Introduction

The U.S. Geological Survey (USGS) recently assessed the potential for undiscovered oil and gas resources of the West Greenland-East Canada Province as part of the USGS Circum-Arctic Resource Appraisal program (fig. 1). The province lies in the offshore area between western Greenland and eastern Canada and includes Baffin Bay, Davis Strait, Lancaster Sound, and Nares Strait west of and including part of Kane Basin. A series of major tectonic events led to the formation of several distinct structural domains that are the geologic basis for defining five assessment units (AU) in the province, all of which are within the Mesozoic-Cenozoic Composite Total Petroleum System (TPS). Potential petroleum source rocks within the TPS include strata of Ordovician, Early and Late Cretaceous, and Paleogene ages. The five AUs defined for this study—the Eurekan Structures AU, Northwest Greenland Rifted Margin AU, Northeast Canada Rifted Margin AU, Baffin Bay Basin AU, and the Greater Ungava Fault Zone AU—encompass the entire province and were assessed for undiscovered, technically recoverable resources.

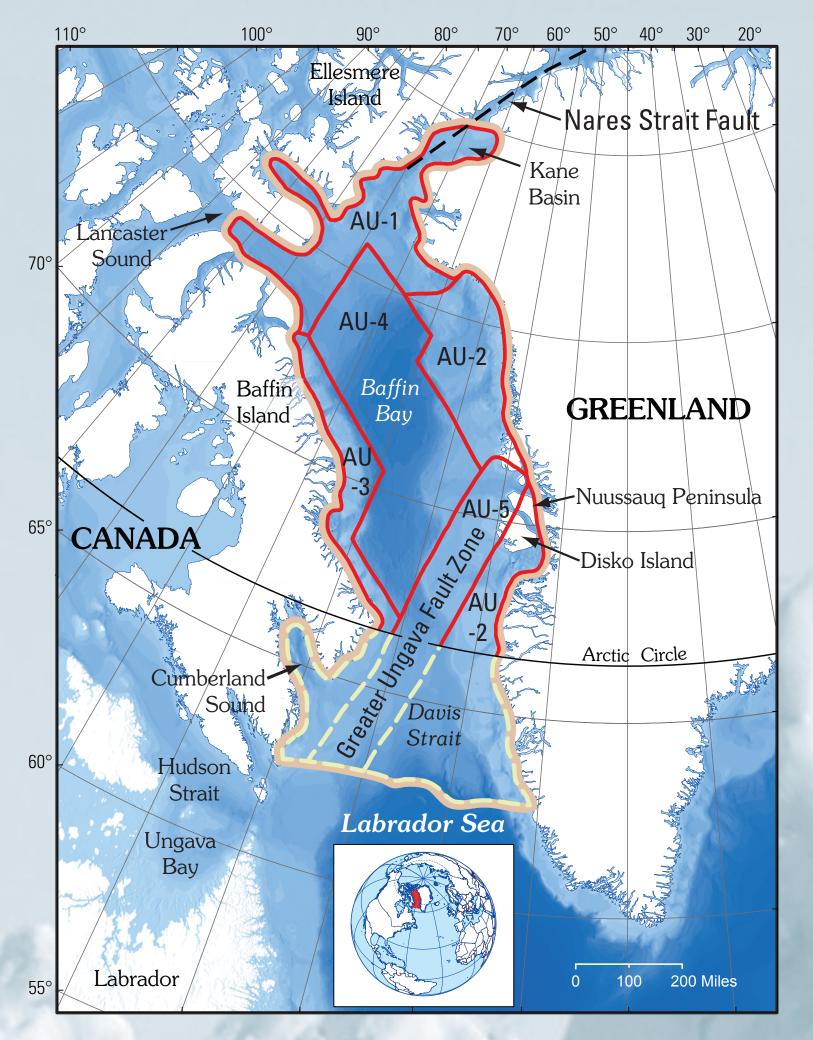


Figure 1. Locations of West Greenland-East Canada Province and five assessment units (AU; red lines). Province includes Baffin Bay, Davis Strait, Cumberland Sound, and Nares Strait west of and including Kane Basin. Note that three of the AUs extend south (yellow dashed lines) of the Arctic Circle. AU-1, Eurekan Structures AU; AU-2, Northwest Greenland Rifted Margin AU; AU-3, Northeast Canada Rifted Margin AU; AU-4, Baffin Bay Basin AU; and AU-5, Greater Ungava Fault Zone AU.

Tectonic Evolution of the West Greenland-East Canada Province

The tectonic evolution of the West Greenland-East Canada Province is complex, involving the rotation of Greenland into Arctic Canada during the Eurekan Orogeny. It included:) multiple phases of rifting, (2) transpressional and transtensional movement along regional transform faults, (3) opening of Baffin Bay Basin, (4) counterclockwise movement of Greenland away from eastern Canada as the Labrador Sea and Norwegian Sea opened along spreading ridges, and (5) late Paleocene and Eocene compression and inversion of extensional structures in the northern part of the province (Grant, 1982; Menzies, 1982; Reideger and others, 1984; Grant and others, 1986; Balkwill, 1987; Rowley and Lottes, 1988; DePaor and others, 1989; Roest and Srivastava, 1989; Chalmers, 1991; Jackson and others, 1992; Chalmers and others, 1993; Chian and Louden, 1994; Jackson and Reid, 1994; Chian and others, 1995; Chalmers and Holt-Laursen, 1995; Arne and others, 1998; Chalmers and others, 1999; Harrison and others, 1999; Dam and others, 2000; Japsen and Chalmers, 2000; Larsen and Pulvertaft 2000; Chalmers and Pulvertaft, 2001; Geoffroy, 2001; Geoffroy and others, 2001; Japsen and others, 2005; Saalmann and others, 2005; Funck and others, 2006, 2007; Skaarup and others, 2006; Wilson and others, 2006). The kinematics of the Greenland and Canada cratons were, according to Harrison and others (1999), strongly influenced by the migration and impingement of a mantle plume that caused thermal uplift and subsequent plate movements.

Mesozoic-Cenozoic Composite Total Petroleum System

Several possible petroleum source rocks have been suggested or interpreted from geochemical data and geological evidence in the province, including Paleogene, Lower and Upper Cretaceous, and Ordovician rocks. To encompass the possibility that several source rocks could have supplied petroleum to reservoirs and traps in this province, a Mesozoic-Cenozoic Composite Total Petroleum System was defined (fig. 2) to encompass the possibility that all or some of these sources have reached thermal maturity and contributed petroleum to reservoirs in the five assessment units described below. Oil seeps described from onshore west Greenland and offshore east Canada provide excellent evidence that, at least in those areas, a petroleum system is or was active (Christiansen and Pulvertaft, 1994; Christiansen and others, 1996; Bojesen-Koefoed and others, 1998; Gregersen and Bidstrup, 2008). An oil seep offshore from Scott Inlet in northeastern Canadian waters (Balkwill and others, 1990) has been interpreted as most likely having an Upper Cretaceous marine shale source (Fowler and others, 2005), and the oil is interpreted to be one that would be derived from Upper Cretaceous shales of the Kanguk Formation exposed on Ellesmere Island.

Oil seeps and oil-stained rocks that are widely distributed in Albian to Paleogene rocks on Nuussuaq Peninsula and Disko Island (fig. 1) of West Greenland have been subjected to extensive geochemical analysis, and five oil types have been defined across this area (Bojesen-Koefoed and others, 1998, 1999, 2001, 2004, 2007; Pedersen and others, 2006). The first oil, called the Marraat oil, is considered to be the best characterized of the five oils; it is a typical "high-wax" oil sourced from a deltaic mudstone with high terrigenous organic matter content. Extracts from thermally immature Paleocene mudstones from Nuussuaq are considered to correlate with the oil from the oil seeps. The second oil, the Kuugannguaq oil, is on Disko Island, and is a "high-wax" oil with source interpreted to have high terrigenous organic matter content. Biomarkers show that the oil was sourced by rocks no younger than Santonian, and the oil was interpreted to be sourced by deeply buried coals and carbonaceous mudstones of the Albian-Cenomanian Atane Formation that have been extensively studied in outcrop (Pedersen and others, 2006). The third oil recognized in the seeps, the Itilli oil, is a "lowwax" oil typical of oil from a marine mudstone. No source rocks of this type are known from outcrops, but the inference was made that the marine source rock might have been shales similar to the Cenomanian-Turonian Kanguk Formation, such as those exposed on Ellesmere Island (Bojesen-Koefoed and others, 1998). The remaining two oils were interpreted to have local sources. Mixing of these several oils was also reported from analyses of the seeps. Other potential source rocks have been postulated from the province. For example, synrights lacustrine and (or) marine petroleum source rocks possibly deposited in Early Cretaceous grabens might have reached thermal maturity and sourced reservoirs in the synrift section. However, drilling to date has provided no evidence of Lower Cretaceous source rocks in this province. The suggestion has also been made that rifting might have begun as early as the Jurassic; if so, petroleum source rocks of that age could be present in these extensional structures, but this remains speculative. There is also the possibility that Ordovician organic bearing shales (McCauley and others, 1990) are a source for petroleum in this province, based on a reported dredge sample of a potential Ordovician source rock from the southeastern part of the province (Geological Survey of Denmark and Greenland, oral commun. 2007), and another sample from an outcrop in southwest Greenland (fig. 2).

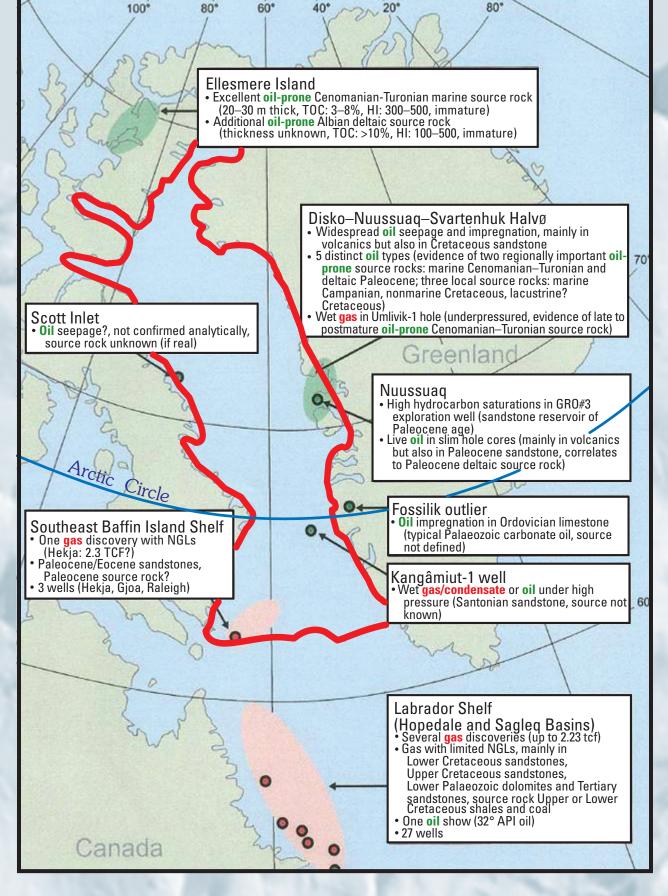


Figure 2. Total petroleum system map for the West Greenland-East Canada Province.

After Bojesen-Koefoed and others (1999). API, American Petroleum Institute; HI, hydrogen index; NGL, natural gas liquids; TCF, trillions of cubic feet; TOC, total organic carbon.

Geologic Models for Assessment Units

Eurekan Structures AU

The Eurekan Structures AU (AU-1, fig. 1) encompasses all reservoirs in traps in the northern Baffin Bay area that might have been affected by Eurekan compressional deformation. Most structures in the AU began as extensional structures in the Cretaceous and possibly were subjected to strike-slip deformation associated with southwest splays of the Nares Fault system in the Paleogene. Finally, these structures were affected by compression associated with the Eurekan Orogeny (Jackson and others, 1992) in the late Paleocene and Eocene as Greenland rotated counterclockwise and collided with Canada. The northern and southern limits of the AU are broadly defined as the limit of Eurekan compression effects on extensional structures, but the geology of this area is not well known. Total area of the Eurekan Structures AU is about 146,000 km², and includes most of Kane, Kap York, Glacier, North Water, Lady Ann, and Lancaster Sound Basins as well as other features (Smith and others, 1989; Harrison and Brent, 2005).

Geologic Model for Assessment

The geologic model for assessment of the Eurekan Structures AU largely involves Early Cretaceous and Late Cretaceous to Paleogene grabens and half-grabens filled with a typical synrift facies, including potential source and reservoir rocks (Brent and others, 2006) (fig. 3). Upper Cretaceous sag strata might include source rocks of Cenomanian-Turonian and Campanian ages. Modeling indicates that, with burial during the passive margin phase, maturation probably commenced in early Paleogene time, followed by migration into reservoirs within structures and into stratigraphic reservoirs including slope and fan reservoirs. Eurekan compression in the late Paleocene to Eocene resulted in the inversion of some of the earlier extensional structures, possibly causing the loss of some petroleum from previous accumulations (Lowell, 1995; MacGregor, 1995). Modeling also indicates that, in addition to oil, gas generation was possible within the deeper extensional structures if source rocks are present. Assessment of geologic risk was necessarily based on the presence of adequate petroleum source rocks and on petroleum being preserved in structural traps following inversion.

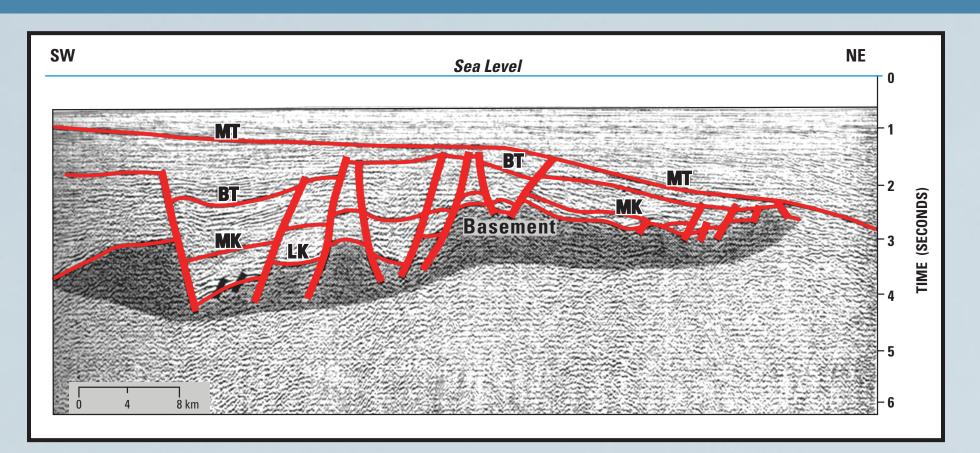


Figure 3. Seismic profile serving as a geologic model for assessment of the Eurekan Structures Assessment Unit (AU-1, fig. 1 from Rice and Shade (1982). MT, mid-Tertiary unconformity; BT, base Tertiary unconformity; MK, mid-Cretaceous unconformity; LK, Lower Cretaceous unconformity.

Northwest Greenland Rifted Margin AU

The Northwest Greenland Rifted Margin AU (AU-2, fig. 1) encompasses all reservoirs in structural and stratigraphic traps along the rifted continental margin of West Greenland that were formed during rifting and post-rift thermal relaxation and sag (Chalmers and Pulvertaft, 1992). The AU is bounded by basement rocks of the Greenland craton to the east, the boundary of the Eurekan Structures AU to the north, the boundary of the Baffin Bay Basin AU to the west, and an arbitrary boundary to the south that is an extension of the northern limit of the Labrador Sea and the southwest Greenland margin (fig. 1). The area of the Northwest Greenland Rifted Margin AU is approximately 286,000 km². The AU is divided into two parts by the north end of the Greater Ungava Fault Zone AU, but the boundary is not well established as the extent of strike-slip deformation that extends laterally from the Greater Ungava Fault Zone is uncertain.

Geologic Model for Assessment

The geologic model for the assessment of the Northwest Greenland Rifted Margin AU includes the formation of extensional structures in the Early Cretaceous and Late Cretaceous-Paleogene as Greenland progressively rifted from eastern Canada (fig. 4). The numerous grabens and half-grabens mapped along this margin were filled with synrift facies (Whittaker and others, 1997) that included potential petroleum source rocks and reservoir rocks. Sag-phase reservoirs of the passive margin include marginal marine to deep marine slope and fan sandstones of Cretaceous and Paleogene age (Rolle, 1985; Pedersen and Pulvertaft, 1992, 1998, a,b,; Dam and Sonderholm, 1994, 1998, a,b,; Midtgaard, 1996: Dam, 2002; Dalhoff and others, 2003; Skaarup and others, 2000, 2006; Gregersen and Skaarup, 2007; Gregersen and Bidstrup, 2008). Most likely source rocks include Cenomanian-Turonian, Campanian, and Paleogene organic-bearing strata. Petroleum generated from the maturation of source rocks during burial by synrift and passive margin sediments might have migrated into traps in extensional structures and into stratigraphic traps within the sag section. Because maturation followed trap formation, timing is not a geologic risk in this AU.

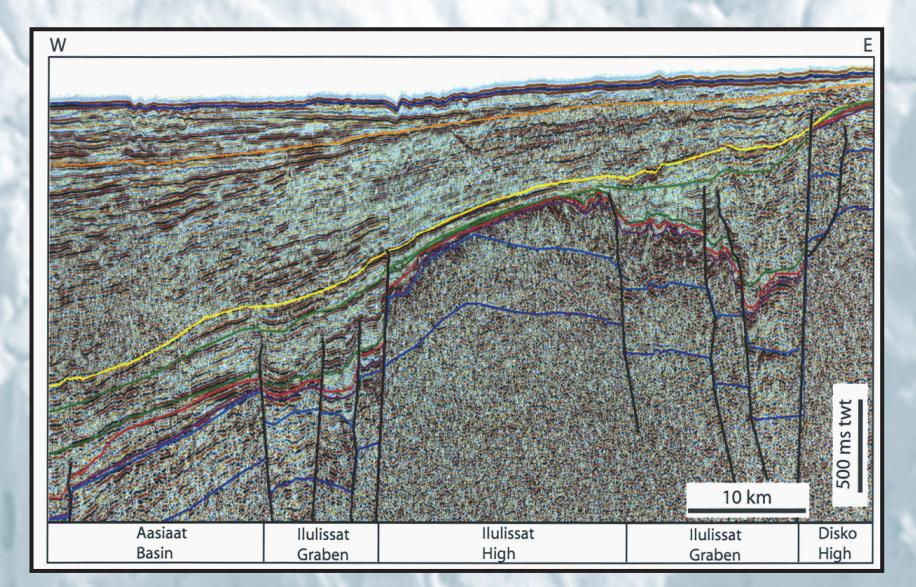


Figure 4. Seismic profile serving as geologic model for the assessment of the Northwest Greenland Rifted Margin Assessment Unit (AU-2, fig. 1 from Geological Survey of Denmark and Greenland (GEUS), written commun., 2007). Orange, yellow, red, and blue lines are internal correlation markers used by GEUS; ms, millisecond; twt, two-way transit.

Northeast Canada Rifted Margin AU

The Northeast Canada Rifted Margin AU (AU-3, fig. 1) encompasses all reservoirs within the extensional, rifted continental margin of northeast Canada. The AU is bounded to the west by the cratonic rocks of Baffin Island, to the north by the common boundary with the Eurekan Structures AU, to the east by the common boundary with the Baffin Bay Basin AU, and to the south with the province boundary at the north end of the Labrador Shelf. The area of the AU is about 111,000 km². The rifted margin of northeast Canada is narrower than the conjugate-rifted margin of West Greenland (fig. 1).

Geologic Model for Assessment

The geologic model for the assessment is for petroleum generated from Cretaceous and possibly Paleogene source rocks within the deeper parts of the grabens and half-grabens, and from within the sag section to migrate into synrift and post-rift reservoirs (fig. 5). Most likely reservoirs are in the Upper Cretaceous post-rift section and Paleogene marginal marine to slope and fan sandstones, which are thought to be similar to the reservoirs postulated for the Northwest Greenland Rifted Margin AU (Issler and Beaumont, 1987; Burden and others, 1990). Generation is postulated to have begun in the Late Cretaceous—Paleogene in most grabens, and the petroleum would have migrated into synrift and post-rift reservoirs. Given the similarity with the margin of West Greenland, the petroleum accumulations in this AU are expected to display a slight preference for oil over gas, except in the deeper grabens. This expectation is similar to the oil/gas mix for the Northwest Greenland Rifted Margin AU.

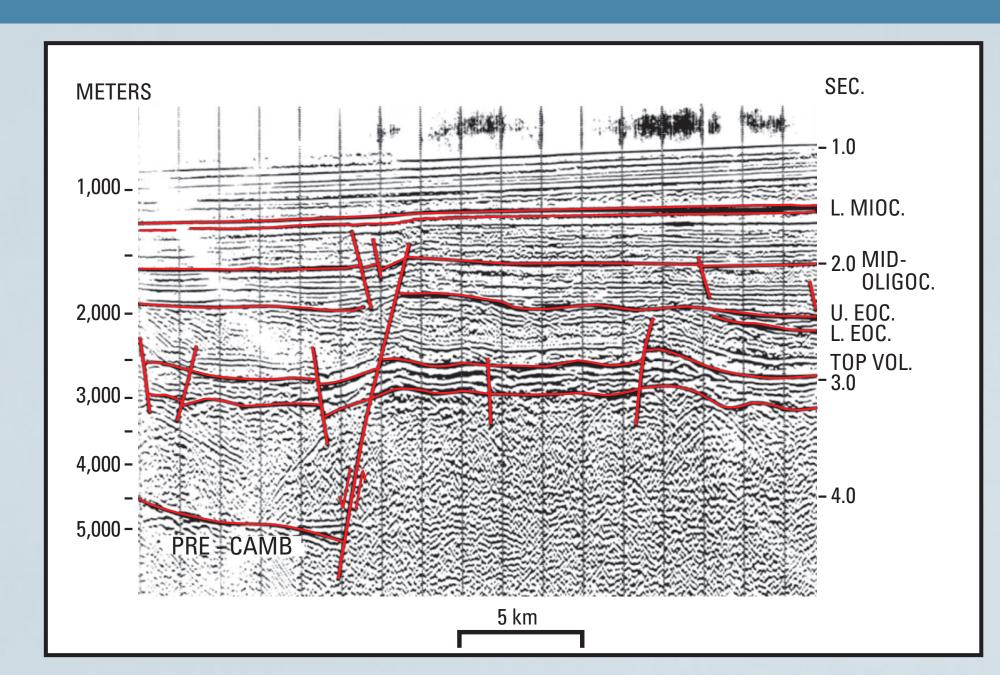


Figure 5. Seismic profile serving as geologic model for the assessment of the Northeast Canada Rifted Margin Assessment Unit (AU-3, fig. 1 from Klose and others (1982)). L. MIOC., Lower Miocene; MID-OLIGOC., Middle Oligocene; U. EOC., Upper Eocene; L. EOC., Lower Eocene; TOP VOL, Top Volcanics; PRE-CAMB, Precambrian.

Baffin Bay Basin AU

The Baffin Bay Basin AU (AU-4, fig. 1) was defined to encompass all potential oil and gas reservoirs that could be within the 8- to 14-km-thick wedge of Paleogene and Neogene strata that occupies Baffin Bay Basin. The crust underlying Baffin Bay Basin, which formed between magnetic isochron 24 to 13, or 58 to 33 Ma (Saalmann and others, 2005), is variously thought to be oceanic crust formed in a spreading center, crust that reflects upwelling of mafic mantle material (Reid and Jackson, 1997), or extremely attenuated continental crust. The Baffin Bay Basin AU is bounded on the north by the Eurekan Structures AU, to the east and south partly by the Northwest Greenland Rifted Margin and Greater Ungava Fault Zone AUs, and to the west by the Northeastern Canada Rifted Margin AU. Magnetic and gravity maps greatly aided in defining these boundaries; the Baffin Bay Basin AU area is about 252,000 km².

Geologic Model for Assessment

The geologic model for this AU includes the southward progradation of Paleogene and Neogene clastic sediments into Baffin Bay Basin from a mostly northerly orogenic source, forming the thick clastic wedge. Sea level changes during deposition resulted in sequence boundaries, condensed sections with possible source rocks, and reservoirs in the lowstand, transgressive, and highstand systems tracts. Source rocks might include the *Azolla* horizon of Eocene age (Brinkhuis and others, 2006). Given burial by several kilometers of overburden, petroleum possibly was generated from upper Paleogene or Neogene source rocks, and petroleum migrated into a wide range of possible reservoirs, including incised valley systems, shelf-edge deltaic systems, shoreline systems, and slope and basin-floor systems (fig. 6). A possible geologic analog is provided by a similar clastic sequence offshore Kalimantan, Indonesia (Peters and others, 2000). Potential structural traps are related to listric faults soling on mudstones, rollovers along faults, and stratigraphic traps including slope and basin-floor fan sandstones enclosed in mudstones. Both oil and gas might have been generated from petroleum source rocks within this system, possibly from condensed sections within several of the sequences.

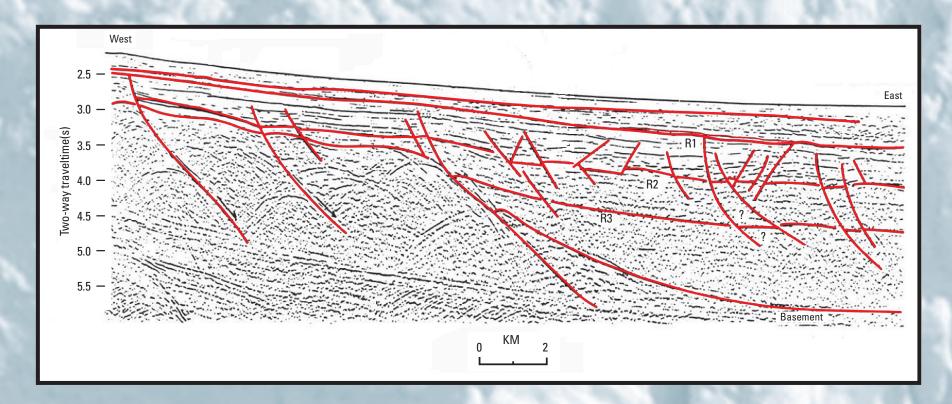


Figure 6. Seismic data used as geologic model for the assessment of the Baffin Bay Basin Assessment Unit (AU-4, fig. 1 from Arthur and others (1989)). R1, R2, and R3 mark internal seism reflector correlations used in the Ocean Drilling Project study.

Greater Ungava Fault Zone AU

The Greater Ungava Fault Zone Assessment Unit (AU-5, fig. 1) encompasses all petroleum reservoirs in the Ungava Fault Zone, a complex fault zone with a history of extension, transtension, and transpression (Beh, 1974; Sorensen, 2006; Skaarup and others, 2006); deformation occurred as the Labrador Sea and Baffin Bay Basin opened and Greenland rotated counterclockwise into northern Canada. The Ungava fault is part of a regional transform fault system that accommodated continental separation between Greenland and Canada and the formation of Baffin Bay Basin and the Labrador Sea. The Greater Ungava Fault Zone AU is bounded to the north by the Baffin Bay Basin AU, to the west by the Northeast Canada Rifted Margin AU, to the east by the West Greenland Rifted Margin AU, and to the south by the province boundary (fig. 1). The area of the Greater Ungava Fault Zone AU is about 145,000 km².

Geologic Model for Assessment

The geologic model used in the assessment involves petroleum source rocks within the extensional and transtensional basins that were buried deep enough to reach thermal maturity and create windows for oil and gas generation (fig. 7). Petroleum migrated updip and vertically into synrift fluvial and deltaic sandstones and post-rift marginal marine to deep marine slope and fan sandstones. Subsequent strike-slip movement along the Ungava fault system might have caused previously reservoired fluids to remigrate, causing a loss of petroleum from some structures. Both oil and gas are predicted to have been generated within this AU.

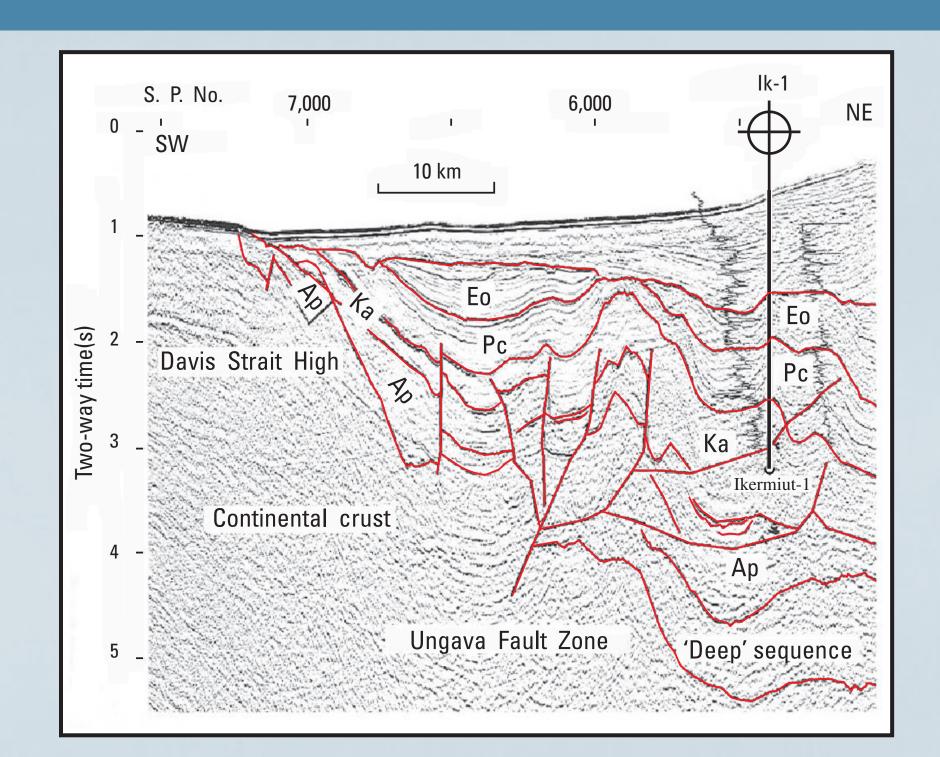


Figure 7. Seismic profile serving as geologic model for assessment of Greater Ungava Fault Zone Assessment Unit (AU-5, fig. 1). From Chalmers (1991). Eo, Eocene; Pc, Paleocene; Ka, Kangeq Sequence (Cenomanian-Santonian); Ap, Appat Sequence (Aptian-Albian); Ik-1, Ikermiut-1 well location.

Assessment Results

ndicates not applicable; oil field sizes in MMBO; gas field sizes in BCFG1

Table 1. West Greenland-East Canada Province assessment results.

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included as NGL (natural gas liquids). Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. AU probability is the chance of at least one accumulation of minimum size within the AU. TPS, total petroleum system; AU, assessment unit. Gray shading

Total Petroleum Systems (TPS) and Assessment Units (AU)	AU Probability	Field Type	Largest . Expected Oil Field Size	Total Undiscovered Resources												
				Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)				
				F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean	
Assessment Results–Entire Prov	rince															
Mesozoic-Cenozoic Composite 1	ΓPS															
Eurekan Structures AU	0.25	0il	1,086	0	0	6,626	1,133	0	0	10,490	1,784	0	0	285	48	
		Gas	6,485					0	0	39,428	6,806	0	0	1,055	181	
Northwest Greenland Rifted Margin AU	0.50	Oil	2,273	0	464	19,465	4,903	0	280	18,728	4,548	0	6	423	102	
		Gas	13,222					0	1,946	109,082	27,235	0	45	2,475	606	
Northeast Canada Rifted Margin AU	0.50	Oil	860	0	0	5,847	1,431	0	0	5,591	1,325	0	0	128	30	
		Gas	4,759					0	0	31,192	7,369	0	0	704	164	
Baffin Bay Basin AU	0.28	0il	1,346	0	0	8,470	1,555	0	0	16,128	2,934	0	0	244	44	
		Gas	8,054					0	0	50,598	9,338	0	0	1,126	206	
Greater Ungava Fault Zone AU	0.30	0il	1,193	0	0	8,514	1,675	0	0	18,771	3,622	0	0	329	64	
		Gas	7,164					0	0	50,625	9,892	0	0	1,073	209	
Total Conventional Resources							10,697				74,853				1,654	

Resources							10,697				74,853				1,654
					40										
Assessment Results–North of Ar	ctic Circle														
Mesozoic-Cenozoic Composite T	PS														
Eurekan Structures AU	0.25	Oil	1,086	0	0	6,626	1,133	0	0	10,490	1,784	0	0	285	48
		Gas	6,485					0	0	39,428	6,806	0	0	1,055	181
Northwest Greenland Rifted Margin AU	0.50	0il	2,273	0	260	10,900	2,746	0	157	10,488	2,547	0	4	237	57
		Gas	13,222					0	1,090	61,086	15,251	0	25	1,386	339
Northeast Canada Rifted Margin AU	0.50	Oil	860	0	0	3,470	850	0	0	3,318	787	0	0	76	18
		Gas	4,759					0	0	17,577	4,374	0	0	418	97
Baffin Bay Basin AU	0.28	0il	1,346	0	0	8,470	1,555	0	0	16,128	2,934	0	0	244	44
		Gas	8,054					0	0	50,598	9,338	0	0	1,126	206
Greater Ungava Fault Zone AU	0.30	0il	1,193	0	0	5,037	991	0	0	11,105	2,143	0	0	195	38
		Gas	7,164					0	0	29,950	5,852	0	0	635	124
Total Conventional Resources							7,275				51,816				1,15

The assessment results for the five AUs in the West Greenland-East Canada Province are summarized in table 1. The upper part of table 1 reflects the assessment of the full geographic extent of each AU (fig. 1). Three of the AUs in this study extend south of the Arctic Circle, so the resources above the Arctic Circle were allocated from the undiscovered oil and gas volumes calculated for the entire AU area (lower part of table 1).

The estimated means for undiscovered resources in the five AUs defined in this study are oil, 10,697 MMB; gas, 74,853 BCF; and NGL,1,655 MMB (table 1).

The estimated means for undiscovered resources for the areas of the AUs that are north of the Arctic Circle are oil, 7,274 MMB; gas, 51,815 BCF, and NGL, 1,153 MMB (table 1).

The geologic probabilities for the five AUs were determined based on a consideration of the

geology of this province, but also on the geologic probabilities assigned to assessment units during the assessment of all Arctic basins. In this manner the probabilities were consistently applied throughout the Arctic on this assessment project.

The assessment results presented here reflect the state of geologic knowledge of the West

The assessment results presented here reflect the state of geologic knowledge of the West Greenland-East Canada Province at the time of the assessment. Future drilling and evaluation of the petroleum systems within the province will greatly add to the geologic knowledge base, and will lead to a refinement of these assessment results.



References

logical Society of London, v. 148, p. 899–908.

Arne, D.C., Zentilli, M., Grist, A.M., and Collins, M., 1998, Constraints on the timing of thrusting during the Eurekan orogeny, Canadian Arctic archipelago: an integrated approach to thermal history analysis: Canadian Journal of Earth Sciences,

Arthur, M.A., Srivastava, S.P., Kaminski, M., Jarrard, R., and Osler, J., 1989, Seismic stratigraphy and history of deep circulation and sediment drift development in Baffin Bay and the Labrador Sea, *in* Srivastava, S.P., Arthur, M.A., and Clement, B., 1989, eds., Proceedings of the Ocean Drilling Program, Scientific Results, v. 105, Sites 645–647, Baffin Bay and Labrador Sea, p. 957–988.

Balkwill, H.R., 1987, Labrador Basin: structural and stratigraphic style, *in* Beaumont, C., and Tankard, A.J., eds., Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists Memoir, no. 12, p. 17–43.

Balkwill, H.R., McMillan, N.J., MacLean, B., Williams, G.L., and Srivastava, S.P., 1990, Geology of the Labrador Shelf, Baffin Bay, and Davis Strait, *in* Keen, M.J., and Williams, G.L., eds., Geology of the continental margin of eastern Canada: Geological Survey of Canada, Geology of Canada, v. 2, p. 293–348

Beh, R.L., 1974, Evolution and geology of western Baffin Bay and Davis Strait, Canada, *in* Yorath, C.J., Parker, E.R., and Glass, D.J., eds., Canada's continental margins and offshore petroleum exploration: Canadian Society of Petroleum Geologists Memoir, no. 4, p. 453–476.

Bojesen-Koefoed, J.A., Bidstrup, T., Christiansen, F.G., Dalhoff, F., Gregersen, U., Nytoft, H.P., Nohr-Hansen, H., Pedersen, A.K., and Sonderholm, M., 2007, Petroleum seepages at Asuk, Disko, West Greenland: implications for regional petroleum exploration: Journal of Petroleum Geology, v. 30, no. 3, p. 219–236.

Bojesen-Koefoed, J.A., Christiansen, F.G., Nytoft, H.P., and Pedersen, A.K., 1999, Oil seepage onshore West Greenland: evidence of multiple source rocks and oil mixing, *in* Fleet, A.J., and Boldy, S.A.R., eds., Petroleum geology of northwest Europe: Proceedings of the 5th Conference: Geological Society of London, p. 305–314.

Bojesen-Koefoed, J.A., Christiansen, F.G., Nytoft, H.P., and Petersen, H.I., 1998, Petroleum source potential and the importance of marine versus terrestrial organic matter input: a comparative study of mid-Cretaceous deposits from Ellesmere Island, Northwest Territories, Canada, *in* Mukhopadhyay, P.K., Avery, M.P., Calder, J.H., and Goodarzi, F., eds., Sailing into the Millenium: Halifax, Nova Scotia, Fifteenth Annual Meeting of the Society of Organic Petrology, July 26–30, 1998, Abstracts Volume, p. 57–59.

Bojesen-Koefoed, J.A., Dam, G., Nytoft, H.P., Pedersen, G.K., and Petersen, H.I., 2001, Drowning of a nearshore peatforming environment, Atane Formation (Cretaceous) at Asuk, West Greenland: sedimentology, organic petrography, and geochemistry: Organic Geochemistry, v. 32, p. 967–980.
Bojesen-Koefoed, J.A., Nytoft, H.P., and Christiansen, F.G., 2004, Age of oils in West Greenland: was there a Mesozoic

seaway between Greenland and Canada?: Geological Survey of Denmark and Greenland Bulletin, v. 4, p. 49–52.

Brent, T.A., Oakley, G.N., and Harrison, J.C., 2006, Progress towards understanding petroleum potential of the Lancaster Sound region, northern Nunavut [abs.], *in* History of convergent and passive margins in the polar realm: sedimentary and tectonic processes, transitions, and resources: University Laval, Quebec City, Quebec, September 18–22, 2006, p. 15.

Ocean: Nature, v. 441, p. 606–609.

Burden, E.T., and Langille, A.B., 1990, Stratigraphy and sedimentology of Cretaceous and Paleocene strata in half-grabens on the southeast coast of Baffin Island, Northwest Territories: Canadian Petroleum Geologists Bulletin, v. 38, no. 2, p.

on the southeast coast of Baffin Island, Northwest Territories: Canadian Petroleum Geologists Bulletin, v. 38, no. 2, p. 185–196.

Chalmers, J.A., 1991, New evidence on the structure of the Labrador Sea/Greenland continental margin: Journal of the Geo-

Brinkhuis, H., Schouten, S., Collinson, M.E., and 20 others, 2006, Episodic fresh surface waters in the Eocene Arctic

Chalmers, J.A., and Holt-Laursen, K., 1995, Labrador Sea: the extent of continental and oceanic crust and the timing of the onset of seafloor spreading: Marine and Petroleum Geology, v. 12, no. 2, p. 205–217.
Chalmers, J.A., and Pulvertaft, T.C.R., 1992, The southern West Greenland continental shelf–was petroleum exploration abandoned prematurely?, *in* Vorren, T.O., Bergsager, E., Dahl-Stamnes, O.A., Holter, E., Johansen, B., Lie, E., and Lund, T.B., eds., Arctic geology and petroleum potential: Norwegian Petroleum Society Special Publication, no. 2, p. 55–66.

Chalmers, J.A., and Pulvertaft, T.C.R., 2001, Development of the continental margins of the Labrador Sea: a review, *in* Wilson, R.C.L., Whitmarsh, R.B., Taylor, B., and Froitzheim, N., eds., Non-volcanic rifting of continental margins: a comparison of evidence from land and sea: Geological Society of London Special Publication, no. 187, p. 77–105.

Chalmers, J.A., Pulvertaft, T.C.R., Christiansen, F.G., Larsen, H.C., Laursen, K.H., and Ottesen, T.G., 1993, The southern West Greenland continental margin: rifting history, basin development, and petroleum potential, *in* Parker, J.R., ed., Petroleum geology of northwest Europe: Proceedings of the 4th Conference: Geological Society of London, p. 915–931.

Chalmers, J.A., Pulvertaft, T.C.R., Marcussen, C., and Pedersen, A.K., 1999, New insight into the structure of the Nuussuaq Basin, central West Greenland: Marine and Petroleum Geology, v. 16, p. 197–224.

gate margins of the Labrador Sea: Geology, v. 23, no. 7, p. 589–592.

Chian, D., and Louden, K.E., 1994, The continent-ocean crustal transition across the southwest Greenland margin: Journal of Geophysical Research, v. 99, no. B5, p. 9117–9135.

Christiansen, F.G., Bojesen-Koefoed, J., Dam, G., Nytoft, H.P., Larsen, L.M., Pedersen, A.K., and Pulvertaft, T.C.R., 1996, The Marraat oil discovery on Nuussuaq, West Greenland: evidence for a latest Cretaceous-earliest Tertiary oil prone

The Marraat oil discovery on Nuussuaq, West Greenland: evidence for a latest Cretaceous-earliest Tertiary oil prone source rock in the Labrador Sea-Melville Bay region: Bulletin of Canadian Petroleum Geology, v. 44, no. 1, p. 39–54.

Christiansen, F.G., and Pulvertaft, T.C.R., 1994, Petroleum-geological activities in 1993: oil source rocks the dominant theme of the season's field programme: Gronlands Geologike Underssogelse Rapport, v. 160, p. 52–56.

Dalhoff, F., Chalmers, J.A., Gregersen, U., Nohr-Hansen, H., Rasmussen, J.A., and Sheldon, E., 2003, Mapping and facies analysis of Paleocene-Mid Eocene seismic sequences, offshore southern West Greenland: Marine and Petroleum Geology,

v. 20, p. 935–986.

Dam, G., 2002, Sedimentology of magmatically and structurally controlled outburst valleys along volcanic margins: examples from the Nuussuaq Basin, West Greenland: Sedimentology, v. 49, p. 505–532.

Dam, G., Larsen, M., and Sonderholm, M., 1998a, Sedimentary response to mantle plumes: implications from Paleocene

onshore successions, West and East Greenland: Geology, v. 26, p. 207–210.

Dam, G., Nohnr-Hansen, H., Pedersen, A.K., and Sonderholm, M., 2000, Sedimentary and structural evidence of a new early Campanian rift phase in the Nuussuaq Basin, West Greenland: Cretaceous Research, v. 21, p. 127–154.

Dam, G., and Sonderholm, M., 1994, Lowstand slope channels of the Itilli succession (Maastrichtian-Lower Paleocene), Nuussuaq, West Greenland: Sedimentary Geology, v. 94, p. 49–71.

Dam, G., and Sonderholm, M., 1998b, Sedimentological evolution of a fault-controlled Early Paleocene incised valley system, Nuussuaq Basin, West Greenland, *in* Shanley, K.W., and McCabe, P.J., eds., Relative role of eustacy, climate, and tectonism in continental rocks: Tulsa, Okla., Society of Economic Paleontologists and Mineralogists Special Publication, no. 59, p. 109–121.

DePaor, D.G., Bradley, D.C., Eisenstadt, G., and Phillips, S.M., 1989, The Arctic Eurekan orogen: a most unusual fold-and-

thrust belt: Geological Society of America Bulletin, v. 101, p. 952–967.

Fowler, M., Stasiuk, L., and Avery, M., 2005, Potential petroleum systems in the Labrador Sea and Baffin shelf areas, offshore northeastern Canada [abs.], *in* Organic Geochemistry: Challenges for the 21st Century: Seville, Spain, 22nd International Meeting on Organic Geochemistry, European Association of Organic Geochemists, September 12–16, 2005, p. 463–464

Funck, T., Jackson, H.R., Dehler, S.A., and Reid, I.D., 2006, A refraction seismic transect from Greenland to Ellesmere Island, Canada; the crustal structure in southern Nares Strait: Polarforschung, v. 74, p. 94–112.
Funck, T., Jackson, H.R., Louden, K.E., and Klingelhofer, F., 2007, Seismic study of the transform-rifted margin in Davis Strait between Baffin Island (Canada) and Greenland: what happens when a plume meets a transform: Journal of Geophysical Research, v. 112, B04402, 22 p.

Geoffroy, L., 2001, The structure of volcanic margins: some problematics from the North Atlantic/Labrador-Baffin system: Marine and Petroleum Geology, v. 18, p. 463–469.
Geoffroy, L., Callot, J.P., Scaillet, S., Skuce, A., Gelard, J.P., Ravilly, M., Bonin, B., Cayet, C., Perrot, K., and Lapvrier, C., 2001, Southeast Baffin volcanic margin and the North American-Greenland plate separation: Tectonics, v. 20, no. 4, p.

Grant, A.C., 1982, Problems with plate tectonic models for Baffin Bay–Nares Strait: evidence from the Labrador Sea, *in* Dawes, P.R., and Kerr, J.W., eds., Nares Strait and the drift of Greenland: a conflict in plate tectonics: Meddelelser om Gronland, Geosciences 8, p. 313–326.

petroleum potential, *in* Future petroleum provinces of the world: Tulsa, Okla., American Association of Petroleum Geologists Memoir, no. 40, p. 177–205.

Gregersen, Ulrik, and Bidstrup, Torben, 2008, Structures and hydrocarbon prospectivity in the northern Davis Strait area, offshore West Greenland: Petroleum Geoscience, v. 14, p. 151–166

Grant, A.C., McAlpine, K.D., and Wade, J.A., 1986, The continental margin of eastern Canada: geological framework and

Gregersen, Ulrik, and Skaarup, Nina, 2007, A mid-Cretaceous prograding sedimentary complex in the Sisimuit Basin, offshore West Greenland—stratigraphy and hydrocarbon potential: Marine and Petroleum Geology, v. 24, p. 15–28.

Harrison, J.C., and Brent, T.A., 2005, Untested Cretaceous-Paleogene sedimentary basins of northern Baffin Bay and Nares Strait region, Arctic Canada and Greenland [abs.]: American Association of Petroleum Geologists Annual Convention, Calgary, Alberta, Canada, June 19–22, 2005, Search and Discovery Article, no. 90039.

Harrison, J.C., Mayr, U., McNeil, D.H., Sweet, A.R., McIntyre, D.J., Eberle, J.J., Harington, C.R., Chalmers, J.A., Dam, G., and Nohr-Hansen, H., 1999, Correlation of Cenozoic sequences of the Canadian Arctic region and Greenland: implications for the tectonic history of northern North America: Canadian Petroleum Geology Bulletin, v. 47, no. 3, p. 223–254.

Issler, D.R., and Beaumont, C., 1987, Thermal and subsidence history of the Labrador and West Greenland continental margins, *in* Beaumont, C., and Tankard, A.J., eds., Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists Memoir, no. 12, p. 45–69.

Jackson, H.R., Dickie, K., and Marillier, F., 1992, A seismic reflection study of northern Baffin Bay: implications for tectonic

Jackson, H.R., and Reid, I.D., 1994, Crustal thickness between the Greenland and Ellesmere Island margins determined from seismic refraction: Canadian Journal of Earth Sciences, v. 31, p. 1407–1418.
Japsen, P., and Chalmers, J.A., 2000, Neogene uplift and tectonics around the north Atlantic: overview: Global and Planetary Change, v. 24, p. 165–173.

Japsen, P., Green, P.F., and Chalmers, J.A., 2005, Separation of Paleogene and Neogene uplift on Nuussuaq, West Greenland: Journal of the Geological Society of London, v. 162, p. 299–314.
Klose, G.W., Malterre, E., McMillan, N.J., and Zinkan, C.G., 1982, Petroleum exploration offshore southern Baffin Island, northern Labrador Sea, Canada, *in* Embry, A.F., and Balkwill, H.R., eds., Arctic geology and geophysics: Canadian Society

of Petroleum Geologists Memoir, no. 8, p. 233–244.

Larsen, J.G., and Pulvertaft, T.C.R., 2000, The structure of the Cretaceous–Paleogene sedimentary–volcanic area of Svartenhuk Halvo, central West Greenland: Geology of Greenland Survey Bulletin, no. 188, 39 p.

Lowell, J.D., 1995, Mechanics of basin inversion from worldwide examples, *in* Buchanan, J.G., and Buchanan, P.G., eds., Basin Inversion: Geological Society of London Special Publication, no. 88, p. 39–57.

Macauley, G., Fowler, M.G., Goodarzi, F., Snowdon, L.R., and Stasiuk, L.D., 1990, Ordovician oil shale-source rock sedi-

ments in the central and eastern Canada mainland and eastern Arctic areas and their significance to frontier exploration: Geological Survey of Canada Paper 90–14, 51 p.

MacGregor, D.S., 1995, Hydrocarbon habitat and classification of inverted rift basins, *in* Buchanan, J.G., and Buchanan, P.G., eds., Basin Inversion: Geological Society of London Special Publication, no. 88, p. 83–93.

central Ellesmere Island: Canadian Journal of Earth Sciences, v. 21, p. 1286–1295.

evolution: Canadian Journal of Earth Sciences, v. 29, p. 2353–2369.

Menzies, A.W., 1982, Crustal history and basin development of Baffin Bay: Meddelelser om Gronland, v. 8, p. 295–312.
Midtgaard, H.H., 1996, Inner-shelf to lower shoreface hummocky sandstone bodies with evidence for geostrophically influenced combined flow, Lower Cretaceous, West Greenland: Journal of Sedimentary Petrology, v. 66, no. 2, p. 343–353.
Pedersen, G.K., Andersen, L.A., Lundsteen, E.B., Petersen, H.I., Bojesen-Koefoed, J.A., and Nytoft, H.P., 2006, Depositional environments, organic maturity and petroleum potential of the Cretaceous coal-bearing Atane Formation at Qullissat, Nuussuaq Basin, West Greenland: Journal of Petroleum Geology, v. 29, no. 1, p. 3–26.
Pedersen, G.V., and Pulvertaft, T.C.R., 1992, The non-marine Cretaceous of the West Greenland basin, onshore West Green-

land: Cretaceous Research, v. 13, p. 263–272.

Peters, K.E., Snedden, J.W., Sulaeman, A., Sarg, J.F., and Enrico, R.J., 2000, A new geochemical-sequence stratigraphic model for the Mahakam Delta and Makassar slope, Kalimantan, Indonesia: American Association of Petroleum Geologists Bulletin, v. 84, no. 1, p. 12–44.

Reid, I., and Jackson, H.R., 1997, Crustal structure of northern Baffin Bay: seismic refraction results and tectonic implica-

tions: Journal of Geophysical Research, v. 102, no. B1, p. 523–542.

Rice, P.D., and Shade, B.D., 1982, Reflection seismic interpretation and sea–floor spreading history of Baffin Bay, *in* Embry A.F., and Balkwill, H.R., eds., Arctic Geology and Geophysics: Calgary, Alberta, Canada, Canadian Society of Petroleum Geologists Memoir, no. 8, p. 245–265.

Riediger, C.L., Bustin, R.M., and Rouse, G.E., 1984, New evidence for the chronology of the Eurekan orogeny from south-

Roest, W.R., and Srivastava, S.P., 1989, Sea-floor spreading in the Labrador Sea: a new reconstruction: Geology, v. 17, p. 1000–1003.

Rolle, F., 1985, Late Cretaceous-Tertiary sediments offshore central West Greenland lithostratigraphy, sedimentary evoluti and petroleum potential: Canadian Journal of Earth Sciences, v. 22, p. 1001–1019.

Rowley, D.B., and Lottes, A.L., 1988, Plate-kinematic reconstructions of the North Atlantic and Arctic: Late Jurassic to present: Tectonophysics, v. 155, p. 73–120.

Saalmann, K., Tessensohn, F., Piepjohn, K., von Gosen, W., and Mayr, U., 2005, Structure of Paleogene sediments in east Ellesmere Island: constraints on Eurekan tectonic evolution and implications for the Nares Strait problem: Tectonophysics, v. 406, p. 81–113.

Greenland: American Association of Petroleum Geologists Bulletin, v. 84, no. 2, p. 174–182.

Smith, D.R., Gowen, R.J., and McComb, M., 1989, Geology and Resource Potential of a Proposed National Marine Park, Lancaster Sound. Northwest Territories: Geological Survey of Canada, Open File 20022, 52 p.

Skaarup, N., Jackson, H.R., and Oakey, G., 2006, Margin segmentation of Baffin Bay/Davis Strait, eastern Canada based on seismic reflection and potential field data: Marine and Petroleum Geology, v. 23, p. 127–144.

Sorensen, A.B., 2006, Stratigraphy, structure and petroleum potential of the Lady Franklin and Maniitsoq Basins, offshore southern West Greenland: Petroleum Geoscience, v. 12, p. 221–234.
Whittaker, R.C., Hamann, N.E., and Pulvertaft, T.C.R., 1997, A new frontier province offshore northwest Greenland: structure, basin development, and petroleum potential of the Melville Bay area: American Association of Petroleum Geologists

Wilson, R.W., Klint, K.E.S., Van Gool, J.A.M., McCaffrey, J.W., Holdsworth, R.E., and Chalmers, J.A., 2006, Faults and fractures in central West Greenland: onshore expression of continental break-up and sea-floor spreading in the Labrador–Baffin Bay Sea, *in* Garde, A.A., and Kalsbeek, F., eds., Precambrian crustal evolution and Cretaceous-Paleogene faulting in

West Greenland: Geological Survey of Denmark and Greenland Bulletin, no. 11, p. 185–204.

Acknowledgments

I want to thank the personnel from the Geological Survey of Denmark and Greenland for allowing me to participate in field work on Disko Island and Nuussauq Peninsula during 2004. Special thanks to Wayne Husband for design and construction of this poster.

Publishing support provided by:
Denver Publishing Service Center
Manuscript approved for publication January 13, 2010

For more information concerning this publication, contact:
Team Chief Scientist, USGS Central Energy Resources
Box 25046, Mail Stop 939
Denver, Colo. 80225
(303)236-1647

Or visit the Central Energy Resources Team site at:
http://energy.cr.usgs.gov/

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this information product, for the most part, is in the public domain, it also contains copyrighted materials as noted in the text.

Permission to reproduce copyrighted items for other than personal use

must be secured from the copyright owner.

For sale by U.S. Geological Survey Information Services
Box 25286, Federal Center, Denver, Colo. 80225

Box 25286, Federal Center, Denver, Colo. 80225
1-888-ASK-USGS

This and other USGS products are available on the World Wide Web at: http://store.usgs.gov/

This report is available at: http://pubs.usgs.gov

Suggested citation:
Schenk, C.J., 2010, Geologic assessment of undiscovered oil and gas resources of the West Greenland–East Canada Province:
U.S. Geological Survey Open-File Report 2010–1012, 1 sheet.

GEOLOGIC ASSESSMENT OF UNDISCOVERED OIL AND GAS RESOURCES OF THE WEST GREENLAND-EAST CANADA PROVINCE

schenk@usgs.gov, U.S. Geological Survey, Denver, Colo. 80225

By
Christopher J. Schenk