Slab rollback-driven exhumation of the southern Sierra Nevada batholith and the Rand and Sierra de Salinas schists, California

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The Rand, Pelona, Orocopia, and Sierra de Salinas schists are a high P – intermediate to high T terrane that underlies much of southern California and southwestern Arizona along detachment structures (Cheadle et al.,1986; Li et al., 1992; Malin et al., 1995; Yan et al., 2005). Intensive study of Rand and Sierra de Salinas schist indicate that they formed by 1) deposition of Late Cretaceous arc-derived detritus at the North America / Farallon plate margin (Grove et al., 2003); 2) underplating and metamorphism along a shallow segment of the subducting Farallon slab (Saleeby, 2003); and 3) exhumation along ductile to brittle low angle normal faults.

The spatial distribution of the schist (**Fig. 1**) was controlled, to first order, by the geometrical evolution of the Farallon slab. As the slab was underthrust to the east beneath North America in the Late Cretaceous, a south to north inflection from shallow to normal subduction trajectories developed, leaving the lithospheric mantle of the greater Sierra Nevada Batholith (SNB) intact, while first removing the mantle and subsequently juxtaposing subducted schist beneath the southern SNB and the adjacent northern Salina terrane (Malin et al., 1995; Ducea and Saleeby, 1998; Saleeby et al., 2003; Saleeby, 2003, Nadin and Saleeby, 2008). This inflection zone resembled a regional lateral ramp in the subduction megathrust, akin to active lateral ramping in the subduction system beneath the Andean arc (Gutscher et al., 2000). Intense contractile deformation along the shallow megathrust flat virtually destroyed the entire forearc and frontal arc plutonic zone, and led to rapid uplift and erosional denudation of the residual arc to mid-crustal levels (Saleeby et al., 2007). Following the unroofing of the Cretaceous arc, the transport direction in the subduction wedge reversed, and the schist was educted from the subduction zone. In the southern SNB and northern Salinia, the schist crops out beneath deeply exhumed mafic SNB assemblages (the "upper plate") along the remains of the Late Cretaceous megathrust flat (the Rand fault and Salinas shear zone, respectively) immediately south of the lateral ramp. We compile here new and published structural data from the principle exposures of Rand and Sierra de Salinas schists (**Fig. 1**) to 1) elucidate the kinematic regime in which the schist was exhumed, and 2) to relate lower plate kinematics to phases of Farallon plate subduction.

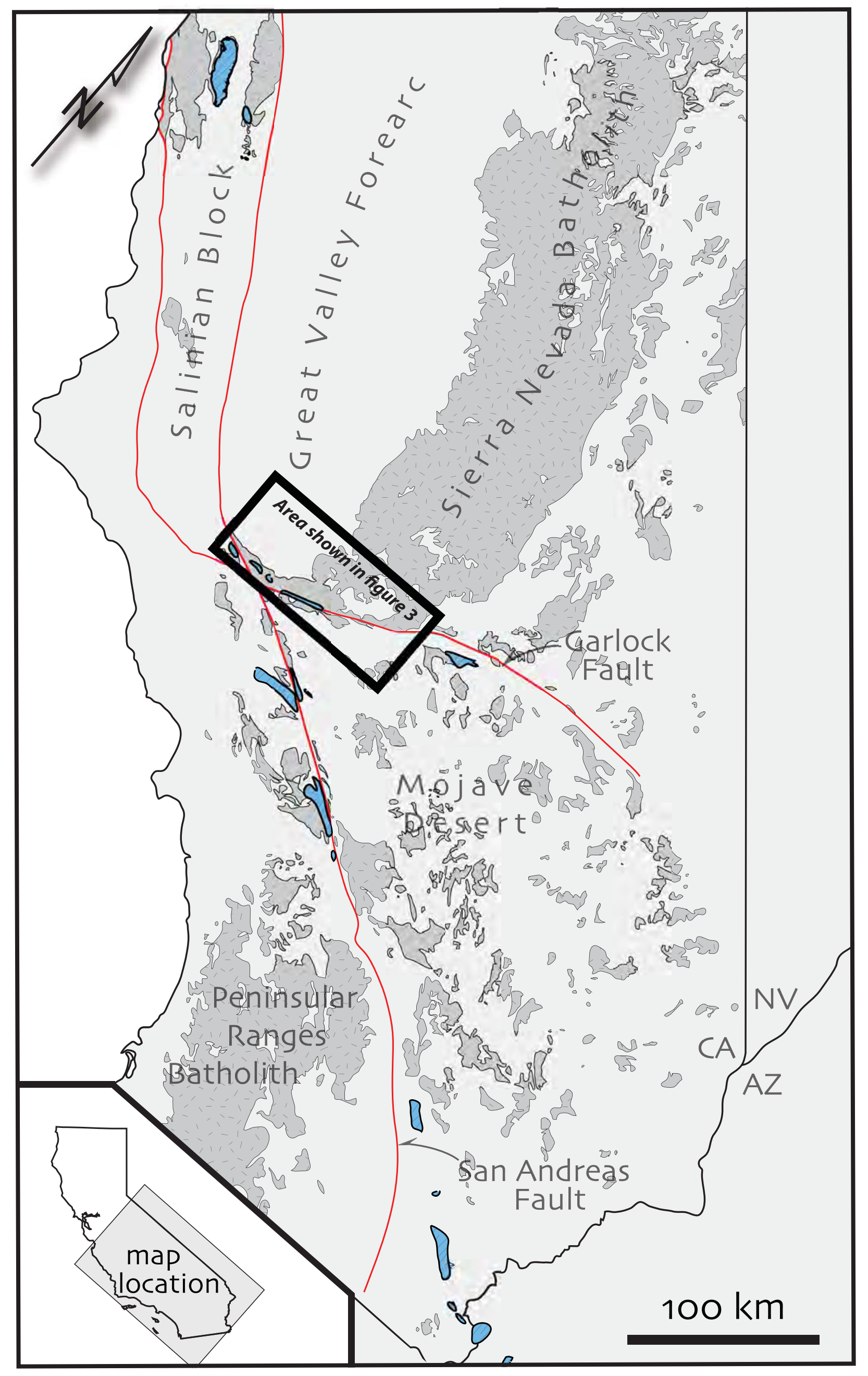

Figure 1. Map of Late Cretaceous to Early Tertiary POR schist distribution throughout southern California and adjacent areas. Cretaceous and older batholithic and metamorphic rocks are shown in gray with pattern, redrawn after Kidder and Ducea (2006)

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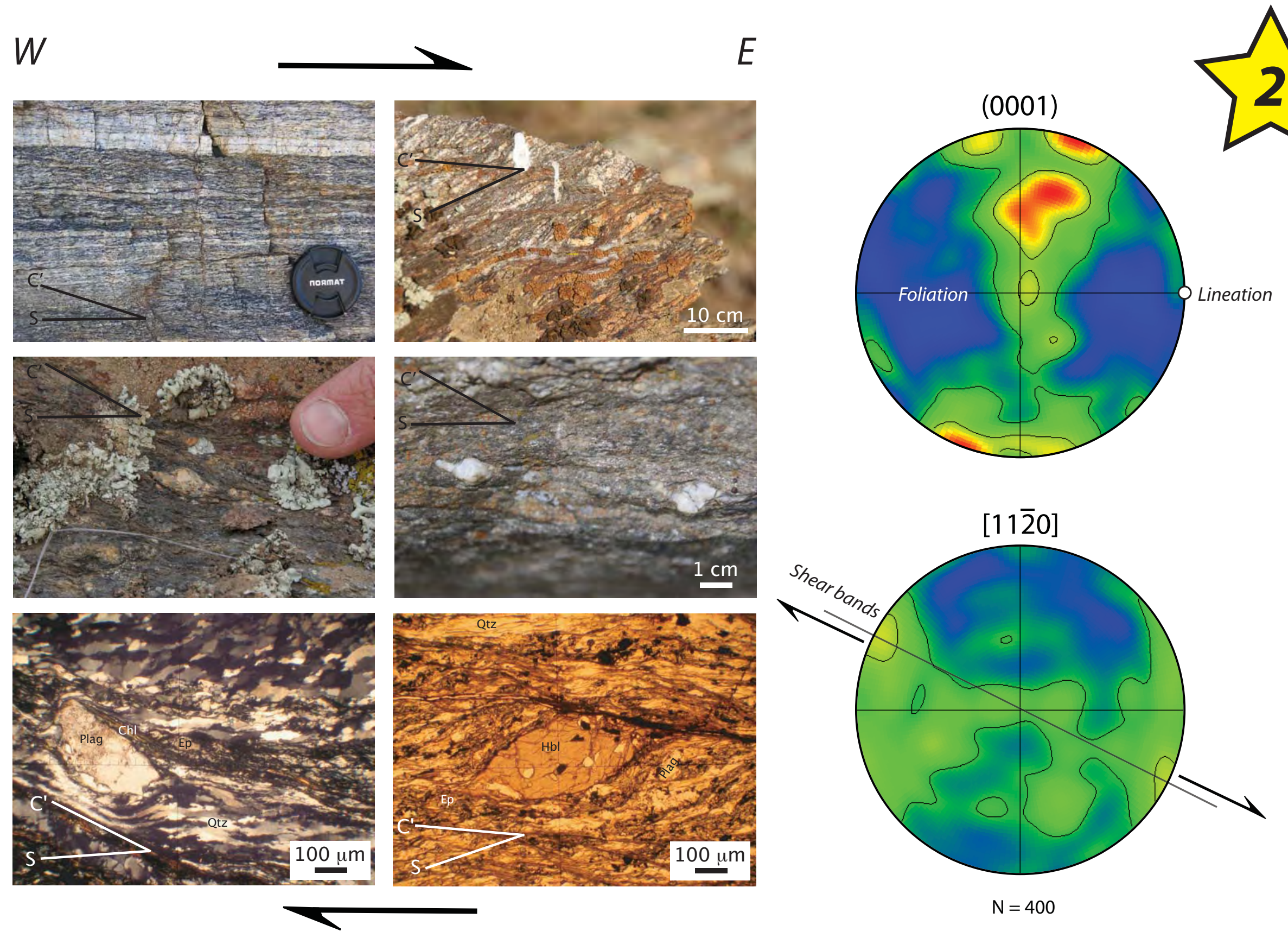
Figure 2. Field photographs, photomicrographs, and electron backscatter diffraction results from the Rand schist of the San Emigdio Mountains. Each photo is oriented parallel to stretching lineation and perpendicular to foliation. S-C′ fabrics (Lister and Snoke) and asymmetric quartz c-axis fabrics indicate ~upper plate-east fabrics in the San Emigdio Mountains.



In both the southern SNB and northern Salinia, a narrow (<10 m) zone of mylonite and cataclasite marks the contact between the schist and upper plate. Both the schist and the upper plate contain gently plunging stretching lineations and fold hinges that are most penetrative within 100 m of the shear zone.

Kinematic indicators in Rand fault and Salinas shear zone mylonites (**Fig. 2**) document a regional rotation of the prevailing transport direction from ~upper plate-north in the Rand Mountains (Postlethwaite and Jacobson, 1987; Nourse, 1989) to ~upper plate-east in the San Emigdio Mountains (**Fig. 3**). Evidence for the direction of transport is best expressed in type II S-C mylonites (Lister and Snoke, 1984) and asymmetric pressure shadows surrounding garnet and/or plagioclase porphyoblasts in the schist, upper plate, and intervening mylonite. In addition, quartz crystallographic preferred orientations from the highest structural levels of the schist show strong fabrics with c-axes populating asymmetric type I girdles (Postlethwaite and Jacobson, 1987; Nourse, 1989; Chapman et al., in prep). Regime II quartz microstructures (Hirth and Tullis, 1992), inferred crystallographic slip along the basal and rhomb planes (Lister, 1979), and small opening angles (<35 °) of quartz c-axis fabrics all indicate low greenschist facies deformation temperatures (Law, 2004). Along this zone, retrograde metamorphic reactions proceeded in concert with mylonitization, indicating progressive shearing during decreasing temperature.

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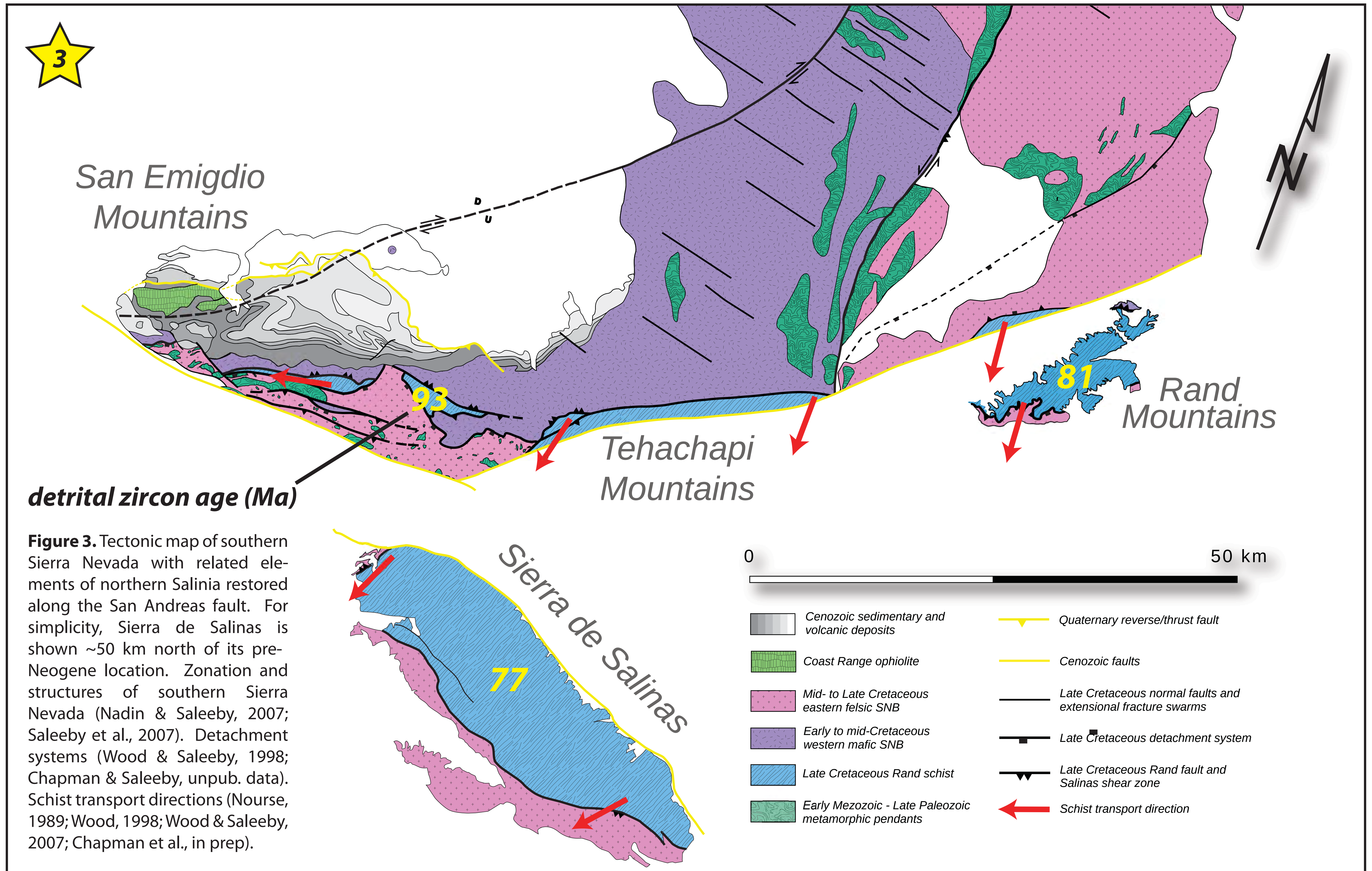

Figure 3. Tectonic map of southern Sierra Nevada with related elements of northern Salinia restored along the San Andreas fault. For simplicity, Sierra de Salinas is shown ~50 km north of its pre-Neogene location. Zonation and structures of southern Sierra Nevada (Nadin & Saleeby, 2007; Saleeby et al., 2007). Detachment systems (Wood & Saleeby, 1998; Chapman & Saleeby, unpub. data). Schist transport directions (Nourse, 1989; Wood, 1998; Wood & Saleeby, 2007; Chapman et al., in prep).

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The deposition, subduction, and exhumation of Rand and Sierra de Salinas schist is temporally and spatially associated with the shallow subduction of a conjugate massif to the Shatsky Rise, a large igneous province (LIP) that sits ~2000 km SE of Japan (Saleeby, 2003; Müeller et al., in prep; Liu et al., in prep). To explain northwest to southeast younging patterns in protolith and cooling age of the schist (Grove et al., 2003), we view this conjugate LIP as an elongate body that first collided with North America at the latitude of the San Emigdio Mountains and propagated to the southeast (Barth and Schneiderman, 1996). Therefore, the events outlined below progressed from northwest to southeast from ca. 95-70 Ma. As the LIP entered the trench at ca. 95 Ma, the angle of subduction shallowed in response to the positive buoyancy of the slab. During shallow subduction, arc volcanism abruptly ceased as the mantle wedge was sheared off. During this phase, strong coupling between the upper and lower plates led to intense contractile deformation in the upper plate, driving uplift and generating high relief in the southern SNB. Erosion of the newly formed topography shed a pulse of detritus into the subducting trench, which was subsequently underplated and metamorphosed beneath the disrupted arc as the schist. Following the passage of overthickened oceanic lithosphere, the less buoyant slab reverted to a steeper trajectory. Ensuing rollback-induced trench-directed suction created a regionally extensive flowing channel in the low viscosity underplated schist (Saleeby, 2003). Strong coupling between the base of the thickened upper plate and the top of the channel drove large magnitude extensional collapse of the upper plate and westward transport of the southernmost SNB and Salinia above the lateral ramp of the Cretaceous slab. Flow of relatively hot schist against the upper plate assisted in the attenuation of the upper plate by thermal weakening, creating the conditions necessary for core complex-style low angle normal faulting (Buck, 1991) along the Rand fault.

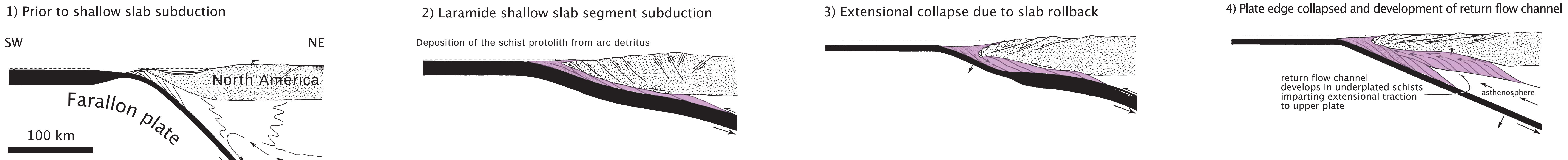

Figure 4. Model for slab rollback-driven exhumation of the southern SNB and the Rand and Sierra de Salinas schists (after Saleeby, 2003). See text for discussion.