Basin Types and Their Exploration and Production

Reserves and Resources

Content Review

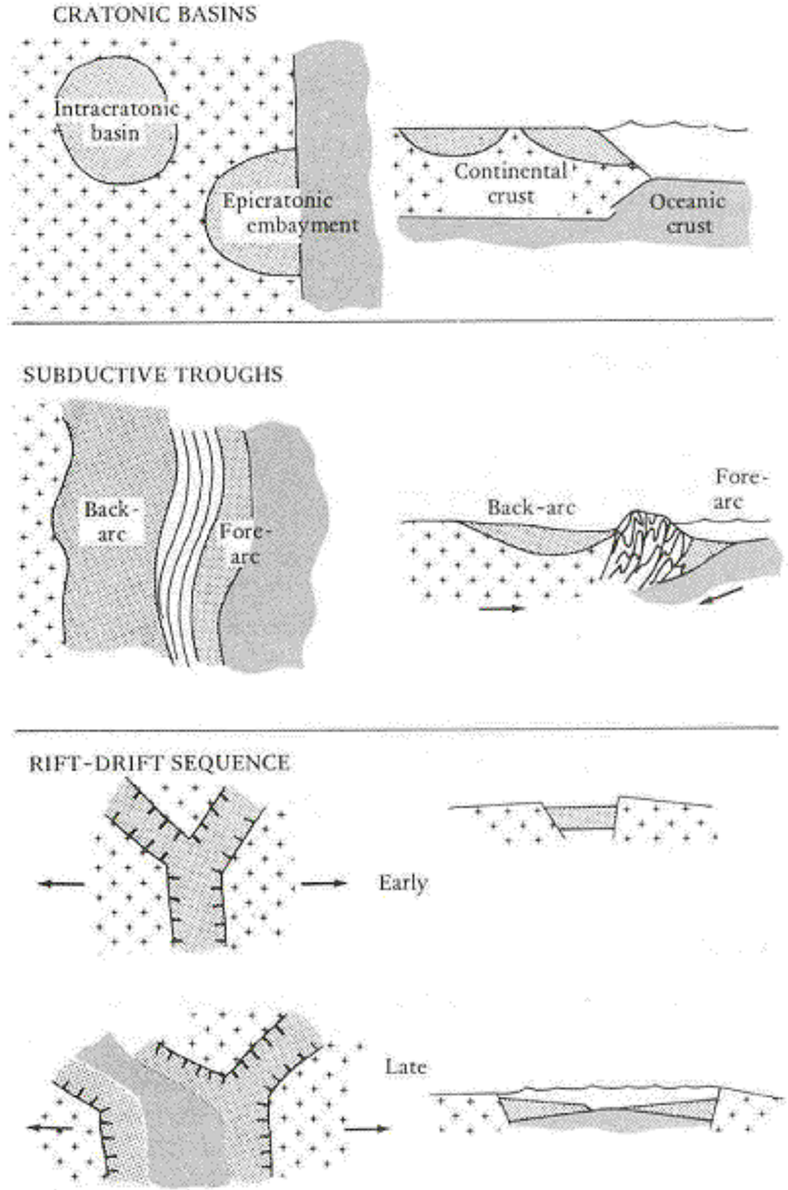
- Why it matters: Some basics
- History of petroleum
- The carbon cycle, organic matter and maturation
- Composition of oil and gas
- Migration from source to reservoir
- Reservoir rock properties
- Trapping
- Basin types and their exploration and development
- Reserves and resources

Basin Types

This is a very simplified representation depicting the various sedimentary basin types. Transitions from one type to another are possible.

Notice that topographic gradients are in general conducive to increased sediment transport and deposition. These often occur at basement boundaries.

Which plate-tectonic situation is not depicted? How would those basins look like?



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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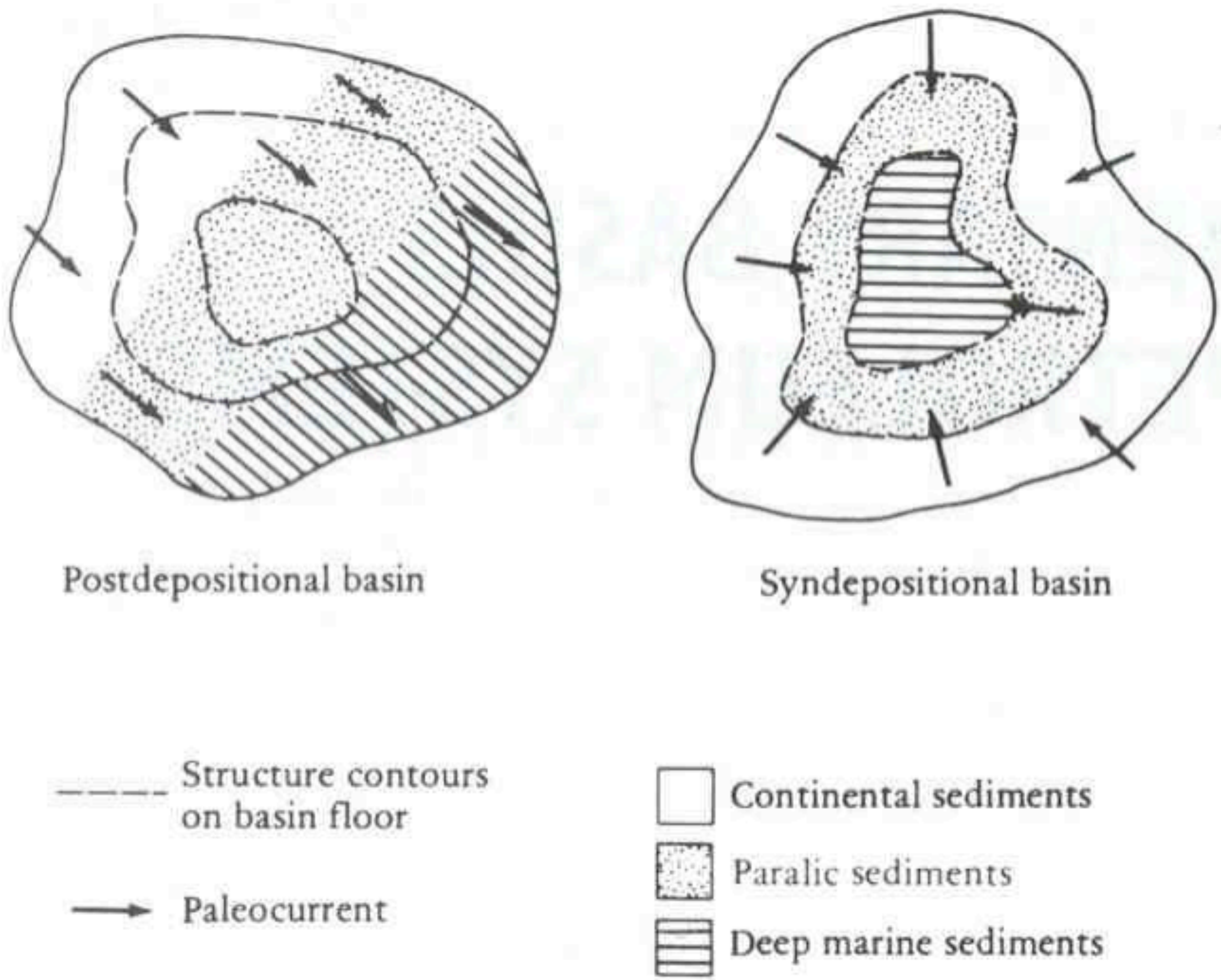
Basin Types /2

In a post-depositional basin there is no relationship between the basin infill and the basin floor contours, as the former occurred prior to the latter.

In a syn-depositional basin the sedimentary facies and basin contours are correlated.



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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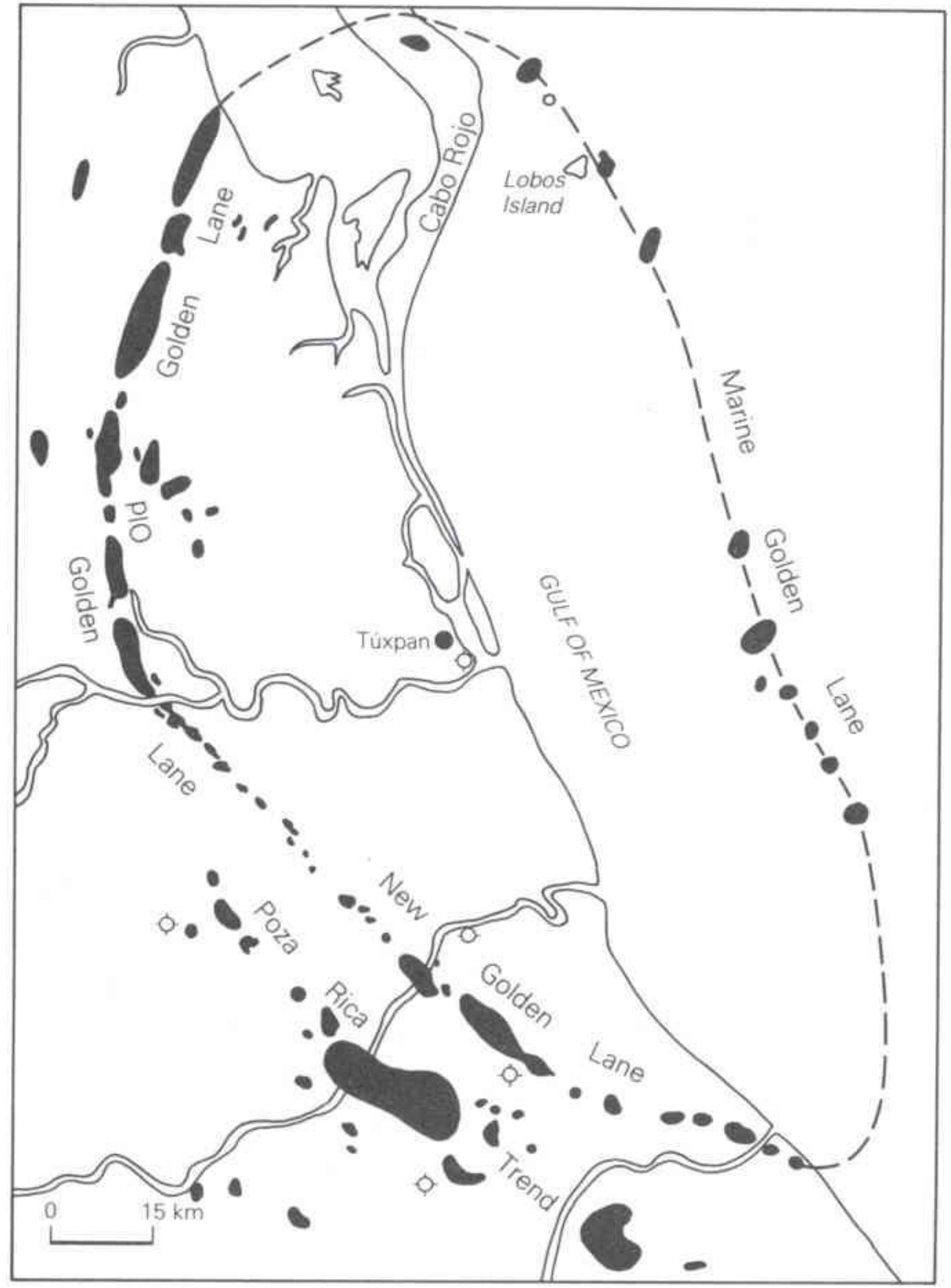
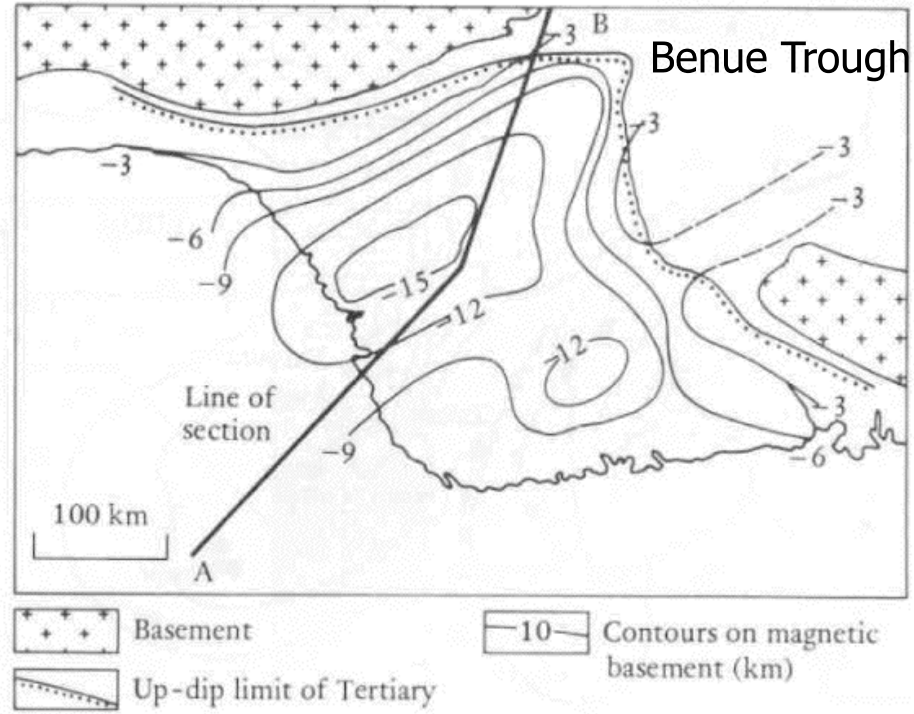


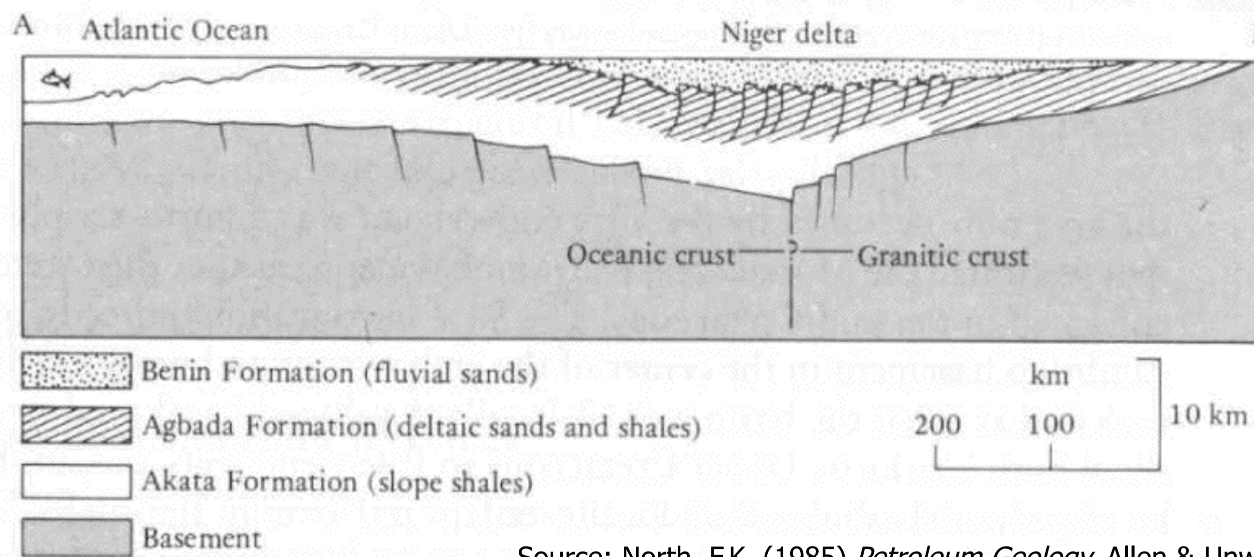
Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Case Study: Niger Delta

Notice the main elements on the sketch above: The magnetic signature, the transition from continental to oceanic crust, and the aulacogen rift branching off into the Benue trough.

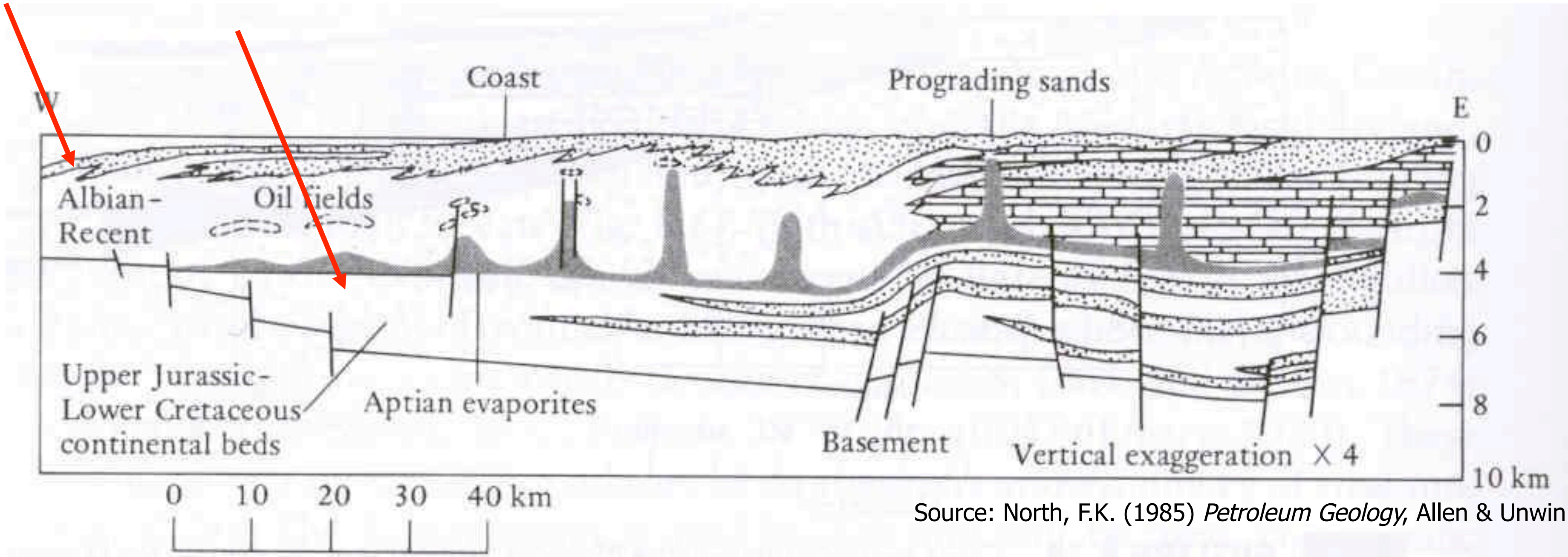
The main productive horizon is the Agbada Formation





Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Case Study: Gabon Basin (W. Africa)



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

An transgressive-regressive sequence caused by the rifting, drifting and collapse of the continental margin, followed by infill. The evaporitic phase was caused by enclosure of the initial South Atlantic by the Walvis Ridge in the south, leading to hyper-saline conditions. Today's prospects are all deep offshore turbidites and subsalt plays to the west of the cross-section (arrows). The Brazilian margin is almost an exact mirror-image of this cross-section.

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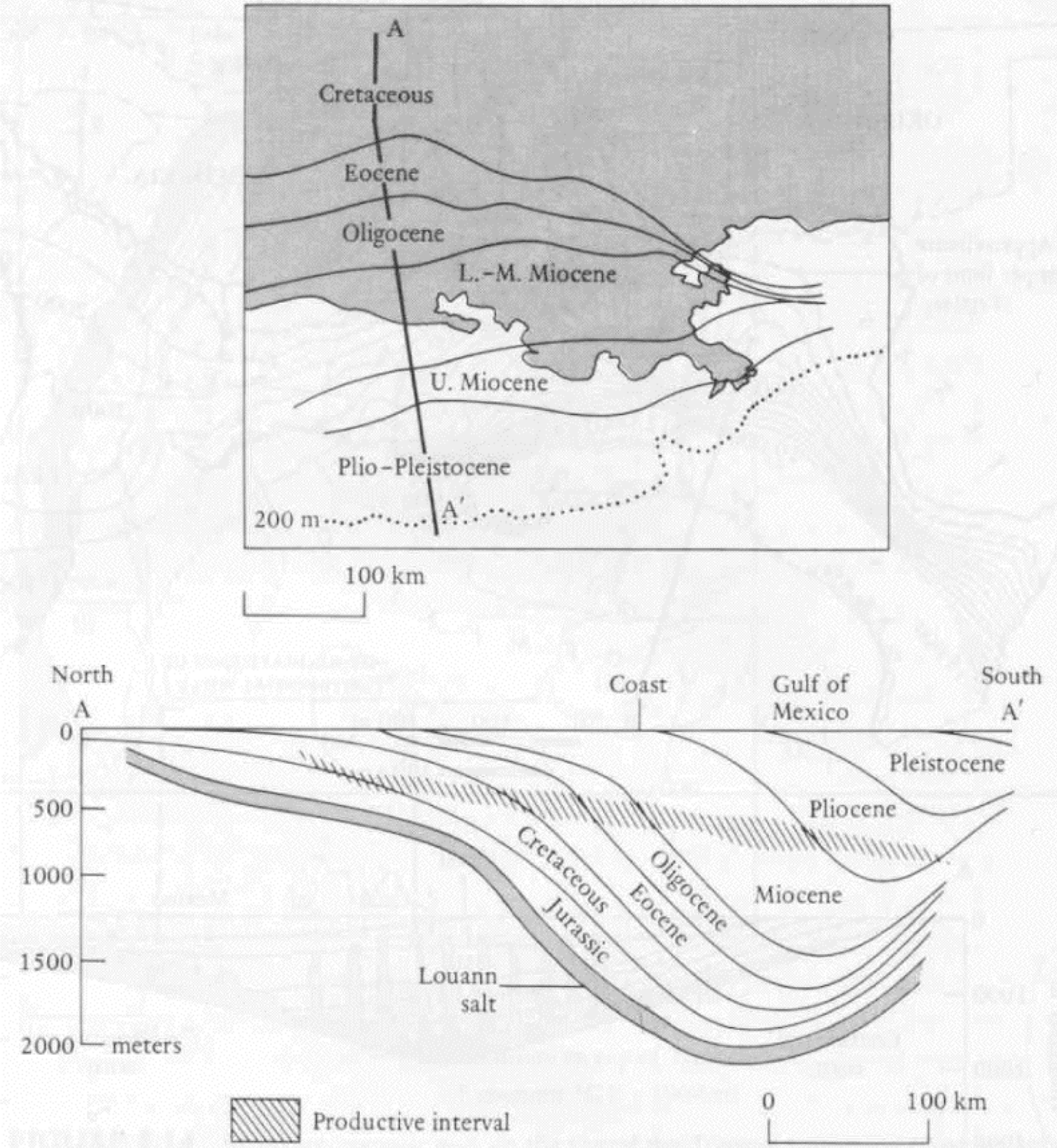
Case Study: Gulf of Mexico

Notice how the productive zones become progressively younger and deeper towards the south. This is a clear indication that time as well as temperature are important for maturation (remember the Lopatin TTI index!).

Why is the onshore productive zone so shallow?

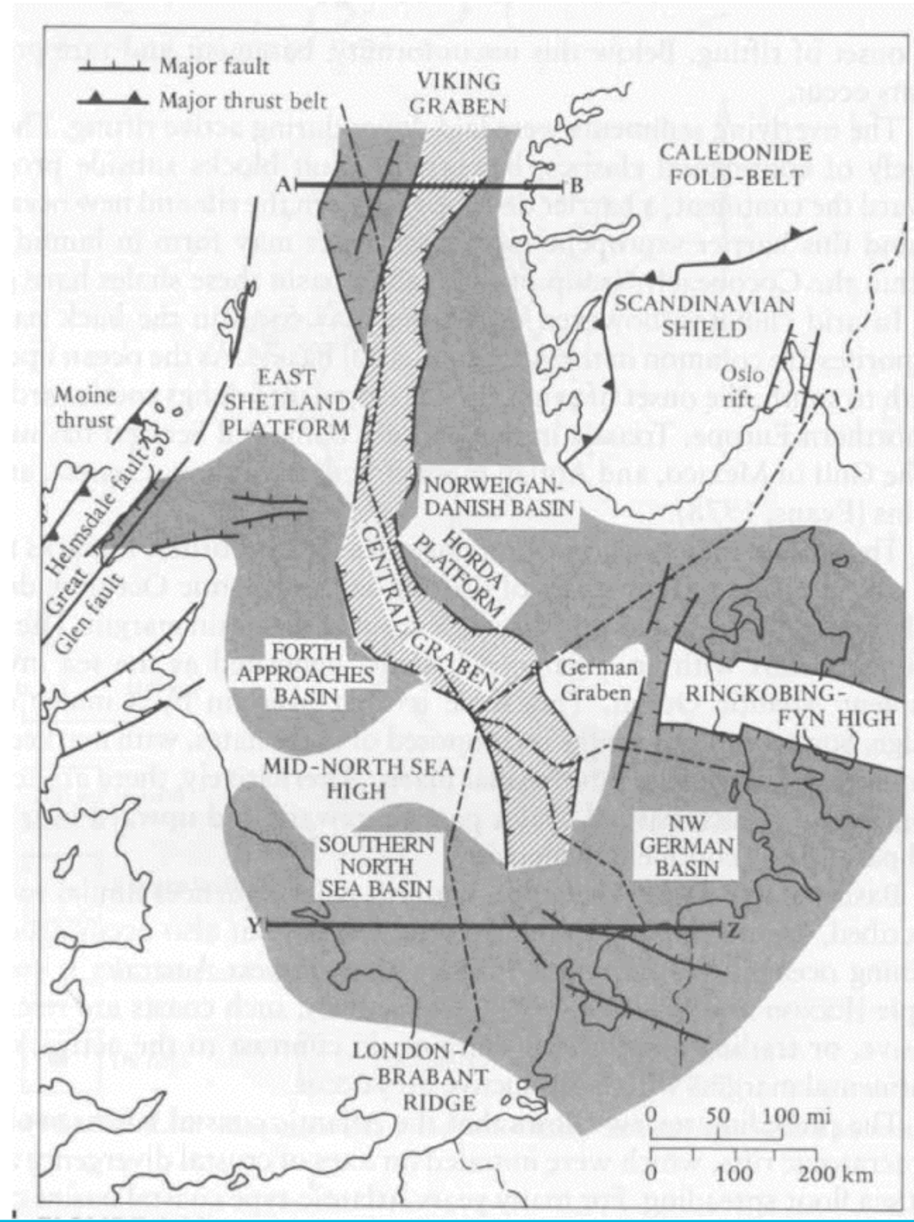


Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Case Study: North Sea

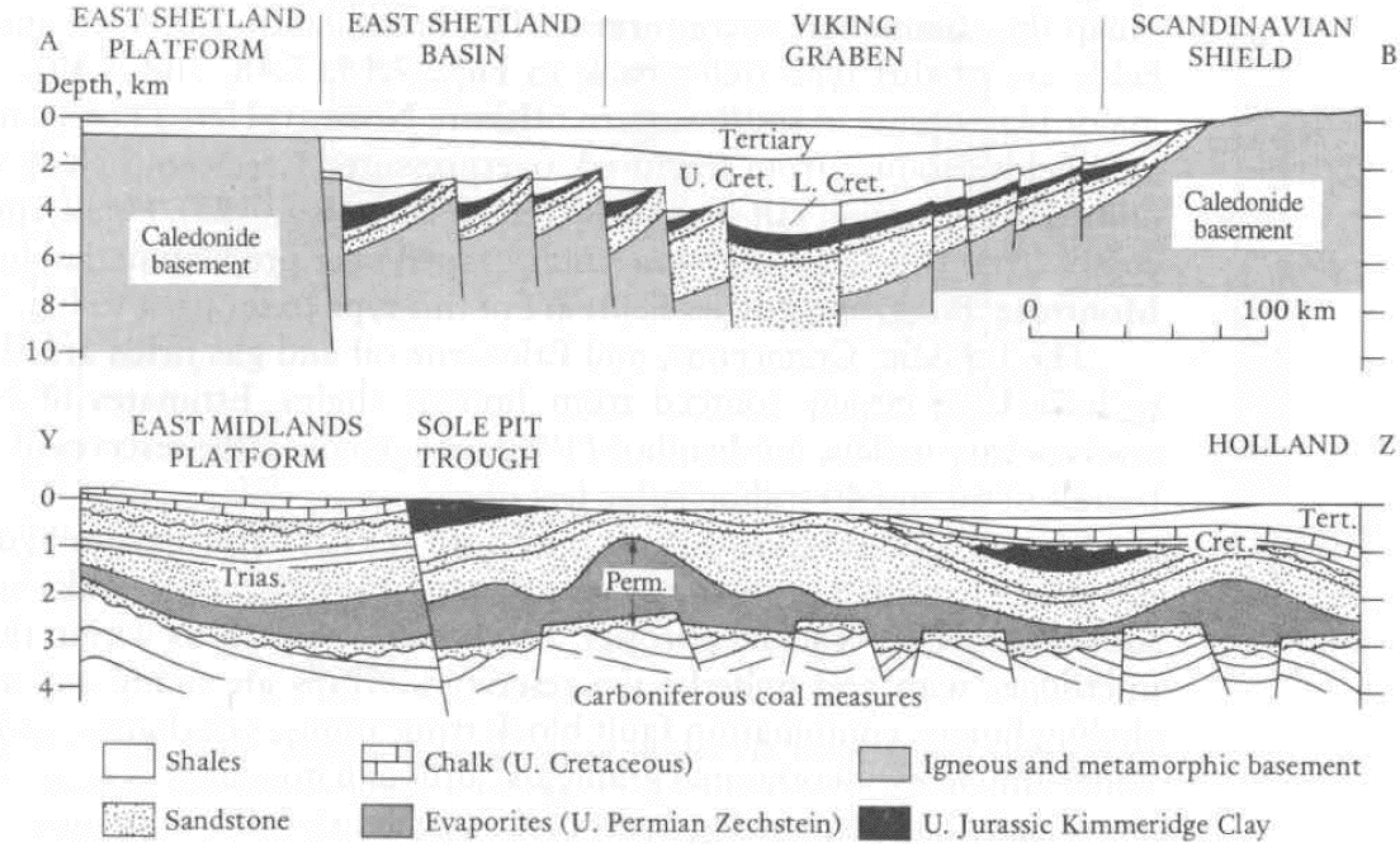
Shown are the tectonic units in the North Sea. The principal features are the graben formed during Jurassic rifting. Many oil and gas fields are related to these features, but the Rotliegend and the chalk fields in the South are not.

The next slide shows the two cross-sections A-B and Y-Z.



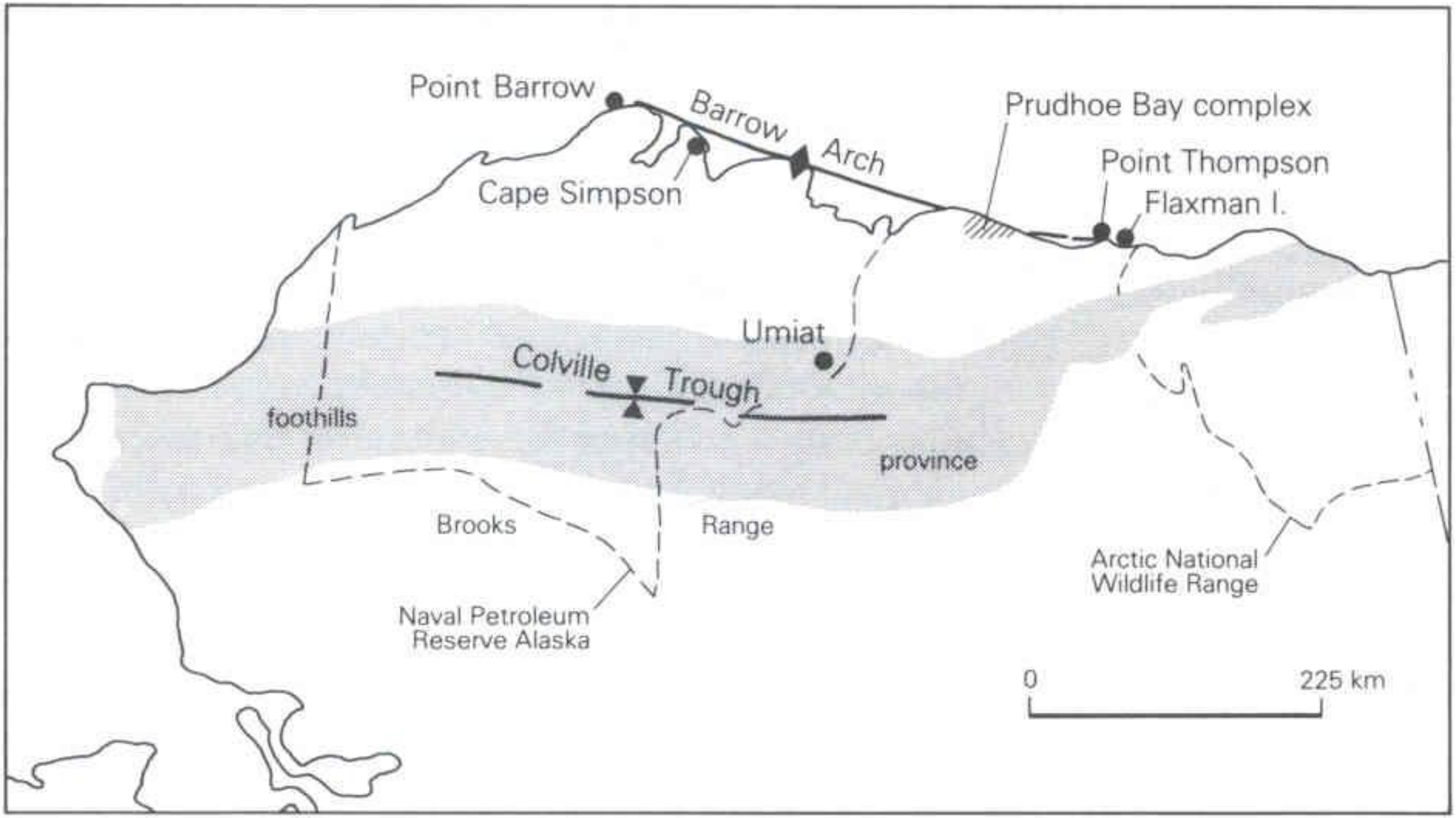
Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Case Study: North Sea /2



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Case Study: Alaskan North Slope



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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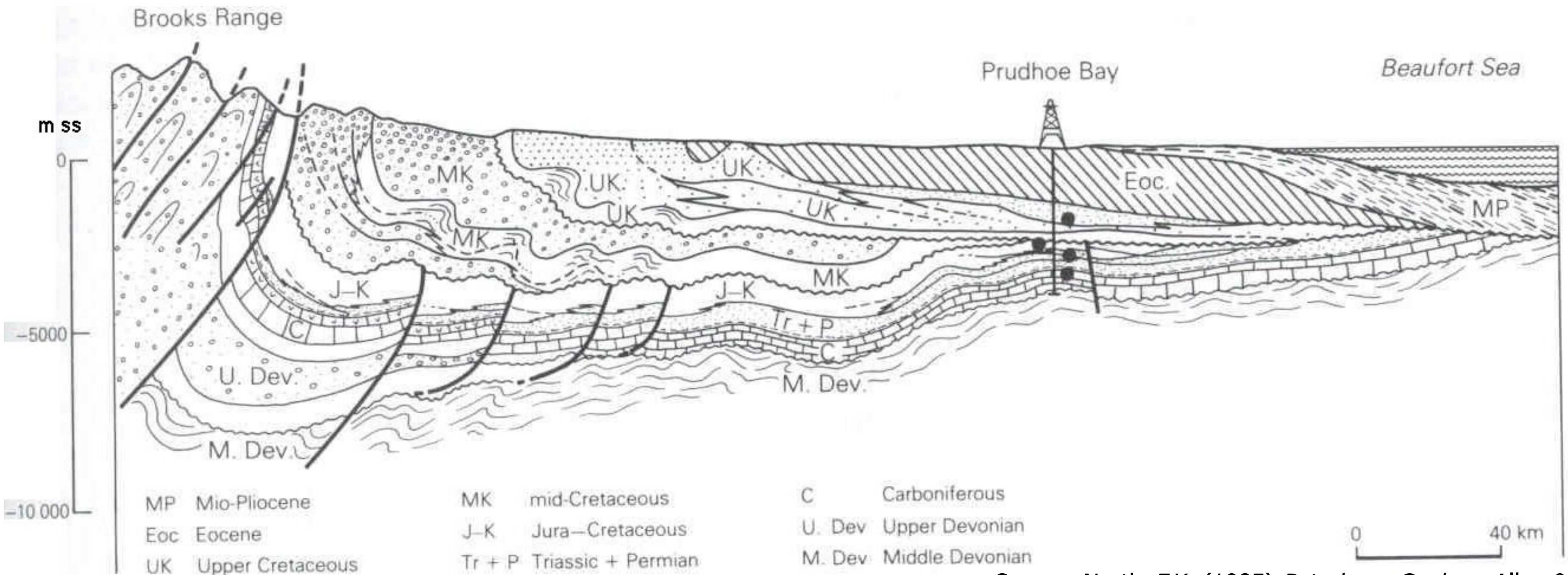
Case Study: North Slope - Prudhoe Bay



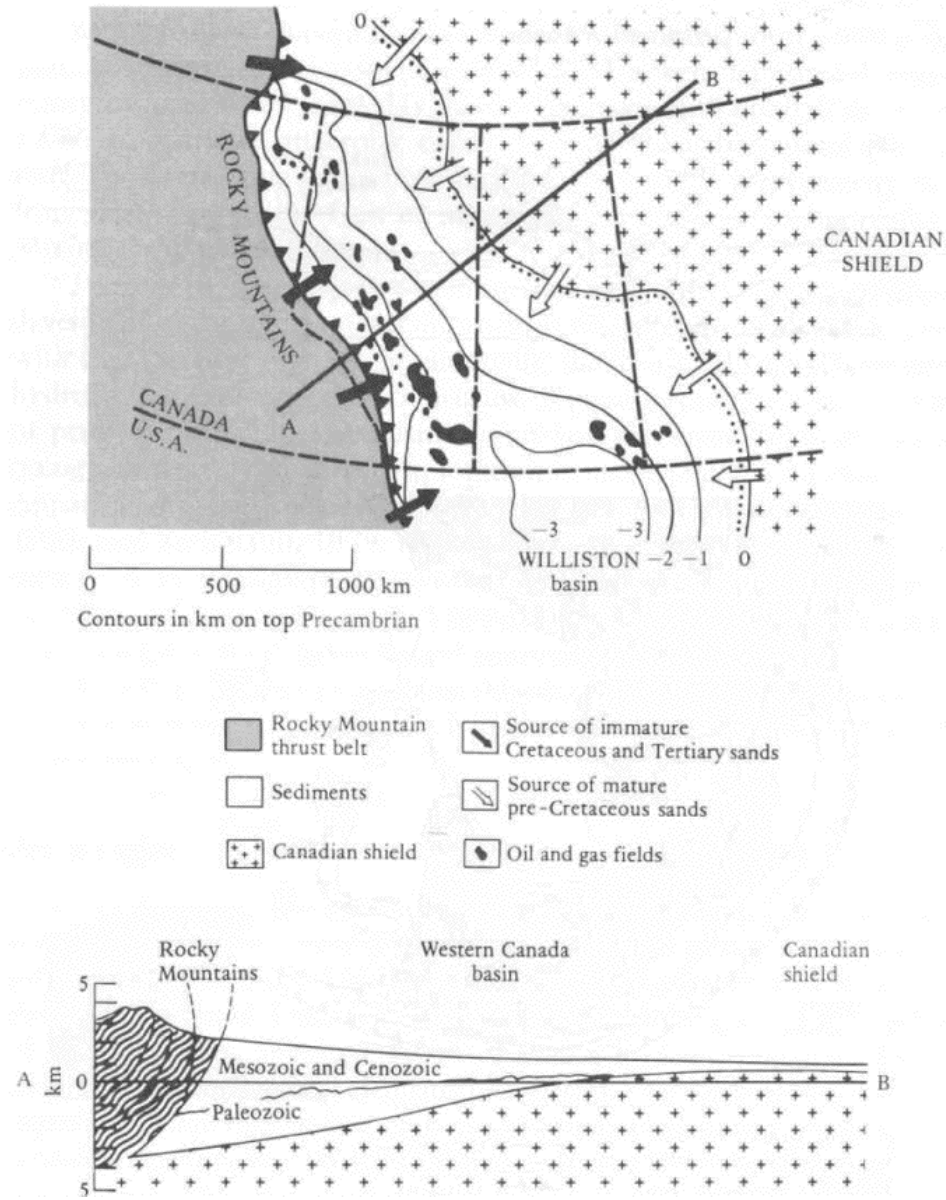
Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Example of a fore-arc basin. Notice the decreasing influence of tectonic deformation with distance away from the Brooks Range. At the Barrow Arch (previous slide) there is only gentle arching without major faulting. Here the best trapping conditions are found. Notice also the presence of an unconformity, which makes this a giant combination trap.

Case Study: Alberta Basin

The Western Canada trough is a major hydrocarbon province that includes the giant Elmsworth gas field. This is a retroarc-foreland basin; it was originally created as a backarc basin due to subduction in the West, then thrusting led to sagging of the continental crust and sedimentary infill.

Notice the change in sediment transport direction through time. It reflects the uplifting of the Rocky Mountain chain.



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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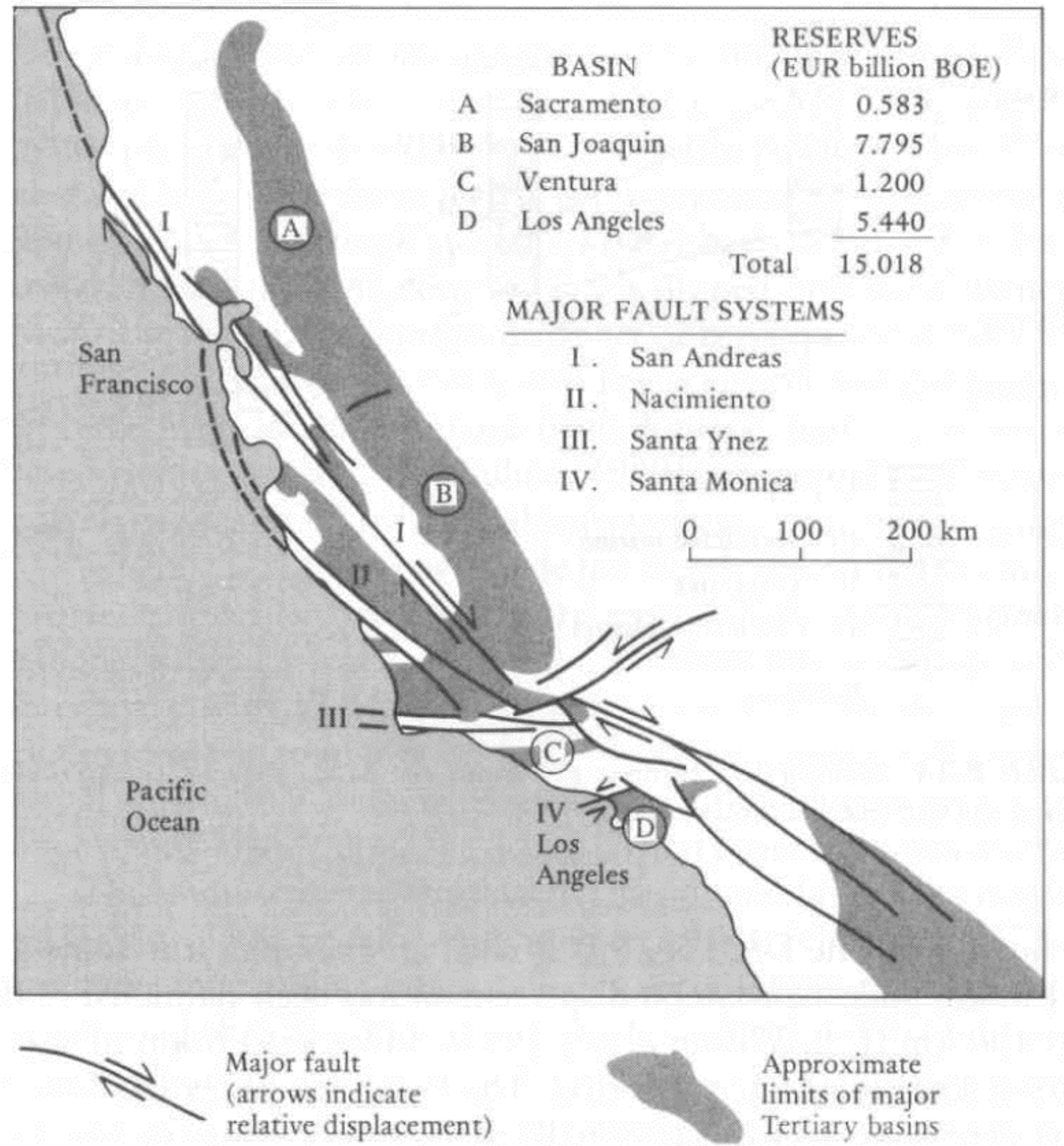
Case Study: California

The basins found here are back-arc, strike-slip and pull-apart basins, some with very deep infills. Most reservoirs are in Late Tertiary sandstones and some contain very young oil (Plio- to Pleistocene)



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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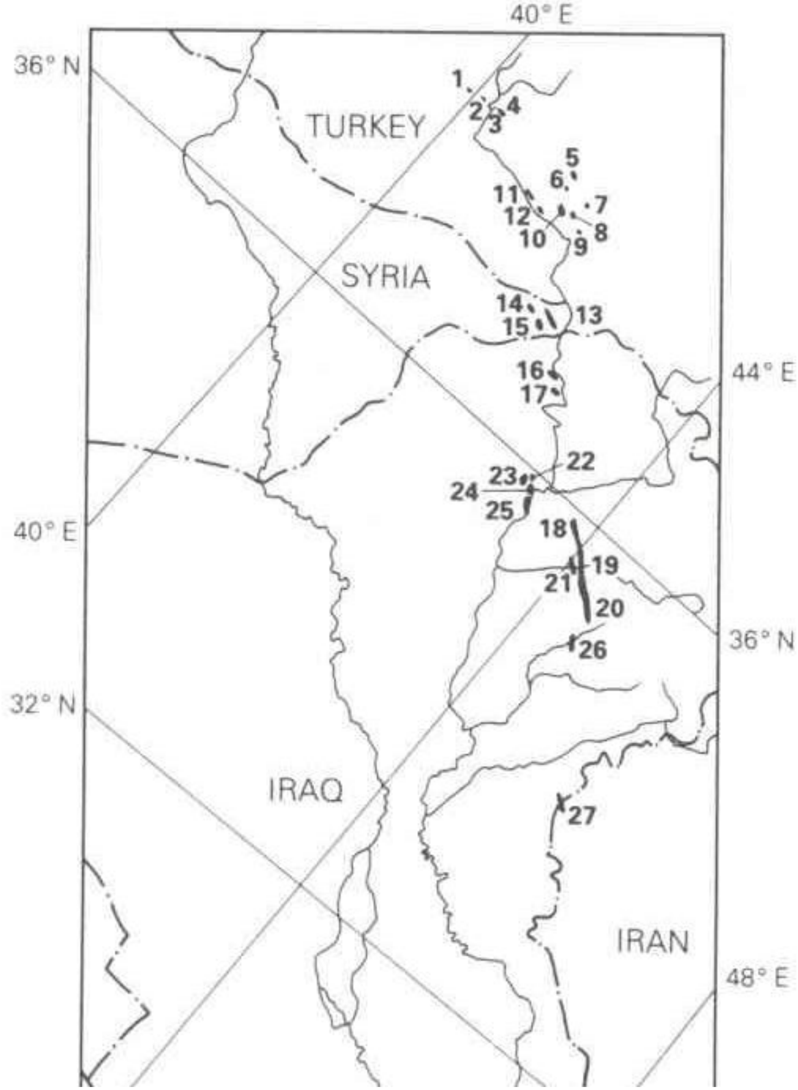
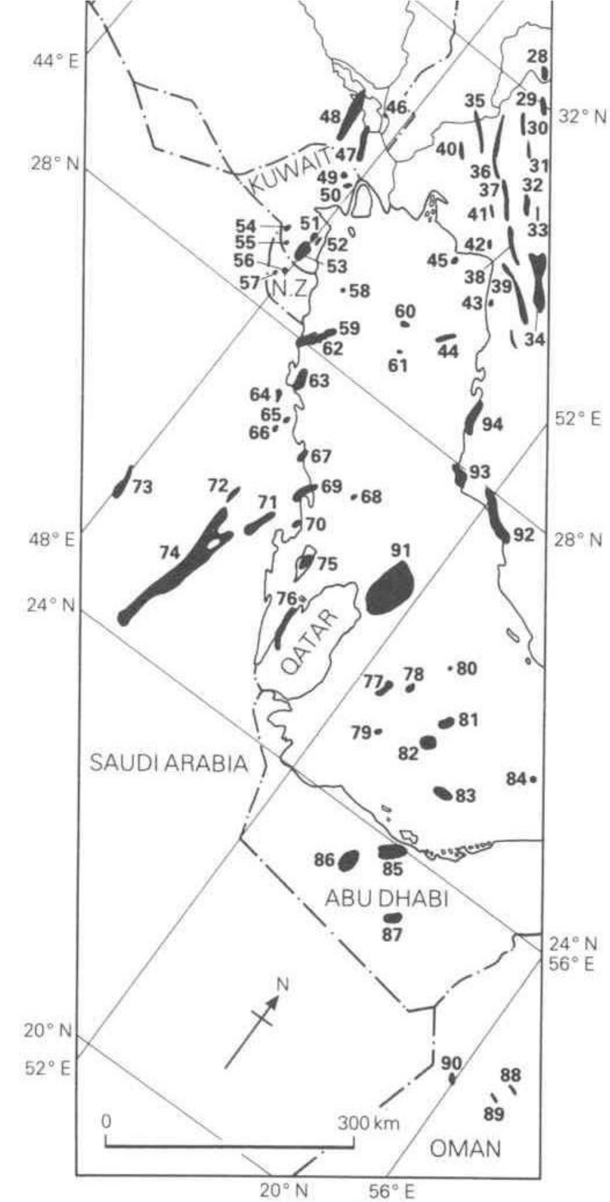
Case Study: Middle East

Case Study: Middle East /2

Observe the alignment and shape of the fields in the different parts of the Middle East.

Try to interpret the origin of their structures.





Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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Case Study: Middle East /3

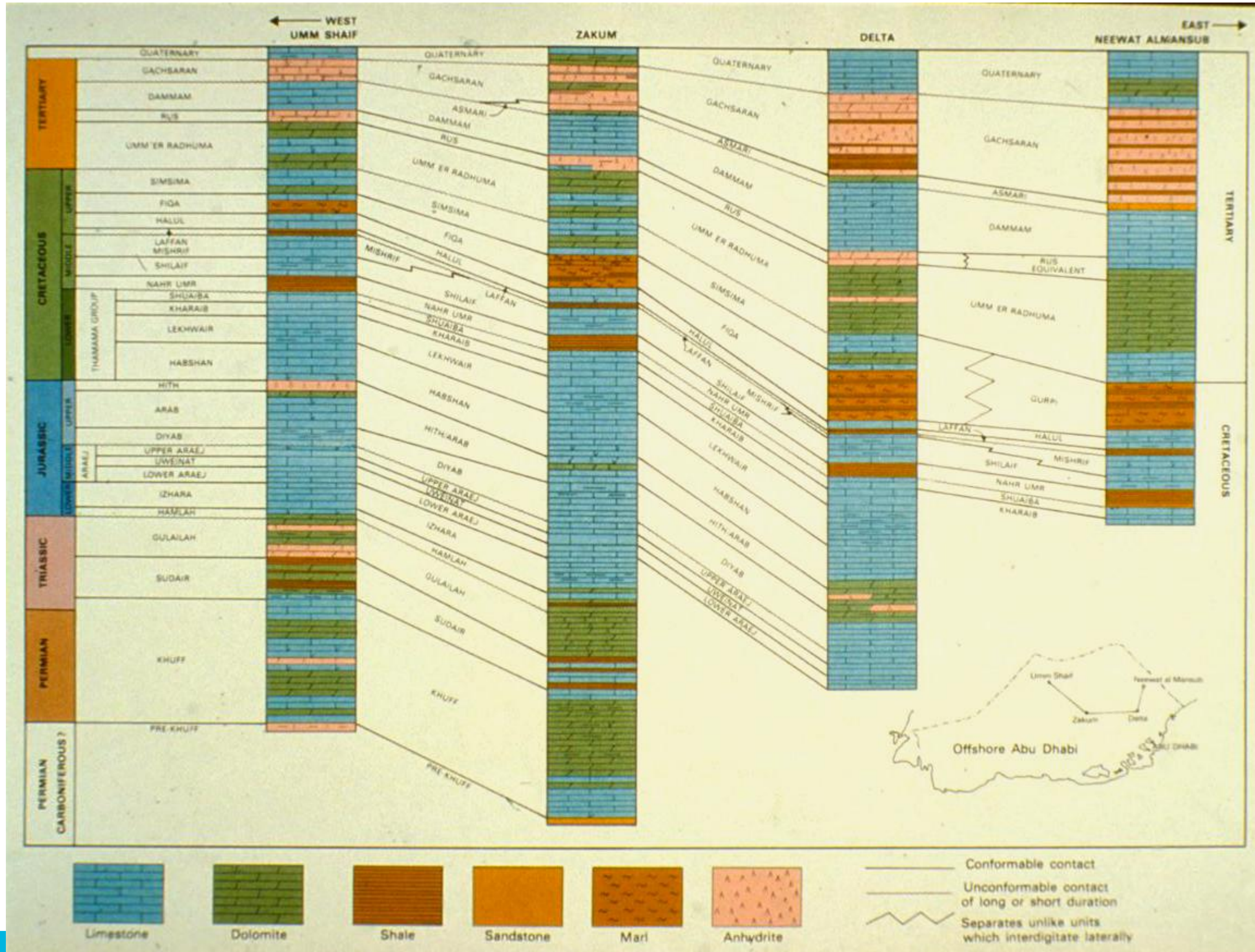

Fig. 1-8 — Stratigraphic correlation of Abu Dhabi offshore wells.

Source: Murris, R. J. (1980) *Middle East; stratigraphic evolution and oil habitat,* AAPG Bulletin

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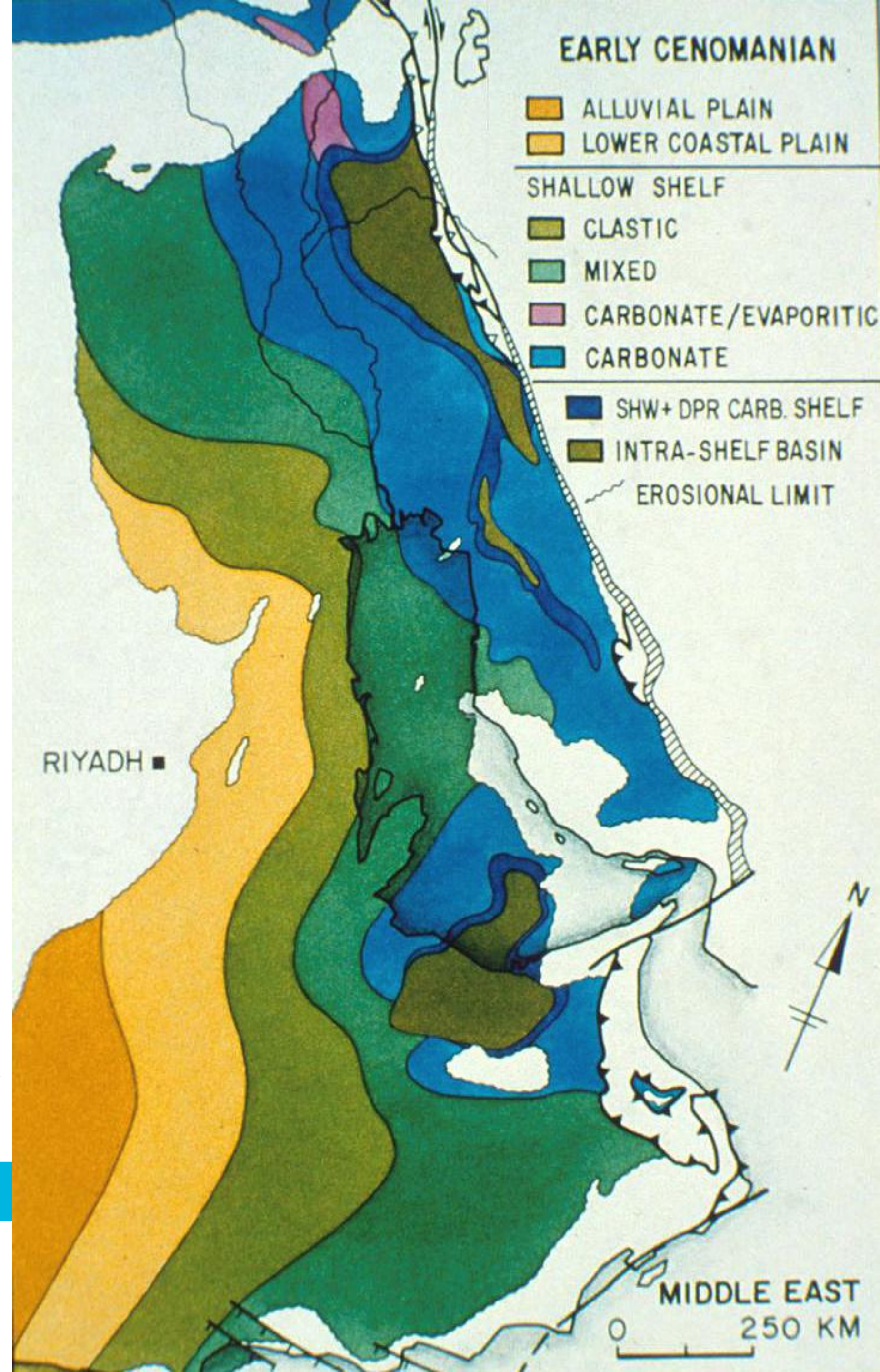
Case Study: Middle East /4

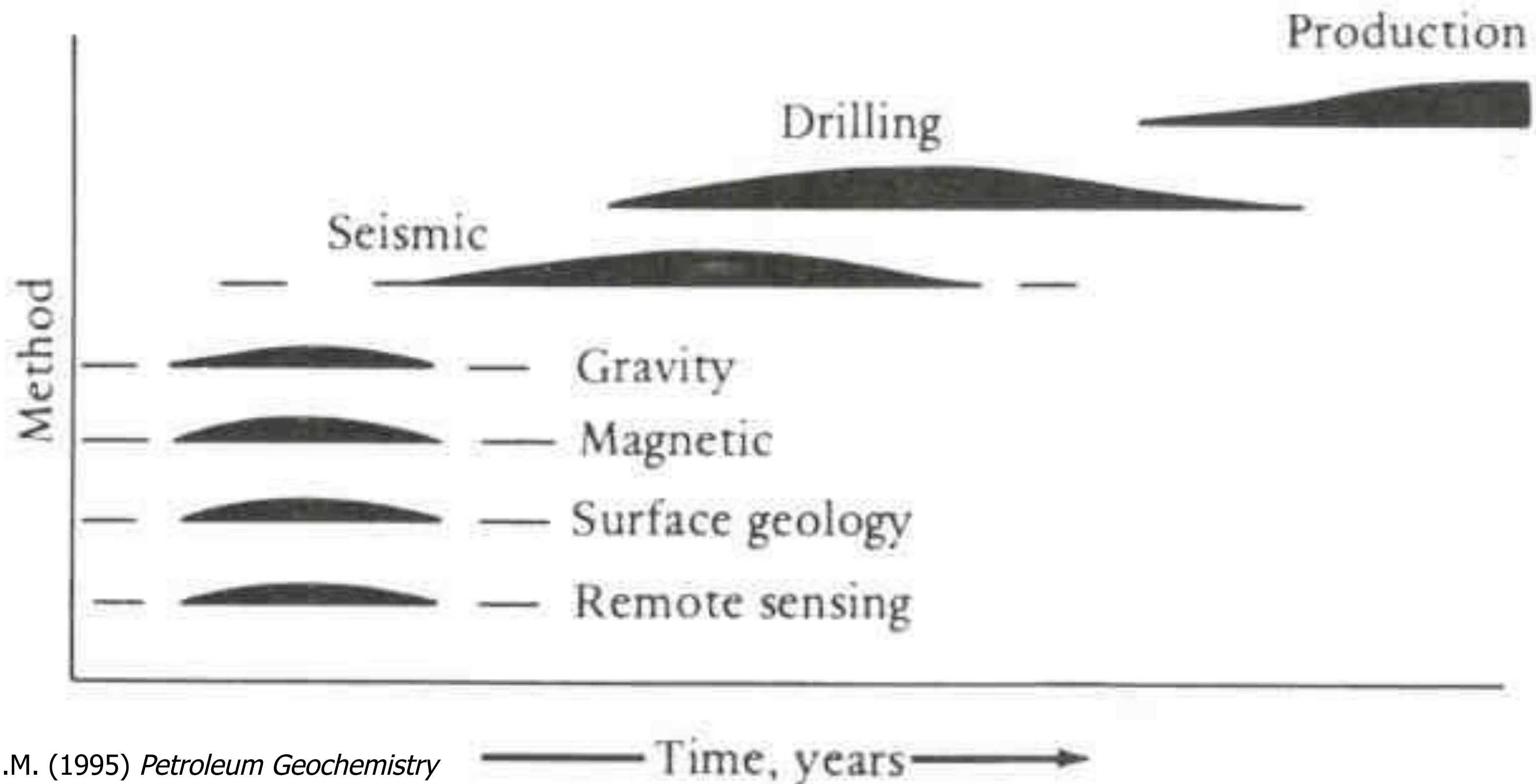
Situation during the Early Cenomanian. Notice the gentle, monotonic changes across the platform, and incipient thrusting along the Zagros thrust.

Compare this paleogeographic reconstruction with the present-day situation and comment on the differences.



Source: Murris, R. J. (1980) *Middle East; stratigraphic evolution and oil habitat,* AAPG Bulletin

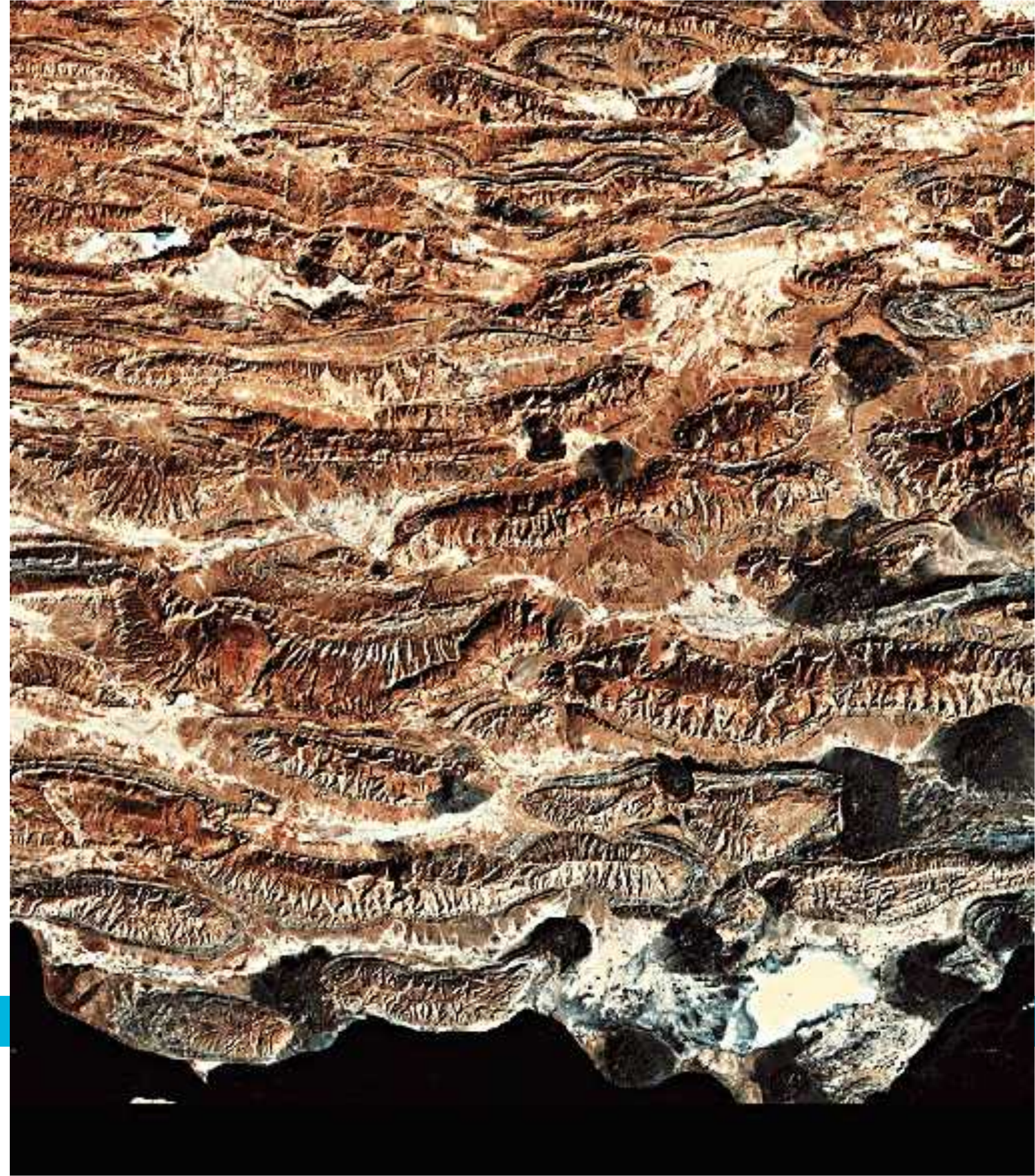
Exploration and Production



Source: Hunt, J.M. (1995) *Petroleum Geochemistry and Geology*, 2nd edition. W.H. Freeman & Co

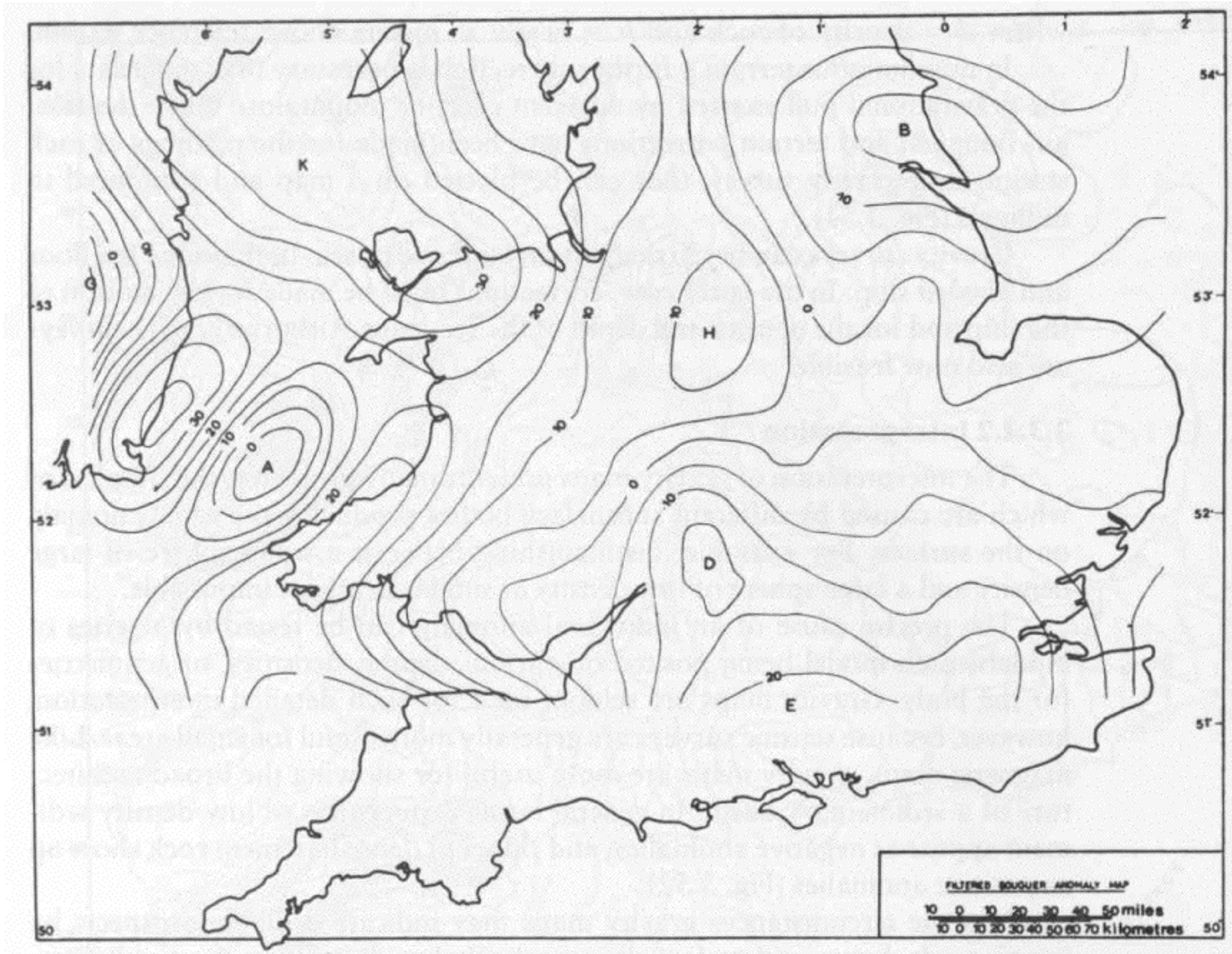
Remote Sensing

This satellite image from NASA shows the southeastern Zagros mountains, with giant anticlines and pierced salt domes that locally develop into salt glaciers (black). This region is devoid of major oil fields but it is quite under-explored.



Gravimetry

Gravimetric anomaly map of South England, showing large-scale structures and basins



Source: Levorsen, A.I. (1967) *Geology of Petroleum*, W.H. Freeman and Co

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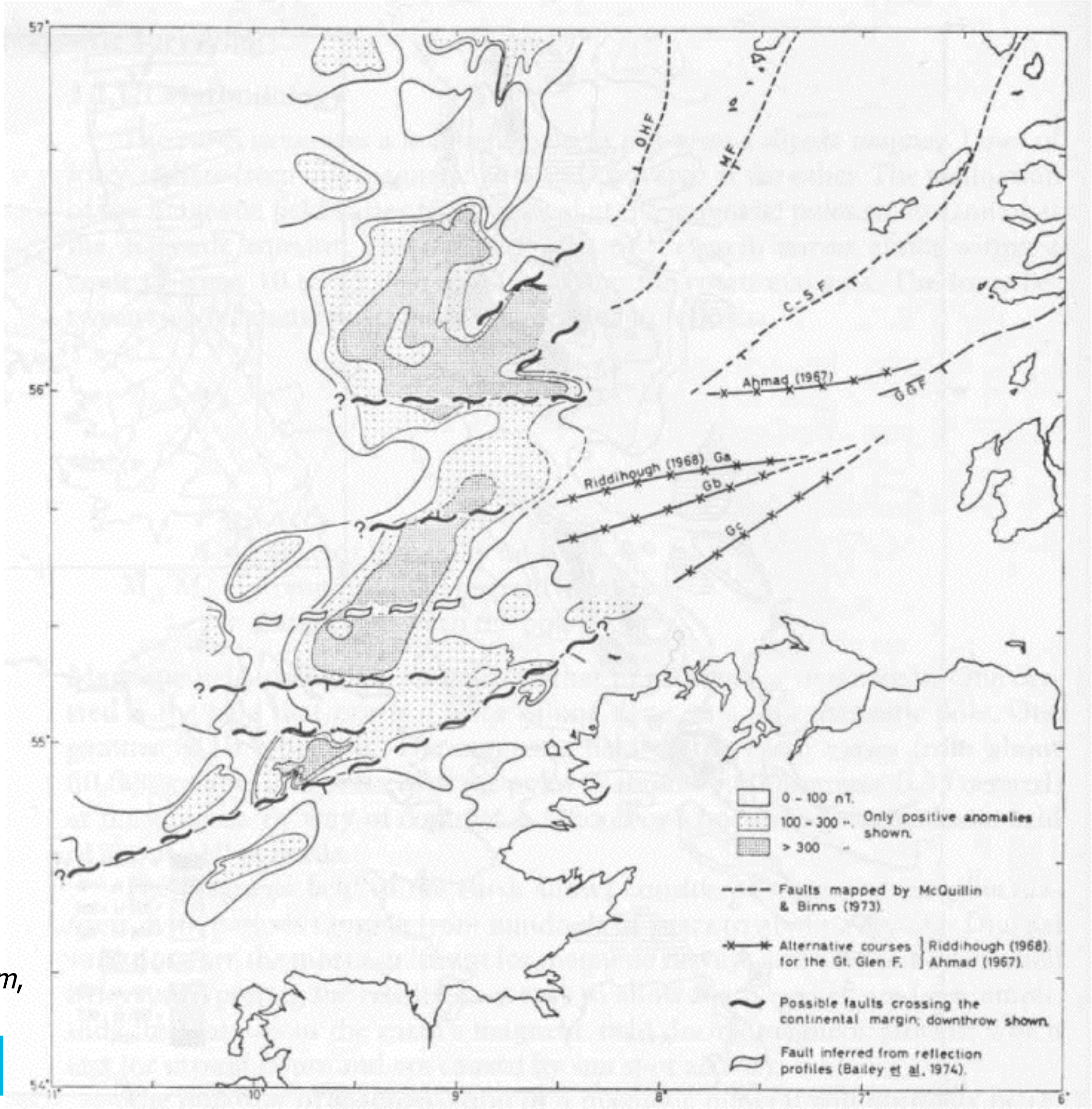
Magnetometry

Magnetic anomalies off the northern coast of Ireland, with their interpretations superposed.

This gives a general picture of the larger-scale tectonic units



Source: Levorsen, A.I. (1967) *Geology of Petroleum*, W.H. Freeman and Co

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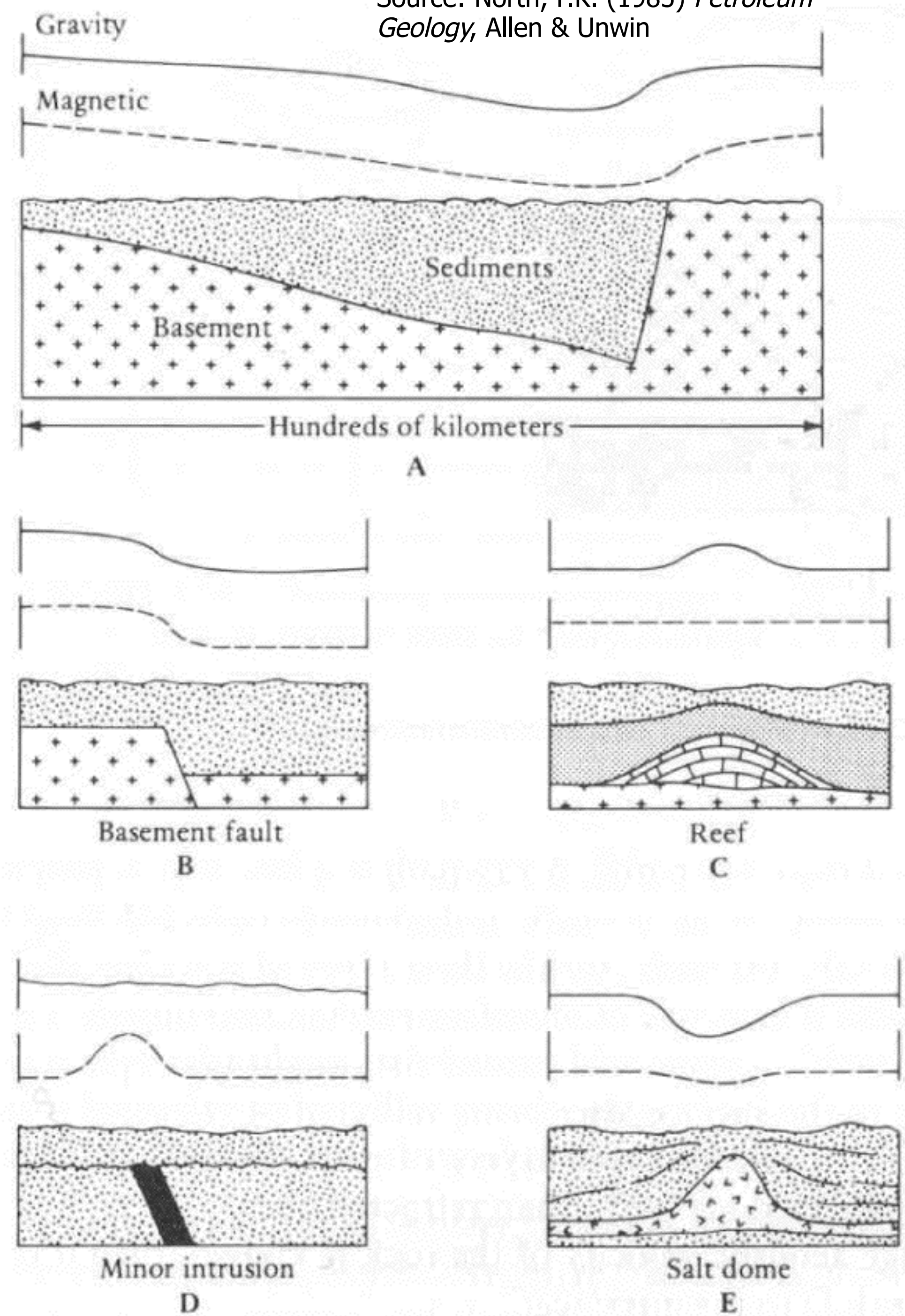
Gravimetry and Magnetometry Interpretation

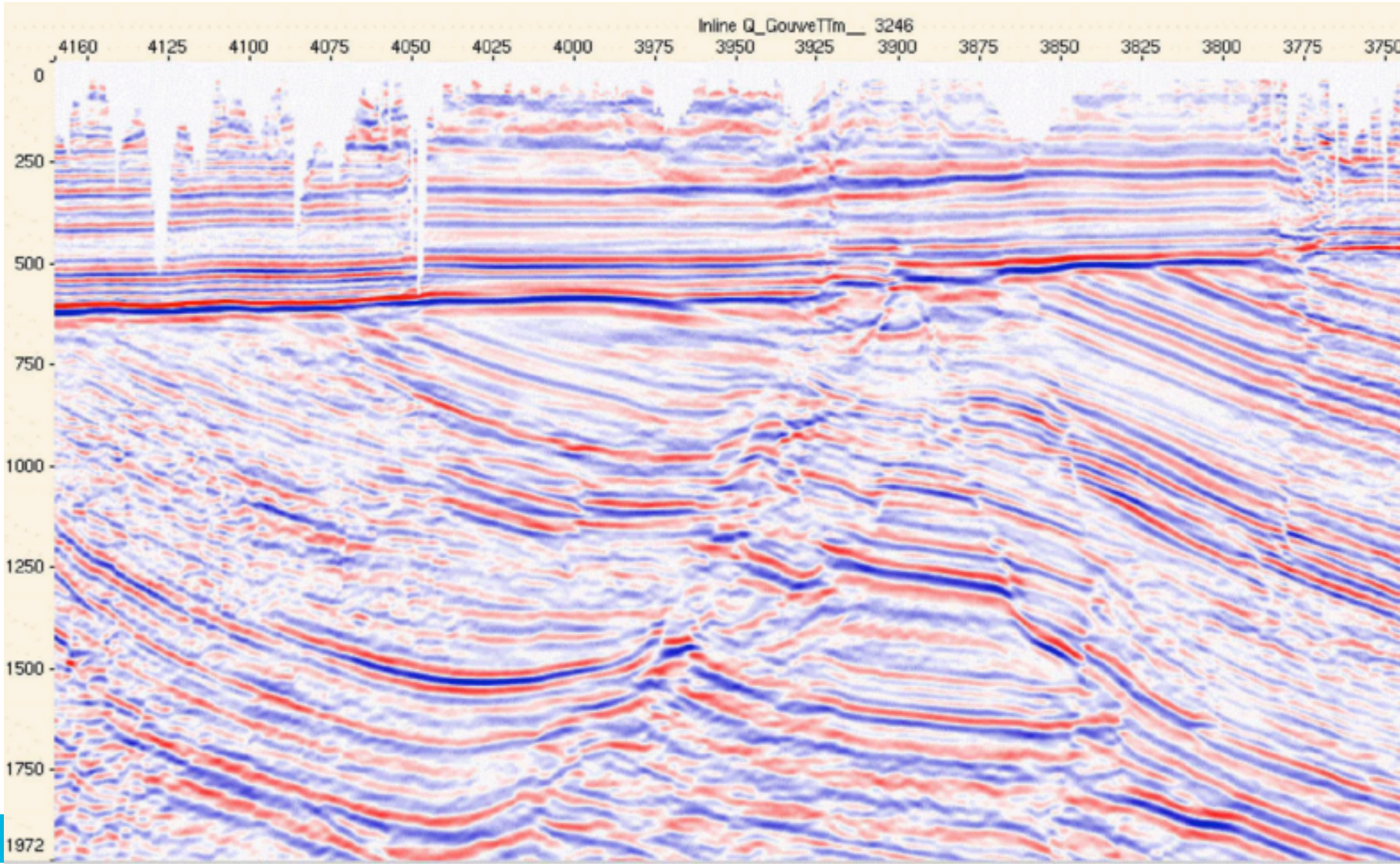
These sketches show typical structural situations and the corresponding gravimetric and magnetic responses.

Quantitative inversions of these measurements need such model assumptions as well as ground truth data from wells in order to constrain them. Otherwise, they remain ambiguous.

Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

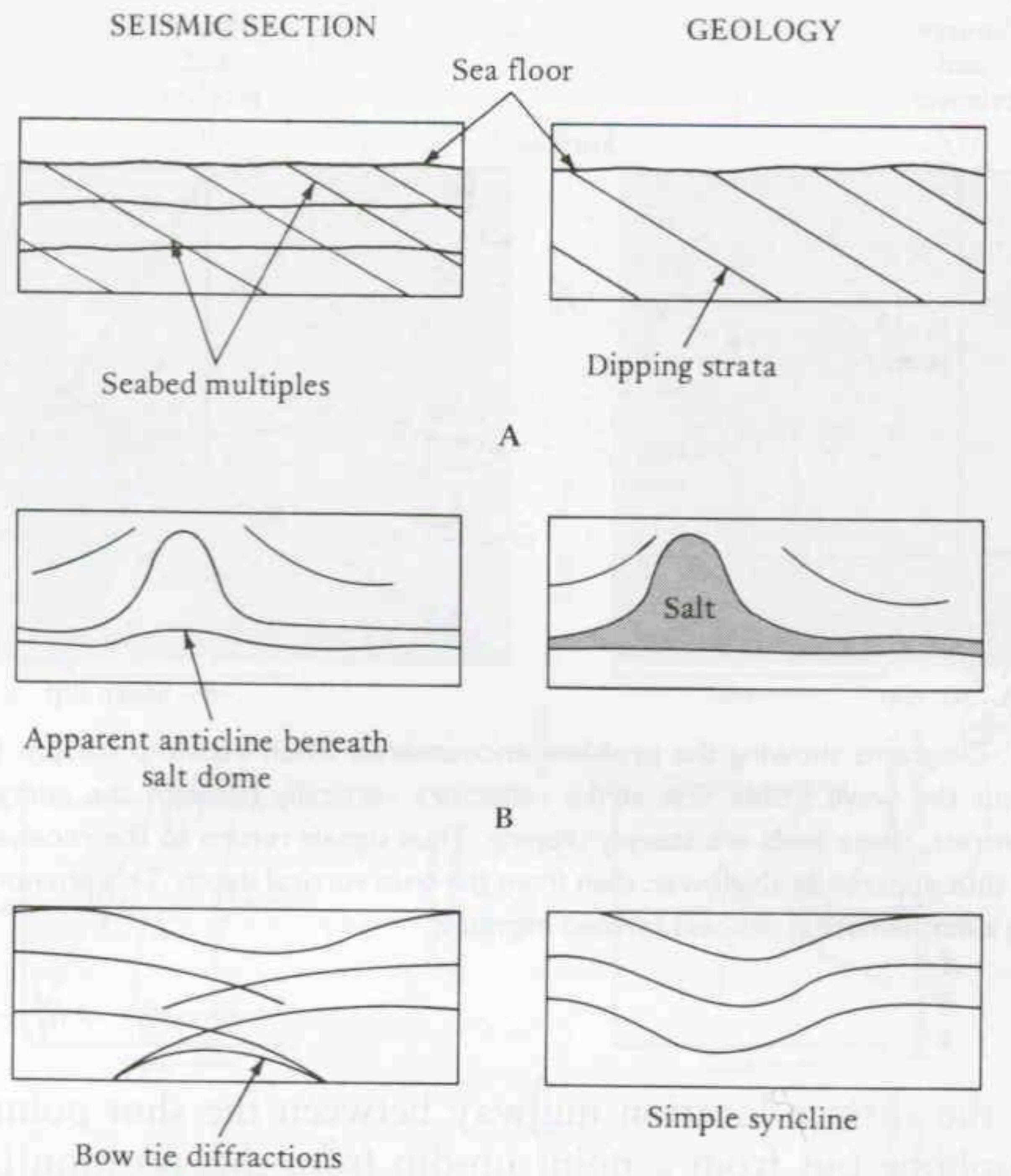


Seismic Surveys



Seismic line across the Moerkapelle field, Southern Netherlands

Seismic Interpretation - Pitfalls



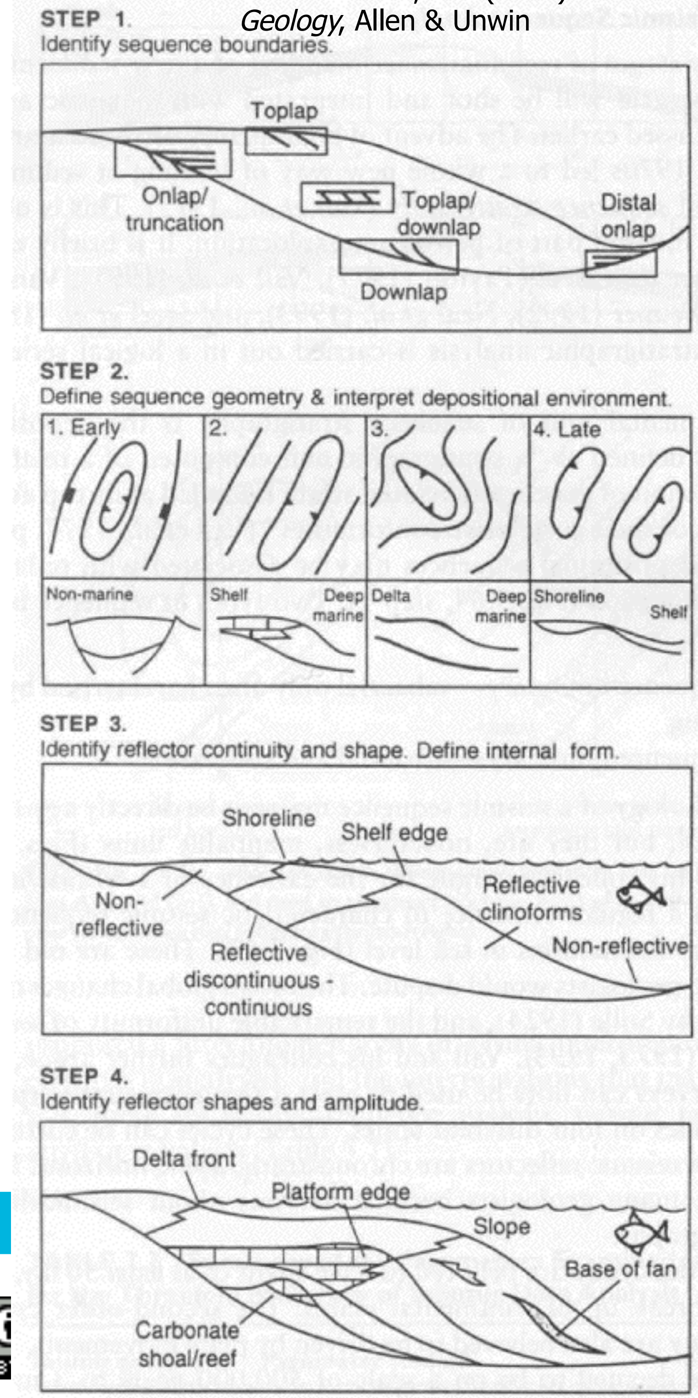
Source: North, F.K. (1985) *Petroleum Geology,* Allen & Unwin

Seismic Interpretation - Sequence Stratigraphy

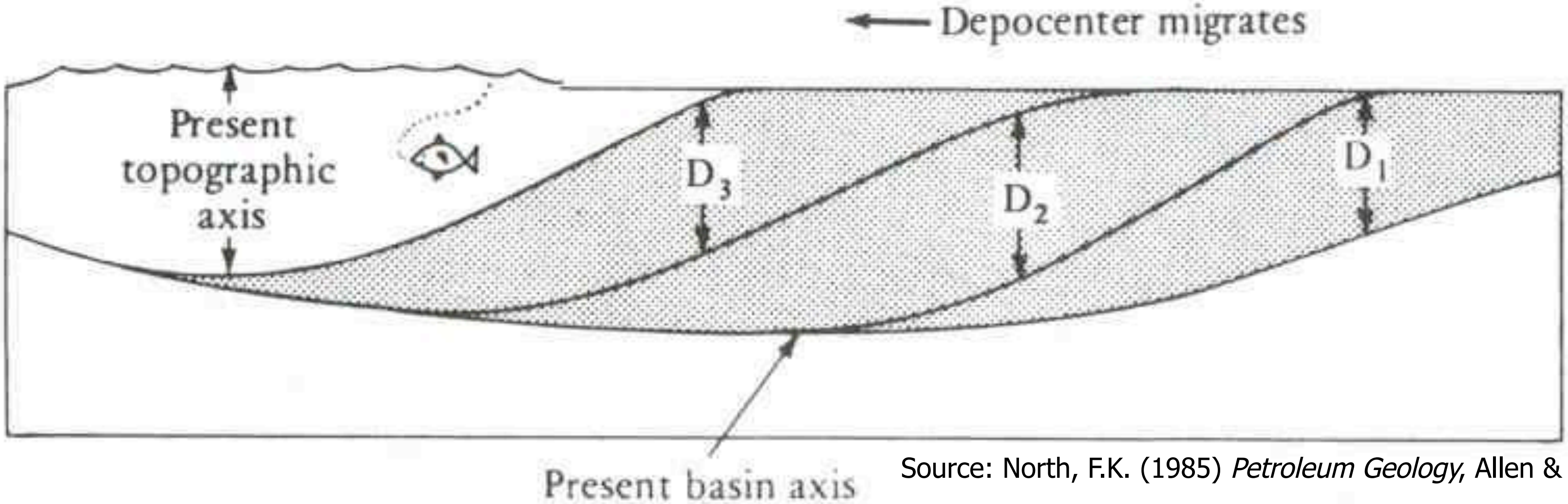
The slide on the right shows several steps performed in the seismic interpretation of a passive margin sequence. In the end (step 4) an accurate idea of where the most prospective parts of the sedimentary sequence can be found, thereby helping to define potential drilling targets.

Sequence stratigraphy has been developed by Exxon researchers and is now widely used by seismic interpreters.

Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin



Seismic Interpretation ctd.



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Due to depocenter migration in a pre- or syn-depositional basin the individual stratigraphic thicknesses cannot be added up to obtain the total thickness of the sequence.

Prospect Evaluation

Probabilities	Prospects A	B	C	D
Probability of a source rock	0.9	0.6	0.7	0.3
Probability of a reservoir	1.0	0.7	0.5	0.4
Probability of a trap	0.7	0.6	0.5	0.6
Probability of a seal	0.8	0.5	0.6	0.0
Probability of correct maturation level	0.6	0.4	0.4	0.1
PROBABILITY OF SUCCESS	0.302	0.050	0.042	0.000

Decreasing probability of success →

Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

In order to evaluate a prospect, geologists calculate the probability of success by multiplying the probabilities for the principal conditions for reservoir accumulation.

If the combined probability is high, it is worthwhile drilling an exploration well.

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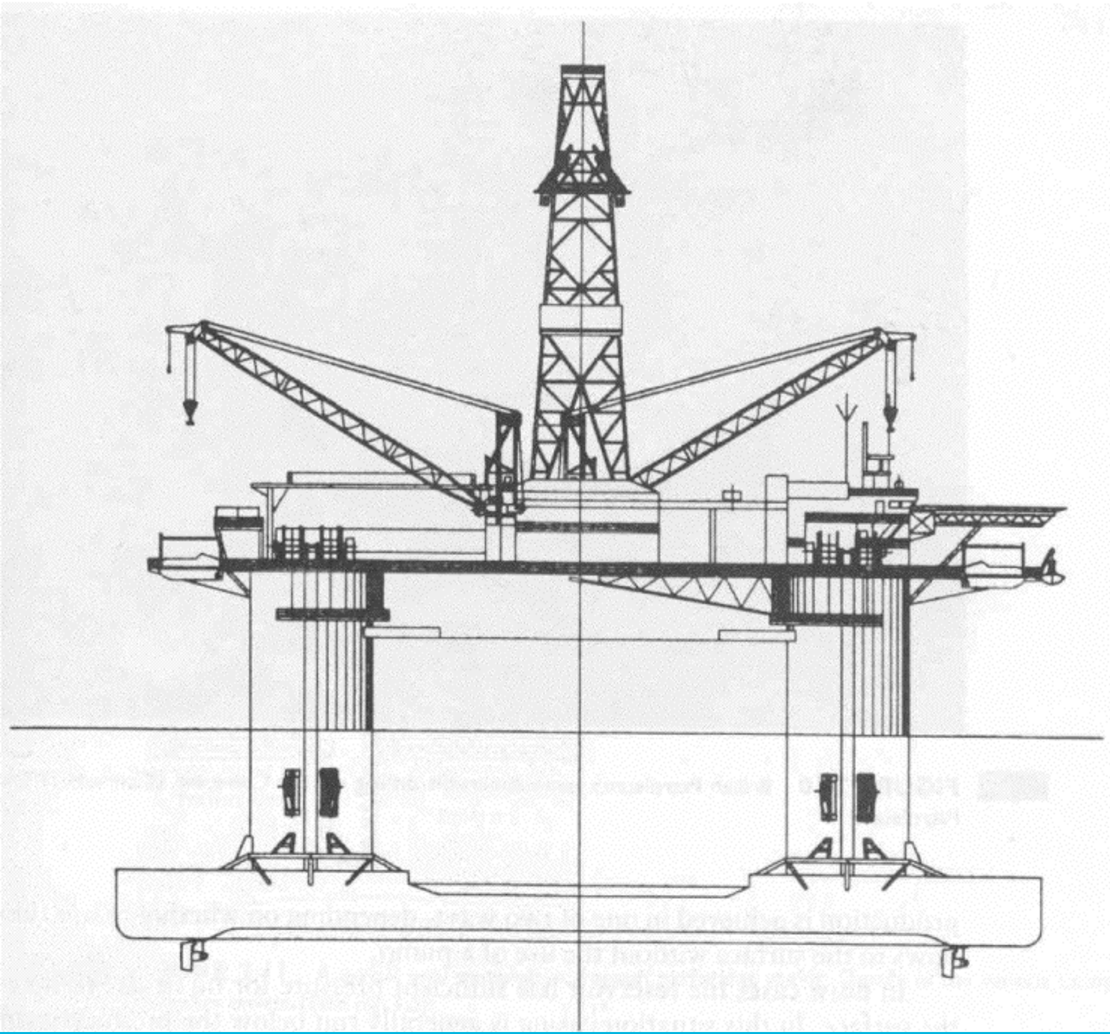
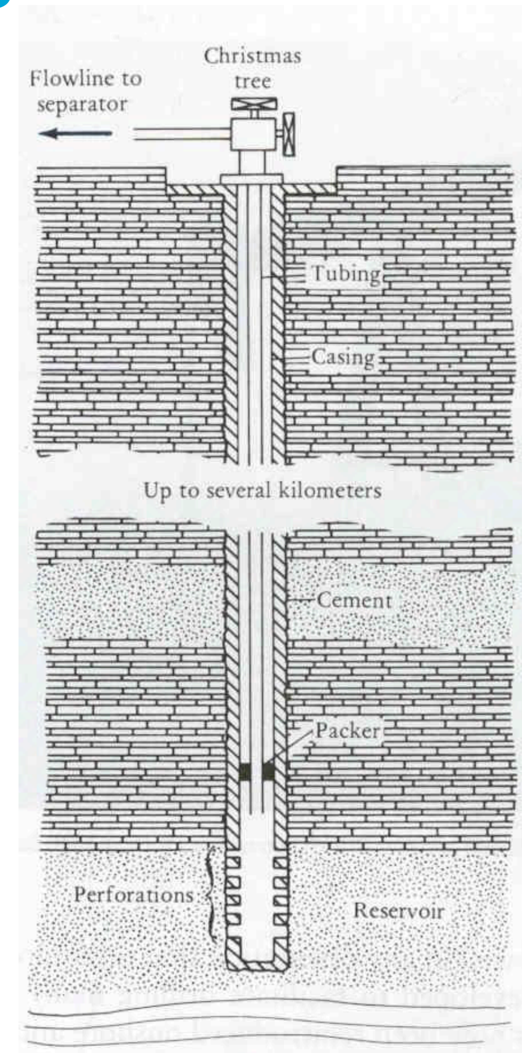
Exploration Drilling

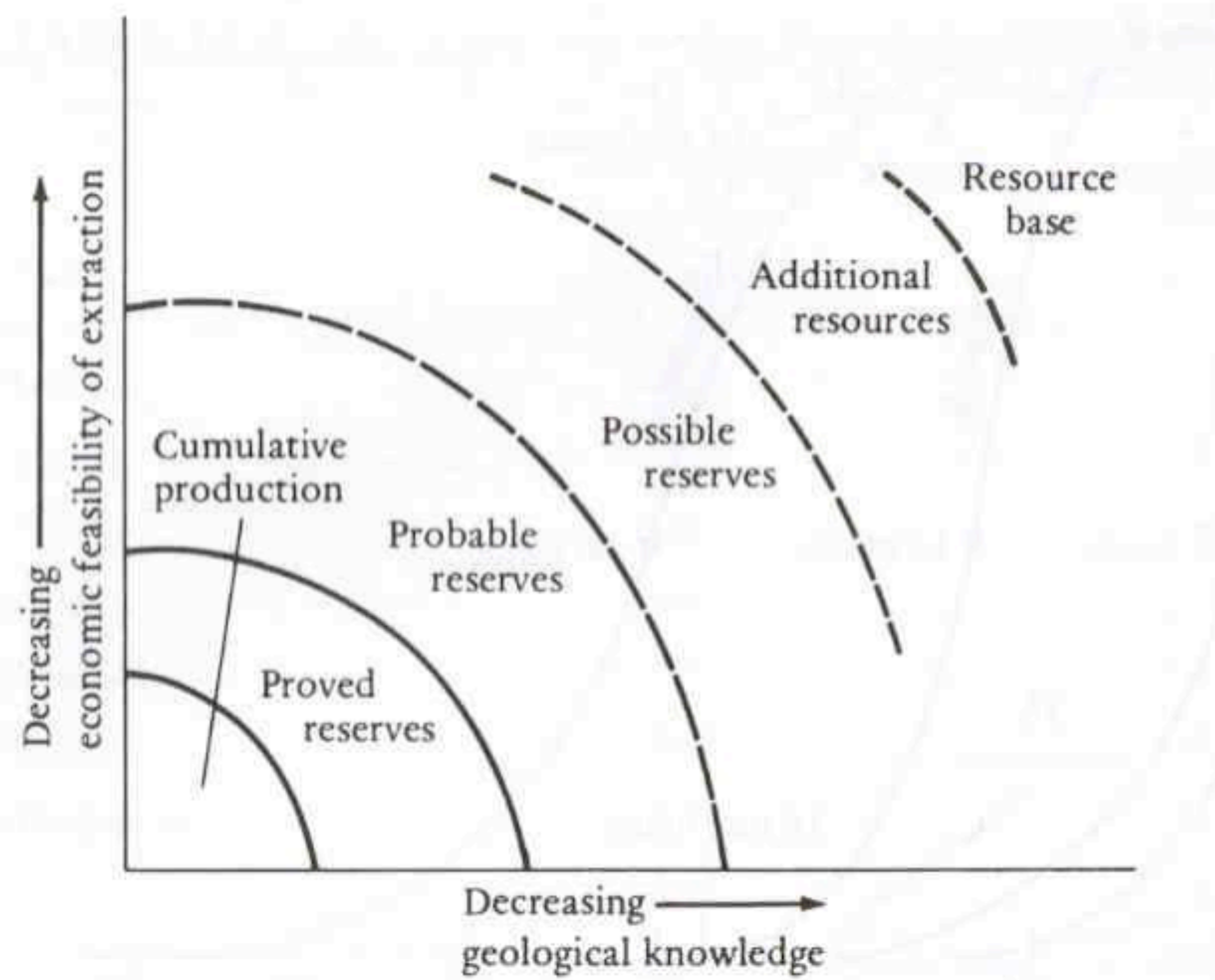




Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Reserves and Resources

Geological knowledge and economic feasibility define the various types of prospects, from resources to reserves



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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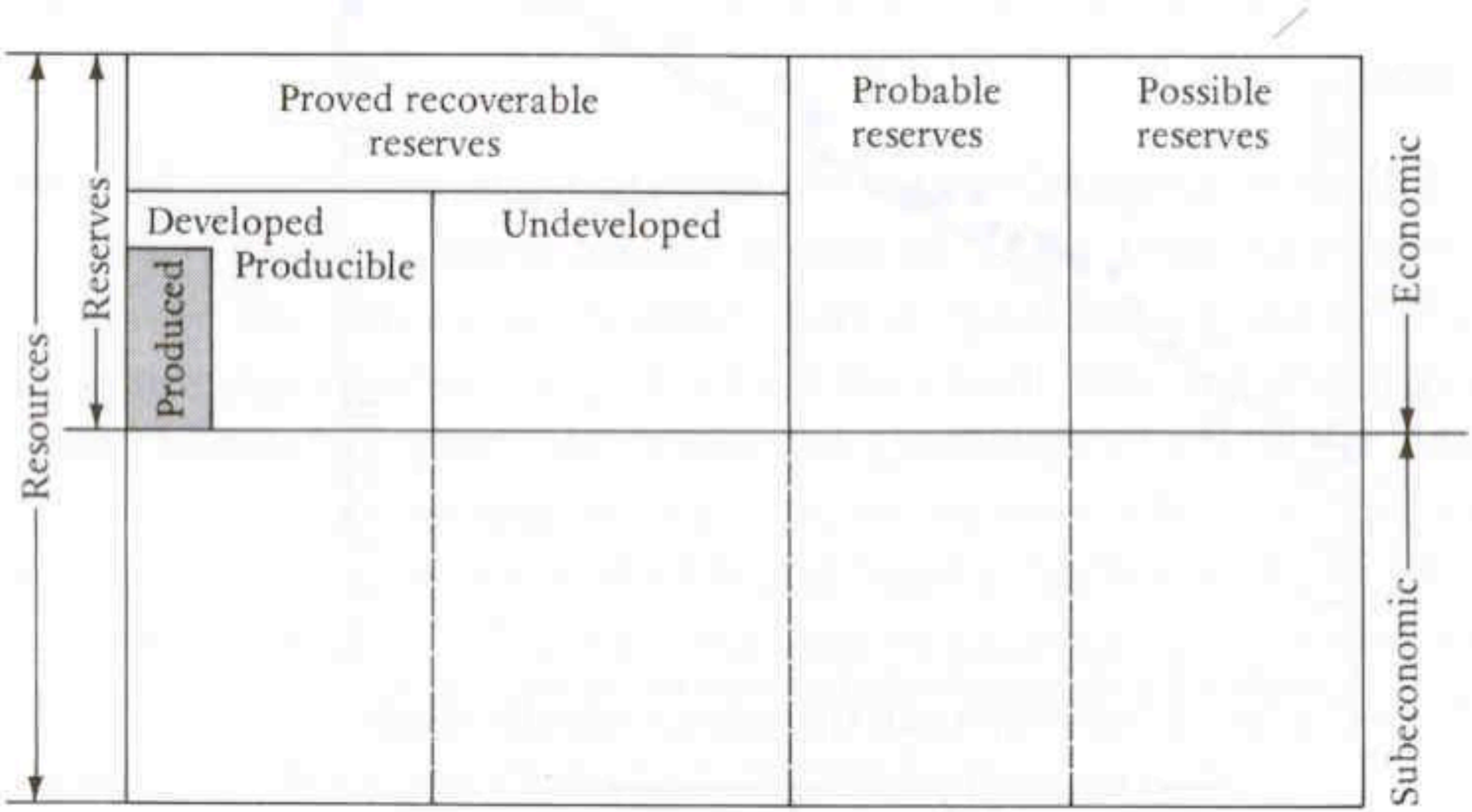
Reserves and Resources /2



Another way of defining the different prospects.
Geological knowledge decreases from left to right

Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

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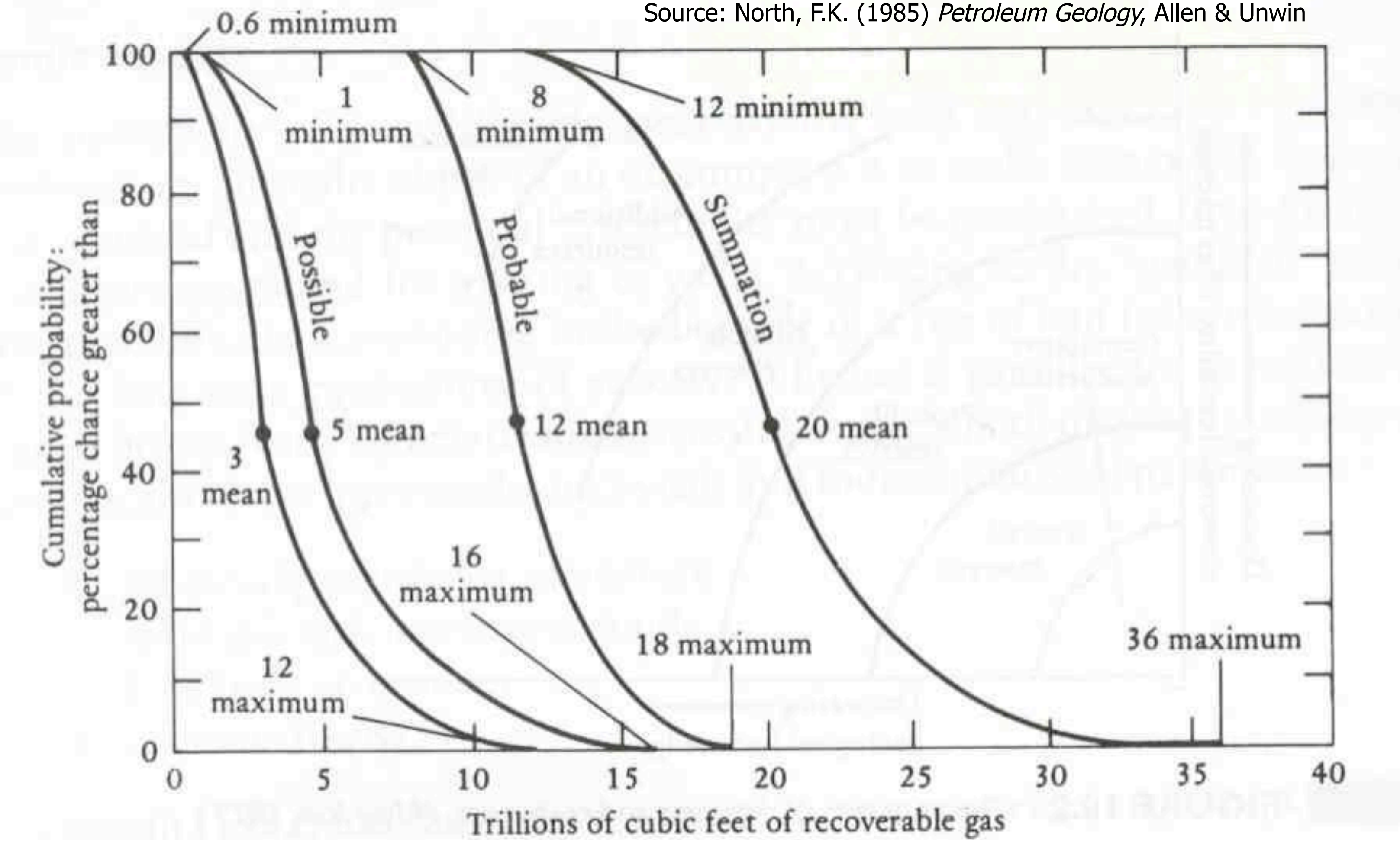
Estimates of Producible Reserves

Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin



Cumulative probabilities of speculative, possible, and probable gas reserves in South Louisiana and their summation.
From the latter the P90, P50 and P10 values can be calculated

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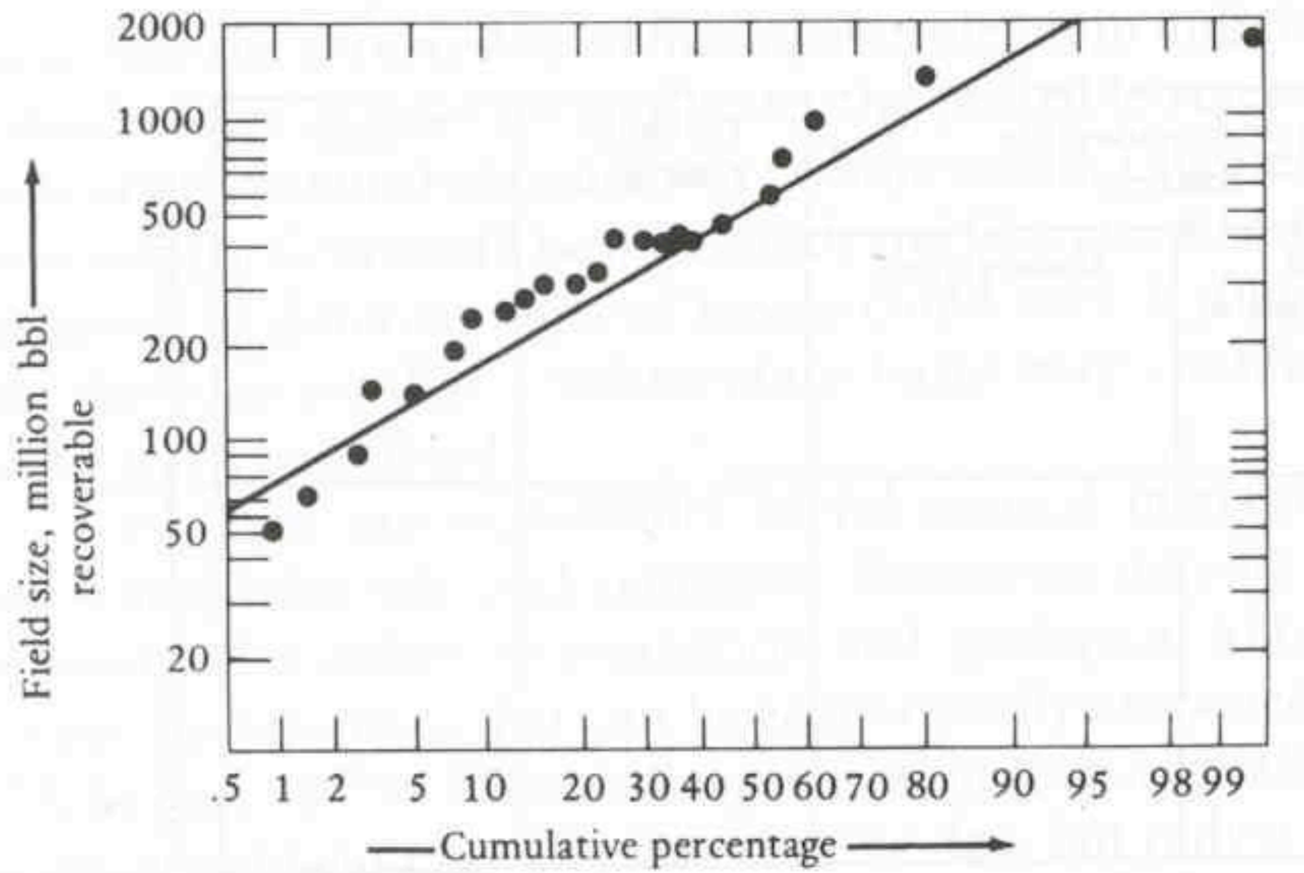
Oil Reserves, North Sea



Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Oil reserves in the UK sector of the North Sea. Plotted are all fields known up to 1981. The trend line shows that it is more or less a log-normal distribution. Such graphs can be used to predict total basin resource.

Reserves by Basin

Notice:

Current world consumption is about 31 Gbo per year

Kashgan discovery may be 70 Gbo (?)

Average deepwater discovery in Angola is 2 Gbo

Source: North, F.K. (1985) *Petroleum Geology*, Allen & Unwin

Basin	Total petroleum (10^9 BOE[a])	World ranking
Arabian/Iranian[b]	651	1
West Siberian (CIS)	167	2
Volga-Ural	58	3
Maracaibo (Venezuela)	50.2	4
Mississippi delta	49.7	5
Permian basin (USA)	42.3	6
Texas Gulf Coast (USA and NE Mexico)	41.6	7
Reforma-Campeche (Mexico)	40.6	8
Northern North Sea (UK and Norway)	40	9
Sirte (Libya)	35.3	10
Alberta (Canada)	32.0	11
Amarillo-Anadarko-Ardmore (USA)	29.2	12
Niger delta	29.0	13
Triassic (Algeria)	25.8	14
E. Texas-Arkla (USA)	23.7	15
N. Caucasus-Mangyshlak (CIS)	20.8	16
Netherlands and NW Germany	17.5	17
E. Venezuela and Trinidad	16.6	18
South Caspian (Azerbaydzhan)	14.5	19
North Slope Alaska (USA)	14.2	20
San Joaquin (USA)	13.6	21
Tampico-Misantla (Mexico)	12.2	22
Amu Daryu (CIS)	10.5	23
Appalachian (USA)	10.4	24
Los Angeles (USA)	10.0	25
TOTAL	1700.0	

[a] BOE = barrels of oil equivalent.
[b] Note that nearly 40 percent of the world's known reserves occur in the Arabian/Iranian basin.

Ultimate Recoverable Reserves

Consult slides at the beginning of the presentation material

Thank you and good luck with your study!