CENOZOIC EXTENSION AND MAGMATISM IN ARIZONA; S. J. Reynolds and J. E. Spencer, Arizona Bureau of Geology and Mineral Technology, 845 N. Park, Tucson, AZ 85719

The Basin and Range Province of Arizona was the site of two episodes of Cenozoic extension that can be distinguished on the basis of timing, direction and style of extension, and associated magmatism (1,2). The first episode of extension occurred during Oligocene to mid-Miocene time and resulted in the formation of low-angle detachment faults, ductile shear zones (metamorphic core complexes), and regional domains of tilted fault blocks. Evidence for extreme middle Tertiary crustal extension in a NE-SW to ENE-WSW direction has been recognized in various parts of the Basin and Range of Arizona, especially in the Lake Mead area (3) and along the belt of metamorphic core complexes that crosses southern Arizona from Parker to Tucson (4). New geologic mapping and scrutiny of published geologic maps indicates that significant middle Tertiary extension is more widely distributed than previously thought. The state can be subdivided into regional tilt-block domains in which middle Tertiary rocks dip consistently in one direction (Fig. 1). The dip direction in any tilt-block domain is generally toward the breakaway of a low-angle detachment fault that underlies the tilt-block domain; we interpret this as indicating that normal faults in the upper plate of a detachment fault are generally synthetic, rather than antithetic, with respect to the detachment fault.

Detachment faults are subregional fault zones that originally formed with a low dip and that have accommodated normal slip of several kilometers to tens of kilometers (5,6). Large amounts of normal slip on some detachment faults have exhumed metamorphic core complexes that contain gently dipping mylonitic fabrics whose overall sense of shear is parallel to and in the same sense as transport on the associated detachment fault (7,8). These core-complex mylonites were formed by noncoaxial laminar flow along deeper segments of the detachment zone that were below the ductile-brittle transition. The principle causes of uplift and arching of the detachment zone are considered to be the following: 1) laterally variable isostatic uplift due to differential denudation; and 2) reverse drag above structurally deeper, listric normal faults (9) (Fig. 2). The relative importance of these two processes is generally unknown, and is probably quite variable between different detachment zones.

Middle Tertiary extension has exposed different levels of the pre-middle Tertiary crust. Rocks that were at mid-crustal levels prior to faulting are exposed in core complexes that contain thick (>1km) zones of penetrative mylonitic fabric, whereas shallower crustal levels are represented by thin (<100m) zones of less penetrative mylonitic fabrics that are confined to middle Tertiary plutons and their wall rocks. In these latter areas, the emplacement of synkinematic middle Tertiary plutons has caused local raising of geotherms and has permitted mylonitization to occur at levels that might otherwise have been above the brittle-ductile transition. Various levels of middle Tertiary crust are also exposed by wholesale rotation and subsequent erosion of large fault blocks. Some tilted fault blocks expose middle Tertiary plutons and dike swarms that represent the subsurface magma chambers and pathways, respectively, of middle Tertiary volcanics.

The main pulse of middle Tertiary felsic to mafic magmatism is time transgressive from east to west (10), but existing data are not sufficient to clearly demonstrate a state-wide, time-transgressive character for either the initiation or termination of detachment faulting. Extension and detachment faulting began in some areas before significant magmatism, which suggests that magmatism and the associated elevation of geotherms are not necessary preconditions for the initiation of detachment faults. Numerical modeling requires that some of the proposed increases in geothermal gradients in middle Tertiary time are a consequence, not a cause, of detachment faulting.

Magnitudes of middle Tertiary extension of 50 to 100 percent are indicated by cross-sectional reconstructions of distended terrains and by evidence for total tectonic denudation of mid-crustal, core-complex tectonites during detachment faulting. This estimate is supported by comparisons of present crustal thickness (25km) of the Basin and Range Province with those that must have existed prior to extension in order to account for early Tertiary drainages that flowed onto the Colorado Plateau (present crustal thickness 40 km) from the presently topographically lower Basin and Range Province (11,12) (Fig. 3).

The middle Tertiary episode of extension and magmatism ended approximately 15 m.y. ago in all of Arizona except the Lake Mead area. It was replaced by the Basin and Range disturbance, which occurred in late Miocene and younger time and was characterized by dominantly basaltic volcanism and high-angle normal faulting that formed locally deep grabens filled with clastic sediments and nonmarine evaporites. The amount of extension during this event was relatively small (<15 percent) and occurred in an approximately east-west direction. The change to dominantly basaltic volcanism can be attributed to the initiation of through-going, high-angle faults that penetrated the cooling continental crust and permitted the easy ascent of mantle-derived magmas.

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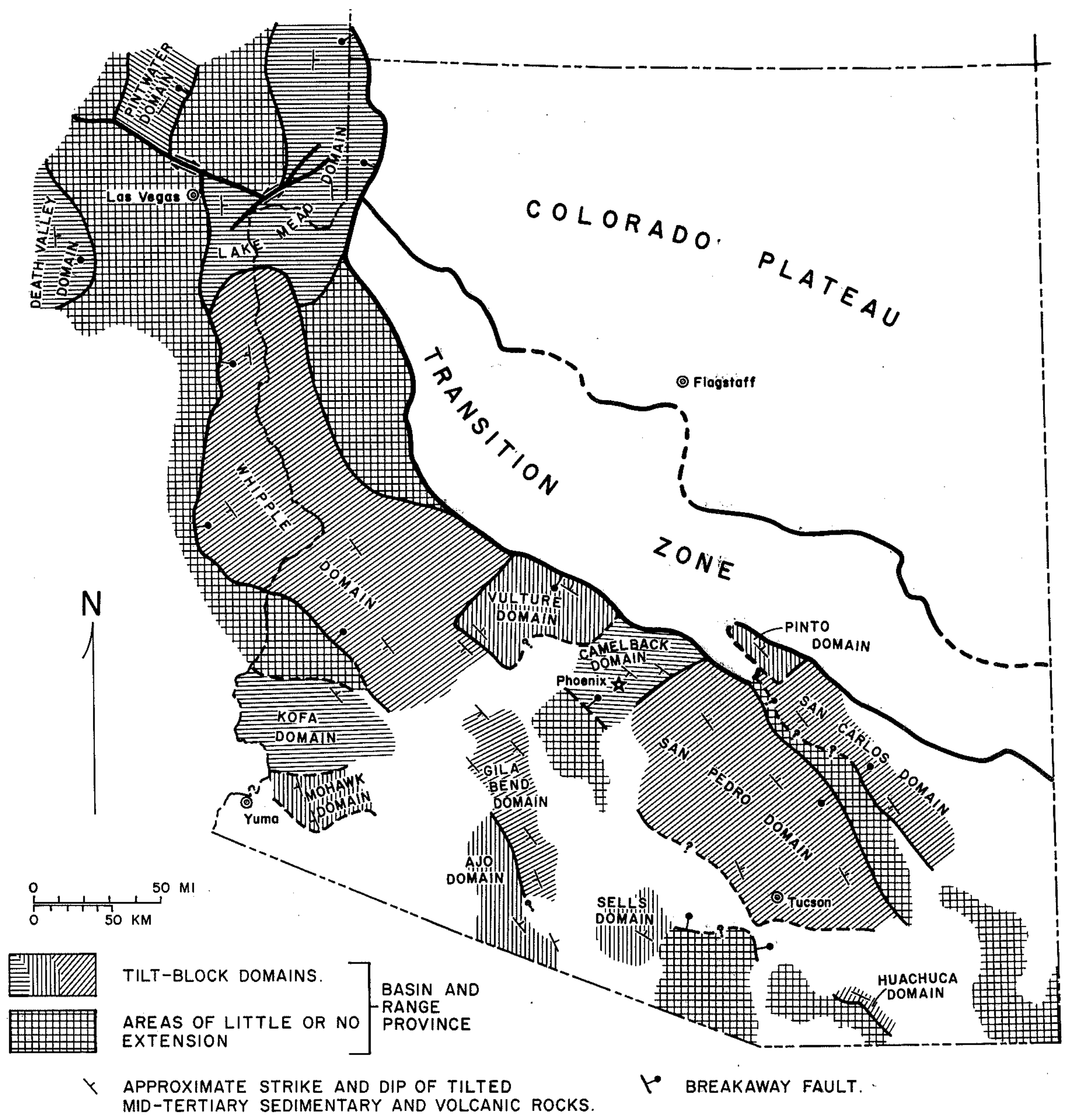


Figure 1. Map of tilt-block domains in the Basin and Range Province of Arizona and adjacent areas.

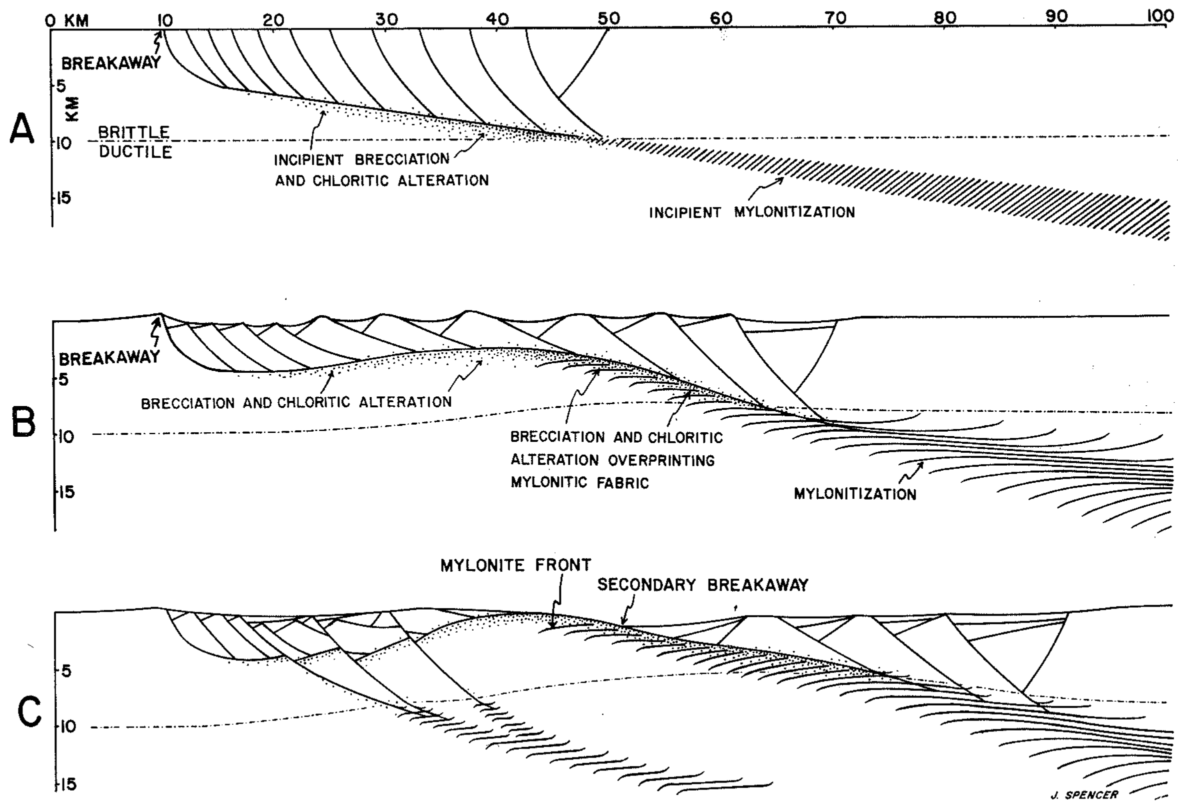
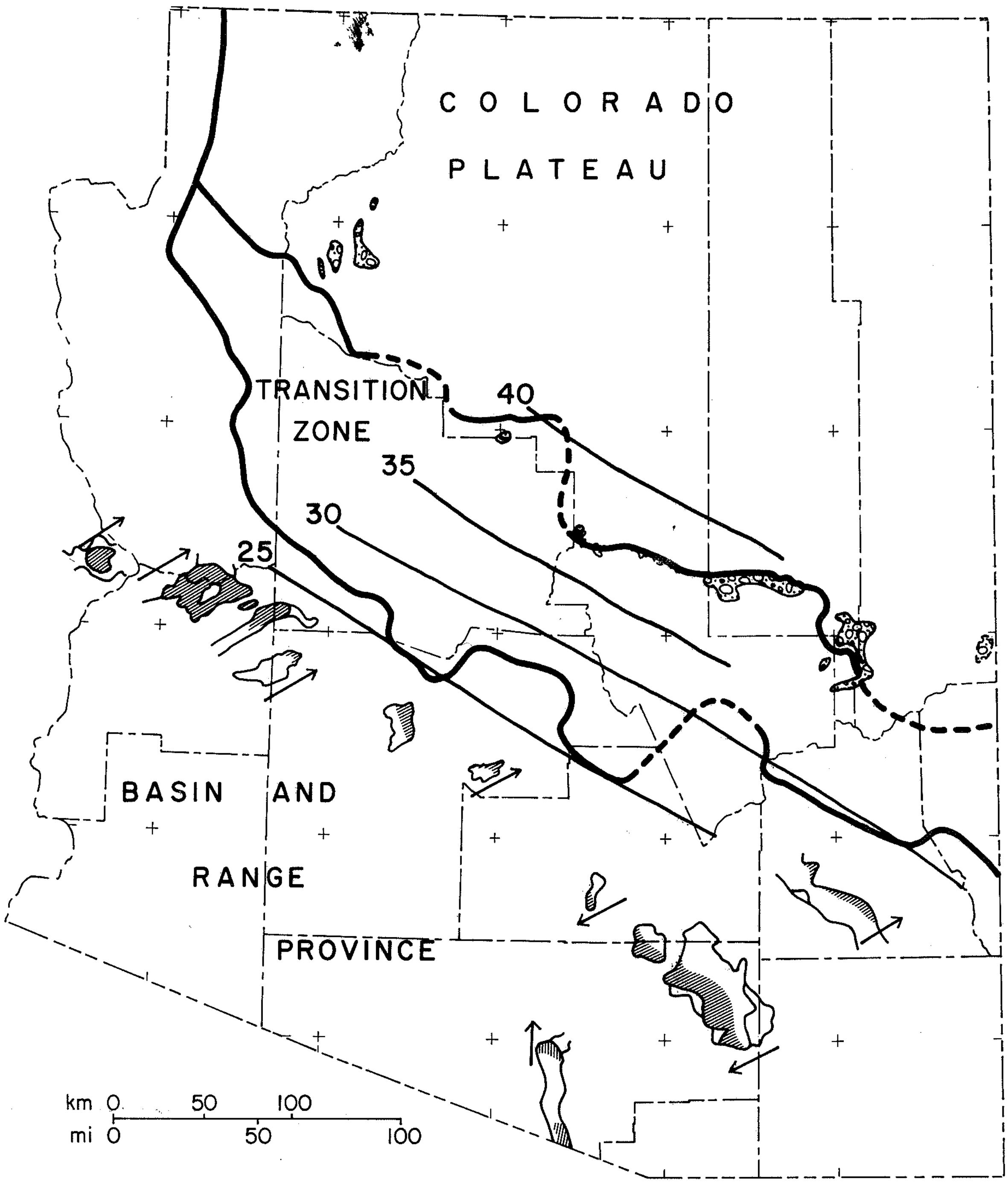


Figure 2. Schematic cross sections showing the evolution of detachment zones; (a) initiation of movement on the detachment zone; (b) isostatic uplift and arching due to variable amounts of upper-plate distension; and (c) one-sided denudation of original detachment zone, and arching caused by reverse drag above structurally deeper, listric normal faults.

Figure 3. Map of Arizona depicting crustal thicknesses and the location of metamorphic core complexes and early to middle Tertiary Rim gravels. The Rim gravels are located along the topographically high margin of the Colorado Plateau and were deposited by northeast-flowing drainages that drained the presently topographically lower Transition Zone and Basin and Range Provinces.



35 — Crustal thickness contour (in km)

→ Sense of shear indicated by S and C surfaces in mylonitic rocks (relative movement direction of upper plate)

Lineated mylonitic rocks in metamorphic core complexes

Rim gravels (early to middle Tertiary)

Figure 3