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Stable isotope evidence for a foggy climate on Santa Cruz Island, California at ~16,600 cal. yr. B.P.

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ABSTRACT

In this study we use stable isotope analysis to investigate the climate in southern coastal California during the last 10,000 years of the Pleistocene by comparing the carbon and oxygen stable isotope ratios of preserved Douglas-fir (*Pseudotsuga menziesii*) wood from Santa Cruz Island to modern Douglas-fir wood from northern California. AMS age determination indicates that the preserved trees grew at about 16,600±270 cal. yr. B.P. After isolating cellulose from both the modern and Pleistocene wood to remove any potential bias due to differential decomposition rates of wood components [Loader, N.J., Robertson, I., McCarroll, D., 2003. Comparison of stable carbon isotope ratios in whole wood, cellulose, and lignin of oak tree-rings. Palaeogeography, Palaeoclimatology, Palaeoecology 196, 395–407.], we find that the Pleistocene Douglas-fir wood has significantly greater carbon isotope discrimination and significantly more enriched $\delta^{18}O$ than the modern Douglas-fir wood, which suggests that the Douglas-fir trees growing on Santa Cruz Island at ~16,600 cal. yr. B.P. experienced less moisture stress and used more enriched water from fog than Douglas-fir trees at Point Reyes today.

1. Introduction

Macroscopic plant remains indicate that many plant taxa grew further south along the California coast during the last 10,000 years of the Pleistocene than they do today (Chaney and Mason, 1930; Johnson, 1978; Raven and Axelrod, 1995). In this paper, we use stable isotope analysis of Pleistocene wood to investigate the climate in coastal California during this era.

In 1930, Chaney and Mason described Pleistocene plant material, including large Douglas-fir (*Pseudotsuga menziesii*) logs, in the fine-grained alluvial deposits of Willow Creek Canyon, now known as Sauces Canyon, on the western side of Santa Cruz Island (Fig. 1). Prior to our work, the sole radiocarbon date for the wood near this site was 14,200±250 ^{14}C yr. B.P. (Fergusson and Libby, 1963). When we adjust the ^{14}C radiocarbon date to reflect the changing $^{14}C/^{12}C$ in the atmosphere, the ^{14}C date is equivalent to 17,500–16,000 cal. yr. B.P. (Stuiver and Reimer, 1993). Chaney and Mason also collected specimens of Bishop pine (*Pinus muricata*) and Gowen cypress (*Cupressus goveniana*) wood and cones. While Bishop pine still grows on Santa Cruz Island, Gowen cypress and Douglas-fir do not. The closest Douglas-fir stand is approximately 100 km to the northwest in Santa Barbara County (Griffin and Critchfield, 1977).

Paleobotanists studying this and other flora from coastal California concluded that during the glacial phases of the Pleistocene there was greater effective precipitation than today and that coastal lowland California was covered by a forest dominated by closed-cone species such as Bishop pine and Monterey pine (*Pinus radiata*) (Chaney and Mason, 1930; Raven and Axelrod, 1978; Axelrod, 1980; Raven and Axelrod, 1995). They proposed that the development of warm dry summers after ~10,000 cal. yr. B.P. restricted this closed-cone pine forest to a few locations in northern California and Baja California where maritime conditions, such as summer fog, reduced the moisture stress to plants during the summer drought (Chaney and Mason, 1930; Raven and Axelrod, 1978; Axelrod, 1980; Raven and Axelrod, 1995).

Here we report on stable isotope analysis of the Douglas-fir logs from Santa Cruz Island (Fig. 1). We collected wood samples from eight logs, verified the species identification, and had them radiocarbon dated by Accelerator Mass Spectrometry (AMS). We also compared the carbon and oxygen stable isotope ratios from the Pleistocene Douglas-fir wood to modern Douglas-fir wood from Point Reyes in northern coastal California. We selected Point Reyes for the modern site because Bishop pine and Douglas-fir grow there together today, and because there is a weather station at approximately the same elevation as the Douglas-fir logs on Santa Cruz Island (~30 masl). In the following sections we first introduce the use of carbon and oxygen stable isotope analysis as tools for climate reconstruction, and then present the results and discuss what they suggest about the climate on Santa Cruz Island during the last 10,000 years of the Pleistocene.

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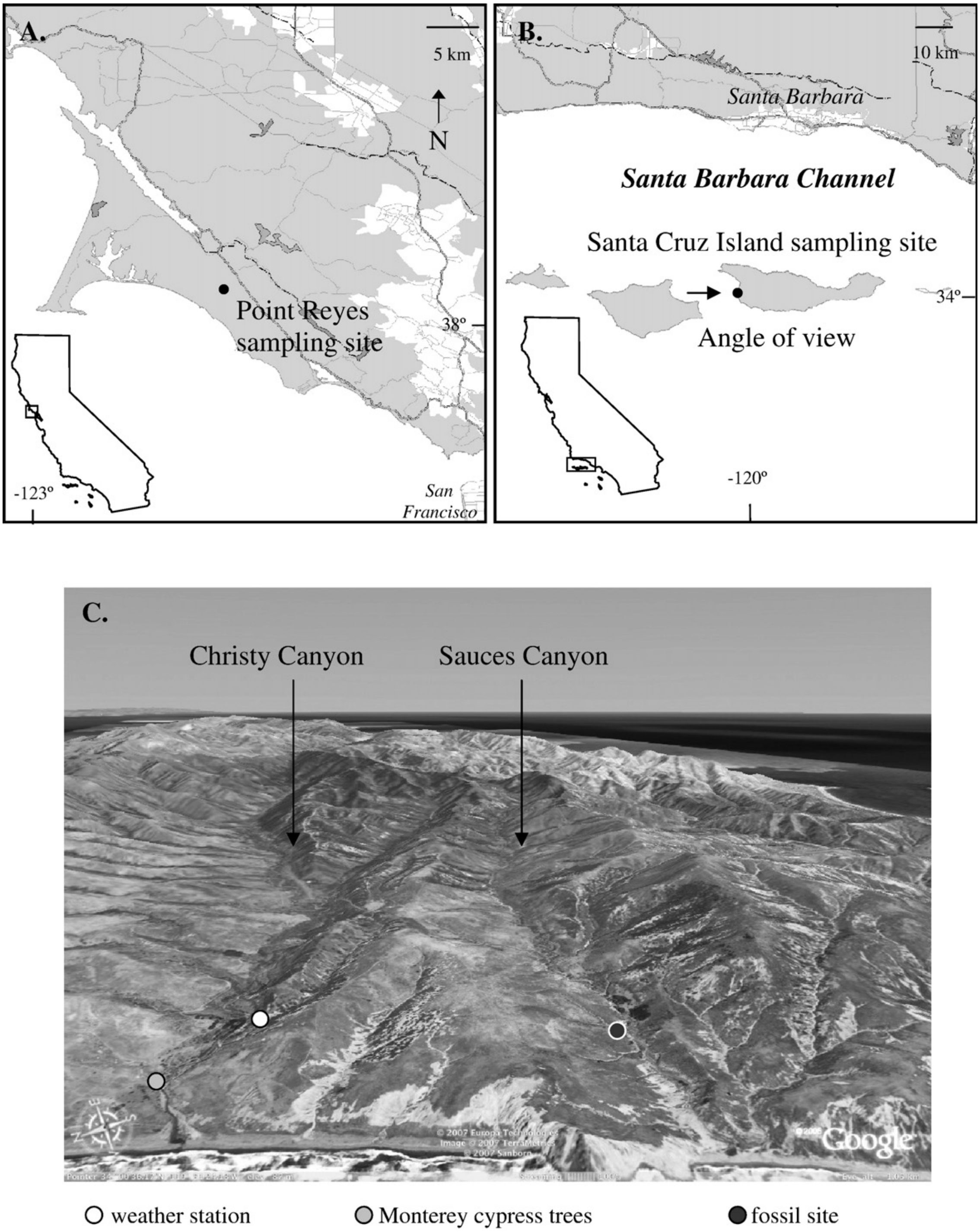

Fig. 1. Locations of sites mentioned in the text. The modern Douglas-fir trees are at Point Reyes (A.), and the Pleistocene Douglas-fir trees are on Santa Cruz Island (B. and C.).

1.1. Stable isotopes in wood as climate indicators

Wood is an archive of the carbon, hydrogen, and oxygen that the tree extracts from the environment (Loader et al., 2003). As the tree takes up carbon dioxide and water, the carbon and oxygen isotope ratios are modified by both physiological processes and the environmental conditions of the site (Dawson et al., 2002). These small changes in carbon and oxygen isotope compositions (expressed as changes in isotope ratios: $^{13}C/^{12}C$, $^{18}O/^{16}O$) can be used to reconstruct past environments (Edwards et al., 1985; Buhay and Edwards, 1995; Pendall et al., 1999; Turney et al., 1999; Ward et al., 2005).

Paleoclimate studies relate changes in carbon isotope discrimination (Δ), the ability to utilize preferentially ^{12}C instead of ^{13}C, to shifts in environmental factors that influence moisture stress, such as relative humidity (Pendall et al., 1999; Ward et al., 2005; Fischer and Still, 2007) or vapor pressure deficit (Turney et al., 1999). The ratio of ^{13}C to ^{12}C (expressed as $\delta^{13}C$; Dawson et al., 2002) increases and the carbon discrimination value becomes more negative (Farquhar et al., 1982) when a plant grows in environmental conditions that cause moisture stress.

There are two significant controls on the $^{18}O/^{16}O$ of wood cellulose. The first is the isotope ratio of the water the tree takes up through its roots, which can vary with season, source, and/or temperature