Rotational Kinematics of the Rocky Mountain Thrust Belt of Northern Montana

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ABSTRACT

The massive Lewis-Eldorado-Hoadley (LEH) thrust slab dominates the northern Montana thrust belt. Its emplacement history explains much about the evolution of the kinematically-linked Montana Disturbed Belt. The LEH slab consists of a 100 km wide, wedge-shaped thrust plate that is 30 km thick in the southwest and 7 km thick in the northeast, along the Rocky Mountain front. From the base up, the southwest edge of the slab comprises a 6-km thick set of gabbroic sills, the 16-km thick basinal facies of the Mesoproterozoic Belt-Purcell Supergroup, 2 km of Paleozoic platform strata, and 6 km of Mesozoic foreland basin sedimentary and volcanic rocks. The slab is broadly folded into the Purcell anticlinorium, which represents the inverted form of the horizontally displaced Belt-Purcell basin. The northeast limb of the anticlinorium represents the displaced hingeline of the Belt-Purcell basin, and the southwest limb drapes a large southwest-facing footwall ramp that represents the autochthonous position of the Belt-Purcell basin hingeline. The width of the anticlinorium therefore measures the horizontal displacement of the LEH slab. This width increases systematically northwest from Helena, where the anticlinorium plunges out into a structural trough, to the Canadian border. The increasing displacement indicates that the LEH slab underwent about 30 degrees of clockwise rotation about a pole near Helena during its emplacement. The displacement of the LEH slab as measured by the width of the Purcell anticlinorium is compatible with the net displacement of the thrust faults in the adjacent Montana Disturbed Belt. This indicates that movement of the great LEH slab was accommodated by thrust shortening in the adjacent foreland.

The LEH slab had great structural strength, because it was dominated by strong Precambrian quartzite and gabbro. The slab had a cold geothermal gradient; temperatures during thrusting never exceeded the greenschist facies conditions of Mesoproterozoic burial metamorphism. Consequently, the slab deformed in its dry brittle field, and its fracture strength increased with depth to >2 GPa. Therefore, it retained great internal structural coherence during its rotational emplacement, although lateral transfer zones between the interleaved Lewis, Eldorado, and Hoadley thrust faults at the leading wedge-edge of the slab did accommodate smaller-scale rotations within the overall clockwise-rotating slab.

The slab was emplaced during the interval 74-58 Ma, as shown by stratigraphic and geochronological relationships. As the slab overrode the Belt-Purcell basin-margin ramp, the ramp isostatically subsided in its van, and the flexural strength of the lithosphere extended the subsidence outward across the foreland basin to the forebulge, 400 km to the east. Movement of the slab may be reflected in the reciprocal sequence stratigraphy of the foreland basin, as reported by Catuneanu and Sweet (1999). Paleozoic and Mesozoic rocks were buried to a depth of >20 km beneath the advancing slab. Unlike the Belt-Purcell Supergroup, these rocks had never been metamorphosed. Increasing temperature and pressure drove connate fluids from these buried rocks, resulting in formation of pre- and syntectonic calcite veins in foreland basin rocks as young as 76 Ma. R. Lerman (1999) measured fluid inclusions as hot as 347° C in some calcite veins. The flux of hot fluids driven from beneath the massive LEH slab may have resulted in chemical remagnetization of rocks in the foreland basin, as detected by Enkin and others (1998). Such a fluid flux may also have affected the hydrocarbon budget in the foreland basin.

Upon cessation of thrusting at 58 Ma, the Belt-Purcell basin hingeline ramp rebounded, and at that time the form of the LEH slab was inverted into the Purcell anticlinorium. During the Tertiary, deep erosion truncated the anticlinorium, and numerous half-grabens formed, in part in response to stretching of the slab over the rebounding ramp. Rebound-driven Tertiary erosion also partly exhumed the footwall of the LEH slab, revealing the classic structures of the Montana Disturbed Belt.