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Intermediate crust (IC); its construction at continent edges, distinctive epeirogenic behaviour and identification as sedimentary basins within continents: new light on pre-oceanic plate motions

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Introduction. The plate tectonics paradigm currently posits that the Earth has only two kinds of crust - continental and oceanic - and that the former may be stretched to form sedimentary basins or the latter may be modified by arc or collision until it looks continental. But global analysis of the dynamics of actual plate motions for the past 150 Ma indicates [1 - 3] that continental tectospheres must be immensely thicker and rheologically stiffer than previously thought; almost certainly too thick to be stretched with the forces available. In the extreme case of cratons, these tectospheric keels evidently extend to 600 km or more [2, 3]. This thick-plate behaviour is attributable, not to cooling but to a petrological 'stiffening' effect, associated with a loss of water-weakening of the mineral crystals, which also applies to the hitherto supposedly mobile LVZ below MORs [4, 5].

The corresponding thick-plate version of the mid-ocean ridge (MOR) process [6 - 8], replacing the divergent mantle flow model, has a deep, narrow wall-accreting axial crack which not only provides the seismic anisotropy beneath the flanks but also brings two outstanding additional benefits:- (i) why, at medium to fast spreading rates, MOR axes become straight and orthogonally segmented [6], (ii) not being driven by body forces, it can achieve the sudden jumps of axis, spreading-rate and direction widely present in the ocean-floor record. Furthermore, as we will illustrate, the crack walls push themselves apart at depth by a thermodynamic mechanism, so the plates are not being **pulled** apart. So the presence of this process at a continental edge would not imply the application of extensional force to the margin.

Intermediate Crust (IC). In seeking to resolve the paradox that superficially extensional structures are often seen at margins we will first consider how this MOR process would be affected by the heavy *concurrent* sedimentation to be expected when splitting a mature continent. I reason that, by blocking the hydrothermal cooling widely seen along MOR axes this must inhibit the freezing-in of diagnostic spreading-type magnetic anomalies and would prolong magmagenesis to give a thicker-than-oceanic mafic crust. I have called this Intermediate Crust (IC) [9, 10], to distinguish it from Mature Continental Crust (MCC). Plate separation will continue to generate IC along the margins for as long/far as the sedimentation input is sufficient to have this effect. Transition to the MOR process will then follow. But if, contrary to the general plate tectonics assumption, based on body forces, plate separation ceases after a limited separation (or perhaps several in differing directions), without proceeding to the oceanic condition, the resulting IC areas will be incorporated within the continent [11].

Where does this lead us? With examples drawn from 40 years' study, I will contend that this is indeed the way the Earth has worked and that it offers potential plate kinematic explanation of the origin of the block-and-sedimentary basin layouts abundantly present in the non-craton areas of continents. I will show that in some cases the intricacy of block outlines and the precision with which they can be fitted together in a kinematically consistent manner rules out that this was purely by chance. The evidently meaningful character of those outlines means that they have been drawn by a narrow-crack separative mechanism which reflects that of our new MOR model. To provide a basis for such Plate Kinematic Analysis (PKA) we now link and compare some features of IC-formation at continental edges and of the crust of sedimentary basins**.**

Characteristics of IC and of sedimentary basin crust (SBC). **1. IC basement**, with expected seismic *Vp* around 6km/s, must look deceptively like that assigned to supposedly stretched MCC. **2. For thermodynamic** reasons, the hydrous metamorphic content of deep MCC and of deeply subducted UHP slices of it gives them a big thermal epeirogenic sensitivity which IC lacks. Calculation [8, 9] shows that this type of process yields some 12-30 times more column density reduction per joule than does pure thermal expansivity. So IC and MCC are clearly distinguishable epeirogenically. **3. The mantle below forming IC** will be similar thermally to that at under young oceanic crust (OC), which habitually subsides under water about 3km with age. If the water + OC is replaced with IC and isostasy is applied we get an IC thickness of around 27km, typical of SBC. **4. The magmatic generation**

of IC basement will incorporate many interlayers of (now dry) *HT*-metamorphosed sediment. At the sediment-deprived transition to the formation of OC with its intense hydrothermal cooling and rapid off-axis subsidence, this IC basement structure could be what we see as 'steeply dipping reflectors' (SDRs). **5. Multiple horizontal seismic reflectors**, first extensively observed during the BIRPs programme in the British Isles region, were noted [10] as characteristic of the basement of SBC of western Europe, but were interpreted as shear zones denoting extension. Geologically it is unlikely that shear zones would be thick enough to cause such reflections. The layered structure of IC basement is the preferred interpretation. **6. In near-margin places** where the sub-MCC mantle had a hydrous content, this, combined with the thermal volume-increase (2, above) of the MCC lower crust, can cause an oceanward-directed laccolith of both, beneath the upper crust of the margin, which therefore undergoes extensional tectonics, but which is not *plate* extension. This phenomenon has been recorded offshore Gabon and Galicia. In Gabon this laccolith is seen in seismics to have overthrust existing OC, showing that this was a thermally delayed response, some time after plate separation had got going.

In conclusion. Intermediate crust (IC) is the product of the gross modification of the MOR process by the heavy sedimentation to be expected for a time after the onset of plate separation. IC areas thus created by limited plate separation events that did not proceed to oceans then become the floors of sedimentary basins, thus extending very precisely the study of plate relative motions - Plate Kinematic Analysis (PKA) - to much further into the past than is obtainable from the present ocean floor. Concurrent flood magmatism is induced where thermal upwarping at a fresh margin also splits the deep tectosphere of near-by craton.

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