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Did clockwise rotation of Antarctica cause the break-up of Gondwanaland? An investigation in the 'deep-keeled cratons' frame for global dynamics

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Introduction. The 'deep-keeled cratons' frame for global dynamics is the result of seeking Earth-behaviour answers to the following outside-the-box proposition:- "If cratons have tectospheric keels that reach or approach the 660 km discontinuity, AND the 660 level is an effective barrier to mantle circulation, then obviously (i) when two cratons separate, the upper mantle to put under the nascent ocean must arrive by a circuitous route and, conversely, (ii) if they approach one another, the mantle volume that was in between them must get extruded sideways." Surprisingly it has turned out [1 - 4] that Earth dynamical behaviour for at least the past 150 Ma provides persuasive affirmation of both these expectations and that there is a rational petrological explanation for the otherwise-unexpected immobility of subcratonic material to such depths [5 - 7].

Clockwise rotation of Antarctica? This contribution greatly amplifies my original plate dynamical arguments for suggesting [8] that such rotation is ongoing. Convection is unsuited to causing rotation about a pole within the plate so, as noted then, a gearwheel-like linkage to Africa at the SWIR would provide its clearly CCW (Biscay-Caucasus) relationship to the Mediterranean belt for the past 100 Ma, also seen in its separation from South America. Gearwheel-like linkage of motion requires the presence of some kind of E-W restraint further north. In that case it was the N Africa/Arabia involvement in the Alpide belt, but the earlier opening of the central Atlantic by the eastward motion of Africa, suggests its rigid Gondwanan attachment to Antarctica rotation at that time, with little constraint in the north.

Further east, the seafloor data show that Australia-Antarctica separation involved no such opposite rotational linkage, so, with no E-W mechanical constraint in the north by Indonesia, they must have rotated together, as is recorded by Australia's eastward motion to generate the Mesozoic seafloor at its western side. Moving east again, the sigmoidal fracture-zone pattern between W Antarctica and Tonga Trench seems consistent with a gearwheel-linked relative rotation of the Pacific plate by about 35^o CCW since about 120 Ma, so about half that (clockwise) by Antarctica. The triangular Cocos plate is then in the position where the two gearwheels separate. Further north, the dextral slip on the San Andreas Fault and the opening of the Gorda Ridge are broadly consistent with such rotation. Note that with our two-layer mantle all reference to 'absolute', lower mantle-related, positions is inappropriate. Our sole concern now is with *relative* motions of plates.

Driving torque on the cratonic keel of East Antarctica. I maintain here my suggestion [8] that this keel, in actual contact with the lower mantle at its boundary, is picking up an electromagnetically generated torque, transmitted up from the polar zone of the CMB through the higher viscosity lower mantle. The reality of the rotation now invites more attention to this mechanism. The involvement of the cratonic keel is supported, as noted [8], by the apparent absence of rotational effects in the Arctic, where there is no keel in the polar position, although a similar CMB coupling to the lower mantle seems likely. The involvement of geomagnetism is supported by the sharp changes in central Pacific fracture zone orientation and the onset of the Ontong Java magmatism, correlating with the start and end of the Cretaceous long normal geochron [8, 9]. Such a change is also seen at M0 time in the Weddell Sea. Presumably the speed of Antarctica rotation was affected.

Gondwanaland break-up. In view of these abundant tectonic effects attributable to Antarctica rotation, I propose that this was what broke up Gondwanaland, not a plume, as no such things are recognized in this thick-plate, two-layer mantle, version of the Earth-function paradigm. In this version, magmas with apparently lower mantle chemical signatures can be sourced within the upper mantle [10] and flood basalts can be generated by splitting cratons [11]. So the $\sim$176 Ma age of the Ferrar Dolerite in Antarctica is a record of one of those splits.

Gaps in the PalaeoPacific rim. If we restore Australia both westward to before the spreading at its western side and southward to its position against Antarctica, the Pacific rim was a fair approximation to a great circle, so it covered a hemisphere. Spreading of the other oceans, initiated by Gondwanaland break-up, must have been at the expense of the size of the Pacific, so it must formerly have covered much more than a hemisphere, and had a periphery correspondingly rather shorter than a great circle. Thus we have the surprising result that *reducing* the area of the Pacific actually required that its rim be made *longer*, by making gaps between the previously defining cratonic keels. A further result was that now-excess upper mantle material from below the Pacific had to flow through those gaps to put beneath the widening 'new' oceans. For all four of the obvious gaps - Caribbean, Scotia, Australia-Antarctica, Bering - there is evidence to support the presence of that outflow, and in two of the cases there is evidence that motions to open the gaps began very soon after Gondwana began to break up.

Subduction and a two-layer mantle? In another contribution at this meeting (GD5.1) I explain that, in the thick-plate frame adopted here, subduction is neither a motivating player (for break-up purposes) in plate dynamics nor does it breach significantly our 2-layer mantle picture. The underlying reason is that oceanic 'tectosphere' is actually thicker for the same reason [5 - 7] as that of cratons, giving it ex-LVZ heat content which transforms the subduction picture.

Three Conclusions. (1) The thick-plate, 2-layer mantle version of the earth-function paradigm [1 - 7] is alive and well. **(2)** The break-up of Gondwanaland was caused by Antarctica's clockwise rotation. **(3)** Such rotation is now to be considered a major agent in plate motion dynamics for the period during which East Antarctica, or any other sufficiently deep-keeled craton previously, was located at one of the Earth's poles.

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