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A 50,000 year insect record from Rancho La Brea, Southern California: Insights into past climate and fossil deposition

Anna R. Holden [a, b, c, *], John R. Southon [d], Kipling Will [e], Matthew E. Kirby [f], Rolf L. Aalbu [g], Molly J. Markey [h]

[a] *Richard Gilder Graduate School at the American Museum of Natural History, 79th at Central Park West, New York City, NY 10024, USA*
[b] *Department of Entomology, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, CA 90007, USA*
[c] *La Brea Tar Pits and Museum, 5801 Wilshire Boulevard, Los Angeles, CA 90036, USA*
[d] *Department of Earth System Science, University of California-Irvine, Irvine, CA 92697, USA*
[e] *Essig Museum of Entomology, University of California, Berkeley, CA 94720, USA*
[f] *California State University, Fullerton, Department of Geological Sciences, Fullerton, CA 92834, USA*
[g] *California Academy of Sciences, 55 Music Concourse Drive, San Francisco, CA 94118, USA*
[h] *AIR Worldwide, 131 Dartmouth St, Boston, MA 02116, USA*

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A B S T R A C T

Rigorously studied and dated Late Quaternary paleoenvironmental reconstructions from Ranch La Brea (RLB) and the Los Angeles Basin are scarce. Here, we use data from AMS radiocarbon dated insect fragments to infer local climates over the past 50,000 years. Our results indicate: 1) Quaternary insect remains can be located with great accuracy in radiocarbon time, and 2) well-dated and documented climate indicator beetle species are sensitive proxies for environmental change in the Los Angeles Basin. A total of 182 extant RLB ground and darkling beetle species (Coleoptera: Carabidae, Tenebrionidae) were radiocarbon dated. The resulting radiocarbon dates form a semi-continuous range from ~50 to 28, 16–7.5, and 4 kcal yrs BP to the present. Associated insect climate ranges indicate past conditions consistent with, or very similar to, the current Los Angeles Basin Mediterranean climate. Importantly, these insect data suggest higher temperatures and aridity than inferred previously from other RLB proxies. Furthermore, wider-than-assumed dating spreads for some deposits emphasize the lack of biostratigraphy for RLB, and challenge inferences based on limited sets of radiocarbon dates and assumptions about stratigraphic integrity. Our results demonstrate the necessity to independently radiocarbon date each taxon. The insect paleoclimate interpretations were compared to regional pollen data, primarily from various southern Californian sites including Lake Elsinore and Santa Barbara Basin. These comparisons reveal an important difference in climate interpretations for the last Glacial: the RLB insect data suggest climate similar to the current one, while the regional pollen data have been interpreted as indicating a climate wetter than present.

1. Introduction

Despite Rancho La Brea's (RLB) enduring significance as one of North America's premier Late Pleistocene localities, there remain critical gaps in our understanding of its biotic history and regional paleoenvironment. These gaps in turn affect inferences concerning long-term environmental change or stasis, the timing and duration of asphaltic entrapment periods, and turnover in biological communities, as well as the question whether RLB has any significance for understanding larger-scale events such as the timing and agency of the megafaunal extinctions (Stock and Harris, 1992).

Vertebrate species such as those found in abundance at RLB are not optimal as environmental indicators because they are often highly mobile or migratory (Stock and Harris, 1992). For purposes of paleoenvironmental reconstruction, potentially much more climatically-sensitive taxa are required. At RLB, such taxa are under-examined, or have not been collected and interpreted using modern methods. For example, until recently, relatively few plant

* Corresponding author. 22 East St., Northampton, MA 01060, USA.
E-mail addresses: aholden@amnh.org (A.R. Holden), jsouthon@uci.edu (J.R. Southon), kipwill@berkeley.edu (K. Will), mkirby@fullerton.edu (M.E. Kirby), raalbu@comcast.net (R.L. Aalbu), mmarkey@air-worldwide.com (M.J. Markey).

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fossils were excavated at RLB. Only a small fraction of have been properly curated, and of these, an even smaller fraction has been taxonomically identified or dated by radiocarbon (Stock and Harris, 1992; Fuller et al., 2015).

Recent advances in radiocarbon dating methods of insect chitin (Holden and Southon, 2016) present an opportunity to use RLB insect proxies as a means of circumventing the lack of reliable biostratigraphy at RLB, and, for the first time, place environmental data extracted from RLB insects on accurate spatial and temporal scales. Because RLB's insect collection is vast, abundantly represented insect species can be dated with high replication without the same constraints that destructive sampling poses for many other taxa (Holden and Southon, 2016). We are now able to cover all of radiocarbon time - the past 50,000 years - at a sufficiently high density to permit near-continuous temporal coverage and on this basis establish a secure paleoenvironmental chronology.

Here we present results from radiocarbon-dating of 182 insect specimens. This is the largest single set of radiocarbon dates on RLB organic remains and the largest for any single taxonomic class, as well as the first to set climate ranges within a robust chronology. These results provide a scaffolding on which additional paleoenvironmental indicators from RLB may be added in order to develop multiple proxies for inferring climatic change and continuity in southern California.

1.1. Background

1.1.1. Existing RLB paleoenvironmental interpretations

Although most recently-obtained radiocarbon dates on RLB megafaunal species are considered reliable (for problems with dates collected earlier, see Fuller et al., 2015), a recognized problem is pit averaging, “where an average age of entrapment is used for undated specimens from a given asphalt deposit” (Fuller et al., 2015). Fuller et al. (2015) observe that because there are only 138 reliable dates from RLB, many researchers have been forced to assign pit averages to specimens of unknown ages (Coltrain et al., 2004; Chamberlain et al., 2005; Bump et al., 2007; Fox-Dobbs et al., 2007; Meachen-Samuels, 2012; Prothero et al., 2012; Meachen et al., 2014). As Fuller et al. (2015) note, “such methods can lead to serious errors of chronology and interpretation” because asphalt flows are typically intermittent and fluid, allowing the periodic mixing of disarticulated fossils of different ages (Woodward and Marcus, 1973; Stock and Harris, 1992; Friscia et al., 2008; O'Keefe et al., 2009; Holden and Southon, 2016).

In principle, in the absence of dependable stratigraphy, each specimen studied should be independently dated and “average” pit ages based solely on proximity of samples within a pit ought to be avoided. Given the limited monies available for such purposes, it is unsurprising that investigators have tried to overcome limitations in their dating pools with other strategies. Thus Heusser (1998) attempted to correlate RLB pit averages with data from other paleoenvironmental studies such as offshore Santa Barbara marine cores. Another approach has been to utilize plant macrofossil identifications—themselves often severely limited taxonomically–from a single deposit, Pit 91, and to generalize from there (Coltrain et al., 2004; Fragomeni and Prothero, 2011; Prothero et al., 2012). Hence, climate inferences based on pit average dates should be treated with extreme caution.

In addition, there are disagreements regarding how robust paleoclimate inferences are from different RLB taxa. Some vertebrates and invertebrates known from fossils at RLB are regionally endemic today (Stock and Harris, 1992). Because these species have constrained current geographic ranges, and therefore reflect local environmental conditions, Stock and Harris (1992) inferred that little environmental change may have occurred in the RLB region during the late Quaternary. This inference is supported by previous work on RLB insects which indicate that paleotemperatures in the Los Angeles Basin were similar to present day conditions. Doyen and Miller (1980), for example, observed that RLB tenebrionids “suggest a drier and warmer period than implied by most Rancho La Brea fossils” though these earlier insect studies lacked radiocarbon dates or involved relatively few specimens (Holden et al., 2013, 2015).

At the same time, Stock and Harris (1992) noted various lines of proxy evidence for cooler summer minimum temperatures at RLB. These proxies include limited plant data (Johnson, 1977), a large and well-identified (but not yet radiocarbon dated) sample of mollusks and gastropods (Lamb, 1989), and stable isotope analyses of radiocarbon dated bone collagen (Marcus and Berger, 1984). These data, in combination with results from the Santa Barbara marine cores (Heusser, 1998) and limited and undated plant macrofossils from Pit 91 (Warter, 1976), are the basis for the more common interpretation that the climate during the Late Pleistocene at RLB and within Los Angeles Basin was distinctly cooler and more mesic than today.

1.1.2. Insects as paleoenvironmental indicators

Insects are generally adapted to highly specific environmental conditions (Triplehorn and Johnson, 2005). Consequently, environmentally sensitive insects can provide useful insights into local ecological conditions (Elias, 1994, 2010; Coope, 2004, 2009). While fossil insects have been well studied at numerous Quaternary and Tertiary sites the world over (Elias, 2010), they require further exploration at RLB. Fortunately, the life-history and present day climate-restricted geographic distributions for all of the species selected for this study are well documented (Matthews, 1977; Ashworth, 1979; Elias, 1994, 2010; Coope, 2004, 2009). Predatory and scavenging species, in particular, which do not rely on a specific food source (e.g., obligate plant host) can migrate independent of flora into suitable habitat as environmental conditions change (Coope, 2009; Elias, 1994, 2010).

The opportunity to use insects as paleoenvironmental indicators (when confidently identified and with provenance established) exists because most Quaternary, and even many Tertiary, insect species are extant. It is surely plausible to assume that they would have occurred and thrived under the same conditions that they do today (Matthews, 1977; Ashworth, 1979; Elias, 1994, 2010; Coope, 2004, 2009). Further, ecological associations of insect species can be traced back for millions of years in some cases, strongly supporting the inference that the ecological requirements of insects identified from the Late Pleistocene in RLB have not changed up to the present (Elias, 1994, 2010; Personal comm., S. Elias, 2016). Notably, apart from two scarab beetles that may have specialized on the dung of large and now-extinct mammals (Miller, 1983), all RLB fossil insects have been identified as representatives of extant species.

Fossils of extant insect species whose temperature ranges are well documented can provide quantitative constraints on both summer and winter paleotemperatures (Elias, 1994, 2010; Coope, 2004, 2009). The use of insects as a paleoclimate proxy is an established technique (Coope, 2004, 2009; Elias, 2010; Brooks and Langdon, 2014). For example, it is possible to document rapid climate change using fossils of winged predaceous or scavenging insects, particularly ground beetles (Carabidae) and darkling beetles (Tenebrionidae) since many species in these families are able to disperse rapidly to more suitable territory in response to abrupt variations in environmental conditions (Coope, 2004, 2009; Elias, 1994, 2010). Multiple species of tenebrionids, and carabids in particular, have been used as paleoclimate indicators for many decades (Coope, 2004, 2009; Elias, 1994, 2010). They may respond