15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. 7 Ext. Abs. GSG2019-211

Spatial Sedimentological, Geochemical and Mineralogical Characterization of Vouliagmeni Coastal Lake, Greece

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Background

Coastal lakes and lagoons are highly dynamic and prone to changes like human impact, climatic influences or changes in depositional environments and many more all of which are imprinted in the sediment characteristics and chemistry. Grain size distribution and moment measurements provide an insight into transport-deposition processes while pointing out driving forces (Gao and Collins, 1992; le Roux, 1994,). Sedimentological analyses are generally coupled with geochemical focusing on major oxides, trace elements as well as mineralogy which provide information concerning the provenance and geochemical processes of the sedimentological basement (Panagiotaras et al., 2012). Preserved organic matter in sediments comprises carbon assessed mainly as Total Organic Carbon (TOC) and nutrients as Total Phosphorus (TP) and Total Nitrogen (TN) with organic as well as inorganic sources.

Objectives

Vouliagmeni is a coastal lake located in the SW Perachora peninsula extending into the eastern Gulf of Corinth (Greece) while with a maximum depth of around 49m (Katsanevakis, 2005). At the northern and southern part of the lake, due to normal dipping faults, the lake is characterized by steep bathymetry unlike the eastern and western part where the transition is smoother. Until the late 19th century the lake was separated from the Gulf of Corinth by an isthmus when a narrow (18m) canal was constructed leading to the present lagoonal state. In the current study we present a spatial characterization of the lake bottom sediments based on sedimentological, geochemical and mineralogical analyses providing an insight into depositional environments and processes presently active in the lagoon.

Methods

A total of nineteen (19) samples consisting of upper 1-2cm lake bottom sediments were collected. For the grain size analysis, coarser material (>4 Φ) was dry sieved whereas finer (<4 Φ) was measured with the use of a Malvern Mastersizer 2000 followed by the moment measures' calculation using GRADISTAT V.4. (Blott and Pye, 2001). The $CaCO_3$ content was measured with a FOG II/Digital hand-held soil calcimeter (BD Inventions), the TOC using the (Walkley and Black 1934, Avramidis *et al*., 2015) tritation method, TN content was measured using a Carlo Erba CHNS-O EA 1108 Elemental Analyzer while the TP content was measured using a HACH photometer, based on APHA 2005-4500-P.

In a geochemical framework, concentrations of 10 major elements (Si, Al, Ca, Mg, Mn, P, Fe, Na, K and Ti) and 19 trace elements (Sc, V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb, Ba, Hf, W, Pb, La, Ce and Th) were measured by comparison of X-ray intensities for each element with calibration lines constructed from the analysis of known concentrations in 32 international standards. Powdered samples where pressed into pellets and analyzed with a RIGAKU ZSX PRIMUS II wavelength dispersive spectrometer equipped with a 4KW Rh X-ray tube which is located at the Laboratory of Electron Microscopy and Microanalysis of the University of Patras, Greece. A predominant mineralogical composition was determined for each of the nineteen samples by powder X-Ray diffraction (XRD) using a Bruckner D8 advance diffractometer with Ni-filtered CuKα radiation and analyzing the results with the DIFFRACplus EVA 12 software.

Results

The central part of the lagoon is characterized by fine sediment, whereas the shallower parts of the lagoon are mostly associated with coarser material. In samples located near the artificial channel and at the north east part of the lagoon, the coarser material is attributed to bivalve assemblages. These bivalve assemblages, which represent around the 70 % of these samples, are highly linked to the hydrological regime of the lagoon, since they show clear evidence of transport before their burial (broken bivalves, cracks). Samples from depth less than 20 m present higher $CaCO_3$ being attributed to the high presence of micro-macrofaunal assemblages (Fig. 1d). Low $CaCO_3$ content is apparent in the deep horizons of the lake. Higher TOC, TN and TP concentrations are observed in the depths beyond 20m sediments (Fig. 1a, b, c).

Statistical analysis on the geochemical data shows that all elements are associated with the organic content and the clay fraction of the sediments except that for Na, Sr and Co. High correlation ($r>0.83$) for Ni, Cu, Pb, Zn and Rb with the Al_2O_3 shows the same origin of these metals and their association with the detrital materials from the catchment. The elements Fe, Mn, Mg, K, Ti, P and TP are well correlated with the aluminosilicate fraction of the sediments. However, Ca and $CaCO_3$ show complex geochemical association with high negative loadings ($r>-0.95$) been observed with Al_2O_3. Negative loadings ($r=-0.56$ and $r=-0.66$) have been found between TOC and $CaCO_3$ and TOC and CaO respectively. This finding implies both a non biogenic and a biogenic origin of these components. The same geochemical feature is observed with the TN. High positive correlation ($r=0.83$) is found between TOC and TN and also a positive correlation is apparent ($r=0.66$) between TN and Al_2O_3.

The mineralogical composition showed little spatial diversity throughout the samples and was mostly represented by Quartz (mean: 33.7%), Aragonite (mean: 30.5%), Calcite (mean: 18.2%), Biotite (mean: 13.7%), Halite (mean: 6.5%) and Pyrite (mean: 11.4%, in samples 5, 6, 7) indicating anoxic/hypoxic conditions.

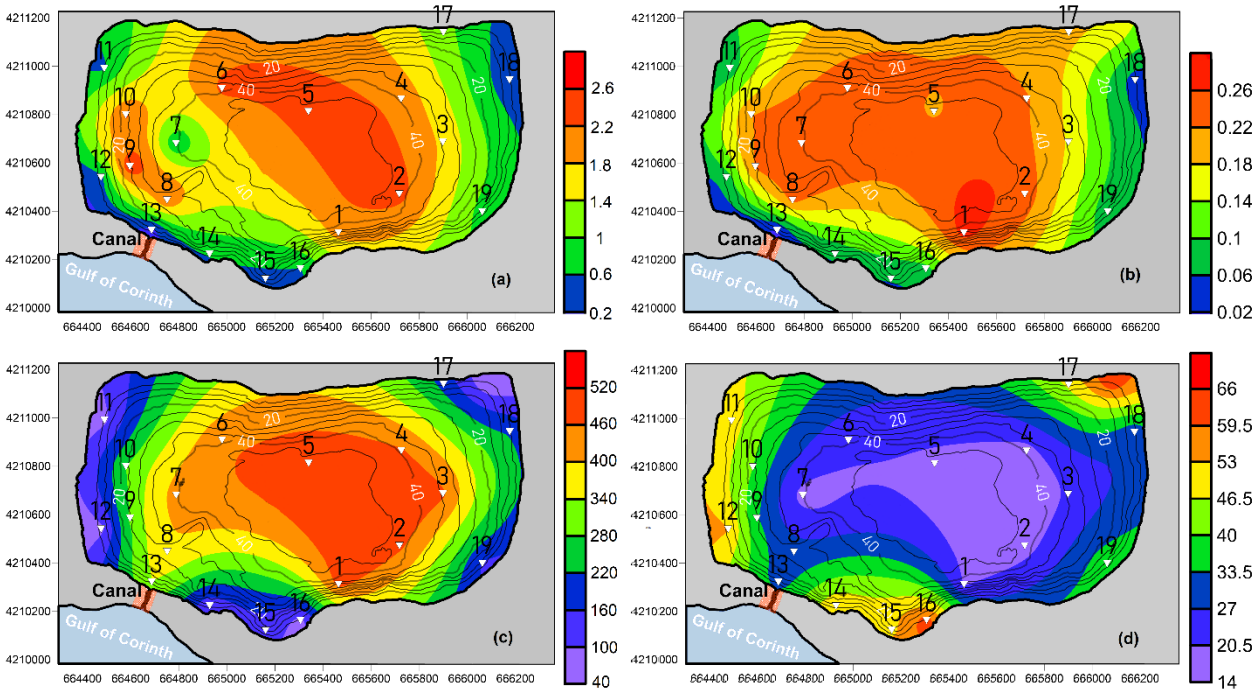

Figure 1. Bathymetry modified after Katsanevakis, 2005 a) TOC(%) b) TN(%) c) TP(mg/kg) d) $CaCO_3$(%)

Conclusions

Based on grain size analysis, sedimentological, geochemical and mineralogical analyses a division of the lake in two distinct environments by depth is recognized, shallow (0-20m) and deep (>20m). The grain size distribution, from coarse to fine progressing from the coast (until 20m) to the deeper part is controlled by the hydrodynamic regime. The oxidation conditions in the deep part due to the preservation of organic matter as well as the existence of Pyrite below 35m indicate anoxia.

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