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Canada's Beaufort-Mackenzie Submarine Foldbelt: Fresh Look at a Frontier Giant Petroleum System with the BeaufortSPAN™ 40-Km PSDM Survey

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The Beaufort Foldbelt is the submarine portion of the Tertiary fold and thrust belt straddling the US/Canada border along the Arctic margin, in the Beaufort Sea, including the offshore Mackenzie Delta (Lane, 2002). The Canadian segment, the site of numerous petroleum discoveries in shallow water, covers 35,000 km^2 and terminates eastward against the Tarsiut-Amuligak Fault System. ION Geophysical (GX Technology) has collected more than 16,000 km of long-offset seismic data in three seasons since 2006 in the Canadian Beaufort Sea, and the majority of seismic coverage is in the foldbelt. These programs are designed to image down to the base of the crust with a 9-km long cable, 18-second recording, and final depth processing (Prestack Depth Migration) to 40 km (Dinkelman and others, 2008a, b). The seismic profiles are tied to well control to identify the major stratigraphic sequences formed since the opening of the Canada Basin, to interpret the deep crustal structure, and to define the geometry of the foldbelt.

The new seismic data reveal a foldbelt geometry and history explained by syn-depositional compressional deformation of a 12 to15 km thick Cretaceous-Tertiary succession above a deep geopressured mobile shale detachment horizon. The full geometry of structures, including vertical and overturned dips, is imaged by advanced acquisition and processing methods. Complex fold-fault geometry is the expression of interaction of compressive folding, detachment, growth sedimentation and erosion, inversion, and gravity-induced loading above the mobile substrate, all operating progressively in different zones. The detachment depth of the thrust belt is proven by isoclinal detached folds exceeding 5 km amplitude, mud volcanoes that rise from depths exceeding 8 km, and the discordant reflectors of the underlying pre-rift units.

The new seismic data and interpretation provide a foundation to reconstruct the geological history of the continental margin and foldbelt. For discussion of the geology of the adjacent passive margin, see the accompanying paper (Kumar and others, 2009). After rifting and sea-floor spreading formed the Canada Basin in Late Jurassic to Early Cretaceous time, deposition of the thick (12 to 15 km) Mackenzie River passive-margin clastic prism began in the mid-Cretaceous. Deep seismic data show burial of the southeast end of the extinct spreading ridge by the prograding prism beneath the outer portion of the foldbelt.

From Paleocene through Oligocene time, detached compressional and gravity-modified folds and thrusts developed. In this episode, at least two major phases of deformation are recorded by growth synclines and

growth unconformities, creating numerous structural, stratigraphic and combination traps both on and off anticlinal highs. The Beaufort Foldbelt was driven by compression caused by Tertiary thrusting in the onshore northeastern Brooks Range in Alaska and British-Barn Mountains, Yukon, and the temporal-spatial growth of the foldbelt described by Lane (2004) is elaborated by the improved marine seismic data.

The youngest episode of folding (late-Oligocene to early-Miocene) was caused by deep-seated inversion of faults in the oceanic crust along the axis of the extinct spreading ridge of the Canada Basin. This created a major oblique outer structural high, the Tulluk High, characterized by limited deposition or erosion.

The structural and stratigraphic complexity of the Beaufort Foldbelt provides a rich palette of possibilities for play types. The timing and growth of each structure and its control upon faults, unconformities and growth sequences results in numerous configurations of structural relief, paleobathymetry, depositional facies, reservoir sand geometry, seals, and migration paths. Oil and gas discoveries to date confirm the widespread and diverse habitats of petroleum in the Beaufort Foldbelt and imply a large number and variety of targets for exploration.

Gas chimneys, sea floor craters, and amplitude anomalies are visible in the seismic data over much of the foldbelt and indicate a very active petroleum system. Study of subsurface temperatures supports the view of active upward expulsion of fluids from deep overpressured zones (Chen et al, 2008). The Geological Survey of Canada (Chen and others, 2007) estimates mean undiscovered oil in the Canadian Beaufort-Mackenzie basin down to 2,500 m water depth at 16.8 billion barrels. Although major questions about the nature and assessment of the petroleum system remain, the results of recent bidding in the area show that industry recognizes the petroleum potential of the entire Beaufort Foldbelt including deep water of the slope.

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