Secção B

Exemplos de Sistemas Petrolíferos

Introduction

To better understand how a petroleum system is mapped and described, two examples are presented: the Mandal-Ekofisk(!) and the Ellesmerian(!) petroleum systems (from Cornford, 1994, and Bird, 1994, respectively). The petroleum in the former system migrated across stratigraphic units (or vertically) into many accumulations, whereas the latter migrated along stratigraphic units (or laterally) into a few accumulations. Both oil systems are multibillion barrels in size. These two examples illustrate many of the concepts and principles discussed in section A.

In this section

This section contains the following topics.

SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

Introduction

The Mandal–Ekofisk(!) petroleum system in the Central Graben of the North Sea contains 21.4 billion bbl of oil and 39.4 trillion ft^3 of gas in 39 fields (Cornford, 1994). The age of the reservoir rock ranges from Devonian to Tertiary age with about 85% of the petroleum in rock adjacent to the Cretaceous–Tertiary boundary, specifically the Ekofisk Formation of Late Cretaceous age. Based on geochemical evidence, the Upper Jurassic (Kimmeridgian) to Lower Cretaceous source rock is the Mandal Formation. A positive oil–source rock correlation indicates a known system.

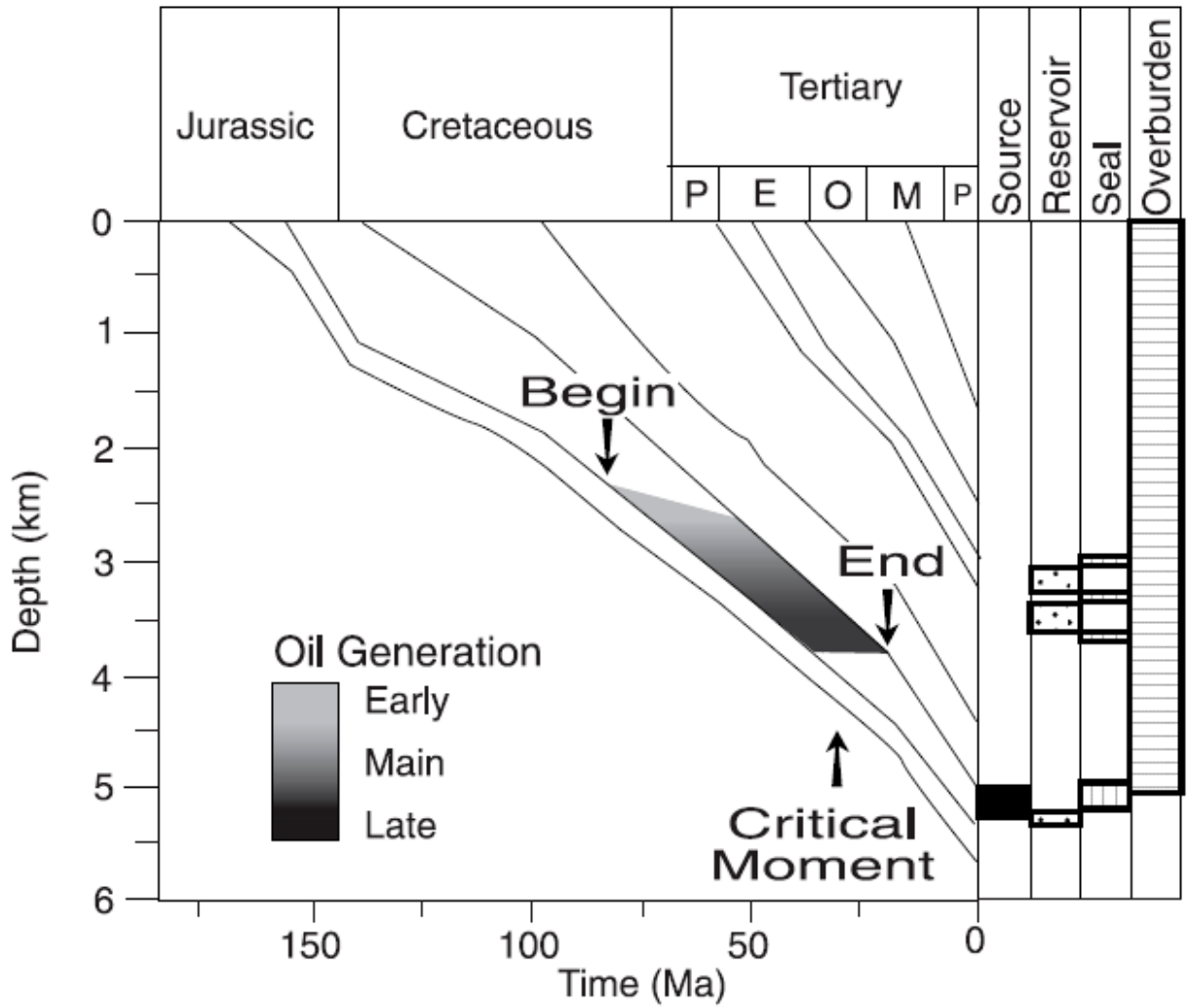
Geologic setting

This petroleum system formed in sedimentary rocks deposited in a failed rift system in the North Sea between Great Britain, Norway, and Denmark. The prerift rocks are mostly underburden rocks and are not involved in this petroleum system except as reservoir rocks for a minor amount of petroleum. The synrift sedimentary section contains the source rock. The reservoir rock, seal rock, and overburden rock were deposited during the postrift period of sedimentation.

Burial history chart

To better determine when the Mandal source rock was actively generating petroleum, a burial history chart (shown below) was constructed. Based on this and other charts, peak generation of petroleum occurred at about 30 Ma, selected as the critical moment.

SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)



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SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

Petroleum system map

The petroleum system map in Figure 3–8 shows the pod of active source rock and the oil and gas accumulations that were charged by this same pod of active source rock; all are within the geographic or known extent of the system. Most accumulations for the Mandal–Ekofisk(!) overly the active source rock, and the gas/condensate fields overlie the most mature source rock.

Petroleum system cross section

The petroleum system cross section in Figure 3–9 shows migration pathways and the spatial relation of the active source rock to the reservoir rocks. This section trends longitudinally (see Figure 3–8 for location) along the Central Graben and shows the vertical migration path from the active source rock through the Cretaceous rocks and horizontally along the basal Paleogene reservoir rocks until it accumulates in various traps. The underburden rock is pre-Late Jurassic in age and is not involved in the petroleum system except as minor reservoir rocks and where the Permian salt (Zechstein Group) creates diapirs that form petroleum traps and migration paths in fractured chalk.

SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

CARTOGRAFIA

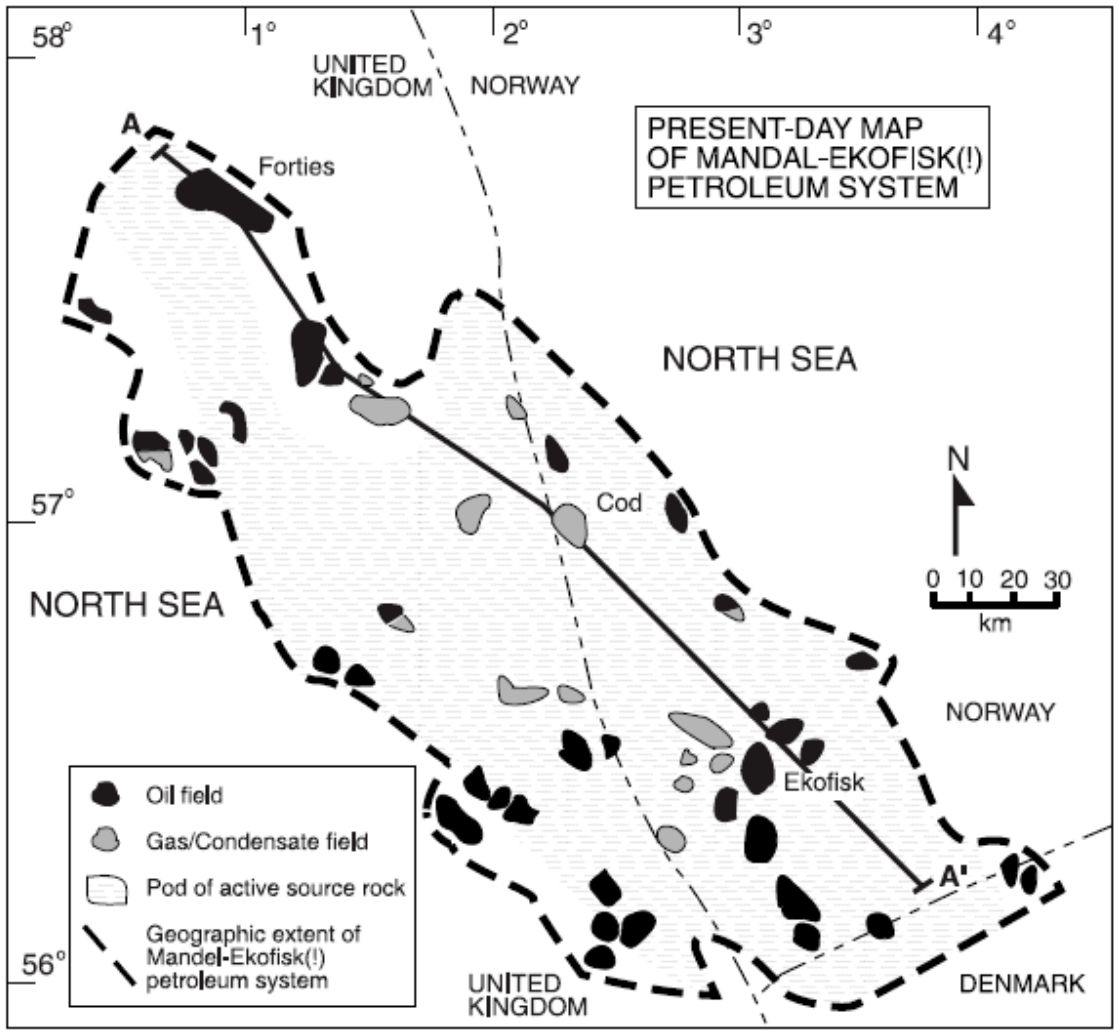

Figure 3–8. Modified from Cornford, 1994; courtesy AAPG.

SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

SECÇÃO

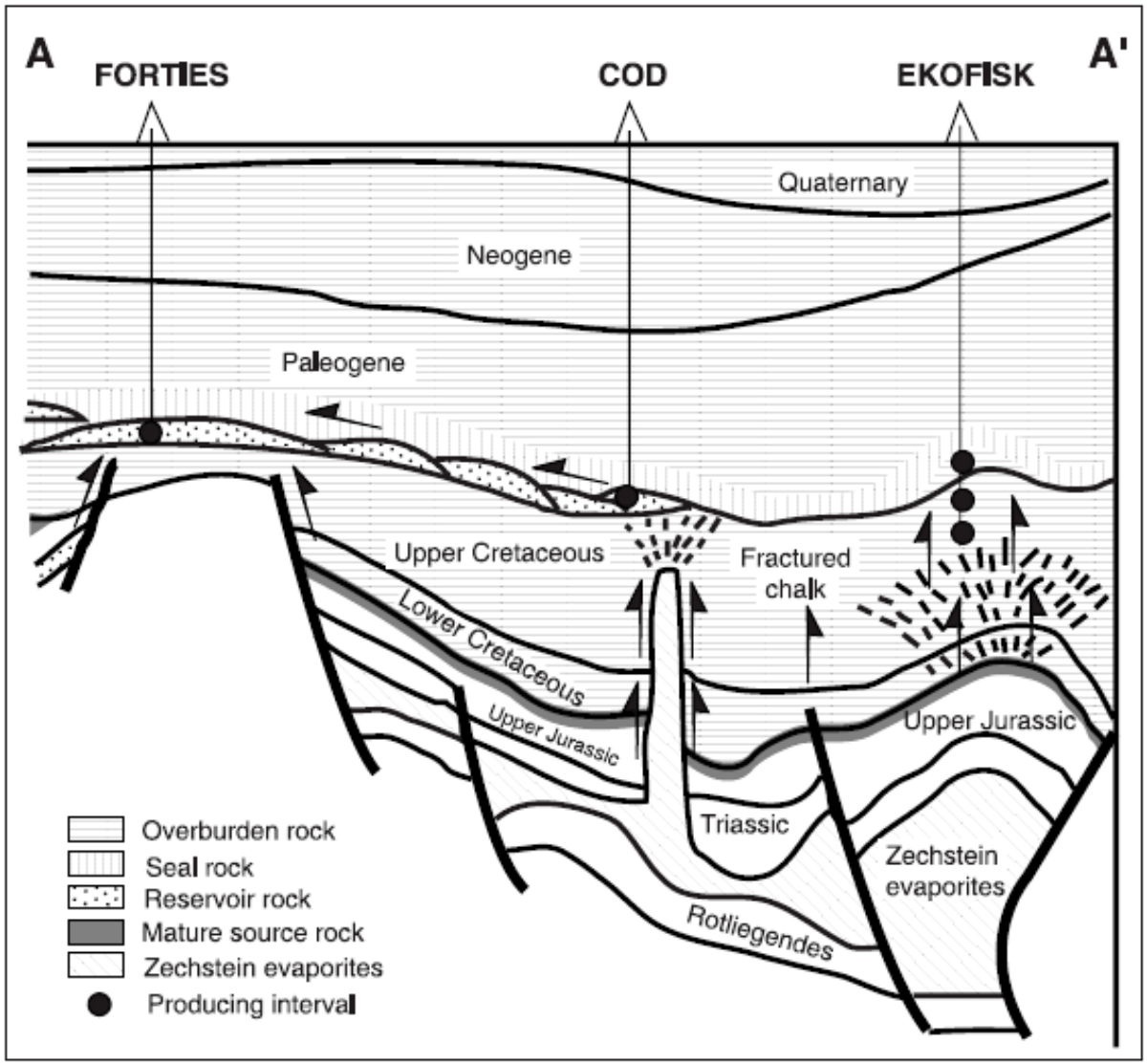

Figure 3–9. Modified from Cornford, 1994; courtesy AAPG.

SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

CORRELAÇÃO ÓLEO – ROCHA-MÃE

The oil–source rock correlation is a multiparameter geochemical approach; biological markers are one parameter. Biological marker analysis by Mackenzie et al. (1983) and Hughes et al. (1985) from reservoirs in the Greater Ekofisk, Forties, Montrose, and Argyll fields shows that these oils originated from the Mandal Formation source rock, as illustrated in the figure below.

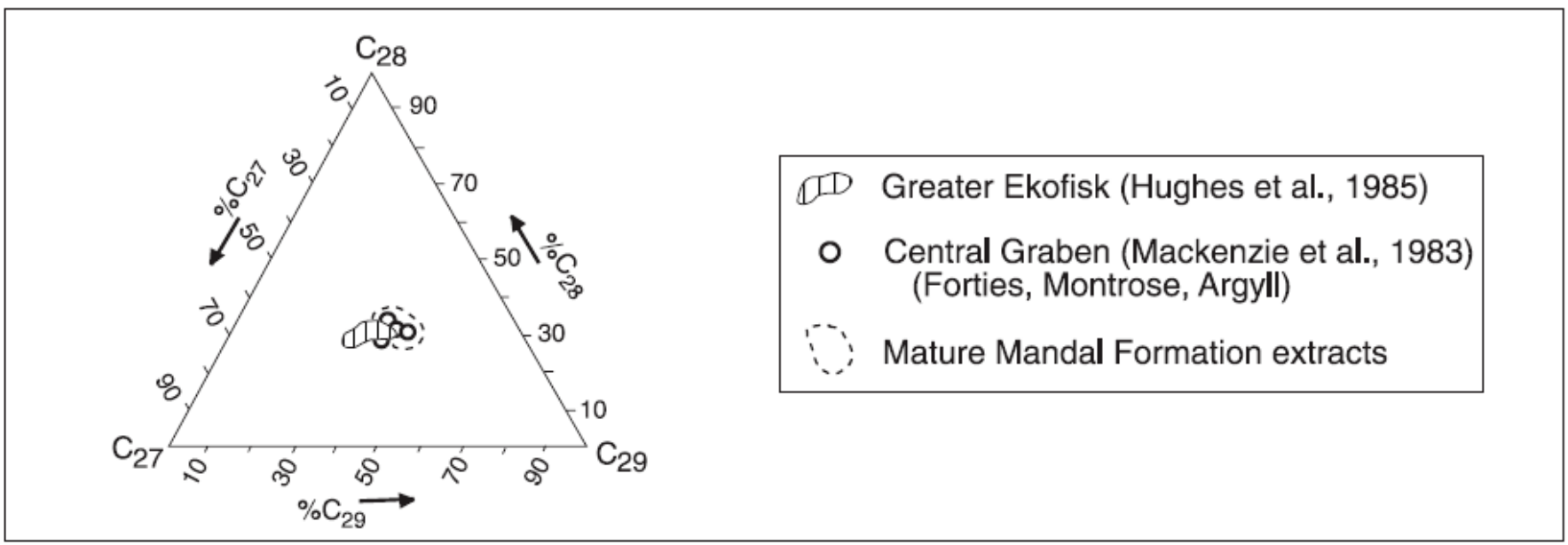

Figure 3–10. From Cornford, 1994; courtesy AAPG.

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SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

TABELA DE EVENTOS

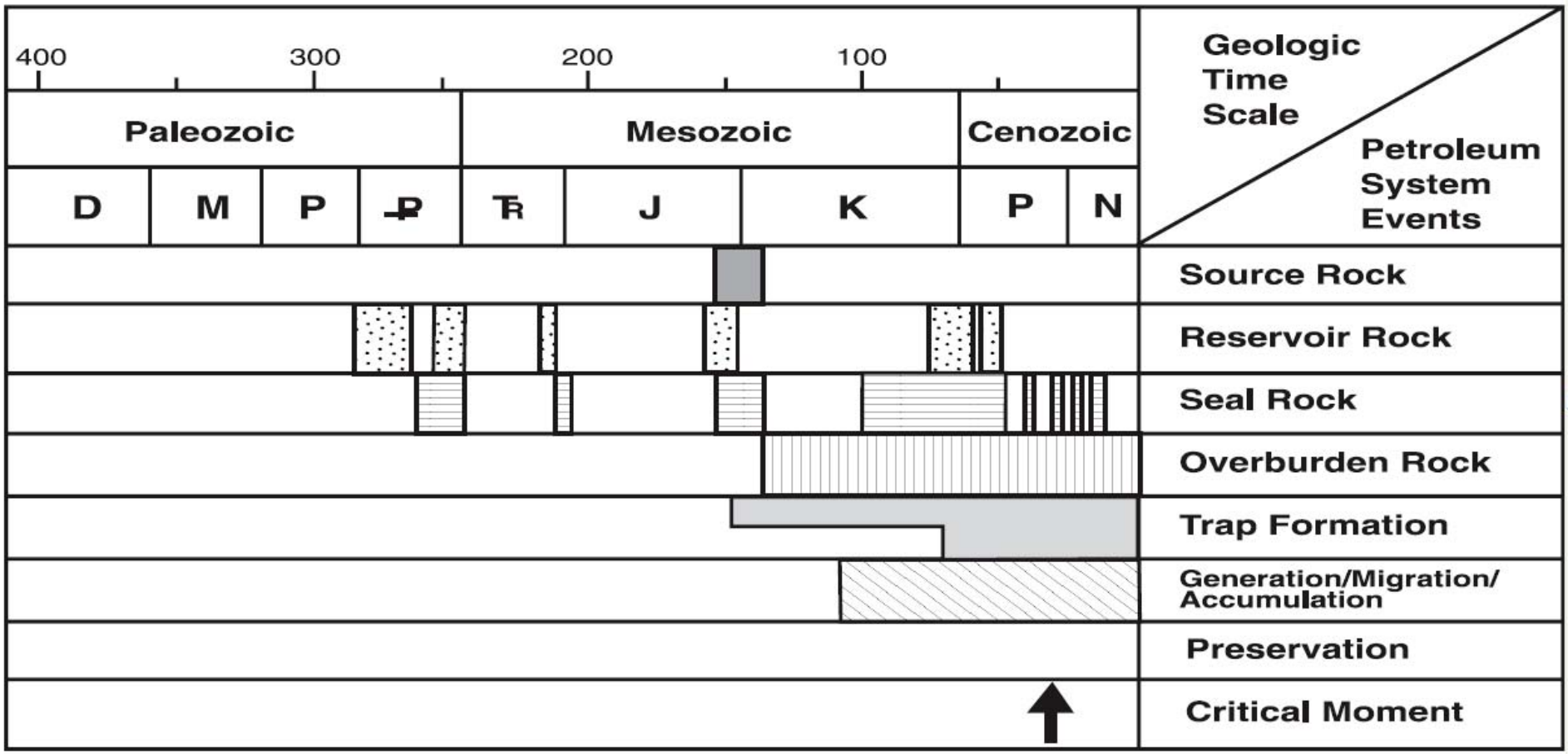

Figure 3–11. Modified from Cornford, 1994; courtesy AAPG.

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SISTEMA PETROLÍFERO MANDAL – EKOFISK(!)

Size of the petroleum system

The size of the Mandal-Ekofisk(!) petroleum system, as shown in the table below, is determined by the total volume of in-place hydrocarbons that originated from the pod of active Mandal source rock. The in-place hydrocarbons are determined from the recoverable hydrocarbons and, where possible, surface deposits, seeps, and shows.

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EKOFISK

Field name	In-place petroleum resources					
	Oil		Condensate		Gas	
	($\times 10^6$ bbl)	($\times 10^6$ m^3)	($\times 10^6$ bbl)	($\times 10^6$ m^3)	($\times 10^9$ ft^3)	($\times 10^9$ m^3)
Acorn	—	—	—	—	—	—
Albuskjell	—	—	67	11	848	24
Arbroath	340	54	—	—	83	2
Argyl	218	35	—	—	257	7
Auk	517	82	—	—	98	3
Beechnut	—	—	—	—	—	—
Clyde	405	64	—	—	138	4
Cod	—	—	21	3	489	14
Duncan	49	8	—	—	69	2
Edda	114	18	—	—	353	10
Ekofisk	7,099	1,129	404	64	21,189	600
Eldfisk	1,589	253	—	—	7,249	205
Erskine	—	—	—	—	—	—
Flyndra	—	—	—	—	—	—
Forties	4,333	689	—	—	1,313	37
Fulmar	812	129	—	—	499	14
Gannet	800	127	—	—	1,000	28
Gert	—	—	—	—	—	—
Gyda	—	—	—	—	—	—
Hod	236	38	—	—	207	6
Innes	19	3	—	—	43	1
Joanne	—	—	—	—	—	—
Josephine	—	—	—	—	—	—
Judy	—	—	—	—	—	—
Kittiwake	175	28	—	—	60	2
Lomond	—	—	—	—	—	—
Lulu(Harald)	—	—	—	—	—	—
Marnock	—	—	—	—	—	—
Montrose	327	52	—	—	114	3
N7/11-5	210	33	—	—	236	10
N2/2 Struct.	—	—	—	—	—	—
Sam	—	—	—	—	—	—
Tommeliten	94	15	50	8	330	9
Tor	539	86	—	—	788	71
Ula	825	131	—	—	413	12
Ula Trend	600	95	—	—	450	13
Valhal	1,405	223	66	10	1,823	52
Fiddich	—	—	—	—	—	—
West Ekofisk	—	—	84	13	1,315	37
Sums	**20,706**	**3292**	**692**	**110**	**39,361**	**1167**

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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Introduction

The Ellesmerian(!) petroleum system of the North Slope, Alaska, contains approximately 77 billion bbl of oil equivalent (Bird, 1994). The age of the reservoir rock ranges from Mississippian to early Tertiary. Total organic carbon and assumed hydrogen indices from the marine shale source rocks indicate the mass of petroleum generated to be approximately 8 trillion barrels of oil (Bird, 1994). These estimates indicate about 1% of the generated hydrocarbons are contained in known traps. More importantly, the U.S. Geological Survey estimates another 1% is trapped in undiscovered accumulations in the Ellesmerian(!) petroleum system (Bird, 1994).

Geologic setting

The North Slope evolved from a passive continental margin to a foredeep during the Jurassic. Prior to the Jurassic, Paleozoic and Mesozoic strata were deposited on a passive continental margin. They consist of Carboniferous platform carbonate rocks and Permian to Jurassic shelf to basinal siliciclastic rocks. The passive margin converted to a foredeep during the Jurassic and Cretaceous when it collided with an ocean island arc. The foredeep began to fill with sediments in the Middle Jurassic and continues to do so.

The foredeep basin fill consists of orogenic sedimentary materials eroded from the nearby ancestral Brooks Range that were deposited as a northeasterly prograding wedge of nonmarine, shallow marine, basin-slope, and basin conglomerates, sandstones, and mudstones.

Petroleum system map

The map below shows the Ellesmerian(!) petroleum system geographic extent. The limit is determined by the extent of the contiguous active source rock and the related petroleum accumulations.

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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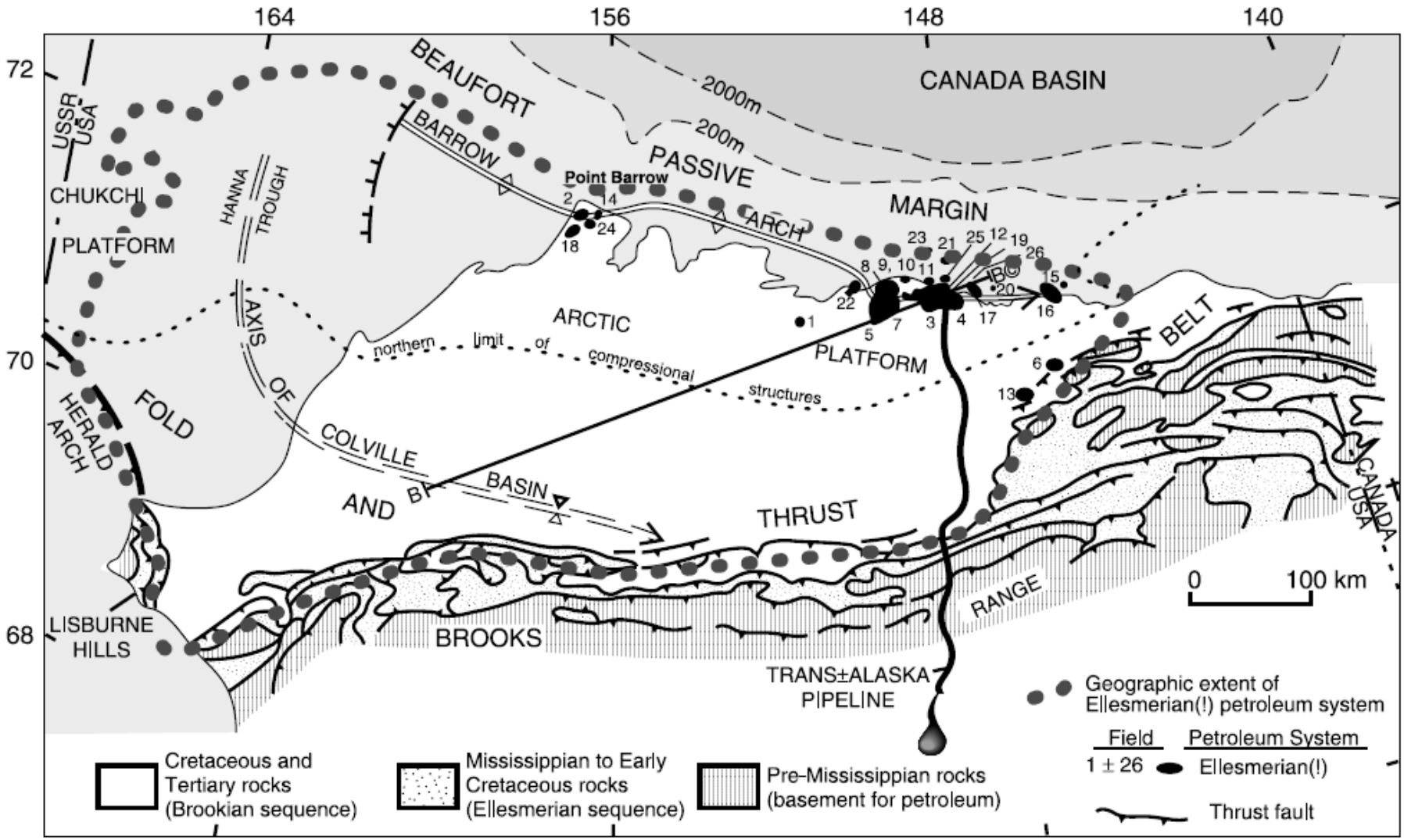

Figure 3–12. From Bird, 1994; courtesy AAPG.

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MAPA DE MATURIDADE

The map below shows the thermal maturity of the two main Ellesmerian(!) petroleum system source rocks, the Shublik Formation and the Kingak Shale. Note that Ellesmerian(!) petroleum system traps (shown in Figure 3–12) are mostly located above immature source rocks.

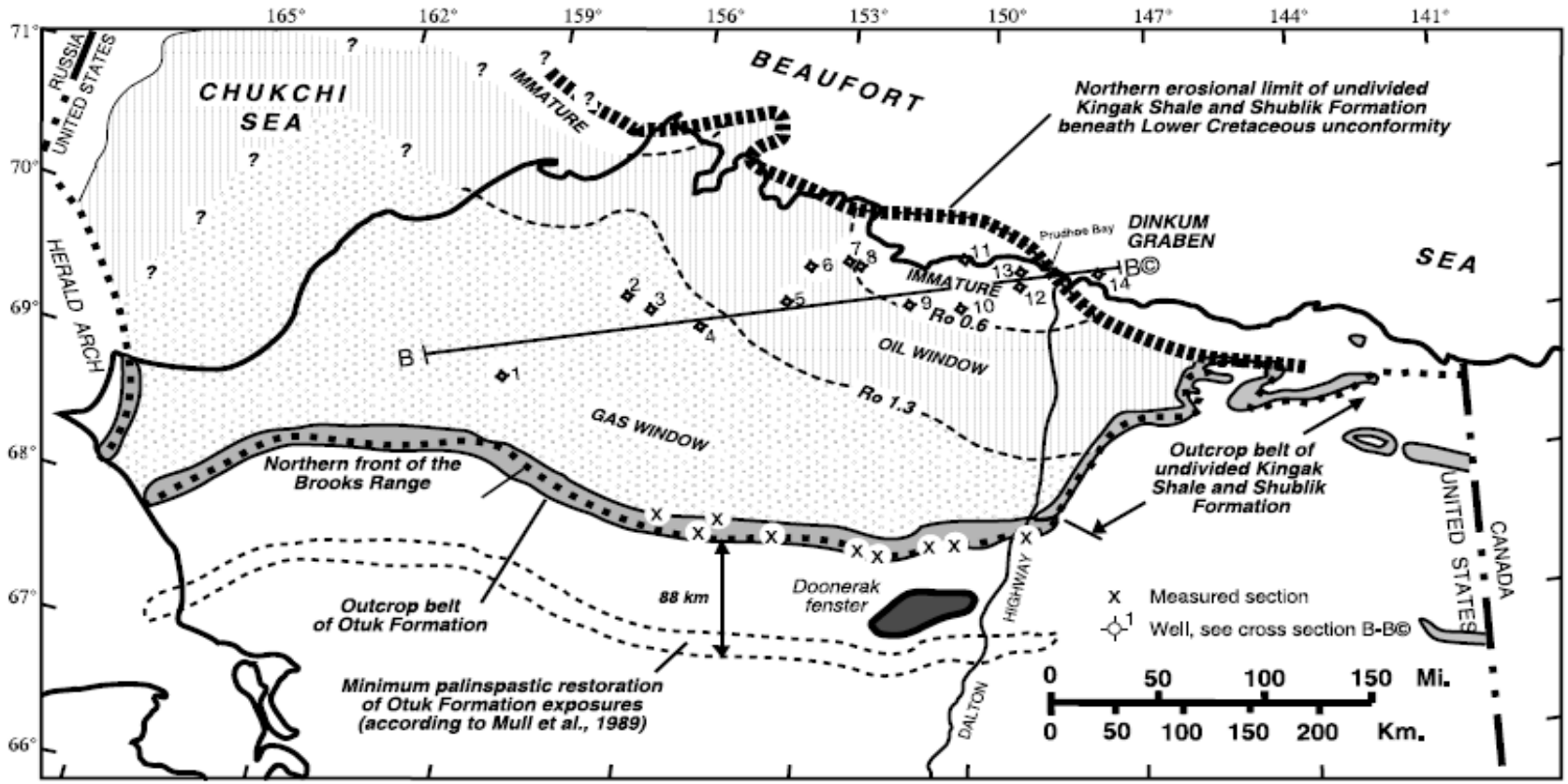

Figure 3–13. From Bird, 1994; courtesy AAPG.

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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SECÇÃO

The cross section of the Ellesmerian(!) petroleum system (below) shows major structural–stratigraphic elements, the occurrence of oil fields, elevation of selected vitrinite reflectance values, and reflectance isograds. For the location, refer to Figure 3–12.

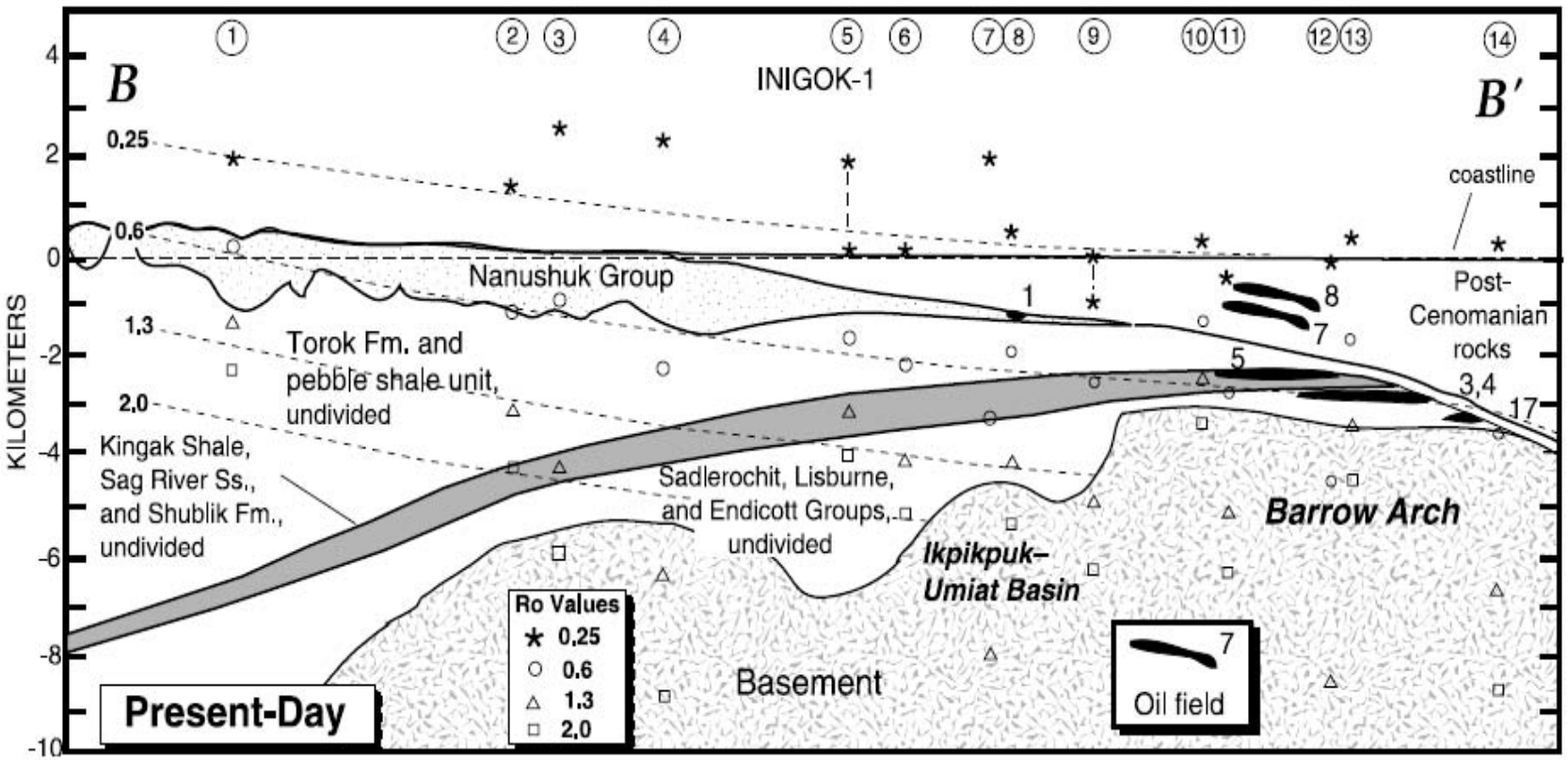

Figure 3–14. From Bird, 1994; courtesy AAPG.

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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Burial history chart

Analysis of the burial history chart of the Inigok 1 well (below) and other burial history charts indicates peak petroleum generation (the critical moment) probably occurred in Late Cretaceous time (approximately 75 Ma) in the western North Slope and in early Tertiary time (approximately 50 Ma) in the central and eastern part of the North Slope. Also, note the large increase in the rate of sedimentation during the Early Cretaceous.

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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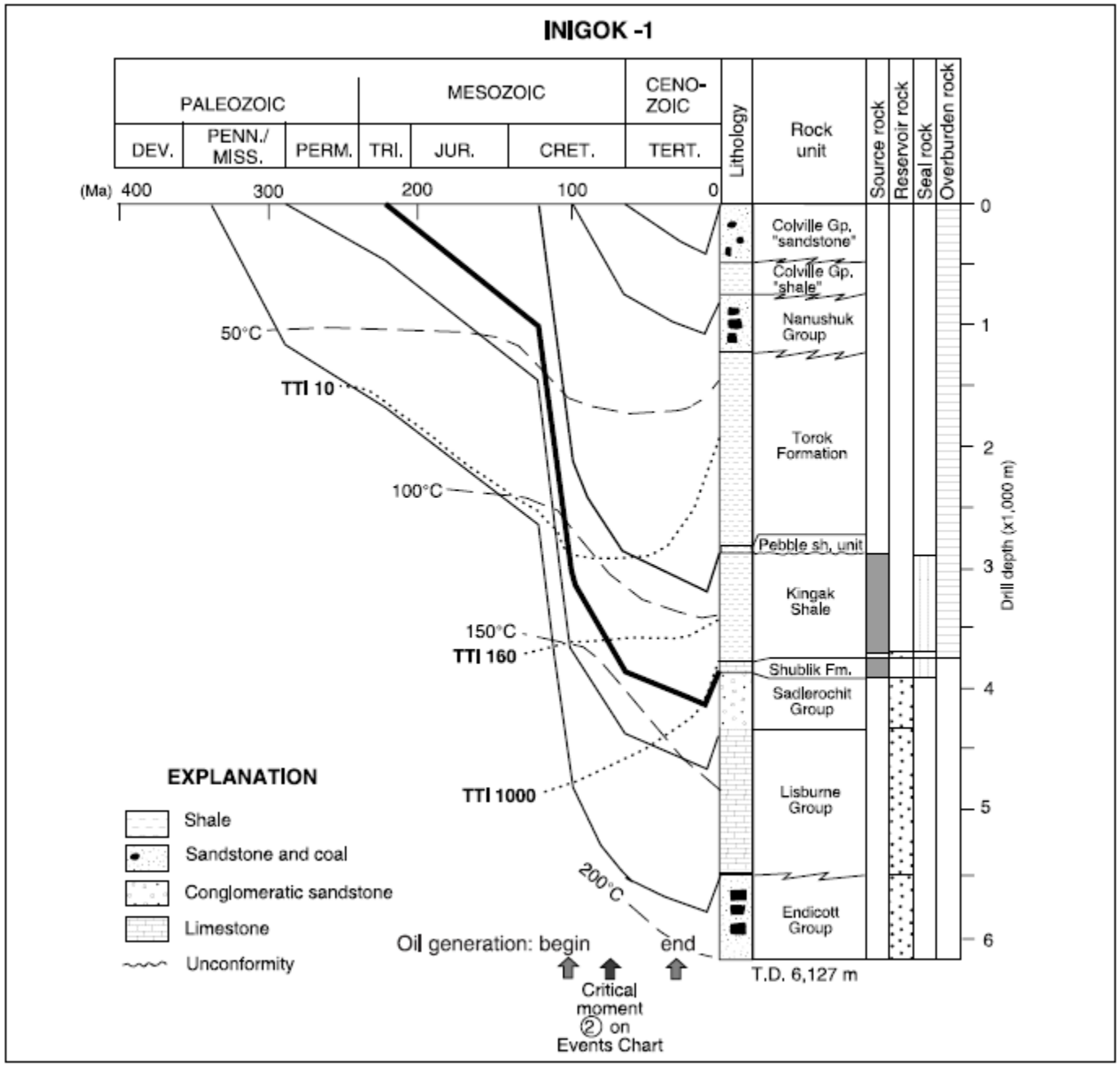

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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Oil–source rock correlation

Biological marker analysis (below, left) from the main reservoir rock, Sadlerochit Group, of Prudhoe Bay field shows that the oil originated from the Shublik Formation, the Kingak Shale, and the Hue Shale. Carbon isotopic composition comparisons (below, right) indicate that Shublik and Kingak share similar ^{13}C values with oil from the Prudhoe Bay field, whereas the Hue Shale does not.

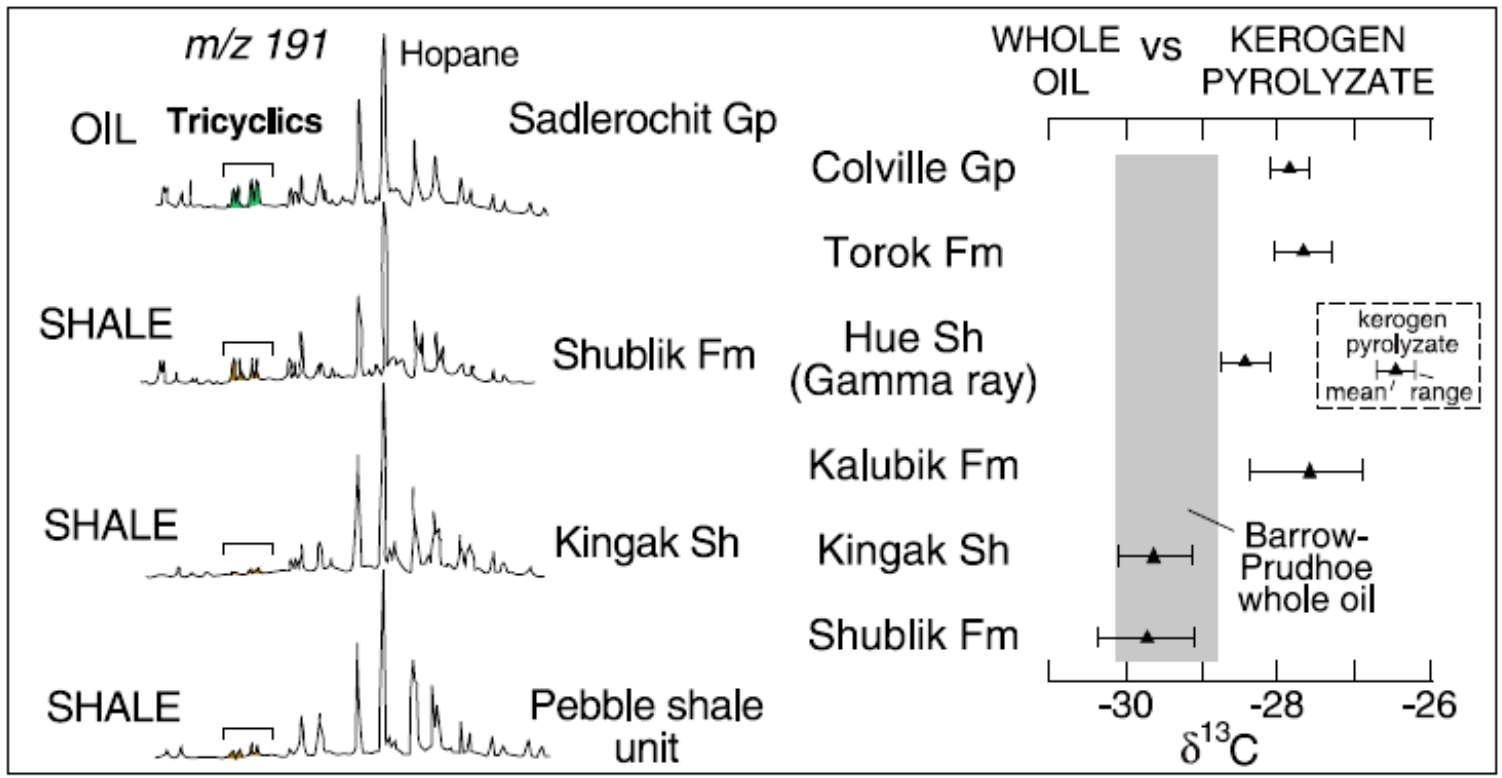

Figure 3–16. (left) From Seifert et al., 1980; courtesy World Petroleum Conference. (right) From Sedivy et al., 1987; courtesy Pacific Section of SEPM.

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SISTEMA PETROLÍFERO ELLESMERIAN(!)

TABELA DE ACONTECIMENTOS

The events chart below for the Ellesmerian(!) petroleum system indicates when its elements and processes occurred. The cross-hatched pattern shows the estimated time of the tilting of the Barrow Arch, which resulted in remigration of petroleum from older to younger (early Tertiary) reservoir rocks.

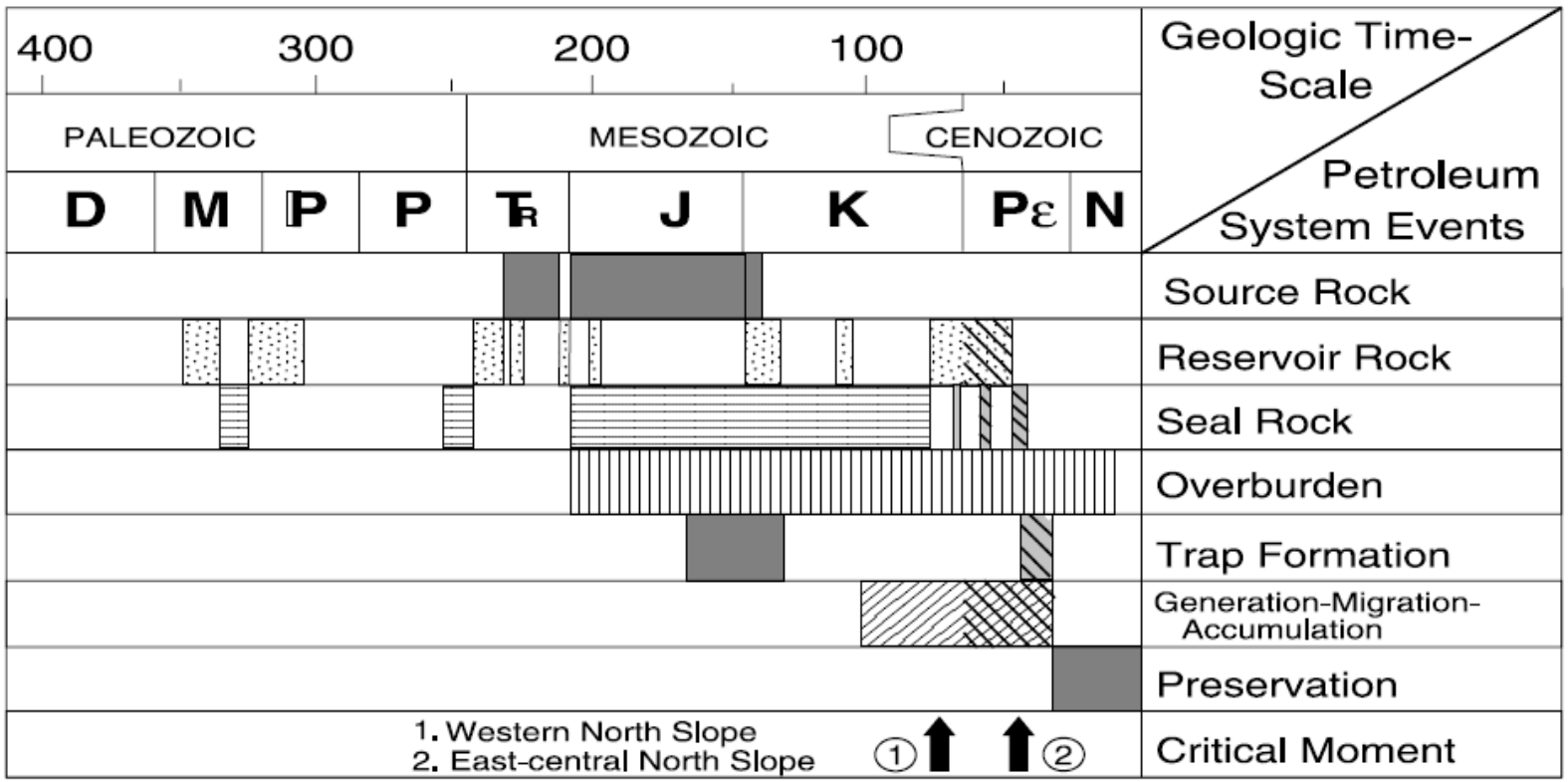

Figure 3–17. From Bird, 1994; courtesy AAPG.

SISTEMA PETROLÍFERO ELLESMERIAN(!)

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Size of the petroleum system

The size of the Ellesmerian(!) petroleum system, shown in the table below, is determined by the total volume of in-place petroleum that originated from the pod of active Ellesmerian(!) petroleum system source rock. The in-place petroleum is determined from the recoverable petroleum and, where possible, surface deposits, seeps, and shows. In the table below, trap type A is structural, B is stratigraphic, and C is combination.

Map ID	Accumulation	Res. Depth (m)	Trap Type	In Place Oil (Bbbl)	In Place Gas (Tcf)	Cum. Prod. Oil (Mbbl)	Cum. Prod. Gas (Bcf)	Reserves Oil (Mbbl)	Reserves Gas (Bcf)
1	Fish Creek	915	B?	<<1	—	—	—	?	?
2	South Barrow	685	A	—	<<1	—	20	—	5
3	Prudhoe Bay	2440	C	23	27	7026	11951	2700	23441
4	Prudhoe Bay	2685	C	3	3	64	382	101	406
5	Kuparuk River	1830	C	-4	-2	723	814	780	634
6	Kavik	1435	A	—	<1	—	—	—	?
7	West Sak		B?	20	<<1	1	—	—	—
8	Ugnu		B?	15	—	—	—	—	—
9	Milne Point		A	<1	<<1	—	—	—	?
10	Milne Point		A	<1	<<1	16	6	84	?
11	Gwydyr Bay		A	<1	<<1	—	—	60	?
12	North Prudhoe		A	<1	<<1	—	—	75	?
13	Kemik	2625	A	—	<1	—	—	—	?
14	East Barrow		A	—	<<1	—	6	—	6
15	Flaxman Island	3810	B?	?	?	—	—	?	?
16	Point Thomson	3960	C	<1	6	—	—	350	5000
17	Endicott		C	1	<2	118	127	272	907
18	Walakpa		B	—	<<1	—	—	—	?
19	Niakuk		C	<1	<<1	—	—	58	30
20	Tern Island		C	?	?	—	—	?	?
21	Seal Island		A	<1	<1	—	—	150	?
22	Colville Delta	1950	C?	?	?	—	—	?	?
23	Sandpiper		A	?	?	—	—	?	?
24	Sikulik		A	—	<<1	—	—	—	?
25	Point McIntyre		C	1	?	—	—	-300	?
26	Sag Delta North		C	<1	<<1	2	2	?	?
	TOTALS			**>67**	**>39**	**7950**	**13308**	**4930**	**30423**

From Bird, 1994; courtesy AAPG.