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POSSIBLE ROLE OF CRUSTAL FLEXURE IN THE INITIAL DETACHMENT OF EXTENSIONAL ALLOCHTHONS;

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The existence of low-angle normal faults indicates that the ratio of shear stress (τ) to normal stress (σ_N) needed to cause slip on faults is substantially less than would be predicted based on experimental data. Because the tensional strength of rock at a large scale is exceedingly low, the upper plate of a low-angle normal fault cannot be pulled down the fault ramp, but must be driven down it by its own weight. The active or recently active Sevier Desert detachment fault in western Utah dips regionally at 12° (1). The ratio of shear stress to normal stress due to the weight of the upper plate on a 12°-dipping fault surface is 0.2. In contrast, laboratory experiments indicate that slip on fracture surfaces occurs with almost all rock types when (τ / σ_N) reaches values of 0.6 to 0.85 (2), corresponding to normal-fault dips of 30° to 40°. Seismological data indicate that low deviatoric stresses are associated with movement on faults of other geometries (3,4) and are not unique to low-angle normal faults. It thus appears that approximately planar fault zones with surface areas of hundreds to thousands of square kilometers have different mechanical properties than would be predicted based on laboratory studies of fractured rock.

Modeling of stresses associated with flexure of oceanic lithosphere at outer-arc rises indicates that deviatoric stresses greater than 5kb exist and are sustainable in oceanic lithosphere, and that failure occurs when τ / σ_N approaches 0.6 to 0.85 (5). Continental lithosphere differs from oceanic lithosphere in that a low-strength zone in the middle and lower crust is predicted to separate strong upper crust and strong upper mantle (6). This three-layer lithosphere rheology is consistent with seismicity data (7), and indicates that stresses of up to several kilobars should be sustainable in the upper crust. In situ stress measurements support the applicability of laboratory data to models of crustal rheology at near-surface levels away from fault zones (8).

I therefore conclude that fault initiation is a major tectonic event that results in formation of planar zones of weakness within which sustainable deviatoric stresses are only a small fraction of sustainable deviatoric stress levels in rocks that are fractured but do not contain throughgoing fault zones. The transition from fractured rock to a throughgoing, planar fault zone must result from many seismic events or from aseismic processes. If it occurred during a single seismic event, the stress drop would be very large and would be recognizable in seismological data; such events are not observed (3). The deviatoric stresses needed for formation of low-angle normal faults and initial mobilization of extensional allochthons are far greater than those produced by the weight of crustal rock on a gently dipping surface. This points to a fundamental mechanical problem: how are such high shear stresses achieved on gently dipping surfaces.

I propose that stresses associated with crustal flexure are essential for initial detachment of extensional allochthons, at least in cases where pre-existing faults are not utilized as detachment fault surfaces. Low-angle normal faults form as slip surfaces that release elastic energy associated with crustal flexure. Flexure in the western United States possibly resulted from at least two processes: [1] initial moderate- to high-angle normal faulting caused unloading of the footwall block, resulting in slight to moderate isostatic uplift and concave-upward flexure of the footwall and associated development of flexure-generated stresses. Sequential initiation of progressively shallower faults resulted from continued extensional faulting and associated denudation, isostatic uplift, and flexure of the footwall. [2] Erosional denudation of the overthickened and topographically high, Mesozoic compressional orogenic belt caused isostatic uplift of the belt and flexure on its flanks. In this case, extensional faulting began in an upper crust that was already highly stressed due to flexure associated with erosional denudation and isostatic rebound. This second mechanism for flexure is consistent with some sedimentological data that suggest that subsidence over a broad area due to initial extension on gently dipping faults is followed by internal distension and high-angle faulting of the upper plate (9), rather than the reverse sequence in which initial high-angle faulting is followed by progressively lower angle faulting.

The sense of shear along the gently to moderately dipping neutral surface of a tapered lower plate undergoing concave-upward flexure would tend to drive rock above the surface down the regional dip of the surface. In an extensional environment of reduced lateral confining stress, the weight of the rock above the neutral surface would also tend to drive overlying rock down the surface. Stresses originating from both flexure and gravity interfere constructively, and the resultant state of stress may be essential for low-angle normal fault initiation (10).

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