Source-to-margin behavior of an arid, El Niño-influenced mountain drainage and coastal plain: The Chicama River, northern Peru

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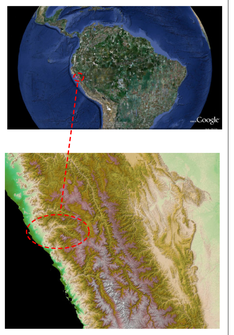
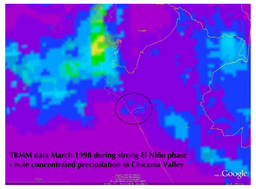
ABSTRACT

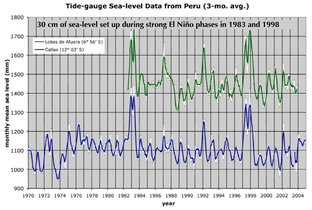
The steep gradients, active hillslopes, and limited storage capacity of small mountainous dispersal systems make them good candidates for studying the linkages between source terrains and downstream depositional settings. Where such landscapes are also arid, the sparse vegetation, high runoff, and high sediment yield promote sharp responses that propagate quickly through the source- to-sink system. The sum of these characteristics are common to the desert coastal basins of Peru's collision margin, which are fed by short, seasonal rivers draining the west slope of the Andes range. Our study site, the Chicama river basin, lies along a largely aseismic reach of the margin where there are few earthquakes and little to no tectonic uplift. At 8°S latitude, though, the Chicama River is strongly impacted by El Niño phenomenon, which brings excessive precipitation and transforms the river into a sediment-laden flood. In the coastal lowlands, these floods broadcast their suspended load and have built a large silty floodplain. In the main channel, much of the gravelly bedload reaches the coast to form prograding sandy gravel shorefaces. In the early Holocene, though, this characteristic ENSO-forcing was weak to absent, and sediment flux to the coast was limited. At that time the coastal plain actually supported a freshwater lagoon with abundant algal carbonates, an environment that persisted from 8.0-6.5 ka. With the onset of El Niño flooding beginning ~6.5 ka, the increased sediment flux infilled the lagoon and initiated widespread floodplain development. Upstream in the arid mountains, the rocky hillslopes and abundant alluvial fans appear to have been largely inactive at this time based on their heavy desert varnish. However, the channels at the base of these valleys are active and braided, heavily truncating valley fans through channel migration and widening. Although we do not have ages on the bank erosion, we speculate that this reactivation of the fluvial system is associated with the onset of El Niño flooding ~6.5 ka. It is also uncertain why the hillslopes remain stable through the Holocene despite increased channel activity and fluvial sediment transport. One hypothesis is that most of the El Niño-related precipitation falls in the humid highlands (>2500 m), whereas precipitation on the talus-covered lower slopes reaches the valley floor as groundwater. Many compelling questions about source-to-sink behavior emerge from these initial observations of the Chicama River valley. Furthermore, an overarching interest in this particular system is that it hosts one of the longest-lived pre-ceramic cultural sites in the Peruvian Andes. The principal archaeological site at the coast is continuously occupied for 5000 years from 8-3 ka. During this time the society is able to adapt to changing source-to-sink behavior by shifting



CLIMATIC SETTING

- arid desert coast
- river and precipitation are strongly ENSO forced
- El Niño precipitation intense but very local
- ENSO forcing appears by mid-Holocene (~5ka) and increases to modern frequencies by 3 ka
- modest river discharge normally driven by snowmelt from Amazon moisture source

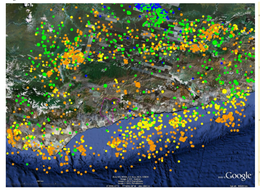




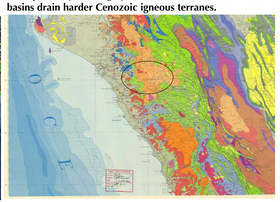
GEOLOGIC SETTING

- only major portion of shoreline not uplifted or cliff bound, supporting broad floodplain, suitable for agriculture (only after El Niño floods begin to deliver fines)

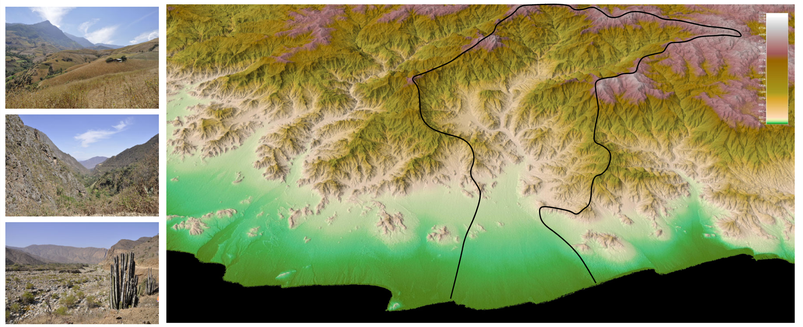
- largely aseismic area within tectonically active region, and located north of Andean volcanoes



- only river basin along Peruvian coast draining Mesozoic rock, primarily soft, highly sheared metasediments. Other basins drain harder Cenozoic igneous terranes.



SOURCE-TO-MARGIN PHYSIOGRAPHY

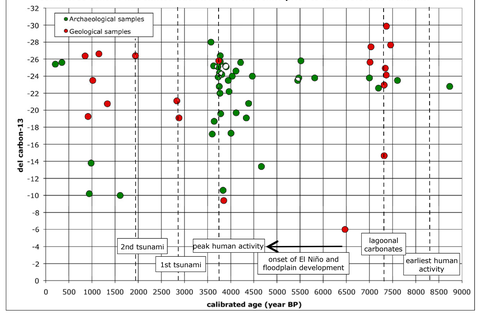


HUACA PRIETA ARCHAEOLOGICAL SITE

- permanently occupied 8.5-3 ka
- shift from maritime to agricultural economy ~4.5 ka

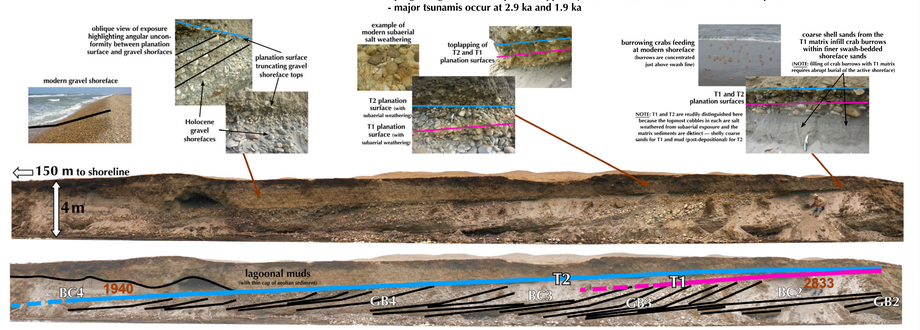
HOLOCENE CHRONOLOGY

- permanent settlement associated with establishment of stable coastal lagoon setting
- onset of El Niño flooding causes demise of lagoon and development of arable floodplain
- floodplain corresponds to shift from maritime econony to large-scale agriculture
- commerce centers had shifted back from the shoreline prior to late Holocene tsunamis



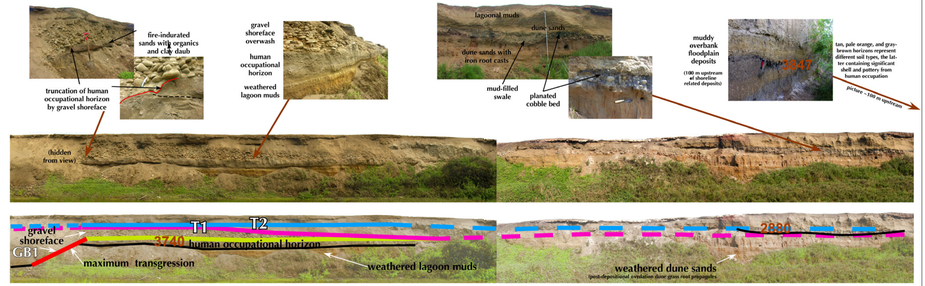
SHORELINE and COASTAL PLAIN DYNAMICS

- shoreline transgresses slowly from 7-5ka
- regression initiates at 4ka following onset of frequent El Niño floods -- supply forced
- prograding shoreface sequence capped by 1-2 m of late Holocene El Niño flood deposits
- major tsunamis occur at 2.9 ka and 1.9 ka



BC and GB units reflect sequentially alternating beach complexes (BC) and gravel bar shoreface (GB) deposits formed during an extended period of shoreline regression.

T1 and T2 surfaces are interpreted as being formed by tsunami events – perhaps a few hundred years apart. Tropical storms do not form at 8°S and an are thus an unlikely cause. Both the T1 and T2 surfaces sharply truncate cobble shoreface bars and extend hundreds of meters landward over 4+ m of elevation, terminating in a thin (~1 cm) sand bed.



EARLY HOLOCENE LAGOONAL CARBONATES

- lagoon fauna/flora oligotrophic, oligohaline, clearwater community
- cool, arid climate, no ENSO
- likely groundwater fed lagoon, with modest, episodic fluvial input