A New Look at the Tectonostratigraphic Evolution of the Labrador Shelf

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Summary

Based on new seismic and biostratigraphic analyses, we will present a revised stratigraphic column for the Labrador Shelf. This column provides a means of correlating and summarizing paleooceanographic, sedimentological and tectonic influences on the development of the margin in the Cretaceous and Tertiary.

Introduction

In September 2008, companies successfully bid over $186 million for exploration rights to 4 parcels of land in the central Hopedale Basin, on the Labrador shelf (Figure 1). This is indicative of the renewed interested in the hydrocarbon potential of the region, which has been the focus of intensive seismic exploration in the last 5 years (over 38,000 km of data have been acquired by seismic acquisition companies).

Exploration, from the late 1960’s to the early 1980’s, resulted in: a) acquisition of about 120,000 kilometers of seismic, b) drilling of 24 wells on the Labrador margin, and 3 offshore southeast Baffin Island, and c) delineation of five significant discoveries in the Hopedale Basin. The recoverable reserves are 4.2 tcf gas and 123 Mbbs of condensate (Gov. Nfld and Labrador, 2000).

Regional geological and geophysical studies of the Labrador margin were summarized for the early phase of exploration, by McWhae et al (1980), Bell (1989), and Balkwill and McMillan (1990), among others. After a period of about 20 years, renewed interest prompted a study of old and new datasets including seismic data and the biostratigraphy and paleoenvironments of the well sections. Tying together the seismic and paleontologic data provides more precise age control on key seismic markers and clearly identifies the regional unconformities. Another significant advance has been the definition of the deep structure of the Labrador continental margins (Keen et al 1994, Chian et al, 1995, Funck et al, 2007). This has led to an improved understanding of the tectonic history of the Labrador margin, which has been pivotal in documenting the complex structure and evolution of non-volcanic margins globally (Peron-Pinvidic et al, 2007). Also, major paleooceanographic events affecting the Labrador Sea have become well documented through deep drilling in the Arctic and elsewhere (Moran et al, 2006). We show in this presentation, how both tectonic and environmental events relate to the stratigraphic development of the margin.

Data and Methods

The three stratigraphic columns published for the Labrador margin by McWhae et al (1980), Balkwill (1987) and Moir (1989), are shown in Figure 2. These columns were developed with timescales that are no longer in use, so are difficult to use for comparison with recent work. A standard timescale is needed.

Gradstein et al (2004) proposed a global timescale (International Commission on Stratigraphy, ICS) which is rapidly becoming the standard; for example, Haq and Al-Qahtani (2005) published their latest global sea-level curve against the ICS 2004 timescale. To compare the Labrador stratigraphy to this sea-level curve and other events, the stratigraphic columns of McWhae (1980) and Balkwill (1987), were replotted using the ICS timescale. We also simplified Balkwill's column, by only including the shelf portion; that area from which he obtained most of his seismic data. Once the columns were displayed on a standard timescale, it was possible to compare them and to add other information relevant to the evolution of Labrador, such as, a) global sea-level curves, b) the oxygen isotope curve of Zachos et al (2001), c) significant Arctic cooling events (Moran et al, 2006) and, d) tectonic events. These were included as separate columns beside the adjusted stratigraphic column, and as such, the new stratigraphic column becomes a correlation tool for comparison of a wide body of information.

The key to linking the stratigraphy on the margin with causal events, is the biostratigraphy. Recent work on dinoflagellate species zonation on Labrador conjugate margins by Williams et al (in prep), provides the basis for higher biostratigraphic resolution (by stages) than the work done during the earlier phase of exploration (i.e. Gradstein and Williams, 1980). This in turn, allows us to make better ties between wells and the seismic interpretation. Major markers on the adjusted stratigraphic columns will be further refined to reflect recent biostratigraphic dating.

Tectonics and Paleoenvironments

Palynological analyses of four wells from the Hopedale Basin (Bjarni O-82, Roberval K-92, Snorri J-90, and South Labrador N-79; Williams, 2007) supports the Labrador Sea rift-drift history model with Barremian to Danian rifting, Selandian to early Rupelian drifting and late Rupelian to Recent post-drifting. Further, there are five regional unconformities of the following ages: Aptian-Turonian, Selandian, Lutetian, Rupelian-Chattian, and middle-late Miocene. A Maastrichtian-Danian unconformity appears to be restricted to the Greenland margin of the Labrador Sea (Nohr-Hansen, 2003). Paleoenvironmentally, a marginal marine to lagoonal episode in the Barremian-Albian, was followed by a marine transgression in the Cenomanian. Paleoenvironments in the late Cretaceous were offshelf, changing to outer shelf to marginal marine in most of the Tertiary. Climatic conditions varied from more temperate at the Paleocene-Eocene boundary to much cooler in the Oligocene and Neogene.

Seismic examples of biostratigraphic ties to wells will be shown in this presentation. The age-dating of the top Bjarni formation and the so-called "breakup" unconformity, will be discussed in light of the new tectonic framework. The unconformity may correspond to the transition to the mantle exhumation phase of rifting (see below); if so, mantle exhumation may involve the Bjarni in the highly faulted areas offshore, where it could be mistaken for seismic "basement".

The top Markland corresponds to the Selandian unconformity, the onset of sea-floor spreading and a period of global sea-level lowering in the Paleocene. The Gudrid member of the Cartwright formation may represent material eroded from a Markland delta and redeposited in a more seaward location during the global sea-level lowering. The subsequent rapid rise in global sea-level, along with a change in sea-floor spreading direction, appears to be reflected in a "healing phase" at the top of the Cartwright and a major transgression in the lower to middle Kenamu (Eocene time).

Questions remain about the nature of upper Kenamu seismic markers although the top Kenamu presents a consistent Bartonian biostratigraphic age. Efforts have been made to date a major seismic marker in the Mokami which is likely the Rupelian-Chattian unconformity, and to understand its genesis.

The tectonics of the margin exert major control on the stratigraphy. Recent crustal studies of non-volcanic margins (eg. Peron-Pinvidic et al, 2007) generally recognize three main phases of rifting: 1) stretching phase - high angle listric faulting and classical half-grabens, 2) thinning phase – extension focuses on low-angle detachment faults throught the crust, and 3) exhumation phase – where extension is sufficient to exhume the upper mantle to the seafloor and allow serpentinization of these rocks . These phases will be indicated in the tectonics column on the correlation chart, along with the sea-floor spreading phase (drift) and the youngest phase after cessation of spreading (post-drift). New subsidence plots have been generated for some of the Labrador shelf wells, using the insights from the recent biostratigraphy and 2-dimensional flexural backstripping. Their significance will be discussed in the presentation along with a general discussion of the tectonics. The prevalence of basalts on the margin and the role of volcanism will be included in the discussion.

Conclusions

Displaying generalized geologic columns on a standard timescale makes it possible to compare the stratigraphy with the tectonics and paleoenvironments that control the configuration of the margin. Improved biostratigraphic resolution is key to linking these. Five regional unconformities on the Labrador margin, are the following ages: Aptian-Turonian, Selandian, Lutetian, Rupelian-Chattian, and middle-late Miocene. The oldest are related to major tectonic events with the influence of the paleoenvironment becoming increasingly dominant in the younger ones. Comparisons of the available datasets will improve our understanding of some of the large forces which have shaped the stratigraphy of the Labrador margin.

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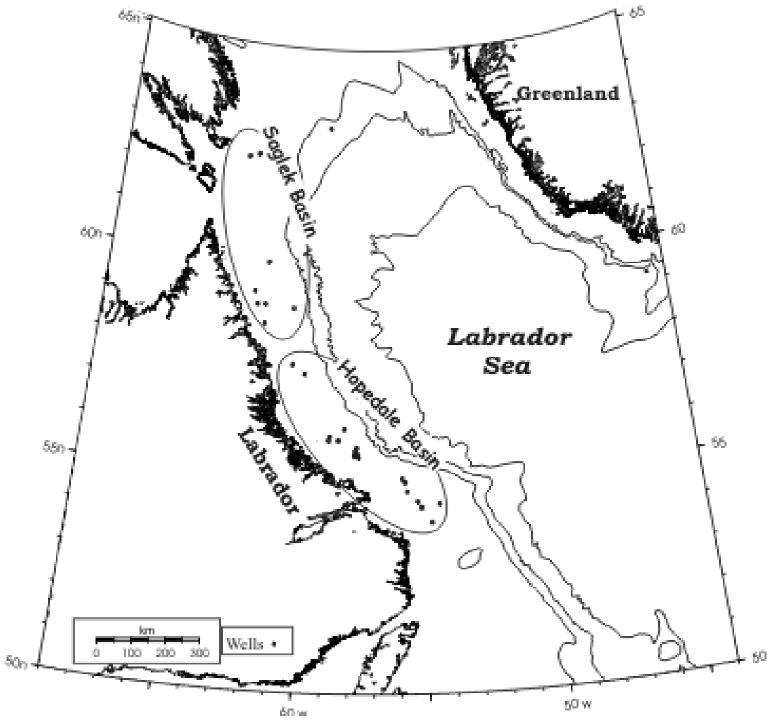

Figure 1: Location of the Hopedale and Saglek basins on the Labrador margin. Wells are indicated.

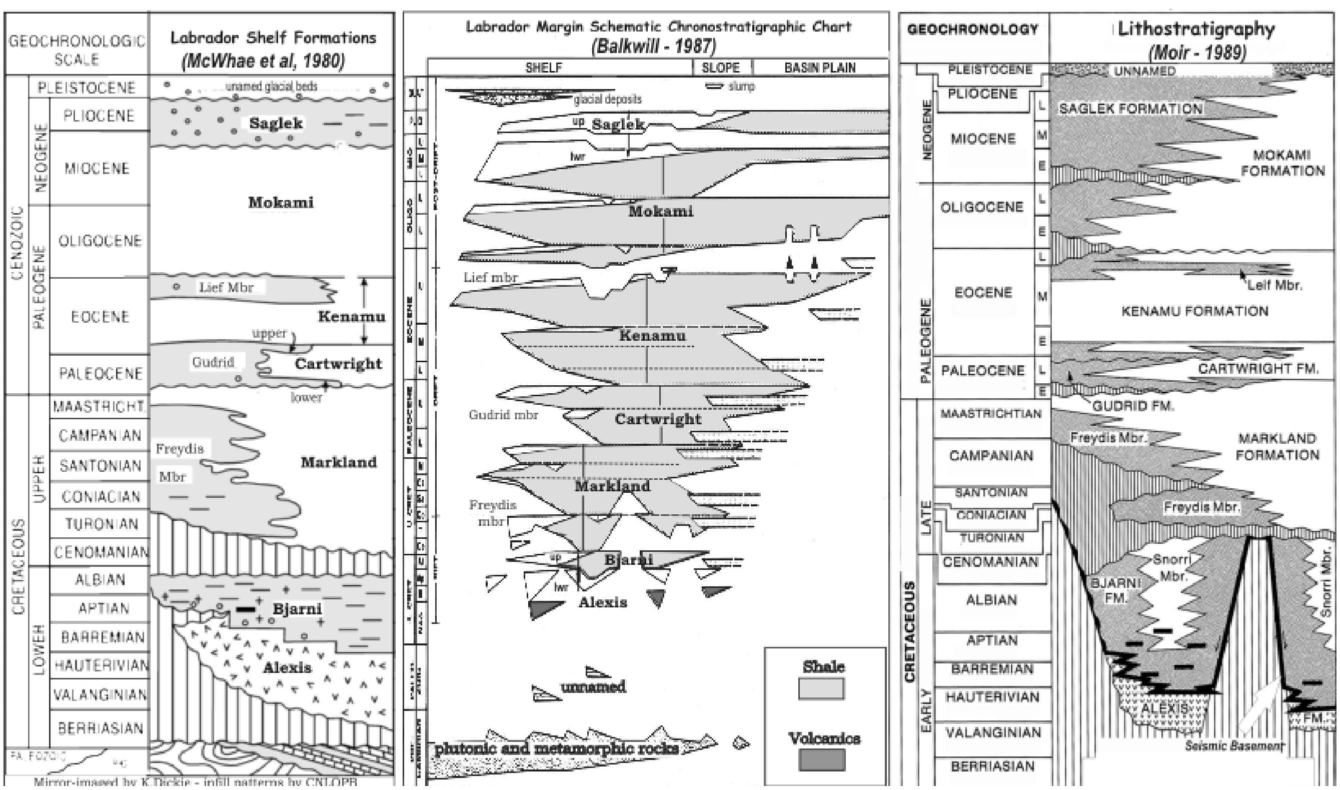

Figure 2: Left to right are stratigraphic columns of McWhae (1980), Balkwill (1987) and Moir (1989). These are based on the earlier phase of exploration on the margin. Timescales used on these versions need to be updated.