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Historical continuity in Sonoran Desert free-range ranching practices: Carbon, oxygen, and strontium isotope evidence from two 18th-century missions

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ABSTRACT

Carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$), and strontium ($^{87}Sr/^{86}Sr$) isotopes from cattle, caprine, and small mammal teeth from two historic-period Spanish missions, and modern cattle, were assayed with the goal of reconstructing historic ranching practices in the Sonoran Desert of southwestern North America. $\delta^{13}C$ values from modern cattle indicates it is possible to distinguish cattle free-ranged within upper elevation desert habitats (−11.9 to −7.8‰) from lower elevations or possibly foddered animals (−2.5 to 0.8‰). It is not possible to distinguish maize-foddering versus low elevation free-ranging of livestock in the Sonoran Desert; however, the data indicates free-ranging occurred in both upland and lowland ecosystems, with some animals exhibiting evidence of a mixed upland/lowland strategy. $\delta^{18}O$ values in mission livestock (−3.0 to 2.5‰) overlap with modern cattle (−3.1 to −0.1‰) watered from evaporated reservoirs, suggesting missions managed water for livestock, and livestock were likely kept away from riparian zones. $^{87}Sr/^{86}Sr$ results demonstrate that livestock were moved, likely through trade, some coming from a minimum distance of 40 km. Taken together these results are consistent with continuity in Sonoran Desert free-ranged herd management from the historic era to present. These results also point to continuity in water management strategies extending well prior to the colonial period.

1. Introduction

Eurasian domesticated animals were introduced to the borderlands region of the North American Southwest by Spanish missionaries in the 17th century. These livestock formed the economic foundation for European colonization in the Pimería Alta, encompassing present-day southern Arizona (U.S.) and northern Sonora (Mexico) and including the ancestral land of the O'odham people (Pavao-Zuckerman, 2011; Radding, 1997; Sheridan, 1988). The introduction of livestock was not without significant effects on human populations, land, and water—the latter a particularly scarce commodity in the desert. Native people quickly understood the threat that livestock posed to drinking water and riparian zones (Radding, 1997), and frequently voiced concerns that the animals fouled water needed for human consumption.

Livestock, however, were an attractive resource in an ecosystem with low densities of large mammals. Archaeological and documentary evidence indicates that livestock herds were well established at most Pimería Alta missions by the mid- to late-18th century. Ranching became the dominant economic activity of missionized Native Americans (Pavao-Zuckerman, 2011; Pavao-Zuckerman and LaMotta, 2007). The broad arc of ranching history is known, but the details of ranching practices are not (Pavao-Zuckerman, 2008). Historical documents rarely address how water, food, and land resources were managed to serve both livestock and human needs. This information, however, is accessible through the archaeological record.

Isotopic analyses of zooarchaeological remains, in particular, allow a level of behavioral visibility that is not possible through the documentary record or traditional zooarchaeological methods. Carbon ($\delta^{13}C$) isotopes are useful for reconstructing the diet of livestock, particularly whether animals were free-ranged or foddered (e.g. Makarewicz and Tuross, 2006, 2012; Pearson et al., 2007; Pechenkina et al., 2005). Oxygen isotopes ($\delta^{18}O$) may illuminate how water resources were managed for livestock use (e.g. Bocherens et al., 2001). Strontium ($^{87}Sr/^{86}Sr$) isotopes have wide applicability in archaeological research (Bentley, 2006), and the literature has seen a steady increase in zooarchaeological applications over the past decade. Analyses utilizing $^{87}Sr/^{86}Sr$ ratios can identify non-local individuals, illuminate husbandry practices, and the movement of livestock (e.g. Balasse et al., 2002; Bendrey et al., 2009; Grimstead et al., 2014; Knudson et al., 2012; Shaw et al., 2009). For example, among the Inka of the Andean Late Horizon (ca. CE 1400–1532), $^{87}Sr/^{86}Sr$ ratio analyses indicate that both local and non-local camelids were consumed during feasting events, with the latter likely serving an integrative function

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throughout the Inca Empire's regional territory (Knudson et al., 2012). In another example, Britton et al. (2011) sequentially sampled Middle Paleolithic reindeer (*Rangifer tarandus*) and bison (cf. *Bison priscus*) teeth from Jonzac, France in order to reconstruct seasonal migratory behaviors. They found that reindeer migrated seasonally and displayed philopatry during these movements, while bison did not display $^{87}Sr/^{86}Sr$ ratio variability, indicating non-migratory behavior (Britton et al., 2011). These data support a Neanderthal hunting strategy where reindeer were hunted during the same seasonal time period, and perhaps from the same philopatric migratory herd.

These studies, along with many others (e.g. Dufour et al., 2007; Pellegrini et al., 2008; Thornton, 2011) support the premise that $^{87}Sr/^{86}Sr$ analyses in domesticated historic mission period livestock may provide a means for reconstructing colonial period land-use practices, environmental impacts, and the role of Native labor at missions. Foddering and the production of food for livestock consumption is more labor intensive than free-range ranching, and missionized Native peoples were the primary source of labor at the Spanish colonial missions. Free-ranged livestock, however, can have far-reaching environmental effects, posing a risk to grazing lands, water, and agriculture,

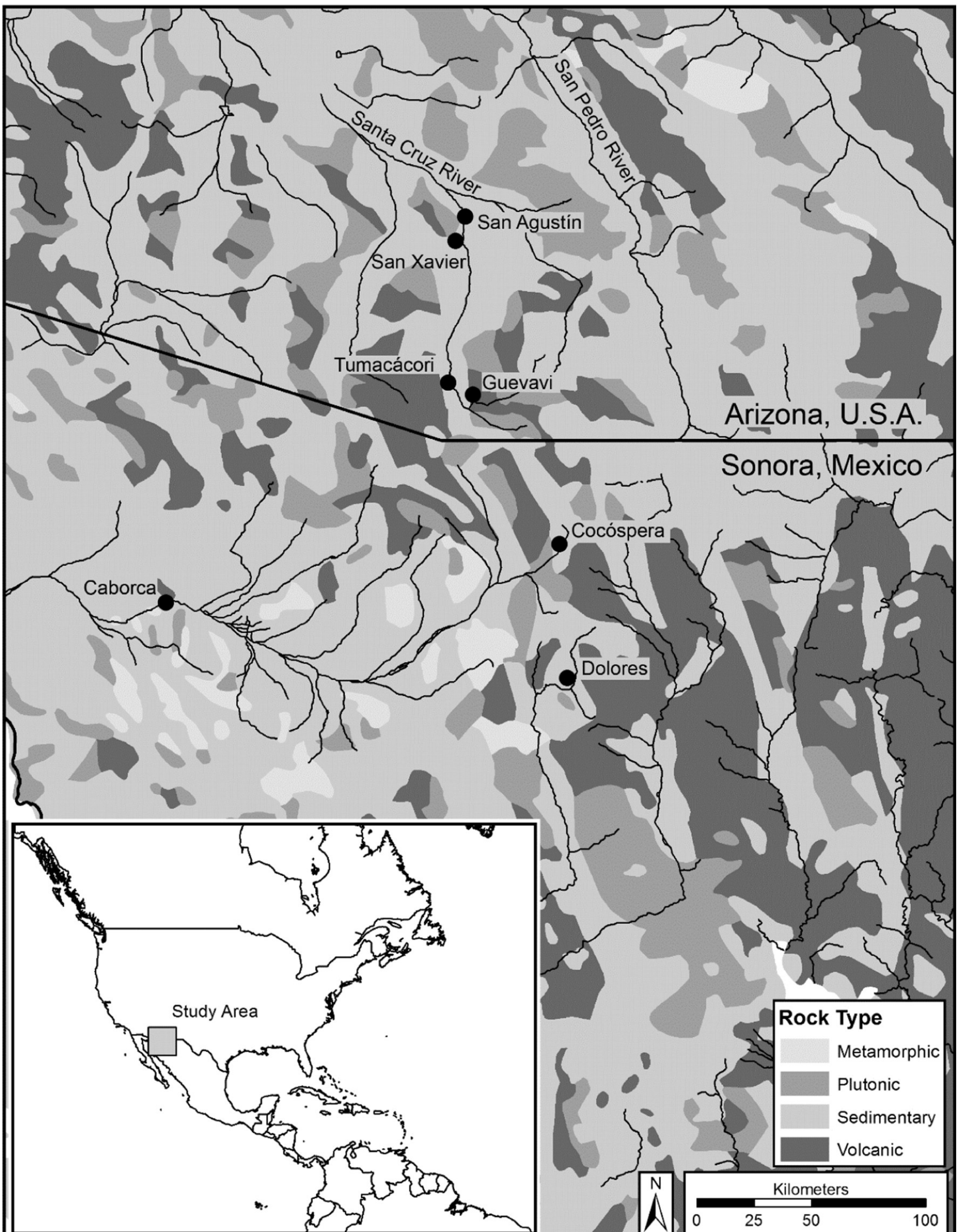

Fig. 1. Map of the study region showing geological rock type and location of sites named in the text. Map prepared by Aaron Comstock.