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The lay of land: Strontium isotope variability in the dietary catchment of the Late Iron Age proto-urban settlement of Basel-Gasfabrik, Switzerland

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ABSTRACT

Basel-Gasfabrik (Switzerland) comprises an extensive La Tène (chiefly Lt D, 150–80 BCE) settlement and two associated cemeteries at which strontium ($^{87}Sr/^{86}Sr$) isotope analysis of human and animal teeth investigated regional and supra-regional contacts. The interpretation of the analytic data, however, requires information on the isotopic baseline values around the site. Using 102 modern vegetation and 9 water samples from 51 localities, this study characterizes the isotopic ratios of the biologically available strontium of geological units and watercourses around Basel and compares these to 28 human infant, 6 pig, and 5 dog teeth from the site. Furthermore, pedological criteria evaluate the suitability of landforms for crop and pasturelands. The $^{87}Sr/^{86}Sr$ ratios of the environmental samples from geological units in up to 50 km distance varied between 0.70776 and 0.71794. Human infant teeth exhibited much more homogeneous $^{87}Sr/^{86}Sr$ ratios (0.70847–0.70950), which coincided largely with those of potential arable soils around Basel and indicate targeted exploitation of landscapes for agriculture. The more variable values of the faunal teeth suggest more widely ranging habitats or imports from the site's hinterlands. Two local isotope ranges were defined based on archaeological enamel samples and modern vegetation data from a confined radius around Basel. The study documents the complexity of distinguishing local and non-local individuals in a geologically heterogeneous region as well as the potential of isotope analyses to explore prehistoric land-use patterns.

1. Introduction

Strontium isotope ratios ($^{87}Sr/^{86}Sr$) are widely used to investigate mobility and migration in (pre-) historic communities (e.g. Chenery et al., 2010; Knipper et al., 2012; Neil et al., 2016; Nehlich et al., 2009), the origin of single human individuals and animals (e.g. Alt et al., 2013; Müller et al., 2003; Lamb et al., 2014; Tütken et al., 2004) or animal husbandry and land-use around settlements (e.g. Knipper, 2011; Stephan et al., 2012; van der Jagt et al., 2012). Strontium is a trace element, which commonly occurs in rocks (Bentley, 2006). It has four stable isotopes, of which the radiogenic isotope ^{87}Sr results from β-decay of ^{87}Rb (rubidium). Depending on the original rubidium content and the age of bedrock formations, the relative amount of ^{87}Sr varies among geological units, which is expressed as $^{87}Sr/^{86}Sr$ ratios. Due to weathering, strontium is released into the soil and ground water. From there it is biologically available, meaning that it can be taken up by plants and transported along food chains with very little isotopic fractionation. In humans and animals, strontium substitutes for calcium in the biogenic hard tissues of teeth and bones. While bones are constantly remodelled and also fairly prone to postdepositional alteration of the

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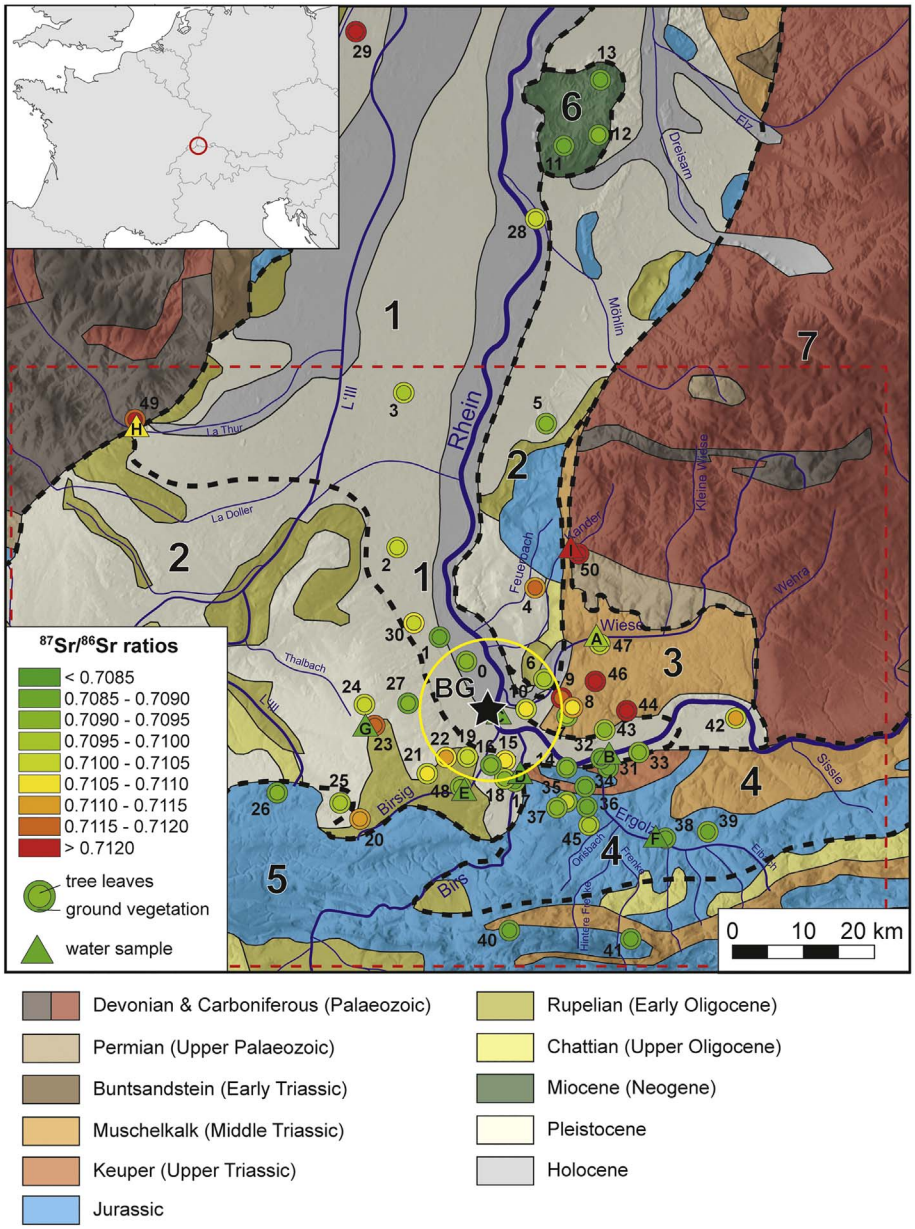

Fig. 1. General map of the geology of the Upper Rhine Valley with landscapes: 1) Upper Rhine Valley; 2) Sundgau hill country; 3) Table and hill country; 4) Table Jura; 5) Folded Jura; 6) Kaiserstuhl (KS); 7) Low mountain ranges (Vosges and Black Forest; LMR). $^{87}Sr/^{86}Sr$ ratios of the modern vegetation and water samples are indicated by the symbol colour. The red bordered box indicates the map section enlarged in Fig. 2. Yellow circle: 7 km radius around the site. Geological map after Röhr, 2006 (modified).

chemical composition (e.g. Budd et al., 2000; Trickett et al., 2003), the isotopic composition of tooth enamel goes back to the age of dental formation. Provided that humans or animals lived on local resources, the $^{87}Sr/^{86}Sr$ ratios of their tooth enamel reflect the habitat in which they grew up, and are thus a key to the identification of non-local individuals. This, however, requires a profound characterisation of the isotope composition of the biologically available strontium at the site where their remains were found.

The strontium isotope study was carried out on human teeth from the Late Iron Age settlement of Basel-Gasfabrik and its cemeteries (Knipper et al., in review). Basel-Gasfabrik is situated in north-western Switzerland on the left bank of the Rhine River (Figs. 1 and 2). Since 1911, numerous excavations revealed an unfortified settlement with domestic and economic structures covering an area of about 150,000 m^2 (Hecht and Niederhäuser, 2011) as well as two associated cemeteries with about 170 inhumation burials. Additionally, complete skeletons in settlement features such as pits and wells along with hundreds of isolated human bones scattered throughout the settlement reflect a highly diverse and complex treatment of the dead (Pichler et al., 2013; Pichler et al., 2015; Rissanen et al., 2013). Settlement and cemeteries were in use during the La Tène period (200/150–80 BCE). Millstone fragments of *Rotliegend* breccia and certain ceramic wares can be linked with neighbouring areas (Black Forest, Swiss Jura Mountains), whereas amphorae, *Campana* and other imports document Mediterranean contacts (Blöck et al., 2014). Furthermore, bioarchaeological data suggest imports of cereals, meat or animals on the hoof from the hinterland (Knipper et al., 2017; Kühn and Iseli, 2008; Stopp, 2008) and thus show close contacts to the surrounding countryside (Swiss Jura Mountains, Sundgau, Upper Rhine Valley, Vosges and Black Forest).

Strontium and oxygen isotope analyses on enamel of burials in the cemeteries and human remains from settlement features aimed at disclosing whether these (bio-) archaeologically indicated contacts of the Basel-Gasfabrik community were also reflected in residential moves (Knipper et al., in review). However, the interpretation of the analytic data requires the characterisation of the isotopic baseline values of the investigated elements in the potentially exploited habitats. This study, therefore, presents strontium isotope data of modern vegetation and water samples from the prevailing geological units in up to 50 km distance from the site. Moreover, we discuss the suitability of strontium