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Relationship of Basement Faulting to Laccolithic Centers of Southeastern Utah and Vicinity

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Recent interpretation of more than 3,500 km of seismic lines in the San Juan and southeastern Paradox Basins has enabled us to map a large number of faults that have measurable offset at the top of the basement and to speculate about possible structural control on intrusive activity. Basement faults throughout the region form an orthogonal pattern: in the San Juan Basin they have average trends of N. 60°–70° W. and N. 30°–40° E. and a typical spacing of 6–16 km, whereas those in the southeastern Paradox Basin are more closely spaced and are rotated 10°–15° clockwise. Apparent vertical displacement in the plane of section is commonly 50–75 m, measured at the top of the basement. Strike-slip movement on many faults is also suggested by the map pattern, but no reliable measurements have yet been made.

The faults probably originated in the Precambrian but had major episodic movement again in the late Paleozoic, in Jurassic to Early Cretaceous time, in Late Cretaceous to early Tertiary time, and perhaps in mid-Tertiary time. The present basement offset represents the sum of all previous movements, but the actual sense of movement on any particular fault was governed by its orientation in the stress field existing at the time. The offset of most faults is not detectable above Permian strata on the available seismic sections; however, the sections do show draping, measurable differences in thickness, and lithologic changes in Mesozoic rocks above many fault zones.

Basement fault patterns and fault movement are reflected by depositional patterns throughout the Phanerozoic section. Many of the Pennsylvanian through Jurassic patterns can be explained as a result of differential movement on large blocks, which typically are 50–80 km on a side and are bounded by dominant faults. Basin subsidence in the Late Cretaceous was apparently controlled to some extent by movement along some of the northwest-trending faults, as sandstone buildups marking many of the transgressive and regressive shorelines overlie and parallel the basement faults. Recent seismicity and present-day drainage patterns suggest that the basement faults still influence tectonics, sedimentation, and erosion in the San Juan Basin. Fault patterns and movement histories in the southeastern Paradox Basin are nearly identical to those of the San Juan Basin, and we believe that this is also true throughout the remainder of the Paradox Basin, although we do not have sufficient data to fully document such an argument.

Baars (1966) first called attention to the large northwest-trending structures (Grenadier and Sneffels Horsts) in the San Juan Mountains north of the San Juan Basin and projected them into some of the large salt structures of the Paradox Basin. There is little direct evidence in the outcrops of the San Juans to define the geometry of the bounding faults of these structures, so many of the published reconstructions are somewhat speculative. Although the extensions of these fault systems to the northwest in the central Paradox Basin are better known because of seismic surveys and drilling for oil and gas, the fault geometries and movement histories are still poorly understood. In both areas, available information can be interpreted in several different ways; the late Paleozoic stress field remains ambiguous.

Farther to the northwest along the basin margin, in the vicinity of Cisco, Utah, Frahme and Vaughn (1983) showed

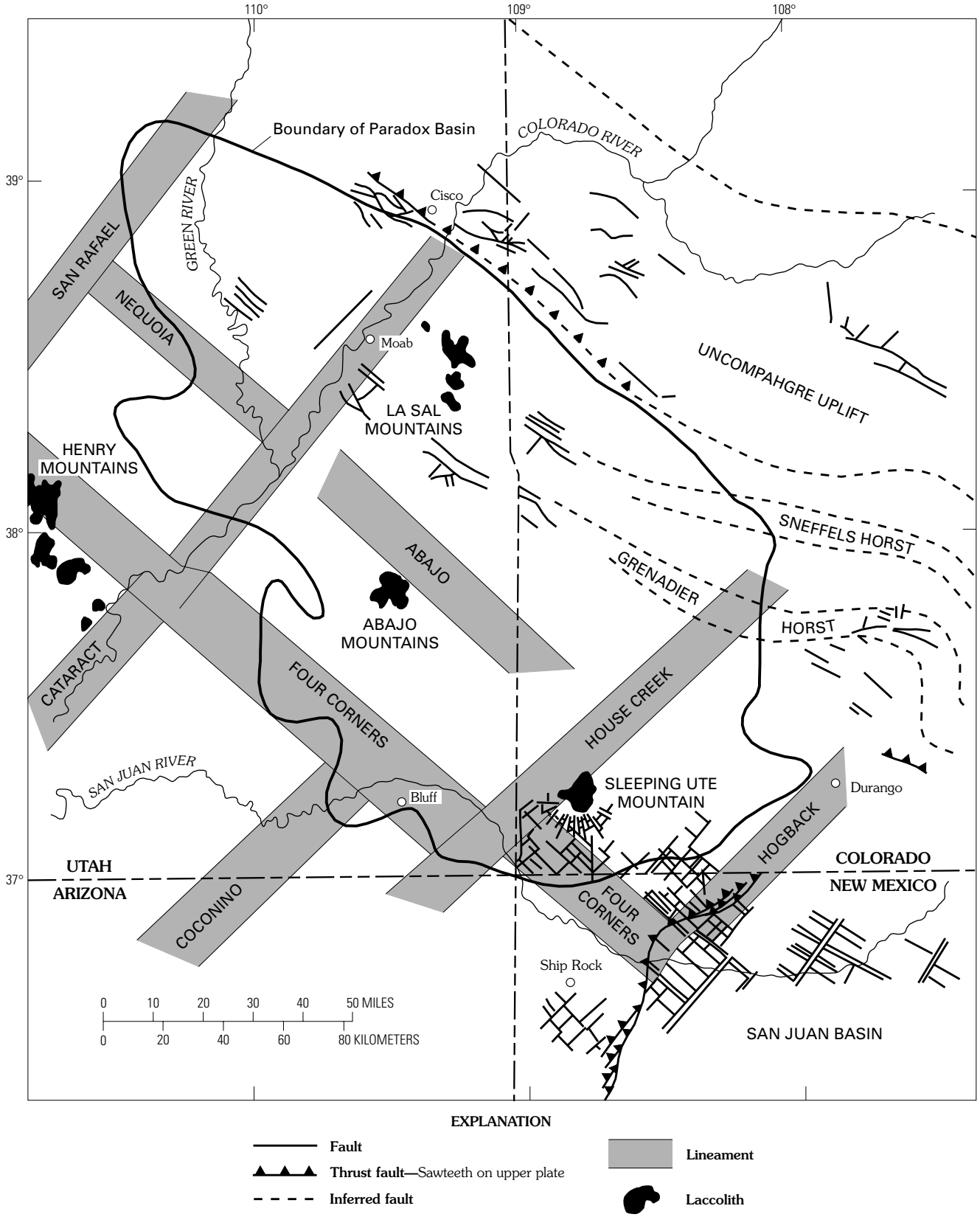

Figure 1. Location of faults in rocks older than the Paradox Formation in the Paradox basin and vicinity. Lineaments and Grenadier and Sneffels structures from Stevenson and Baars (1986).

that the Uncompahgre uplift had a large southwestward thrust component from late Desmoinesian time through Wolfcampian time. They concluded that this thrusting caused folding and faulting in the Paradox Basin and coincided with major salt movement. Even in this area, however, the actual movement on the faults has not yet been demonstrated adequately.

Movement on these fault systems during the mid-Tertiary period of laccolith emplacement is even more conjectural because of the lack of Oligocene and younger sedimentary deposits in the Paradox and San Juan Basins. Recent analyses of the Oligocene stress field based on dike orientations and other criteria (Delaney and others, 1986; Ren and others, 1987; Tingey and others, 1990) suggested that the least principal horizontal stress was oriented northwest to nearly east-west in the Colorado Plateau and north-south to north-northeast in the eastern Basin and Range province and the Wasatch Plateau. Delaney and others (1986) discussed the difficulties inherent in this type of analysis and noted that the magnitudes of the horizontal regional stresses may have been nearly equal in the vicinity of Ship Rock in northwestern New Mexico. A similar conclusion was reached by Marie Jackson (USGS, oral commun., 1992) for the stress field during emplacement of the Henry Mountains laccoliths. Without more information, it is difficult to determine whether the area of the Paradox and San Juan Basins was under compression or extension in mid-Tertiary time, but the presence of large numbers of dikes, as on the Wasatch Plateau, argues for extension.

Under extensional conditions, particularly north-south or east-west directed, nearly any of the mapped basement faults and especially their intersections would be appropriate sites for intrusive activity. Compression would limit the likely areas of intrusion, as would any significant wrench component. The master faults that bound the large blocks would have been the most likely sites in any stress regime. Figure 1 suggests possible correlations of laccolithic centers with major lineaments and with the extended Sneffels and Grenadier structures proposed by Stevenson and Baars (1986).

Our interpretation of the seismic data has not yet proceeded far enough into the Paradox Basin to evaluate many of the proposed lineaments or fault zones properly . We have found little evidence to suggest major movement on the southeastern end of the Four Corners lineament, but the Hogback lineament has been a major structure, intermittently active, at least since Pennsylvanian time (Taylor and Huffman, 1988). Work is currently underway to evaluate several of the other structures.

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