

ALASKA FEDERAL OFFSHORE
Descriptions of Geologic Plays
1995 National Resource Assessment
U.S. Minerals Management Service

CHUKCHI SHELF ASSESSMENT PROVINCE

(Kirk W. Sherwood, James D. Craig, Richard T. Lothamer, Peter P. Johnson, S.A. Zerwick)

PLAY ORGANIZATION

At the most fundamental level, plays are organized around the five major tectonostratigraphic sequences recognized beneath Chukchi shelf. These sequences define play groups that contain prospects involving reservoirs within the major sequences. We therefore recognize the Lower Ellesmerian, Upper Ellesmerian, Rift, Lower Brookian, and Upper Brookian play groups. Within each play group, plays are distinguished on the basis of paleogeographic setting (opposite sides of basin, with different sediment source terranes), reservoir facies (e.g., carbonates versus various types of clastic deposits), structural setting (trap type), play petroleum charging system, or reservoir fluid content (all gas plays are set aside). The distinguishing attributes of each play are given below with individual play descriptions.

Of the 22 plays proposed for Chukchi shelf assessment province, 15 were sampled by wells offshore or along the west coast of Arctic Alaska. Only 7 of the sampled plays, however, were actually in closed volumes (prospects) at the sites of the wells. Klondike well tested prospects in plays 5, 8, 12, and 13, encountering pooled oil in plays 5, 8, and 12. Burger well tested gas pools in plays 7 and 18. Popcorn well tested prospects in plays 3 and 7, encountering pooled gas in play 7. Crackerjack well tested a prospect in play 5, encountering pooled gas in play 5 and pooled oil in an unmapped stratigraphic trap in play 12.

PLAY DESCRIPTIONS

Play 1 (UACS0100¹). Lower Ellesmerian Sequence—Endicott Clastics-Chukchi Platform:

Reservoir objectives primarily include Late Devonian(?) to Mississippian sandstones deposited in marginal marine to fluvial environments in Hanna trough during an early rift- or fault-driven phase of subsidence. Trap types on the east flank of Chukchi platform include early-formed horsts and stratigraphic wedges that were possibly disrupted by Paleocene transtensional

¹The "UA" Code is the "Unique Assessment Identifier" for each play, and is the principal guide to GRASP data files.

faults. This play is charged by the Hanna trough play charging system, in which petroleum generated from Triassic sources in Hanna trough migrated laterally northward and westward beneath regional seals to traps on the Arctic and Chukchi platforms. Play 1 was not tested by any wells.

Play 2 (UACS0200). Lower Ellesmerian Sequence—Endicott Clastics-Arctic Platform:

Reservoir objectives primarily include Late Devonian(?) to Mississippian sandstones deposited in marginal- to non-marine environments on the east side of Hanna trough during the early rift- or fault-driven phase of subsidence. Early-formed horst and stratigraphic wedge traps have been buried to greater depths than their Chukchi platform counterparts and are associated with higher levels of thermal maturity and poorer reservoir properties. The play is charged by the Hanna trough play charging system (described in play 1). Most identified prospects lie considerably deeper than the primary regional source rock (Shublik), and high thermal maturity of traps suggests the hydrocarbon endowment is largely dry gas. Play 2 is therefore modeled with a higher gas content than the other plays charged by the Hanna trough play charging system. Play 2 was not tested by any wells. Play 2 extends into western parts of Beaufort shelf assessment province and was there assessed as Beaufort shelf play UABS1800.

Play 3 (UACS0300). Lower Ellesmerian Sequence—Lisburne Carbonates: Reservoir objectives include Mississippian to Permian carbonates that were deposited on a stable marine shelf, with deeper water facies in the southeast part of the province in axial parts of Hanna trough. Porosity in Lisburne carbonates is associated with sparse porous zones in limestones and thin dolomite beds. No reef facies have been documented within the Lisburne carbonate assemblage, which ranges in age from Mississippian to Permian. The play is primarily charged by the Hanna trough play charging system (described in play 1), with minor contributions from interbedded organically-lean and gas-prone shales. Incomplete penetrations of the Lisburne carbonates occurred at Popcorn, Crackerjack, and Diamond wells, which encountered carbonates with porosities ranging from 0 to 14%. No hydrocarbons were encountered in Lisburne carbonates in these wells. Play 3 extends into western parts of Beaufort shelf assessment province and was there assessed as Beaufort shelf play UABS1900.

Play 4 (UACS0400). Ellesmerian Sequence—Overmature "Deep Gas" (Lower and Upper Ellesmerian Sequences): Reservoir objectives include all potential reservoirs in both Lower Ellesmerian and Upper Ellesmerian sequences (reservoir strata described in Plays 1,2,3,5, and 6). Prospects in the "Deep Gas" play occur at subsurface depths beneath the oil floor (2.0% vitrinite reflectance) and would contain only gas. High thermal maturities have a detrimental effect on reservoir properties and multi-cycle tectonic history combined with extremely deep burial at present (to 38,000 ft) result in high exploration risks for play 4. Play 4 was penetrated at Tunalik well in northwestern Alaska with no hydrocarbons present. At the level of Lower Ellesmerian rocks, play 4 extends into western parts of Beaufort shelf assessment province and was assessed there as Beaufort shelf play UABS2000.

Play 5 (UACS0500). Upper Ellesmerian Sequence—Sadlerochit Group-Chukchi Platform:

Reservoir objectives include Late Permian to Triassic marine strata deposited on the western side of Hanna trough, mostly during a "sag" or thermal phase of subsidence that followed the fault-driven subsidence of Lower Ellesmerian sedimentation in Hanna trough. The only potential reservoirs encountered in wells are spiculitic siltstones and cherts offering sparse moldic porosity. More proximal (nearshore, littoral) sandstones postulated to have been deposited to the west may now be lost to unconformable truncation at Mesozoic unconformities. The possible loss of this reservoir facies forms a major risk element for Chukchi shelf play 5. Hydrocarbons are primarily derived from Triassic source beds of the Hanna trough play charging system (described in play 1), with migration paths to the west beneath regional seals into areally large stratigraphic traps. Early-formed stratigraphic traps were disrupted by late-stage wrench tectonics. Trap disruption may be an additional risk element for this play. Play 5 was penetrated by Crackerjack and Klondike wells, both of which encountered pooled hydrocarbons within the play sequence.

Play 6 (UACS0600). Upper Ellesmerian Sequence—Sadlerochit Group-Arctic Platform:

Reservoir objectives primarily include Late Permian to Triassic marginal to shallow marine sandstones of the Sadlerochit Group that were deposited on the south-facing shelf that then existed on the Arctic platform. Diamond well, offshore on the east flank of Hanna trough, encountered over 500 feet of potential reservoir strata that are correlative to the Permian Echooka Formation. Primary trap styles include stratigraphic wedges and fault traps, with hydrocarbons migrating northward into traps from the Hanna trough play charging system (described in play 1) on the south. A prospect in play 6 was penetrated at Diamond well and found to be barren of hydrocarbons. Several wells also penetrated the play sequence (with no pooled hydrocarbons) in northwestern Alaska. Play 6 extends into western parts of Beaufort shelf assessment province and was assessed there as Beaufort shelf play UABS2100.

Play 7 (UACS0700). Rift Sequence—Active Margin Clastics: Reservoirs are primarily Late Jurassic to Early Cretaceous sandstones (equivalent to the Kuparuk Formation of Arctic Alaska) that were deposited in a zone of active faulting and flexural subsidence near an active rift margin which lay north of the hinge line along the south margin of North Chukchi basin. This tectonic environment produced a pattern of abrupt thickness changes among stratigraphic units making up the Rift sequence, and provides an opportunity for local development of reservoir sequences of great, potentially commercial, thicknesses. The inference of development of thick reservoirs in this play draws upon analogy to the abrupt expansion of Kuparuk sandstones from typical regional thicknesses of about 100 ft to the 450 gross feet observed in the fault-bounded depression hosting Point McIntyre field near Prudhoe Bay (AOGCC, 1993, p.102). In play 7, some sandstones may have been derived from local emergent uplifts. This play is charged by the Hanna trough play charging system (described in play 1). Three wells (Burger, Crackerjack, Popcorn) penetrated the play. Burger and Popcorn wells encountered gas (with condensate) in sandstones ranging up to 115 feet in thickness. Burger structure probably houses a multi-TCF gas pool, although no accurate estimate is yet available. At Crackerjack well, no sandstones are preserved within a Rift sequence highly abbreviated at the Lower Cretaceous unconformity (LCU).

Play 8 (UACS0800). Rift Sequence—Stable Marine Shelf: Reservoirs are primarily Late Jurassic to Early Cretaceous sandstones equivalent to the Kuparuk Formation of Arctic Alaska. Unlike the sandstones in the tectonically active rift zone (play 7) to the north, these rocks were instead deposited south of the rift zone on a tectonically stable shelf and slope that rimmed a deep water area in southernmost Hanna trough. Here, we anticipate fine-grained marine shelf sandstones that are thinner at the extremes and probably less continuous laterally than their counterparts in play 7. This play is charged by the Hanna trough play charging system (described in play 1). A prospect within play 8 was incidentally tested by Klondike well while drilling to a deeper objective (in play 5) and encountered pooled oil in a Kuparuk-equivalent sandstone 80 feet thick. Diamond well encountered no sandstones (only the Pebble Shale was present) and was barren of hydrocarbons. Play 8 extends into large parts of Beaufort shelf assessment province and was assessed there as Beaufort shelf play UABS2200.

Play 9 (UACS0900). Rift Sequence—Overmature "Deep Gas": This play includes prospects that lie at subsurface depths beneath the oil preservation floor (2.0% vitrinite reflectance) and would contain only gas. Reservoir objectives would be primarily thin, basin-floor turbidite sandstones deposited in deep water areas south of the shelf and slope of play 8. However, in western Arctic Alaska, shelf deposits in the play sequence (e.g., at Tunalik well) enter the gas window as well. The anticipated hydrocarbon mix is 100% gas, probably derived from underlying, oil-expended Shublik source beds in gas-generating areas of the Hanna trough play charging system (described in play 1), or interbedded marine shales (Kingak Formation, Pebble Shale). High levels of thermal maturity are expected to have an adverse effect on reservoir properties, which primarily accounts for the small endowment of this play. Play 9 was penetrated at Tunalik well, which encountered pooled gas in a Kuparuk-equivalent sandstone within the play sequence.

Play 10 (UACS1000). Lower Brookian Sequence—Herald Arch and Thrust Zone: This play involves highly-deformed Cretaceous and older rocks that comprise acoustic basement beneath Herald arch and Herald thrust zone. Although fragments of axial areas of synclines are visible in some seismic profiles in Herald thrust zone, no traps can be reliably mapped. However, we speculate that viable anticlinal traps are present, but generally with steep flanks and small in size consistent with the small fold wavelengths suggested by seismically-visible synclines. High levels of thermal maturity suggest that any pooled hydrocarbons will be only gas (1.76 percent vitrinite reflectance in Jurassic argillite cored at the seafloor south of Herald fault; Fugro-McClelland, 1985, USGS-7). This play was tested at Eagle Creek and Akulik wells onshore, both of which recovered gas in drill stem tests from Nanushuk or Torok Formation sandstones.

Play 11 (UACS1100). Lower Brookian Sequence—Foreland Basin Foldbelt: Reservoir objectives are primarily deltaic sandstones of the Nanushuk Group deposited in Colville basin in Early Cretaceous time and subsequently deformed by north-verging Brooks Range deformation in earliest Paleocene time. Structural deformation increases toward the south, and broad unfaulted anticlines in the northern part of the play area grade into steep-limbed, thrust-faulted, and breached anticlines to the south. Potential reservoir sandstones in the folded sequence are

charged by the Colville basin play charging system in which traps receive hydrocarbons generated from underlying, thermally mature, gas-prone shales of the Torok and Pebble Shale Formations. Play 11 was not tested offshore. Onshore exploratory drilling of about 30 anticlinal prospects over about 50 years discovered 6 sites of pooled gas (Tungak Creek(?), Wolf Creek, Gubik, Meade, Square Lake, and East Umiat) and one oil field (Umiat) with estimated reserves of 70 million barrels (Thomas and others, 1991, table 2-5).

Play 12 (UACS1200). Lower Brookian Sequence—Torok Turbidites-Chukchi Platform

Wrench Zone: Potential reservoirs are primarily turbidite sandstones within Lower Cretaceous Torok Formation shales deposited in a prodelta system on the shelf terrace between Colville and North Chukchi basins and on Chukchi platform. Prospects are fault traps and faulted anticlines along transtensional faults that were active in early Tertiary time. The transtensional faults lie in several discrete north-trending, densely-faulted zones. Several evaporite diapirs pierce this play in a narrow graben just west of Popcorn well. Play 12 therefore includes traps involving truncation of Torok Formation turbidites against diapir flanks. This play is charged by the Hanna trough play charging system (described in play 1), with some hydrocarbons possibly re-migrating into Brookian sandstones from deeper Ellesmerian stratigraphic traps disrupted by Paleocene faults. The play was penetrated at three wells, with pooled, recoverable oil apparently present (log interpretation) at Crackerjack and Klondike wells. No hydrocarbons were present in the play sequence at Popcorn well. A sequence of turbiditic sandstones over 400 ft thick was encountered at the base of the Torok Formation in Crackerjack well.

Play 13 (UACS1300). Lower Brookian Sequence—Nanushuk Topset-Chukchi Platform

Wrench Zone: Potential reservoirs are primarily sandstones of the Albian-Cenomanian Nanushuk Group that were deposited in delta-plain and nearshore environments on the shelf terrace between Colville and North Chukchi basins and on Chukchi platform. Prospects are fault traps, faulted anticlines, and diapir-flank traps, as in underlying play 12. This play, like play 12, is charged by the Hanna trough play charging system (described in play 1), with some hydrocarbons possibly re-migrated out of deeper Ellesmerian stratigraphic traps disrupted by faults. The play was penetrated by three wells (Popcorn, Crackerjack, Klondike), which encountered only very sparse sandstones and no pooled hydrocarbons.

Play 14 (UACS1400). Sand Apron-North Chukchi High (Upper and Lower Brookian sequences):

Potential reservoirs are inferred to consist primarily of shallow marine to fluvial sandstones of Early Cretaceous to Tertiary age that are hypothesized to have been deposited in littoral systems that fringed North Chukchi high, an area of recurrent uplift throughout Albian-Aptian (post-Brookian unconformity) and later time (Johnson, 1992). Play 14 therefore includes both Lower and Upper Brookian sequences. The play is probably charged primarily from the west by the North Chukchi basin play charging system (Lower Cretaceous to Tertiary Brookian shales generating gas and oil that rose along faults into shallow traps in North Chukchi basin and perhaps conducted up carrier beds to nearby structural uplifts like North Chukchi high). Play 14 extends into the Beaufort shelf assessment province and was assessed there as Beaufort shelf play UABS2300.

Play 15 (UACS1500). Lower Brookian Sequence—Cretaceous Topset-North Chukchi

Basin: Potential reservoirs are hypothesized to be deltaic sandstones of Cretaceous (possibly Late Cretaceous?) age that concluded an early cycle (Beaufort margin rifting) of filling of North Chukchi basin. We speculate that these deposits represent the filling of the basin to baseline prior to renewed subsidence in Paleocene time. Traps are primarily north-trending horsts formed during early Tertiary time. The play is presumed to be charged by the North Chukchi basin play charging system (described in play 14). Neither the play nor any rocks correlative to the proposed Upper Cretaceous(?) reservoir sequence were tested by any well on Chukchi shelf.

Play 16 (UACS1600). Brookian Sequence (Upper and Lower Brookian)—Overmature

"Deep Gas": Potential reservoir objectives include mostly Early Cretaceous and Tertiary sandstones in both Colville and North Chukchi basins that lie at depths below the oil floor at 2.0% vitrinite reflectance. Play 16 therefore includes mostly rocks of the Lower Brookian sequence, but also Upper Brookian rocks in a small, deep graben in North Chukchi basin. All pools within this play are modeled as consisting completely of gas. In Colville basin, the traps are primarily located in the undeformed plate below the regional decollement at the base of the foldbelt play (11). The subthrust plate probably consists of Torok Formation shales and turbiditic sandstones. This play was not tested by any well.

Play 17 (UACS1700). Lower Brookian Sequence—Torok Turbidites-Arctic Platform

(Unstructured): This play addresses the unstructured area of the Arctic platform that lies south of Barrow arch, east of the wrench fault province of western Chukchi shelf (equivalent play 12), and north of the foldbelt (play 11). Play 17 overlaps western parts of the Beaufort shelf assessment province and was assessed there as Beaufort shelf play UABS2400. Potential reservoirs are turbidite sandstones within the Lower Cretaceous Torok Formation. Exploratory drilling has shown that sandstone is quite sparse within the Torok Formation in this play. Reservoir presence is therefore one important risk element for the play. Low-relief anticlines, possibly related to compaction, mounded fan complexes, and slope turbidites isolated within slope shales form the primary anticipated trap types, few of which are readily observable in seismic data. The play is modeled as predominately charged by the Hanna trough play charging system (described in play 1), although some contribution from the gas-rich Colville basin play charging system (described in play 11) is also possible. The play was tested by Burger and Diamond wells and several wells onshore. No pooled hydrocarbons were encountered in any well.

Play 18 (UACS1800). Lower Brookian Sequence—Nanushuk Topset-Arctic Platform

(Unstructured): Like play 17, play 18 addresses the unstructured area of the Arctic platform that lies south of Barrow arch, east of the wrench fault province of western Chukchi shelf (equivalent play 13), and north of the foldbelt (play 11). Play 18 overlaps western parts of the Beaufort shelf assessment province and was assessed there as Beaufort shelf play UABS2500. Reservoir objectives include delta-plain and nearshore sandstones of the Lower Cretaceous Nanushuk Group. Low-relief anticlines possibly related to differential compaction and stratigraphic terminations of homoclinally-dipping sandstones form the primary trap types. Like play 17, the play is modeled as predominately charged by the Hanna trough play charging system,

OIL AND GAS ENDOWMENTS OF CHUKCHI SHELF PLAYS

Risked, Undiscovered, Conventionally Recoverable Oil and Gas

PLAY NO.	PLAY NAME (UAI * CODE)	OIL (BBO)			GAS (TCFG)		
		F95	MEAN	F05	F95	MEAN	F05
1.	Endicott-Chukchi Platform (UACS0100)	0.000	3.001	6.696	0.000	9.762	19.377
2.	Endicott-Arctic Platform (UACS0200)	0.000	0.002	0.006	0.000	0.035	0.133
3.	Lisburne Carbonates (UACS0300)	0.000	0.041	0.149	0.000	0.137	0.509
4.	Ellesmerian Deep Gas (UACS0400)	0.000	0.016	0.049	0.000	0.629	1.962
5.	Sadlerochit-Chukchi Platform (UACS0500)	0.257	0.537	1.098	1.478	2.993	5.823
6.	Sadlerochit-Arctic Platform (UACS0600)	0.000	0.660	1.818	0.000	1.935	5.314
7.	Rift - Active Margin (UACS0700)	2.385	4.136	7.770	5.314	8.547	14.204
8.	Rift - Stable Shelf (UACS0800)	0.910	1.645	3.121	3.118	5.026	8.193
9.	Rift - Deep Gas (UACS0900)	0.0003	0.003	0.007	0.012	0.108	0.269
10.	Herald Arch (UACS1000)	0.000	0.00002	0.00008	0.000	0.0006	0.003
11.	L. Brook. Foldbelt (UACS1100)	0.149	0.265	0.430	2.328	4.491	8.225
12.	L. Brook. Turbidites/Wrench Zn (UACS1200)	0.054	0.147	0.331	0.240	0.635	1.384
13.	L. Brook. Topset/Wrench Zn (UACS1300)	0.000	0.110	0.371	0.000	0.326	1.376
14.	N. Chukchi High/Sand Apron (UACS1400)	0.000	1.182	3.497	0.000	13.082	36.046
15.	L. Brook. Topset/N. Chukchi Basin (UACS1500)	0.000	0.099	0.283	0.000	1.491	4.564
16.	Brookian Deep Gas (UACS1600)	0.000	0.006	0.028	0.000	0.237	1.076
17.	L. Brookian/Turbidites/Arct. Plat. (UACS1700)	0.000	0.003	0.021	0.000	0.008	0.053
18.	L. Brookian/Topset/Arctic Platform (UACS1800)	0.000	0.045	0.173	0.000	0.034	0.121
19.	U. Brookian/Sag Phase/N. Chuk. Bsn. (UACS1900)	0.000	0.002	0.012	0.000	0.038	0.171
20.	U. Brookian/Turbidites/N.Chuk.Bsn. (UACS2000)	0.000	0.027	0.068	0.000	0.484	1.306
21.	U. Brookian/Paleovalleys (UACS2100)	0.000	0.886	2.283	0.000	1.637	3.961
22.	U. Brookian/Intervalley Highs (UACS2200)	0.000	0.204	0.697	0.000	0.203	0.740
	FASPAG AGGREGATION	6.801	13.015	21.943	9.808	51.840	141.754

* *Unique Assessment Identifier, code unique to play.*

although some contribution from the gas-rich Colville basin system is possible. The play was tested at Diamond and Burger wells. A gas-charged sandstone 36 feet thick was encountered at Burger well, which is located within several miles of the easternmost fault of a fault system that passes downward into the Burger gas pool. This fault may have formed a migration conduit for gas escaping upward from Kuparuk sandstones within the underlying Burger gas pool.

Play 19 (UACS1900). Upper Brookian Sequence—Upper Tertiary Sag Phase-North

Chukchi Basin: Potential reservoirs include Eocene(?) and younger marine sandstones deposited in North Chukchi basin during the post-rift thermal or "sag" phase of basin subsidence. Some sandstones in this sequence may be associated with an Eocene regression marked by an unconformity at Popcorn well (Micropaleo Consultants, 1989) and widely observed and mapped in seismic data in North Chukchi basin (Lothamer, 1994). Prospects include fault traps, faulted anticlines, and diapir-flank traps, the latter in a graben west of Popcorn well. This play is charged by the North Chukchi basin play charging system (described in play 14). Play 19 was tested in a proximal setting by Popcorn well, which encountered only very sparse sandstone in the play sequence. Reservoir presence is therefore considered a major risk element for this play.

Play 20 (UACS2000). Upper Brookian Sequence—Lower Tertiary Turbidites-North

Chukchi Basin: Potential reservoirs are mostly turbidite sandstones hypothesized to have been deposited within north-trending, faulted-bounded seafloor grabens formed during Paleocene transtensional rifting in North Chukchi basin. Play 20 is charged by the North Chukchi basin play charging system (described in play 14). This play was not tested by any well.

Play 21 (UACS2100). Upper Brookian Sequence—Lower Tertiary Paleovalley Fill:

Potential reservoirs include fluvial sandstone reservoirs deposited in fault-bounded paleovalleys that emptied northward from Chukchi platform into North Chukchi basin in early Tertiary time. The fluvial sandstones lie at the base of a transgressive Paleocene-Eocene sequence that records progressive drowning of the valleys. Traps are primarily stratigraphic pinch-outs or fault truncations of the fluvial sandstones along the north-trending valley margins, as well as diapir-flank traps in a narrow graben west of Popcorn well. The play is modeled as predominantly charged by the Hanna trough play charging system (described in play 1), although some parts of the play extend north into North Chukchi basin and may be charged by that petroleum generation system (described in play 14). This play was tested at Popcorn, Crackerjack, and Klondike wells. All wells encountered highly porous sandstones, with the maximum observed thickness reaching 540 feet at Popcorn well. No pooled oil or gas were encountered in any Upper Brookian sandstones.

Play 22 (UACS2200). Upper Brookian Sequence—Tertiary Basal Transgressive Sand-

Intervalley Uplifts: Potential reservoirs include transgressive-lag sandstone reservoirs deposited on wrench-fault-bounded structural ridges in Paleocene time. Because of the transgressive nature of the sandstones and the low inclination of flooding surfaces at the crests of intervalley uplifts, reservoirs are modeled as thin relative to play 21 (see discussion by Abbott, 1985, p. 158). The play is modeled as predominantly charged by the Hanna trough play charging

system. This play was not tested by any well.

REFERENCES CITED

- Abbott, W.O., 1985, The recognition and mapping of a basal transgressive sand from outcrop, subsurface, and seismic data: *in*: "Seismic Stratigraphy II, An Integrated Approach to Hydrocarbon Exploration", Berg, O.R., and Woolverton, D.G. (eds.), American Association of Petroleum Geologists Memoir 39, p. 156-167.
- AOGCC (Alaska Oil and Gas Conservation Commission), 1993, Statistical Report: State of Alaska, published by Alaska Oil and Gas Conservation Commission, 3001 Porcupine Dr., Anchorage, AK 99501, 221 p.
- Fugro-McClelland, 1985, *Proprietary Geological Data Collected Under U.S. Minerals Management Service OCS Permits 85-40 and 85-41*. Selected Data Released to MMS for Publication in Memorandum Dated December 03, 1993.
- Johnson, P.P., 1992, The North Chukchi high - compressional structures in a rift setting (abs): Abstracts with Program, 1992 International Conference on Arctic Margins, September 2-4, 1992, Anchorage, Alaska, p. 28.
- Lothamer, R.T., 1994, "Early Tertiary Wrench Faulting in the North Chukchi Basin, Chukchi Sea, Alaska," *U.S. Minerals Management Service OCS Study*, MMS 94-0040, pp 251-256.
- Micropaleo Consultants, 1989, Biostratigraphy Report, Shell et al. OCS-Y-1275 No. 1 (Popcorn), OCS Block #NR3-1-150, Chukchi Sea, Alaska: Technical Report M.C.I. Job No. 89-118 prepared for Shell Oil and partners in Popcorn Well.
- Thomas, C.P., Doughty, T.C., Faulder, D.D., Harrison, W.E., Irving, J.S., Jamison, H.C., and White, G.J. (1991). "Alaskan Oil and Gas - Energy Wealth or Vanishing Opportunity?," *U.S. Department of Energy Report DOE/ID/01570-H1*, prepared by EG&G Idaho, Inc., Idaho National Engineering Laboratory, Idaho Falls, Idaho 83415, 267 pp.