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Distribution of biologic, anthropogenic, and volcanic constituents as a proxy for sediment transport in the San Francisco Bay Coastal System

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ABSTRACT

Although conventional sediment parameters (mean grain size, sorting, and skewness) and provenance have typically been used to infer sediment transport pathways, most freshwater, brackish, and marine environments are also characterized by abundant sediment constituents of biological, and possibly anthropogenic and volcanic, origin that can provide additional insight into local sedimentary processes. The biota will be spatially distributed according to its response to environmental parameters such as water temperature, salinity, dissolved oxygen, organic carbon content, grain size, and intensity of currents and tidal flow, whereas the presence of anthropogenic and volcanic constituents will reflect proximity to source areas and whether they are fluvially- or aerially-transported. Because each of these constituents have a unique environmental signature, they are a more precise proxy for that source area than the conventional sedimentary process indicators.

This San Francisco Bay Coastal System study demonstrates that by applying a multi-proxy approach, the primary sites of sediment transport can be identified. Many of these sites are far from where the constituents originated, showing that sediment transport is widespread in the region. Although not often used, identifying and interpreting the distribution of naturally-occurring and allochthonous biologic, anthropogenic, and volcanic sediment constituents is a powerful tool to aid in the investigation of sediment transport pathways in other coastal systems.

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1. Introduction

With a population now exceeding seven million people, the San Francisco Bay area's economy is one of the largest in the world (Forbes, 2013). The region's financial health is dependent upon access to the major population, commerce, and recreation centers. Whether these include commercial shipping lanes, recreational watercourses, or tidal wetlands, the estuary is the primary gateway to them all. For more than a century, these waterways have been subjected to human modification by means of influx of hydraulic mining debris, infilling of tidelands to create habitable land, wetland restoration, and dredging and lowering the tops of bedrock knobs to facilitate ship traffic (Chin et al., 2004), to name a few. Because San Francisco Bay influences so many aspects of life in the area, these waterways must be maintained and understanding the regional sediment dynamics is key to this process.

Although the distribution of sediments is typically discussed in terms of sediment grain size, composition, and provenance, nothing has been previously reported on the distribution of the biological, anthropogenic, and volcanic constituents associated with the sediment. Each element provides unique information about the freshwater, estuarine, and/or marine environment in which they naturally occur. By identifying these constituents, and especially those that are allochthonous, this multi-proxy approach provides another method by which to discern patterns of sediment transport and deposition in San Francisco Bay and the nearby offshore realm.

2. Setting

San Francisco Bay consists of three subembayments—North Bay (San Pablo and Suisun Bays, including the shallow embayments referred to as Grizzly and Honker Bays), Central Bay (including Richardson Bay), and South Bay (Fig. 1A) (Chin et al., 2004). The estuary is the largest on the west coast of the United States, ranking second only to Chesapeake Bay as the largest in the United States in terms of surface area (1240 km^2; Conomos et al., 1985). It is a structural trough that formed during the late Cenozoic when the ancestral San Joaquin and Sacramento Rivers, and Coyote Creek formed a drainage basin parallel to a coastline west of the present Golden Gate Bridge (Lawson, 1894, 1914; Atwater et al., 1977; Atwater, 1979). At least four estuaries were created during the Pleistocene and Holocene (Sloan, 1992; McGann et al., 2002) as a result of a cyclical pattern of rising seawater inundating the region during interglacials and an ensuing drop in sea level during glaciation, as well

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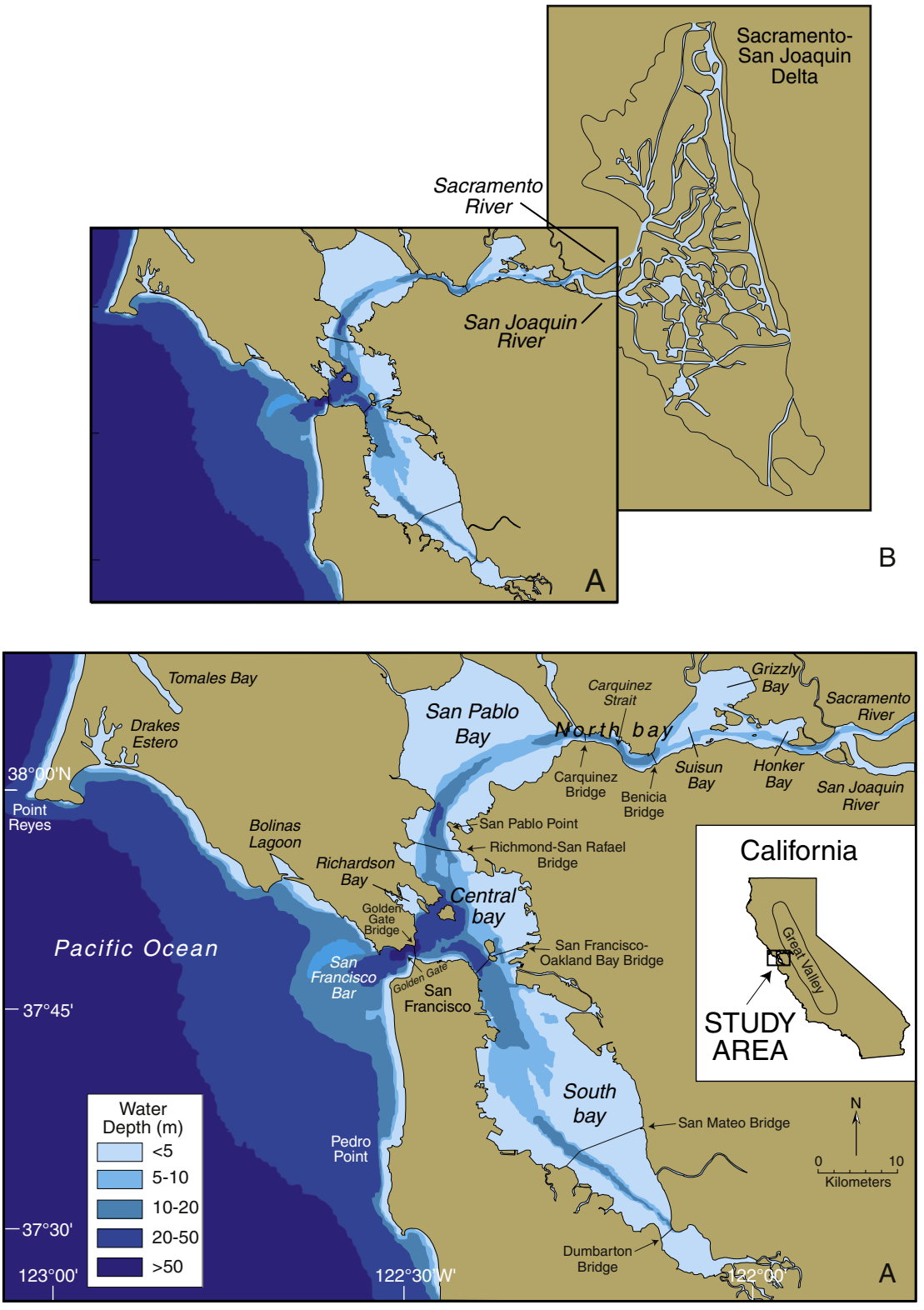

Fig. 1. A. Location map and water depth (in meters) of the San Francisco Bay Coastal System, including the offshore region and the three subembayments of San Francisco Bay: North Bay (including San Pablo, Suisun, Grizzly, and Honker Bays), Central Bay (including Richardson Bay), and South Bay. San Francisco Bar is an informal name for Potato Patch Shoal. Inset of the state of California includes the location of the Great Valley. B. Location of the Sacramento–San Joaquin Delta in relation to the San Francisco Bay Coastal System.

as tectonic subsidence between the San Andreas Fault to the west and the Hayward Fault to the east (Atwater et al., 1977). These four estuaries have been dated as early to middle Pleistocene based on the presence of the Rockland Ash (600–570 ka; Lanphere et al., 2004), an overlying Pleistocene deposit the age of which has not been precisely determined (Sloan, 1992; McGann et al., 2002), late Pleistocene (~125–120 ka; Sloan, 1992; McGann et al., 2002), and late Pleistocene to Holocene (11–10 ka; Gilbert, 1917; Louderback, 1941, 1951; Atwater et al., 1977; McGann et al., 2002). As a consequence of this last transgression, the modern estuary was established by 7.7 ka (Schweikhardt et al., 2010),