Dynamic Earth Evolution and Paleogeography through Tomographic Imaging of the Mantle

Reporting

Project Information

DEEP TIME

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Project closed

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Periodic Reporting for period 5 - DEEP TIME (Dynamic Earth Evolution and Paleogeography through Tomographic Imaging of the Mantle)

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Summary of the context and overall objectives of the project

DEEP TIME unearthed a record of geological time that is buried thousands of kilometres deep. The seafloor that covers two-thirds of the earth's surface is a tiny fraction of all seafloor created during the earth’s history – the rest has sunk back into the viscous mantle, where it originated. Slabs of subducted seafloor carry a record of surface history: how continents and oceans were configured over time and where their tectonic plate boundaries lay. DEEP TIME followed former surface oceans as far back in time as the convecting mantle system allowed, by imaging subducted slabs down to the core with cutting-edge seismological techniques. Previous tectonic plate reconstructions incorporated little if any of this deep structural information, which reaches back to at least 300 million years; these reconstructions are mostly based on present-day seafloor, which constrains only the past 100-150 million years. For earlier times, paleo-oceanic areas in these reconstructions become an unconstrained as the backside of the moon used to be, and even the continental hemisphere (“Pangea”) is subject to large quantitative uncertainties.

The spatial configuration of continents, oceans and plate boundaries (and their changes over time) sets boundary conditions for almost every physical, chemical and biological process at the surface. It determines how ocean currents develop and therefore climate; where physical barriers inhibit or enhance the evolution and dispersal of biota; and where the natural resources form that have supported every human society. Thus there is a fundamental interest in paleo-geographic reconstructions that are reliable, quantifiable and testable. The state of the knowledge is particularly lacking for paleo-oceanic areas, which tend to self-destroy the records of their existence, except if one succeeds in imaging their remains deep in the earth’s mantle.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

DEEP TIME matched deep slab structures to the geological surface record of subduction – volcanic arcs and other crustal slivers that stayed afloat, survived collisions, and now form the world’s largest mountain belts. It worked on improved observation and conceptual understanding of these records individually – in the earth’s two large collisional mountain systems of the past 200 million years, and through better observations in the deepest mantle.

DEEP TIME then integrated the surface and subsurface record of subduction into quantified reconstructions of paleo-oceanic areas, in a hypothesis-driven and testable new approach termed “tomotectonics”.

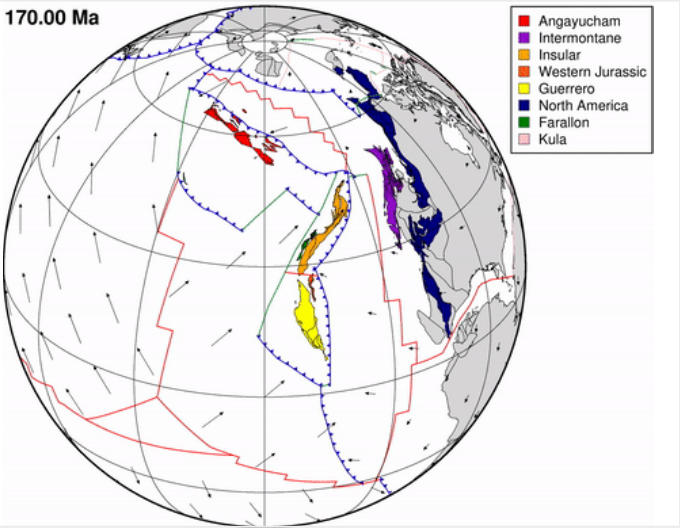
Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

Subducted seafloor seems to have sunk uniformly and not to have translated much laterally since entering the mantle, as compared to the scales of the ocean basins and continents to be reconstructed. Seafloor thickens several-fold while transitioning from the upper to the lower mantle, and sink much more slowly thereafter. Pervasive folding was inferred from global slab observations, tomotectonic inference, and newly explained by numerical subduction modelling that featured a realistically weak asthenosphere.

The focus of these reconstructions was on the oceanic subduction that constructed the western sectors of the Americas (Cordillera mountain belts), and on the continental collision events between Asia and India/Indochina (“Tethys” belts).

DEEP TIME contributed significant technical innovation to imaging the lowermost mantle with seismic tomography. This yielded a step change in resolving the deepest, oldest subducted seafloor that survives in the mantle. Its well-defined shapes, absolute locations, and insights gleaned from the younger regions suggest that with slabs we will indeed be able to reconstruct back quantitatively to 300+ million years.

DEEP TIME has also contributed two significant pieces of free, open-source community software: the “Submachine” web portal for displaying, comparing and downloading global tomography models and related data sets; and the “ObsPyDMT” suite for managing large seismological waveform data sets.



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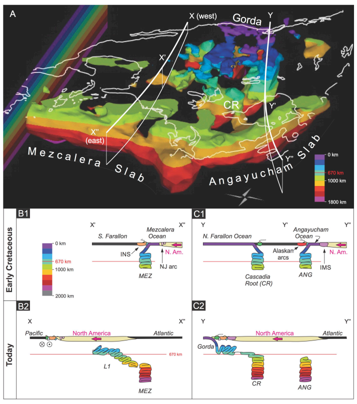

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