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Plate tectonics beyond plate boundaries: the role of ancient structures in intraplate orogenesis

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The development of orogens that occur at a distance from plate boundaries (i.e. 'intraplate' deformation) cannot be adequately explained through conventional plate tectonic theory. Intraplate deformation infers a more complex argument for lithospheric and mantle interaction than plate tectonic theory allows. As a result, the origins of intraplate orogenesis are enigmatic. One hypothesis is the amalgamation of continental material (i.e. micro-plates) leaves inherent scars on the crust and mantle lithosphere. Previous studies into continent-continent collisions identify a number of scenarios from accretionary tectonics that affect the crust and mantle (namely, the development of a Rayleigh-Taylor instability, lithospheric underplating, lithospheric delamination, and lithospheric subduction). Any of these processes may weaken the lithosphere allowing episodic reactivation of faults within continental interiors. Hence, continental convergence (i.e. shortening) at a time after continental collision may cause the already weakened crust and mantle lithosphere to produce intraplate deformation. In order to better understand the processes involved in deformation away from plate boundaries, we present suites of continental shortening models (using the high-resolution thermal-mechanical modelling code SOPALE) to identify the preferred style of deformation. We model ancient structures by applying weak subduction scarring, changing the rheological conditions, and modifying the thermal structure within the lithosphere. To highlight the role of surface processes on plate and lithosphere deformation, the effect of climate-driven erosion and deposition on the tectonic structure of intraplate deformation is also addressed. We explore the relevance of the models to previously studied regions of intraplate orogenesis, including the Pyrenees in Europe, the Laramide orogen in North America, Tien Shan orogen in Central Asia, and Central Australia. The findings of the simulations with regards to past and future North American intraplate deformation are also discussed. Our results indicate that there exists a number of tectonic environments that can be produced relating to continental accretion, and that specific observational constraints to the local area (e.g., geological, geophysical, geodetic) are required to be integrated directly into the analyses for better interpretation. The models shown here find that although rheological changes to the lithosphere can produce a range of deformation during continental convergence (i.e. crustal thickening, thinning, and folding), mantle weak zones from ancient subduction can generate more localized deformation and topography.