Folded Sills and Fault-Propagation Folds in Northern Sierra del Carmen, Big Bend Region, Texas

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Detailed, 1:12:000-scale surface geologic mapping of excellent exposures in northern Sierra del Carmen (SDC) in the Stairway Mountain area within Black Gap Wildlife Management Area and in the Dagger Mountain area within Big Bend National Park is revealing two key points about the timing and nature of Laramide and Basin and Range structures that affect margins of the Permian basin. In addition, SDC fold styles could have Paleozoic analogs in the Permian basin. The SDC exposes Cretaceous carbonate and siliciclastic rocks intruded by felsic sills, mafic sills, and 32.1 Ma McKinney Hills laccolith. The SDC, within the easternmost Cordilleran orogen and Basin and Range province, contains two phases of Laramide folds cross-cut by high-angle Basin and Range faults and drag folds.

First, geologic mapping and descriptive structural analysis in eastern Big Bend National Park document that sills were folded by Laramide folds. If sparse isotopic dates are applicable, local Laramide deformation continued after 32.5 Ma. A northern SDC sill was dated at 32.5 Ma ($^{40}Ar/^{39}Ar$ on groundmass; Morgan and Shanks, 2008). Intrusions are part of the Trans-Pecos Magmatic province; isotopic dates range from 64 to 17 Ma (Henry and McDowell, 1986). Several lines of evidence indicate sills are pretectonic: a) one continuous, well-exposed sill displays a folded shape within a map-scale Laramide anticline and syncline, b) sills remain constant in thickness and do not thicken in hinge areas, c) sills do not reorient Laramide folds, and d) sills do not intrude along syn-folding joint sets. The simplest sequence of events that fits current data is: 1) Sills intruded by inflation at 32.5 Ma, but

did not reorient bedding, 2) Sills folded during Laramide orogeny, 3) Basin and Range faults cross-cut sills and Laramide folds. However, elsewhere in SDC unfolded 51-48 Ma Canoe Formation unconformably overlies a Laramide anticline (Lehman, 2004), raising the alternative that some northern SDC sills intruded before 48 Ma.

Second, mapping in the Stairway Mountain area is documenting at least one fault-propagation fold above an exposed normal fault. This extensional fault-propagation fold was first described by Ferrill and others (2004) and Smart and others (2010). Many map-scale monoclines previously assumed to be Laramide fault-propagation folds above reverse faults may actually be Basin and Range fault-propagation folds above normal faults. Overturned map-scale folds, mapped in the Dagger Mountain area, are characteristic of contractional fault-propagation folds.