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CONTROL OS SMALL-SCALE CHANGES OF SEA LEVEL FROM COASTAL DEPOSITS IN SE SPAIN

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The study of coastal morphology and detailed analysis of the sedimentary features provides useful tools for monitoring small scale changes of sea level, inside larger eustatic cycles, which are usually ignored. The recognition of the several types of cycles in sedimentary sequences can be a useful tool for constructing curves of sea-level changes and calculating uplift/subsidence rates. This can be achieved in many places of the western Mediterranean where tectonic trends during the Pleistocene times can be established (Bardají *et al.*, 1990).

This is the case of the Plio-Pleistocene basins of Cuatro Calas and Cope in Aguilas. Mutual interference of the three factors produced complex offlapping sequences (which are commonly referred to as "sequences of marine and terrestrial levels" or "marine terraces") and compound fan delta complexes. Short-term sea-level changes are deduced from the study of Pleistocene fan-delta deposits in the tectonic depression of Cuatro Calas. These deposits consist of units with large-scale foresets that filled most of this depression and were covered by a tabular topset (more properly called a transition-zone) of offlapping units. As a whole, they generated a Gilbert-type delta morphology with a subaerially-exposed topset and foreset and a bottomset laying under the present Mediterranean sea. This is due to the moderate trend of uplift during the Pleistocene. Average uplift rates calculated for the last 100 Ka range from 0.09 and 0.05 m/Ka (Zazo *et al., in press*). The Gilbert-type delta morphology is actually a summatory of smaller-scale delta units deposited during successive highstands inside a longer, larger highstand phase of sea level, probably one (or more) Interglacial stage.

The recorded pattern of offlapping marine and terrestrial units of the the transition zone (topset) implies repeated oscillations of relative sea level. A common feature of these deposits is their scour-and-fill trend: they fill spaces eroded into previous coastal units and adapt to each other's morphology using the compensation space available. The plunge-step deposits of the lower foreshore facies fairly mark the zero level in tideless beaches. The study of the vertical displacements of the plunge-step deposits indicates that, apparently, there is almost no difference in absolute water-depth involved in these changes. We take this as evidence of the scarcity of vertical accommodation space left for deposition, because the top of the fan-delta prism and the sea level or the base level of rivers were too close to each other. Relative changes of sea level are necessary to explain the seaward stacking of units (offlap) and the repeated incision without further evidence of neat increase of sea level.

Such changes are observed both in the topset and foreset parts of the delta complex. At least five main depositional events are distinguished in the topset (transition zone) but only four are visible in the foreset deposits.

Sea level changes control the sequence stratigraphy of these fan-delta deposits, but the various parts of the delta reacted differently to these changes of sea level (Fig. 1).

encountered sudden increases in coastal wave heights that were not tsunami related nor associated with any local weather disturbance. These *oleajes* are little studied but are generally believed to be the result of distant storm systems in the southeastern Pacific that create strong wave trains. I have observed these swells breaking on the shores of Chile and Peru with amplitudes approaching 4m. At such times rocks of boulder size and weighting far more than any mollusk are thrown inland and accumulate above spring high tide lines. Lighter material accumulates even farther inland becomes incorporated in the newest beach ridge actually in formation.

It is clear that under the circunstances outlined above it is possible for offshore bar and trough sediments, especially those recently deposited as a result of an ENSO event, to be swept onshore by these waves where conditions for progradation are favorable. But the same set of circunstances can also lead to scour of even older ENSO sediments that would then be mixed with younger material to create a beach ridge containing shell material of diverse age.

Of course, we must remember that the datable organic fossils and sub-fossils now found in beach ridges were never brought down to the sea by ENSO-related flash floods. They were all previously in place before such events, and in fact may well have been thousands of years old before being added to the beach ridge deposits.

For these reasons, I believe it is incorrect to assume each beach ridge can be correlated with an ENSO event and the error is made worse by using mollusks to date either the formation of the ridge, or the supposed ENSO event itself.

If members of the ORSTOM field trip encounter evidence to the contrary, I would be pleased to learn of it and re-think my position on this interesting problem.

In the case of the topset (transition zone) deposits, the highstand (to early lowstand) prograding beach units were partly eroded during the succeeding relative fall of sea level (lowstand), and lowstand-to-early-transgressive deposits covered the resulting valleys. Marine transgressive-to-highstand deposits covered the encased terrestrial deposits. Alluvial deposits filled scoured topographies eroded in older coastal beach deposits well below the sea level that existed during the sedimentation of the beach units.

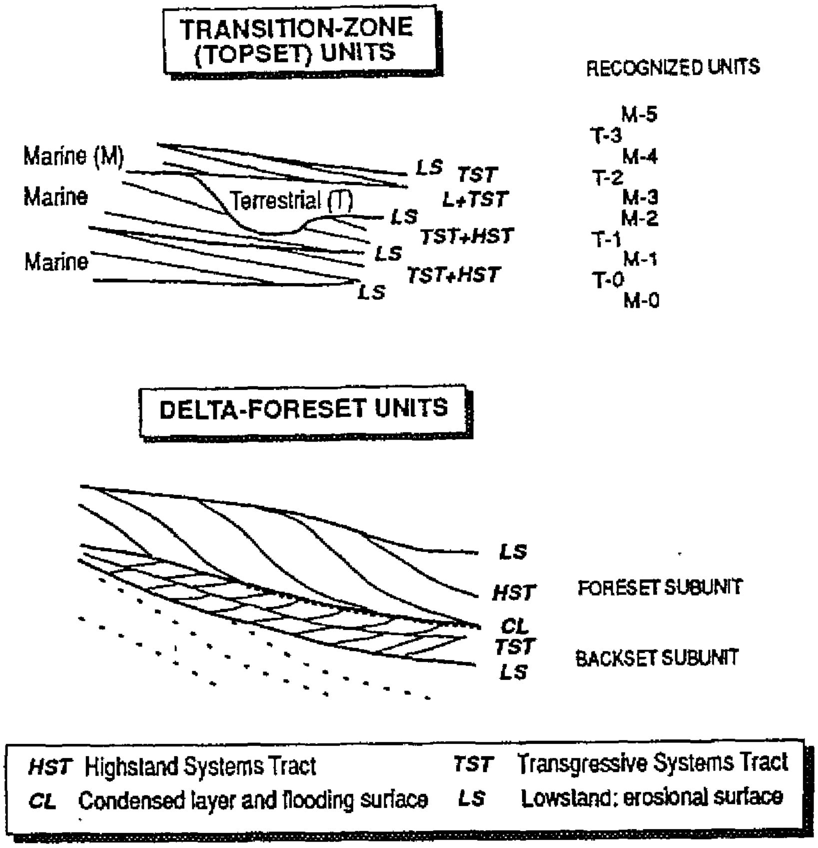

Figure 1.- Response of delta front and slope of a Gilbert-type delta to sea-level changes and resulting sequence stratigraphy of Cuatro Calas.

Sea level fluctuations also control the sequence stratigraphy of the delta-foreset units. Erosional incisions were excavated during lowstands in the foreset deposits. The erosional surfaces are covered by coarse-grained sub-units, with cross-bedding directed up the paleoslope (backsets). These deposits represent transgressive systems tracts followed by a condensation layer (ferruginous gravels) when transgression progressed. The foreset units *s. str.* are the highstand systems tracts of the successive units which downlap the transgressive systems tract. New falls of sea level produced erosional surfaces.

The development of the complex Gilbert-type delta followed a repetitive pattern in response to relative changes of sea level (Fig. 2): progradation occurred in highstands and entrenchment and coastal wedge in lowstand and early transgression. A highstand Gilbert-type delta (Stage 1) prograded when the sea level rose above the delta prism. Falls of sea level induced erosion of part of the delta prism (Stage 2), both by wave action and by entrenchment of fluvial channels. The cannibalized detritus and the fluvial input were carried down to the shelf and accumulated into lowstand (? deltas) wedges

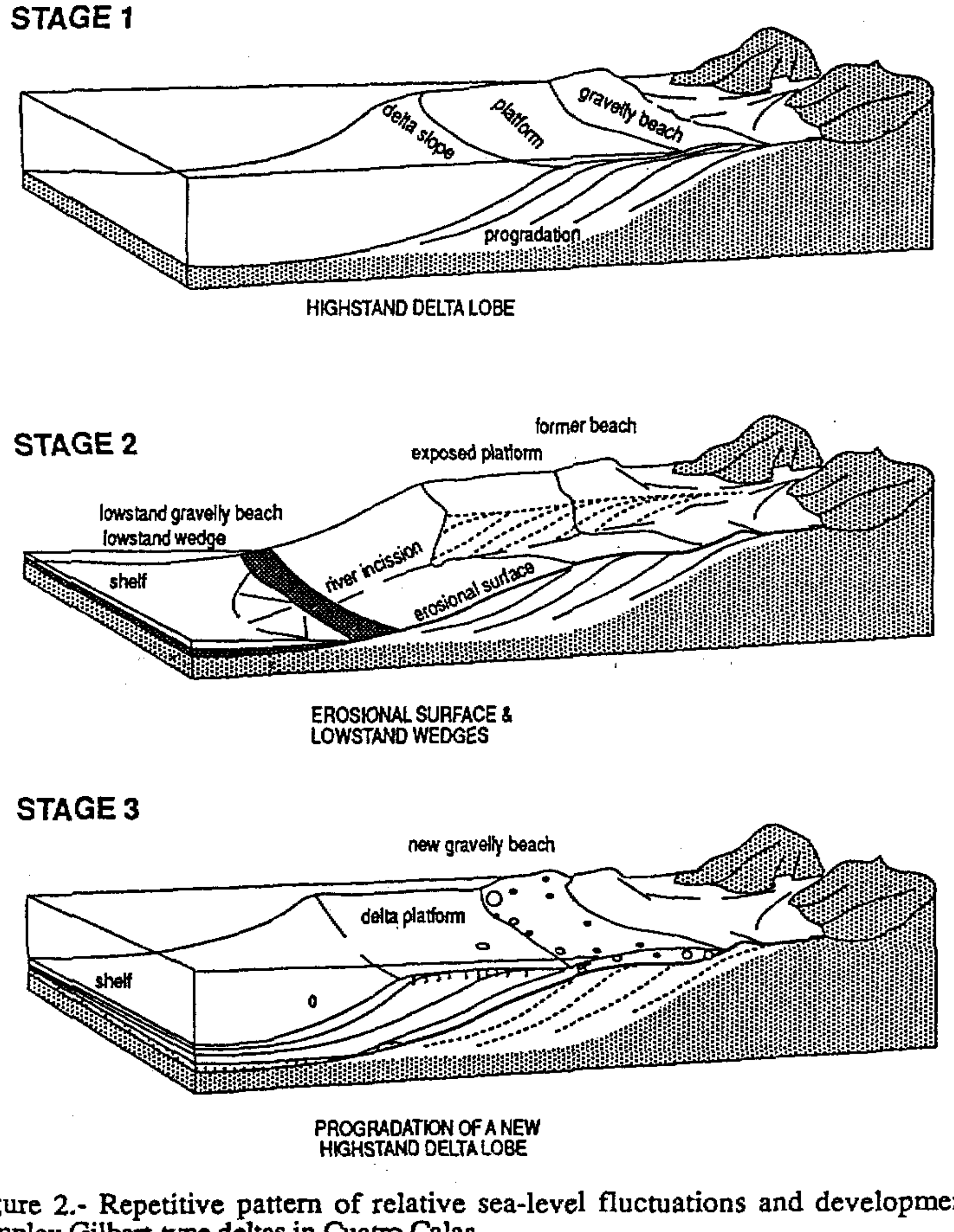

Figure 2.- Repetitive pattern of relative sea-level fluctuations and development of complex Gilbert-type deltas in Cuatro Calas.

Later rises of sea level allowed progradation of the partly-destroyed highstand delta (Stage 3). Beaches in the delta front prograded seaward with variable angles because of changes in the shore orientations induced by littoral drift and local constraints. Consequently they may diverge somewhat from the average delta-lobe progradation. This also illustrates that the progradation of complex delta prisms does not imply a continuous stillstand as usually assumed for simple Gilbert-type deltas.