

T33A CC: 516 D Wednesday 1330h

Plate Reorganization Events:
Observations and Models I (*joint with
GP, S*)

Presiding: S King, Purdue University;
J Lowman, University of Leeds

T33A-01 1330h

Plate Reorganisation Events and
Geodynamo Events

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Plate reorganisation events are registered in the world since 180 Ma. We compare with the geomagnetic reversal sequence since 160 Ma. This sequence was submitted to a wavelet analysis. It evidences singularities that correspond to high reversal frequency peaks. These singularities correspond to plate reorganisation events with a few Ma delay.

T33A-02 1345h

PLATE REORGANIZATIONS IN THE
CONTEXT OF EARTH'S
THERMAL EVOLUTION

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Global isotopic age peaks have suggested four major episodes of supercontinental assembly throughout Earth history: 2700 Ma (assembly of Kenorland), 2100-1800 Ma (Nuna), 1300-1100 Ma (Rodinia), and 600-300 Ma (Gondwanaland-Pangea). Assembly of the next supercontinent is ongoing as Asia acquires landmasses to grow into Super-Asia. Because the configurations of Precambrian supercontinents are poorly understood, there is great difficulty in evaluating the dynamic processes controlling their amalgamations and disaggregations. Most kinematic models of the Rodinia-Gondwanaland transition invoke substantial toroidal motion of continental blocks crossing a Tethys-like ocean; however, a new, alternative model of Rodinia (Evans, 2004, Intl Geol Congress) suggests that predominantly poloidal motion characterized the Neoproterozoic transition to Gondwanaland. The new Rodinia reconstruction also suggests that its assembly was almost complete by 1800 Ma (Nuna supercontinent), and that only minor additions joined the landmass during "Grenvillian" time (1300-1100 Ma). If true, then Earth has experienced a more fitful history of plate reorganizations, rather than the quasi-regular periodicity suggested by the isotopic age peaks cited above. Supercontinental breakup intervals would then be limited to 2450-2100 Ma (Kenorland), 830-615 Ma (Rodinia), and 200-60 Ma (Gondwanaland-Pangea). In this view, accelerating tempo of plate reorganizations would appear at odds with standard thermal evolution models of the Earth, which contend that greater rates of plate reorganization should be found in the distant past. A more thorough perspective on global plate rates in the milieu of higher global heat flow (Korenaga, 2003, Fall AGU) suggests that past plate rates should be limited by bending resistance of subducting slabs, which in early Earth history would have been greater due to a deeper zone of melt extraction and dehydration at primitive mid-ocean ridges. In other words, despite a steady cooling of the Earth, plate tectonics should have accelerated, not slowed, during the past 2700 million years. Critical evaluations of plate reconstructions and geodynamic concepts have thus led to a self-consistent model that opposes conventional wisdom in both the inverse and forward approaches to the problem of historical geodynamics.

T33A-03 1400h

Late Miocene Changes in Angular
Velocity and Torques on the Indian,
Capricorn, and Australian
Component Plates and Speculative
Implications for Global Plate Motion
Reorganizations

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Important changes in plate motion occurred between the Indian, Capricorn, and adjacent plates in Late Miocene time. In particular, at about 8 to 9 Ma, the motion between the Indian and Capricorn plates accelerated to a rate of rotation similar to the current rate (Gordon et al., 1998; DeMets, Gordon, & Royer, 2004). It is likely that that motion between the Capricorn and Australian plates began or accelerated at about the same time (Royer & Gordon, 1997). Here we integrate stresses across the India-Capricorn and Capricorn-Australia diffuse oceanic plate boundaries to estimate the torque that each of these plates exerts on the other across their mutual boundaries (Zatman et al. 2001, 2004). We find that the India-Capricorn torque is nearly parallel to the torque that the Tibetan plateau and the Indian component plate exert on one another. This result is consistent with the cause of deformation in the India-Capricorn diffuse oceanic plate boundary being the attainment of maximum elevation of the Tibetan plateau (Molnar et al. 1993). This result is furthermore consistent with the evidence for little or no change in India-Somalia motion anytime during the past 20 Myr (DeMets et al. 2004). In contrast, the torque across the Capricorn-Australia boundary has a very different orientation and cannot, by itself, balance the torque across the India-Capricorn boundary. Hence a third torque is needed, which we speculate is contributed by the interaction of the attached subducting slab with the mantle as the motion of the Capricorn plate changes relative to the mantle. This is consistent with the easily discerned change in Capricorn-Somalia motion at about 8 to 9 Ma (DeMets et al. 2004). It follows that an increased torque is transmitted across the Capricorn-Australia boundary, which we hypothesize to have been the cause in the change in Australia-Antarctic motion at about 6 to 7 Ma (Vogt et al. 1983). Speculative extrapolation of this pattern leads to the hypothesis that the change in motion of the Australian plate led to a change in the torque that the Australian plate exerted on the Pacific plate, which may have been all or part of the cause of its most recent major change in Pacific-Antarctic plate motion, that at about 6 Ma (Cande et al., 1995). The final step in the reorganization is that the change in Pacific plate motion caused a change in motion of the Sierra Nevada microplate (Argus & Gordon, 2001), which led to a change in the orientation of extensional deformation in the Great Basin in Late Miocene time (Zoback & Thompson, 1978). Thus, we speculate that the rise of the Tibetan plateau is the cause of the Late Miocene change in extension direction in the Great Basin. We will use simple physics to test the plausibility and uniqueness of these hypotheses. In any event, interactions across diffuse plate boundaries provide ways of changing plate motion on a relatively short time scale.

T33A-04 1415h

Plate Reorganisation Events Governed
by Episodic Mismatch Between
Mantle Convection and Plate Network

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Based on the current plate motion, we analyse the distribution of spreading and subduction. Subduction tends to be grouped around two poles while spreading tends to form a girdle, with attests for the evolutionary tendency of the plate network. This degree two pattern is the opposite of the deep mantle convection pattern, which shows on the contrary two upwelling columns separated by a downwelling wall. The present plate network shows a compromise between the two opposite patterns. Based on the tectonic history since 550 Ma, we claim that episodic plate reorganizations, because they counteract the evolutionary trend of the plate network, maintain the compromise.

T33A-05 1430h

Assessing Why Plates Move

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Over the past 42 years, since the first realization that the ocean floors are youthful (not ancient relics from early in the history of the Earth), and the concomitant development of the Theory of Plate Tectonics, an understanding of the observed motions has been sought. Speculation and analyses have concentrated upon three principal forces: ridge push, subducted slab pull, and sub-lithosphere traction from Earth's internal convection motions, with forces due to subducted slabs dominating. Some researchers have speculated that the motions of plates are random, however, the author in 1974 noting that a pattern of spreading between Australia and Antarctica progressed in time westward across the Indian Ocean, and then continued opening the Gulf of Aden and on into the Red Sea concluded that plate motions were not random. Recent evidence from the broad exposure of upper mantle rocks (peridotite) on the ocean floor at the ultra slow spreading Gakkel Ridge in the Arctic Ocean, indicate to the author that there is no ridge push force. Thus, seafloor-spreading sites are reactive features, not driving force contributors. A reconstruction of past absolute plate motions shows that sites of subduction have remained near their same arc/trench locations, but spreading centers and transform faults have moved about. Hence, confirming that sites of subduction are an important control for plate motions. The author's analysis of the positive residual geoid anomalies (spherical harmonic degrees 4-10) over arc/trench systems of the world, suggested forces of 2.8×10^{20} - 3.2×10^{21} N are available to drive plate tectonics. Some studies have proposed models for how such forces might couple to plate motions, but none have yet been definitive. New clues are being sought from the unique change in absolute plate motion of the Pacific plate, at about 46-48 Ma ago: from a northward subduction beneath the Aleutian trench/arc during the time when the Emperor seamount chain was formed, to its' present north of west motion subducting beneath the western Pacific trench/arcs, the direction during which the Hawaiian volcanic trend has been formed. Only the Pacific plate shows such a major change in absolute plate motion at that time, and the author takes this change, in but a few million years, to indicate that masses linked to slab subduction are more important than traction from an underlying mantle convection.

T33A-06 1445h

The Strength of Fracture Zones and
their Role in Plate Boundary
Evolution

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The strength of fracture zones, and whether they inhibit or aid changes in oceanic plate motions, is of great importance in understanding plate reorganizations. For example, self-sustaining subduction zones form if convergence during plate reorganizations exceeds 100 km across fracture zones, but only if they yield at 10 MPa with low coefficients of friction. Convergence across fracture zones with higher yield strengths requires forces in excess of those likely available from plate tectonics, and typically does not lead to sustained subduction. Many fracture zones are indeed thought to be strong since they preserve bathymetric steps from when they transitioned from transform faults, while far-field differential subsidence leads to elastic flexure of the lithosphere. These evolutionary models fix the bathymetric step at the value determined by the lithospheric age offset. In contrast, we use a two dimensional visco-elastoplastic numerical scheme in which the fracture zone offset is determined dynamically and explore fracture zone offset as a function of yield properties. We show that oceanic lithosphere can be locally weakened at a fracture zone while still preserving long-lived bathymetric steps and flexural responses to differential subsidence, in agreement with observed gravity profiles. Models that best fit the observations typically yield at less than 10 MPa and may have very low coefficients of friction, whereas models with stronger fracture zones over-predict the amplitude of the bathymetric step. Furthermore, local gravity highs above the older plate near the fracture zone cannot typically be fit by the locked fault model and could be the result of partial convective removal of the thermal boundary layer. The extent of convective removal necessary offers a means of constraining the effective temperature dependence of viscosity in oceanic lithosphere. Our analysis of gravity profiles across fracture zones suggests that they are weaknesses in oceanic lithosphere that may, for example, allow localized convergence that can lead to the initiation of subduction.