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Strontium isotope evidence for human mobility in the Neolithic of northern Greece

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ABSTRACT

Strontium isotope ratios are widely used in archaeology to differentiate between local and non-local populations. Herein, strontium isotope ratios of 36 human tooth enamels from seven archaeological sites spanning the Early to Late Neolithic of northern Greece (7th–5th millennia B.C.E.) were analysed with the aim of providing new information relating to the movement of humans across the region. Local bioavailable $^{87}Sr/^{86}Sr$ signals were established using tooth enamel from 26 domestic animals from the same Neolithic sites. $^{87}Sr/^{86}Sr$ values of faunal enamel correlate well with predicted strontium isotope ratios of the local geology. This is consistent with animal management occurring at a local level, although at Late Neolithic sites strontium isotope values became more varied, potentially indicating changing herding practices. The strontium isotope analysis of human tooth enamel likewise suggests limited population movement within the Neolithic of northern Greece. Almost all individuals sampled exhibited $^{87}Sr/^{86}Sr$ values consistent with having spent their early life (during the period of tooth mineralisation) in the local area, although movement could have occurred between isotopically homogeneous areas. The strontium isotope ratios of only three individuals lay outside of the local bioavailable $^{87}Sr/^{86}Sr$ range and these individuals are interpreted as having spent their early lives in a region with a more radiogenic biologically available $^{87}Sr/^{86}Sr$. Mobility patterns determined using Sr isotope analysis supports the current evidence for movement and exchange observed through studies of pottery circulation. Suggesting limited movement in the Early and Middle Neolithic and greater movement in the Late Neolithic.

1. Introduction

The application of strontium isotope analyses to archaeological skeletal remains can provide information regarding the movement of humans and animals by comparing the strontium isotope signature of an individual to the biologically available signature determined by the surrounding biosphere (Bentley, 2006). Given suitable variation in the biologically available signatures in a region, strontium isotope ratios are able to differentiate between local and non-local populations. This can be used as complementary evidence to that obtained from the traded and exchanged goods, identified through material cultural remains, which together can provide a record of movement and exchange networks across a region. Strontium isotope analyses have thus been widely utilised to explore the mobility of early Hominins (Balter et al., 2012), Pliocene mammals (Hoppe et al., 1999), Neanderthal populations (Britton et al., 2011) and Pre-historic human and animal mobility (Grupe et al., 1997; Viner et al., 2010; Bentley, 2013; Boric and Price, 2013; Giblin et al., 2013; Gerling, 2015; Henton et al., 2017).

Evidence for movement and exchange has been identified in the Greek Neolithic from the movement of material culture, including pottery, stone tools and shell ornaments. The study of fine-decorated pottery assemblages has shown that the circulation of pottery in northern Greece was very limited (Pentedeka, 2011; Urem-Kotsou et al., 2014). Due to the low amount of pottery found in the Early Neolithic (EN) it is difficult to ascertain if exchanges of pottery took place (Perlès and Vitelli, 1999). However, indications of pottery exchange, in the form of imported pottery is found in the Middle Neolithic (MN) where stylistic developments were shared, and small-scale

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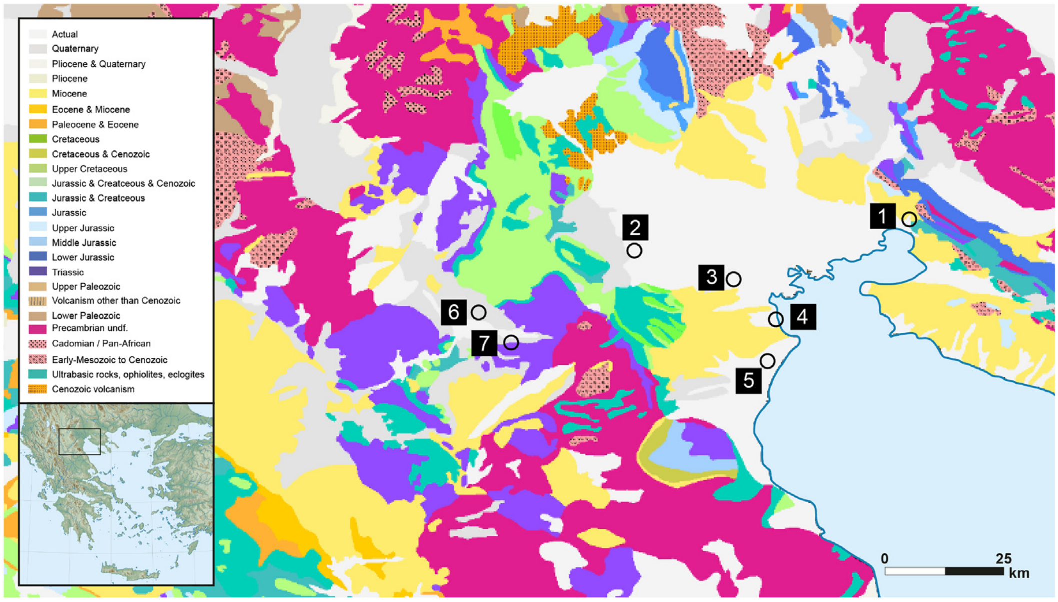

Fig. 1. Geological map of the study area with the location of settlements. 1. Stavroupoli (LN), 2. Nea Nikomedeia (EN), 3. Paliambela (MN), 4. Makriyalos (LN), 5. Revenia (EN), 6. Kleitos (LN), 7. Toumba Kremastis Koiladas (LN) (base map from US Geological survey 1:1.5M world geology map, 2017).

exchanges took place (Perlès and Vitelli, 1999; Pentedeka, 2011; Urem-Kotsou et al., 2014). Analogous traits between vessel technology, shapes and cultural styles infers networks of communication and exchange operational on regional and inter-regional levels at this time (Çilingiroglu, 2010; Dimoula et al., 2014; Urem-Kotsou et al., 2016). Analysis of lithics from across the period have shown that stone tools were produced in the vicinity, from locally sourced raw materials (Perlès and Vitelli, 1999; Pentedeka, 2011). In the Late Neolithic (LN), common pottery wares (black burnished and red slipped) are widespread, thus making it difficult to determine if the pots are locally produced or exchanged (Perlès and Vitelli, 1999). Widespread distribution of materials with limited production sites, such as obsidian, flint and jasper have been identified in the LN (Perlès and Vitelli, 1999; Milić, 2014) as have the movement of stone and spondylus shell ornaments, which circulated over large distances (Pentedeka, 2011; Veropoulidou, 2014). This demonstrates contact between human groups, however, given the small sample size and the number of sites and locations, any suggestion of diachronic change should arguably be made more cautiously. In contrast, $^{87}Sr/^{86}Sr$ values from human and animal teeth can be used to infer mobility over longer distances.

Thus far, the use of strontium isotope ratios to identify mobility during the Neolithic of Greece has been restricted to Crete. This small scale study demonstrated that mobility in Crete during the Neolithic was limited or that movements occurred between areas of homogenous underlying geology (Triantaphyllou et al., 2015). To date, no isotopic studies have been conducted on other Neolithic Greek assemblages and aside from movements identified through material culture (Perlès, 2001; Urem-Kotsou et al., 2014; Triantaphyllou et al., 2015) little is known about human mobility in northern Greece. A greater number of mobility studies using strontium isotope ratios have been conducted on Bronze Age tooth enamel and modern reference material from sites situated in the southern Greek mainland and Crete (Nafplioti, 2008; Nafplioti, 2009, 2011). Consequently, this study of strontium isotope analysis on human tooth enamel aims to shed light on the extent of mobility throughout the Neolithic of northern Greece.

The study area in the central and western regions of Greek Macedonia comprises fertile basins separated by mountain ranges. Three broad NE-SW trending geographical ranges give rise to three geological zones bounded by faults which share a common history of deposition and formation (Higgins and Higgins, 1996). The western Pelagonian zone, comprising Triassic and Jurassic limestones and marbles deposited over gneiss. The central Vardar zone, once part of the Tethys Ocean, is made up of Mesozoic deep-water sedimentary and ophiolites, occasionally overlain by limestone and Eocene sediments. The eastern Serbo-Macedonian massif is dominated by metamorphic and plutonic rocks uplifted and faulted by Alpine compressions (Higgins and Higgins, 1996).

Strontium isotope analyses were performed on 36 human tooth enamels from seven archaeological sites spanning the Early to Late Neolithic of northern Greece (Fig. 1). The sites in this study were chosen to chronologically span a large period of the Neolithic and, in addition, cover a range of geographical environments and terrains from coastal to inland locations and fertile basins to mountainous localities (Fig. 1). This allowed temporal study of mobility and comparisons between settlements which are in geographically close proximity with those that are spatially apart. The majority of the human remains studied comprise single burials with minimal grave goods located within the settlements (Triantaphyllou, 2001; Bessios et al., 2005; Triantaphyllou, 2008; Ziota et al., 2013). However, at two of the study sites, Stavroupoli and Toumba Kremastis Koiladas, human burials comprise disarticulated remains and articulated burials are rare (Chondrogianni-Metoki, 2001; Triantaphyllou, 2002, 2004, 2008); at Toumba Kremastis Koiladas many of the dead were cremated (Chondrogianni-Metoki, 2009).

Given the complexity of the regional geology, it is difficult to accurately predict the bioavailable $^{87}Sr/^{86}Sr$ values in the vegetation local to each Neolithic site. For LN Makriyalos, values estimated from modern vegetation (of deep-rooted trees and ground vegetation, n = 20), collected from within 15 km of the archaeological site and determined by Vaiglova et al., 2018, were used for this purpose. These values are also extended to and combined with the information from geographically and geologically similar sites of Revenia and Paliambela to establish a local $^{87}Sr/^{86}Sr$ ratio. For six other sites, bioavailable $^{87}Sr/^{86}Sr$ values were estimated from tooth enamel from archaeological specimens of domestic animals recovered by excavation. Cattle were excluded as they have been shown to be herded over long distances through-out Europe during the Neolithic (Knipper, 2009; Towers et al., 2010; Viner et al., 2010; Sjögren and Price, 2013; Gerling et al., 2017). For this reason, teeth of sheep, goats and pigs were selected where possible for the estimation of locally bioavailable Sr values. There is a