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Late Quaternary pollen record from the central California continental margin

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ABSTRACT

A pollen record obtained from a deep-sea core from the continental margin off central California contains evidence of the terrestrial floral adaptation to changing climatic conditions over the last ca. 20,000 cal BP. The pollen record is divided into three pollen zones, two of which are late Pleistocene in age (Glacial and Transitional) and the third is Holocene (Interglacial).

The Glacial Pollen Zone (ca. 20,000–17,000 cal BP) is characterized by *Pinus* and *Abies* pollen, reflecting environmental conditions during the last glacial maximum. Overlying this (ca. 17,000–11,600 cal BP) is the Transitional Pollen Zone containing a pollen assemblage indicative of a transitional climatic regime, with species that reflect more arid environmental conditions (*Pinus* and *Artemisia*) decreasing in abundance and those reflecting moister conditions (*Sequoia* and *Alnus*) rising in abundance. *Pediastrum* and dinoflagellates are common and are attributable to increased nutrient-rich coastal runoff. The Bølling–Allerød (295–256 cm; ca. 14,600–12,900 BP) and Younger Dryas (256–243 cm; ca. 12,900 –11,600 BP) events occur within the Transitional Pollen Zone as well. The Interglacial Pollen Zone (ca. 11,600 cal BP to present) is characterized by decreasing *Pinus* and increasing *Sequoia*, *Quercus*, and Asteraceae, reflecting changes in vegetation during the climatic warming of the Holocene. Two brief dry periods are represented in this pollen zone, one from 150 to 125 cm (ca. 8000–6400 cal BP) and the other at 22–20 cm (ca. 800–700 cal BP). They are correlated with the middle Holocene dry period and the Medieval Climate Anomaly, respectively.

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1. Introduction

1.1. Setting

Marine palynology can provide insight into the floral patterns and terrestrial climate of the adjacent continent from which the pollen and spores were derived (Groot and Groot, 1964, 1966; Cronin et al., 1981), yet few such investigations have been undertaken off central California. In May and June 1978, several piston and gravity cores were obtained on a geophysical and sediment sampling cruise (USGS cruise S3-78-SC) off central California to explore sediment depositional processes and the geologic and biologic effects of climate change. One of the longest and best preserved of these deep-sea cores (gravity core S3-15G) was selected for detailed quantitative pollen and benthic foraminiferal analysis. Core S3-15G is 4.72 m in length and was recovered at a depth of 3491 m approximately 135 km southwest of Santa Cruz, California (36°23.53′N, 123°20.52′W; Fig. 1). This study investigates the pollen record of core S3-15G from the continental margin off central California in order to document the regional floral response to the changing climatic conditions during the late Quaternary.

1.2. Modern terrestrial vegetation

The plant associations presently occupying coastal central California are diverse and geographically localized (Critchfield, 1971; Little, 1971; Munz and Keck, 1973; Griffin and Critchfield, 1976; Barbour and Major, 1977; Kuchler, 1977; Zinke, 1977). In the Monterey Bay region, *Pinus radiata* (Monterey pine), *Pinus muricata* (Bishop pine), *Cupressus goveniana* (Gowen cypress), *Cupressus macrocarpa* (Monterey cypress), and *Quercus agrifolia* (coast live oak) are distributed sporadically in the coastal zone; other nearshore regions are characterized by grassy meadows and low shrubs. Locally important is *Baccharis pilularis* (coyote brush), together with *Artemisia californica* (California sagebrush), *Ceanothus thyrsiflorus* (blue brush) and *Rhamnus californicus* (coffeeberry). In drier coastal regions drought-deciduous shrubs such as *A. californica*,

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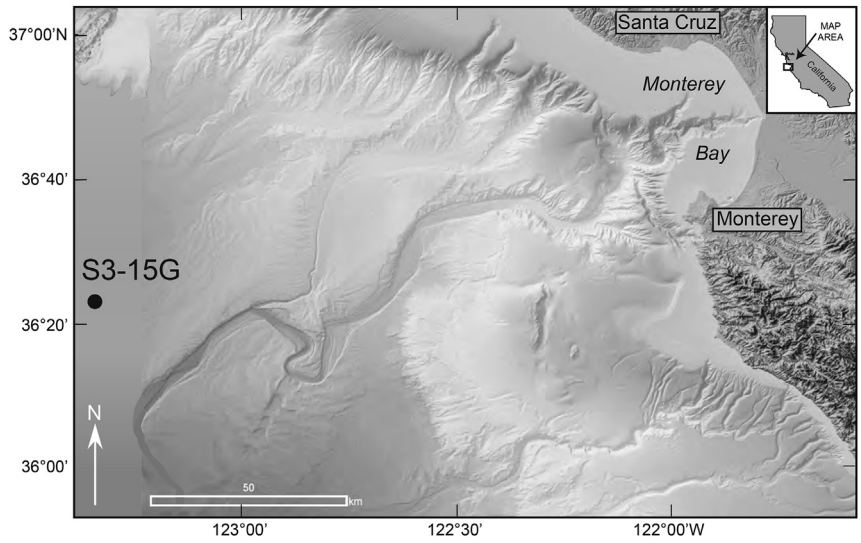

Fig. 1. Location map of core S3-15G off central California. Image courtesy of Monterey Bay Aquarium Research Institute.

Eriogonum fasciculatum (California buckwheat), *Salvia apiana* and *Salvia mellifera* (white and black sage), and *B. pilularis* are locally common.

Further inland, mesic sites are dominated by *Sequoia sempervirens* (redwood), *Notholithocarpus densiflora* (tanoak), *Umbellularia californica* (California bay), *Arbutus menziesii* (madrone), and *Quercus wislizenii* (interior live oak). *Pseudotsuga menziesii* (Douglas fir) dominates drier locations and is commonly associated with *Quercus garryana* (Oregon white oak). Riparian woodland bordering local rivers and creeks includes *Alnus rubra* and *Alnus rhombifolia* (red and white alders), *Acer macrophyllum* (bigleaf maple), and *Salix* spp. (willow).

On progressively warmer and drier slopes in the eastern Coast Ranges, the vegetation consists primarily of *Q. agrifolia*, *Quercus chrysolepis* (canyon oak), and *A. menziesii*, as well as *Aesculus californica* (California buckeye), *N. densiflora*, *Pinus coulteri* and *Pinus lambertiana* (Coulter and sugar pines), *B. pilularis*, and *Abies bracteata* (Santa Lucia fir).

1.3. Pollen transport to the core site

Pollen and spores may be transported to the core site by wind, water, and sediment. Due to the prevailing onshore and along shelf winds in the Monterey Bay region (Halliwell and Allen, 1987; Winant et al., 1987; Dorman and Winant, 1995), however, eolian transport of palynomorphs from the adjacent mainland to the core site is probably negligible at the present time. Any wind-transported pollen most likely is derived from vegetation directly along the coast, with the amount of pollen in the marine sediments controlled by the distance of the source from the shore. Heusser and Balsam (1977) found this to be true for *Pinus* pollen in the northeast Pacific Ocean, leading Gardner et al. (1988) to conclude that the *Pinus* record in a core offshore of the Russian River off central California (V1-80-P3; Fig. 2) reflected the overall California Coast Ranges floral record. The same is likely to be true of the record in core S3-15G. However, changes in upwelling patterns during the late Quaternary off central California (Gardner and Hemphill-Haley, 1986) suggest that wind patterns also varied during this time. Because the common limit of wind dispersion of pollen is 10–150 km (Heusser, 1978b), wind has probably played a significant role, at least at times, in transporting pollen to the core site.

It has been demonstrated that terrigenous influx via rivers correlates positively with pollen concentration (Cross, 1973; Peck, 1973) and that the highest pollen concentrations in surface sediments in the marine realm occur opposite major rivers that reflect the vegetation along their course (Cross et al., 1966; Groot et al., 1967; Heusser and Balsam, 1977; Heusser, 1978a; Heusser et al., 2015). Griggs and Hein (1980) determined that coastal rivers are the major source of fine-grained Holocene sediments in the ocean off northern and central California and that sediment plumes enter Monterey Bay from the rivers and creeks of its drainage basins (Fig. 3). With a combined total of suspended sediment in excess of 1.8 million tons annually (Griggs and Hein, 1980), these rivers are thought to be the major transport mechanism of pollen and spores to the continental margin off central California.

Upon reaching the ocean, palynomorphs are subjected to net southward transport by the wind-and wave-induced littoral current system (Storlazzi and Field, 2000; Barnard et al., 2013). Consequently, some pollen and spores from the major streams to the north (e.g., Sacramento, Russian, Eel, and Klamath) may be included in the deposits of core S3-15G. Therefore, the pollen record of this deep-sea core is dominated by the adjacent continental vegetation, but includes some minor allochthonous components as well that may have been transported over long distances (Faegri and Iverson, 1964; Heusser and Balsam, 1977).

2. Material and methods

Twenty-one samples, each sample consisting of 1 cm^3 of sediment, were obtained down the length of core S3-15G. Wet and dry weights were obtained for these samples, after which each was spiked with an exotic tracer (*Lycopodium*) in order to determine the absolute pollen concentration. The pollen samples were then prepared in the following manner: successive immersion in 10% hydrochloric acid (overnight), warm sodium pyrophosphate (15 min), 52% hydrofluoric acid (overnight), 10% hydrochloric acid (2 min), 70% nitric acid (3 min), and a modified acetolysis solution of nine parts glacial acetic acid to one part concentrated sulfuric acid (5 min). Subsequently, the residues were stained with two drops of safranin and mounted in silicone oil.

At least 300 pollen grains were identified for each sample based on reference material from western North America. Very poorly preserved grains were assigned to the indeterminate category, while representatives of the Polypodiaceae and Lycopodiaceae, as well as rare constituents of other related families, were placed in

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