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A model for the three-stage development of Sierra Nevada geomorphology and its relationship with the San Joaquin Basin

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ABSTRACT

The Sierra Nevada and adjacent Great Valley constitute a semi-rigid lithospheric block commonly termed the Sierran microplate. This microplate is bounded on the east by the eastern Sierra frontal fault system, marking the western edge of the Basin and Range province, and to the west by the Coast Range transpressive fold belt and its controlling San Andreas plate juncture. To the south the microplate is bounded by the Garlock fault, a left-lateral transfer structure linked to Basin and Range extension. The microplate is commonly regarded as a westward tilted fault block with the Sierran uplift to the east coupled to asymmetric subsidence in the Great Valley to the west. Recent analysis of southern Sierra topography coupled to low-temperature thermochronological studies indicate that this simple tilted fault block model breaks down within and south of the Kings River drainage. Furthermore, internal deformation of the Sierran basement from the region of the upper Kaweah River drainage southward, as well as the adjacent Tulare sub-basin and its south-bounding Bakersfield Arch, reveal the non-rigidity of the microplate within a substantial tract of its southern reaches. Analysis of Digital Elevation Models (DEM's) clearly shows that the southern Sierra diverges from the simple rigid fault block model in its first-order topographic features. The distinctiveness of southern Sierra topography is considered from the perspective of a working model for three stages of its development, with each stage rendering a distinctive pattern in basement exhumation. These three stages appear to have correlative stratigraphic expressions in the adjacent San Joaquin basin (SJB).

Stage 1 entailed Late Cretaceous-early Paleogene erosional, and dominantly tectonic, denudation of the southernmost Sierra Nevada batholith (SNB) that occurred in conjunction with shallow flat-slab segment subduction in the southern California region. SNB rocks of the Tehachapi Range were denuded to ~35 km depths at this time, with the northern extent of tectonic denudation approximated by the trace of the lower Kern River and South Fork Valley of the Kern. By comparison, most of the SNB to the north has only been exhumed to 5-10 km depths. During this event the sub-SNB mantle lithosphere was sheared off by shallow subduction in the south, but remained intact beneath the greater SNB to the north. Extensional nappes of the southernmost SNB upper crust are identified in the western Tehachapi-San Emigdio Ranges and the Gabilan Range of restored Salinia. The first-order topographic feature developed at this time was a broad southerly slope to the sub-Eocene erosional surface which descended to a transverse marine embayment that developed across the deeply exhumed batholithic rocks of the southernmost Sierra, adjacent western Mojave, and restored Salinia core area. In contrast, the sub-Eocene surface is one of the defining datums for the west-tilt pattern of the central and northern Sierra known widely for the overlying auriferous gravels of the Ione Formation. Deep exhumation of the southernmost SNB is paralleled in the southern SJB by the erosional truncation of the Cretaceous-early Paleogene forearc basin sequence.

Stage 2 is common to the entire Sierra Nevada, and is marked by the ~10 Ma inception of the microplate with the westward encroachment of Basin and Range extensional faulting coalescing into the eastern Sierra range front system. The Late Cretaceous Kern Canyon fault system was remobilized as a normal fault at this time, and the Garlock transfer system started its most vigorous phases of displacement. Major river incision throughout the Sierra appears to have accelerated at this time with the accenting of SJV stratigraphy by the extensive Santa Margarita marine sand sheet, and its incursion into the predominantly subaerial Sacramento basin. Central and northern Sierra Neogene (ancestral Cascades) arc volcanism was also accented at this time by a distinct alkalic excursion. Topography of the central and northern Sierra reflects the persistence of this stage of microplate

evolution to the present day.

Stage 3 entailed the surface response to the Pliocene-Quaternary convective removal of the residual high-density mantle lithosphere that was left beneath the southern Sierra region following Stage 1. Replacement of the sub-batholithic lithosphere by ascended asthenosphere resulted in a second uplift pulse in the southern Sierra, and rejuvenated river incision. The high-density mantle lithosphere was mobilized westward as a drip-like structure beneath the westernmost Sierra and adjacent SJB. Viscous coupling between the mantle drip and overlying crust resulted in a high-strain channel in the lower crust with its partial entrainment into the upper levels of the drip, and dampened subsidence of the elastic upper crust. Surface features that can be directly related to such dynamics include: 1) distinctly higher elevations throughout much of the southern Sierra, relative to those of the central and northern Sierra, 2) sharp subsidence of the western Sierra, resulting in river aggradation with the burial of mountainous topography continuing, and 3) accelerated SJB subsidence of the Tulare sub-basin. Anomalous topographic positive features of the Greenhorn Mountains and adjacent Bakersfield Arch may also be linked to this dynamic system. Warping of the Sierran basement in concert with this regional deformation pattern is also recorded in regional curvilinear patterns in the remnants of the sub-Eocene surface that was inherited from Stage 1.