

Oil and Gas Resources, Kopanoar Play, Beaufort Sea*

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Abstract

The Beaufort Sea has a large resource of discovered oil and gas and a very significant potential for future undiscovered oil and gas. The Kopanoar play is one of the more important plays in the Beaufort Sea, with discovered resources of 234 MMB of recoverable oil and 822 BCF of recoverable gas. The mean undiscovered potential is estimated to be 1,866 MMB of recoverable oil and 7,044 BCF of recoverable gas.

The southern margin of the Kopanoar play is the shelf-to-slope transition of Oligocene strata. The play extends northward beneath the outer portions of the modern shelf. The northern limit is arbitrary and is drawn at the present day shelf edge. The play area is entirely offshore in water depths between 60 and 100 metres.

The Kopanoar play area includes two plays, the Kugmallit play and the Mackenzie Bay play. The Kugmallit is the primary play and includes all pools and prospects within deep water sandstones deposited on the continental slope and basin plain. The principal reservoirs of the Kugmallit play are in Upper Kugmallit slope sandstones and Kugmallit basin floor submarine fan deposits. The Kugmallit play includes sandstones of the deeper Richards sequence. The Mackenzie Bay play is characterized by slope to basinal facies, mainly shale with some sandstone.

Potential reservoir sections in the Kugmallit comprise packages of thinly bedded sandstone up to several hundred feet in overall thickness. Pools of the Upper Kugmallit sequence have reservoir sandstones between 20 and 98 feet thick, with an average porosity of 19 percent. For the Mackenzie Bay sequence pools have net pays of 8 to 49 feet, with average porosity of 22 percent. The larger fields

contain numerous stacked pools. Thick interbedded shales and the overlying Mackenzie Bay shale succession provide a good seal. In general, Kugmallit reservoirs are overpressured.

The majority of traps in the play are structural. The Kopanoar play area is characterized by easterly trending folds of the Beaufort Fold Belt. The Beaufort Fold Belt involves Upper Cretaceous to Miocene strata. Principal trap type is structural drape over the pre-Richards fold belt of late middle Miocene age. Stratigraphic plays off the flanks of these folds could also be important.

Exploration began with the spudding of Dome et al. Nektoralik K-59 and Hunt Dome Kopanoar M-13 in the summer of 1976. During the years 1976 to 1984 a total of 15 wells were drilled in the play, with seven successful wells, resulting in the issue of 6 Significant Discovery Licences, for a success rate of 47%. Four other wells had shows of oil/and or gas on drill stem test and only four wells had no occurrence of oil or gas. The last well drilled was Dome Nerlerk J-67, drilled and abandoned in 1984.

The largest field of the Kopanoar play area on an oil equivalent basis is Koakoak, followed by Kopanoar. The total discovered recoverable resource is 234.1 MMB of oil and 822.5 BCF of gas, for a total oil equivalent of 376.6 million barrels.

The ultimate recoverable oil resource is estimated to be 2,100 million barrels, of which 1,866 million barrels (87%) remain to be discovered. The ultimate recoverable gas resource is estimated to be 7,867 billion cubic feet, of which 7,044 billion cubic feet (89.5%) remain to be discovered.

Selected References

Dixon, J., 1995, (ed.) Geological Atlas of the Beaufort-Mackenzie area: Geological Survey of Canada, Miscellaneous Report 59, Ottawa, Canada, 173 p.

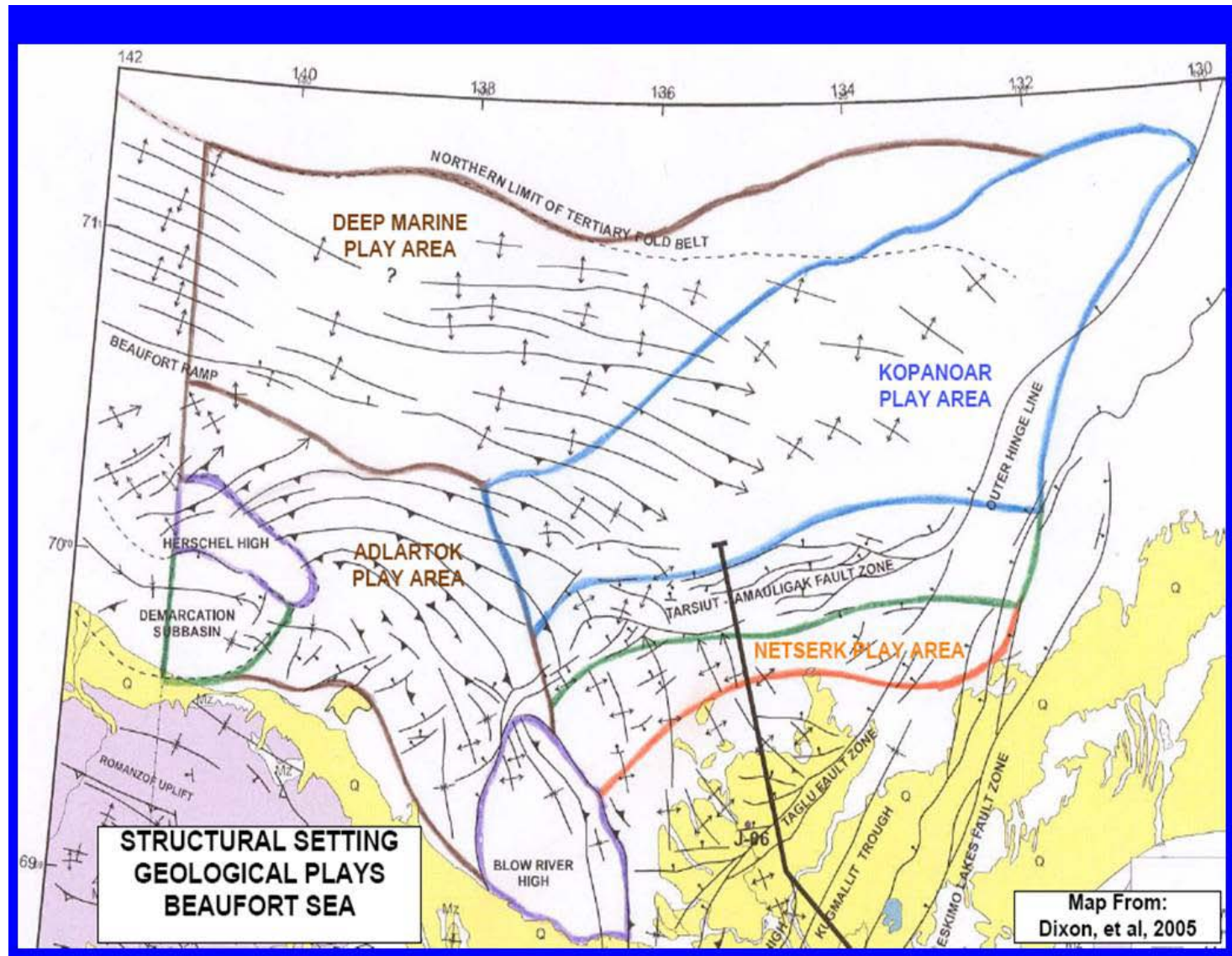
Morrell, G.R., 1996, Tuk discoveries, *in* J. Dixon (ed.), Geological Atlas of the Beaufort-Mackenzie Area: Geological Survey of Canada, Miscellaneous Report 59, p. 155-156.

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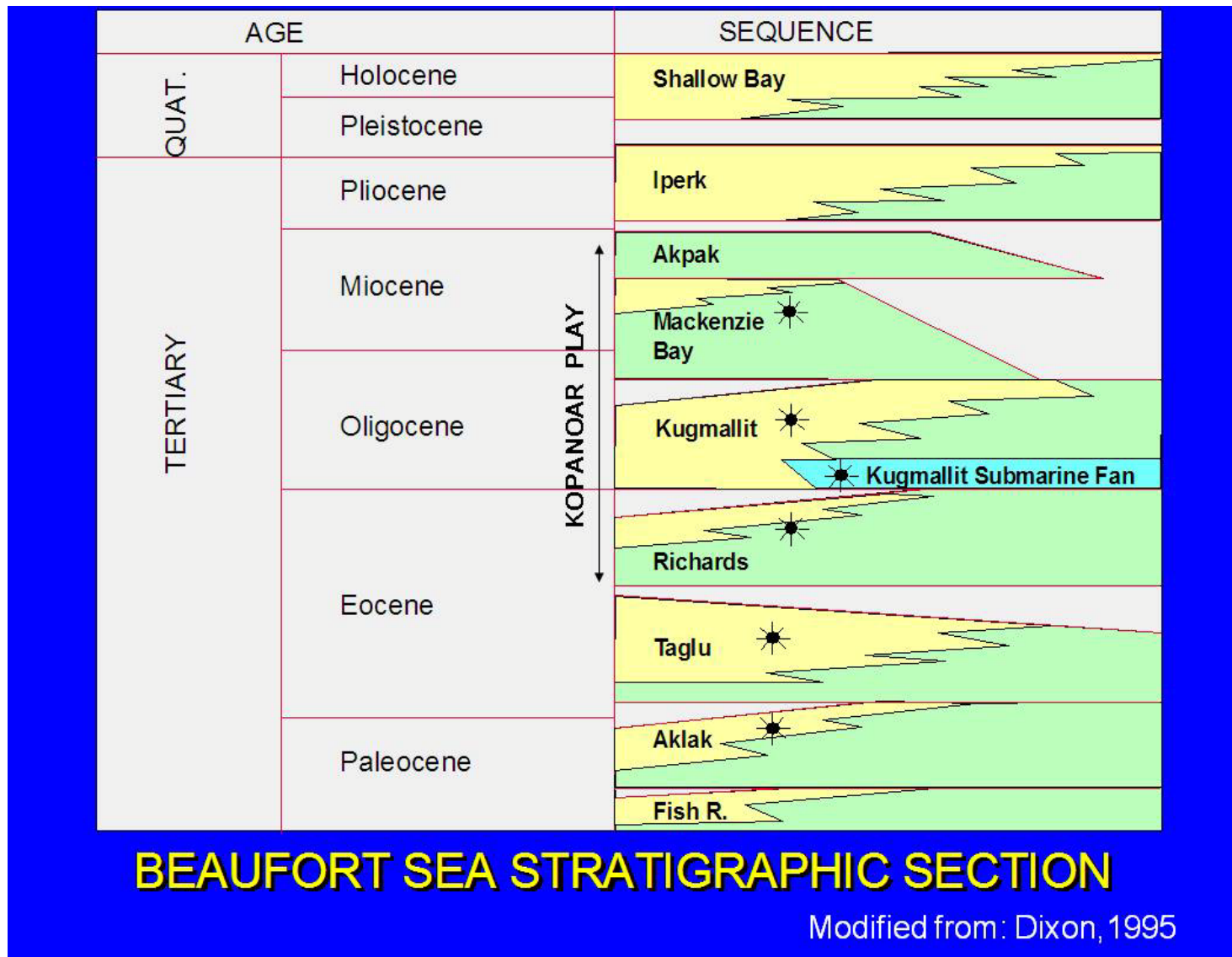
Oil and Gas Resources
Kopanoar Play
Beaufort Sea

Kenneth J. Drummond



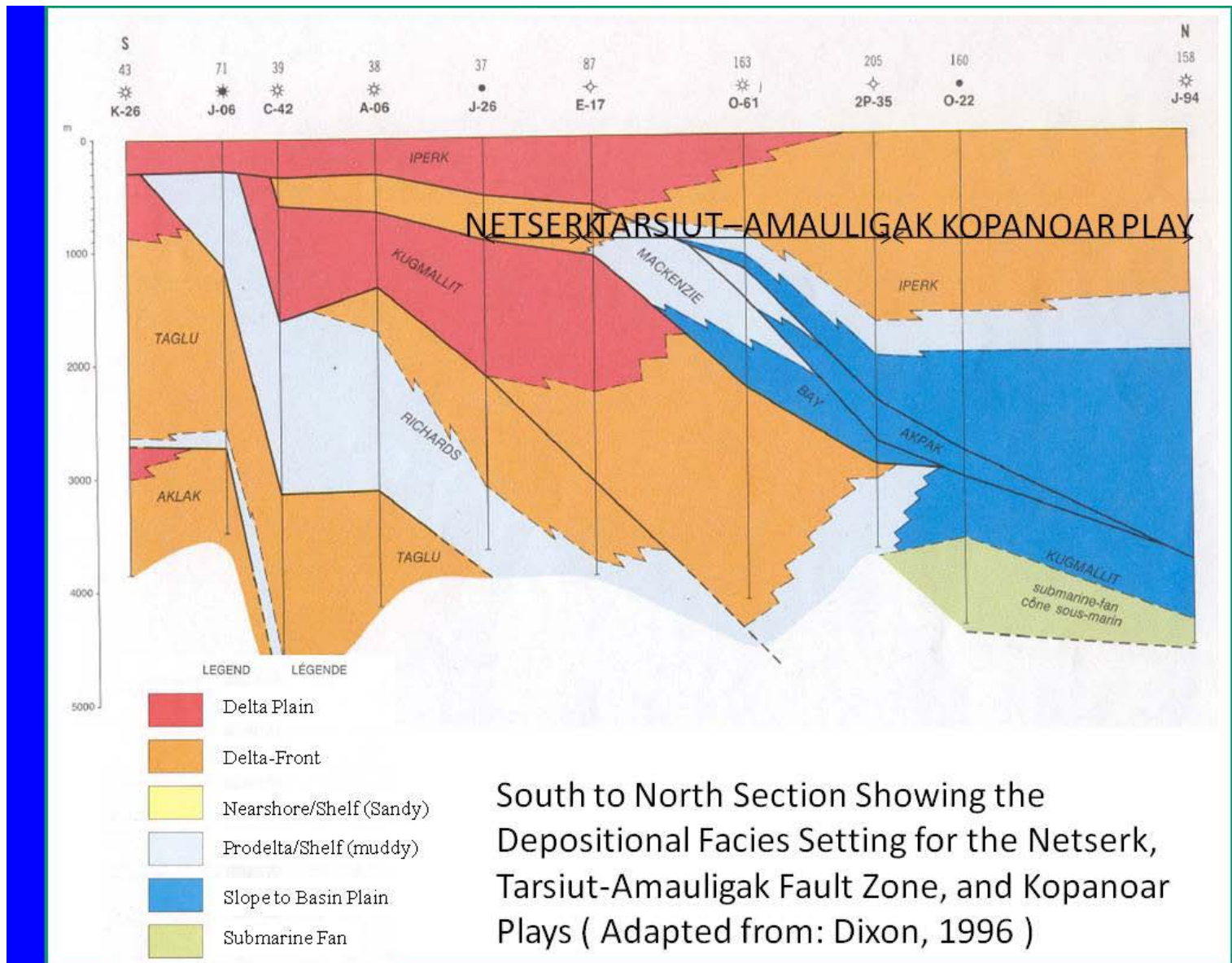


Presenter's notes: The slide shows the structural setting for the geological plays of the Beaufort Sea, and in particular the Kopanoar play. The geological plays for the Beaufort Sea include the Netserk, Tarsiut-Amauligak Fault Zone, Kopanoar, Deep Marine West, Adlartok, Herschel and Demarcation geological plays. Shown on the map is the long easterly trending folds characterizing the Kopanoar play. The Kopanoar play area is bound to the south by the Tarsiut-Amauligak Fault Zone, to the west by the Adlartok play and to the north by the Deep Water Marine play area. The Tarsiut-Amauligak Fault Zone is a structurally defined east-west trending listric fault zone involving Kugmallit delta-front sandstones. The delta front sandstones pass northward into the Kugmallit slope and basin floor submarine fan deposits of the Kopanoar play. The Kugmallit submarine fan, also called Kopanoar subsequence, is a base of slope fan complex. The Upper Kugmallit is a slope, basinal facies

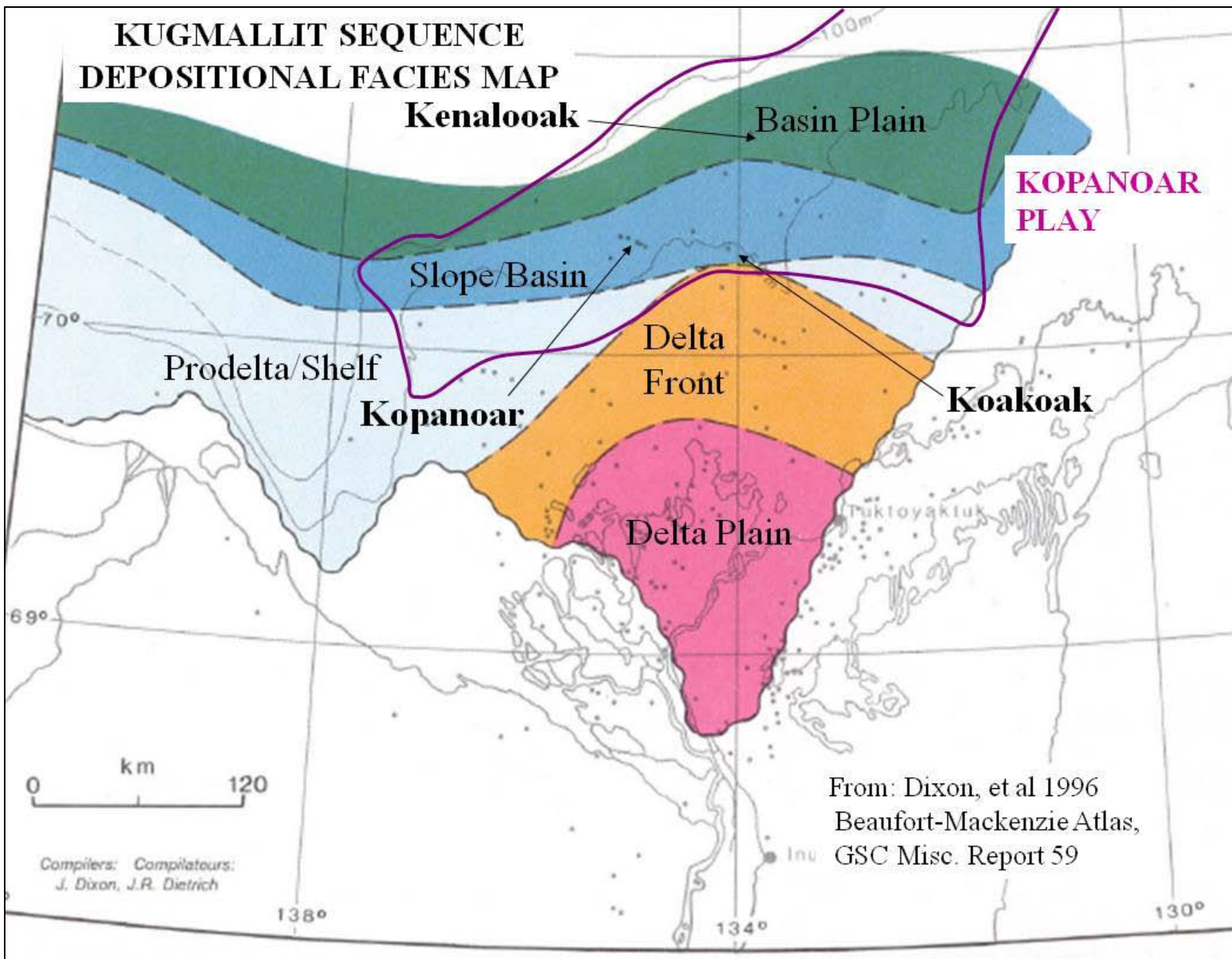


Presenter's notes: The stratigraphic section in the Beaufort Sea is comprised of a number of prograding deltaic sequences from the Paleocene to the Holocene, with a thickness of 12 to 14 kilometres. Hydrocarbons have been recovered from the Aklak, Taglu, Richards, Kugmallit, and Mackenzie Bay. The Fish River, Akpak and Iperk could also be prospective targets.

The primary reservoirs in the Beaufort Sea are the deltaic and submarine fan clastics of the Kugmallit sequence. The main reservoir targets for the Kopanoar play is the Kugmallit, the Upper Kugmallit and the Kugmallit submarine Fan. The play area also covers additional reservoirs in the deeper Richards Sequence and the overlying Mackenzie Bay and Akpak sequences.



Presenter's notes: Slide shows the depositional setting for the prograding deltaic sequences. The Netserk play is primarily in the delta plain. The Tarsiut-Amauligak Fault Zone is a structurally defined east-west trending listric fault zone involving Kugmallit delta-front sandstones. The delta front sandstones pass northward into the Kugmallit slope and basin floor submarine fan deposits of the Kopanoar play. The Kugmallit submarine fan, also called Kopanoar subsequence, is a base of slope fan complex. The Upper Kugmallit is a slope, basinal facies. The Kopanoar Play is in the slope to basin floor facies with submarine turbidite fan deposits. The section shows the seaward depositional thinning of the Mackenzie Bay and Akpak sequences.



Presenter's notes: The map from Dixon, et al shows the prograding delta of the Kugmallit Sequence, and illustrates the facies distribution for the various sequences present in the Kopanoar play area. In general the various sequences in the Kopanoar play area are represented by shelf to basinal facies. The Koakoak and Kopanoar discoveries are shown on the depositional slope of the Kugmallit Delta. Kenalooak is a gas discovery in the Kugmallit submarine fan in the basin plain.

Kopanoar Play

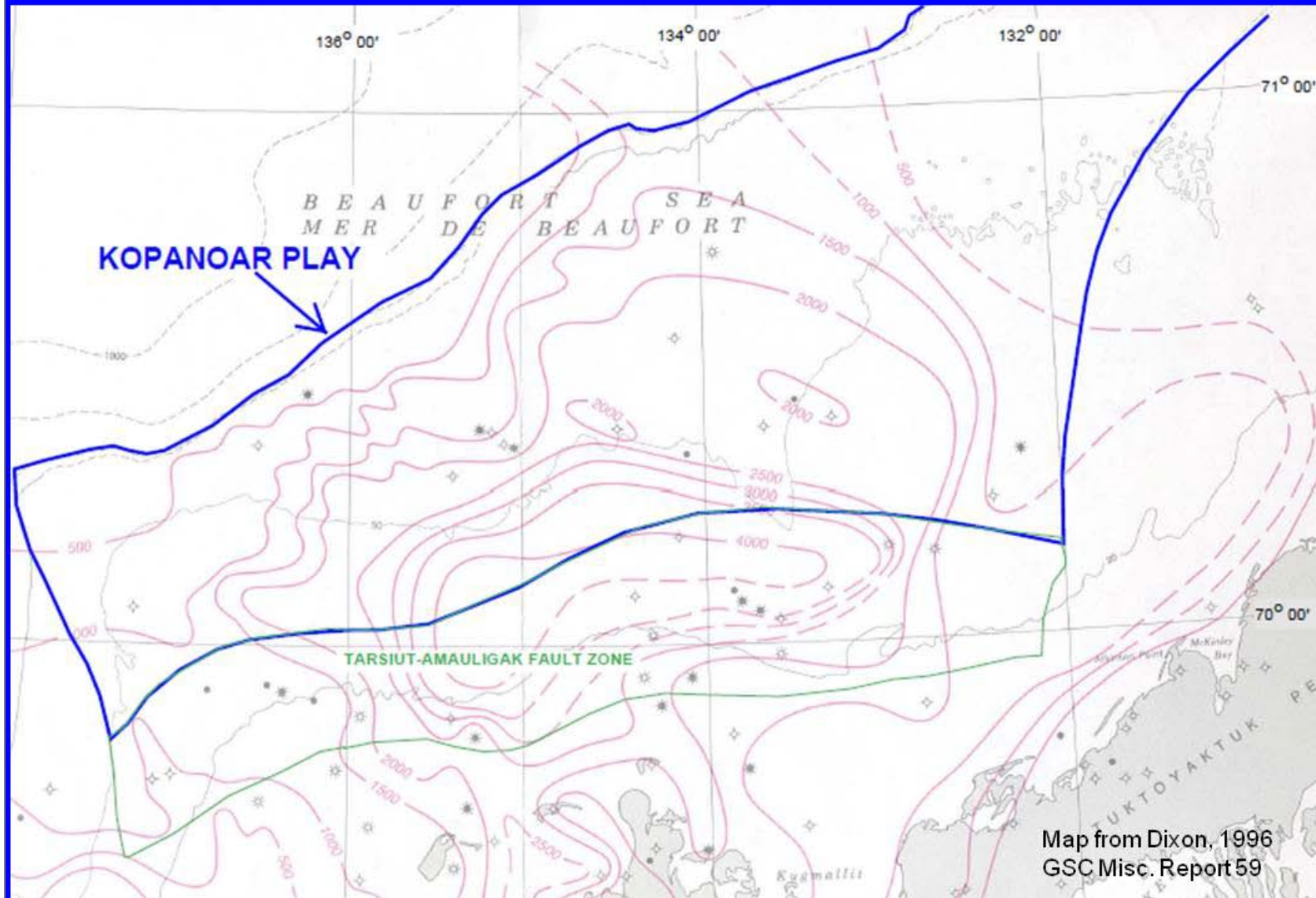
Reservoirs in Kugmallit Distal Delta Front sandstones and Kugmallit Deep Sea Fan Deposits.

Also may include clastics of the Mackenzie Bay and Richards sequences.

East-West Trending Folds of the Beaufort Fold Belt

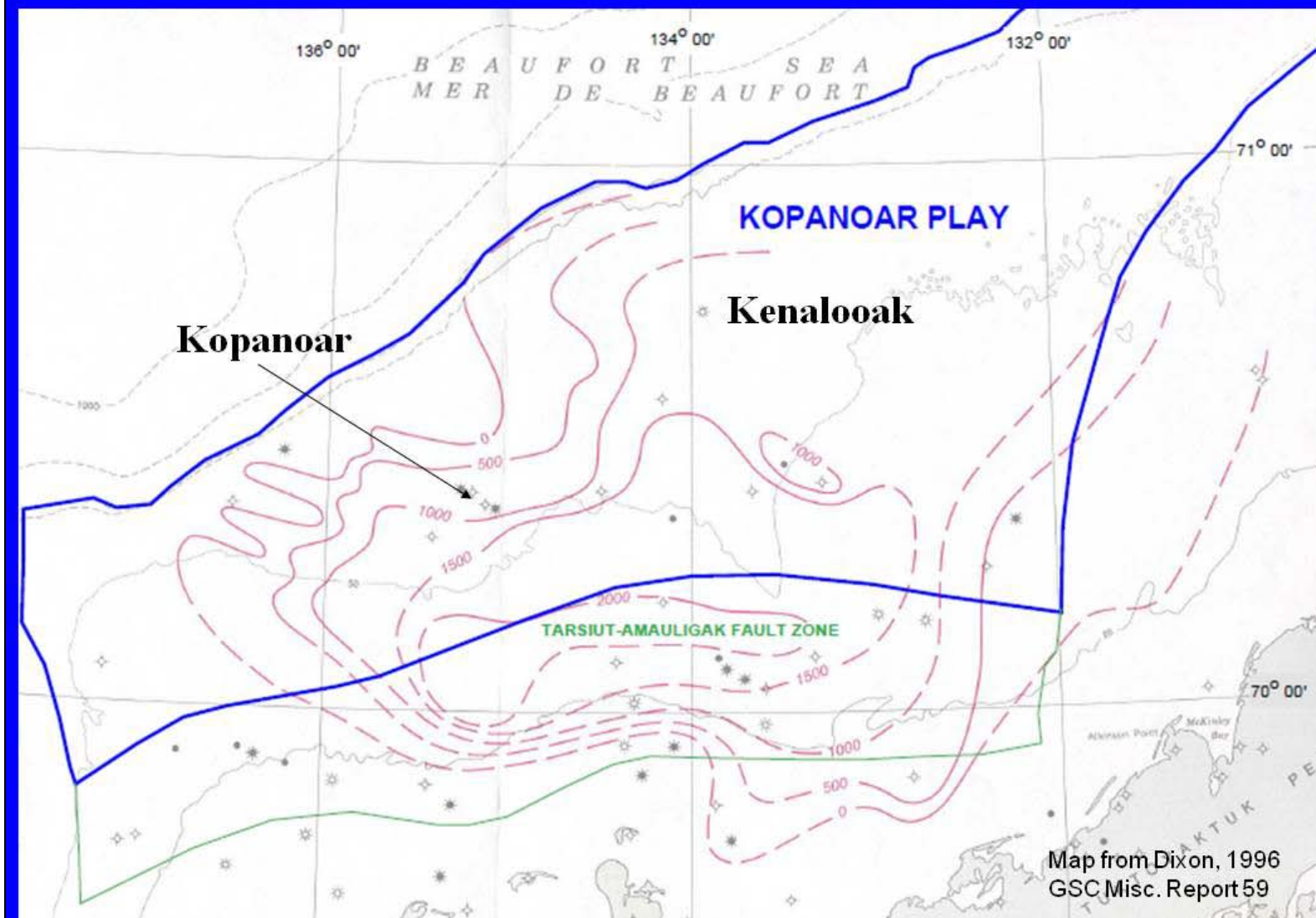
Presenter's notes: The primary reservoirs for the Kopanoar play are the Kugmallit Sequence distal delta front and slope sandstones, and deep sea fan deposits. Reservoirs also include clastics of the Mackenzie Bay and Richards sequences. Traps are formed by structural drape over the long easterly trending folds of the Beaufort Fold Belt.

KUGMALLIT SEQUENCE ISOPACH MAP



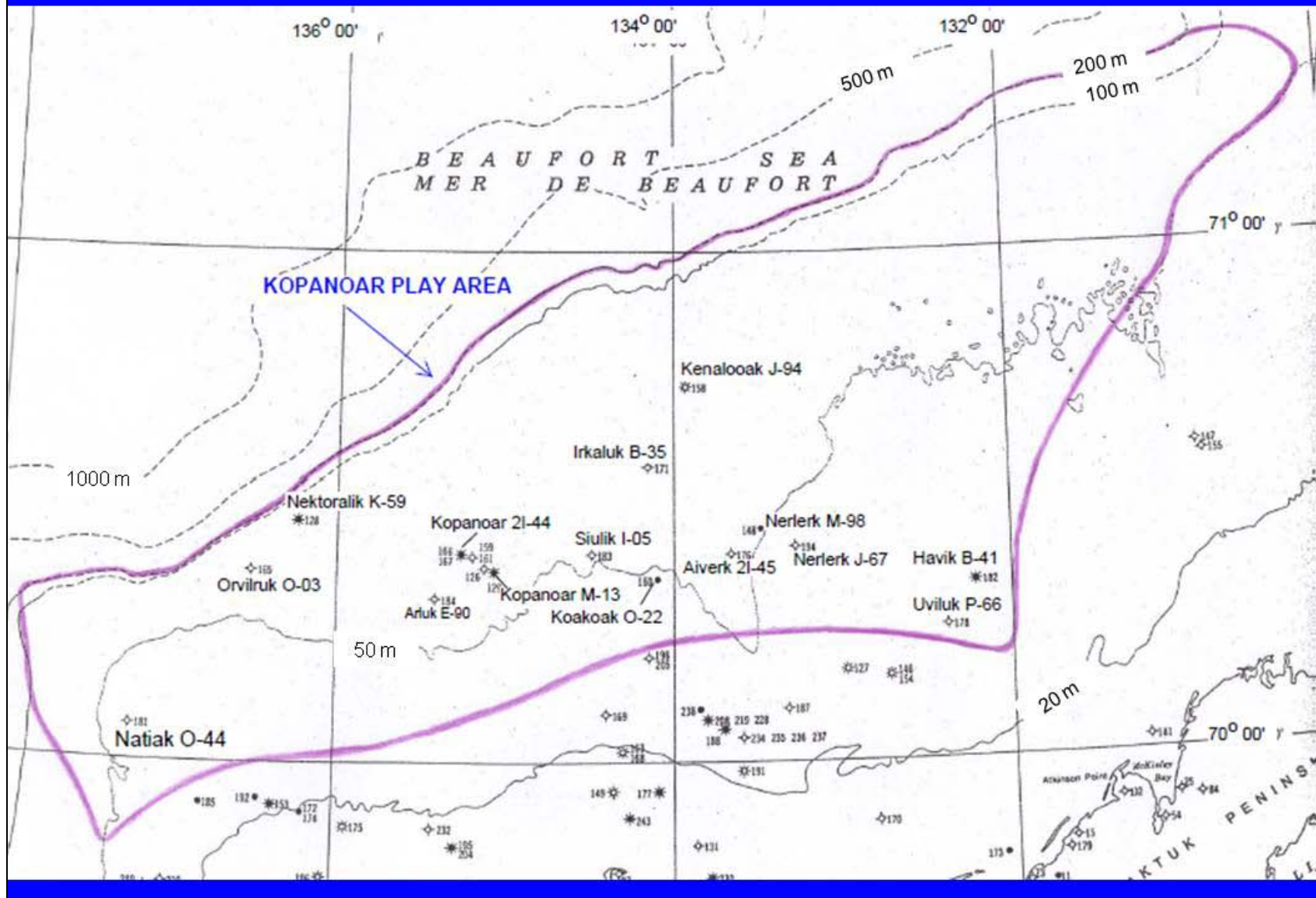
Presenter's notes: The Kugmallit sequence is thickest along the southern margin in the northern part of the Tarsiut-Amailigak Fault Zone where it is about 4000 metres thick. The sequence thins both to the west and east to the edges of the delta. To the north the sequence thins to about 500 metres.

KUGMALLIT SUBMARINE FAN ISOPACH MAP



Presenter's notes: The Kugmallit submarine Fan sequence is thickest along the southern margin where it is 2 kilometres thick in the northern part of the Tarsiut-Amailigak Fault Zone. The fan sequence thins both to the west and east to the edges of the delta, and the depositional edge occurs along the northern margin of the play. Kopanoar is an oil discovery in the submarine fan and Kenalooak is a gas discovery. Shows of oil and gas were encountered in 3 other wells; Arluk E-60, Nerlerk M-98, and Siulik I-05.

KOPANOAR PLAY AREA and WELLS DRILLED



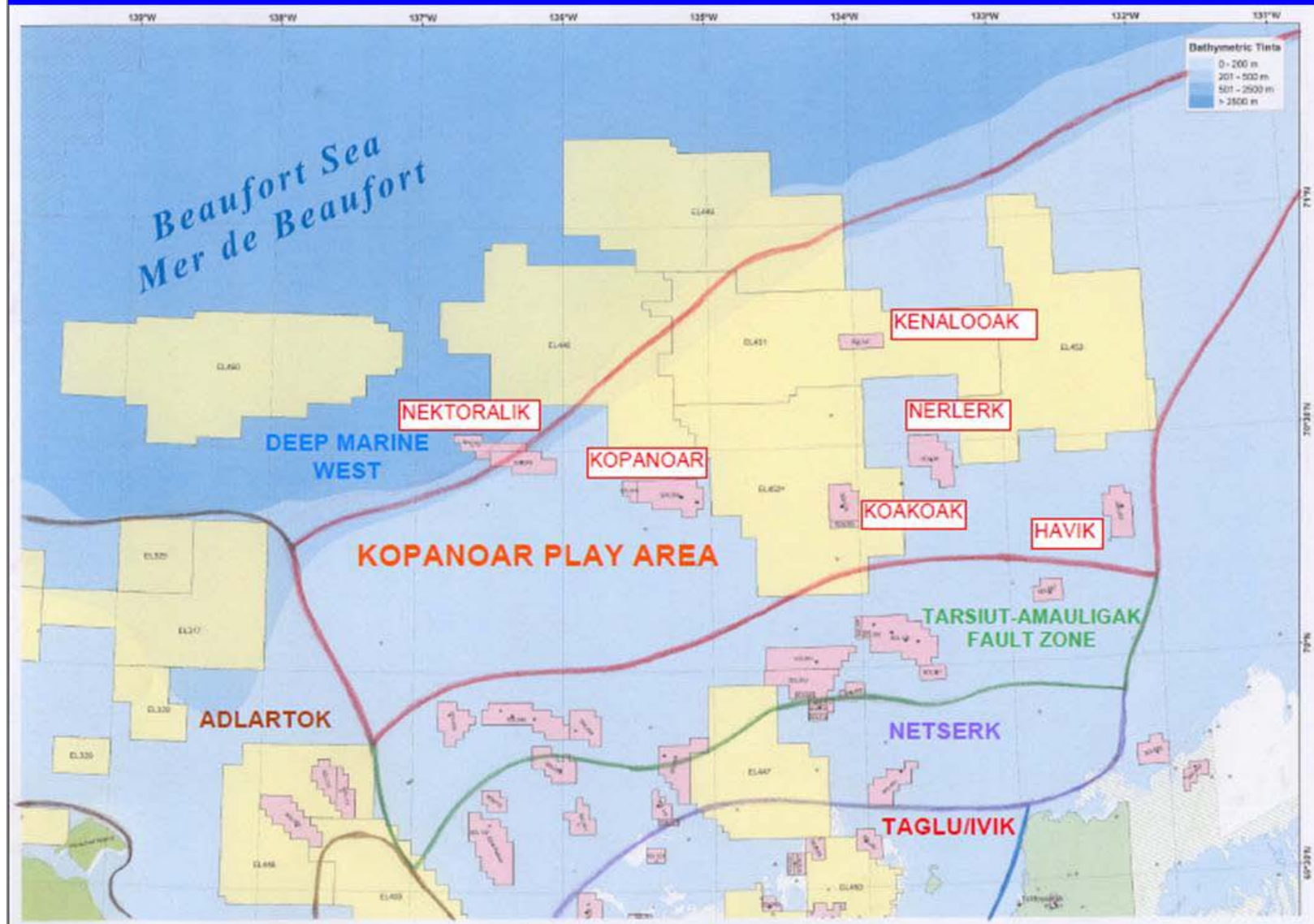
Presenter's notes: The map shows the Kopanoar play area and the 15 wells drilled in the area. All wells, except Nektoralik drilled into the upper Kugmallit, and all wells east of 136 degrees encountered the Kugmallit submarine fan facies.

KOPANOAR PLAY, BEAUFORT SEA - LIST OF WELLS

WELL NAME	YEAR	Water Depth metres	Total Depth metres	Drill Stem Test Gas_mcfpd	Drill Stem Test Oil_bpd
DOME ET AL NATIAK O-44	1983		4,652		
DOME TEXACO ET AL UVILUK P-66	1983	29.7	4,758		338
DOME ET AL ARLUK E-90	1983	58.0	4,300	159	
DOME ET AL HAVIK B-41	1983	30.0	4,753	788	635
DOME HUNT GULF KOAKOAK O-22	1979	47.2	4,365	19308	2580
DOME ET AL ORVILRUK O-03	1980	59.9	4,572	15	
HUNT DOME KOPANOAR M-13	1976	57.3	4,282		
DOME GULF HUNT KOPANOAR 2/I-44	1980	58.7	4,010	4792	1126
DOME ET AL SIULIK I-05	1983	52.0	4,824	355	64
DOME AIVERK 2 I-45	1982	60.6	5,034	TSTM	
DOME NERLERK J-67	1984	45.0	4,904		
DOME NERLERK M-98	1977	52.0	4,940		403
DOME ET AL NEKTORALIK K-59	1976	64.0	2,790	5500	1150
DOME HUNT IRKALUK B-35	1981	56.4	2,211	TSTM	
DOME HUNT KENALOOAK J-94	1979	67.7	4,568	4010	

Presenter's notes: Exploration began with the spudding of Dome et al Nektoralik K-59 and Hunt Dome Kopanoar M-13 in the summer of 1976. During the years 1976 to 1984 a total of 15 wells, shown on this slide, were drilled in the play, with seven successful wells, resulting in the issue of 6 Significant Discovery Licences, for a success rate of 47%. Four other wells had shows of oil/and or gas on drill stem test and only four wells had no occurrence of oil or gas. The last well drilled was Dome Nerlerk J-67, drilled and abandoned in 1984.

KOPANOAR PLAY – SIGNIFICANT DISCOVERY LICENCES

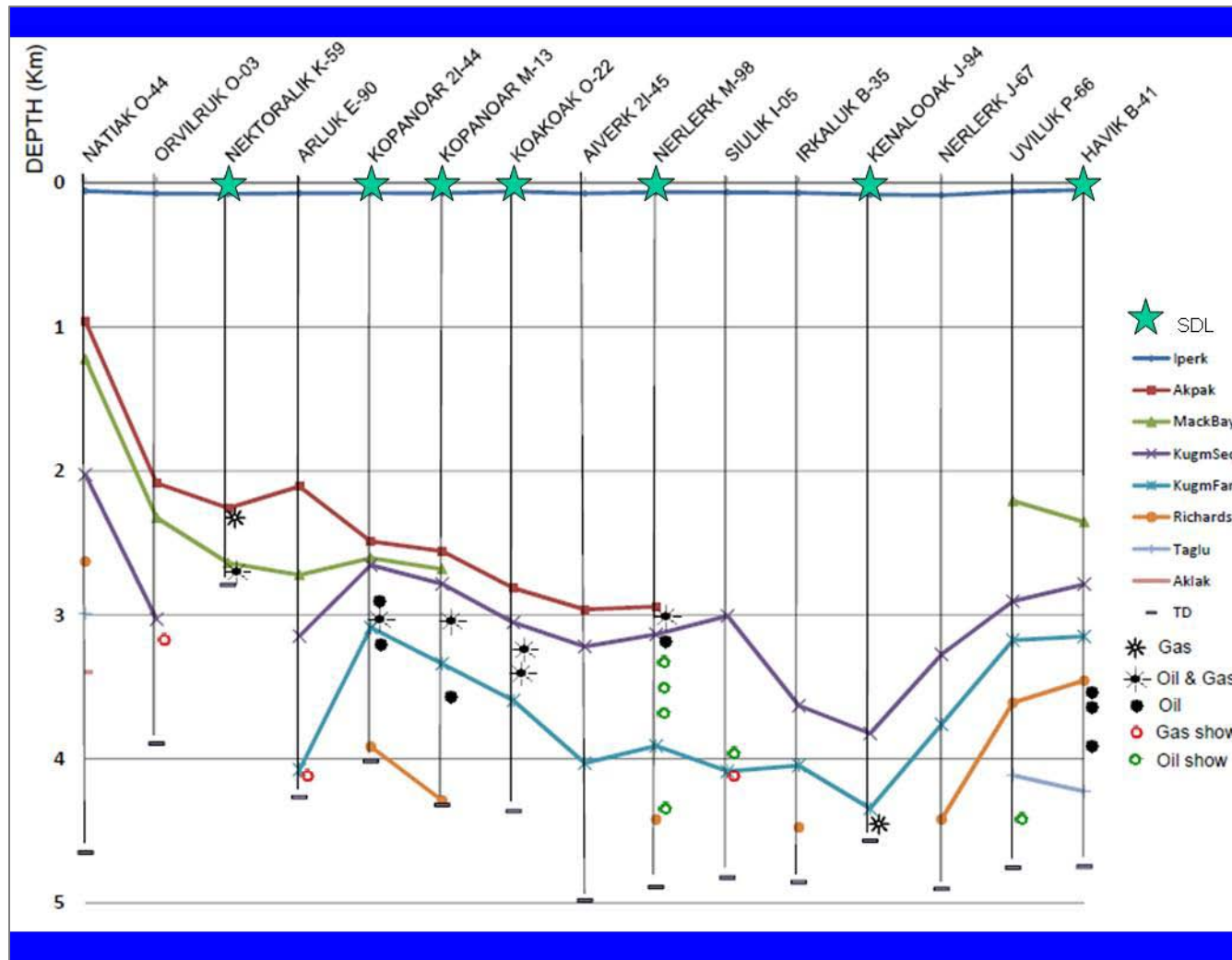


Presenter's notes: A total of six discovery licences have been issued in the Kopanoar play area. The total discovered resources are 822.5 BCF of recoverable gas and 234 million barrels of recoverable oil. The slide also shows the recent deeper water exploration licences, where total work commitments are some 3 billion dollars.

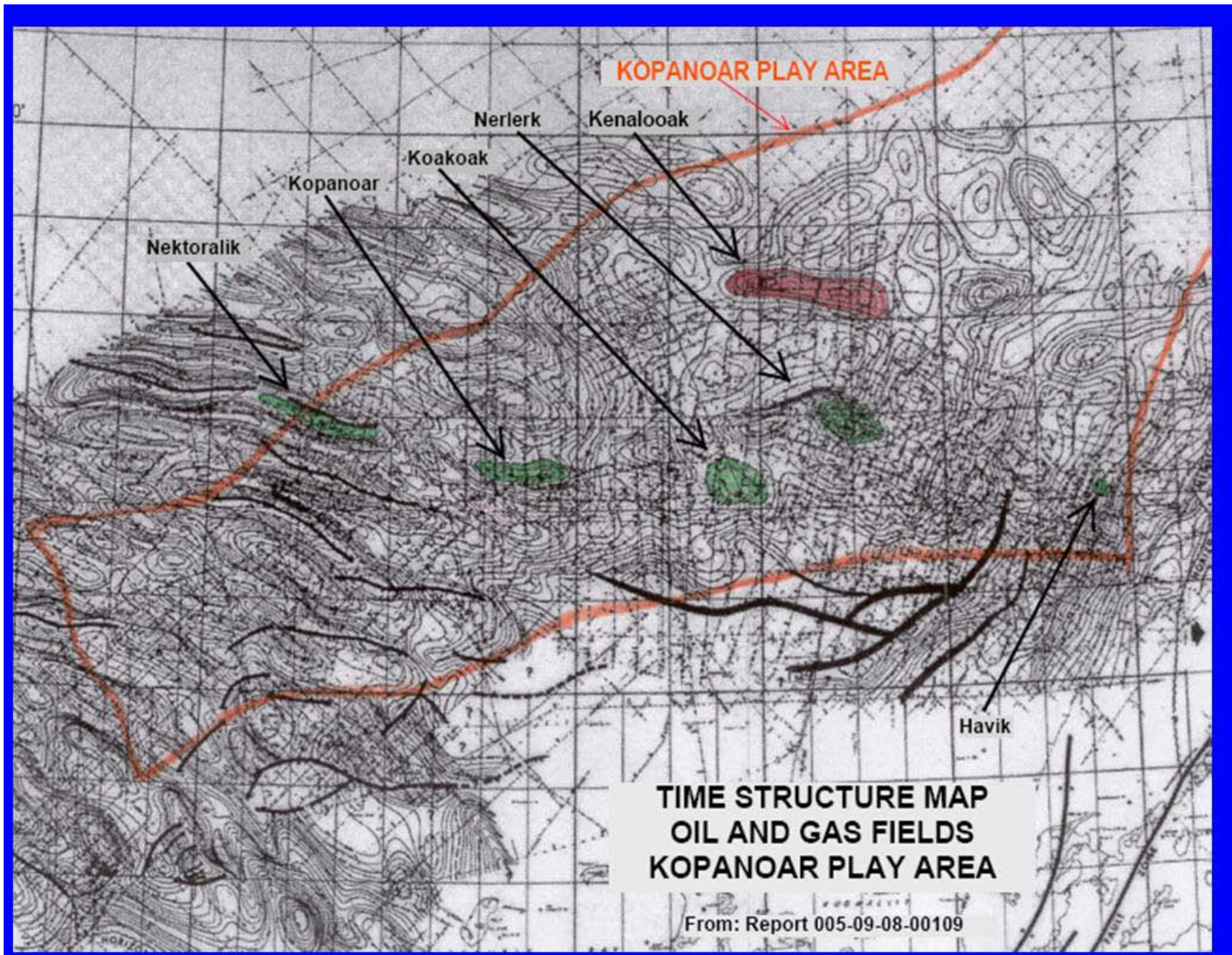
KOPANOAR PLAY – DISCOVERED FIELD RESOURCES

	RECOVERABLE RESOURCES		
FIELD	GAS (BCF)	OIL (MMB)	MMBOE
KOAKOAK	339.7	81.4	141.2
KOPANOAR	94.6	65.6	82.1
HAVIK	39.7	37.1	43.7
NERLERK	52.5	31.5	40.5
KENALOOAK	211.7	0	35.4
NEKTORALIK	84.3	18.5	33.8
TOTAL	822.5	234.1	376.7

Presenter's notes: The oil and gas resources for the discovered fields of the Kopanoar play area are shown on this slide, ranked by oil equivalent. The largest field on an oil equivalent basis is Koakoak, followed by Kopanoar. The total discovered recoverable resource is 234.1 MMB of oil and 822.5 BCF of gas, for a total oil equivalent of 376.6 million barrels



Presenter's notes: This slide shows all fifteen wells with discovered oil and gas and shows indicated for the various stratigraphic horizons. Purple line is the top of the Kugmallit and the blue line below that is the Kugmallit submarine fan. Depths to the top of the Kugmallit range from 2000 metres just south of Natiak to 4000 metres just north of Kenalooak J-94. There are seven successful wells indicated by the star in six SDL's. Oil and gas shows were recorded in 4 other wells, Orvilruk O-03, Arluk E-90, Siulik I-05 and Uviluk P-66. Only 4 wells, Natiak O-44, Aiverk 2I-45, Irkaluk B-35 and Nerlerk J-67, had no shows. Discoveries in the Kugmallit submarine fan include oil in the 2 Kopanoar wells and gas in Kenalooak, with shows of oil or gas in Arluk E-90, Nerlerk M-98 and Siulik B-35. Discovered oil and gas in the Upper Kugmallit occurs in Kopanoar, Koakoak and Nerlerk M-98. Nektoralik K-59 discovered oil and gas in the Mackenzie Bay and gas in the Akpak. Nektoralik K-59 did not drill deep enough to test the Kugmallit. Nerlerk has oil and gas in the Mackenzie Bay, as well as the Upper Kugmallit. Havik B-41 is an oil discovery in the Richards Sequence.

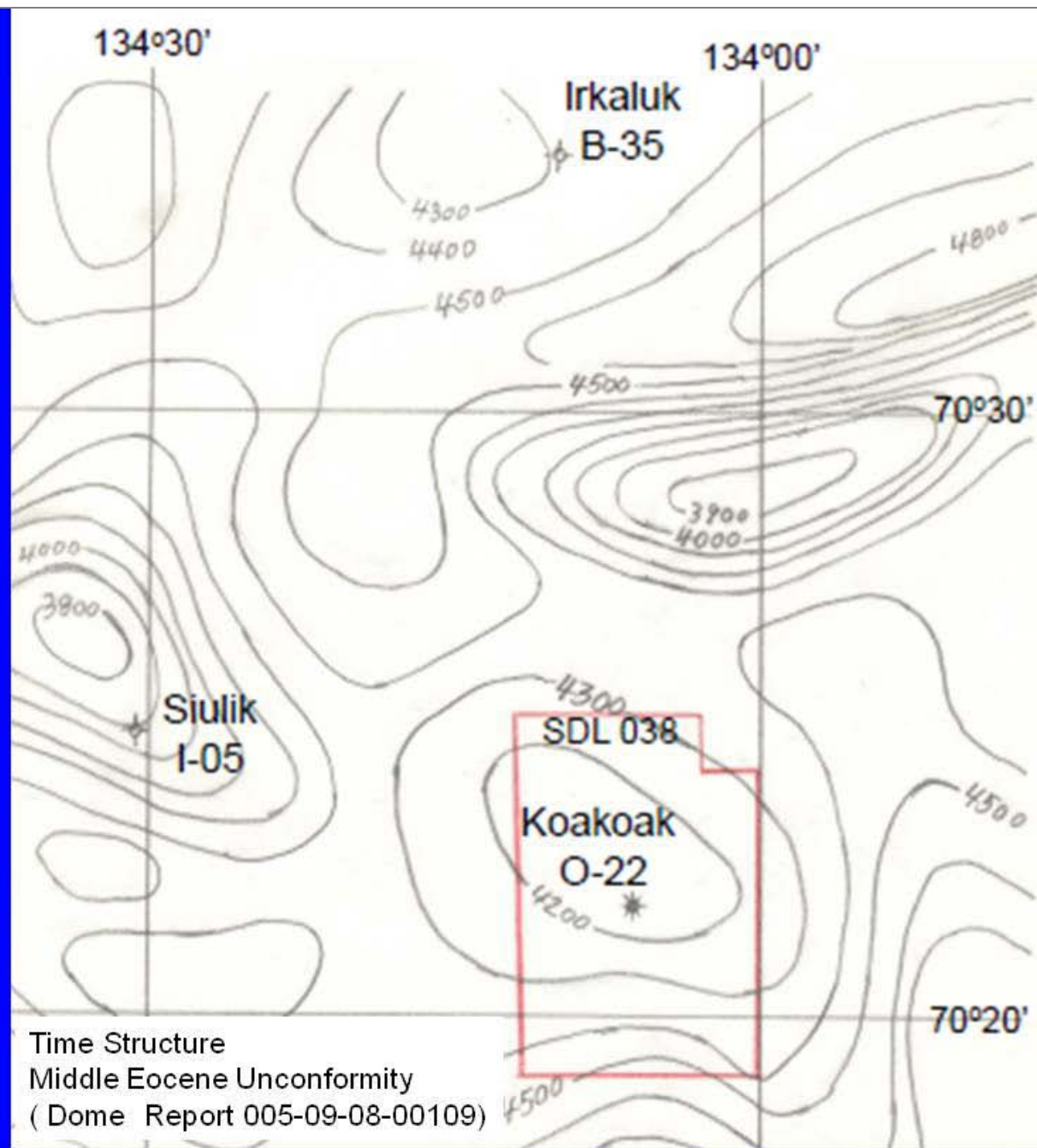


Presenter's notes: This is a composite time structure map to show the structural trends within the Kopanoar play area. It is characterized by long east-west trending closures of the Beaufort Fold Belt. To the south is the east-west trending Tarsiut-Amauligak Fault Zone.

**KOAKOAK O-22
SIGNIFICANT
DISCOVERY
LICENCE**

6,620 Ha

**81.4 MMB
339.7 BCF**



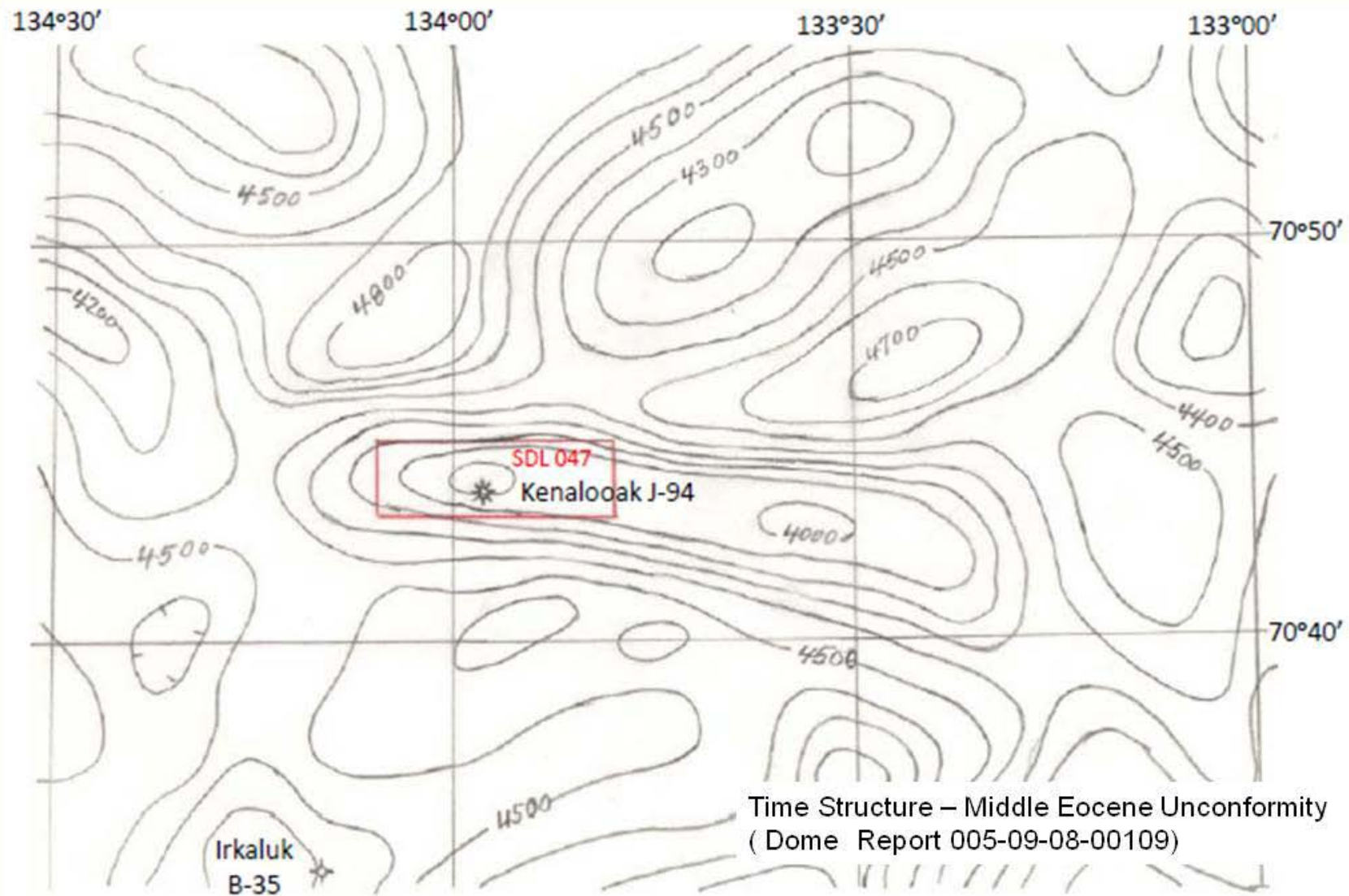
Presenter's notes on following slide.

Presenter's notes for previous slide: SDL 038 for Koakoak covers 6,620 hectares, approximately equal to the mapped area of closure. 2,000 hectares was assigned to the well for estimation of discovered oil and gas.

Koakoak O-22 spudded November 5, 1979 was drilled over 3 seasons, and suspended on October 31, 1981. The well was drilled in 161.4 feet of water (49.2 metres). Koakoak O-22 has two oil zones with associated gas in the Kugmallit Submarine Fan Sequence. The National Energy Board has assigned oil resources, with associated gas to two zones; oil 1 and gas 1 over the interval 3308 to 3330 metres (10,853 to 10,925 feet) and oil 2 and gas 2 over the interval from 3465 to 3496 metres (11,368 to 11,470 feet). Zone 1 on DST #5 tested 29.6 ° oil at 189 BPD (30 m³/d) and gas at 7.3 MMcf/d (207,000 m³/d). Zone 2 on DST #4 (3,465 to 3,496m) tested 28° API oil at 818 BPD (130 m³/d) with gas at 6.3 MMcf/d (177,000 m³/d) and on DST 4A (3465 to 3496 m) tested oil at 2,580 BPD (410 m³/c) and gas at 19.3 MMcf/d (544,000 m³/d) with 1,617 barrels of water per day (257 m³/d). SDL 038 over Koakoak O-22 covers an area of 8,016 hectares (19,800 acres). The mean area assigned by the NEB to the Koakoak O-22 discovery and used in this evaluation is a conservative 2,000 hectares to oil 1 and 2,600 hectares to oil 2. Only 200 hectares was assigned to the associated gas cap of both gas 1 and gas 2. The seismic map closure as shown on the seismic map from NEB report 005-09-08-00109 is in the order of some 9,000 hectares. The aerial extent of the reservoir sands over the structure is unknown, however the assigned areas are most likely conservative and the discovered volume of oil and gas could be larger. Koakoak O-22 pay zones are; Gas 1 from 3303 to 3318 metres, Oil 1 from 3318 to 3381 metres, Gas 2 from 3458 to 3473 metres and Oil 2 from 3473 to 3493 metres. Core no. 1, 3484.65 to 3493.7 metres covers the lower part of the Oil 2.

KENALOOK J-94 SIGNIFICANT DISCOVERY LICENCE

4,104 Hectares, 211.7 BCF



Presenter's notes on following slide.

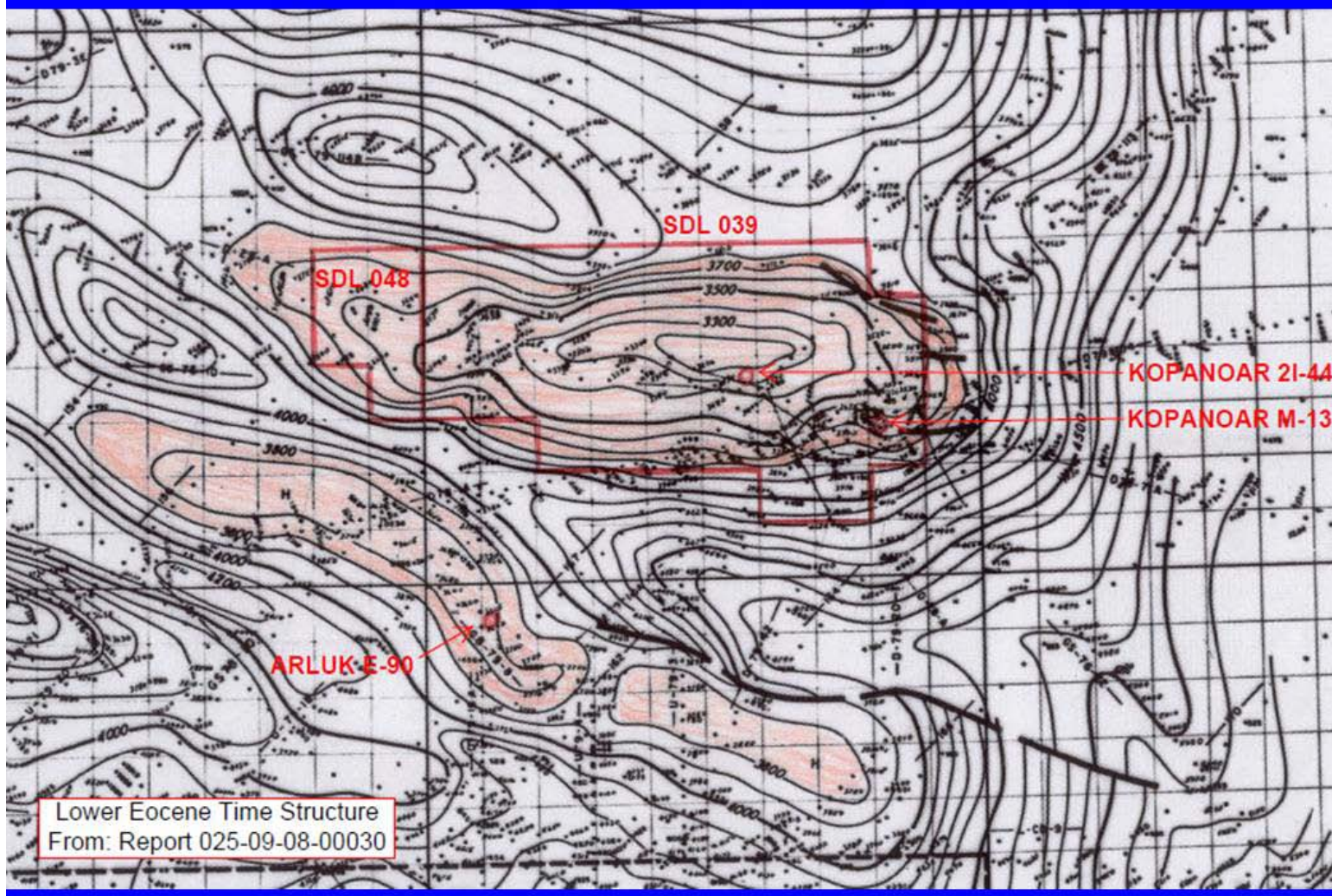
Presenter's notes for previous slide.

Kenalooak J-94 has one gas pool from 4503 to 4523 metres, with estimated recoverable gas resource of 211.7 BCF. The size of the SDL, which is only a small portion of the mapped closure is 4,104 hectares. A total of 1,00 hectares was attributed to the well for estimation of discovered gas. Kenalooak J-94 spudded on September 20, 1979, and drilled over the seasons of 1979, 1980, 1981, and 1982. The well was suspended November 1, 1982. The original well was drilled to 4049 metres. Due to stuck pipe a sidetrack was drilled to 4650 metres, and again stuck. Sidetrack number 2 was drilled to 4568.5 metres, true vertical depth of 4565 metres, which is the official total depth for the well.

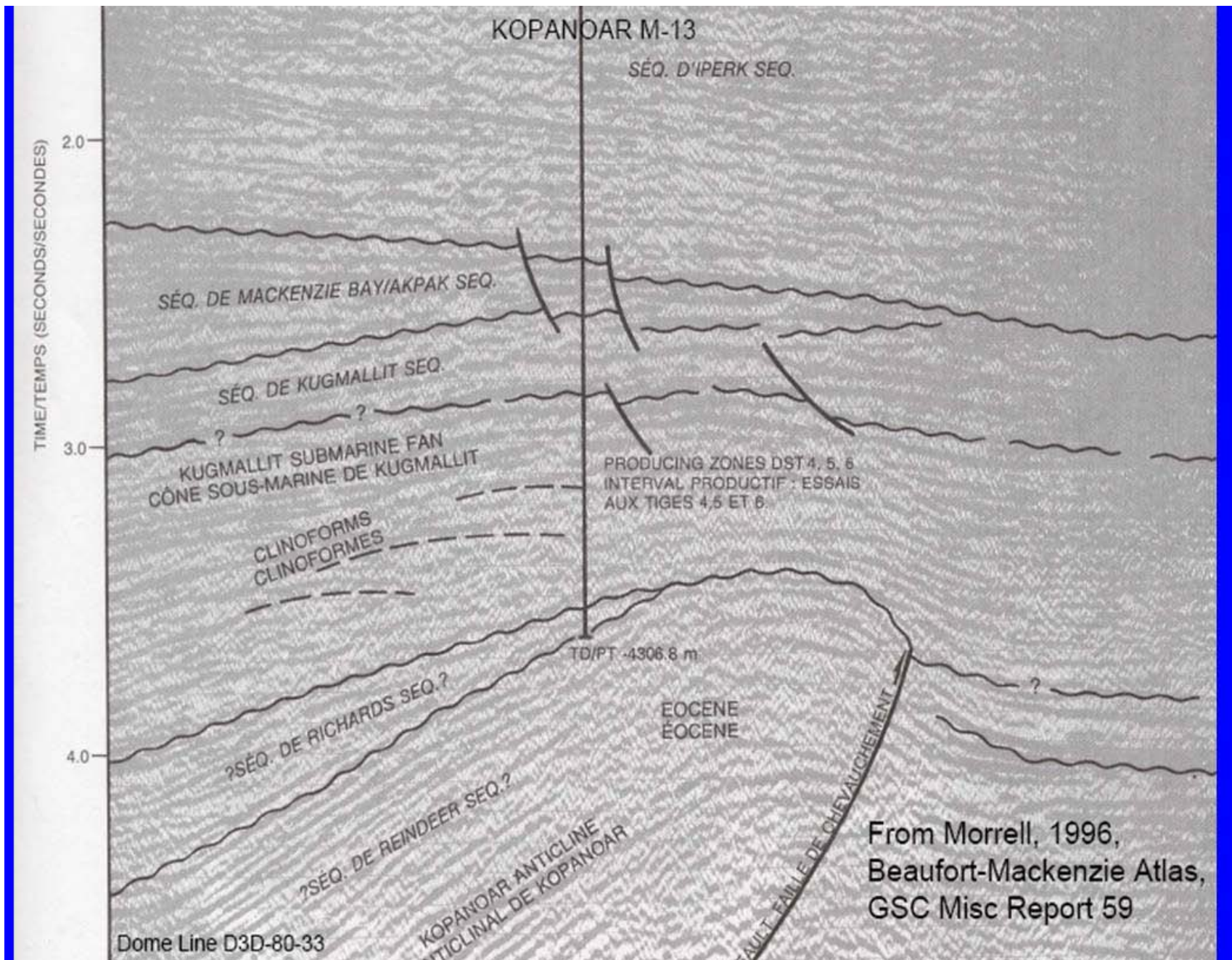
Kenalooak J-94 has one gas pool from 4503 to 4523 metres (14,774 to 14,839 feet), identified by the NEB. There is a discrepancy between the zone identified by the NEB, and the interval that tested gas. DST number 2 tested gas at 113,000 m³/d (4.0 mmcf/d) from the interval 4490 to 4501 metres (14,731 to 14,767 feet). DST #1A, 4519 to 4532.8 metres (14,826 to 14,871 feet) tested water at 317.7 m³/d (2,000 B/d). It did test the basal part of the NEB pay zone and would confirm the gas water content of 4523 metres (14,839n feet) by the NEB. DST 1A had gas at a rate too small to measure. Well history report, for DST 2, reports average gas rate of 103,000 m³/d (3.65 mmcf/d). Schedule of wells shows gas at 113,000 m³/d (4.011 mcf/d). The maximum measured rate was 116,600 m³/d (4,139 mcf/d). There are no reports of gas analysis for Kenalooak J-94. The gas analysis from DST 16, of Kopanoar M-13 was used in the evaluation of gas resources for Kenalooak J-94.

KOPANOAR SIGNIFICANT DISCOVERY LICENCE

13,922 Hectares, 65.6 MMB, 94.6 BCF

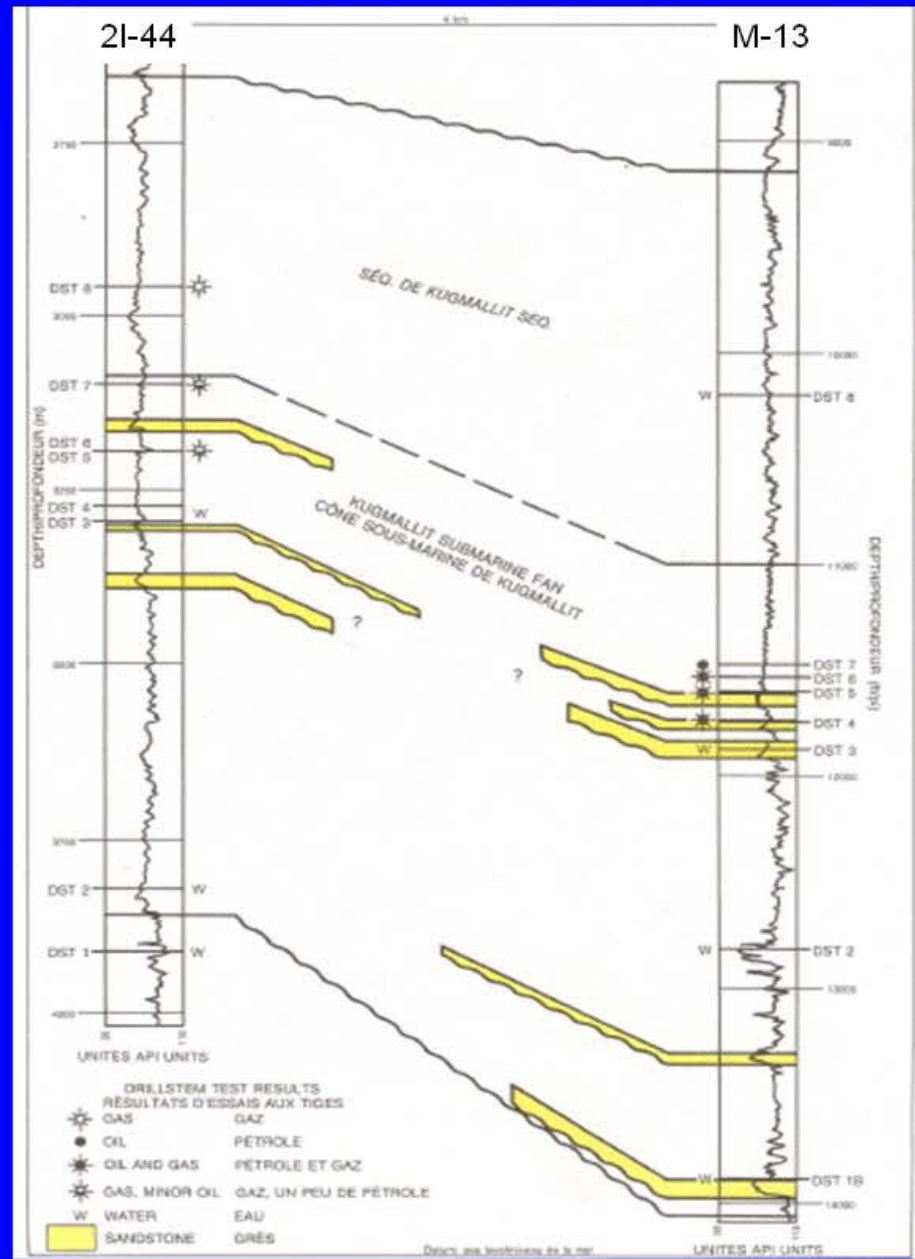


Presenter's notes: Time structure map on the lower Eocene showing the Kopanoar structure, a long east-west trending fold, with two discovery wells. The estimated discovered resources are 65.6 MMB of recoverable oil and 94.6 BCF of recoverable gas. The two SDL's, which corresponds closely with the mapped closure, cover an area of 13,922 hectares. The area used for calculation of resources for the wells was 2,000 hectares. Note the Arluk E-90 structure to the south. This well tested gas (159 mcf/d) and water (450 b/d) from the Kugmallit submarine fan. No resources have been assigned.



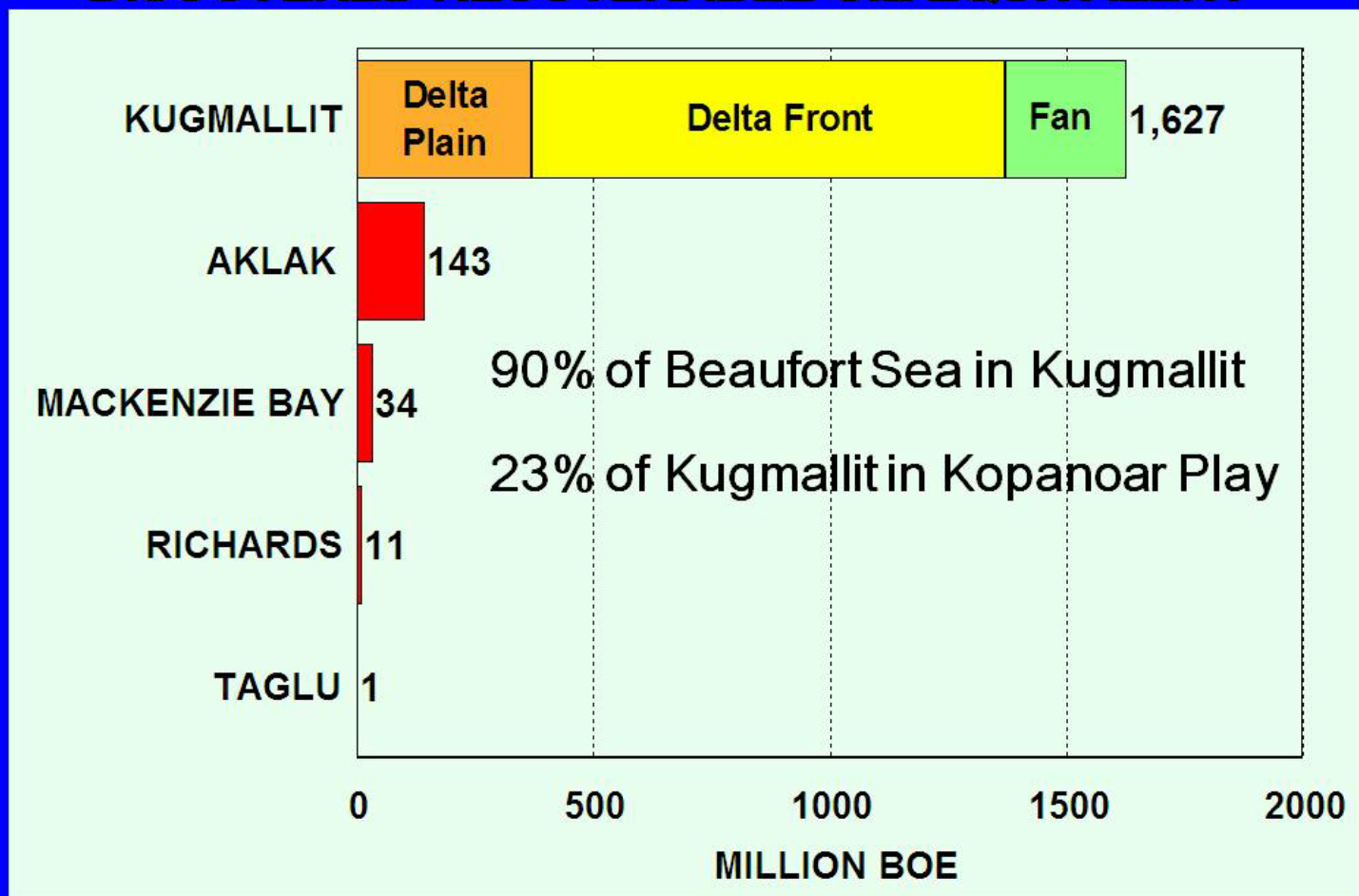
Presenter's notes: Seismic section across the Kopanoar M-13 well, showing the Kugmallit unconformably overlying a deep seated thrust faulted fold.

CORRELATION SECTION KOPANOAR 2I-44 AND KOPANOAR M-13 From: Morrell, 1996



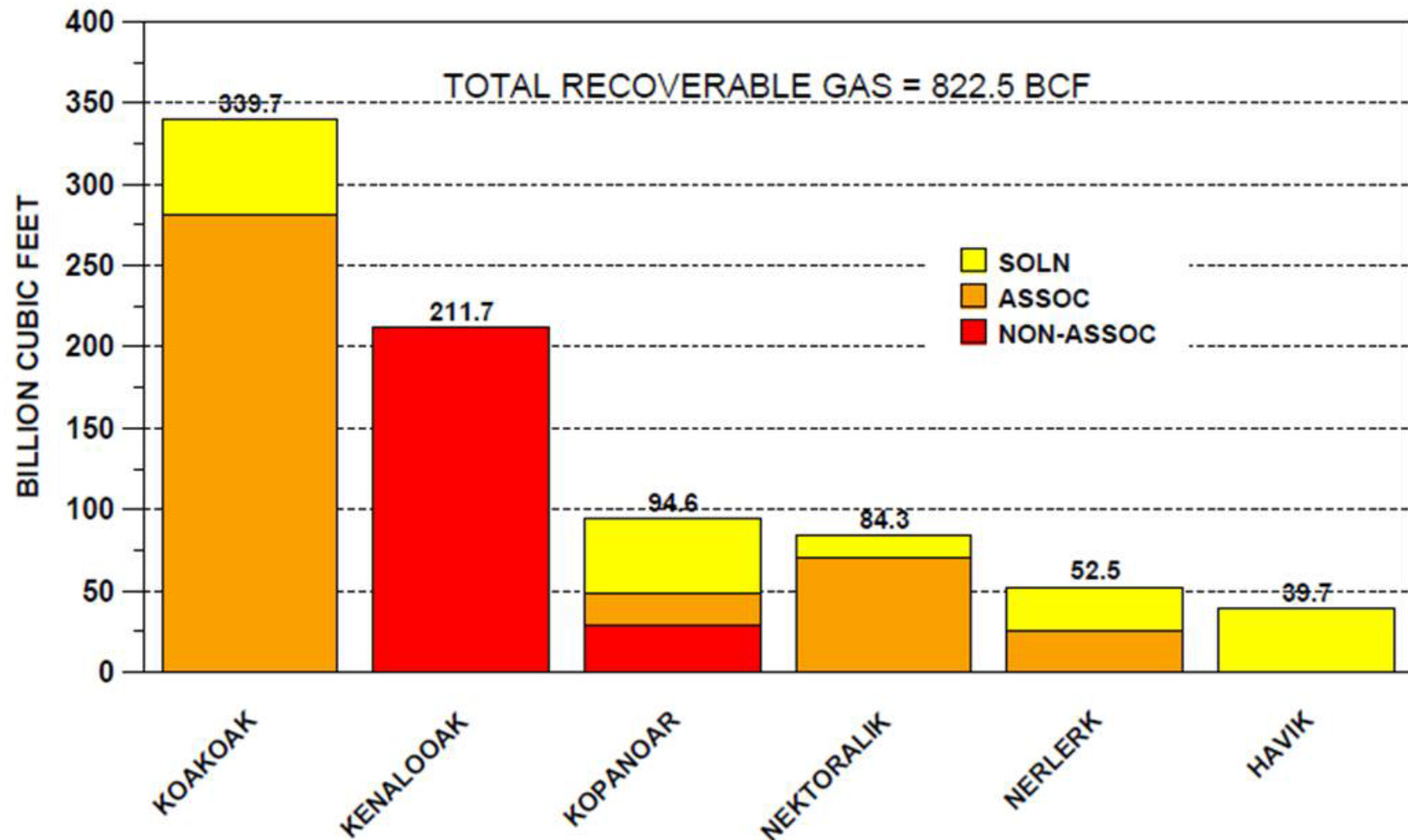
Presenter's notes: As noted by Morrell, 1996 correlation of zones between the two Kopanoar wells across the structure is difficult. It appears the zones are not connected across the structure and are restricted to an individual well. Although the structures are large, the continuity of reservoirs within the Kugmallit submarine fan may be questionable.

BEAUFORT SEA - STRATIRAPHIC DISTRIBUTION DISCOVERED RECOVERABLE OIL EQUIVALENT



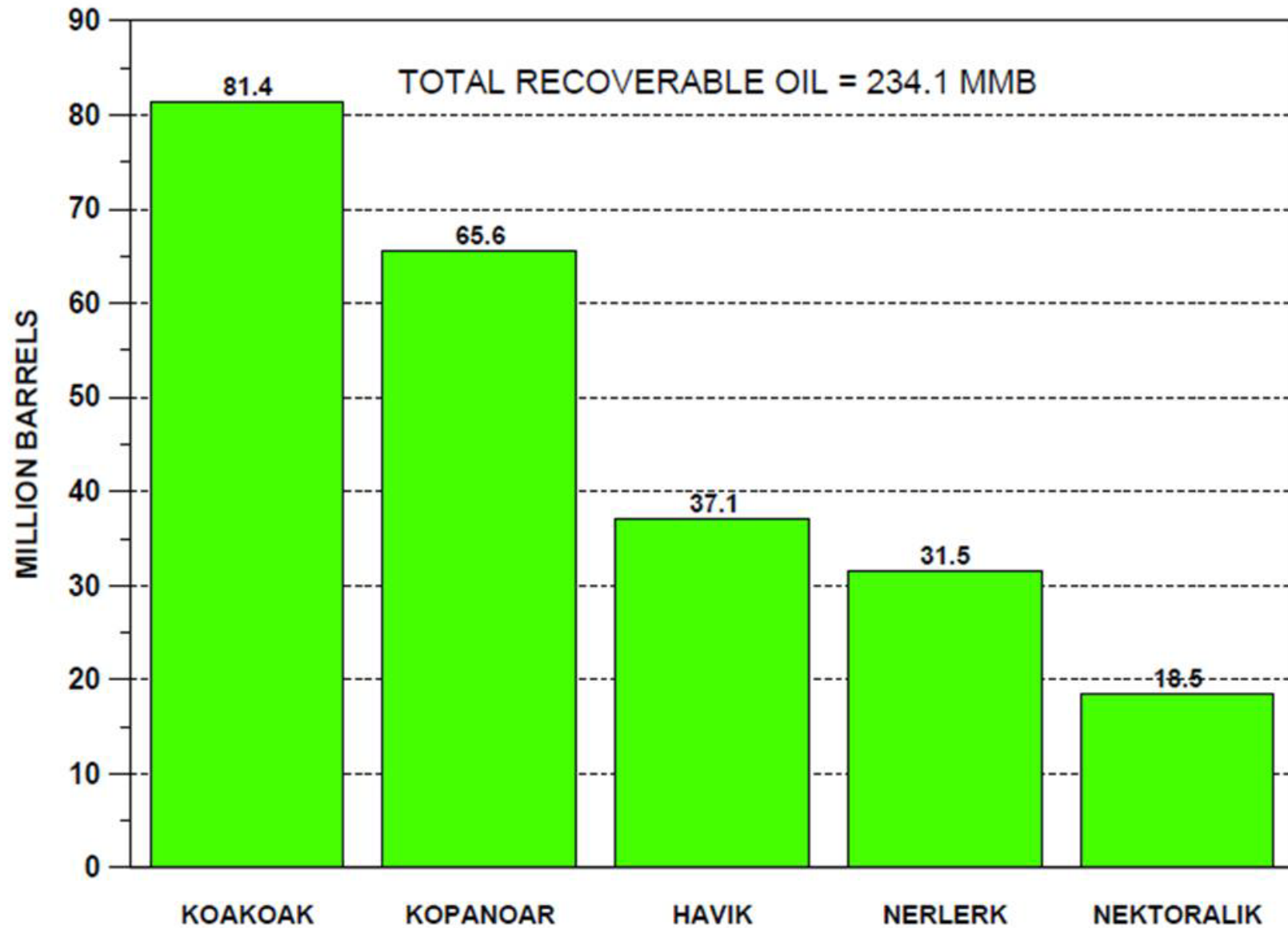
Presenter's notes: The importance of the Kugmallit Sequence is shown by this slide of the discovered BOE by sequence for the Beaufort Sea. The Kugmallit Sequence with a discovered 1.6 billion barrels of recoverable oil equivalent contains 90% of the total resource discovered to date in the Beaufort Sea, with 55% in the delta front facies. The delta front sandstones are primarily in the Tarsiut-Amauligak Fault Zone play area, with some in the Kopanoar Play. Most of the discovered resource for the Kugmallit Sequence is in the Tarsiut-Amauligak Fault Zone, with 377 MMBOE (23.2%) in the Kopanoar Play. The Delta Plain discoveries are primarily in the Netserk Play. Submarine Fan discoveries are in the Kopanoar Play area. Aklak discoveries are in the Adlartok play area.

OIL/GAS FIELDS - KOPANOAR PLAY, BEAUFORT SEA RECOVERABLE GAS

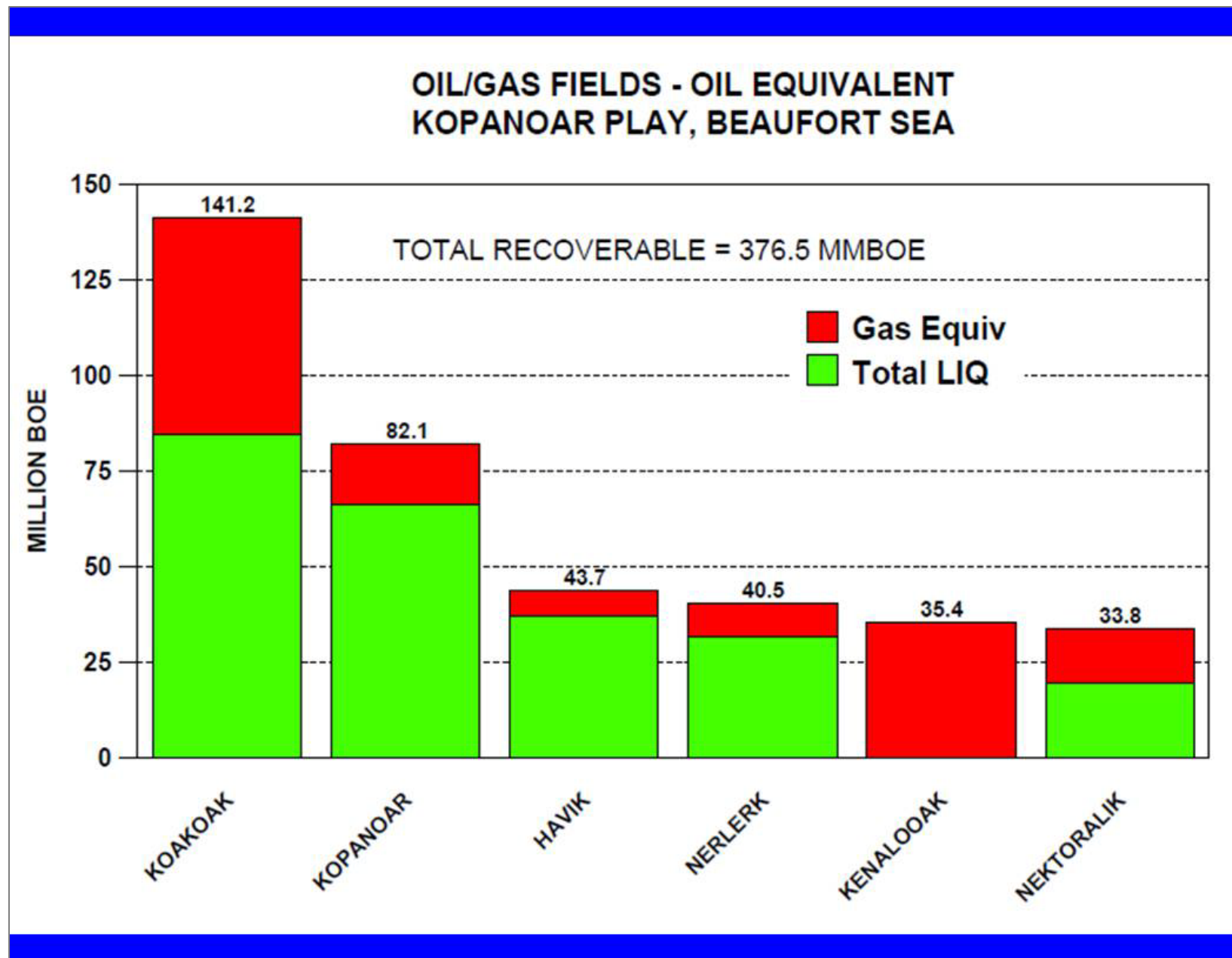


Presenter's notes: Total discovered recoverable gas is 822.5 BCF in six fields of the Kopanoar play. Koakoak is the field with the largest volume of recoverable gas. Note that most of the gas discovered in the Kopanoar play is associated with oil. The only non-associated gas field is Kenalooak.

OIL FIELDS - KOPANOAR PLAY, BEAUFORT SEA

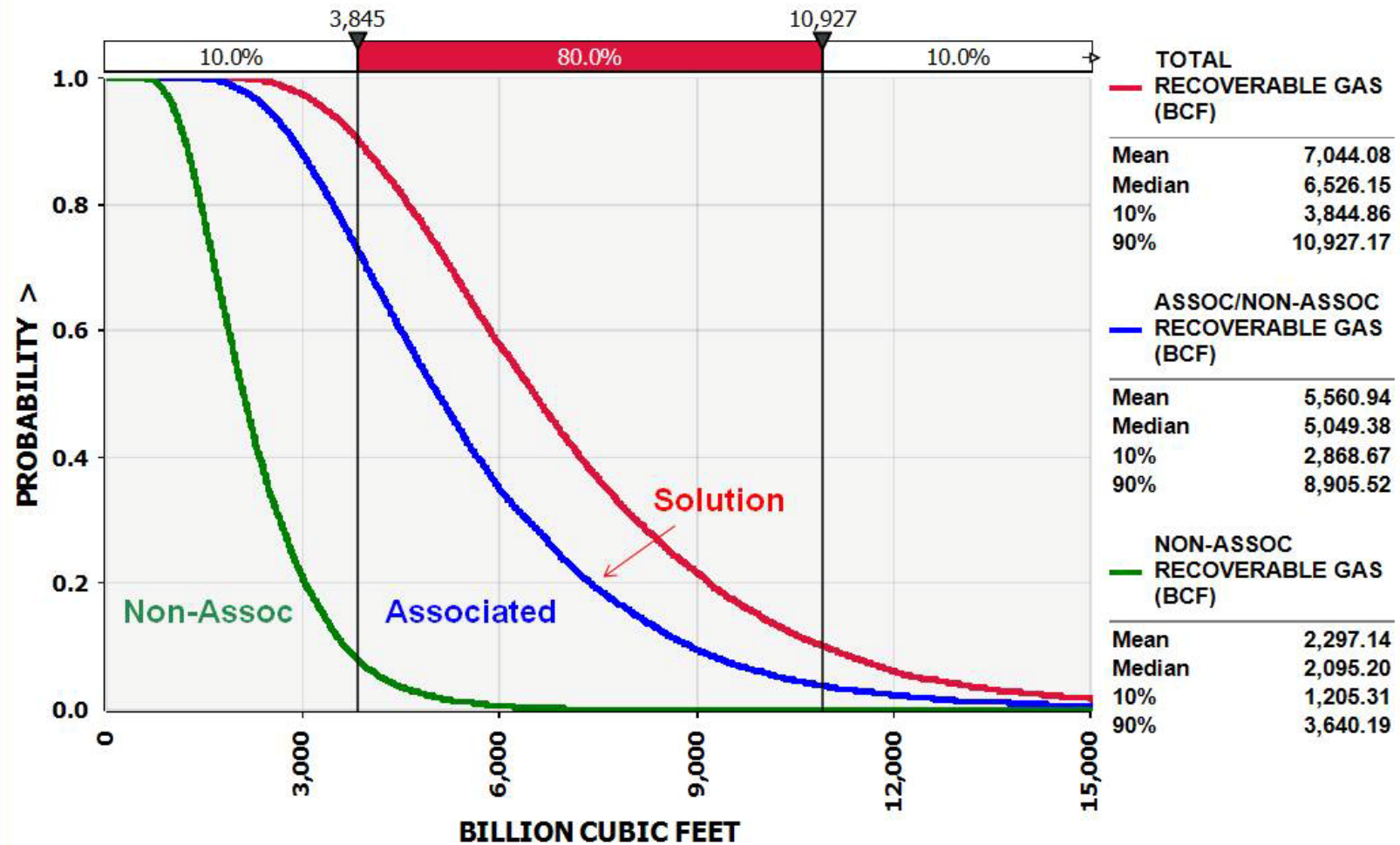


Presenter's notes: There are a total of 5 fields with a total recoverable oil of 234.1 MMB for the Kopanoar play. The largest oil field is Koakoak with 81.4 MMB of recoverable oil.

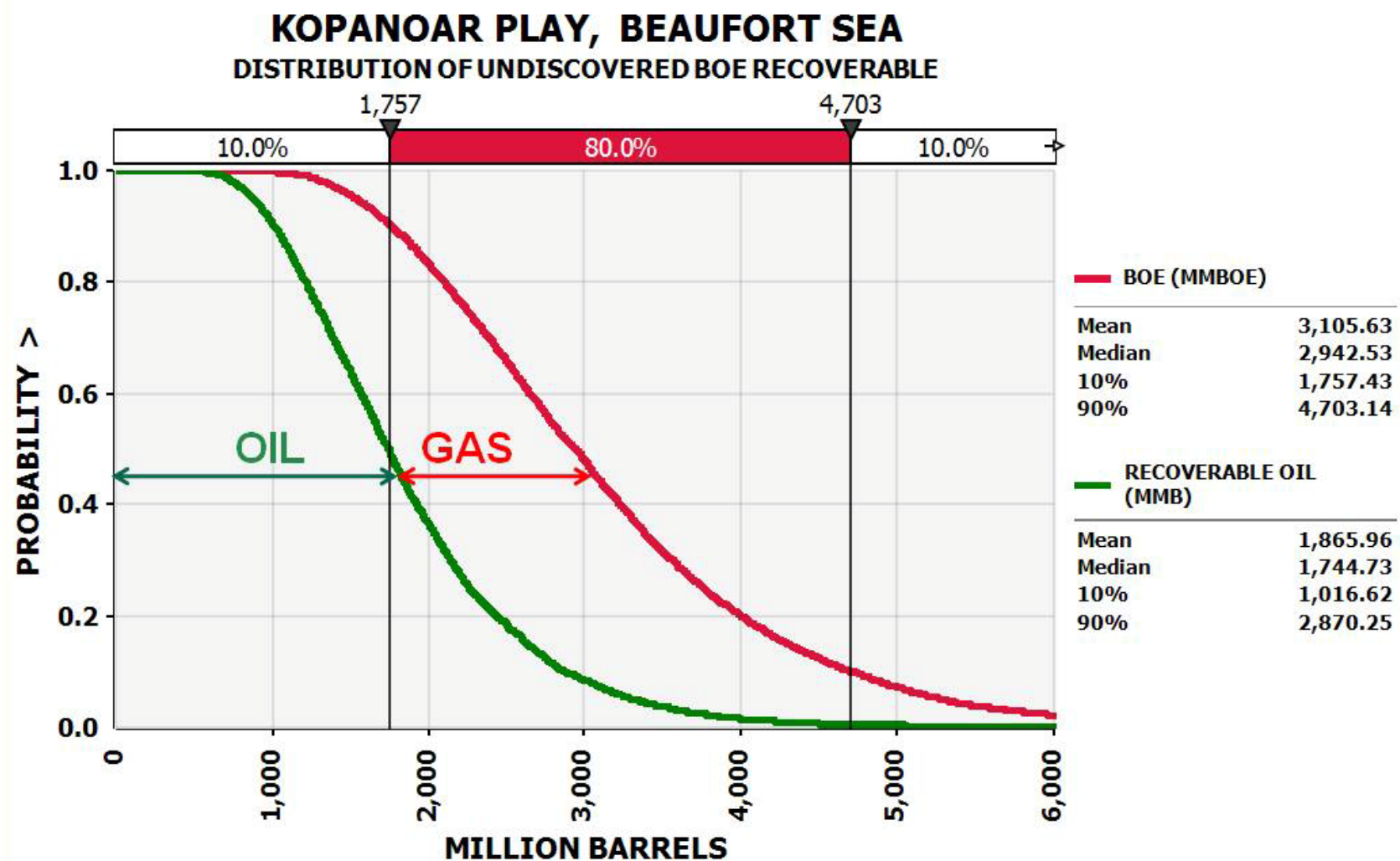


Presenter's notes: As shown by the chart of oil equivalent by rank, the Kopanoar play is predominantly an oil play. Liquids total 240 MMB (63.6%) of the total 376.6 MMBOE. Gas equivalent is 6 MCF equals 1 barrel. The largest field on a BOE basis is Koakoak with 339.7 BCF (56.6 MMBOE) of recoverable gas and 81.4 MMB of liquids (81.4 MMB of oil).

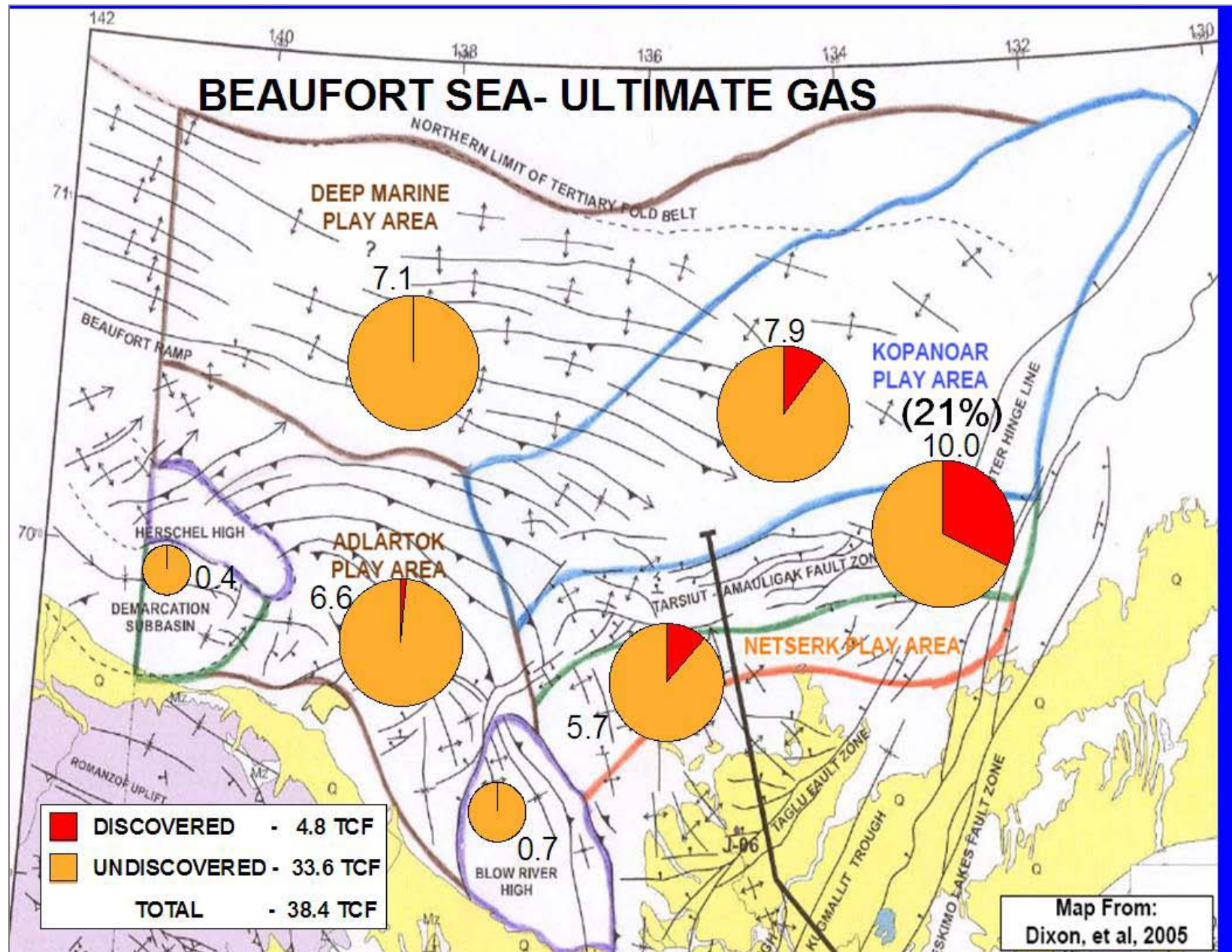
KOPANOAR PLAY, BEAUFORT SEA DISTRIBUTION OF UNDISCOVERED RECOVERABLE GAS



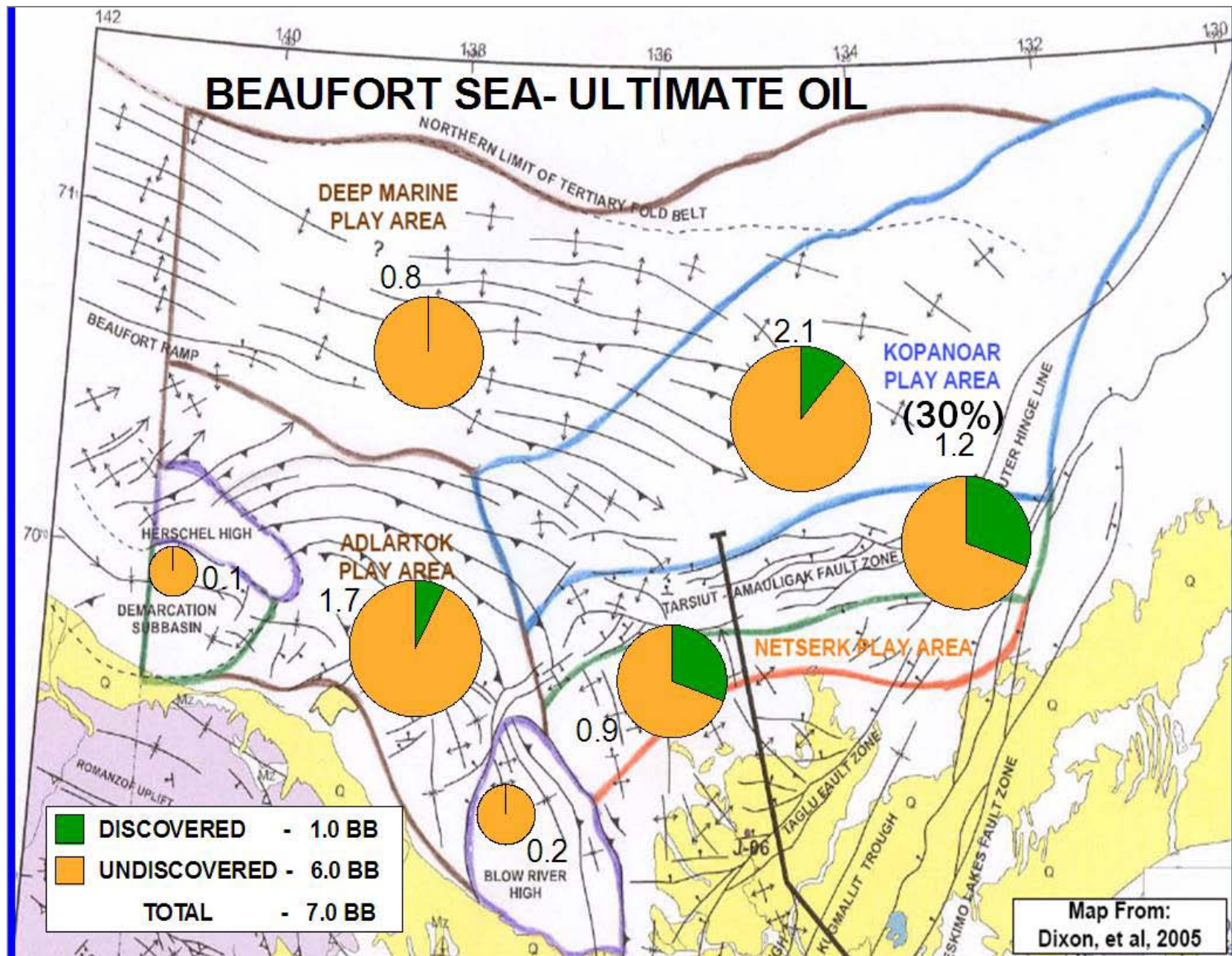
Presenter's notes: Slide shows the cumulative frequency distribution for undiscovered recoverable gas for the Kopanoar play. The total estimated undiscovered recoverable gas ranges from 3.8 tcf at 90% probability to 10.9 tcf at 10% probability with a mean of 7.0 tcf and median of 6.5 tcf. Note the greater part of the estimated undiscovered gas (5.6 tcf) is associated with oil. Non-associated gas is only 2.3 tcf of the total.



Presenter's notes: Undiscovered recoverable oil ranges from 1.0 BB (90% probability) to 2.9 BB (10% probability), with a mean of 1.9 BB, and a median of 1.7 BB. For oil equivalent the range is 1.8 to 4.7 BB, with a mean of 3.1 BB and median of 2.9 BB. Again the play is dominantly oil prone.

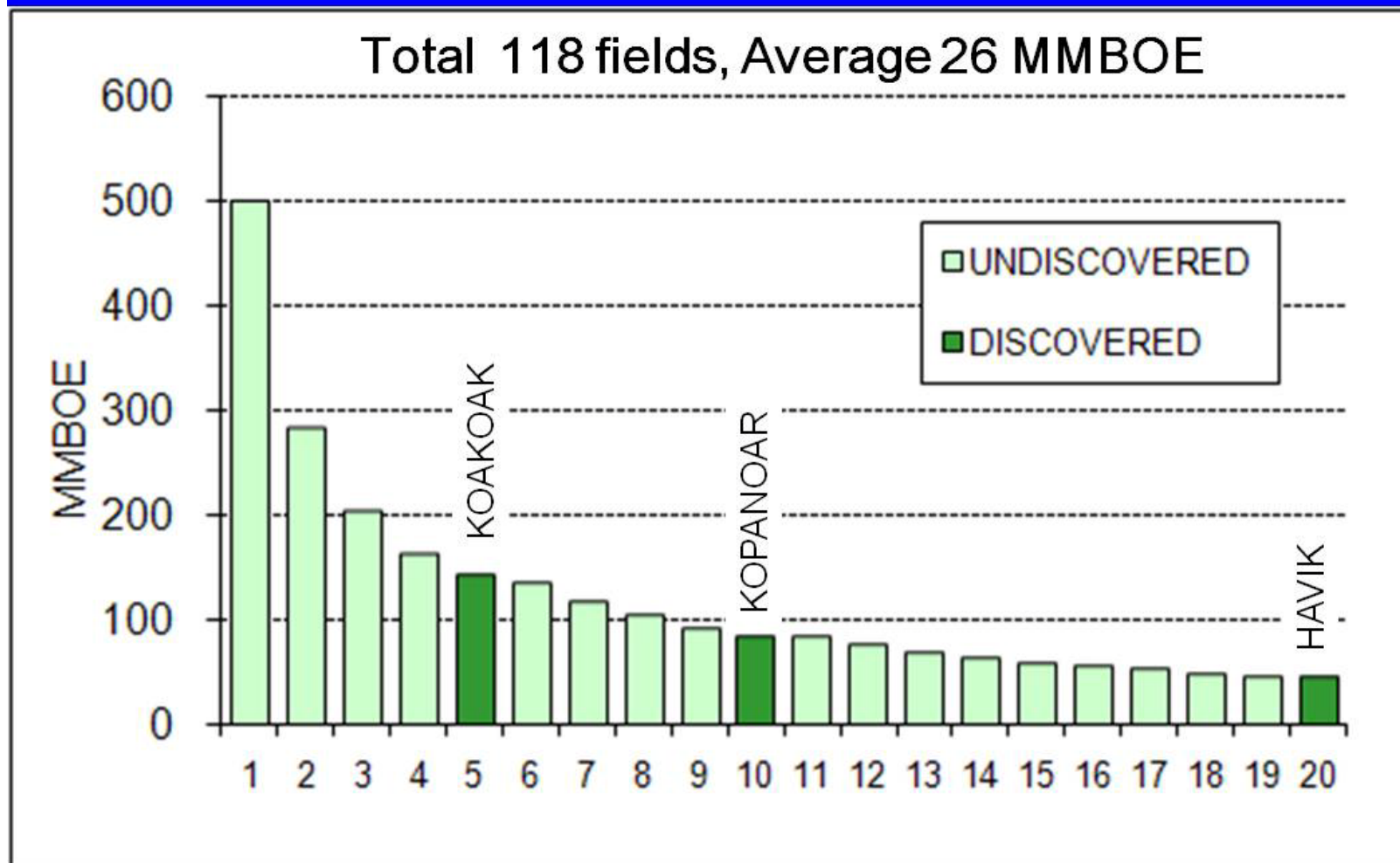


Presenter's notes: This slide shows the distribution of ultimate recoverable natural gas for the Beaufort Sea. The Kopanoar play, with 7.9 TCF of ultimate recoverable gas has 21% of the estimated ultimate gas potential for the Beaufort Sea. The discovered recoverable gas in the Kopanoar play is 822 BCF, 17% of the total for the Beaufort Sea.



Presenter's notes: This slide shows the distribution of ultimate recoverable oil for the Beaufort Sea. The Kopanoar play, with 2.1 BB of ultimate recoverable oil has 30% of the estimated ultimate oil potential for the Beaufort Sea. The discovered recoverable oil is 234 MMB, 23% of the total for the Beaufort Sea.

KOPANOAR PLAY – BEAUFORT SEA OIL EQUIVALENT ULTIMATE FIELD SIZE DISTRIBUTION TOP 20



Presenter's notes: This is one scenario for a possible ultimate field size distribution for the Kopanoar play. It is assumed the largest fields are still to be found or that one or more of the discovered fields could be larger than currently estimated. In the scenario shown here the largest undiscovered field is assumed to be 500 MMBOE with 4 undiscovered larger than Koakoak. A total of 118 fields are undiscovered with an average of 26.3 MMBOE compared to the discovered average of 62.8 MMBOE. 8 fields, of which 7 are undiscovered, would be larger than 100 MMBOE.

CONCLUSIONS

**THE KOPANOAR PLAY IN THE BEAUFORT
SEA HAS A LARGE DISCOVERED OIL AND
GAS RESOURCE**

**SUCCESS RATE IS HIGH WITH SIX
SIGNIFICANT DISCOVERIES FROM 15
WELLS DRILLED**

**THERE IS EXCELLENT POTENTIAL FOR
SIGNIFICANT VOLUMES OF UNDISCOVERED
OIL AND GAS IN THE KOPANOAR PLAY IN
THE BEAUFORT SEA**

THANK YOU

