the Danube delta are currently available reflecting changes in sediment deposition processes. Those data are not sufficiently detailed (data obtained for short intervals of time) to isolate the anthropogenic signal (constructions of dams or hydroelectric power plants).

Radiometric methods applications to Danube delta sediments can be found in the literature but those investigate the pollutant agents (heavy metals) in recent sediment layers. The accumulation rate of recent sediments from radiocesium profile was not estimated by using the ^{210}Pb methods (Dinescu and Duliu, 2001). The estimation based on radiocesium does not provide a good time resolution because it is reported on two maximum concentration peaks that can be found in sediment columns, one from 1963 (nuclear weapon test) and the second from 1986 (Chernobyl nuclear power plant disaster). A detailed study with high time resolution on the sedimentation pattern changes in the Danube delta was not made until now. The ^{210}Pb radiometric method which will be proposed in this project, aims to obtain that high time resolution data. By this we will be able to reconstruct all events that happened in the last 150 years in the Danube delta sedimentation processes, making it possible to differentiate between the anthropogenic influences and natural events. ^{210}Pb method was used in dating some sediment sequences from Black Sea (Ayçik et. al., 2004; Florea et.al., 2011) in order to investigate sediment rate and chemical composition.

***Ojectives*.** The study aims to determinate the magnitude of the anthrogenic influence on the basic processes that regulate the dynamic behavior of the sedimentary system (Danube Delta). This overall objective will be achieved through compliance with a series of specific objectives, which are detailed below:

O1. Determination of sedimentation rate in several lacustrine units from Danube delta area, lakes in which the sedimentation rate clearly reflects the variation of the river solid discharge. Undisturbed bottom sediments from several lakes form the Danube delta will be extruded and the analysis of the

vertical variation of the sedimentary facies combined with ^{210}Pb and ^{137}Cs radiometric methods will be undertaken in order to get a high resolution data of the sedimentation rates during the last two centuries. Additionally, sedimentation pattern in the proximity of the fluvial levees will be investigated for the first time at several locations in order to get insight into the lateral and temporal variations in sediment accumulation rates. This information is necessary for the quantification of the sediment volume changes at different times and the present tendency.

O2. The assessment of the sedimentation rates on the Danubian continental shelf. This investigation will identify the tendency of the sediment deposition rates offshore of the closure depths (inner continental shelf: -20…-50m) during the last century. More important, the main actual depocenters repartition and the associated sedimentation rates will be identified. This data, together with the data of sedimentation rates within the Danube delta and the existing rates of shoreline dynamics will give an account on the volume of the danubian sediments which exit the deltaic system. The sedimentation rates data will contribute to the analysis of the sedimentary linkage between the river discharge, the longshore currents and the shoreline dynamics in order to isolate and quantify the role of the river solid discharge contribution to the long shore transport and to the shoreline dynamics and river distributaries mouth changes.

O3. Geochronological investigation of the youngest deltaic lobes (Sfantu Gheorghe, Sfantu Gheorghe secondary delta, Chilia secondary delta by means of luminescence dating in order to obtain a high accuracy of their development rate. High resolution dating of the most recently formed Danube delta lobes (e.g. post 3000 yrs) will be undertaken using Optical Luminescence Dating and ^{210}Pb and ^{137}Cs radiometric methods to get a detailed insight of the dynamics of the sedimentation processes involved in its evolution. Some data exist about the chronology and Danube delta evolution (Panin, 1989, 2007, Giosan et al., 2006). Additional geochronologic analysis of the morpho-sedimentaty units developed during the Late Holocene (e.g. last 3000 yrs) will be undertaken in order to determine the rates of the youngest deltaic lobes development. The presently missing data about the sediment availability at different times will be obtained. It is expected that the analysis of the sediment availability oscillations since the youngest deltaic lobes started to form will deliver a high resolution picture of the sedimentation events which will enable to distinguish between the natural processes and the anthropogenic impact on the sediment disposal and sedimentation rates. The comparative assessment of the past and present functionality of the deltaic system will enable us to evaluate the impact of the anthropogenic interventions in the Danube Delta development.

O4. Update and set up the necessary radiochemical and infrastructure in our laboratories in order to measure a large number of samples.

The study represents the first investigation of sedimentation rates and fluxes within the Danube delta and over the associated Danubian continental shelf, using the radiometric method of ^{210}Pb and ^{137}Cs. The detailed stratigraphical survey of the deltaic sediments will provide an accurate view of the deltaic geomophological evolution in the last 150 years, including the impact of the hydrotechnical works built within the Danube basin on the sedimentation pattern in the Danube delta and on the deltaic continental shelf. Another important aspect of the present project is featured by the alpha measurements of ^{210}Pb, through its daughter ^{210}Po. These measurements will be made in Romania, where only the alpha spectrometry laboratory from Cluj-Napoca have published data made on alpha spectrometry measurements of ^{210}Pb in sediments (Begy et.al, 2011). The alpha spectrometry has a number of advantages on measuring low-level activities, including high sensitivity, low intrinsic detector background, the elimination of the possible interference by chemical separation. Also, the use of a tracer makes the method more reliable. Worldwide laboratories have been utilized this technique for measuring ^{210}Pb in sub-recent deposits through its grand-daughter ^{210}Po. The project involves three complex radiometric and nuclear tools: alpha, gamma-spectrometry the determination of radionuclides of interest (^{210}Pb, ^{137}Cs, ^{210}Po and ^{226}Ra) and luminescence absolute method.

C3. *Impact.* The project represents a cross-disciplinary collaboration between universities (Babeş-Bolyai University and The University of Bucharest) and also integrates a young multidisciplinary research team of geographers, geologists, chemists and physicians. The results of this research proposal will provide the first data of the sediment accumulation rates and the antrophic influence within the Danube delta and over the Danubian continental shelf using the new approach of ^{210}Pb radiometric dating. Also, the research represents the first luminescence dating of the most recently formed Danube delta lobes. High resolution geochronological data on sediment accumulation rates within the deltaic system will give an accurate picture of the sedimentation change events occurrence and will contribute to the assessment of the anthropogenic impact on the sedimentation rates. This information is crucial in the attempt to elaborate models of the future sedimentation pattern in the Danube delta and the deltaic shoreline evolution. Significantly, these evolutionary models will contribute to the development of a necessary analytical tool to assess the erosion control measures along the deltaic shoreline. The conclusions of this proposal will be integrated in recommendations for the management of the Danube Delta. The obtained data will build the basis of new extensive research in this direction, extended all over the delta. It is important to note that the Danube Delta is an UNESCO monument since 1991 and also represents the biggest natural reservation of damp areas from Europe. The results of the project will be communicated to the scientific community through workshops and conferences and will be published in peer-reviewed journals, specialized in the earth and environmental sciences or high resolution dating methods.

This will facilitate the onset of long-term science collaboration, research sharing, and more international visibility for the Romanian research. The target international conferences are IAS ANNUAL MEETING OF SEDIMENTOLOGY 2014 (for two project members) and the 3rd International Conference on Radioecology and Environmental Radioactivity, Barcelona, Spain from 7 to 12 September 2014 (for two project members). For strengthening the team in the research field, one PhD student/young researcher will be train by participation at an international summer school: International Geochronology Summer School, Switzerland: Dating anthropogenic and natural changes in a fragile alpine environment.

C4. *Methodology.* For aquatic sediments, the use of ^{210}Pb originating from the decay of atmospheric ^{222}Rn is a well established methodology to estimate sediment ages and sedimentation rates on a time scale of 100–150 years. The ^{210}Pb method was first developed by Goldberg (1963), then applied to lake sediments by Krishnaswamy et al. (1971), and subsequently introduced to marine sediments by Koide et. al. (1972). More recent studies applied the ^{210}Pb radiometric methods in the study of the changes due to human-induced geomorphic change, rather than climate change in riverine-lacustrine systems, estuaries or bay in different parts of the world (Sert et. al., 2012, Jweda and Baskaran, 2011, Sabaris and Bonotto, 2011, Bruschi et.al., 2012). There are two models which have been widely and successfully applied: the 'constant flux/constant sedimentation rate' model (Robbins, 1978) and the 'constant rate of supply (C.R.S.)' (Appleby and Oldfield, 1978).

The sampling strategy will aim to obtain data from relevant locations with meet the conditions of a continuous, undisturbed sediment deposition and to be spatially representative. A sensible aspect of our research will be the access of the most representative locations for sediment samples collections. Continuous, undisturbed stratigraphic sequences will be extruded from representative lacustrine units after a preliminary review of their physical characteristics (i.g. lake bottom morphology, shoreline morphology, water circulation regime, depth, exposure to the prevalent wind direction and fetch). This is why successive fieldwork campaigns will be performed in order to test both the radiometric signal of the sediments, their sedimentation pattern and their preservation. Moreover, the luminescence dating of the youngest deltaic lobes, together with the radiometric dating of the sediment samples and continental self will give a complete overview of the anthropic influence on the geomorphologic evolution of the Danube delta.

The methodology planned for the project will be discussed following the proposed objectives.

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