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Oligo-Miocene mafic intrusions of the San Juan Volcanic Field, southwestern Colorado, and their relationship to voluminous, caldera-forming magmas

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Abstract

The trigger(s) of ignimbrite flare-ups in continental environments and their connection to "high power" mantle-melting events are the subject of ongoing debate, often hampered by the relative scarcity of mantle-derived basalts compared to voluminous amounts of intermediate and silicic lavas, intrusions, and welded-tuffs. This study focused on locating and analyzing mafic magmas in the San Juan Mountains of Colorado, the largest erosional remnant of the Oligocene Southern Rocky Mountain ignimbrite flare-up. The "flare-up in" the San Juan Volcanic Field (SJVF) has several potential explanations including: crustal anatexis or MASH processes from either an asthenospheric "high power" melting event triggered by rifting and/or lithospheric delamination or a lithospheric mantle "high power" event caused by exposure of Farallon metasomatism to the underlying asthenosphere. The required volumes of crustal melt (a column 34–45 km tall over an area of 10,000 km^2) and crustal heterogeneity disqualify anatexis as a source of the SJVF. Basalt and basaltic andesite magmas of the SJVF have εNd (−6 to −8) and $^{87}Sr/^{86}Sr$ (0.705–0.706), high Ba concentrations (750–1500 ppm) with low Rb/Zr (0.25–0.5) compatible with a lithospheric basalt MASH model. An OIB-like basalt source would require nearly twice the crustal assimilation (50%+) and MASH zone thickness (~17 km) to produce the isotopic ratios of intermediate to silicic SJVF rocks and could not produce their elevated Ba concentrations. The location of the SJVF may be controlled by its maximum distance of magma capture and lateral transport or by the underlying lithospheric mantle.

1. INTRODUCTION

The eruption of thousands of cubic kilometers of magma during a caldera-forming event presents one of the greatest natural geologic hazards on Earth. Such events, termed "super-eruptions" by some, are an area of intense active geologic research (e.g. Hildreth, 2004; de Silva, 2008; Huber et al., 2009; Gregg et al., 2012). No giant eruptions have occurred in recorded history, so the conditions that allow 1000+ km^3 of magma to be extracted from the mantle, collected in the upper crust, and drained in a single paroxysmal event can only be inferred.

These eruptions are thought to be the product of transient, "high power" (unusually high mantle magma flux, i.e. 10+ km^3/1000 yr. per volcanic center) melting events in the mantle (de Silva and Gosnold, 2007). Mantle-derived magma supply to arcs is approximately 1–2 km^3/1000 yr. per volcanic center (Crisp, 1984; Reymer and Schubert, 1984; Annen and Sparks, 2002); magma supply for a "flare-up" event in a giant ignimbrite-producing volcanic

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field exceeds that volume by an order of magnitude for a few million years (de Silva and Gosnold, 2007; Lipman, 2007). Hypotheses for triggering a mantle "high power" event include discrete mantle sources (e.g. Long Valley – Hildreth, 2004; Yellowstone – Christiansen et al., 2002), continental rifting (e.g. the Taupo Volcanic Field – Parson and Wright, 1996), lithospheric delamination and syn-orogenic extension (e.g. the Altiplano-Puna volcanic complex – Kay and Coira, 2009; Ramos, 2009), and extensive lithospheric metasomatism and melting (Farmer et al., 2008). This study is focused on mafic rocks from the San Juan Mountains of southwestern Colorado to examine if the injection of anomalous volumes of mantle-derived magmas during a "high power event" triggered the intermediate to silicic volcanism in the San Juan Volcanic Field. Secondly, if a "high power event" did trigger the San Juan Volcanic Field, where in the mantle did it originate, what volumes of basalt were involved, and how did the basalt interact with the continental crust?

1.1. Geologic setting

The San Juan Volcanic Field (SJVF) is the largest erosional remnant of the Southern Rocky Mountain Volcanic Field (SRMVF), an Oligocene volcanic field which covers southern Colorado and northern New Mexico. In addition to the SJVF, the SRMVF encompasses the West Elk locus of central Colorado, the 39 Mile volcanic area of central Colorado, the Grizzley Peak caldera and Mt. Princeton batholith of central Colorado, and the Questa-Latir caldera complex of northern New Mexico (Lipman, 2007). The SJVF is comprised of 25,000 km^3 of intermediate small-volume breccias and lava flows and 16,000 km^3 of silicic ignimbrites from at least twenty-two caldera-forming eruptions (Lipman, 2007), including the 5000+ km^3 Fish Canyon Tuff, the largest known explosive eruption on Earth (Fig. 1). The SJVF is likely underlain by a voluminous (~100,000 km^3) granitic batholith, which is inferred to encompass up to half of the crustal column of southwestern Colorado (Plouff and Pakiser, 1972; Drenth et al., 2012). Volcanism within the San Juan region initiated at ~35 Ma and swept from NE to SW over the following 10 million years. The oldest volcanic units are inter-bedded and inter-tongued andesitic ashes, lava flows, and reworked volcanic breccias variably designated the Conejos or San Juan formations (Lipman et al., 1970, 1973; Lipman, 2007; Lipman and McIntosh, 2008). The earliest caldera-forming ignimbrites associated with San Juan magmatism erupted from the Bonanza complex at the northeastern end of the field at around 33 Ma and terminated with the eruption of the Snowshoe Mountain Tuff at 26.9 Ma in the central caldera complex near Creede, CO. Volcanism associated with the San Juan magmatic locus ended by 25 Ma (Lipman, 2007). After a brief respite

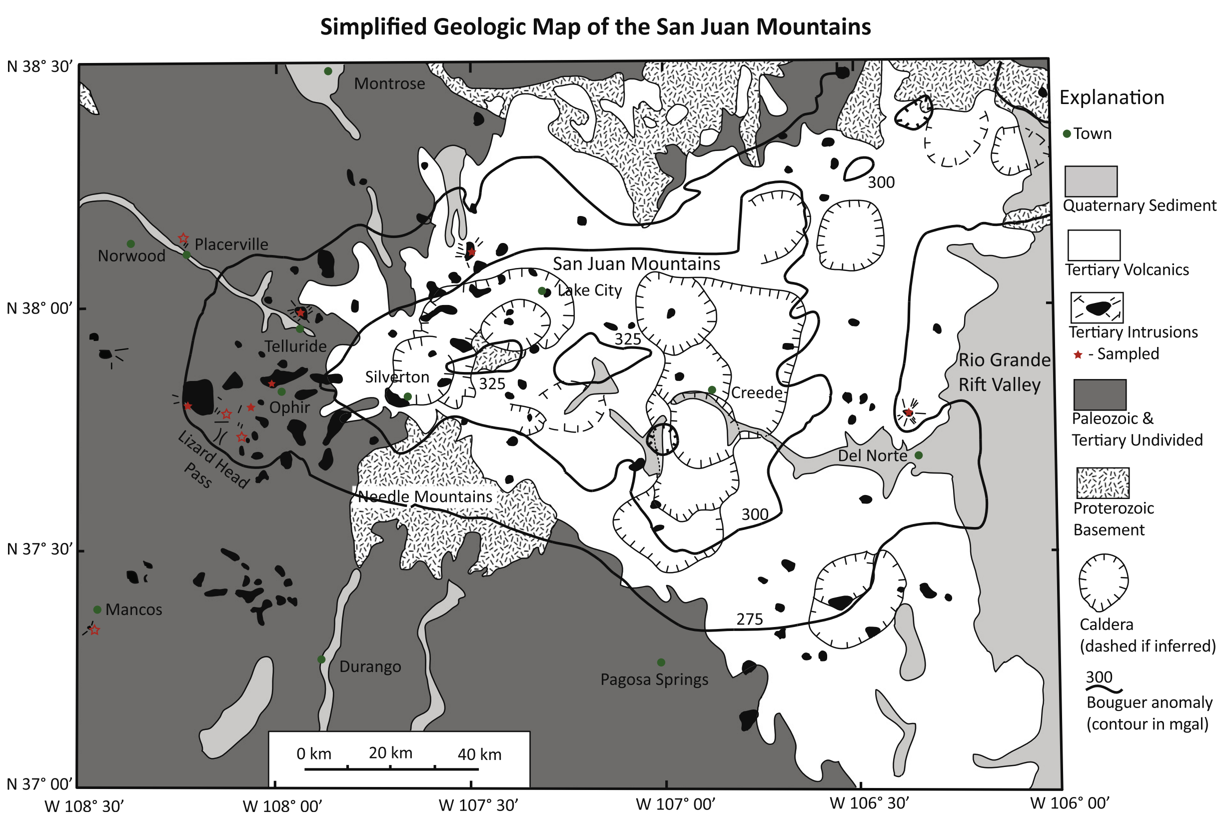

Fig. 1. Simplified geologic map of the San Juan Mountains including Oligocene calderas and intrusions. Open red stars indicate lamprophyre locations, closed red stars indicate basalt–andesite locations (see Suppl. Table 1 for GPS coordinates and sample descriptions). Adapted from Plouff and Pakiser (1972), Lipman (2007), and Drenth et al. (2012).