Sediment accretion against a buttress beneath the Peruvian continental margin at 12° S as simulated with sandbox modeling

Abstract Reflection seismic data from the Peruvian continental margin at 12° S clearly reveal an accretionary wedge and buttress. Sandbox experiments applying the physical concept of the Coulomb theory allow the systematic investigation of the growth and deformation of such an accretionary structure. The style of deformation of the buttress and the internal structure of the wedge is observed in the sandbox models. The possibility of underplating material beneath the buttress and the amount of tectonic erosion depend on the physical properties of the materials, mainly internal friction, cohesion and basal friction. Boundary conditions such as the height of the subduction gate and the thickness of incoming sand also constrain the style of growth of the model accretionary structure.

The configurations of two experiments were closely scaled to reflection seismic depth sections across the Peruvian margin. A deformable buttress constructed of compacted rock powder is introduced to replicate the basement rock which allows deformation similar to that in the seismic data. With the sandbox models it is possible to verify a proposed accretionary history derived from seismic and borehole data. The models also help in understanding the mechanisms which control the amount of accretion, subduction and underplating as a function of physical properties, boundary conditions and the duration of convergence.

Key words Accretionary prisms • Convergent margins • Peru • Analogue modeling • Tectonics • Accretion • Tectonic erosion • Marine geophysics

Introduction

The concept of a buttress or backstop has been firmly implanted in published work on convergent margins (Byrne et al., 1988; 1993). It is considered to be the seaward edge of the island arc or continental margin older rock framework against which an accretionary prism forms (von Huene and Scholl, 1993). Conceptually, this body is the anvil against which offscraped trench sediment is accreted and tectonically deformed.

A good example of an actual buttress is imaged in seismic records across the Peruvian continental margin. Beneath the slope, a wedge-shaped body of crystalline rock with probable continental affinity has been imaged through careful processing of seismic records (Moore and Taylor 1988; von Huene and Miller 1988; von Huene, in press). Against this wedge-shaped buttress a prism of trench sediment about 10 km wide has been accreted. Deformation visible in the overlying sediments may give a hint that deformation also occurs in the narrow tapered end of the buttress.

The evolution and deformation of the accretionary body in front of a buttress can be forward modeled applying a sandbox technique. However, in most former models the buttress was modeled as a hard, non-deformable member and sand was accreted against a landward or seaward dipping rigid stationary buttress (Byrne et al., 1988; Mulugeta 1988; Lallemand et al., 1992). To achieve more realistic conditions, Byrne et al. (1993) used a deformable backstop made of wet sand. Considering the tectonic deformation in the buttress off Peru, we introduced a deformable buttress (compacted rock powder) in the sandbox modeling. Furthermore, we scaled the models after observations in seismic records across the Peruvian margin to replicate features observed in nature and we allowed material to leave the system through a ‘subduction window’ to simulate that in nature a certain amount of material is transported to greater depths.

In this paper we report the results of our sandbox modeling. A main objective of our models was to test...
Fig. 1. Map of the Peruvian continental margin showing available reflection seismic lines near 9°S and 12°S latitude and ODP drillholes

Tectonic history of the Peruvian margin

Four seismic lines (1017, 1018, CDP-1, HIG-14) covering about 30 km along the Peru margin near 12° S show the accretionary wedge and the buttress (Fig. 1). Line CDP-1 from the Nazca Plate Project and Shell 1017 were processed in the time domain to a pre-stack migration in preparation for ODP drilling on leg 112 (von Huene and Miller, 1988). HIG-14, which was also a part of the drilling transect (Moore and Taylor, 1988), was post-stack time migrated. The Shell line 1018 is also very close to the main drilling sites. Because of this proximity and because the Shell data are of fairly high quality, both Shell lines were pre-stack depth migrated at GEOMAR (von Huene and Pecher, unpublished data).

From early wide-angle seismic data (Hussong and Wipperman, 1981) it was known that seismic velocities of 5 km s⁻¹ and greater characterize upper plate rocks landward of the first 10 km of the margin. In seismic reflection records, coherent reflections were visible along boundaries above and below a high velocity wedge, but incoherent events characterized its interior. Rocks recovered from outcrops at the edge of the shelf and along the lower slope indicated that the area of incoherent reflections could represent equivalents of the schists and gneisses that are exposed in the coastal mountains. After drilling leg 112, these rocks were observed from a submersible in outcrops at the foot of the margin in Chiclayo Canyon (Sosson et al., 1992). During leg 112 a shallow water Eocene sandstone which is known to rest unconformably on the metamorphic rock cropping out at the edge of the shelf was recovered from two sites on the lower slope near 12° S. The unconformity is seen in all multi-channel seismic records across the continental shelf and is inferred to extend onshore. This regional unconformity, now up to 5 km below sea level, was a subaerial erosion surface in pre-Middle Eocene time (von Huene, Suess et al., 1988) because the shallow water continental origin of the sandstone on the unconformity makes it unlikely that the underlying basement is an Eocene deep water accretionary wedge. Minor deformation affects the thin tapered part and only extensional deformation of the basement is observed to cut the basement from the middle slope landward (Fig. 2). These observations indicate that the wedge-shaped buttress is a relatively rigid body probably composed of metamorphic rock similar to that in the coastal massif (Kulm et al., 1988).