Petroleum Systems

(Part One)

Source, Generation, and Migration

GEOL 4233 Class
January 2008

Petroleum Systems

Elements	Processes
Source Rock	Generation
Migration Route	Migration
Reservoir Rock	Accumulation
Seal Rock	Preservation
Trap	

Petroleum System Summary

- **Source (Material and Rocks)**
- **Generation (Maturation)**
- **Migration**
- **Trap**
- **Reservoir**

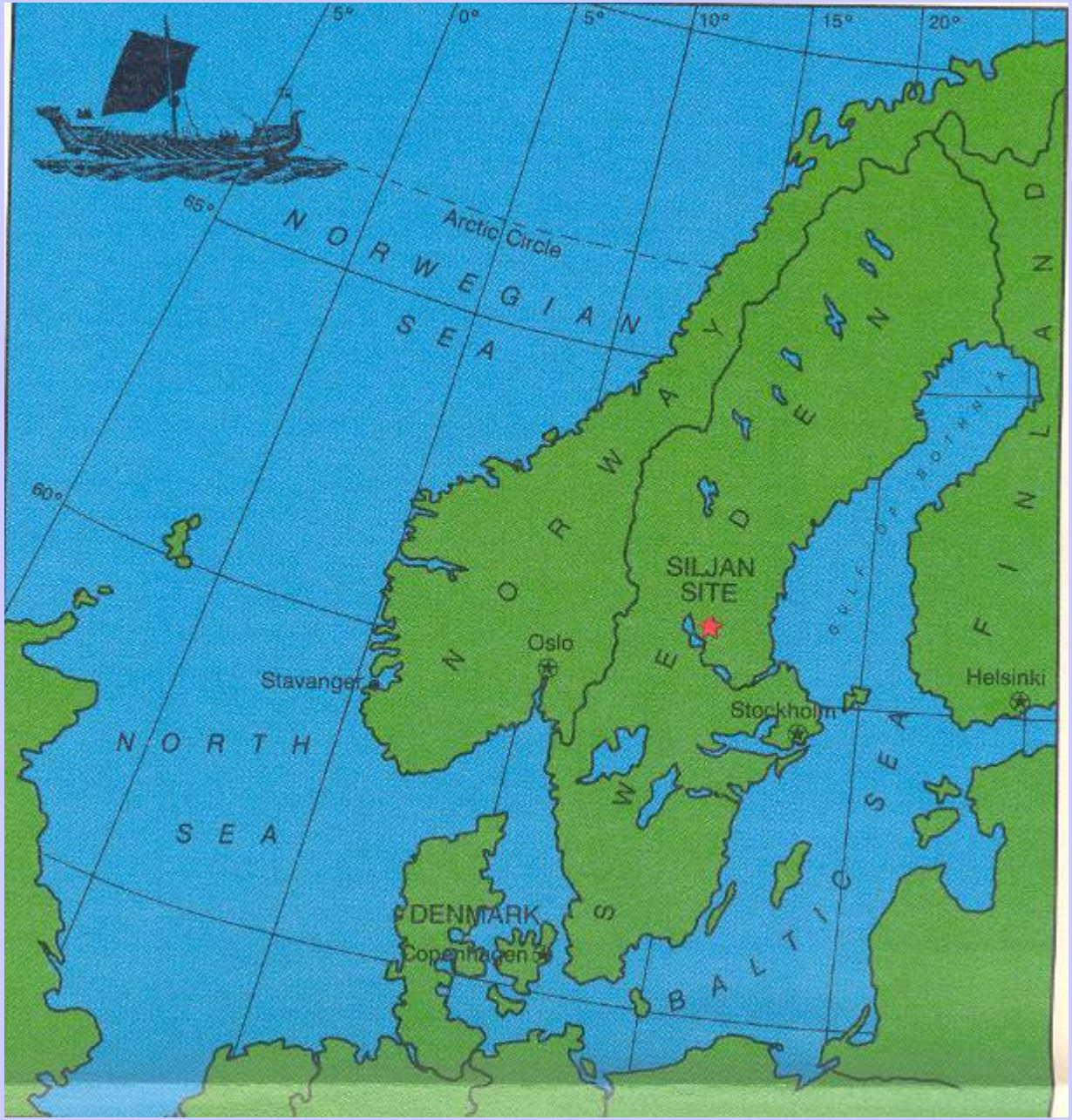
Source Material

Non-Biogenic Origins

Biogenic (Kerogen) – Host rock (Shales and Coals)

Kerogen Types

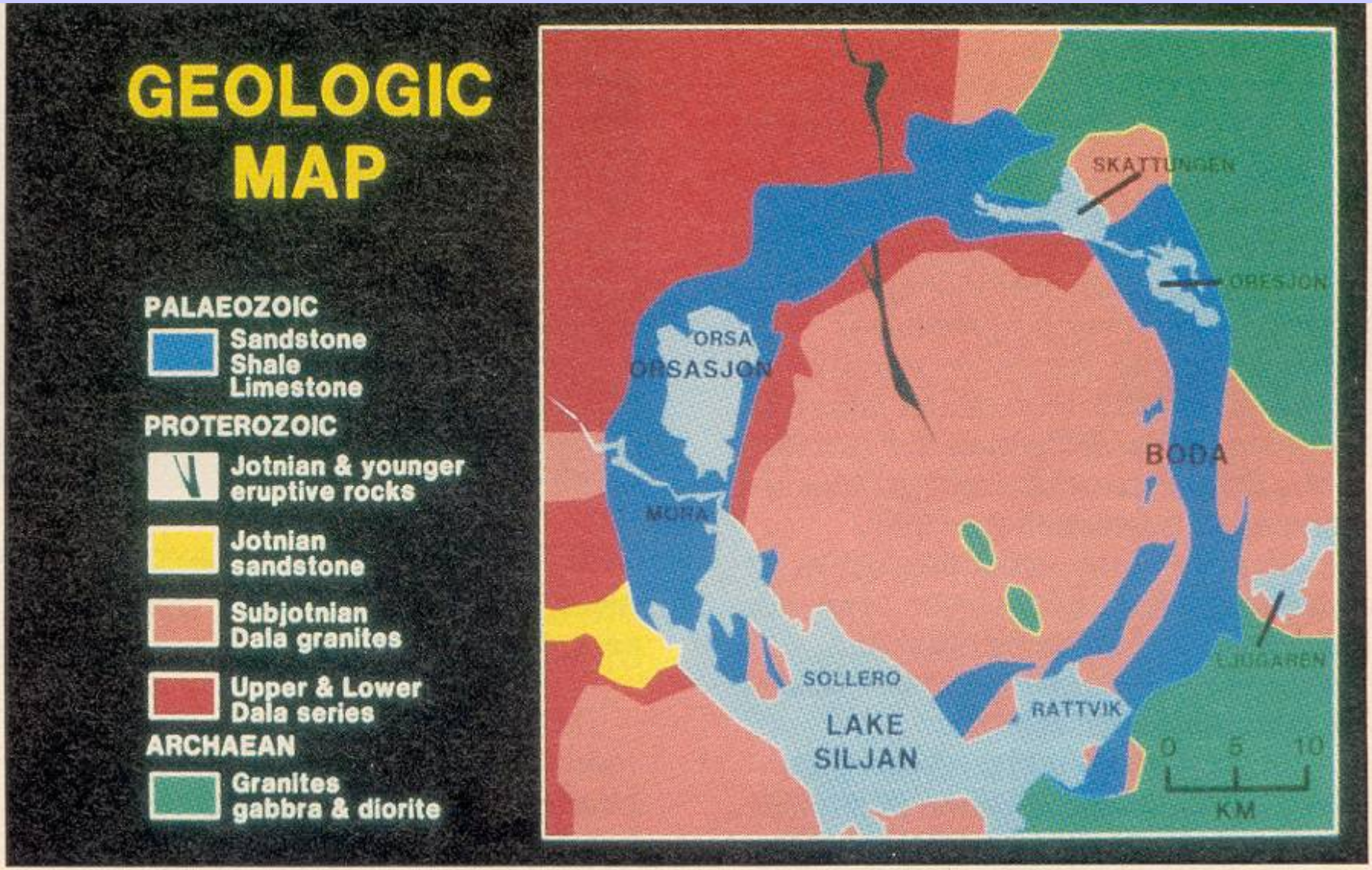
- **Type I – Algal (oil prone)** **sapropelic**
- **Type II – Mixed**
- **Type III – Woody (gas prone)** **humic**



Siljan 'Ring'

Inorganic Gas Prospect

Drilled to ~22,000' in 1987
Found abiogenic methane, but no poro-perm



This geologic map shows the rock types and ages found at the Siljan Ring meteorite crater.

Sedimentary Rocks – Where the Action Is

Source Material

Non-Biogenic Origins

Biogenic (Kerogen Types)

- **Type I – Algal (oil prone)** **sapropelic**
- **Type II – Mixed**
- **Type III – Woody (gas prone)** **humic**

Host rock (Shales and Coals)

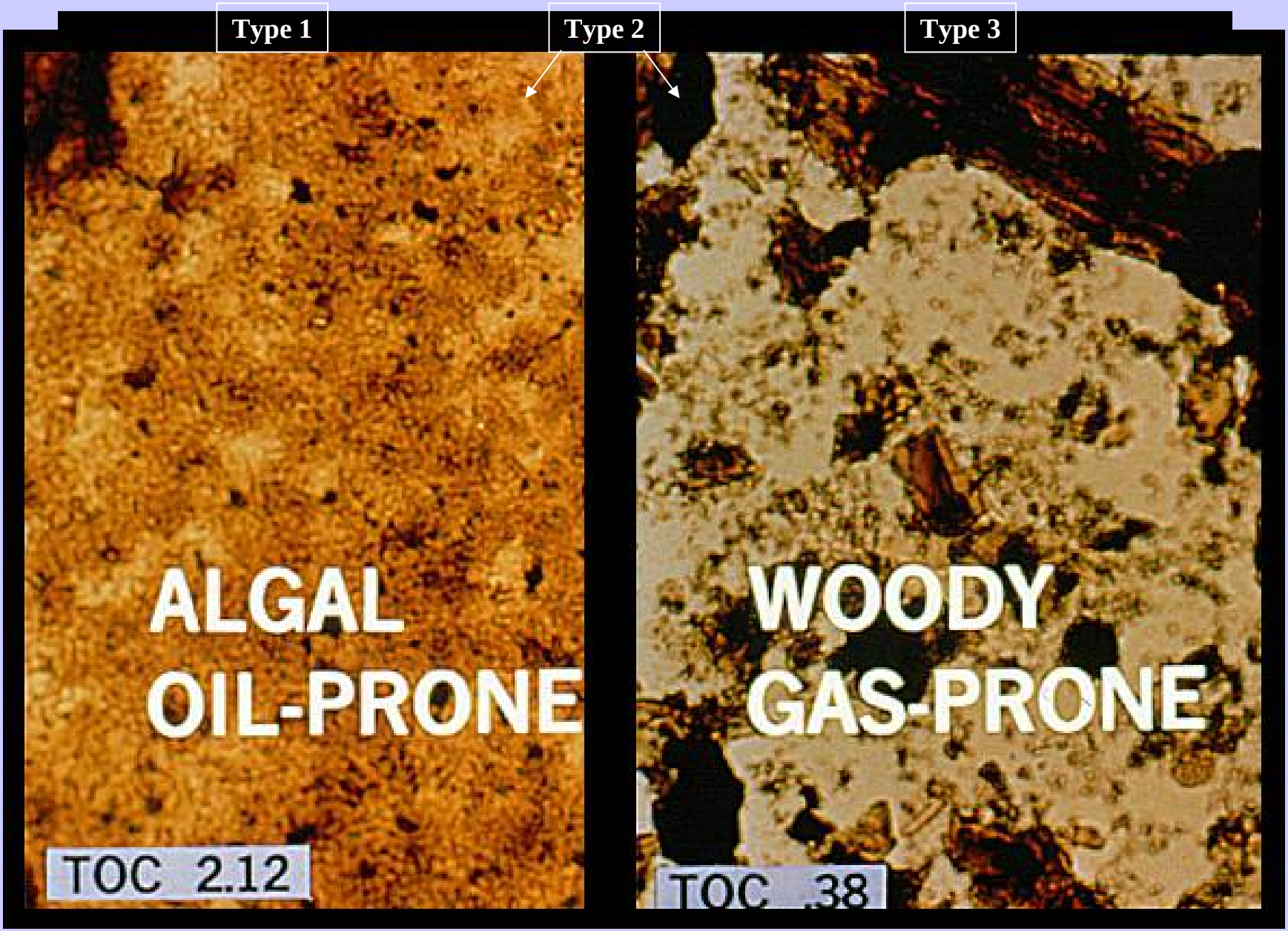
Types of Petroleum

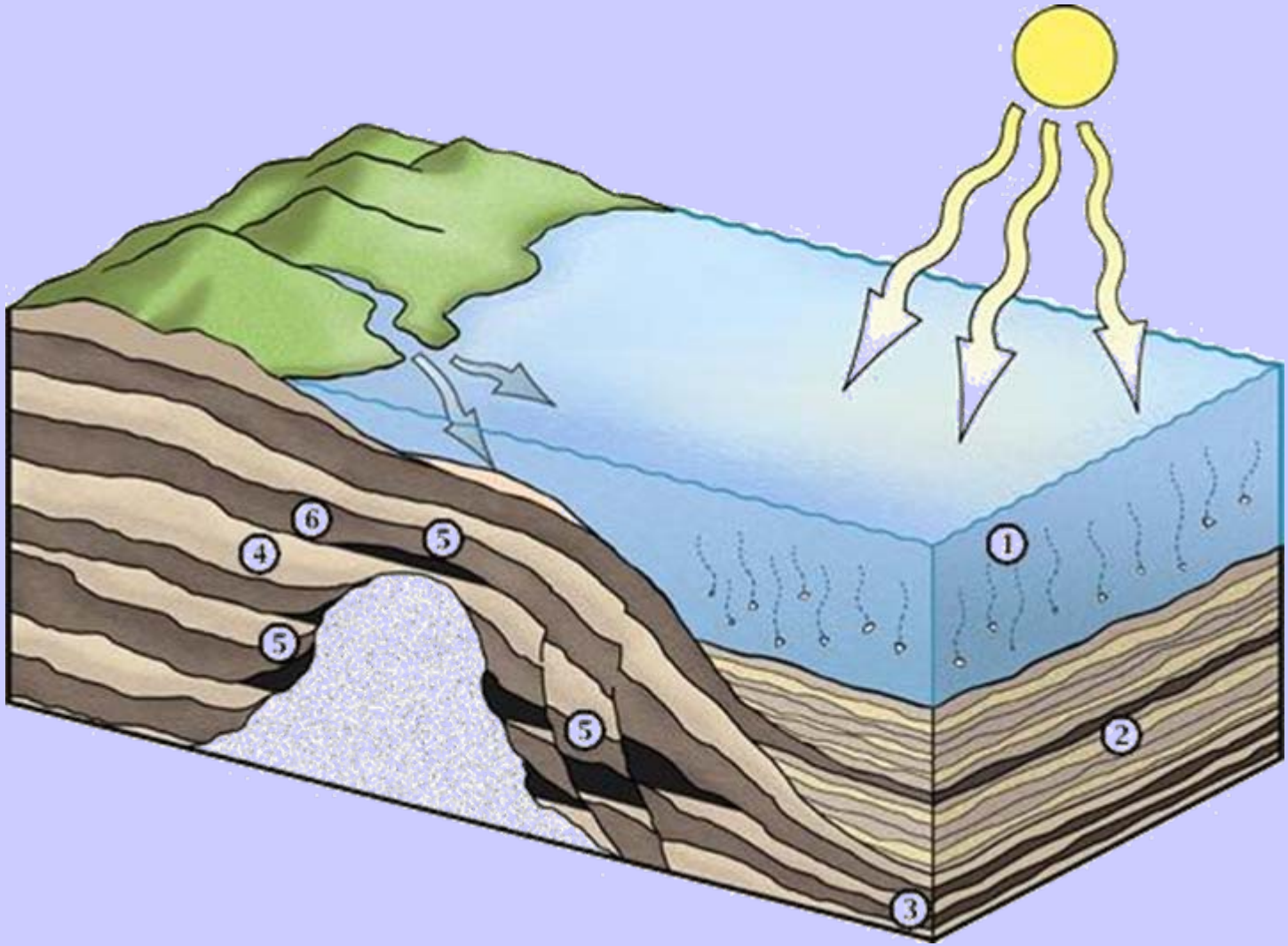
Oil and gas are formed by the thermal cracking of organic compounds buried in fine-grained rocks.

Algae = Hydrogen rich = Oil-prone

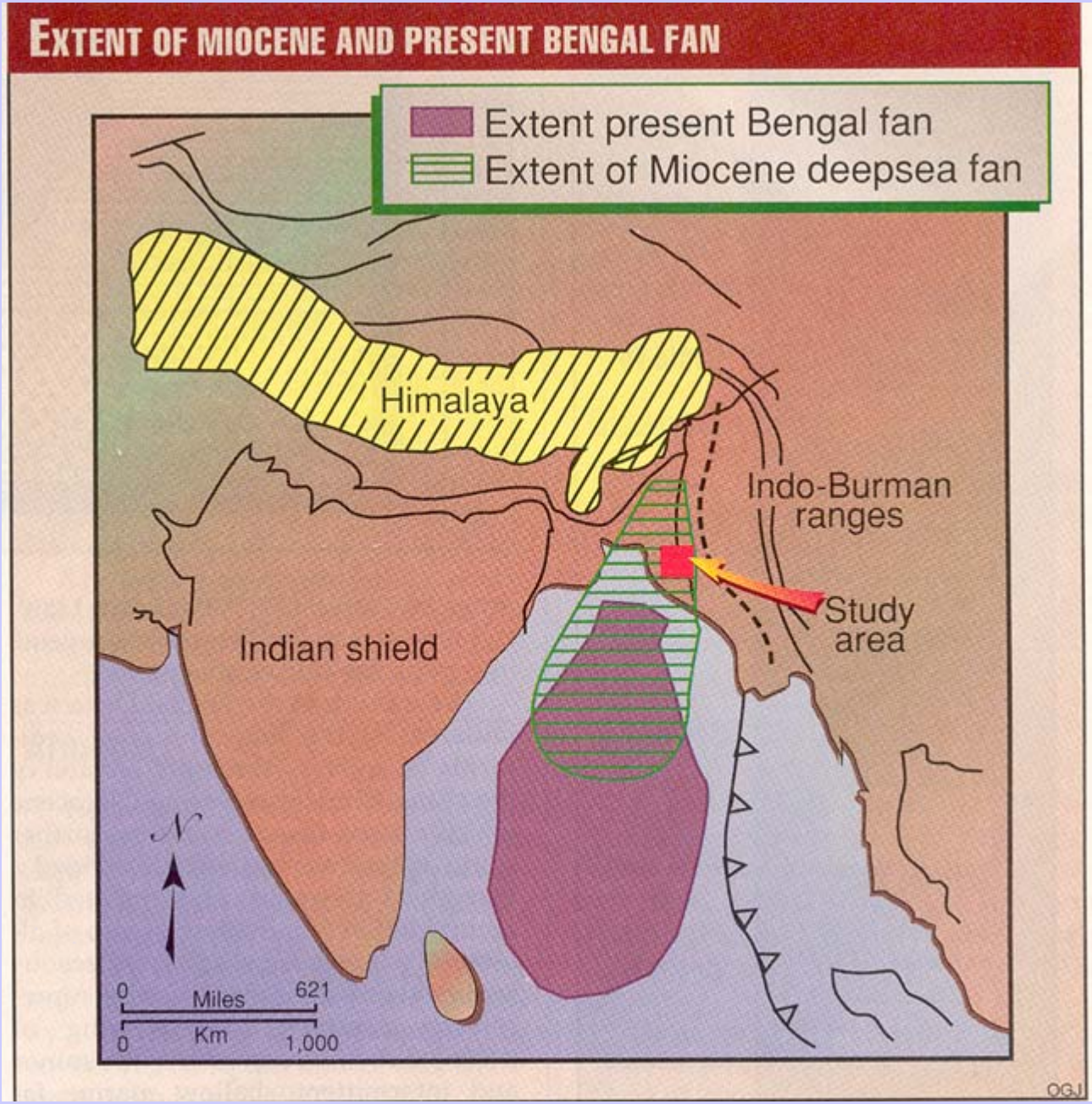
Wood = Hydrogen poor = Gas-prone

Kerogen Types





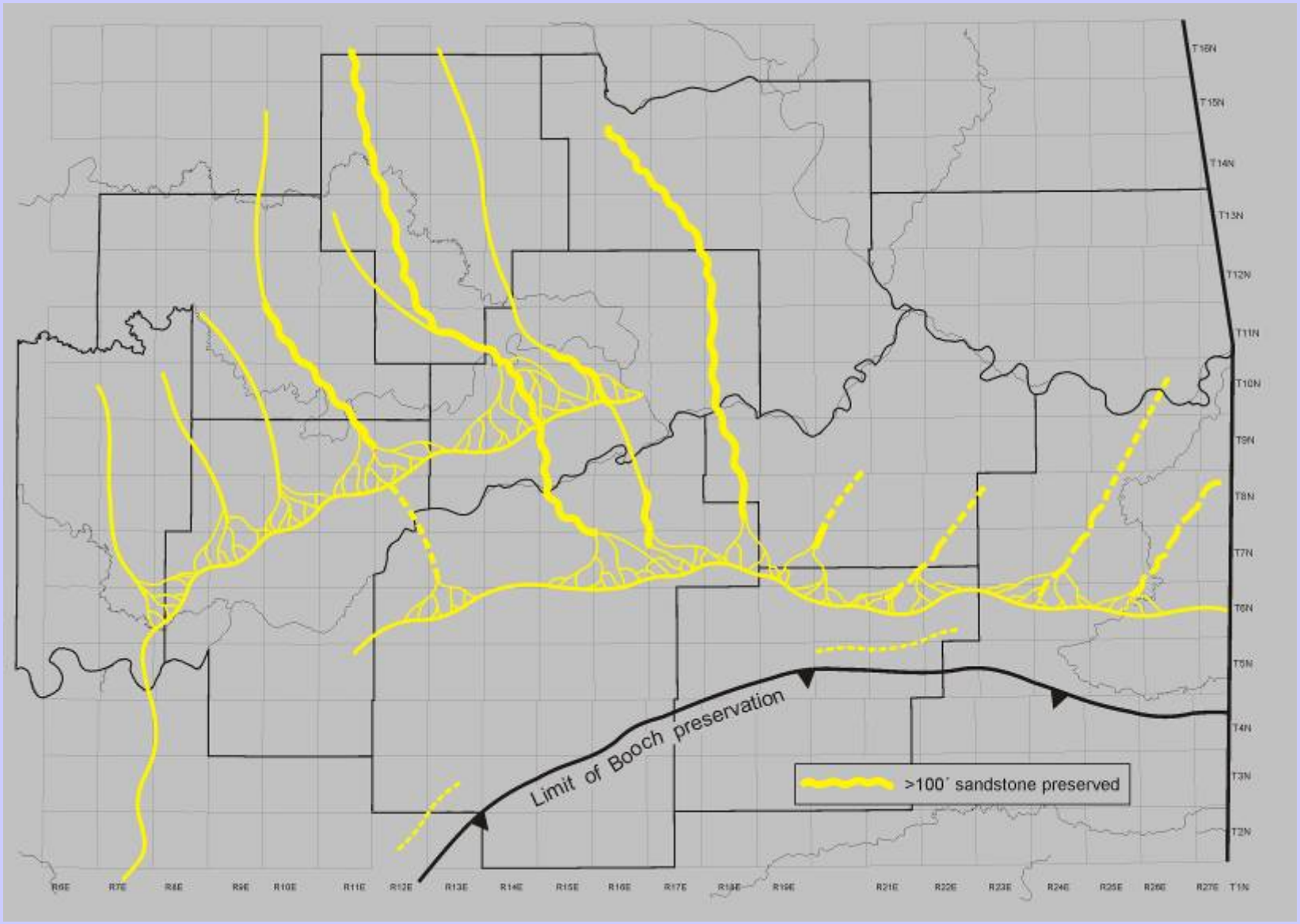
From the Paleontological Research Institute <http://www.priweb.org/ed/pgws/history/pennsylvania/pennsylvania.html>



Ganges Deltaic Sediments

Modern Mahakam Delta Plain
East Kalimantan, Indonesia
(A Rich Source of Kerogen)

Inferred Middle Booch Depositional Environments
Arkoma Basin in Oklahoma



Source Material

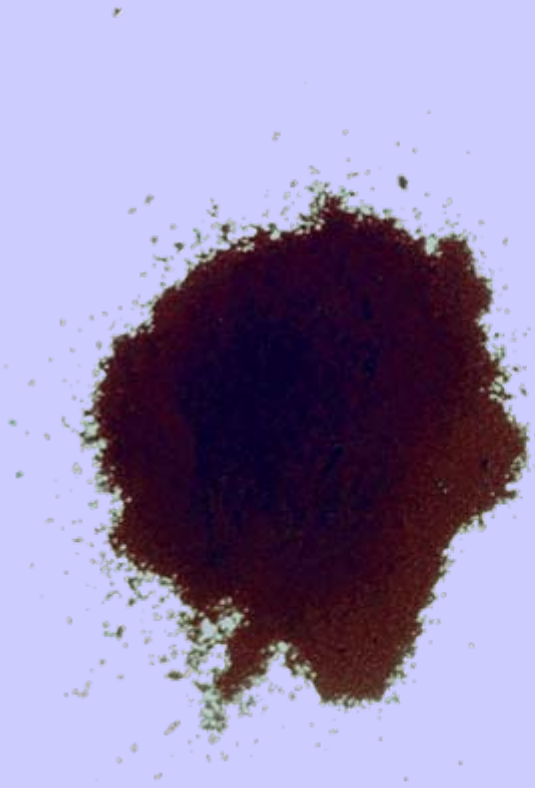
Non-Biogenic Origins

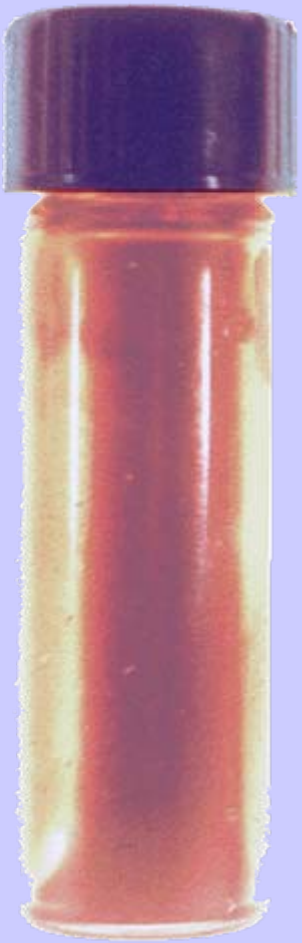
Biogenic (Kerogen Types)

- **Type I – Algal (oil prone)** **sapropelic**
- **Type II – Mixed**
- **Type III – Woody (gas prone)** **humic**

Host Rock **(Shales and Coals)**

The Origin of Petroleum





Organic-rich Source Rock

Thermally Matured Organic Matter

Oil

Source Rock for Petroleum

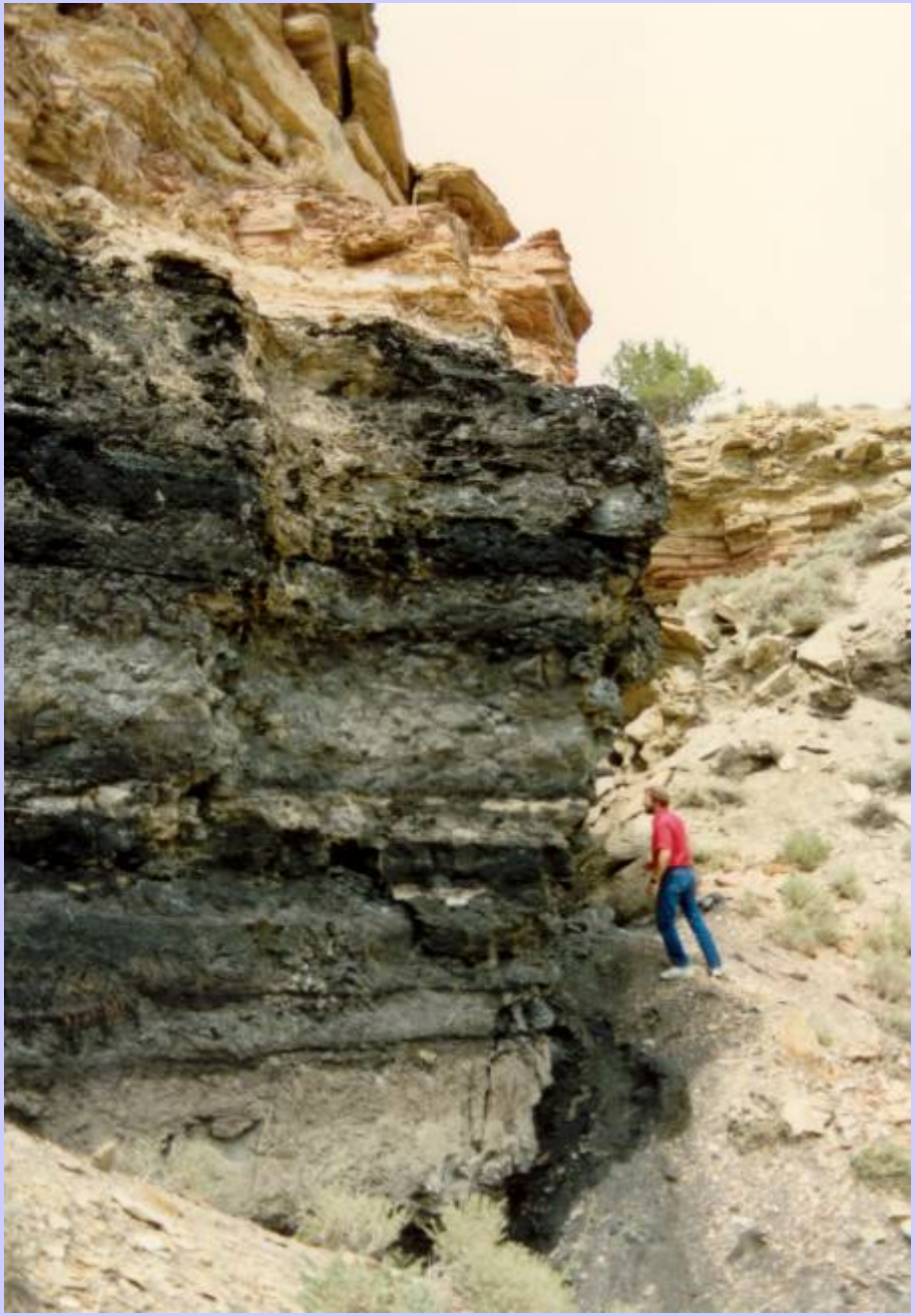
Organic-Rich **Thin Laminae**

Total Organic Carbon	Hydrogen Index
3.39	378

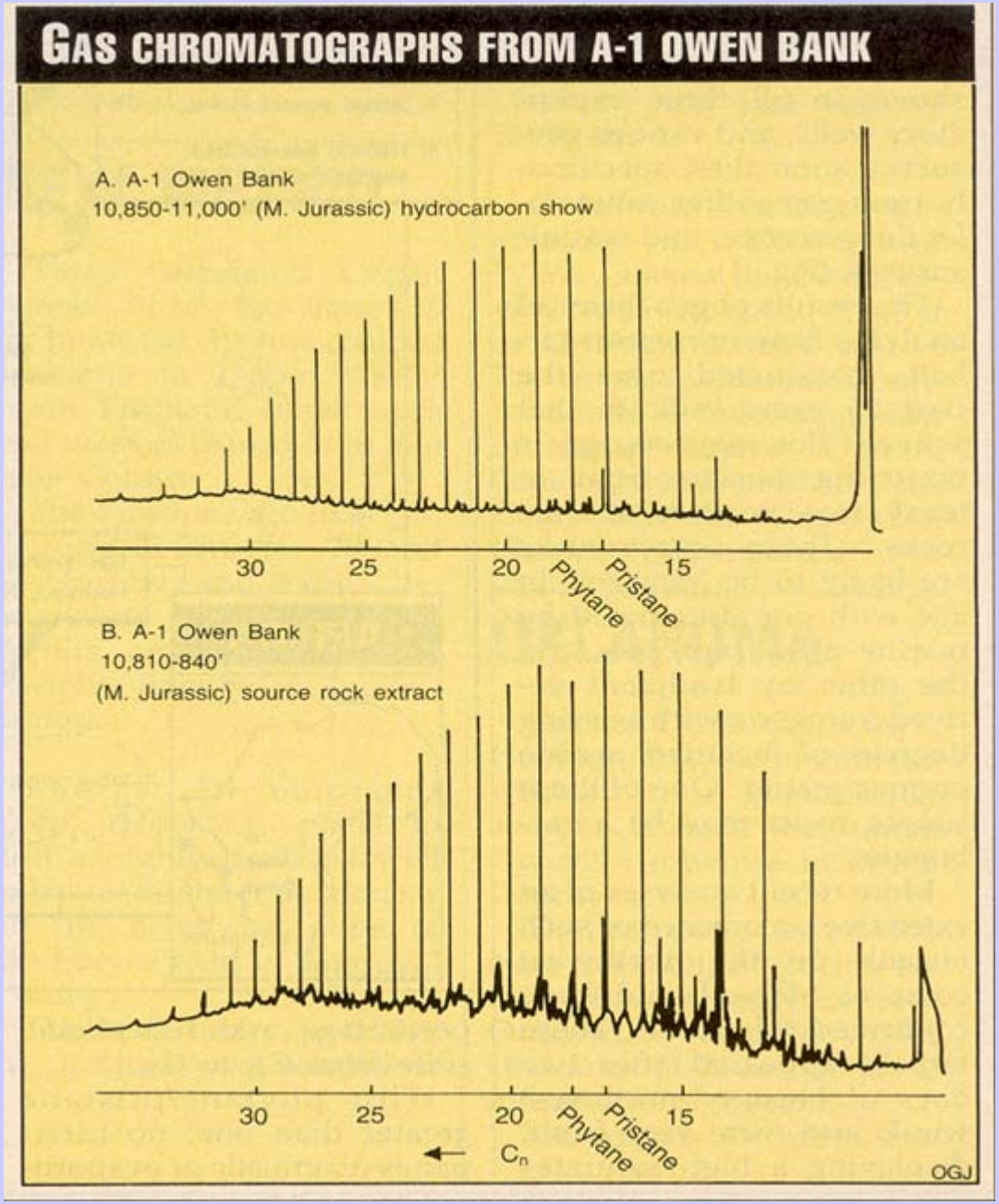
LOMPOC Quarry Sample
Monterey Formation, CA

Woodford Shale (Oklahoma)

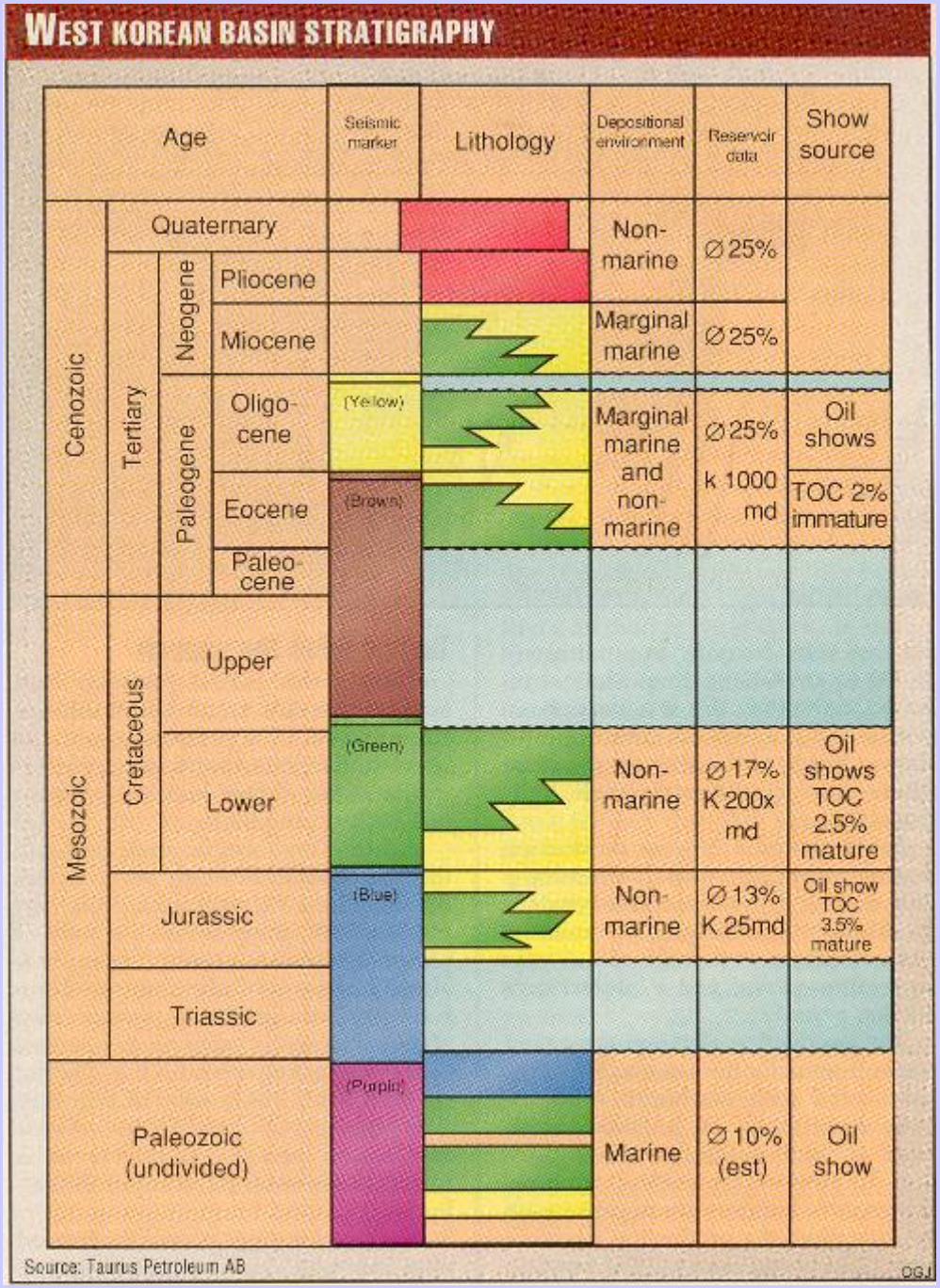
Channel-Fill Sandstone Resting on Marine Shale
Red Fork (Oklahoma)



Coals and Coaly Shales
San Juan Basin (New Mexico)



Source rock kerogen can be correlated to oil/gas found in carrier beds and reservoirs



Basinal Summary Chart

T.O.C.
Total Organic Carbon

Petroleum System Summary

- **Source (Material and Rocks)**
- **Generation (Maturation)**
- **Migration**
- **Trap**
- **Reservoir**

The Petroleum Kitchen

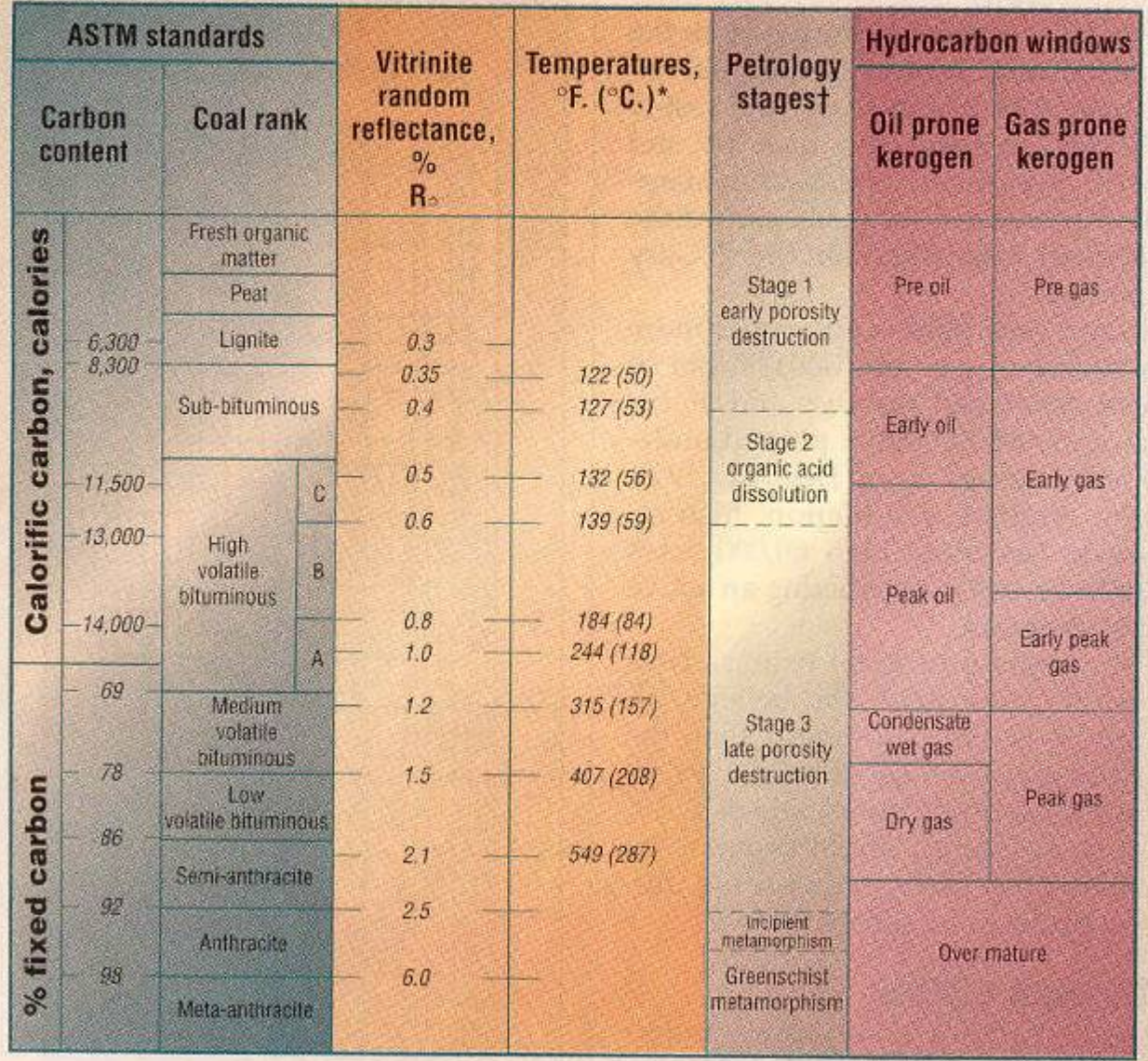
Temperature-Pressure-Time

Geothermal Gradient: (thermogenic hydrocarbons)

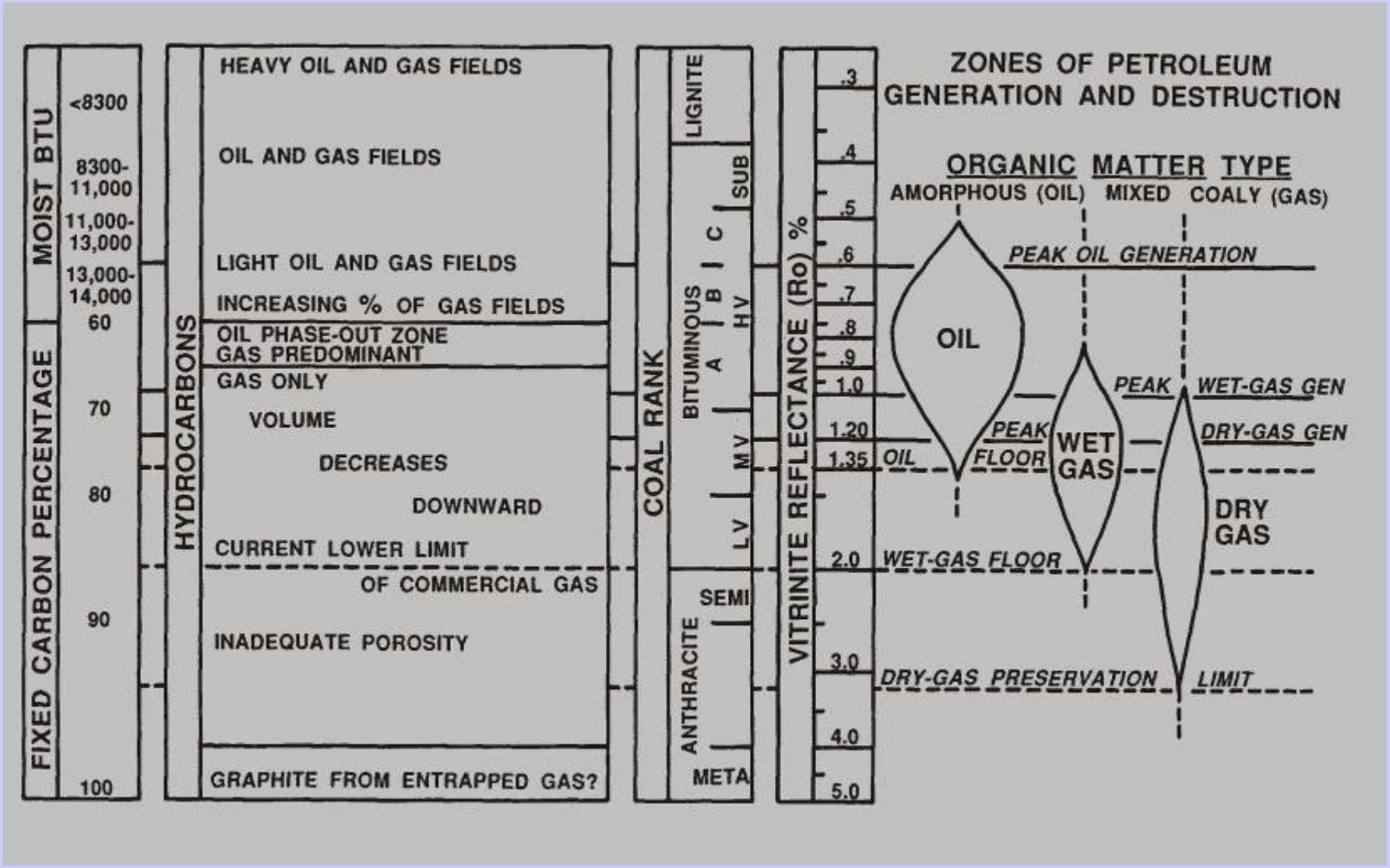
- Range: <1 to 11 degrees F per 100’
- Typical Sedimentary Basins: 1.0-1.7 degrees F per 100’
- Good average 1.2
  - Oil window of ~ 120-300F (50-150C), or about 5,000-20,000’
  - In practice, oil below 15,000’ rare

- Gas – no practical limit to stable depth
- Cracking of oil to gas controlled by source kerogen and temperature
- Deep basins mostly gas
- Practical limits related to maturity of source – not reservoir

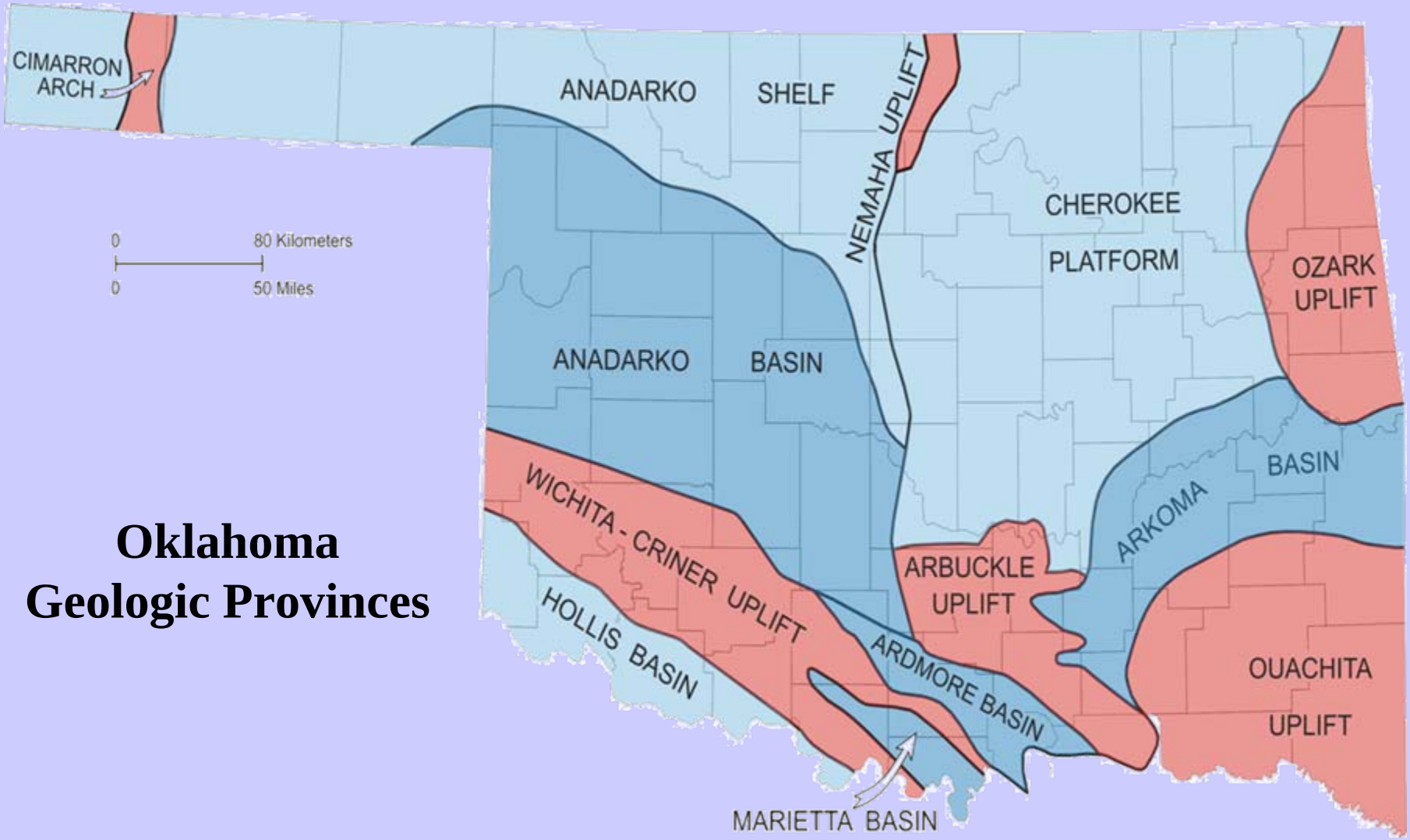
CORRELATION CHART FOR MATURATION INDICES



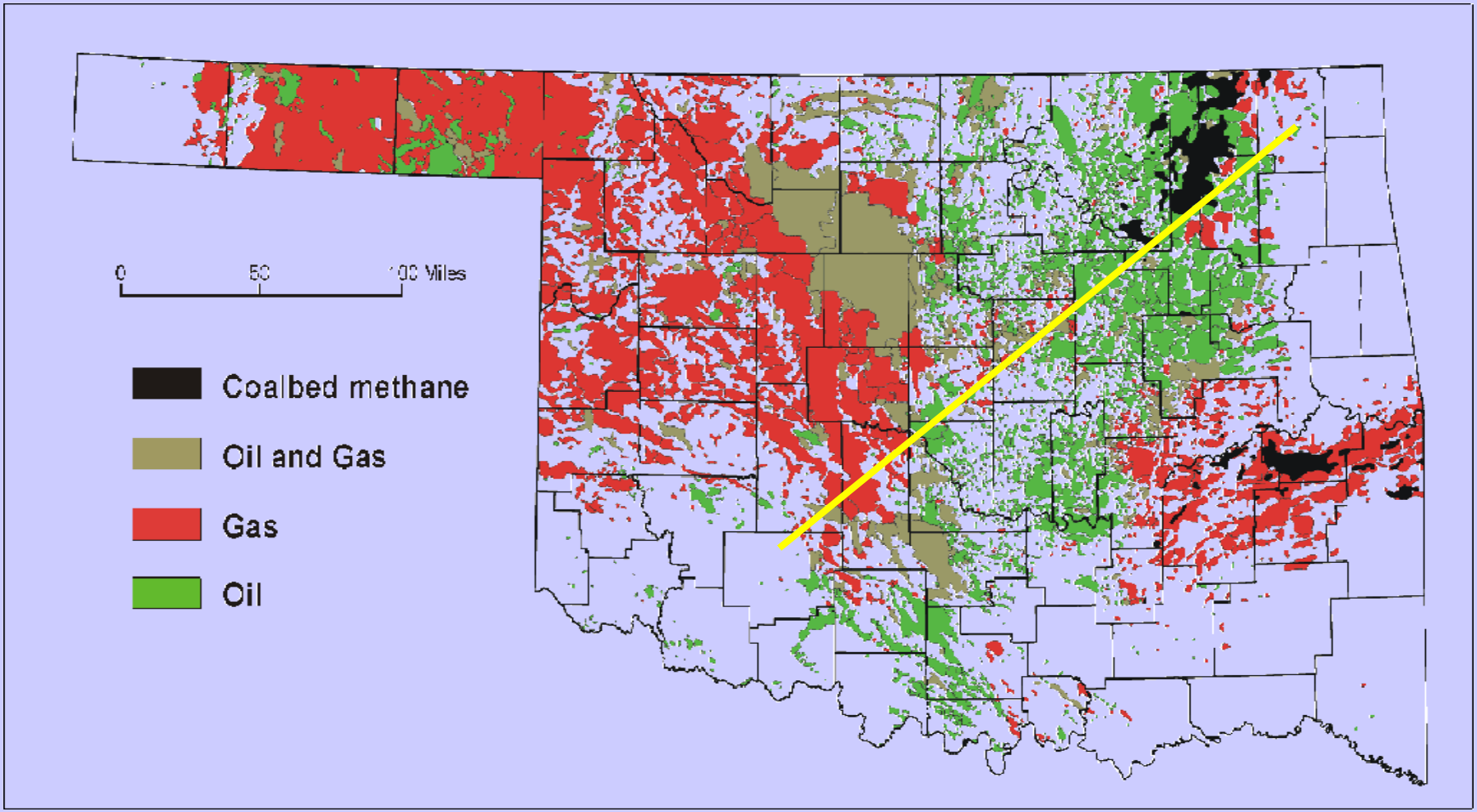
Hydrocarbon Occurrence & Thermal Maturity



Oklahoma Geologic Provinces

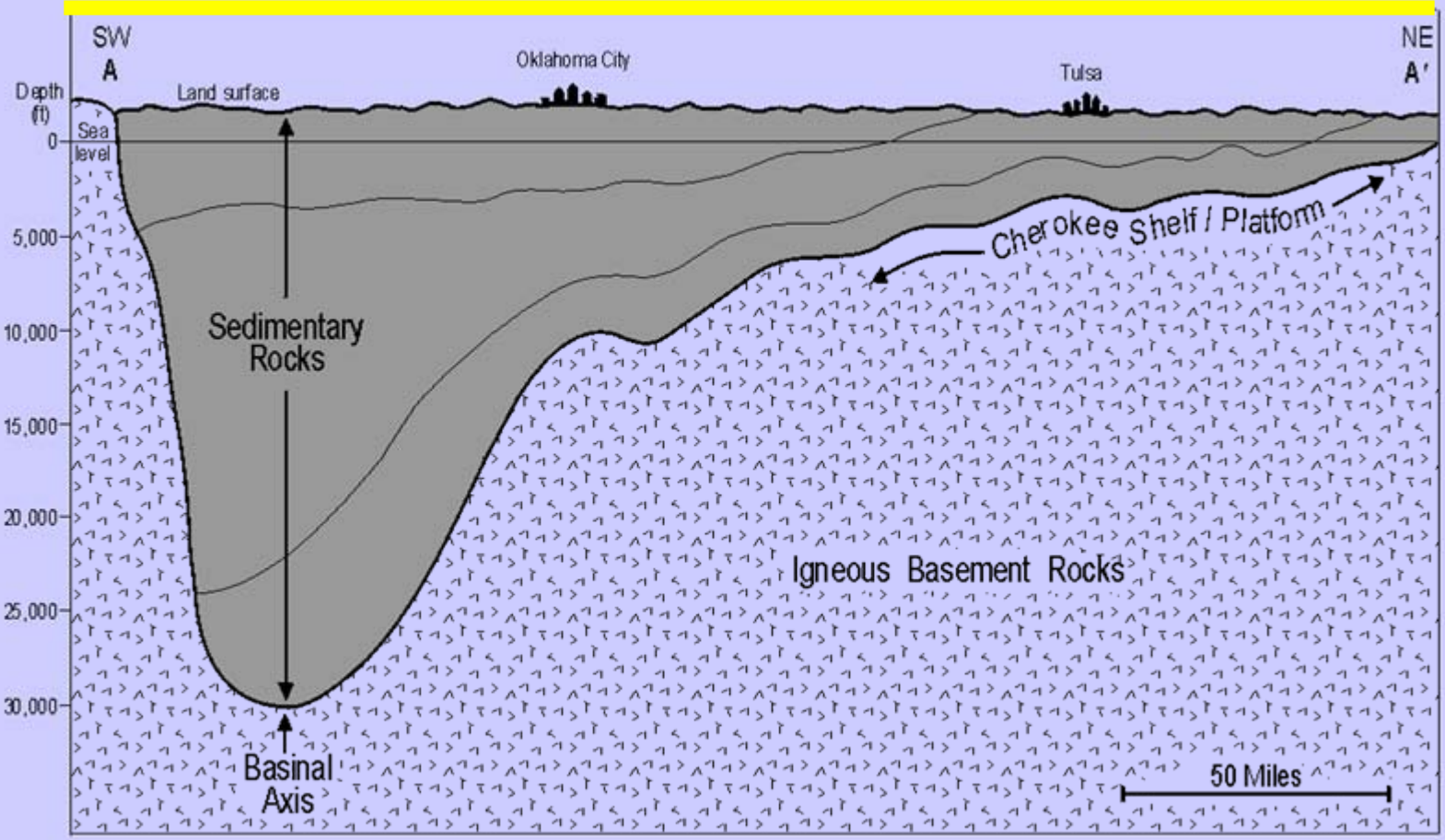


Map of Oklahoma Oil and Gas Fields; Distinguished By GOR and Coalbed Methane Production. From Boyd (2002)
(GOR Cutoffs: Oil <5,000; Oil and Gas 5,000-20,000; Gas > 20,000)

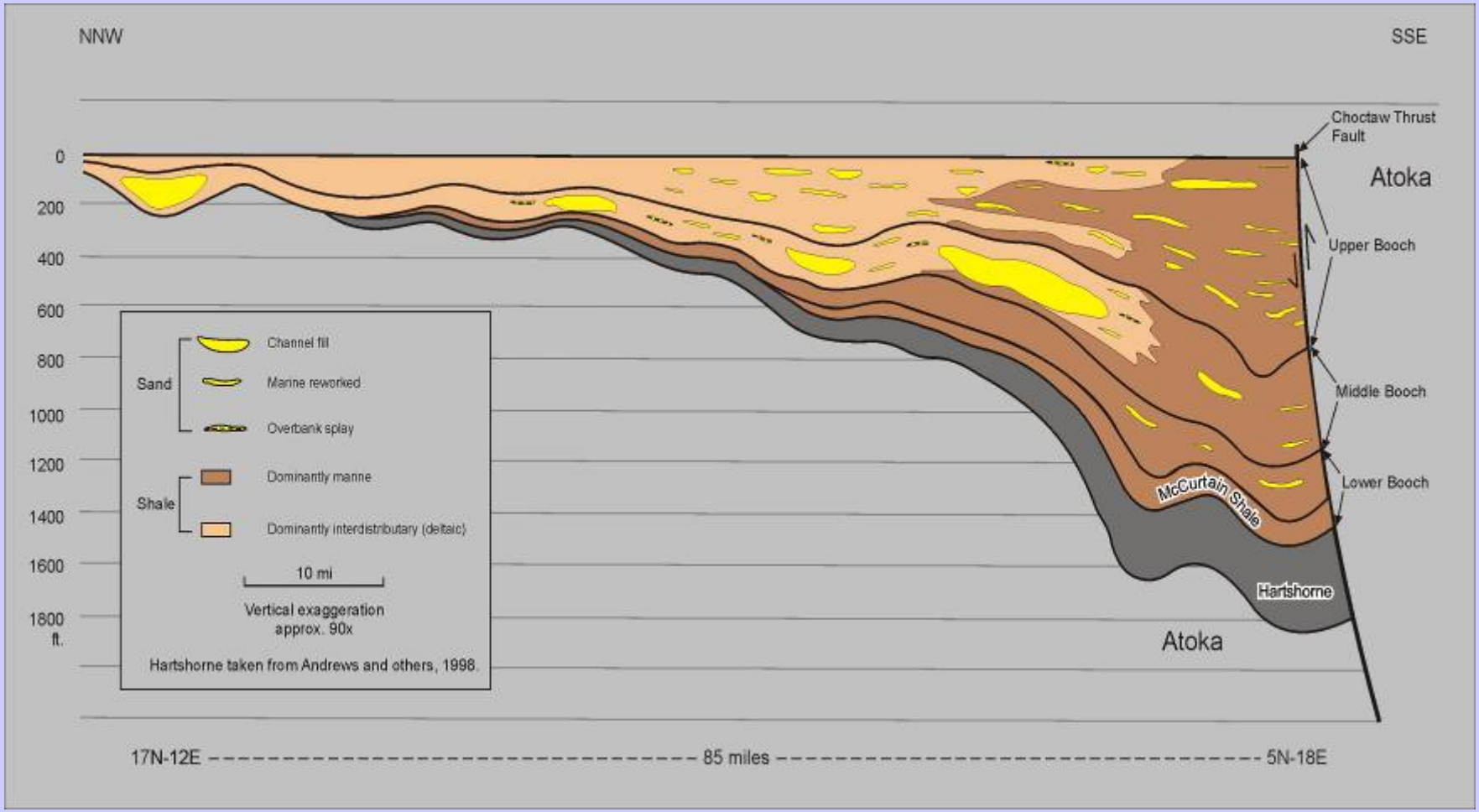


Schematic Cross-section of the Anadarko Basin

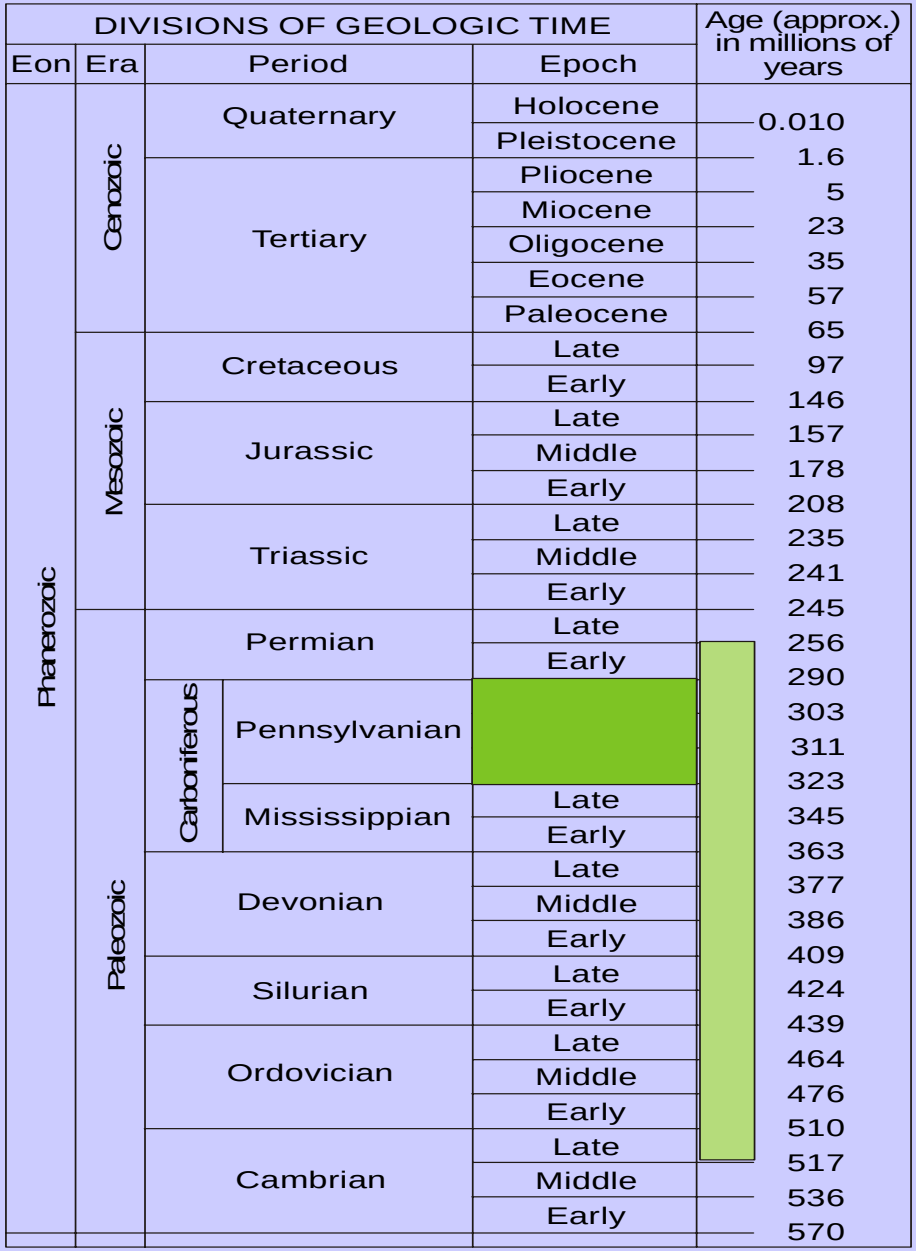
Modified from Witt and others (1971).



Regional Stratigraphic Cross-Section
(Hung from Top of Booch)
Oklahoma Arkoma Basin (Booch)



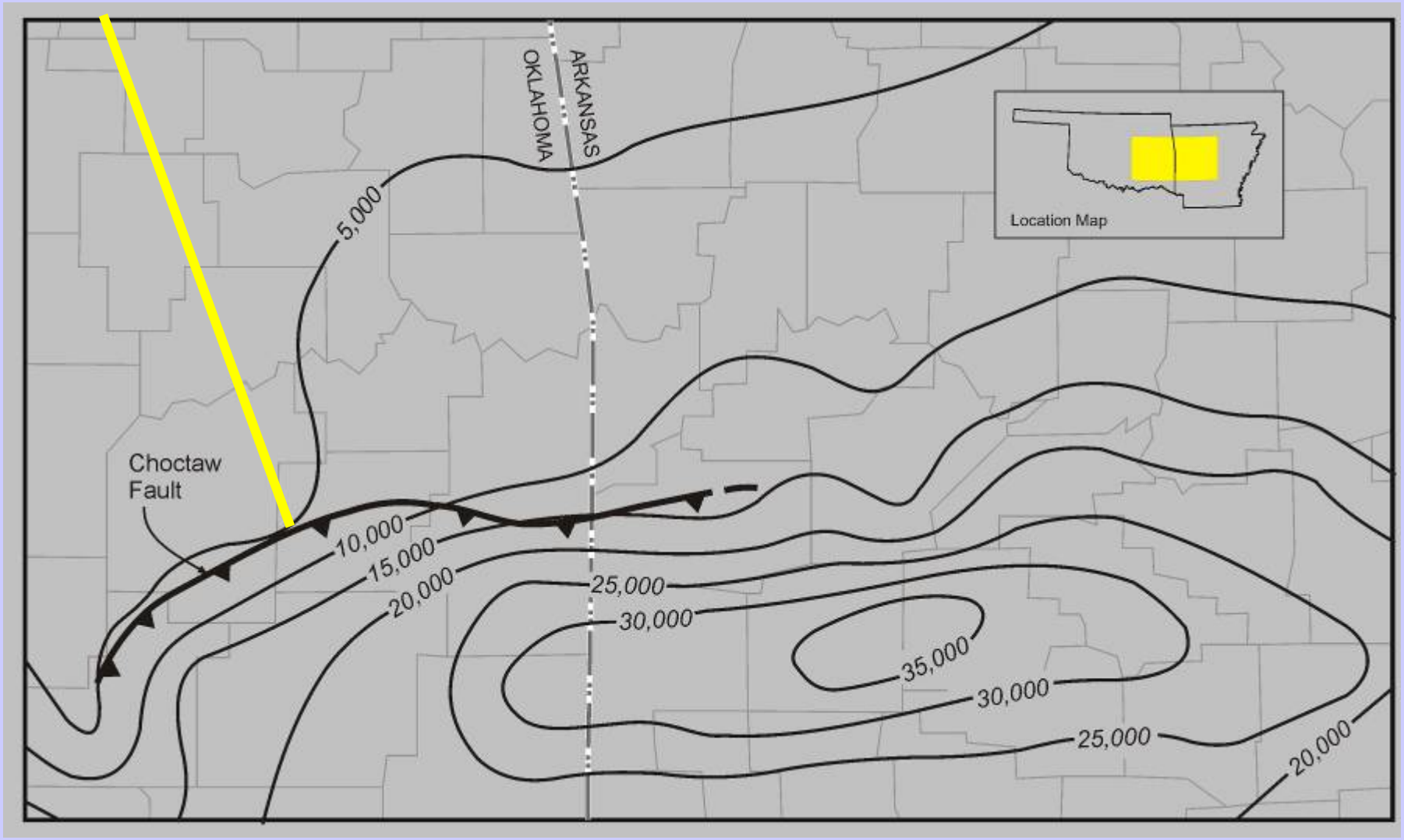
(Present burial depth not necessarily maximum burial depth)



Geologic Time Scale

Modified From Harland (1990) and Hansen (1991).

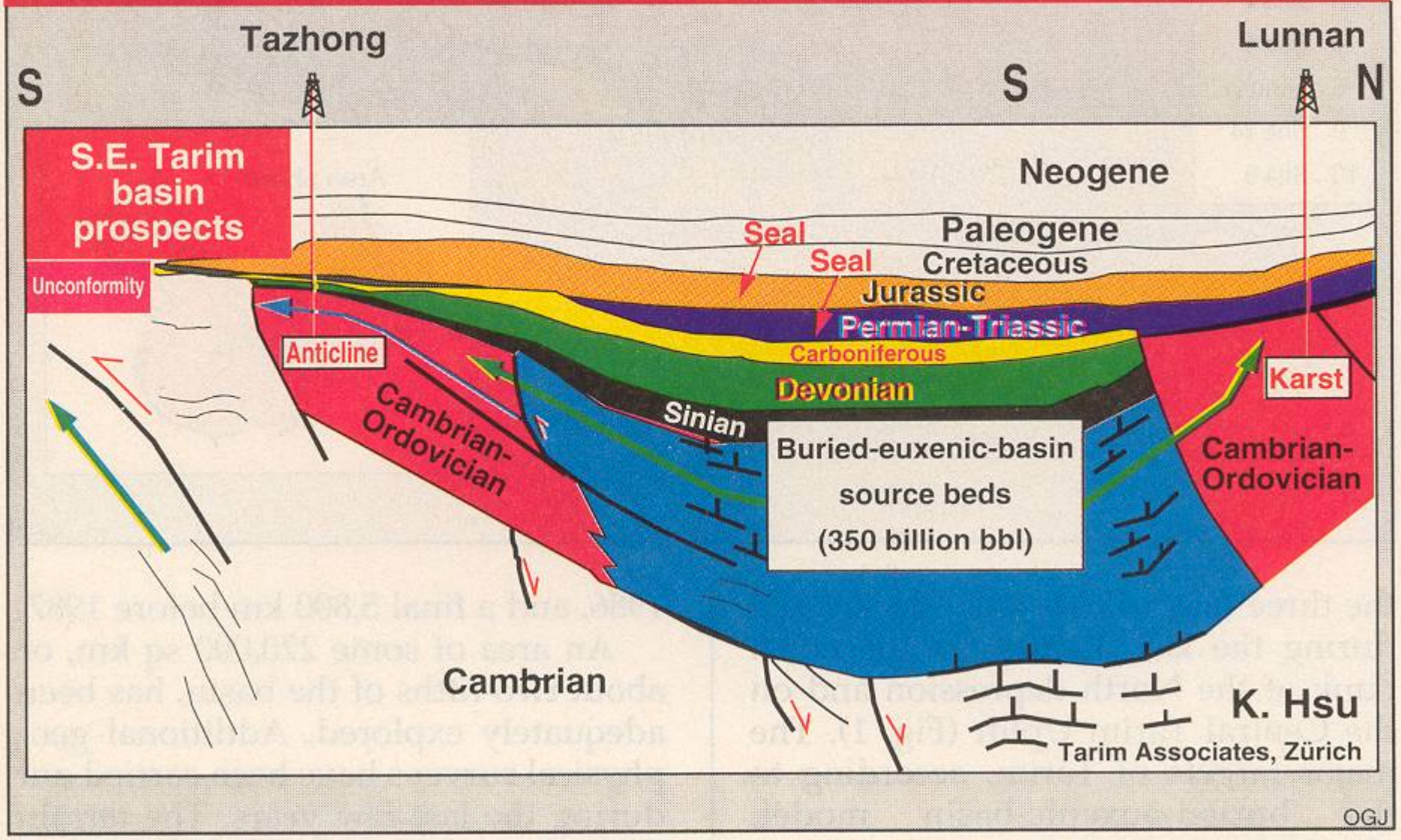
Arkoma Basin
Estimated Overburden Removal



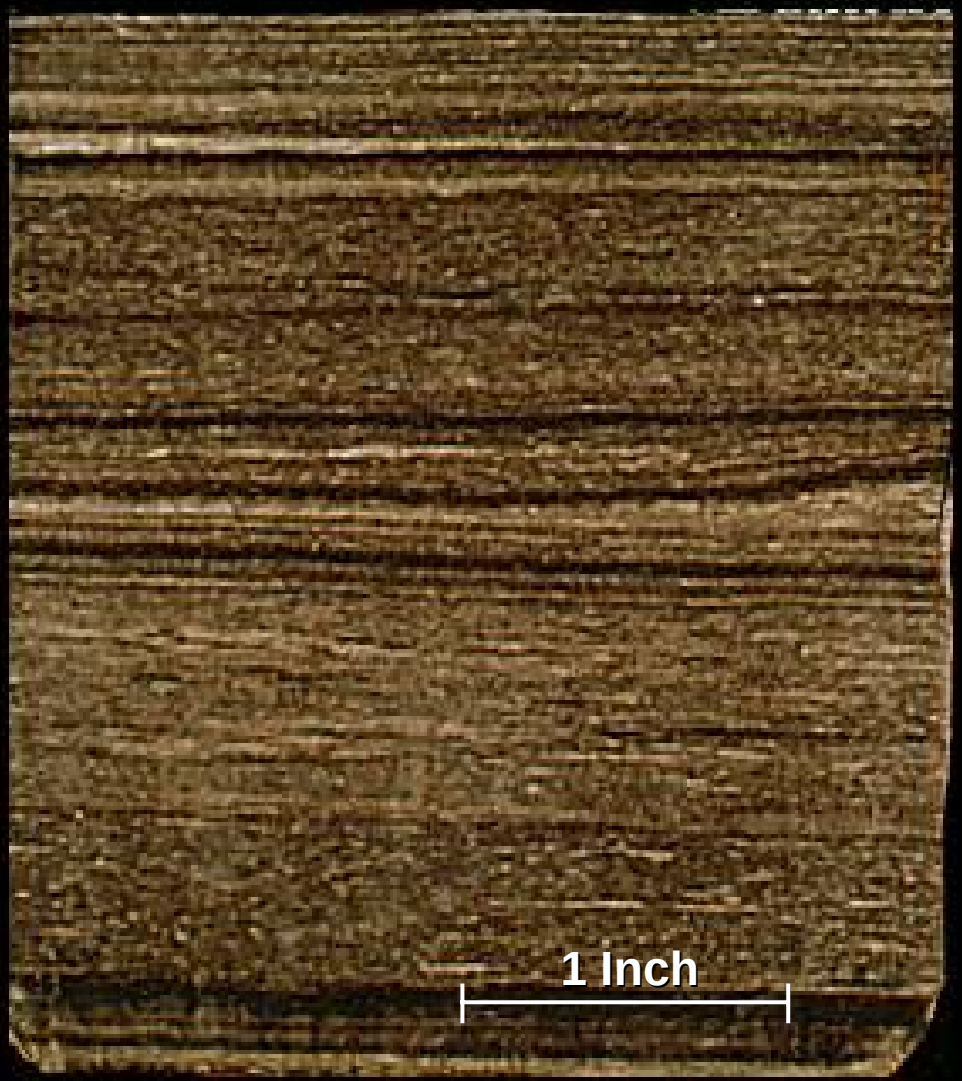
Petroleum System Summary

- **Source (Material and Rocks)**
- **Generation (Maturation)**
- **Migration (Expulsion)**
- **Trap**
- **Reservoir**

BURIED-EUXENIC-BASIN MODEL



Source Rock for Petroleum



Organic-Rich

Thin Laminae

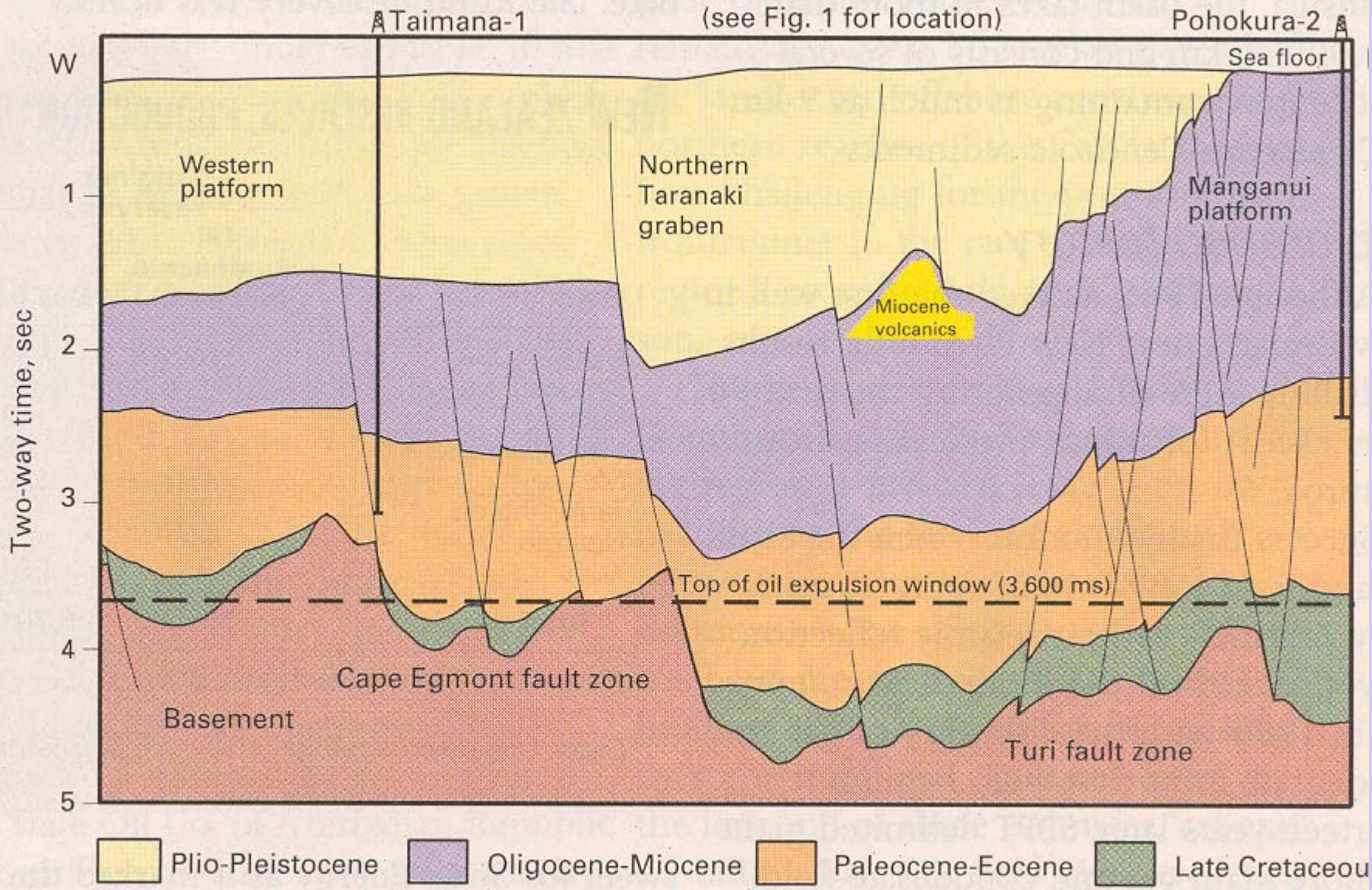
LOMPOC Quarry Sample
Monterey Formation, CA

Migration Pathways

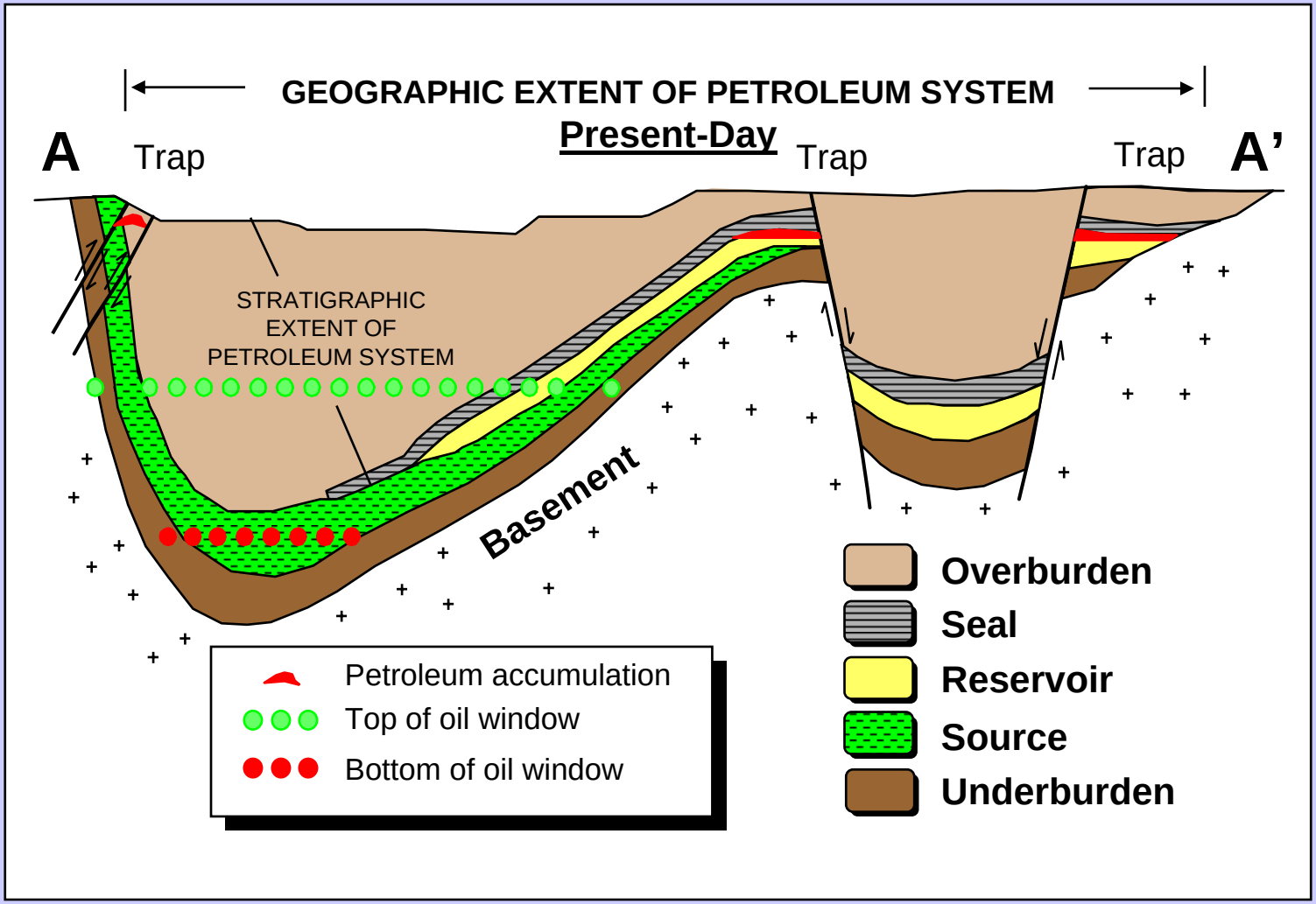
- Hydrocarbon Expulsion
- Vertical vs. Horizontal Migration
- Residual Saturations

SCHEMATIC INTERPRETATION, NM-16 REGIONAL SEISMIC LINE

Fig.

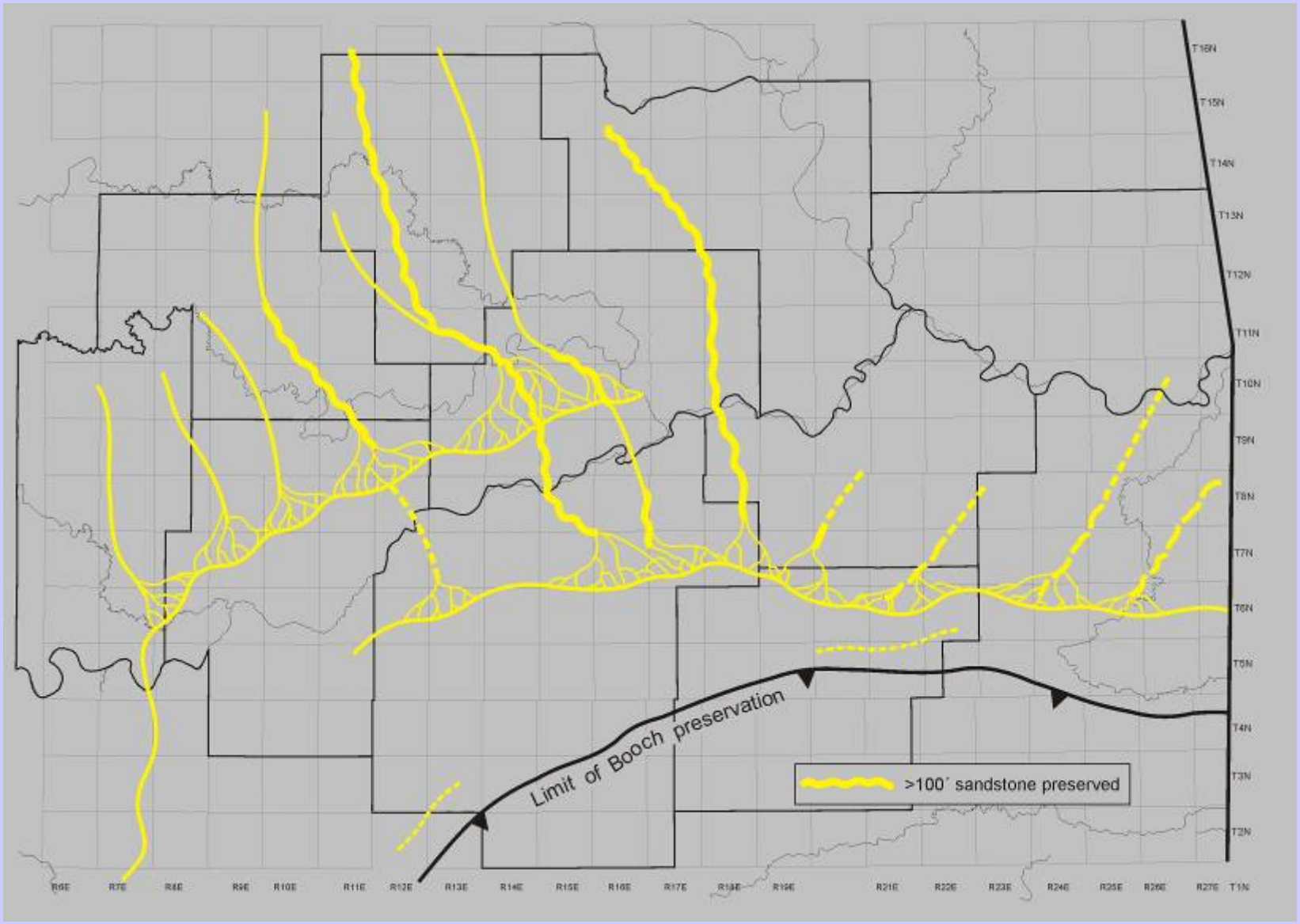


Present-Day Petroleum System

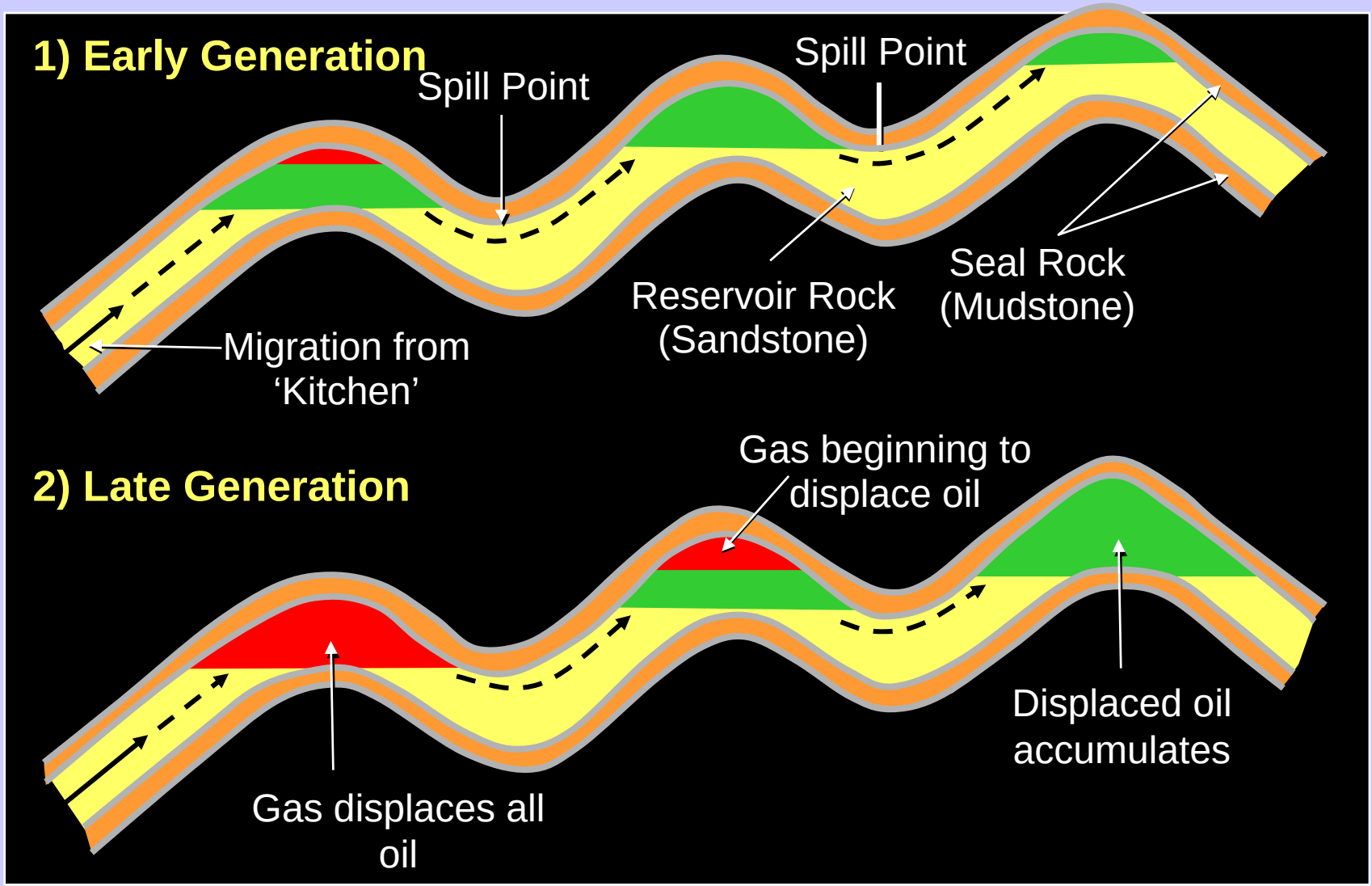


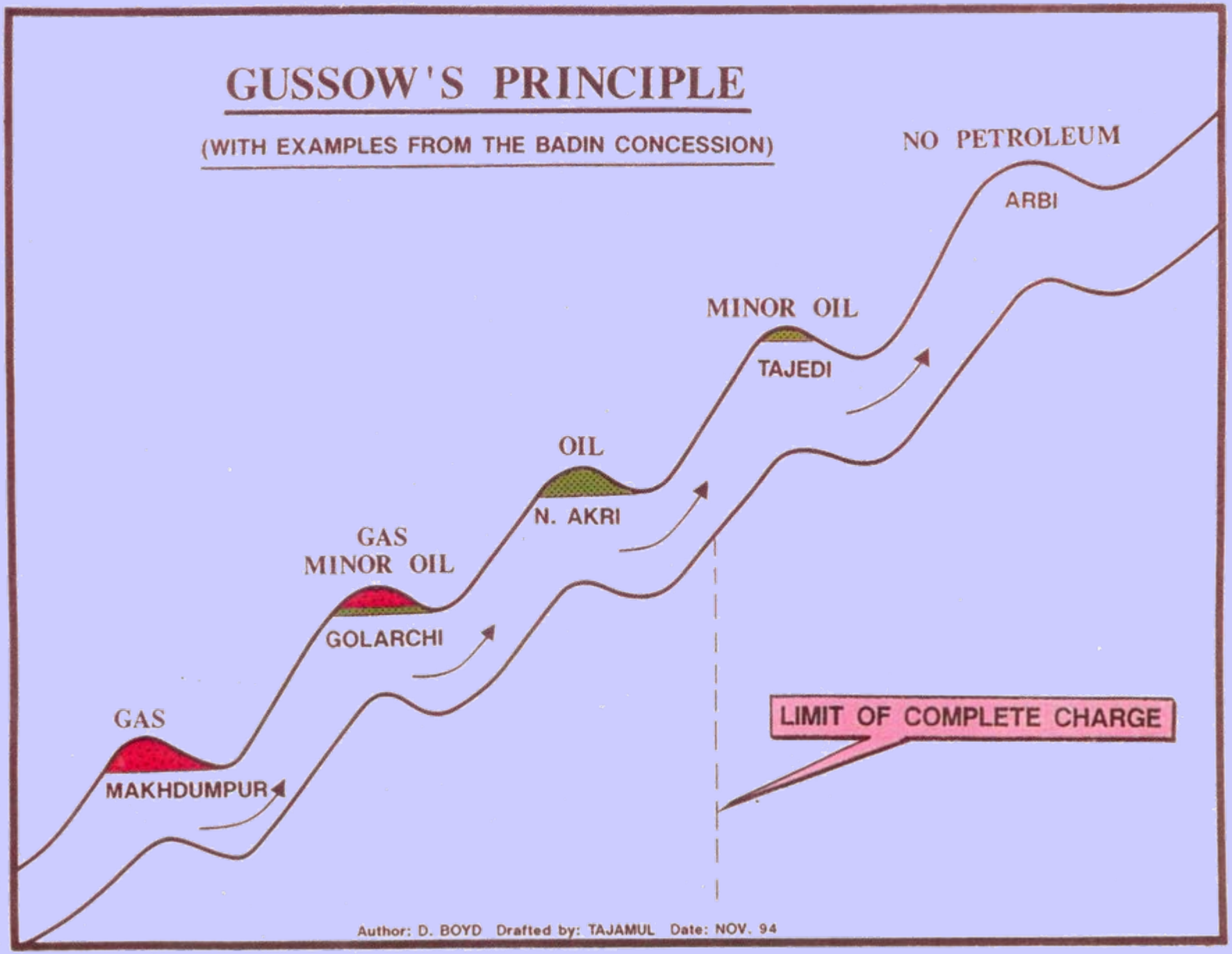
Magoon and Dow, 1994

Inferred Middle Booch Depositional Environments
Arkoma Basin in Oklahoma



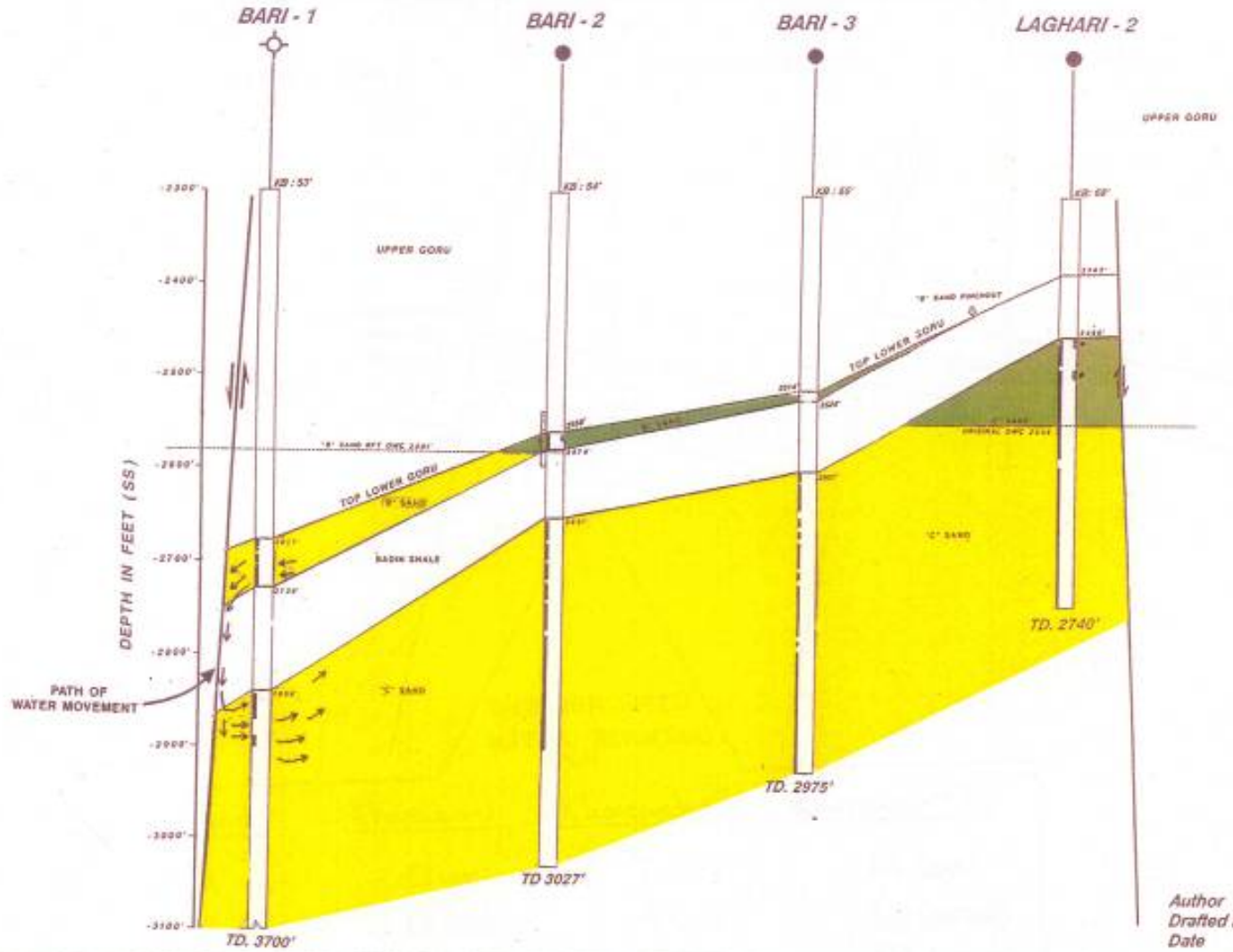
Petroleum System



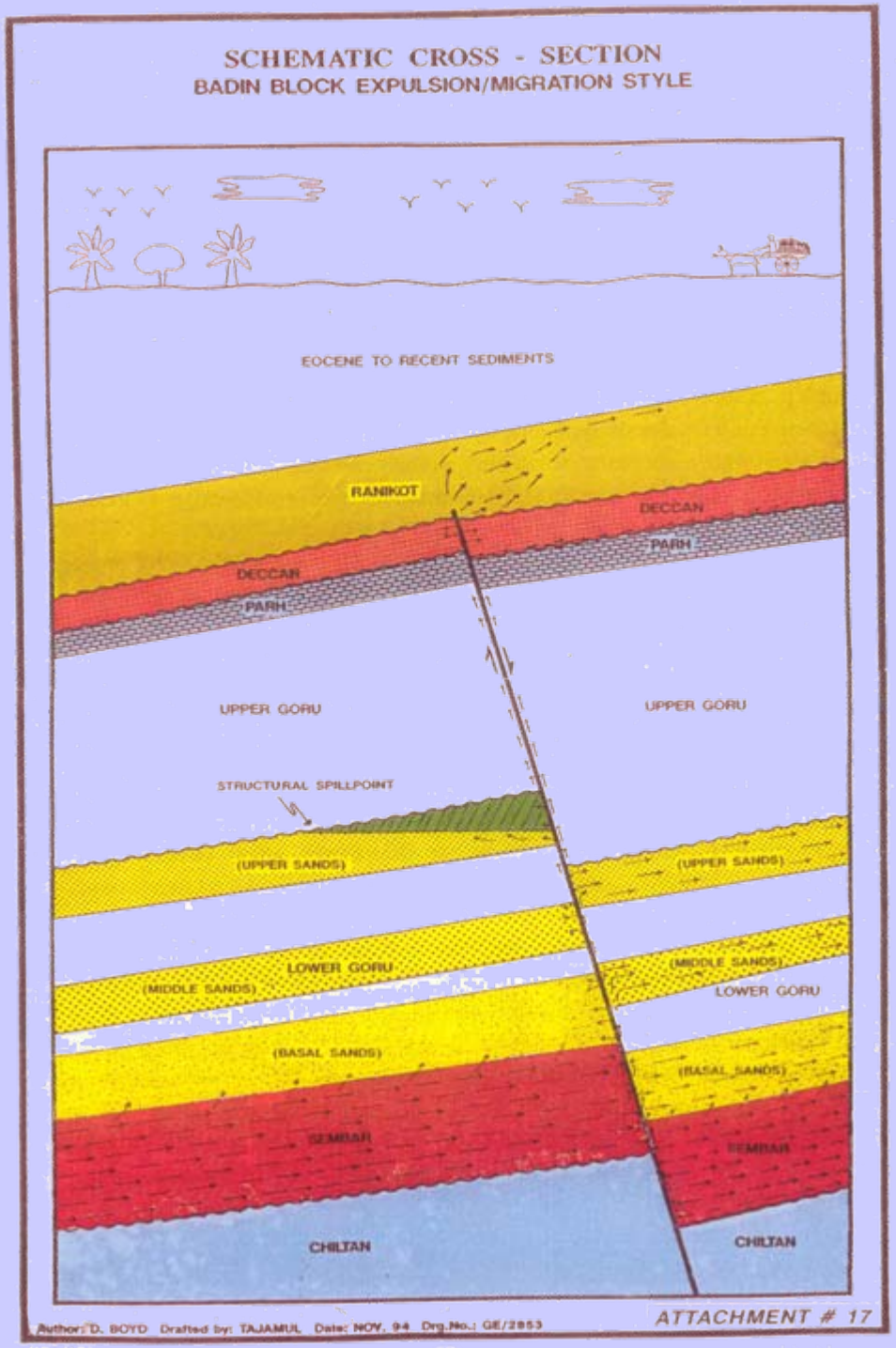

GUSSOW'S PRINCIPLE
(WITH EXAMPLES FROM THE BADIN CONCESSION)
NO PETROLEUM
ARBI
MINOR OIL
TAJEDI
OIL
N. AKRI
GAS
MINOR OIL
GOLARCHI
GAS
MAKHDUMPUR
LIMIT OF COMPLETE CHARGE
Author: D. BOYD Drafted by: TAJAMUL Date: NOV. 94

BARI FIELD

SCHEMATIC CROSS SECTION

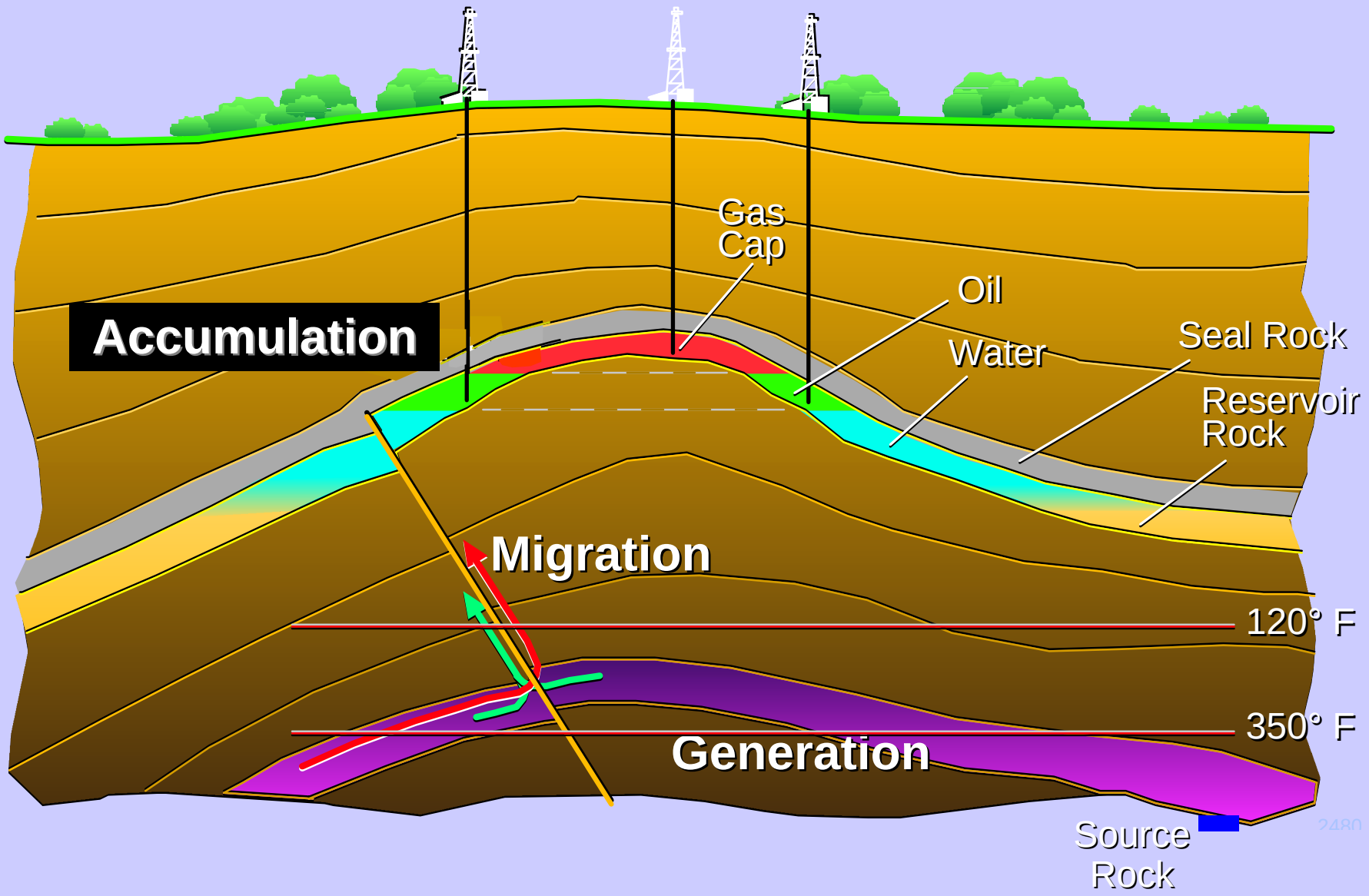


Author : D. BOYD
Drafted by : A. JAVED
Date : AUGUST, 1993

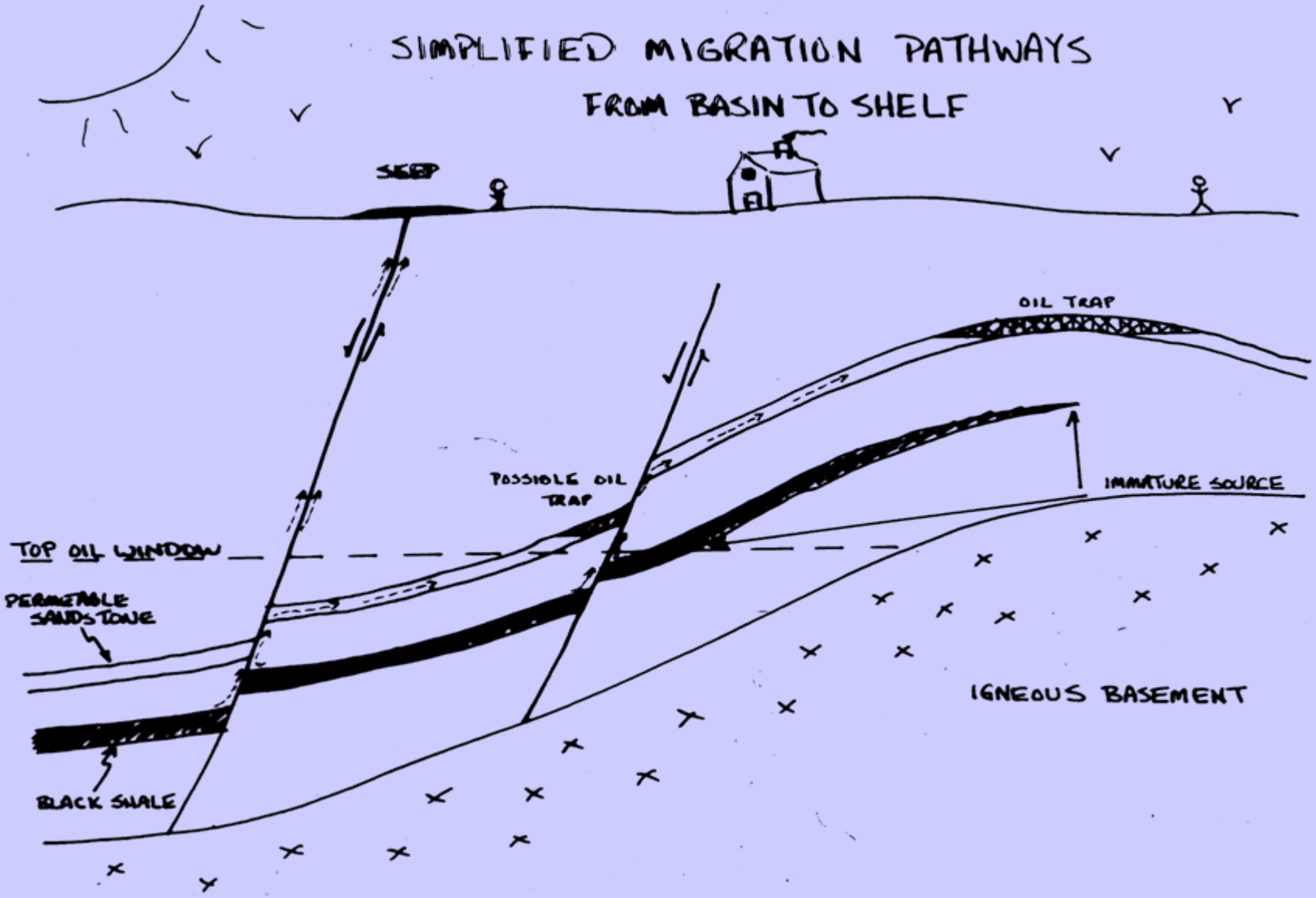


The Leaky Trap

Petroleum System Processes



Schematic Migrational Pathways
From Basin to Shelf



Asphalt Seep
Viola Limestone (Oklahoma)

The End of the Road

On to the Trap

One More Thing…….

Basin Assignments

- North American
  - San Juan
  - East Texas
  - Gulf Coast
  - Anadarko
  - Arkoma
  - Powder River
  - Wind River
  - Green River
  - Williston
  - Delaware
  - Midland
  - Black Warrior
  - Fort Worth
  - Others……..

Facts to Consider

Basin

Location, Size, Maximum Depth, Age (from basement to outcrop + max subsidence), Stratigraphy
Other items; eg - Structure (extensional, compressional)

Petroleum System

Source Rocks: Name(s), kerogen type(s), TOC, depth to top of oil window, kitchen location

Migration Pathways: Carrier bed(s), faults, distance (vertical and horizontal)

Traps: Structural, Stratigraphic, Combination (dominant type)

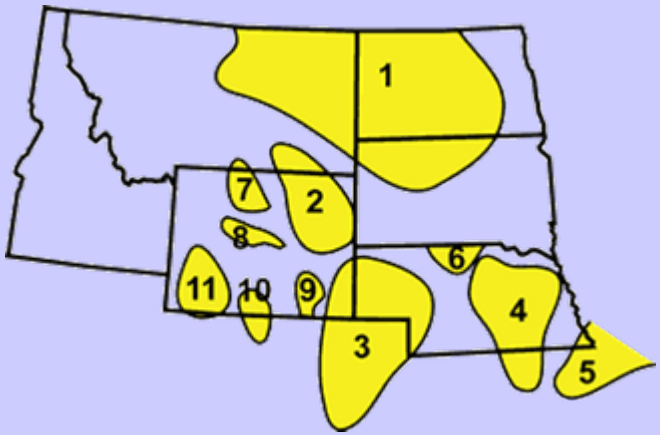
Reservoirs: Names, Rock types (both reservoir and seal)

Representative Fields (The biggest ones)
OOIP, OGIP, RF, Cum Prod

Other notable Facts – anything else you want to add (history, technology, companies, etc)

Powerpoint presentation: 10-12 slides (or more), approach as management presentation in which object is to highgrade future exploration opportunities for your company. For any answers you cannot find, treat as source of increased risk of entry.

Map of Selected Sedimentary Basins



1-Williston Basin
2-Powder River Basin
3-Denver Basin
4-Salina Basin
5-Forest City Basin
6-Kennedy Basin
7-Big Horn Basin
8-Wind River Basin
9-Laramide Basin
10-Washakie-Red Desert B.
11-Green River Basin

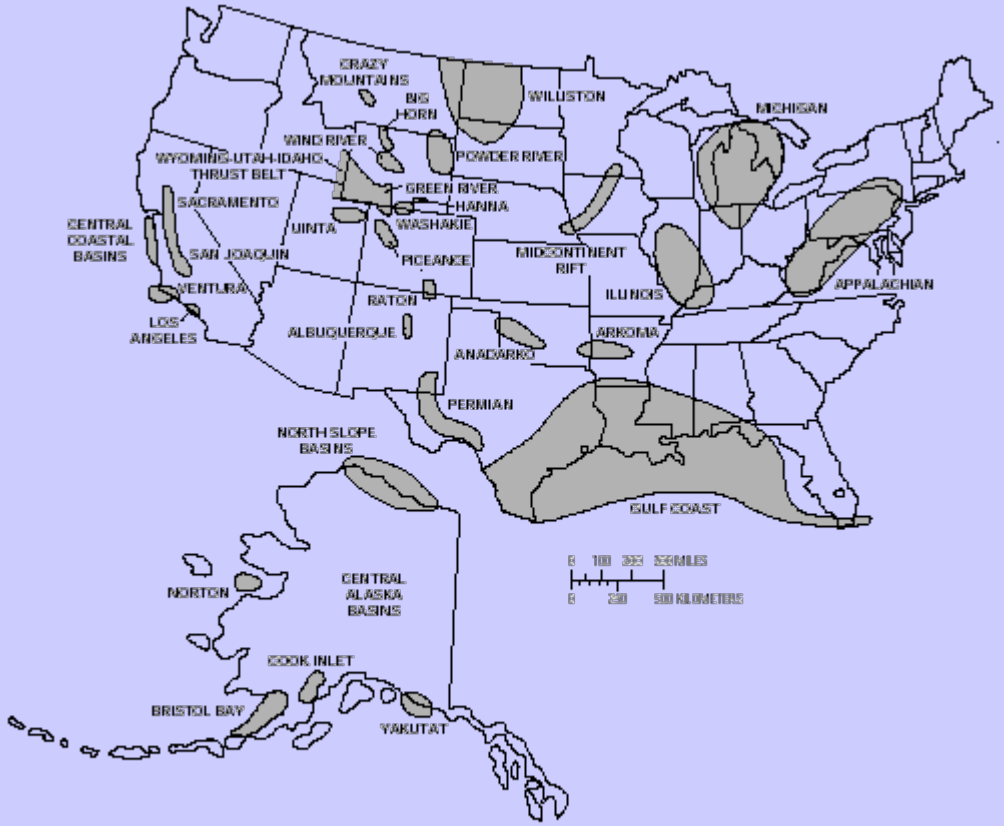
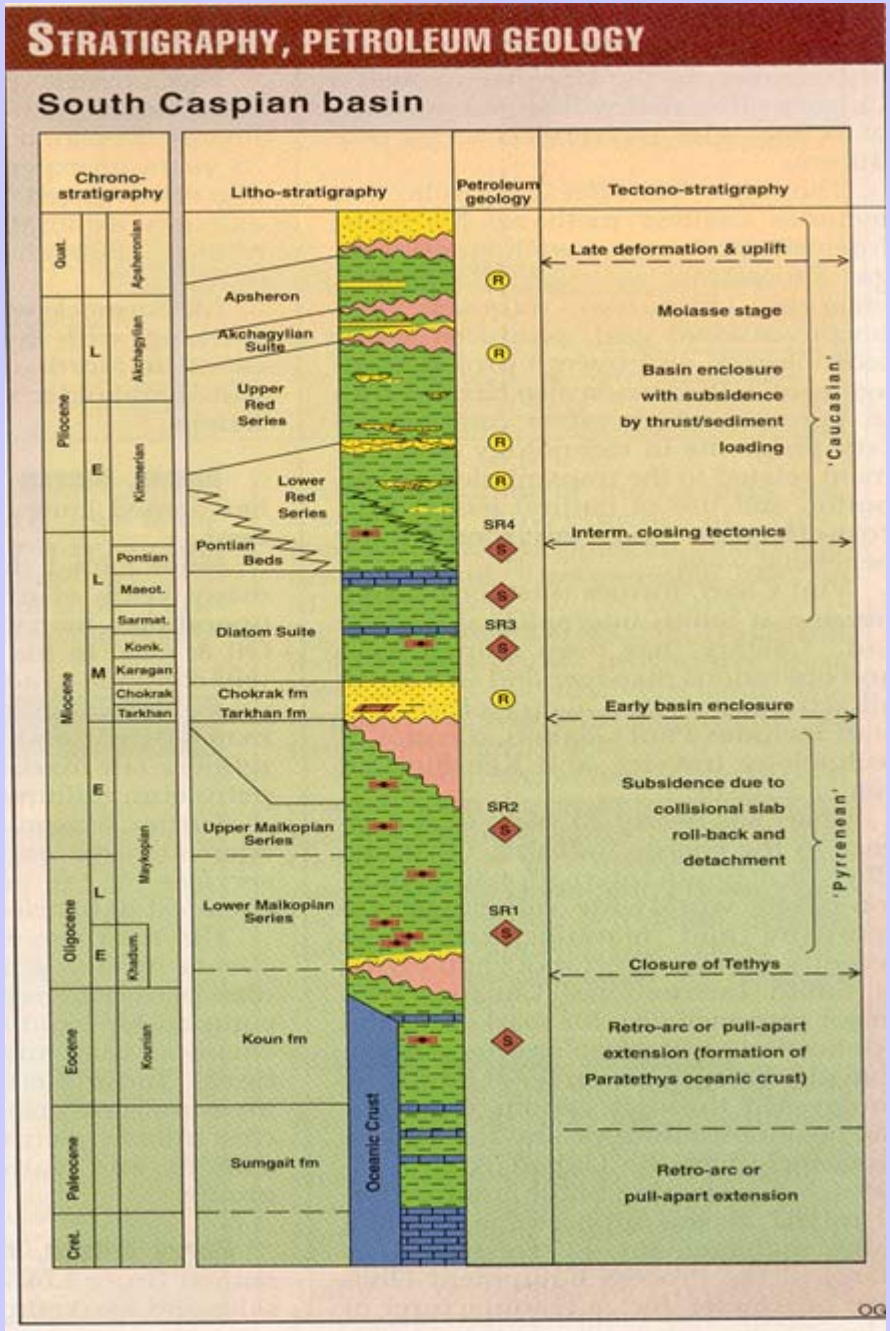
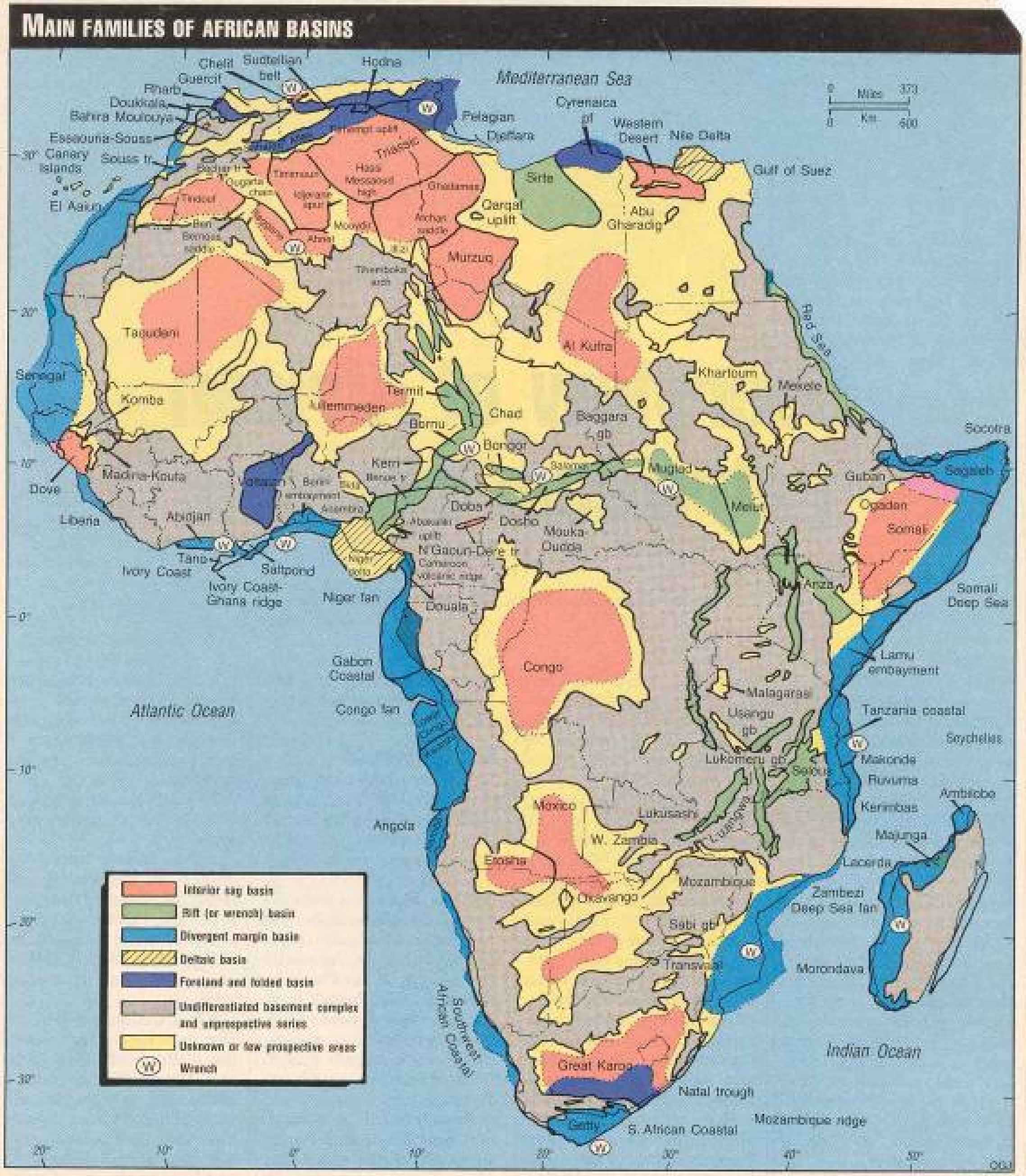
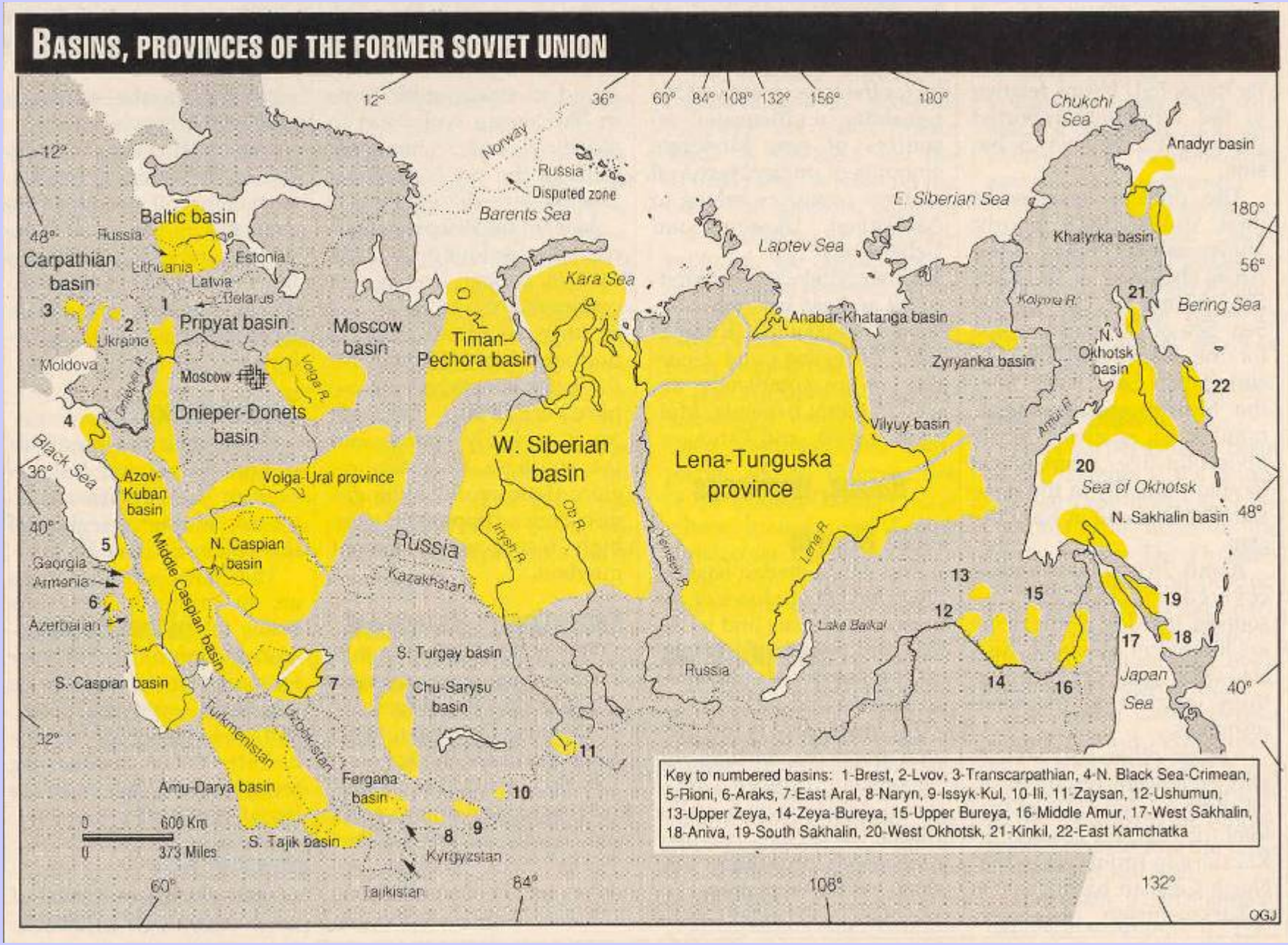


Figure 1. Map of the United States showing basins containing sedimentary rocks more than 15,000 ft (4,572 m) deep. Shading indicates entire basin area, in which some of the sedimentary rocks are at shallow depths.


STRATIGRAPHY, PETROLEUM GEOLOGY
South Caspian basin
Chrono-stratigraphy
Litho-stratigraphy
Petroleum geology
Tectono-stratigraphy
Quat.
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Cret.
L
E
M
Apsheronian
Akchagylian
Kimmerian
Pontian
Maeot.
Sarmat.
Konk.
Karagan
Chokrak
Tarkhan
Maykopian
Khadum.
Kounian
Apsheron
Akchagylian Suite
Upper Red Series
Lower Red Series
Pontian Beds
Diatom Suite
Chokrak fm
Tarkhan fm
Upper Maikopian Series
Lower Maikopian Series
Koun fm
Sumgait fm
Oceanic Crust
R
SR4
S
SR3
G
SR2
SR1
Late deformation & uplift
Molasse stage
Basin enclosure with subsidence by thrust/sediment loading
'Caucasian'
Interm. closing tectonics
Early basin enclosure
Subsidence due to collisional slab roll-back and detachment
'Pyrrenean'
Closure of Tethys
Retro-arc or pull-apart extension (formation of Paratethys oceanic crust)
Retro-arc or pull-apart extension


MAIN FAMILIES OF AFRICAN BASINS
Mediterranean Sea
Atlantic Ocean
Indian Ocean
Chelif
Sudtellian belt
Hodna
Guercif
Rharb
Doukkala
Bahira Moulouya
Essaouira-Souss
Canary Islands
Souss tr
El Aaiun
Tindouf
Triassic
Hassi Messaoud high
Ghadames
Pelagian
Djeffara
Cyrenaica pf
Western Desert
Nile Delta
Gulf of Suez
Sirte
Qarqaf uplift
Abu Gharadig
Murzuq
Taoudeni
Al Kufra
Red Sea
Khartoum
Mekele
Senegal
Komba
Iullemmeden
Termit
Chad
Bornu
Baggara gb
Bongor
Salamat
Muglad
Melut
Socotra
Guban
Sagaleh
Ogaden
Somali
Dove
Madina-Kouta
Voltaian
Liberia
Abidjan
Kerri
Benue tr
Doba
Doseo
Mouka-Ouadda
Niger delta
Tano
Saltpond
Ivory Coast
Ivory Coast-Ghana ridge
Niger fan
Abakaliki uplift
N'Gaoun-Dere tr
Cameroon volcanic ridge
Douala
Anza
Somali Deep Sea
Gabon Coastal
Congo
Congo fan
Lamu embayment
Malagarasi
Usangu gb
Tanzania coastal
Seychelles
Lukomeru gb
Selous
Makonde
Ruvuma
Kerimbas
Ambilobe
Majunga
Lacerda
Angola
Mexico
Lukusashi
W. Zambia
Etosha
Okavango
Mozambique
Zambezi Deep Sea fan
Sabi gb
Transvaal
Morondava
Southwest African Coastal
Great Karoo
Natal trough
Mozambique ridge
Getty
S. African Coastal
Interior sag basin
Rift (or wrench) basin
Divergent margin basin
Deltaic basin
Foreland and folded basin
Undifferentiated basement complex and unprospective series
Unknown or few prospective areas
Wrench
Miles
Km
OGJ


BASINS, PROVINCES OF THE FORMER SOVIET UNION
Baltic basin
Carpathian basin
Pripyat basin
Moscow basin
Timan-Pechora basin
Dnieper-Donets basin
Volga-Ural province
W. Siberian basin
Lena-Tunguska province
Anabar-Khatanga basin
Khatyrka basin
Anadyr basin
Zyryanka basin
N. Okhotsk basin
Vilyuy basin
Azov-Kuban basin
N. Caspian basin
Middle Caspian basin
S. Caspian basin
S. Turgay basin
Chu-Sarysu basin
Fergana basin
Amu-Darya basin
S. Tajik basin
N. Sakhalin basin
Russia
Kazakhstan
Turkmenistan
Uzbekistan
Kyrgyzstan
Tajikistan
Mongolia
Norway
Russia
Disputed zone
Barents Sea
Kara Sea
Laptev Sea
E. Siberian Sea
Chukchi Sea
Bering Sea
Sea of Okhotsk
Japan Sea
Lake Baikal
Black Sea
Moldova
Ukraine
Belarus
Lithuania
Latvia
Estonia
Georgia
Armenia
Azerbaijan
Moscow
Dniepr R.
Volga R.
Ob R.
Irtysh R.
Yenisey R.
Lena R.
Amur R.
Kolyma R.
0 600 Km
0 373 Miles
Key to numbered basins: 1-Brest, 2-Lvov, 3-Transcarpathian, 4-N. Black Sea-Crimean, 5-Rioni, 6-Araks, 7-East Aral, 8-Naryn, 9-Issyk-Kul, 10-Ili, 11-Zaysan, 12-Ushumun, 13-Upper Zeya, 14-Zeya-Bureya, 15-Upper Bureya, 16-Middle Amur, 17-West Sakhalin, 18-Aniva, 19-South Sakhalin, 20-West Okhotsk, 21-Kinkil, 22-East Kamchatka
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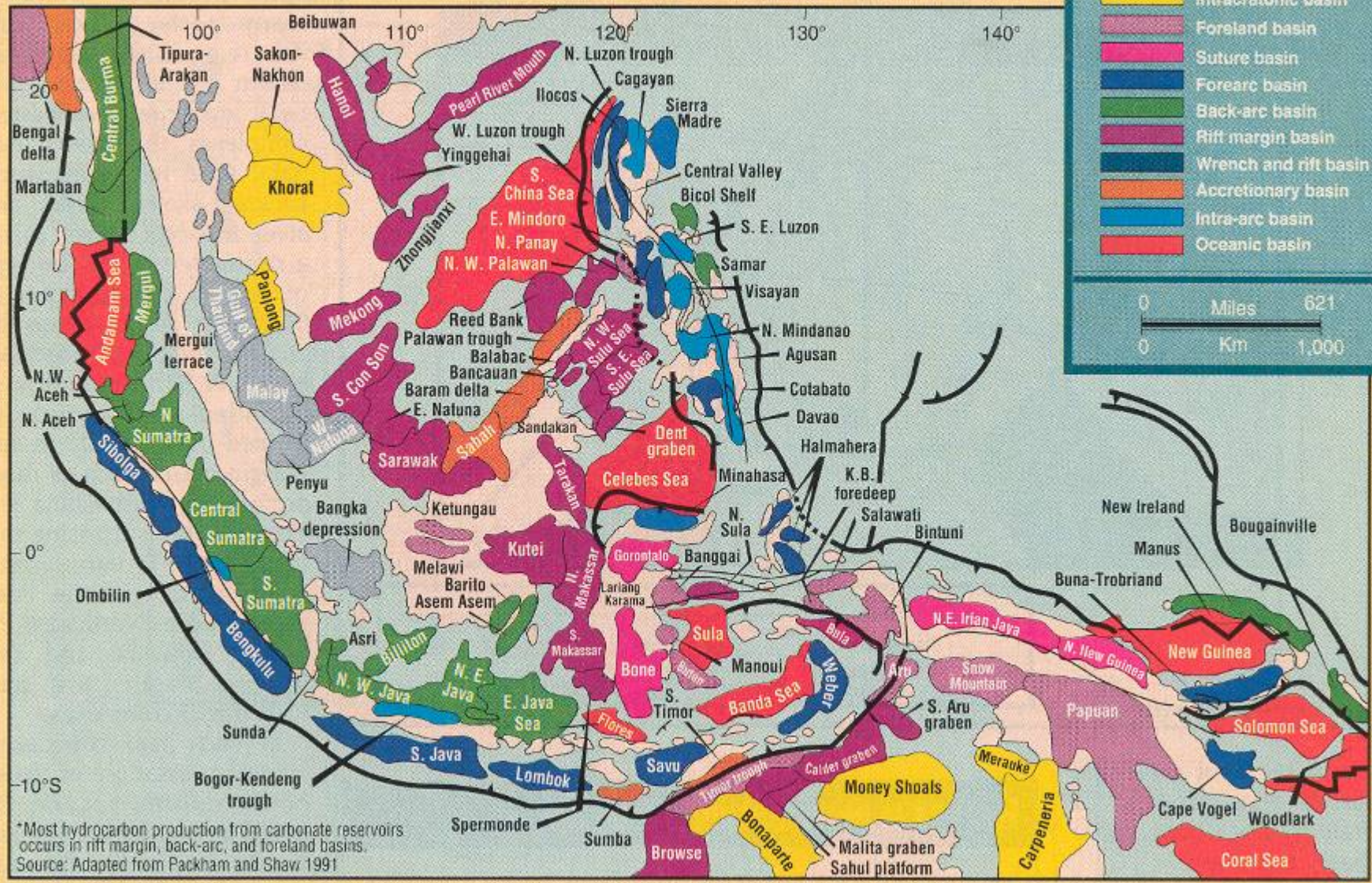
TERTIARY BASINS OF SOUTHEAST ASIA*



*Most hydrocarbon production from carbonate reservoirs occurs in rift margin, back-arc, and foreland basins.
Source: Adapted from Packham and Shaw 1991

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