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Correlation of marine and coastal terrestrial records of central California: Response to paleoceanographic and paleoclimatic change during the past 19,000 years

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ABSTRACT

New benthic foraminiferal census data combined with previously published planktic foraminiferal and pollen data from the continental margin off central California provide a unique opportunity to document concurrent paleoceanographic and paleoclimatic changes in the region during the late Quaternary. All three datasets were evaluated in gravity core S3-15G, collected at a depth of 3491 on the western levy of the Monterey Fan (36°23.53′N, 123°20.52′W). Accelerator mass spectrometry radiocarbon dates and the ratio of the planktic foraminiferal species *Neogloboquardrina pachyderma* (Ehrenberg) to *Neogloboquadrina incompta* (Cifelli) provide a good age-depth model for the last 19,000 years, covering the last glacial, Bølling–Allerød, Younger Dryas, and Holocene intervals. Separate Q-mode cluster analyses of the hemipelagic as well as mixed (combined hemipelagic and turbiditic) mud samples grouped the benthic foraminiferal fauna into two clusters reflecting faunal adaptation to changing climatic conditions during the Pleistocene and Holocene. R-mode cluster analysis also differentiated glacial (*Uvigerina senticosa* and *Globobulimina auriculata*) and interglacial (*Melonis pompilioides* and *Gyroidina planulata*) faunas. A general trend of slightly increasing oxygen in the deep sea is suggested from the Pleistocene to Holocene based on the reduction in abundance of *G. auriculata* and increased frequency of *M. pompilioides*. Q-mode cluster analysis of the planktic foraminifera illustrates a change in the surface water from a glacial subpolar fauna in the Pleistocene to a transitional fauna in the Holocene, whereas the pollen record separated into three clusters, two of Pleistocene age (glacial and transitional) and one in the Holocene (interglacial), reflecting the terrestrial floral adaptation in the California Coast Ranges of central California to the warmer climate in the Holocene. Decoupling is evident between the benthic and planktic foraminiferal and terrestrial floral responses to changing oceanographic and climatic conditions. The floral response leads the surface-dwelling fauna by several millennia, and is followed by the deep-dwelling benthic foraminiferal fauna a millennium later.

1. Introduction

During May and June 1978, a geophysical and sediment sampling cruise (USGS cruise S3-78-SC) embarked off central California to investigate the characteristics and growth patterns of Monterey Fan, and the sediment transport processes associated with it. Core S3-15G was one of the longest and best preserved of the deep-sea cores obtained during the cruise, and therefore was selected for detailed quantitative analyses of benthic foraminifera, planktic foraminifera, and pollen. The availability of census data for these sediment constituents provides a unique opportunity to compare the microfaunal response to changing paleoceanographic conditions in the deep ocean and surface waters, as well as the concurrent terrestrial response to climate change in the California Coast Ranges of central California during the late Quaternary. The census counts and analysis of the planktic foraminiferal record have been previously reported in Brunner and Ledbetter (1989), whereas the pollen data are presented in McGann (2015).

The following is a synthesis of the microfaunal and pollen analysis for core S3-15G. Included are new observations on simultaneous faunal variability between deep- and surface-water foraminifera and inferred climatic changes based on the foraminiferal records. Additionally, the marine paleoceanographic and terrestrial

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climate records during the late Quaternary time period are correlated based on paired foraminiferal and pollen datasets.

2. Setting

2.1. Regional submarine geomorphology and recovery of core S3-15G

Submarine canyons play an important role in transporting sediment to deep-sea fans and are found along the slopes of most continental margins (Garfield et al., 1994; Paull et al., 2003). Monterey Canyon, off central California (Fig. 1), receives more than 400,000 m^3 of sand and organic-rich material transported from the littoral zone each year (Paull et al., 2003). The trail of sand down the axis of the canyon demonstrates that it is the major conduit for sediment transport from the continental shelf to Monterey Fan (Greene and Hicks, 1990; Greene et al., 2002; Fildani and Normark, 2004; Paull et al., 2005). Presently, Monterey Fan has an area of active fan growth that extends more than 300 km from the base of the central California continental slope (Normark and Hess, 1980). This deep-sea turbiditic deposit constitutes the largest submarine fan off California (Normark, 1970a, 1999; Hess and Normark, 1976; Normark et al., 1984; EEZ-SCAN 84 Scientific Staff, 1986) and is one of the most extensive found offshore the contiguous United States (Greene and Hicks, 1990). Further discussion of Monterey Fan morphology and evolution can be found in Fildani et al. (1999), Normark (1999), Fildani and Normark (2004), and summarized in McGann (2014).

As the sand is carried down Monterey Canyon toward the fan, it is generally restricted to the channel except for rare overbank transport. However, because of the volume of sediment being transported downslope and the length of time over which this process occurs, the fan valley is characterized by extensive levee development, the largest of which is the western levee (Normark, 1970a, 1970b; Hess and Normark, 1976; Normark et al., 1984). Gravity core S3-15G, 4.72 m in length, was recovered by the R/V *Sea Sounder* (USGS cruise S-3-78-SC) 18 km from the crest of the western levee of the Monterey Fan Valley (36°23.53′N, 123°20.52′W; Fig. 1). It was obtained at a depth of 3491 m, approximately 135 km southwest of Santa Cruz. S3-15G is a mud-dominated deep-sea core, consisting of hemipelagic mud (Bouma, 1962) interspersed with overbank turbiditic mud and rare fine-grained sand deposits. The hemipelagic and turbiditic muds are easily distinguished by color, appearing lighter and darker, respectively, as is often seen in deep-sea deposits (Howell and Normark, 1982; Piper and Normark, 1983; Brunner and Normark, 1985; Normark and Damuth, 1997).

2.2. Oceanography

Hydrographic depth profiles acquired 15 times between 2003 and 2005 off central California in the vicinity of S3-15G (Fig. 1) provide data showing the variability in temperature, salinity, and dissolved oxygen in the water column from the surface to a depth of 3500 m (Fig. 2). As reported by Robison et al. (2010), the data show that temperature declines from 14.0 °C at the surface to about 1.5 °C at 3500 m, salinity increases from 32.9 psu to 34.65 psu, and oxygen decreases from 5.55 ml/L at the surface to about 0.25 ml/L at a depth of 700–800 m, and then increases to 9.5 ml/L at the bottom. These oceanographic parameters reflect the water masses of the region.

The dominant surficial water mass off central California is the southward-flowing California Current, which constitutes the eastern limb of the North Pacific gyre and is restricted to the upper 200 m over the continental shelf (Hickey, 1979). The California Current is composed of subarctic water and, therefore, is characterized by cool temperature, low salinity, and a high concentration of dissolved oxygen (Reid et al., 1958; Robinson, 1976; Hickey, 1979, 1998; Simpson et al., 1984).

Below the California Current is the poleward-flowing California Undercurrent (Cannon et al., 1975), which is comprised of Equatorial Pacific Water, and is characterized by warm and saline water with low oxygen content (Pickard, 1964; Cannon et al., 1975). Unlike the California Current, the California Undercurrent is seasonally variable in location, depth and intensity (Sverdrup and Fleming, 1941; Hickey, 1979), but usually becomes fully developed off central California between the depths of 200 and 500 m (Wickham, 1975).

North Pacific Intermediate Water (Reid and Mantyla, 1978) underlies the California Undercurrent at depths from 500 m to about 1000 m and is characterized by cool, low-salinity, and oxygen-

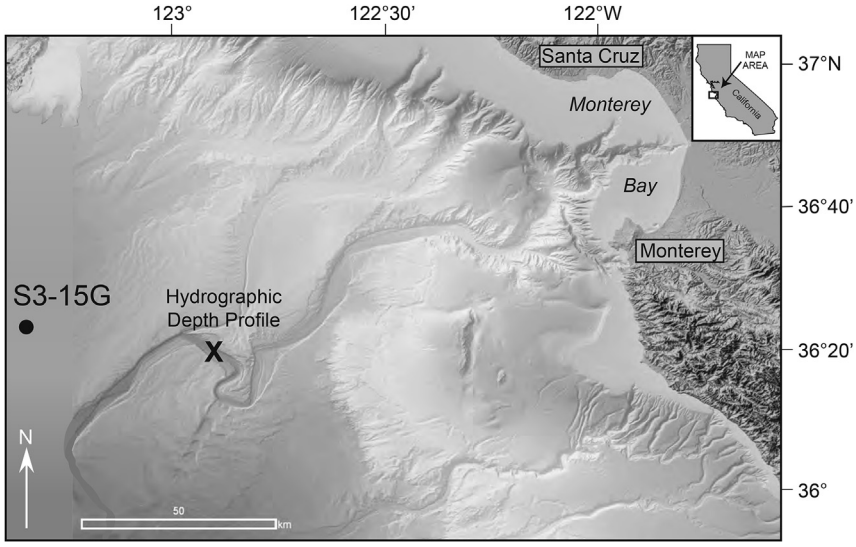

Fig. 1. Map of Monterey Canyon off central California with the location of core S3-15G and the site of the average 3500-m hydrographic depth profile from Robison et al. (2010). Image courtesy of Monterey Bay Aquarium Research Institute.