Peninsular Ranges Batholith, Baja California and Southern California

edited by

Douglas M. Morton
U.S. Geological Survey and Department of Earth Sciences
University of California
Riverside, California 92521
USA

Fred K. Miller
U.S. Geological Survey
904 West Riverside Ave.
Spokane, Washington 99201
USA

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Cover: Geologic map of the Ramona plutonic complex, Peninsular Ranges batholith, southern California (from V.R. Todd et al., 2006, Geologic Map of the Ramona 7.5-Minute Quadrangle, San Diego, California: A Digital Database: Version 1: California Geological Survey Preliminary Geologic Map, scale 1:24,000). See V.R. Todd et al., Chapter 17, this volume, doi:10.1130/2014.1211(17), for legend and more information.

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Dedication

This Memoir is dedicated to those
Peninsular Ranges batholith researchers
on whose shoulders we stand, and especially
to the four chapter authors who are no longer with us—
Alex Baird, Barney Berger, Gordon Gastil, and Stirling Shaw.

Contents

Foreword

Douglas M. Morton
U.S. Geological Survey and Department of Earth Sciences, University of California, Riverside, California 92521, USA

Isotopic, geochemical, and geophysical research, combined with new regional and detailed geologic mapping over the past several decades has identified the Peninsular Ranges batholith as a world-class example of continental growth by island-arc accretion. Our current understanding of the nature and origin of the batholith was preceded by the progressive advances of earlier workers. The batholith has long been recognized to consist of a relatively mafic western part and a less mafic eastern part (e.g., Larsen, 1948). Major-element variation, based on exhaustive, systematic sampling of plutons in the northern part of the Peninsular Ranges batholith by Baird and colleagues at Pomona College, led them to interpret the western part to have been derived from magma sources having more oceanic affinities, and the eastern part from sources having more continental affinities (Baird and Miesch, 1984). Krummenacher et al. (1975) documented a systematic age gradient of conventional K-Ar ages from old in the west to young in the east. Although conventional K-Ar ages were subsequently recognized to be largely affected by the regional cooling history, later work using U-Pb methods on zircons established the emplacement ages of Peninsular Ranges batholith plutons and verified a west-to-east emplacement sequence (e.g., Silver and Chappell, 1988; Ortega-Rivera, 2003). This earlier work, combined with that done in the past decade, has led to the Peninsular Ranges batholith and its coeval volcanic rocks being viewed in terms of continental growth through the accretion of an oceanic arc (e.g., Busby, 2004; Lee et al., 2007).

Understanding of the Peninsular Ranges batholith, especially in Baja California, was greatly advanced through the dedication of Gordon Gastil, and his colleagues and students at San Diego State University, from 1963 to his death in 2013. His early major work in Baja California, GSA Memoir 140 (Gastil et al., 1975), was published in 1975, and his last paper, on the Sierra San Pedro Mártir pluton, is included in this volume. California Institute of Technology geologists, especially Leon Silver and his students, have contributed a number of topical studies on both the southern California and Baja California parts of the Peninsular Ranges batholith. Our understanding of the Baja California portion of the batholith has been greatly advanced by researchers at Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), by faculty and students from Stanford University, and by Scott Paterson and his students at the University of Southern California. GSA Special Paper 374 (Johnson et al., 2003) produced a large number of papers covering a broad breadth of batholith-related work. As of the time of this publication, most of the Peninsular Ranges batholith in southern California has been covered by 1:24,000-scale geologic maps, which, in combination with modern isotopic, geochemical, and geophysical studies, have provided the necessary foundation for initial regional synthesis (e.g., Shaw et al., 2003; Todd et al., 2003).

Contributions to this volume build on those in GSA Special Paper 374, and include revised and (or) updated work, in addition to new interpretations of the Peninsular Ranges batholith. In the current volume,

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considerable effort has been made to make available large databases of geochemical and isotopic data that have previously been unpublished or available only in older, difficult-to-access publications. It is intended that ready access to these databases will be utilized and beneficial to future studies.

The geophysical framework for the batholith is defined by Langenheim et al. (Chapter 1). They show clearly that for its entire length, the batholith consists of a mafic, dense, and magnetic western part that has relatively high seismic velocities and a less dense, weakly magnetic eastern part having lower seismic velocities.

Most of the papers herein fall into one of three geographic areas: (1) the northern part of the Peninsular Ranges batholith south to 33° N, (2) the area of San Diego County, and (3) Baja California, south of the Agua Blanca fault between 32° and 29° N.

NORTHERN PENINSULAR RANGES BATHOLITH

The northwestern part of the Peninsular Ranges batholith is covered by sedimentary rocks of the Los Angeles basin. New isotopic data obtained from a combination of surface and subsurface samples by Premo et al. (Chapter 2) and Miggins et al. (Chapter 6) help to clarify and distinguish batholith basement from the Transverse Ranges basement to the north. Distinction of the two basement types, which has been inconclusive in the past, is fundamental to structural interpretations involving Peninsular Ranges batholith and Transverse Ranges Province granitic rocks.

Morton et al. (Chapter 3) interpret the Peninsular Ranges batholith from the southern edge of the Transverse Ranges basement, south to 33° N, to consist of five domains; four are autochthonous and one is allochthonous. Systematic differences between the four autochthonous domains are interpreted to reflect subduction magmatism transiting from emplacement though oceanic crust in the west to emplacement though continental crust in the east.

Based on U-Pb zircon dating by Premo et al. (Chapter 4), emplacement ages of plutons in the northern part of the autochthonous Peninsular Ranges batholith have a relatively smooth transition from 126 Ma in the west to 91 Ma in the east; the allochthonous easternmost Peninsular Ranges batholith has an age of ca. 85 Ma. Miller et al. (Chapter 5) provide a comparison of conventional K-Ar ages and U-Pb isotope ages. Miggins et al. (Chapter 6) present extensive new data on the thermochronology of the northern Peninsular Ranges batholith, integrating U-Pb, ^{40}Ar-^{39}Ar, and fission-track data for specific minerals. Kistler et al. (Chapter 7) developed extensive initial ^{87}Sr/^{86}Sr isotope data for the northern Peninsular Ranges batholith that shows a progressive increase in ^{87}Sr/^{86}Sr values from west to east. Clausen et al. (Chapter 8) interpret chemical variation of the low ^{87}Sr/^{86}Sr rocks of the western part of the Peninsular Ranges batholith as a product of magma mixing.

The Santiago Peak Volcanics have commonly been interpreted as "slightly" metamorphosed, and Jurassic in age (e.g., Larsen, 1948; Jahns, 1954). Using detailed mapping, geochemistry, and isotopic data in the "type locality" in the Santa Ana Mountains, Herzig and Kimbrough (Chapter 9) clearly show that the volcanics are unmetamorphosed Cretaceous suprabatholithic rocks.

Two plutonic complexes in this part of the batholith are treated in detail. Berger (Chapter 10) presents detailed geochemical data on the Green Acres gabbro, and Morton et al. (Chapter 11) discuss the adjacent dynamically emplaced Lakeview Mountains pluton. X-ray diffraction modal data are given by Baird et al. (Chapter 12) for the extremely heterogeneous tonalite of the Lakeview Mountains pluton. Structural imprint of deformation and an abrupt metamorphic gradient in the prebatholithic rocks in the Winchester area (Schwarcz, 1969) are interpreted to be the result of subduction transitioning from oceanic crust to continental crust by Morton et al. (Chapter 13). Premo and Morton (Chapter 14), based on U-Pb isotopes from metamorphic zircon rims on detrital zircons, interpreted subduction transitioning from oceanic to continental crust to have occurred at 105–97 Ma. Miggins et al. (Chapter 6) present an interpretation of the thermal history of this deformation zone.

SAN DIEGO COUNTY PENINSULAR RANGES BATHOLITH

Todd et al. (Chapter 16) and Shaw et al. (Chapter 15) build on their earlier, comprehensive, batholith-wide synthesis (Todd et al., 2003; Shaw et al., 2003). New zircon Hf isotope data by Shaw et al. unexpectedly include Neoproterozoic components in the western part of the batholith that are considered to be otherwise isotopically primitive. For the same area, Todd et al. (Chapter 16) provide extensive data on the mineralogy and physical properties of the batholith. The Ramona ring complex, first described by Merriam (1941), was mapped in detail by Todd et al. [(Chapter 17). Based on the new mapping, accompanied by new chemical and age data, they show the Ramona ring complex to be composed of 12 separate plutonic bodies, representing six regional geologic suites, and emplaced over a period of ca. 14 Ma.

In the area of the Rattlesnake Valley and Oriflamme Canyon plutons, located in the transition area between the western and eastern parts of the batholith, Bethel-Thompson et al. (Chapter 18) interpreted S_1 cleavage to be the result of oblique sinistral convergence between the Farallon and North American plates, followed by orthogonal convergence from 140 Ma to 125 Ma, and then normal convergence continuing until ca. 115 Ma.

Correlation and the regional relationships of the interbedded marine sedimentary rocks and volcaniclastic rocks in the area of Rancho Santa Fe and the City of San Diego have long been an unresolved problem. Kimbrough et al. (Chapter 19) name this sequence the Peñasquitos Formation, and have determined new U-Pb isotopic ages of 144.5–148 Ma for the constituent volcaniclastic rocks. These new dates clearly distinguish the Peñasquitos sequence from the 128 Ma to 110 Ma Santiago Peak Volcanics (see Herzig and Kimbrough, Chapter 9) with which they have commonly been correlated (e.g., Fife et al., 1967).

BAJA CALIFORNIA PENINSULAR RANGES BATHOLITH

Research in Baja California reported in this volume is concentrated south of the Agua Blanca fault, between 32° and 29° N. Much of it is the outgrowth of work done by Scott Paterson and his students. Schmidt et al. (Chapter 20) interpret the Triassic and Jurassic accretionary prism and forearc basin assemblages and the Cretaceous Santiago Peak continental arc to be continuous from the northern Peninsular Ranges batholith to south of the Agua Blanca fault. The Alisitos oceanic arc is interpreted to be older than previously thought, originating in the Jurassic and possibly the Triassic. Part of the Santiago Peak continental arc is interpreted to have been removed during collision of the Alisitos oceanic arc.

Wetmore et al. (Chapter 21) present data that suggests the Alisitos oceanic arc was accreted during the Cretaceous, resulting in collision-produced deformation concentrated along the northern and eastern margins of the arc. Magmatism occurred before, during, and after accretion, and the collision caused a major increase in magma generation and emplacement.

In the Sierra Calamajue area, Alsleben et al. (Chapter 22) describe an eastward increase in the degree of deformation and an increase in metamorphism, from greenschist to amphibolite grade. These changes are interpreted to be the result of the accretion of the Alisitos oceanic arc.

Molina-Garza et al. (Chapter 23) provide a structural, paleomagnetic, and magnetic fabric transect across the batholith. Plutons in the western zone of the Peninsular Ranges batholith, after rotation to compensate for closure of the Gulf of California, have paleopoles concordant with the North American reference pole. For plutons in the transition between the western and eastern zones of the batholith, the paleopoles are discordant indicating clockwise rotation of 31° to 46°. Paleopoles from the eastern zone are slightly discordant due to a westward tilt of 15°. Molina-Garza et al. interpret their data to reflect slight, if any, internal deformation in the western zone, intense deformation in the transition zone, and slight deformation in the eastern zone.

Gastil et al. (Chapter 24) present a detailed study of the compositionally zoned Sierra San Pedro Mártir pluton, which is one of the earliest described plutons in Baja California (Woodford and Harris, 1938). It is a major La Posta–type pluton located at 32° N. New U-Pb ages indicate the pluton was emplaced over a 6 Ma period, and has a 96 Ma outer part and a 90 Ma core. Unlike La Posta–type plutons to the north, the Sierra San Pedro Mártir pluton is both ilmenite and magnetite bearing.

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