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Fault strength and the formation of rider blocks and domes in continental and oceanic core complexes

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Core complexes are places where slip of normal sense ‘detachment’ faults exhumes rocks from more than 10 km depth. We first present 2D cross-sectional model results showing that core complex detachment faults are strong and that their strength has to be in a narrow range to allow kilometer scale "rider blocks" to develop. Previous numerical simulations of lithospheric extension produced the large offset, core complex-forming, normal faults only when the faults were weaker than a given threshold. High-resolution simulations are needed to resolve rider blocks and they only form when the faults are stronger than a given level. A narrow range of fault weakening, relative to intact surrounding rock, allows for a consecutive series of rider blocks to emerge in a core complex-like geometry. Rider blocks develop when the dominant form of weakening is by reduction of fault cohesion while faults that weaken primarily by friction reduction do not form distinct rider blocks.

The term ‘core’ refers to the oval region of rocks exhumed from depth and surrounded by rocks formed at shallower depths. Cores are typically 10-15 km wide and longer in the extension direction. 2 and 3D numerical and analog models are used to show that the cores could form as a result of ‘continuous casting’ of warm, ductile lower plate rocks pulled up against a cold upper plate (Spencer, 1999). Spencer (1999) considered undulations in the surface of a brittle plate while here we consider how a both the surface and base of the plate can be “cast” with a nearly parallel shape. Ridges can locally migrate in time and may do so in response to along-axis variations in the magmatic accommodation of plate separation. We suggest that the core geometry is formed by along strike variations in the horizontal position of the detachment boundary. Long wavelength (compared to the brittle layer thickness) horizontal undulations in the position of the detachment can produce parallel undulations in both the surface and base of the plate. This occurs because brittle plate thickness is controlled by cooling from the surface of the plate. The wavelength of the cores represents the longest load wavelength that can be flexurally supported by the brittle lower plate. Models of brittle plate flexure indicate that the longest supportable wavelength is dependent on the amplitude of the loads. Large loads, and so kilometer-scale undulations, are likely to be less than 20 – 30 km in wavelength. The down-flexed part of the lower plate can be covered by rider blocks while the exposed higher grade rocks form the core.