Crustal and Petroleum Framework of the Beaufort-Mackenzie Basin as Interpreted from 9-km Long-Offset ArcticSPANTM 2-D Seismic Data*

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Abstract

In three decades of exploration in the Beaufort-Mackenzie Basin (Arctic Canada), 48 oil and gas discoveries have not resulted in significant production, but the USGS (2006) estimates mean undiscovered resources in the basin in shallow water at 14.5 BB of liquids (2.3 BCM) and 86.6 TCF of gas (2.32 TCM).

To address major questions regarding the basin architecture and petroleum systems, especially in deep water, ION Geophysical (GX Technology) acquired 3,534 km of 2-D long-offset seismic data in late 2006. The program was designed to image down to the base of the crust with a 9-km long cable, 18-second recording, and final depth processing (PSDM) to 40 km. We have interpreted the new data to regionally map the ocean-continent boundary and the top of MOHO discontinuity, as well as to identify the major stratigraphic sequences formed since the opening of the Canada Basin. Building on this success, in 2007 a second phase of 5,561 kms of data extended the survey north along Banks Island with the same parameters.

Highlights of interpretation include 1) offshore Mackenzie Delta system is underlain by almost 15 km of sediments, 2) complex structure includes compressive folding, wrenching, extension, inversion and gravity-induced loading, essentially all operating approximately at the same time within various segments of this region, 3) the ocean/continent boundary is mapped in the area; and 4) besides "normal" oceanic and continental crusts, an area underlain by "anomalous" crust is mapped beneath the thickest sedimentary section in the basin.

AAPG International Conference, Cape Town October 26-29, 2008

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and

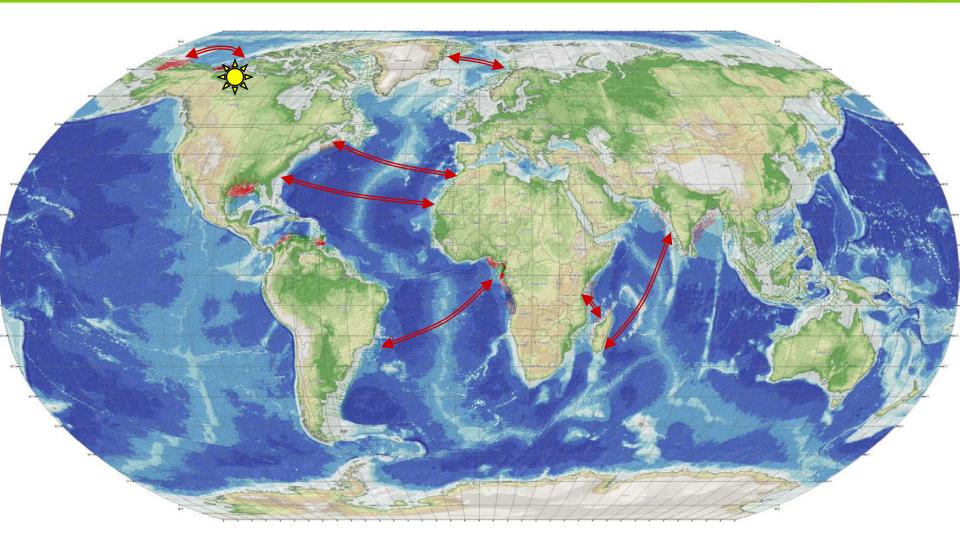
Naresh Kumar, James A. Helwig, Pete Emmet, and Jim Granath Consultants on the ArcticSPAN Team



BasinSPAN Programs

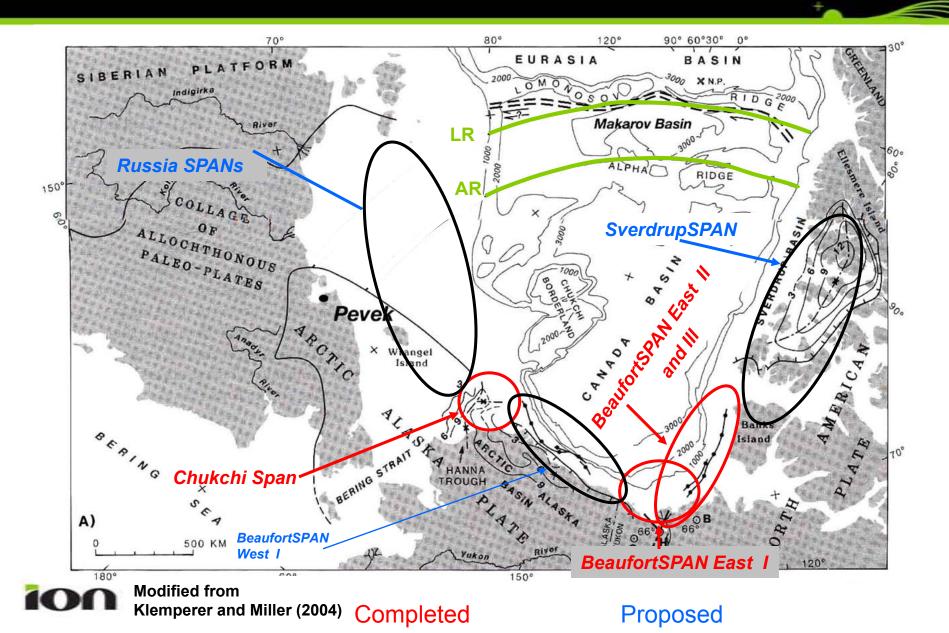
With contributions from Dale Bird, consultant to ION

Conjugate Margins





Canada Basin Conjugate Margin Focus



Beaufort-Mackenzie Basin

- "World Class" Petroleum Province
- 2nd Largest deltaic system in North America
- More than 40 discoveries in multiple reservoirs
- More than 1 billion barrels discovered
- Mean undiscovered resource:

	Geol. Surv. Canada (2007)	US Geol. Survey (2006)
Oil (BBO)	16.8 (to 2,500 m water depth)	14.5 (to 1,000 m water depth)
Gas (TCF)		86.6

 Area >100m water depth essentially untested; recent bids of \$585 m (2007) and \$1.1b (2008) indicate industry cognizant of potential



Technical Specifications: ArcticSPANs

Acquisition Parameters:

50 meter SP interval 25 meter Rec interval **9,000 meter cable length** Record Length: 18.0 sec Sampling Interval 2 ms Tape O/P – 3590 - SEGD

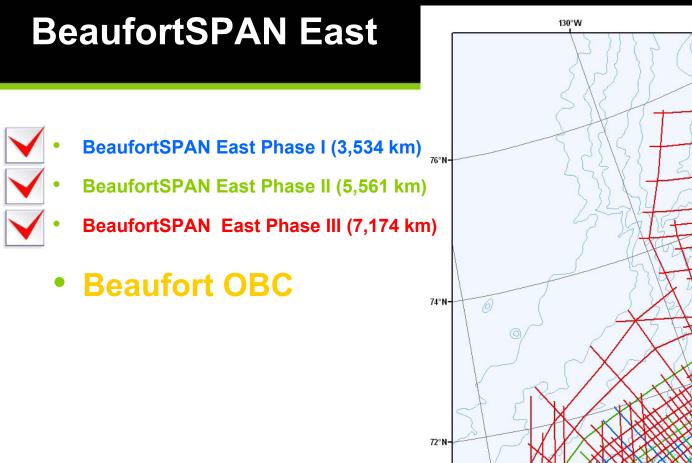
Processing Parameters:

12.5 meter bin size90 Full foldSampling Interval 4 ms

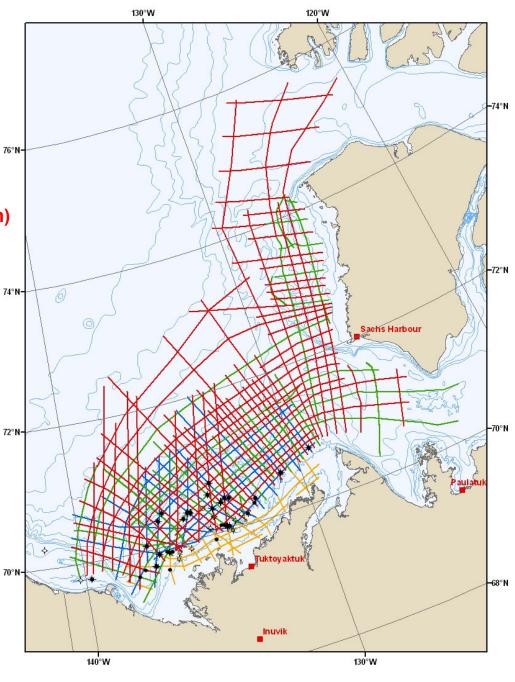
Displays and Results:

Raw Navigation Merged Shot Gathers *Kirchoff PSDM stack to 40 km* Final PSDM Depth-Interval Velocity Model Structural and Stratigraphic Interpretation

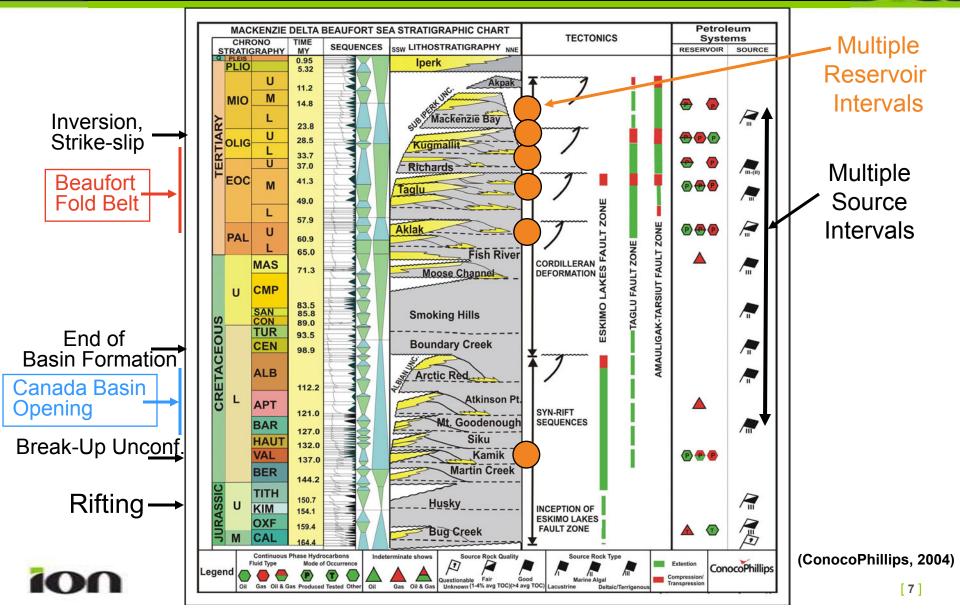








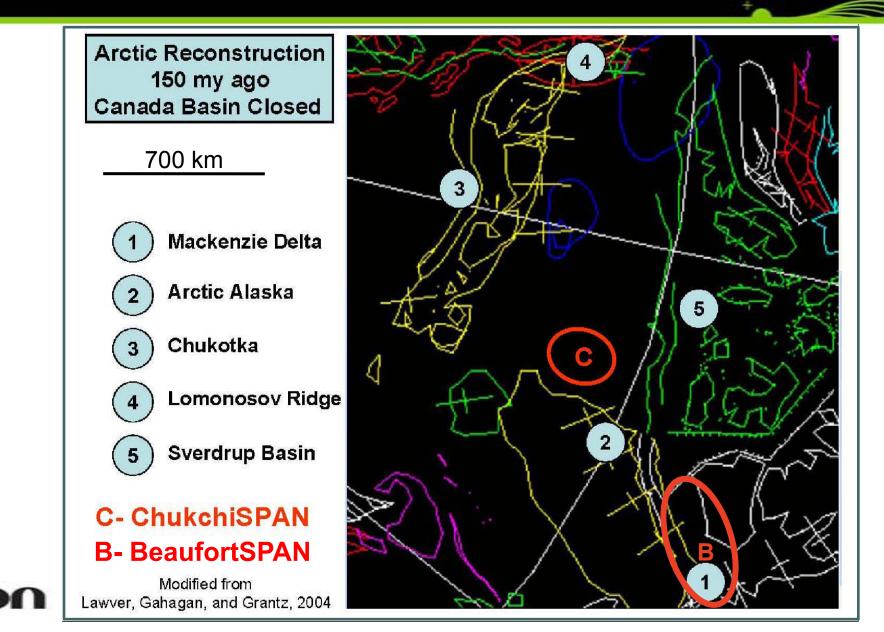
Canada Basin "Post-Rift" Stratigraphy



Seismic Horizons Identified on the SPAN data

	Seismic Horizons Identified and Mapped in the BeaufortSPAN East Data				
Key Reservoir Intervals		Canadian Arctic Passive Margin and Inner Mackenzie Delta		Canada Basin Deep water and Outer Mackenzie Delta	
	Estimated Age (m.y.) at Base	Sequence/Formation on Cont. Crust	Reflector Name and Character	Sequence/Formation on Oceanic Crust	
	5.3	lperk	5.3_LATE MIO (Trough)	lperk	
	11.6	Akpak	11.6_MID MIO (Peak)	Akpak	
	23.0	Mackenzie Bay	23.0_LATE OLIG (Trough)	Mackenzie Bay	
	33.9	Kugmallit	33.9_BASE OLIG (Trough)	Kugmallit	
	41.0	Richards	41.0_MID EOCENE (Trough)	Richards	
	52.2	Taglu	52.2_EARLY EOCENE (Peak)	Taglu	
	61.0	Aklak	61.0_MID PAL (Peak)	Aklak	
	83.5	Fish River	83.5_LateCRET (Peak)	Fish River	
	136.4	Smoking Hills-Siku	136.4_Valangianian_BKUP (Peak)	Smoking Hills-Siku	
	135-155?	Synrift	TOP_OCEANIC_CRUST (Peak)	Synrift Ocean crust	
	Ages Below are at Top 359.2	Missing Section	360_LateDev (Peak)	моно	
	Siluro-Devonian	Weatherall	Siluro_Dev_ Carbonate (Peak)		
?	Ordovician-Silurian	Early Paleozoic	Ordovician-Silurian Marker		
·	542		Proterozoic (Peak)		
	?	Proterozoic	Cryst_BSMT (Peak)		
	?	Cryst_BSMT	MOHO (Peak)		
		моно			

Canada Basin Reconstruction

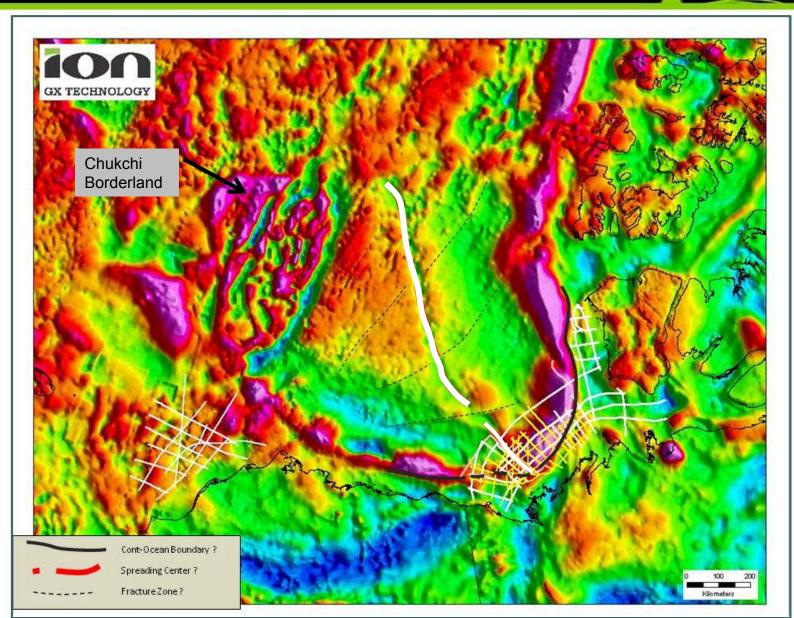


Crustal Framework for BeaufortSPAN[™] Program

Free Air: Offshore Bouguer: Onshore



(Gravity from Arctic Gravity Project)



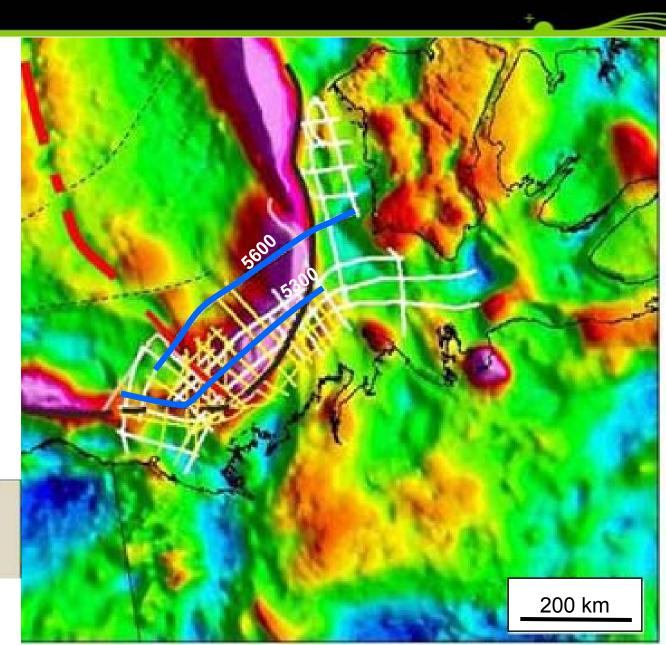
Crustal Framework for BeaufortSPAN[™] Program

Free Air: Offshore Bouguer: Onshore

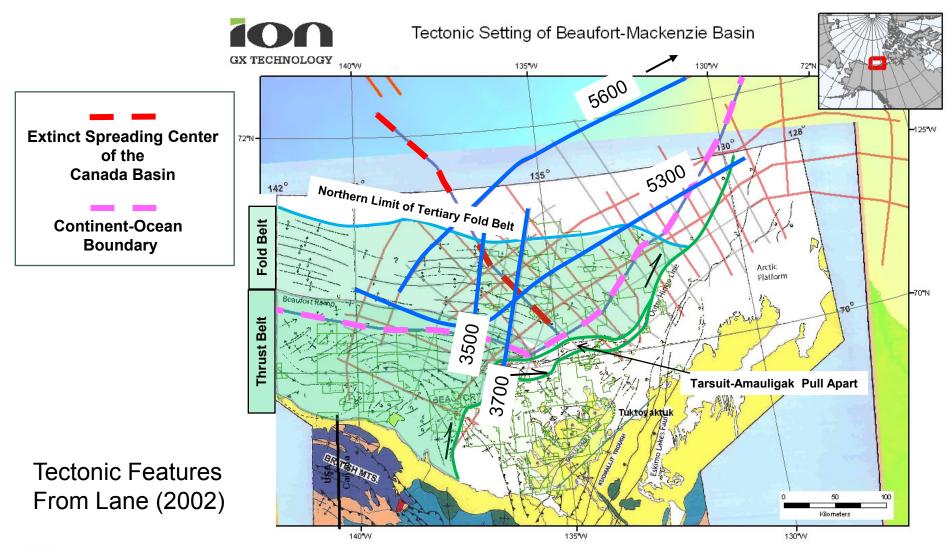
<u>300 km</u>

(Gravity from Arctic Gravity Project)



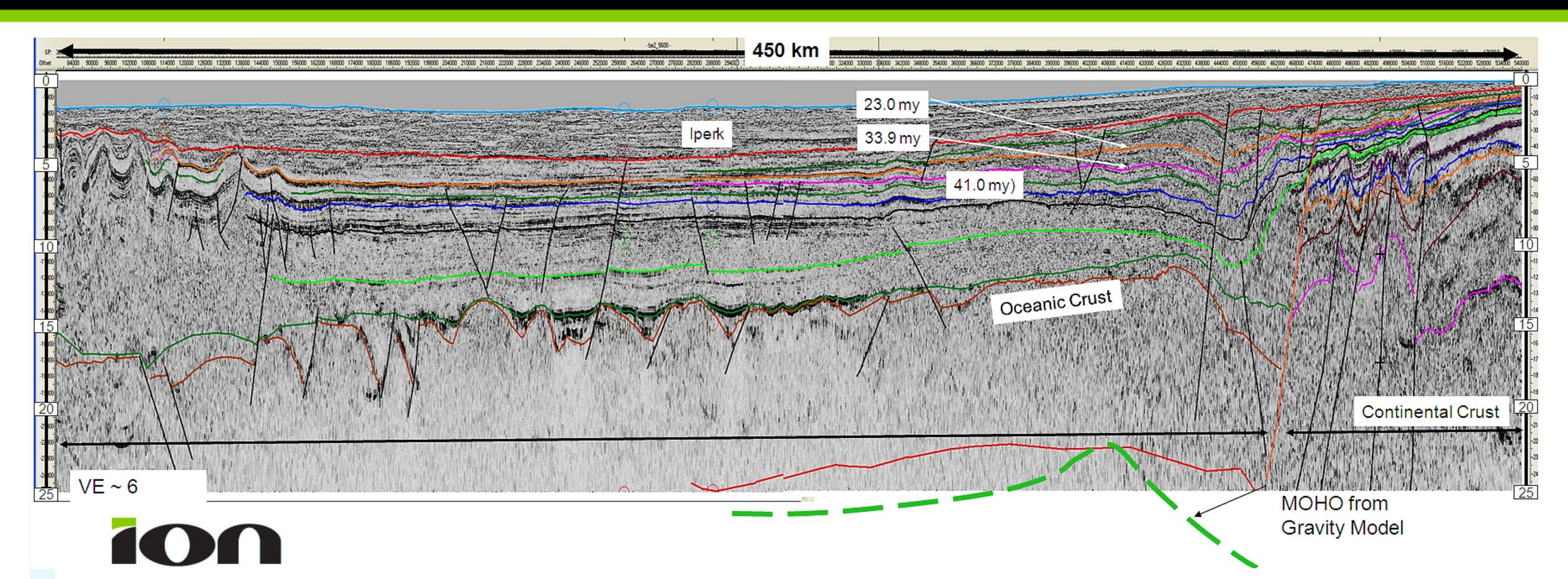


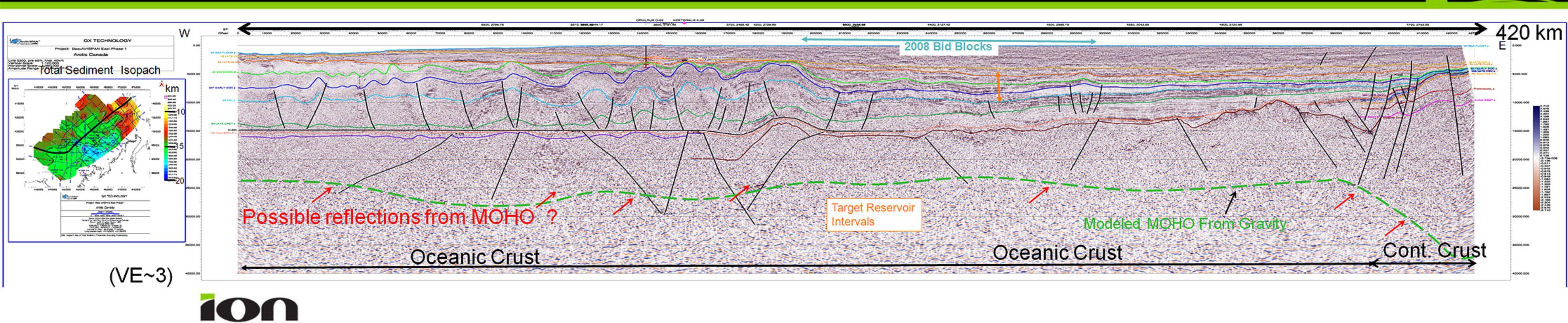
Locations of Selected Lines





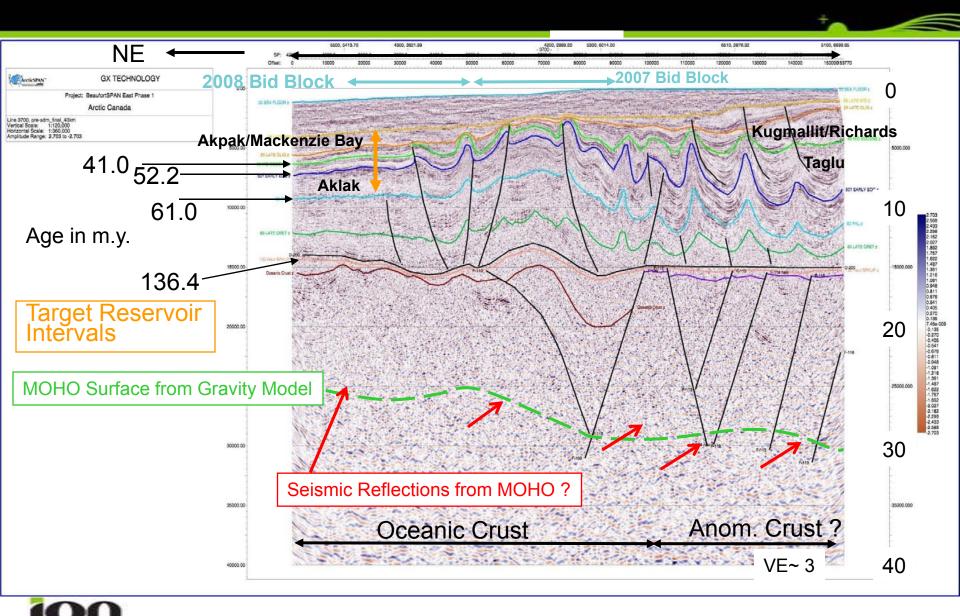
LINE 5600 ACROSS THE BASIN (450 km)



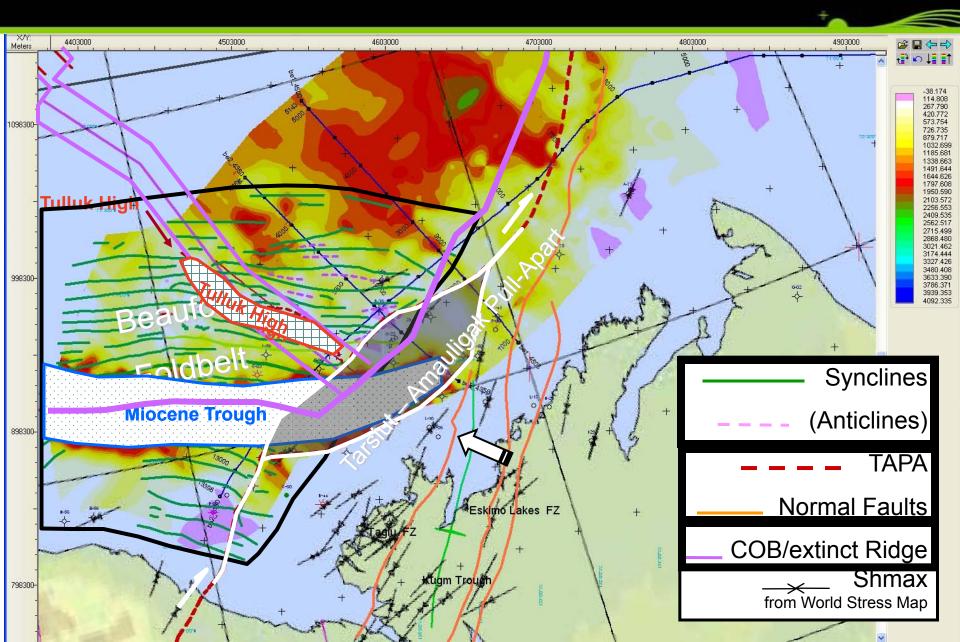


STRIKE LINE 5600 ACROSS THE BASIN (450 km)

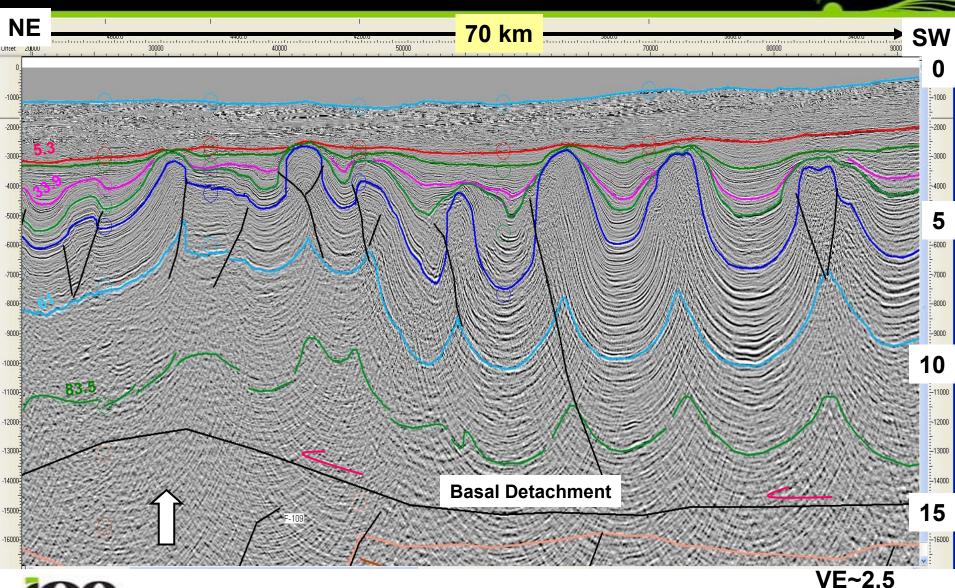
Dip Line 3700: Fold and Thrust Belt



Miocene Depocenters & Structural Elements

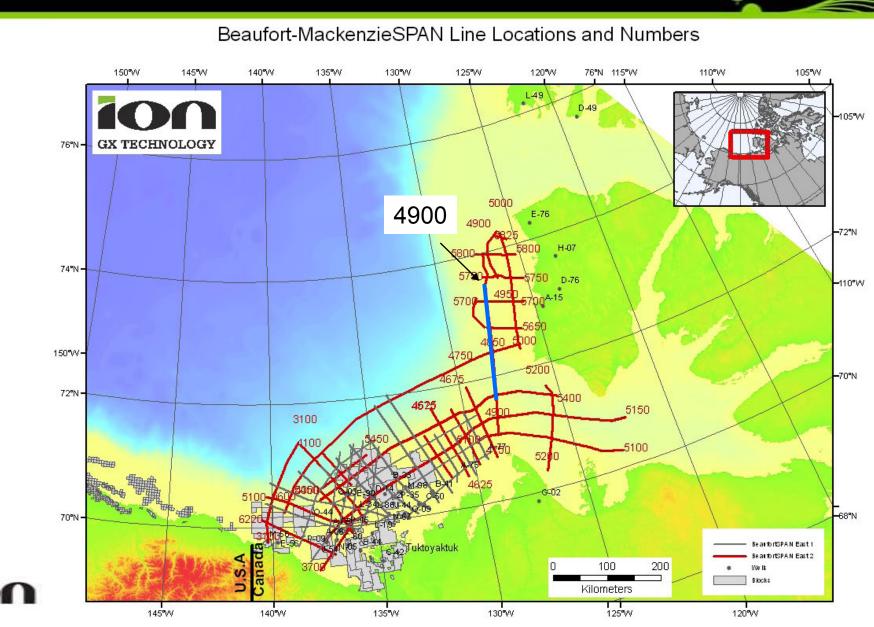


Highly compressed folds (segment of Line 3500)

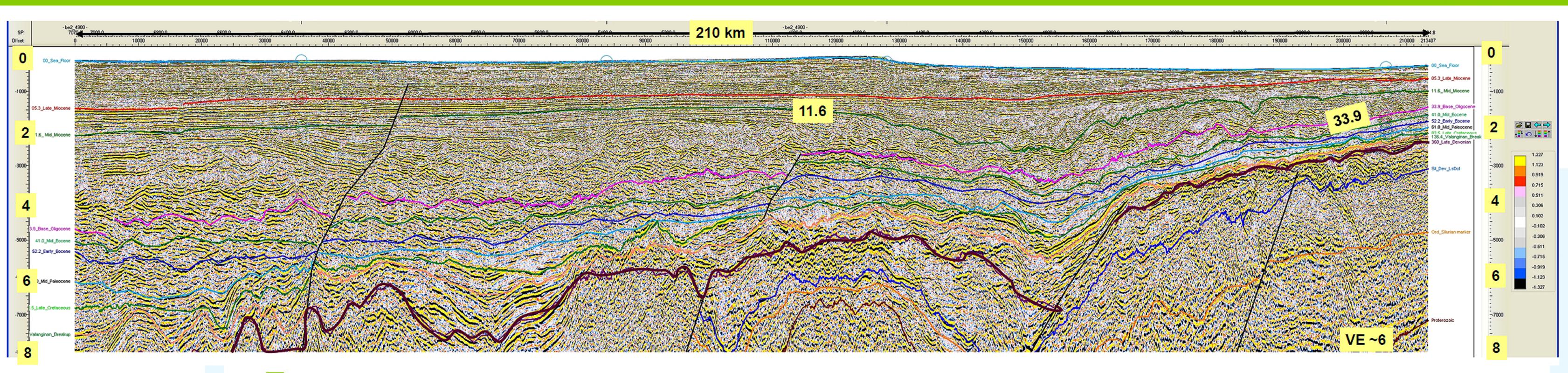




Strike Line Offshore Banks Island



STRIKE LINE 4900 ACROSS BANKS ISLAND SLOPE FACIES (210 km)





Summary and Conclusions

•Active Petroleum System proven by discoveries in the Beaufort-Mackenzie Basin.

•Complex tectonic/sedimentary history of extensional, compressional, strikeslip and gravity-induced deformation.

•Growth sedimentation during both compression and extension, and related unconformities, control sequence stratigraphy.

•"Diapir-like" features include mud volcanoes, but most are cores of steep detachment folds as revealed by SPAN imaging of steep dips.

•Significant exploration opportunities in outer shelf, upper slope and deep basin in the delta area and along the passive margin. The latter is in the earliest stages of investigation.

•Regional deep crustal seismic profiles using advanced imaging technology yield improvement in the knowledge of basin evolution and thus, in petroleum-system assessment.



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THANK YOU



References

Klemperer, S.I. and E. Miller, 2004, Collaborative Research, *in* Crustal evolution of the Bering Shelf-Chukchi Sea, results from prior support: Web accessed 15 April 2009 <u>http://www.geo.wvu.edu/~jtoro/download/NewNSFtex_fig.doc</u>

Lawver, L., L.M. Gahagan, and A. Grantz, 2004, Ordovician to recent reconstructions of the Arctic: A set of animations, Presented to Parvenov symposium, Stanford, California, 10 December 2004, 479 slides: Web accessed 15 April 2009 http://pangea.stanford.edu/research/structure/nerussia/presentations.html

USGS Mackenzie Delta Province Assessment Team, 2006, Assessment of undiscovered oil and gas resources of the Mackenzie Delta province, North America, 2004, World Energy Assessment Project Fact Sheet, 2 p. Web accessed 15 April 2009 http://pubs.usgs.gov/fs/2006/3002/pdf/FS-2006-3002.pdf