A new Norwegian Centre of Excellence at the Department of Geosciences, University of Oslo (2013-2023)

Norwegian
Centre of
Excellence

CEED

The Centre for Earth Evolution and Dynamics

Lost Land Beneath the Waves, Indian Ocean

- Geological detectives are piecing together an intriguing seafloor puzzle. The Indian Ocean and some of its islands, scientists say, may lie on top of the remains of an ancient continent pulled apart by plate tectonics between 50 million and 100 million years ago. *ScienceNOW. 24.2.2013*. CEED researchers are among the detectives.

WHO ARE WE?

CEED

Geo

PGP NGU

NHM

CEED include scientists from the Physics of Geological Processes (PGP), the Natural History Museum (NHM) and the department of Geosciences (all parts of UiO). In addition, current/former members of the Geodynamics Group at NGU are fully/partly assimilated within the Centre.

The Research Council of Norway

Norwegian Geosciences was evaluated in 2011 by an international committee: *Only PGP & NGU Geodynamics* received top ranking in Geology/Solid Earth Geophysics.

4 winners

erc

European Research Council

3 finalists

CEED/GEO scientists are also *the only Earth System Scientists in Norway* that have won both the esteemed ERC Advanced (2.5 mill. EUR) and ERC Starting Grants (1.5 Mill EUR).

OSLO

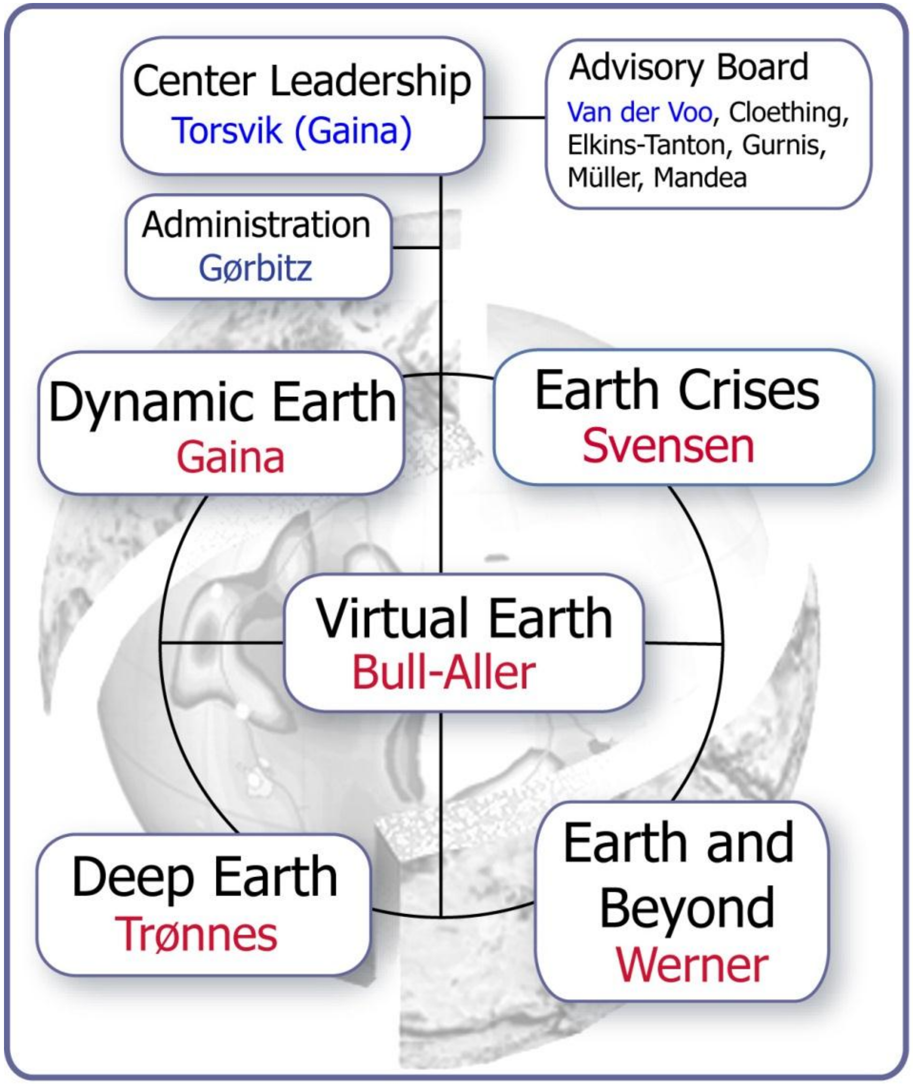
Geomagnetic Laboratory

2013 Finalist

CEED LEADERSHIP

Director: Trond Helge Torsvik

Assistant Director: Carmen Gaina



Center Leadership
Torsvik (Gaina)

Advisory Board
Van der Voo, Cloething, Elkins-Tanton, Gurnis, Müller, Mandea

Administration
Gørbitz

Dynamic Earth
Gaina

Earth Crises
Svensen

Virtual Earth
Bull-Aller

Deep Earth
Trønnes

Earth and Beyond
Werner

Advisory Board

CEED Project Structure

Torsvik (Director) & Gørbitz (Administrator)

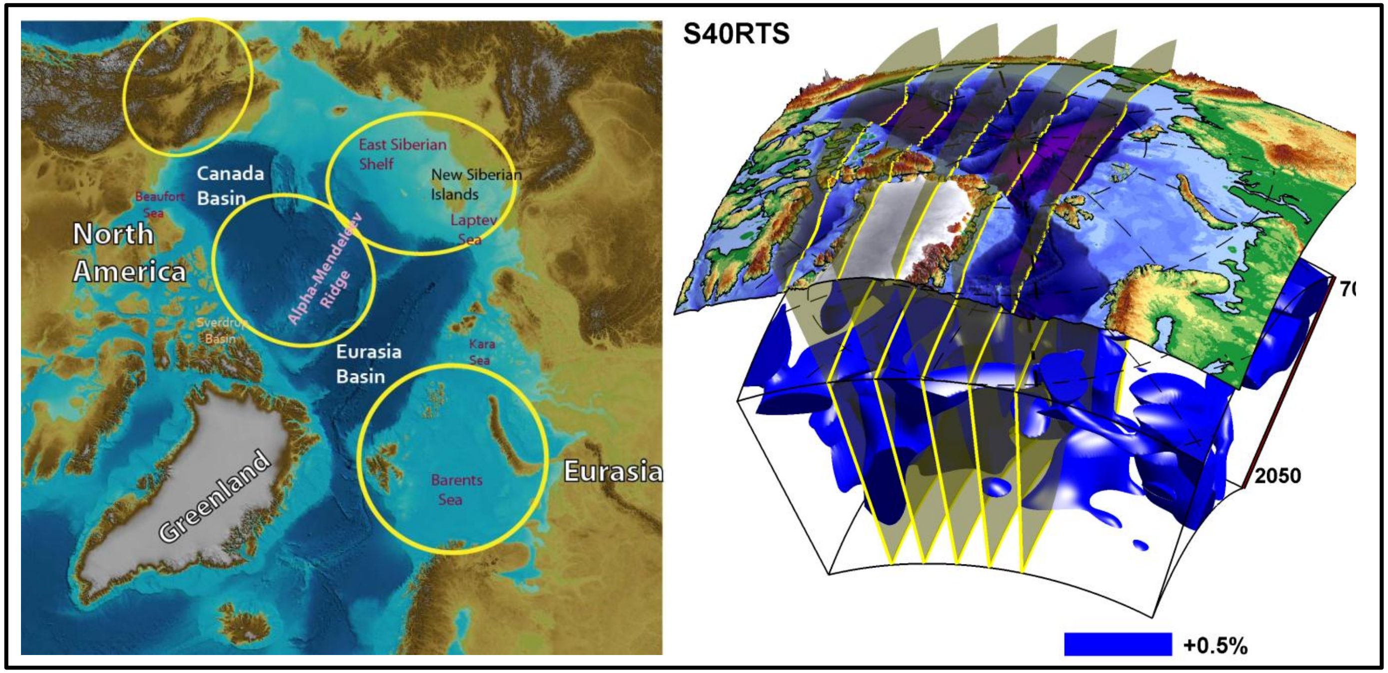
- **Dynamic Earth**
  Dr. C. Gaina
  - **OMNIS** 2011-14
    Prof. R.H. Gabrielsen
  - **4D-Arctic 2013-16**
    Dr. C. Gaina
  - **CHRONOS** 2012-17
    Profs. Stein/Hannah
  - **BARMOD 2011-**
    Prof. Jan-Inge Faleide
  - **PRESSICE 2013-16**
    Dr. S. Medvedev
- **Deep Earth**
  Prof. R.G. Trønnes
  - **BPT** 2011-16
    Prof. T.H. Torsvik
    ERC AdvGr
- **Earth Crises**
  Dr. H. Svensen
  - **EPIC** 2013-16
    Dr. H. Svensen
  - **LUSI LAB** 2013-17
    Dr. A. Mazzini
    (ERC StGr)
- **Earth & Beyond**
  Dr. S. C. Werner
  - **IMPACT EFFECTS**
    2012-13
    Dr. G. Gisler
  - **CRATER CLOCK**
    Dr. S.C. Werner
    (ERC StGr Finalist)
- **Virtual Earth**
  Dr. A. Bull-Aller
  - **MODCONF 2013**
    Prof. T.H. Torsvik
  - **NOTUR**
    Dr. A. Bull-Aller

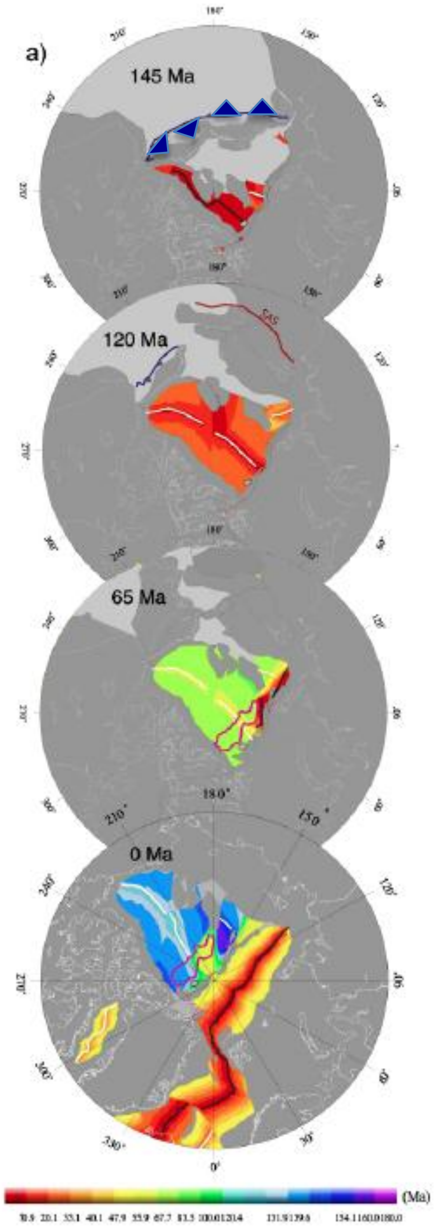
  - **GPlates**
    FORCE?

⬛ Industry 🟧 NFR 🟥 EU

4D-Arctic (Carmen Gaina)

- *What is the nature of the crust and the timing of Basin formation*
- *Timing, mechanism and extent of volcanism in the High Arctic*
- *What is the structure of the mantle ?*

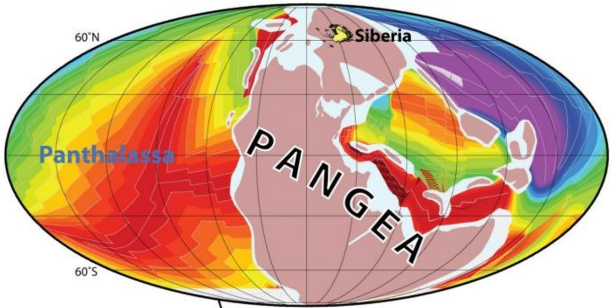


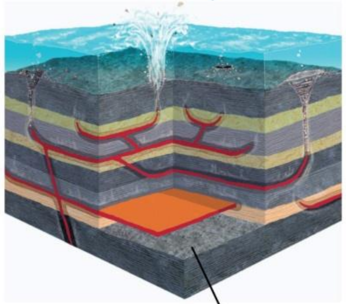


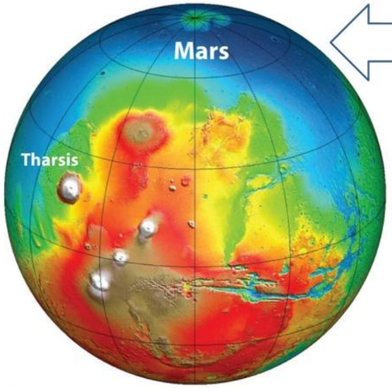
CEED VISION: Develop an Earth model that explains how mantle processes drive plate tectonics and trigger massive volcanism and associated environmental and climate changes throughout Earth history

Dynamic Earth: Build a consistent global plate tectonic model for the past 1100 Ma

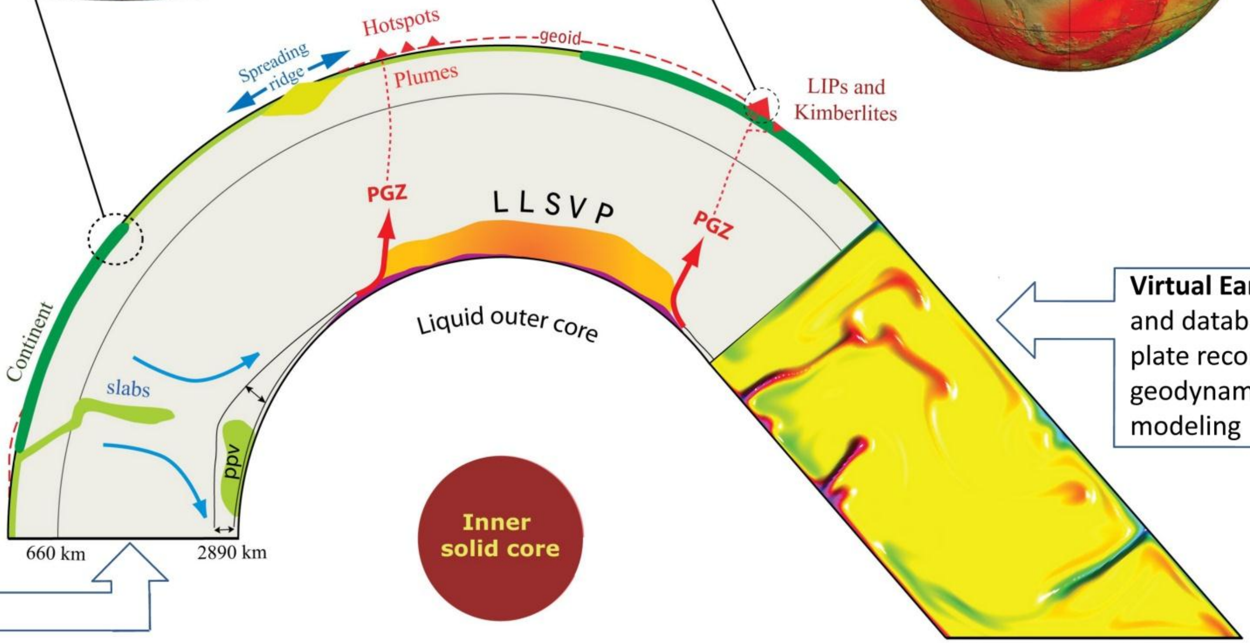
Earth Crises: Understand the role of voluminous volcanism on global climate changes and extinctions





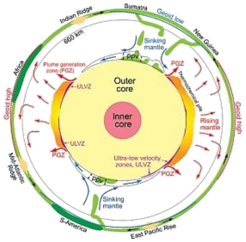


Earth and Beyond: Understand similarities and differences between the Earth and the other terrestrial planets



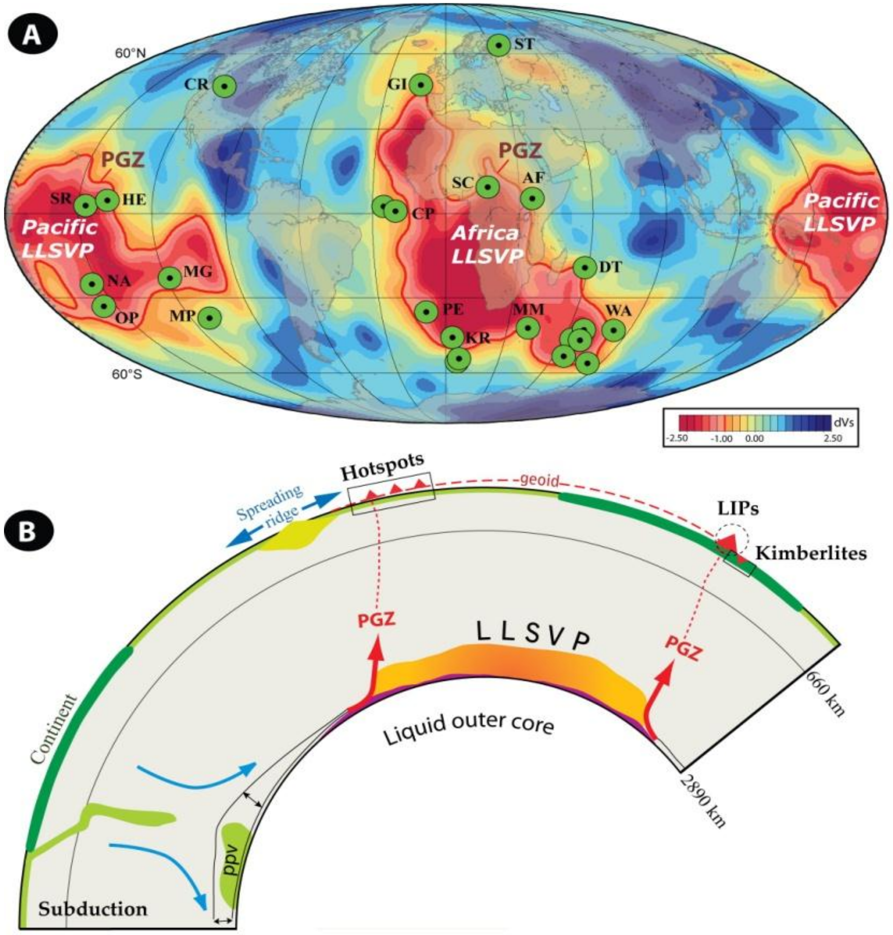
Virtual Earth: Develop tools and databases that integrate plate reconstructions with geodynamic and climate modeling

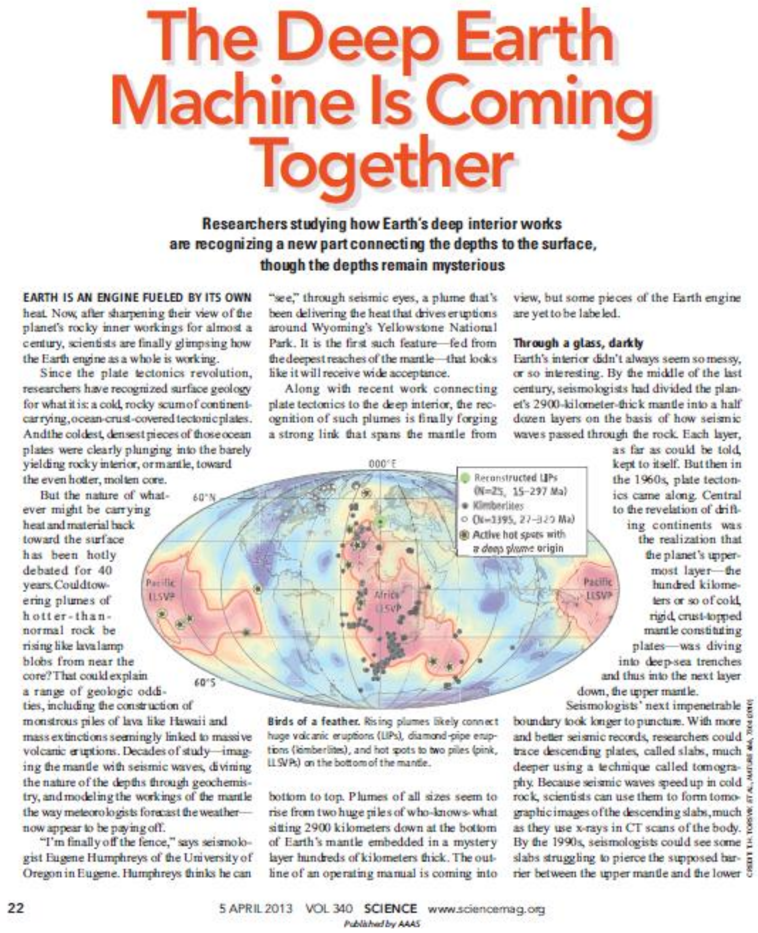
Deep Earth: Understand the link between the surface and the deep mantle



Deep Earth: Materials, structure and dynamics

Reidar G. Trønnes (r.g.tronnes@nhm.uio.no)





The Deep Earth Machine Is Coming Together

Researchers studying how Earth's deep interior works are recognizing a new part connecting the depths to the surface, though the depths remain mysterious

EARTH IS AN ENGINE FUELED BY ITS OWN heat. Now, after sharpening their view of the planet's rocky inner workings for almost a century, scientists are finally glimpsing how the Earth engine as a whole is working.

Since the plate tectonics revolution, researchers have recognized surface geology for what it is: a cold, rocky scum of continent-carrying, ocean-crust-covered tectonic plates. And the coldest, densest pieces of those ocean plates were clearly plunging into the barely yielding rocky interior, or mantle, toward the even hotter, molten core.

But the nature of whatever might be carrying heat and material back toward the surface has been hotly debated for 40 years. Could towering plumes of hotter-than-normal rock be rising like lava lamp blobs from near the core? That could explain a range of geologic oddities, including the construction of monstrous piles of lava like Hawaii and mass extinctions seemingly linked to massive volcanic eruptions. Decades of study—imaging the mantle with seismic waves, divining the nature of the depths through geochemistry, and modeling the workings of the mantle the way meteorologists forecast the weather—now appear to be paying off.

"I'm finally off the fence," says seismologist Eugene Humphreys of the University of Oregon in Eugene. Humphreys thinks he can "see," through seismic eyes, a plume that's been delivering the heat that drives eruptions around Wyoming's Yellowstone National Park. It is the first such feature—fed from the deepest reaches of the mantle—that looks like it will receive wide acceptance.

Along with recent work connecting plate tectonics to the deep interior, the recognition of such plumes is finally forging a strong link that spans the mantle from bottom to top. Plumes of all sizes seem to rise from two huge piles of who-knows-what sitting 2900 kilometers down at the bottom of Earth's mantle embedded in a mystery layer hundreds of kilometers thick. The outline of an operating manual is coming into view, but some pieces of the Earth engine are yet to be labeled.

Birds of a feather. Rising plumes likely connect huge volcanic eruptions (LIPs), diamond-pipe eruptions (kimberlites), and hot spots to two piles (pink, LLSVPs) on the bottom of the mantle.

Through a glass, darkly

Earth's interior didn't always seem so messy, or so interesting. By the middle of the last century, seismologists had divided the planet's 2900-kilometer-thick mantle into a half dozen layers on the basis of how seismic waves passed through the rock. Each layer, as far as could be told, kept to itself. But then in the 1960s, plate tectonics came along. Central to the revelation of drifting continents was the realization that the planet's uppermost layer—the hundred kilometers or so of cold, rigid, crust-topped mantle constituting plates—was diving into deep-sea trenches and thus into the next layer down, the upper mantle.

Seismologists' next impenetrable boundary took longer to puncture. With more and better seismic records, researchers could trace descending plates, called slabs, much deeper using a technique called tomography. Because seismic waves speed up in cold rock, scientists can use them to form tomographic images of the descending slabs, much as they use x-rays in CT scans of the body. By the 1990s, seismologists could see some slabs struggling to pierce the supposed barrier between the upper mantle and the lower

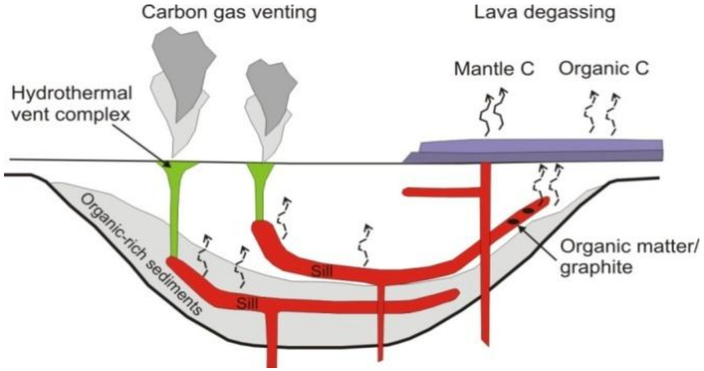
CREDIT: T.H. TORSVIK ET AL., NATURE 466, 7304 (2010)

Published by AAAS

Earth Crises: LIPs, mass extinctions and environmental changes

Henrik Svensen (henrik.svensen@mn.uio.no)

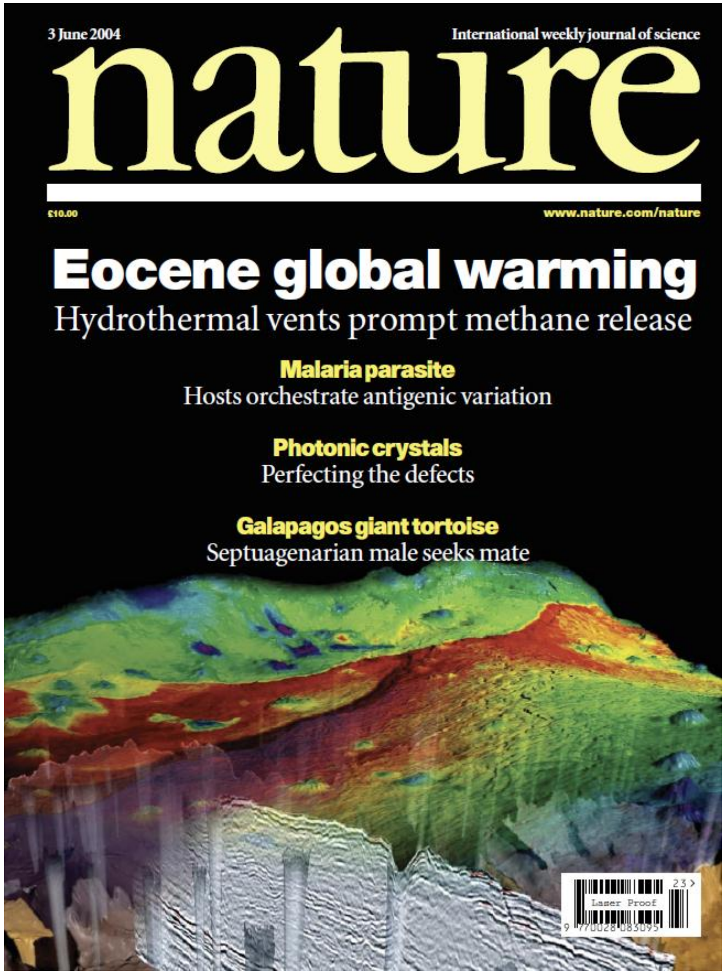
Sub-theme 1: Large Igneous Provinces and Global Warming
Sub-theme 2: Emplacement Environment and Killer Mechanisms
Sub-theme 3: Geochemical Cycles and Paleoenviroment



CROSS-SECTION THROUGH A LIP VOLCANIC BASIN.
Different types of solid Earth degassing are shown.

Mission: To understand the role of voluminous intrusive and extrusive volcanism on rapid global climate change and mass extinction in Earth history.

Main Hypothesis: LIPs have caused most of the mass extinctions and major climate changes of Phanerozoic times.



3 June 2004

International weekly journal of science

nature

£10.00

www.nature.com/nature

Eocene global warming

Hydrothermal vents prompt methane release

Malaria parasite

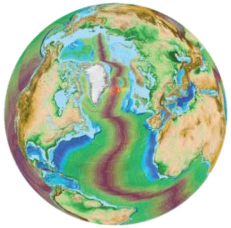
Hosts orchestrate antigenic variation

Photonic crystals

Perfecting the defects

Galapagos giant tortoise

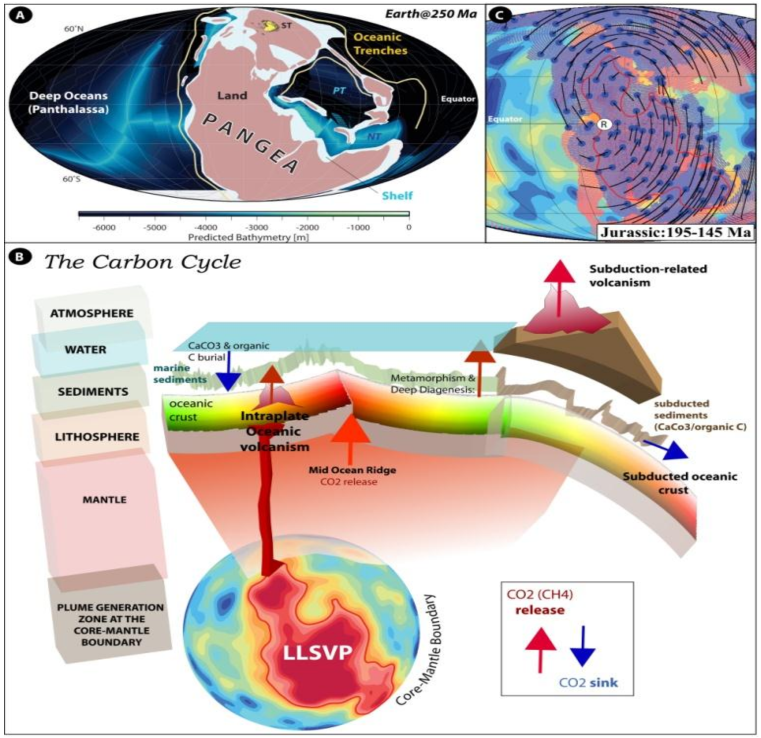
Septuagenarian male seeks mate



Dynamic Earth: Plate motions and Earth history

Carmen Gaina (carmen.gaina@fys.uio.no)

Sub-theme 1: Supercontinents, Palaeogeography and Biogeography
Sub-theme 2: Wilson Kickoff: Passive Margins and Break-up
Sub-theme 3: Continents adrift and oceanic basin formation, TPW & climate changes
Sub-theme 4: Terminal Wilson: Subduction and Collision

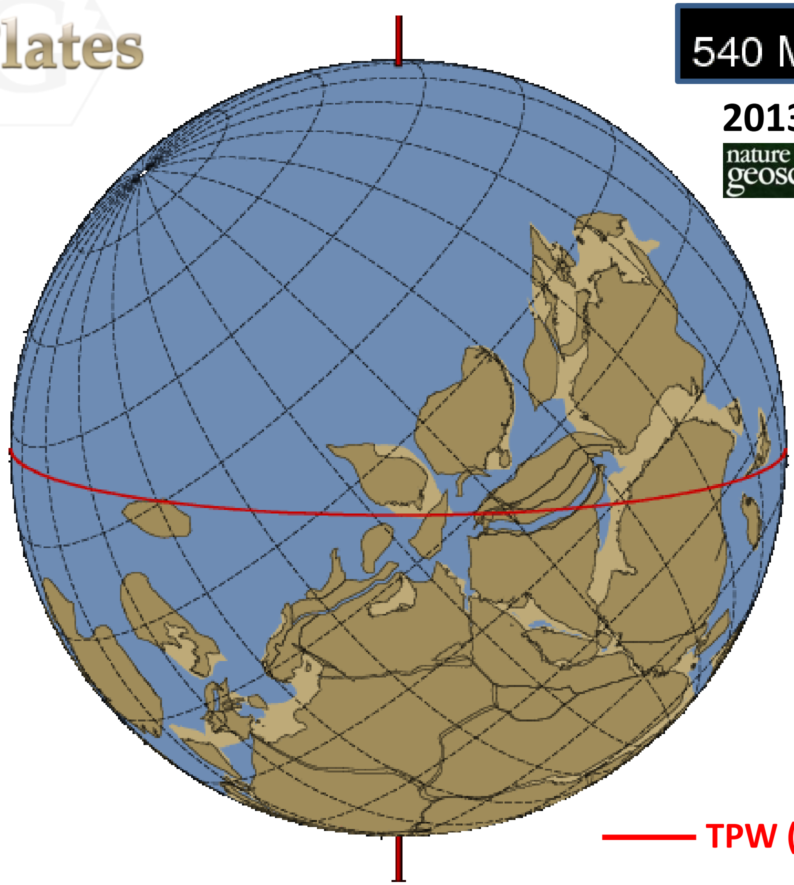


Mission: To explore the link between the lithosphere and the convecting mantle and quantify how palaeogeography and TPW have influenced the climate system.

Main Hypothesis: Motion of tectonic plates is closely related to mantle dynamics and the mantle-lithospheric dynamics drives major changes in Earth's life.

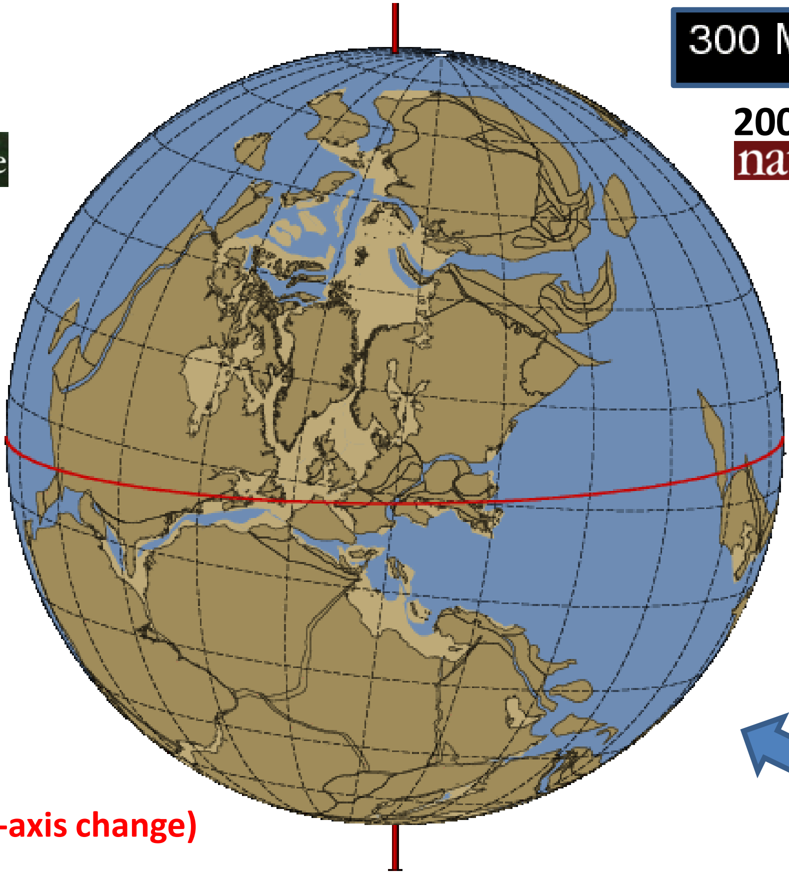
DYNAMIC EARTH: Build a consistent global plate tectonic model for the past 1100 Ma (2015?)

GPlates



2013

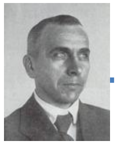
nature geoscience



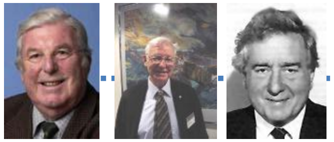
2008

nature

TPW (spin-axis change)



WEGENER
1912



Cambridge (1954, 56)

1962 1967

CEED
2020

Revolutions in Earth Sciences: From Wegener to CEED

CONTINENTAL DRIFT

SEAFLOOR SPREADING

PLATE TECTONICS

MANTLE DYNAMICS

Trondheim 2002

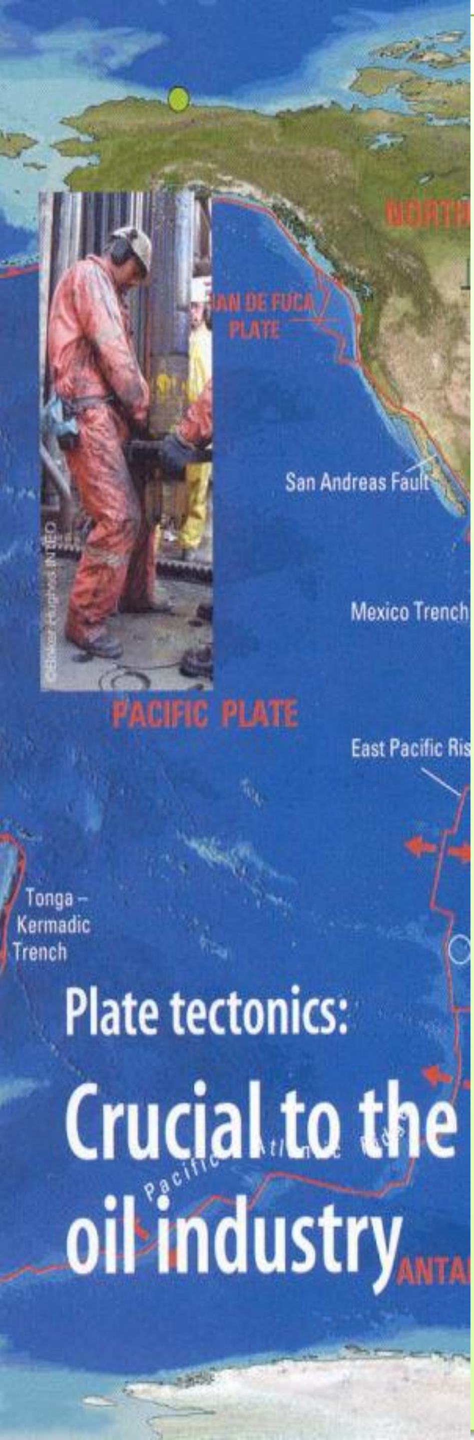
R. Dietmar Müller
EarthByte Group, *School of Geosciences,*
The University of Sydney

Michael Gurnis
California Institute of Technology

Trond H. Torsvik
CEED (University of Oslo) & Geodynamics (NGU)

The consortium has been run under funding provided by Australian, US, Norwegian and Japanese National funding agencies, Statoil & NGU.

GPlates was conceived as an international open software project. The earliest documented conceptual design activity in this regard is represented by the first GPlates workshop in 2002 (NGU, Trondheim), hosted and financially supported by NGU Geodynamics. This 5-day workshop laid the foundation for GPlates design.

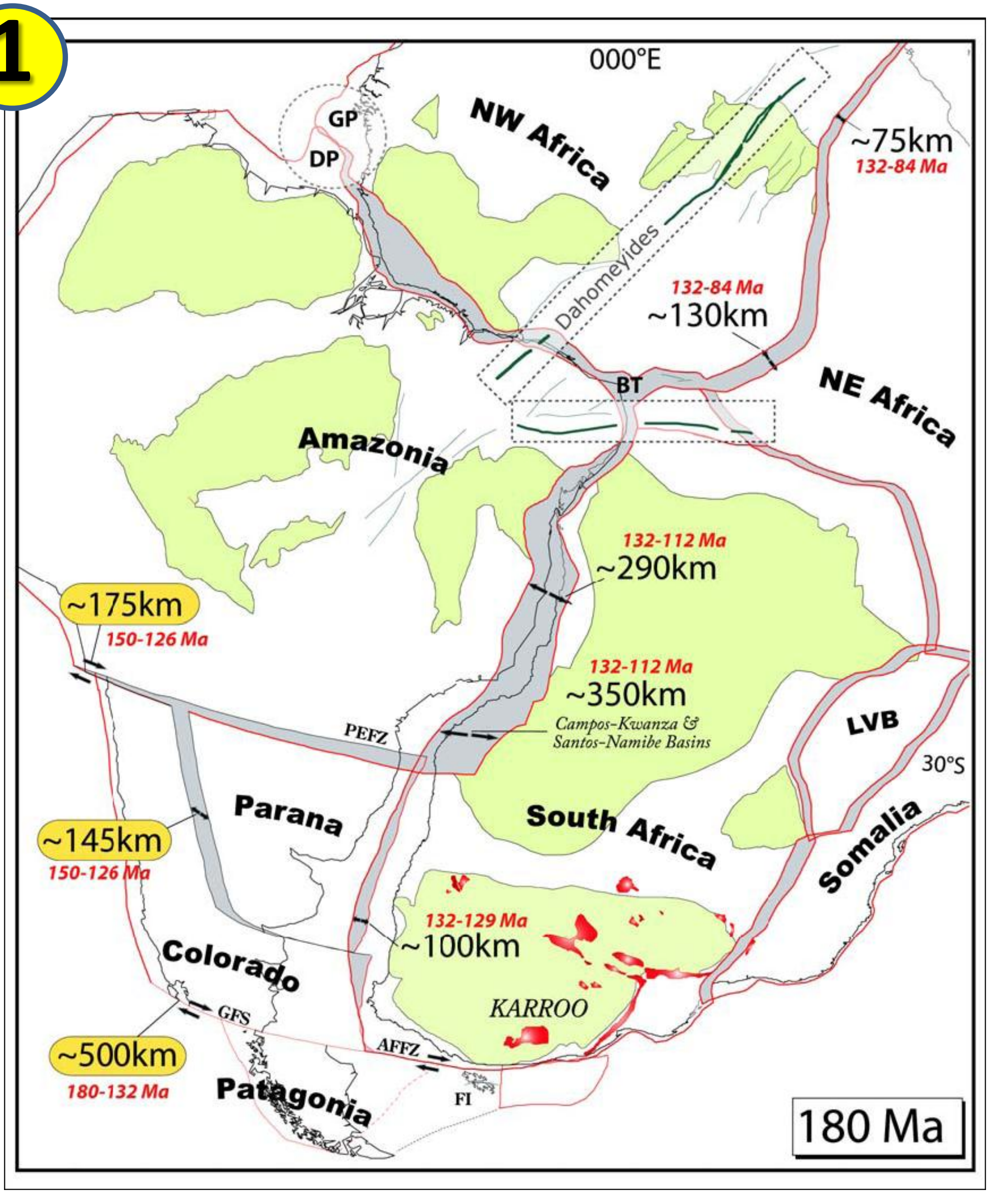


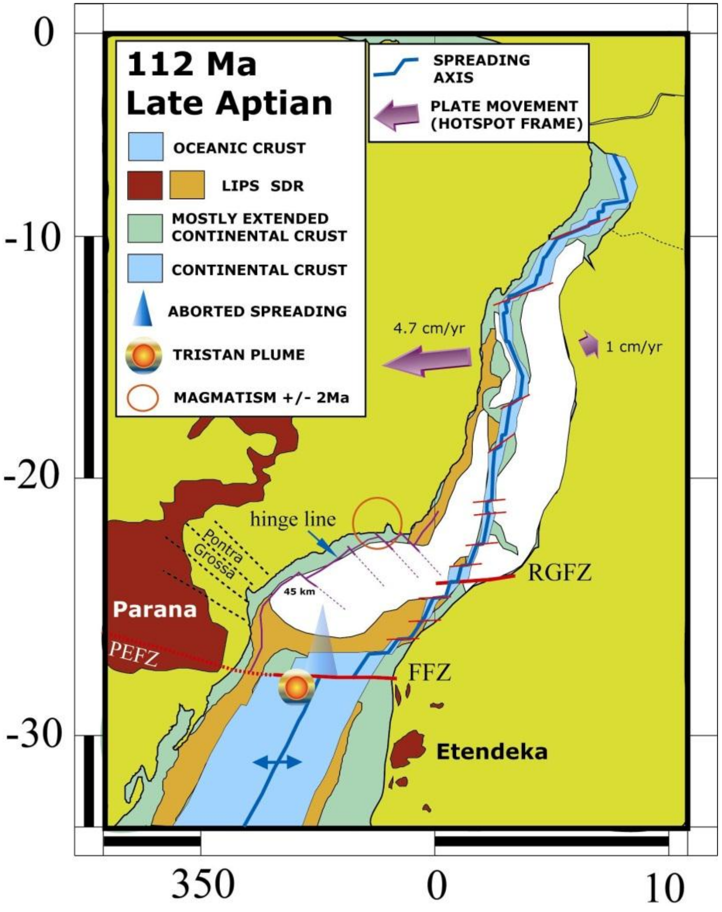
SOME INDUSTRY BENEFITS OF GPLATES & PLATE RECONSTRUCTIONS INCLUDE

1. Easy comparison of COB overlap between conjugate margins and calculation of plate tectonic scale stretching factors.
2. Location of emergent land masses (provenance) and depositional facies
3. Location of thermal ‘hot spots’ such as plumes and LIPs through time with implication for hydrocarbon maturation and migration.
4. Dynamic topography yielding information about which areas are likely to have been below *sea-level*, at what depth, uplift/subsidence and sedimentation rates
5. Paleobathymetry and consequent ocean and basin circulation models.
6. Plate kinematic modeling
7. Deformation of tectonic plates (coming soon)

COB overlap between conjugate margins & calculation of plate tectonic scale stretching factors.

1

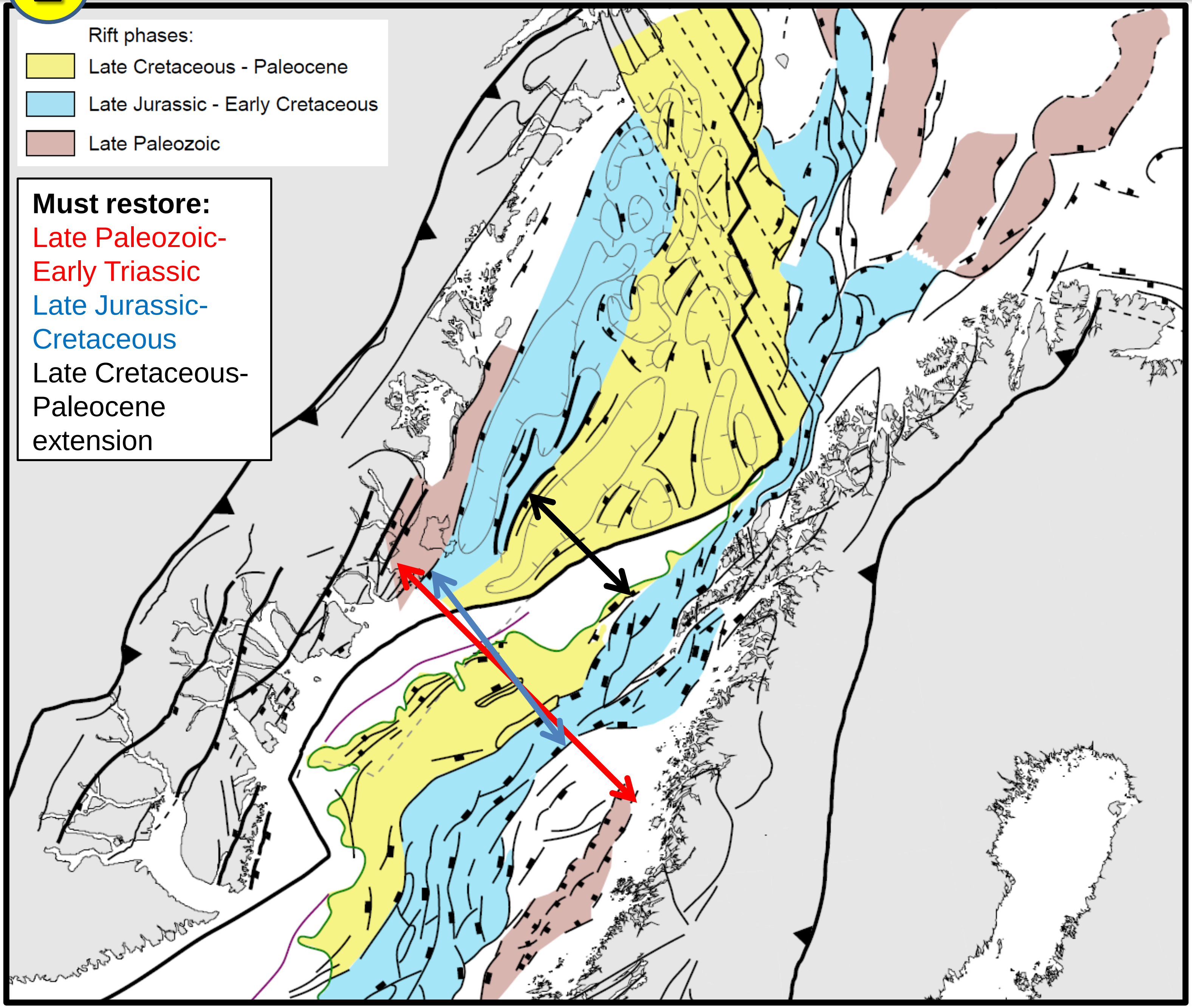




Ages in red denote the total length of pre-drift extension/strike-slip.

1

Passive Margins (pre-drift extension) and Break-up



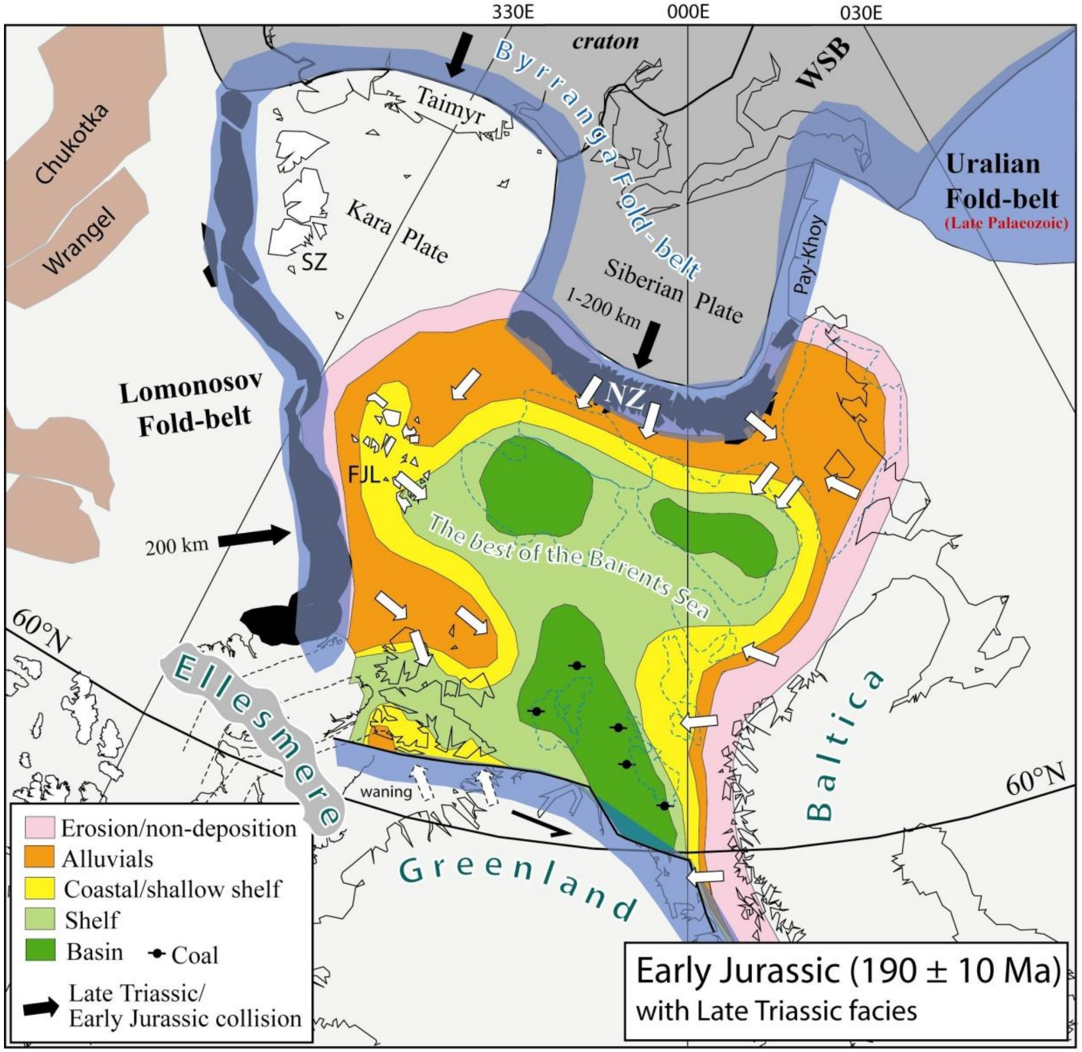
Must restore:
Late Paleozoic-Early Triassic
Late Jurassic-Cretaceous
Late Cretaceous-Paleocene extension

Faleide et al. (2010)

2

Location of emergent land masses (provenance) and depositional facies

Early Jurassic (Barents Sea)



Torsvik et al. (2005)

Late Ordovician (Africa)

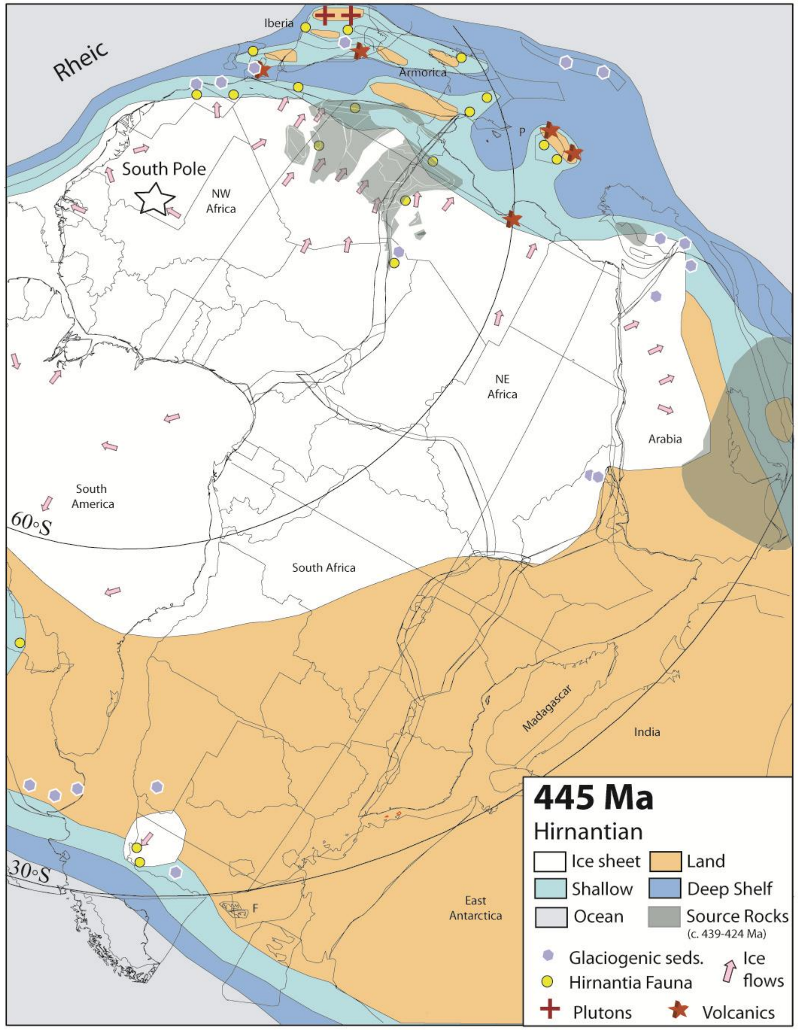
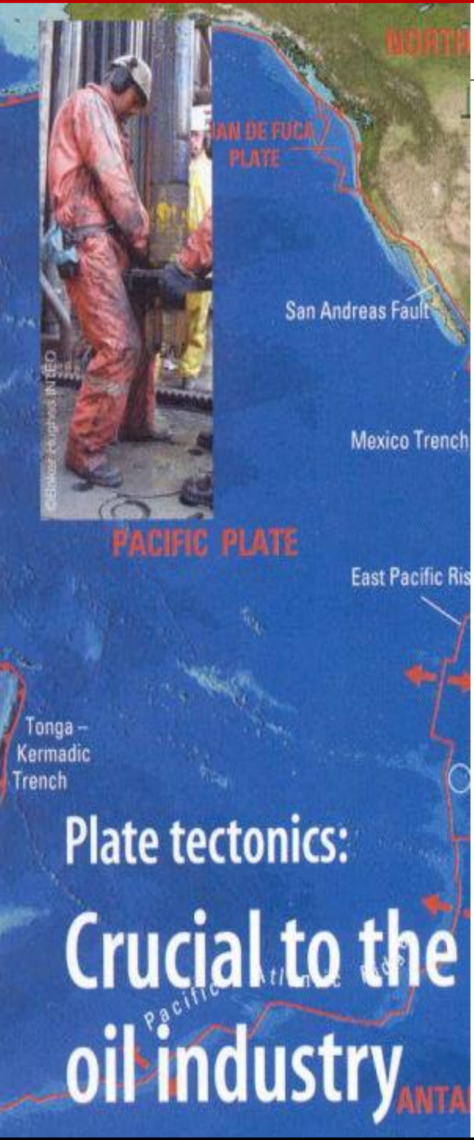
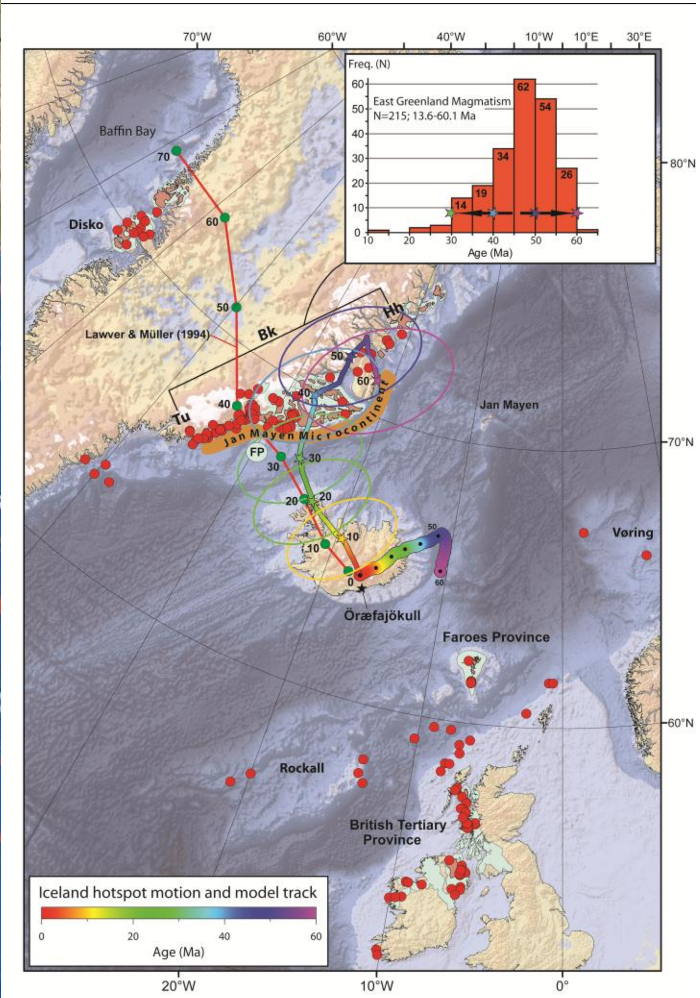
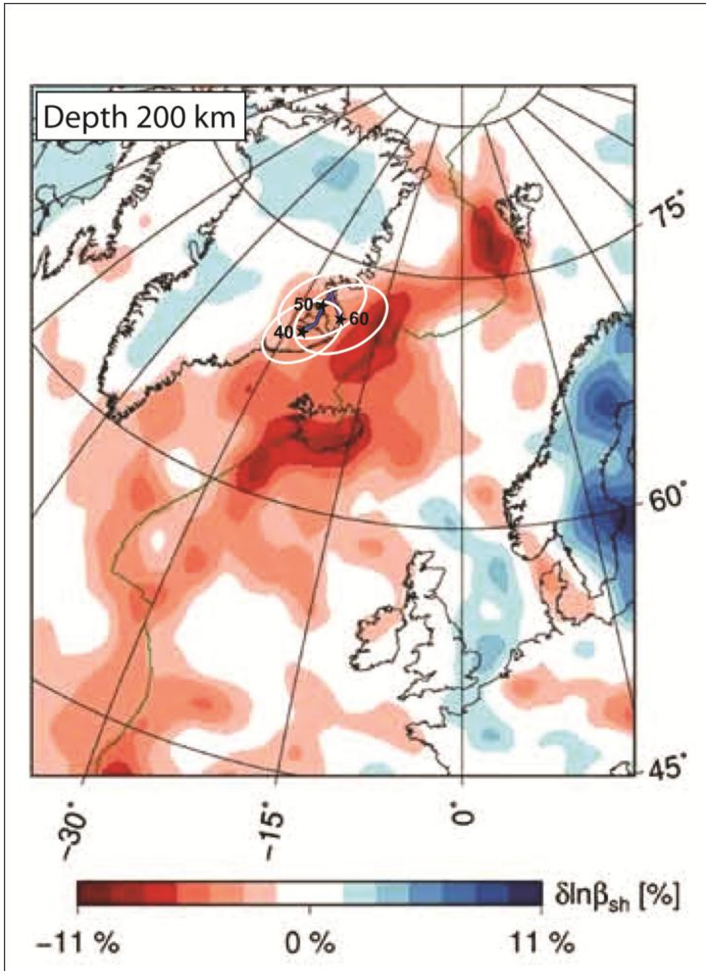


Figure 7 (Torsvik & Cocks)

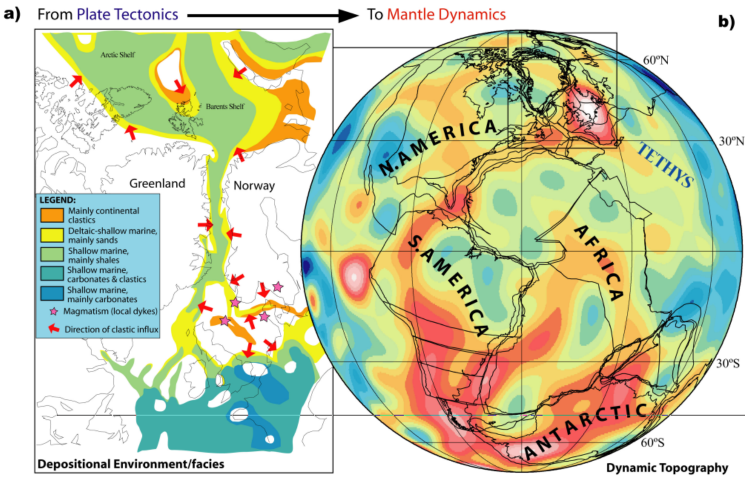
3 Location of thermal 'hot spots' such as plumes and LIPs through time has implication for hydrocarbon maturation and migration.





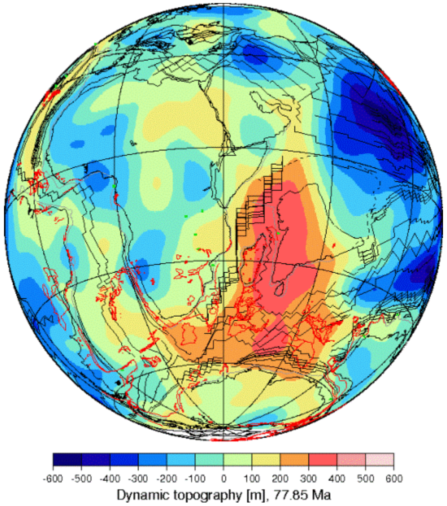


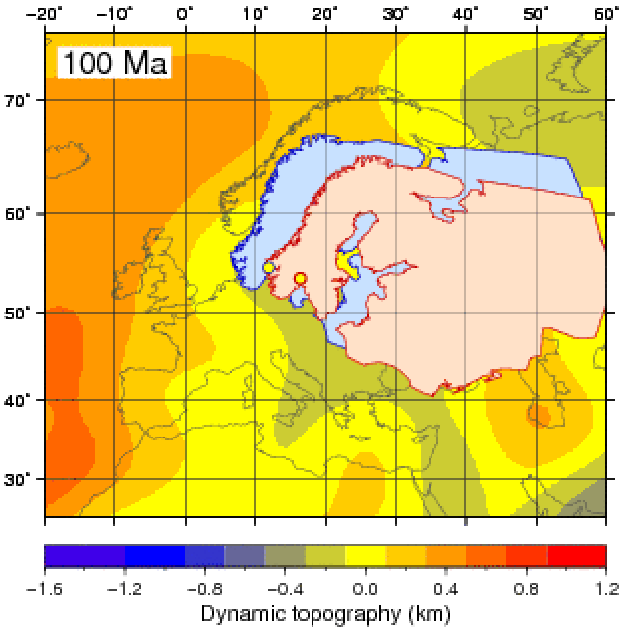
4 Dynamic topography yield information about which areas are likely to have been below *sea-level*, at what depth, uplift/subsidence and sedimentation rates



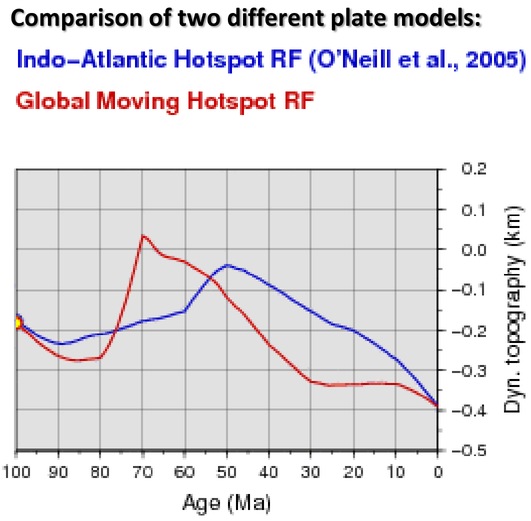
Torsvik & Steinberger (2006)

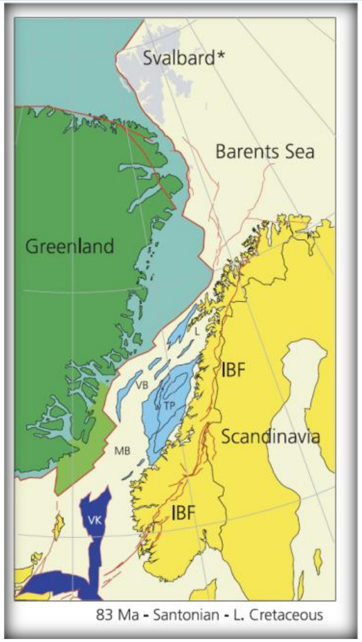
Prediction of surface uplift and subsidence over time on a large scale is one of the most important outcomes of mantle flow models





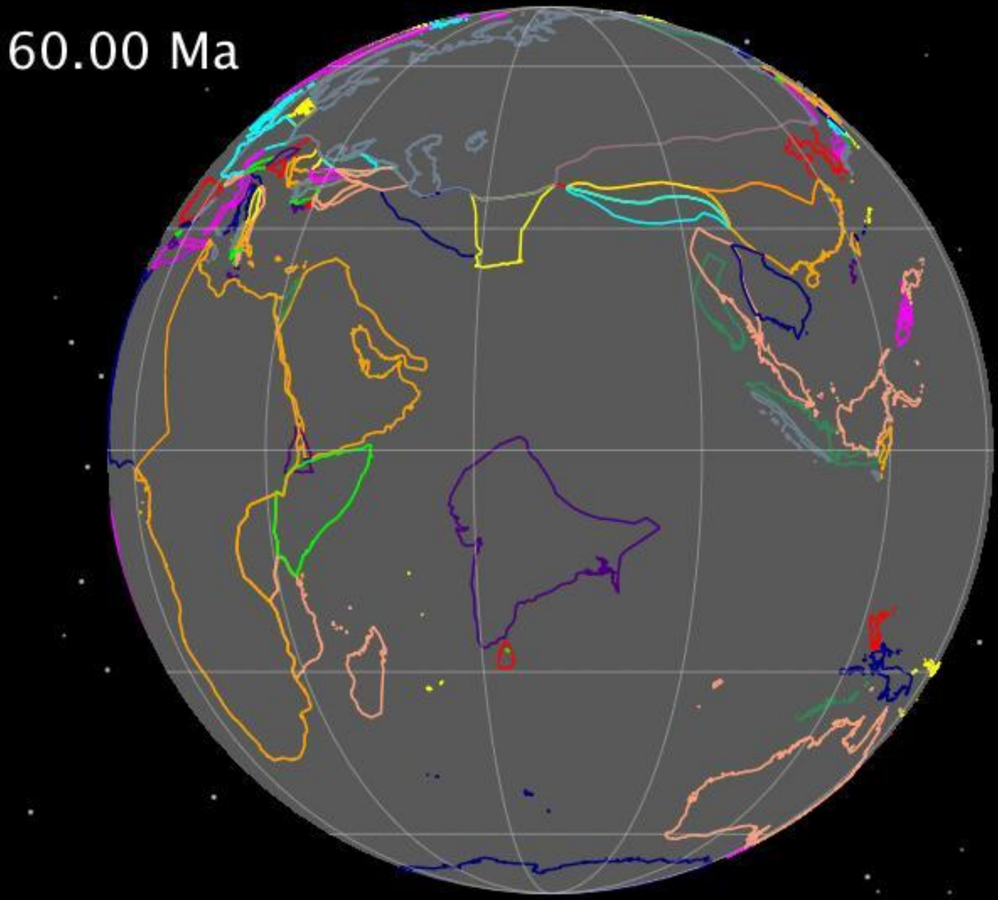
Doubrovine, Steinberger & Torsvik (2012)





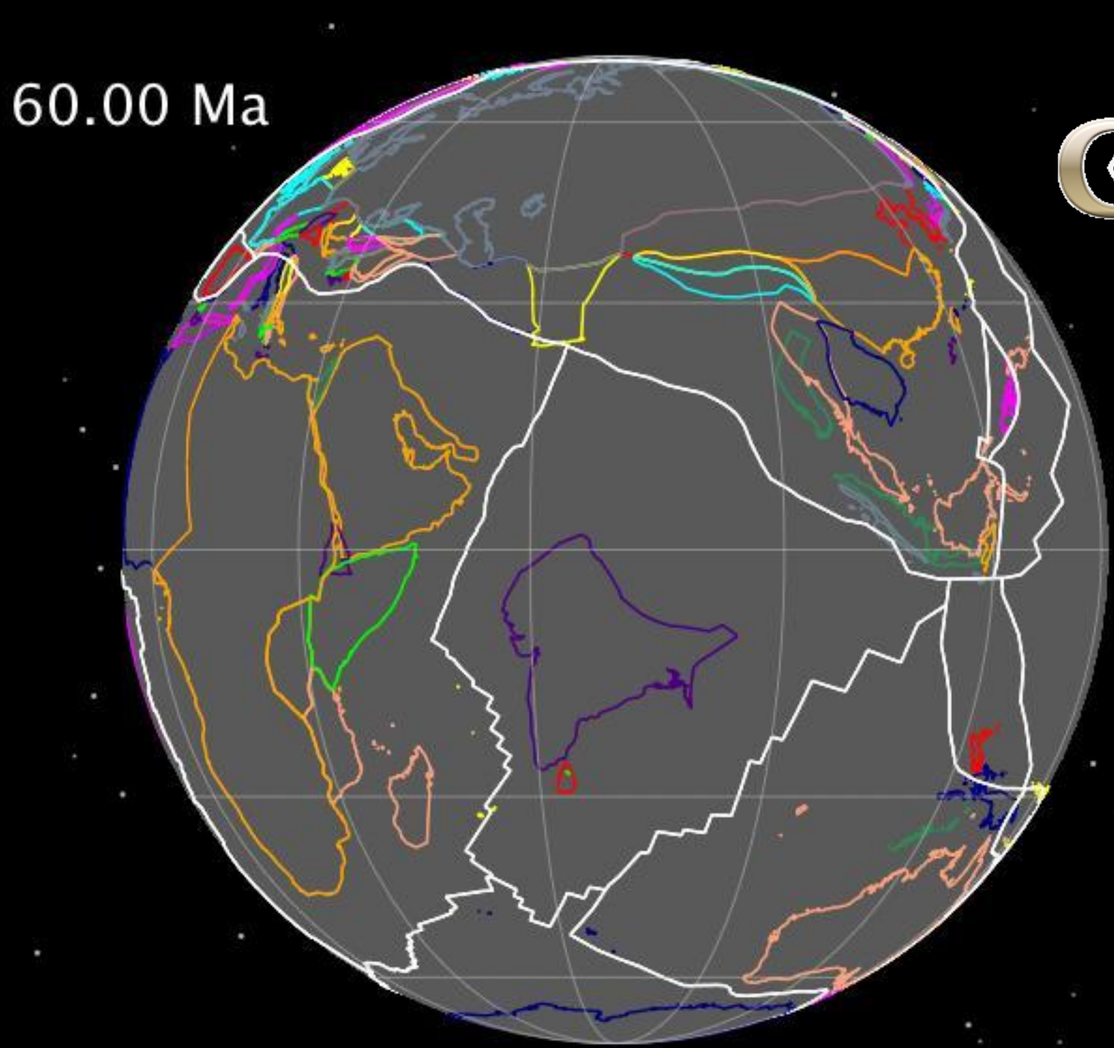
Mosar & Torsvik (2002)

DEMO:Indian Ocean example – free data

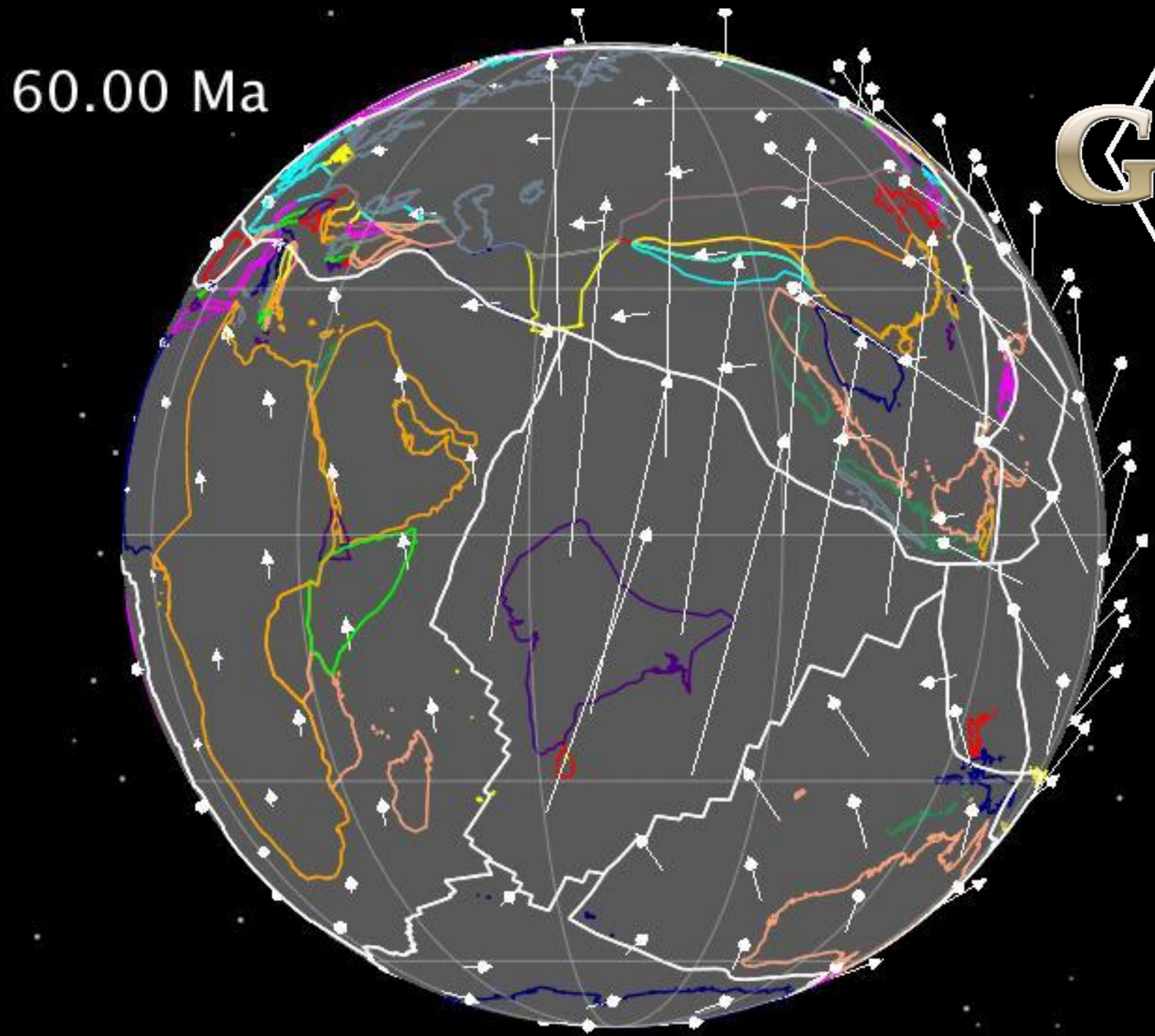


GPlates

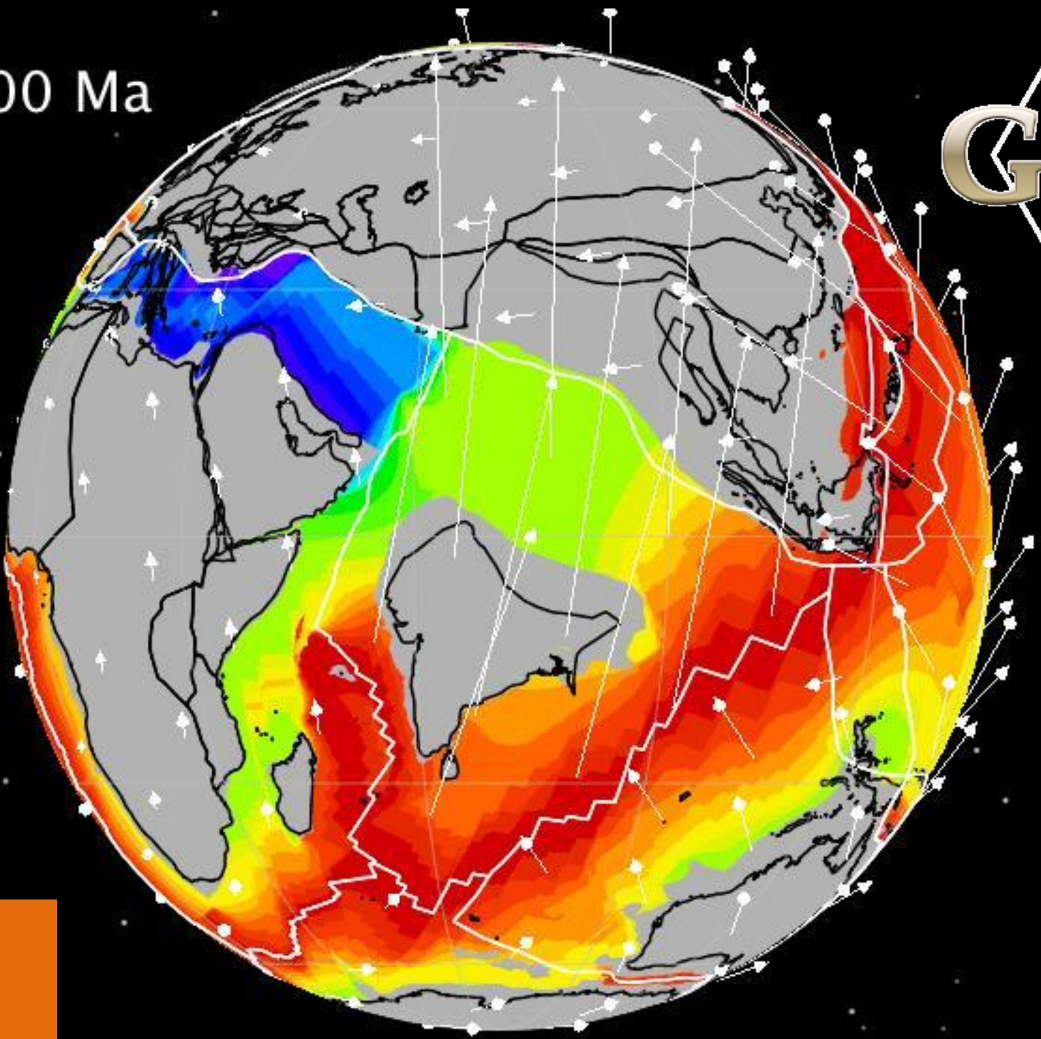
DEMO:Closed plate polygons



DEMO:Plate motion vectors

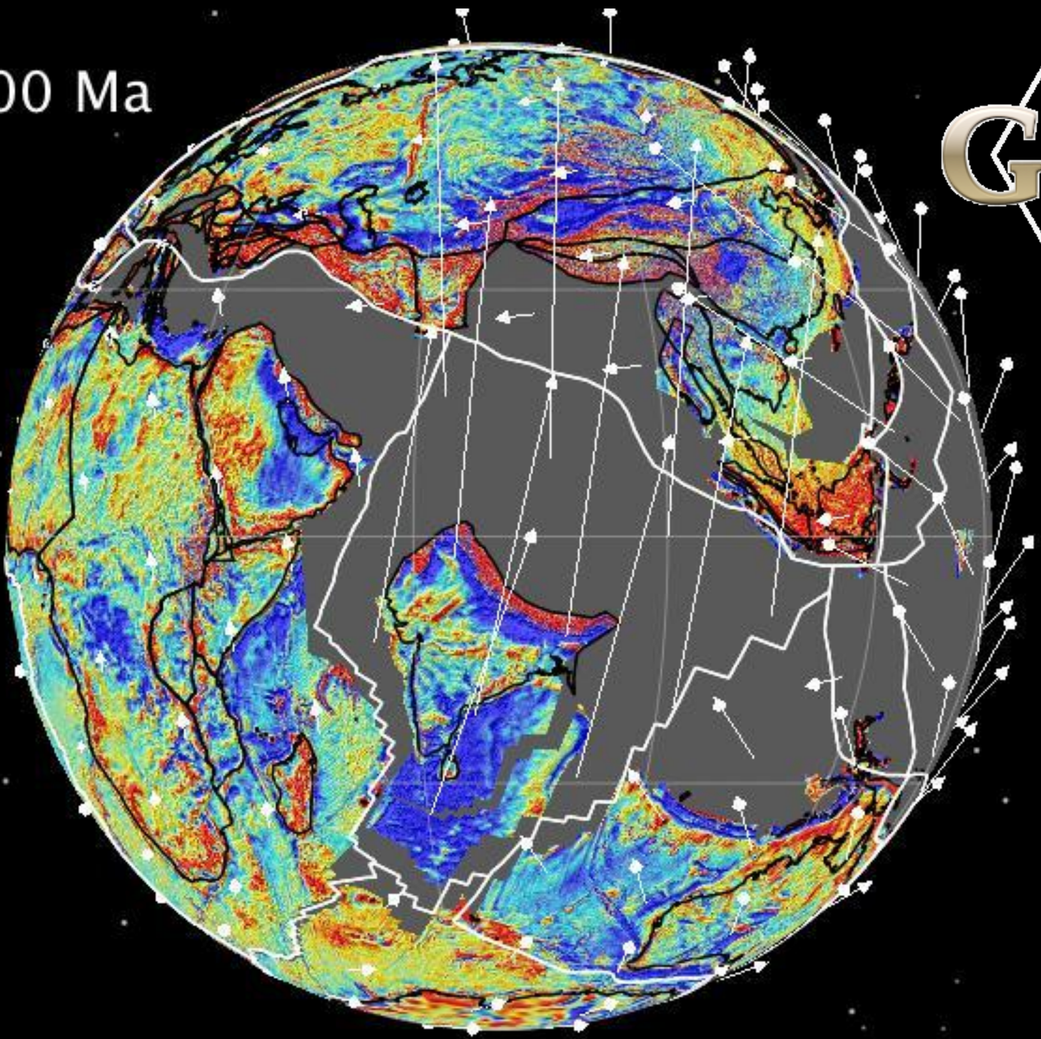


DEMO:Oceanic palaeo-age grid

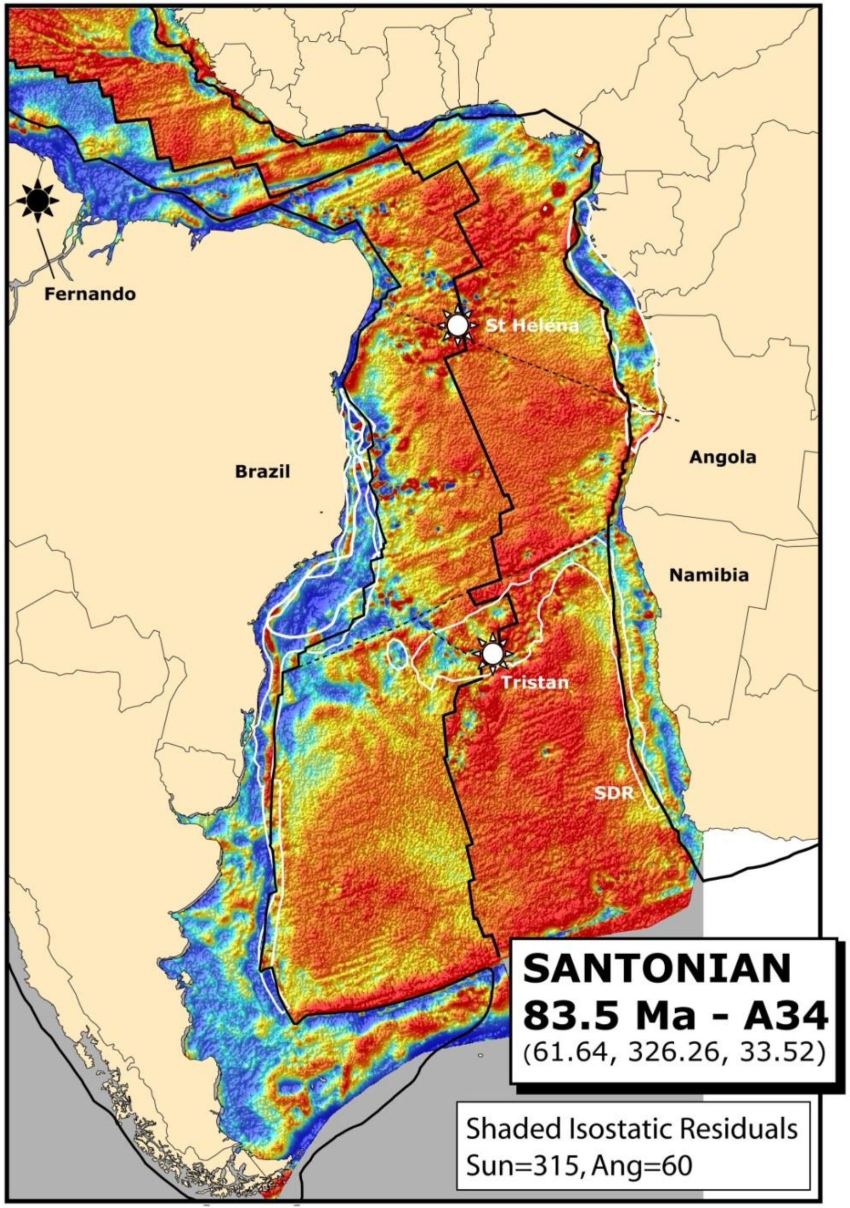


From the age grid we calculate bathymetry and heat flow

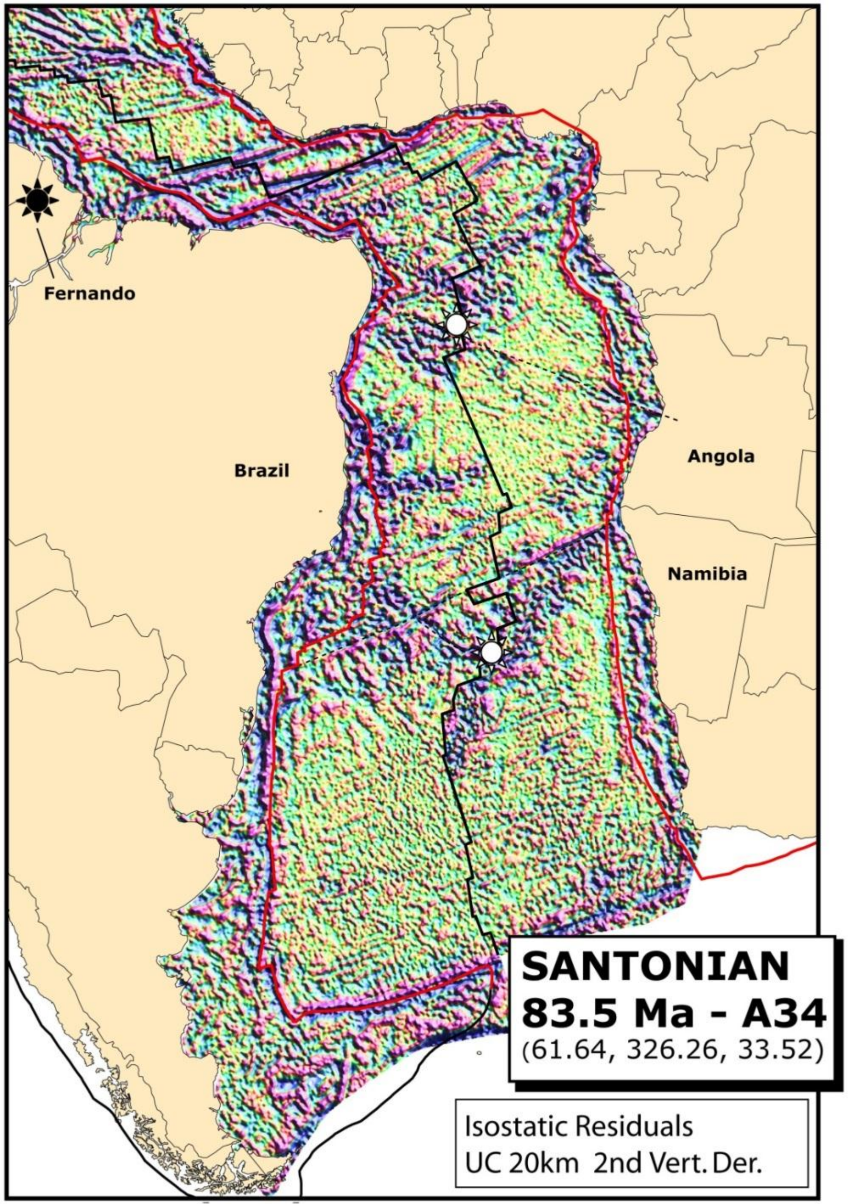
DEMO:Free-air gravity



Reconstruction of gravity residuals



Torsvik et al. (2008)



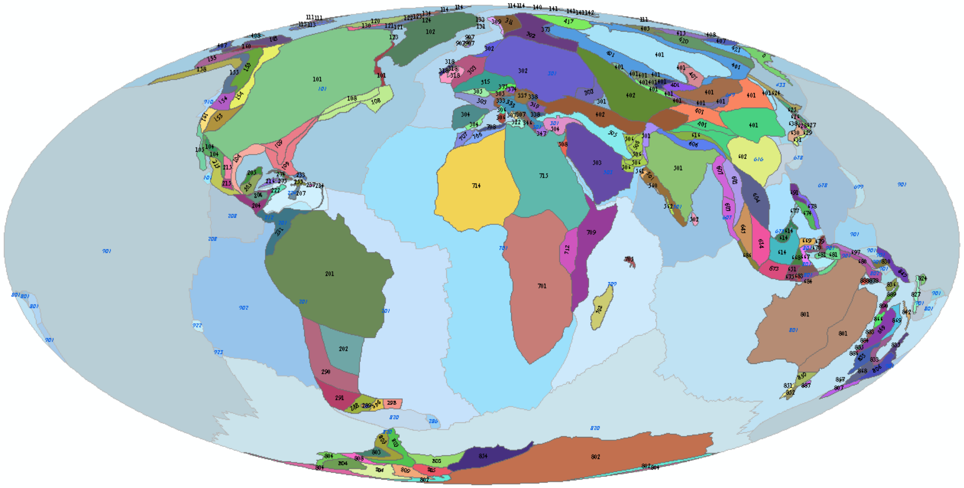
GPlates

Sponsoring benefits

- CEED plate model & rotation engine
- Training
- Assistance to implement your own data
- Influencing the development of GPlates

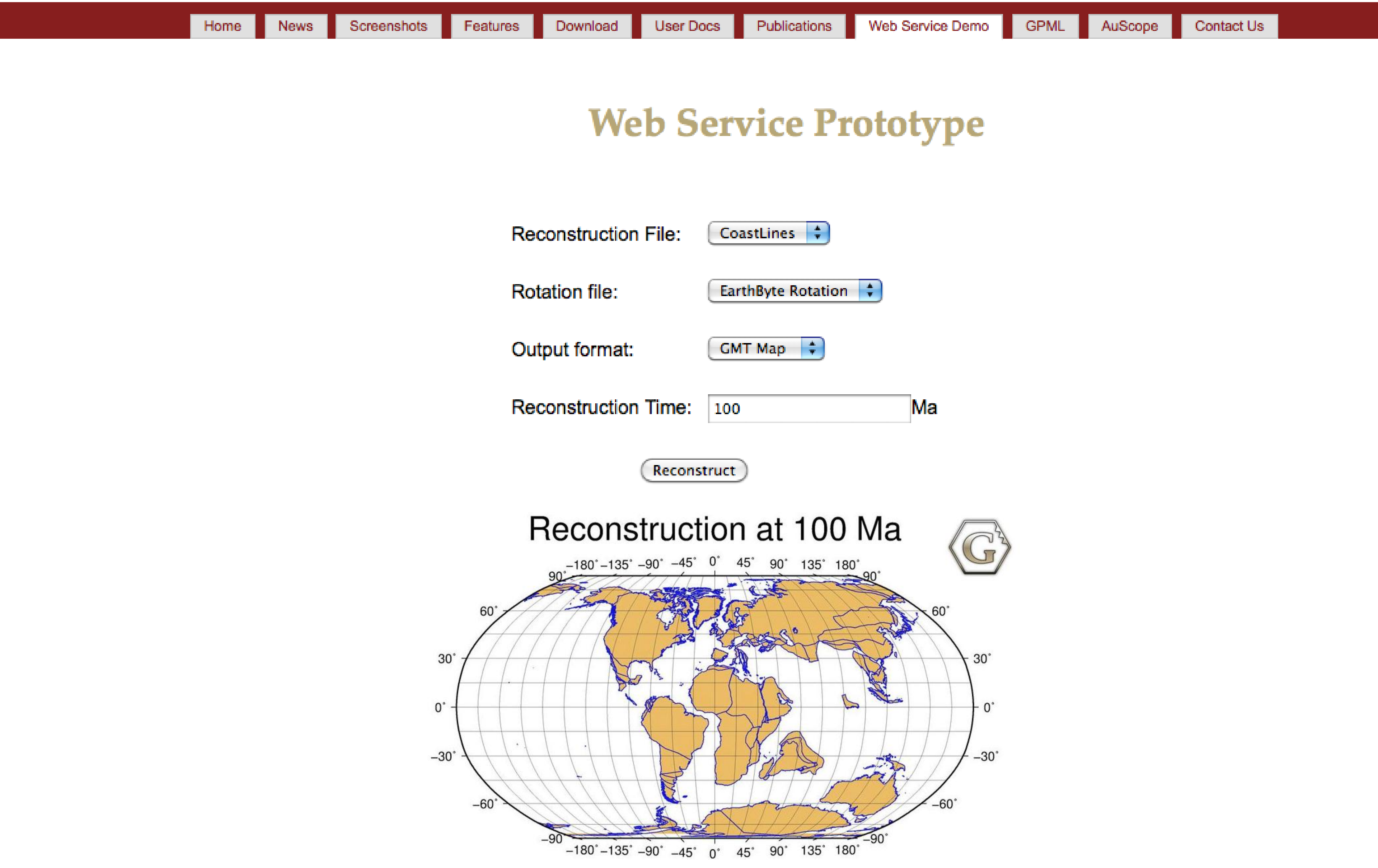
Annual Fee

- 400.000 per year (minimum 3 yrs)



CEED PLATE MODEL

WEB SERVICE



Web Service Prototype

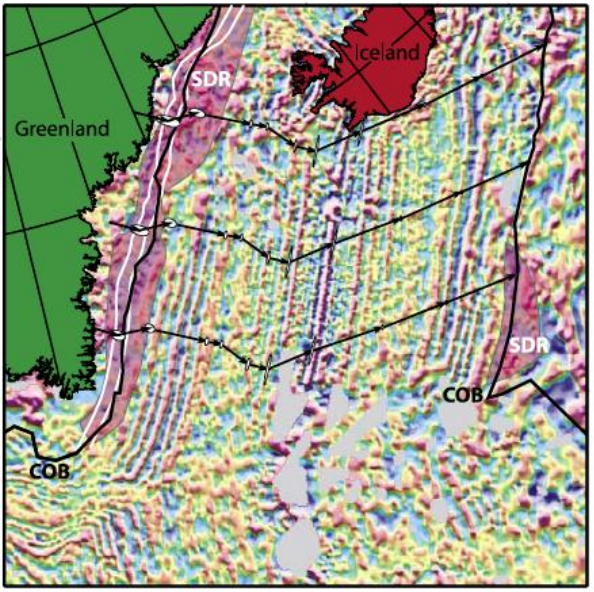
Reconstruction File: CoastLines

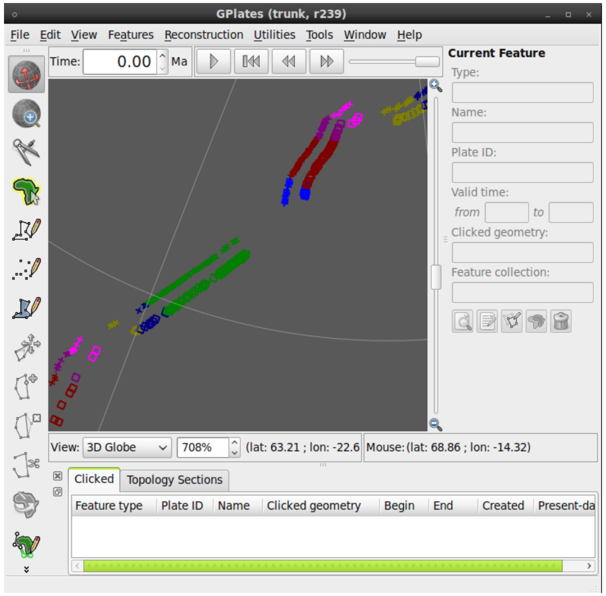
Rotation file: EarthByte Rotation

Output format: GMT Map

Reconstruction Time: 100 Ma

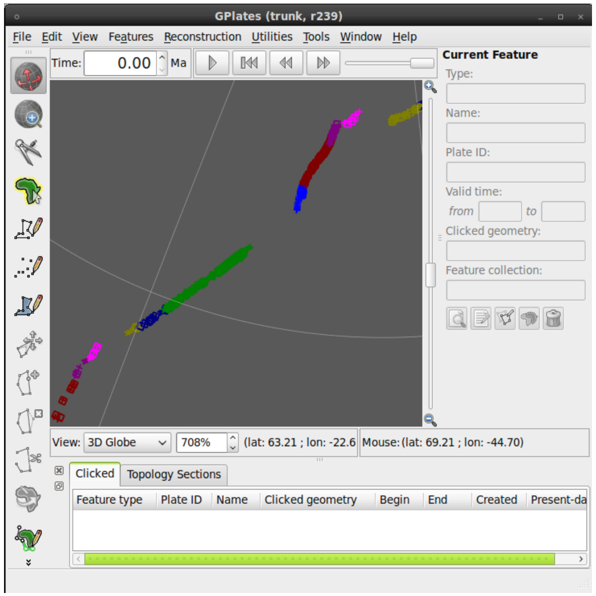
The Hellinger Quantitative Reconstruction Tool: Currently in development at NGU/UiO





Time: 0.00 Ma

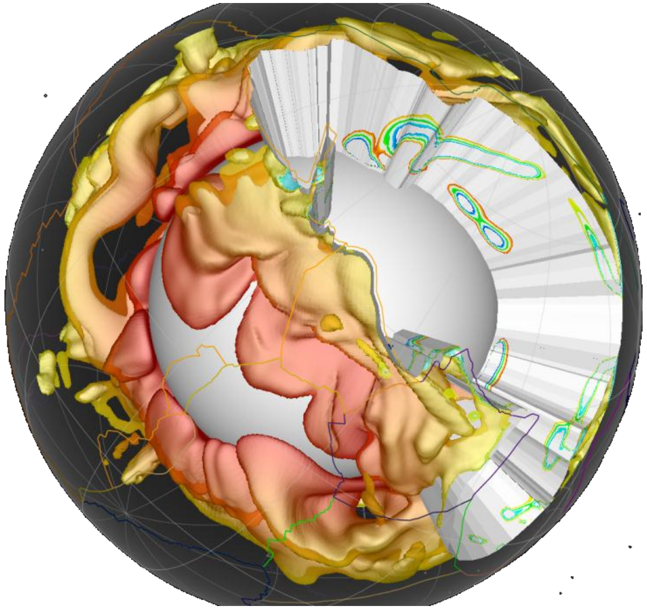
View: 3D Globe 708% (lat: 63.21 ; lon: -22.6 Mouse: (lat: 68.86 ; lon: -14.32)

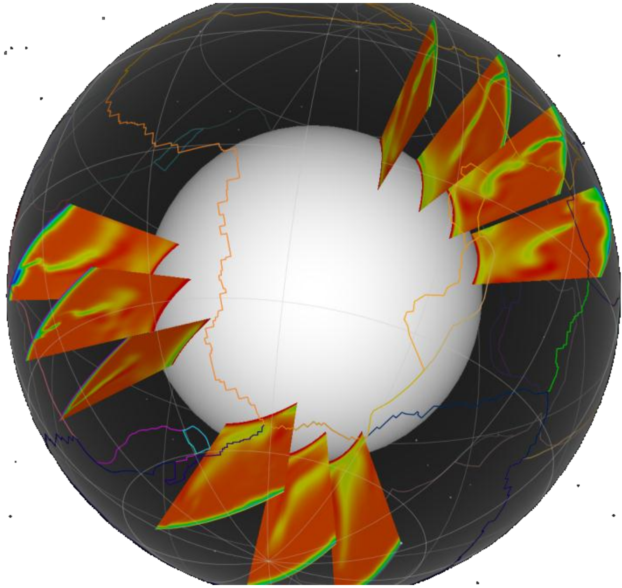


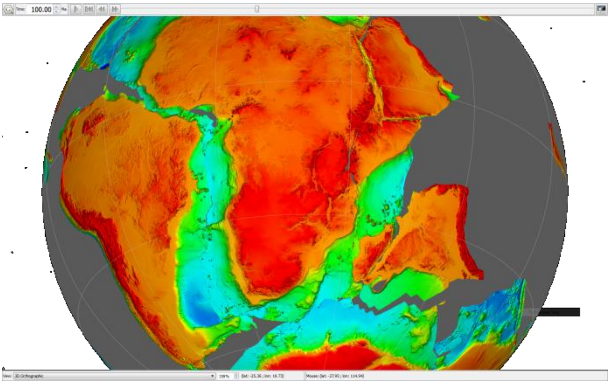
Time: 0.00 Ma

View: 3D Globe 708% (lat: 63.21 ; lon: -22.6 Mouse: (lat: 69.21 ; lon: -44.70)

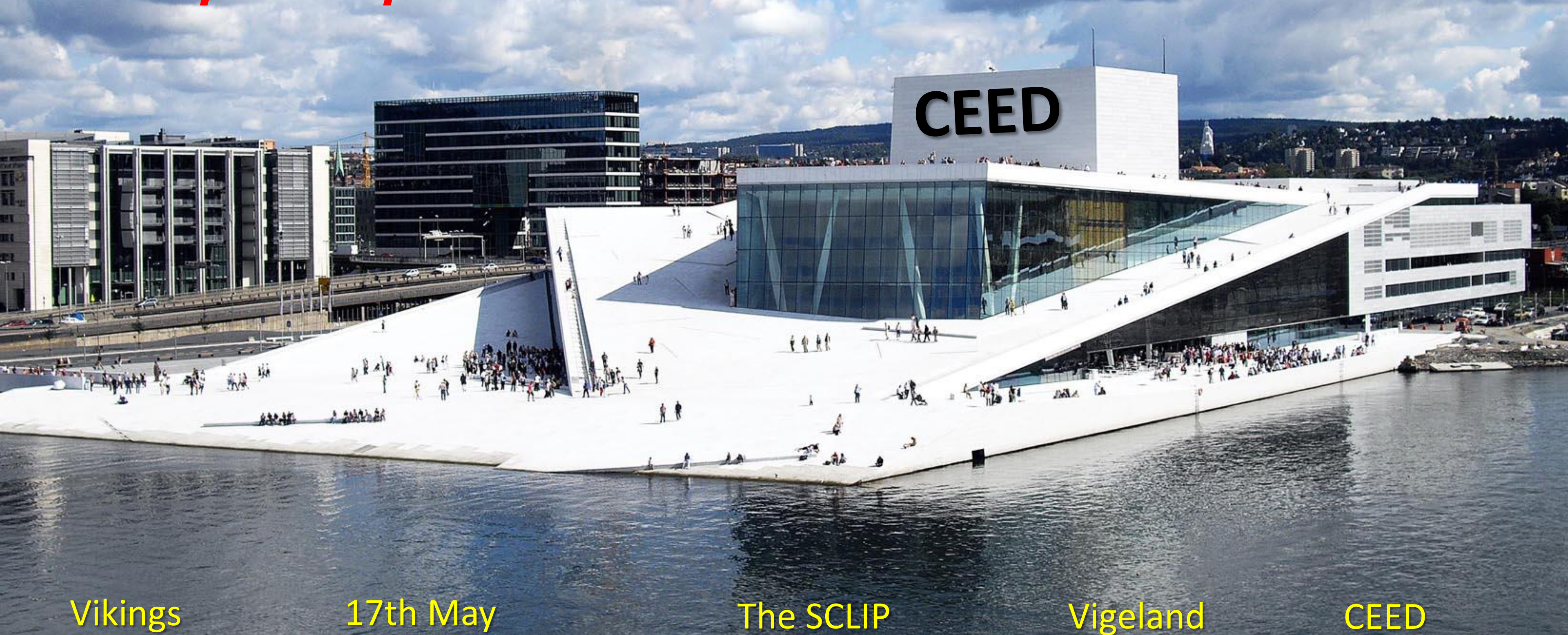
Volume visualization & Raster surface lighting







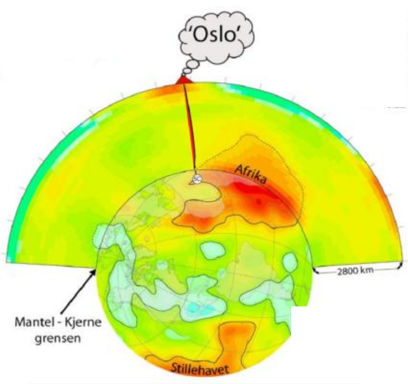
Thank you for your attention



Vikings

17th May

The SCLIP



Vigeland

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