Neogene tectonic and geomorphologic evolution of the Chilean coast between 30°s and 32°s: Study of marine abrasion surfaces

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INTRODUCTION

The Pacific coast morphology and especially the presence of marine abrasion surfaces gives information on the dynamics of Andean forearc evolution from the Neogene. In this paper, we analyse the geomorphology of the northern Chilean coast between Tongoy (30°15'S) and Los Vilos (31°55'S). That area is situated above a flat subduction segment that could result from the subduction of the Juan Fernandez ridge at around 33°S since 10 My (Yañez et al, 2001). Along that part of the coastal zone, we observe discontinuous, parallel to the coast, gently seaward-sloping marine abrasion surfaces. They are limited by a scarp both their base and their top. In the following, we characterise these surfaces by the altitude of their upper internal limit, at the foot of the top scarp, called shoreline angle (Fig.1) ; we recognize up to four surface levels corresponding to terraces reaching more than 500 m of elevation (above present-day MSL): T_0, T_1, T_2, T_3 ; T_0 being the younger and T_3 the older surface. According to their geographical location, their width is more or less important and their characteristic elevation varies (Fig.2-3).

COASTAL MORPHOLOGY

Distribution of marine abrasion surfaces: T_0 is the less-developed abrasion surface. It corresponds to the active abrasion surface which is still submitted to marine action in its lower part; it contains relicts of the previous surface which are not completely levelled yet. The maximum elevation of the shoreline angle is comprised between 12 and 18 m (Fig.2-3). The T_1 surface has the most regular and continuous geographical distribution along the coast ; generally, its width is about 500 m and the higher part of this surface is comprised between 20 and 76 m of elevation, depending on its latitudinal location (Fig.2-3). South of the study area, T_1 is lower and wider: its shoreline angle varies between 26 and 59 m and its width can reach 3 km (Fig.2-3). The T_1 morphology often shows relict parts of the previous surface. No sediment was found on the whole surface. The T_2 surface is only present in the northern part of the study area, it disappears south of *Punta Talca*; its average width is 2 km but it can reach locally more than 3 km at the *Río Limarí* mouth or at *Punta Lengua de Vaca*. The shoreline angle elevation is very variable, between 114 m and 250 m. Maximum elevations are reached at the *Altos de Talinay* and *Río Limarí*, and they decrease laterally on both sides. This surface is deformed by a lot of faults explaining its variable elevation along the coast (Fig.2-3). Again, there is no sediment covering this surface. T_3 is continuous south of *Punta Limarí Sur* up to 32°S. We find it again, northward, on the *Altos de Talinay*, above *Punta Farellones*. It extends over a large surface area, its average width being roughly 6 km on average and up to 11 km above *Punta Talca*. The elevation of the upper part of that surface varies a lot, between 112 and 528 m asl (Fig.2-3). Indeed, this surface is cut by many faults that displace it vertically. Among these faults, the *Teniente Fault* cuts this surface with an average vertical slip of 40 m. The surface elevation decreases of approximately 200 m from North to South. Moreover, from *Bahia Teniente* up to the mouth of the *Río Choapa*, the surface overhangs directly the Pacific Ocean: T_2 is absent and the T_1 surface is discontinuous and narrow in that area (Fig.2-3).

Lithology influence: we observe that the lithology of the substratum does not exert a major control on the surface distribution: in the north, the four levels are developed over magmatic rocks and in the south, the T_3 surface extends indifferently over different lithologies.

Neotectonic evidences: in the study area, faults cutting sediment or displacing abrasion surfaces correspond to normal faults striking more or less parallel to the coast (between about N340° and N40°), with a vertical slip, without any strike-slip component (Fig.2). These faults do not influence markedly the morphology of surfaces; they just influence their width and elevation. All the faults don't move the different surfaces of the same amount of displacement. Within a same surface, the vertical movement of a fault can also vary; for instance, from 9 m (*Punta Limarí Sur*) to 54 m (*Punta Limarí Norte*) for T_2. More generally, on the one hand, we observe that the T_3 surface is more deformed by faults than the three other surfaces: it is cut by a greater number of faults, and their vertical offset is also larger; and on the other hand, we observe that the northwestern part of the study area (*Altos* *de Talinay*) is more deformed than the southern (*Caleta Manso-Los Vilos*) and the eastern (*Bahia Tongoy*) zones (Fig.2).

N-S variations of marine abrasion surfaces elevation: in the north, at *Altos de Talinay*, we note the four surfaces whereas in the south, at *Caleta Derumbe* for instance, only the T_3 surface is visible (Fig.2-3). South 30°58', the T_2 surface disappears; the T_3 surface becomes wider and its shoreline angle elevation decreases from north to south (Fig.2-3). Generally, we notice that surface elevations are smaller in the south than in the north (Fig.3). This shows that the northern part of the study area was further uplifted than its southern part.

MARINE ABRASION SURFACE AGE

None dating has been done on these four marine abrasion surfaces for this study although several dating have been realised along the Chilean coast on marine terraces (Radtke, 1989; Leonard and Wehmiller, 1992; Ota and Paskoff, 1993; Ota et al., 1995; Ortlieb et al., 1996; Marquardt et al., 2004...). They assigned them a late Pliocene-Pleistocene age. Moreover, four marine terraces have been dated in Bahia Coquimbo area, 80 Km to the north of Tongoy, and assigned to a late Pliocene-early Pleistocene age for the two older terraces and to the oxygen isotope stage 9 and 5e for the two younger (Radtke, 1989; Leonard and Wehmiller, 1992). So, we could infer that the four marine surfaces of the study area are approximately from the same age, because of the small distance between the two areas.

DISCUSSION: Causes of the tectonics and uplift of the Tongoy-Los Vilos coastal area

Marine abrasion surfaces formation results from the interaction of eustatism and regional tectonic effects in the coastal zone. Eustatism alone cannot explain the present-day surface elevation since the higher see level reached in the Neogene is 15,5 Ma-old and is only 150 m above the present see level (Hardenbol et al., 1998). In our study area, in contrast, the older abrasion surface is higher than 500 m asl, evidencing the uplift of that part of the Chilean coast.

The observed uplift cannot result from the subduction of the Juan Fernandez ridge since the north of the study area, far from the ridge, is more uplifted than the southern part. Moreover, we mostly observe N-S striking normal faults, whereas the subduction of the Juan Fernandez ridge should be result in the formation of E-W faults in this part of the Chilean coast. We also note that abrasion surfaces are also present in other parts of the Chilean coast, such as in the Mejillones Peninsula (about 23°15'S), where 400 m-high Quaternary surfaces have been described (Ortlieb et al., 1996a). This shows that the subduction plane geometry is not responsible for the coastal uplift since the Mejillones Peninsula is located above an inclined subduction segment, contrary to our study area. We observe that the region studied here is situated at a particularly small distance from the trench and that this distance is smaller in the northern part of our study area. In fact, the trench closest area is also the most uplifted. The same phenomenon is observed by Ortlieb et al (1996a) for the Mejillones Peninsula. Thus, we argue that the phenomenon that could explain the tectonics affecting the Chilean coast is the underplating below the Coastal Cordillera (Lallemand et al., 1994; Adam et Reuther, 2000), resulting in the formation of normal faults and in uplift.

Several authors have linked the coastal deformation with coseismic vertical movements, studying coralline algae records in the Antofagasta area (around 23°40'S, Ortlieb et al., 1996b), and the uplift of emerged marine platforms and of the coastal cliff along the Chilean coast (Marquardt et al., 2004; Quezada et al., 2005). They argue that the long-term uplift is positively correlated with the coseismic uplift, i.e. that the post seismic and interseismic subsidence of the coast does not completely compensate the uplift that occurs during earthquakes. The coseismic uplift being larger when the coast approaches the trench, this could explain why we observe higher terraces in the northwestern part of our study area.

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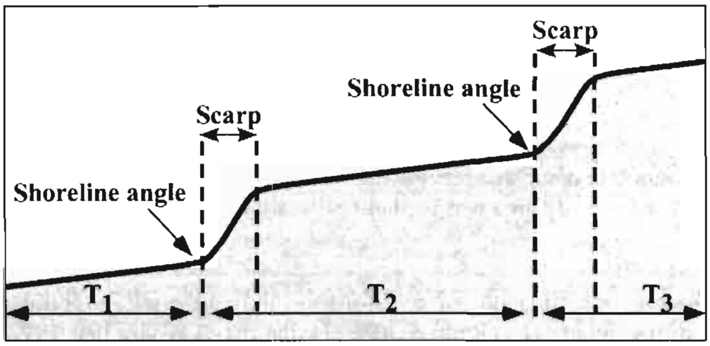
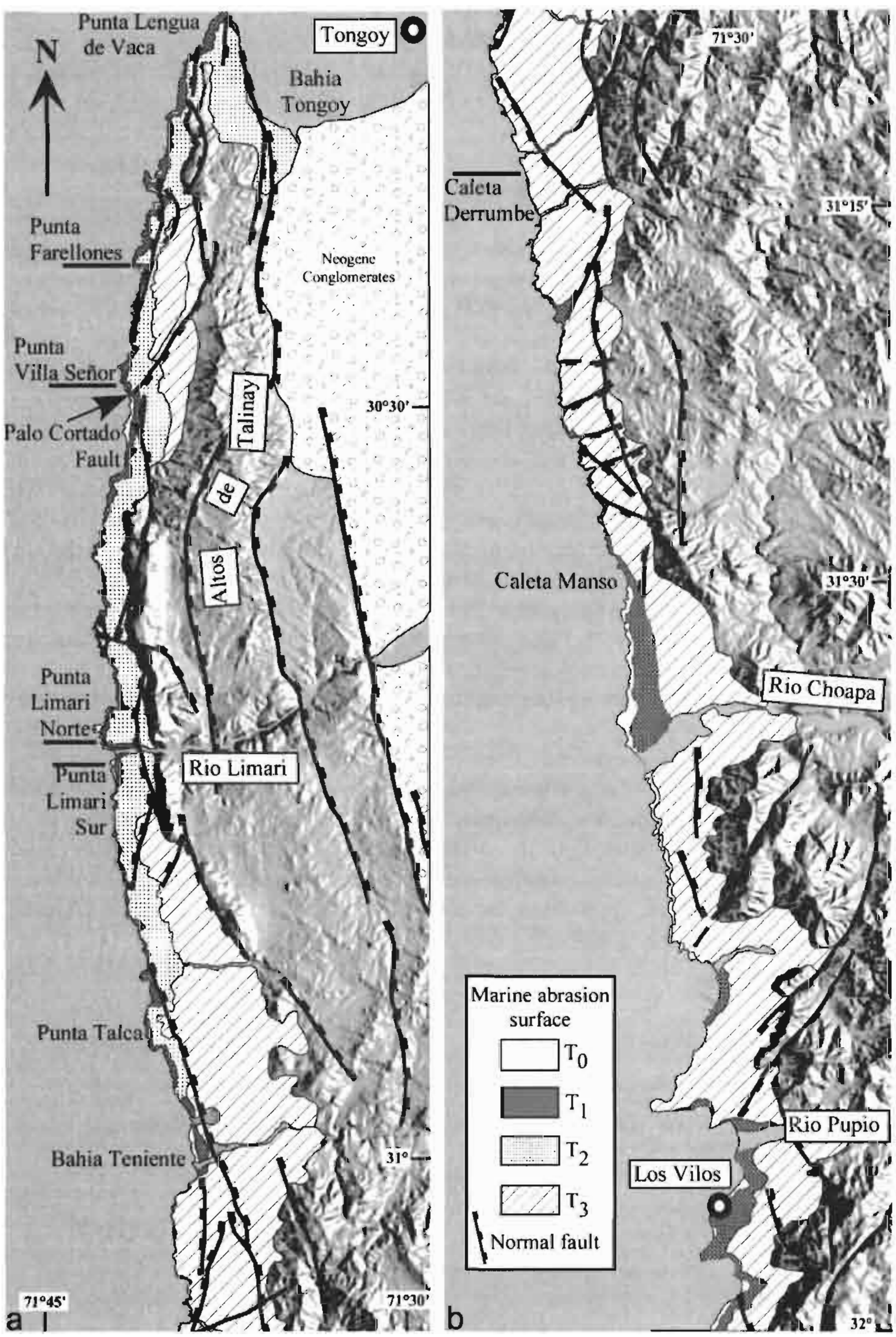


Fig.1: Marine abrasion surfaces morphology



a
b
Fig.2 : Marine abrasion surfaces and fault distribution between Tongoy and Los Vilos on a hill shade DEM.

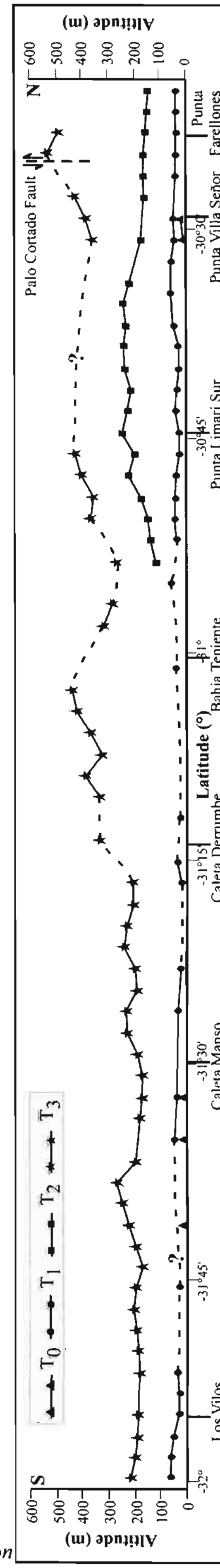


Fig.3: N-S variation of marine abrasion surfaces elevation