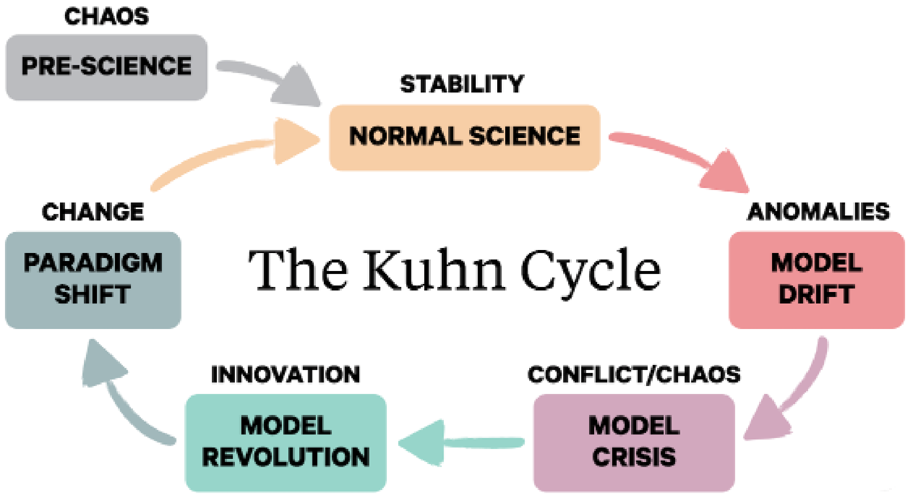
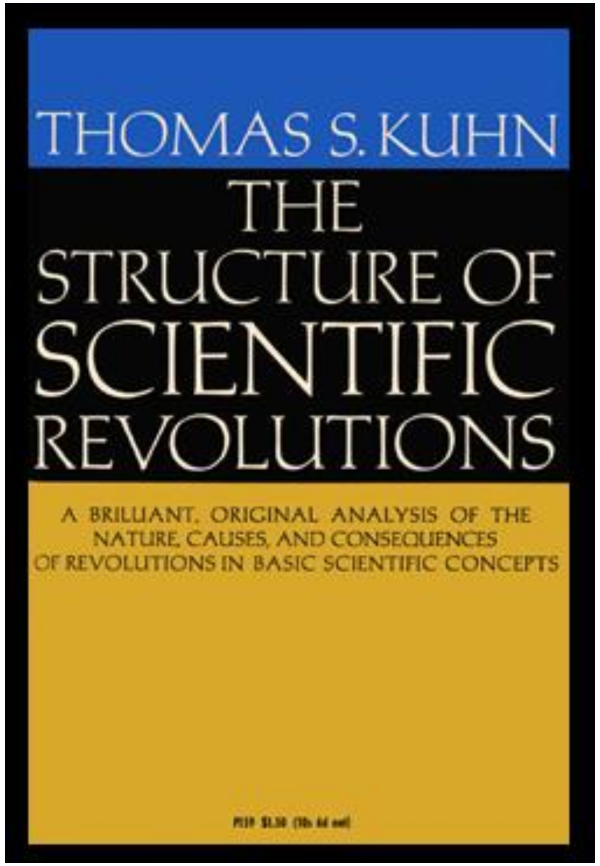
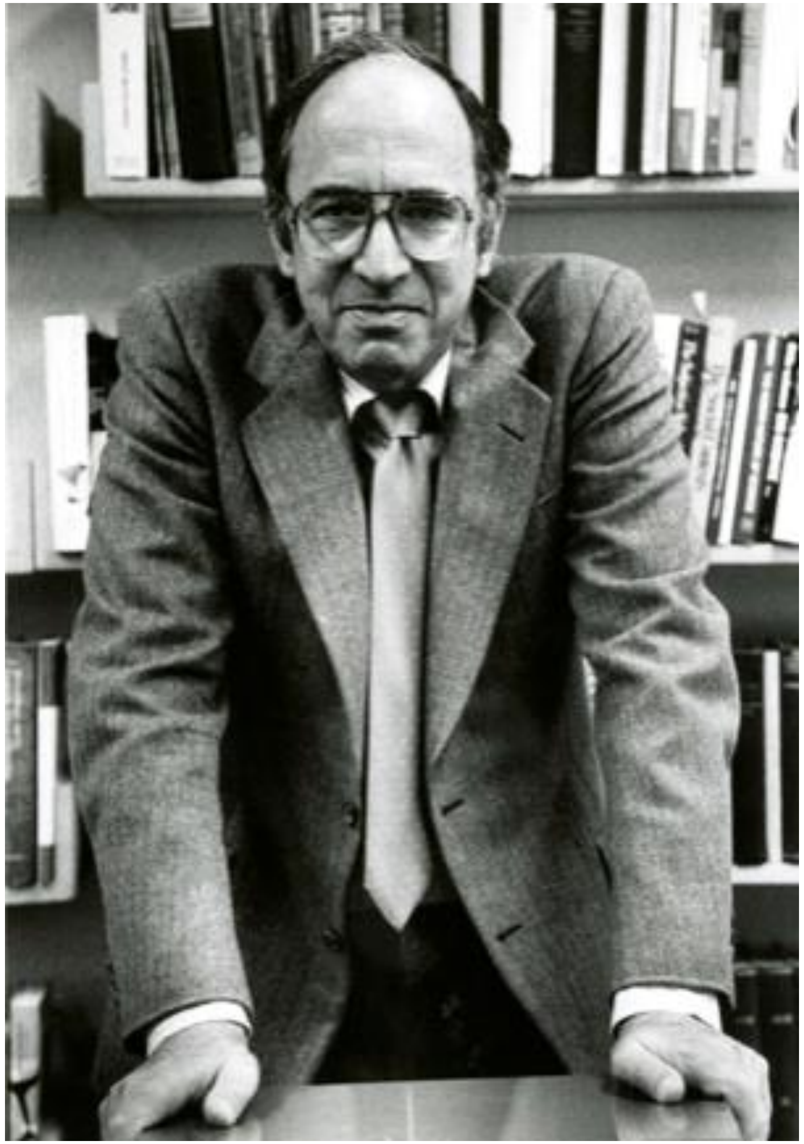
What *is* Science?



"Paradigm shifts become necessary when the plausibility structure of the previous paradigm becomes so full of holes and patchwork "fixes" that a complete overhaul, which once looked utterly threatening, now appears as a lifeline."





Thomas S. Kuhn, PhD
(July 1922 – June 1996)

Is it a Method? What is that Method for? What does that Method do?

A **statistical hypothesis test** is a method of statistical inference used to decide whether the data at hand sufficiently support a particular hypothesis. Hypothesis testing allows us to make probabilistic statements about population parameters.
This is normal science (as per TK).

"**But is it science**?" ask the sceptics. Perhaps "No", under the old definitions of chemistry, physics and biology. But "Yes", as a new discipline, with an intellectual skeleton based on understanding complexity and simplicity, and on developing strategies for integrating information originating in entirely different fields" – GW (2011) This is innovation (as per TK).

The frugal way

George Whitesides CAMBRIDGE, MASSACHUSETTS

The promise of cost-conscious science

Western science, particularly academic science, is culturally obsessed with superlatives, and often separated from technology: the most accurate measure of time, the most detailed accounting of a genome, the most distant star, the highest-energy particle. Why? Superlatives are necessary in some areas, and easy to keep score with in others. And there are technologies (such as GPS) that absolutely require extreme precision.

But superlatives tend to be expensive. Should cost be an issue in science? If knowledge is a treasure beyond price, perhaps obtaining it should be similarly cost-unconstrained—an idea enthusiastically supported by expensive fields such as high-energy physics. And even the most expensive science is cheap relative to, say, a war or a tsunami. Yet science in 2012 and beyond will be evolving a new variant of itself: frugal science, designed to generate knowledge (and technology based on that knowledge) with cost as an integral part of the subject.

George Whitesides: professor of chemistry and principal investigator, Whitesides Research Group, Harvard University

2012 IN BRIEF
Computer geeks and universities salute and mourn **Alan Turing**, born a century ago

The idea of including "cost" in science is perhaps déclassé in Western research universities, but it is based on an important change in the world. The 80% of the global population that is poor (and has long been excluded from science, technology and the benefits of both) would like to join the party. China, India and Brazil have already muscled their way into technology, and other less-developed countries will follow.

Behind the argument between "superlative" and "cost-effective" lie differences of opinion about the purpose of science. Is it the job of science to generate knowledge as an abstract good, with the benefits to the society that pays for it unpredictable, or should science at least think of serving society?

In the West, the answer is often two words: "quantum mechanics". Its development revolutionised both science and technology, and was indeed a product of pure curiosity. But there have been only one or two such events in fundamental science in the past century (genomics may eventually be as important); and the birth of quantum mechanics was not expensive, although its applications in technology were.

In the rich world, maintaining a distinction between curiosity-driven science and applications-driven technology may or may not be an affordable luxury. In the developing world, there are pressing problems whose solutions require relevant science and technology now.

Quick, pass me the screwdriver!

Health care is one example. Western medicine does many things well, but it is not affordable in, or very useful to, most poor populations. What then should be the technology base for affordable health care? Answering that question requires the development of science that is conscious of cost from the beginning—a frugal health care that might, perhaps, be more related to Western public health than to end-of-life, high-tech medicine. What about other problems: the management of megacities, development of radically effective ways of delivering education, or providing water and energy? All of these problems can be phrased as technologies, which will require an appropriate foundation in science—and that must include cost. The race may not be to the swift, but rather to the cheap.

The race may not be to the swift, but rather to the cheap

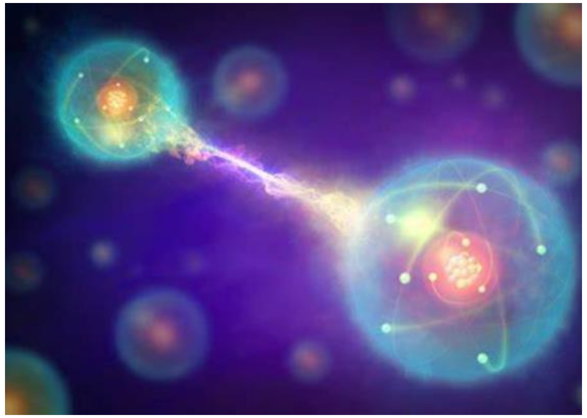
There is another reason to be encouraging frugal science: jobs. Frugal science has a chance of yielding cheap products, and thus jobs and other understandable benefits. The developing world is pioneering telecoms systems with structures quite different from those used in the rich world. The Shenzhen gene factories, using American technology, are among the lowest-cost producers of genomic information. The Tata Nano car represents a creative step towards low-cost personal transport. And the science that leads to affordable health care for Africa may provide some of the best approaches to reducing the no-longer-affordable cost of health care in America.

Foundations (Gates, Wellcome and others) are already developing frugal medicine, and much of the health-care spending in developing countries is on technology that is, of necessity, frugal. The science base for this—low-cost diagnostics, epidemiology and nutrition informed by mobile-phone reporting—is developing rapidly. Tata, GM, Toyota and their kin are all thinking about radically different concepts for the car: smaller, lighter, cheaper. To sell in world markets, affordability may in future be the first requirement, not an afterthought.

"But is it science?" ask the sceptics. Perhaps "No", under the old definitions of chemistry, physics and biology. But "Yes", as a new discipline, with an intellectual skeleton based on understanding complexity and simplicity, and on developing strategies for integrating information, including economic information, originating in entirely different fields. It will probably get a reluctant welcome at first in the mandarin research universities of America and Europe, but it may flourish in Beijing, Mumbai and Cairo. And where it flourishes best may determine whose grandchildren have jobs. ■

SCIENCE_2012_US.indd (harvard.edu)

Some Current Paradigms:



Evolution through natural selection

(but what about horizontal gene transfer?!)

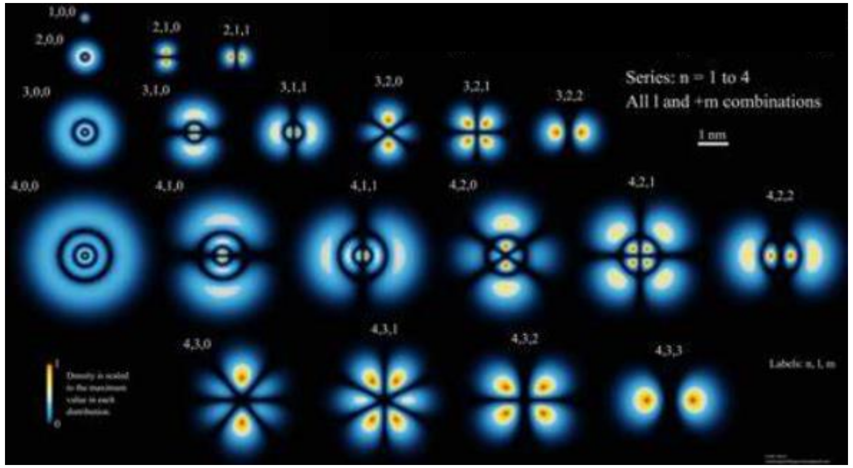
Orbital theory

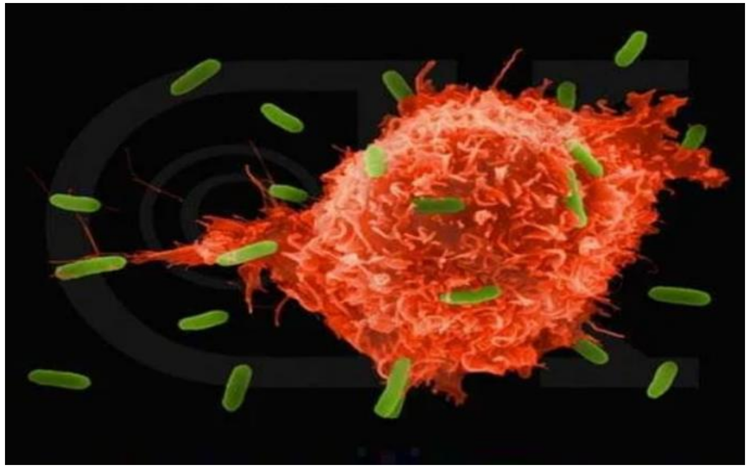
Quantum mechanics

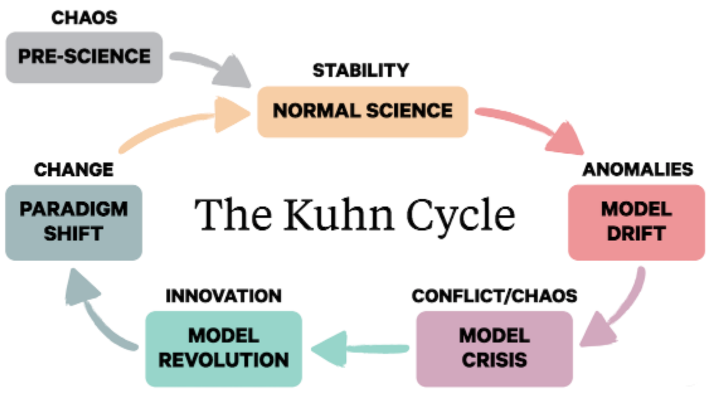
(but what about gravitation?!)

Germ theory of disease transmission

Plate tectonics







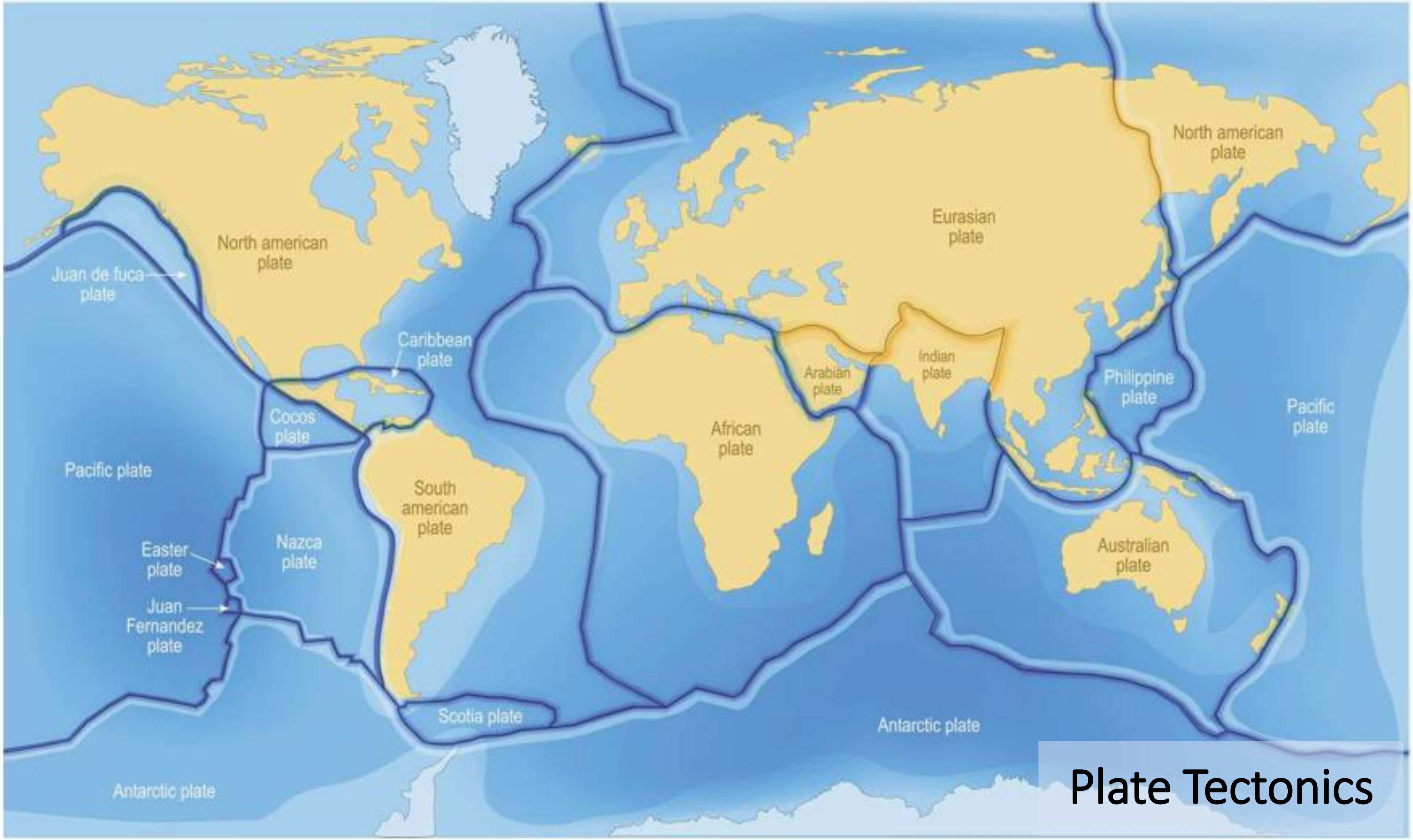
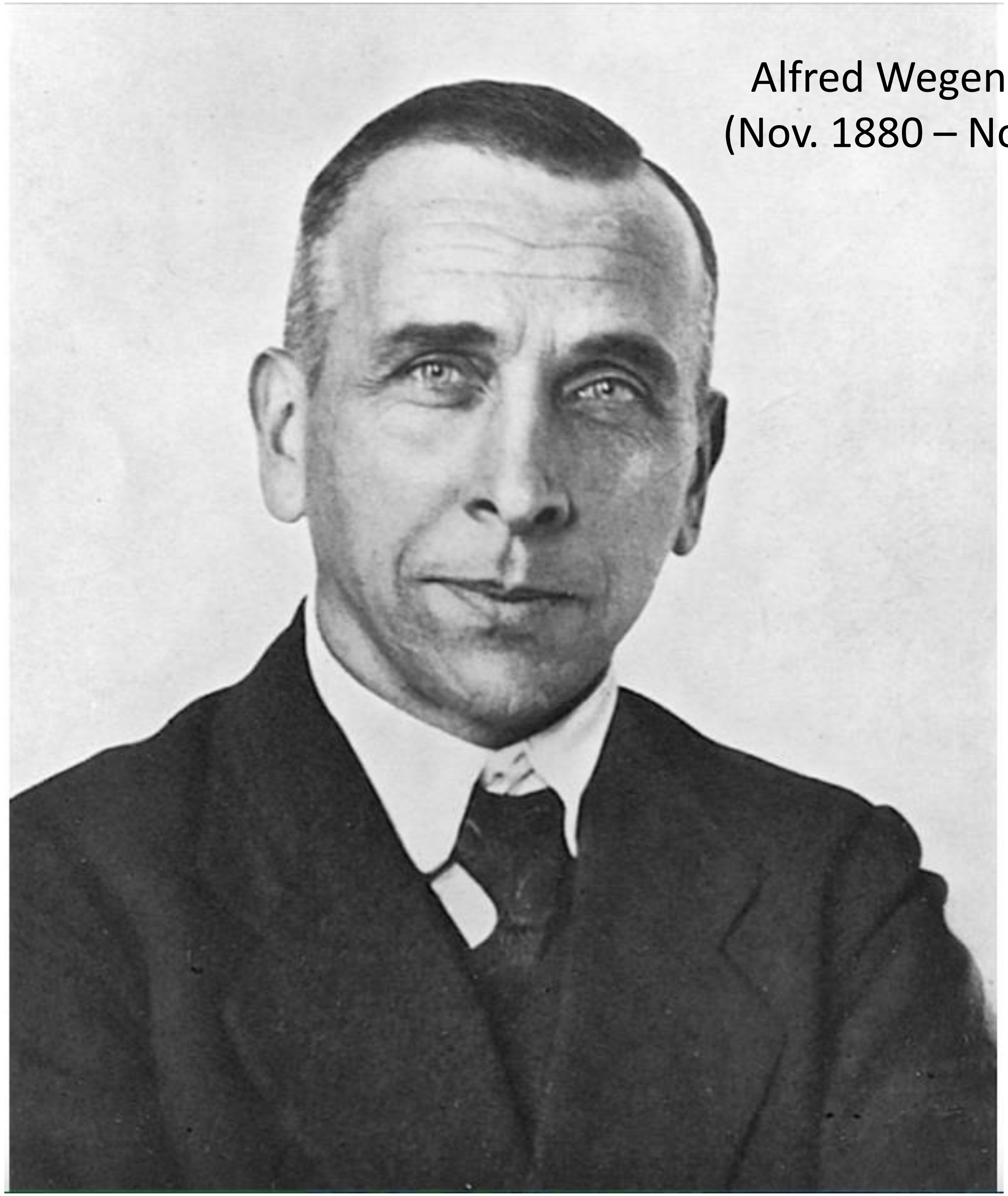


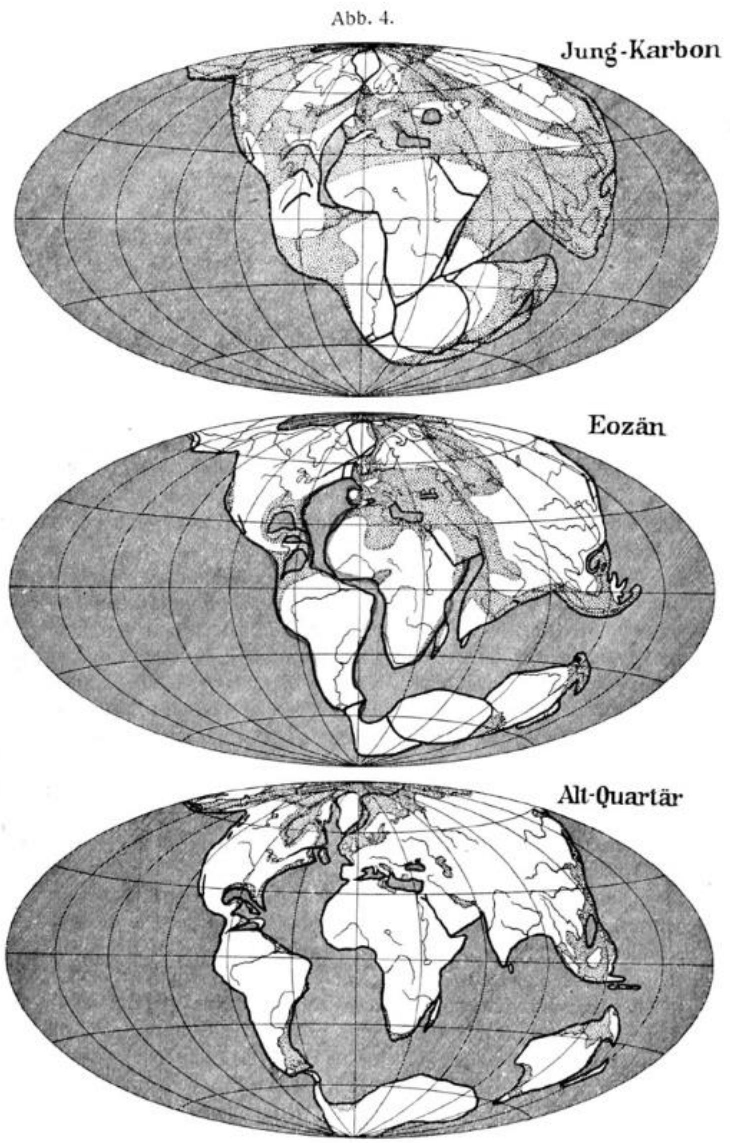
Plate Tectonics

Alfred Wegener, PhD
(Nov. 1880 – Nov. 1930)



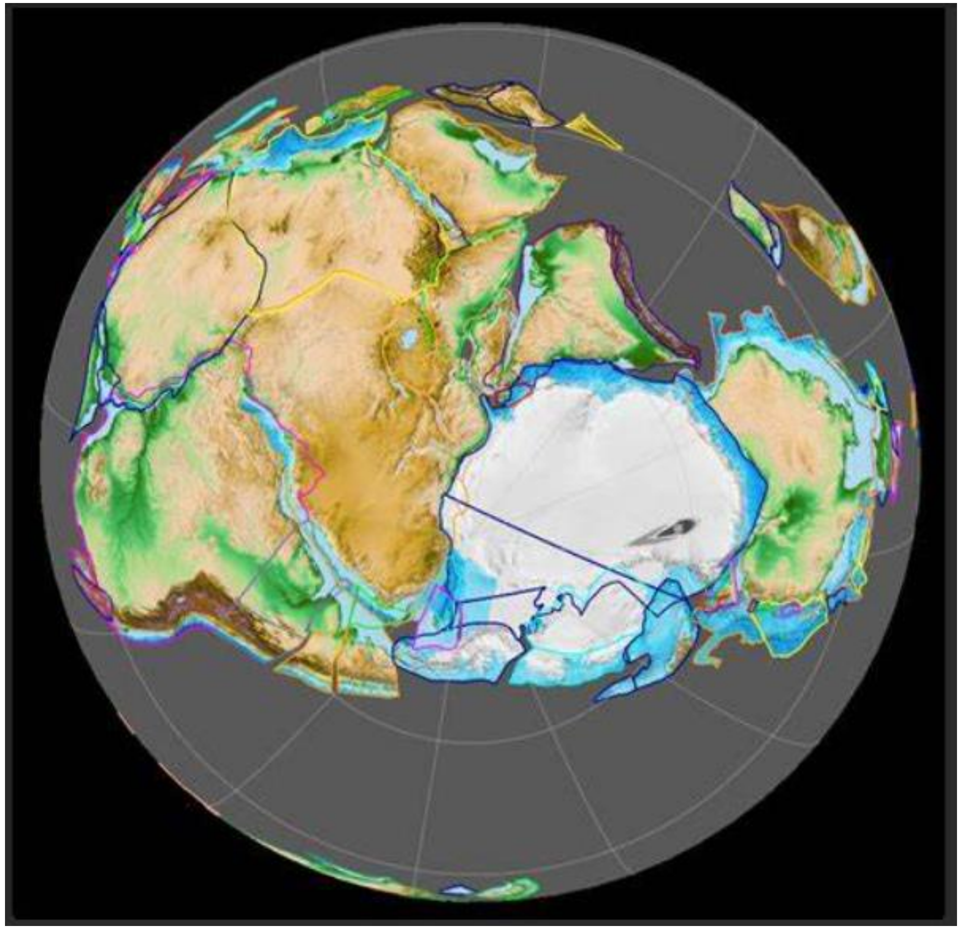
Theory of Continental Drift

- 1912 – P1 of the hypothesis – ‘*interesting, but wha…?! no no no!*’
- 1915 – P2 of the hypothesis – pretty much ignored (WWI happening)
- 1926 – P3 of the hypothesis (in English in NY) – mostly misunderstood
- 1929 – P4 of the hypothesis published in full – ‘*okay, right, so maybe…*’

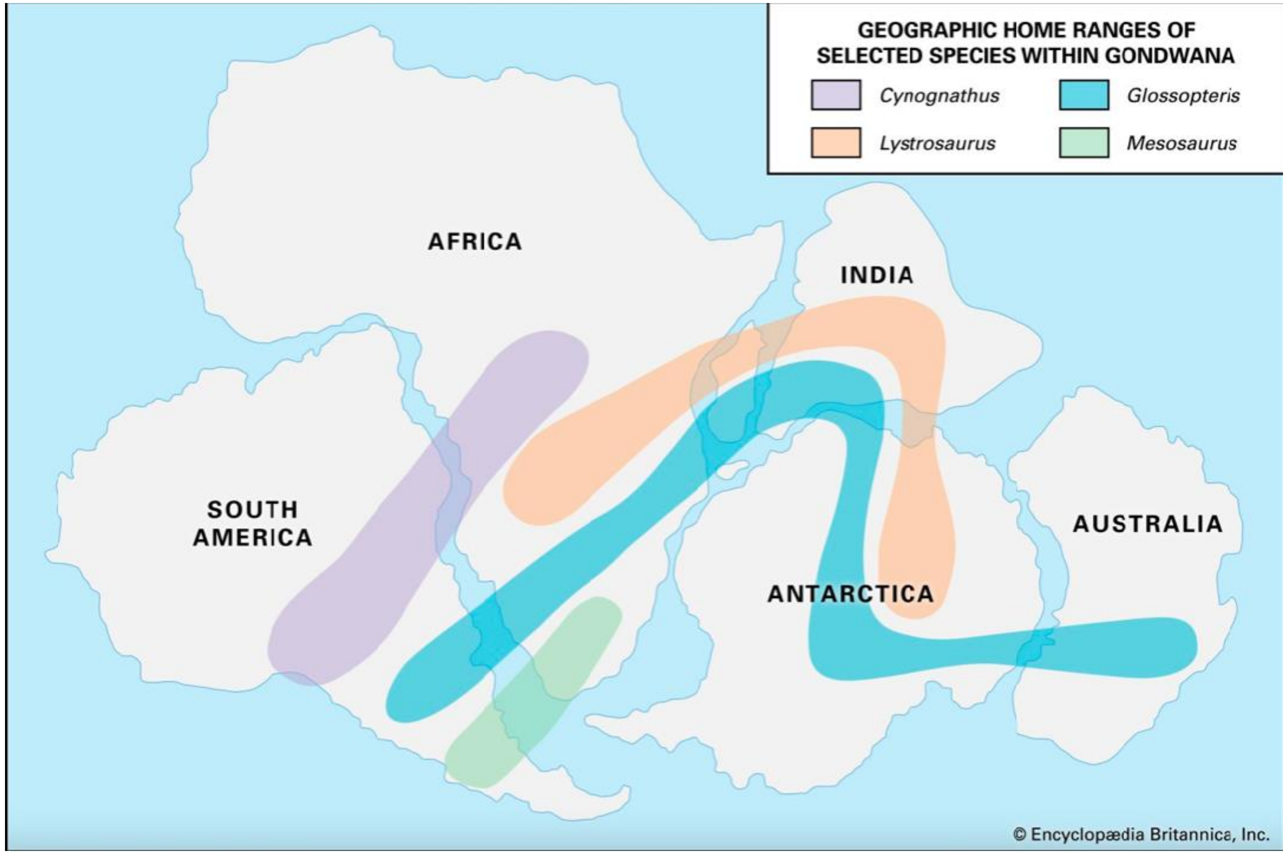


Rekonstruktionen der Erdkarte nach der Verschiebungstheorie für drei Zeiten.

Schraffiert: Tiefsee; punktiert: Flachsee; heutige Konturen und Flüsse nur zum Erkennen. Gradnetz willkürlich (das heutige von Afrika).



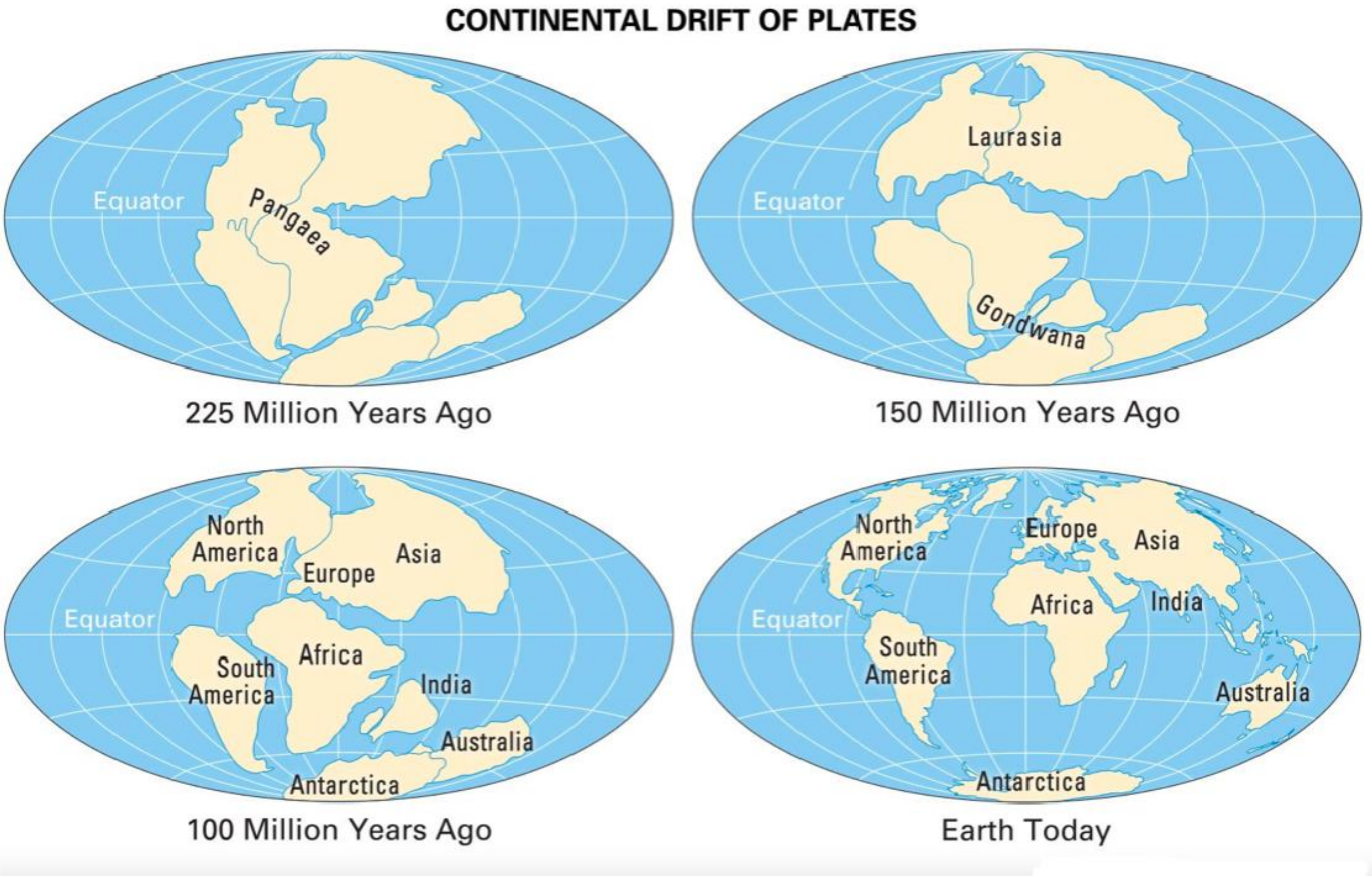
AW: Species distributions as found in plant and animal fossils dated from between 300 – 240 MYA also suggest previous connection between now separated landmasses



AW: Alignment isn't at the current coastline; it's at the depth (~ 200 m) of the continental shelf

So, this story of supercontinents forming and breaking apart could be true…

…but HOW does it happen? What is the driving mechanism?? How do we verify that mechanism???



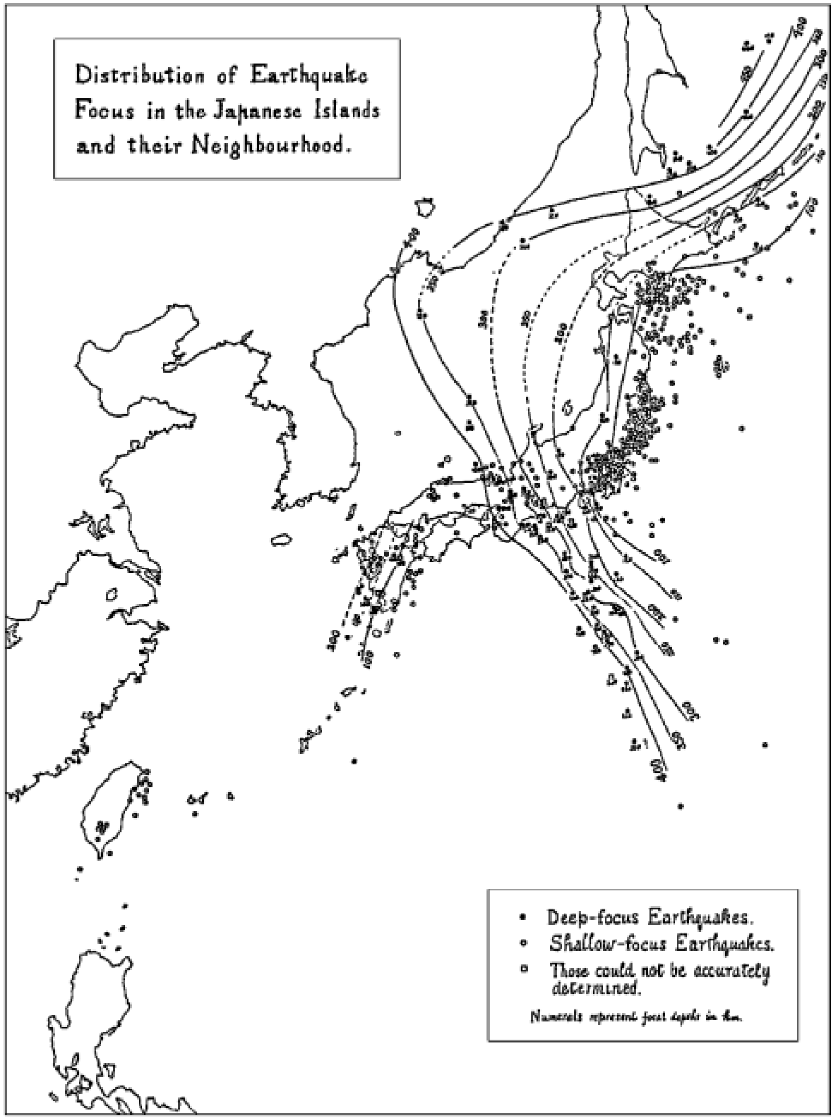
Kiyoo Wadati, PhD
(Sept. 1902 – Jan. 1995)

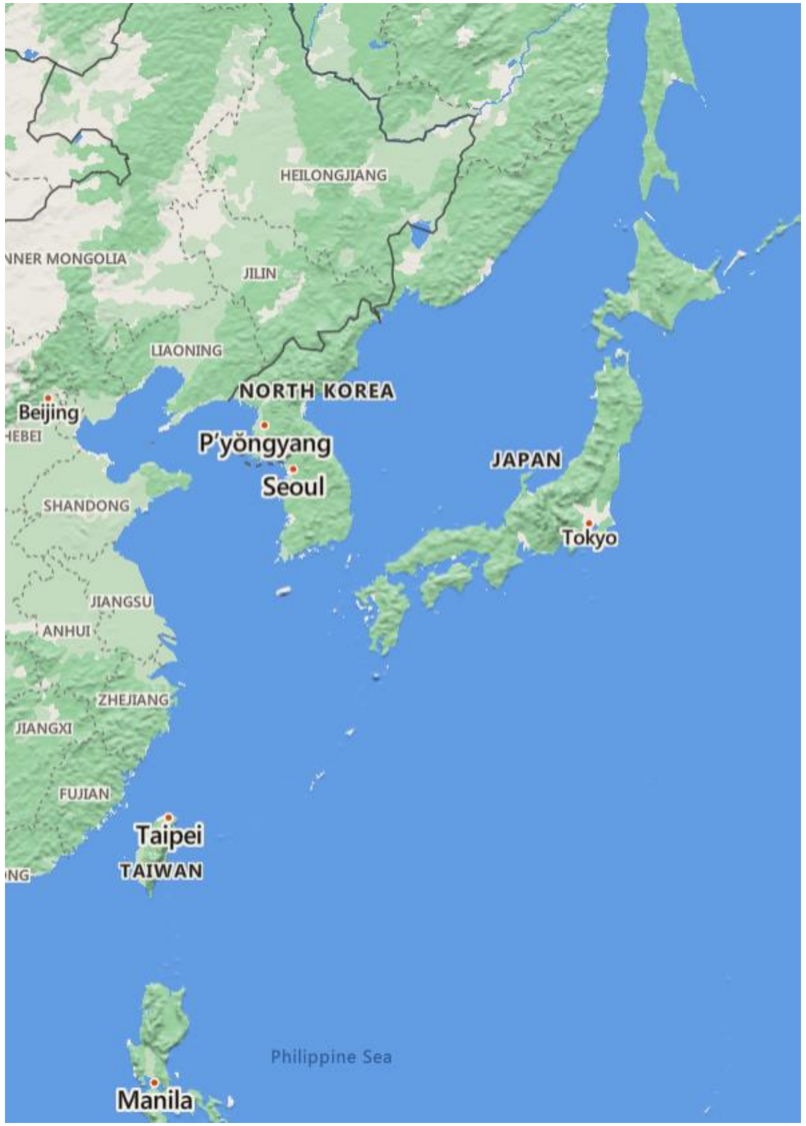
Two researchers working on different continents using different tools to study earthquakes made two separate observations during the 1920s – 1930s:

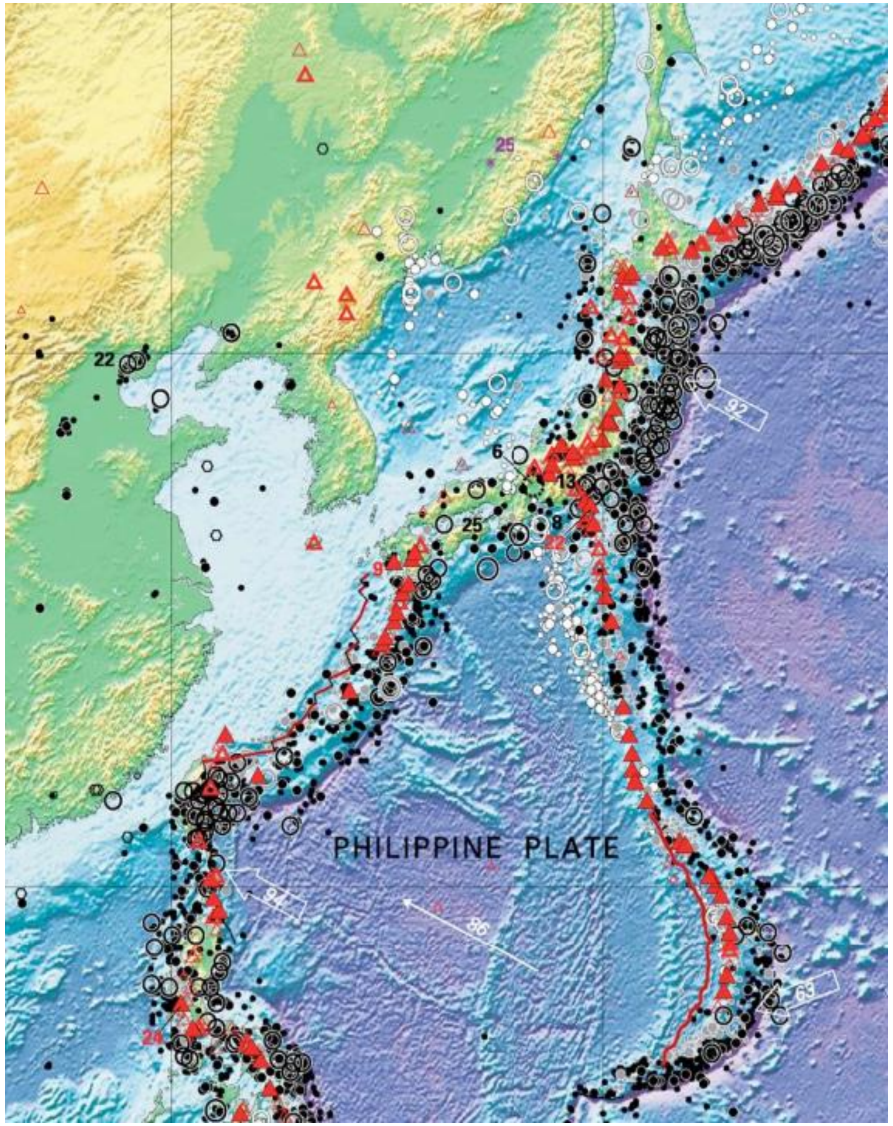
1. Earthquake depth under Japan slopes to the West such that deeper quakes are further West than shallower quakes (KW)

2. The location of quakes on a sloping plane is consistent with how it might look if they were (are) occurring along a subducting or submerged plate (HB)

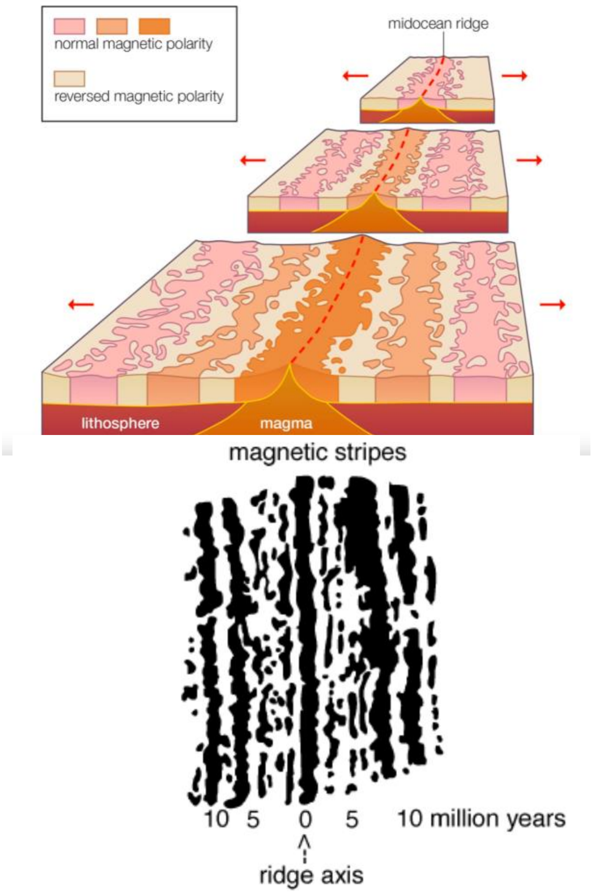
Hugo Benioff, PhD
(Sept. 1899 – Feb. 1968)



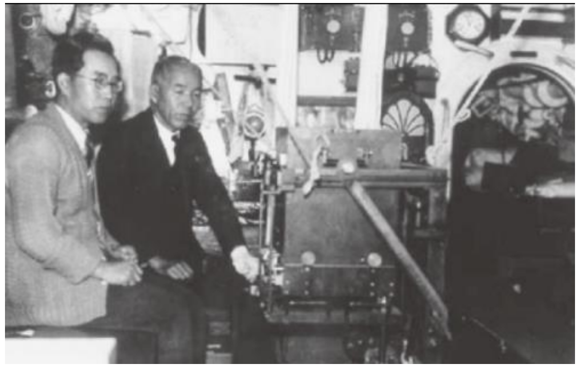




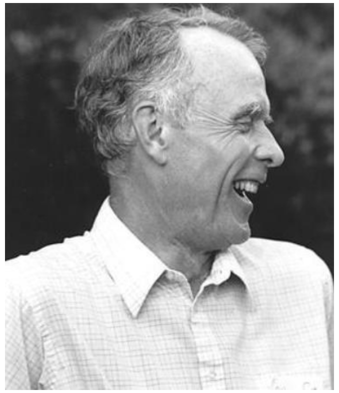
Okay, so now we're adding the depth dimension – we're starting to think about the how….but so many questions still….How deep does this process go? How fast is it happening? Oh no…there's another WW starting…

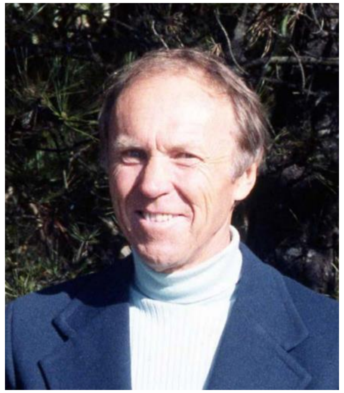


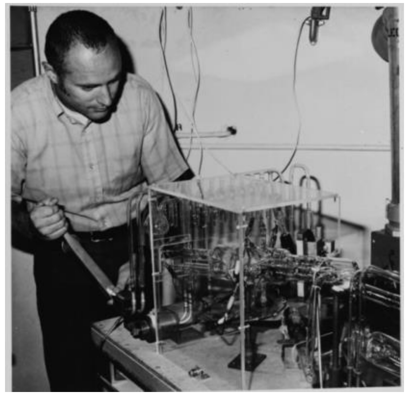
Matsuyama Motonori
Magnetic polarities reverse (1920s)



Allan Cox, Richard Doell and Brent Dalrymple
Magnetic polarity timescale (1959)

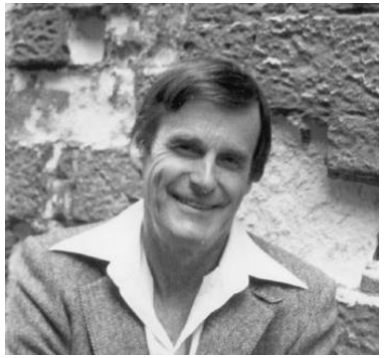




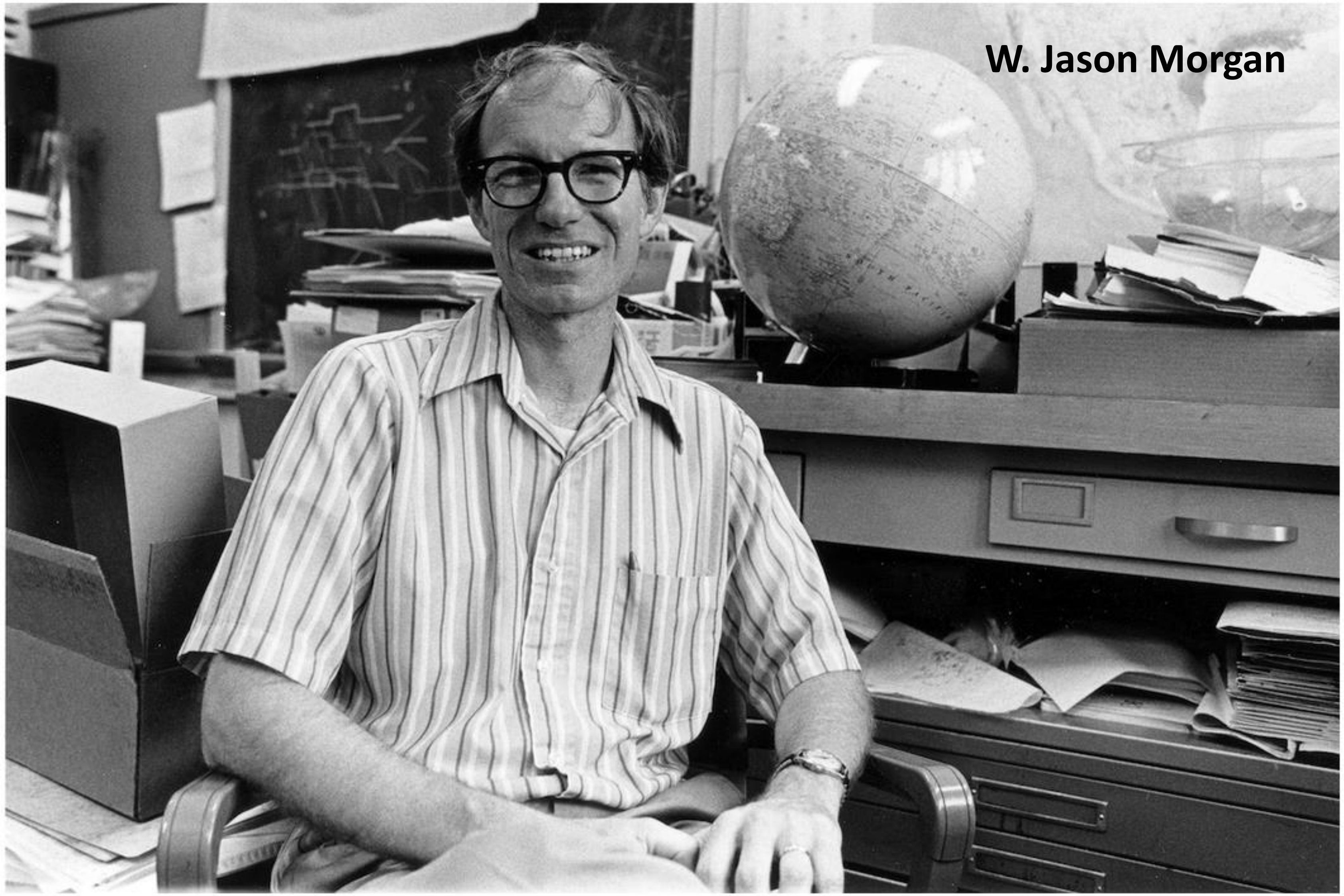


Neil D. Opdyke
Oceanic sediment
evidence (1962)

Now we have a process that we can measure. Which means we can make predictions. And test them. Does geology have its paradigm?



Frederick Vine, Lawrence Morley and Drummond Matthews
Vine-Matthews-Morley Hypothesis (1963)




JOURNAL OF GEOPHYSICAL RESEARCH VOL. 73, NO. 6, MARCH 15, 1968

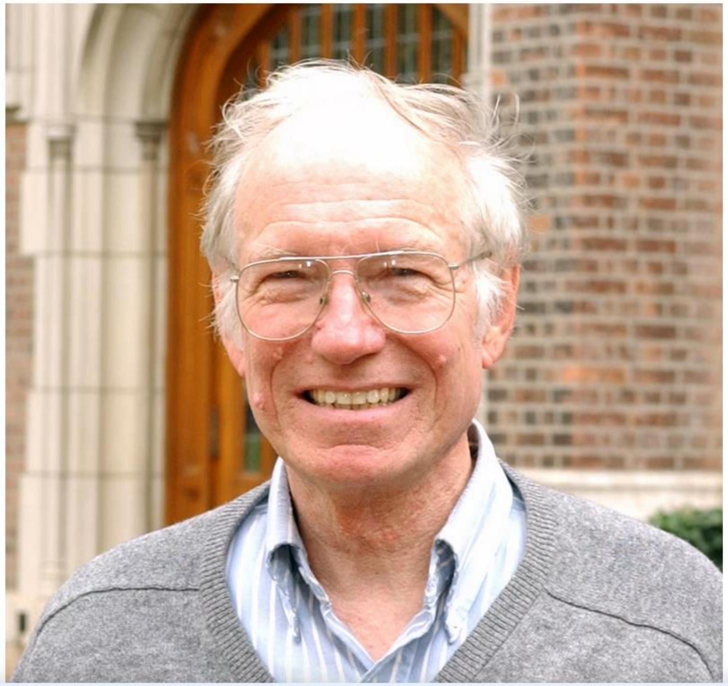
Rises, Trenches, Great Faults, and Crustal Blocks[1]

W. JASON MORGAN

Department of Geology, Princeton University, Princeton, New Jersey 08540
and Department of Geology and Geophysics, Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

The transform fault concept is extended to a spherical surface. The earth's surface is considered to be made of a number of rigid crustal blocks. It is assumed that each block is bounded by rises (where new surface is formed), trenches or young fold mountains (where surface is being destroyed), and great faults, and that there is no stretching, folding, or distortion of any kind within a given block. On a spherical surface, the motion of one block (over the mantle) relative to another block may then be described by a rotation of one block relative to the other block. This rotation requires three parameters, two to locate the pole of relative rotation and one to specify the magnitude of the angular velocity. If two adjacent blocks have as common boundaries a number of great faults, all of these faults must lie on 'circles of latitude' about the pole of relative rotation. The velocity of one block relative to the other must vary along their common boundary; this velocity would have a maximum at the 'equator' and would vanish at a pole of relative rotation.

The motion of Africa relative to South America is a case for which enough data are available to critically test this hypothesis. The many offsets on the mid-Atlantic ridge appear to be compatible with a pole of relative rotation at 62°N (±5°), 36°W (±2°). The velocity pattern predicted by this choice of pole roughly agrees with the spreading velocities determined from magnetic anomalies. The motion of the Pacific block relative to North America is also examined. The strike of faults from the Gulf of California to Alaska and the angles inferred from earthquake mechanism solutions both imply a pole of relative rotation at 53°N (±3°), 53°W (±5°). The spreading of the Pacific–Antarctic ridge shows the best agreement with this hypothesis. The Antarctic block is found to be moving relative to the Pacific block about a pole at 71°S (±2°), 118°E (±5°) with a maximum spreading rate of 5.7 (±0.2) cm/yr. An estimate of the motion of the Antarctic block relative to Africa is made by assuming closure of the Africa–America–Pacific–Antarctica–Africa circuit and summing the three angular velocity vectors for the cases above.



Rises, Trenches, Great Faults and Crustal Blocks

April 1967 – American Geophysical Union (AGU) meeting – D.C.

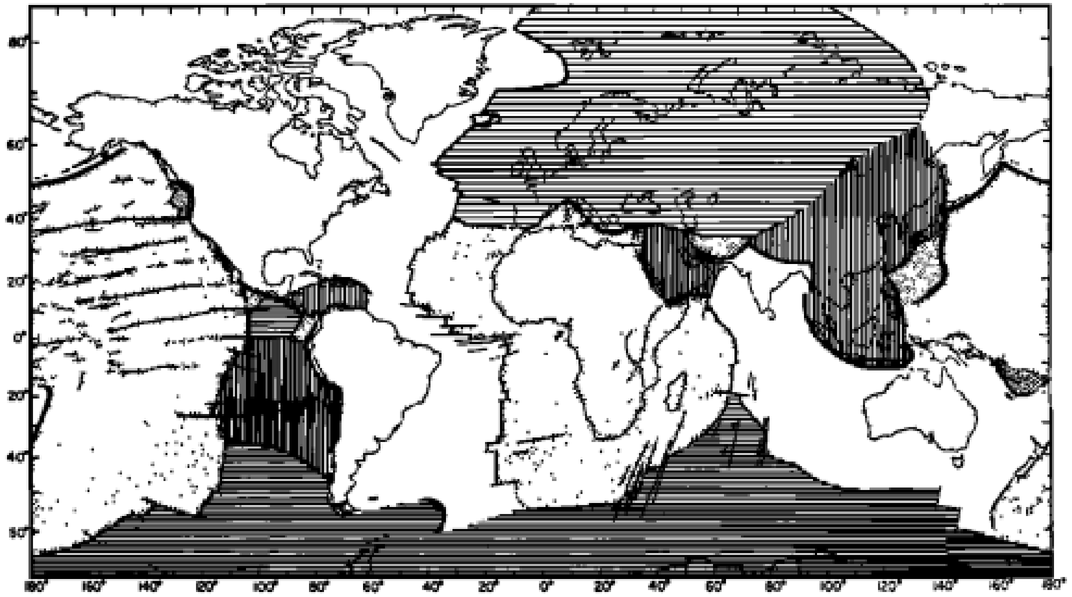


Fig. 1. The crust is divided into units that move as rigid blocks. The boundaries between blocks are rises, trenches (or young fold mountains), and faults. The boundaries drawn in Asia are tentative, and additional sub-blocks may be required. (Figure is based on *Sykes*'s [1968*b*] map of the ridge system with additional features from *Heezen and Tharp*'s [1965] tectonic map.)

Conclusion

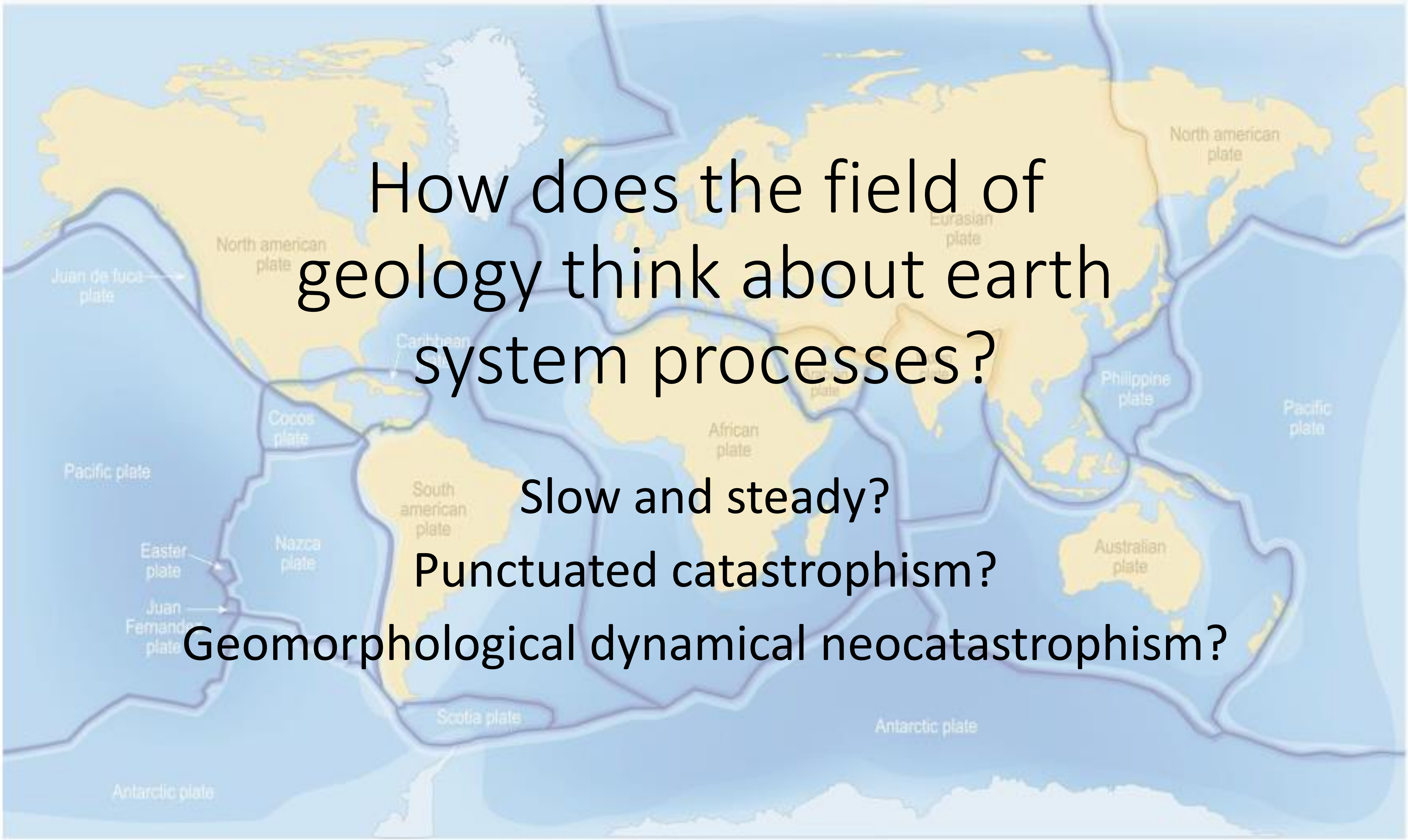
The evidence presented here favors the existence of large 'rigid' blocks of crust. That continental units have this rigidity has been implicit in the concept of continental drift. That large oceanic regions should also have this rigidity is perhaps unexpected. The required strength cannot be in the crust alone; the oceanic crust is too thin for this. We instead favor a strong tectosphere, perhaps 100 km thick, sliding over a weak asthenosphere. Theoretical justification for a model of this type has been advanced by *Elsasser* [1967]. In the simple two-dimensional picture of a rise and a trench with a continent between them, we imagine a conveyer-belt process in which the drifting continent need have no great strength. In the model considered here, we may have local hot spots on the rise and faster sinking at some places on the trenches. The crustal blocks should have the mechanical strength necessary to average out irregular driving sources into a uniform motion; the tectosphere should be capable of transmitting even tensile stresses. The crustal block model can possibly explain the median position of most oceanic rises and the symmetry of their magnetic pattern. We assume that the location of the rises is not fixed by some deep-seated thermal source but is determined by the motion of the blocks. Suppose a crustal block is under tension and splits along some line of weakness. The forces that tore it apart continue to act, and the blocks move apart creating a void, say, 1 km wide and 100 km deep, which is filled with mantle material. As the blocks move farther apart, they split down the center of the most recently injected dike, since this is the hottest and weakest portion between the two blocks. Even if one block remains stationary with respect to the mantle and only one block moves, we will have a symmetric pattern if a new dike is always injected up the center of the most recent dike. If the initial split was entirely within a large continental block, this control of mantle convection by boundary conditions at the top surface will result in a ridge crest with a median position.

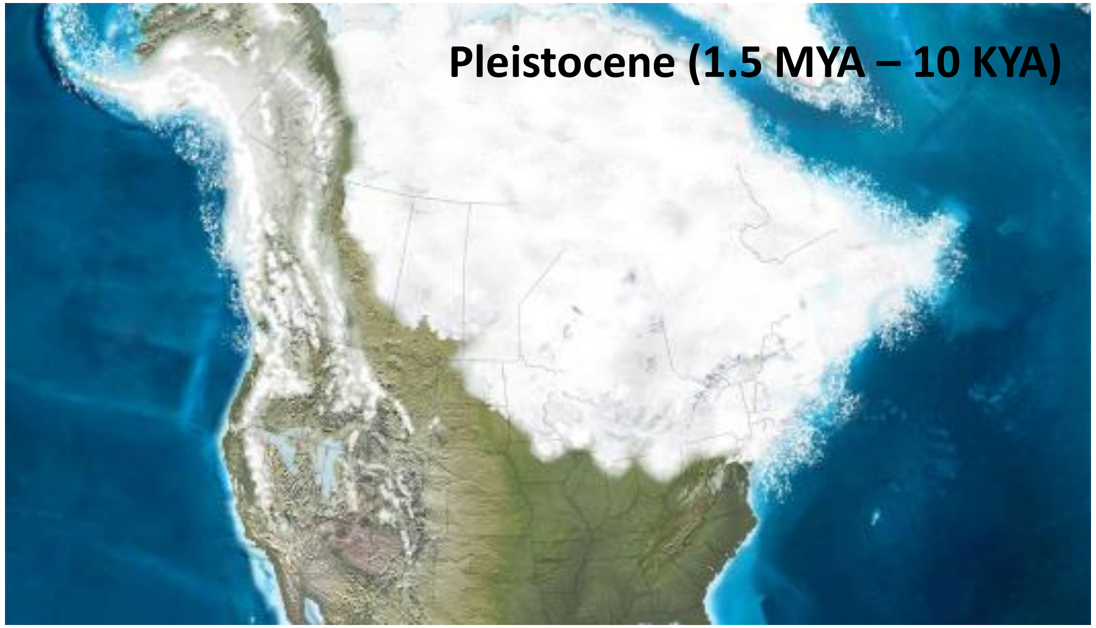
How does the field of geology think about earth system processes?

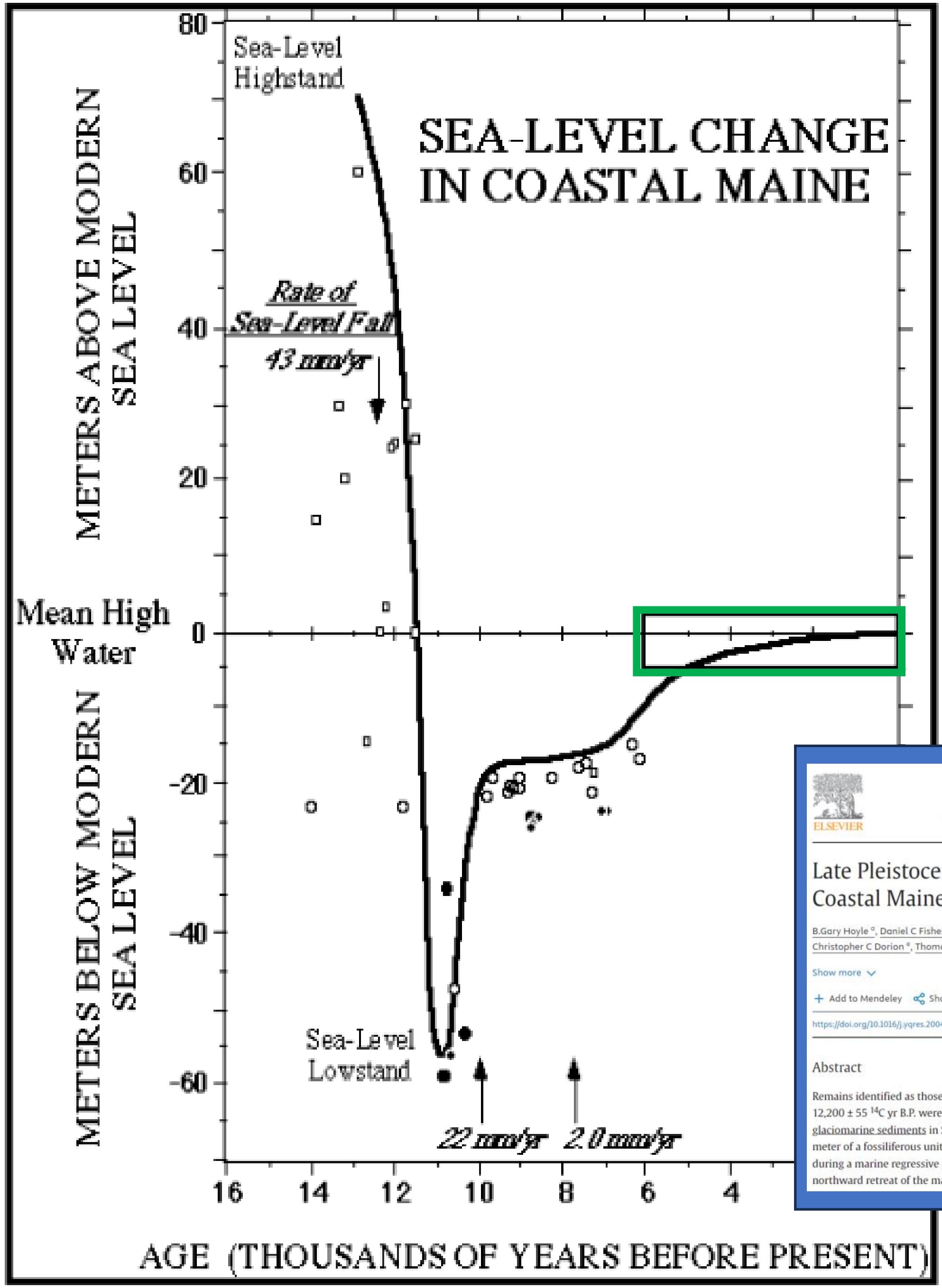
Slow and steady?

Punctuated catastrophism?

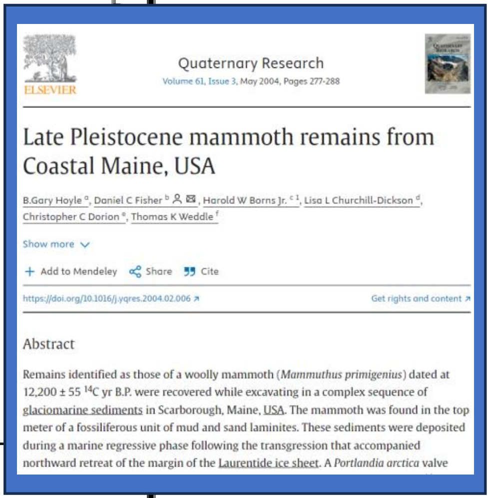
Geomorphological dynamical neocatastrophism?







Maine Geological Survey



ELSEVIER
Quaternary Research
Volume 61, Issue 3, May 2004, Pages 277-288

Late Pleistocene mammoth remains from Coastal Maine, USA

B.Gary Hoyle [a], Daniel C Fisher [b], Harold W Borns Jr. [c 1], Lisa L Churchill-Dickson [d], Christopher C Dorion [e], Thomas K Weddle [f]

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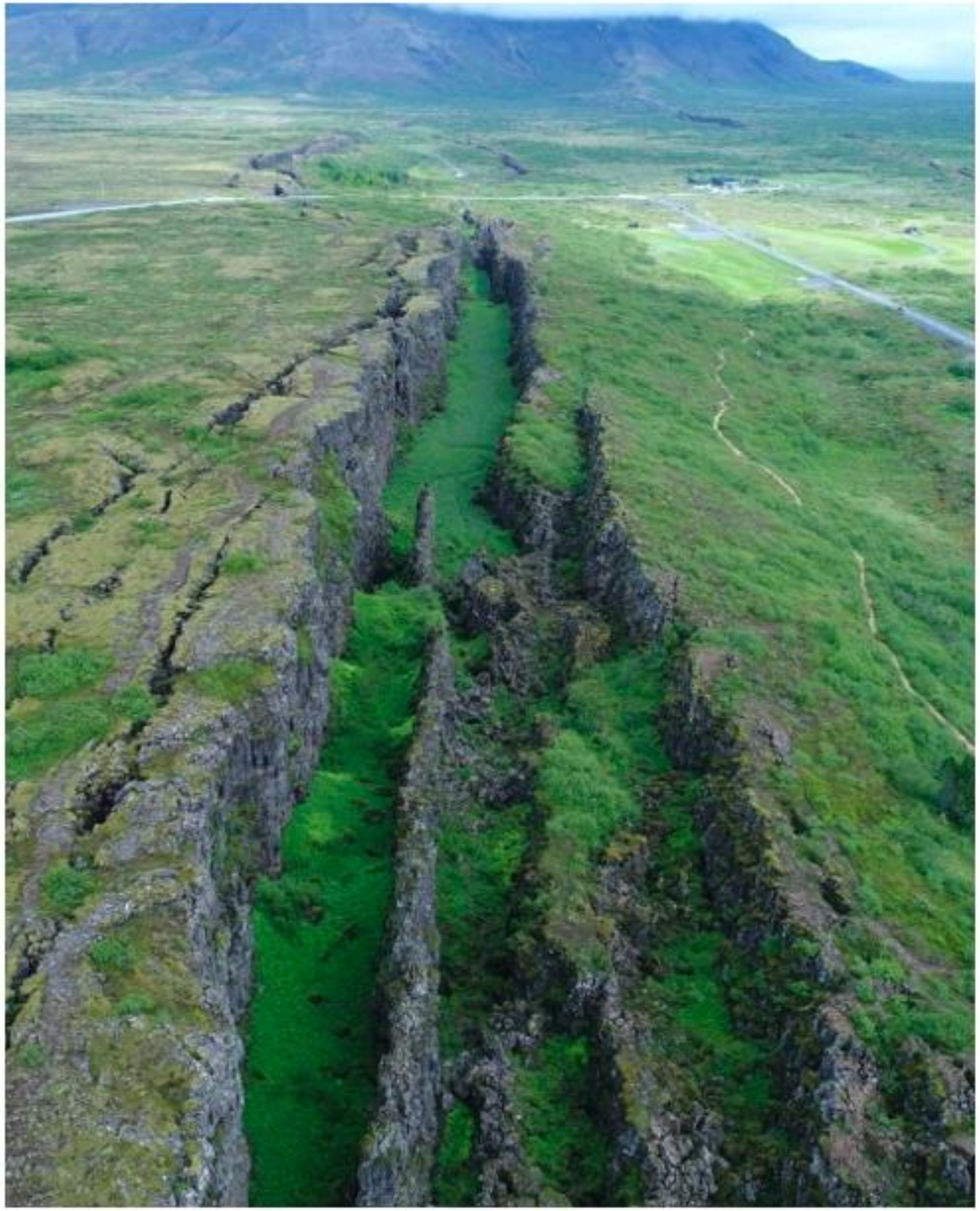
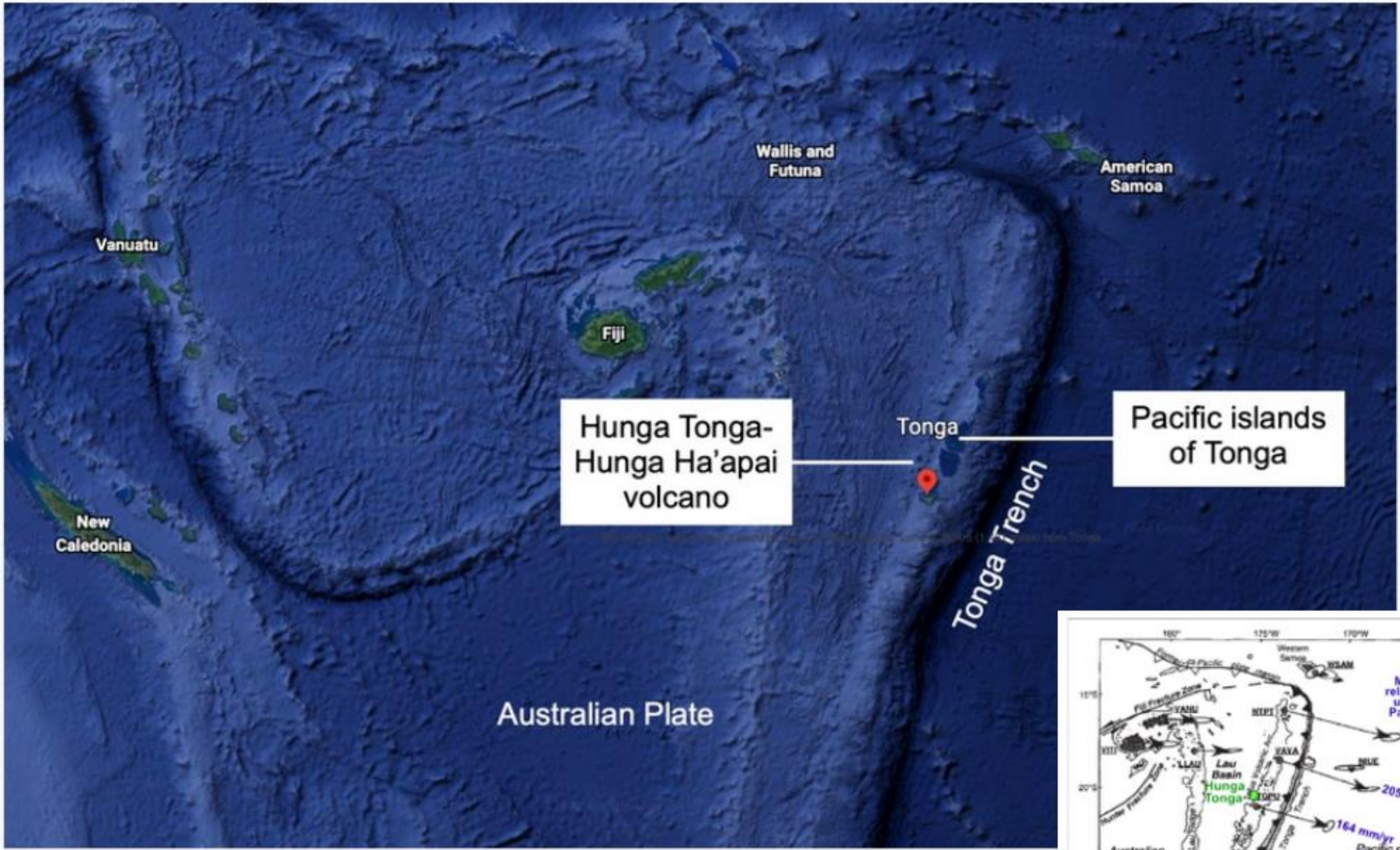
Abstract

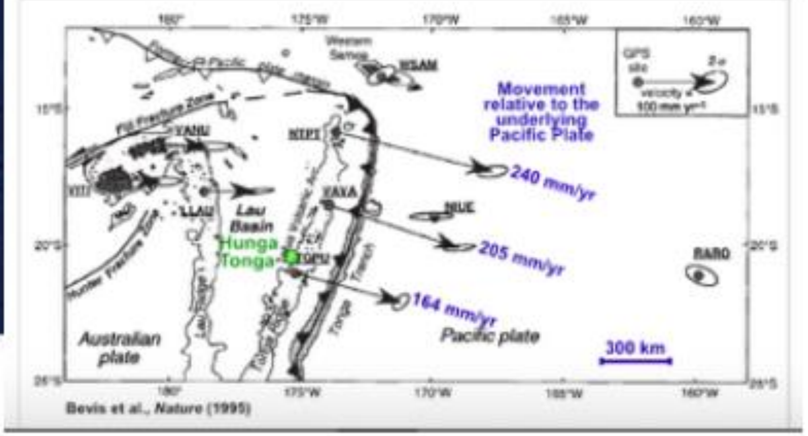
Remains identified as those of a woolly mammoth (*Mammuthus primigenius*) dated at 12,200 ± 55 ^{14}C yr B.P. were recovered while excavating in a complex sequence of glaciomarine sediments in Scarborough, Maine, USA. The mammoth was found in the top meter of a fossiliferous unit of mud and sand laminites. These sediments were deposited during a marine regressive phase following the transgression that accompanied northward retreat of the margin of the Laurentide ice sheet. A *Portlandia arctica* valve

What about Ice and Sea Level?



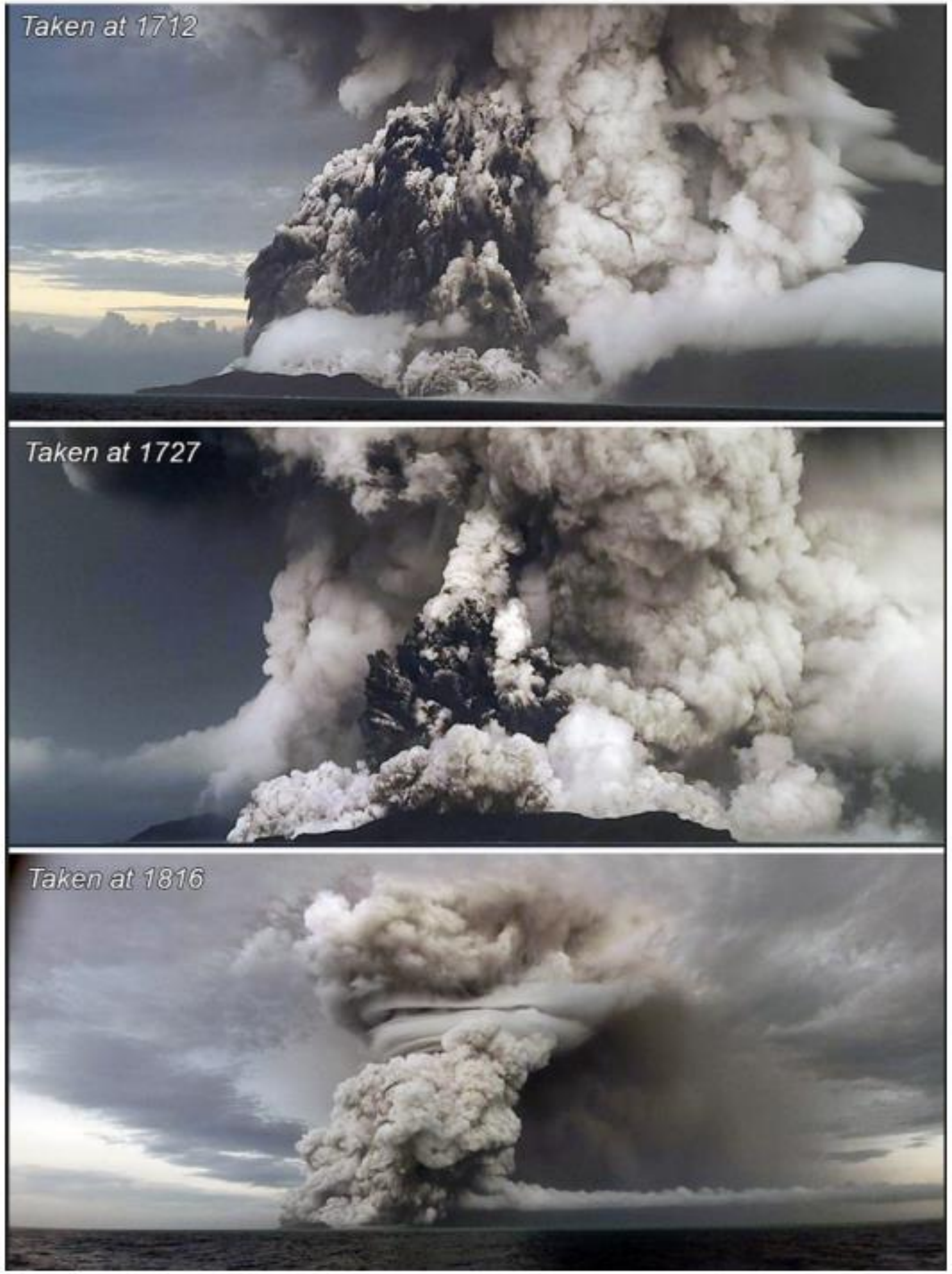
What about plate tectonics and the opening of ocean basins?





What about volcanism?

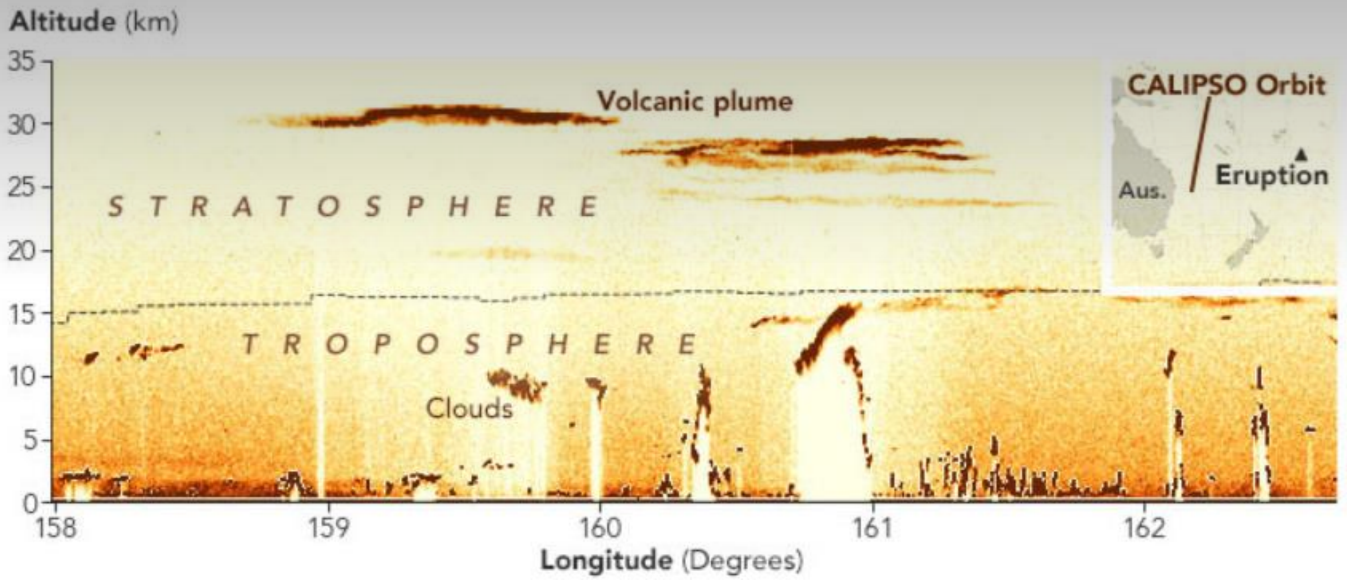

N
500 m
2019
Tonga
Pre-eruption (2010)
Hunga Tonga
Hunga
Ha'apai
HTHH
Nuku'alofa
WV02 image © DigitalGlobe 2019
WV02 image © DigitalGlobe 2019



Taken at 1712
Taken at 1727
Taken at 1816

HUNGA-TONGA-HUNGA-HA'APAI PRE-ERUPTION · Tonga · January 15, 2022 · 3:25 p.m. TOT
planet.

On January 15, the Hunga Tonga - Hunga Ha'apai volcano north of Tongatapu in the south west Pacific erupted with ash and sulfur dioxide (SO_2) gas reaching into the stratosphere to altitudes up to or higher than 30 km. This eruption provided the opportunity to study the microphysical processes that occur when SO_2 gas is emitted into the stratosphere and will help to improve the accuracy of atmospheric models. To take advantage of this rare opportunity, NOAA and CIRES scientists from CSL and researchers from the University of Houston traveled to La Réunion,



Projects: TR2EX