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LATE HOLOCENE BEACH RIDGE SEQUENCES IN NORTHERN PERU:
DID THEY REGISTER THE STRONGEST PALEO-EL NIÑOS?

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Along the northwestern coast of Perú, a few sequences of Holocene beach ridges have recently attracted the interest of several investigators. These coastal features have been interpreted, first as evidence for tectonic and/or seismo-tectonic repeated events, and more recently as the result of paleo-El Niño phenomena.

Most of the previous studies have been conducted in close relationship with archeological research programs, and a large proportion of the available radiocarbon data on the Peruvian beach ridges was provided by anthropic remains (charcoals and midden shells) collected on top of the ridges. Therefore these data do not yield ages of the edification of the ridges. A re-examination of the previous studies and a new investigation on the sequence located at Colán have been undertaken in 1988. The main objective is to determine whether the ridges have been formed during the strongest past El Niños. If the beach ridges did record paleo-El Niño conditions, a precise dating of each ridge would contribute to an historical reconstruction of these events in the upper Holocene, once post-glacial sea-level reached its present position.

Four main sequences of beach ridges are known in northern Peru. Three of them are located on the northern side

(down longshore current) of the mouth of permanent rivers (Rios Chira, Sechura/Piura, and Santa) and the fourth one is found at Colán, between Paita and the mouth of Rio Chira. In all four localities, one can count 8 or 9 ridges, the oldest one generally appearing as a compound feature. This observation leads to hypothesize that in the distinct areas the ridges have been formed contemporaneously, in response to some regional geodynamic repeated event.

The nine Holocene ridges which spread northward from the mouth of Rio Chira have been subdivided on a morphological basis (Chigne Campos, 1975; Richardson, 1983) into two sets. The older set (ridges # 9 to # 7) is characterized by a higher elevation of the ridges (up to + 4m) and deeper inter-ridge troughs (-1 to -2m) than the younger set (ridges # 6 to # 2). The twelve (uncorrected) radiocarbon dates obtained on archaeological material, thus postdating the formation of the concerned ridges, spread between 4485 \pm 90 BP (ridge # 9) and 805 \pm 60 BP (ridge # 2) (Richardson, 1983). Maximum C-14 age differences between consecutive ridges are of the order of 500 years.

In the Santa region (= Pampa las Salinas), nine beach ridges have also been mentioned by Sandweiss (1986) and Rollins *et al.* (1986). Sandweiss (1986) distinguished an older set of higher ridges (# 8 and # 7) from the six younger ridges. A radiocarbon date of 4235 \pm 115 BP (uncorrected) has been obtained from an "in situ" shell in ridge # 8 (Sandweiss *et al.*, 1983). Wells (1988) actually reported that the ridges are more numerous and that they pertain to four morphostratigraphic groups (one of them containing locally up to 24 small ridges). Furthermore, this author obtained a 4040 \pm 100 BC (calibrated) radiocarbon age for a shell deposit postdating the oldest (# 9) ridge and proposed a calibrated date of 1530 \pm 160 BC for the above cited 4235 BP C-14 date. Sandweiss (1986) and Wells (1988) agree that no neotectonic factor is involved in the formation of the Santa ridge sequence.

The beach ridge series located immediately to the NW of the town of Sechura, which also seems to possess 9 ridges, has not yet been thoroughly studied (Richardson & McConaughy, 1987).

The Colán sequence, previously described by Woodman & Polia (1974), contains eight main beach ridges, excluding the present-day coastal sand dune complex. The oldest ridge (# 8) is a compound feature including four or five consecutive individual ridges. Most of the sedimentary material of the ridges and particularly the pebbles are derived from the high cliffs which surround the Bay of Colán. A new topographic survey of the ridge sequence indicates that the crest of

most of the beach ridges (# 2 to # 8) reaches a +3 to +4m elevation (above MSL); ridge # 1 and subdued remnants of more recent shorelines are close to present high tide level. Partially reworked marine shells (s) and charcoals (c) interstratified in the ridge deposits yielded the following (uncorrected) radio-carbon results:

- ridge # 8: 3170 +/- 300 BP (c); 3020 +/-250 BP (s); 2890 +/-250 BP (s);
- ridge # 5: 2550 +/- 500 BP (c); 2510 +/-250 BP (s);
- ridge # 3: 2170 +/- 300 BP (s); 2080 +/-560 BP (c); 2040 +/-400 BP (c);
- ridge # 1: 960 +/-230 BP (s).

These preliminary results do not preclude a chronologic correlation with the nearby Rio Chira sequence, even if the oldest Colán ridge seems relatively young.

The eolian sand ridge which runs along the present shoreline does not compare with the older beach ridges. During the strong 1982-83 El Niño event, a former coastal sand ridge, similar to the present one, has been almost completely washed off by the waves (R. Woodman, pers. comm.). In the present conditions, and for the last centuries, no beach ridges have been built. Because of the configuration and the topography of the Bay of Colán the availability of sedimentary material has decreased through time, the height of the last ridges has diminished, and the main component of the ridges has evolved from cobbles to pebbles and finally to sand.

At Colán, there is no indication of recent tectonic activity which would have favoured the building of the beach ridges. These coastal features have been formed at a time when sea-level was close to its present position, but during short episodes of high wave energy and of increased availability of coarse material. Such conditions were most probably met during the major El Niño events (heavy rains and consecutive cliff erosion, sea-level rise of several decimeters, storminess).

Beach ridges are forming under varying conditions. In northern Peru, the occurrence of beach ridge sequences seems directly related to local parameters which fit with the effects of the El Niño climatic and oceanographic anomalies. By comparison with localities where there is a single conspicuous Holocene beach ridge, it is inferred that the sudden supply of coarse material brought to the coastline by discharge of the largest rivers (or by strong erosion of sea cliffs, in the case of Colán) is the main limiting factor of beach ridge formation. In the arid Peruvian coastal region, important runoff and river flows are primarily controlled by the El Niño rains.

It should be added that beach ridges are also observed atop two distinct Pleistocene marine terraces in the close vicinity of Colán. Further studies of these pre-Holocene features should be useful to reconstruct the conditions of formation of the Holocene sequence and the impact of the El Niño events.

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