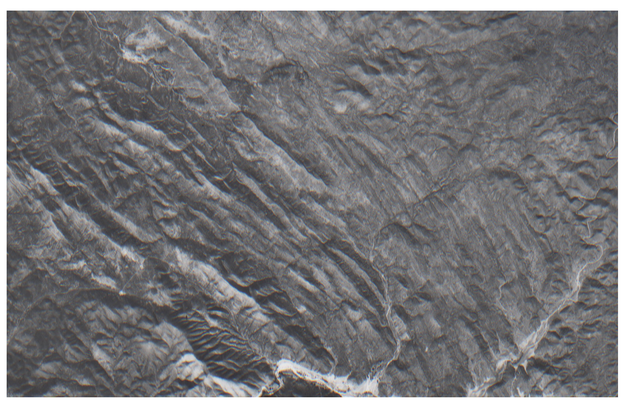
# THE SAN MARCOS DIKE SWARM (SMDS) OF NORTHERN BAJA CALIFORNIA

## ABSTRACT

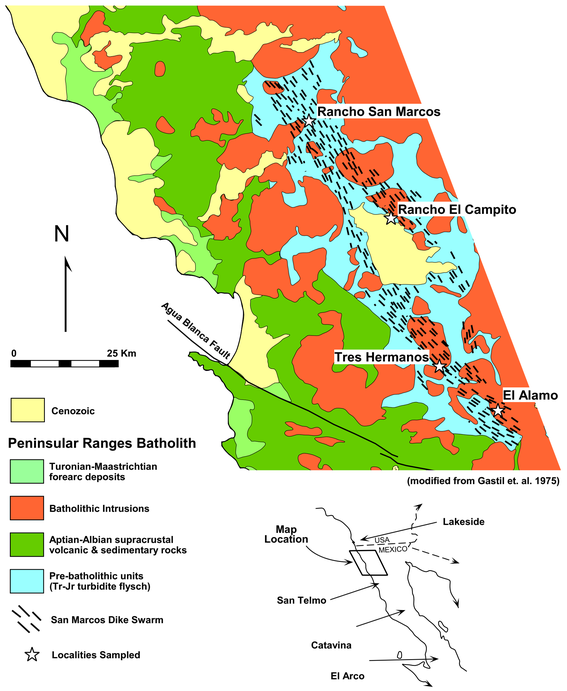
A densely intruded, northwest-striking, predominantly silicic regional dike swarm is exposed over an approximately 100 km-long segment in the west-central portion of the Cretaceous Peninsular Ranges batholith (PRB) in northern Baja California. Dike compositions range from basalt to rhyolite and are locally strongly bimodal. The swarm is intruded into two main units; 1) Triassic-Jurassic (?) turbidite flysch and 2) older, presumably pre-120 Ma batholithic rocks. Cross-cutting field relationships and a preliminary U-Pb zircon age of 120±1 Ma clearly establish the swarm as an integral feature in the magmatic evolution of the PRB. Surprisingly, despite spectacular exposure of the swarm in easily accessible regions of the PRB, as well as associated gold mineralization in the southern part of the swarm that has been mined off and on for over 100 years, this prominent feature of the PRB is virtually undescribed in the literature.
Unique characteristics of the dike swarm provide important opportunities to address two distinct classes of problems: ascent mechanisms of granitoid magma through continental crust, and regional tectonic/stratigraphic studies of the PRB using the swarm as a strain/temporal marker. Reconnaissance data on dike attitudes from two widely separated areas of the dike swarm suggest a regionally consistent approximately N30°W strike and 75°NE dip. The dike attitudes are consistent with a common westward tilt on the order of 15° about the N30°W longitudinal axis of the PRB. The SMDS may present clear structural evidence in support of hypothesized regional tilting in the PRB, hence allowing for the mechanics and timing of this process to be understood.

View northeast toward densely intruded northwest-striking dike swarm exposed above Rancho San Marcos. Hundreds of individual rhyolite and andesite dikes, locally sheeted, are exposed across the 460 meter-high skyline ridge in the distance. Rancho Vallecitos Fm turbidite flysch is hosting the swarm in this view. The most prominent dikes visible here are 5-10 m wide high-silica rhyolite dikes that are exposed along strike continuously for up to 3 km distance.

Numerous dikes exposed in the Rancho El Campito area, on the northeast margin of the Ojos Negros valley. Note the granitoid dikes that have been cross-cut by the rhyolite dike..



Dikes exposed in the Tres Hermanos area. Note the single prominent dike which extends northwest from the center of the image for almost 3 kilometers.




## PENINSULAR RANGES BATHOLITH

The SMDS occurs entirely within the western province of the PRB, which is characterized by gabbro-tonalite-granodiorite plutons with primitive island arc geochemical affinities (DePaolo, 1981; Silver & Chappell, 1988; Todd et al., 1988, 1994), and U/Pb zircon ages of 120-100 Ma. The extent of the swarm is shown schematically on the Gastil et al. (1975) 1:250 000 map of Baja California.
The swarm is intruded into two main units; 1) Triassic-Jurassic(?) turbidite flysch of the Rancho Vallecitos Formation (Reed, 1993) that is correlated to Julian Schist and Middle Jurassic Bedford Canyon Formation north of the border, and 2) older, presumably pre-120 Ma batholithic rocks for which little data is currently available. Low-grade greenschist facies of the Rancho Vallecitos Formation in the northwest area of the swarm indicate shallow emplacement depths. Significantly deeper crustal levels are exposed at Tres Hermanos where amphibolite facies schist occurs (Chadwick, 1987).
As shown on the Gastil et al. (1975) map, and supported by additional data presented below, dikes within the swarm parallel the overall trend of the swarm, which in turn is parallel to the overall ~N30°W structural grain of the PRB. At it's northern end, the dike swarm is intruded by younger ~120-100 Ma PRB intrusions. At it's southern end, it is partly intruded by younger plutons and partly blanketed by Aptian-Albian supracrustal volcanic sequences, which form a nearly continuous ~10-30 km-wide belt of volcanic rocks along the western margin of the PRB throughout its ~800-km long extent.
The exposure of the SMDS within a restricted ~100 km-long segment of the 800 km-long PRB appears to be the result of two fortuitous circumstances; 1) the relative paucity of ~120-100 Ma intrusions in this segment which elsewhere heavily intrude the western zone of the PRB (e.g. Silver and Chappell, 1988; Kimbrough et al., in review.), and 2) erosional stripping of the extensive Aptian-Albian supracrustal volcanic rocks from this region to expose a deeper structural level relative to areas along strike to the north and south.
Dikes potentially correlative to the main ~100 km-long swarm occur to the north in the Lakeside area of southern San Diego County, and to the south near San Telmo, Catavina, and at El Arco near the southernmost extent of the PRB (see inset map to Fig. 1). These possible correlatives suggest the dike swarm may have been much more extensive than its present exposure suggests.

## DIKES vs. DIAPIRS

Intrusion of felsic batholiths in continental margin magmatic arcs is a fundamental process of continental growth. Partial melting, segregation, and ascent mechanisms of felsic magma however remain poorly understood mechanical aspects of this process. The uncertainties are highlighted by the current debate between diapir versus diking ascent mechanisms which began in the 1980's when several investigators concluded that the crust was too viscous to allow diapirs to rise fast, and thus would freeze after travelling only short distances (Petford, 1996). Conversely, the viscosity of felsic magmas appeared too high to permit significant upward propagation without freezing, a view strengthened by the observation that granitic composition dike swarms are rare compared with mafic swarms (Weinberg, 1996).
Recent modeling and theoretical considerations now suggest that dike transport of silicic magma is an efficient, and perhaps dominant mechanism for large-scale transfer of silicic magma in the crust (Clemens & Mawer, 1992, Petford et al., 1994, Lister, 1995). Rapid ascent of silicic melts may allow them to rise adiabatically and become superheated, leading to resorption of entrained material and a reduction in effective viscosity that would accelerate ascent (Holtz & Johannes, 1994; Clemens et al. 1996).
Weinberg (1996) concludes that the ideal condition for initiation of silicic dikes is in strongly extentional environments, where melt segregation produces a dense network of veins that drains within the source into a few high pressure dikes; and further, that intermediate to felsic magmas may start their ascent initially as diapirs but swap to dikes as they slow down when reaching stiffer rocks.
Understanding of felsic magma ascent via diking is still badly hampered however by a paucity of actual examples where observational data can be made to constrain the various mechanisms that might enhance or inhibit dike transport. Here we outline a multidisciplinary investigation of a densely intruded bimodal but predominantly silicic regional dike swarm that is exposed over a ~100 km-long segment of the Peninsular Ranges batholith (PRB) in northern Baja California (Fig.1). This dike swarm is informally referred to here as the San Marcos Dike Swarm (SMDS) after easily accessible exposures near Rancho San Marcos in the northern part of the belt (Fig. 2). Surprisingly, despite the PRB's status as one of the most intensively studied Cordilleran batholiths, the SMDS has never been a focus of investigation, apart from interest in gold mineralization that is likely hosted by the dikes at El Alamo (Fig. 1) and areas farther north in the swarm that have been mined off and on dating back to the late 19th Century.

## LANDSAT