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Shedding light on the past

A.P.J. Stampfl[a,b,*], E.S. Friedman[c], T.J. Wilkinson[c,d], E.E. Alp[b], K.A. Yener[c,d]

[a] *Physics Division, Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW 2234, Australia*
[b] *Experimental Facilities Division, Argonne National Laboratory, Argonne, IL 60439-4856, USA*
[c] *Department of Near Eastern Languages and Civilizations, University of Chicago, IL 60637, USA*
[d] *Oriental Institute, University of Chicago, IL 60637, USA*

Abstract

The Amuq valley in southern Turkey is an important and interesting area in the Near East forming a space-time bridge for archaeologists and scientists to ancient and modern civilizations. The Lake of Antioch which evolved during the mid-late Holocene appears to have been located nearby some of the largest human settlements existing during this period. By documenting the conditions of the lake in time, using classical and modern approaches, the climate and geomorphology of the basin may be reconstructed. Synchrotron X-ray fluorescence measurements were performed on sections of a sedimentary core from the lake, representing an estimated 7500 yr of history. Analysis yielded the distribution of elemental masses spanning Ca to Mo as a function of depth from the surface. We find that the elemental concentrations measured follow a number of distinct patterns that may be related to local geomorphology, climate and human activities.

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1. Introduction

The Amuq valley or plain of Antioch, located in the Hatay province of south central Turkey has been inhabited by humans for some 9000 yr and miraculously, some of the underlying environment and ancient sites have been preserved. The fertile valley is surrounded by mountains and is fed by three rivers. All three rivers have drained into the basin and lake over last 7500 yr leading to a rich sequence of alluvial deposits from the surrounding mountains. Much of mans activities in the area has been buried beneath these alluvial deposits.

Not only a meeting point of civilizations and a fertile agricultural area, the Amanus Mountains to the west and northwest are a source of raw and precious materials which may have been sought by the urban sites in lowland Syria, Anatolia and Mesopotamia. A number of archaeological investigations have been undertaken since 1995 [1] to map out the geomorphology and geo-archaeology of the plain, using both traditional and modern techniques. Preliminary X-ray fluorescence results of the elemental content of a

*Corresponding author. Experimental Facilities Division, Advanced Photon Source, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439-4856, USA. Tel.: +1-630-252-6275; fax: +1-630-252-0161.

E-mail address: stampfl@aps.anl.gov (A.P.J. Stampfl).

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deeply drilled sedimentary core taken from Lake Antioch are presented. The immediate aims are to determine whether any elemental trends may be observed in such cores and to determine whether any trends may be linked to known environmental changes.

2. Experiment

A core from Lake Antioch, its position recorded using the global positioning system as GPS 61, was sampled over its first 5 m of length, corresponding to approximately a 7500 yr span from the present. Sediment was further sampled at 10 cm intervals. Pellets were pressed, using dried and homogenized material from each sample, into $1 \times 0.25\,cm^2$ disks: a pressure of $8\,ton/cm^2$ was applied using a stainless steel die and hydraulic press. Canadian Lake sediment standards, LKSD-1, LKSD-2, LKSD-3, LKSD-4 [2] were also pressed into pellets of the same dimensions. These standards ranged over the elemental concentrations expected at GPS-61 therefore allowing standardized quantification of elemental masses. All pellets were accurately weighed and were found to be approximately 0.5 g each. X-ray fluorescence measurements were made at the Advanced Photon Source, Argonne National Laboratory on bending magnetic line 2-BM [3]. Monochromatic light was delivered to the sample using a double Si crystal configuration. Two excitation energies were used, 10.7 and 32 keV, allowing the K-lines of elements from Ca to Mo to be observed. A Canberra solid state fluorescence Si(Li)-detector was placed at right angles to the incoming X-ray beam. Each sample being placed at 45° to the detector. Up-stream and down-stream slits were adjusted so that a X-ray spot of $1 \times 1\,mm^2$ illuminated the sample. The amount of incoming flux dosed was the same for each pellet and was monitored by an ionization chamber placed just upstream from the sample holder. Good statistics were obtained for each spectrum, whose full widths at half maxima (FWHM) were between 250 and 300 eV, after approximately 6 minutes.

3. Results

To determine elemental masses found in each pellet, spectra were fitted and compared to the fits of standards. Fitting assumed Gaussian broadening for each possible fluorescence line. Backgrounds were estimated using an enhanced version of a non-polynomial algorithm for approximating backgrounds in X-ray spectra [4]. Fig. 1 shows the spectrum taken from sediment found 20 cm below the surface using an excitation energy of 10.7 keV. Gaussian fitting was performed after background subtraction. A number of parameters were optimized for every fit until the value of χ^2 for the spectrum changed by less than 10^{-4} between two successive iterations.

After fitting, peak areas for each line were determined. Certified Canadian lake sediment standards [2] were used to determine the elemental masses found in the core. Fig. 2 shows the copper distribution along the core, which is about half the concentration found in the earth's crust (60 ppm). All other elemental distributions mapped were also comparable to crustal values. Error bars show the statistical variation of our measurements. A third order polynomial may be fitted to the results, which is useful to highlight trends. Interestingly, we find a maximum in the concentrations of Rb, Cu and Zn and a minimum in Ca, Cr and Ni at

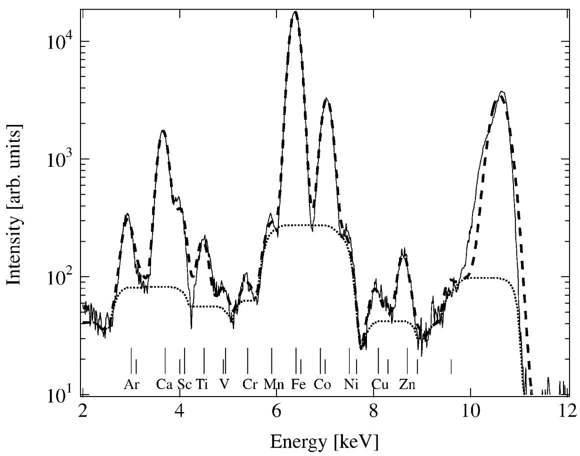

Fig. 1. X-ray fluorescence spectrum (full line) of sediment taken from Lake of Antioch. Fit (dashed line) and background (dotted line) also shown.

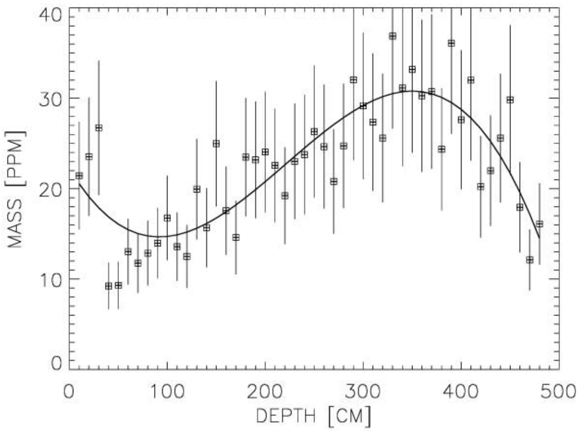

Fig. 2. Copper distribution along the core.

350 cm, where as the opposite is observed for these elements at 100 cm.

3.1. Discussion and conclusions

The chronological sequence of the core was dated radiometrically and with respect to archaeological strata. The derived sedimentation rate was assumed to be constant at 6.7×10^{-4} m/yr, but this value should be regarded as approximate especially when sedimentation decreased to zero at 100–140 cm [5].

The elemental distribution of sediments along the core can reflect the conditions of the lake at the time of deposition [6]. The amount of Rb may be related to the quantity of silt/clay deposited on the lakebed. The high concentration at 350 cm, or 5200 yr before present (BP), indicates the presence of bodies of still water of unknown size whereas the low concentration before 1500 BP (100 cm) indicates a period when soils formed on the lake floor prior to its rapid growth around 1500 BP. These observations are backed up by the opposite behavior observed in Ca. Calcium mainly originates as calcium carbonate, which will tend to remain in solution longer when a lake is full. During arid periods when a lake recedes calcium precipitates within the soil at a faster rate, therefore leading to higher Ca accumulations. The development of the lake corresponds to a period in which the Orontes River increased its flow and to the development of large nucleated settlements [1]. During this period Cu and Zn deposits were at their highest, elements which are associated with metal working and smelting activity. Before 1500 BP, these settlements had dispersed widely into smaller ones located both on the plains and surrounding uplands [7]. This period appears to have been dry (high in Ca) with the lake receding (low in Rb). Copper and Zn deposits are observed to be at their lowest, suggesting a possible decrease in metal working activities. Lastly Cr and Ni deposits which are derived from erosion of the metamorphic belt around the Amanus Mountains, are found to be highest during the dry period and lowest during lake development. The increase of human settlements especially in the upland areas may have contributed to this degradation process.

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