Supplementary Text S1

**Multi-scale, open-system magmatic and sub-solidus processes contribute to the chemical and isotopic characteristics of the Jurassic Guadalupe Igneous Complex, Sierra Nevada, California**

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**Extended analytical methods:**

1. Whole rock Sr-Nd isotope geochemistry

The isotopic ratios of 87Sr/86Sr and 143Nd/144Nd have been analyzed at the University of Arizona using thermal ionization mass spectrometry on whole rock samples. The following analytical details are taken from Otamendi et al. (2009) and further describe analytical details and quality control specifics:

Rock powders were put in large Savillex vials and dissolved in mixtures of hot concentrated HF-HNO3 or alternatively, mixtures of cold concentrated HF-HClO4. The dissolved samples were spiked with the Caltech Rb, Sr, and mixed Sm-Nd spikes (Wasserburg et al.,1981; Ducea & Saleeby, 1998) after dissolution. Rb, Sr, and the bulk of the REE were separated in cation columns containing AG50W-X4 resin, using1N-4N HCl. Separation of Sm and Nd was achieved in anion columns containing LN Spec resin, using 0.1N-2.5N HCl. Rb was loaded onto single Re filaments using silica gel and H3PO4. Sr was loaded onto single Ta filaments with Ta2O5 powder. Sm and Nd were loaded onto single Re filaments using platinized carbon, and resin beads, respectively. Mass spectrometric analyses were carried out at the University of Arizona on an automated VG Sector multicollector instrument fitted with adjustable Faraday collectors and a Daly photomultiplier (Ducea & Saleeby, 1998). Concentrations of Rb, Sr, Sm, Nd were determined by isotope dilution, with isotopic compositions determined on the same spiked runs. An off-line program was used for the isotope dilution calculations. Typical runs consisted of acquisition of 100 isotopic ratios.

Standards used with analyses: NRbAAA, Sr987, nSmβ, LaJolla Nd

Reference:

Ducea, M. N., & Saleeby, J. B., 1998, The age and origin of a thick mafic–ultramafic keel from beneath the Sierra Nevada batholith: Contributions to Mineralogy and Petrology, v. 133, p. 169-185.

Otamendi, J. E., Ducea, M. N., Tibaldi, A. M., Bergantz, G. W., de la Rosa, J. D., and Vujovich, G. I., 2009, Generation of tonalitic and dioritic magmas by coupled partial melting of gabbroic and metasedimentary rocks within the deep crust of the Famatinian magmatic arc, Argentina: Journal of Petrology, v. 50, no. 5, p. 841-873.

Wasserburg, G. J., Jacobsen, S. B., DePaolo, D. J., McCulloch, M. T., Wen T., 1981, Precise determination of SmNd ratios, Sm and Nd isotopic abundances in standard solutions: Geochimica et Cosmochimica Acta, v. 45, no. 12, p. 2311-2323.

1. Whole rock oxygen isotopes and major element geochemistry

Thirty-five whole rock oxygen isotope analyses were carried out at Indiana University using a Finnigan Delta-E and a Finnigan MAT 252 mass spectrometers. Oxygen was liberated from the sample material using the BrF2 method (Clayton and Mayeda, 1963) and converted to CO2 by reaction with heated graphite disks. The results are reported in the δ notation relative to VSMOW (Vienna Standard Mean Ocean Water). Analytical precision is better than 0.06 ‰ (2 S.D.). Whole rock major and selected trace elements were measured for the same samples by solution inductively coupled plasma (ICP) source emission spectroscopy, using a Jarrall Ash Atom Comp II at Indiana University and by instrumental neutron activation analysis (INAA) at the Phoenix Memorial Laboratory at the University of Michigan following the procedures described in Webster and Wintsch (1987). Rock powders were fused with a lithium borate flux and dissolved in nitric acid. Solutions were then analyzed using a granodiorite standard (GSP-1).

Reference:

Clayton, R.N. and Mayeda, T.K., 1963. The use of bromine pentafluoride in the extraction of oxygen from oxides and silicates for isotopic analysis: Geochimica et Cosmochimica Acta, v. 27(1), p.43-52.

Webster, J.R. and Wintsch, R.P., 1987. Petrochemistry and origin of the Killingworth dome rocks, Bronson Hill anticlinorium, south-central Connecticut: Geological Society of America Bulletin, v. 98(4), p.465-474.

1. LA-ICP-MS zircon geochemistry

Zircon trace elements were analyzed at the University of California Santa Barbara using an Agilent 7700 quadrupole ICP-MS following the procedure described in Kylander-Clark et al. (2013). The laser parameters for analysis consisted of a 25 µm spot for unpolished grain surfaces and 15 μm spot for polished grains. Spots were ablated at ~1 j/cm2 and 5 Hz for 12 seconds, following a 20 second baseline and two-shot pre-ablation. 90Zr was used as the internal standard, assuming 48 wt. %; 91500 (Wiedenbeck et al., 1995) was used as the reference material for all elements and GJ1 (Liu et al., 2004) for quality control and yielded results within 10 % of accepted values. U-Pb ages were calculated (to confirm final igneous crystallization) from 206Pb/238U and 207Pb/206Pb ratios using 91500 as the primary reference material; GJ1 yielded a 206Pb/238U age within 2 % of the accepted value (Jackson et al., 2004). The Iolite software (Paton et al., 2011) was used to perform all data reduction and to correct for instrument drift, laser-ablation-induced down-hole elemental fractionation, plasma-induced elemental fractionation, and instrumental mass bias.

Reference:

Liu, Y., Hu, Z., Zong, K., Gao, C., Gao, S., Xu, J., and Chen, H., 2004, Reappraisement and refinement of zircon U-Pb isotope and trace element analyses by LA-ICP-MS: Chinese Science Bulletin, v. 55, p. 1535–1546.

Paton, C., Hellstrom, J., Paul, B., Woodhead, J., Hergt, J., 2011, Iolite: Freeware for the visualisation and processing of mass spectrometric data: Journal of Analytical Atomic Spectrometry, 26, v. 12, p. 2508-2518.

Wiedenbeck, M.A.P.C., Alle, P., Corfu, F.Y., Griffin, W.L., Meier, M., Oberli, F.V., Quadt, A.V., Roddick, J.C. and Spiegel, W., 1995, Three natural zircon standards for U‐Th‐Pb, Lu‐Hf, trace element and REE analyses: Geostandards newsletter, v.19, pp.1-23.

Jackson, S.E., Pearson, N.J., Griffin, W.L., Belousova, E.A., 2004. The application of laser ablation-inductively coupled plasma-mass spectrometry to in situ U–Pb zircon geochronology. Chemical Geology 211, 47-69.

**Mineralogy and Textures**

***Gabbro units*** – The principal minerals in the gabbros are plagioclase, pyroxene, and Fe-Ti oxide (Fig. 4A-F), but the mineralogy and modal proportions vary widely. Olivine is restricted to the lower gabbros, and amphibole and biotite are more abundant in the upper gabbros. Plagioclase is typically hypidiomorphic and aligned in some samples (Fig. 4A-D). Clinopyroxene prevails over orthopyroxene; both have a granular texture and contain exsolution lamellae (Fig. 4E). Amphibole in the upper gabbros is an anhedral secondary magmatic phase, replacing pyroxene and filling interconnected spaces (red arrows; Fig. 4A). Biotite is a late-crystallizing phase in some gabbros. Accessory minerals are titanite, apatite, and zircon. Secondary chlorite, epidote, and actinolite replace feldspar and pyroxenes. Grain size varies from fine-grained (<1 mm) to medium-grained (1-5 mm). Sample BRGIC13, a hornblendite, located in the area affected by solid-state deformation along BMFZ (Fig. 2) shows polygonal amphibole and feldspar crystal shapes, indicating re-crystallization at high temperatures (Fig. 4F) and retrograde replacement of ilmenite by titanite (Angiboust and Harlov, 2017; white rectangle in Fig. 4F). These textures indicate high-temperature solid-state recrystallization. Minor solid-state deformation (e.g., deformation twinning and undulose extinction in plagioclase; white rectangles in Fig. 4B) occurs in gabbros outside the BMFZ.

***Felsic segregations in the upper gabbros***– The centimeter- to meter-sizedfelsic segregations are coarse-grained (>0.5 cm) and consist of plagioclase, amphibole, biotite, quartz, and alkali feldspar (Fig. 4G,H). Accessory phases are apatite and zircon (≤0.3 mm; Fig. 4G). Clinopyroxene and oxides are rare in felsic segregations. Amphibole is a primary magmatic phase and has a green color (Fig. 4G), which is distinct from the brown color of secondary magmatic amphibole in the upper gabbros (Fig. 4A). Graphic intergrowth of feldspar and quartz is common (Fig. 4H).

***Meladiorite unit***– The meladiorite unit has a diverse mineralogy, ranging from gabbros similar to those found in the gabbro units (Fig. 4I) to high-silica rocks (Fig, 4J) in pods and layers similar to the felsic segregations in the gabbros, but larger (0.5-20 m; Putirka et al., 2014). No compositional layering occurs in the meladiorite unit. Primary magmatic minerals are pyroxene, amphibole, biotite, plagioclase, alkali feldspar, Fe-Ti oxides, and quartz. Accessory phases are titanite, zircon, and apatite. Alteration minerals are chlorite, epidote, and actinolite (Fig. 4J). Many feldspars are clouded and in most altered samples, feldspars are sericitized (Fig. 4J). Grain size ranges from fine- to coarse-grained. One fine-grained pyroxene gabbro from the meladiorite unit contains granular pyroxenes, Fe-Ti oxides, hypidiomorphic plagioclase with concentric zonation, and 5-10 % interstitial biotite (no amphibole; Fig. 4I); despite having biotite as an interstitial phase, this sample is similar to the gabbros of the upper gabbro unit. One diorite sample shows spectacular poikilitic textures (Fig. 4K,L): poikilitic amphiboles enclose feldspar laths, and show embayments (red arrows; Fig. 4K,L). These poikilitic amphiboles are clustered, similar to glomerocrysts in volcanic rocks (white rectangle; Fig. 4L) and are themselves inclusions in large poikilitic alkali feldspar and quartz grains (Fig. 4J).

***Mingling zone***– Primary minerals are amphibole, biotite, plagioclase, alkali feldspar, quartz, and titanite (Fig. 4M). Accessory phases are zircon, apatite, and Fe-Ti oxides. Feldspars are idiomorphic to hypidiomorphic in the felsic part, while anhedral and interstitial in the mafic part. Biotite replaces amphibole but also occurs as interstitial grains in both the mafic and felsic parts. Titanite is anhedral and more common in the felsic domains. In some samples, primary magmatic amphibole is almost completely replaced by secondary actinolite, and feldspars are sericitized. In one sample, we observed aligned plagioclase and amphibole inclusions in poikilitic quartz and alkali feldspar at the contact to a mafic enclave (Fig. 4M). Felsic samples are medium- to coarse-grained, while mafic samples are fine-grained.

***Granite and Granophyre units***– Rocks consist of various amounts of quartz, plagioclase, alkali feldspar, biotite, amphibole, and titanite (Fig. 4N,O). Rare clinopyroxene occurs in the cores of amphibole. Accessory minerals are titanite, zircon, and apatite. Fe-Ti oxides are rare. Grain size varies considerably (fine- to coarse-grained) across both units, as does the extent of alteration, with some samples being strongly affected by sericitization and replacement of amphibole and biotite by chlorite, actinolite, and epidote. The granites show equigranular textures of feldspar and quartz (≤2 mm; Fig. 4N). In our samples, mafic phases are rare, but if present, biotite dominates over amphibole. The granophyre unit is distinguished from the underlying granite unit by the appearance of abundant granophyric intergrowth textures. One sample from the granophyre unit shows large (>1 mm) hypidiomorphic, albite-rich alkali feldspar laths randomly oriented between interstitial graphic textures (Fig. 4O).