The curious decoupling of Cenozoic magmatism and plate tectonics in western North America: A NAVDAT analysis

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Since the widespread acceptance of plate tectonics, magmatism in the western U.S. has been explained by subduction along the west coast of North America and destruction of the subduction system by development of the San Andreas transform fault system. However, re-analysis of space-time patterns of magmatism in western North America calls many of these inferred patterns of magmatism into question. Animation of space-time patterns found in the developing NAVDAT dataset (navdat.geongrid.org), demonstrates that: (1) subduction-type volcanism is poorly linked to the subduction system; (2) there is little evidence that slab windows controlled magmatism; (3) magmatism was clearly migratory, but not in ways that can be explained by plate-tectonic processes; and (4) magmatism was migratory at length scales ranging from 1000s of km (continental) to 10s of km (county).

Several space-time patterns are evident in the NAVDAT animations, including: (1) a sweep from Montana into Nevada from 50 to about 20 Ma; (2) a clockwise sweep around the Colorado Plateau from New Mexico to southern Nevada, from about 30 to 15 Ma; (3) a burst of magmatism at about 16 Ma in northern Nevada, followed by outward sweeps to Yellowstone, central Oregon, and the Sierra Nevada; (4) a burst of magmatism in the Sierra Nevada at 3.5 Ma; and (5) several local migrations, including from Phoenix north onto the Colorado Plateau and from the San Francisco Bay area north to the Geysers geothermal field.

Some of these patterns have been tied to specific events (e.g., impingement of the Yellowstone plume and Pliocene delamination), but the others are difficult to relate to plate-tectonic events. They may be caused by local tectonic events (propagating rifts?), minor convective rolls in the asthenosphere, lithospheric delamination, or delamination of a flat Laramide slab.

Puzzling aspects of Cenozoic Cordilleran magmatic activity: Do we need a new paradigm?

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Attempts to explain space-time-composition patterns of Cordilleran Cenozoic magmatic activity within a plate tectonic framework have not been very successful. The widely quoted paradigm of early to middle Tertiary, intermed. to silicic, "subduction-related" magmatism progressively replaced by bimodal or basaltic "rift-related" magmatism inboard of the growing transform (± "plume-related" magmatism in the Pacific Northwest) is difficult to reconcile with several observations:

(1) Spatial and temporal patterns of early to mid- Tertiary volcanic activity do not resemble modern "Andean" arcs. Instead, belts of isochronous volcanic activity extended up to 1000 km inboard and migrated erratically, often parallel to the trench.

(2) The character and major and trace element compositions of pre- and post- subduction volcanic rocks at any particular latutude are often not very different, suggesting primary control by lithospheric processes rather than ultimate source region or melting mechanism.

(3) Cenozoic magmatism appears to be distinctly episodic, with distinct peaks in activity ranging from early Eocene to late Miocene and Quaternary. Some episodes (e.g. middle Miocene) affected the entire Cordillera from southern Mexico to Canada.

(4) A close spatial and temporal association of magmatism and local tectonism (e.g., extension) is evident in many places, regardless of the plate tectonic setting.

These patterns of Cordilleran magmatism attest to an unstable mantle under western North America during much of the Tertiary. Explanations for this instability (e.g. subduction, rifting, slab rot, slab windows, plumes, delamination) remain speculative; Some nicely account for magmatic histories in some areas, but fail to account for nearly identical histories in distant areas.

The magmatic/tectonic histories of 3 areas (southern Sonora, central California, and eastern Nevada are used to illustrate some of these complexities.