The Next Cycle of HC Discoveries

Presentation
for
IV Seminario Recursos Geológicos
(Vila Real University)

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(i) The Next Cycle of HC Discoveries

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Foredeep Basins;

Folded Belts;

(viii) Examples:

Cusiana, Lombo East, Villeperdue, Peciko, Ben Berkin fields.

Contents (cont.)

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(i) Examples:

- Cusiana Field (Colombia);
- Lombo East Field (Angola);
- Villeperdue Field (France);
- Peciko Field (Indonesia);
- Ben Berkine (Algeria.

(viii) Suggestions:

a) Offshore Angola (Block 2 and 3);
b) North & Central Sumatra basins;
c) Offshore Cameroon (Douala basin);
d) SE Bolivian Foredeep;
e) Onshore Morocco

Abstract:

The chief natural laws are briefly summarised and depicted. Applying the available data base (OPEC, OGJ, Petroconsultants, BP review, World Oil and USDOE/EIA), few general hypotheses related to HC exploration and production can be advanced:

- Publishing reserves is a political act. There are several category of reserves (ex: in Norway, NPD recognises as many as 12 categories.
- Field growth (reserves appreciation) corresponds mainly to bad practices of reserves reporting.
- Technological progress lead to faster and cheaper production, but has not much impact on conventional reserves revisions. Technological progress is needed for unconventional resources.
- Oil price increase will raise unconventional resources not yet listed as reserves, but it does not increase conventional reserves.
- Cheap oil will peak soon in North Sea and Non-OPEC countries. For the world, it will peak around 2005.

Abstract: (cont)

- Excluding the Eastern deep water of the South Atlantic margin, where large fields (± 500 Mb) are likely (subsalt plays unexplored), the future short term reserves are those that in past:
  - ★ Have been missed
  - ★ Have not take into account.

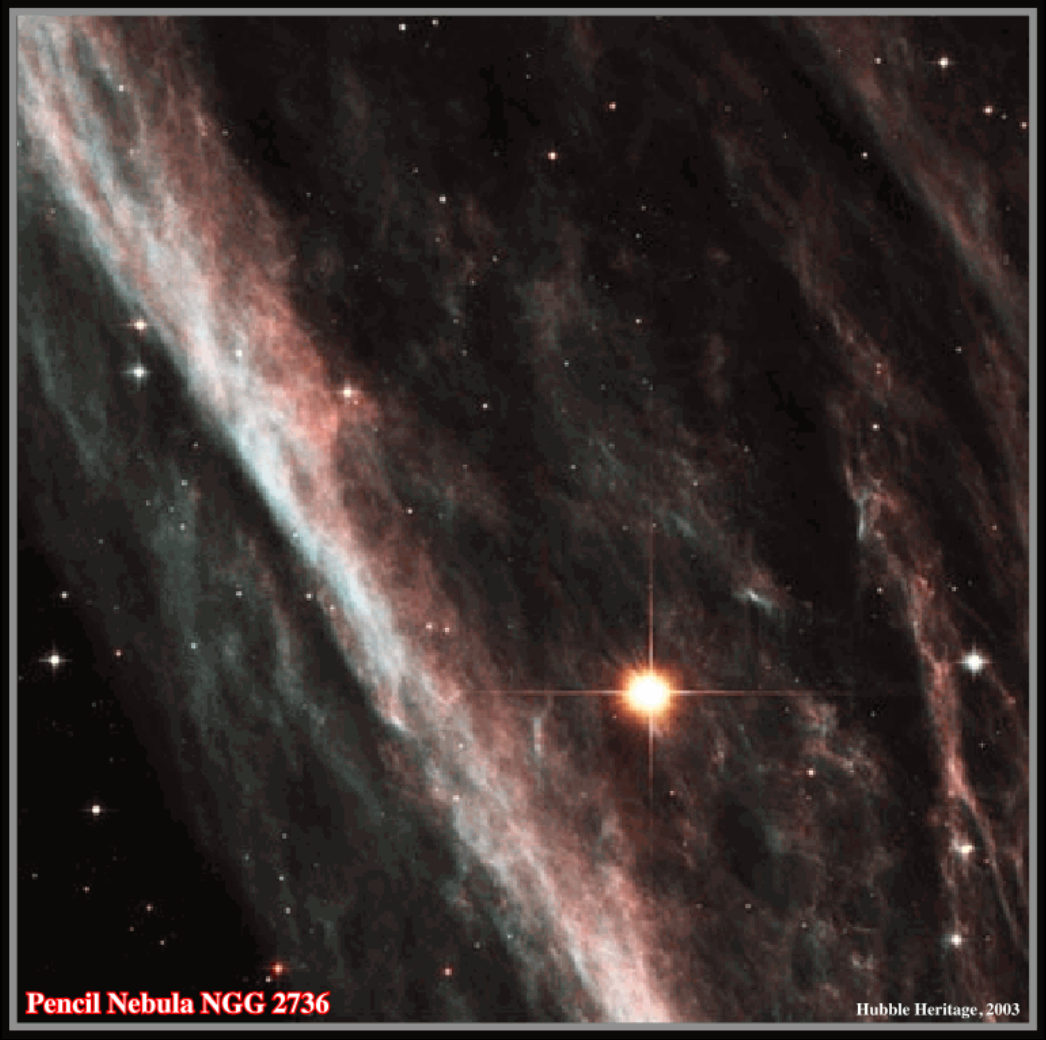
  Since 1990, these hypotheses have been corroborated (Cusiana, Lombo-East, Villeperdue, Peciko, Ben Berkine, etc.).
- Long term reserves will be chiefly associated with few foredeep basin and folded belts in which seismic data is whether impossible to acquire or useless (reflection free). Ex: Papua New Guinea, Andes, Rocky Mountains, Ural Mountains, Assam, etc.
- Future exploration requires a good data base and explorationists with an appropriate experience in all branches of exploration.

Examples of this type of exploration and suggestions for future international exploration are proposed.

Part I

Basic Principles

Nature is ruled by some basic Principles



Basic principles:

Inequality

Equality may exist at the starting line, but at the end there is usually only a winner. Inequality is the rule in Nature.

Self-Similarity

Natural objects have a fractal geometry.

Parabolic Fractal Distribution

Galaxies, earthquakes, oilfields, urban agglomerations, etc. present the same distribution (parabolic fractal).

Cyclicity

All natural events can be depicted by one or several cycles. Nothing is eternal. What is born will die. What goes up will come down. Sun, earth, mankind, civilisation will die.

Finiteness

Infinite (as perpetual growth) does not exist. Earth (as well Universe) is limited.

(cont.)

Gravitation

Everything is curved. Linearity exists only locally.

Life

Controlled by the principle of minimum action (Fermat-Maupertius law), minimum time (Snell's law), maximum room (Fibonacci series).

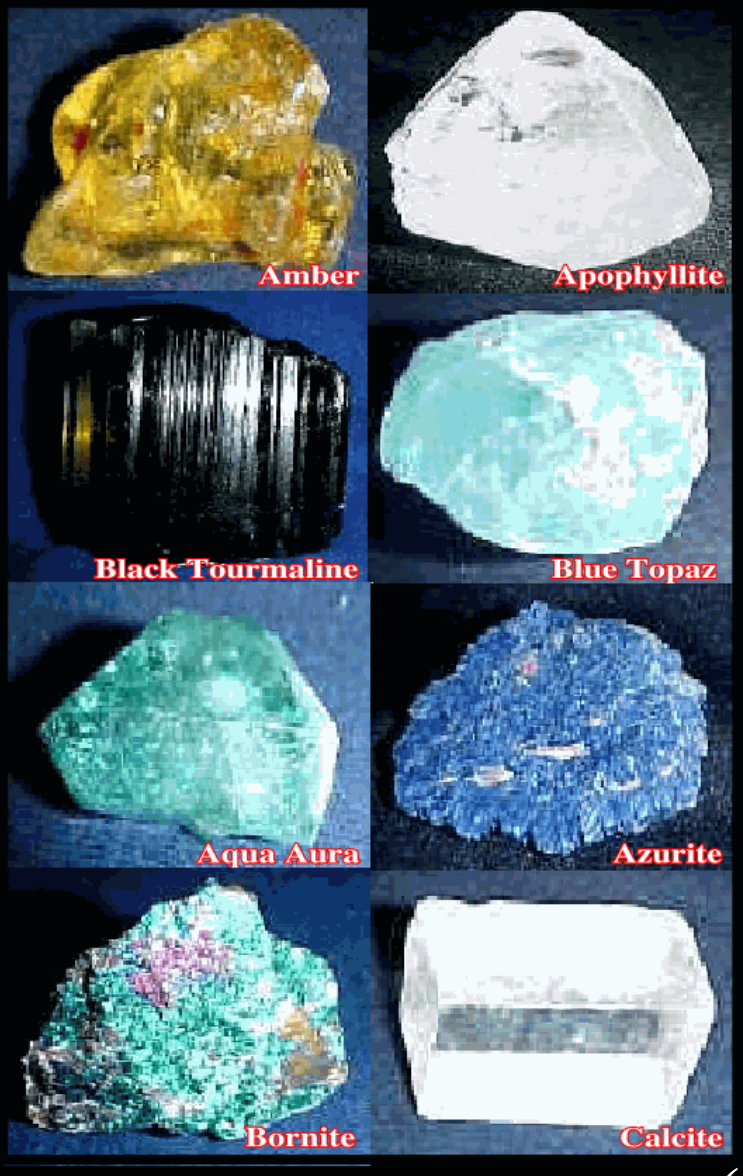
Determinism & Probabilism

In the nature, the matter has different behaviours when it is in conditions of equilibrium (determinism) or non-equilibrium (probabilism).

Symmetry (Central Limit Theory)

Symmetry is major characteristic of Nature. In probabilities, adding a large number of assymetric distributions gives a symmetrical normal distribution.

1) Inequality



(cont.)

CPE
(Consumption of Primary Energy)

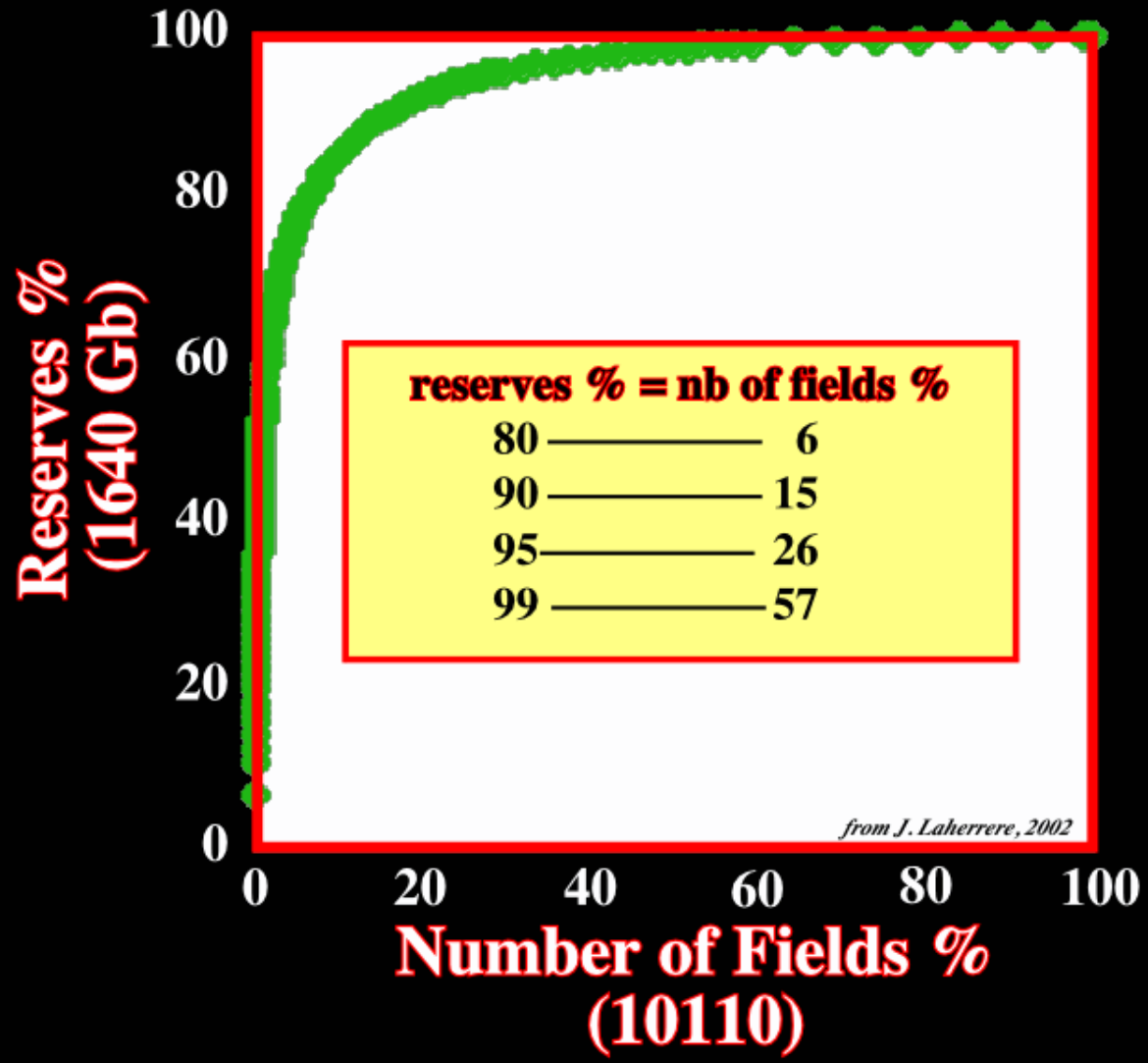
Region	CEP Gtep	Population G	CEP/capita tep
North America	2,5	0,31	8,1
Japon/Australia/New Zelande	0,7	0,15	4,7
Western Europe	1,8	0,52	3,5
ex-URSS	1,1	0,35	3,4
Middle East	0,4	0,17	2,4
South America	0,6	0,52	1,2
China	1,1	1,26	1
Asia (without China)	0,8	0,96	0,8
Africa	0,5	0,79	0,6
India	0,5	1	0,5
World	10	6	1,7

from CME, 2000

(cont.)

Reserves (%) & Number of Fields

(oustide USA & Canada)



(cont.)

2) Self-similarity

All explorationists know that a scale is absolutely necessary to interpret an outcrop (pencil or man) or a seismic line (h. scale, in meters, and v. scale, in seconds or meters). Without scale all proposed interpretations meaningless.

Why?

Self-similarity = Fractal

- A natural object or a geometric figure is fractal (Latin *fractus*, i.e. broken and not fraction) when:
  - ☑ Its parts have the same shape or structure so well that they have a different scale and be slightly deformed.
  - ☑ Its shape is either extremely irregular, either extremely interrupted or fragmented, what-ever is the scale of observation.
  - ☑ It contains "distinctive elements" which scales are very varied and covering a very wide range.

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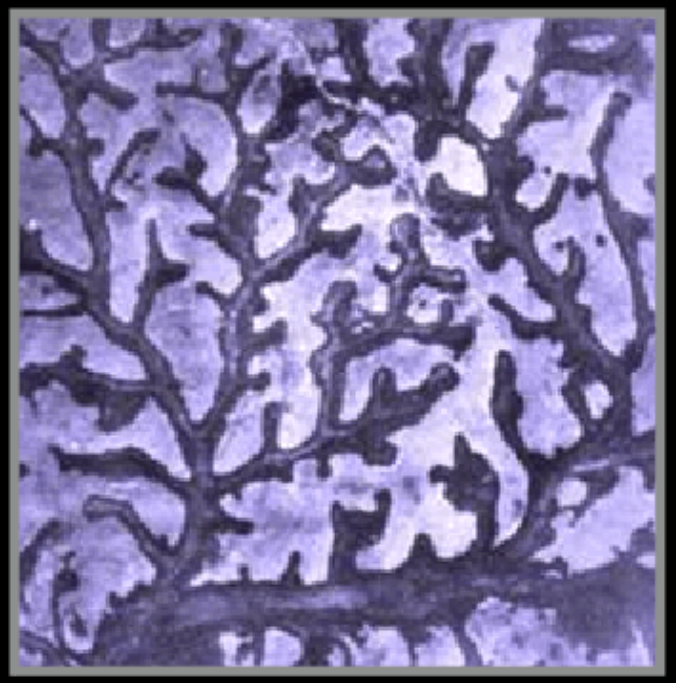
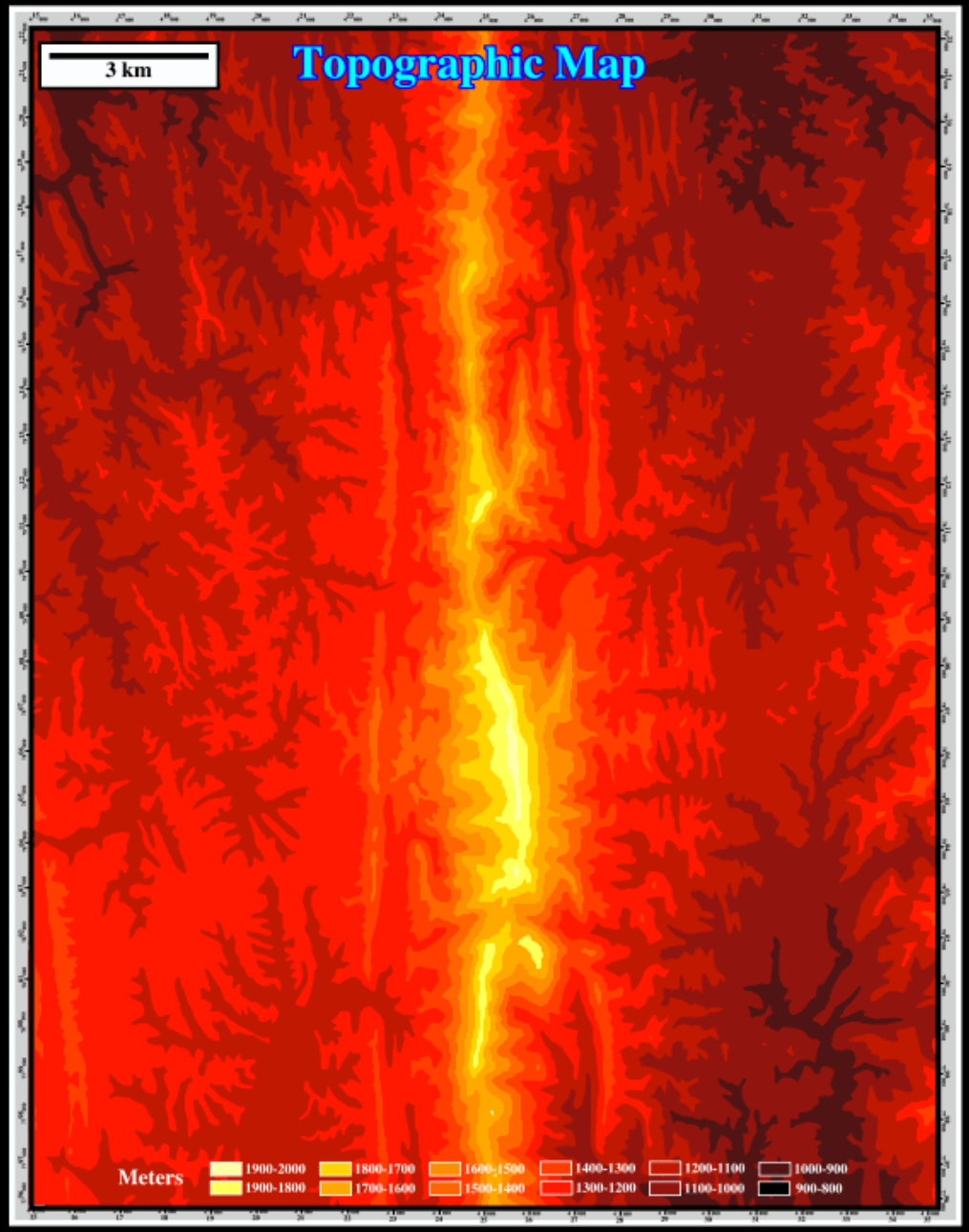
Mandelbrot's theory is particularly relevant to physical geographers since it deals in part with the spatial variability of natural phenomena, scales of observation, and resultant geometric properties



Fractal concepts are clearly predominant in the study of dynamic systems behaviour and dissipative systems (SOCs). (cont.)



In spite of the tectonic uplift, the Aquio fluvial basin (SE Bolivia), here illustrated by the topographic map, can be considered as a fractal object with D±1,3 (fractal dimension).

Fractal dimension is a number that quantify the degree of irregularity and fragmentation of a geometric set or a natural object and which is reduced, in the case of the objects of the Euclide's usual geometry, in their usual dimensions (point, D=0; line, D=1; plane, D=2; cube, D=3).

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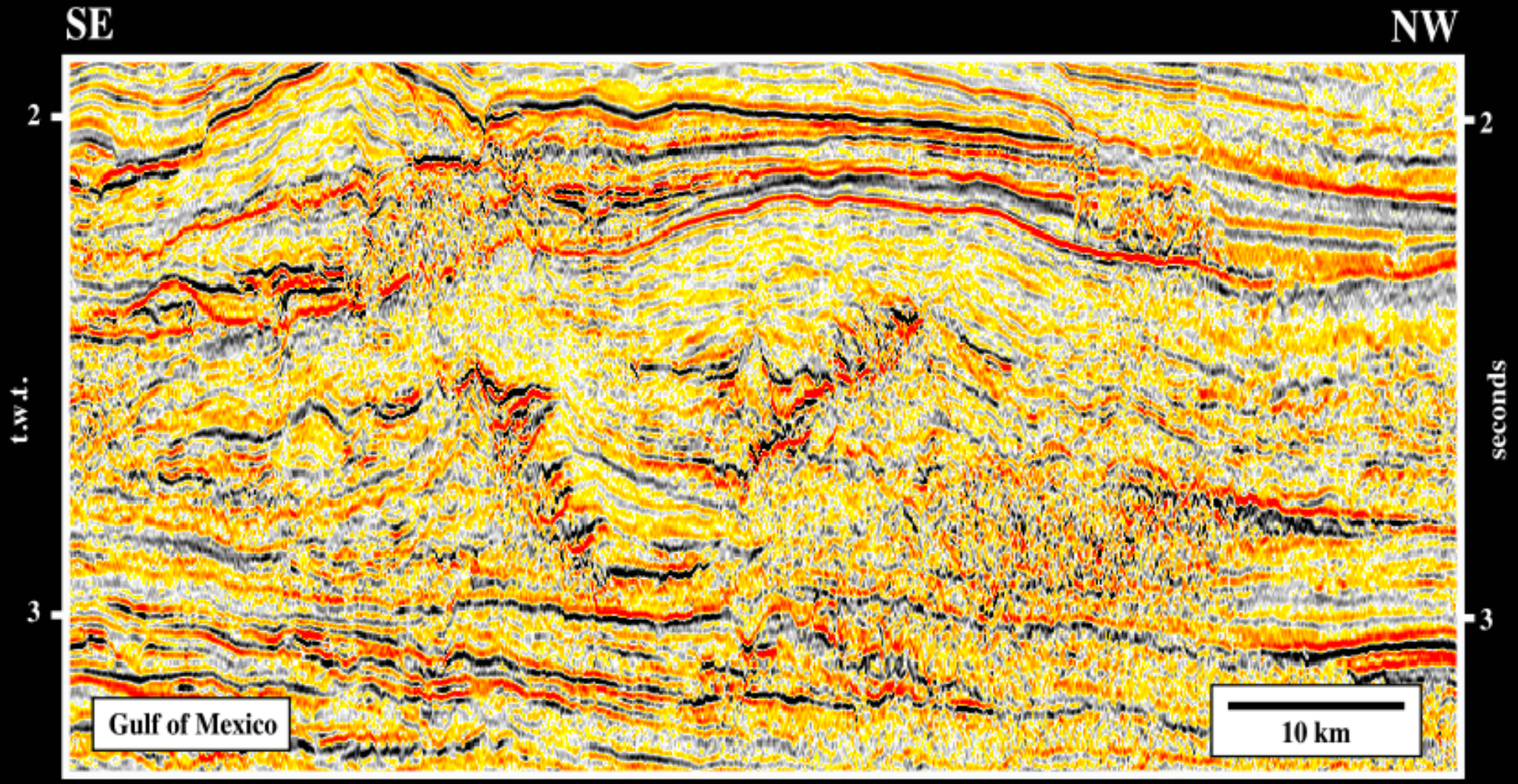


Notice the self similarity of the channel-leveed complexes

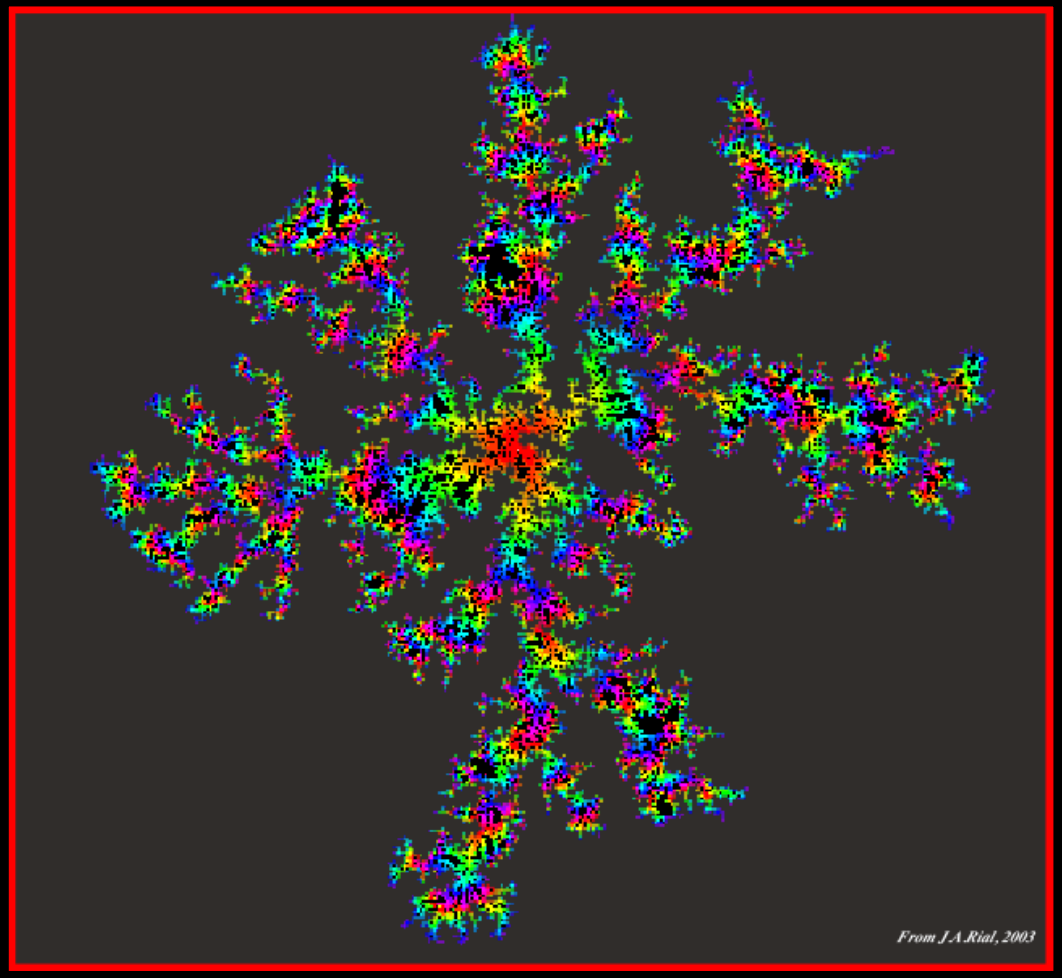
(cont.)

It is clear that the dimension fractale of the relief is not the same everywhere on Earth. But it rarely falls below 1,1 or overtake the brownian value 1,5 (Mandelbrot, on 1975).

3D View of SE Bolivia

(cont.)

- **Nature** is characterised by self-similarity, that is to say, a part is similar to the whole (ex: cauliflower, crystals, etc).



Simulation of crystal growth. The fine structure of the "crystal", it is self-similar indeed.

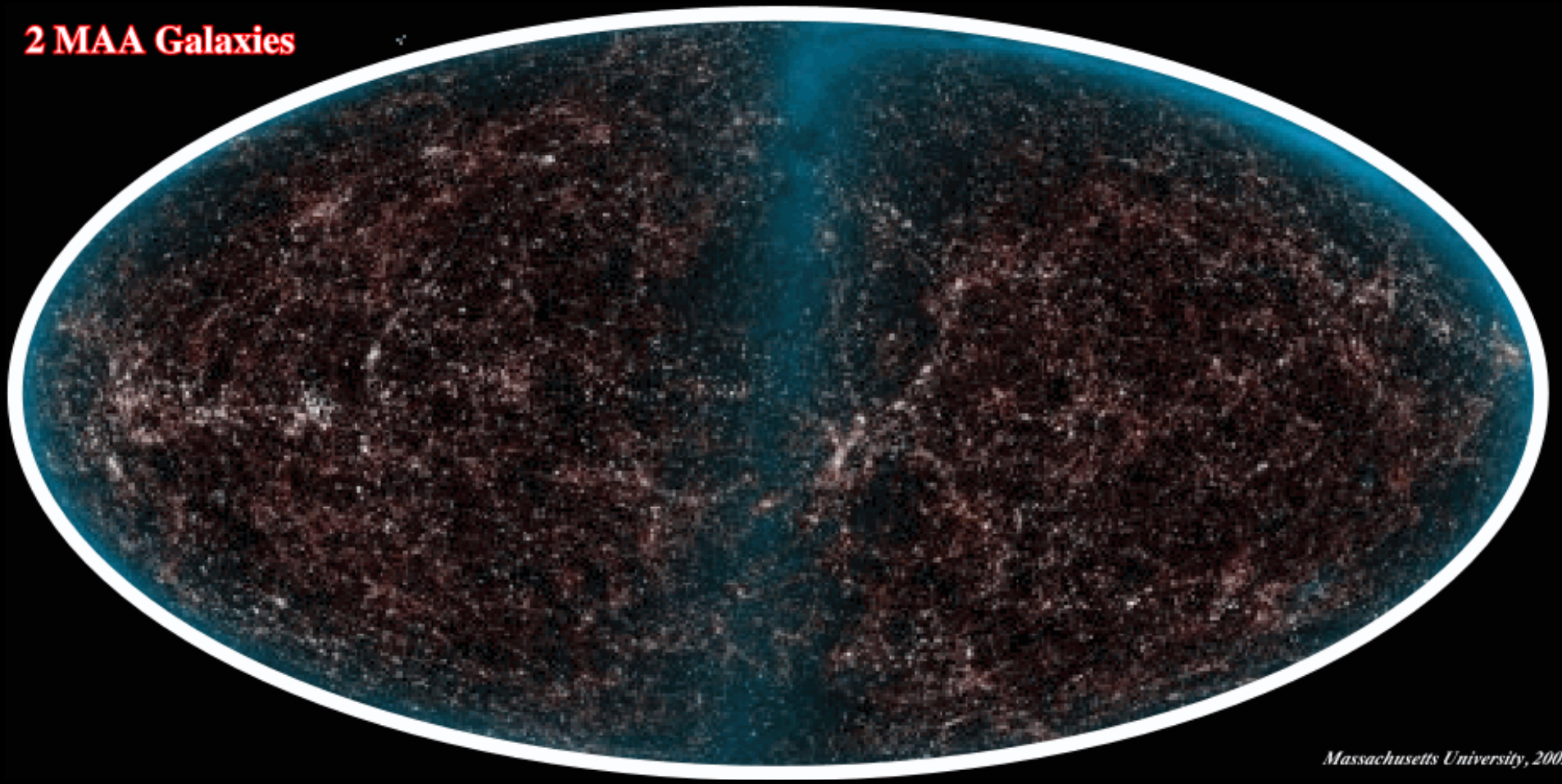
(cont.)

3) Fractal Distribution

- Natural objects or natural events when listed in decreasing size and plotted on a log-log format with size against rank show parabolic fractal distribution:
  - Galactic intensity,
  - Town sizes,
  - Reserves,
  - Field sizes,
  - HC accumulations within a given PS, etc..

(cont.)

2 MAA Galaxies



In this infrared view of the entire sky, blue represents close and bright stars in the Milky Way. It also reveals the distribution of the galaxies beyond the Milky Way, presenting galaxy clusters and superclusters as filamenets throughout the image.

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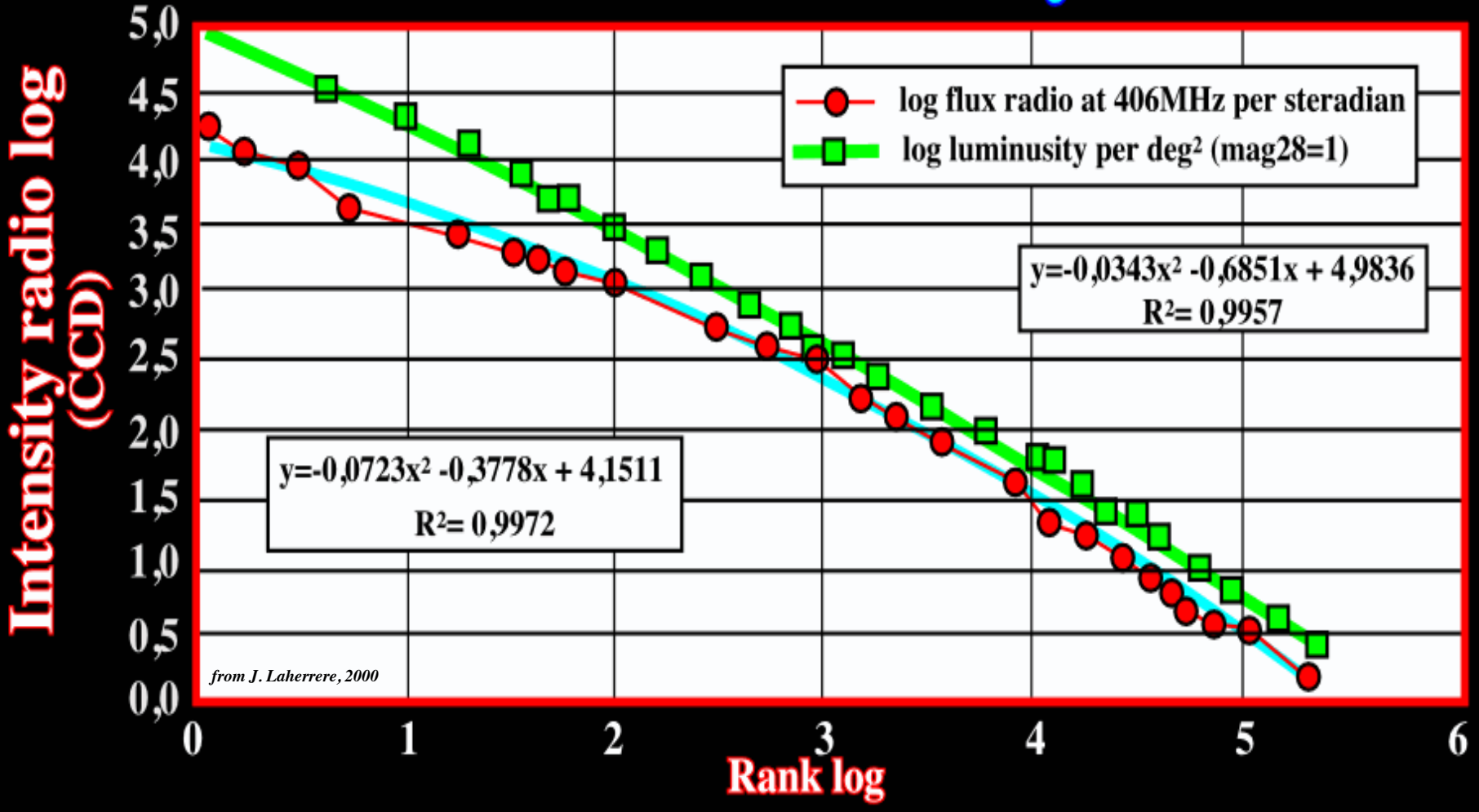
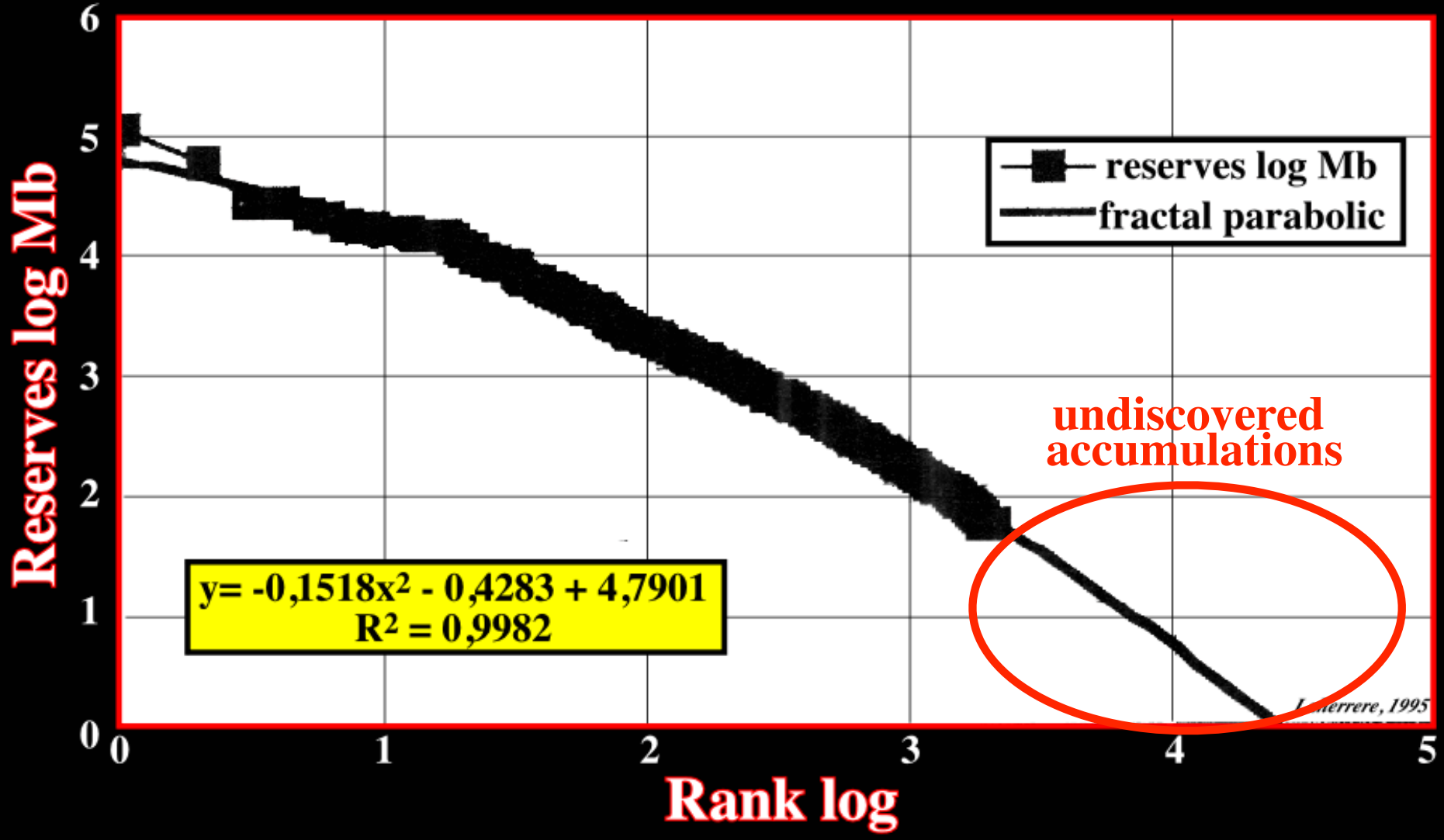
Galactic Intensity



The principal models to describe the distribution of natural events will be discussed later " Model to Assess Oil & Gas (discoveries & production)". (cont.)

Fractal Parabolic



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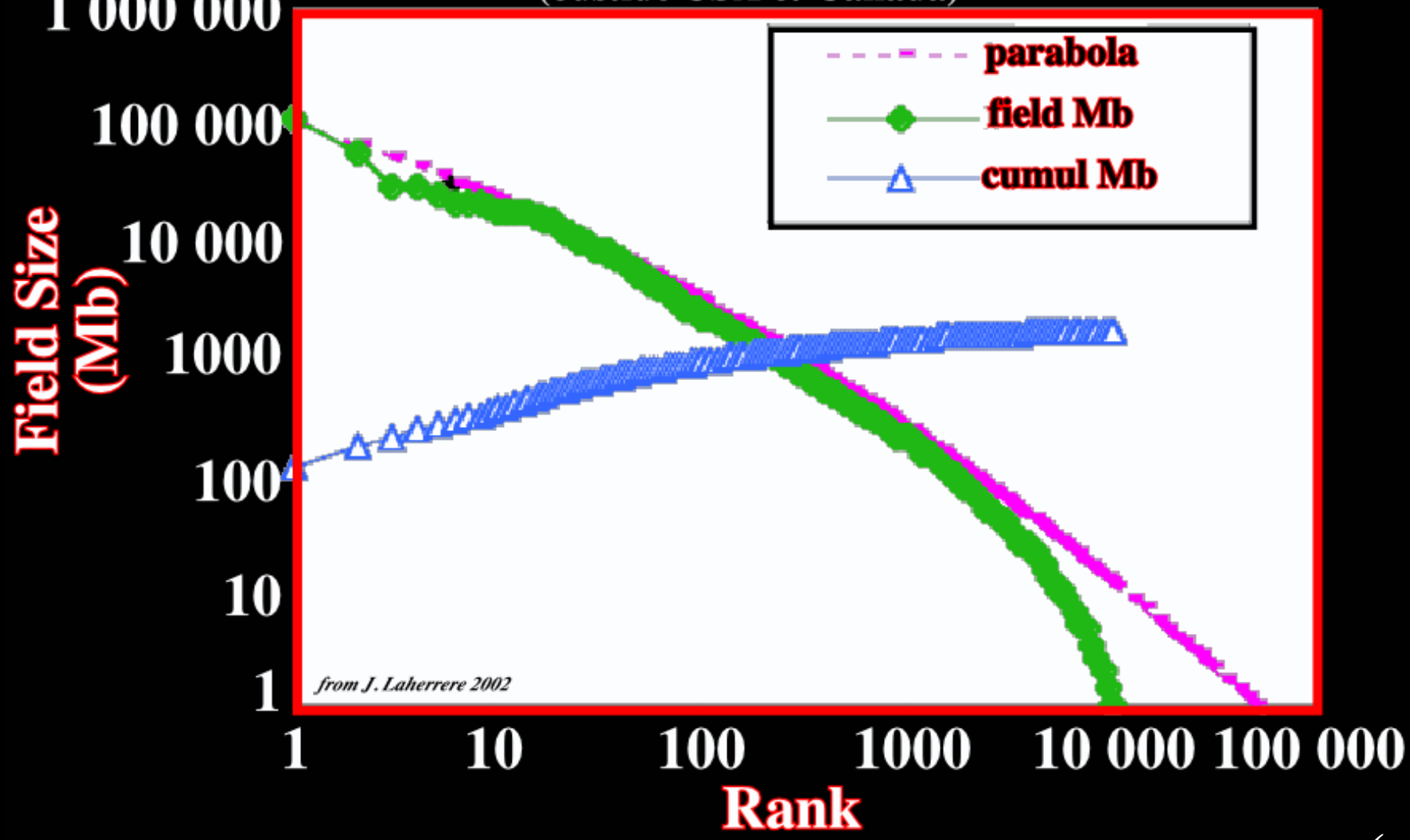
Oil Fields Size

Parabolic Fractal

(oustide USA & Canada)



(cont.)

Late Cretaceous Monte Cassio Flysch (Northern Apennines)

In turbidite deposition, the plot of the lobe thickness against rank, on a log-log format, shows a parabolic fractal distribution.

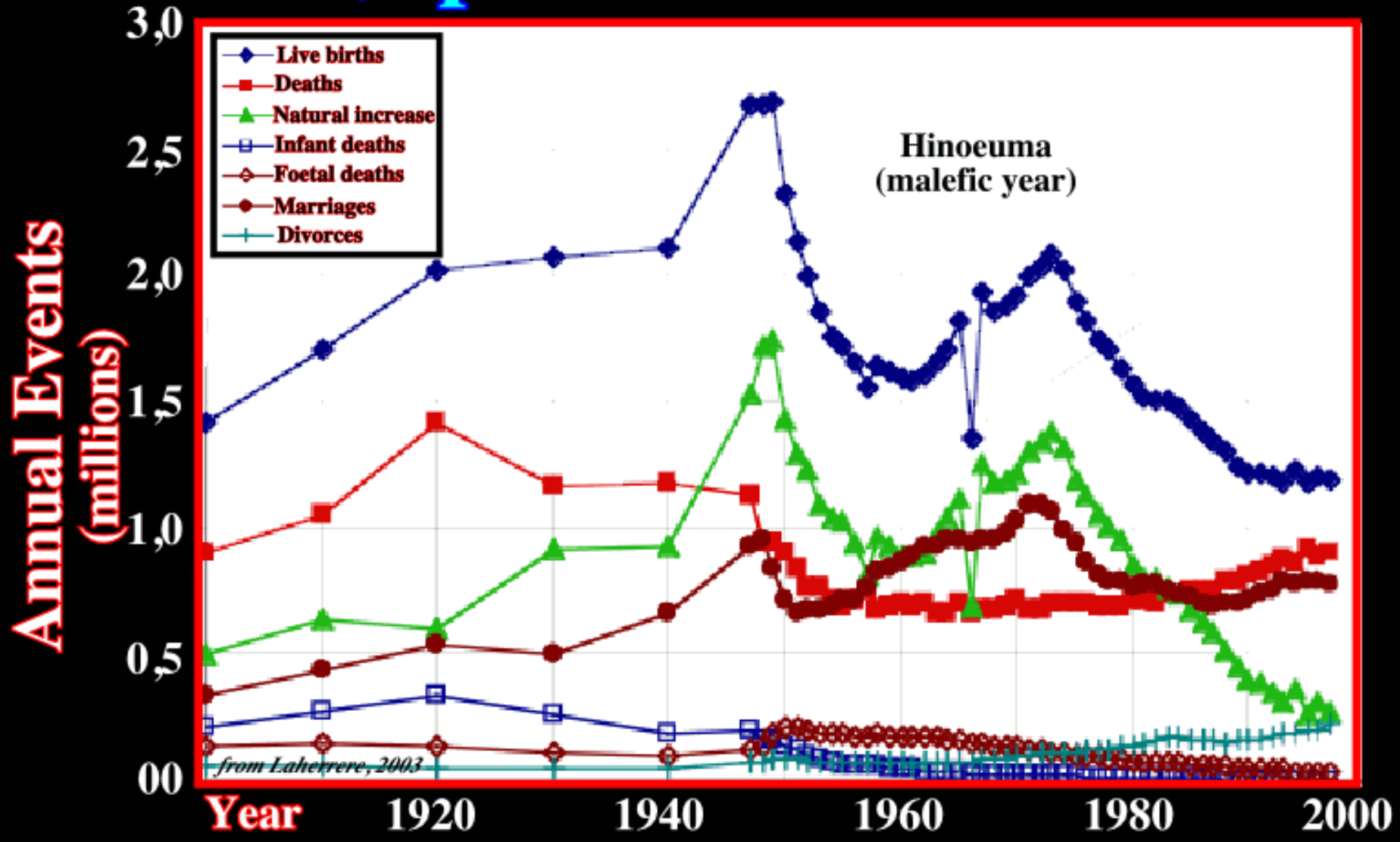
(cont.)

4) Cyclycity (events vs time)

All natural events can be depicted by one or several cycles.

(cont.)

Japan Annual Events



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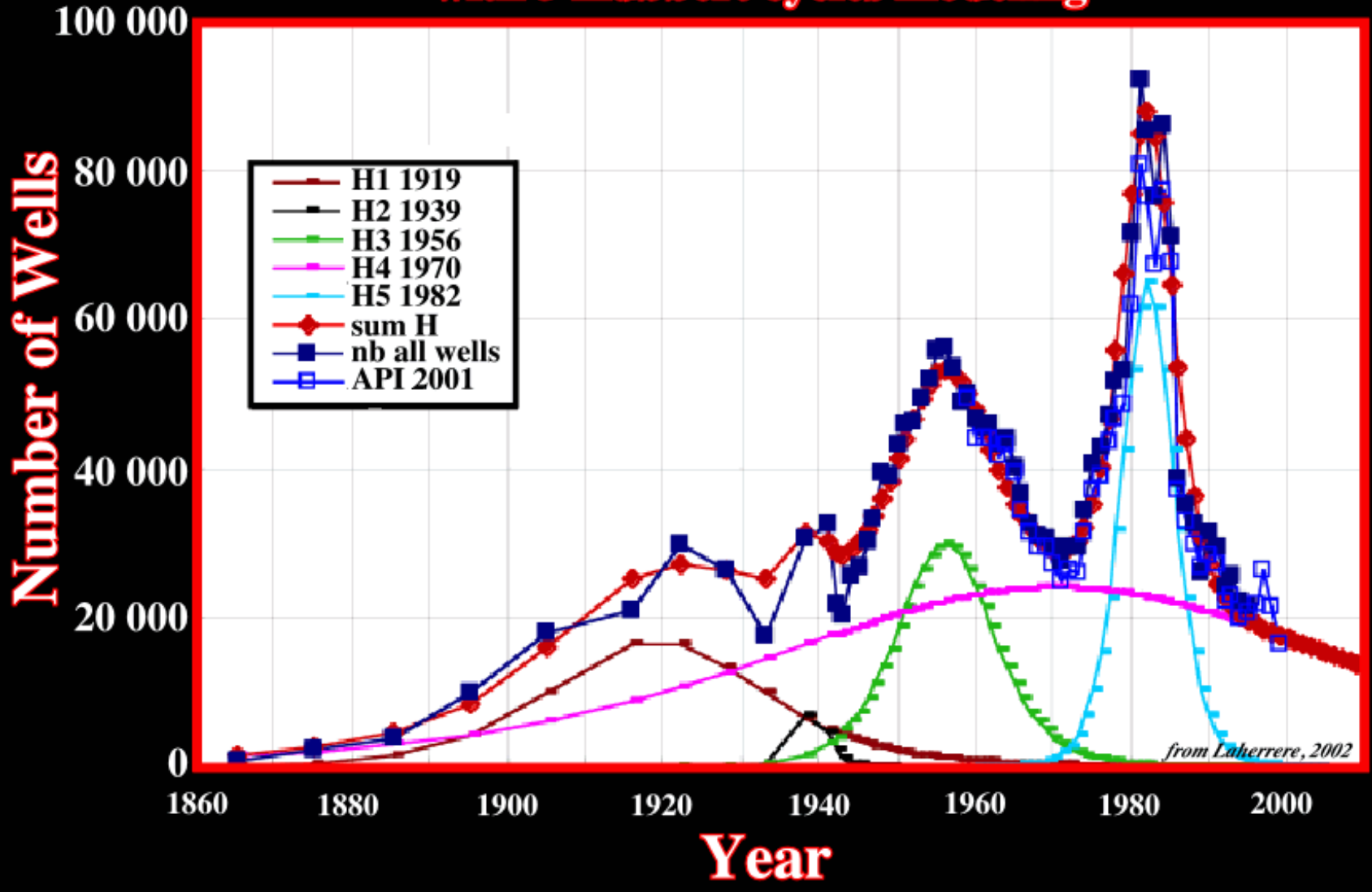
USA Drilling (all wells)

with 5 Hubbert cycles modeling



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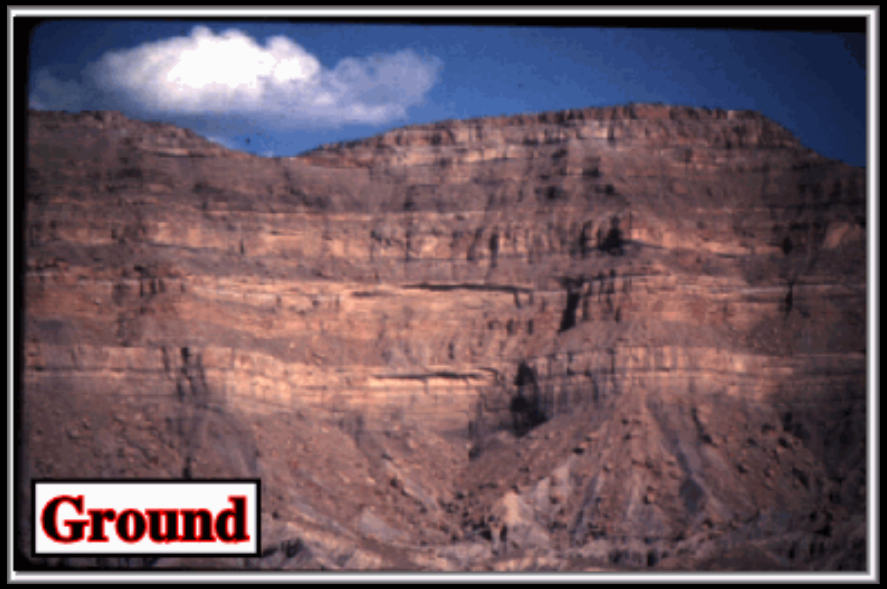
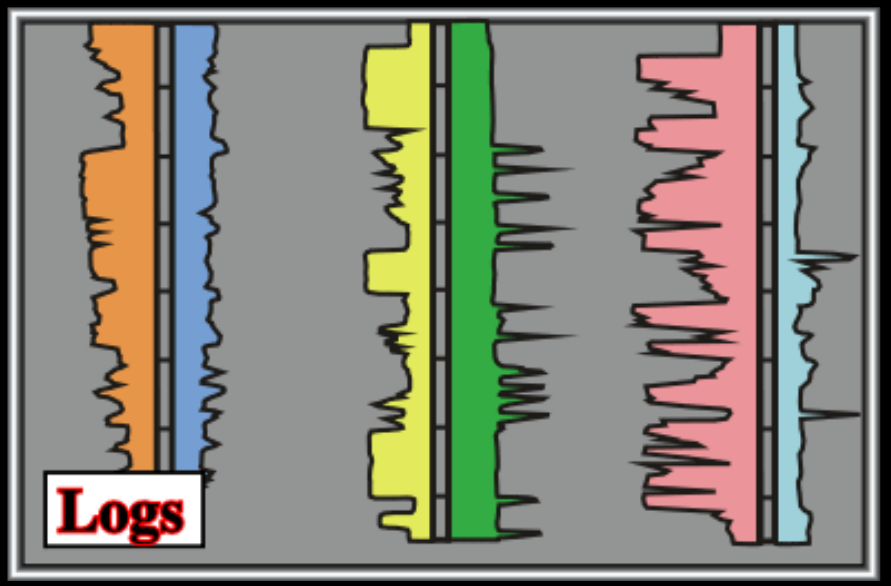
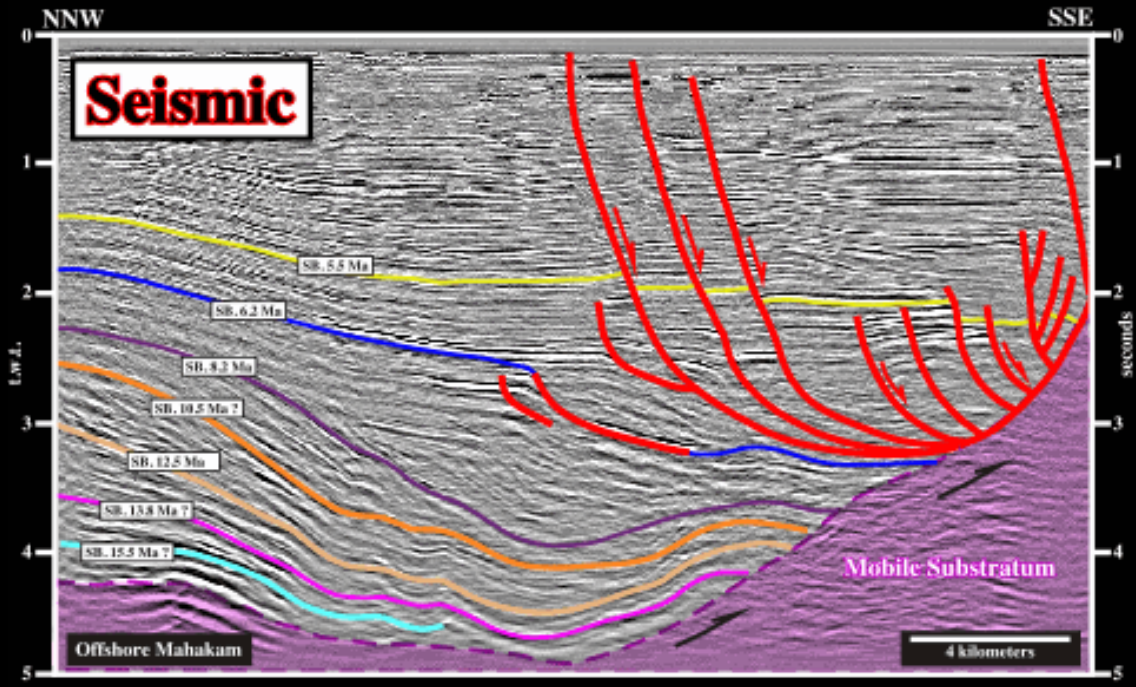
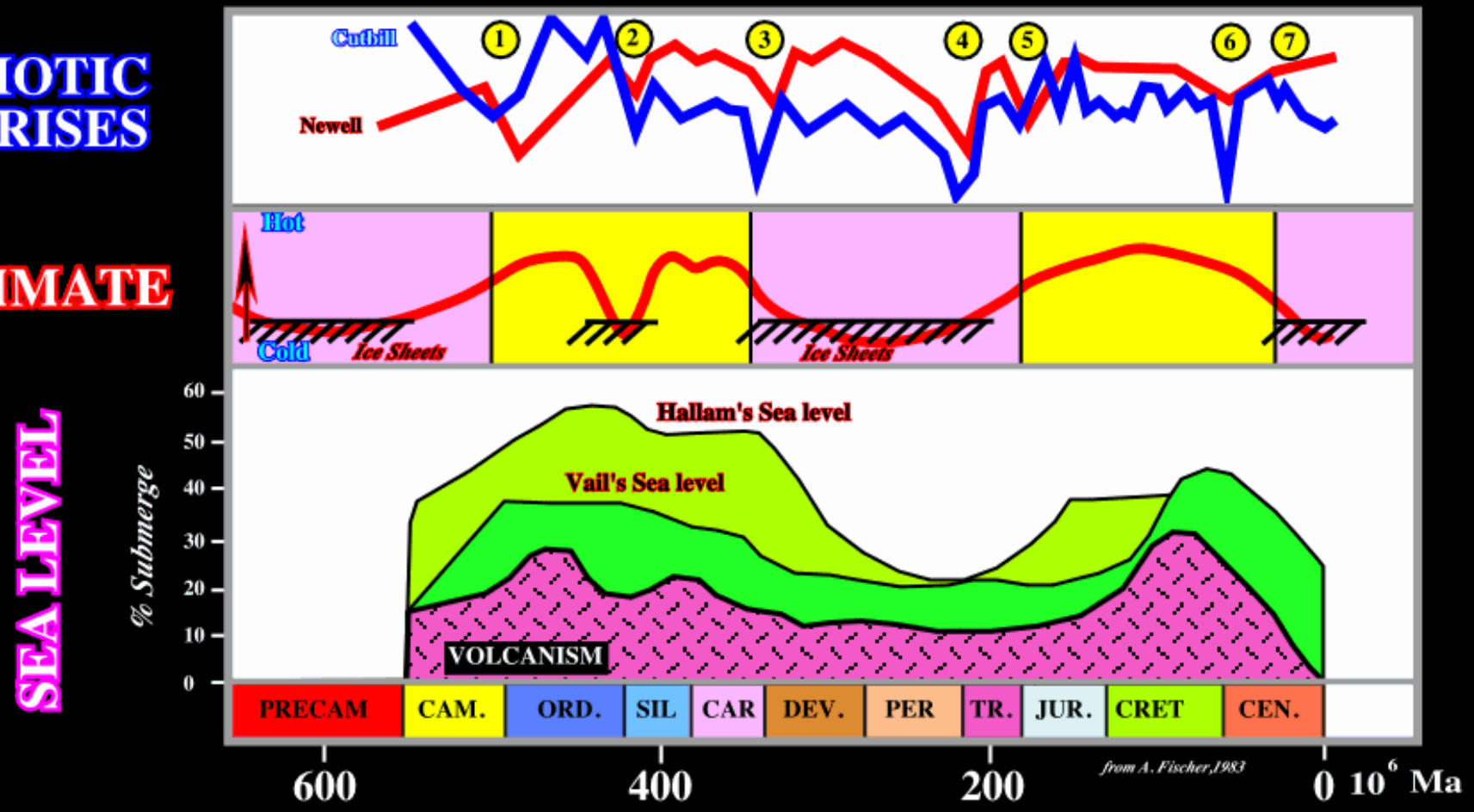

Ground


Logs


NNW
SSE
Seismic
SB. 5.5 Ma
SB. 6.2 Ma
SB. 8.2 Ma
SB. 10.5 Ma ?
SB. 12.5 Ma
SB. 13.8 Ma ?
SB. 15.5 Ma ?
Mobile Substratum
Offshore Mahakam
4 kilometers
t.w.t.
seconds

(cont.)

Biotic Crises, Climate, Long term Sea Level Changes & Vulcanism



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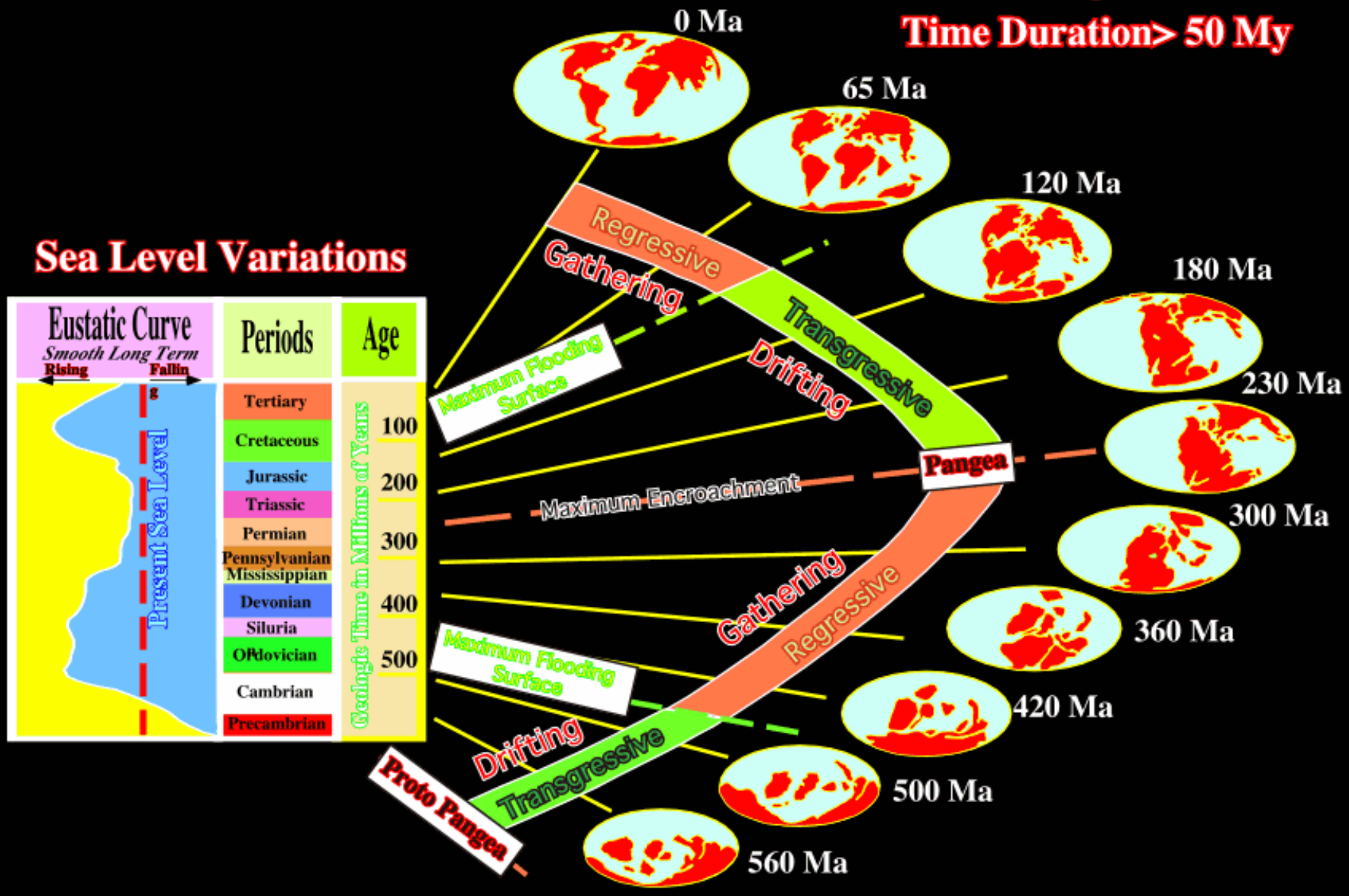
Continental Encroachment Cycles



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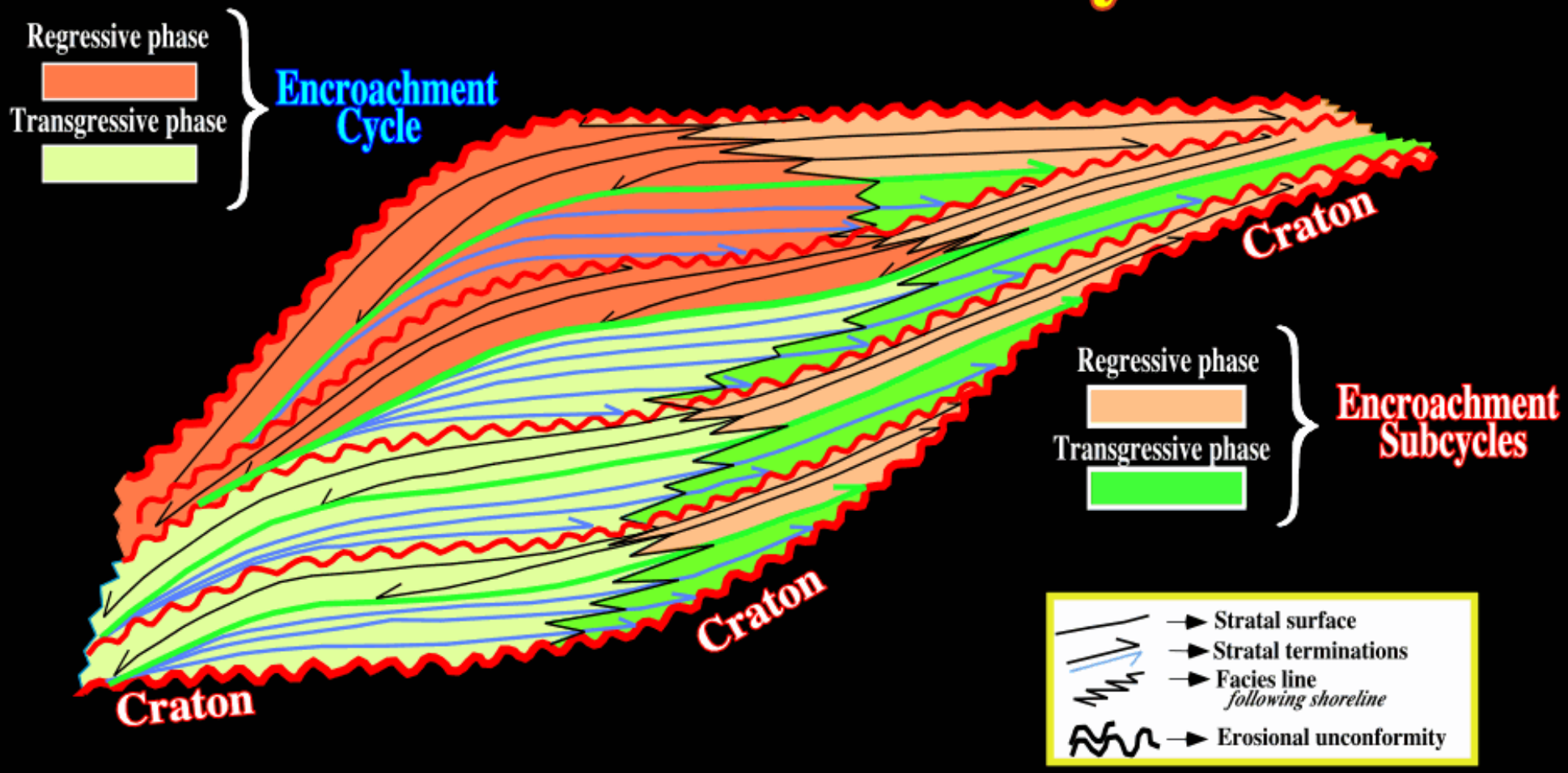
Encroachment Subcycles



Encroachment Subcycles are characterized by Major Downward Shifts in Continental Encroachment.

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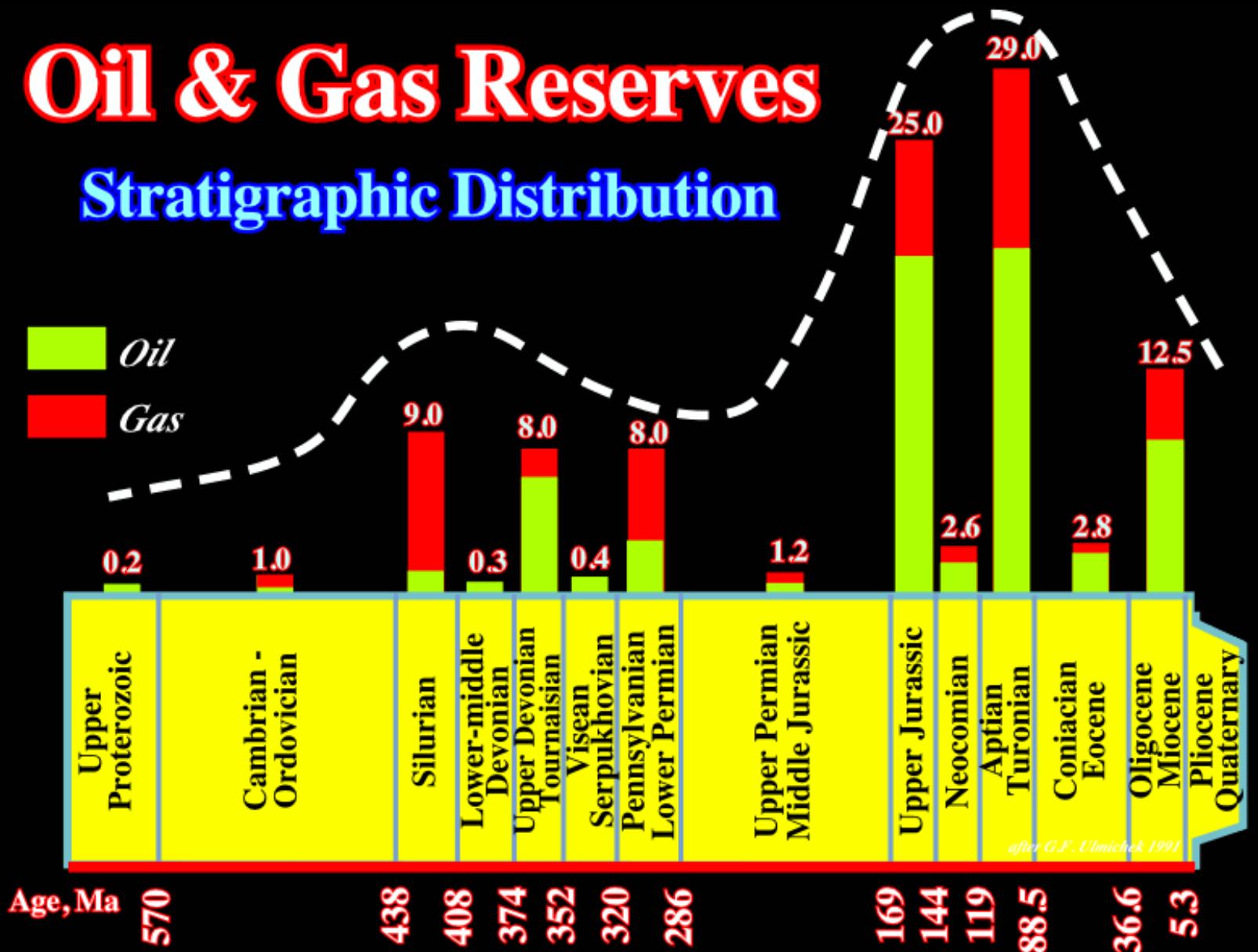
Oil & Gas Reserves

Stratigraphic Distribution



Percent of world's original petroleum reserves (BOE) generated by source rocks of a stratigraphy interval

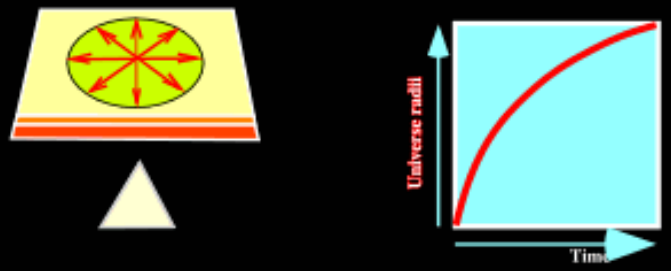
(cont.)

5) Finiteness

Three spaces are possible in Relativity, however the more likely is the one with positive curvature (2)

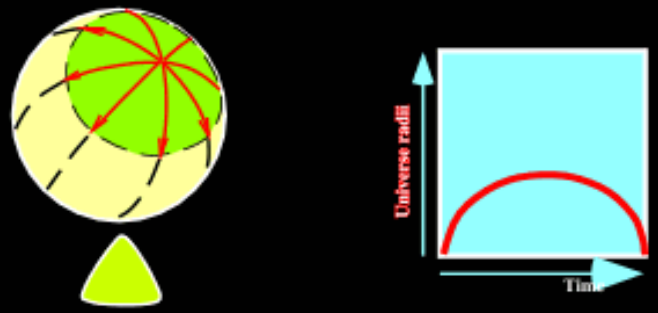
1) Nul curvature

Flat Universe



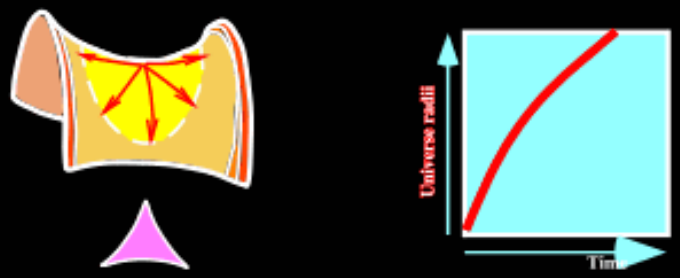
2) Positive curvature

Closed Universe



3) Negative curvature

Open Universe



(cont.)

In the Nature, there is no permanent growth, that is to say, all which is born, has to die, or all which rises, has to come down again.

Suppose a bacteria doubling every 30 minutes. After one week all Solar System will be filled, and after 11 days all Universe will be filled.

Let's see what that means in mathematical terms

(cont.)

H.E.A.T. Switzerland

Let's suppose this natural distribution:

2, 4, 6, ?, ?, ?

rank: 1,2,3,.....n-2, n-1, n

value: 2, 4, 6,.....N-2, N-1, N

There a a large number of solution as:

2, 4, 6, 8, 10, 12, 14, 16	N=2n or N=(N-1)+2
2, 4, 6, 10, 16, 26, 42, 68	N=(N-1)+(N-2)
2, 4, 6, 8, 10, 12, 14, 16	N=2(N-1)-(N-2)
2, 4, 6, 6, 0, -18, -54, -108	N=3(N-1)-3(N-2)
2, 4, 6, 4, -14, -76, -234, -556	N=4(N-1)- 9(N-2)

Occam's razor suggests the simplest, i.e. minimum complexity

2, 4, 6, 8, 10, 12, 14, 16 N=2n

But (cont.)

In Nature, too simple is often false:

Continuous growth is impossible in Nature

a) Principle of minimum action (Fermat-Maupertuis),
b) Principle or minimum time (Snell's Law),
c) Principle of maximum room (Fibonnacci Series).

The series 2, 4, 6, ?, ?, ?, has a beginning and grows, in life, it should peak and decline (negative values do not exist). The simplest natural answer is

2, 4, 6, 6, 0 $\qquad$ $N=3(N-1)-3(N-2)$

Therefore, the same happens with oil production, remaining reserves, oil discoveries,

(cont.)

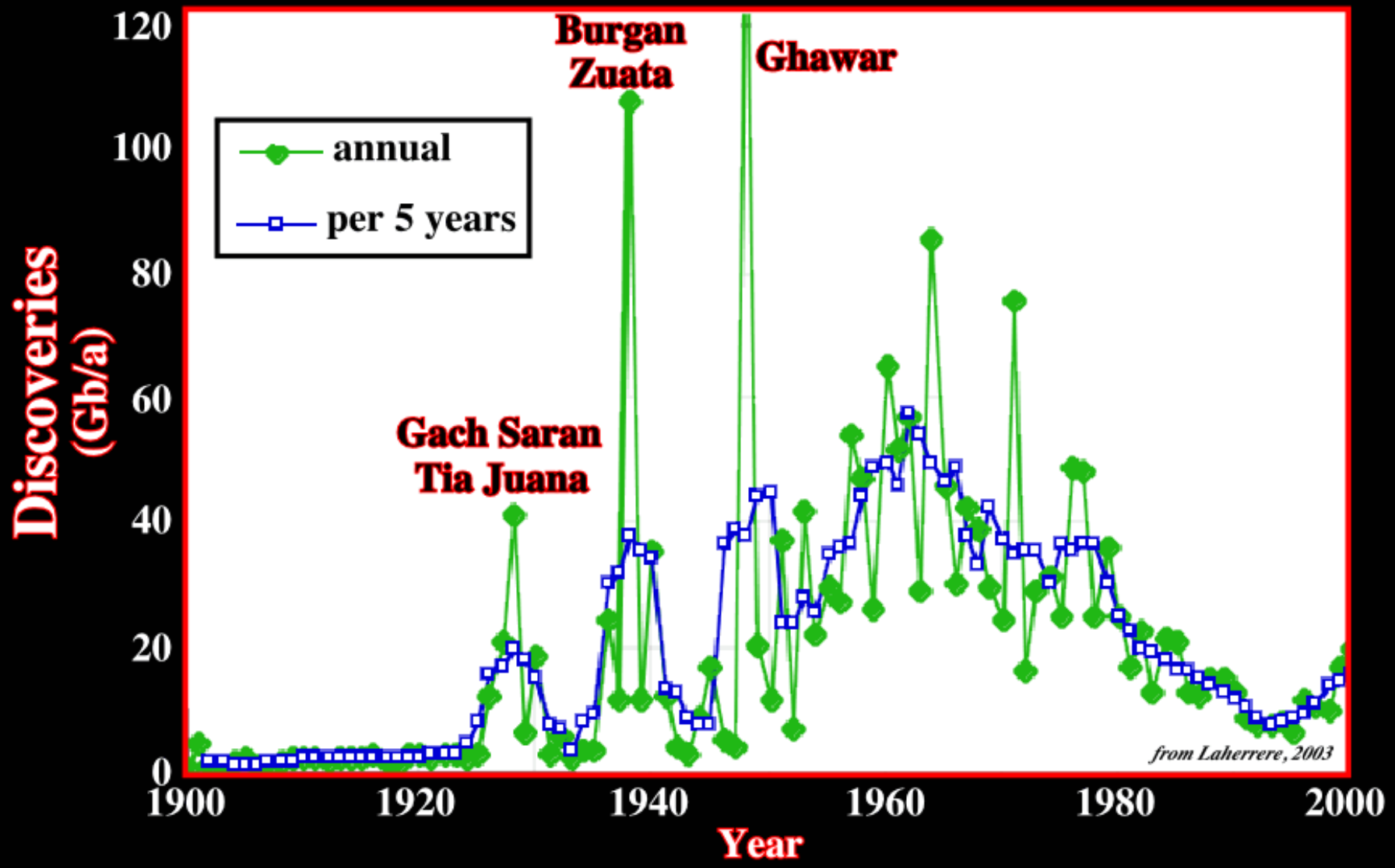
Economic growing is presented by politician as the medicine to world's problems.

Unfortunately, such a medicine is chiefly based on cheap oil, which erroneously still is supposed drowning the Earth.

The bad reporting by the IEA in 1998 led to the « missing barrels » (600 MB) between supply and demand, giving a false abundance of oil and the low price of 10$/b.

(cont.)

World: Discoveries Oil+Condensate



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- Civilisations (Maya, Greek, Roman, etc.) peaked and declined.

- Europe population have peaked and declines.

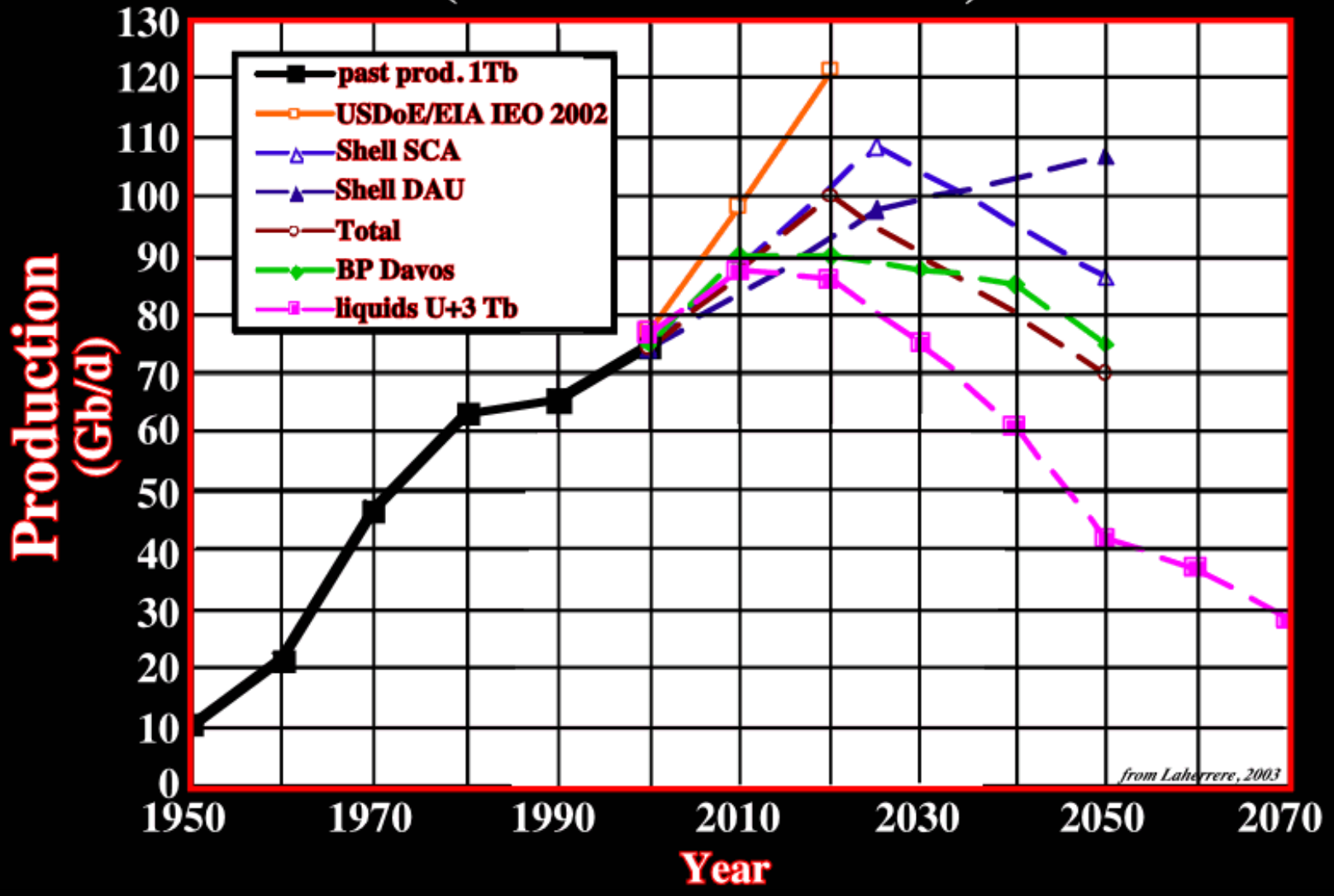
- The western civilisation will decline in few decades because its fertility rate is falling and will be replaced by other civilisation.

Oil production has peaked in USA and it will peak again in the world after the first peak of 1979. Then it will decline.

(cont.)

World Oil Discoveries

(different scenarios)

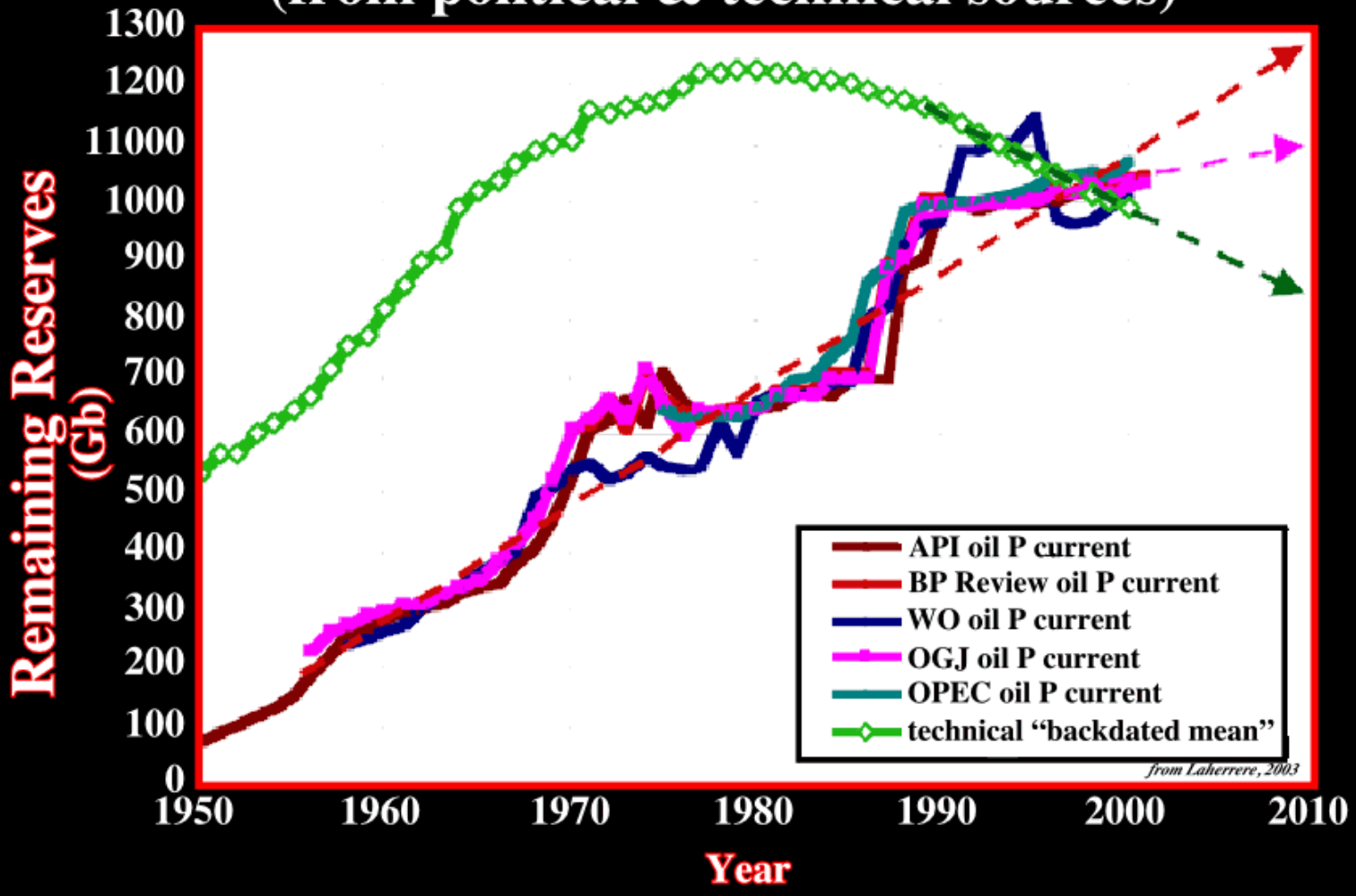


Later, we will see how to asses future oil & gas production.

(cont.)

World: Oil remaining Reserves

(from political & technical sources)



The USA companies follow the Securities and Exchange Commission which, contrariwise to the all other countries, publicates only proved reserves (financial data) and not probable reserves (technical data).

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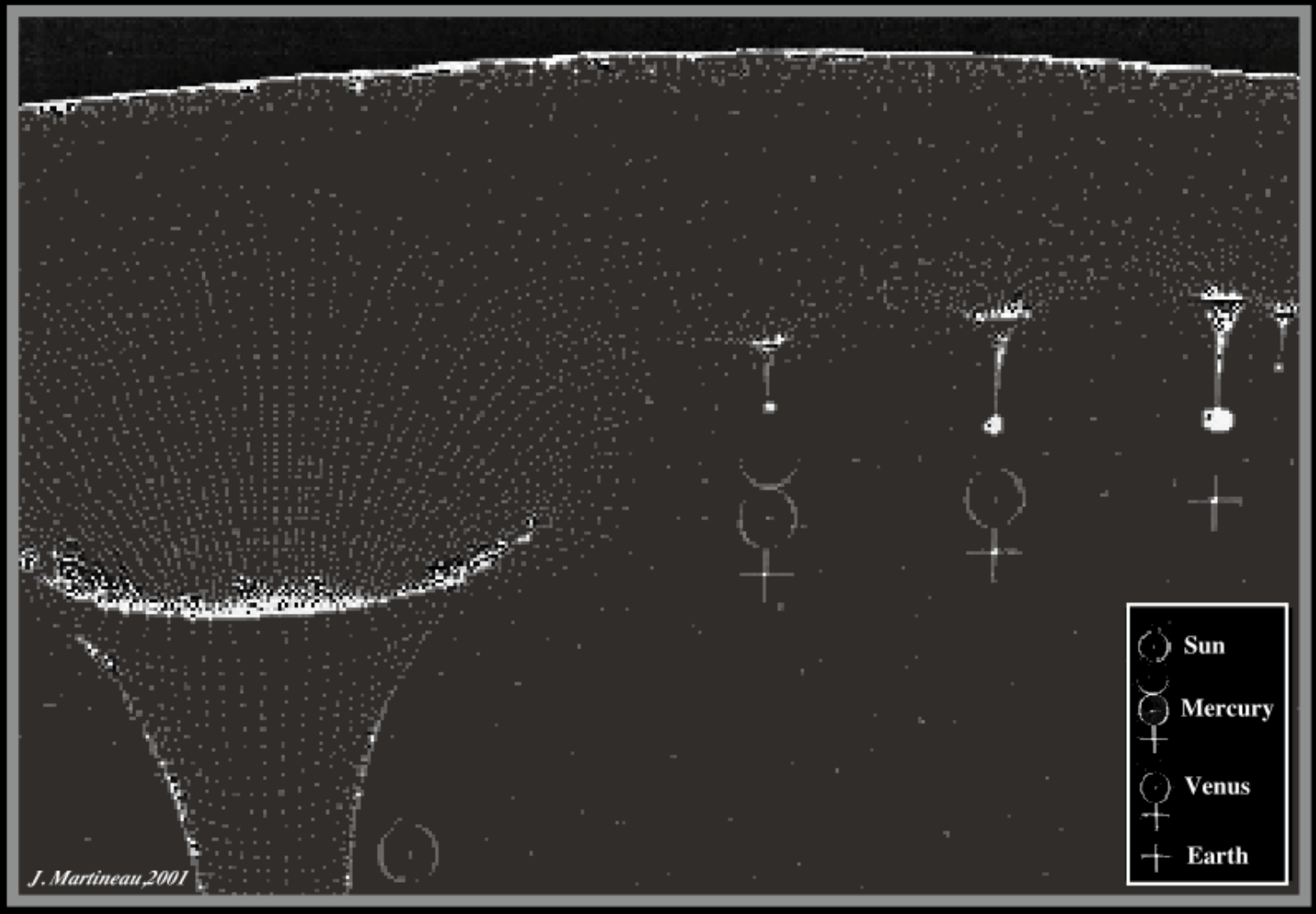
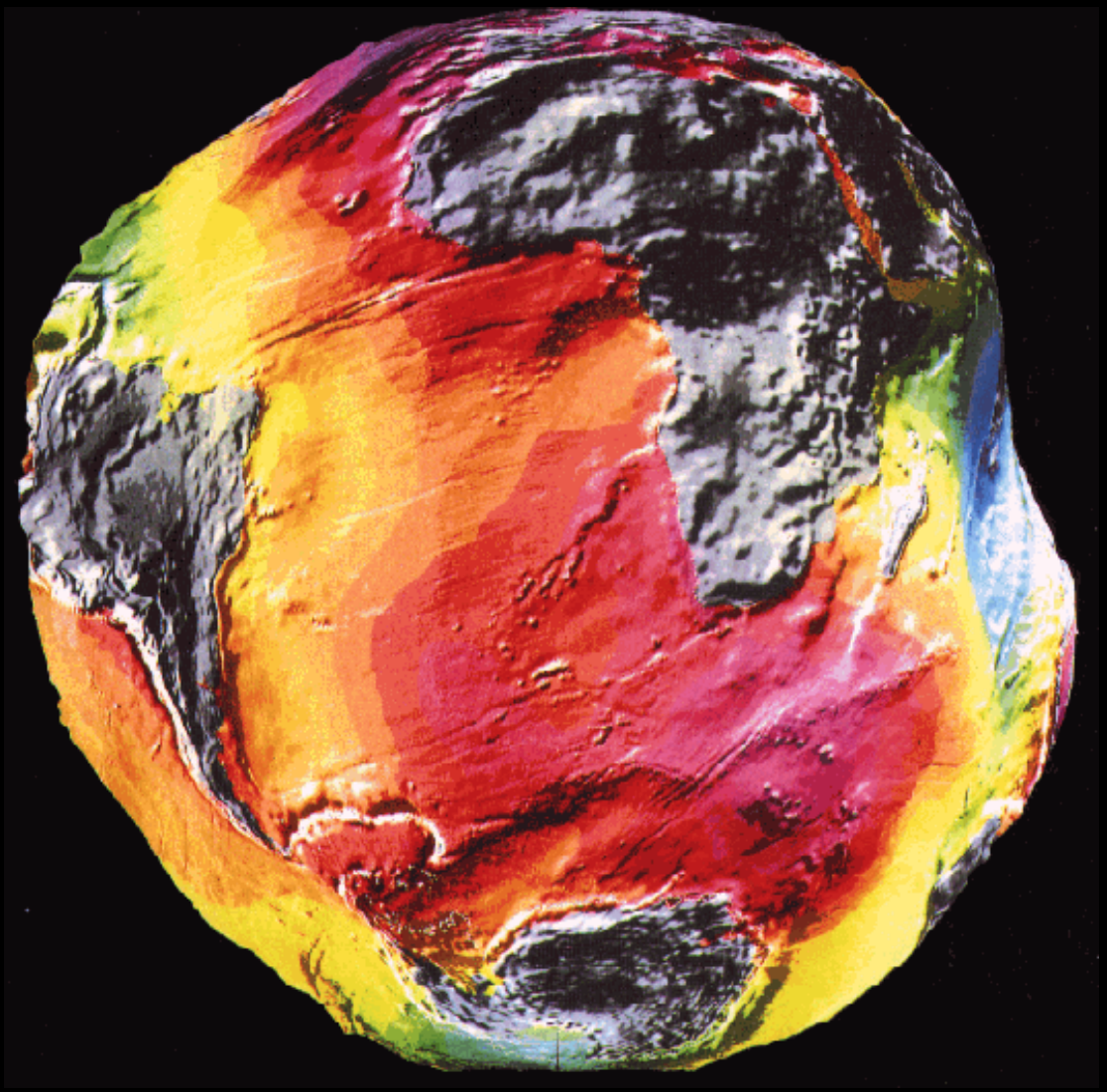
6) Gravitation

Everything is curved by gravitation.



A nice way to picture the solar system is by thinking of space-time as a rubber sheet with the Sun as a heavy ball and planets as a marble place on it. This is Einstein's model of the way matter curves space-time and helps visualise the force of gravity between masses.



Earth's Morphology

The geoid is that equipotential surface of the Earth gravity field that most closely approximates the mean sea surface.

The geoid is the most graphical representation of the Earth gravity field. The largest positive geoid heights are associated with subduction zones and hotspots and have no simple relationship to other high regions such as continents and ridges.

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All clastic sediments are deposited by gravity.

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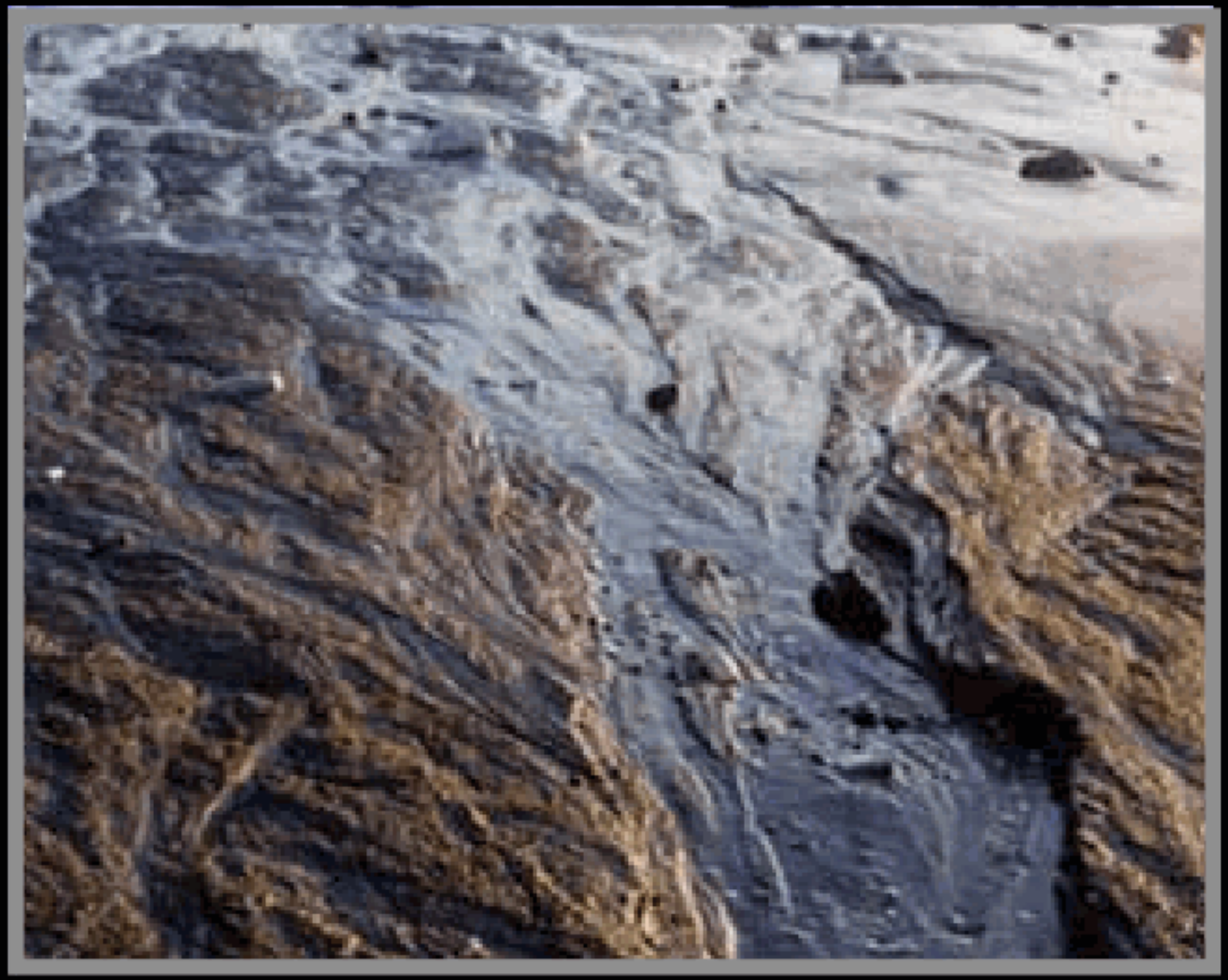


Braided stream deposits

(cont.)

This gravity current in the atmosphere is the front of an outflow of cold air from a thunderstorm. It is about 1000 metres high and advancing at 25 m/s.

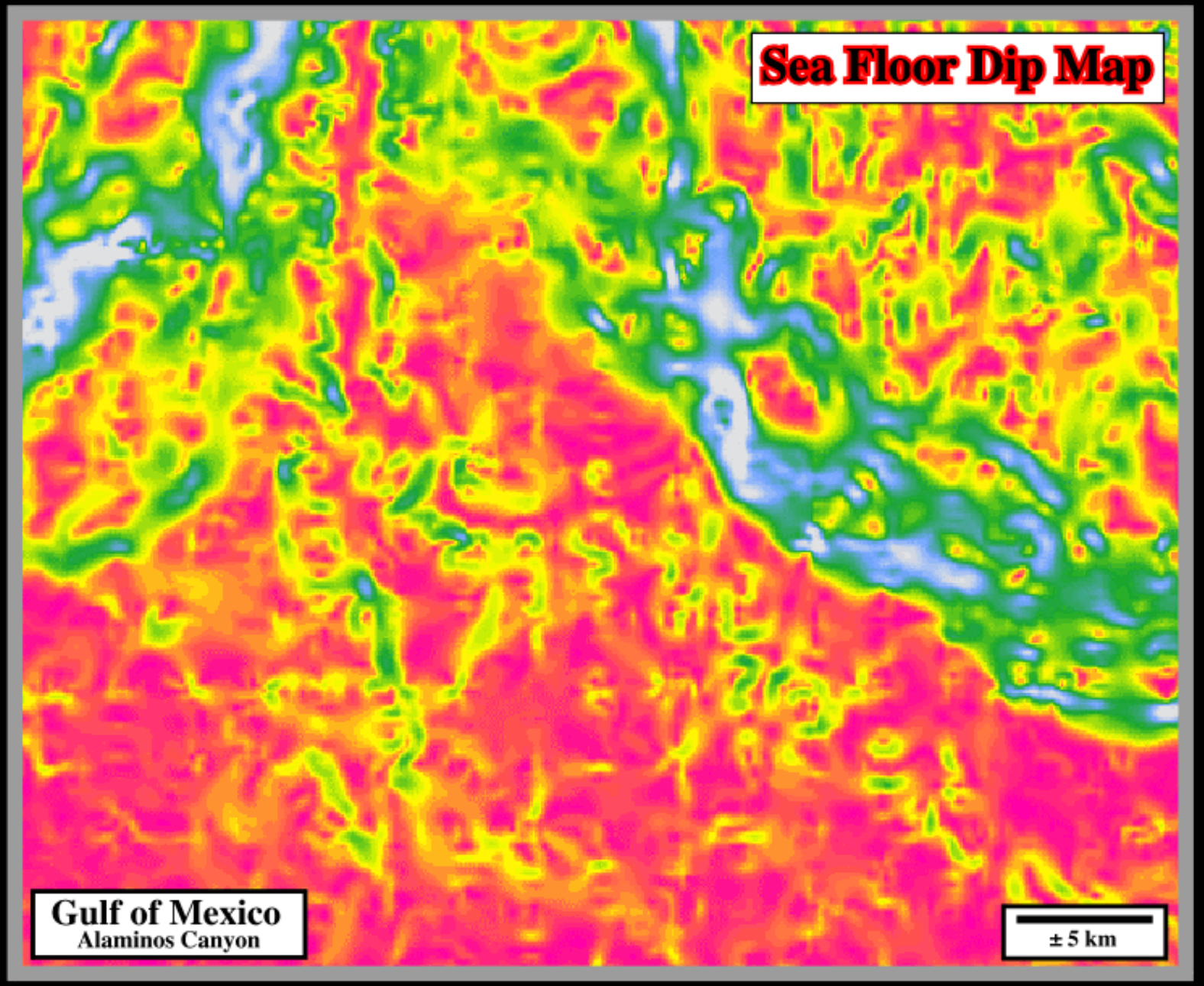
(cont.)

Snow avalanches are familiar to most people, and much effort has gone into trying to understand how they are formed and how they behave.

(cont.)

A pyroclastic gravity current on Mt. Ngaurahoe, New Zealand.

(cont.)



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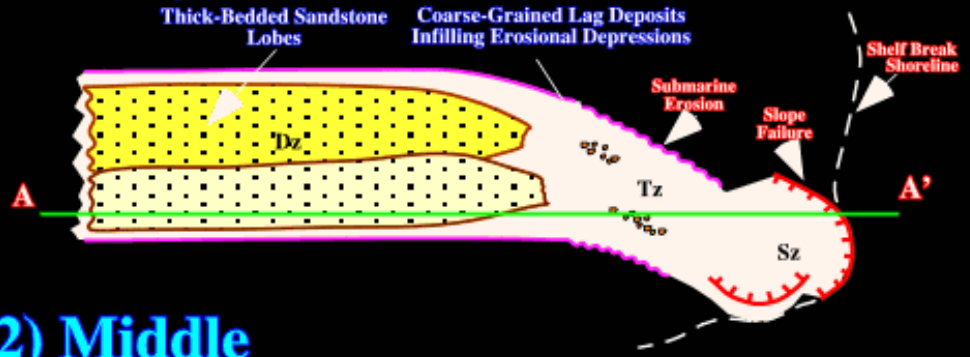
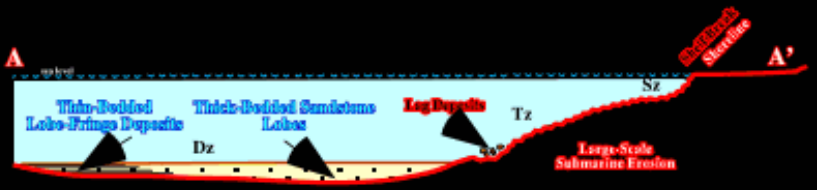
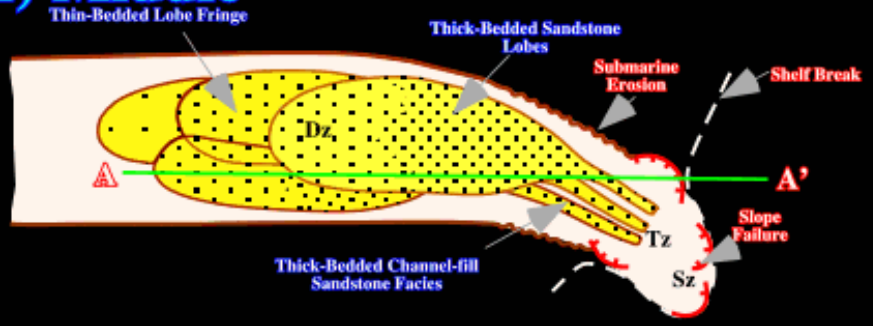
Turbidite Depositional Systems

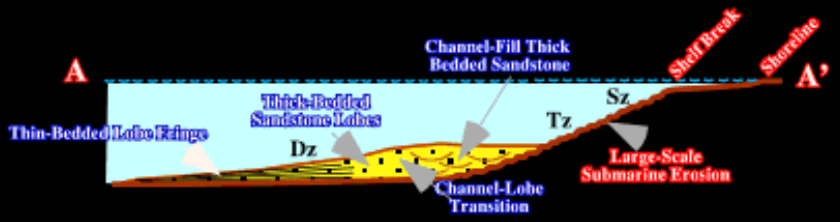
1) Large



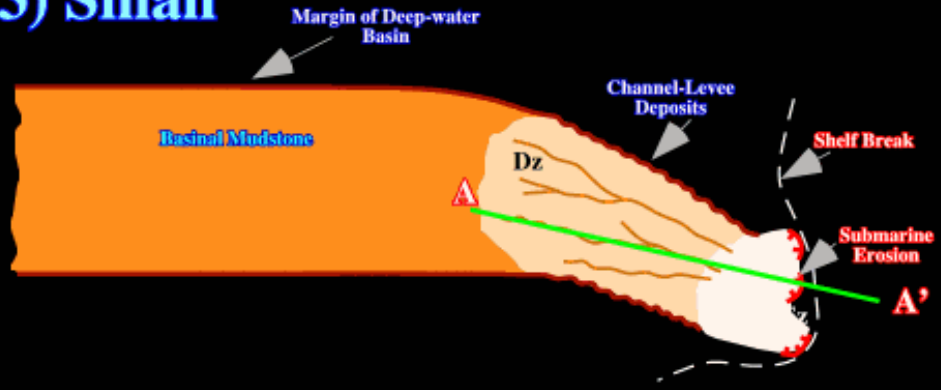


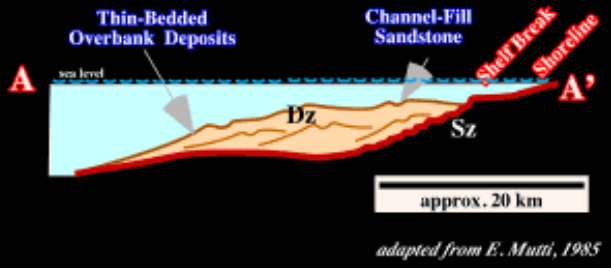
2) Middle





3) Small

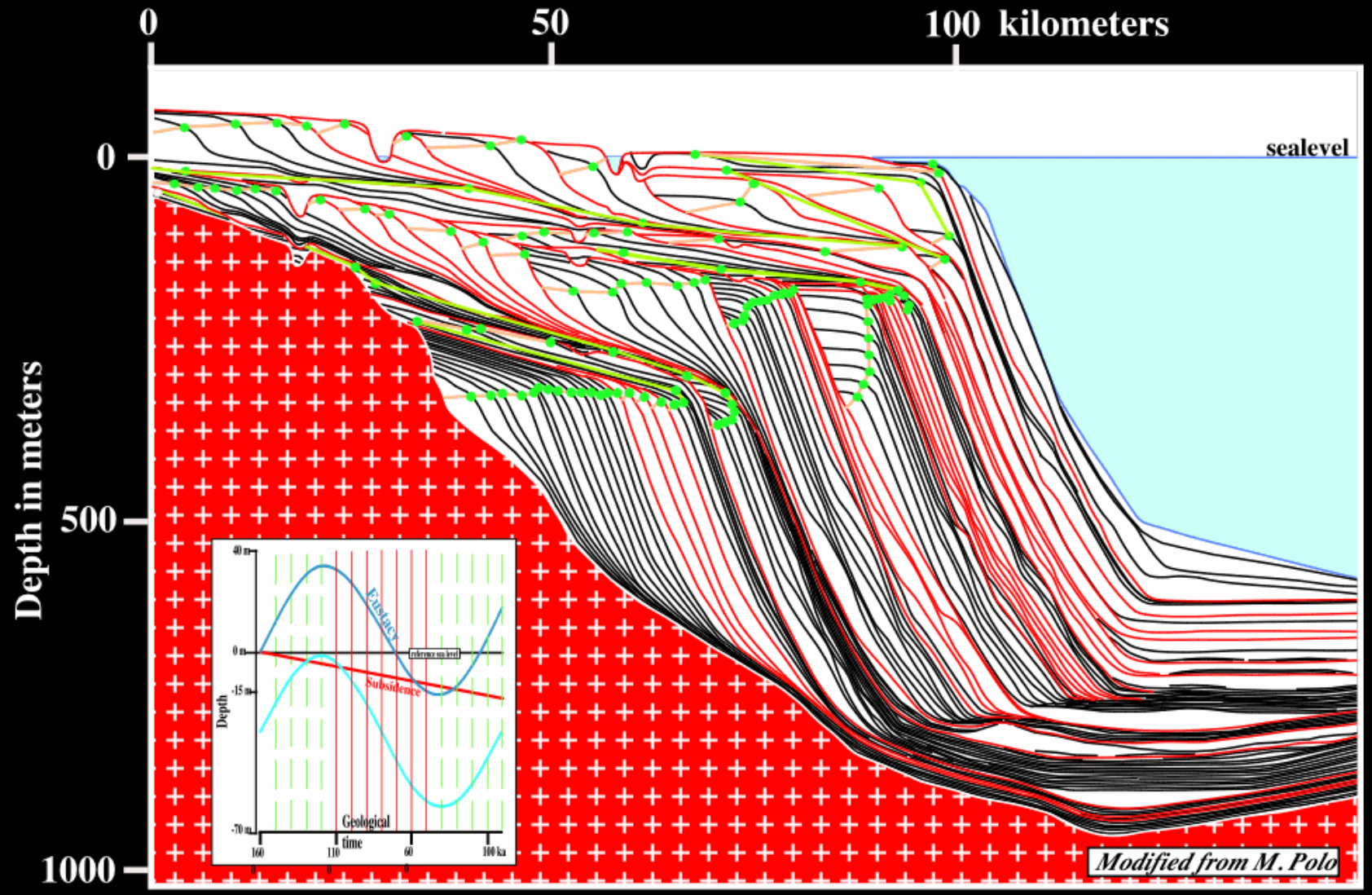




adapted from E. Mutti, 1985

(cont.)

P. Vail's model for clastics



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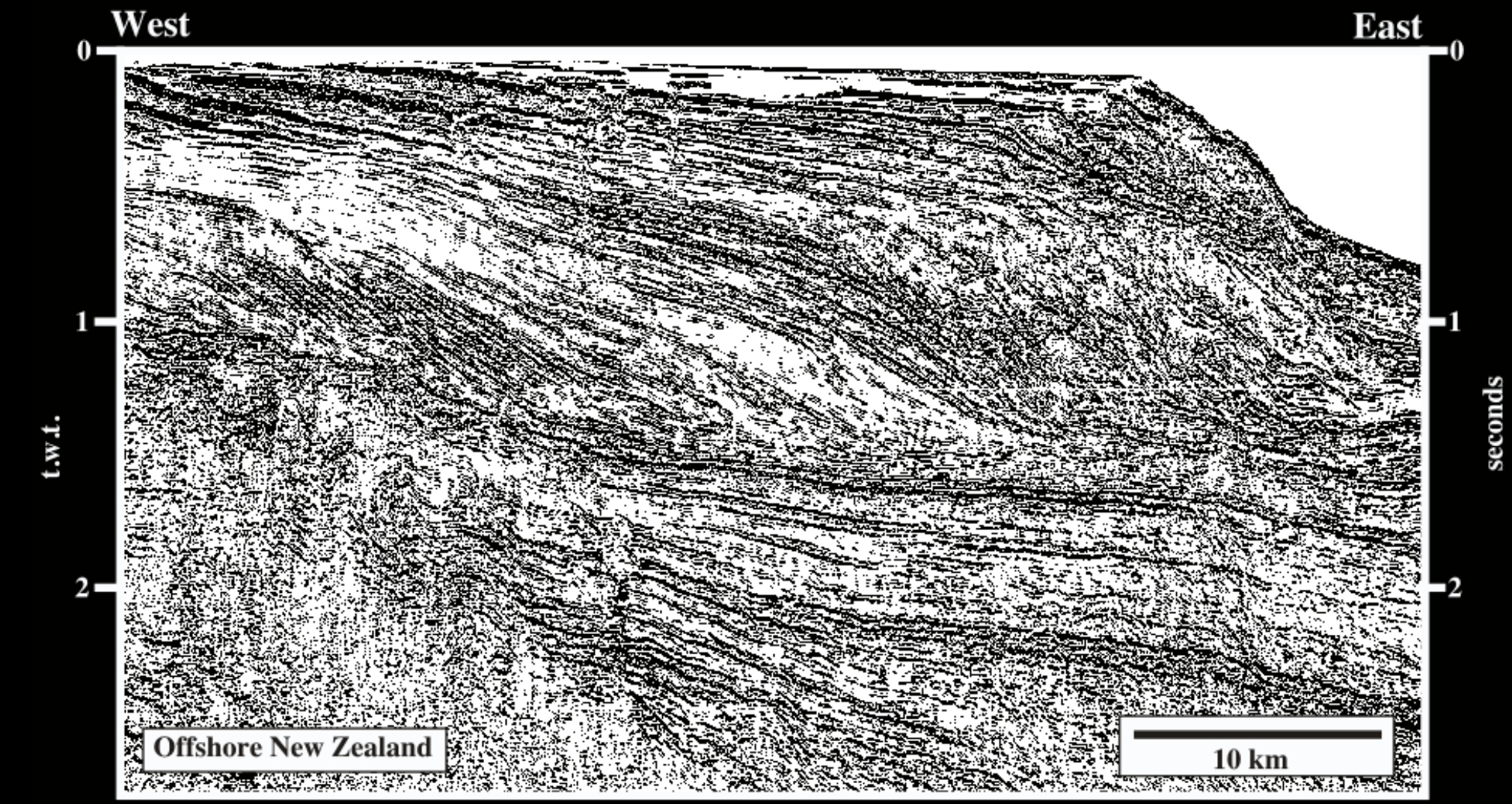


(cont.)

7) Life

Life is controlled by three major laws:

a) **Fermat-Maupertius's law** or principle of minimum action.

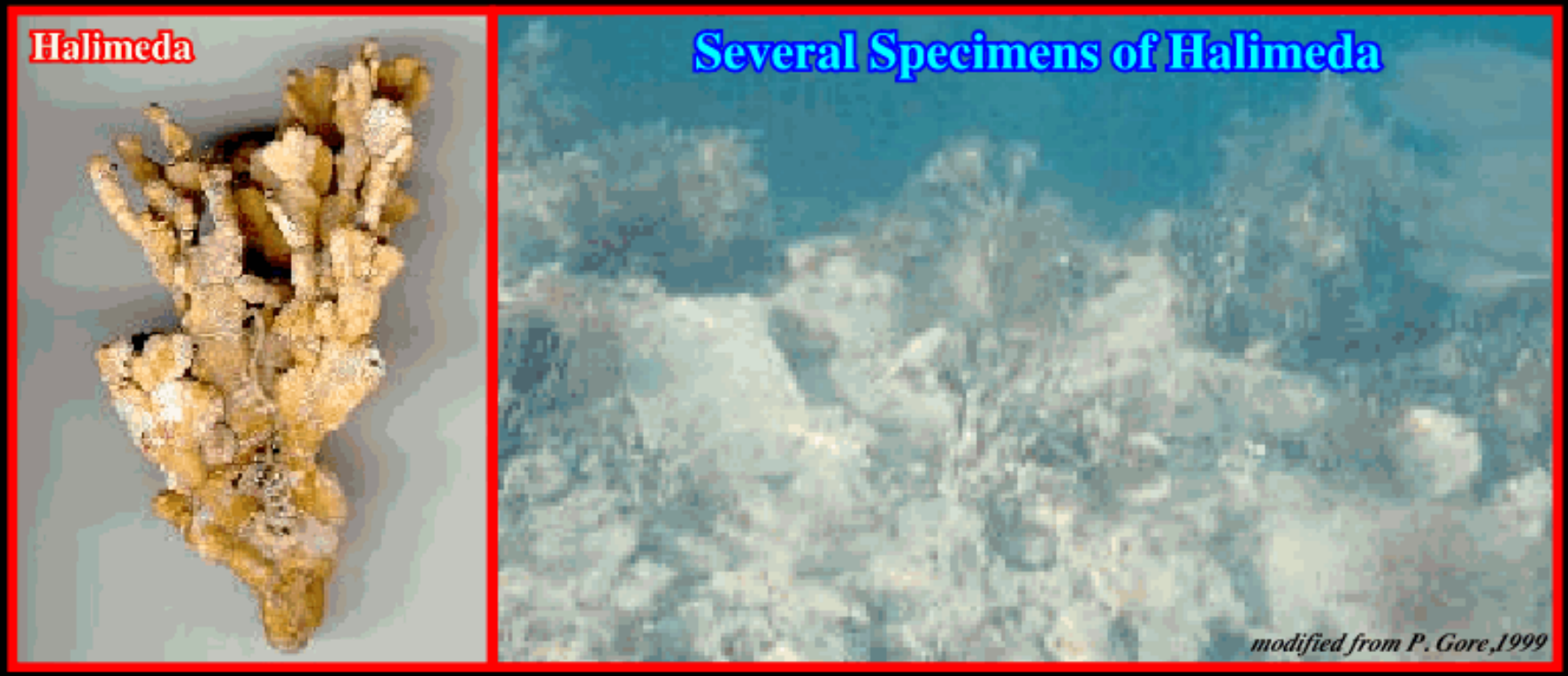
b) **Snell's law** or principle of minimum time.

c) **Fibonacci's law** or principle of maximum room.

(cont.)

Florida Continental Shelf

Under-water View of Calcareous Algae



(cont.)

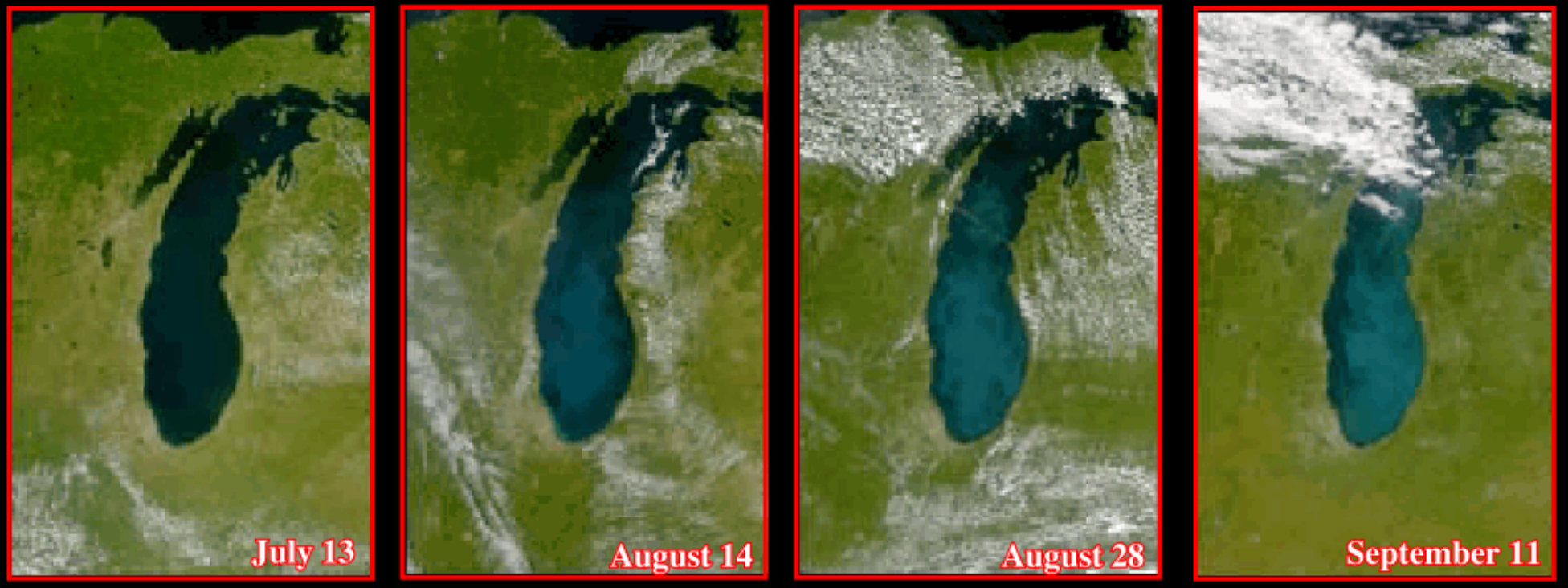
Coral Reefs

(cont.)

Atoll Reef (SE Pacific)

(cont.)

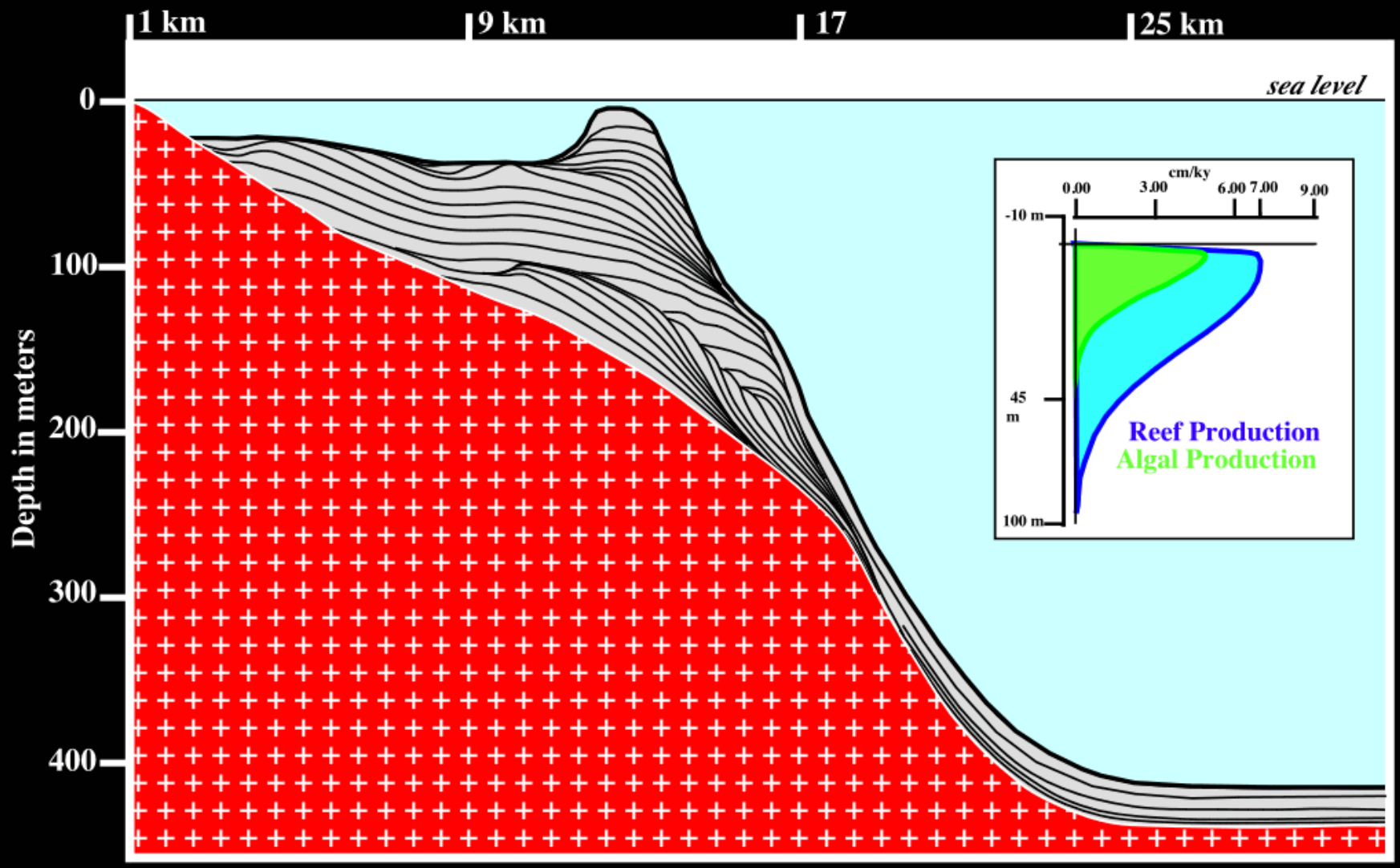
Lake Michigan



The bright color that appears in late summer in Lake Michigan is caused by the calcium carbonate in the water and not by life. Lake Michigan always has a lot a calcium carbonate because the floor of the lake is limestone. During most of the year the calcium carbonate remains dissloved in the cold water, but at the end of summer the lake warls up, lowering the solubility of calcium.

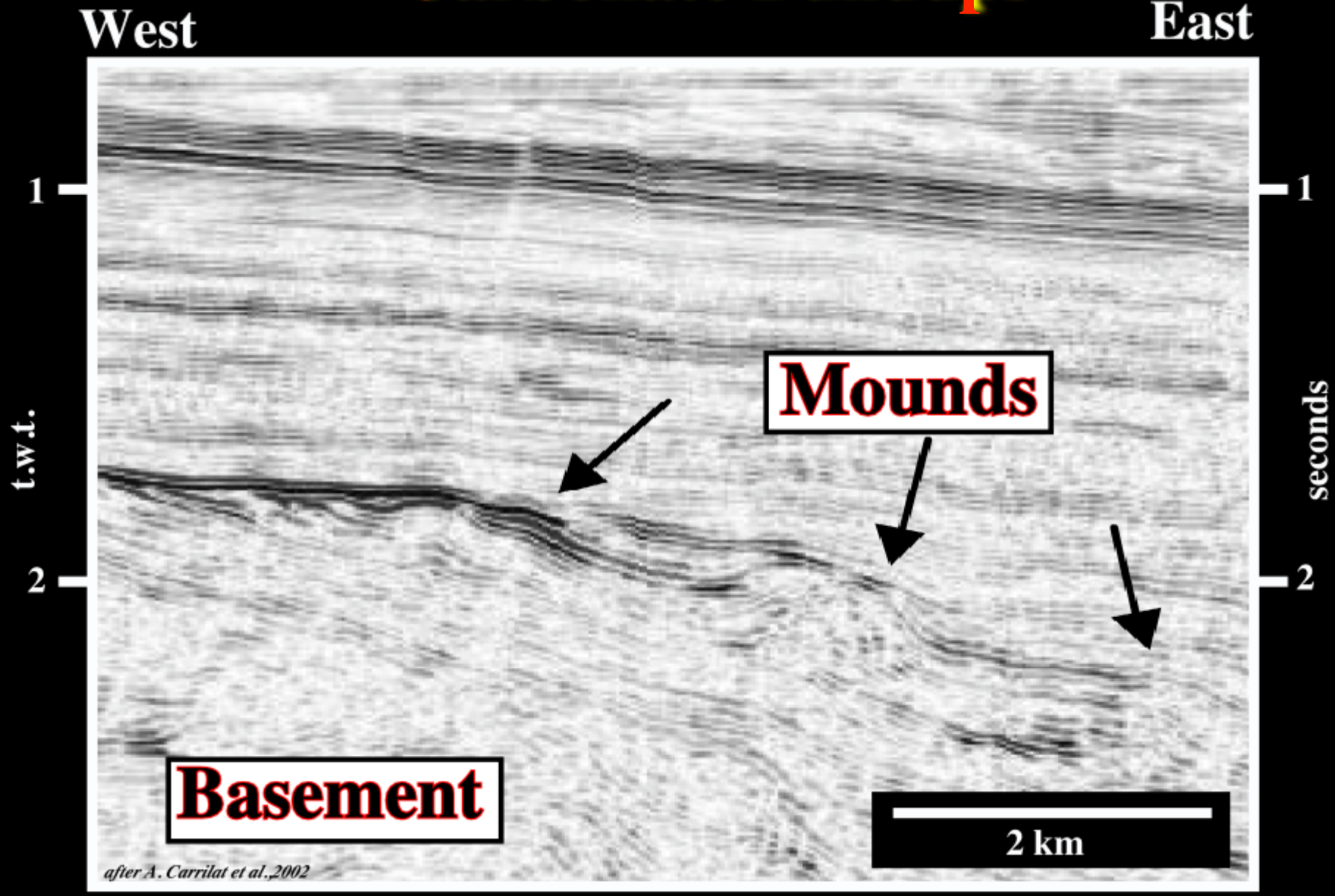
(cont.)

P. Vail's model for carbonate



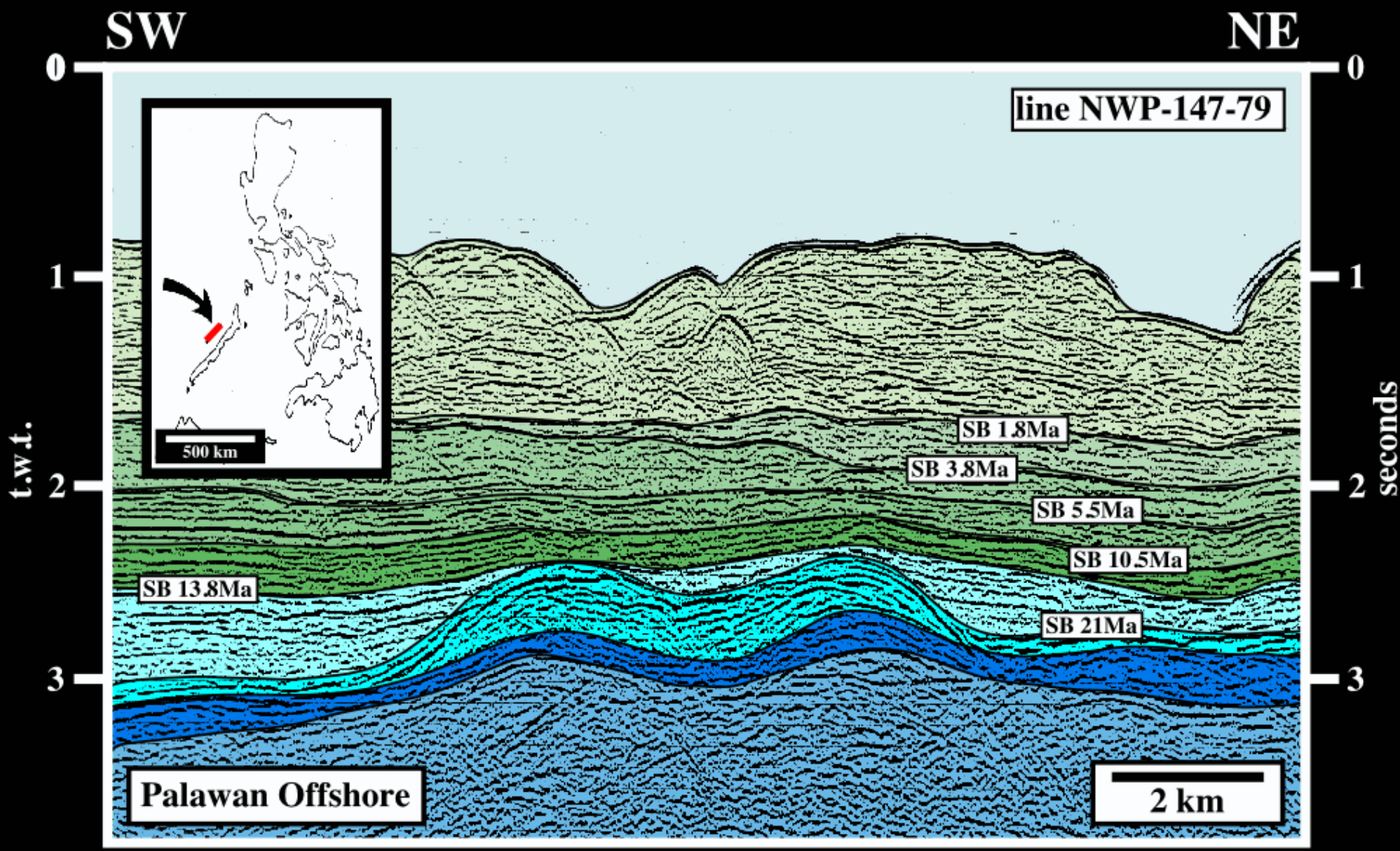
(cont.)

Carbonate Buildups



(cont.)

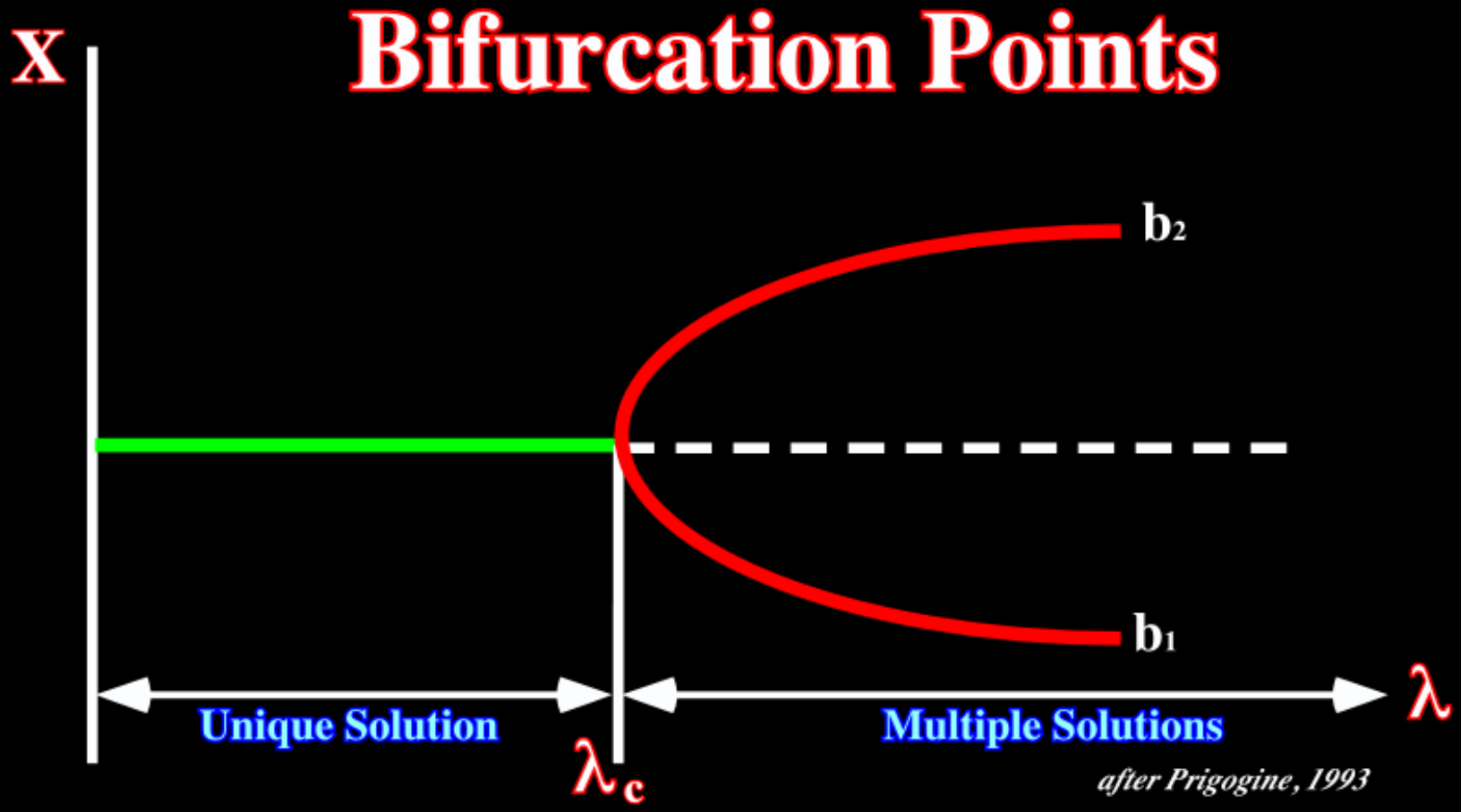
Carbonate Buildups



(cont.)

8) Determinism & Probabilism

Natural evolution is a succession of stages described by determinist laws and stages described by probabilistic laws



(cont.)

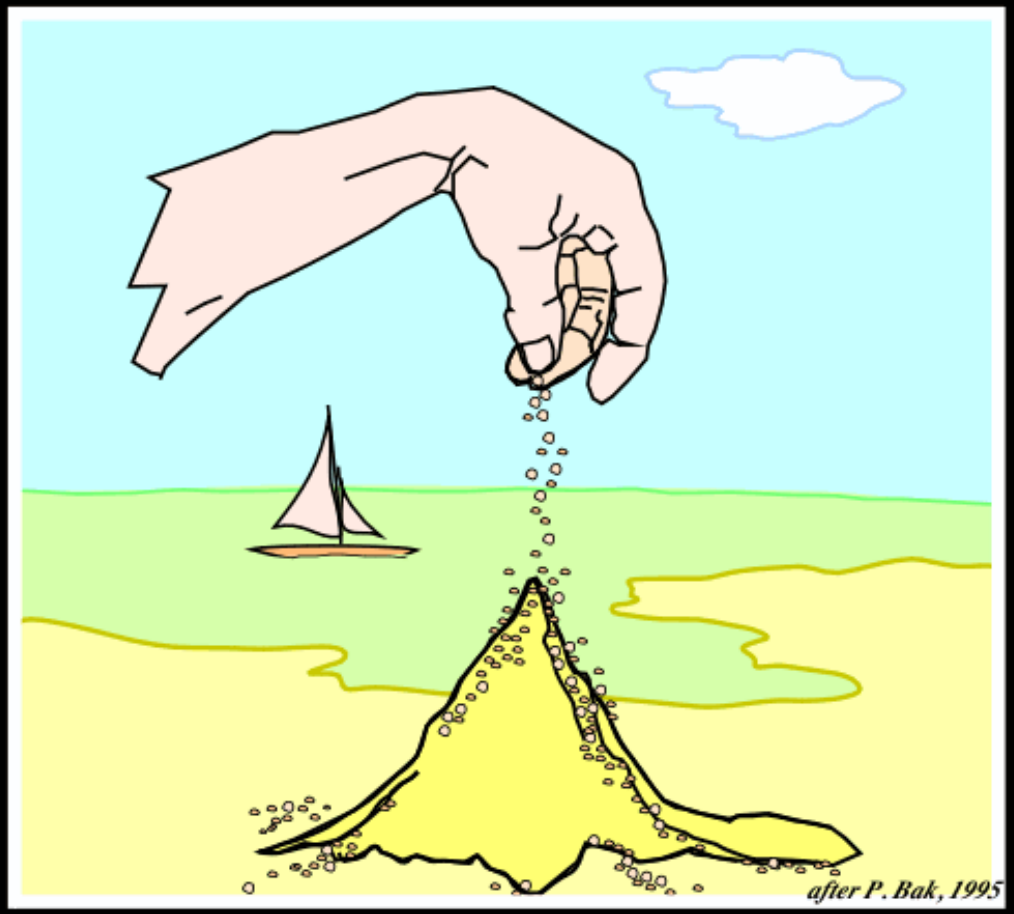
Geoscientists consider Earth as an open system far-from-equilibrium and self organized critically (SOC), that is to say, a dissipative structure using Prigogine's terminology.

In fact, Earth receives a continuous flux of matter or energy from the sun, which allows it to survive, in other words to encounter instabilities leading to new forms of order that move it farther and farther away from the equilibrium state, that means, away from death.

A dissipative structure is a structure of non-equilibrium which exists as long as the system dissipates energy and stays in interaction with the outside world.

(cont.)

Sandpile Model



The sandpile is the canonical example of a Self-Organized Critical system (SOC). It exhibits a punctuated equilibrium behavior, where periods of stasis are interrupted by intermittent sand slides (as in turbidite systems). It can be expressed as a straight line on a double logarithmic plot, which indicates that the number of events is given by a simple power law:

$$N(s) = s^{-\pi}$$

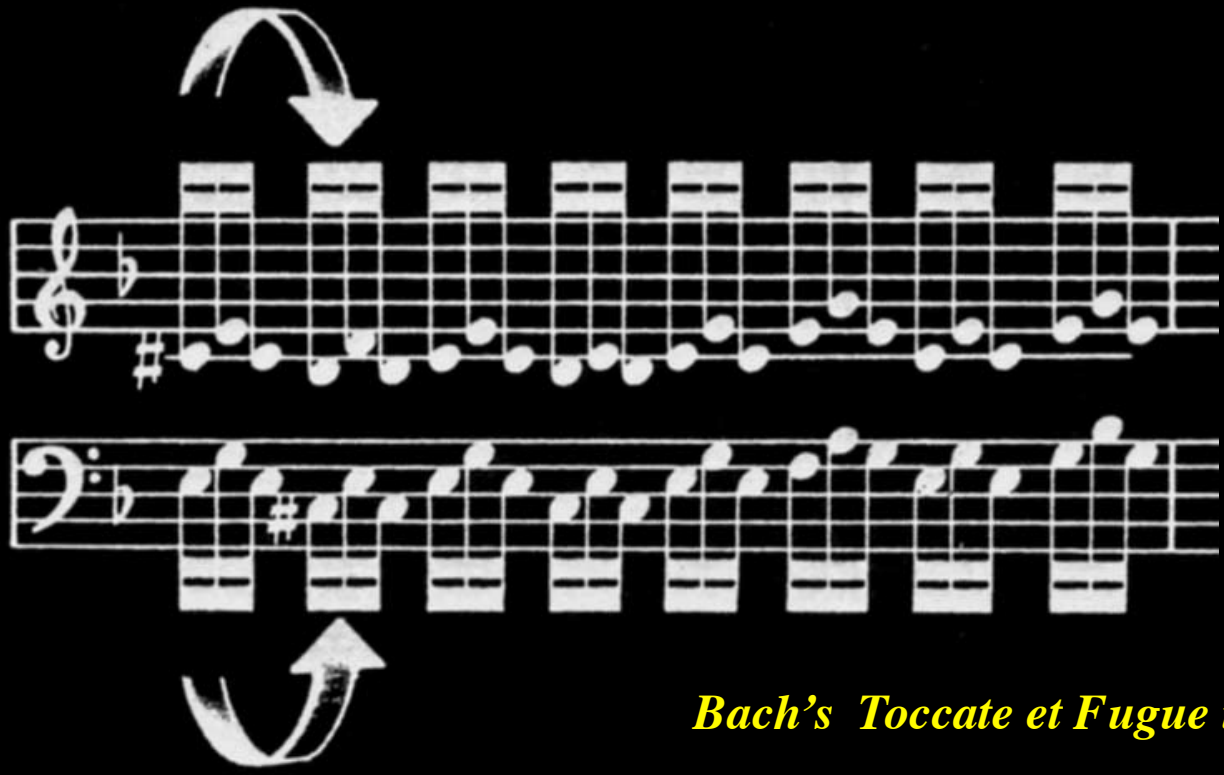
The exponent π is defined as the slope of the curve. Catastrophic events, fractals, 1/f noise (fractals in time), Zipf's law, etc., are examples of SOCs. They evolved to complex critical state without interference from any outside agent.

(cont.)

9) Symmetry (Central Limit Theorem)

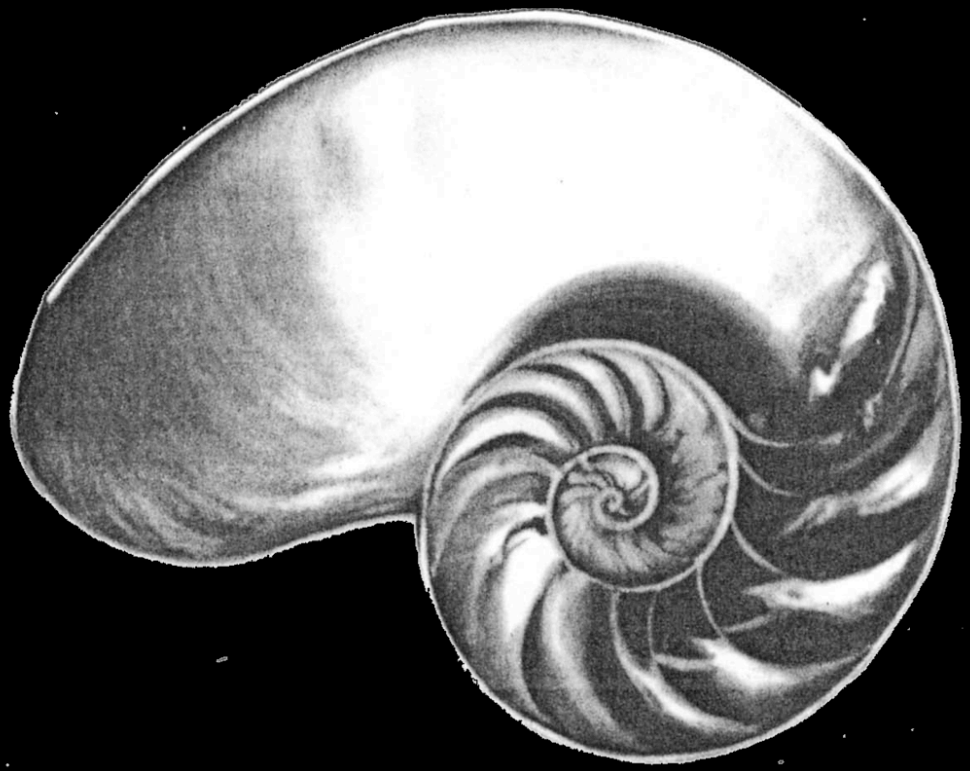
One speaks of symmetry when a quantity remains **invariant** (unchanged) during a **transformation** (a change).

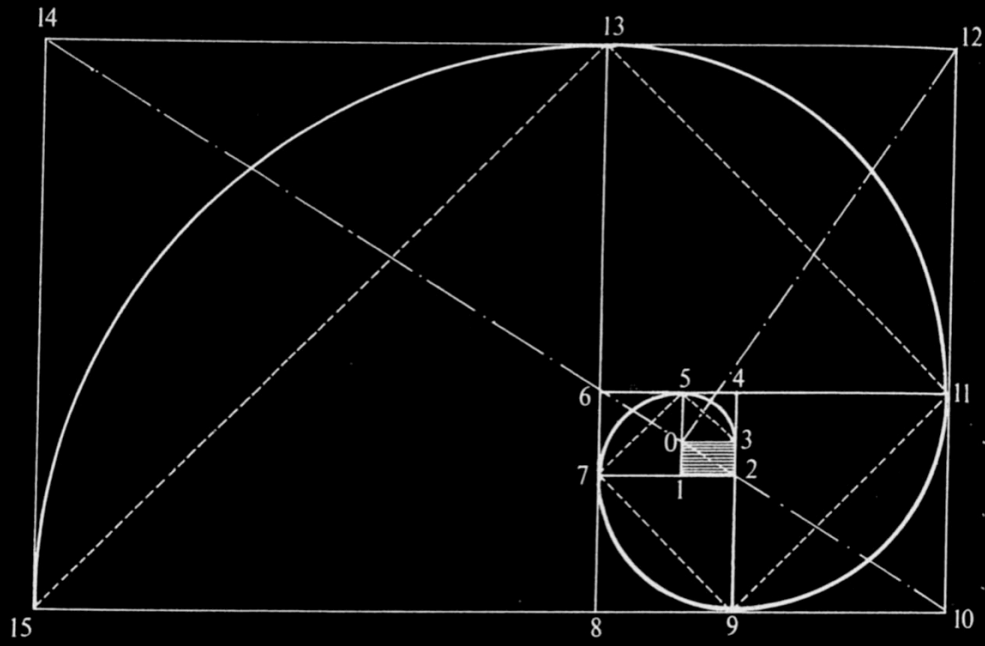
In this sense, one can say that **Symmetry** is a major characteristics of Nature.



Bach's Toccate et Fugue in mi minor

(cont.)





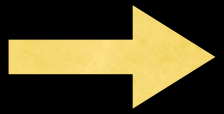
T. Ferris, 1992

The architecture of Nautillus' shell can be depicted by Fibonacci series. Symmetry is nature's characteristic.

(cont.)

(Central Limit Theorem)
Large numbers

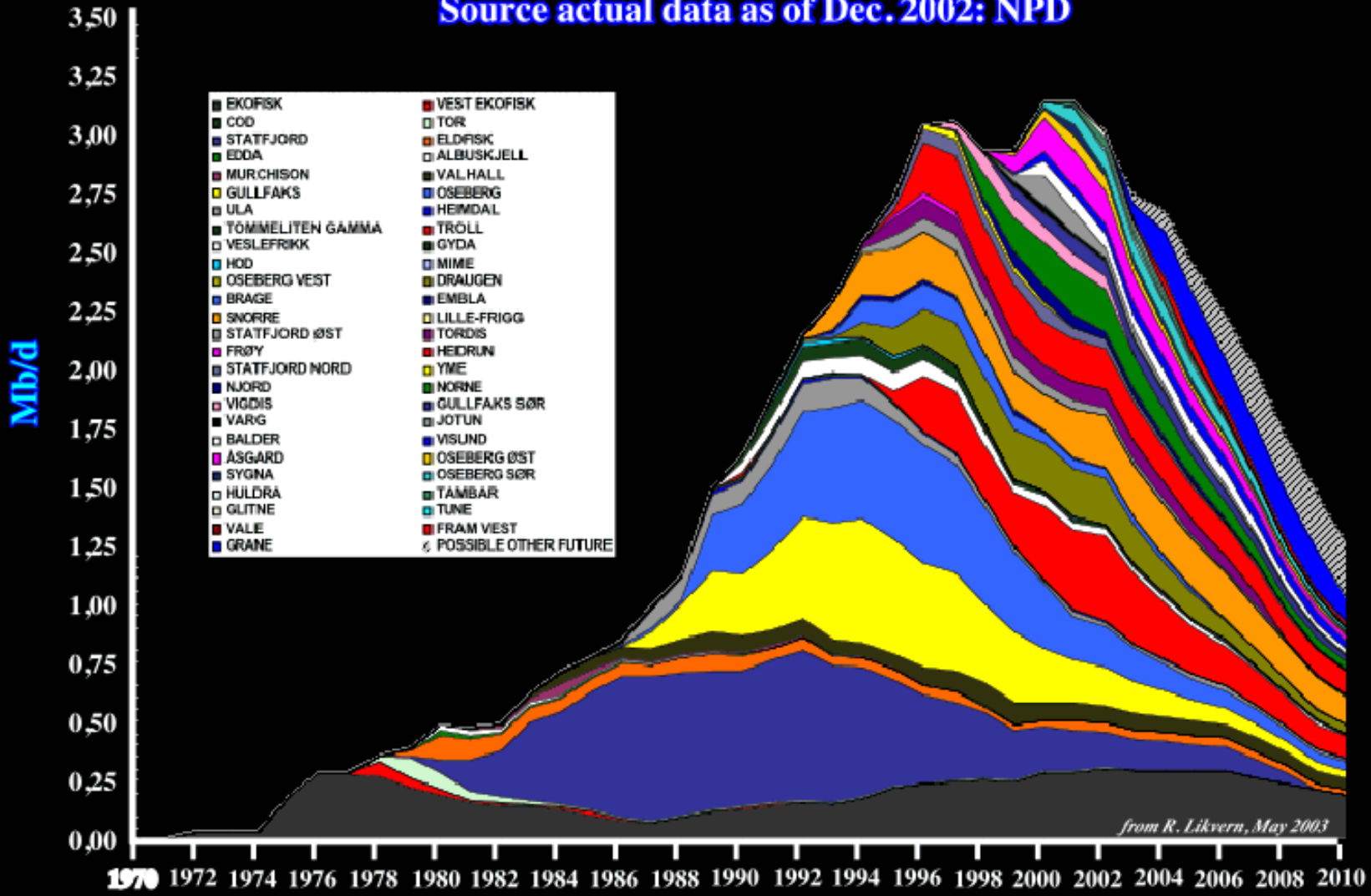
In probabilities, adding a large number of assymetric distributions gives a symmetrical normal distribution.



(cont.)

Actual and Forecast Oil Production From NCS

Source actual data as of Dec. 2002: NPD



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