A Review and Synthesis of the Geology and Gem Resources of Granitic Pegmatites in Southern California, USA

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Keywords: Pegmatite, tourmaline, morganite, aquamarine, kunzite, spessartine, San Diego County, California

Introduction

Gem-bearing pegmatites in Southern California are hosted by the Peninsular Ranges batholith, and occur in ten districts in San Diego and Riverside counties (Figure 1a and Table 1). They are important historic sources of high-quality gem rough and world-class mineral specimens of various minerals, including tourmaline (Figure 1b), spodumene (Figure 1c), beryl, topaz and spessartine), and have also been mined for industrial materials (quartz, feldspar and Li minerals).

Most of the mining took place during the first decade of the twentieth century, and subsequently in the 1970s-1980s. Despite some changes in land-use policies, and increasing regulations and costs associated with mining, a few of the mines are still being worked today for gem rough and mineral specimens. Impressive examples of gemstones and crystals are found in numerous museums and important private collections, and also continue to circulate on the market. The tourmaline is revered for its pure vibrant pink and bicolored pink-green appearance, while the kunzite shows an attractive lavender coloration, and the spessartine exhibits a bright orange color even in relatively small sizes.

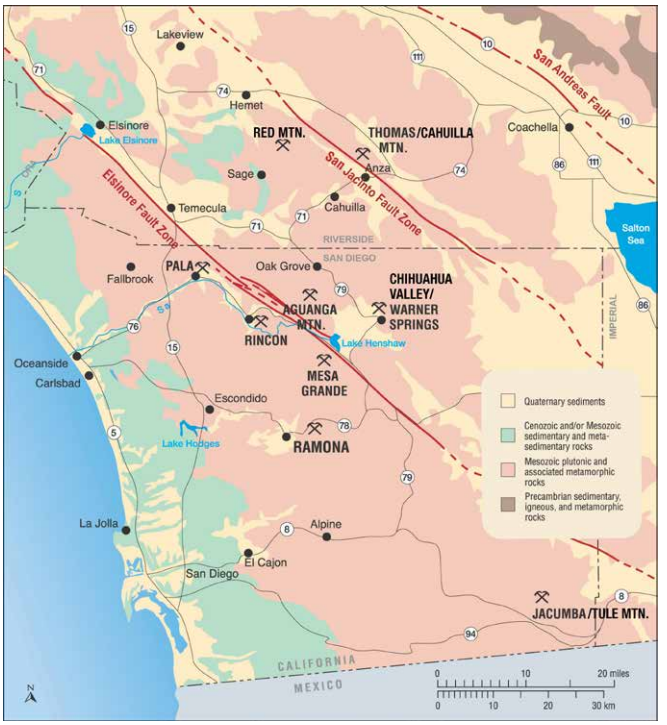

Figure 1: (a) Map showing main gem pegmatite districts in Southern California (after Shigley & Laurs 2006). (b) Tourmaline from the Himalaya mine, Mesa Grande (21.51 ct gem and 5.0 cm crystal). (c) Kunzite from the Oceanview mine, Pala (40.71 ct gem and 4.7 cm crystal). Stones courtesy of Bill Larson; photos by Robert Weldon.

District	County	Principal gem minerals	Pegmatite age*
Aguanga Mountain	San Diego	Topaz, tourmaline	—
Chihuahua Valley/ Warner Springs	San Diego	Tourmaline, beryl (aquamarine, morganite), quartz	94 Ma (Ar-Ar; M. Taylor, pers. comm.)
Jacumba/ Tule Mountain	San Diego	Beryl (aquamarine), spodumene (kunzite), spessartine	90 Ma (Ar-Ar; M. Taylor, pers. comm.)
Mesa Grande	San Diego	Tourmaline, quartz	95.4 Ma (Ar-Ar; Snee & Foord 1991)
Pala	San Diego	Tourmaline, beryl (morganite), spodumene (kunzite), quartz	99.4 Ma (Ar-Ar; Snee & Foord 1991)
Ramona	San Diego	Spessartine, topaz, tourmaline, beryl (aquamarine, morganite), quartz	97.0–98.7 Ma (Ar-Ar; Snee & Foord 1991)
Red Mountain	Riverside	Tourmaline	—
Rincon	San Diego	Beryl (aquamarine), tourmaline, quartz	
Thomas Mountain/ Cahuilla Mountain	Riverside	Tourmaline, beryl (aquamarine, morganite), quartz	94.4 Ma (U-Pb; M. Taylor, pers. comm.)

Table 1: Gem pegmatite districts in Southern California, their gem minerals, and their ages.

* The argon closure temperature for muscovite is ~350°C. Matthew Taylor is thanked for providing unpublished age data.

Pioneering geological and mineralogical studies of the pegmatites were done by Richard H. Jahns (e.g. Jahns & Wright 1951), John Hanley (1951), Dale R. Simpson (1960), and Eugene E. Foord (1976). More recently, various researchers have focused on the geological setting and petrogenesis of the pegmatites (e.g. Symons et al. 2009; Morton et al. 2018). In addition, summary descriptions of various S. California pegmatite localities were provided by Fisher (2002, 2011).

Geological History of the Peninsular Ranges Batholith and Characteristics of the Pegmatites

Dating by the $^{235}U/^{207Pb}$ and $^{40}Ar/^{39}Ar$ methods have yielded pegmatite ages ranging from 99.4 to 90 million years (Ma), younging to the east (see Table 1). Nearly all of the pegmatites are hosted by igneous rocks of the Peninsular Ranges Batholith (PRB), which extends from near San Jacinto Mountains in Riverside County southward into Baja California. The PRB has been broadly divided into western and eastern zones according to differences in the physical, compositional and isotopic properties of its plutons. These two zones are contiguous products of Cretaceous subduction (i.e. of the Farallon plate beneath the North American plate), which transitioned from a Mesozoic oceanic arc setting in the western PRB to a continental-margin arc setting in the eastern PRB (Hildebrand & Whalen 2014; Premo et al. 2014). Rocks of the western zone include weakly to moderately deformed ~128–120 Ma gabbros (and associated volcanics), ~118–115 Ma granodiorite–monzogranite plutons, and ~108–102 Ma quartz diorite–tonalite plutons (which are most abundant). Rocks of the eastern zone consist of large, undeformed, ~99–92 Ma 'La Posta'-type plutons that are compositionally zoned with a tonalite to granodiorite composition. The youngest of these intrusions (<95 Ma) are small (1–2 km) two-mica granites and associated pegmatites.

The economically important pegmatite districts (Pala, Mesa Grande, and Ramona) are hosted by gabbroic or tonalitic rocks in the western zone of the PRB. The source of these pegmatites has not been identified, while some of those

of the eastern zone (i.e. in the Jacumba/Tule Mountain District) appear to be related to partial melting caused by heat from the La Posta pluton. Geological, geochemical and paleomagnetic evidence indicate that the pegmatites in both zones are broadly cogenetic, but differences in their age, composition and mineralization between the various districts suggests to the present author that they each formed independently from discrete local sources.

The pegmatites occur in groups of subparallel dikes and sills that were emplaced along a well-developed set of fractures (typically in gabbros and norites), which may have been produced by regional contraction during batholithic cooling. Although up to several hundred pegmatite bodies can be present in a particular district, only a few of them are economically important sources of gems and mineral specimens. The pegmatites dip shallowly to moderately (south)west, generally 10°–35°, and are typically several 10s of meters long and 2–8 m thick (exceptionally up to 30+ m thick). The best-quality minerals and gems occur in specific portions of the pegmatites, where they are concentrated in crystal-lined miarolitic cavities referred to as "pockets" by the miners. The pocket zones are most commonly located near the centerline or just below the quartz core of the pegmatites, and they range from several centimeters across to extensive, multiply-projecting, and branching cavities as much as 3 m or more.

Paleomagnetic data by Symons et al. (2009) indicate that at the time the San Diego Co. pegmatites formed, they were located near what is today the northwestern coastline of mainland Mexico (Sonora State). Rapid exhumation of the PRB, combined with recent uplift and northwest transport of the pegmatite districts along the San Andreas Fault system, are responsible for making these gem and mineral resources accessible to us today in Southern California.

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