Gravel on the Road to the Future:

Geological and Geopolitical Insights

Wolfgang E. Schollnberger Vienna, 6.6.2019

Im Salzkammergut da kann man gut lustig sein…

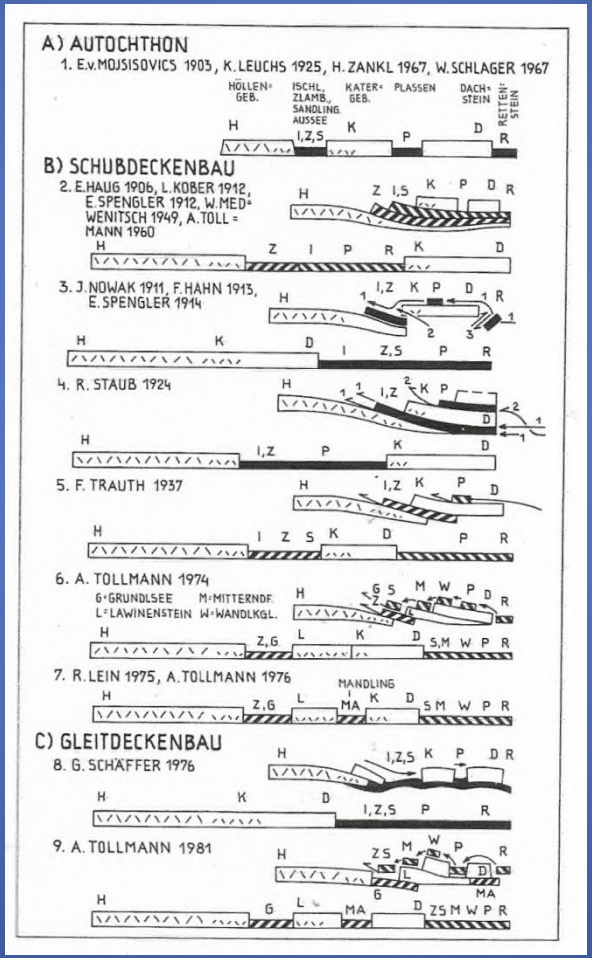
Dialog:

“Georg, ist das kompliziert, was der junge Mann da für seine Dissertation macht? “

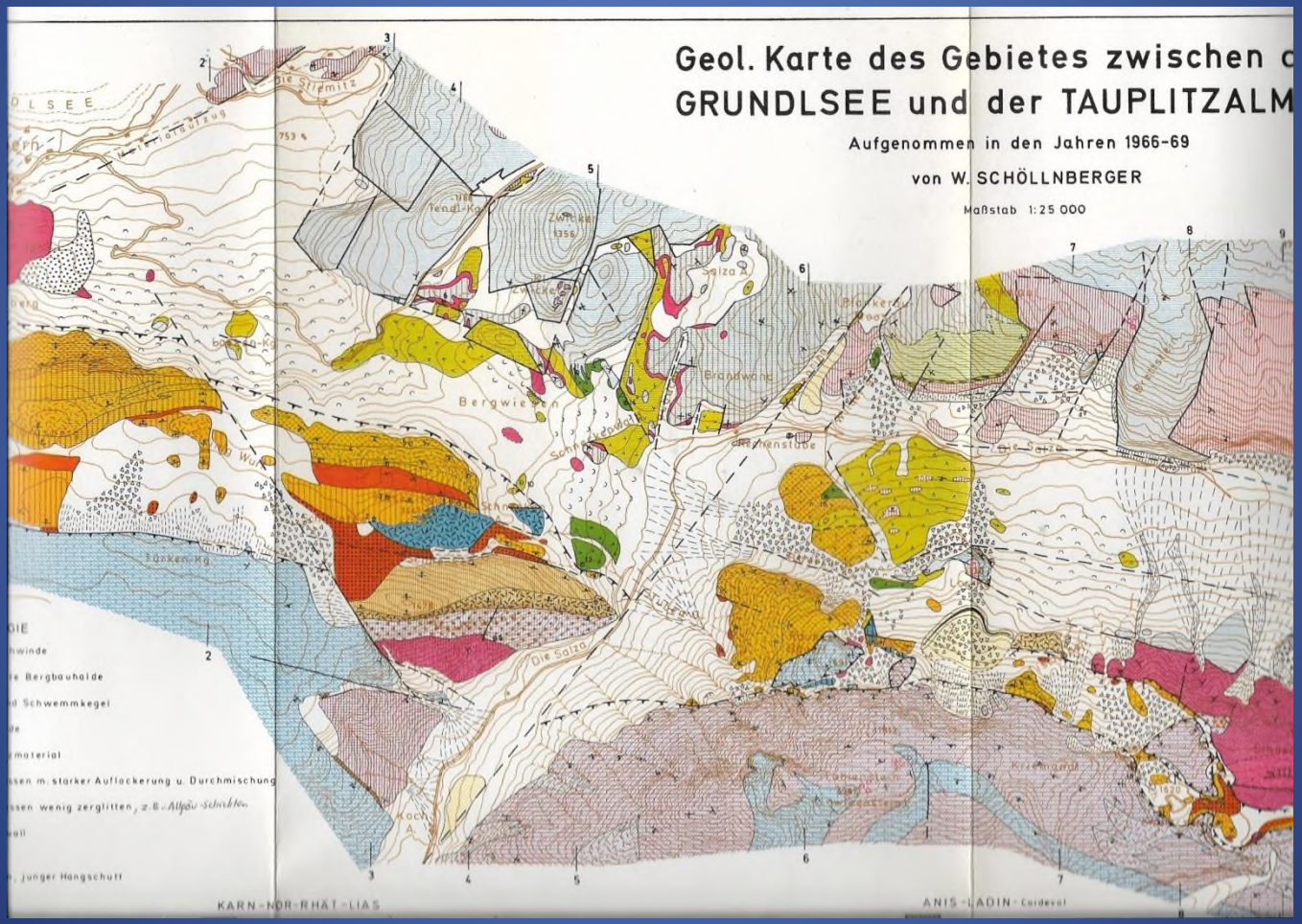
“Kompliziert, unendlich kompliziert, wie alles im Salzkammergut unendlich kompliziert ist”

Georg Rosenberg (25. 8. 1967)

Complicated , indeed

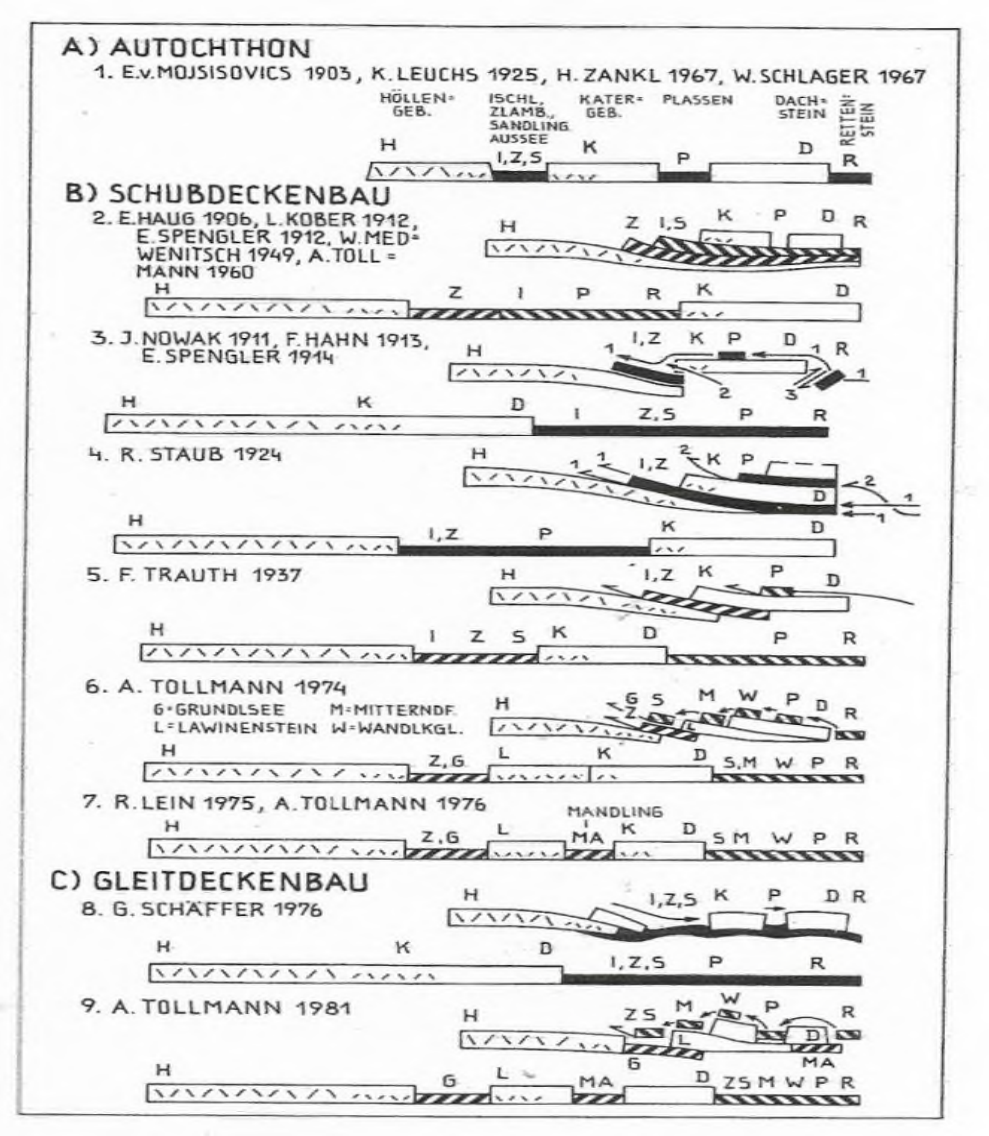


Diss. Karte


Geol. Karte des Gebietes zwischen
GRUNDLSEE und der TAUPLITZALM
Aufgenommen in den Jahren 1966-69
von W. SCHÖLLNBERGER
Maßstab 1:25 000
KARN-NOR-RHÄT-LIAS
ANIS-LADIN

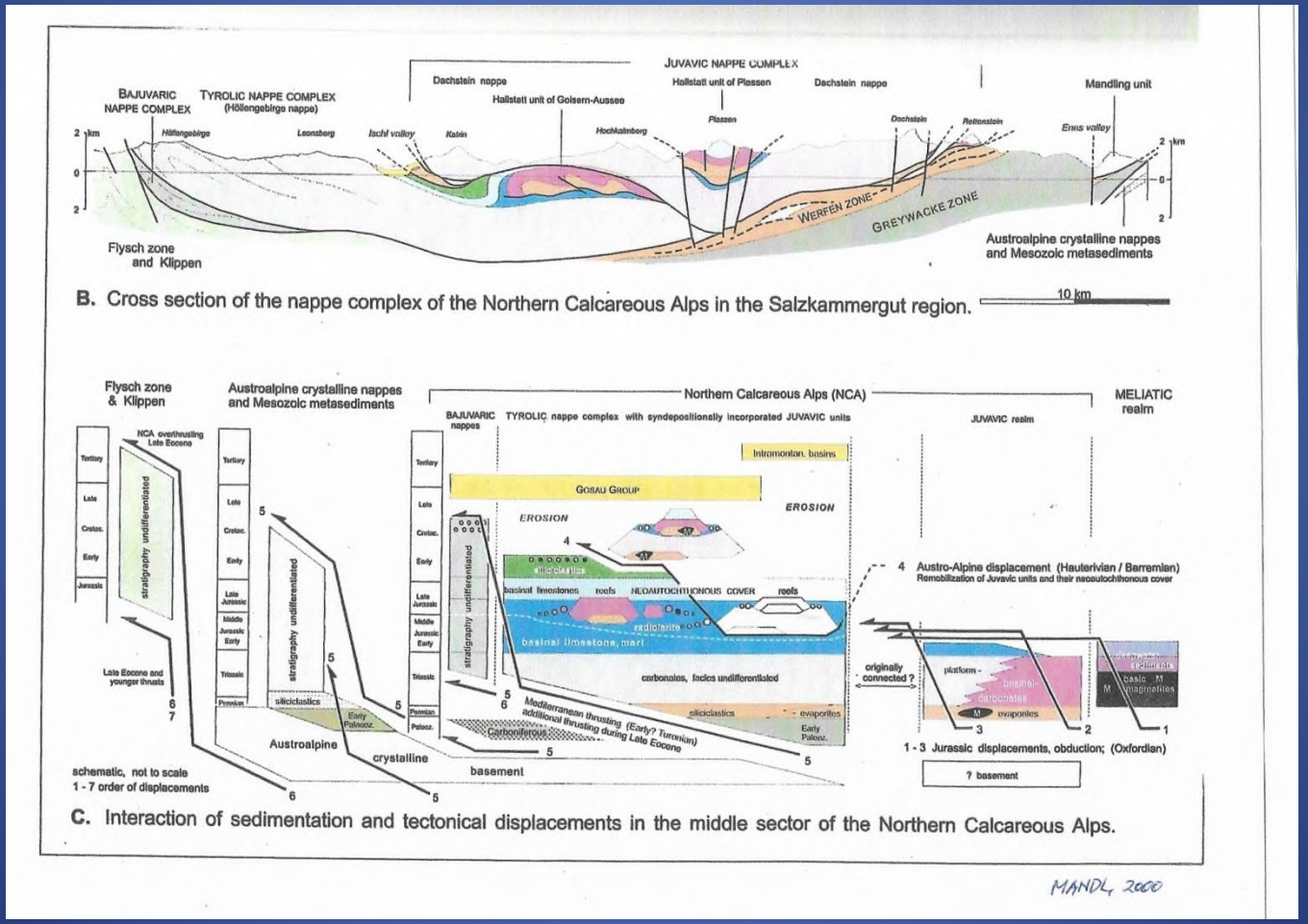
A key locality

Tollmann et. al. slowly “get it”

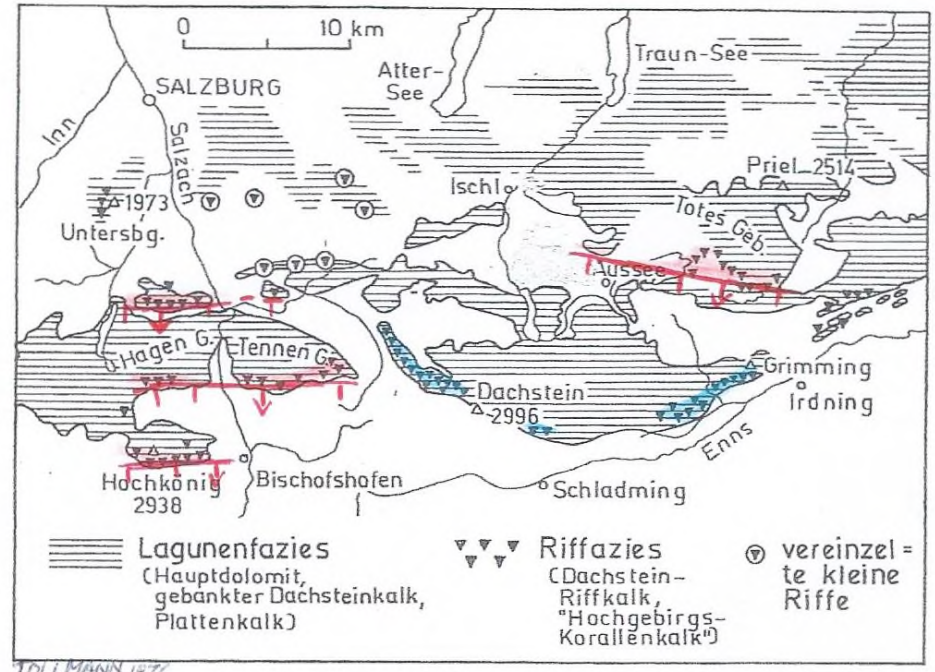


- Tollmann, 1985

Gerhard Mandl's boat enters the canal



…what about U. Triassic reefs “stranded” in the Tirolic lagoon?



TOLLMANN, 1976

Abb. 117: Die Verteilung der Dachsteinkalk-Riffe im Mittelabschnitt der Nördlichen Kalkalpen nach H. ZAPFE, 1962, S. 354; reduziert. modifiziert WES 9/17

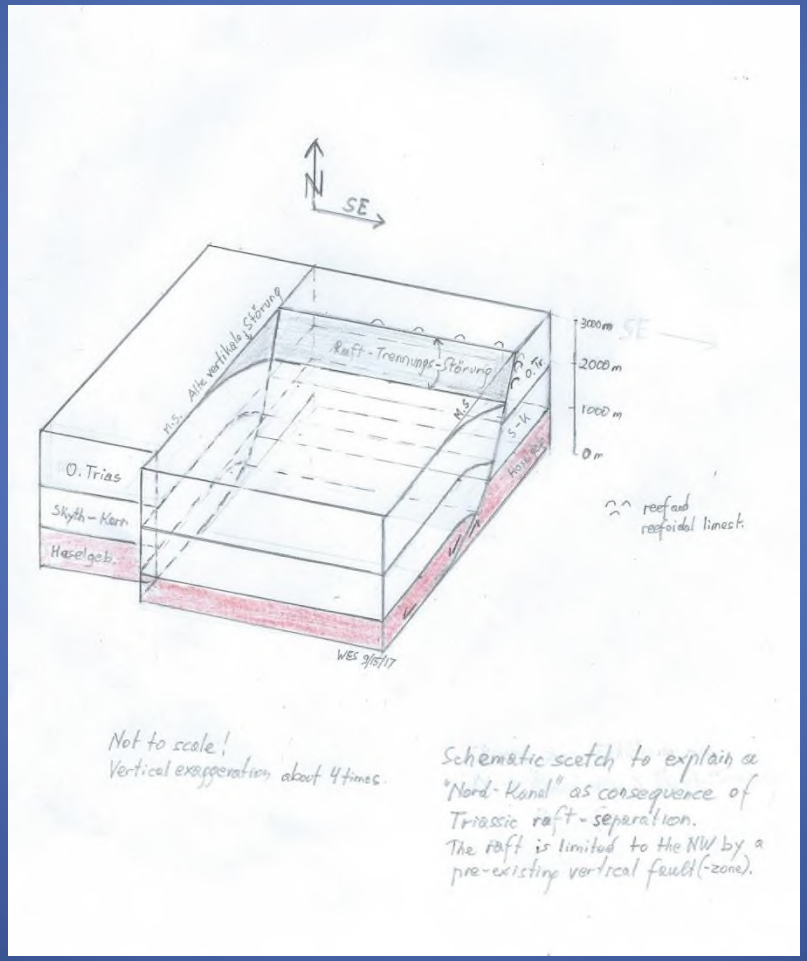
Grössere Riffe, unabhängig von Kössener Becken, Tirolikum

Potenzielle Raft-Trennungszonen in Tirolikum

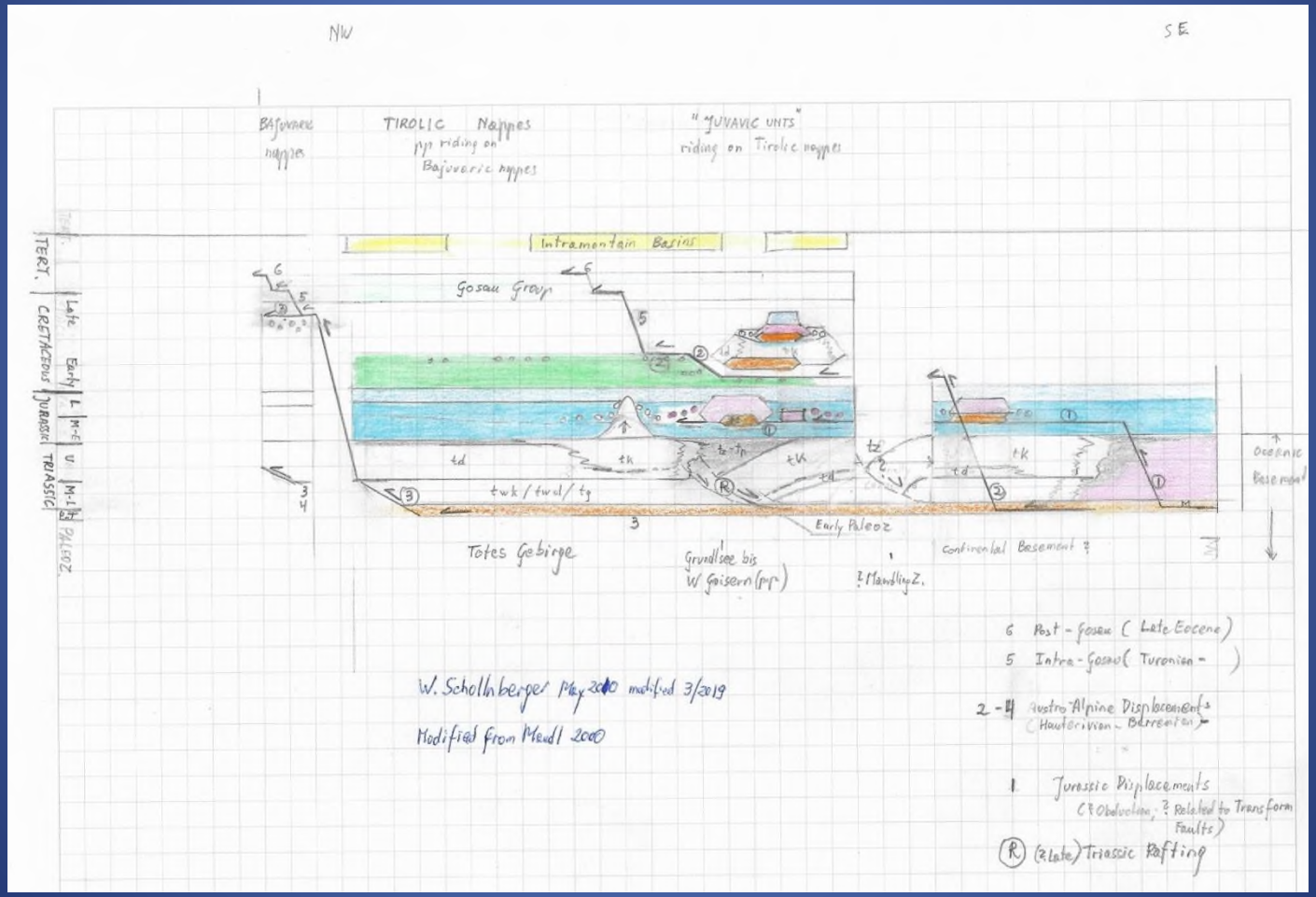
Dachstein-Riffkalke (mit Hallst. Beckensedimenten) am ursprl. S-Rand der NKA


A mighty Dachsteinkalk reef (Sturzhahn) in the middle of the Tirolic Dachsteinkalk lagoon (TragIn)?!
From where would the nutrients for the reef building organisms come? A Nordkanal!!!

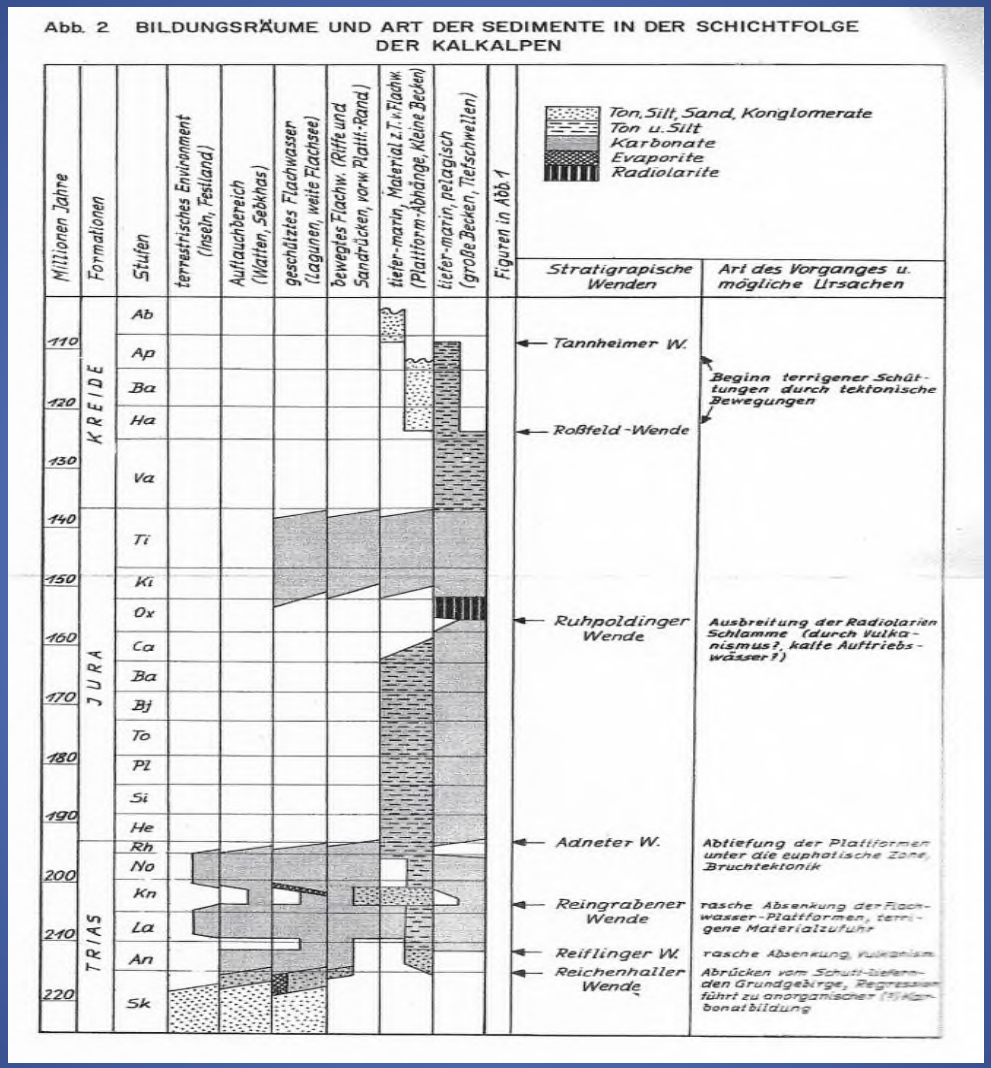
Salt induced raft tectonics to the rescue!



Noch immer: ‘kompliziert, unendlich kompliziert.....

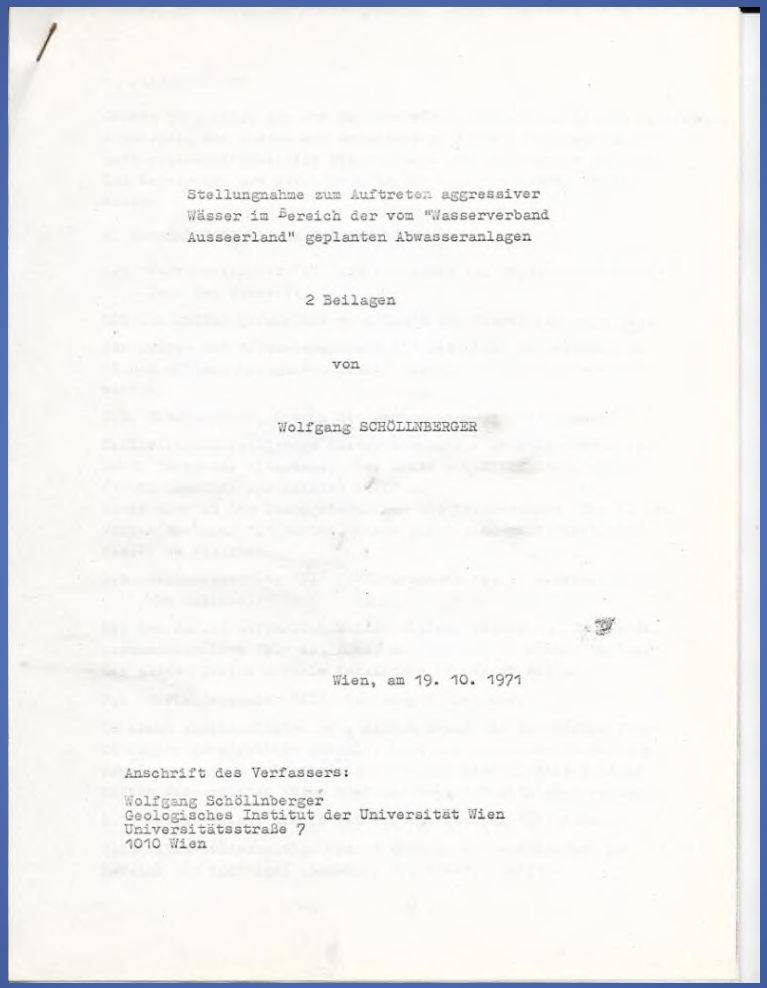


Schlager & Schollnberger (1974): Wenden



2019: Adnet W. is regional, Reingrabener W. is global, linked to the Carnian Pluvial Event

Rettet den Grundlsee, 1971.



Stellungnahme zum Auftreten aggressiver
Wässer im Bereich der vom "Wasserverband
Ausseerland" geplanten Abwasseranlagen

2 Beilagen

von

Wolfgang SCHÖLLNBERGER

Wien, am 19. 10. 1971

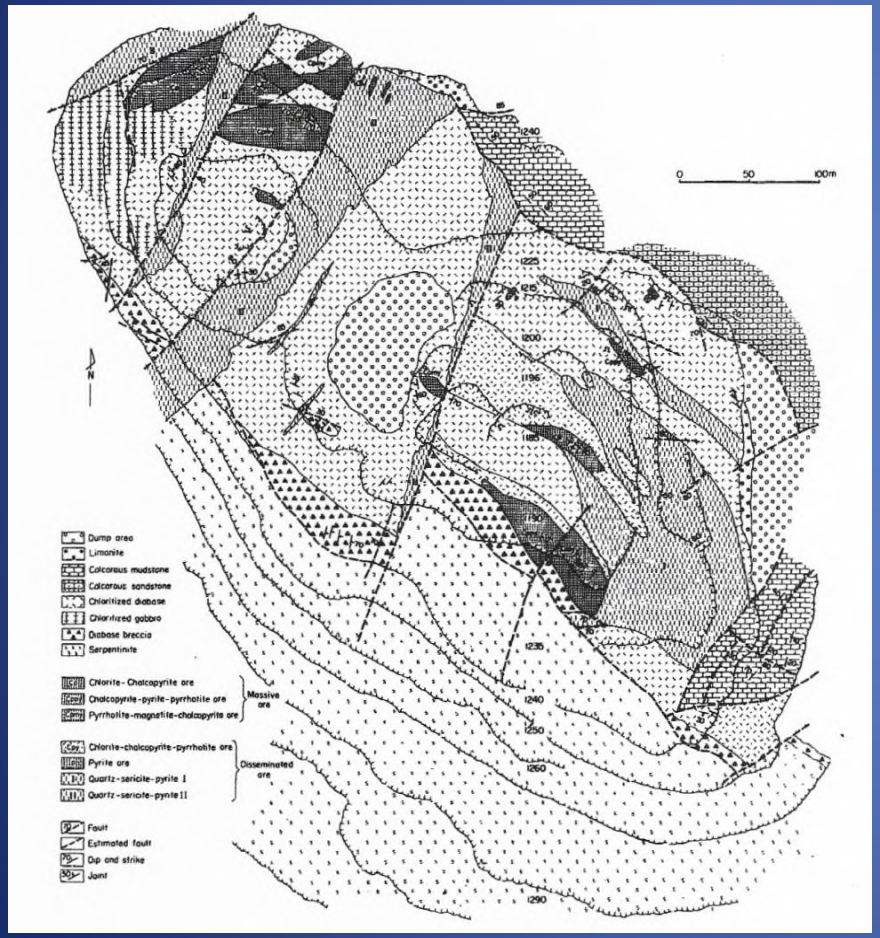
Anschrift des Verfassers:

Wolfgang Schöllnberger
Geologisches Institut der Universität Wien
Universitätsstraße 7
1010 Wien

Applying Geology to solve problems and to find raw materials is my passion

Copper “im wilden Kurdistan”: Ergani Maden, Turkey 1966

Saw it, mapped it, didn't understand it in 1966
(but Bamba understood it in 1974)



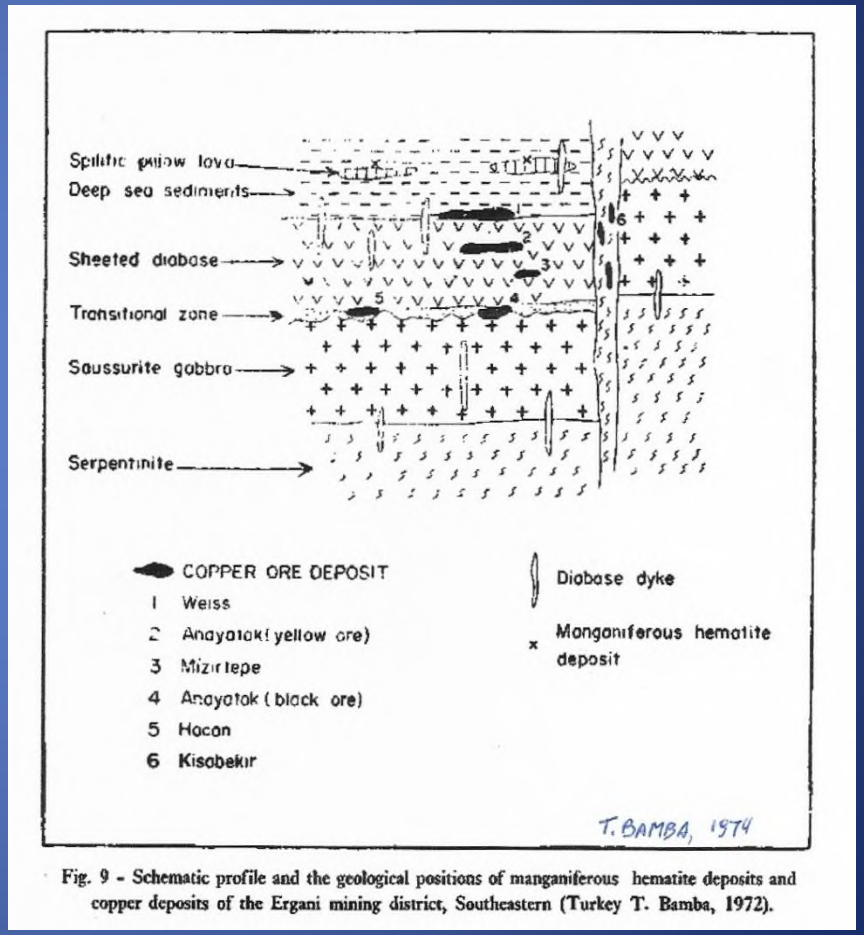
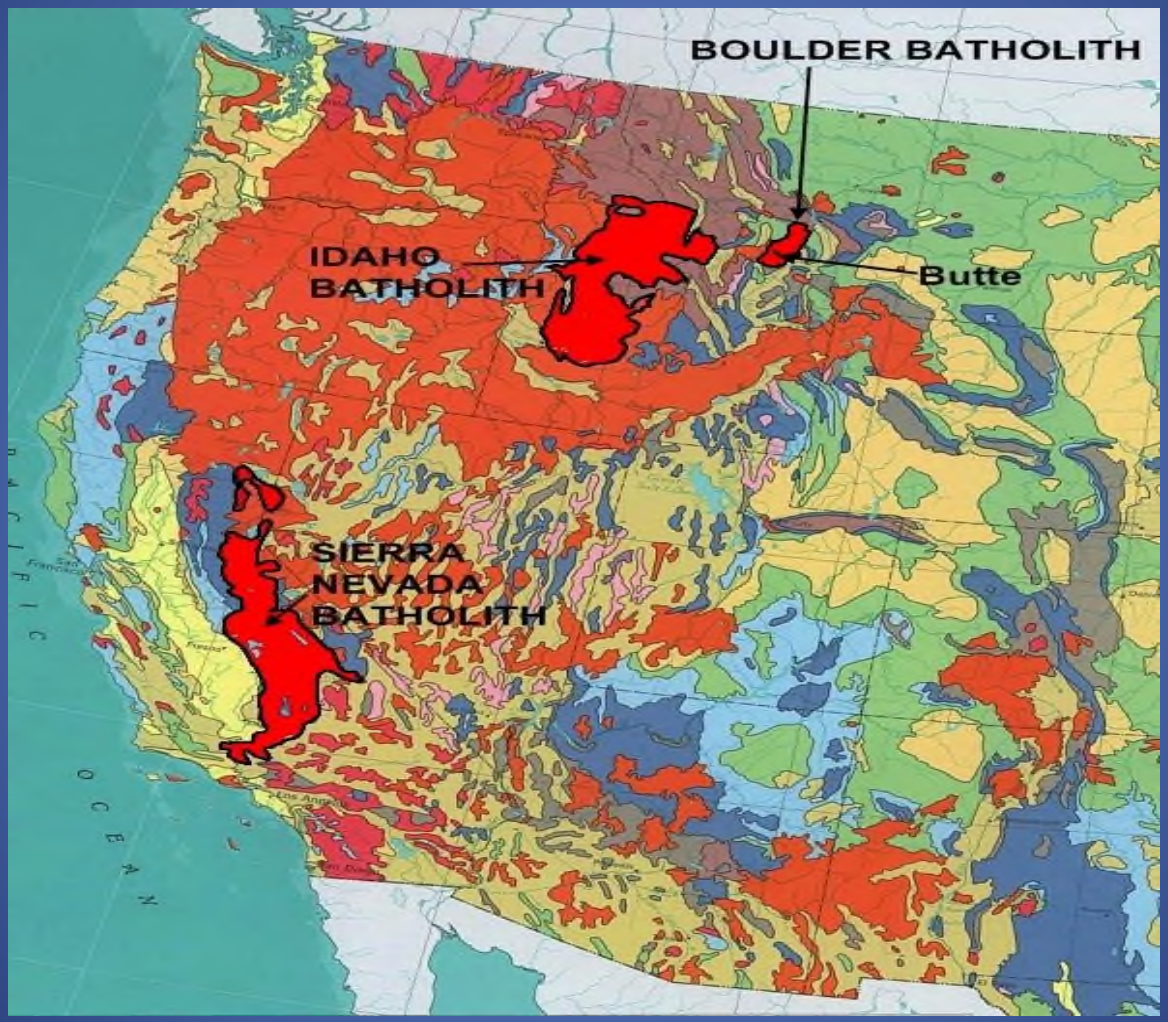


Fig. 9 - Schematic profile and the geological positions of manganiferous hematite deposits and copper deposits of the Ergani mining district, Southeastern (Turkey T. Bamba, 1972).

- Oceanic lithosphere in Maden is 73Ma old. Interesting: the oceanic lithosphere "ophiolite nappe" in the Oman Mountains is also 73Ma old!

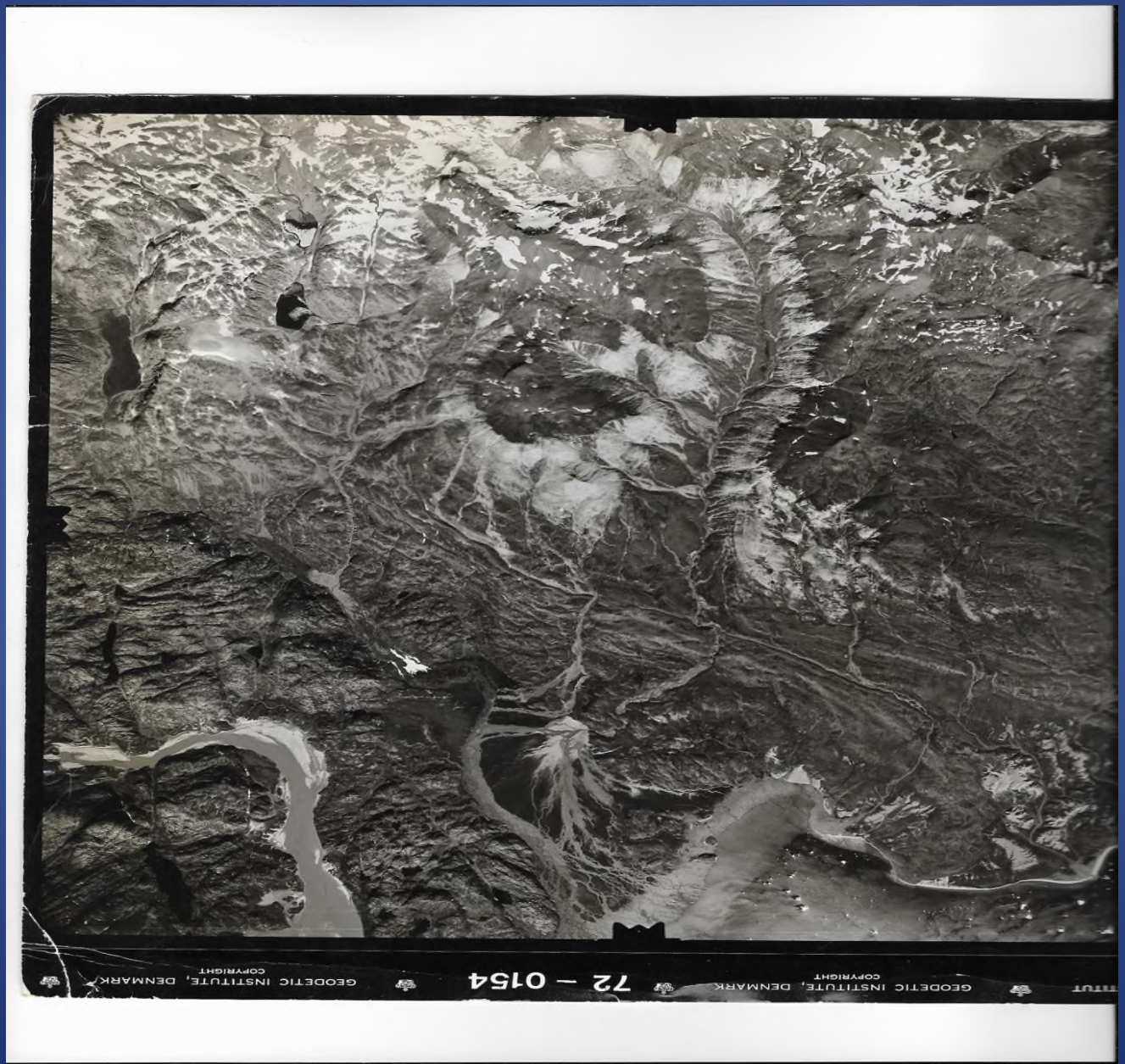
1967: Prospecting near the “richest hill on earth”: Cu, Au ,Ag, Mo…..



- Idaho and Boulder Batholith (granite, granodiorite, 73Ma old)

Finding Rare Earth Minerals on Milneland , E. Greenland

W



E

Charcot Bugt Sst.: Palaeogeography

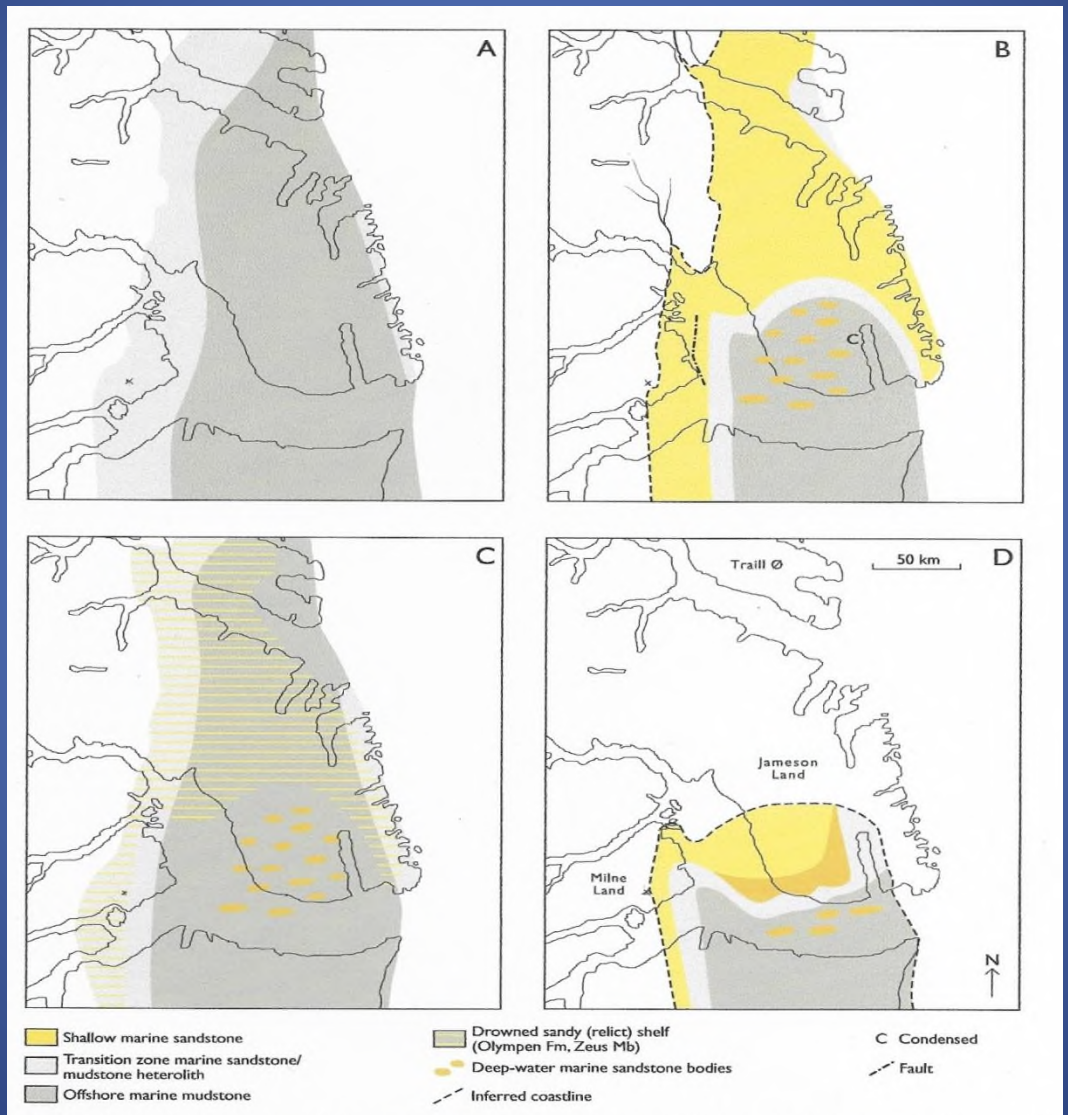


Fig. 5. Late Jurassic palaeogeography of the Jameson Land area, modified after Surlyk (2003). **A**: Early Oxfordian *Q. mariae* Chronozone. **B**: Early–middle Oxfordian *C. cordatum – C. densiplicatum* Chronozones. **C**: Latest Oxfordian – late Kimmeridgian *A. regulare – A. eudoxus* Chronozones. **D**: Early Volgian. Geol. Survey of Denmark and Greenland, Bull. 42, p. 154, 2018; Bjerager et. al.

Charcot Bugt Sst.: Stratigraphy (not quite correct, even in 2018)

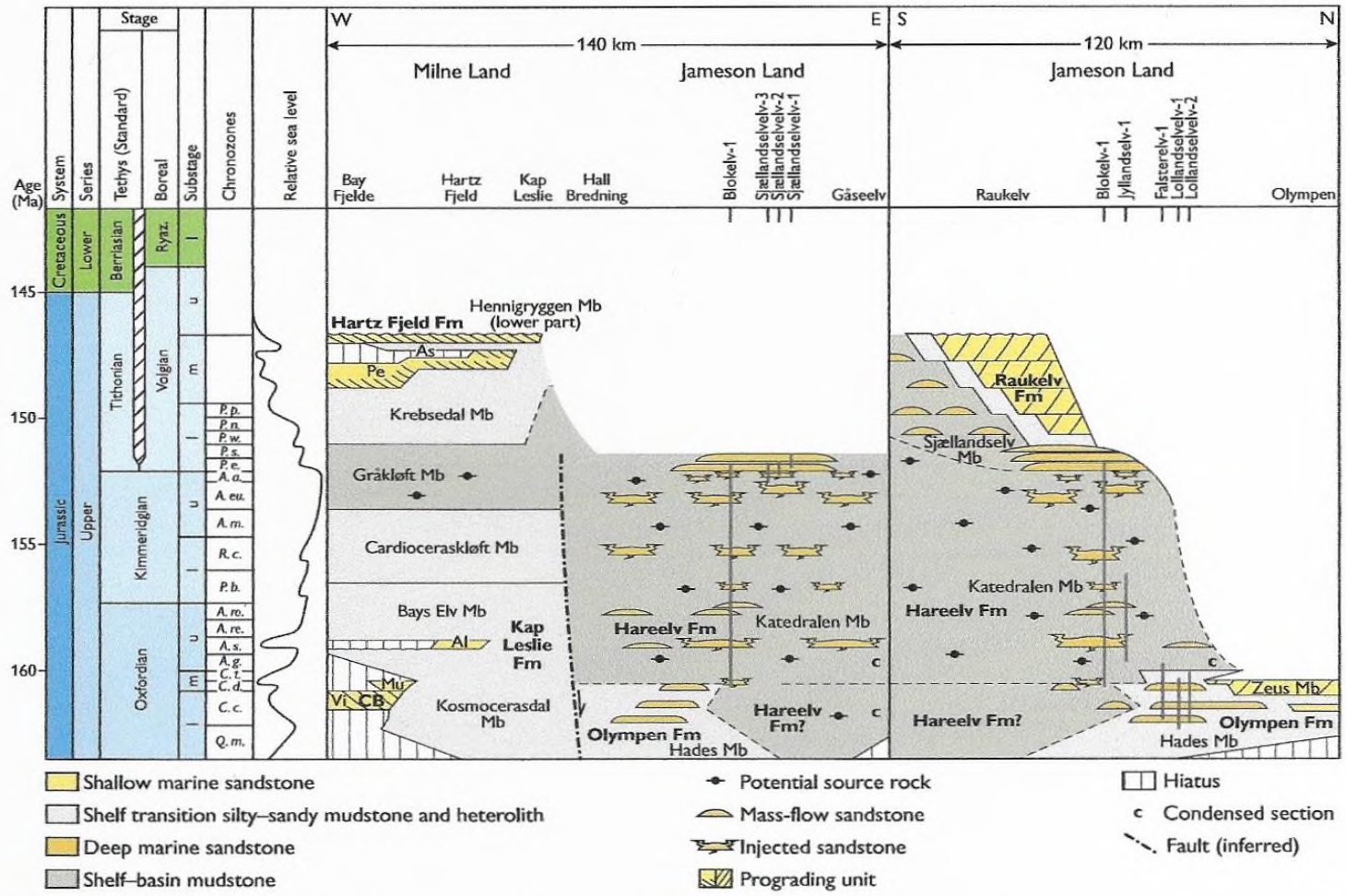
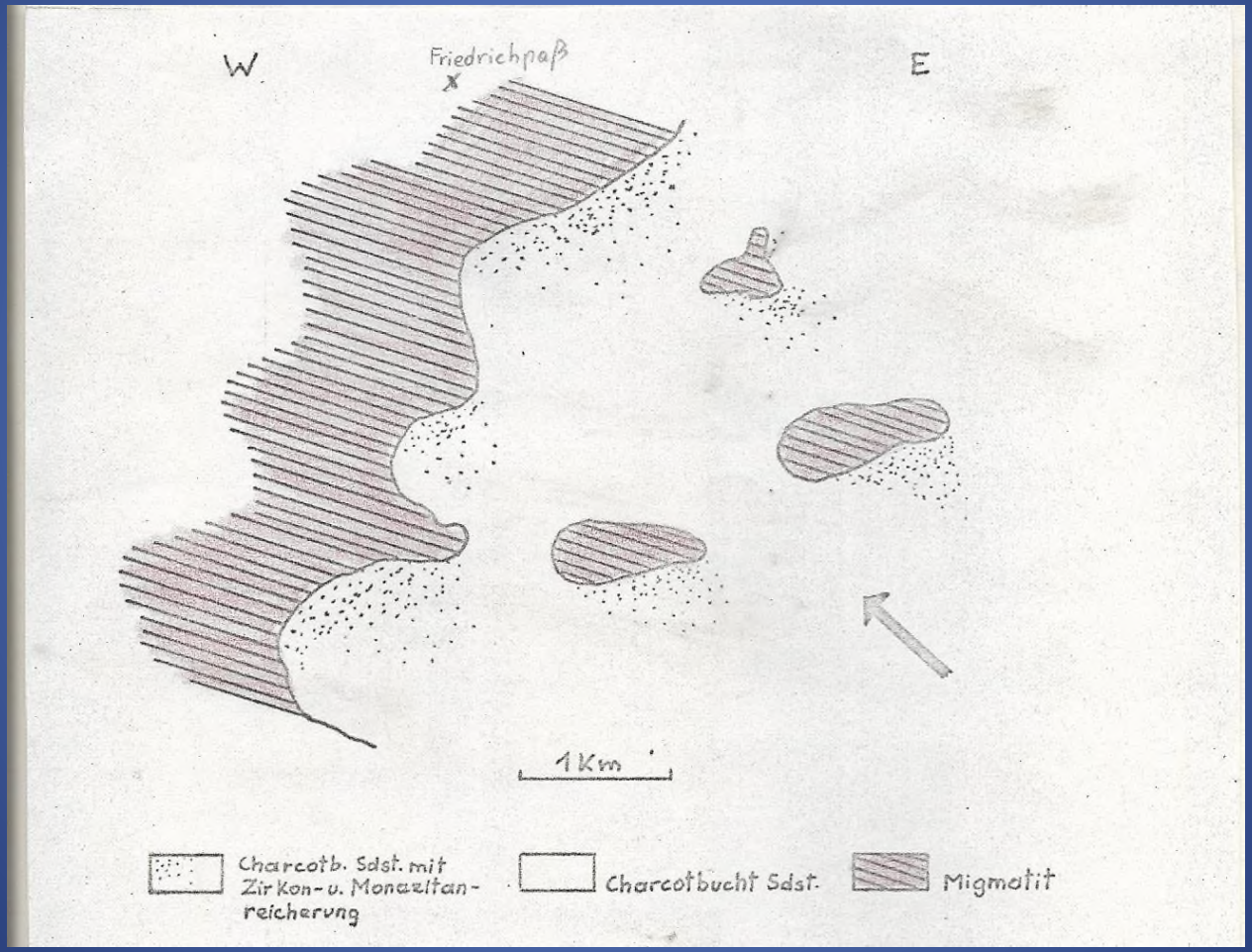
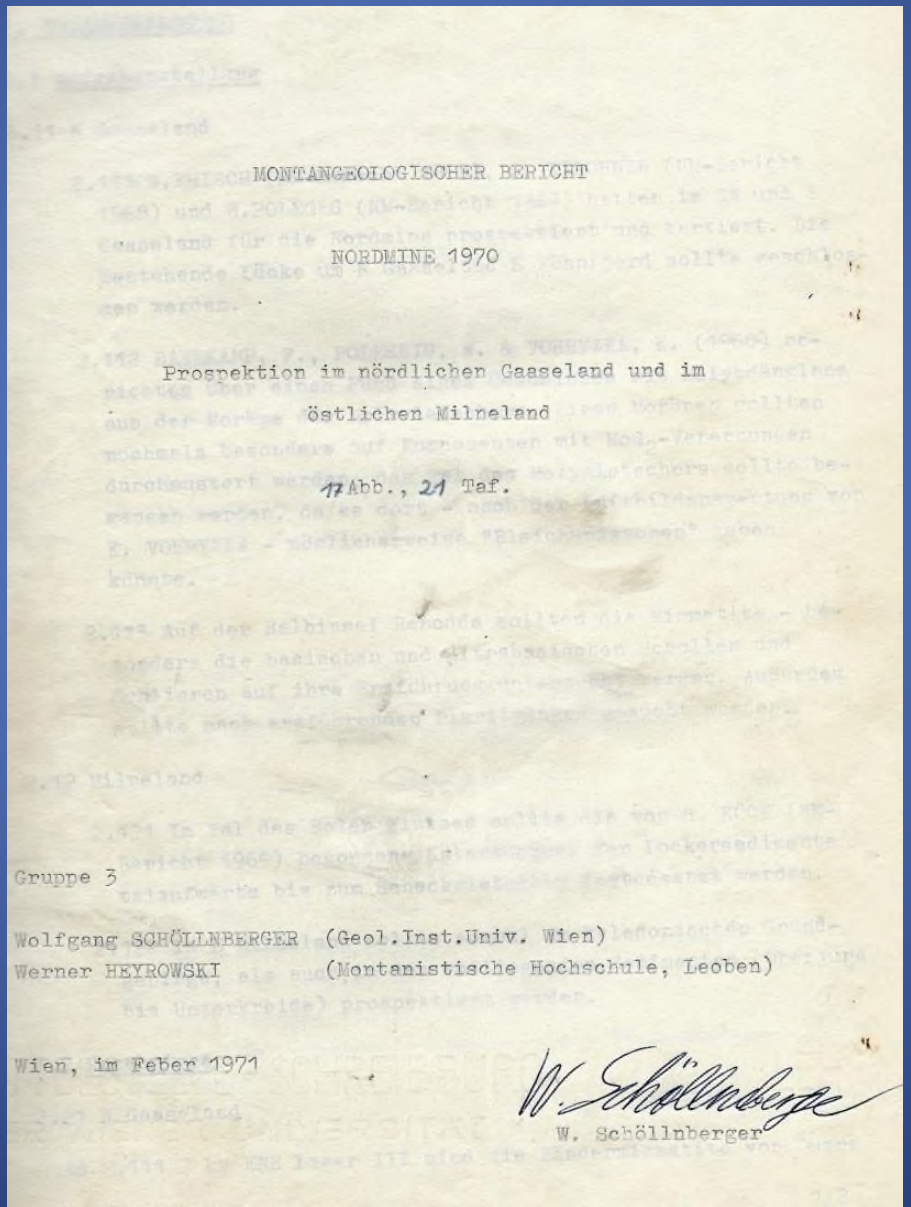


Fig. 4. Stratigraphic scheme based on the geological timescale of Gradstein *et al.* (2012,) showing a W–E cross-section from Milne Land to central Jameson Land, a S–N transect in Jameson Land and an inferred relative sea-level curve. **As**: Astartedal Mb. **CB**: Charcot Bugt Fm. **Mu**: Mudderbugt Mb. **Pe**: Pernaryggen Mb. **Vi**: Visdal Mb. Modified from Larsen *et al.* (2003) and Surlyk (2003). Geol. Survey Den. Greenl., Bull 42 p. 153, /2018

Seifen mit Mineralen der Seltenen Erden



Rare Earth Minerals in E. Greenland, 1970, 1972



MONTANGEOLOGISCHER BERICHT

NORDMINE 1970

Prospektion im nördlichen Gaaseland und im
östlichen Milneland

17 Abb., 21 Taf.

Gruppe 3

Wolfgang SCHÖLLNBERGER (Geol.Inst.Univ. Wien)
Werner HEYROWSKI (Montanistische Hochschule, Leoben)

Wien, im Feber 1971

W. Schöllnberger

W. Schöllnberger

Koid woars …

…… aber der Lachs woar guat!!!

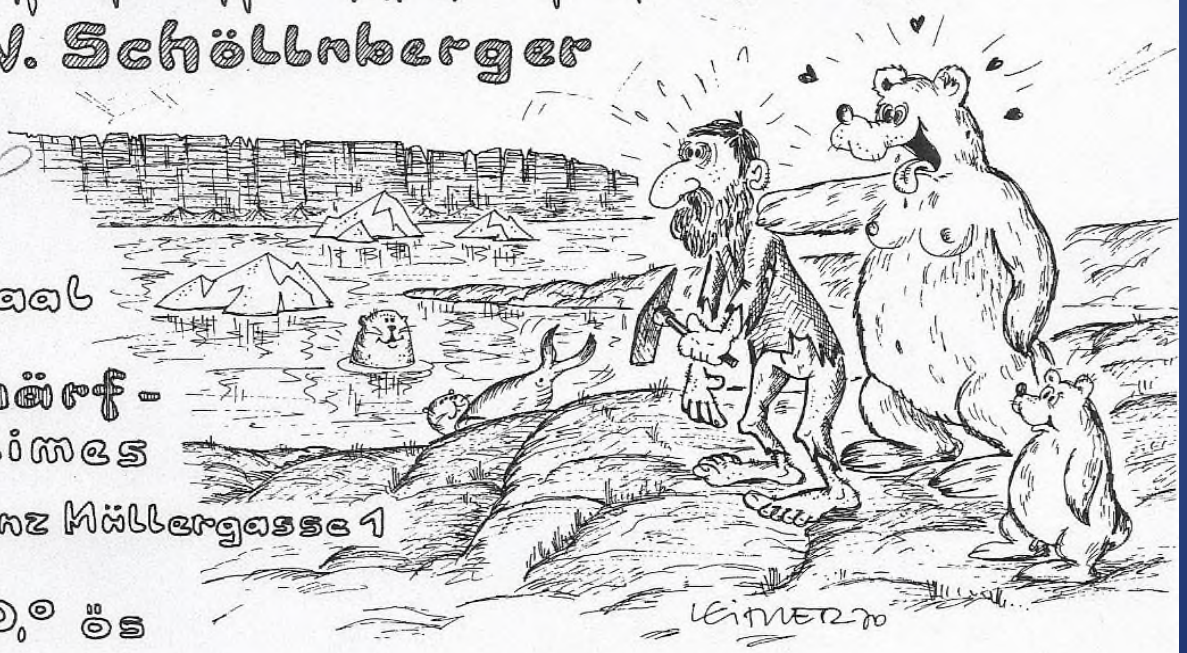
“Heyro”, MU Leoben,1970

FARBDIAS aus GRÖNLAND von W. Schöllnberger

am: Mo, 23.11.70
um: 20 h

im großen Saal
des
Dr. Adolf Schärf-
Studentenheimes
Wien 20, Lorenz Müllergasse 1

Eintritt: 00,° ös



Significant early learnings:

Factory:

Blueprint - Build - Produce.

Mineral Deposit:

Produce-Blueprint-Build-Produce-Blueprint-Build…

Consequences:

+ High production = high reserves

+ **When production ceases, reserves collapse**

+ **Most mineral deposits** (incl. petroleum fields) **reach their low economic limit and are being abandoned before they are fully understood**

“Schöll goes to Shell”(W. Vetters, 1972)

“We won’t have a Viennese coffee shop in (Georg) Mandl’s Structural Team”

(Hans Grunau, Shell)

So, I joined Kees Kruit and the San Sebastian F~~a~~un Club – and became overnight an expert on turbidites

Debris Flow Deposit / Ideal Turbidite

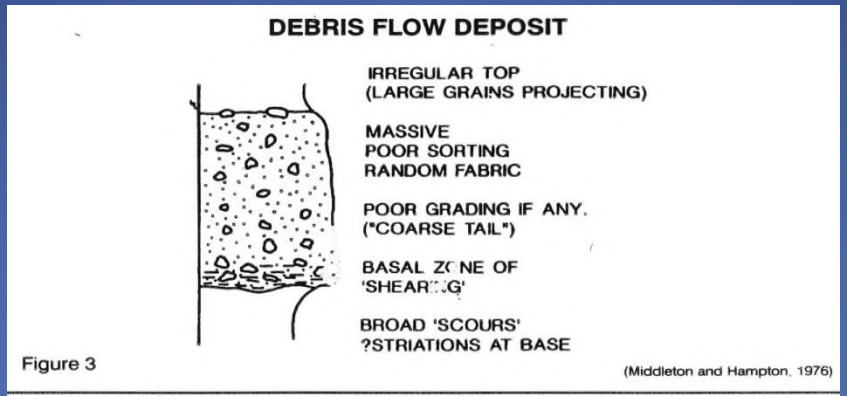


Figure 3 (Middleton and Hampton, 1976)

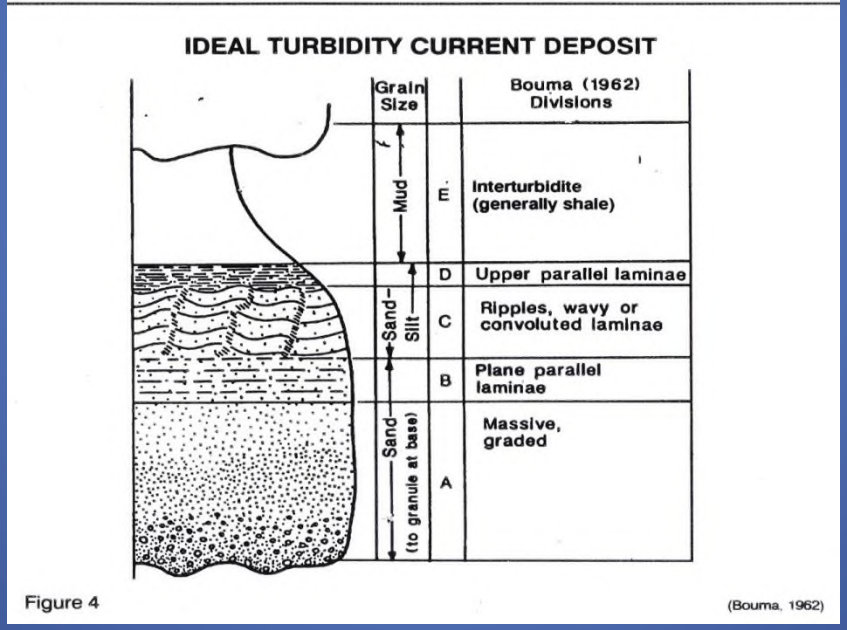
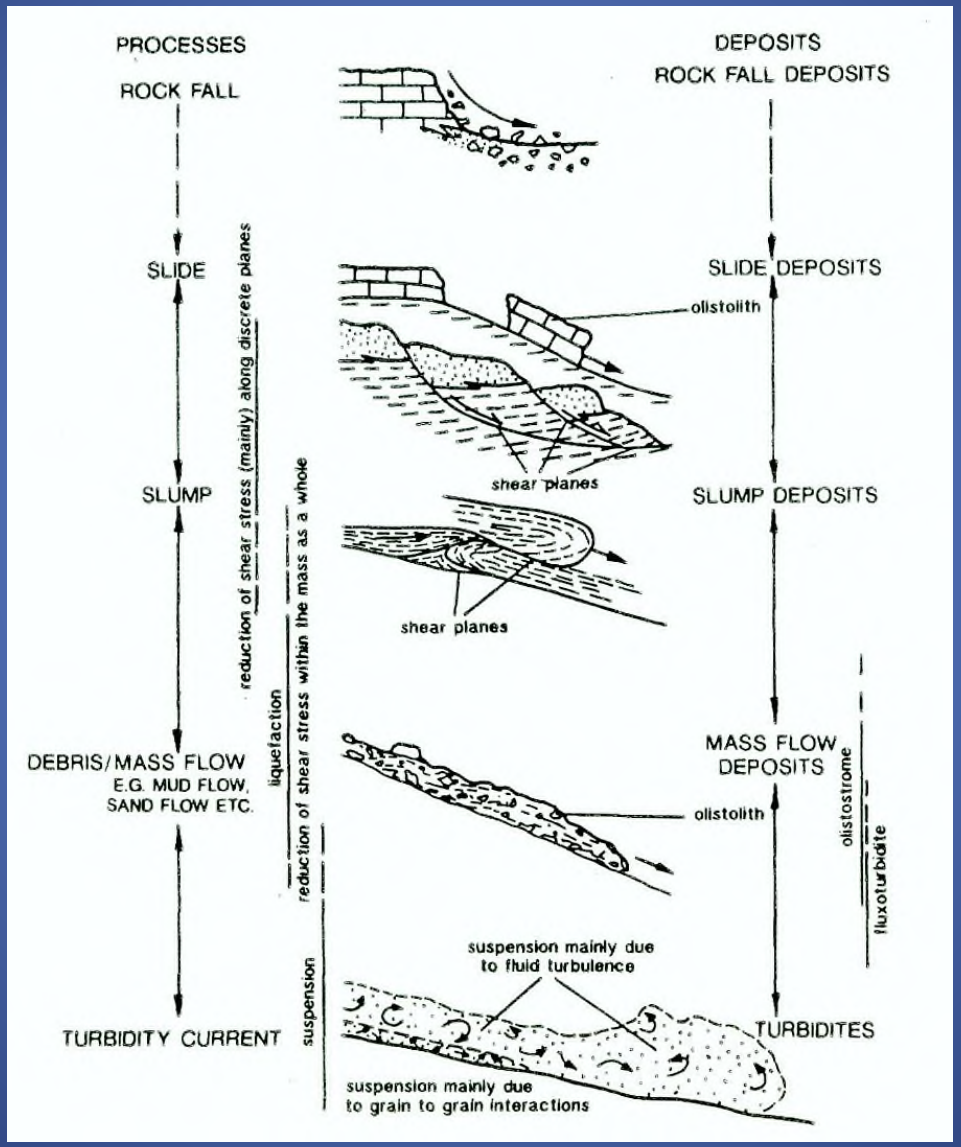


Figure 4 (Bouma, 1962)

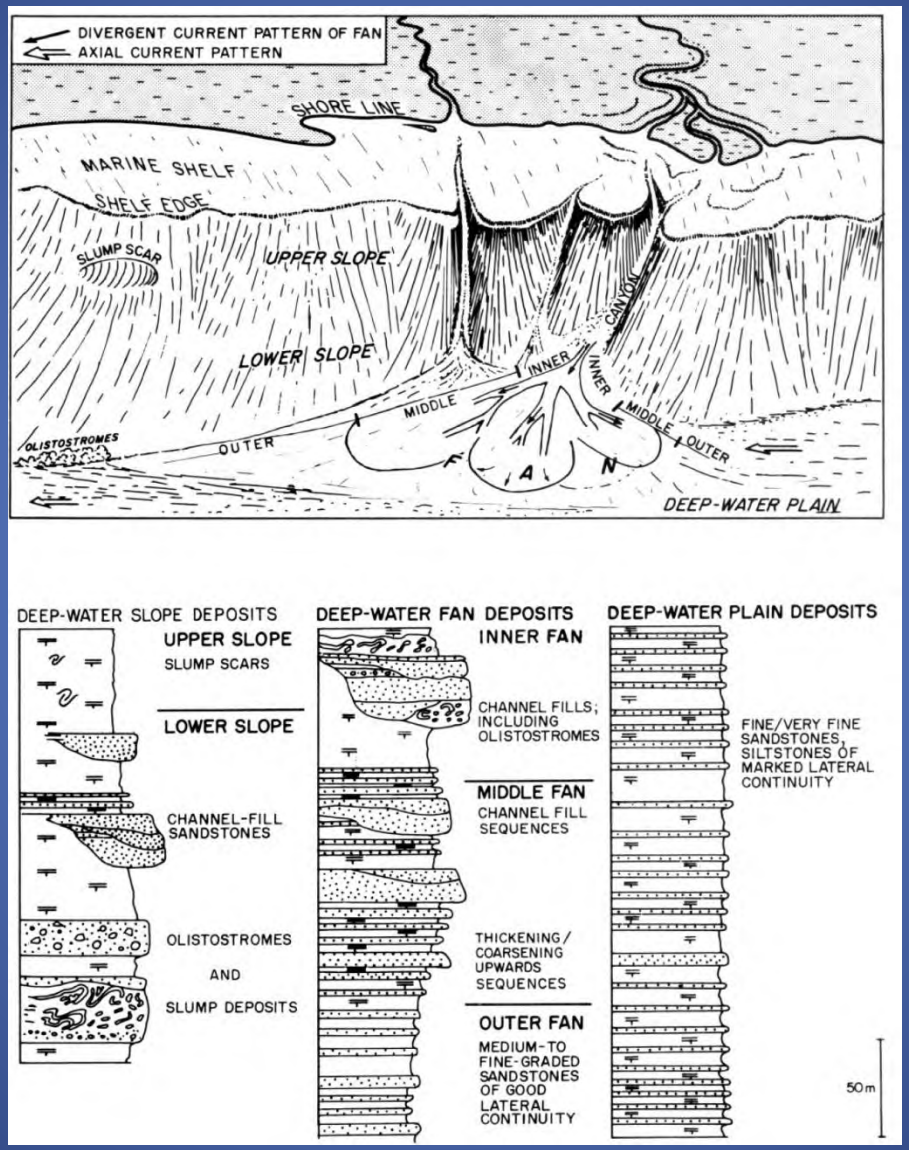
Watch out where you take samples: Heavy mineral assembly changes with grain size

Gravitational subaqueous depositional processes



- Schollnberger, 1974

A model of Subaqueous Slope Channel and Deep-Water Fan Sediments

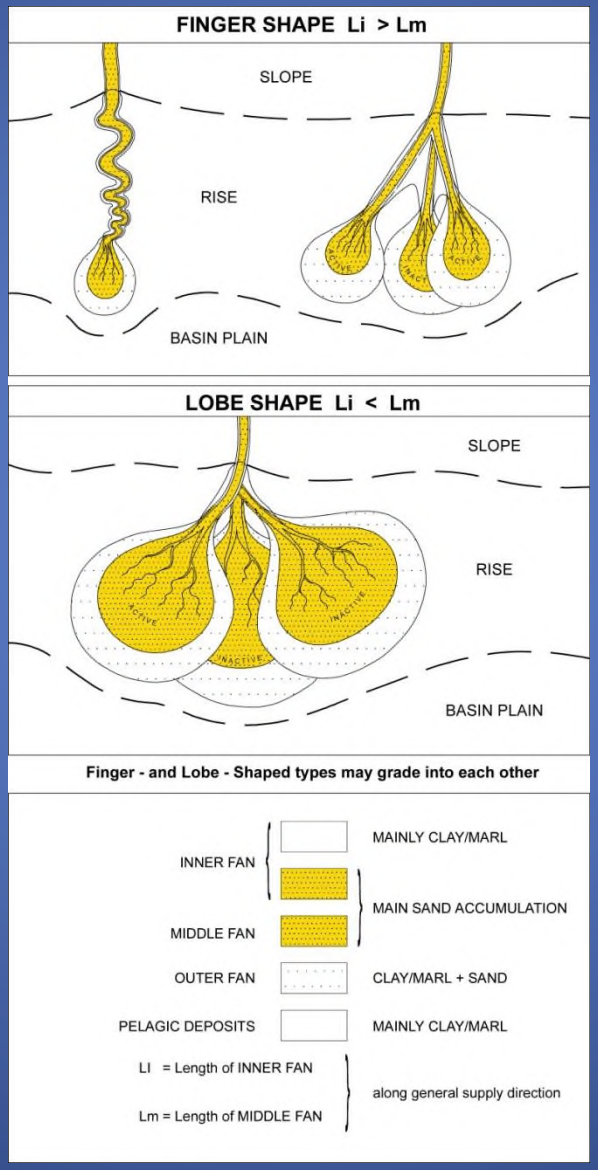


- Schollnberger, 1974

The real thing

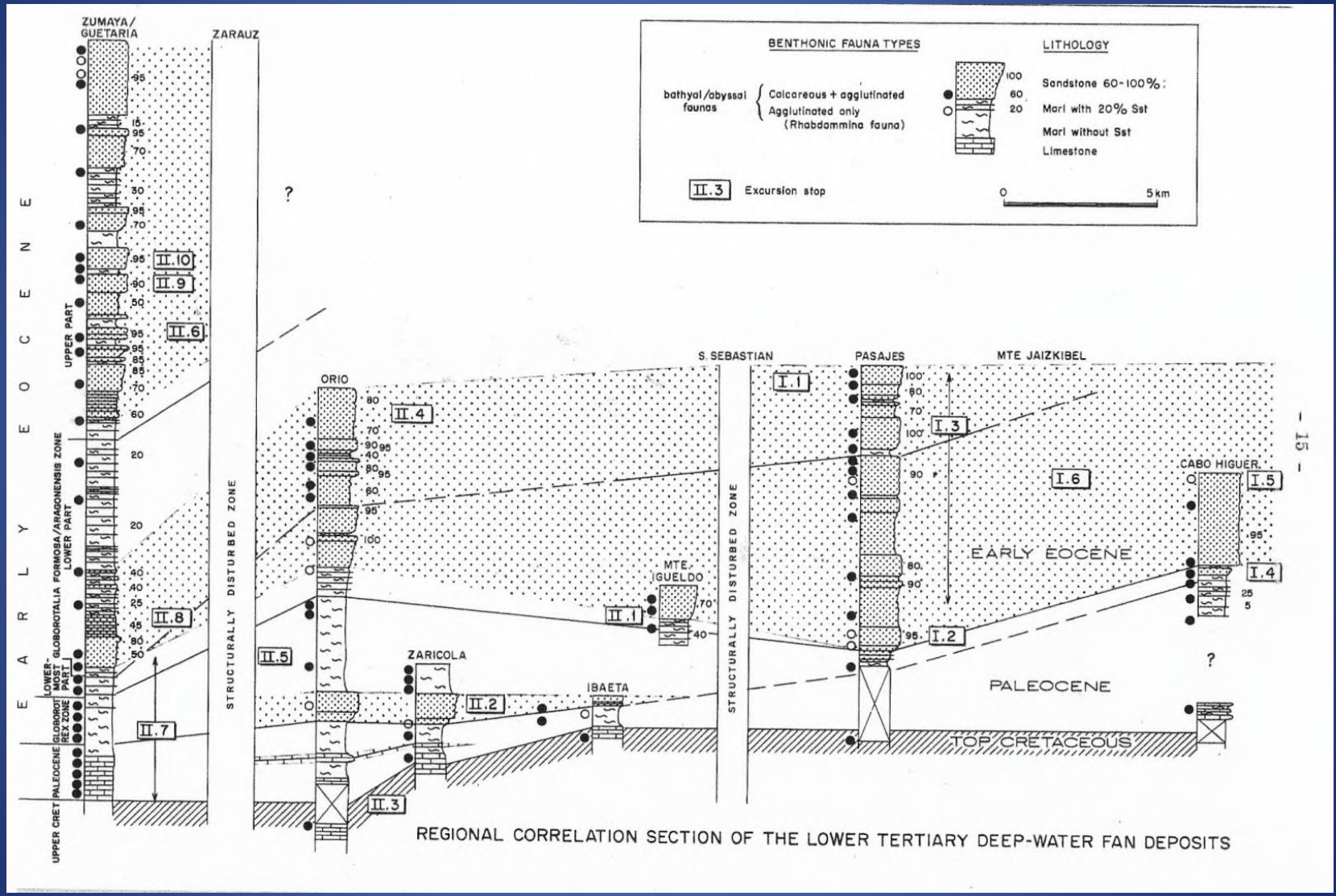
SAN SEBASTIAN FAN (L. EOCENE). MIDDLE FAN LOBES AT HABOR ENTRANCE OF PASAJES (SAN SEBASTIAN, SPAIN).

Most common fan shapes



- Schollnberger, 1974

Reliable correlations need Palaeo!

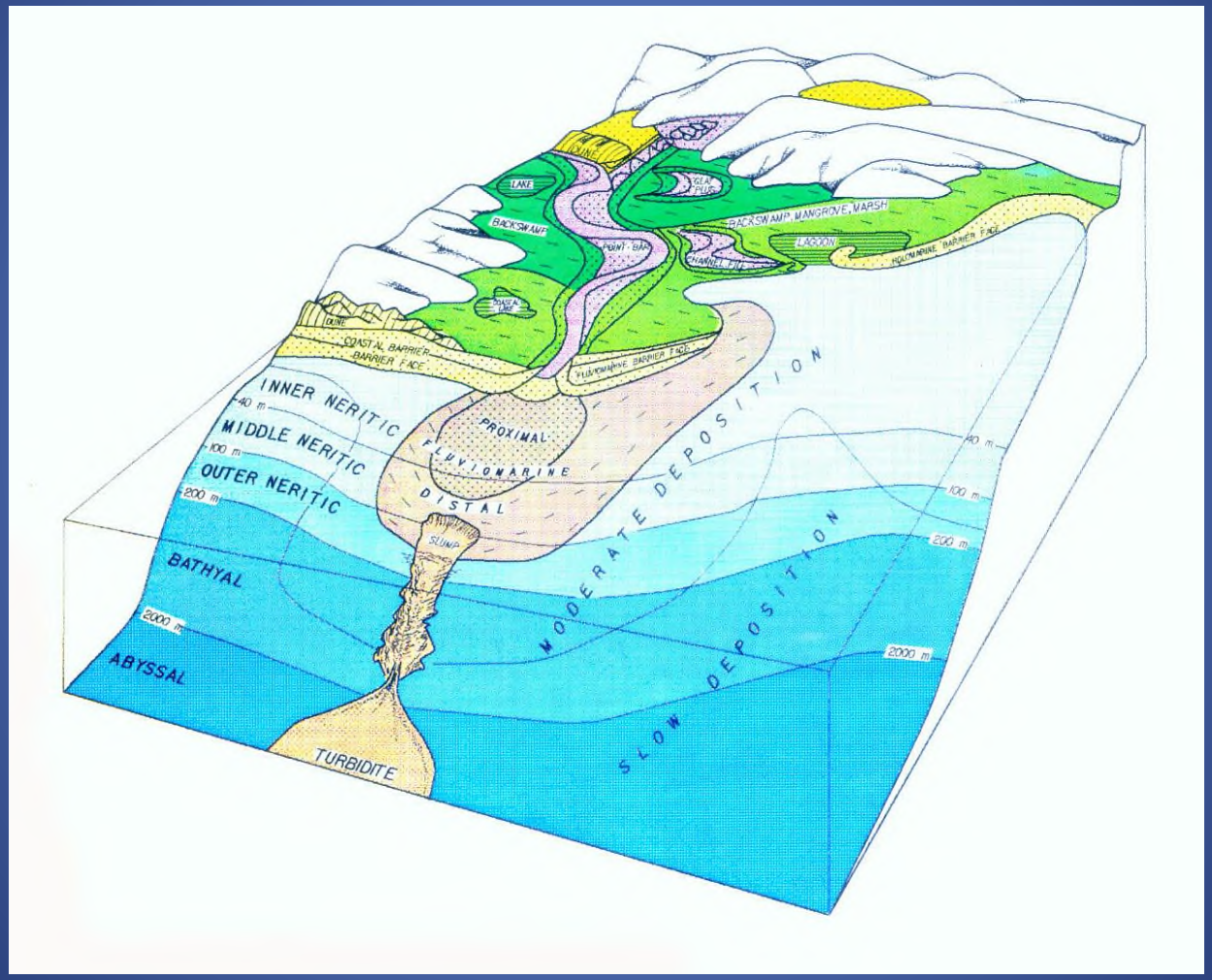


- Kruit et.al ,1974

Bird tracks on graded beds, but birds don’t have 500m long legs!!

The 'bird-track flysch' of Yesa (Oligocene lacustrine deposits)

Interpreting environments of clastic deposition: Palaeo is necessary!!



- Fossils not only tell you how old they are, but also where they live

There is much more missing (ca.80 - 90%) than preserved

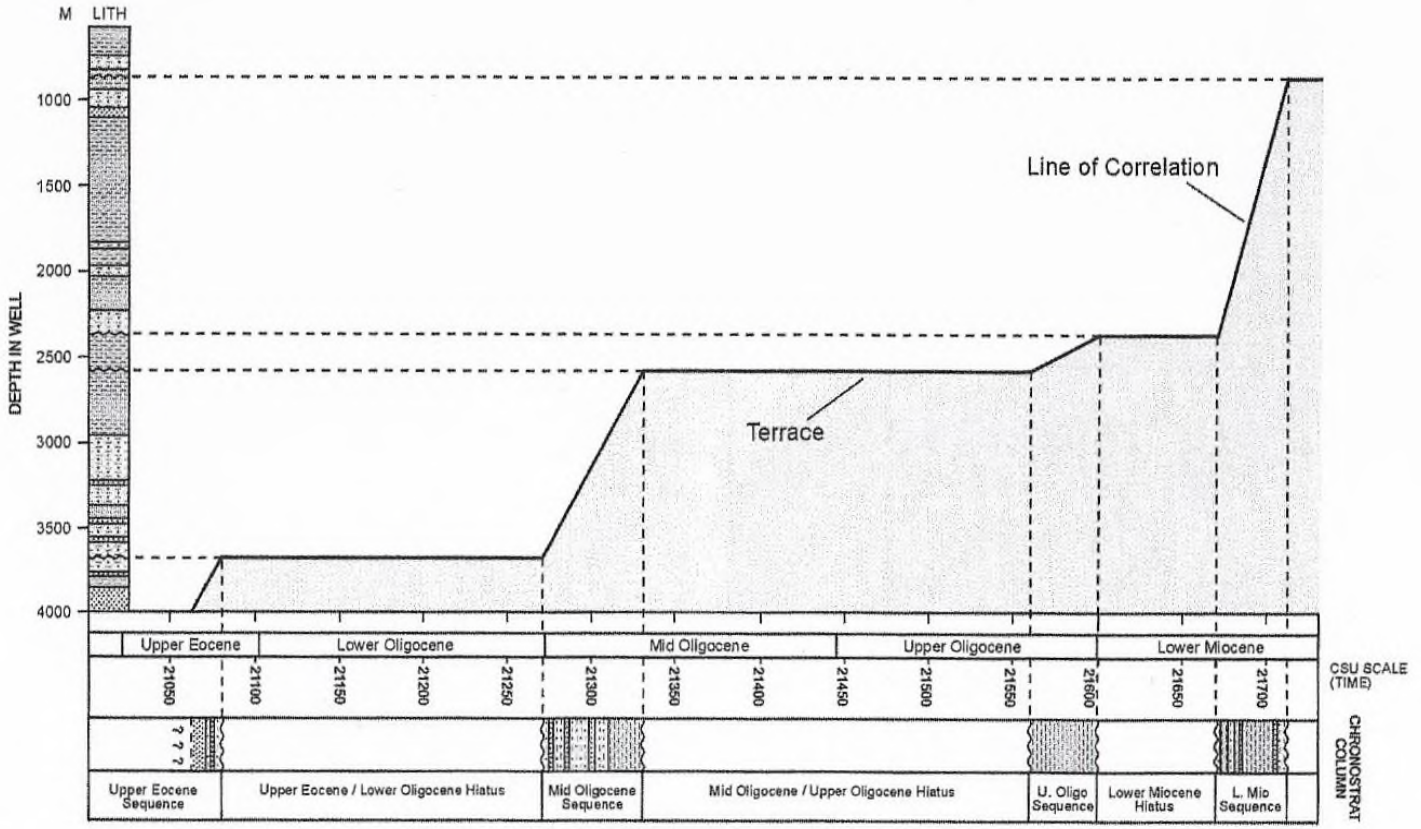
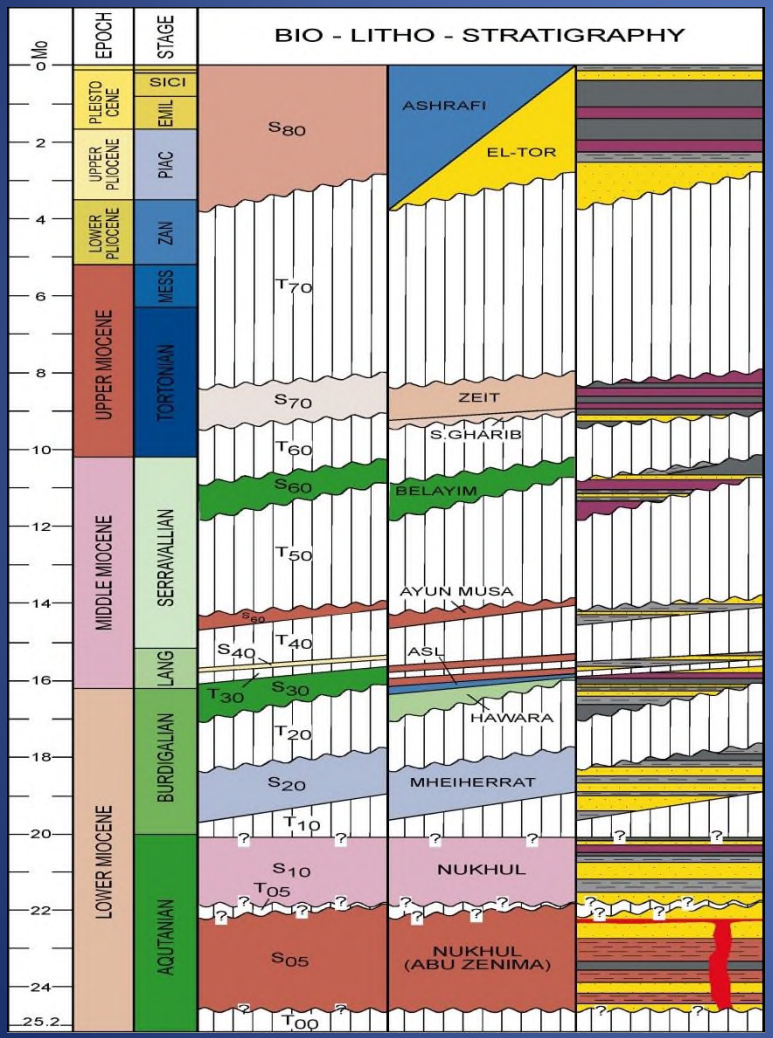
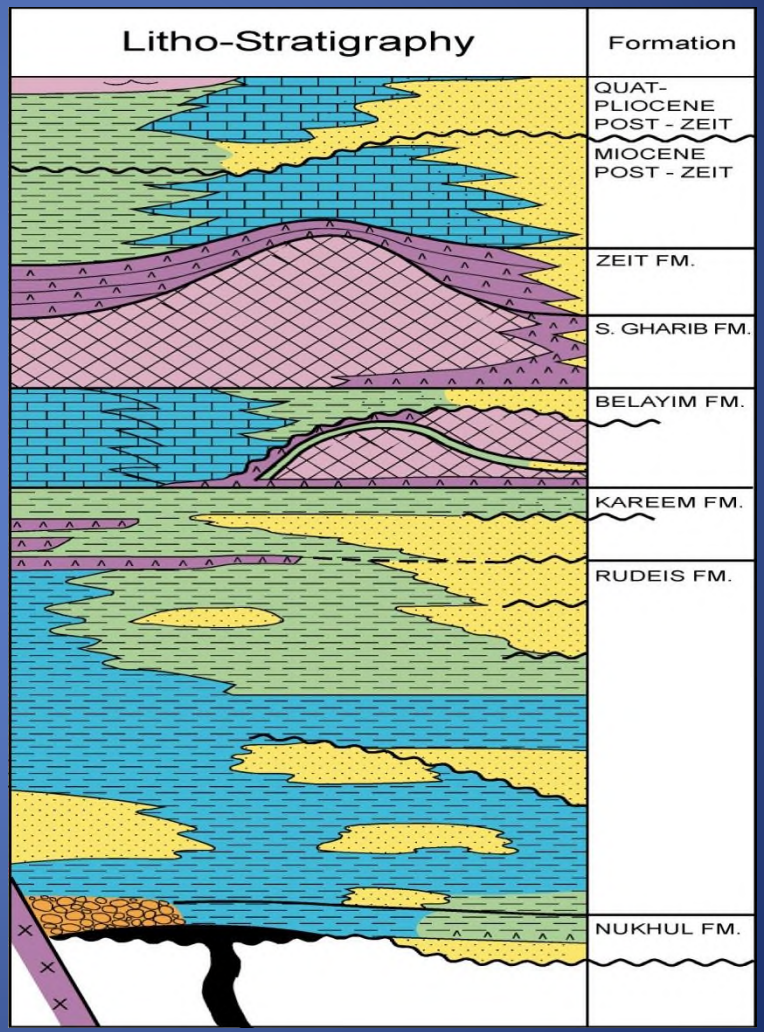


Fig. 36: Plotting the lithology of an actual well against Composite Standard Time Units (CSU, a proxy for absolute time) demonstrates how episodic sedimentation really is: much more time is not represented in the lithologic record than there is (reproduced with permission of BP).

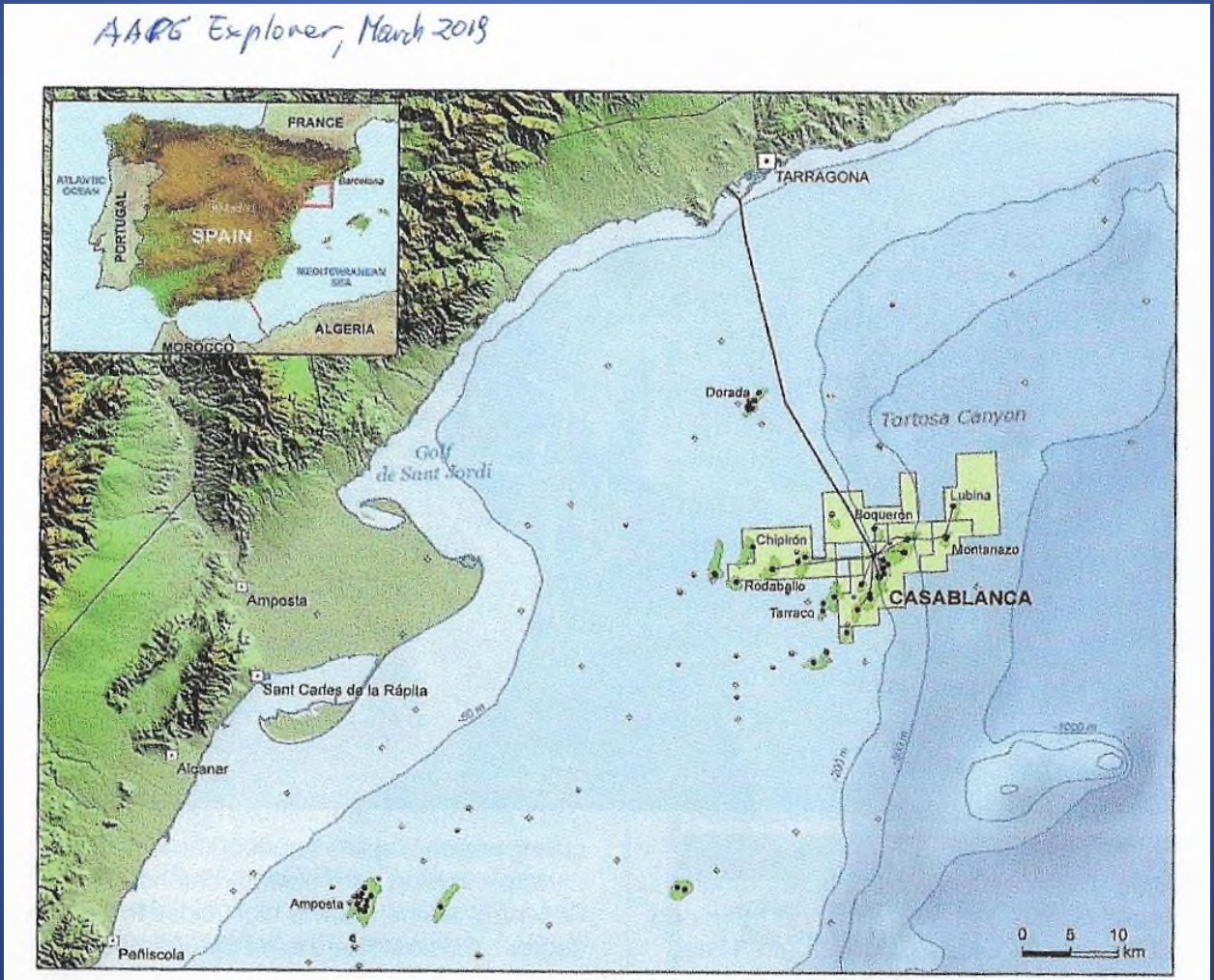
- Schollnberger, 2001

Neogene Stratigraphy, Gulf of Suez



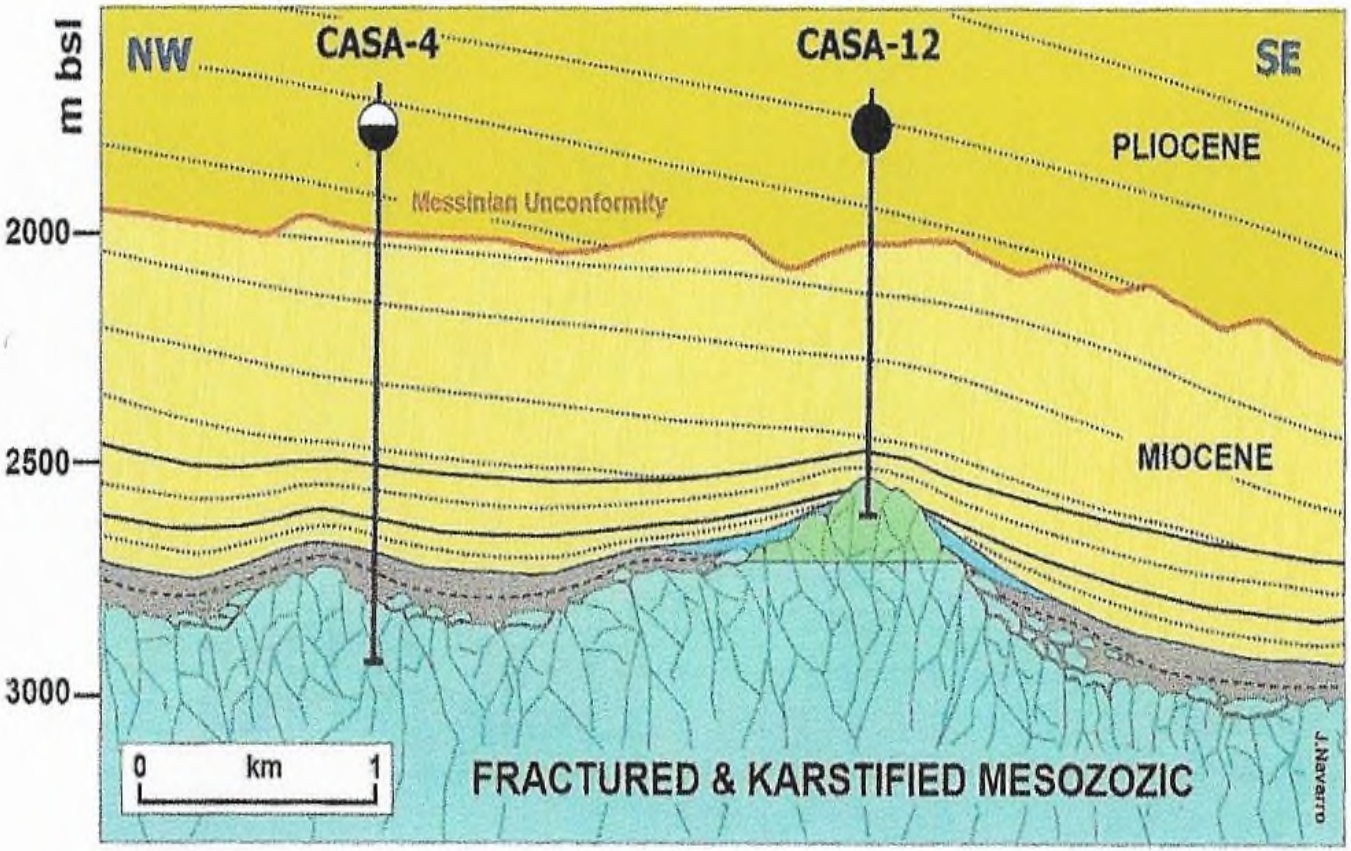


After research in Rijswijk, exploring the Western Mediterranean



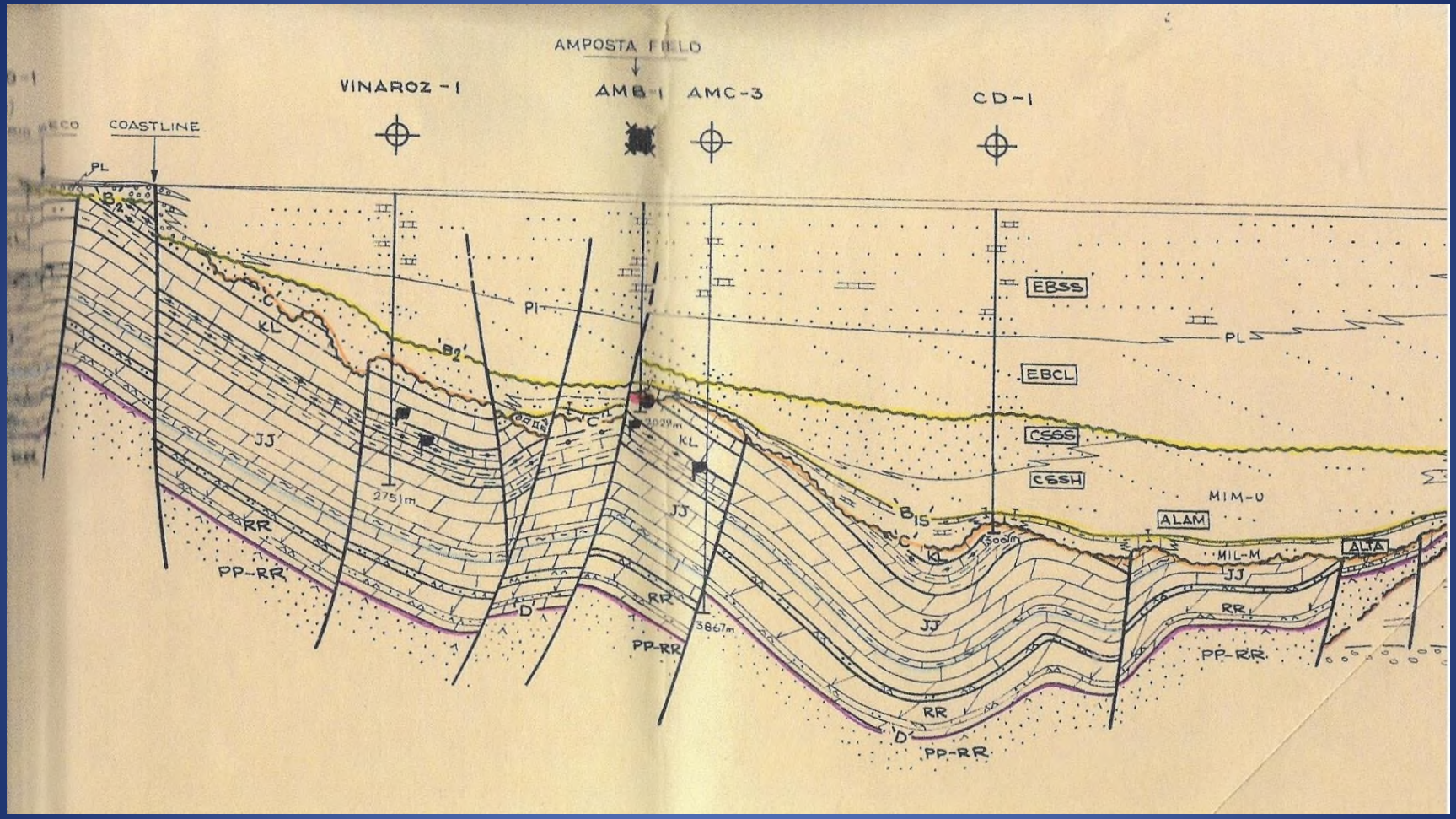
Exploitation concessions and oilfields in the Spanish Mediterranean offshore as of March 2019

How others see it (2019)



Cross-section showing the paleo-geomorphic trap and one of the most prominent field culminations drained by the Casablanca-12 vertical well. AAPG, Explorer March 2019

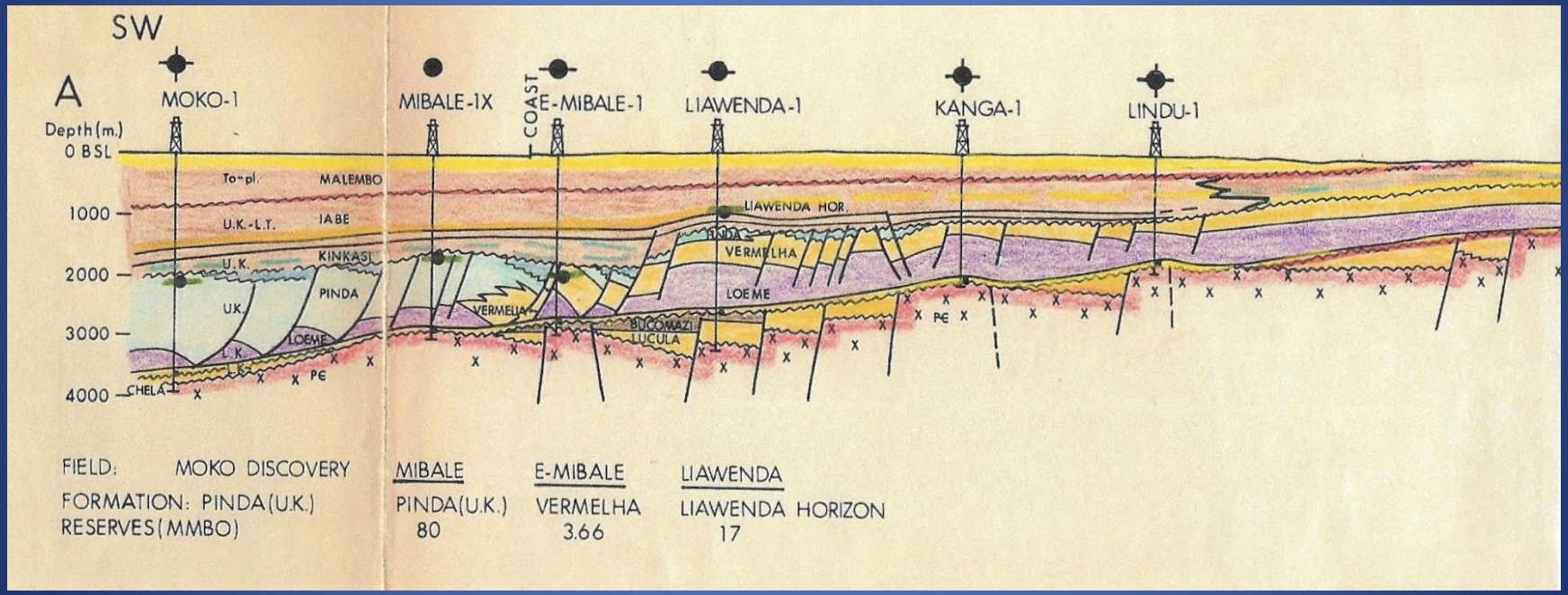
How we saw it: precision pays (1977)



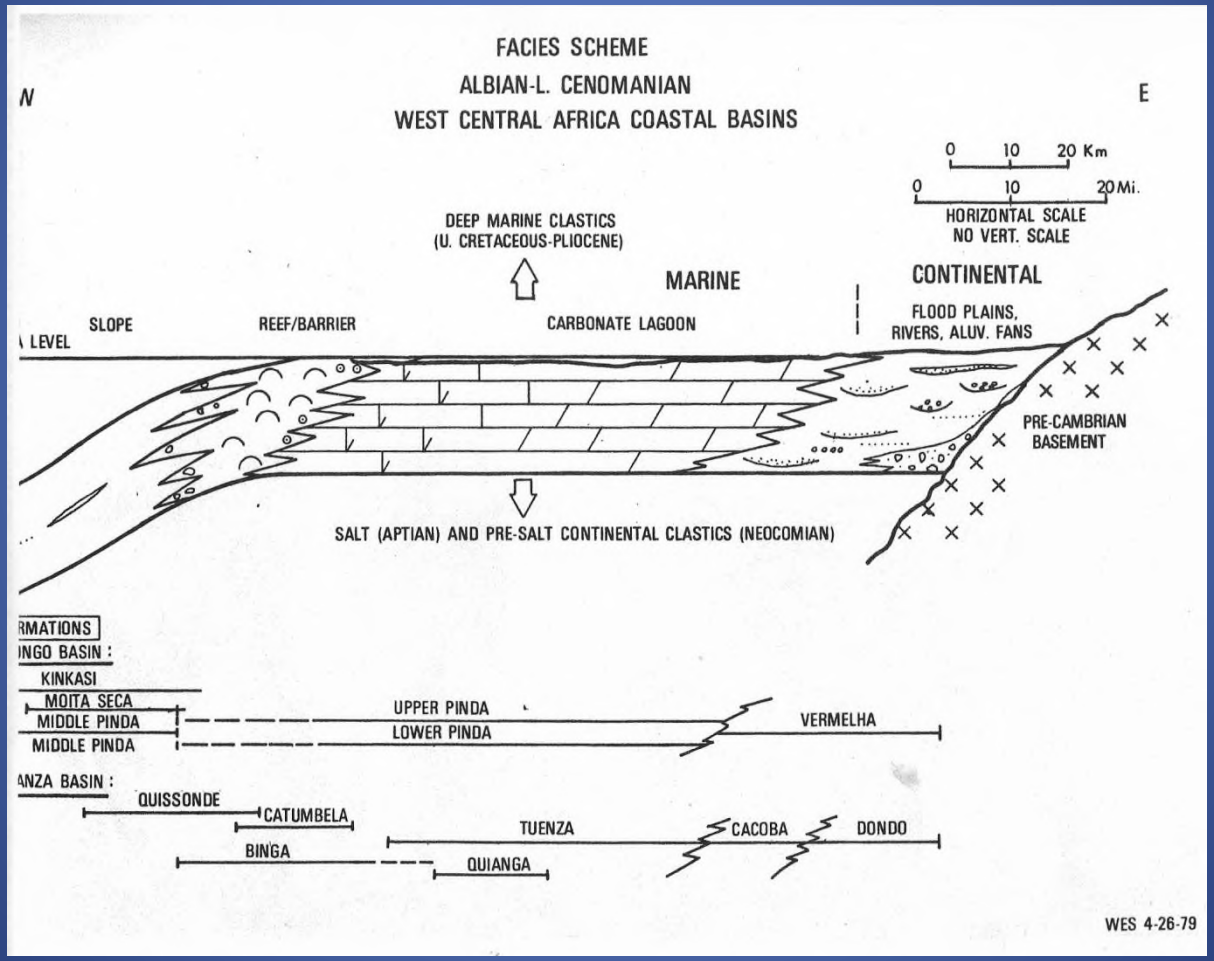
- Filling-in the stratigraphy between the base Bunter and the base Miocene unconformity allows prediction of karstification below base Miocene **and** mapping of Bajocian/ Bathonian and Kimmeridgian source rocks

1979: Change from Shell to Amoco Corporation

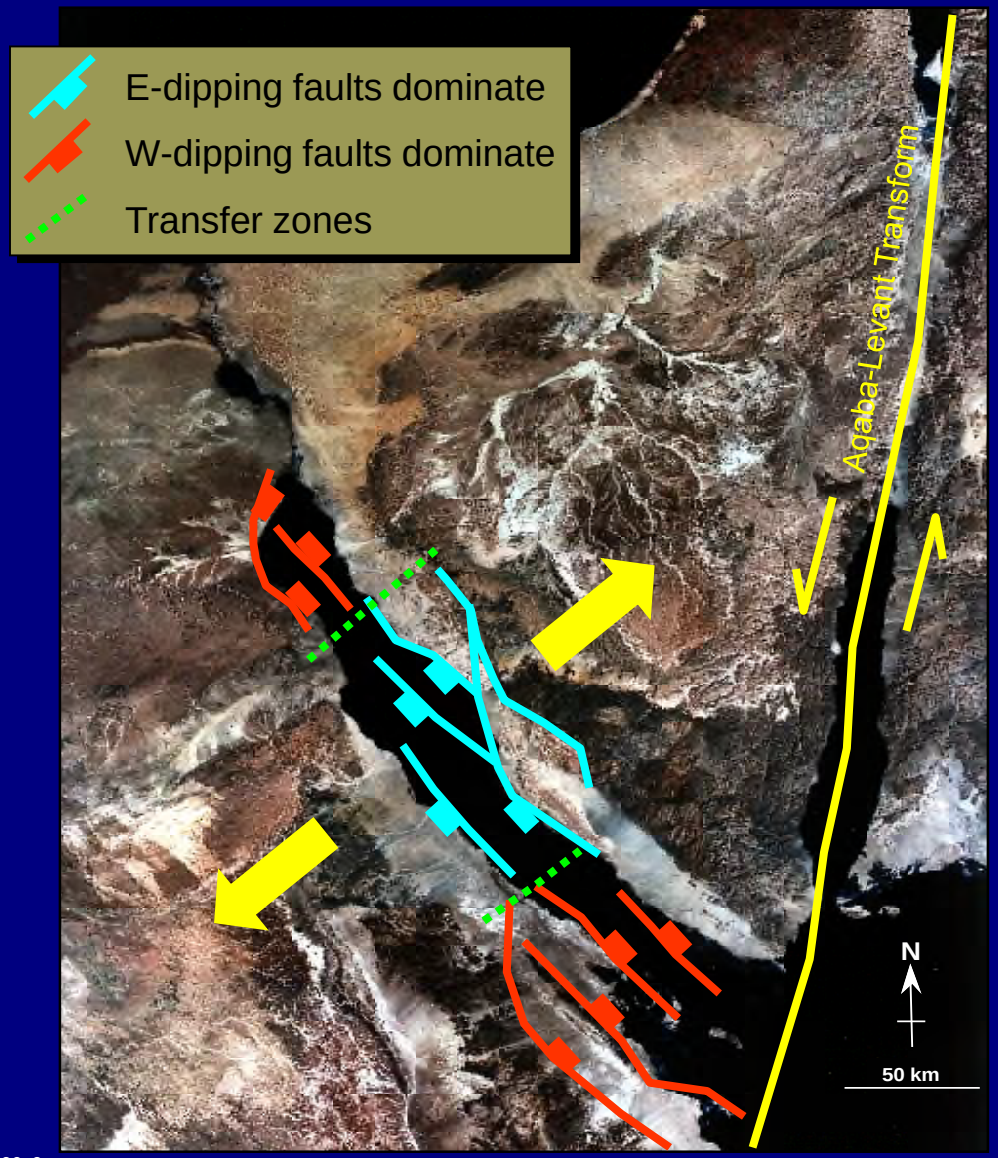
Coastal Congo Basin: raft tectonics



What's in Formation names? Not much, they encrypt and hamper understanding

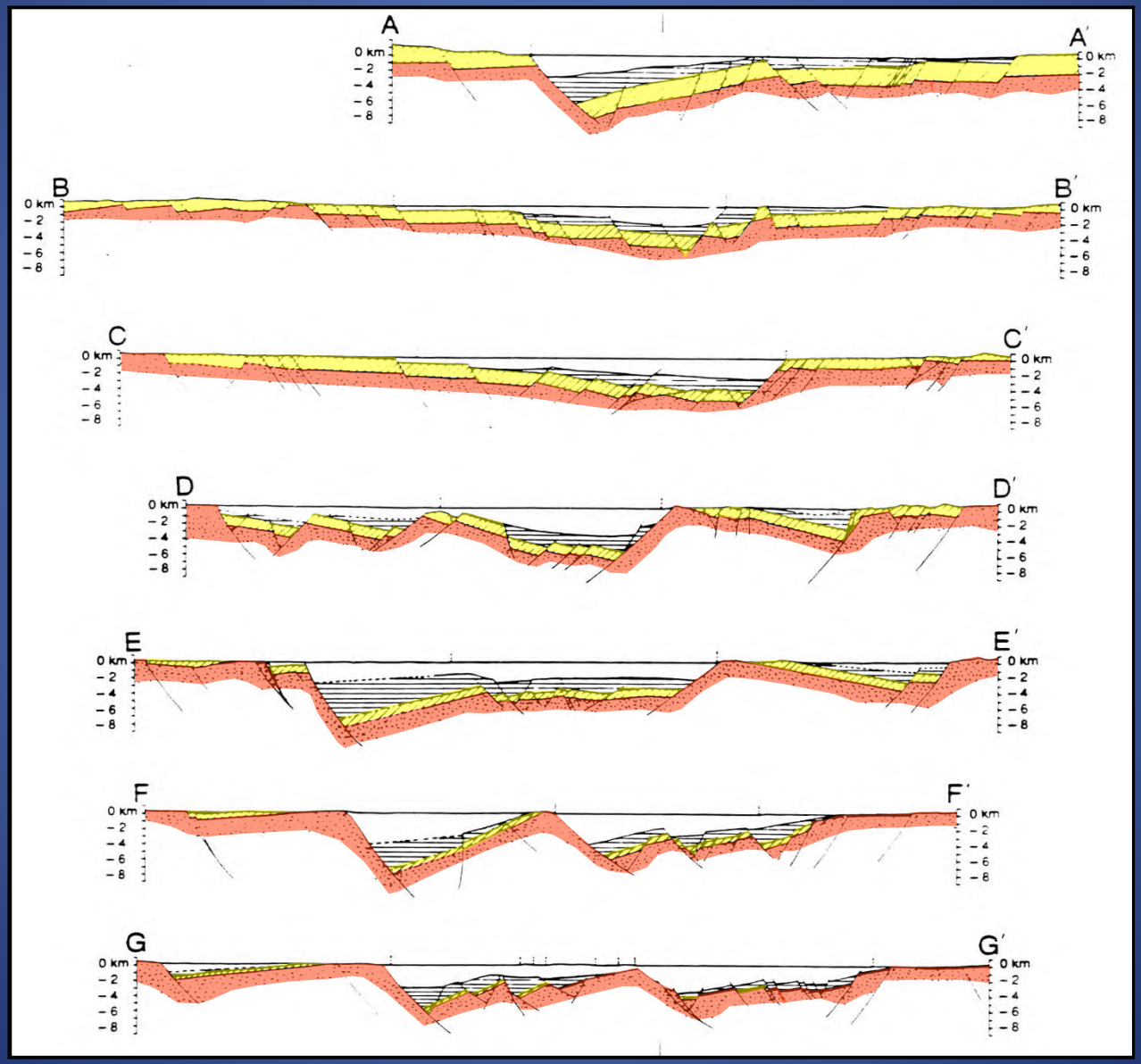


Gulf of Suez

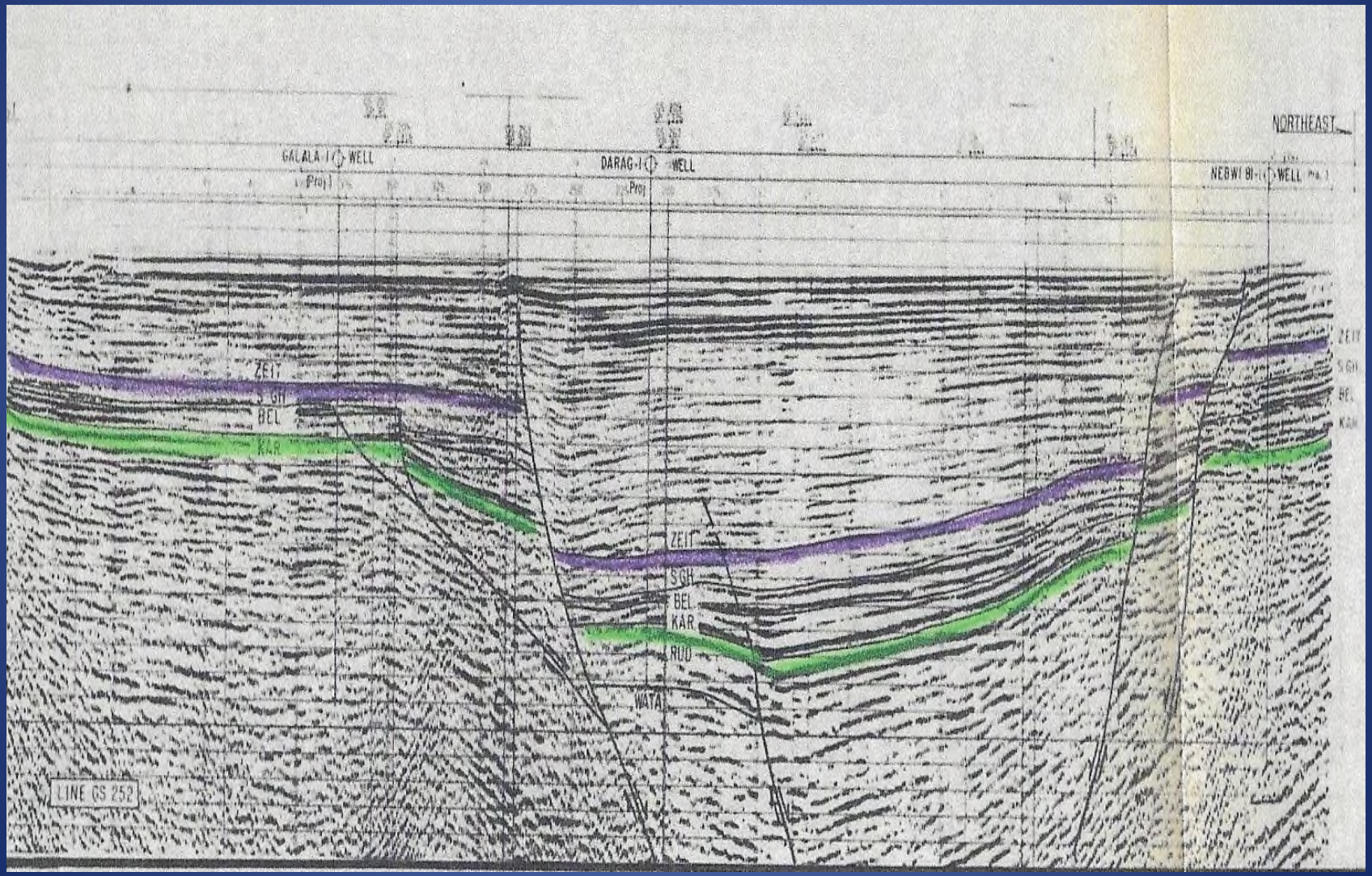


02153306_9

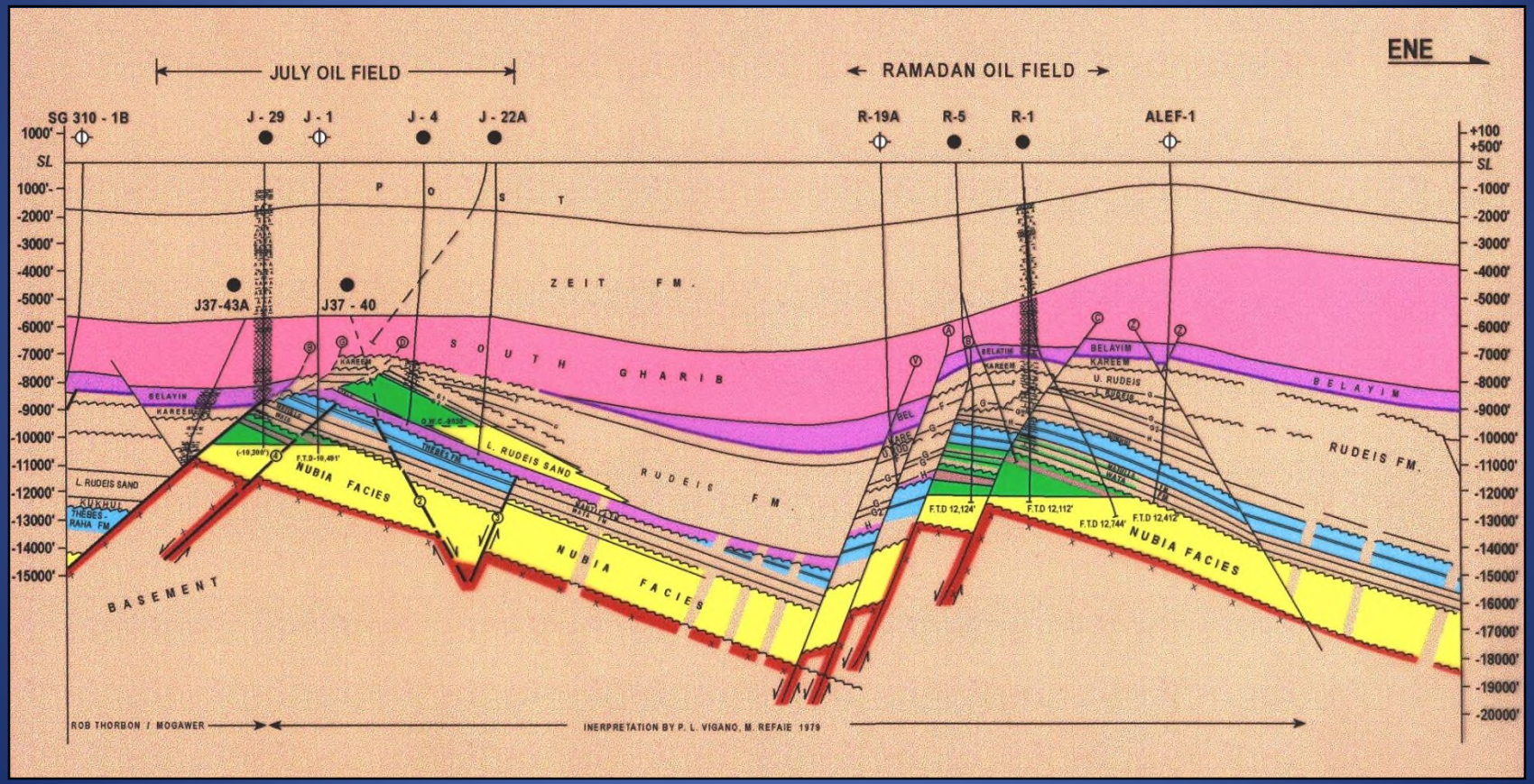
GOS: Dip Regimes



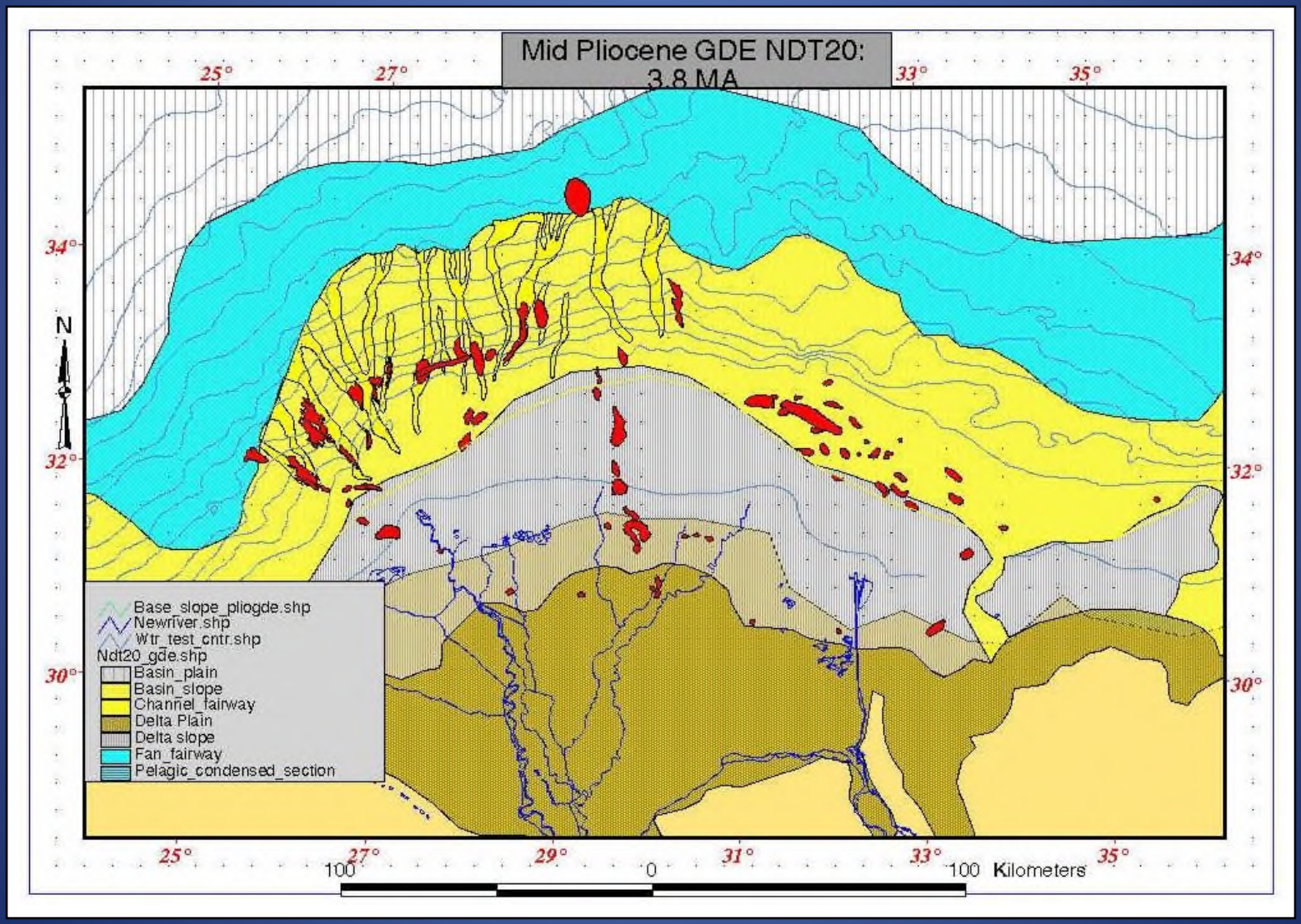
GOS: Shallow multiples mask true reflections of Nubia sandstone reservoirs



GOS: Giant fields



Keep learning and think ahead: despite great success in GOS, I pleaded for Amoco's shift to the Nile Delta (1989)



“All the easy oil has been found”….. Nonsense, it (almost) never was easy!!!!

- Source: Schollnberger Collection
- After having helped to discover a lot of oil and gas in Amoco’s contract areas, I was handed the privilege to lead Amoco to new areas. Just as the Iron Curtain was coming down.

On to forward looking jobs: guiding "New Ventures" and "Technology" within Amoco and BP

Ein wahres Genie

Höfer‘s world view (1909)

- About 70% of all oil and natural gas found so far (2019) could have been discovered by drilling within a 100 km radius of the each dot on Höfer‘s map (who knew?)

Political circumstances on the surface change faster

than (our understanding of) the geology in the subsurface

A. Bally's world map (Roberts and Bally, 2012)

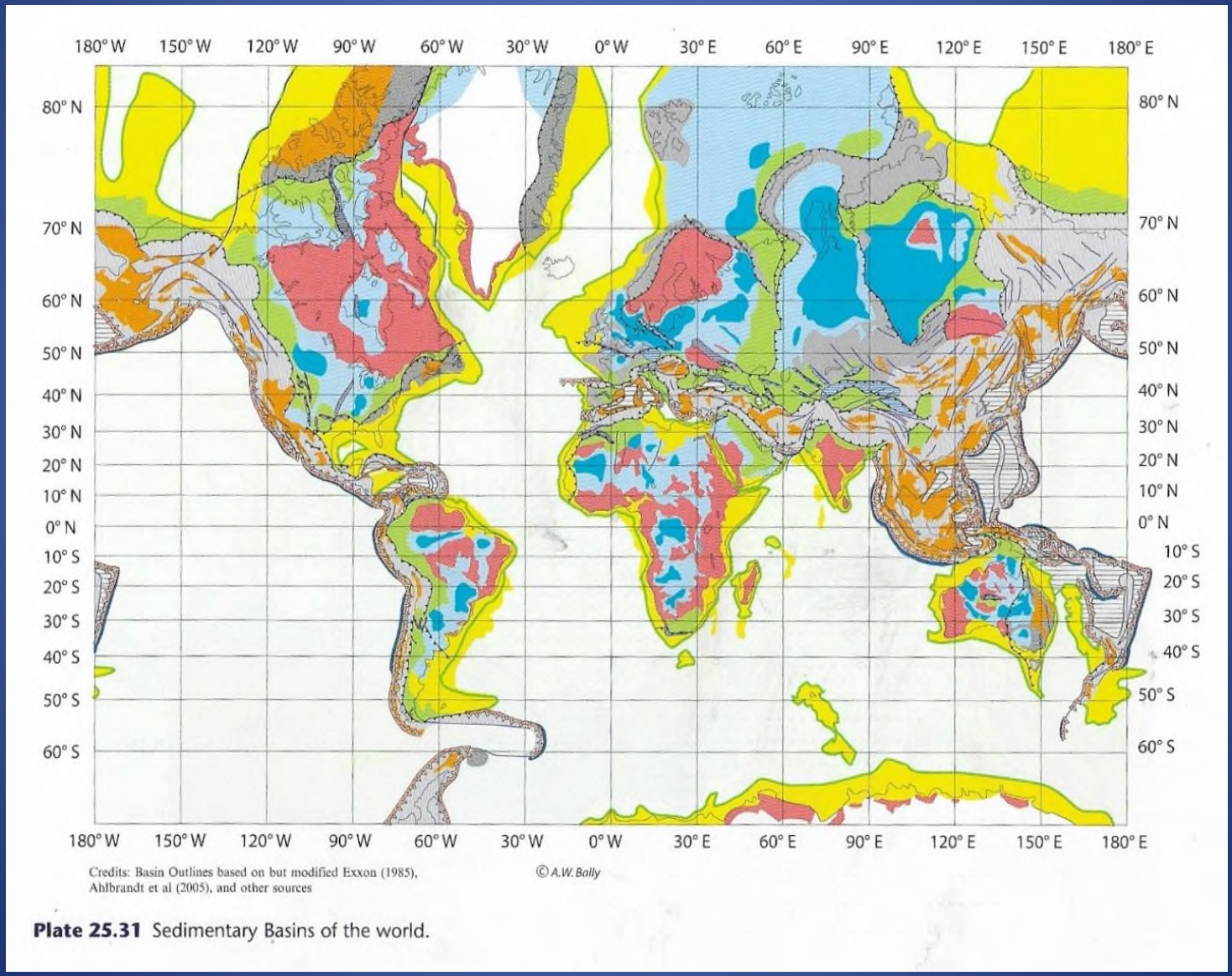


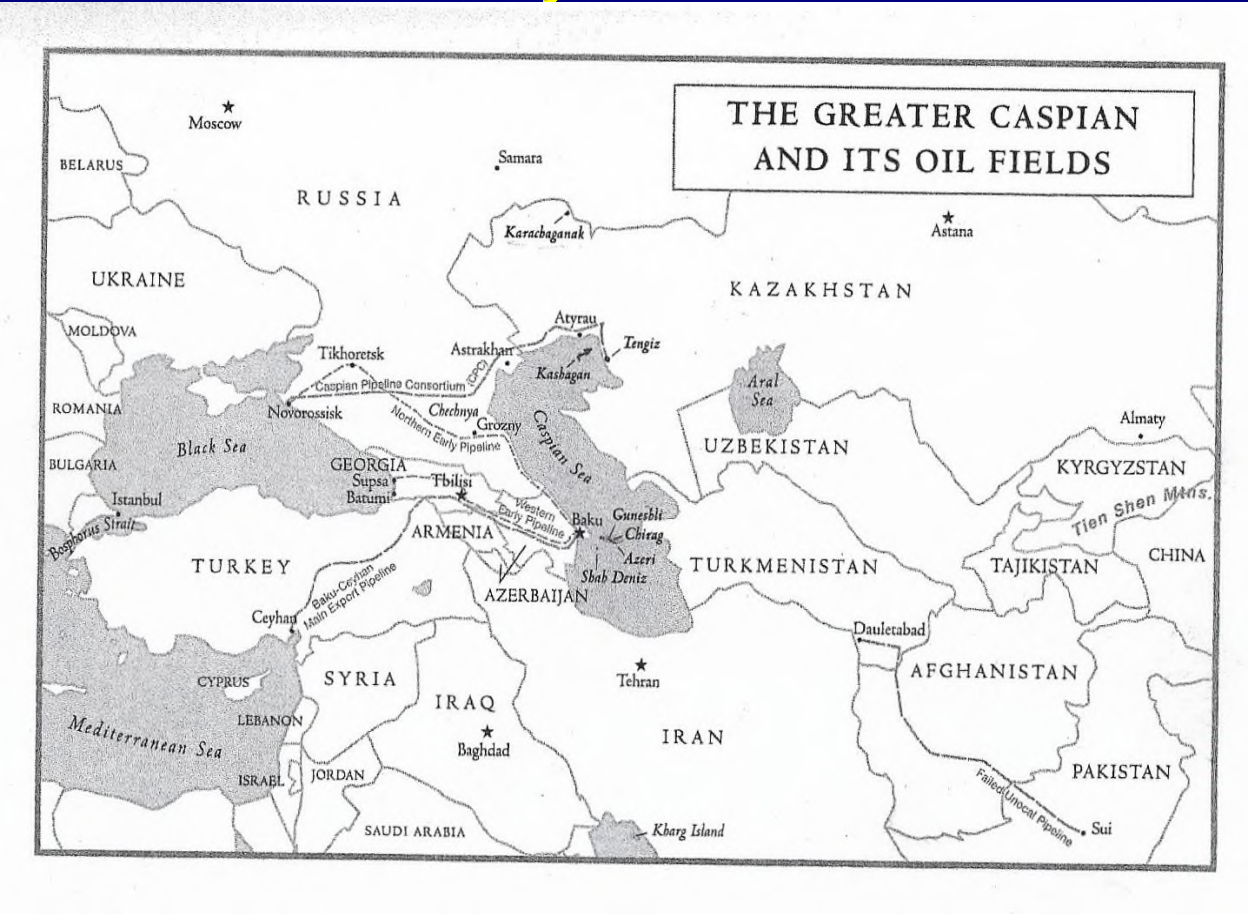
Plate 25.31 Sedimentary Basins of the world.

In Russia

Know the history of your firm and the history of the countries where you want to operate

- with Nelson Mandela, Dec. 7. 1991

Glory in Baku

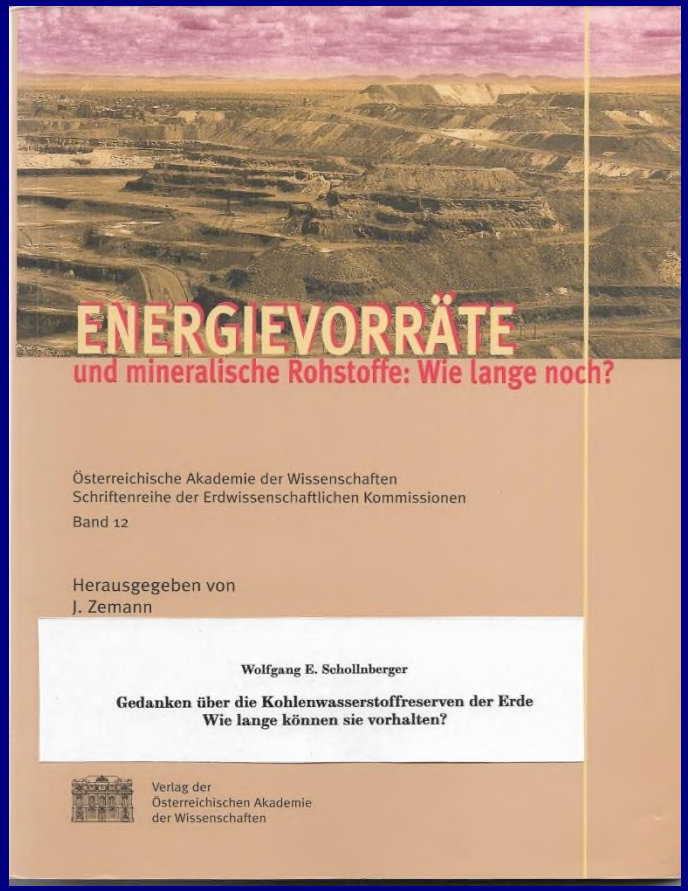


"Wolfgang, in 1990, your people were in the right place at the right time!" (R. Blanton, Amoco, pers. comm. 1994). That led to Amoco co-signing in 1994 the "Contract of the Century" with a 17.1% share. Since the merger of BP and Amoco in 1998, the combined share is 34.27%, worth many billions of $.

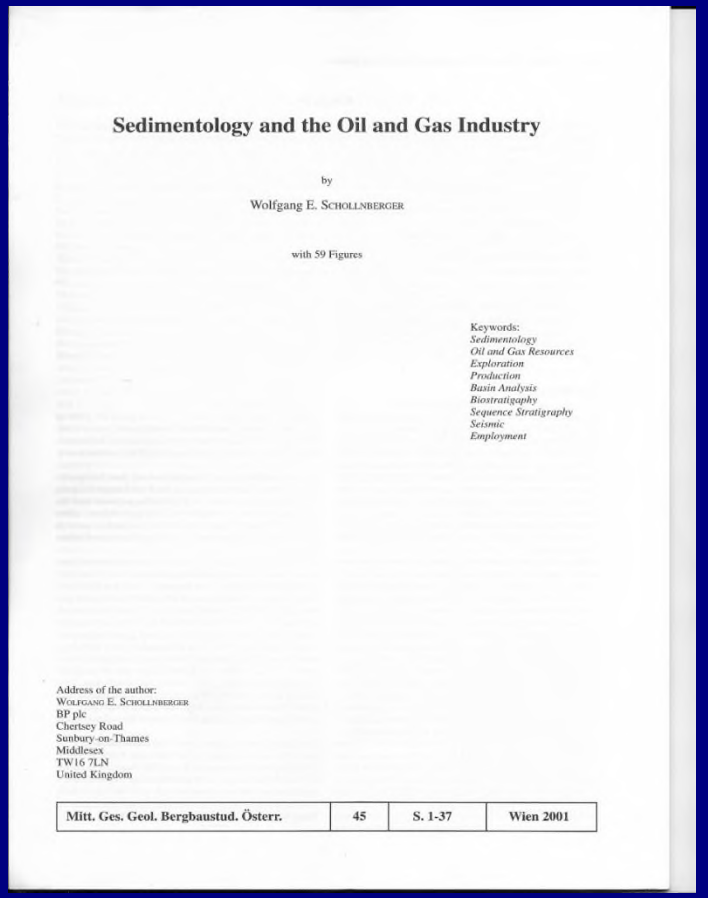
Finding ways to share knowledge

"Wieviel Öl und Gas gibts eigentlich?" (W. Frank,1996)

My answer in 1998:



"Da haben sie ja ein Lehrbuch geschrieben "(Ch. Exner, 2001)



After "retirement" in 2004: Daring estimates and forecasts

Legend for Figure 2-6

Conventional Oil/Conventional + Unconventional Oil References

1 Duce
2 Pogue
3 Weeks
4 Levorsen (and up)
5 Weeks
6 Pratt
7 Hubbert
8 Weeks
9 Weeks
10 Weeks
11 Ryman
12 Weeks (H)
13 Weeks (L)
14 Hubbert (H)
15 Hubbert (L)
16 Moody
17 Weeks (H)
18 Weeks (L)
19 Bauquis
20 Warman
21 Warman
22 Hubbert
23 Odell
24 Schweinfurth
25 Hubbert (H)
26 Hubbert (L)
27 Kirkby, Adams (H)
28 Kirkby, Adams (L)
29 Parent, Linden
30 Parent, Linden (H)
31 Parent, Linden (L)
32 MacKay, North (H)
33 MacKay, North (L)
34 Moody, Esser (H)
35 Moody, Esser
36 Moody, Esser (L)
37 Moody, Geiger
38 Moody, Geiger
39 Moody, Geiger
40 National Academy of Science
41 Odell and Rosing
42 Barthel, BGR
43 Grossling (H)
44 Grossling (L)
45 Folinsbee
46 Klemme
47 Seidl, IIASA (H)
48 Seidl, IIASA (L)
49 Styrikovich
50 Styrikovich
51 World Energy Conference
52 IFP (4 estimates >4 TBO)
53 Klemme
54 Moody
55 Nehring (H)
56 Nehring (L)
57 Halbouty
58 Halbouty
59 Halbouty
60 Meyerhoff
61 Nehring (H)
62 Nehring (L)
63 De Bruyne
64 World Energy Conference
65 Halbouty
66 Masters
67 Masters
68 Masters
69 Odell and Rosing
70 Masters (H)
71 Masters (L)
72 Martin
73 Masters
74 Bookout
75 Campbell
76 Campbell
77 Masters
78 Masters
79 Masters
80 Campbell
81 Campbell
82 Laherrere
83 Campbell
84 Masters
85 Masters
86 Masters
87 Campbell
88 MacKenzie
89 Campbell
90 BP
91 Odell (H)
92 Odell L)
93 Schollnberger
94 Schollnberger
95 Schollnberger
96 USGS
97 USGS
98 USGS
99 Deffeyes
100 SHELL
101 SHELL (H)
102 SHELL (L)
103 Edwards

Legend for Figure 2-7

Convential Gas/Conventional + Unconventional Gas References

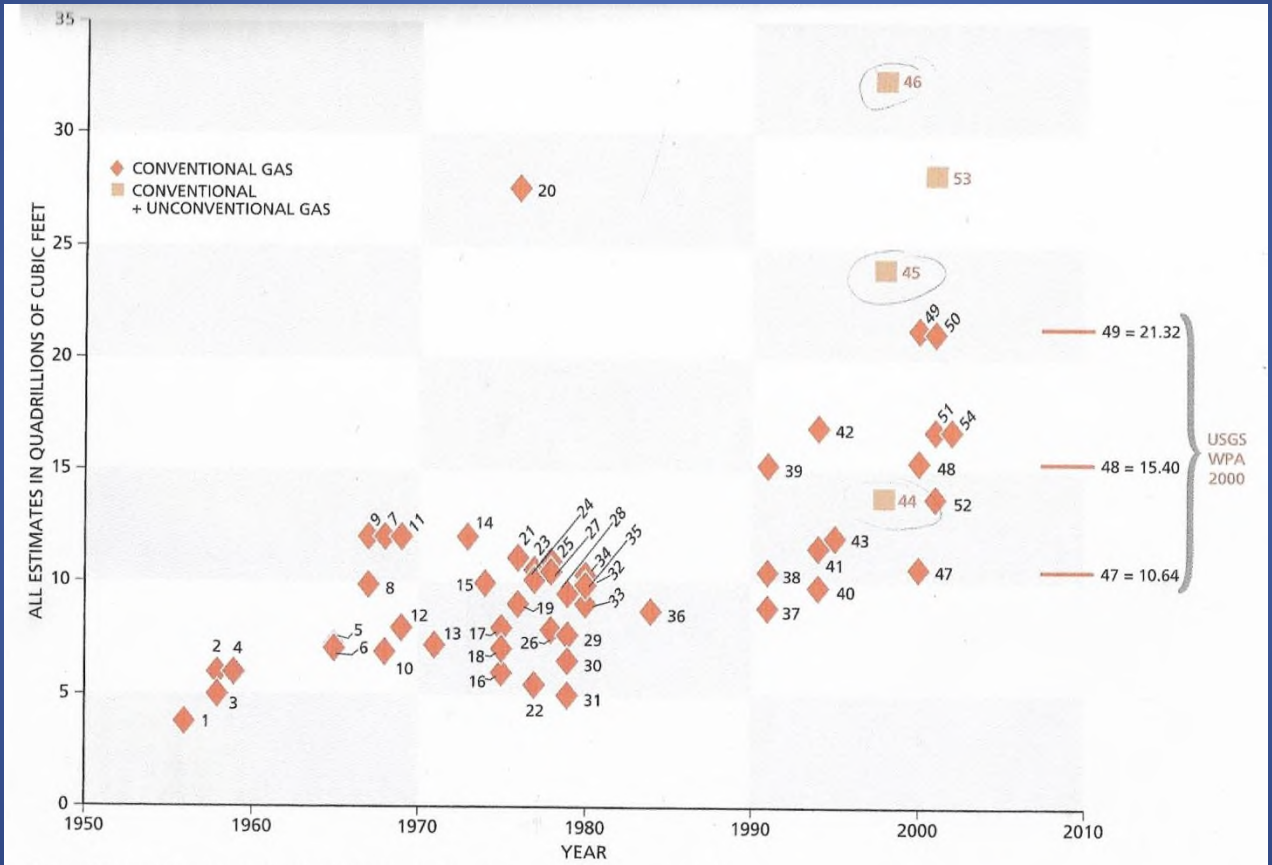
1 MacKinney
2 Weeks (H)
3 Weeks (L)
4 Weeks
5 MacKinney
6 Weeks
7 Ryman
8 SHELL
9 MacKinney
10 Weeks
11 Hubbert (H)
12 Hubbert (L)
13 Weeks
14 Hubbert
15 Parent, Linden (and up)
16 Adams and Kirkby (H)
17 Moody, Geiger
18 National Academy of Science
19 Barthel, BGR (and up)
20 Grossling (H)
21 Grossling (L)
22 International Gas Union
23 Parent, Linden (H) (and up)
24 Parent, Linden (L)
25 Desprairies (H)
26 Desprairies (L)
27 McCormick, AGA
28 Bois
29 Meyerhoff
30 Nehring (H)
31 Nehring (L)
32 Parent, Linden (H) (and up)
33 Parent, Linden (L)
34 Schubert
35 World Energy Conference
36 Masters
37 Masters
38 Masters
39 Masters
40 Masters
41 Masters
42 Masters
43 Riva
44 Schollnberger
45 Schollnberger
46 Schollnberger
47 USGS
48 USGS
49 USGS
50 CEDIGAZ (H)
51 CEDIGAZ (L)
52 SHELL
53 SHELL
54 BGR

- (U.S. Nat. Petrol. Council, 2007)

Oil

Source: Ahlbrandt, Thomas S., and Klett, T.R., "Comparison of methods used to estimate conventional undiscovered petroleum resources: World examples," *Natural Resources Research*, 2005

Natural Gas



Source: Ahlbrandt, Thomas S., and Klett, T.R., "Comparison of methods used to estimate conventional undiscovered petroleum resources: World examples," *Natural Resources Research*, 2005.

FIGURE 2-7. *World Natural Gas Resource Estimates, 1950 – Present*

NPC, 2007: Facing the Hard Truth ...

There is Plenty of Oil and Gas Left

Original Oil in Place

15 000 G barrels = 2 040 Gt (with shale oil, without oil shale),

only 165 Gt produced (= **8%**) so far.

Original Gas in Place

3 100 trillion m^3 (of wich 2 400 trillion m^3 CBM+"tight" gas +shale gas; without gas hydrates) = 2 805 GtOE,

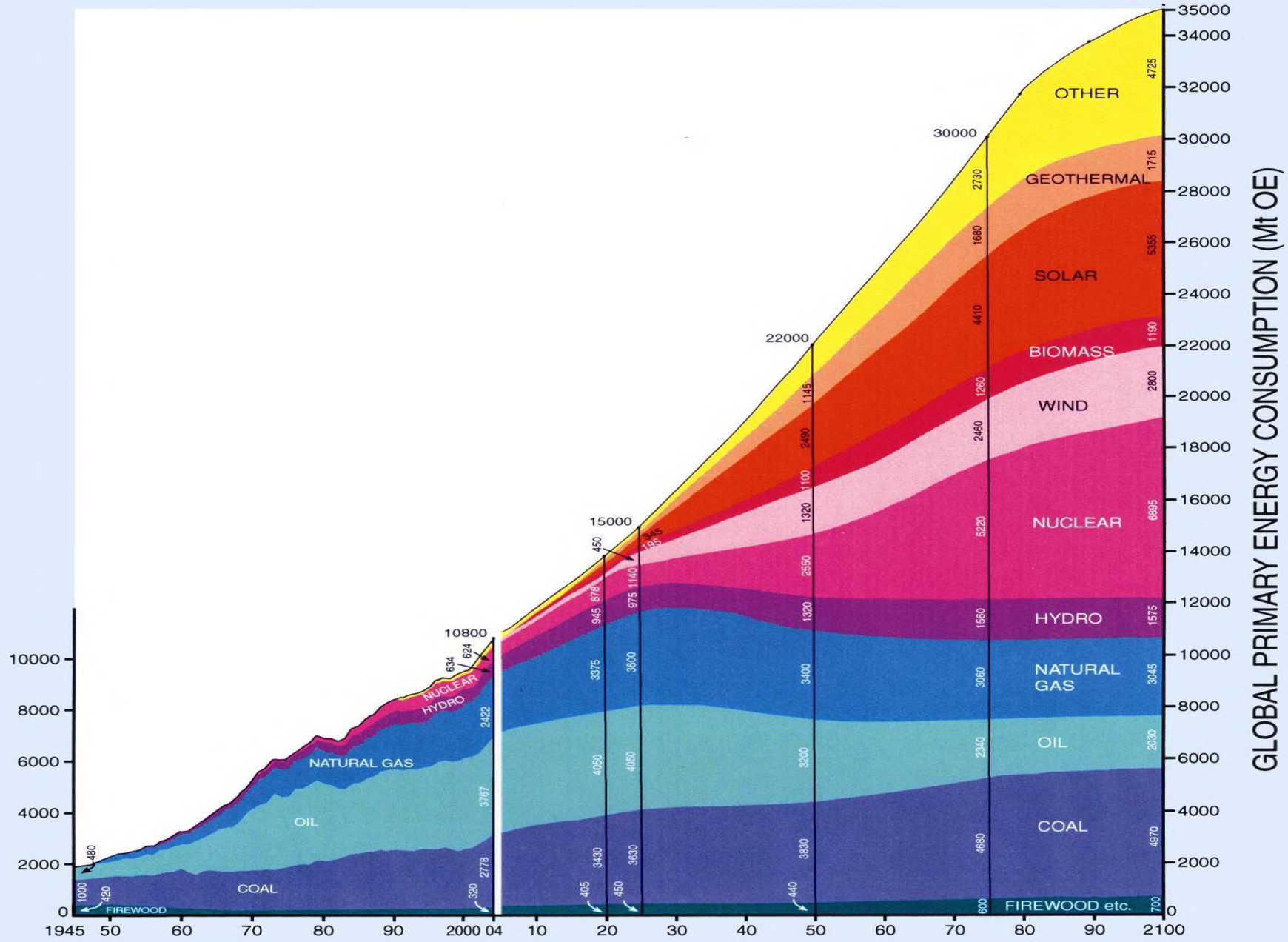
only 88 Gt produced (= **3%**) so far.

Source: Schollnberger 1998, 2006, Holditch et al. 2012))

In Energy Decisions, What is Important to Consumers, Governments and Businesses?

- Economic Growth (0.5 weight)
- Security of Energy Supply (0.3 weight)
- A Clean and Safe Environment for Our and Future Generations (0.2 weight)

Forecast: Energy Spectrum 1945 to 2100 (SCHOLLNBERGER,2006)



Significant Pressure Points on a Global Scale will Force a Juncture in the Primary Energy Mix

Population Growth

Lifestyle Expectations

Access to Fossil Fuels ("haves and have-nots"; Producer's hubris : Russia, USA)

Falling Costs of "Renewables"

Ecologic Precautions

Yellow vests: “Enough is enough!!!”
(They ask: Climate change? What climate change?)

Politicians try to lead, but what are the followers DOING????

Talks Falter as Demonstrations in France Continue

BOUTRIA LUC/MAXPPP/ZUMA PRESS

RESISTANCE: Protests in France, including high-school students marching in Toulon, above, continued Monday. The government was rebuffed in efforts to arrange talks. A9

WSJ 12/4/18

SNCF (but not the French railway company!)

We only re**act** to a threat quickly, when the threat is

Significant

Near

Clear

and the outcome of actions is perceived as

Favorable to us

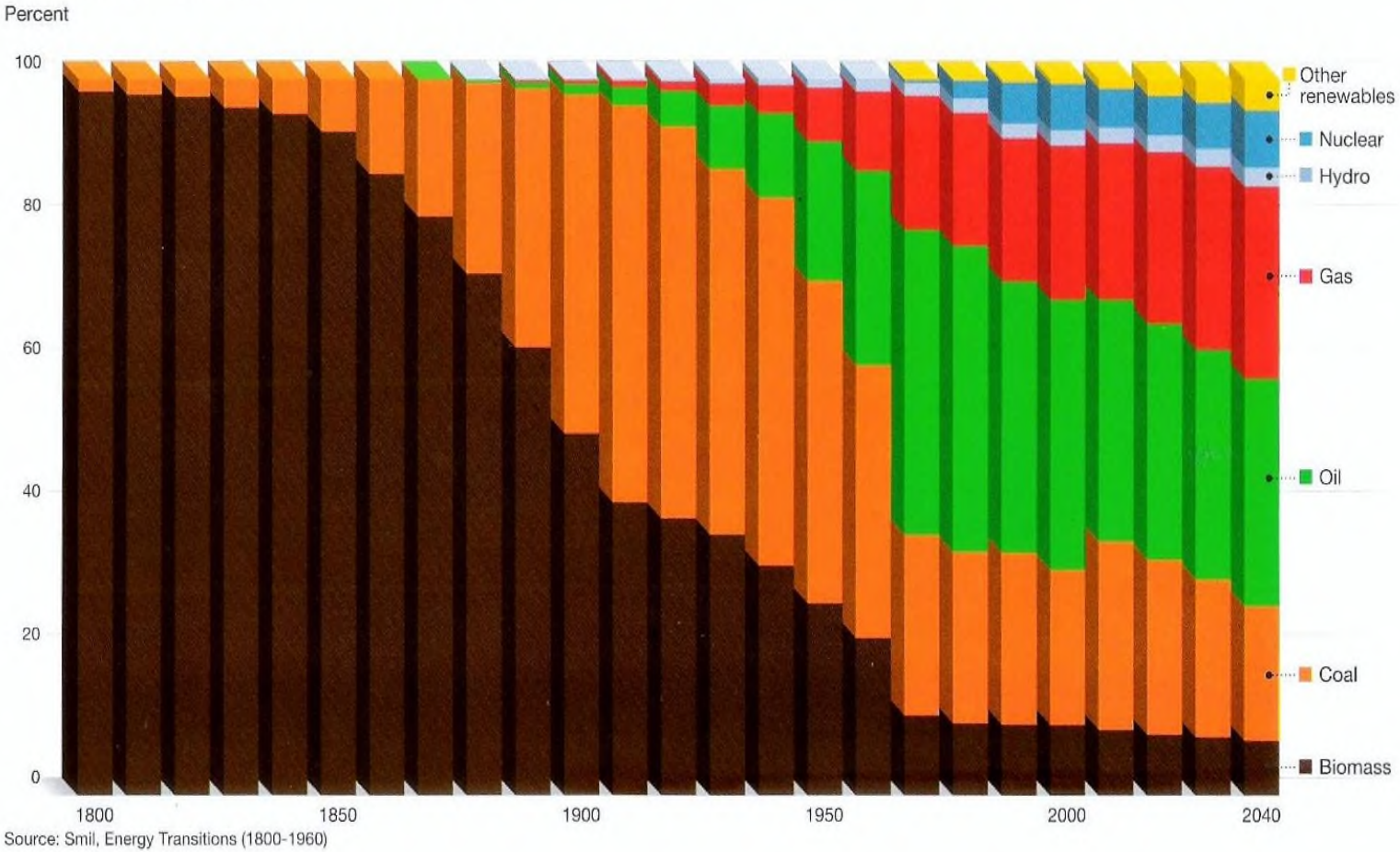
For too many, the current global warming is not SNCF!!

Therefore: **Lots of talk, but no decisive actions**

Demonstrations

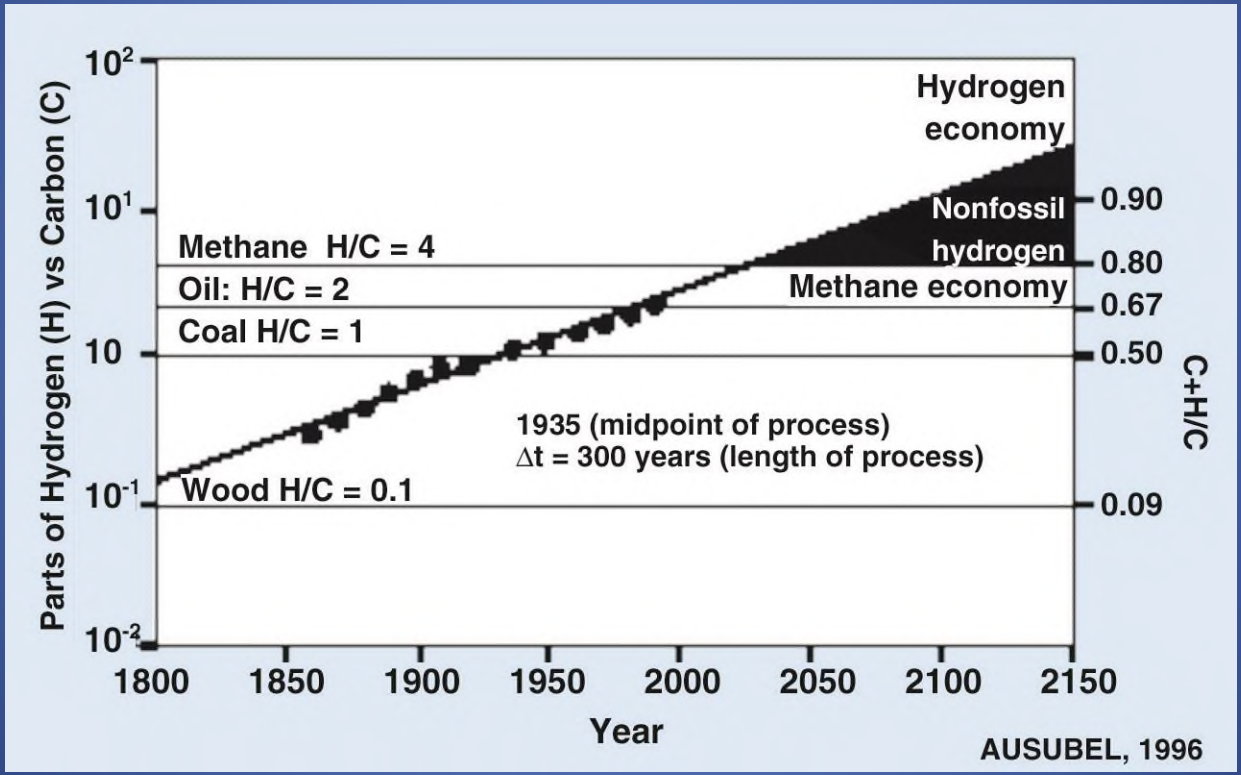
- .. but what are we, as individuals or collectively, willing to SACRIFICE???

There is a long-term trend……

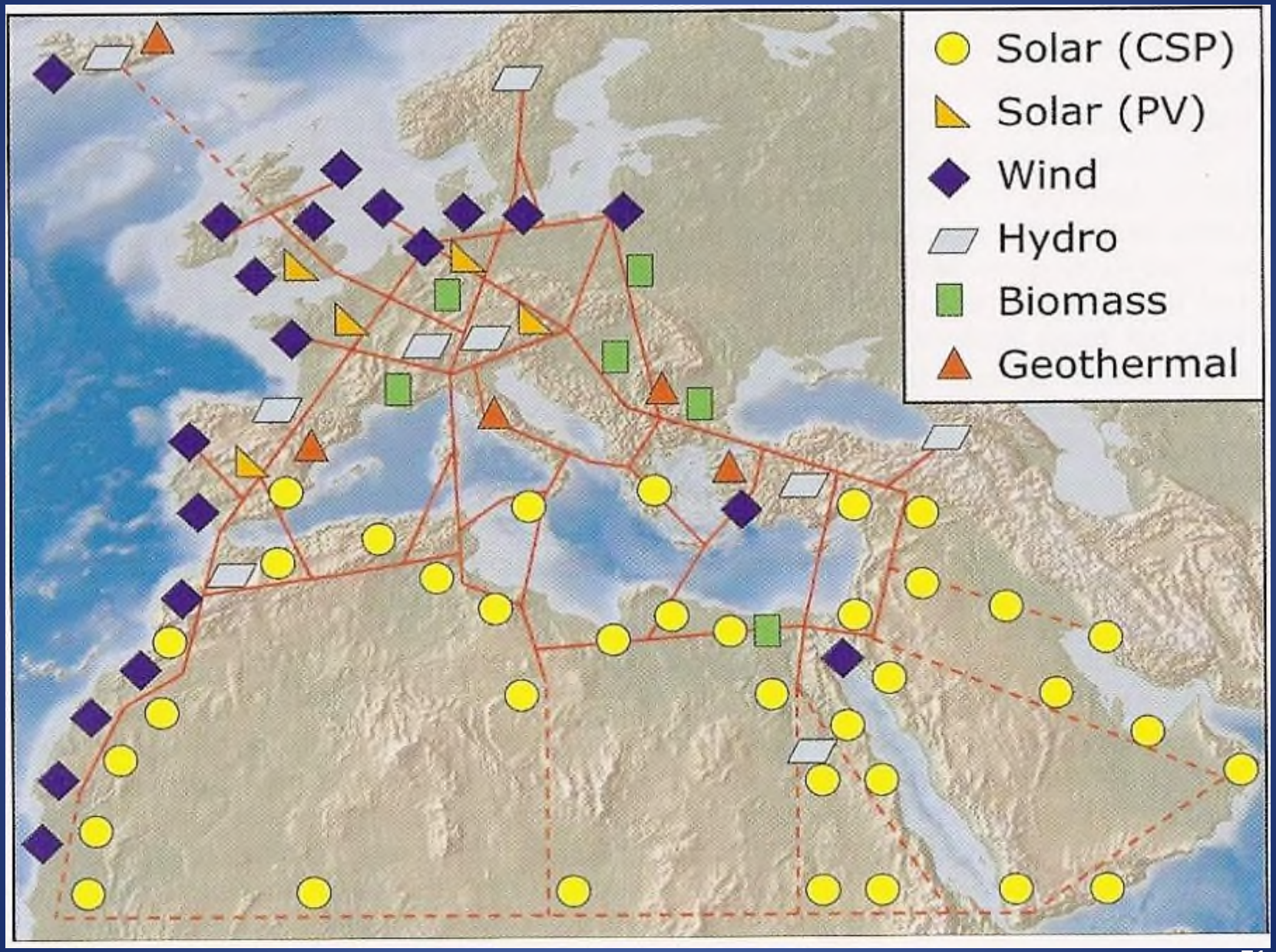


Source: Exxon Mobil: “2012 Outlook for Energy: A View to 2040”

… towards fuels rich in hydrogen



Today's Dream, Tomorrow's Reality?



Source: G. Knies, Trans-Mediterranean Renewable Energy Cooperation, 2008

Consumption of Traded Primary Energy: Early Post-Junction (2040); Pre-Junction (2010)

	2040 (million BOE)	%	**2010** (million BOE)	%
Gas	4 200	26.3	2 848	23.8
Oil	3 800	23.8	4 031	33.7
Coal	3 400	21.3	3 532	29.5
Nuclear	1 200	7.5	626	5.2
Hydro	1 000	6.3	779	6.6
Wind	1 000	6.3	45	0.38
Solar	900	5.6	35	0.29
Bio	300	1.9	78	0.65
Geothermal	200	1.3	6	0.05

- 2010 Actual: 2012 BP Statistical Report
- 2040 Estimate: Schollnberger 2006, updated in 2012

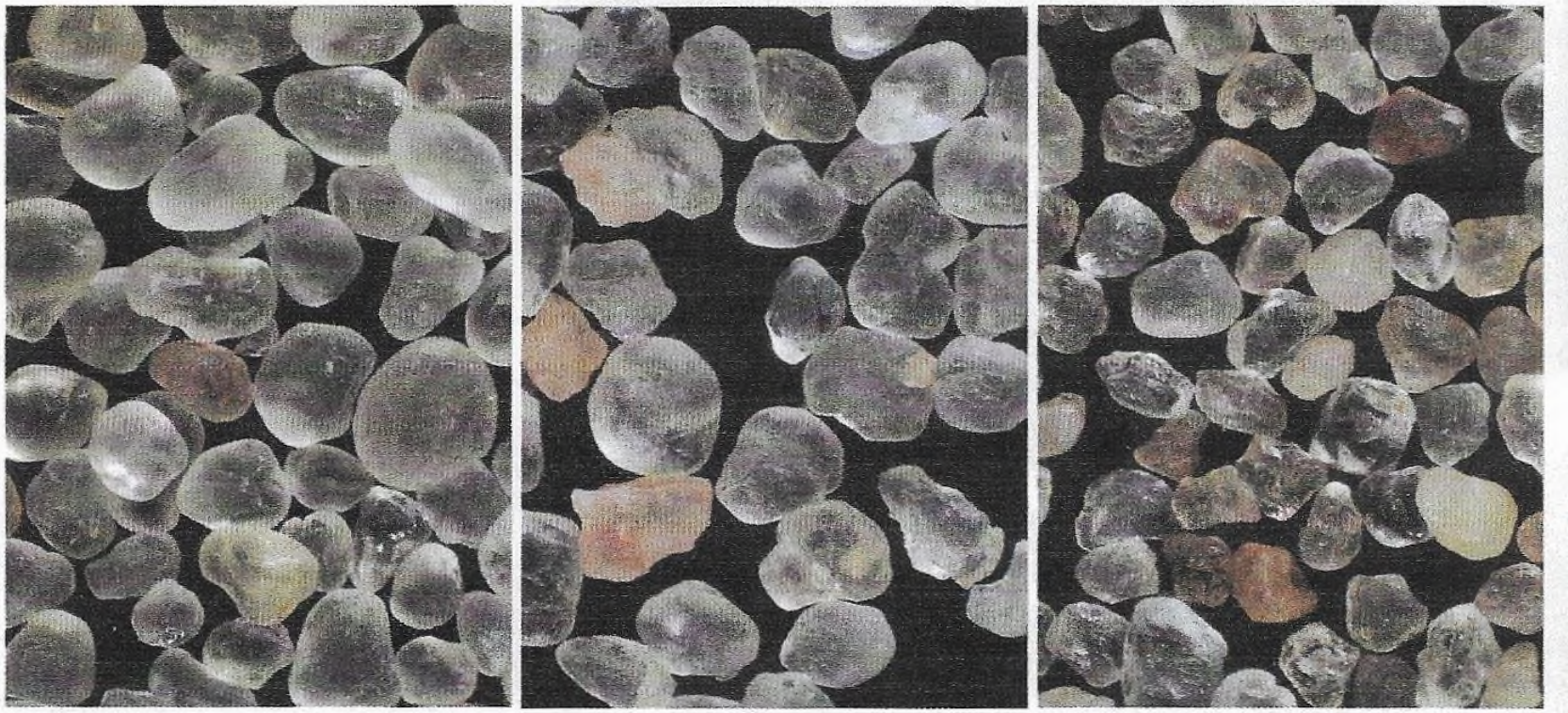
Since Natural Gas will be so important, how does it get to the EU (360 billion cu m, 2017)

- Russia : 190 (43%)
- Norway: 120 (33%)
- Algeria: 45
- Qatar: 24
- Nigeria: 12
- EU Production: 130

EU LNG Terminal capacity: 245 (only 25% used in 2017)

Horizontal drilling and hydraulic fracking with proppants revolutionized the oil and gas industry during the last decade

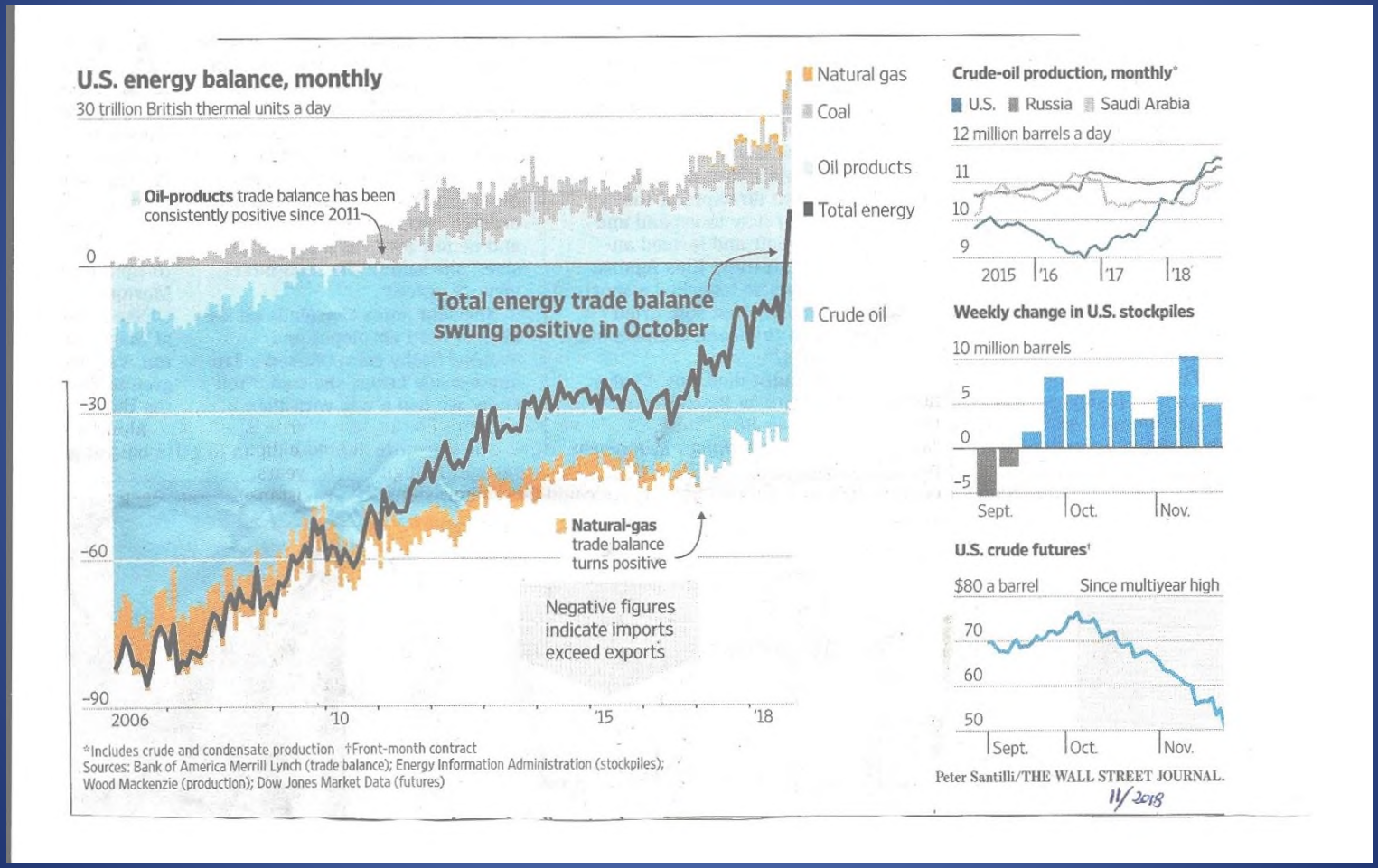
JPT, Feb 2019



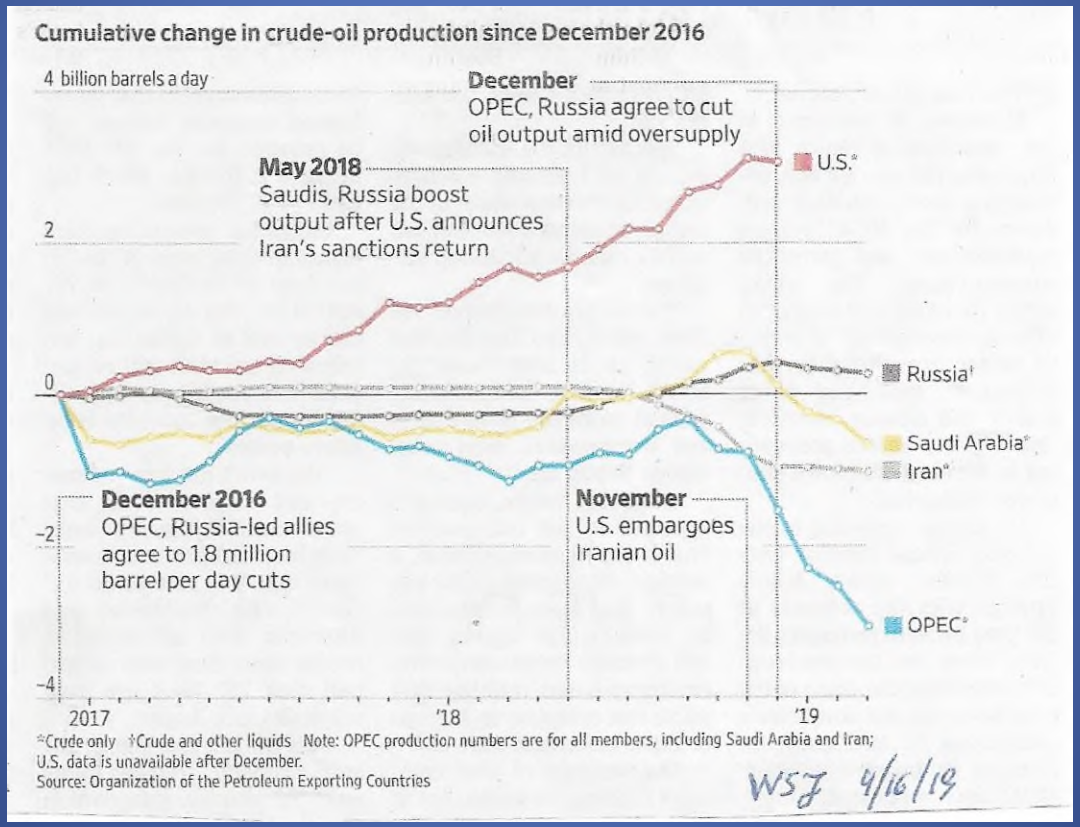
Northern White | Texas Brady (Brown) | Texas Dune

The shape, not the color, is among the most important factors in sand used as proppant. Rounder is better, while more angular grains tend to break down faster. *Source: Core Labs, Stim Labs.*

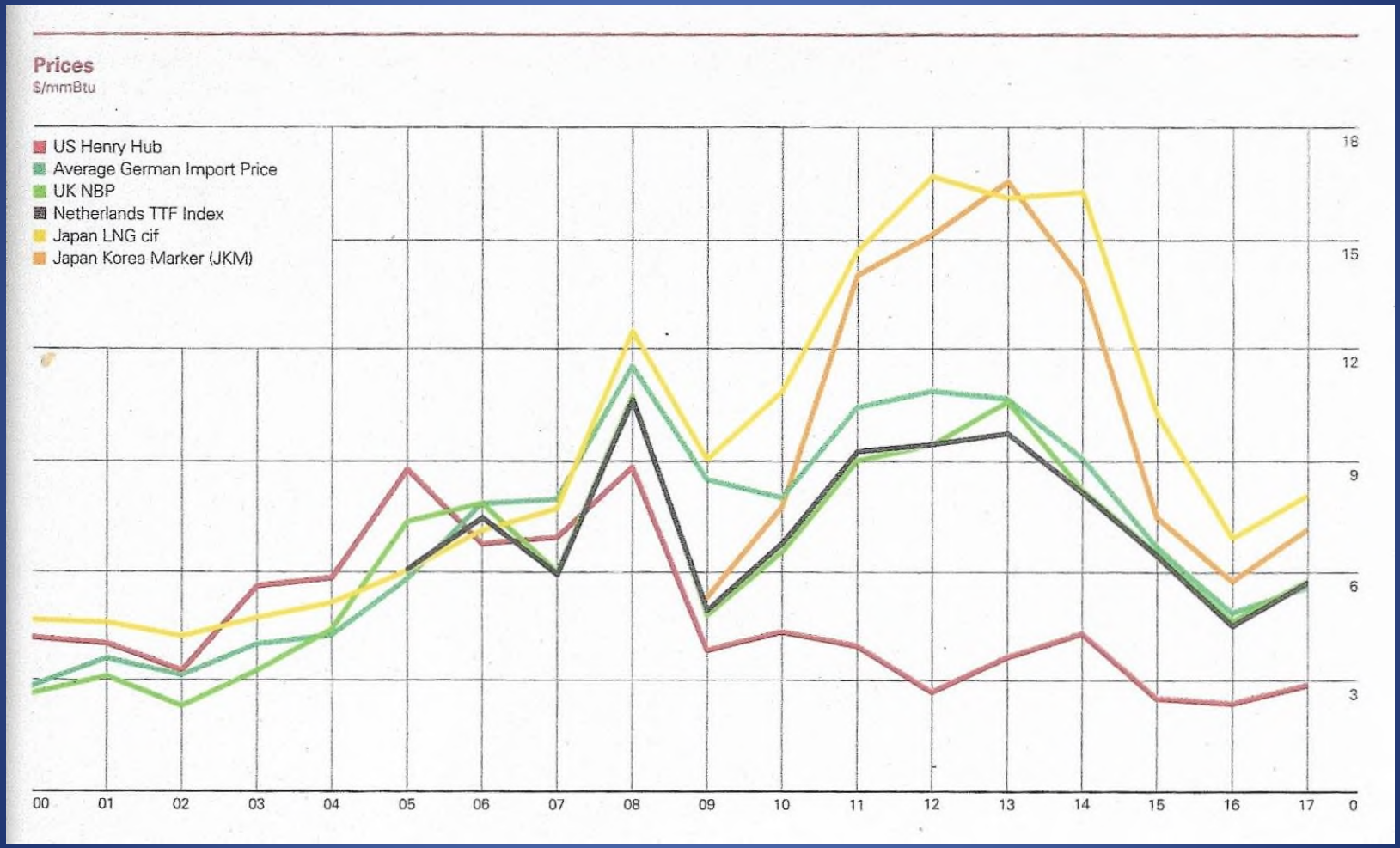
U.S. now is a net energy exporter



The global energy picture and geopolitics have changed
(and with it the global chemical, manufacturing etc… industry)



Prices for Natural Gas



Source: BP Statistical Review of world energy, June 2018

Approx. current price for Natural Gas ($/Million btu, May 2019)

- USA : **2.40**
- EU: **9.50**

- Can the EU afford this difference or an even larger one? (BASF, Borealis, Voest … and many more are disadvantaged in global markets, because of EU price,… and are hurting!)

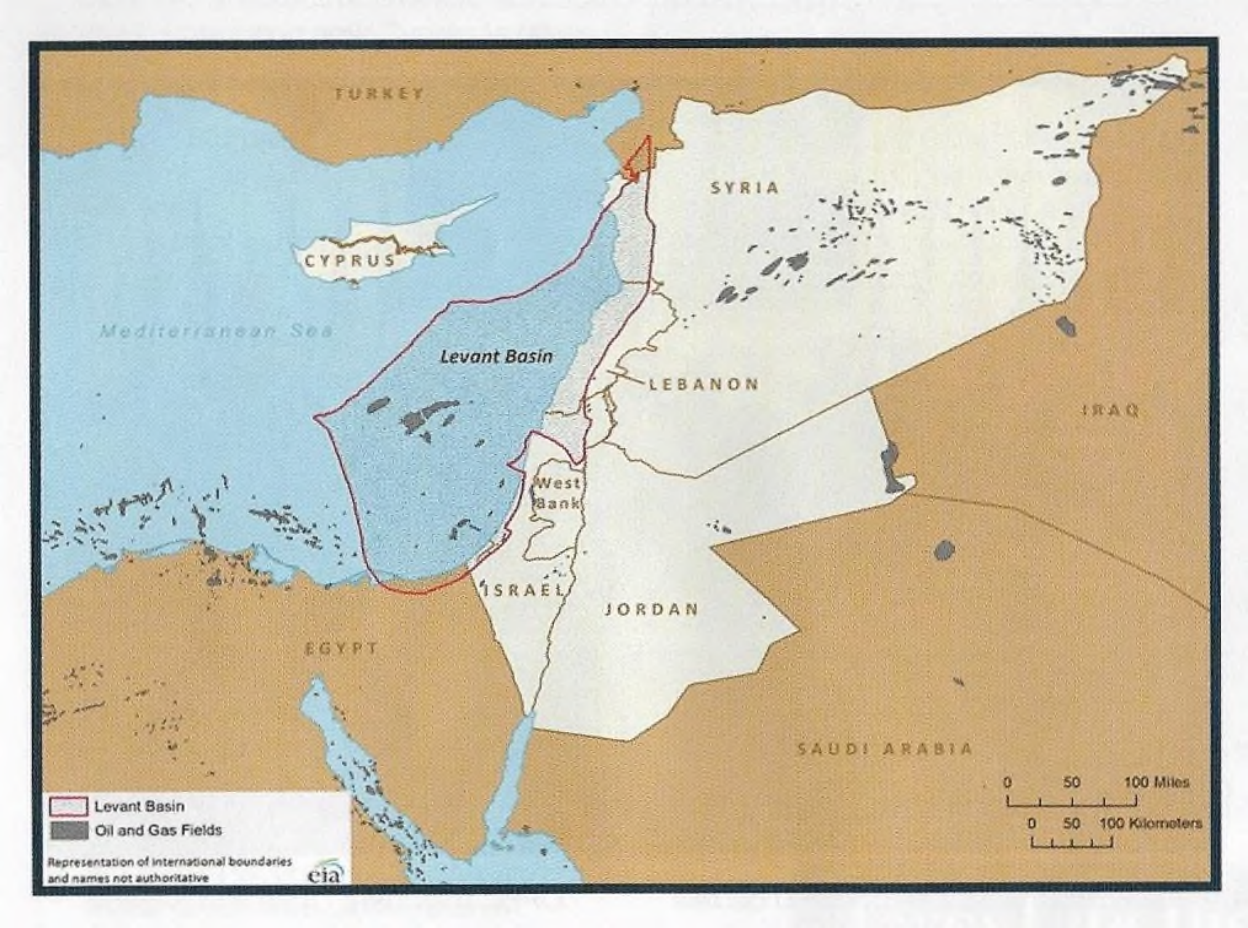
(Almost) “Everything is political”

EU decision for Transadriatic Pipeline and not for Nabucco : a hit under the belt to OMV

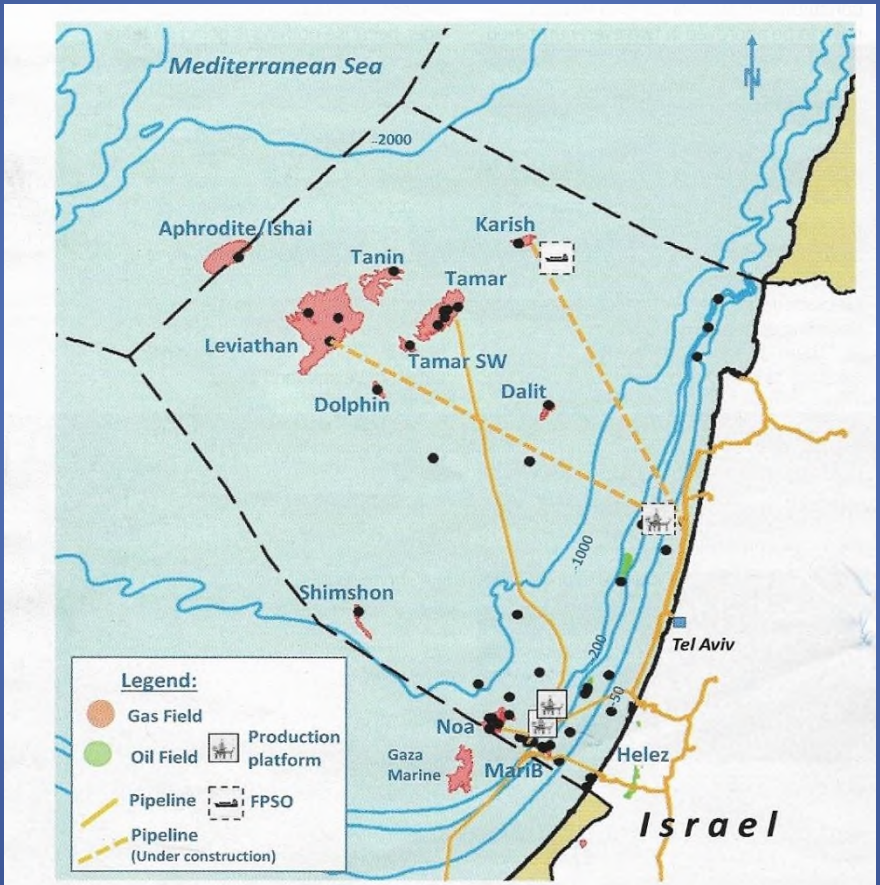
A Nord-Stream 2 pipeline, without gas coming through Ukraine: grave geopoltical and economic consequences for EU

(Baumgarten a dead end instead of central gas hub?)

Eastern Med awash in natural gas



Fields offshore Israel and Cyprus



Gas fields and infrastructures offshore Israel. The Leviathan and Karish production facilities are under construction.

Russia's nightmare: a potential avelanche of natural gas to Europe from many sources . It will come!

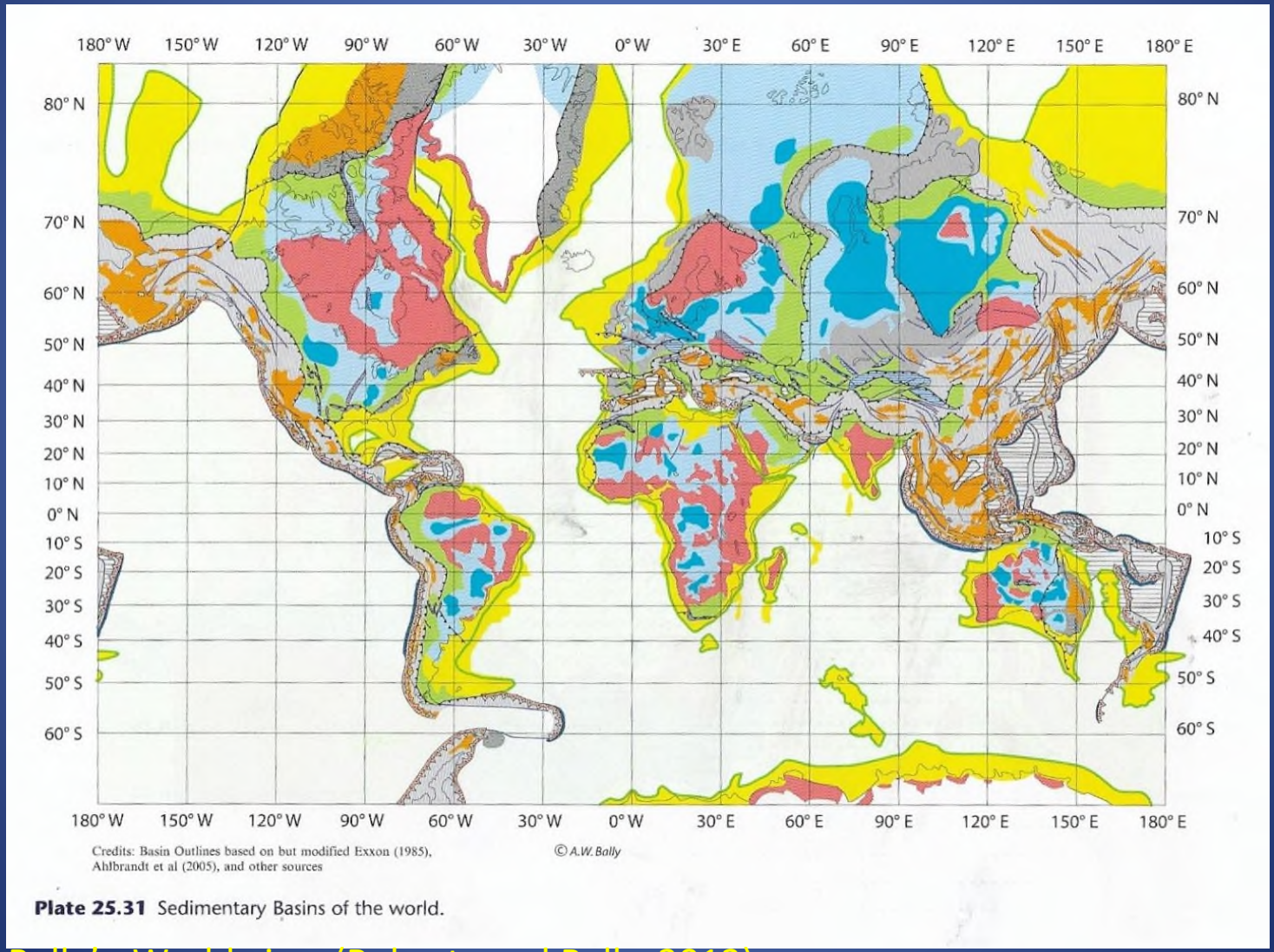


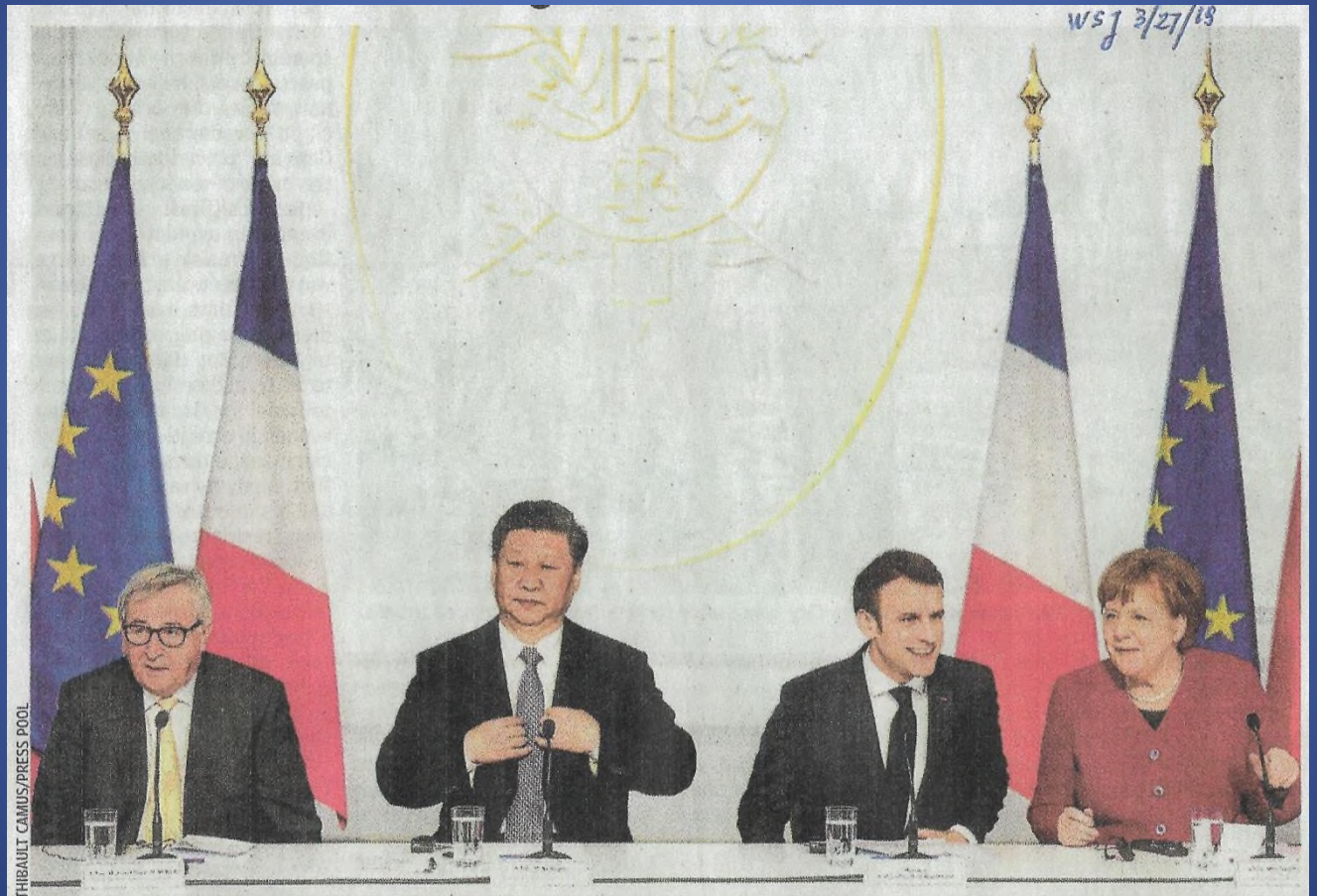
Plate 25.31 Sedimentary Basins of the world.

- A Bally's World view (Roberts and Bally, 2012)

My suggestions to improve Energy Options for the EU:

- Reduce (waste in) energy consumption
- Massively increase of geothermal energy (bonus: Weilheim,Bayern)
- **Massively increase "renewable" forms of energy (co-operate with PR China?)**
- Nuclear energy
- Natural gas from multiple sources, demand a better price than China gets
- Reduce oil
- Minimize coal
- **Deliberately build redundancies in energy forms, sources and infrastructure to allow for instantaneous fuel switching**

PR CHINA, partner or adversary?



European Commission President Juncker, Chinese President Xi, French President Macron and German Chancellor Merkel in Paris.

PR China's "One Belt, One Road" strategy

Make it a two-way-road!

PR CHINA, co-operation is possible!

President Zheng Hu, CPMEC and Vice-president Wolfgand E. Schollnberger, Amoco were signing the technology import contract.

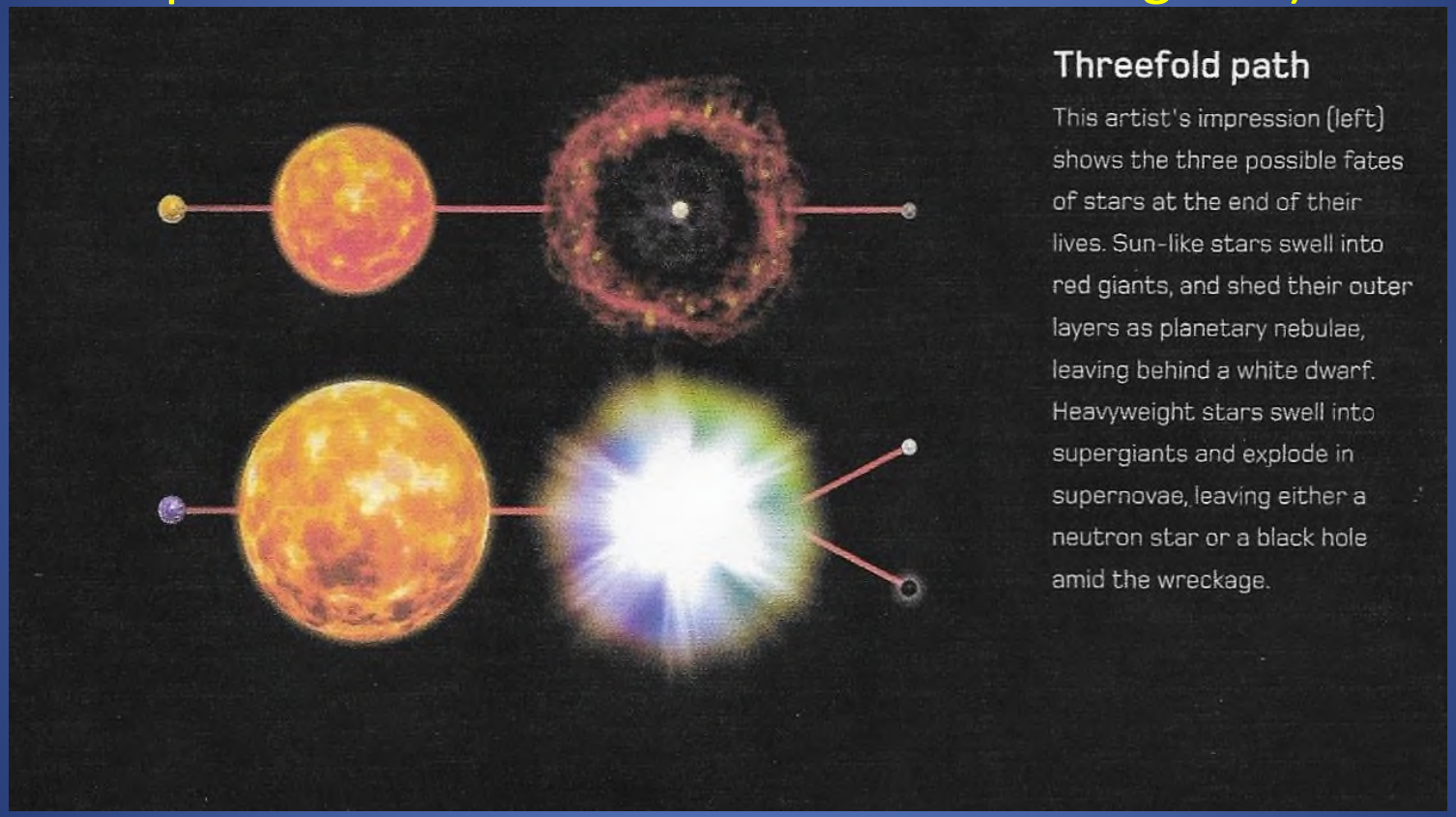
Beijing, July 1997

OUTLOOK

Approx. 4.5 billion years from now…….

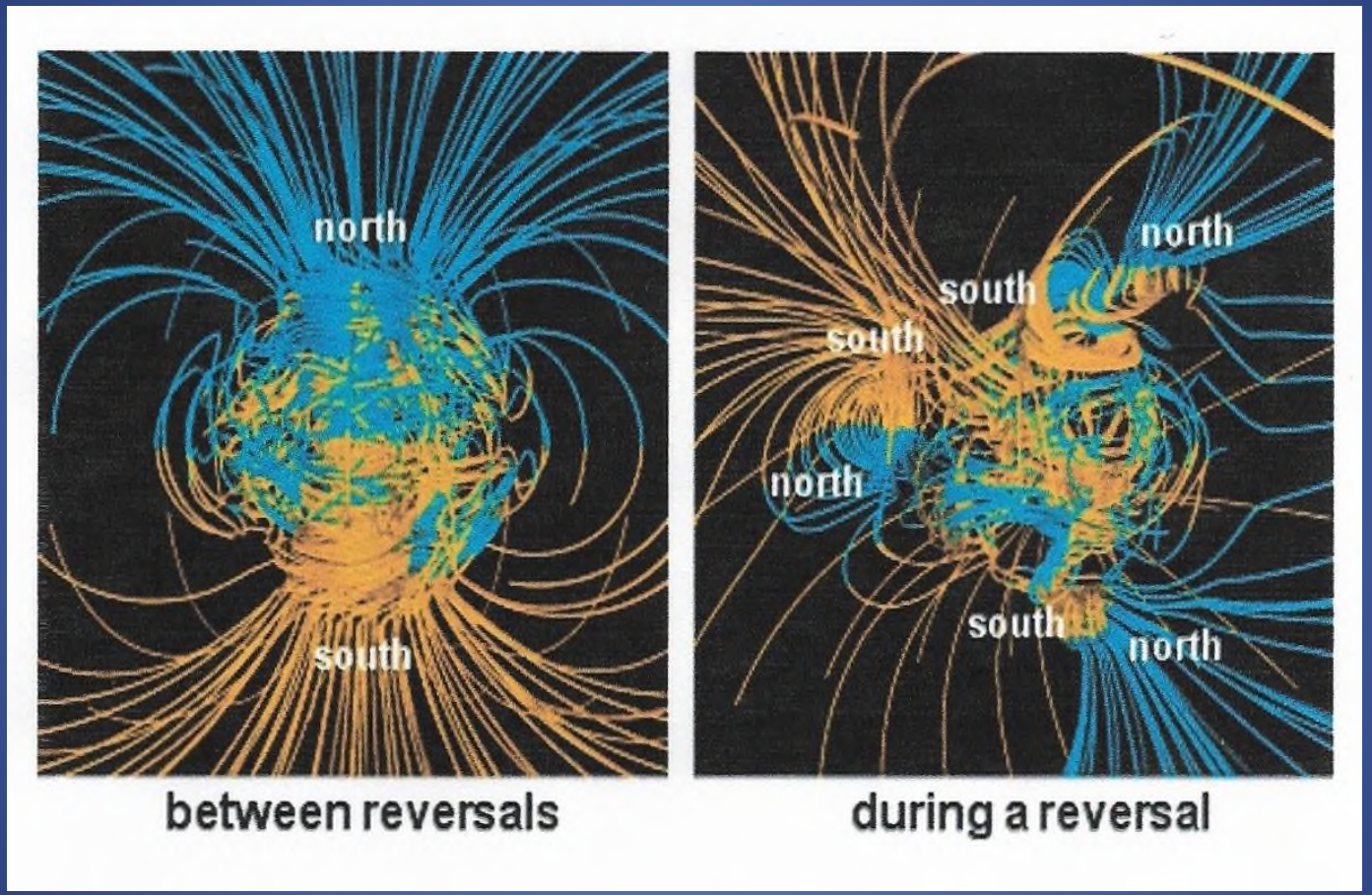
- Interacting Galaxies NGC7318 A and B (source: NASA/ESA/Hubble SM4), as a proxy for the coming collision of the Milky Way galaxy with the Andromeda galaxy 4.5 billion years from now

Sun's expansion to a Red Giant, affecting earth in 1.5 to 4.4 billion years (Surface water will disappear, plate tectonic will come to a crunching end)



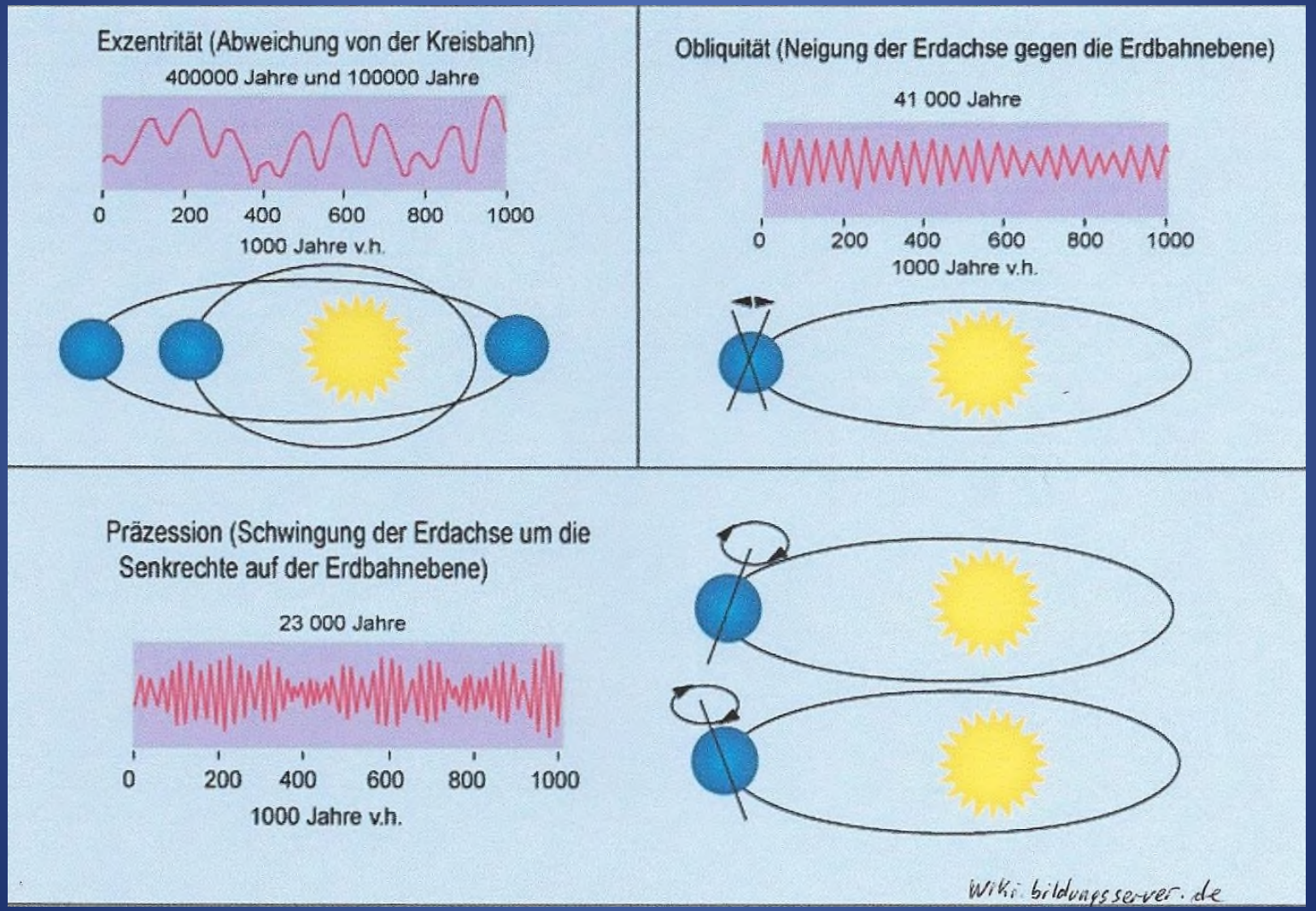
- Picture source: G. Sparrows (2010): Hubble.- Mitra Book (New York).

Geomagnetic reversal (overdue?)



The reversal process itself may last about 1000 to 3000 years

Earth's orbital elements



Artificial Intellegence: The Good

Data and information simultaneously available to masses of persons

Knowledge/ wisdom explosion

Connectivity replaces transportation

Opportunities and wealth for all ; consumer prices will drop dramatically

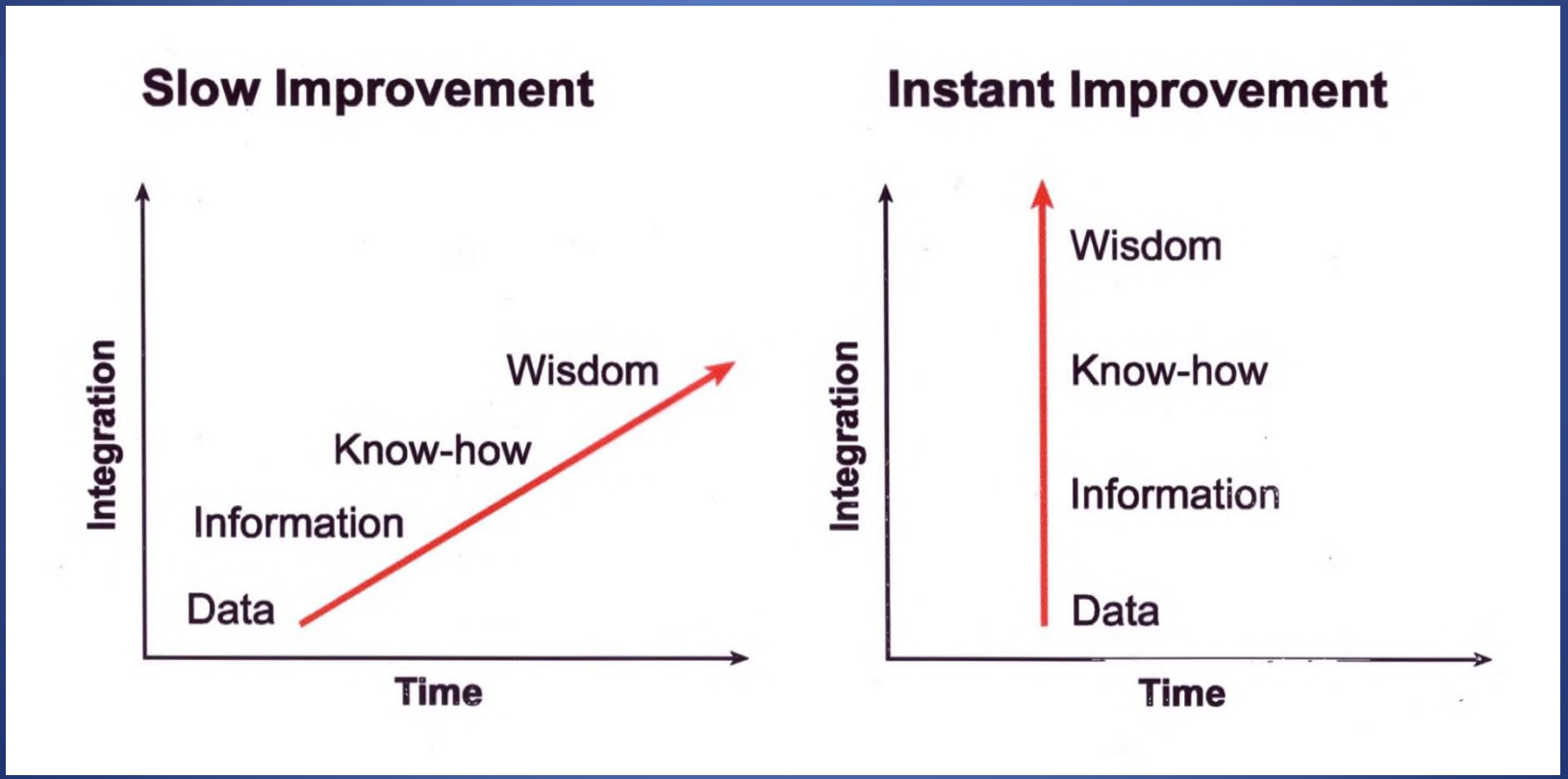
Optimized selection of fit for purpose energy forms

Solutions to current global warming

The basic role of Artificial Intelligence (AI)

From:

To:



Artificial Intelligence will enable us to build a true 3-D picture of the earth's crust and its raw material content. Fritz Ebner, Leopold Weber and I have started between 2011 and 2014, to lay a basis for such an effort, now PR China has announced a much larger project to map the crust in 3-D, which hopefully will lead to large international co-operation.

AI : The Bad

Loss of privacy/individualism

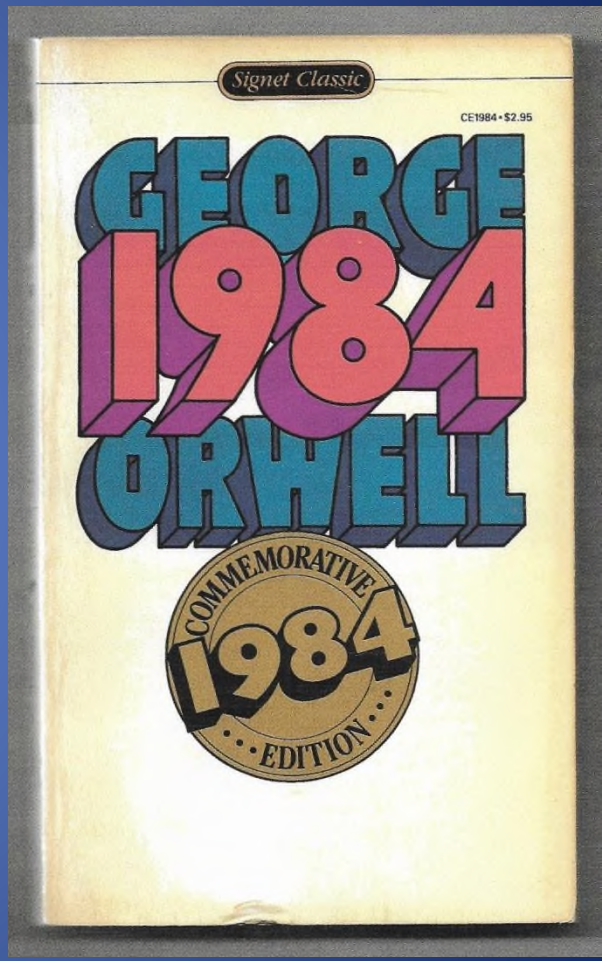
Fake news

“Mass steering”

Large-scale cyber crime

AI: The Ugly

- Deep Fake
- True and false indistinguishable
- Perpetual re-write of history
- Totalitarian surveillance and suppression of the many by the few
- Loss of opportunity for the many
-Destruction of independent thought



We need to remember :“Der materielle Unterbau hat den idellen Überbau überflügelt” (H. Riese,1969, pers. comm.)

Warming and melting

By RAY LEONARD

Commentary

AAPG, Explorer Oct 2018

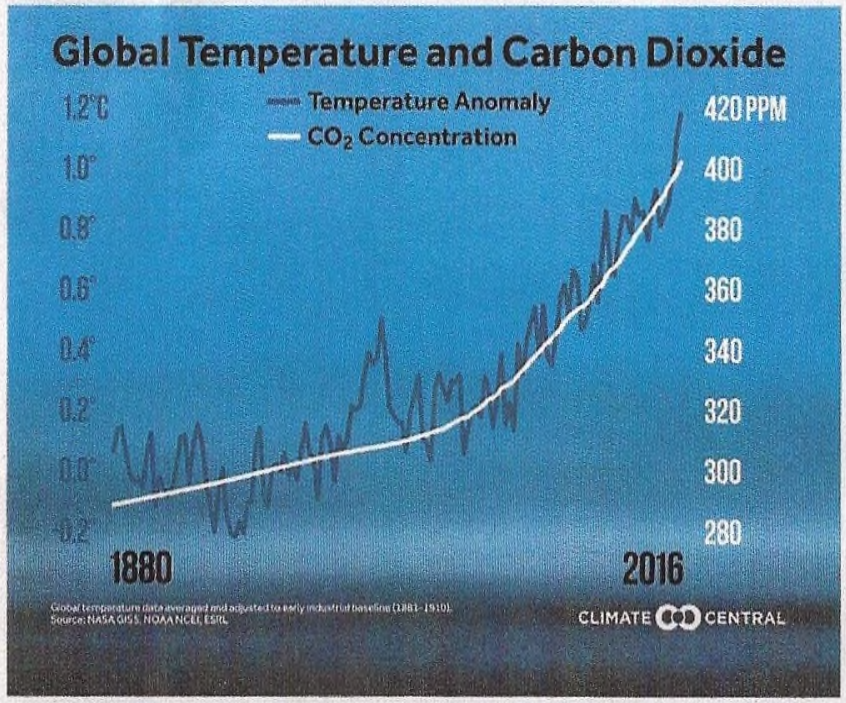


Figure 1. Global temperature has increased approximately 1.3 degrees C since 1880. A sharp increase in the rate of temperature rise was observed after 1950 which coincided with the increase in CO_2 content in the atmosphere. CO_2 content is now 411 ppm.

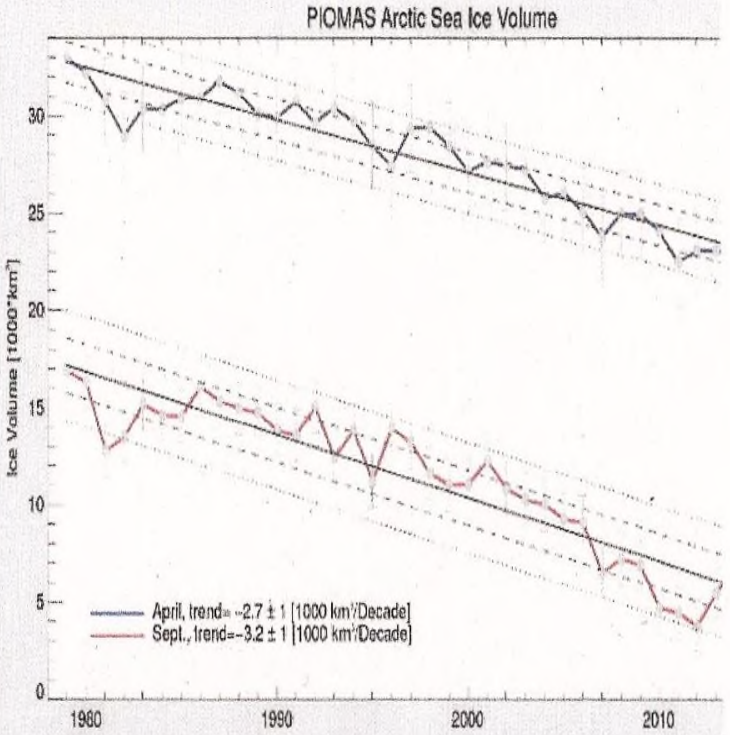


Figure 2. Between 1980 and 2016, the northern polar cap lost 70% of its ice volume during the minimum.

- **Permafrost melting is a major tipping point!!**

Only when **GEOLOGY (s.l.)** is recognized and used as **the PRIMARY SCIENCE** in understanding and tackling current global warming will **MEANINGFUL** solutions emerge.

EPILOGUE

Every generation adds its gravel onto the road to the future

…. not to reach a dead end, but….

..... to reach happiness.

Thank you for listening!

Thank you for the great honor you bestowed onto me today!!!!

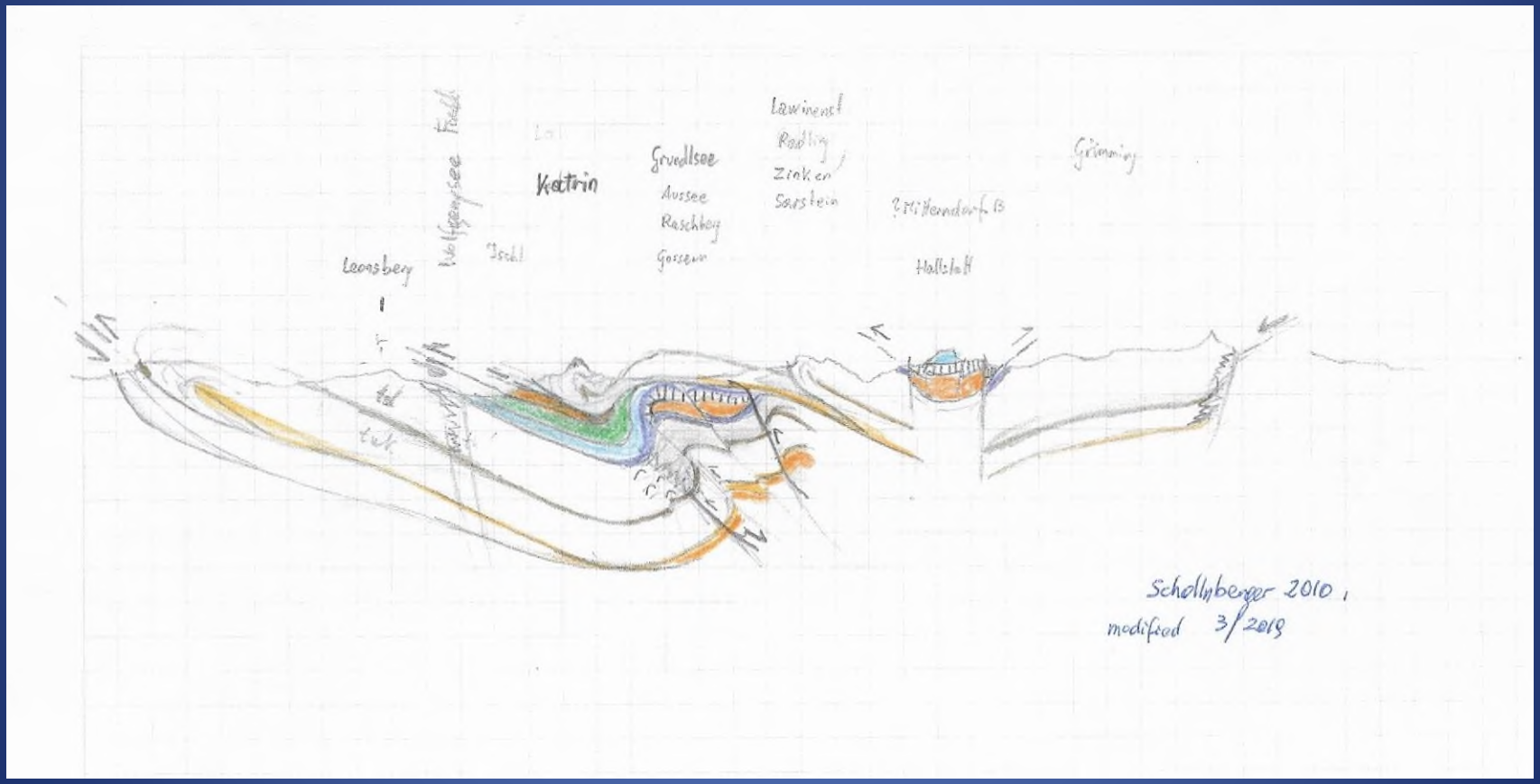
Back – up slides

PROLOG

- ...i hab eine gewisse Reife, wo mir de Dinge gegenüber abgeklärt sind.....

(H. Qualtinger/ Herr Karl)

A possible solution



Unprecedented Global Growth 1950 - 2008

Population: 2 600 000 to 6 600 000

Primary Energy Consumption: 2 to 10 Billion t OE

Wealth: GDP: 4 000 to 70 000 Billion US$ (World Bank)

Health: Life expectancy from 40 years to 67 years

Knowledge: Adult literacy from 56% (ca.700 million people) to 84% (ca. 4 500 million people ,UNESCO)

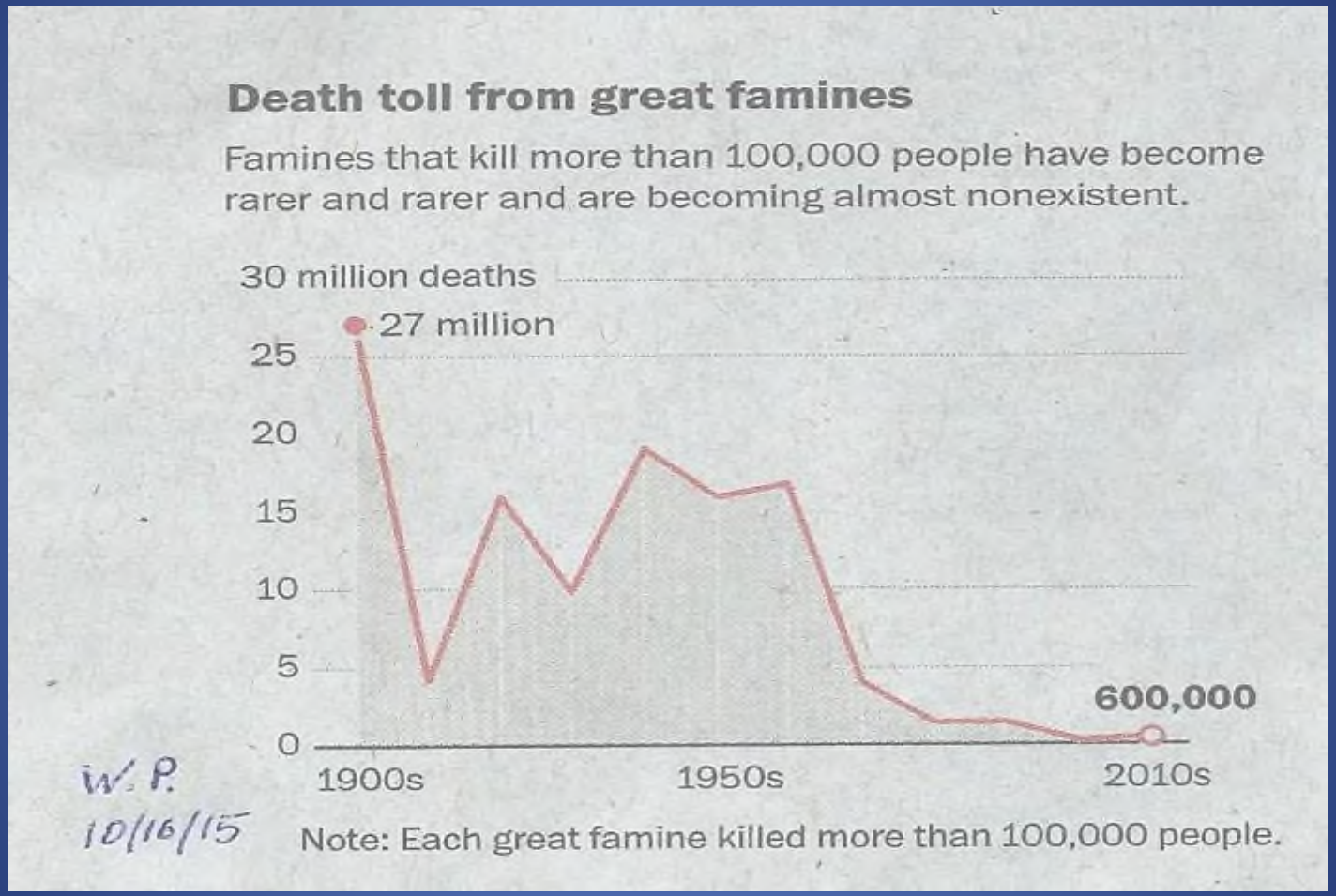
Environmental Awareness

Large Private and Government Debts

Environmental Awareness

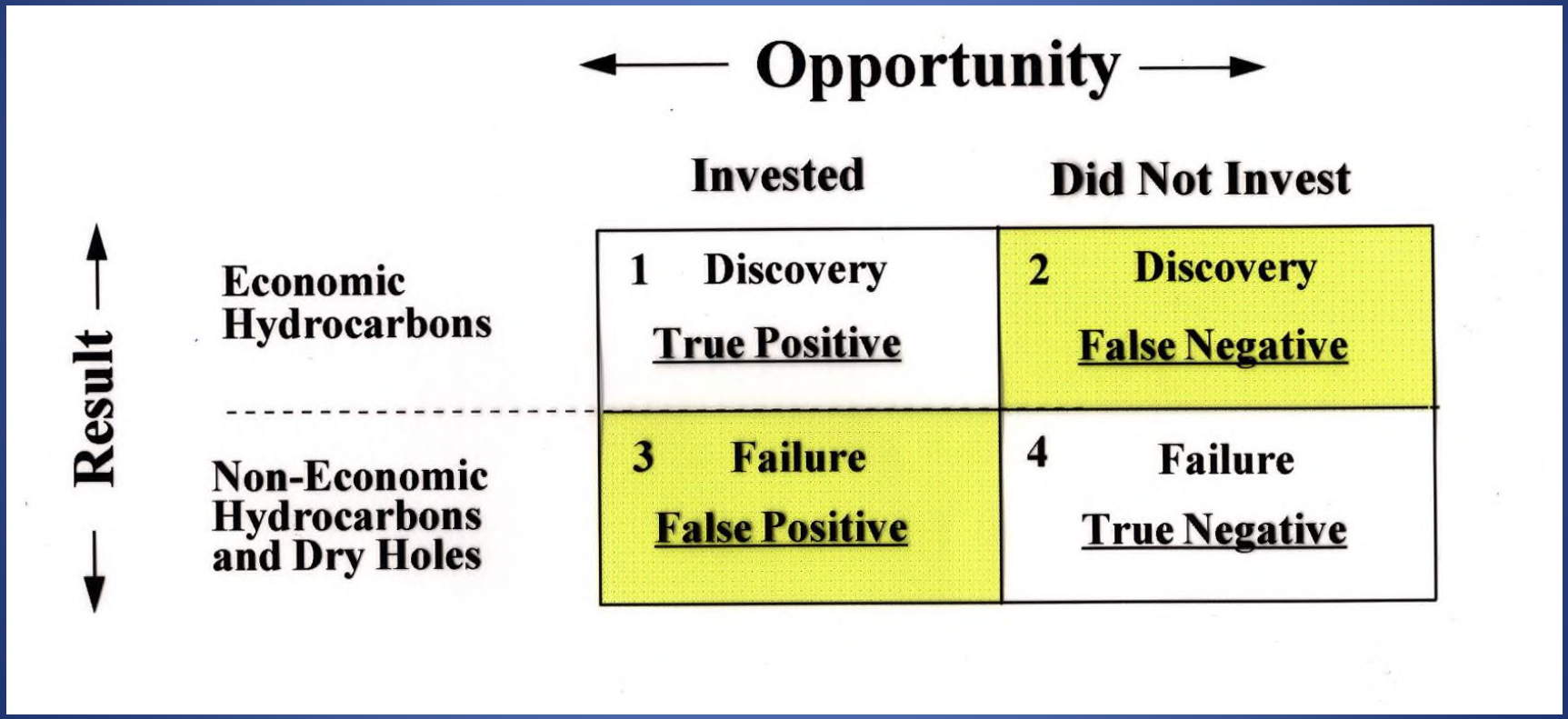
Large Government and Individual Debts

Globalisation sharply reduced great famines

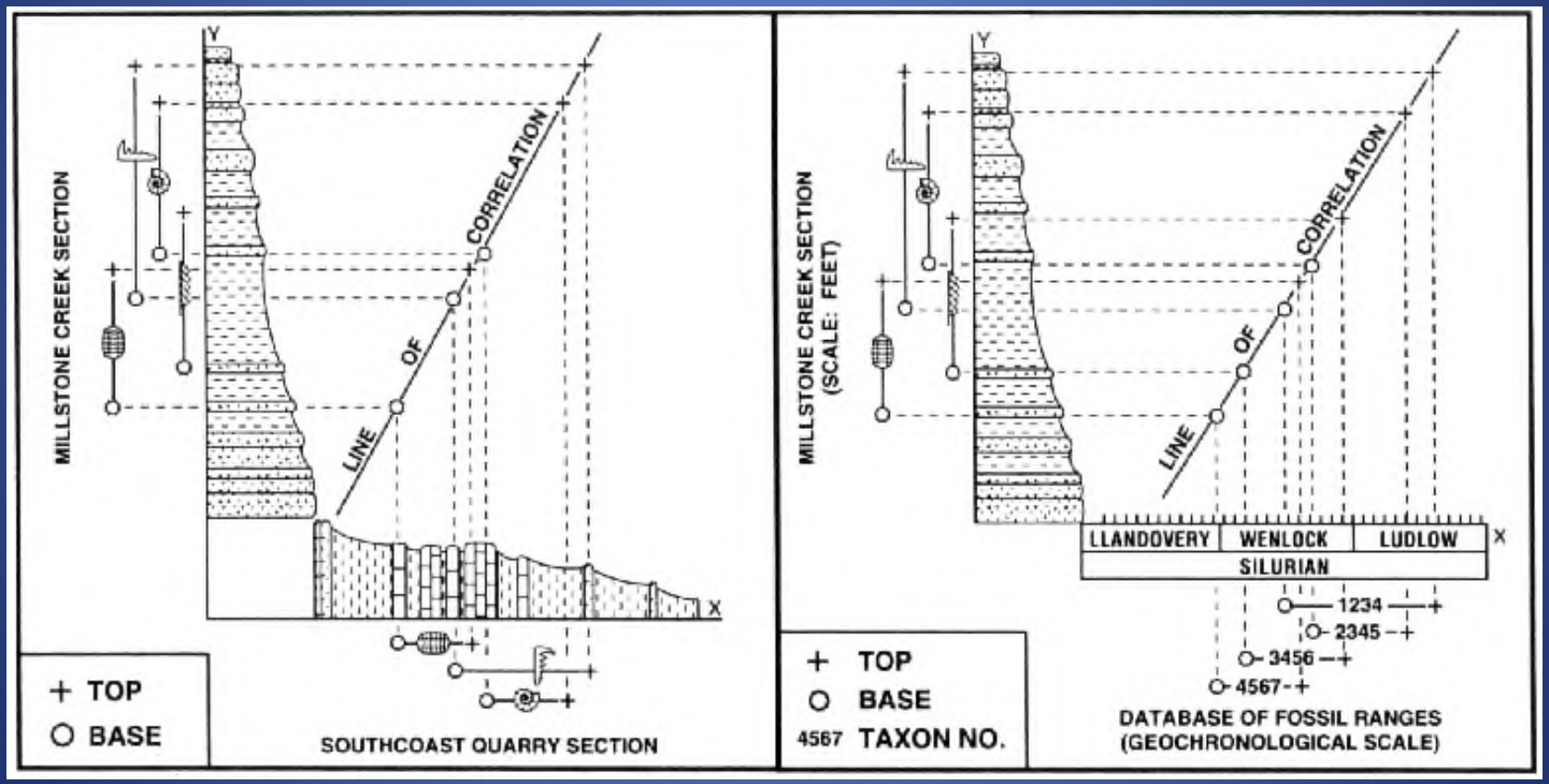


- Washington Post, 10/16/2015

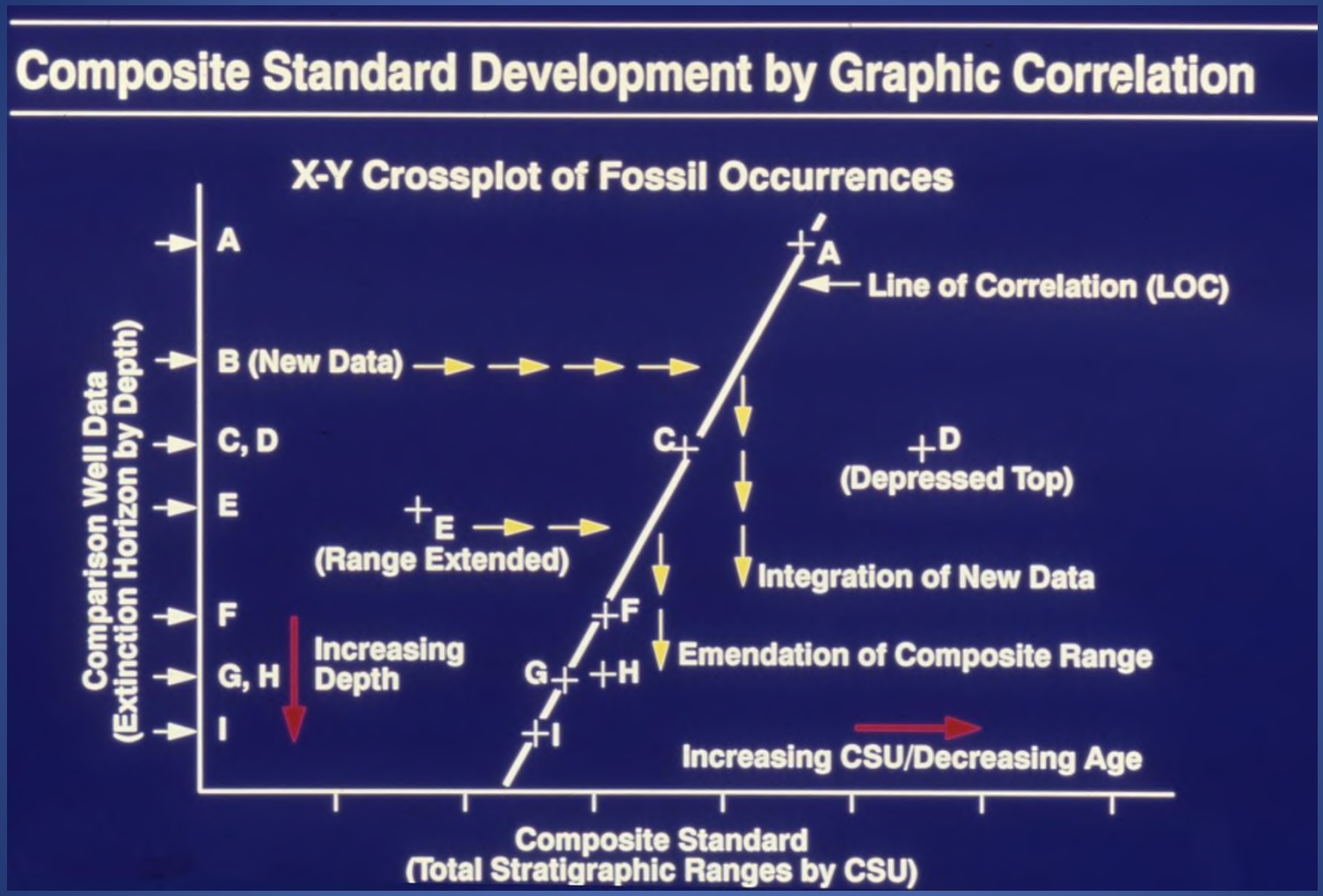
The “False Positive” and “False Negative” Dilemma



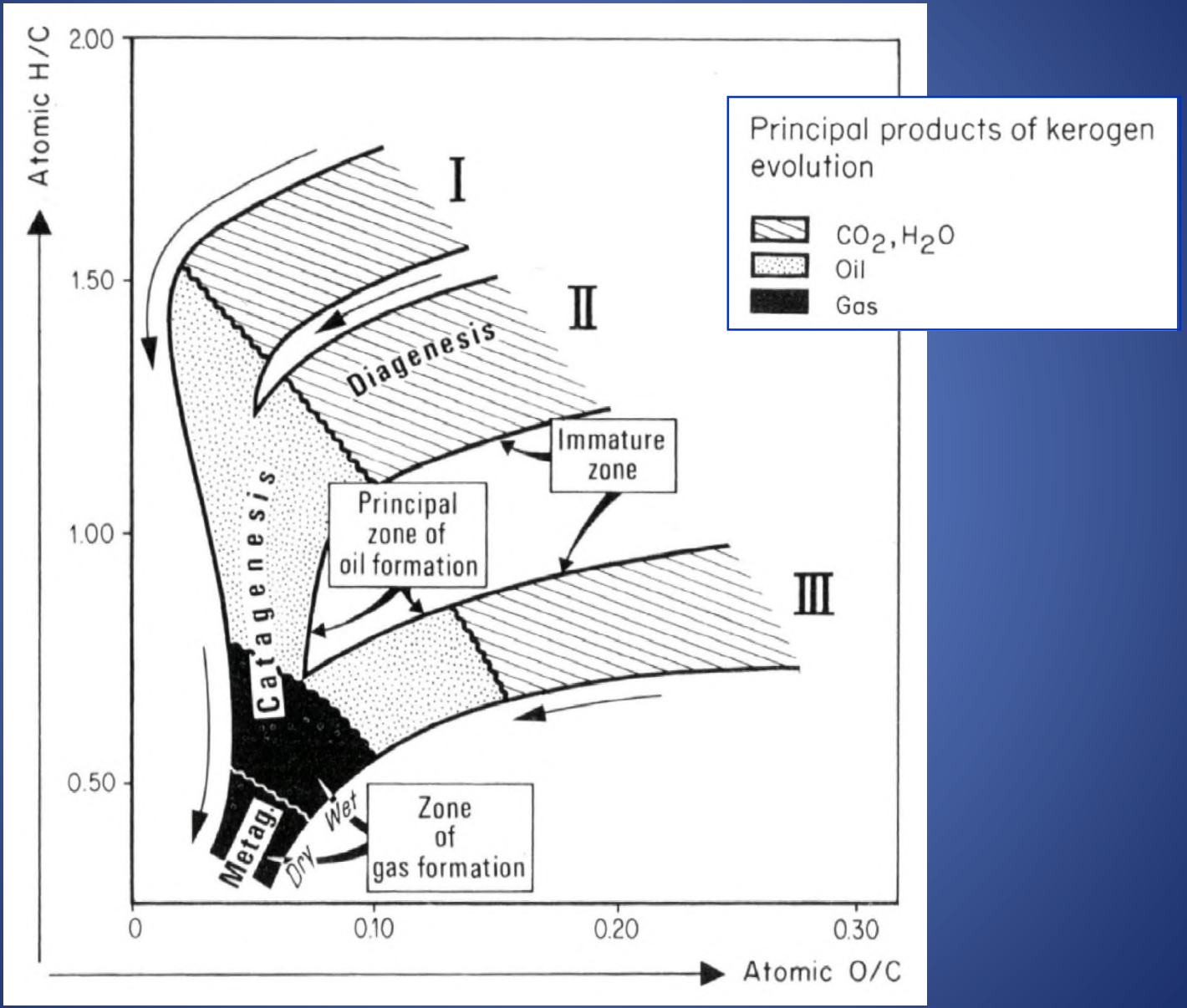
- Developing a Composite Standard by Graphic Correlation (Mann & Lane , 1995, SEPM, Spec. Publ. No 53)



Composite Standard Development by Graphic Correlation



Principal Products of Kerogen



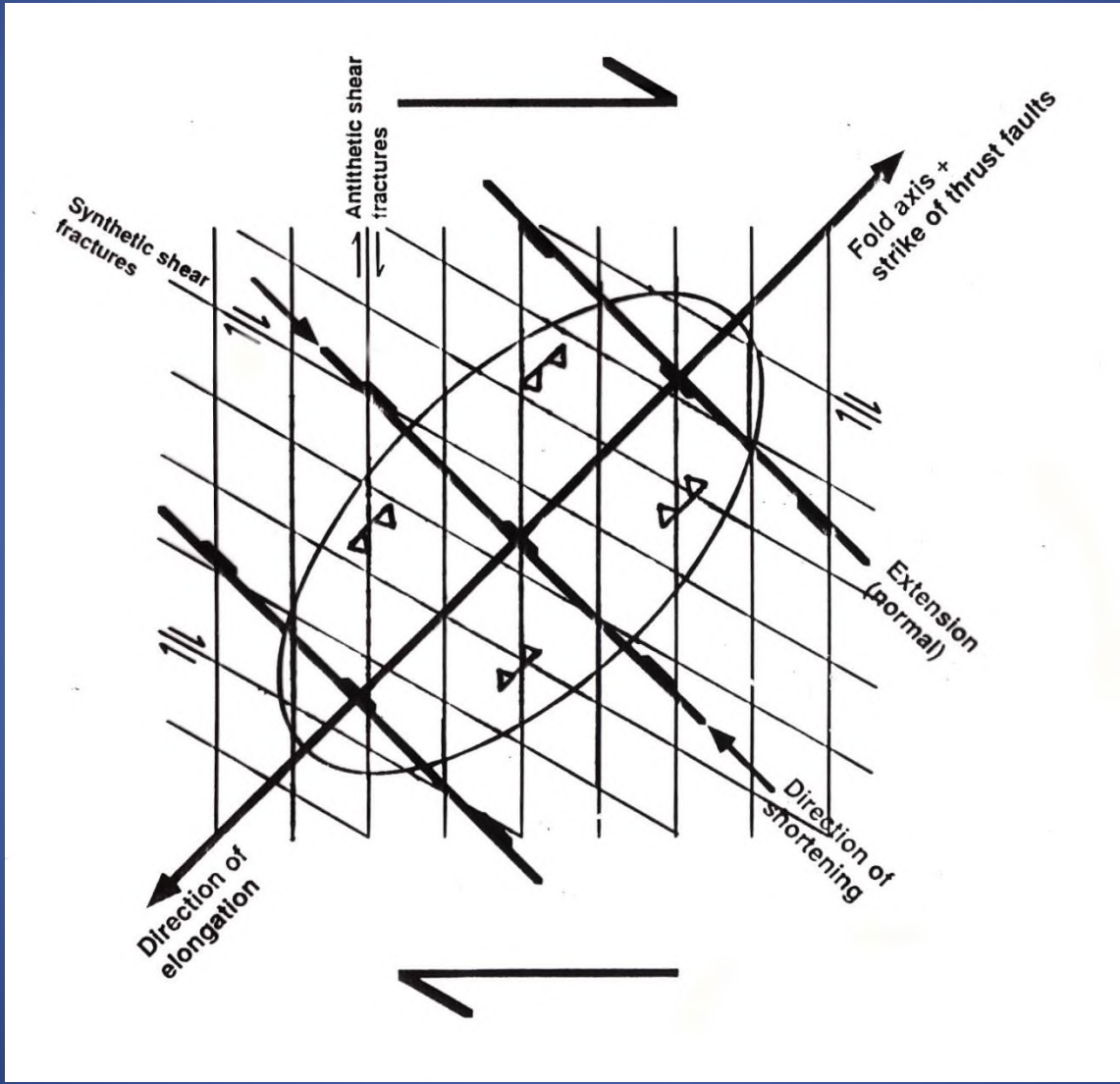
Arrhenius Equation

$$k = A_o e^{\frac{-E_A}{RT}}$$

Fraction of molecules With minimum energy for reaction

k	=	Reaction rate at Temperature T
A_o	=	Constant (frequency factor of collisions with right geometry)
E_A	=	Activation Energy
R	=	Gas Constant
T	=	Temperature

Basic Geometry of Strike Slip Faults



Dr. R. Lukman, Gen. Secretary of OPEC, a Leoben graduate!

Houston, May 2000

“China and the U.S. have each other by the throat”

(Former member Fed. Reserve board of Govenors L. Gramley, pers. comm.,2010)

CHINA DAILY VIA REUTERS

After the benches cleared for the second time in an exhibition game in Beijing, Hoyas Coach John Thompson III took his team off the court.

Beijing, Aug. 18. 2011… in 2019 global supply chains are being rebuilt avoiding PR China!!!!