Heritage Turkey volume 1 (2011) pp. 3-5 | doi: http://dx.doi.org/10.18866/biaa2015.002 | published online: 27 October 2015

CLIMATE HISTORY

The environment of Anatolia has been a perennial subject of interest and research for historians of Turkey and the Black Sea region. In the late 19th century, Sir William Ramsay, a founding father of the study of ancient Asia Minor, remarked that the interplay of history and geography was nowhere better studied or appreciated than in Anatolia, and no scholar or researcher who has followed him would seriously contest the point. Climate history has become a particular focus for environmental scientists in the last 20 years, as the dangers and implications of global warming have been widely studied and publically recognised. The British Institute at Ankara accordingly has supported fieldwork in Anatolia extending from the north-east mountain ranges of the Pontic region, to the valleys of the Gediz and Maeander rivers in the west. Pollen coring has been especially productive of information about vegetation and climate history, and Institute researchers have turned repeatedly to the extraordinary data that is recoverable from the sediments of Nar lake in Cappadocia. These are laminated, year by year, providing a precise chronology which extends through the entire Holocene and into the epi-palaeolithic period. The importance of Nar is not only the long perspective that it offers into the earliest period of human occupation in Anatolia, but also the fine chronological differentiation, which makes it possible, in later periods, to suggest important correlations between environmental and historical data.

A history of long-term climatic and cultural change in Cappadocia

Neil Roberts | University of Plymouth

As part of the British Institute at Ankara's Climate History research initiative, we have been carrying out detailed studies at Nar crater lake in Cappadocia to investigate the relationship between changes in climate and the emergence of complex societies in central Anatolia during the Holocene. One of the most significant features of Nar lake is that it is depositing annually laminated – or varved – bottom muds at the present-day, which potentially provide annual dating precision for past climate changes. From earlier lake coring programmes, we already knew that these laminated sediments extended back at least 1,700 years to late Roman times (Jones et al. 2006; England et al. 2008; Eastwood et al. 2009; Woodbridge, Roberts 2011). In summer 2010, with the support of the Institute, we conducted a successful fieldwork programme which recovered longer sediment cores and extended our record much further back in time. In the last 12 months, we have started laboratory analysis of the new core samples with encouraging results, and also conducted short field seasons in June and September 2011 as part of our on-going monitoring studies at the site.

Laboratory analysis methods

The new cores were opened, split in two lengthways, described and photographed in September 2010, with one half being kept as an archive. Based on these sources we spliced together the 'best' sections from three parallel cores to create a master sequence 21.69m long. Using visible changes in sediment stratigraphy, seven major 'units' have been identified (see figure on next page), four of which are finely laminated, and with a fifth (unit 3) comprising mainly thick laminations which may not be annual in origin. Finely laminated sediments are recorded almost all the way to the base of the sequence, amounting to about 14m thickness in total, or about two-thirds of the master sequence.

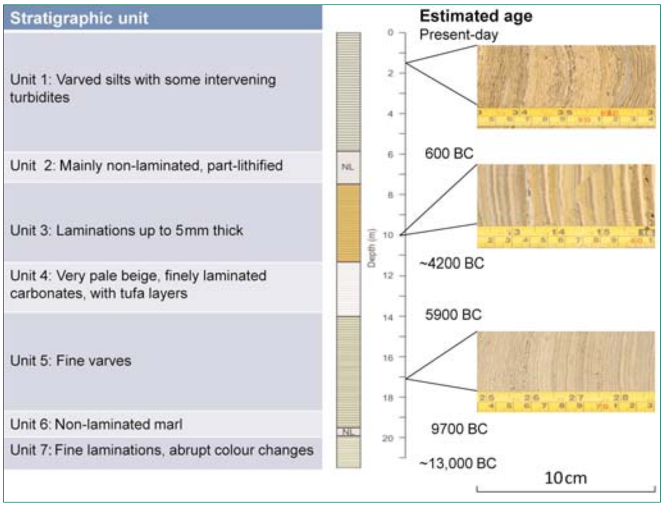
Before sub-sampling of the cores began, the master sequence half-cores were taken to the Itrax scanning facility at Aberystwyth University in Wales. This is a non-destructive technique which uses XRF-scanning to derive the chemical composition of the sediments. Where sediments are laminated, techniques such as Itrax scanning can permit reconstructions of climate variability at high (i.e. sub-annual to decadal) resolution. The Nar10 master sequence half-cores were measured at 200µm resolution – that is, five measurements per mm! This took almost three weeks of more or less continuous operation in November 2010 and will be a key source of data for Plymouth research student Samantha Allcock in her PhD. Using enlarged photographs as an aid, the core laminations were then counted to work out the time duration represented by different sediment layers.

With this information available, core sub-sampling took place between December 2010 and February 2011. Where possible, three consecutive varves were sampled from the cores every 20 varve layers (i.e. every 20 years), starting at 320cm (1,261 years ago) to allow an overlap with previously studied cores, which stopped at 1,720 years BP. Samples were taken from the new cores for stable isotopes (carbon and oxygen on carbonates, plus biogenic silica and cellulose), organic and inorganic carbon content, pollen, diatoms, pigments and other analyses. Samples were also taken from selected points for dating by Uranium-Thorium and Radium-226 radio-isotopes; radiocarbon dating is not being used because of a serious problem of volcanic out-gassing into the lake which makes the ages too old. Altogether this amounted to over 3,000 samples from over 500 sampling depths in the cores! Preliminary work has also begun on resin-embedding 'chips' of sediment from the cores to have a permanent record of the varves and to allow thin sections to be made for microscope analysis.

First results

As can be seen in the figure on the right, there are several important changes in sediment stratigraphy through the sequence, including a change in sediment type at around 19.77m which appears to mark the start of the Holocene. The bottom ~2m of the core therefore dates to the Late Glacial period, corresponding archaeologically to Epi-Palaeolithic times. Overall we estimate that the Nar10 core sequence covers about the last 15,000 years. Varve counting is allowing us to make more precise estimates of the age of different parts of the core. Varves are present continuously from the top of the cores down to 5.92m which has a varve count age of 600 BC. The underlying sediment of unit 2 is often very hard and mostly non-laminated, but laminations appear again below this sediment unit. Varve counts for these lower layers are therefore 'free-floating' in time until we can pin them using other dating methods. One point at which we can pin them is at the start of the Holocene, whose age is well-known from Greenland ice cores and tree-rings, at around 9700 BC. Varve counting up from this datum has given us the provisional ages for the core that are shown in the figure.

To date, we have started study of three main 'proxies' for environmental change, namely, stable isotopes, diatoms, and sediment chemistry and composition. Carbon and oxygen isotope analysis of lake calcite/aragonite is being carried out at the NERC Isotope Geosciences Laboratory by Nottingham PhD student Jonathan Dean, alongside Matt Jones and Melanie Leng. Preliminary results show a sharp isotopic change at 19.77m, confirming that this represents the boundary between the Younger Dryas cold, dry climate stage and the warmer, wetter early Holocene. The isotope record from Nar lake appears to mirror quite closely isotopic changes in other lakes in central and southwestern Turkey (Roberts et al. 2001; Eastwood et al. 2007), which implies that they have experienced similar climate histories. An initial study of the diatom algae has been completed by Plymouth MSc student Gregory Busby (2011). Diatoms are well-preserved throughout the core sequence, and indicate important fluctuations in lake water level and salinity, as the balance between rainfall and evaporation has shifted over time. They confirm the oxygen-isotope signal for wetter climatic conditions during Neolithic times and a series of drought phases during the Bronze Age. Finally, the Itrax-



Nar10 lake core composite sequence showing major sediment units, estimated ages and examples of three different laminated sediment types

XRF geochemistry is providing information about year-to-year climate variability, and consequently how reliable rainfall has been at different times in the past. It is also telling us about erosion from the catchment into the lake. As can be seen in the photo below right, some of the terrain south of the lake is actively eroding from the kind of badland typical of Cappadocia, along with 'fairy chimneys' etc. The Itrax results from Nar show that chemical elements associated with erosion, like iron and titanium, have increased dramatically in recent millennia, as a result of human vegetation clearance and land use, climate change, or both. Our Nar data are therefore likely to provide some of the first hard evidence about the age of Cappadocia's badlands.

Fieldwork

A short field visit took place in June 2011, involving Neil Roberts, Warren Eastwood and Hakan Yiğitbaşıoğlu, and another with Samantha Allcock, Jonathan Dean and Ersin Ateş in September 2011. These field visits form part of the project's long-term monitoring of Nar lake, in order to understand how the lake responds to seasonal changes in weather and climate. We undertook measurements and collected water samples at different depths in the lake, recovered and replaced *Tinytag* temperature data loggers and sediment traps. The data loggers are left in the middle of the lake at a series of depths in order to measure the water temperature every 20 minutes, and they reveal how lake temperatures change over the course of the year. In particular they have shown how the thermocline (or divide between warm upper waters and cold lower lake water) lasts for most of the year, but disappears for the three winter months when the whole lake is well-mixed. This cycle in turn is controlled by seasonal warming and cooling of the air temperature. As part of our outreach work, we also left a basic weather station at Nar köy school, for the pupils to take weather readings over the coming year.

It was noted in last year's report (*Anatolian Archaeology* 16) that the future of Nar lake is somewhat uncertain. It has been designated as a protected site by the Turkish Ministry of Environment and Forests, so that building development is prohibited within 150m of the lake edge. However, a geothermal spa hotel (Narlıgöl Otel) has been built at the crater entrance and is now open, with a second, even larger hotel under construction on the other side of the entrance road. To add further complication, the former is in Niğde province, the latter in Aksaray province! Groundwater for the Narlıgöl Otel derives from two boreholes, ~100m and ~250m deep, at a temperature of 67°C under artesian pressure. It is obviously important that these and other developments do not adversely affect the lake itself, which is a site of rather unique scientific and historical importance.

Occupation history of Cappadocia

In addition to establishing a well-dated climate record for central Anatolia, 'longue-durée' archaeological and historical records of human settlement are being investigated in order for climate-culture relations to be better understood. Cappadocia contains an oft-visited archaeological heritage ranging from Neolithic villages to rock-cut Byzantine churches. In order to put these archaeological data in a synthetic form, Samantha Allcock (with the aid of a BIAA study grant) spent September 2011 based at the Institute in Ankara. She is working alongside Institute Scholar Michele Massa who has been compiling archaeological site distributions by period from the Neolithic to the Iron Age into a GIS database (see Michele's report below, page 39). These data derive from several sources, but especially from Ian Todd's archaeological survey carried out in the 1960s (Todd 1980), and which is being prepared for publication by Geoffrey Summers.

As part of her PhD project, Samantha is exploring culture/climate interactions via themes such as resilience, vulnerability and adaptability in order to establish how people may have responded to, and interacted with, variations in climate over different timescales. Particular attention is being given to periods of stability and instability in climate and how these periods were experienced by societies with different social structures. Documenting artefact variability and regional settlement patterns using the archaeological survey record can provide details of past human coping mechanisms and indicate forms of adaptable behaviour. A good example is the increase in storage facilities and élite control over food resources as a strategy for combating 'unstable' years.

Acknowledgements

In addition to the BIAA, this British-Turkish-French co-project has been supported in 2011 by NERC via NIGSFC grant IP/968/0507 to Matthew Jones (stable isotope analysis) and a research studentship to Jonathan Dean, and by a Plymouth University research studentship to Samantha Allcock.

Bibliography

Busby, G. 2011: *Diatoms as a Record of Holocene Climate Change in the Mediterranean using Cores from Nar Crater Lake, Turkey*. MSc dissertation, University of Plymouth

Eastwood, W.J., Leng, M.J., Roberts, N., Davis, B. 2007: 'Holocene climate change in the eastern Mediterranean region: a comparison of stable isotope and pollen data from Lake Gölhisar, southwest Turkey' *Journal of Quaternary Science* 22: 327–41

Eastwood, W.J., Gümüşçü, O., Yiğitbaşıoğlu, H., Haldon, J.F., England, A. 2009: 'Integrating palaeoecological and archaeo-historical records: land use and landscape change in Cappadocia (central Turkey) since late antiquity' in T. Vorderstrasse, J. Roodenberg (eds), *Archaeology of the Countryside in Medieval Anatolia* (PIHANS 113). Leiden: 45–69

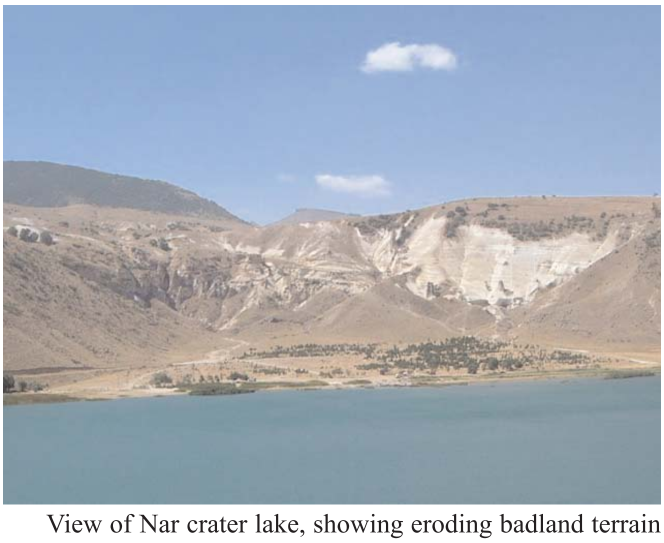
England, A., Eastwood, W.J., Roberts, C.N., Turner, R., Haldon, J.F. 2008: 'Historical landscape change in Cappadocia (central Turkey): a palaeoecological investigation of annually-laminated sediments from Nar lake' *The Holocene* 18: 1229–245

Jones, M.D., Roberts, N., Leng, M.J., Türkeş, M. 2006: 'A high-resolution late Holocene lake isotope record from Turkey and links to North Atlantic and monsoon climate' *Geology* 34.5: 361–64

Roberts, N. et al. 2001: 'The tempo of Holocene climatic change in the eastern Mediterranean region: new high-resolution crater-lake sediment data from central Turkey' *The Holocene* 11: 721–36

Todd, I.A. 1980: *The Prehistory of Central Anatolia* I: *The Neolithic Period*. Göteborg

Woodbridge, J., Roberts, N. 2011: 'Late Holocene climate of the eastern Mediterranean inferred from diatom analysis of annually-laminated lake sediments' *Quaternary Science Reviews* [doi:10.1016/j.quascirev.2011.08.013]



View of Nar crater lake, showing eroding badland terrain (light coloured) in its catchment