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Tectonic settings of deepwater fold and thrust belts

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Deepwater fold and thrust belts (DWFTBs) occur in three main tectonic settings: passive margins, active margins (accretionary prisms), and early stage collision zones. The structural style in DWFTBs tend to be limited to detachment-type systems as the deepwater sedimentary package is typically too incompetent to form large thrust sheets, with displacements of 10's kms. Detachment folds, imbricate folds and thrusts, and pop-up- triangle zone geometries tend to be the dominant deformation style. Folds grow predominantly in poorly to moderately lithified sediments, they cause seafloor topography and consequently interact with gravity-driven sedimentation derived from the shelf or further upslope, as well as creating a more local source for mass wasting deposits. Overpressured pore fluids are a ubiquitous feature, and mud diapirism, mud pipes and fluid escape features are widespread. Despite the overall similarity of structural styles within DWFTBs, the timing of deformation, intensity of overpressure-driven processes, driving mechanisms and stress orientations within DWFTBs may vary considerably depending upon the tectonic setting. Accretionary prisms, driven by lithospheric stresses, are clearly separate from delta-associated gravity driven DWFTBs. However there is overlap and a simple active margin vs passive margin classification belies the range of settings where DWFTBs are present.

Tectonic setting and mode of deformation of DWFTBs, from linked systems where extension up-dip is coupled with folds, thrusts and contractional diapirs down-dip can be divided into:

Type 1) Linked systems on passive margins (shale/salt mobile substratum; gravity sliding/differential loading).
Type 2) Linked systems in collisional zones (shale only?; gravity sliding/differential loading/lithospheric stresses).
Type 3) Weakly linked, or unlinked (superimposed?) deltas-fold belts systems on early stage collisional zones (mostly/entirely driven by lithospheric stresses).

Type 4) Weakly linked, or unlinked (superimposed?) deltas-fold belts systems on active margins (mostly/entirely driven by lithospheric stresses).

Large deltas on passive margins (Type 1) are commonly associated with DWFTBs, in which the deformation can be entirely driven by gravity. The classic model is that extension on the shelf and upper slope passes down-slope into compressional features at the delta toe. Where the basal, overpressured mobile shales dip oceanward this system may be entirely driven by gravity sliding (e.g. Orange River Basin, South Africa; Bight Basin Australia; Rajang Delta, W. Borneo; Sandakan Basin, N. Borneo). However, commonly in very large deltas the basal detachment dips landwards under the DWFTBs belt, and the outer shelf. This geometry seems to exclude a simple gravity sliding model, hence differential loading on the shelf (sometimes referred to as gravity spreading) is thought to drive deformation, as well as more localized gravity sliding (e.g. Niger Delta, Gulf of Mexico). Passive margins where a salt layer is present can also develop gravity-sliding DWFTBs with, or without the presence of a large sediment input from deltas (e.g. West African margin, Angola).

Some areas display DWFTBs that developed by a mixture of gravity driven stresses and lithospheric stresses (Type 2), where input of large volumes of sediment is located on early stage collision zones. The best documented examples come from Borneo, in particular NW Borneo (offshore Brunei and Sabah), and also the Mahakam Delta (east Borneo). Lithospheric-driven deformation occurs primarily as a result of convergence between two regions (rather than the typical active margin combination of spreading centre-push, slab-pull driven subduction). In NW Borneo following complete subduction of the Proto-South China Seas oceanic crust during the early Miocene, the thinned Dangerous Grounds continental crust entered and jammed the SE-dipping subduction zone beneath Borneo. Then during the latest Miocene-Pliocene motion the suture zone was reactivated due to regional plate reorganization. The late Miocene-Holocene DWFTBs developed both in response to gravity driven deformation from the Baram Delta province, and motion along the reactivated suture.

Both Type 2 and Type 3 DWFTBs occur during the early stages of collision zones, the difference between the two is the minor contribution or absence of the gravity-driven component of deformation: in Type 3 DWFTBs deformation is predominantly or entirely driven by lithospheric stresses. Examples include the South Caspian Sea, the Indo-Burma Ranges, and the Makassar Straits. In the case of the South Caspian Sea it is the reorganization of the Arabian-Eurasian collision zone that initiated northwards directed subduction of relic oceanic crust. During the Cenozoic the Indo-Burma Ranges evolved from an active subduction margin (Type 4) to a transpressional collisional zone (Type 3), where the fold and thrust belt propagated into a deepwater foredeep basin.

The most widely represented DWFTBs occur in accretionary prism setting on active margins (Type 4). This setting is generally regarded as having a low chance of economic accumulations of hydrocarbons due to problems with source rock (likely gas-prone if present), and reservoir rock (likely to be thin, and commonly with a considerable component of volcanic-derived clasts), coupled with extreme water depths. Consequently, accretionary prisms remain relatively poorly known, covered largely by 2D surveys acquired by academic institutions, although some exceptions exist (e.g. offshore Makran). The best known hydrocarbon-bearing DWFTB in an active margin setting is the atypical example of Trinidad, where lateral input of sediment from the Orinoco Delta, is caught up the highly oblique transpressional margin of the Caribbean subduction zone.