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Undeformed Sediments in Oceanic Trenches with Sea Floor Spreading

THE study of magnetic anomalies associated with mid-ocean ridges indicates that sea floor spreading is active in the vicinity of these ridges[1]. Mid-ocean ridges are thought likely to be the sites of upwelling convection currents and oceanic trenches to be the sites of descending currents[2]. Most trenches are associated with intense seismic activity[3-6]. The hypocentres of earthquakes occur along almost planar zones (Benioff zones) which may be the result of movement of the sea floor under continents or island arcs. Seismic refraction studies of oceanic trenches, however, indicate that the sediments within the trenches are essentially undeformed and that there is no large accumulation of deformed sediments with a low seismic velocity associated with these trenches[7-10]. The absence of deformed low velocity sediments has been cited as evidence that the sea floor is not descending in the vicinity of these trenches[7,8,10]. Scholl *et al.*[10] assume that deformed pelagic sediments would be expected within the trenches if the sea floor is actively underthrusting a continent or island arc. The centre of the Benioff zone, however, typically intersects the ocean floor landward of the axes of oceanic trenches[4-6]. This indicates that downward movement of the sediments occurs landward of the axes of the trenches rather than directly under the axes of the trenches.

It seems likely that the pelagic sediments and turbidites deposited in trenches would be folded, faulted and thickened as they are carried beneath a continent or island arc (Fig. 1). This would lead to dewatering and perhaps even low grade metamorphism of the sediments converting them into shale, graywacke, slate and metagraywacke. Landward of many trenches, a thin layer of low velocity sediments overlies a layer with a seismic velocity ranging from 4·4–5·0 km/s (refs. 10–13). The layer with a velocity of 4·4–5·0 km/s may be composed of deformed sedimentary and metamorphic rocks which are in part equivalent to, and continuous with, the undeformed sediments in the adjacent trench. Balakrishna and Ramana[14] report compressional wave velocities (measured in the laboratory) for shale ranging from 4·2–5·0 km/s, for slate ranging from 4·2–5·6 km/s and for sandstone ranging from 4·1–6·2 km/s.

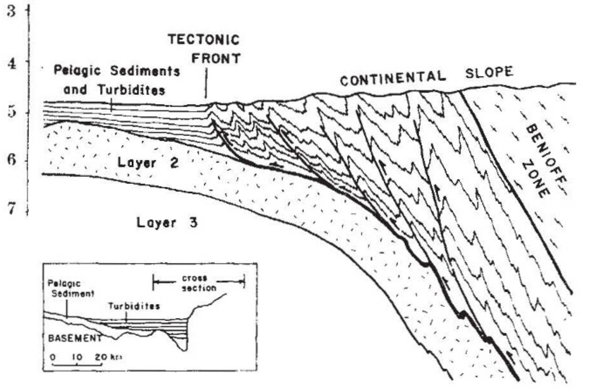

Fig. 1. Hypothetical cross-section through the Peru–Chile trench at approximately 36° S. Sediment thickness from Scholl *et al.*[10] and thickness of layer 2 from Fisher and Raitt[12]. Vertical exaggeration is approximately 2 : 1. Inset is a seismic reflexion profile redrawn after Scholl *et al.*[10] showing the location of the cross-section (vertical exaggeration is approximately 11 : 1).

Seismic reflexion profiling of the Peru–Chile trench by Scholl *et al.*[10] shows that there is a very sharp contact between the undeformed sediments within the trench and the higher seismic velocity layer which underlies the lower part of the continental slope. If the hypothesis proposed here is correct, this would indicate that the transition from undeformed sediments to deformed sedimentary and metamorphic rocks is rather abrupt. This contact may be a tectonic form similar to the Allegheny front in the Appalachian Mountains[15]. Seismic reflexion profiling of the Allegheny front in Pennsylvania indicates that the transition from relatively undeformed Palaeozoic sedimentary rocks to highly deformed sedimentary rocks occurs in less than a quarter of a mile (R. A. Radulski, personal communication). Significantly, no reflexions were received from the steeply dipping beds east of the front. A possible reason that no reflexions have been received from the sedimentary rocks which underlie the lower part of the continental slope in areas such as east of the Peru–Chile trench may be that, as a result of folding, these beds are dipping too steeply to produce reflexions, or that they lack coherent reflectors. The lack of deformation of the sediments within the trench itself may simply indicate that the sediments are not capable of transmitting a compressive stress for large distances.

It is proposed that the reason for the absence of large thicknesses of deformed sediment associated with oceanic trenches is that these sediments have been thickened and converted into sedimentary and metamorphic rocks underlying the continental slope as a result of deformation along Benioff zones. If this is so, the absence of deformed sediments associated with oceanic trenches is not a valid argument against movement of the sea floor under continents and island arcs in the vicinity of these trenches.

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