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The impact of hydroclimate and dam construction on terrigenous detrital sediment composition in a 250-year Santa Barbara Basin record off southern California

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ABSTRACT

The recurrence and magnitude of southern California hydroclimate extremes are poorly resolved due to the relatively short duration (<140 years) of modern instrumental precipitation and stream gauge records. Terrigenous detrital sediments are often used to reconstruct long-term hydroclimate changes as precipitation increases river runoff and sediment transport into nearby basins. Here we assess the potential of elemental and mineralogical sediment composition from Santa Barbara Basin (SBB, California) box core SPR0901-04BC, a ~250 year record, as a proxy for precipitation and/or river runoff. Additionally we explore the impact of anthropogenic modification of rivers on sediment composition. Potassium and Ti concentrations and kaolinite + chlorite abundances are significantly correlated with regional precipitation. Transfer function modeling demonstrates that precipitation alone predicts Ti concentration variability well, but not clay mineral abundances. However, when dam construction within catchments draining into SBB is included, kaolinite + chlorite abundances can be modeled. We propose kaolinite + chlorite and illite sources in the upper reaches of catchments are trapped behind dams, while smectite sources in lower catchment areas are unimpeded and continue to be deposited in the basin. Linear correlations and model results suggest detrital elemental concentrations are more suitable for precipitation and river runoff reconstruction than clay mineral composition. Correlations observed between sediment composition and precipitation demonstrate the potential for marine sediment proxies to extend weather and climate records beyond the instrumental record, however anthropogenic land use modification, specifically damming, must be considered.

1. Introduction

Increased frequency of hydroclimate extremes such as droughts and floods, their physical impacts on the landscape, and related water availability for growing human populations are economically concerning aspects of climate change. The recurrence and magnitude of such events are poorly resolved in part due to relatively short modern instrumental records (<250 years globally; <140 years in southern California), and the uncertainties associated with these events in the sedimentary record. The ability to determine the frequency and character of these events can aid in emergency preparedness and water resource management, if they can be identified in a well-dated sedimentary record and tied to sediment composition.

Southern California is prone to hydroclimate extremes. Drought is a normal, recurrent feature of California's Mediterranean climate (Peel et al., 2007), yet the potential for heavy winter precipitation exists through 'atmospheric rivers' and intense Pacific storm fronts (Browning and Pardoe, 1973; Nezlin and Stein, 2005). Intense precipitation events erode and transport sediment, generating enhanced terrigenous sediment fluxes to nearshore marine basins via flood plumes. When this terrigenous detrital sediment (hereafter referred to as detrital sediment) is preserved in continuous deposits, a sedimentary record of these events is created (Fleischer, 1972; Soutar and Crill, 1977; Stein, 1995; Thunell et al., 1995; Thunell, 1998; Inman and Jenkins, 1999; Hein et al., 2003; Robert, 2004; Warrick and Farnsworth, 2009b), which can enable paleoclimate reconstructions of flood and drought events and extend the instrumental record.

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The Santa Barbara Basin (SBB, California) is ideally positioned to preserve such sedimentary deposits. It is located close to an actively uplifting region, has a two-component (biogenic versus detrital) sediment input, and a high sediment flux that together produce a high-resolution sediment record, while low bottom-water oxygen concentrations prevent bioturbation from smoothing annual sediment variations (Fleischer, 1972; Soutar and Crill, 1977; Thunell et al., 1995; Thunell, 1998; Warrick and Mertes, 2009; Warrick and Farnsworth, 2009b). Flood deposits have been identified in SBB sediments, including the Great Flood of 1861-62 (Hendy et al., 2015) and a well-defined sequence of flood events occurring with a frequency of ~200 years (Schimmelmann et al., 2003).

The composition of detrital sediment is often used to determine many aspects of paleoclimate as well as provenance (e.g., Ergin et al., 2007; Mishra et al., 2015). Climate reconstructions that exploit the high-resolution stratigraphy of SBB have used clay minerals to identify catchment source and classify deposition event type (Fleischer, 1972; Stein, 1995; Schimmelmann et al., 1998; Hein et al., 2003), while clay mineral composition has been used as a precipitation proxy (Robert, 2004). Specifically, smectite has been associated with detrital fluvial input from the Santa Clara River catchment (Fleischer, 1972), and kaolinite and illite with fluvial suspended loads from the Ventura River, Santa Ynez River, and Santa Ynez Mountain catchments (Fig. 1; Stein, 1995; Fleischer, 1972; Robert, 2004). Flood deposits within SBB sediments are classified using clay mineral composition by identifying gray layers containing relatively low chlorite and high smectite concentrations (>18%) (Fleischer, 1972; Stein, 1995; Schimmelmann et al., 1998; Robert, 2004). This flood layer classification is solely based on the clay mineral composition of fluvial suspended loads collected during the 1969 floods in southern California and the associated flood deposit found in SBB (Fleischer, 1972).

Geochemical analyses of sediments provide additional insights into paleoclimate regimes (e.g., Heymann et al., 2013). Elemental abundance determined by non-destructive scanning X-Ray fluorescence (XRF) is used to reconstruct precipitation variability on annual timescales (Lamy et al., 2001; Haug et al., 2003; Tierney et al., 2005). Using this method Hendy et al. (2015) observed annual variability in elemental counts in SBB sediments that could be correlated to interannual and decadal climate regimes. The first principle component of the counts was associated with elements found in detrital sediment, and high

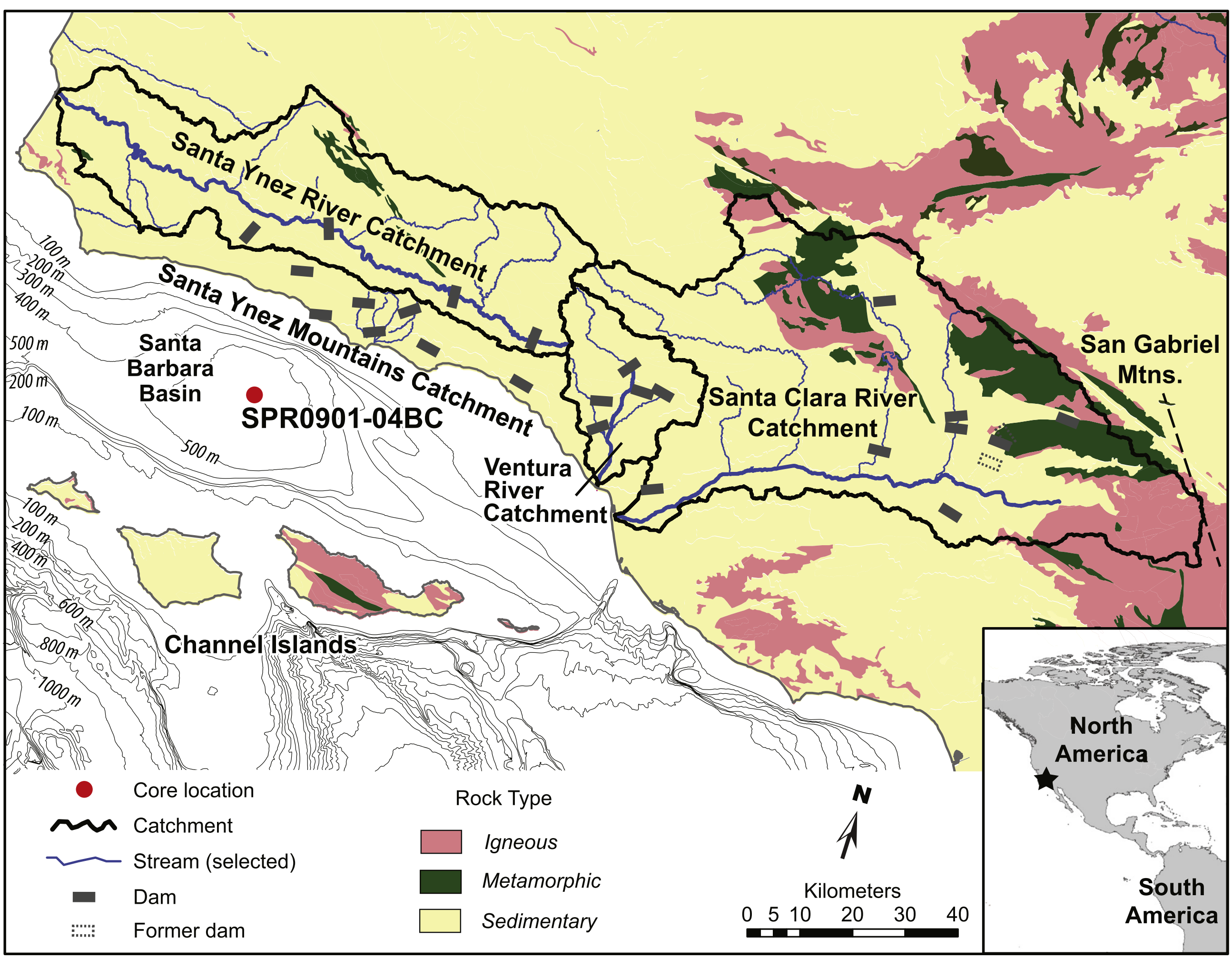

Fig. 1. Geologic map of study area, including Santa Barbara Basin and location of box core SPR0901-04BC, and dams within river catchments that discharge sediment into Santa Barbara Basin. River catchments are outlined in black. Selected rivers are shown by blue lines; main stem of river indicated by thick blue line. Bathymetry contour interval is 100 m. The star in the inset figure denotes the study location. Geologic data from Ludington et al. (2005). Dam information from California Dept. of Water Resources, Division of Safety of Dams [*California Jurisdictional Dams*, http://www.water.ca.gov/damsafety/damlisting/index.cfm, *accessed February 2015*]. Hydrologic data from the National Hydrology Dataset Plus, Version 2 (McKay et al., 2012). Bathymetry from Global Multi-Resolution Topography version 2.6 (Ryan et al., 2009). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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