Part II

HC Exploration

(*a posteriori* **hypotheses**)

(i) Historical Features

- 6 000 years ago, the eternal fires (natural gas) were object of cult at Kirkouk.
- 3000 years ago, the Chinese exploiting salt disco-vered gas (bamboo drilling till 200 m) which they used to dry the brine.
- Asphalt is mentioned in the Bible (Dead Sea). It was used since Antiquity for waterproofness of boats, as mortar for houses and “gregeois” fires.
- The first oil wells were drilled in Baku (by hand), in 1594 (35 m).

(cont.)

- Bituminous sands were exploitet at Pechelbronn since 1735.
- Bituminous schists were exploited as fuels since 1750 in China, and since 1850 in France (Autun) and in the Scotland.
- First modern drilling (cable) took place in 1848 in Baku, in 1854 in Poland, in 1858 in Canada and finally, in 1859, in the United States.
- First drilling rotary date of 1902 and is still used system.

(ii) Basic Concepts

- Annual production of organic matter is roughly 23 Gt, in oceans, and 0,7 Gt, in onshore.
- The big majority of organic matter is oxidized before sedimentation.
- Fossil organic matter in sediments is less than 1 % of the OM accumulated in 500 My.
- Resources of concentrated fossil fuels is roughly 1 % fossil organic matter.
- Ultimate conventional petroleum reserves are roughly 0,3 % of the resources.

(cont.)

- Depending on HC problems explorationists must place themselves between two extreme situations:
  - Simple
  - Complex
- However,

“ All that is simple is false and all that is complex is useless” (P. Valéry)

- In HC exploration, the easy and simple has already been found and produced. It remains the difficult, i.e. the complex.

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(iii) Reserves & Resources

The term "reserves" is often treated as if it were synonymous with "proved reserves". This practice completely ignores the fact that any prudent operator will have, at least internally, estimates of probable and possible reserves .

Similarly, there is often confusion between Reserves (expected production) and Resources (potential in the ground):

Reserves = Future production with the current techniques and economy.

Resources = Either the volume of HC contained in the ground, or the volume of HC which one could produce without technical and economic constraint of the known fields or to discover.

Reserves are confidential and uncertain until the last day of production.

(cont.)

- **In the reserves calculations, there are conflict between the deterministic approach (one value) and the probabilistic approach (three values).**
- **Probabilities are subjective.**
  - **Only expected values can be added.**
  - **Only most likely values can be multiplied.**
- **Similarly, the value of the reserves can change substantial. It depends for they are and from they are.**

(cont.)

When analysing reserves, one must take into account that in a company there are different external and internal reserves.

External reserves:

- for bankers,
- for the shareholder,
- for the tax agencies,
- for the OPEC quotas, etc.

Internal reserves:

- from the geologist-geophysicist,
- from the reservoir engineer,
- from the economist,
- from the manager,
- from the state agency

(cont.)

In addition, the announced reserves can be:

(i) the minimum,

(ii) the maximum,

(iii) the mean.

Motives for declaring the minimum

- **Explorationist**: for large prospects to avoid being regarded as a dreamer.
- **Engineer:** to reduce the risk of being wrong (a mean estimate implies being wrong 60% of the time).
- **Company:** to secure apparent reserve growth over time which presents a more attractive financial image; may reduce tax and, in some cases, to facilitate its competitive position.

(cont.)

Motives for declaring the maximum

- **Explorationist**: to make a small prospect sufficiently economic to pass corporate hurdles.
- **Company:** to augment its share values; sale value; the stock options of its executives; over-come government constraints to depletion rate.
- **Countries:** to provide collateral for debt.
- **OPEC:** to increase quota.
- **Soviet Union:** to show the maximum theoretical reco-very ignoring economic constraints.

(cont.)

Motives for declaring the mean

(expected value)

- Those seeking a valid national total.

Notice that the mean value of a large number of fields is the sum of the mean value of each individual field, despite the fact that, statistically, 60% of the cases will prove incorrect.

To avoid mistakes when comparing reserves proposed by different companies, its important do not forget the different practices, that can be summarised as follows:

(cont.)

Companies listed on US stock market:

Reserves

They have to comply SEC (Securities & Exchange Comission) and to report only proved reserves, that is to say 67% probability (most likely) and not 90% as defined by SPE/WPC.

Field growth (or reserves growth or appreciation)

Part of the neglected probable reserves become proved. It corresponds roughly to the different between the mean (±40%) and the most likely (±65%).

SPE/WPC (1997) reserves definitions are:

Proved = reasonable certainty and high confidence= 90%

Deterministic Probable = as likely as not= 50%

Probabilistic proved+Probable = 50%

(cont.)

Rest of the World:

Reserves

They correspond to 2P = Proved + Probable, which usually is 50% probability.

Field growth (or reserves growth or appreciation)

It corresponds to the difference between mean (±40%) and 2P (±50%)

Why all this uncertainty on reserves estimation?

(cont.)

Because, in exploration there is several actors with different cultures:

Explorationist

- He drills at least 8 dry holes out of 10 wildcats (he has the right to be wrong).

  But only around 500 giants oil & gas fields were found out of around 50.000 fields, i.e. 1% of giants for 75% of reserves.

- He looks for:
  - uncertainty (probability) over large range (<1 to 115.000 Mb).
  - or high investiment with high risk (high profit)

- He plays with large number like the casino owner and he takes partners with same culture.

(cont.)

Reservoir engineer

- He simulates a field development with large number of cells (up to 100.000) and for each production project, he computes just one reserve value

Banker

- He looks for certainty and for one value for large investment for development only with small risk (small profit). His client has a different culture. He relies on outside experts.

Expert

- He is supposed to know and to be always right, so he uses mainly a deterministic approach.

(iv) Ultimate Reserves

Ultimate Reserves correspond to the quantity of HC which will be produced in the end of the exploitation.

As we will see later, ultimate reserves can be estimate in several ways :

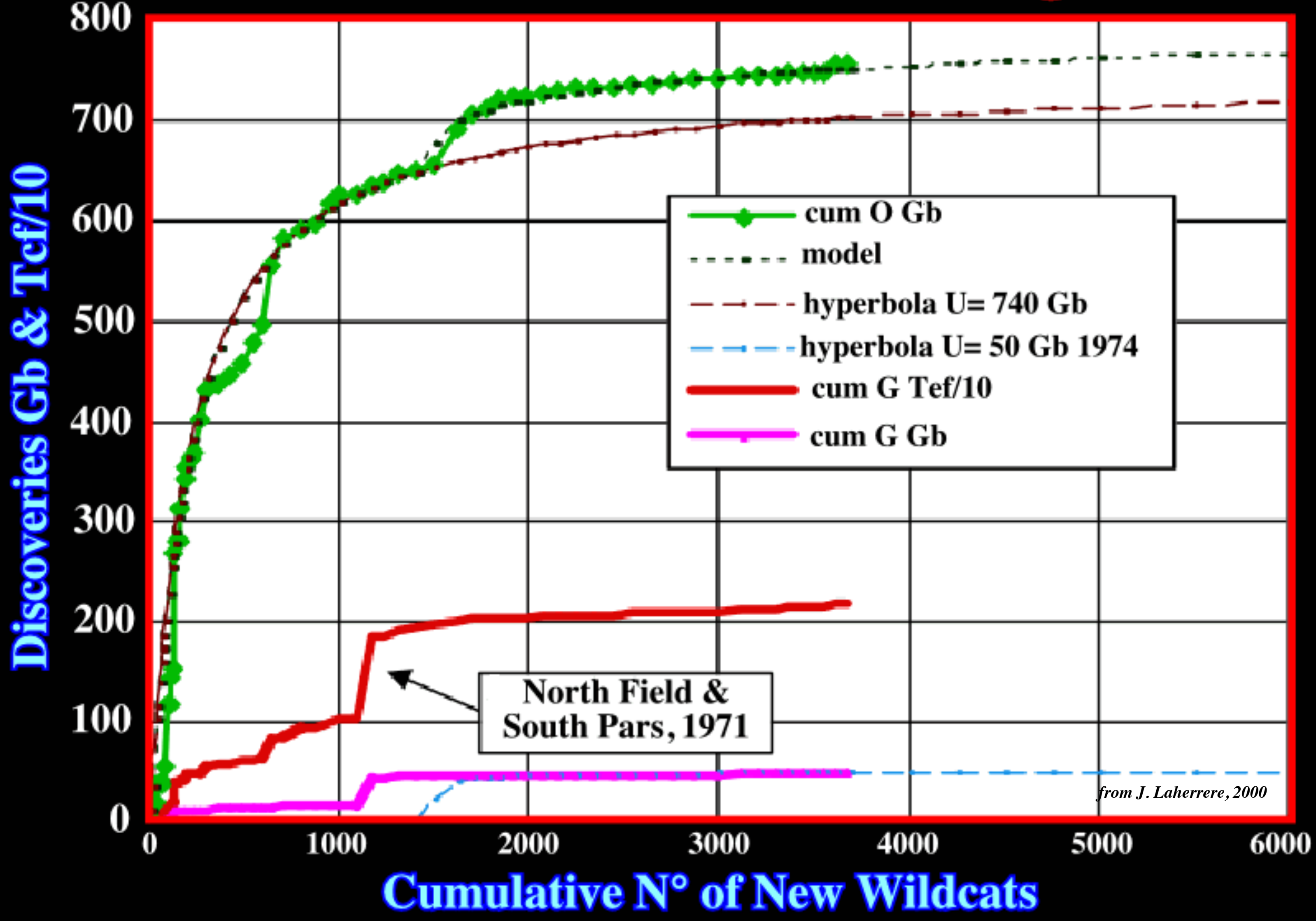
A) Accumulated creaming curves of discoveries versus the accumulated number exploratory wells.

B) Annual percentage curves versus the cumulated accumulated production and discoveries.

C) Correlation production and shifted discoveries.

(cont.)

Middle East Crude Oil: creaming curve



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(v) Models to Assess Oil & Gas
(Discoveries & Production)

Models need to study the past reserves with time. Reserves are in fact the addition of all future productions until the end. The production of today was part of the reserves of yesterday.

There area large range of production and discovery models:

- Creaming curve with hyperbola;
- Cumulative production with logistic curve;
- Annual discovery and production with normal curve or derivative of logistic (Hubbert curve);
- Parabolic fractal for field size-rank in a log-log display;
- Lognormal distribution;
- Stretched exponential, and so on.

(cont.)

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The best approach is to deal with the most homogeneous data covering the most natural area. So, in HC exploration (*senso lato*), gathering the fields by large Petroleum Systems, that is to say, in terms of generation of hydrocarbons, as the most important factor is the source-rocks (which has generated oil and gas), gives much better results than gathering fields by country.

We use mainly:

- **Creaming curve with hyperbola;**
- **Annual discovery and production with normal curve or derivative of logistic (Hubbert curve);**
- **Lognormal;**

The best model is to use a correlation between production and shifted discoveries, since the shift allows the forecast during the shift

(cont.)

Creating curve (Shell):

Creaming curve = Law of diminishing returns

Cumulative discoveries versus the cumulative number of new field wildcats.

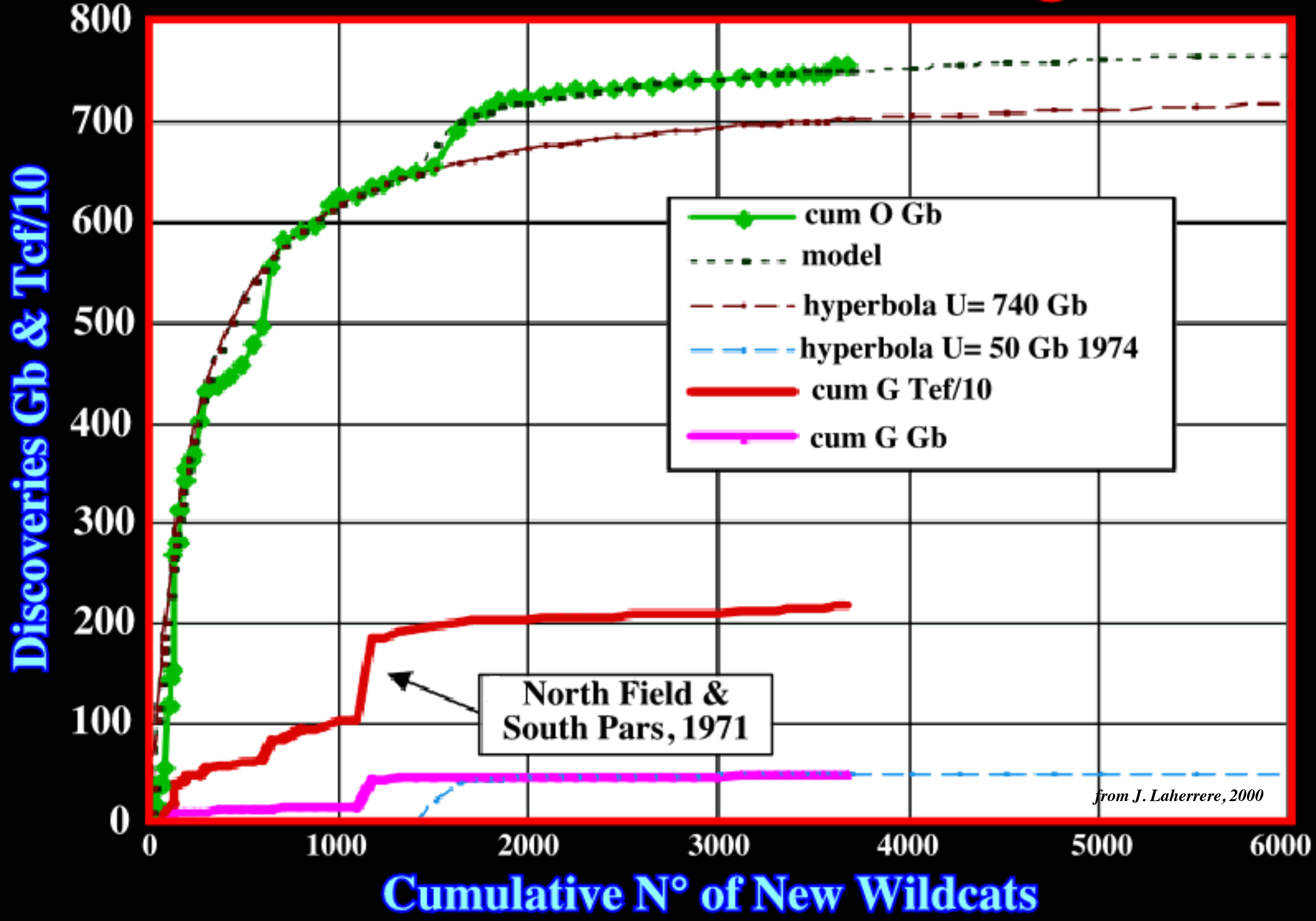
This curve is closer to an hyperbola.

In most mature basins, most of the large fields, for instance, are found and only small fields are undiscovered.

When a new frontier is found, as deepwater in West Africa, another hyperbola starts.

(cont.)

Middle East Crude Oil: creaming curve



The creaming curve was proposed by Shell several years ago. All curves fit with one or several hyperbolas. Each hyperbola represents a new exploration cycle.

(cont.)

The major problem with creaming curves is to guess if a new exploration cycle is possible. Only geologists could answer such a question by studying the petroleum potential.

Africa is an interesting example as the last cycle is recent. It started in 1992 with the deepwater and Sahara discoveries of Berkine. Geologists predict this new cycle, since

a) Ben Berkine (Triassic reservoir) has been badly evaluated by Total (Sit Fatima #1), which was mainly interested in Devonian reservoirs, and

b) The deepwater discoveries, in Angola and Nigeria, are just the extension of some discoveries on the shelf (turbidites).

(cont.)

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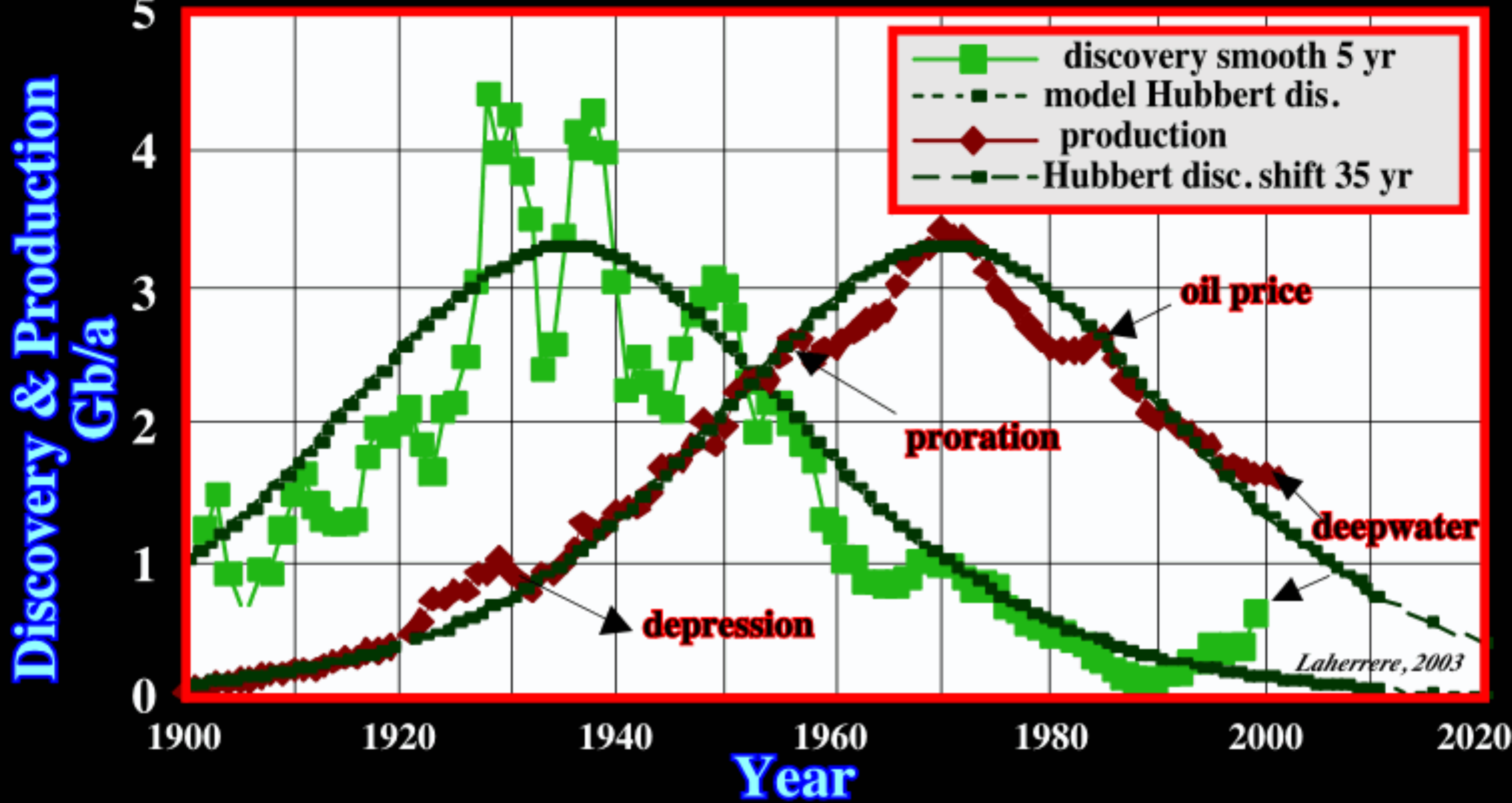
Hubbert Discovery Model (US Lower 48)
"mean" Discovery & Production



The Hubbert curve (production vs time) is a bell-shape curve picking at mid-point. It is based on the logistic function introduced in 1984 by the Belgian mathematician Verhulst as a law for population growth.

(cont.)

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The equation of the Hubbert curve, i.e. for the cumulative production (CP) foe an ultimate (U), where tm is the inflexion point (corresponding to the peak time for the annual production) is:

CP = U / (1+Exp {-b(t-tm)}

In other words, the ultimate reserves are 0.8 times the peak production multiplied by half width, that is to say, the peak production is shifted by one year when ultimate reserves increase by 0.8 times the annual peak production (peak production roughly at middle of ultimate reserves).

Let's see two examples

(cont.)

Example 1:

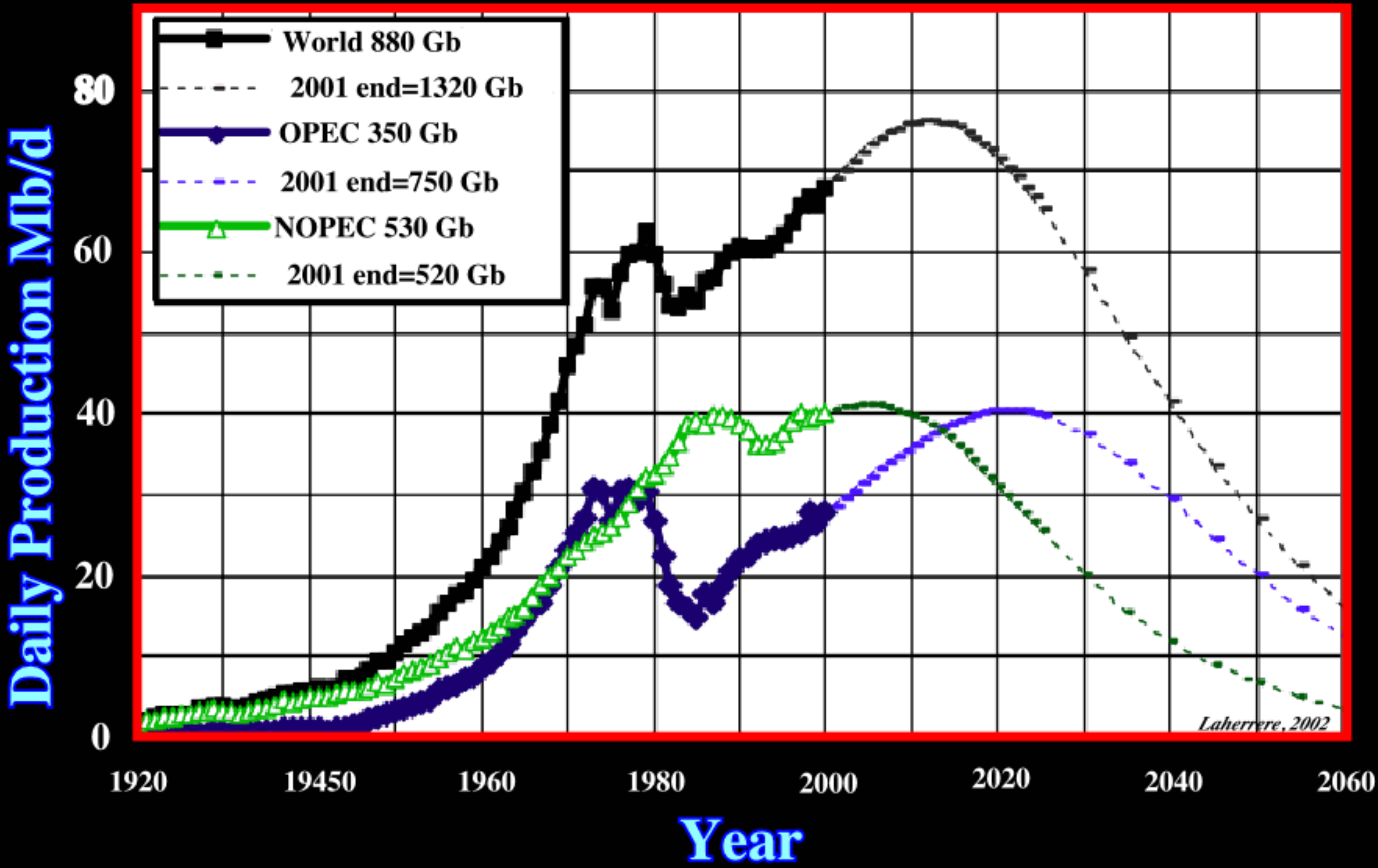
If the peak production is about 45Gb/a (or 120 Mb/d as in the forecast DOE/EIA IOE 98), 36 Gb of new dis-coveries will delay by one year. A discovery of 1 Gb delays the peak by 10 days.

Example 2:

If the peak production is about 32 Gb/a (which is mo-re likely), 26 Gb of discoveries will delay the peak by one year. A discovery of 1Gb delays the peak by 14 days.

(cont.)

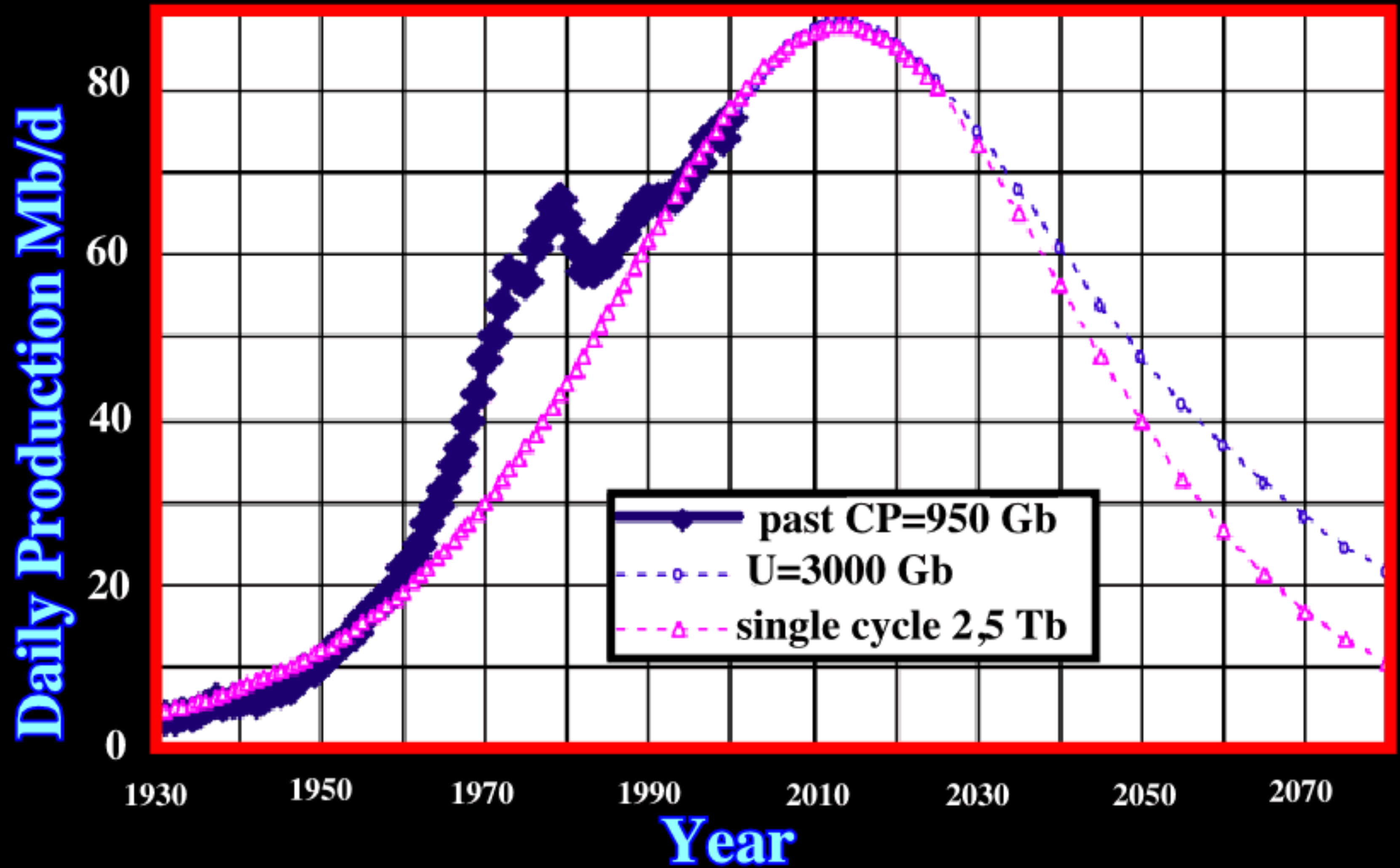
World Conventional Crude Production for an ultimate of 2150 Gb



Future production is estimated either from ultimate reserves assessments or by extrapolating past production with a model.

(cont.)

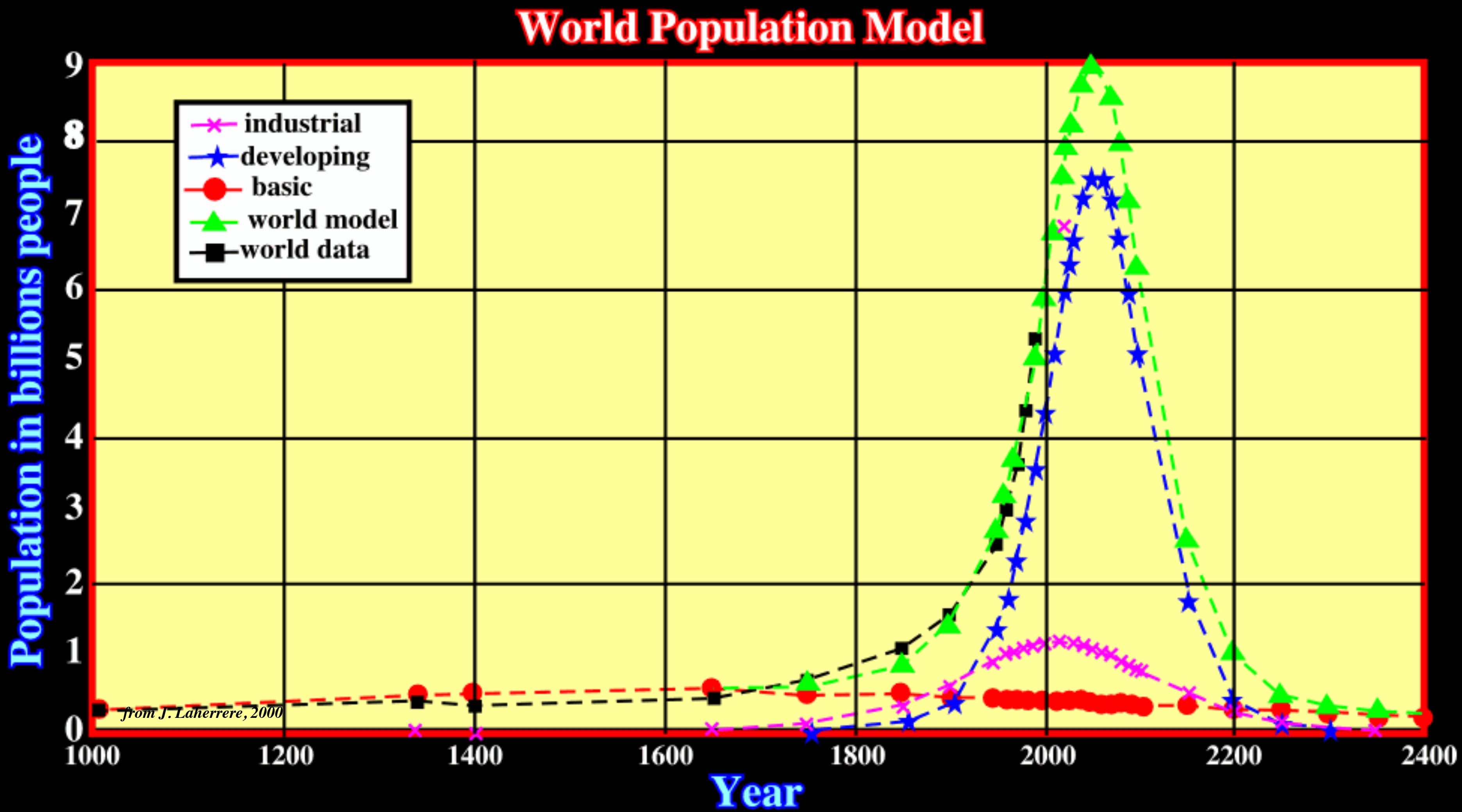
Forecast of all liquids Production with an ultimate of 3Tb



Models are better than numbers, however do not forget that multi-solutions are more than possible.

(cont.)

Lognormal



It is the law of proportionality. Ex: it is easy for a millionaire to spend 1.000$ as for a billionaire to spendend 1.000.000$.

(cont.)

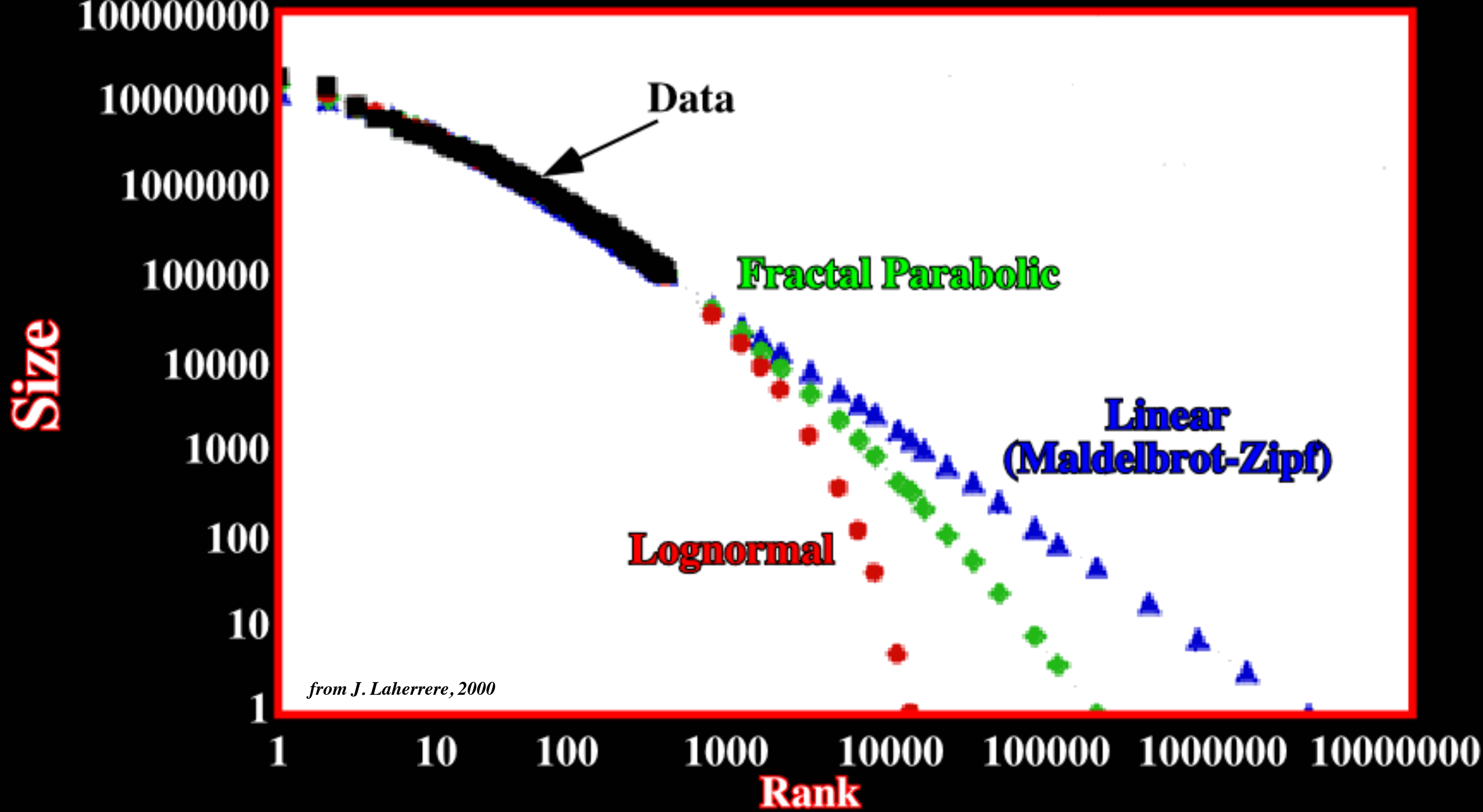
Lognormal:

It works well when the mean is large compared to the standard deviation. When the mean is of the same order as the standard deviation, the probability curve is limited by zero and is deformed by this lower limit becoming asymmetrical.

Lognormal plot needs frequency and if more data (ex: fields) is added, frequency changes. If the same plot is kept, it means that as many large fields as small fields have to be added. However, in mature basins only small are added.

(cont.)

Parabolic Fractal Lognormal Linear



All models can be almost identical for the first 500 ranks, but they are quite different beyond. A model has to be checked on extrapolation for large ranks. The parabolic fractal has very often the best extrapolation.

(cont.)

Mandebrot-Zipf (linear):

Perfect Self-similarity = Power Law

Parabolic fractal in log-log display

size (Sn) rank (n)

$$S_n = S_1 n^{-a}$$

or

$$\log S_n = \log S_1 - a \log n$$

The linear fractal is a theoretical interpretation of the nature. Every natural system (as the urban agglomeration in contrary to the political city boundaries)display a curve pattern as the world earthquakes (the Gutenberg-Richter law being only the tangent to this curve).

(cont.)

Parabolic Fractal:

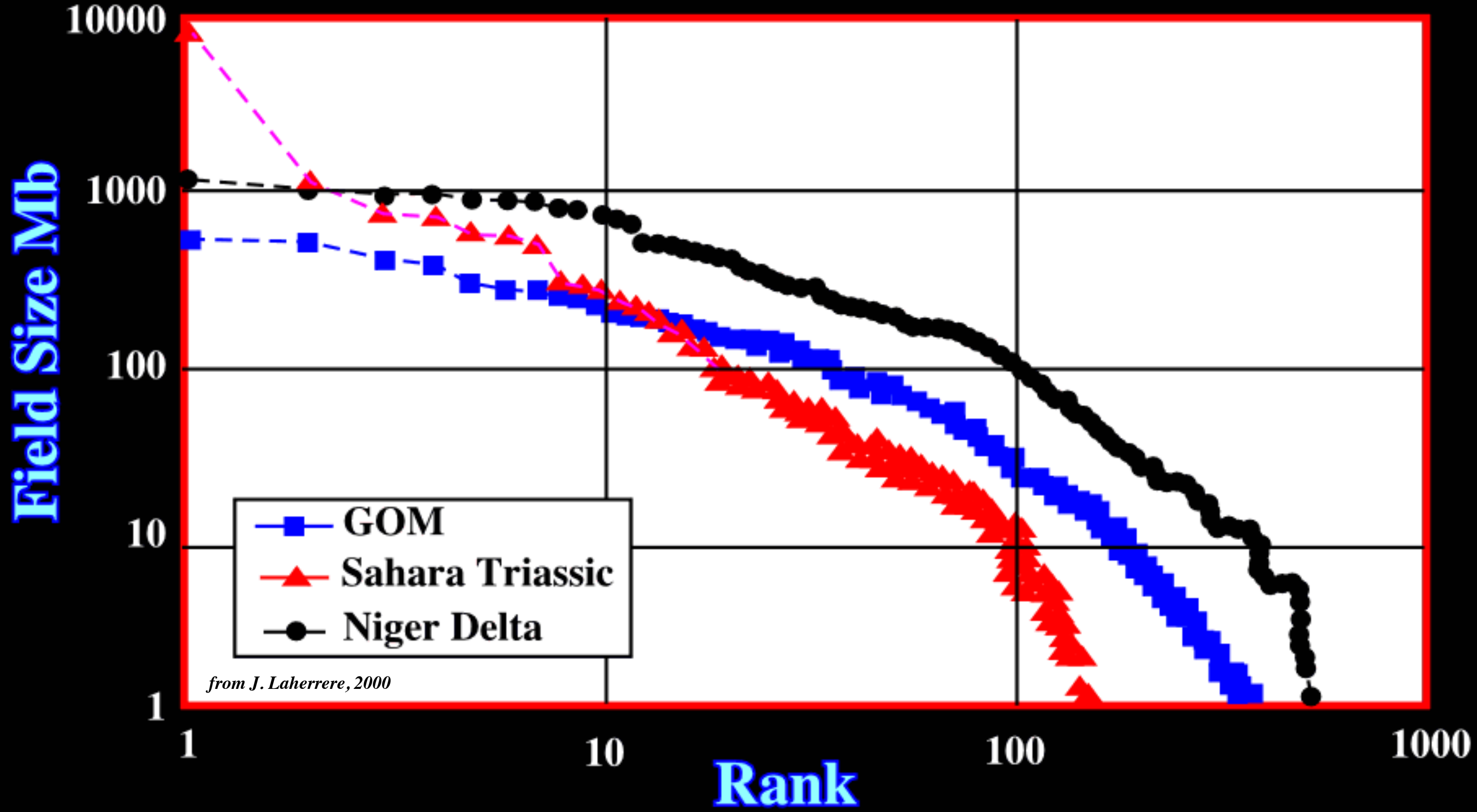
Imperfect Self-similarity = Curved display

Parabolic fractal in log-log display
size (Sn) rank (n)

$$\log S_n = \log S_1 - a \log n - b (\log n)^2$$

(cont.)

Parabolic Fractal
3 Petroleum Systems



GOM, Niger delta and the Saharan Triassic petroleum systems can be compared with a parabolic fractal. GOm and Niger Delta are similar as they are dispersed habitat with many large fields of similar size. Sahara is a concentrated habitat with a "king effect" (Hassi Messaoud).

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(vi) Exploration Messages
(a posterior hypotheses)

Message 1

The technique is much better than 20 years ago, but you discover much lesser.

Technology progress leads to faster and cheaper production. It has not much impact on conventional reserves revision as they are already anticipated. Technology is needed for unconventional resources

(cont.)

Message 2

☑ More than 85% of the conventional petroleum has already been discovered. Energetically, the world is living on the past.

In the futur, the amount HC discovered will be insignificant when compared with the amount of HC badly recognised or neglected within the fields already discovered.

(cont.)

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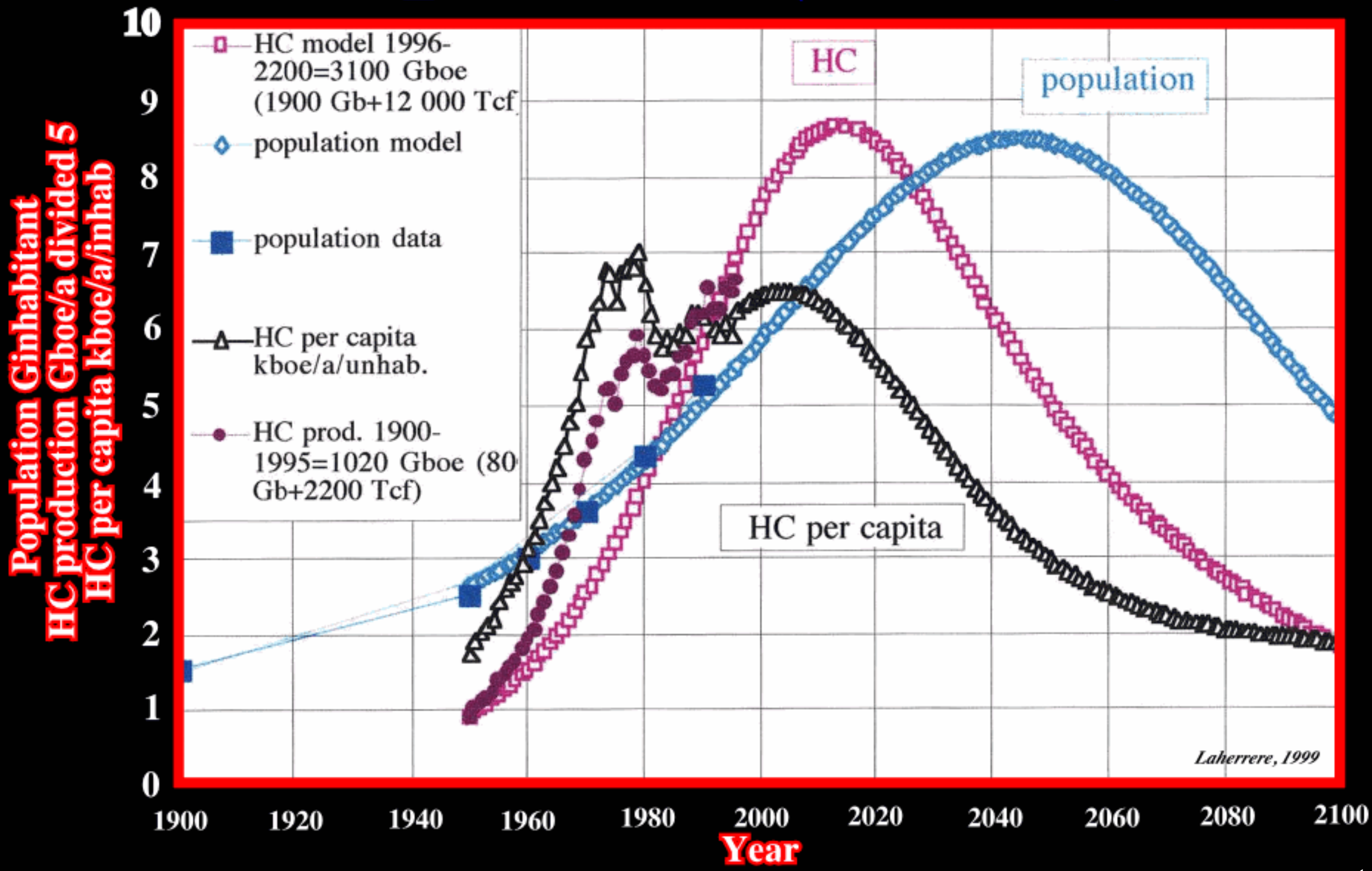
Scenario of world's population & HC production (1900-2100)



(cont.)

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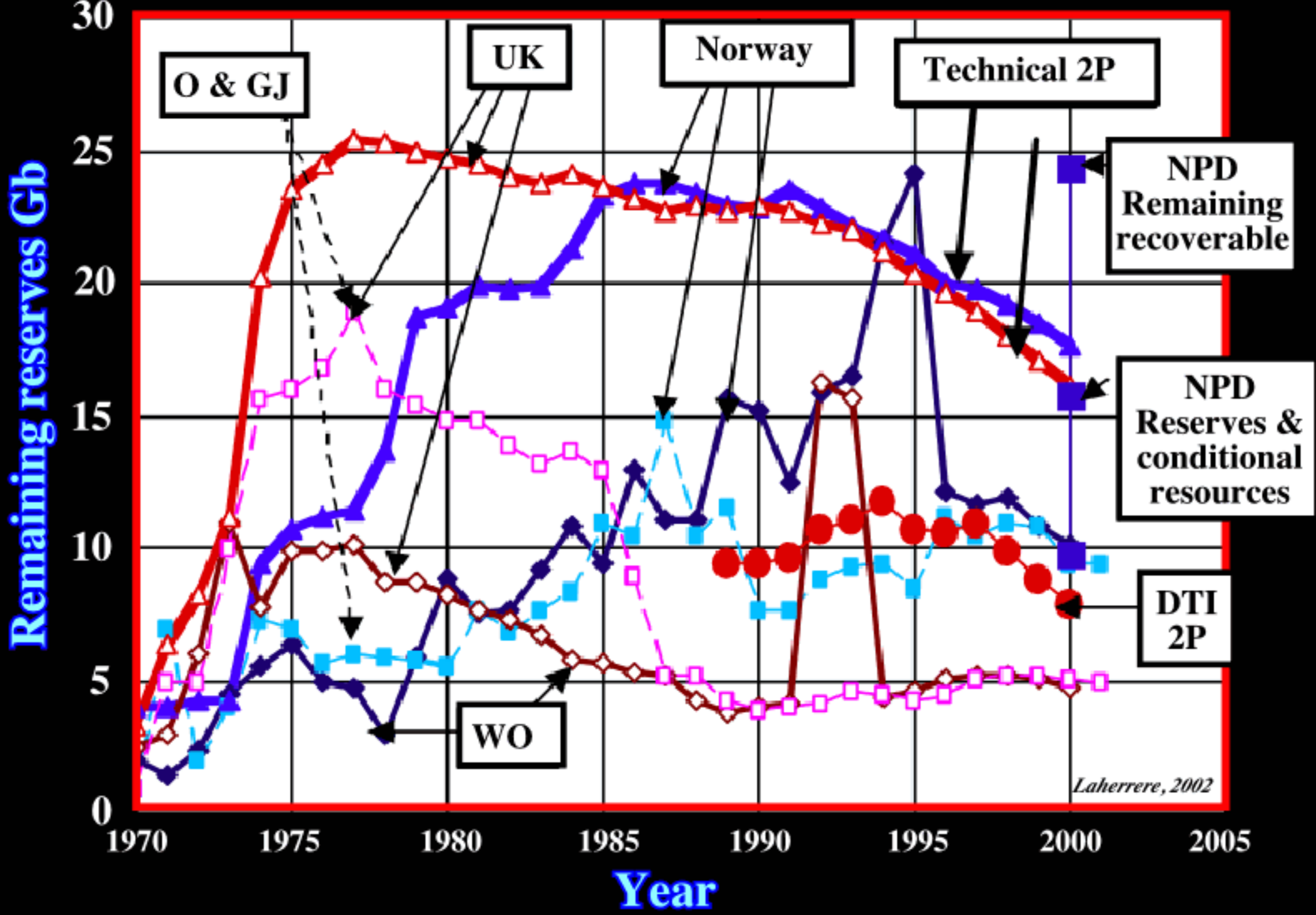
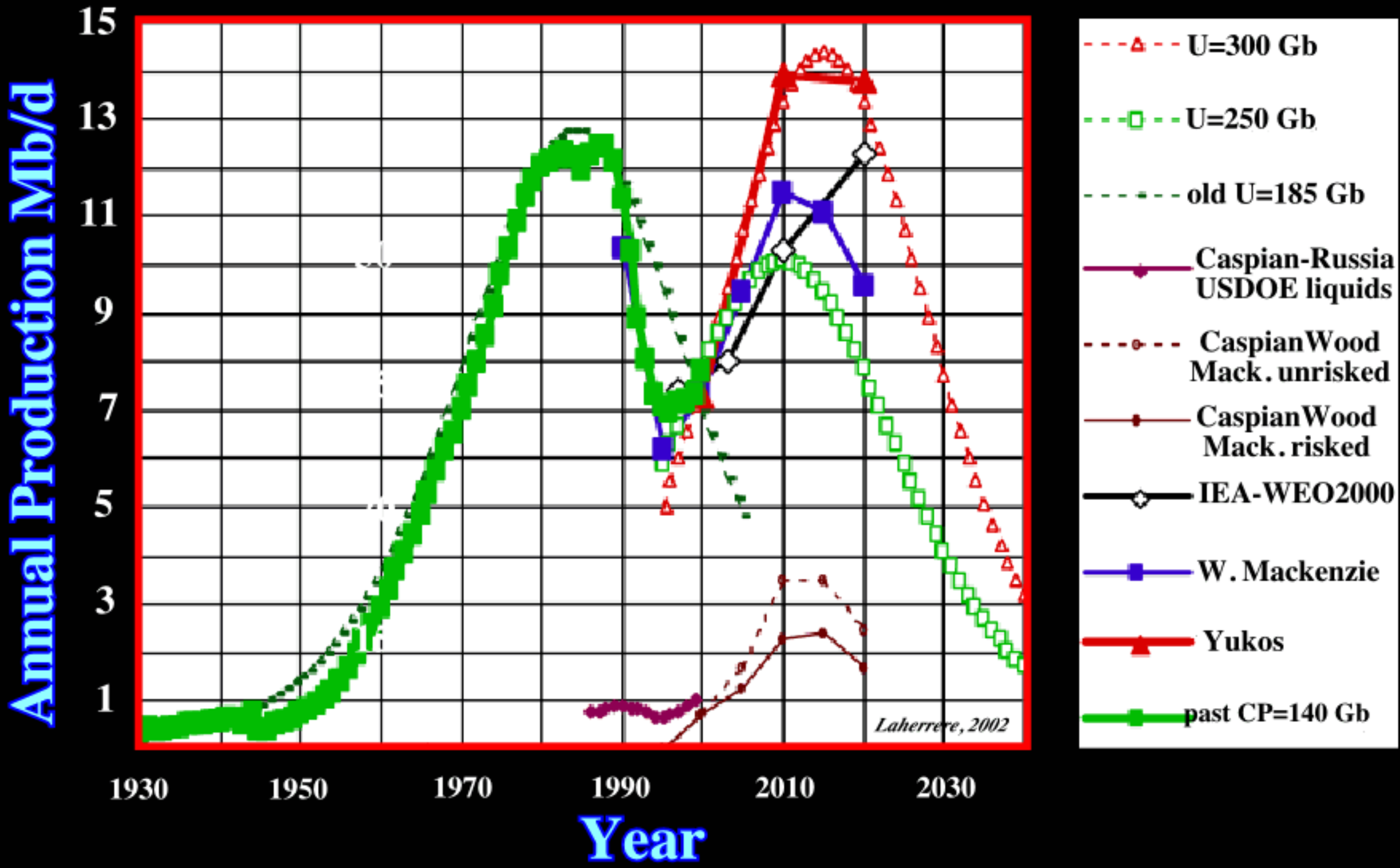
Uk & Norway
Oil remaining Reserves



(cont.)

FSU
Oil production with 2 cycles
Old & new with an likely ultimate of 250 Gb



Excluding USA & Canada, one can say that at the end of the millennium:

Message 3

Giant fields represent

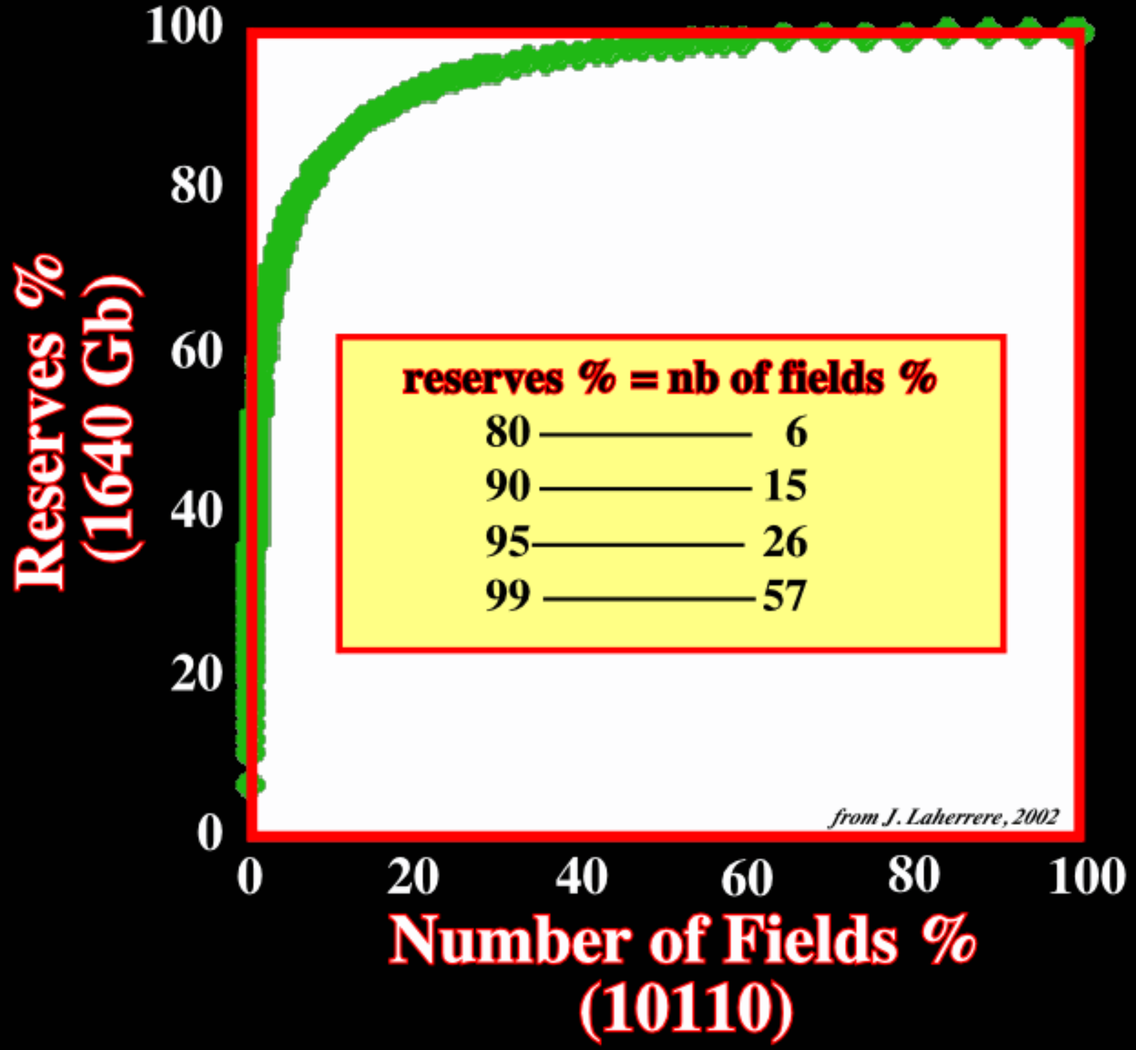
4% of the total fields and

80% of the reserves.

(cont.)

Reserves (%) & Number of Fields

(oustide USA & Canada)



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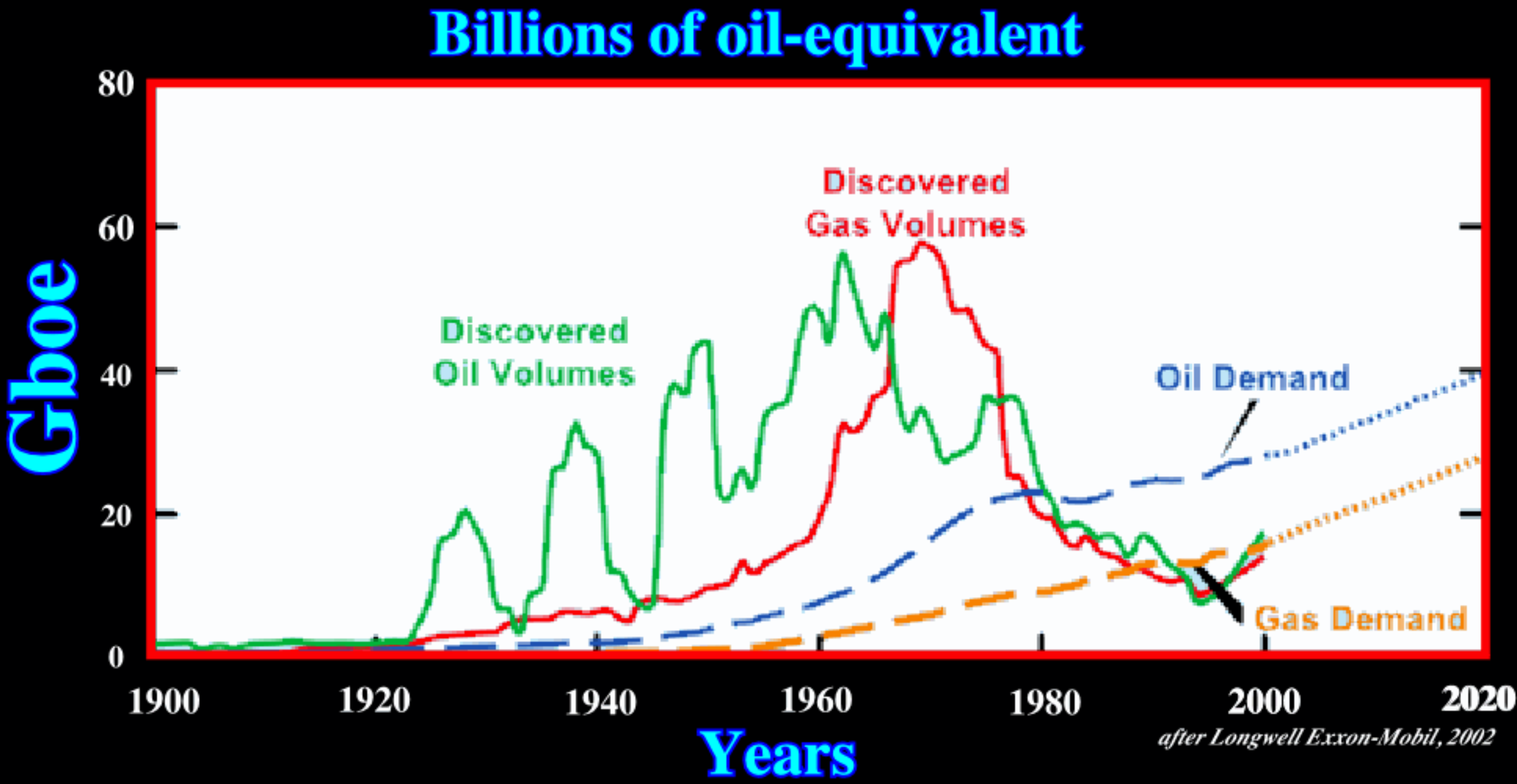
Message 4

The highest number of fields was reached in 1960-1970's.

The highest reserves was reached in 1960's.

(cont.)


Billions of oil-equivalent
Gboe
80
60
40
20
0
Discovered
Gas Volumes
Discovered
Oil Volumes
Oil Demand
Gas Demand
1900
1920
1940
1960
1980
2000
2020
Years
after Longwell Exxon-Mobil, 2002

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Message 5

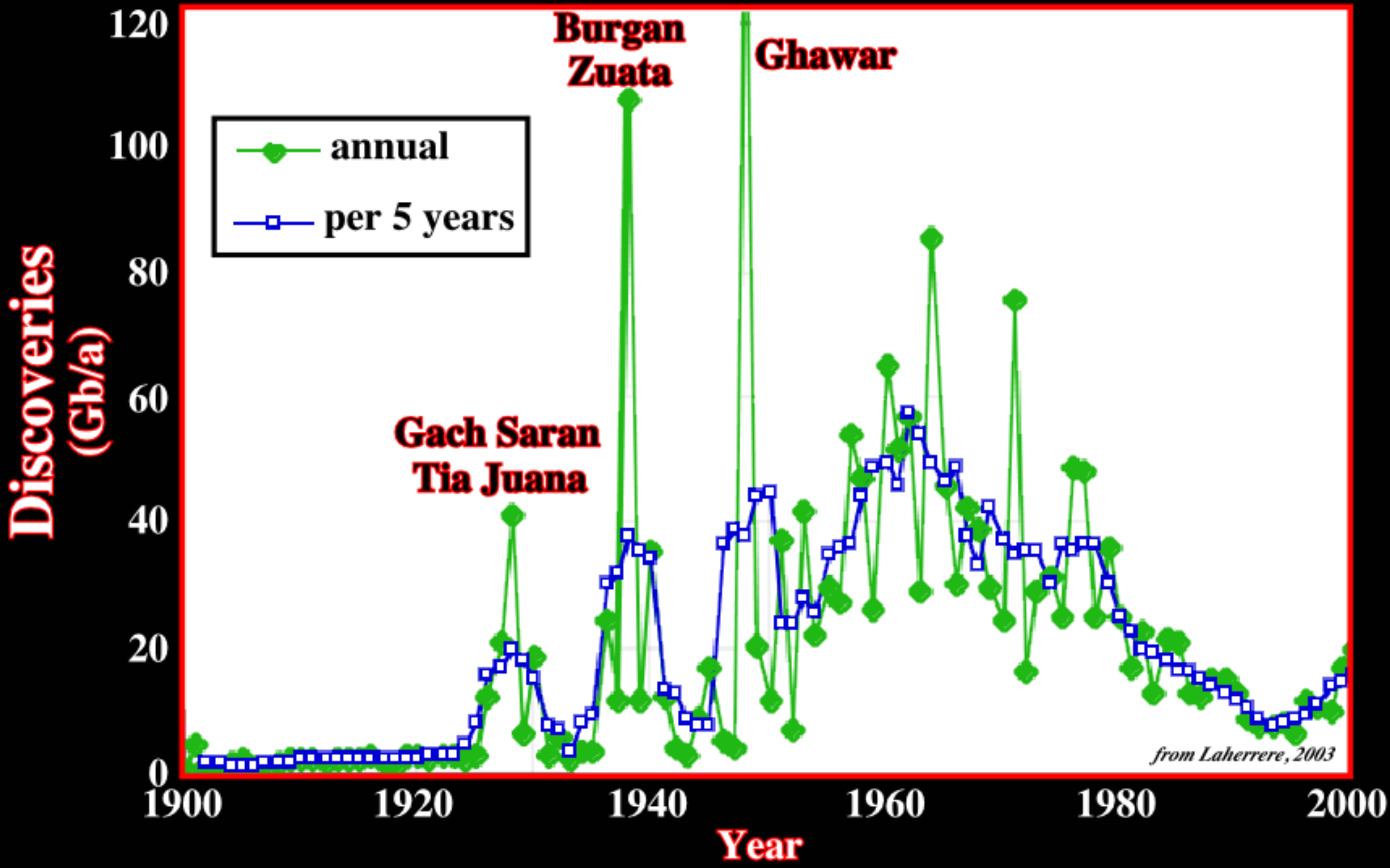
Giants' middle size was ± 1 Gbep in 1920-30.

It increased to ± 11 Gbep in the 1940's.

It decreased to 1 Gbep in the 1980's.

(cont.)

World: Discoveries Oil+Condensate



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Message 6

80% of the remaining reserves (95% of the production) of the giant fields belongs to those dis-covery before 1970.

(Kirkouk, Hassi Messaoud, Rumaila, Ghawar, East Texas, etc.).

(cont.)

Remaining Reserves Ex: Irak

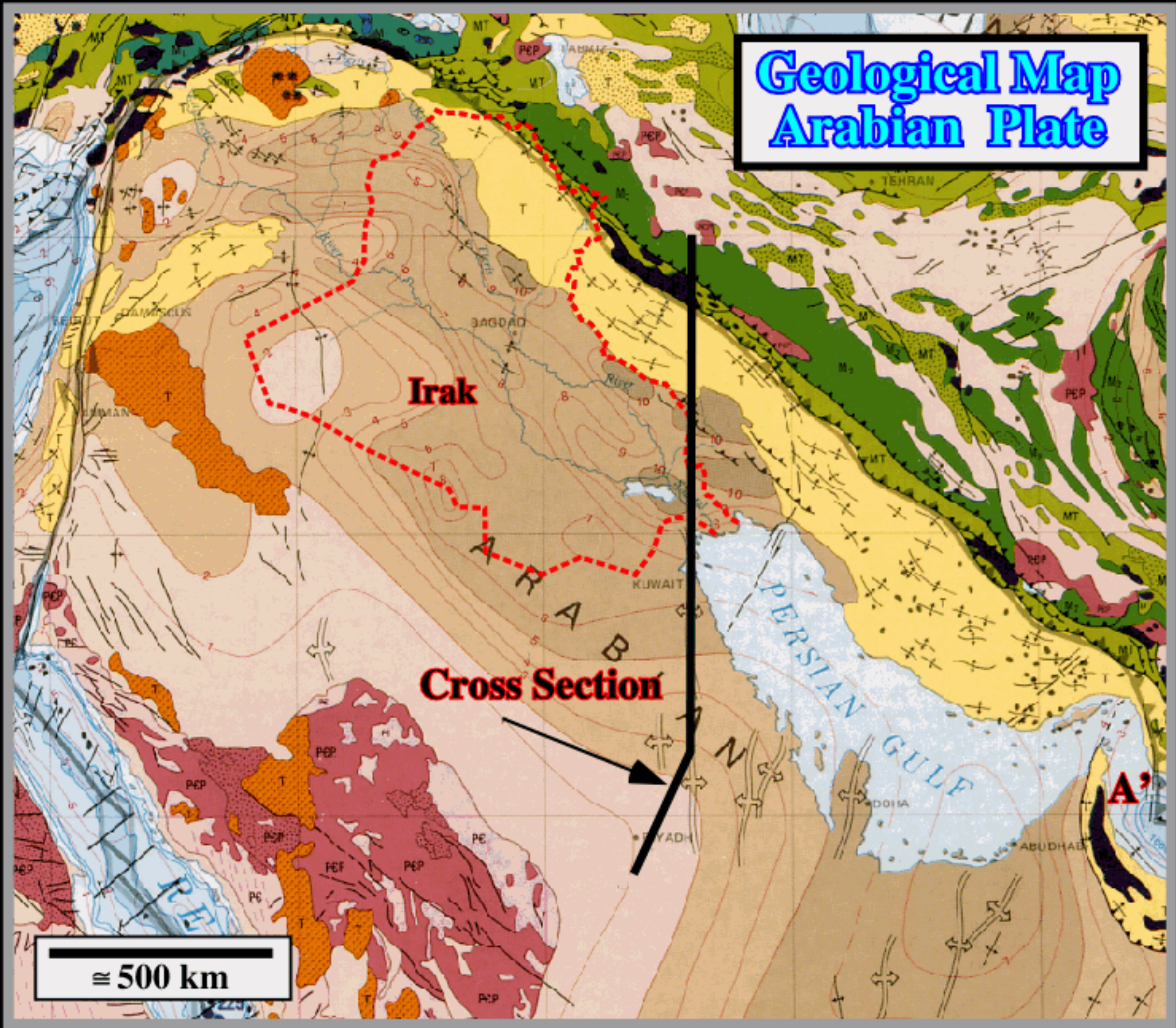
(cont.)

Irak's reserves

- Ultimate recovery from giant fields of Irak is estimated to be 85 Gbbl.
- For comparison:
  - the estimation for North Dome Gas Field, in Qatar, is 160 Gboe and
  - 97 Gbbl for Ghawar Oil Field in Saudi Arabia.
- Remaining recovery, or reserves, for the Iraqi giant fields is estimated to be 41 Gbbl, i.e. approximately one-half of the ultimate recovery (Horn, 2003).

let's be more accurate

(cont.)



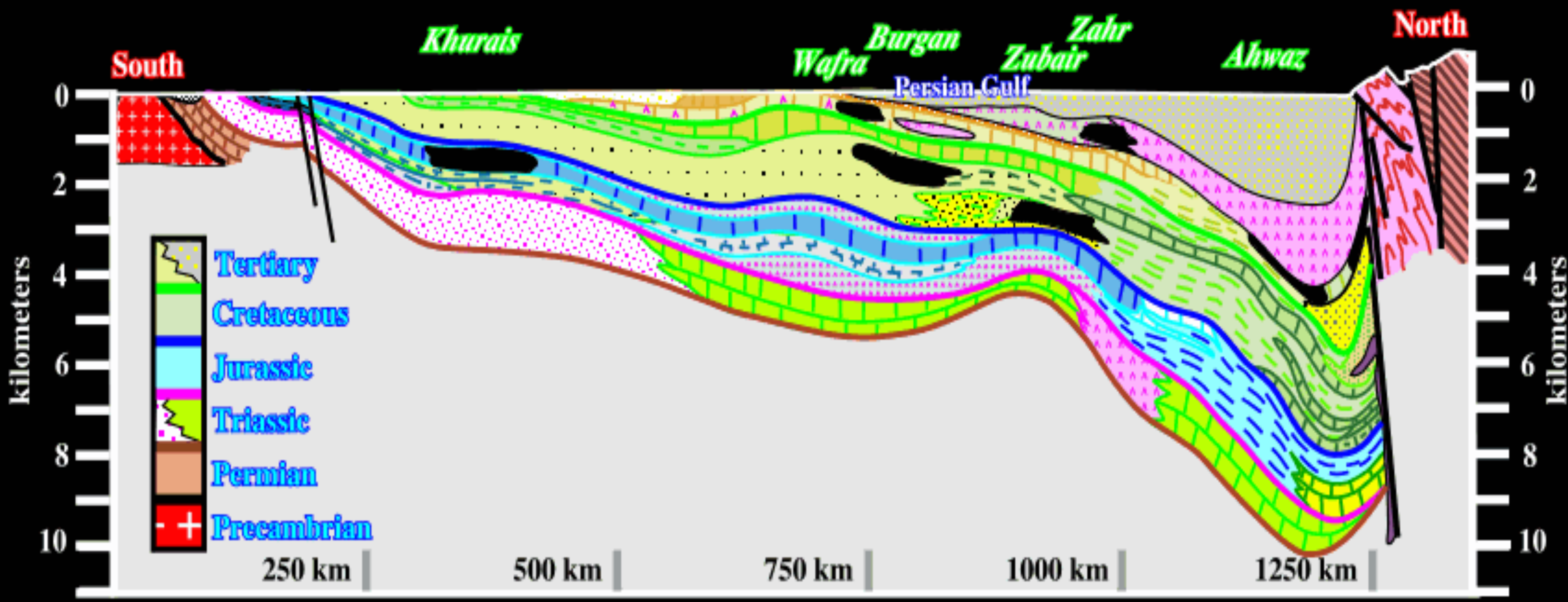
PЄ Precambrian Shield
PЄP Upper Precambrian Middle Cambrian
T Intrusive Triassic
Ophiolite
MT Santonian to Oligocene
M_2 Upper Jurassic to Conacian
T Miocene to Recent

(cont.)

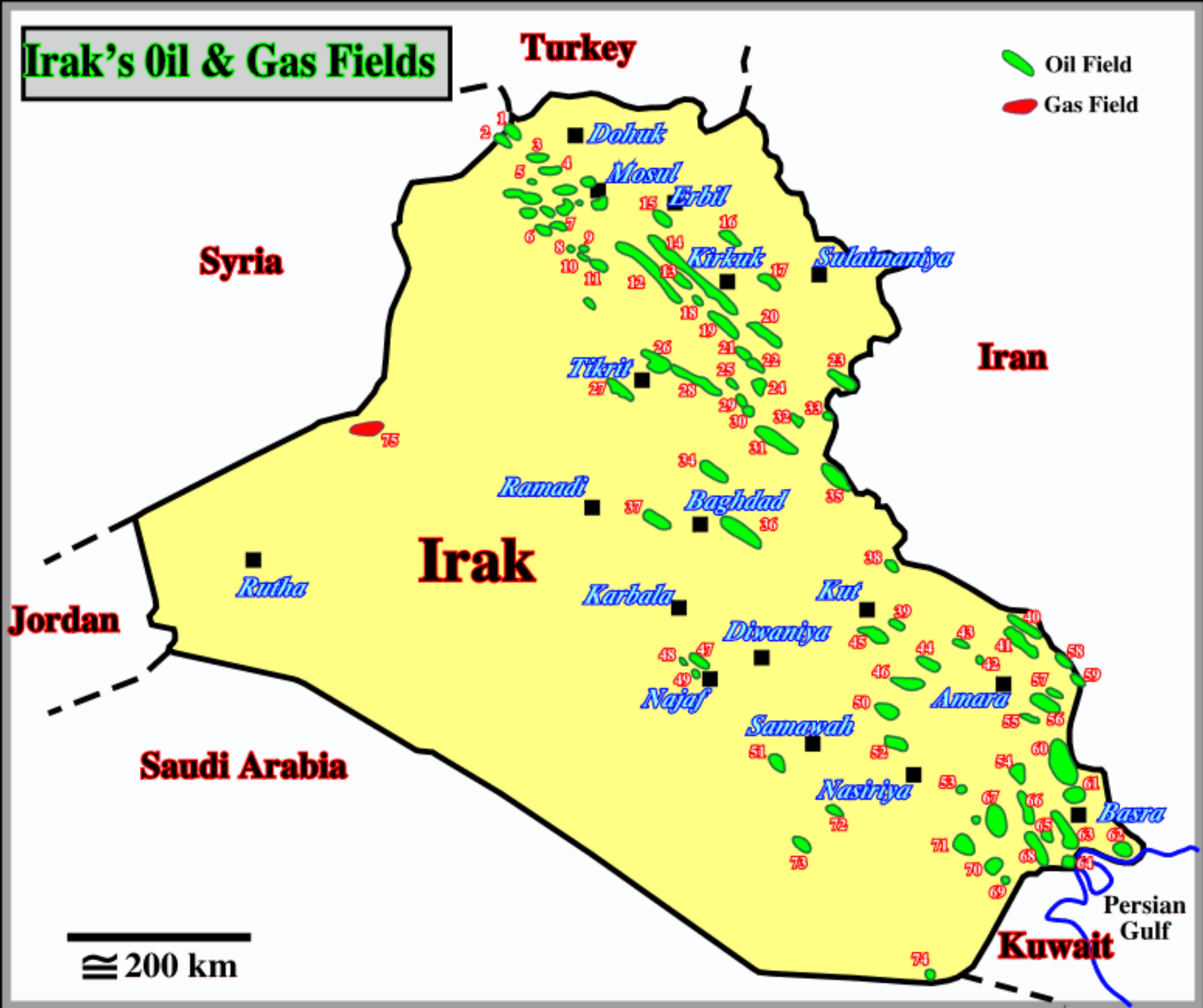
N-S Geological Cross-Section

(Eastern Flank of Arabian Plate)

modified from A. Perrodon, 1966



(cont.)



Irak's 0il & Gas Fields
Oil Field
Gas Field
Turkey
Syria
Iran
Irak
Jordan
Saudi Arabia
Kuwait
Persian Gulf
Dohuk
Mosul
Erbil
Kirkuk
Sulaimaniya
Tikrit
Ramadi
Baghdad
Rutha
Karbala
Kut
Diwaniya
Najaf
Samawah
Amara
Nasiriya
Basra
≅ 200 km

(cont.)

1- Mushorah	21- Pulkhana	41- Buzurgan	61- Nahr Umr (Bin Umr)
2- Sufaya	22- Qamar	42- Kumait	62- Siba
3- Ain Zalah	23- Chia Surkh	43- Amara	63- Zubair
4- Butmah	24- Gilabat	44- Dujaila	64- Safwan
5- Gusair	25- Judaida	45- Ahdab	65- Tuba
6- Sasan	26- Saddam	46- Abu Amud (Rafidain)	66- Rumaila North
7- Alan	27- West Trikrit	47- Kifl	67- Ratawi
8- Jawan	28- Hamrin	48- Marjan	68- Rumaila South
9- Qasab	29- Injana	49- West Kifl	69- Jerishan
10- Najmah	30- Kashm al Ahmar	50- Samawa	70- Rachi
11- Qaiyarah	31- Mansuriya	51- West Tikrit	71- Luhais
12- Qalian	32- Nau Duman	52- Nasiriya	72- Diwan
13- Bai Hassan	33- Jaria Pika	53- Subba	73- Salman
14- Kirkuk	34- Balad	54- West Qurna	74- Abu Khaima
15- Demir Dagh	35- Naft Khaneh	55- Sufaya	75- Akkas
16- Atshan	36- East Baghdad	56- Halfaya	
17- Chemchemal	37- Falluja	57- Noor	
18- Khabbaz	38- Badra	58- Jabal Faiqi (Fuqa)	
19- Jambur	39- Dhafiriya	59- Huwaiza	
20- Kor Mor	40- Abu Ghirab	60- Majnoon	

Field's Names

(cont.)

Fields	RecReserves Mbbl	TCF	Remaining Mbbl	Depth	Reservoir
Abu Ghirab (1971)	638		213	2990 m	Lower Miocene Carbonate
Ahdab (1979)	500	0.1	225	2450 m	Conacian Limestone
Akkas (1992)	100		353		
Bai Hassan (1953)	1882		358	530 m	Lower Miocene Limestone
East Baghdad (1979)	2000	2.5	871	3050 m	Cretaceous Sandstone
Gharraf (1979)	500		218	3050 m	Hauterivian Limestone
Halfayah (1976)	700	0.1	320	730 m	Miocene Limestone
Hamrin (1961)	580		166	430 m	Lower Miocene Limestone
Jabal Fauqui (1974)	1000	0.7	346	3050 m	Miocene Carbonate
Jambur (1954)	2629		1586	1280 m	Lower Miocene Carbonate
Khabbaz (1985)	500	0.8	268		Lower Miocene Limestone
Kirkur (1927)	17000		5866	850 m	Oligocene Carbonate
Luhais (1961)	500		143	2440 m	Cretaceous Sandstone
Majnoon (1977)	12000	11.0	9487	2400 m	Turonian Limestone
Mansuriyah (1978)	50		252	1200 m	Lower Miocene Limestone
Nahr Umr (1948)	3500	7.0	219	2740 m	Cretaceous Sandstone
Nasiryah (1978)	500		210	1990 m	Turonian Limestone
Noor (1977)	500	0.7	203	4100 m	Albian Sandstone
Rachi (1957)	870		177	2890 m	Aptian sandstone
Ratawi (1950)	1400		242	2140 m	Turonian Limestone
Rumalia (1953)	22000	1.0	11022	3250 m	Cretaceous sandstone
Saddam (1978)	500		280	730 m	Miocene Limestone
Safwan (1977)	500	0.4	227	3230 m	Aptian sandstone
Subba (1969)	770		474		
Tuba (1959)	500	0.4	122	2310 m	Turonian dolomite
Falluja (1958)	1000		215	730 m	Maastrichian Limestone
West Qurna (1987)	4885		4827	3700 m	Jura-Cretaceous Limestone
Zubair (1949)	6731		3241	3300 m	Barremian sandstone

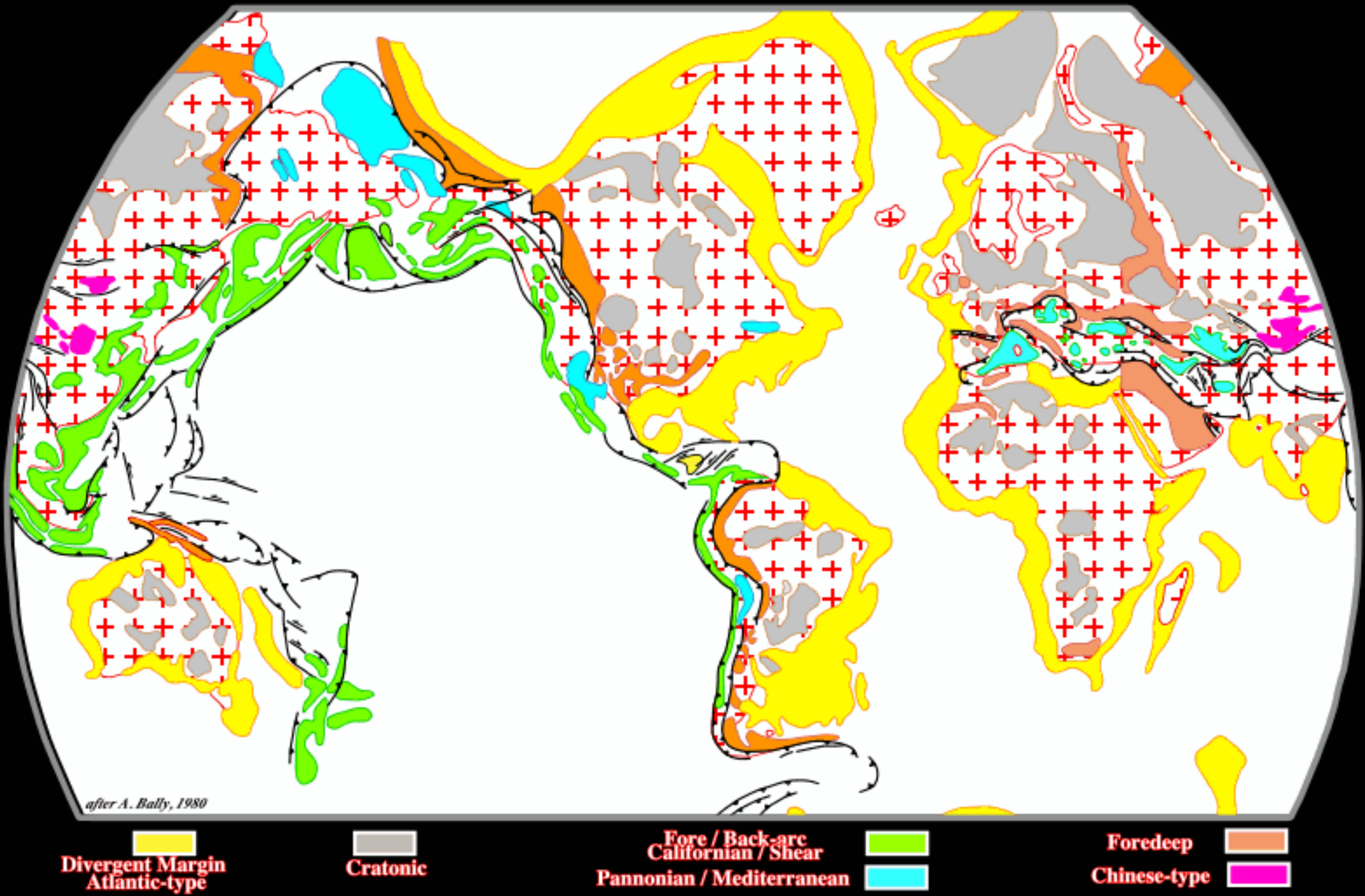
Message 7

The last new HC basin was recognised 30 years.

The world is living on the discoveries of the past.

(cont.)

Sedimentary Basins Message 7



Who knows a petroleum basin that is not take into account in Bally's basin classification?

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Message 8

The oil production in the last 20 years was estimated at 70 Mb/d:

- 40 Mb/d from giant fields,
- 7 Mb/d from small fields,
- 12 Mb/d from new developed fields,
- 10 Mb/d from improved fields and
- 3 Mb/d from new discoveries.

(cont.)

Part III

The Next Cycle
of
HC Discoveries

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In the past, explorationists to find HC should answer the following questions:

a) What basin?

b) Where drill?

c) Where test?

d) How estimate the accumulation?

e) How estimate de reserves?

f) How develop?

g) How maximise the recovery (or profit)?

(cont.)

At present time, as depicted in part I & II, explorationists know that:

1. The large and simple fields were discovered by:
   - Chance (serendipity), or
   - Using simple geologic

One should not forget, that in HC exploration we look for the less probable, the more probable is the failure.

(cont.)

The next cycle of HC discoveries will be composed by:

2. The future Short Term HC reserves* are those that in the past:

- Have been missed.
- Have not been taken into

* Deepwater of Eastern South Atlantic margins excluded

Cusiana (Colombia) and Peciko (Indonesia) are typical examples of rediscovered fields.

Villeperdue (Paris basin) and Lombo East (Angola) are examples of re-evaluated discoveries, Ben Berkine (Algeria).

(cont.)

3. Long Term HCs reserves will be mainly associated with:

- Foredeep basin.
- Folded belts.

Where seismic data is whether impossible to acquire or useless (reflection free). Ex: Papua New Guinea, Andes, Rocky Mountains, Ural Mountains, Assam, etc.

In order to achieve such a discoveries (short & long term), explorationists must have a good data base and an appropriate exploration knowledge, that is to say, they must know how:

(cont.)

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- To read a geologic map;
- To make balanced geological cross-sections;
- To criticise time contour maps;
- To test a trapping mechanism;
- To interpret electrical logs;
- To make sequential interpretations;
- To locate the source rocks;
- To make reservoir predictions;
- To interpret dipmeters
- To interpret tests, pressures, etc.
- To localise hydrodynamism;

and so on.....

Examples

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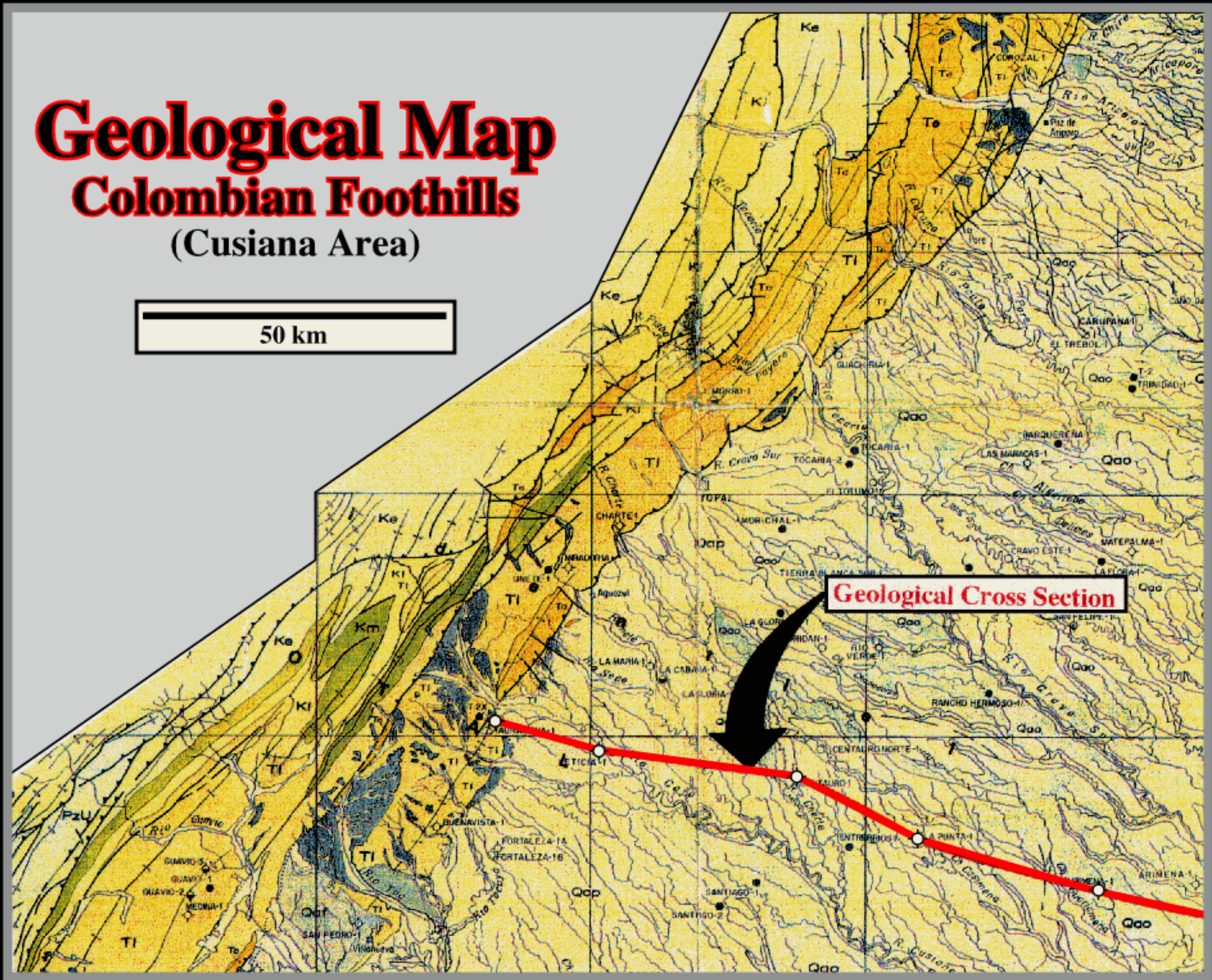
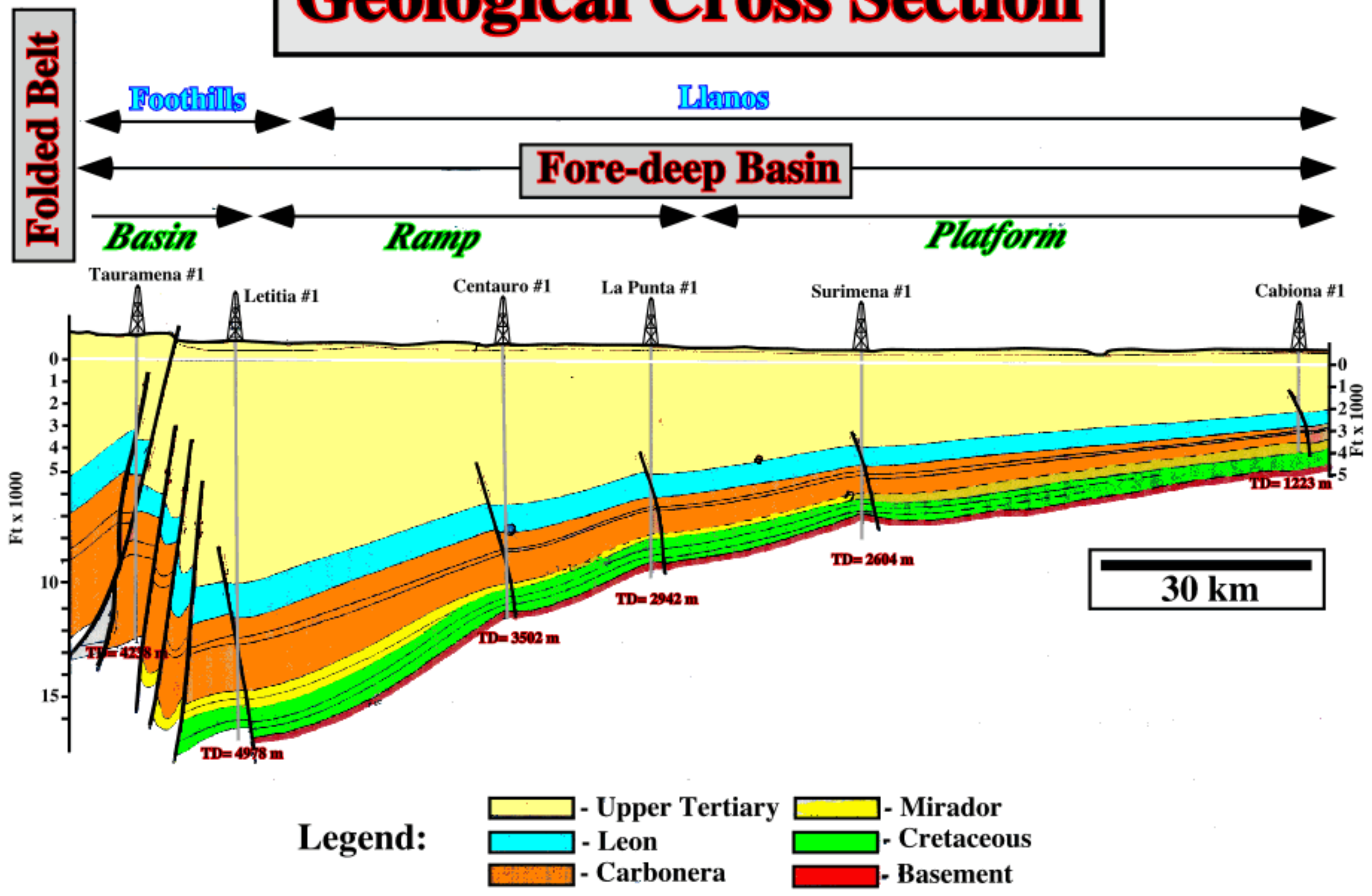
Cusiana Field

(Colombian Foothills)

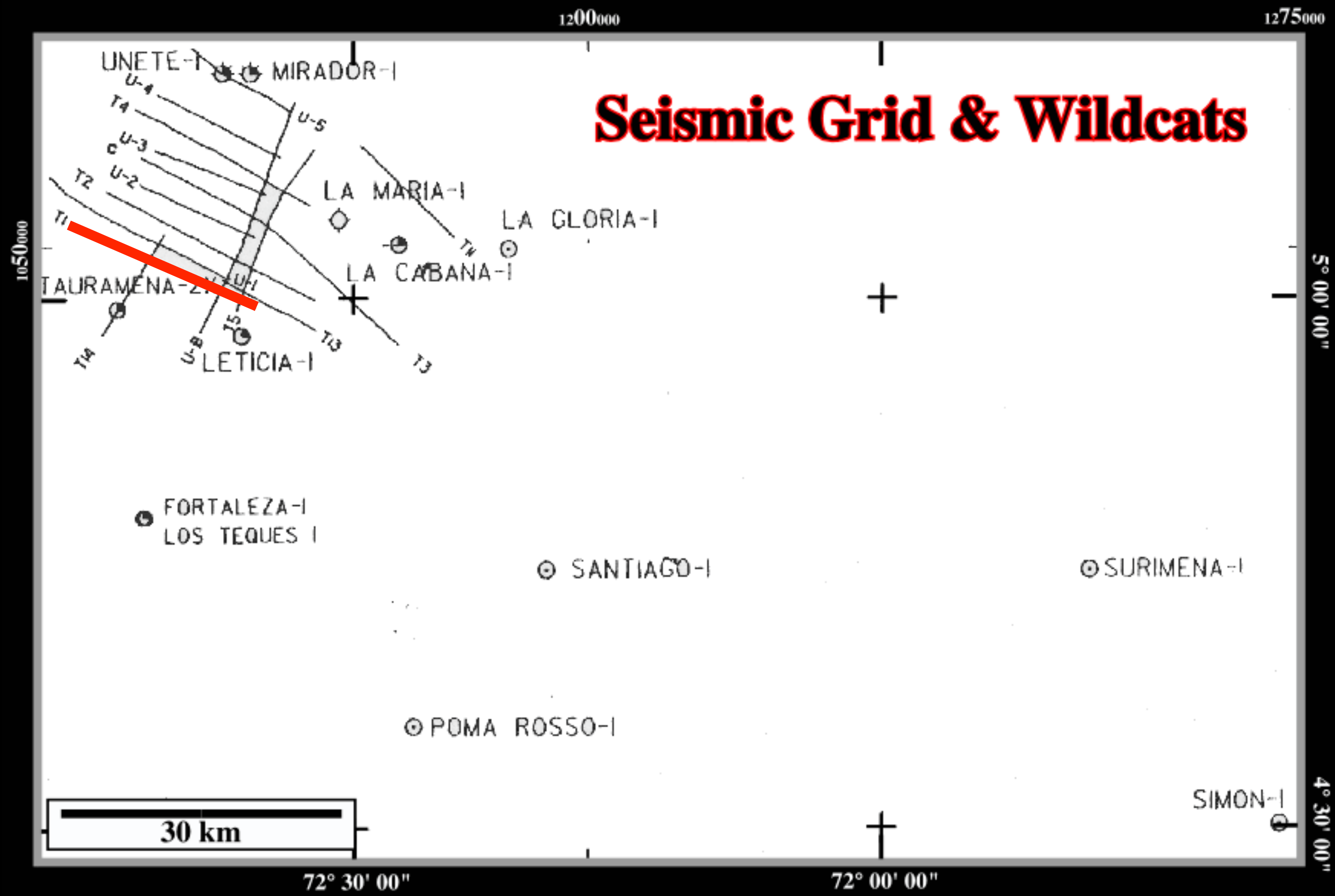
Cuisiana structure (Colombian foothills) was drilled several times (BP included). Hydrocarbons were found. The water plane contact was recognise too high. The accumulations were considered non-economical. The majority of the exploration area was relinquished. Triton took the area (Santiago das Atalayas Block). In 1983, John Durr (Triton) show us the data, where Triton recognised an untested structure of 35 km2. The water-plane contact on the drilled wells was not too evident. Total strongly denied the proposed water-plane contact at such a depth. After recognising the presence of the structure in pre-stacked depth migrated data, Total took 40% of interest leaving the operatorship to Triton. Ten months later, Triton farmout with BP which became operator. The exploration results corroborate the initial Total's hypothesis. In fact, the water-plane 1500 meters below. More than 2 Gb were put in evidence.


Geological Map
Colombian Foothills
(Cusiana Area)
50 km
Geological Cross Section

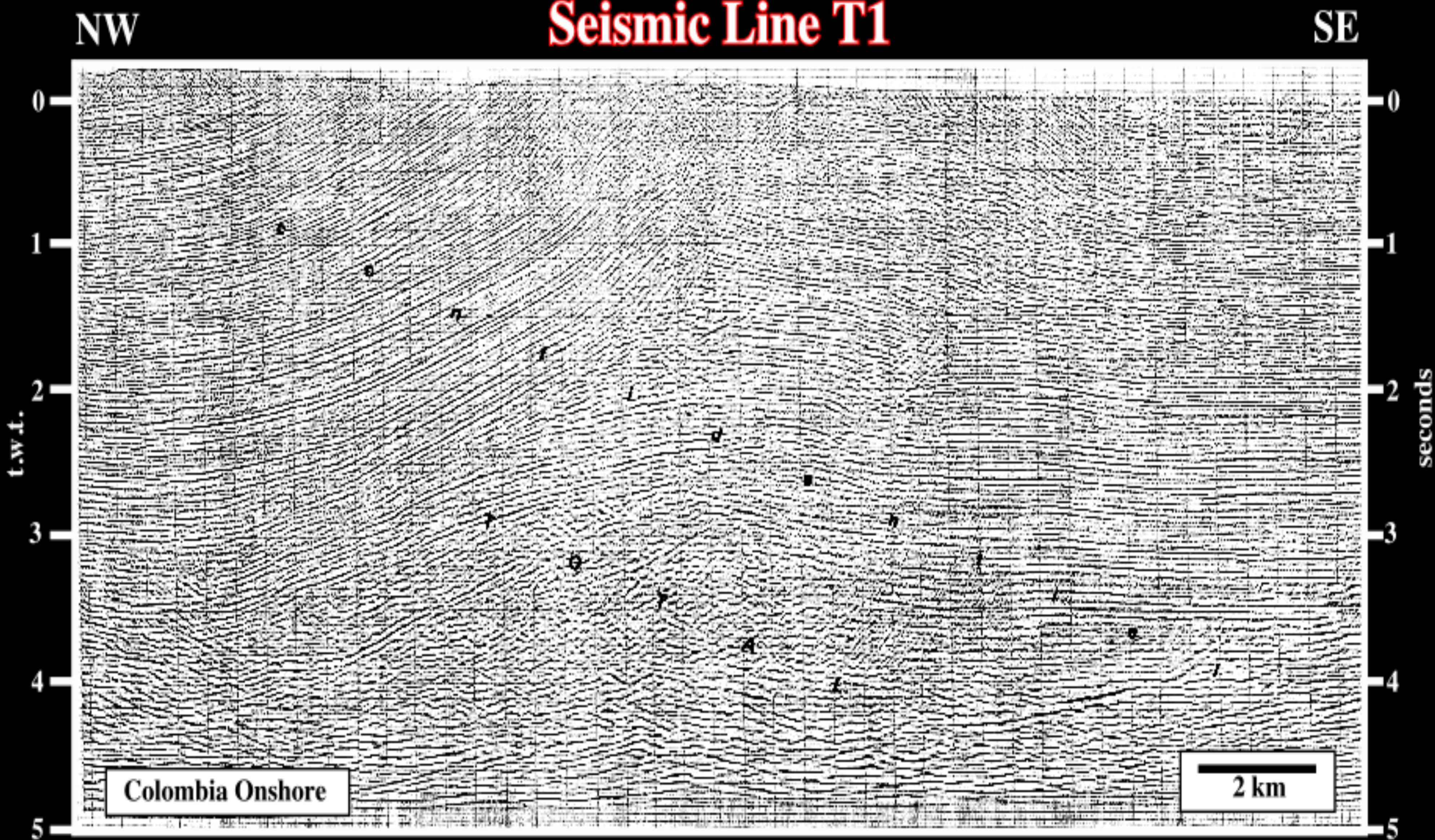
Geological Cross Section

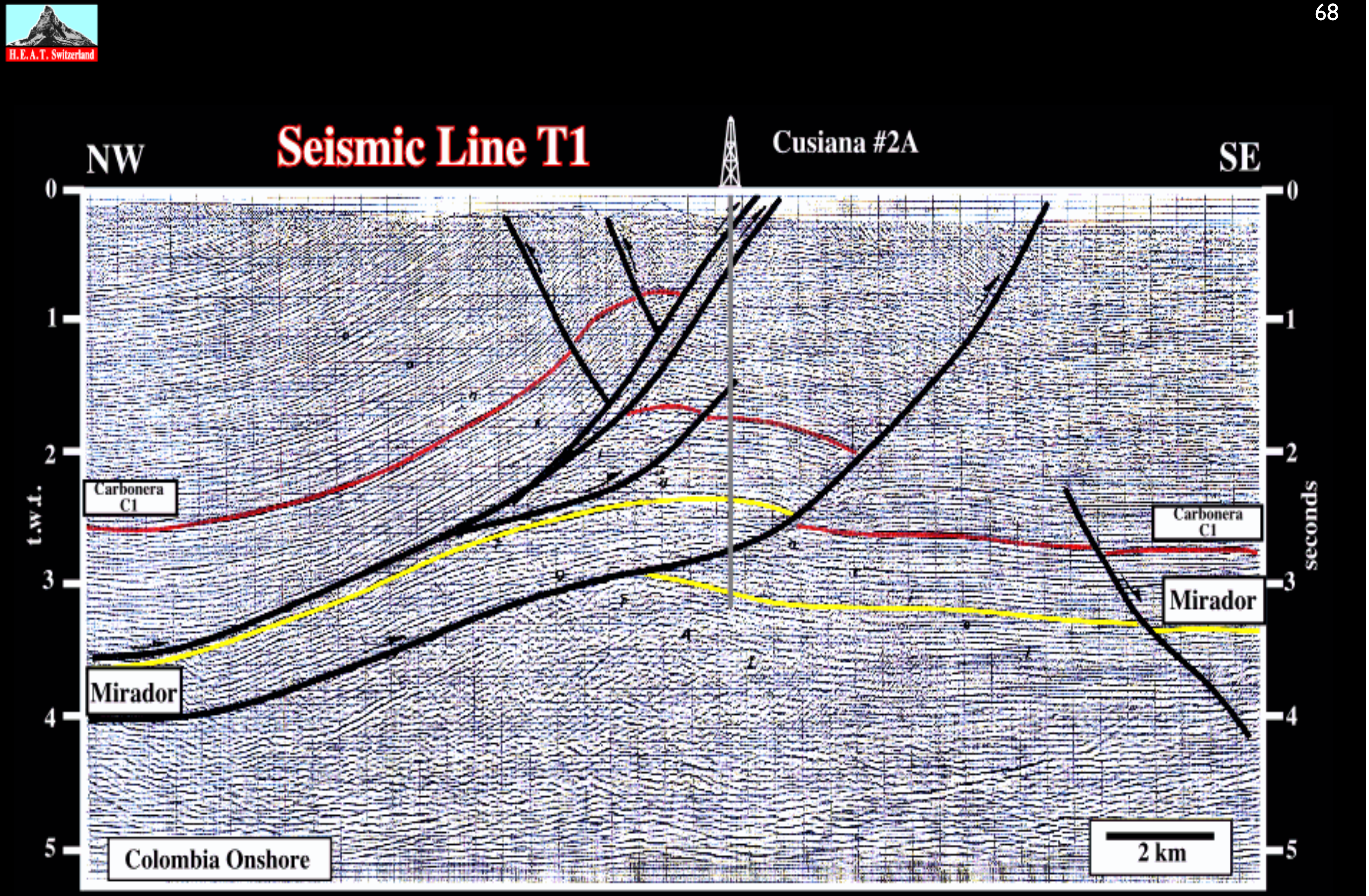


Seismic Grid & Wildcats



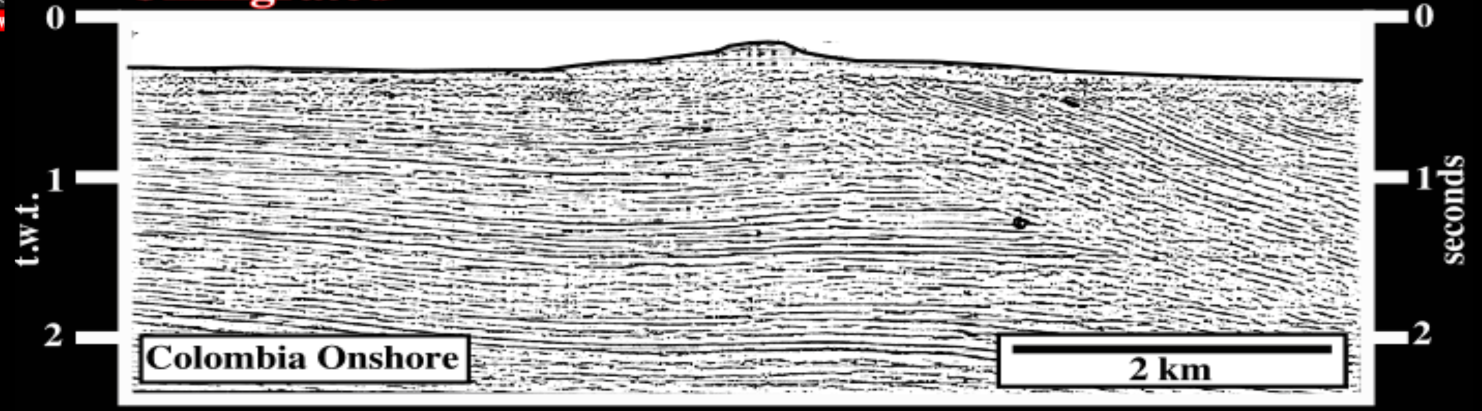
Seismic Line T1



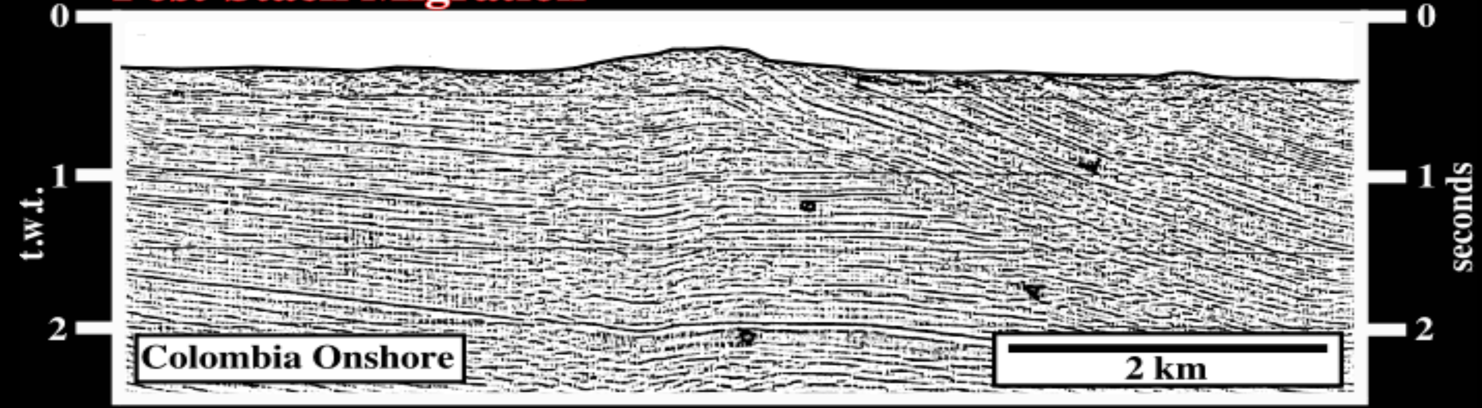


H.E.A.T. Switzerland
Seismic Line T1
Cusiana #2A
NW
SE
0
1
2
3
4
5
t.w.t.
seconds
Carbonera C1
Carbonera C1
Mirador
Mirador
Colombia Onshore
2 km

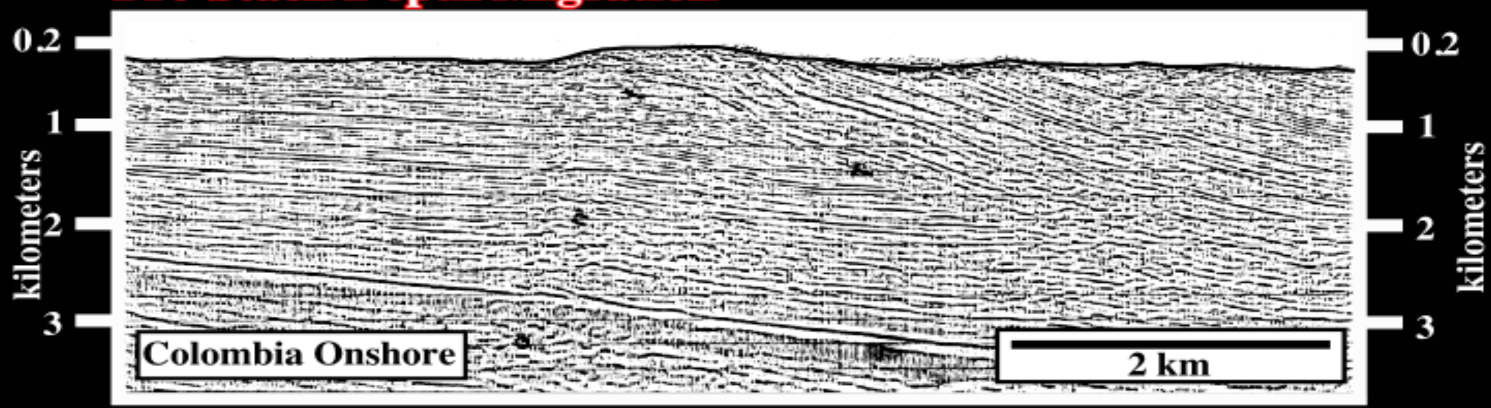
Unmigrated



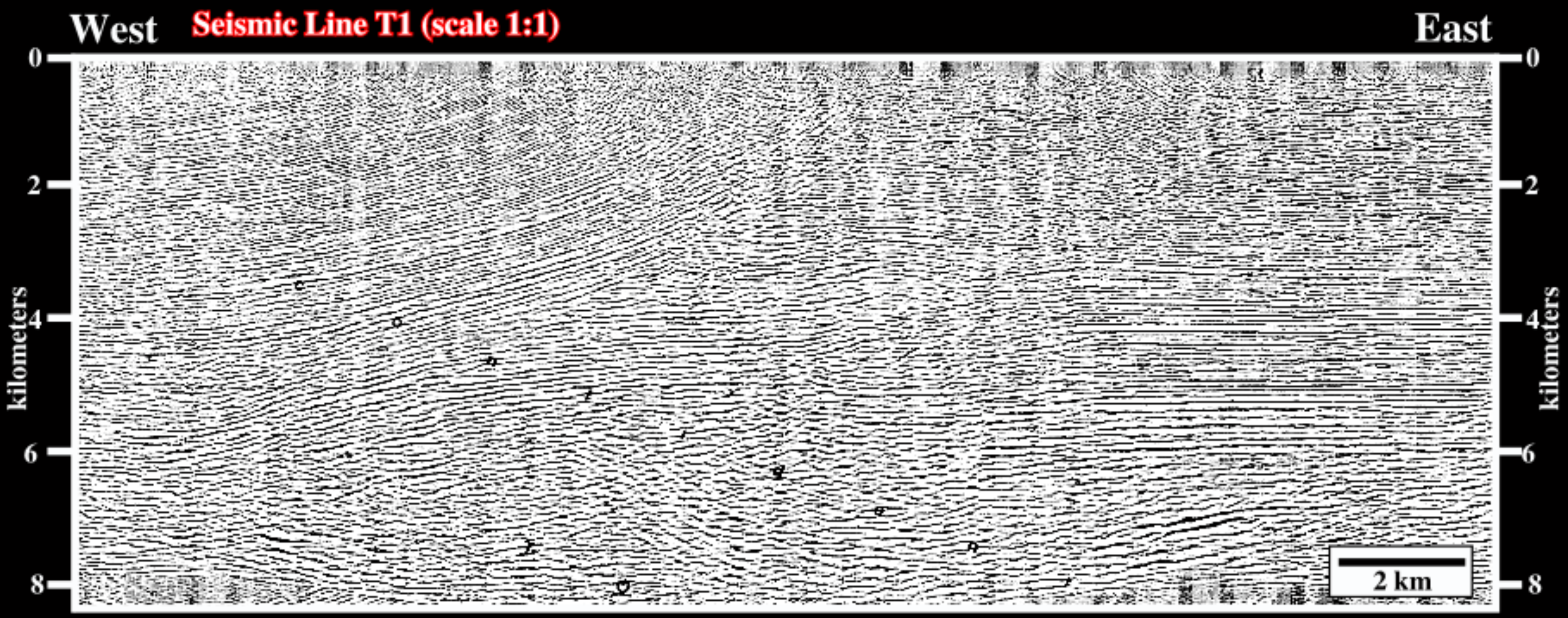
Post-Stack Migration



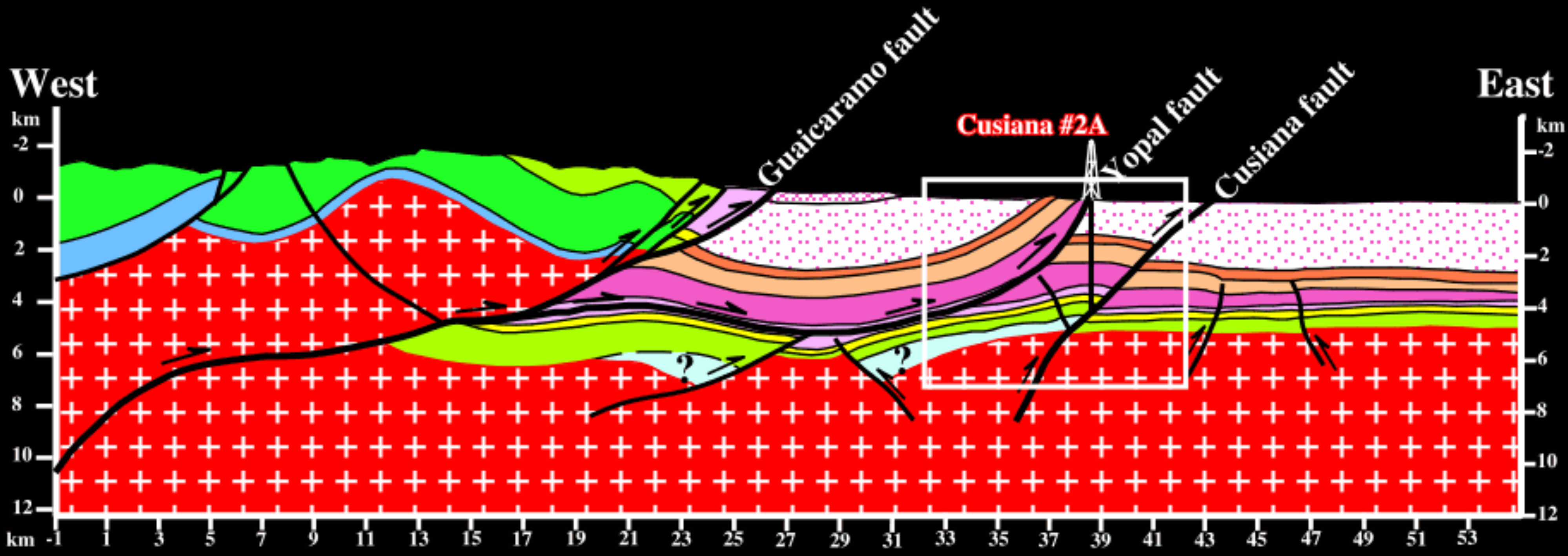
Pre-Stack Depth Migration



Pre-Stack Depth Migration



Cross Section of Bolivian Foothills through Cusiana Field



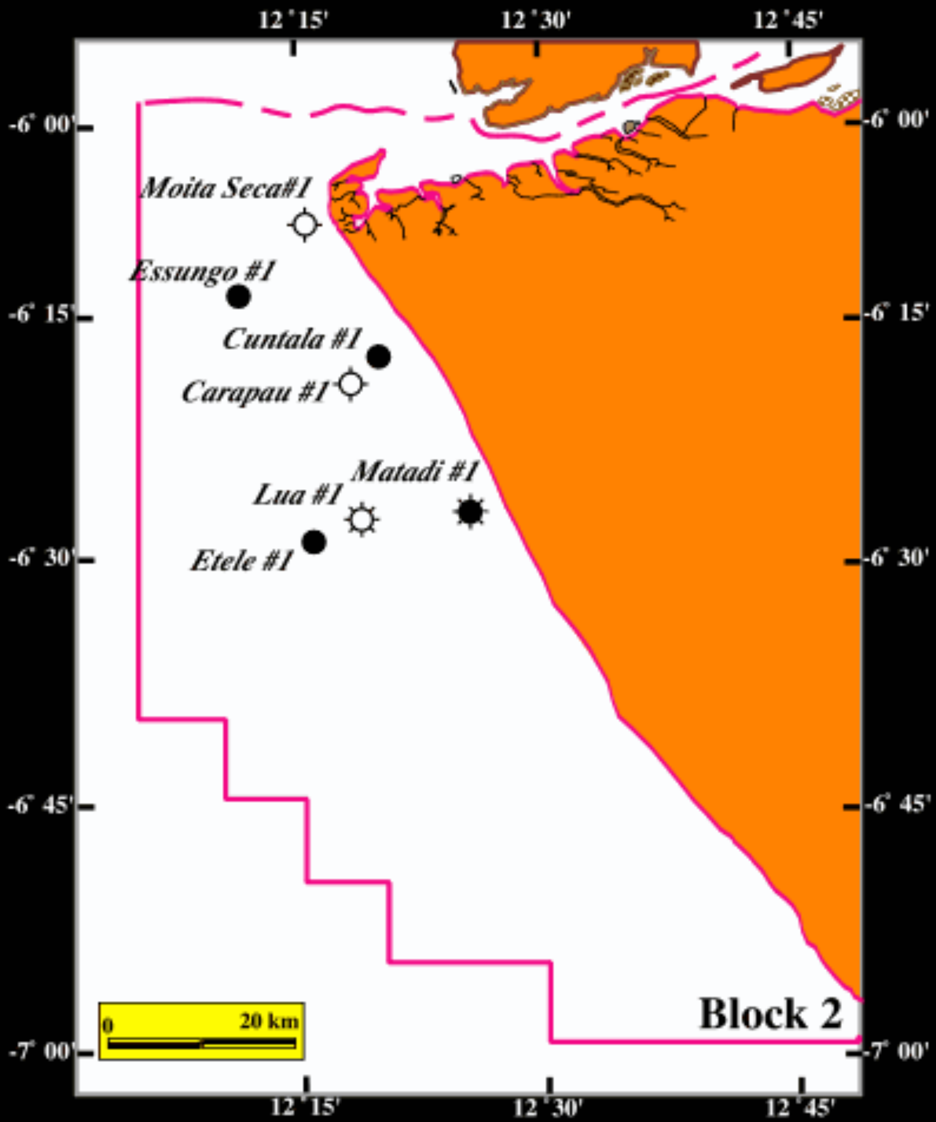
Lombo East Field

(Angola Offshore, Blk. 2)

After 19 wells (dry and non-commercial

H.E.A.T. Switzerland

ANGOLA P.A.T. Offshore



01-01-1969 to 01-04-1980

(Texaco, Petrangol, Angol)

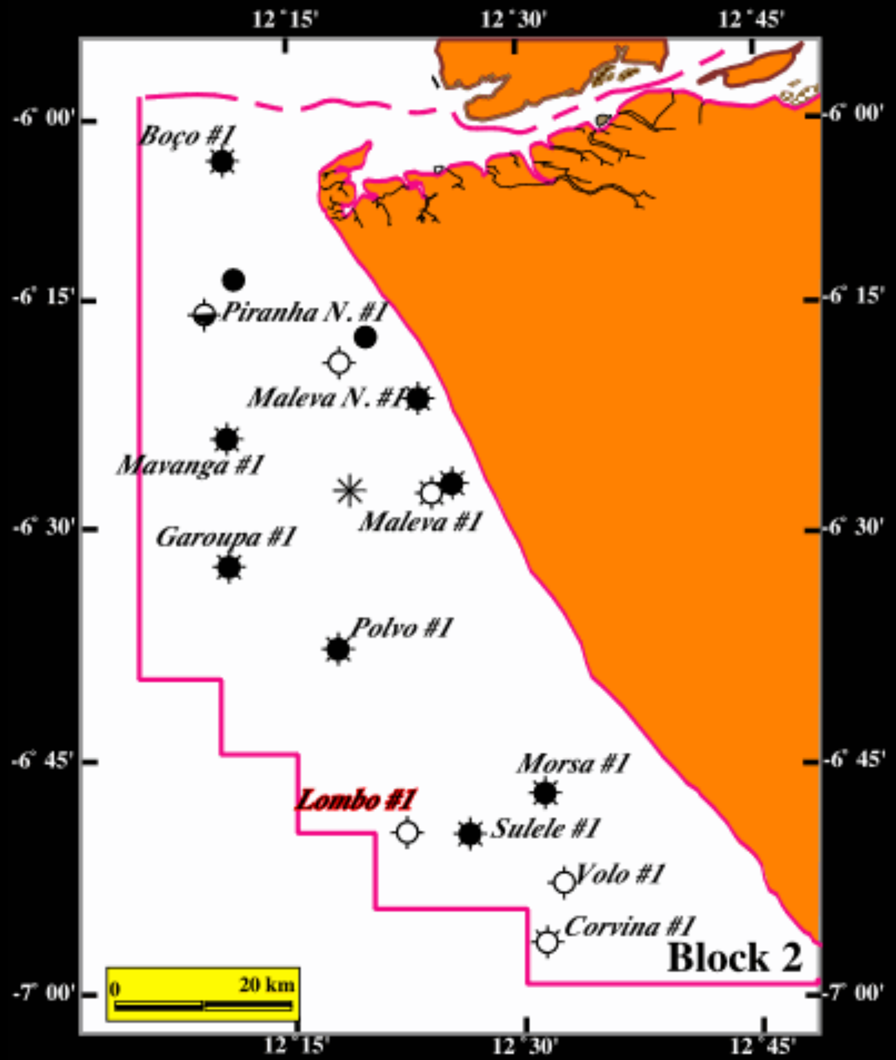
Moita Seca #1-----Mar. 1970------Dry
Essungo #1---------Feb. 1975-------Commercial
Etele #1-------------Jun, 1975-------Non commercial
Carapau #1 -------Sep. 1977 -------Dry
Cuntala #1---------Sep. 1978--------Commercial
Matadi #1----------Nov. 1978-------Non Commercial
Lua #1--------------Feb. 1979--------Gas

Essungo #1 is only commercial in Tertiary turbidites.

WELL LEGEND

Dry Hole · Dry hole with Oil Show · Dry hole with Gas Show
Oil and Gas Producer · Oil Producer · Gas Producer

ANGOLA Block 2 Concession



PSA (1st Exploration Period)

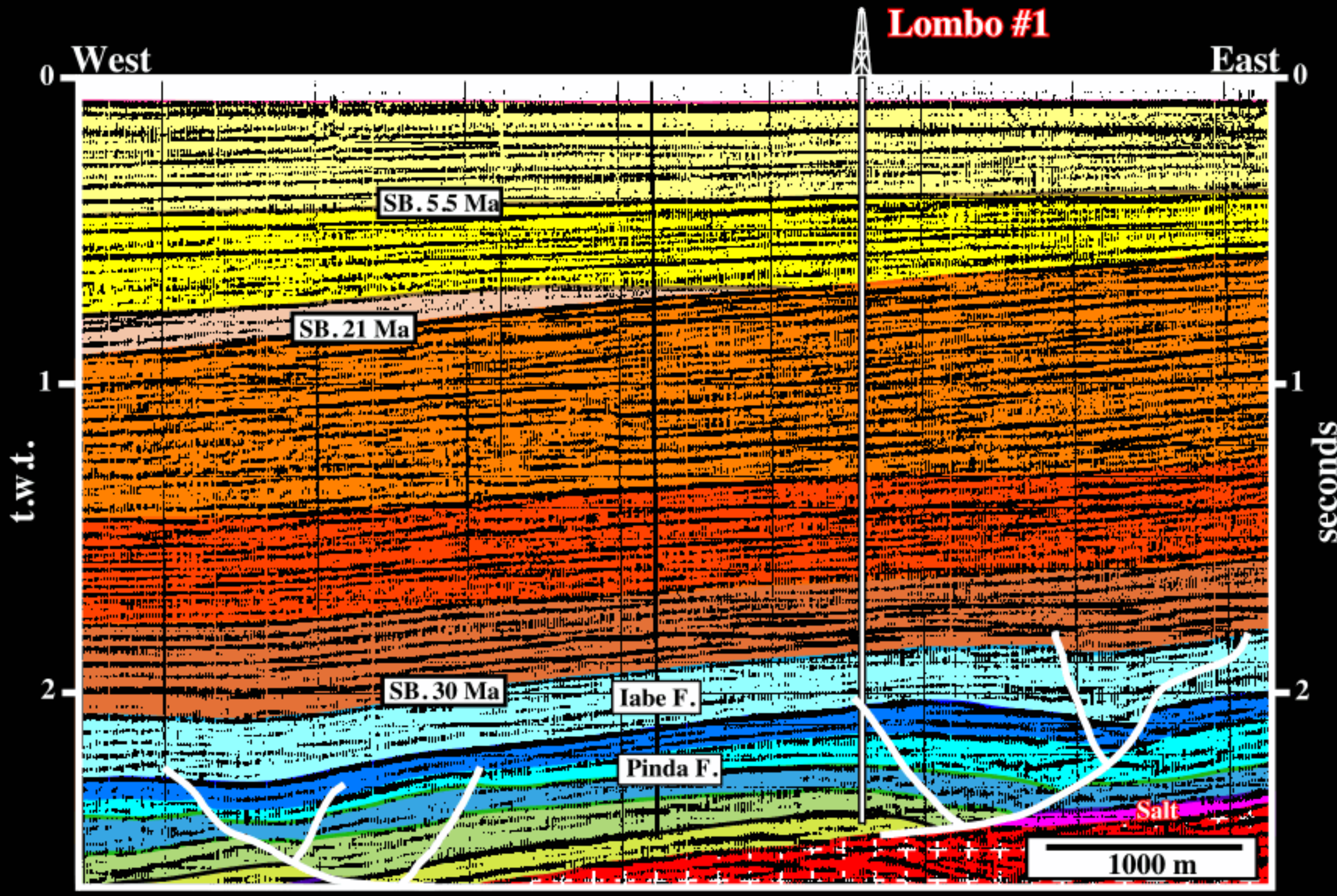
01-04-1980 to 01-04-1983

(Texaco, Total, Petrobràs, Sonangol)

Maleva #1--------------Jun. 1980-----Gas
Boço #1-----------------Mar. 198------Non commercial
Polvo #1----------------Feb, 1981------Non commercial
Garoupa #1 -----------Sep. 1981 -----Non commercial
Morsa #1---------------Nov. 1981-----Non commercial
Lombo #1--------------Fev. 1982------Dry
Sulele #1----------------May 1982-----Marginal
Mavanga #1-----------Jul 1982-------Non commercial
Maleva N. #1----------Aug 1982------Non commercial
Corvina #1-------------Oct 1982-------Gas
Volo #1-----------------Dec 1982-------Dry
Piranha N. #1---------Jan 1983-------Non commercial

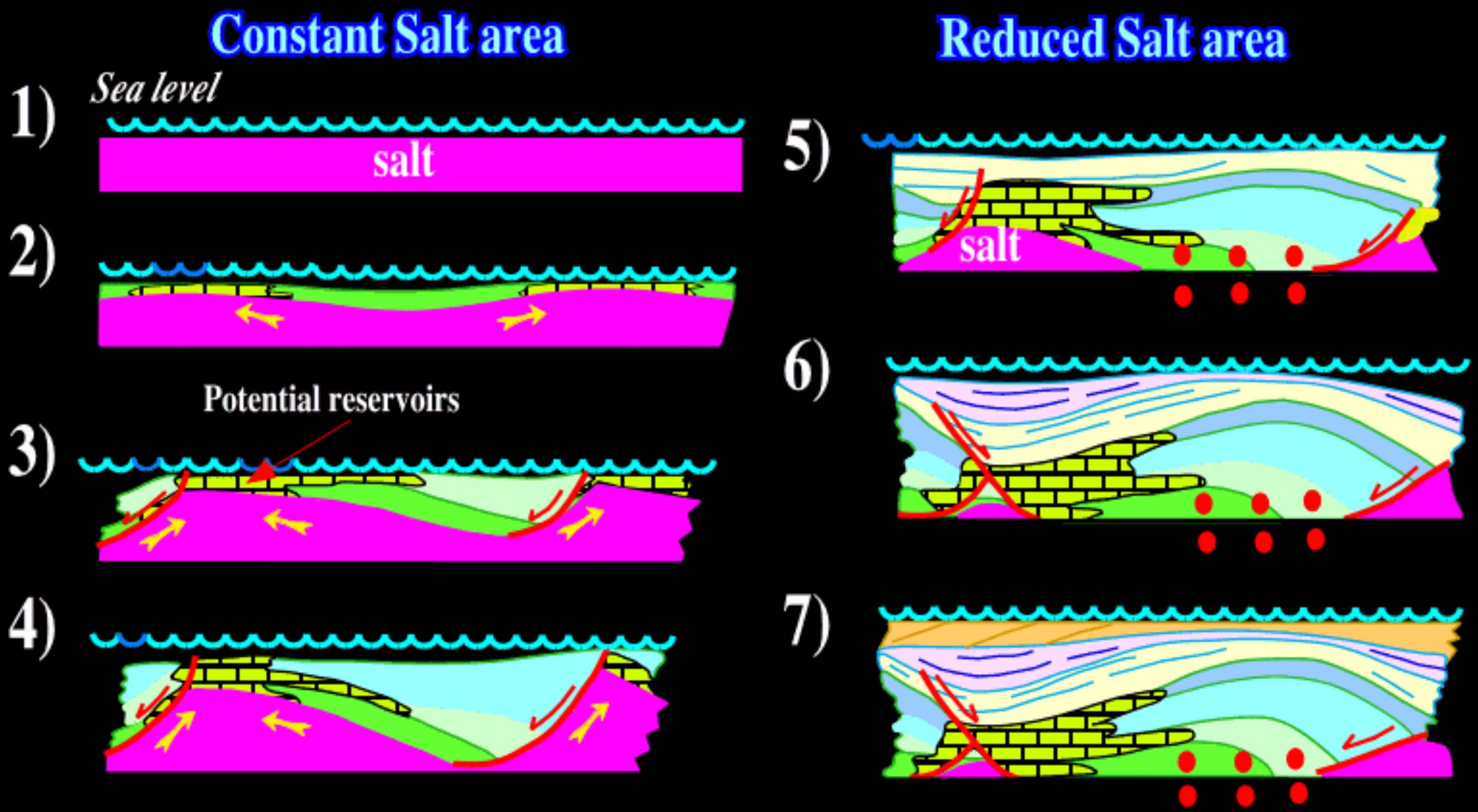
WELL LEGEND

Dry Hole · Dry hole with Oil Show · Dry hole with Gas Show
Oil and Gas Producer · Oil Producer · Gas Producer

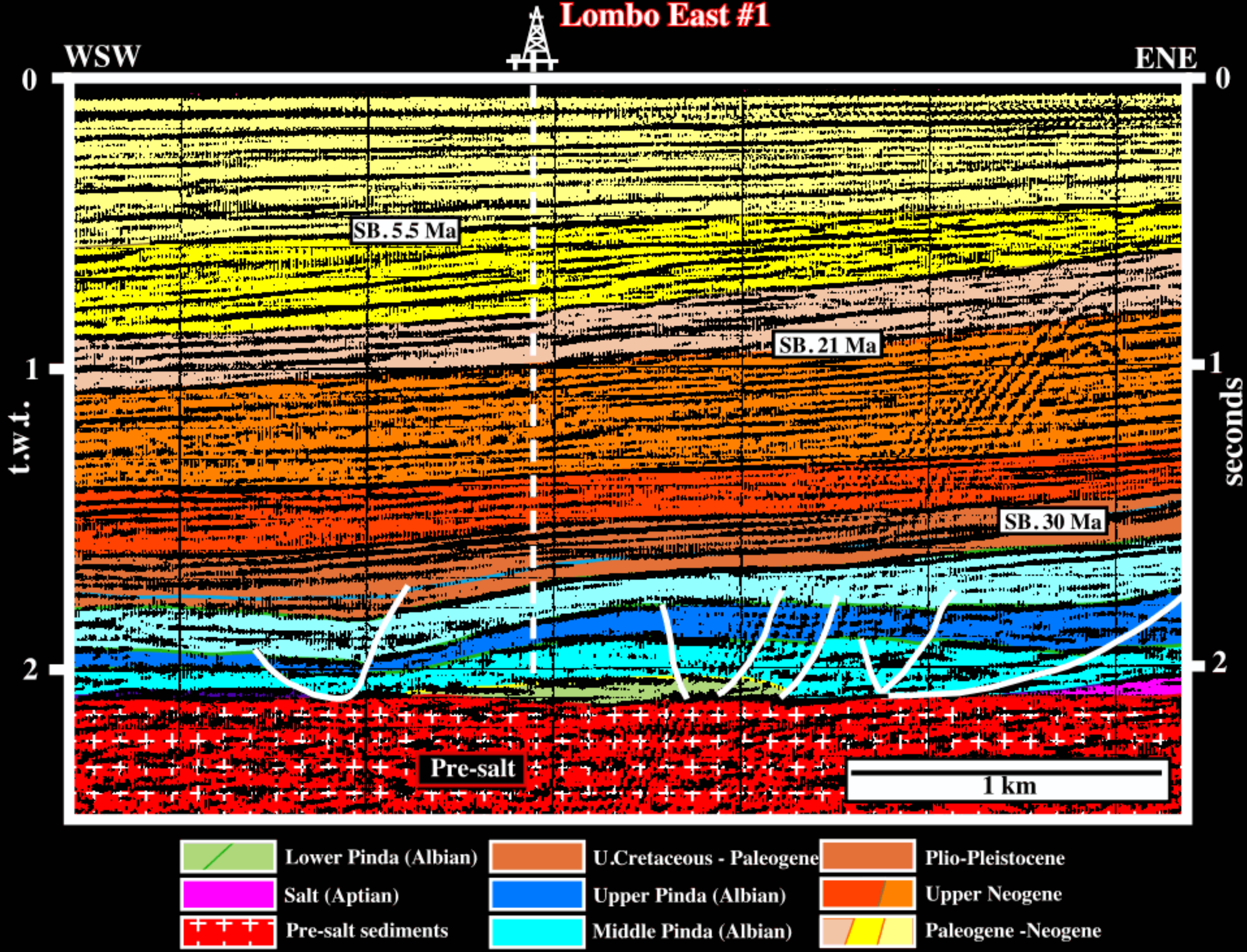

Lombo #1
West
East
0
1
2
t.w.t.
seconds
SB. 5.5 Ma
SB. 21 Ma
SB. 30 Ma
Iabe F.
Pinda F.
Salt
1000 m

H.E.A.T. Switzerland

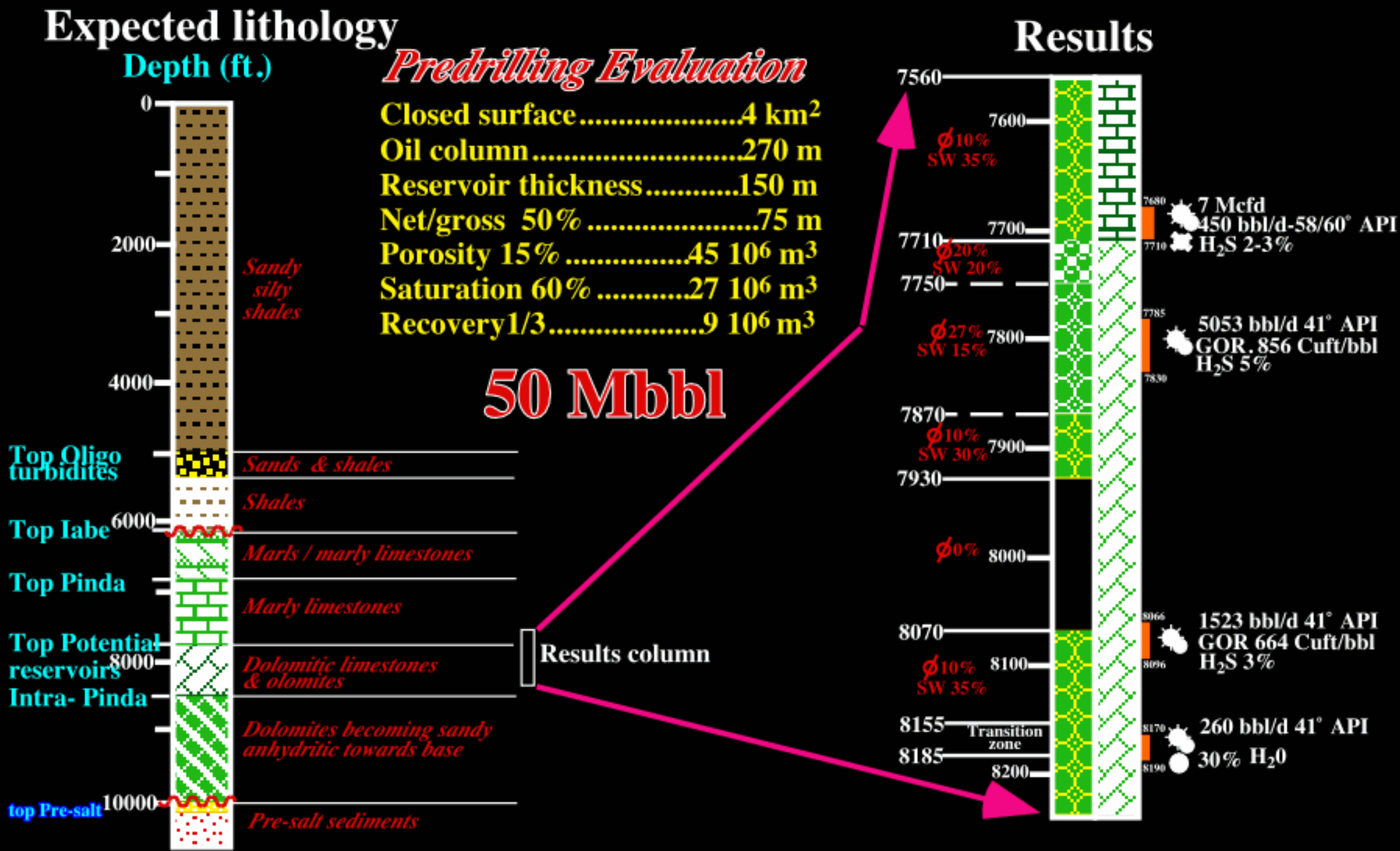
Potential Reservoirs Model

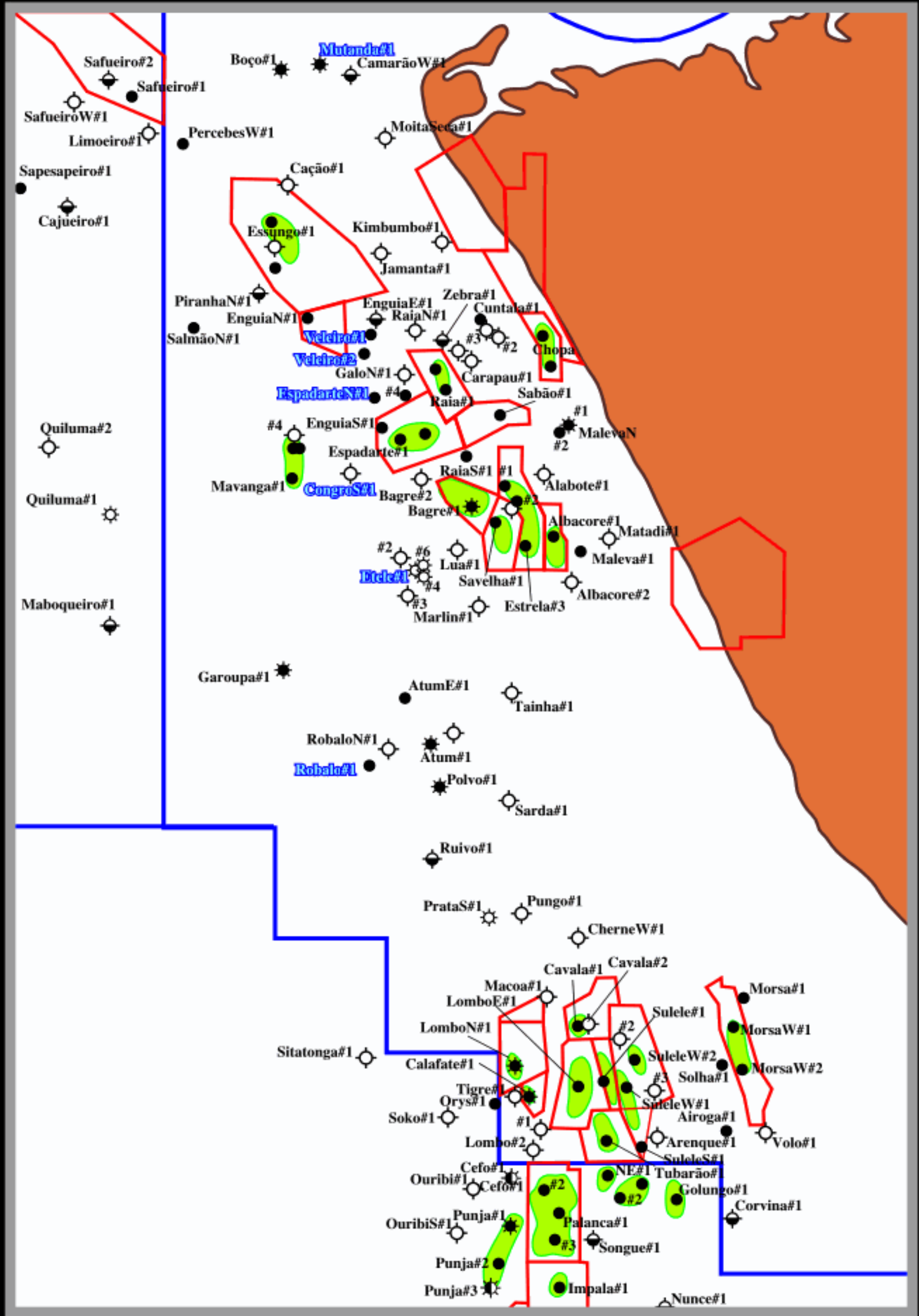


Lombo East #1


WSW
ENE
0
1
2
t.w.t.
seconds
SB. 5.5 Ma
SB. 21 Ma
SB. 30 Ma
Pre-salt
1 km
Lower Pinda (Albian)
Salt (Aptian)
Pre-salt sediments
U.Cretaceous - Paleogene
Upper Pinda (Albian)
Middle Pinda (Albian)
Plio-Pleistocene
Upper Neogene
Paleogene -Neogene

Prospect Lombo East #1





Production Concessions Block 2 Angola Offshore

Mutamba #1 (1997)

W.D. 25m, TMD 3467m. Tested 5200 b/d from 2 intervals
10 MMBO in Malembo at 1600m depth
8 MMBO + 10 BCFG in Middle Pinda at 3000m depth

Veleiro #1 (1996)

W.D. 20m, TMD 3688m. Tested 6400 b/d 35° oil from Pinda
10 MMBO in Pinda at 2500m (Veleiro-2 unsuccessful)

Espadarte N. #1 (1996)

W.D. 23m, TMD 4565m. Tested 9150 b/d light crude from Pinda
5 MMBO in Pinda at 3000m, Wood Mackenzie estimates 30 MMBO

Congro S. #1 (1996)

W.D. 20m, TMD 3813m. 2300 b/d 43° +21 MMCFG/d
17 MMBCond. 150 BCFG in Pinda at 2500m

Etele #1 (1975)

W.D. 29m; TMD 4111m
5 MMBO, 39°, paraffinic oil + 25 BCFG in Tertiary (Eocene/Olig) at 3200m

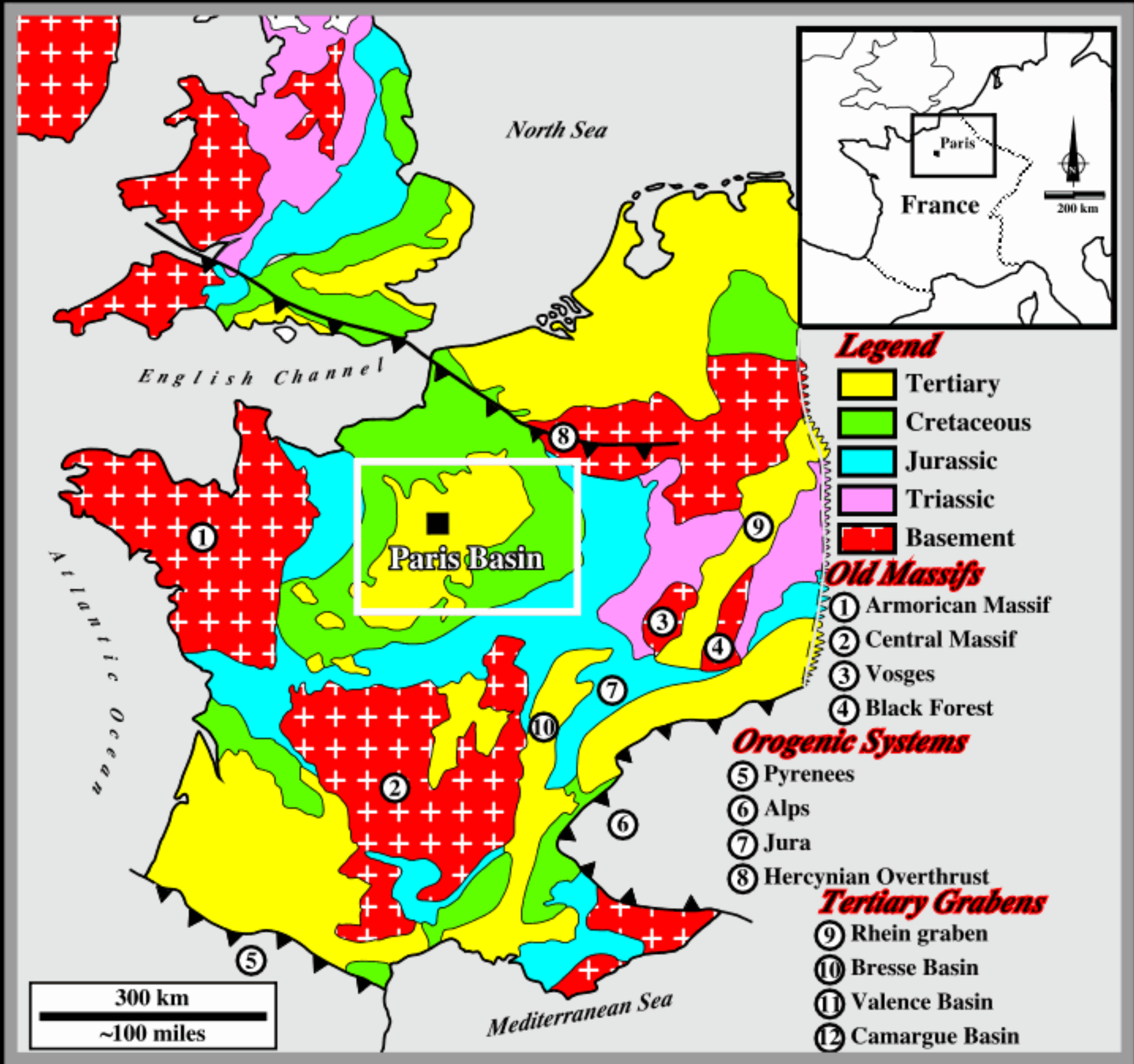
Robalo #1 (1989)

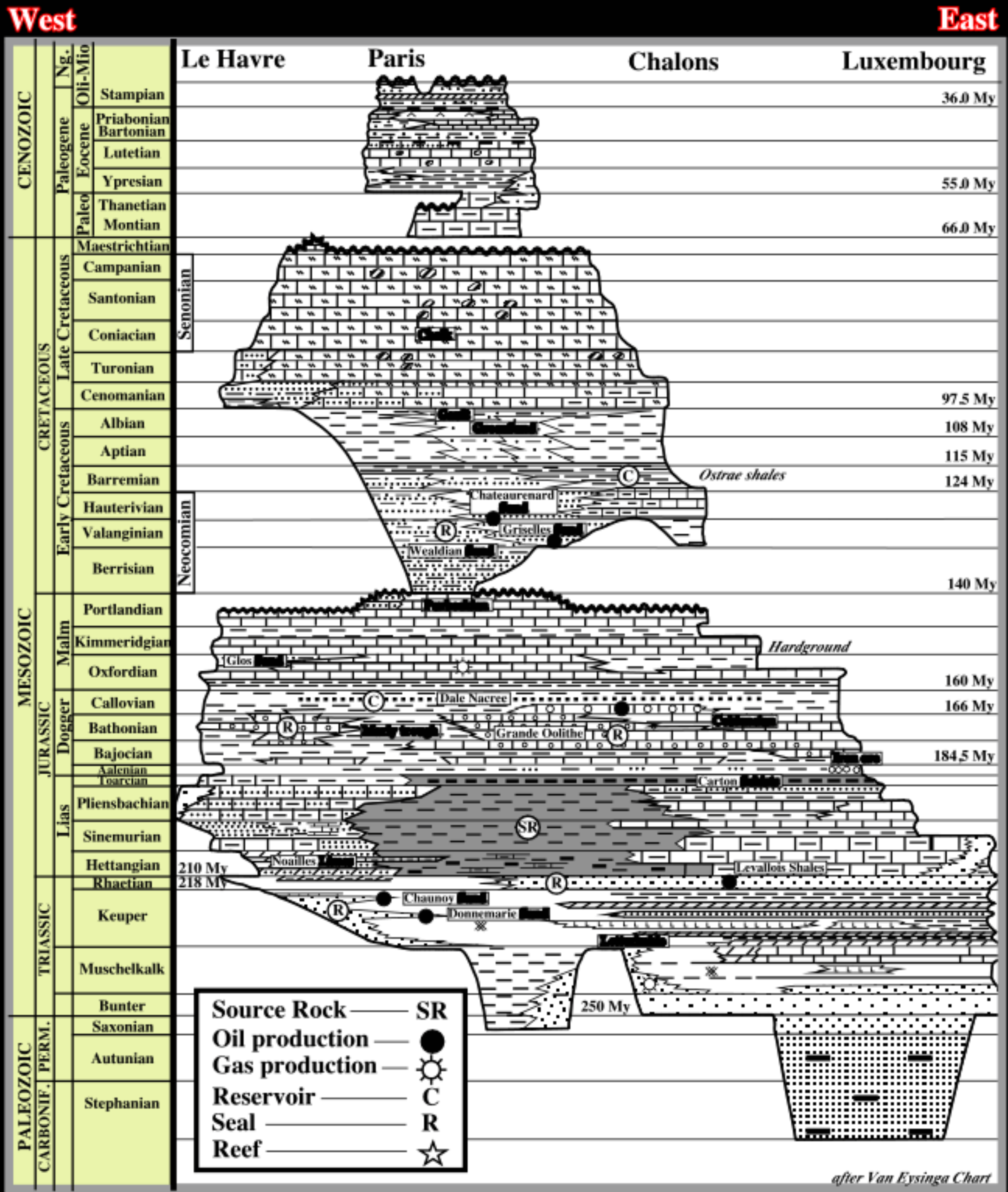
W.D. 50m, TMD 4179m. Tested 3200 and 3500 b/d from two zones in Pinda
with 35 °API oil and 0.5 MMBO in Pinda (Pacassa) at 3300m

Villeperdue Field

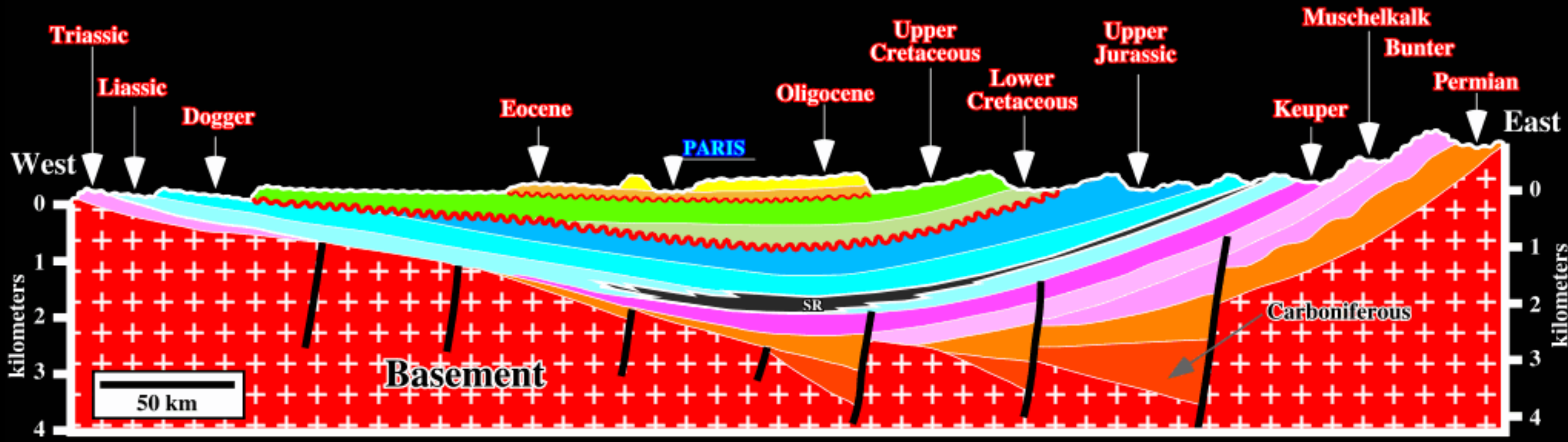
(Paris Basin)

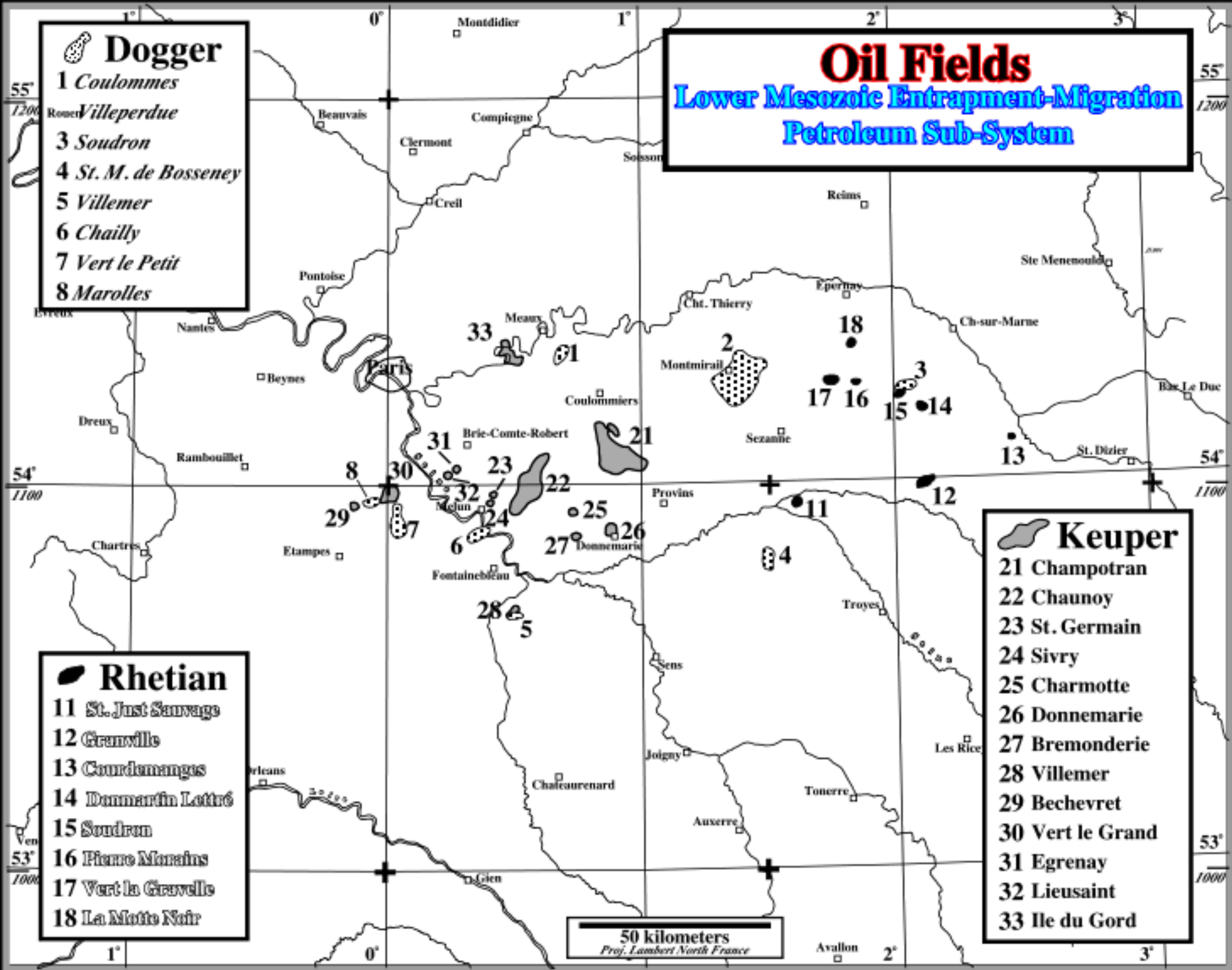
The discovery of Villeperdue was annonced in &982, b ut in fact tyhe reall discovery and even withj a short period of producin corresponds to Montmirail 102 in 1958.


North Sea
English Channel
Atlantic Ocean
Mediterranean Sea
Paris Basin
Paris
France
200 km
300 km
~100 miles
Legend
Tertiary
Cretaceous
Jurassic
Triassic
Basement
Old Massifs
1 Armorican Massif
2 Central Massif
3 Vosges
4 Black Forest
Orogenic Systems
5 Pyrenees
6 Alps
7 Jura
8 Hercynian Overthrust
Tertiary Grabens
9 Rhein graben
10 Bresse Basin
11 Valence Basin
12 Camargue Basin


West
East
Le Havre
Paris
Chalons
Luxembourg
CENOZOIC
MESOZOIC
PALEOZOIC
CRETACEOUS
JURASSIC
TRIASSIC
PERM.
CARBONIF.
Ng.
Oli-Mio
Paleogene
Eocene
Paleo
Late Cretaceous
Early Cretaceous
Senonian
Neocomian
Malm
Dogger
Lias
Stampian
Priabonian
Bartonian
Lutetian
Ypresian
Thanetian
Montian
Maestrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berrisian
Portlandian
Kimmeridgian
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensbachian
Sinemurian
Hettangian
Rhaetian
Keuper
Muschelkalk
Bunter
Saxonian
Autunian
Stephanian
36.0 My
55.0 My
66.0 My
97.5 My
108 My
115 My
124 My
140 My
160 My
166 My
184.5 My
210 My
218 My
250 My
Ostrae shales
Chateaurenard
Griselles
Wealdian
Hardground
Glos
Dale Nacree
Grande Oolithe
Carton
Noailles
Levallois Shales
Chaunoy
Donnemarie
Source Rock SR
Oil production
Gas production
Reservoir C
Seal R
Reef
after Van Eysinga Chart

Geologic Cross-Section
Paris Basin





Oil Fields
Lower Mesozoic Entrapment-Migration
Petroleum Sub-System
Dogger
1 Coulommes
2 Villeperdue
3 Soudron
4 St. M. de Bosseney
5 Villemer
6 Chailly
7 Vert le Petit
8 Marolles
Rhetian
11 St. Just Sauvage
12 Granville
13 Courdemanges
14 Donmartin Lettré
15 Soudron
16 Pierre Morains
17 Vert la Gravelle
18 La Motte Noir
Keuper
21 Champotran
22 Chaunoy
23 St. Germain
24 Sivry
25 Charmotte
26 Donnemarie
27 Bremonderie
28 Villemer
29 Bechevret
30 Vert le Grand
31 Egrenay
32 Lieusaint
33 Ile du Gord
50 kilometers
Proj. Lambert North France
Paris
Montdidier
Beauvais
Compiegne
Clermont
Creil
Reims
Pontoise
Meaux
Cht. Thierry
Epernay
Ch-sur-Marne
Ste Menenould
Montmirail
Coulommiers
Sezanne
Bar Le Duc
St. Dizier
Beynes
Dreux
Rambouillet
Brie-Comte-Robert
Melun
Provins
Donnemarie
Chartres
Etampes
Fontainebleau
Troyes
Sens
Les Rice
Joigny
Chateaurenard
Tonerre
Auxerre
Gien
Avallon
Nantes

Peciko Field

Mahakam Offshore
(Indonesia)

Peciko was in fact discovered in 1983 &bnd declared non commercial, NW Peciko 10 TCF hydrodynamism