Overpressuring and Tectonism in the Sable Sub-Basin, Scotian Shelf, Eastern Canada.

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The Sable Sub-Basin is located 200 km, offshore, to the S.E. of Cape Breton Island, Nova Scotia, and contains up to 18 km of cyclic clastics and minor carbonates which thin shorewards. The sub-basin became a depocentre during rifting in the Triassic and Lower Jurassic and the observed faults that locate most of the Scotian Shelf gas pools are synsedimentary listric normal growth faults that were active from the beginning of sediment filling up until the Lower Tertiary (50 ma). Diapirism from the Lower Jurassic Argo Salts and associated faulting and folding has also occurred. To date, the deepest drilling has been to about 6000m, penetrating only the upper 1/3 of the total sediment fill. Increased overpressuring with depth and the prospect of lower quality reservoirs makes this depth a practical limit to drilling in the area. The Lower Cretaceous Missisauga sandstones which are the reservoirs in the Venture, Sable and Thebaud gas fields are overpressured and form an important part of the Sable Offshore Energy Project.

Mohr Circle analysis of the current stress state in the Sable Sub-Basin, well bore break-out orientation in the Scotian Shelf wells and reversal along the Fundy Fault indicate that the East Coast is now undergoing compression from the N.E. to S.W., parallel to the spreading direction of the Greenland Plate from the North American Continent.

Pressure vs. Elevation plots for the Sable Sub-Basin clearly define the top of overpressuring at the intersection of the normal pressure gradient with the steeply curving overpressured plot. Pressures increase to within about 70% of the overburden stress in the upper 700 m of the overpressured zone and approach the lithostatic line at depth probably reaching it below 6000m. The top of overpressuring varies in depth, for example; in the Sable O-47 well it occurs at -3600m while in the Venture B-43 well, it occurs at -4475m. Analysis of the sonic log usually defines the top of overpressuring by a reversal in trend of sonic vs. depth data, for shales, from decreasing to increasing travel times. This reversal is likely caused by a decrease in effective stress resulting from an increase in pore pressure, and not an increase in shale porosity, since the density log shows a normal compaction profile with very low shale porosities of around 5% to 10% in the overpressured zone.

Katsube and Williamson (1994) reported that at such low porosities, shales below the critical depth of burial, have a permeability in the 1 to 10 nanoDarcy range. Such low permeabilities would greatly restrict water flow resulting from shale pore strain due to framework compression, and produce pressures higher than normal as a result of the low compressibility of water (Osborne and Swarbrick, 1997). The marked contrast in pressures and water salinities between the overpressured and normally pressured reservoirs in the Sable Sub-Basin argues for a very low permeability within the overpressured shales. Furthermore, the upwards directed pressure gradients in the overpressured zone, and the salinity gradients in the normally pressured reservoirs near the top of overpressuring, indicate that the system is dynamic with water flowing outwards from the higher pressured shales.

Plots of leak-off pressure vs. depth for Sable Sub-Basin wells indicate that the minimum principle stress markedly increases within the overpressured zone, as expected from the Biot equation for a passive basin margin. However, the values for the minimum principle stress in the overpressured shales are higher than predicted from the Biot equation indicating horizontal compression. It is this horizontal compression due to tectonism together with any vertical compaction due to recent sedimentation that is likely responsible for the overpressuring below the critical burial depth, in the very low permeability shales on the Scotian Shelf.

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