THE LATE CENOZOIC TECTONO-SEDIMENTARY EVOLUTION OF THE NORTH CHILEAN PACIFIC MARGIN (21°30' - 24°S).

Adrian J. HARTLEY(1) and Elizabeth J. JOLLEY(2)

(1) Department of Geology and Petroleum Geology, Meston Building, King's College, University of Aberdeen, Aberdeen AB9 2UE, U.K.
(2) BP Exploration, Aberdeen.

RESUME: El estudio de la evolucion sedimentologia, geomorfologia y tectonica del Mioceno-Holoceno de la costa norte de Chile entre 21°30' y 24°S ha revelado la siguiente seqeuncia de eventos: 1) Subsidencia y sedimentatcion del mid Mioceno al Pleistoceno, 2) Levantamiento y formacion de terrazas marinas controladas por ascensos eustaticos interglaciones, ascensos tectonico y ascenso controlado por fallamiento asociado a la domacion regional del margen de subduccion.

KEY WORDS: northern Chile, Late Cenozoic, marine terraces, tectonics

INTRODUCTION

The Late Miocene to Recent uplift of the Central Andean Pacific margin of South America is recorded by the development of a number of marine terraces and exposed shallow marine and continental sediments of Miocene to Recent age. However, whilst terrace development has been recognised for some time, correlation along the Pacific margin has proved extremely difficult. Correlation difficulties have arisen because of variations in the ages, numbers and heights of terraces due to a combination of fluctuations in sea-level resulting from the Quaternary glaciation superimposed on areas of differential uplift along the Pacific margin. Here we illustrate how a detailed study of Miocene to Recent sedimentation along the north Chilean coastal margin can help to constrain uplift mechanisms. The understanding of these uplift mechanisms has important implications for the tectonic evolution of the Coastal Cordillera.

PREVIOUS WORK

Previous work on coastal uplift in northern Chile has focussed on marine terrace and beach ridge development across the Mejillones Peninsula (Okada, 1971; Armijo & Thiele, 1990) Descriptions of these uplift related phenomena are restricted to the area around the Mejillones Peninsula and little attention has been paid to uplift related features north and south of the Peninsula. Here we present data on Miocene to Recent shallow marine sedimentation, terrace, beach ridge, alluvial fan and fan delta development along the north Chilean coast between 21°30' and 24°S. These data allow constraints to be placed on the mechanisms of uplift on both local and more regional scales.

MIOCENE-RECENT STRATIGRAPHY

Three Miocene to Recent stratigraphic units can be recognised on the coastal

margin between 21°30' and 24°S overlying the andesitic volcanics of the La Negra Formation, Jurassic granodiorites or Cretaceous sediments: 1) Shallow marine sediments of the 40 m thick La Portada Formation of Mid Miocene-Pliocene age (Herm, 1969; Ferraris & Di Biase, 1978) which crops out over the southern half of the Mejillones Peninsula and extends further southwards to the northern edge of Antofagasta. 2) Pleistocene to Holocene shallow marine and beach sediments of the Mejillones Formation (Ferraris & Di Biase, 1978). The formation is up to 80 m thick and disconformably overlies the La Portada Formation. The Mejillones Formation is exposed over much of the northern part of the Mejillones Peninsula. 3) Pleistocene to Holocene alluvial fan, aeolian, fan delta, beach and shallow marine sediments (up to 50 m thick) which flank the Coastal Cordillera and are equivalent to the Mejillones Formation.

Sedimentology

Detailed sedimentological analysis of these 3 stratigraphic units has led to the following synethesis. Throughout Mid Miocene, Pleistocene and Holocene times virtually continuous shallow marine sedimentation (upper shoreface, shoreface-foreshore trnsition, foreshore and beach) dominated over much of the study area with the exception of 1) a minor interruption in the early Pleistocene indicated by the development of an angular unconformity between the La Portada and Mejillones Formations and 2) localised fault activity during the late Miocene early Pliocene at Caleta Herradura indicated by the development of a minor unconformity restricted to the half-graben. Quaternary alluvial and aeolian sedimentation was restricted to the margins of the basin where sediment was supplied from the Coastal Cordillera and isolated (islands) fault blocks. Areas in the centre of the basin had restricted clastic input during the Pleistocene are characterised by the development of bioclastic limestones with calcareous mudstones and chalks suggesting deposition below fair-weather wave base.

Marine Terraces

Marine terraces (palaeo-clifflines) cut in Miocene-Recent sediments, developed along the coastline of northern Chile in the Holocene (0.5 to 16 m elevation) and Late Pleistocene (16 to 70 m). Up to 6 terrace cutting events are recognised although in a number of places composite terraces are thought to have formed (*i.e.* where 3 or 4 base-level falls are amalgamated to a single cliff line by erosion). A late Pleistocene planation surface and two older planation surfaces are recognised (over 600 m elevation) which are likely to be of Early Pleistocene to Pliocene age. Similar ages for a number of terraces (now at different heights) suggest that terraces were cut by sea-level highstands developed during interglacials. Variations in terrace height are attributed to tectonically-induced tectonic uplift particularly as the highest planation surfaces are associated with active faults.

Regional Uplift

Whilst fault activity and sea-level highstands are responsible for terrace formation

In addition the distribution of Miocene to Recent marine sediments in Northern Chile follows a similar pattern, with the largest preserved record of marine sediments located adjacent to the Mejillones area and a gradual decrease to the north and south of the peninsula, a feature also also recorded by a narrowing of the coastal plain to the north and south of the Peninsula. These observations imply that there has been a broad updoming of the Coastal Cordillera with the main area of uplift located on the Mejillones Peninsula. A hypothesis supported by recent tide-gauge data which indicate that the area around Antofagasta is in net uplift. Interestingly the present day trace of the Atacama Fault Zone parallels this zone of uplift and basin formation - the fault is at its maximum inland distance at Mejillones but to the north and south the fault trend swings out to sea at Salar Grande in the north and Talatal in the south. This suggests a possible causal relationship between uplift and the trace of the Atacama fault Zone.

Origin of Regional Uplift

Pleistocene to Recent marine terraces have been uplifted along much of the Pacific Margin of South America and as such are almost certainly related to changes in the geodynamics of the subduction zone. The scale and aerial extent of uplift in the study area precludes a fault-related origin, particularly as the scale of fault-related uplift can be identified (*e.g.* on the Mejillones Peninsula). In addition, the regional variation in uplift across the study area suggests that another mechanism of uplift is superimposed on the mechanism responsible for uplift of the entire coastal margin of the Central Andes. Given the proximity to the subduction zone it is likely that any potential mechanism will be relalted to heterogeneities at the subduction zone. The most likely mechanism for this regional uplift is that of aseismic ridge subduction, where subduction of anomalously thick bouyant oceanic crust is thought to induce local uplift of the margin. Examination of bathymetric data for the ocean floor of northern Chile west of the study area reveals the presence of an aseismic ridge which forms a spur to the Iquique Ridge and is located due west of the Mejillones Peninsula. It is possible therefore that the regional uplift of the margin in the study area is related to aseismic ridge subduction concentrated around the Mejillones Peninsula.

The origin of the general uplift of the Pacific Margin of South America is beyond the scope of this paper, however, it is a strong coincidence that the start of uplift of the margin at approximately 21 Ma also conicides closely with the propsed time of shallowing of the subduction zone propsed by Kay *et al.* (1988) for the area between 28 and 33°S.

Origin of the Coastal Scarp

Recently the Coastal Scarp has been intepreted as an extensional fault by Armijo & Thiele (1990). The basis for this observation is the presence of surface fault breaks on the scarp. However, detailed observations from aerial photographs and fieldwork have failed to identify any exposed fault breaks along the scarp with the exception of the Cerro Moreno Fault which has demonstrable left-lateral kinematic indicators and extends for approxiately 35 km. As Armijo & Thiele suggest that the Coastal Scarp fault links to the subduction zone it is somewhat strange that there is no evidence of post-Pleistocene fault breaks along its length or any linear features which could be interpreted as possible palaeo-fault traces given that many faults in the area have been active throughout this time period. Consequently, the Coastal Scarp is interpreted here as a degraded palaeo-cliffline possibly of early Pleistocene or older age.

Conclusions

The Late Cenozoic to Recent tectonic evolution of the Coastal Cordillera of northern Chile records the following series of events:

1) Subsidence and sedimentation in a fault-bounded extensional (half-graben style) shallow marine basin (the La Portada Formation) took place in Late Miocene to Pliocene

times, the presence of localised unconformities testifies to sporadic fault movement. The development of the two oldest planation surfaces on northern and central parts of the Mejillones Peninsula and around the Cerro Moreno Fault is also thought to have taken place at this time.

2) Local tilting resulted in the development of a minor unconformity and continued subsidence and sedimentation in a fault-bounded shallow marine basin during Pleistocene times (Mejillones Formation) with marginal marine, alluvial and aeolian sedimentation along the margin of the basin. Cyclicity deveolped within these alternating continental and marine sediments may reflect mid-Pleistocene glacio-eustatically-induced sea-level fluctuations.

3) Sporadic uplift and development of marine terraces in the form of palaeo-cliffiines (up to a maximum of 6) and basment planation surfaces occurred during the Late Pleistocene and Holocene. Uplift resulted in the exposure of Miocene-Pleistocene marine sediments within the terraces and large scale incision within alluvial fan channels, some of which have followed the same course for over 350,000 years.

4) Terrace formation is related to interglacial sea-level highstands.

5) Terraces of the same age are presently at different heights due to differential uplift caused by fault movement.

6) Uplift of a mid to late Pleistocene shoreline within the study area reveals a regional scale uplift phenomena centered on the Mejillones area which is of too large a scale to be fault-related and of too small a scale to account for the uplift of the entire central Andean margin (represented by uplifted marine terraces noted by other workers). Due to the proximity to the subduction zone (16-30 km below the coastline) uplift is considered to be related to local variations in subduction zone geodynamics. The favoured hypothesis is that of aseismic ridge subduction within the study area.

7) The uplifted area forms a broad, easterly convex zone which parallels the trend of the Atacama Fault Zone, possibly indicating that movement of the Atacama Fault Zone in this area may result from strain partioning between the Coastal Cordillera and the Central Depression (Pampa de Tamarugal) caused by aseismic ridge subduction.

8) The Coastal Scarp is considered to be a Miocene to Pliocene palaeo-cliffline and not a major extensional fault, due primarily to the lack of active faulting along the scarp and the