CLIMATE CHANGES & THE ENVIRONMENT

As environmental issues become an increasingly acute concern worldwide, Turkey is a country of prime interest in the field of climate studies. Due to its location, it presents an ideal opportunity for exploring and understanding climate development and the history of global environmental change within the context of contemporary international relations. Lake sediments, tree-rings, speleothems and peat deposits represent valuable natural 'archives' of environmental change which have been under-explored in both Turkey and the wider Black Sea region. This programme of research into the vegetation and climate history of the region focuses on changes in vegetation, water resources, landscape stability and hazards in Turkey, the Black Sea area and much of the wider Middle East over time. It also provides a key context of interaction concerning human use of the landscape from prehistory to the present day.

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Pleistocene environments of the Gediz valley

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Our field area lies within the Kula Volcanic UNESCO Global GeoPark, which, as the name suggests, is a landscape dominated by classical scoria cones and their associated lava flows formed during episodic periods of volcanism during the past 1.4 million years (Ma). Traversing this volcanic field is the Gediz river which has been repeatedly dammed and diverted during these volcanic episodes. The sedimentary archive of the Gediz river has been a focus of our research for nearly 20 years, but our latest project concerns a different part of this hydrological system, namely freshwater springs where emergent calcium-carbonate-rich waters have precipitated extensive travertine deposits. This study is focused on determining the origins of these deposits, especially their association with the volcanism and faulting (neotectonics), and specifically whether their geochemistry can divulge insights into past environmental changes.

During the past year we received our first batch of detailed geochemical analyses of carbonate samples taken during our first field season (2017). These included Miocene lake sediment (Ulubey Formation limestones) together with travertines and calcretes (soil carbonates) both of presumed Plio-Pleistocene age. Our analysis comprised elemental chemistry (using XRF methods) and isotopic analyses. The primary aim of this work was to establish whether each of the carbonate sources could be discriminated based upon their geochemistry, as these deposits are difficult to separate when observed at outcrop. Commercial exploitation of the travertine at Palankaya disputes their mapped assignment to the Ulubey Formation and thus this casts doubt on the mapping elsewhere.

Isotopic analysis of 106 samples suggests a general pattern for $\delta^{13}C$, where the travertines are generally heavier than the Ulubey samples and the calcretes are considerably lighter. A similar, but reversed pattern, is shown for the $\delta^{18}O$ data; i.e. the travertines are the lightest, the Ulubey is slightly heavier on average and the calcrete heavier still. Outliers in each of these groupings blur the general picture however, but the suggested discrimination is promising. The observed pattern is consistent with a thermogenic (warm-water) source for the travertines suggesting rainwater (meteoric) is mixed with waters from deep within the crust, heated and chemically altered during the volcanic episodes. The data also show stratigraphical changes during deposition, but more detailed analysis is needed to establish their meaning.

Our 2018 fieldwork concentrated on further sampling for geochemical analysis and more extensive field observation. Specifically, field observations included detailed travertine facies mapping at outcrop (to determine the architectural elements of the travertine deposits; i.e. how the deposits built up over time) and landform mapping using low-altitude UAV-based ('drone') aerial photography. The travertines were subdivided into sheets, mounds and ridges and, for specific examples, their geometry was accurately positioned and measured. In addition, we examined the casts of plant remains in order to establish the palaeoecology of the cooler and terrestrial peripheral zones of travertine deposition. Samples were also taken for scanning electron micrography to examine their micro character and possible genesis.

UAV aerial photograph of the large Palankaya quarry (higher level) and the adjacent lower mound with clear central feeder. Insets show us preparing for the UAV flight (left) and a detailed fracture (right) within the travertine, infilled with palaeosol material. The Gediz river can be seen at the top left of the picture.

The travertines are the results of carbonate precipitation along spring lines, many of which are positioned along structural fractures in the underlying bedrock. The oldest travertines show clear evidence of contemporaneous (syndepositional and post-depositional) faulting. Some of these movements lie along pre-existing (exhumed) faults, but there is also evidence for new faults, suggesting comparatively recent crustal movement that creates, and reactivates existing, fractures. Detailed analysis of these observations is underway, and their implications will be critical in establishing patterns of recent crustal movement (neotectonics). These movements, which are most likely related to the volcanic episodes, are significant not only for travertine formation but also for our wider study of the Gediz river archive.

Observing these patterns is important, but establishing a geochronology for events is critical to our understanding. Significantly, any new geochronology can be compared directly with our existing Ar-Ar chronologies from the lava flows (see Maddy et al. 2017: ‘The Gediz river fluvial archive: a benchmark for Quaternary research in western Anatolia’ *Quaternary Science Reviews* 166: 289–306, https://doi.org/10.1016/j.quascirev.2016.07.031). This year we have extracted 60 short cores from several travertine sites for palaeomagnetic measurements. These measurements should provide a coarse geochronology; i.e. magnetically reversed thermoremanent magnetism would indicate a high likelihood of early Pleistocene age (deposition in the Matuyama Chron between 2.6Ma and 0.78Ma), whereas normal field orientation would suggest a younger age (deposition in the Brunhes Chron and thus <0.78Ma). Given the stratigraphy of the sampled travertines and their close association with the early phase of volcanism (1.4Ma–0.99Ma), the expectation is that these samples will yield a reversed field. Our previous attempt to measure palaeomagetism, over ten years ago, at the Palankaya quarry yielded only one unequivocal measurement and that was reversed. Hopefully our new dataset will provide more comprehensive information.

In addition to the palaeomagnetic samples we are also attempting to obtain more precise age estimates directly from the travertine using more experimental techniques. Six travertine sites were sampled with a view to possible U-Pb age estimation. An application to measure these samples will be made via the NERC Isotope Geosciences Laboratory in 2019. Samples have also been sent to the Leibnitz Institute in Hanover, Germany, for possible ESR (electron spin resonance) age estimation, but so far these have failed to yield a useful ESR signal. We also continue to extend our Ar-Ar database, with five new basalt samples submitted to the University of Amsterdam laboratory for Ar-Ar age estimation.

Our database of travertine attributes is slowly growing. Each new dataset provides new insights. Our 2018 programme was very successful in generating new ideas and new hypotheses to explore. We have no reason to suspect that work in 2019 will not do the same.