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Late-Holocene fossil rodent middens from the Arica region of northernmost Chile

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Abstract

Identification of >40 taxa of plant macrofossils in 14 rodent (*Abrocoma*) middens collected from 2800 to 3590 m elevation at the latitude of Arica, Chile (18°S) provide snapshots of vegetation in the northernmost Atacama Desert over the past 3000 years. Midden floras show considerable stability throughout the late Holocene, which may be due in part to the broad elevational ranges of many perennial species and midden insensitivity to changes in plant community structure. The greatest variability is found in annuals in the Prepuna, a climatically sensitive zone. This variability, however might also arise from the brevity of midden depositional episodes. As the first midden record from the Arica–Parinacota Region (Chile's northernmost administrative region), this study demonstrates the potential for future midden research in this area.

Keywords: Atacama Desert; Holocene; Paleovegetation; Rodent middens

1. Introduction

Plant macrofossils preserved in rodent middens have proven a valuable source of late Quaternary paleoecological and paleoclimatological evidence in arid and semi-arid regions of the Western Hemisphere and other parts of the world (Betancourt, 2004; Betancourt and Saavedra, 2002; Betancourt et al., 1990; Pearson and Betancourt, 2002). During the past decade, much of the focus has been on developing the midden record from the Pacific slope of the central Andes (16–26°S) just above hyperarid core of the Atacama Desert in southern Peru and northern Chile (Betancourt et al., 2000; Holmgren et al., 2001; Latorre et al., 2002, 2003, 2005, 2006; Maldonado et al., 2005). These studies have been pivotal in chronicling past pluvial events when plant distributions were displaced up to 1000 m in elevation, with the midden assemblages able to resolve both the seasonality and amount of precipitation. As in North America, hundreds of radiocarbon-dated and

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archived middens from the Atacama are now being mined for a variety of studies (e.g., Kuch et al., 2002). Here, we report on plant macrofossil assemblages spanning the last 3200 yr BP from 14 fossil rodent middens collected in the Andean Precordillera east of Arica, Chile, not far from the Peruvian border. Middens from this region can provide vegetation histories to support interpretation of the rich archeological legacies of the Atacama region.

Rodent middens are deposits of plant materials (seeds, leaves, twigs, bones, pollen, and fecal pellets) encased in crystallized urine, and are abundantly preserved in rock shelters, crevices, and caves in the Atacama Desert. Both Pleistocene and Holocene-aged plant macrofossils are often identifiable at the species level, providing high taxonomic resolution. Rock dwelling rodents typically have very limited foraging ranges so these deposits also represent the surrounding vegetation with a high degree of spatial resolution. A recent taphonomic study of *Abrocoma* middens from northern Chile indicated that no plants from beyond 30 m were found within modern middens (Salinas and Latorre, 2007). Radiocarbon dates from midden plant materials or fecal pellets provide excellent chronological control. However, middens are stratigraphically discontinuous; therefore individual middens represent "snapshots" of floral assemblages that have to be collated to develop local chronologies of vegetation change.

Midden-forming rodents in northern Chile include *Abrocoma cinerea* (Abrocomidae), *Lagidium viscacia* (Chinchillidae), and *Phyllotis* spp. (Cricetidae). Based on fecal pellets, all middens in our study were made by *Abrocoma*, although the diurnal *L. viscacia* was often spotted on rocky hillslopes. *A. cinerea* has a generalist diet (Cortés et al., 2002), and in addition to caching food, these rodents collect plant materials for nest and den construction, resulting in midden assemblages that are representative of hillslope vegetation within the foraging ranges of the animals. Although the surrounding vegetation is well represented in modern *A. cinerea* middens, dietary selectivity may increase in more productive environments (Salinas and Latorre, 2007) such as in our study area, potentially introducing bias. A bias in plant abundance in the midden record may also result from variations in the length of depositional episodes and a tendency for rodents to collect plants growing nearest to the midden.

2. Study area

2.1. Geology and climate

The study area is located on the Pacific slope of the Cordillera Occidental of the Andes between 2800 and 3590 m elevation (Fig. 1). This slope consists primarily of Cretaceous–Tertiary volcanic rocks, especially ignimbrites. Ignimbrites form from very mobile volcanic flows consisting of ash particles and heated volcanic gases, with some of the most massive deposits in northern Chile covering 1000–3000 km^3 (Seyfried et al., 1999). Abundant caves and rockshelters within the ignimbrites provide locations suitable for midden preservation throughout the study area. Tertiary eolian and alluvial sediments fill the valleys to the west. Deep, steep-walled valleys oriented east–west surrounding Arica are a result of tectonic destabilization and the collapse of massive packets of sediments (Seyfried et al., 1999). Several volcanoes with peaks between 5000 and 6000 m punctuate the landscape.

The climate of the study area is hyperarid due to a combination of factors including location beneath the South Pacific Anticyclone high-pressure zone, the cold upwelling Peruvian Current offshore that creates a temperature inversion and inhibits convection, and the rainshadow effect of the Andes blocking moisture from the Amazon. The scarce precipitation that does occur comes from three primary sources. At elevations below ~1000 m thick fog develops during the winter due to a temperature inversion off the Pacific coast. Where it intersects the steep coastal slopes it provides sufficient moisture to support "lomas" vegetation. These fog-zone communities exist as bands of vegetation surrounded by hyperarid habitat and consist of highly variable mixtures of annuals, short-lived perennials, succulents, and woody scrub vegetation, often with high levels of endemicity (Rundel et al., 1991). During summer months, the South America Summer Monsoon (SASM) brings convective moisture across the Andes as heating occurs over the Amazon Basin. Because of the strong rainshadow effect of the Andes, much of the moisture from summer monsoon storms that cross the Andes falls at high elevations and rarely reaches the coast (Houston and Hartley, 2003). Interannual summer precipitation variability is primarily influenced by El Niño-Southern Oscillation (ENSO) and the strength and position of