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Geochemistry and geochronology of the Sierra de Gomez Limestone-hosted U deposit, Chihuahua: Implications for distribution of Rio Grande rift mineral deposits in northern Mexico

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ABSTRACT

Uranium deposits form in a variety of settings. They are partially controlled by the secular evolution of Earth processes, including deposits in extension-related settings such as the intra-cratonic Rio Grande rift. Plio-Quaternary volcanism, mineral deposits, and hydrothermal spots occur along the Chihuahua Central Graben. The age of the Sierra de Gomez U-deposit is 1.8 Ma (based on LA-MC-ICP-MS dating on a uranophane monocrystal), which is contemporaneous with the late mineralization event of the Peña Blanca U-deposit, as well as Rio Grande Rift (RGR)-type deposits in Chihuahua and intraplate volcanism. Studies of fluid inclusions in fluorite and late calcite indicate the presence of hydrocarbons and CH_4-rich brine. Homogenization temperatures range from 87 to 112 °C, and the mean composition (2.0 mol NaCl and 0.3 mol CaCl with CH_4) is comparable to mineralizing brines in MVT deposits and carbonated hydrocarbon reservoirs. Evolution of C and O stable isotopic values for the calcite cement in the Sierra de Gomez Limestone-hosted U deposit illustrates that two separate calcite precipitation events occurred: (1) travertine filling karst structures in the presence of meteoric water and (2) U mineralization during deep hydrothermal fluid circulation that included interactions with a heat source and basement leaching. In a regional context, a metallogenic model suggests that the Chihuahua Trough area is deep enough to generate fluid migration by hydrothermal and/or compaction processes through RGR extensional faults until a favorable trapping horizon is reached. This causes uranium precipitation because water/rock interaction processes generate a local redox barrier.

1. Introduction

Mineral deposits are heterogeneously distributed in both space and time. They are formed by a variety of natural processes that concentrate elements at an economic grade. The elemental type, character, and abundance reflect the geodynamic environment in which they formed (Cawood and Hawkesworth, 2013). Mineral deposits are considered to be indicators of the evolution of magmatic, hydrothermal, and tectonic processes over geological time. In addition to the direct generation of magmas, asthenospheric upwelling is a powerful heat source in the crust. These phenomena induce crustal scale hydrothermal circulation, which may result in a wide range of ore deposits in intra-cratonic rift systems; one example is the Rio Grande rift (RGR; McLemore and North, 1984; McLemore et al., 1998; Lueth et al., 2005 and references therein). Uranium (U) deposits form in a variety of settings and are partially controlled by the secular evolution of Earth processes (Cuney, 2010). These include deposits in extension-related settings such as the intra-cratonic Rio Grande rift (McLemore and North, 1984; McLemore et al., 2002; McLemore, 2011).

The RGR is a major tectonomagmatic feature of the North American craton (Fig. 1). Physiographically, this rift is recognized as a series of graben and half-graben structures that can be traced at the surface for over 1000 km, from south-central Colorado until their disappearance in northern Chihuahua, Mexico (Fig. 1; Seager, 1981; Seager et al., 1987; Baldridge et al., 1984; Baldridge, 2004; Keller et al., 1991; Keller and Cather, 1994; DeAngelo and Keller, 1988; Seager, 1995; Seager, 1995, Seager et al., 1987; Torres et al., 1999; Jimenez and Keller et al., 1991; McLemore et al., 2002; Goteti and Mitra, 2013; Cosca et al., 2014; Morton and Bilek, 2014; Koptev et al., 2015; among others). In southern New Mexico and northern Chihuahua, the Rio Grande rift and the Basin and Range province overlap and are not physiographically distinguishable. They share a common style of deformation and are relatively continuous through time. Geophysical, structural, petrographical, geochemical, and geochronological studies in New Mexico, west Texas

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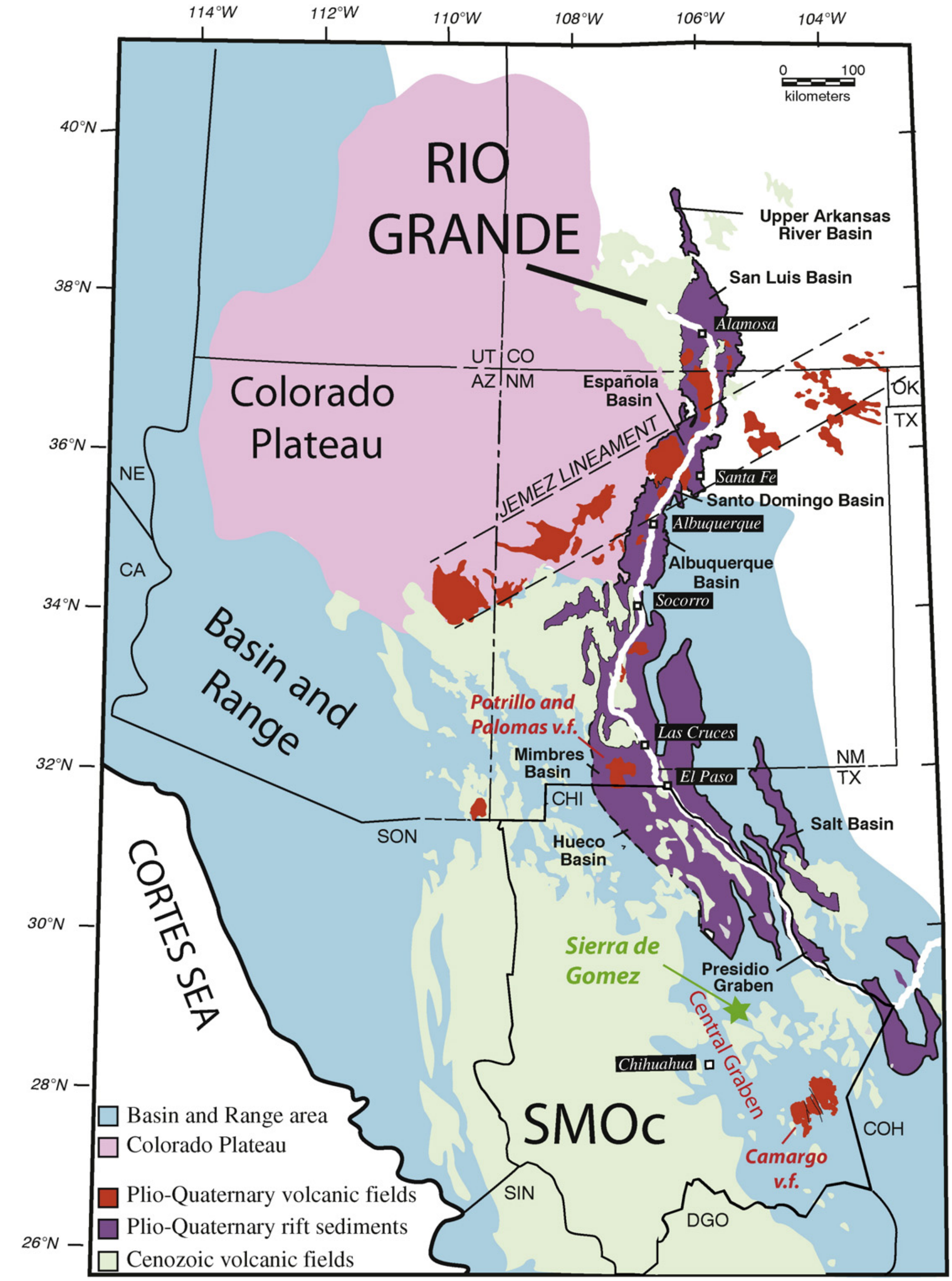

Fig. 1. Main features of the Rio Grande rift, showing basins and the precursory and associated volcanic fields, modified from Hudson and Grauch (2013). The Cenozoic volcanism shape is modified from Ferrari et al. (2005) and the Basin and Range shape and Colorado Plateau are modified from Baldridge (2004). SON: Sonora, CHI: Chihuahua, TX: Texas, OK: Oklahoma, UT: Utah, CO: Colorado, AZ: Arizona, CA: California, NM: New Mexico, COH: Coahuila, DGO: Durango, SIN: Sinaloa.

and adjacent Mexico have elucidated the history of the RGR from 27 Ma to the present (Reiter and Tovar, 1982, Seager et al., 1987; Baldridge et al., 1984; Keller et al., 1991; DeAngelo and Keller, 1988; Seager, 1995; Seager, 1995, Seager et al., 1987; Lawton and McMillan, 1999; Ragnarsdottir and Charlet, 2000; Haenggi, 2002; among others). The region underwent two main phases of extension: low-angle faulting and shallow basin creation (30–18 Ma), followed by high-angle faulting and graben creation (10–5 Ma; Keller et al., 1991; Wilson et al., 2005). Volcanism began at approximately 13 Ma, occurring along and adjacent to the Rio Grande rift valley (Chapin et al., 2004). Alkali olivine basalts first appeared along the southern border of New Mexico at approximately 13 Ma, when the crust became critically extended (Chapin et al., 2004). The youngest volcanism occurs along the Jemez Lineament (at approximately 40 ka) in northeastern New Mexico (Chapin et al., 2004). The RGR is associated with high heat flow, vertical movements, seismic activity and fault scarps (King and Metcalfe, 2013). Geothermal anomalies within the rift system are associated with strike-slip faults, accommodation zones, and fault intersections (Easley et al., 2011).