

**Causes and consequences of
tectonically driven Cretaceous/Tertiary uplift on the Grand Banks**

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The late syn-rift and early post rift stratigraphy of the Grand Banks region contains the record of two important intervals of regional uplift and erosion which have created prominent seismic markers across the entire Grand Banks region. These markers are the base Tertiary unconformity and the Avalon unconformity (Enachescu, 1987, 1992; Tankard and Welsink, 1987; Wade and MacLean, 1990; Grant and McAlpine, 1990). The latter is a complex group of unconformities separating deformed Jurassic and older rocks from undeformed Cretaceous sediments, and may be related to vertical motions during rifting between the Grand Banks and Iberia. The base Tertiary unconformity postdates rifting in the region, and it remains to determine what processes were active at that time.

These tectonically related events are not present, except possibly in a very muted form, on the margins north and south of the Grand Banks. They lie at depths accessible to drilling (typically 0.5 to 4 km bsf). While present data is capable of delineating the first-order nature of these events on the shelf, little data is available in deeper water, below the continental slope and rise. Furthermore, continuous sampling is not available for the pertinent time intervals in the present wells.

The combination of a superb data set on the Grand Banks with the presence of tectonically derived stratigraphic events make this a unique passive margin setting in which to conduct ODP drilling. Several important scientific questions can be posed, related to the tectonic processes driving uplift and to the consequences of uplift:

1. Rifting Processes between Grand Banks and Iberia; the Avalon Unconformity

The Avalon Unconformity has been attributed to rifting between Iberia and the Grand Banks (Wade and MacLean, 1990; Tankard and Welsink, 1987; Enachescu, 1987). Since the Avalon Unconformity is a complex feature, comprising several unconformities from Late Jurassic to mid-Cretaceous in age, its characteristic may reflect varying intensities of extension during this ~50 Ma rift phase. Its most intense expression is below the Avalon uplift on the south-central Grand Banks (Grant and MacAlpine, 1990). Here mid-Cretaceous volcanism has been sampled in several wells (Pe-Piper et al., 1994), and has been attributed to reactivated rifting and transform motion. Some magmatic underplating of the region is also possible; crustal seismic refraction studies (Reid, 1988, 93; Reid and Keen, 1990) provide weak support for minor underplating below the south-central Grand Banks.

Although rift-related tectonics is the most likely cause of the Avalon unconformity, it is not clear how lithospheric deformation created the uplift. Large-scale simple shear (Tankard and Welsink, 1987), diapiric upwelling of mantle, and small-scale convective upwelling (Boutillier and Keen, 1999) are all aspects of rifting that could be involved. Quantification of the amount and distribution of erosion and uplift would narrow the choice. Drilling through the Avalon Unconformity would also address the timing of rifting events.

The seaward extent of the Avalon unconformity is a matter for speculation at present. Some studies suggest that a prominent seismic event, “U”, in the Newfoundland Basin (Tucholke et al, 2000; Srivastava et al., 2000) is the seaward continuation of the Avalon Unconformity. The areal extent and nature of “U” may provide the key to the position of the continent-ocean boundary and the timing of the breakup with Iberia. This needs to be verified, but it illustrates the importance of establishing the extent of possible correlatives of the shelf features, in terms of basic models of non-volcanic margin development. The results may be applied to rift margins globally.

2. In-plane stresses or plume? : Base Tertiary event

The base Tertiary erosional event could be related to changes in in-plane horizontal stresses in the lithosphere, which result in upward flexure of the lithosphere near the margin. This has been suggested as a major factor in creating unconformities below the Grand Banks (Cloetingh et al., 1989). The E. Tertiary was a time of major change in plate motions (Srivastava and Tapscott, 1986; Tankard and Welsink, 1987; Srivastava et al., 2000), which could have been reflected in the regional stress field. The spatial distribution of these stresses is difficult to estimate, because of the 3-dimensional nature of the plates.

Timing of the base Tertiary event coincides with uplift around the North Atlantic (White and Lovell, 1994), most of which may be related to the arrival of the Iceland plume. However, the influence of this plume should be muted, because the plume was centred some 2500 km away from the Grand Banks.

3. Sequence Stratigraphy and the processes controlling stratigraphic development

Significant uplift and erosion of the shelf must be accompanied by lowstand deposits in more distal regions. The amount of erosion is large, much larger than that associated with eustatic sea level changes, and so we have a natural laboratory for exploring the sequence stratigraphy associated with major regressive cycles. The development of lowstand fans may be of particular interest to hydrocarbon exploration as reservoirs and source rocks.

In the North Sea/U.K. region, tectonic uplift of comparable magnitude to that on the Grand Banks is thought responsible for the cyclic deposition of submarine fans in the North Sea and adjacent relatively low-lying regions. This kind of tectonic uplift therefore has demonstrated significance for the development of hydrocarbon systems in deepwater regions.

Other important work directed towards hydrocarbon exploration has been conducted in the Jeanne d'Arc Basin on the Grand Banks, using high-quality 2D and 3D seismic data. These data show corroborative evidence for uplift at the time of the base Tertiary event.

How does drilling address these problems?

Questions of the timing will be addressed with continuous core and biostratigraphy. The magnitude of the erosional events and the associated tectonic uplift can be determined from sonic logs, which yield porosity versus depth. Denudation events appear as anomalously low porosity for a given depth. Similar work is ongoing at GSCA, using the available industry wells.

Relationship to other drilling proposals on the Grand Banks

Sampling these unconformities in strategic locations below the shelf and slope can be combined with other drilling targets. The current drilling proposal for a deep hole in the Newfoundland Basin (Tuckolke et al., 2000) contains some of the same objectives. Drilling the Tertiary section in deep water (Hans Wielens), and several of the objectives defined by Enachescu (1999) are compatible with this proposal. Therefore no specific sites are suggested at this time.

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