TEMPORAL EVOLUTION OF ANTHROPOGENIC POLLUTION AND ENVIRONMENTAL CHANGES IN A MARINE INLET: THE EXAMPLE OF GEMLIK GULF, MARMARA SEA

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INTRODUCTION

Marginal basins are prone to anthropogenic pollution because of restricted water circulation and commonly high population density and industrialization in their drainage basin. Gemlik Gulf, with maximum depth of 113 m and sill depth of 50 m, is such a basin under anthropogenic risk from different industrial and municipal sources (Figs. 1, 2). Moreover, Gemlik Gulf, located on the middle branch of North Anatolian Fault (NAF), is under a future earthquake risk with a high possibility of pollution from disruption to industrial plants and municipal infrastructure. In this study, we investigated the evolution of the heavy metal and organic pollution using ICP-MS, $\delta^{13}C$ ‰ and $\delta^{15}N$ ‰, TOC/TIC, and C/N elemental analysis of a water-sediment interface core from the central part of the basin. Sedimentary, geochemical and physical propertiesof the core were further investigated using XRF Core Scanner and Multi-Sensor Core Logger (MSCL) analyses. Radionuclide (^{210}Pb , ^{137}Cs) dating was used for determining the chronology.

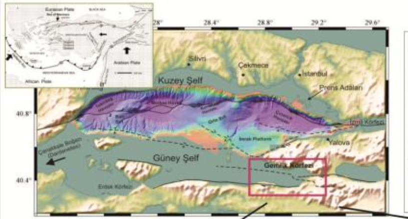

Figure 1. Bathymetry of the Marmara Sea (Armijo, 2005)

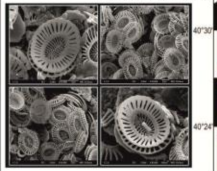

Figure 3. Coccolith plates and spheres Scanning Electron Microscope (SEM) micrograph

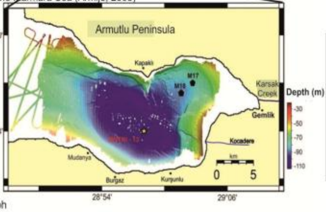

Figure 2. Bathymetry of Gemlik Gulf.

RESULTS AND DISCUSSION

The core covers about last 260 years according to radinuclide dating (Figure 4,5). There are three significant units in the core:
1) a coccolith laminated unit, that was deposited during 1985-1995, when algal blooms (eutrophication) prevailed. 2) A diagenetic carbonate cementation zone, distinguished by its low magnetic susceptibility, high Ca and TIC contents; and its radiographic density. This unit was deposited during 1945-1950 (Figs. 6,8). 3) A red brown mass flow unit, characterized by high Zr, Ti and Fe counts and MS values, . originating from Kocadere river delta during the year 1930 (Figure 2,6).

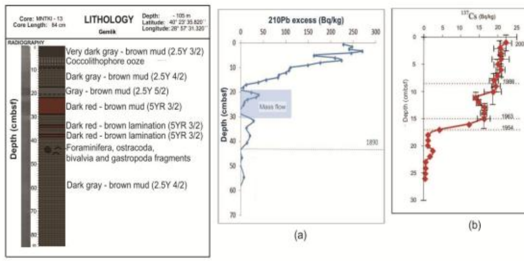

Figure 4. Lithological descriptionand chronology of the core a) 210Pb excess profile b)137Cs profile

Organic matter deposited after 1995 is of terrestrial end - member, whereas it is of marine end - member between 1985 and 1995 (Figs. 7,10). Algal blooms during this coccolith deposition period indicate high nutrient (P, N) input and europhication caused by domestic discharge, sewage and industrial activites since 1930s such as filature production (1937), Gemlik fertilizer industry, and pulp resulting from olive oil production. According to Mn depletion, Mo enrichment (EFmax= 23) and increasing TOC (up to 4% between 1985 - 1995) contents, deep water anoxia started developing since 1965 due to high organic matter input from domestic and industrial sources and density stratification in water column caused by regional oceanographic dynamics leading to oxygen deficiency (Figs. 6, 9,11). Enrichment of $\delta^{15}N$ after 1930 is caused by increasing denitrification under anoxic conditions. Lower values during 1830-1930 indicate more oxic conditions (Figure 8).

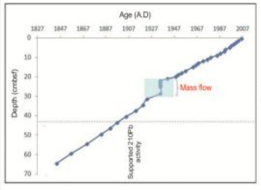

Figure 5. Age depth model of the core according to 210Pb

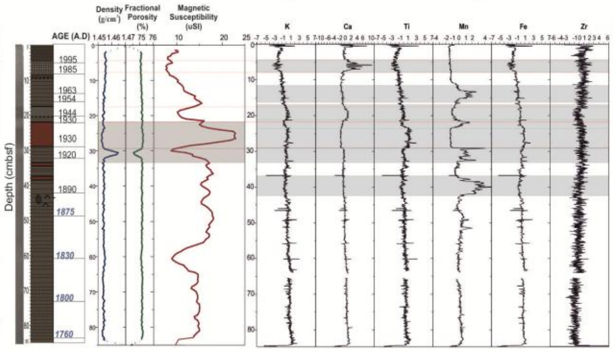

Figure 6. MSCL and XRF results. Enrichment of Ti and Zr, and depletion of other lithophile elements such as Th, La, Nb and Rb in the mass flow unit, indicate heavy mineral (rutile, titanite, zirconium) rich silt sized detrital influx (Figure 10,11).

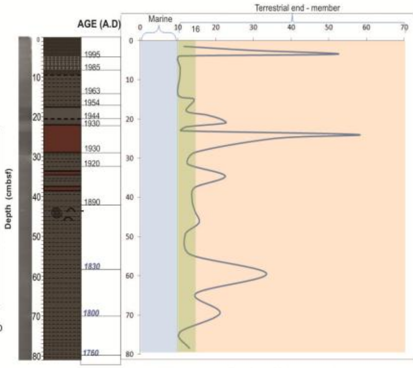

Figure 7. C/N analysis results. The origin of organic matter according to Brodie et al. (2011).

Distribution of K, Rb, and Li suggests relatively arid climatic conditions during 1840 - 1980 and more humid climate during the last 40 years. Concentrations of Sb, Bi, Cu, Pb, Zn, Cd, and Th increase abruptly after 1975 due to anthropogenic pollution. Cd is significantly enriched (enrichment factor = Efmax: 5.8), whereas the enrichments of Zn and Sb are moderate (EF: 2.2 - 2.3), with all heavy metal concentrations rising above treshold level starting around the year 1980. High enrichment of Mo (EF_{max}: 23) , together with the increasing concentrations of U, S and Sb after 1965 is due in part to diagenesis under anoxic bottom waters and in part to increased anthropogenic pollution (Figure 10, 11).

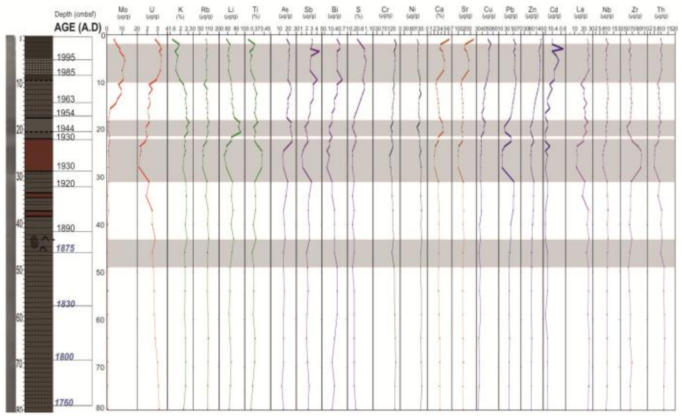

Figure 10. Elemental concentrations of sediments from ICP-MS analysis

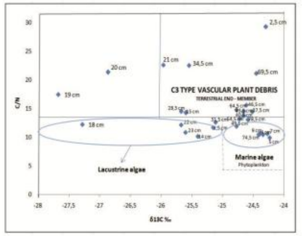

Figure 10. $\delta^{13}C$ ‰ plotted against C/N (Sweeney and Kaplan, 1978; Goni et al., 2003; Tesi et al., 2007; Miserocchi et al., 2007; Sanchez et al., 2013; Souza et al., 2013).

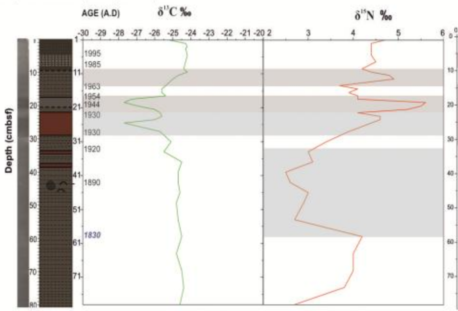

Figure 8. $\delta^{13}C$ ‰ and $\delta^{15}N$ ‰ analysis results

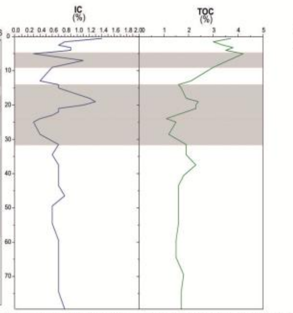

Figure 9. Total organic carbon (%) (TOC) and inorganic carbon content (%) (TIC)

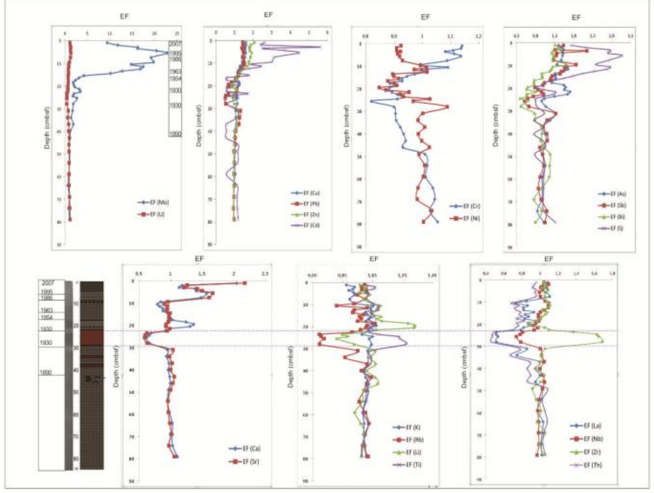

Figure 11. Enrichment factors (EF) of elements plotted against depth.

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