XI Congreso Geológico Chileno
7 al 11 de agosto de 2006
Antofagasta - II Región - Chile

Actas, Vol. 2, Geodinámica Andina

SUBDUCTION EARTHQUAKE SEGMENT BOUNDARY EXPRESSED IN SURFACE DEFORMATION OF MEJILLONES PENINSULA

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INTRODUCTION

Mejillones Peninsula of northern Chile has been recognised as the surface expression of a major segment boundary for large subduction earthquakes since the 1995 M_w=8.0 Antofagasta earthquake (Delouis et al. 1997, Ruegg et al., 1996). A sharp northern boundary of the 1995 rupture surface along the subduction interface is delineated underneath Mejillones Peninsula by the aftershock distribution (Delouis et al., 1997, Sobiesiak 2000, 2005). Also the b-value distribution on the fault plane defines a major asperity close to the segment boundary (Sobiesiak, 2000, 2005). Investigating surface deformation including major fault systems and vertical displacement helps to identify the surface expressions of subduction zone processes including the deformation geometry and kinematics at asperity structures known to accommodate the highest slip values of large subduction earthquakes. Mejillones Peninsula provides an excellent example to study the effect of heterogeneities on the interface on surface deformation. In this study we investigate the uplift history of two Pleistocene sets of fossil strand-lines exposed in the Mejillones Graben (Fig. 1). We demonstrate that the coastal evolution of the Peninsula is the complex interplay between tectonic processes, sea-level fluctuations, rock type, wave energy and sediment supply, but that episodic tectonic uplift occurs only above an asperity at the subduction interface close to the segment boundary.

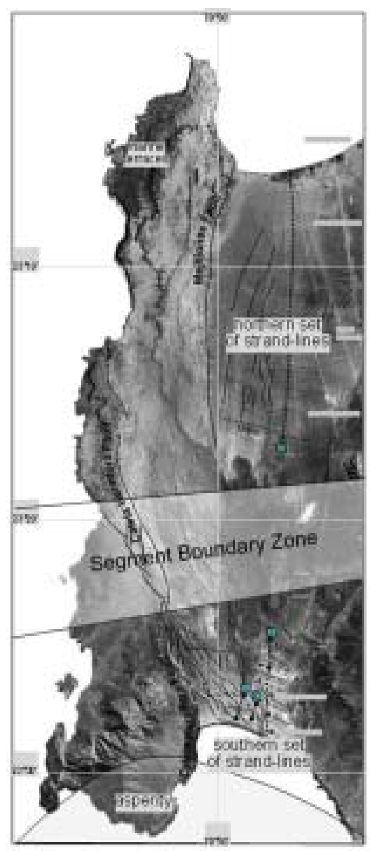

Fig. 1: Location of the segment boundary and asperity structure at Mejillones.

DIFFERENTIAL UPLIFT RATE ACROSS THE SEGMENT BOUNDARY

Uplifted cliffs and beach-ridges representing fossil strand-lines provide valuable information about the uplift history of Mejillones Peninsula. According to the sea-level curve for the Pleistocene (Siddall et al. in press) all of the vertical uplift recorded in fossil strand-lines is attributed to tectonic uplift, otherwise strand-lines would not be preserved today. We compare two sets of fossil strand-lines exposed in the Mejillones Graben (Fig. 1) to investigate the influence of the segment boundary and the asperities on their evolution. Strand-lines were mapped from aerial photographs and detailed topographic profiles were measured across them using differential GPS. Samples for U-Th dating were taken to document possible variations in uplift rates.

In plan view the two sets of strandlines are composed of a series of semi parallel and arcuate shelly beach-ridges with variable relief. They trend roughly parallel to the present shoreline (Fig. 1). The profiles across the southern set of strand-lines show a rugged topography with 3 distinct cliffs (Fig. 2a). The time of cliff formation is 400 ky ago for the uppermost cliff C3 and 330 ky for the second cliff C2 according to published age data (Ortlieb et al., 1996) and the assumption that the cliffs were formed during interglacial highstands. The third and most prominent cliff C1 represents the shoreline of today. The strand plain between the cliffs C3 and C2 is divided by 4 downstepping sets of beach-ridges with up to 6.4 m vertical relief. Mean uplift rate in this section since 400 ky is 0.38 mm/y which is slightly above the uplift rates ranging from 0,15 – 0,24 mm/y in N-Chile for the Quaternary (Ortlieb et al. 1996, Radtke 1989, Zazo 1999). Incremental uplift rates in contrast are as high as 1.2 mm/y for the 70 ky period between formation of C3 and C2 and 0.2 mm/y since 330 ky, pointing to transient changes in uplift rate since at least 400 ky (Fig 2c). The 4 beach-ridges preserved between C3 and C2 indicate that episodic uplift events contributed to the high uplift rate during this time period in the south of the Peninsula.

The 20 km broad strand-plain in the north of Mejillones Peninsula is an almost flat surface inclined to the north with only slight variations in local gradient (Fig. 2b). Except for the present cliff no cliffs are developed. Downstepping beach-ridges are also lacking and strand-lines can only be distinguished by a marked colour contrast of sediments on aerial photographs or satellite images. Age data for Pleistocene sediments are successively younger northward ranging from MIS 11 (400

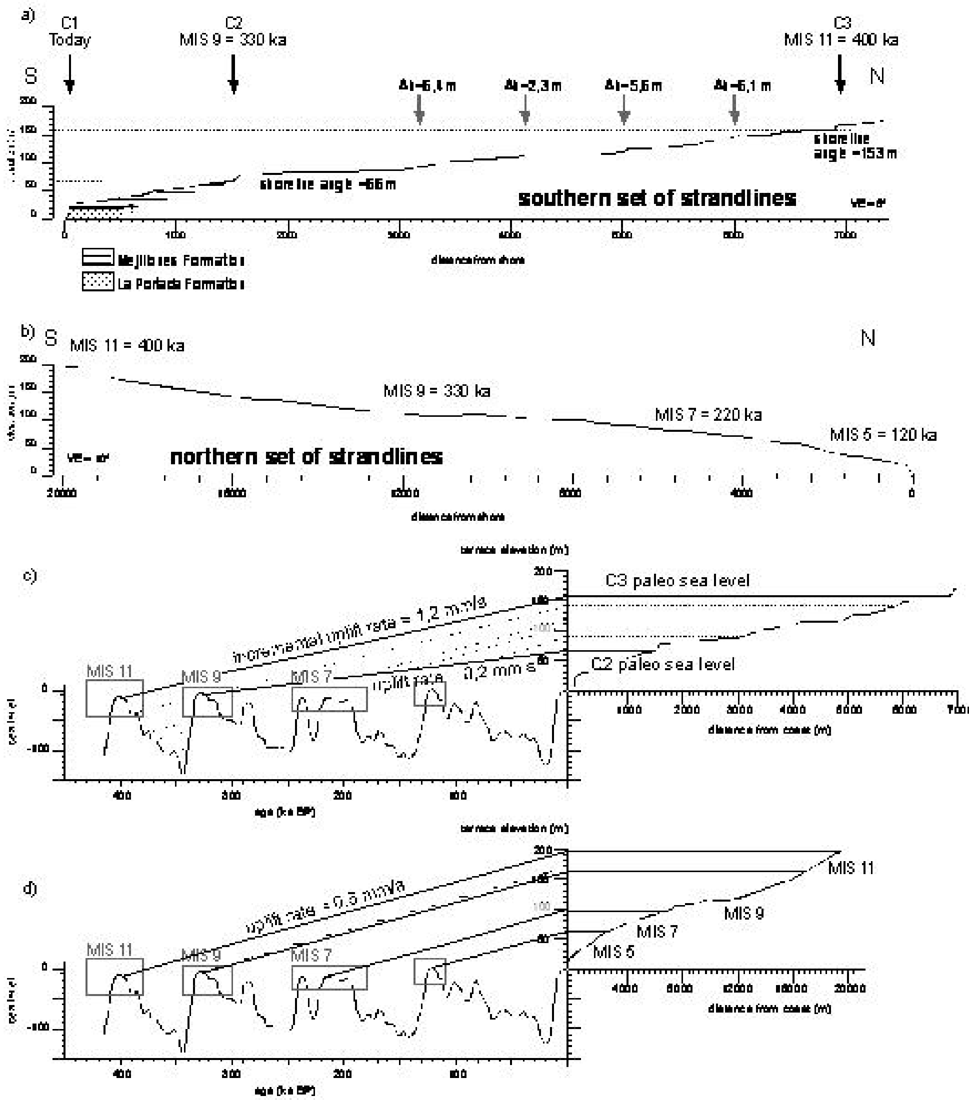

Fig. 2: Topographic profiles showing the coastal morphology a) & b) and uplift rates c) & d).

ky) to MIS 5 (120 ky) (Ortlieb et al. 1996). These observations indicate that the North of the Peninsula uplifted continuously with a mean uplift rate of 0.5 mm/y since 400 ky and strand-lines might be correlated with as many successive interglacial episodes which are preserved due to the continuous tectonic uplift process (Fig. 2d). This uplift rate corresponds well with the uplift rate of 0.6 mm/y for elevated marine terraces exposed at the west coast of northern Mejillones (Casanova et al. 2006). The difference in uplift rate is most probably due to relative motion along the Mejillones fault separating the two blocks. Differences in morphological characteristics between the northwest and the northeast block depend on bedrock and wave energy.

These findings indicate differential uplift since the Mid-Pleistocene over Mejillones Peninsula. Continuous uplift is observed north of the segment boundary since at least 400 ky whereas a discontinuous uplift history is recorded in the South where we observe a particularly high incremental uplift rate for the time period between MIS 11 and MIS 9 followed by an episode of relatively low mean uplift rate since then. We propose that this low mean uplift rate is again the sum of differential vertical displacements including episodes of tectonic subsidence and tectonic uplift of southern Mejillones, which is recorded in marine infill exposed in gullies of the Caleta Heradura Fault scarp.

INFLUENCE OF THE ASPERITY AND THE SEGMENT BOUNDARY ON SURFACE DEFORMATION

The differences in the coastal uplift signal across the segment boundary suggests that surface deformation is intimately tied to the subduction process. Asperity structures on the subduction interface have a strong effect on the temporal evolution of uplift. The discontinuous uplift recorded in the fossil strand-lines south of the segment boundary close to the northern edge of the asperity points to a multiple succession of relatively high incremental uplift rates, low incremental uplift rates and even incremental subsidence in total represented by a slow, but cumulative uplift of the coast. Compared to the continuous uplift signal of northern Mejillones differential uplift of the two blocks helps to identify the segment boundary at surface.

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