Temporal Evolution of Cretaceous to Pleistocene Magmatism in the Chagai Arc, Balochistan, Pakistan

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The Chagai arc is part of the southern Afghan block, a microcontinent of Gondwanan affinity accreted at the southern margin of Eurasia (Jacob and Quittmeyer, 1979). The arc, together with an over 300 km wide classic accretionary prism to its south (Platt and others, 1986), overrides the active Makran subduction zone (MSZ). The Gulf of Oman (and associated Makran trench) represents a unique living remnant of the Neotethys, which has elsewhere been consumed in India-Arabia and Eurasia collision (e.g., Zagros Ranges, Iran and the Kirthar-Sulaiman Ranges, Pakistan). The longstanding activity on the MSZ is manifested in intermittent magmatism in the Chagai Arc spanning about 70 Ma from the Late Cretaceous to the Pleistocene, which is unmatched in Neotethyan arcs preserved elsewhere in the Himalaya and Zagros Ranges.

The Chagai arc exposes a >10,000 m stratigraphic succession from Late Cretaceous to Pliocene-Pleistocene, comprising volcanic, volcano-sedimentary and sedimentary rocks. A thick (~2,500 m) succession of massive basaltic-andesite lava flows (associated with lapilli tuff, volcanoclastic sediments and minor felsic lavas) dominates the Late Cretaceous Sinjarani Group (Ahmed and others, 1972; Siddiqui, 1996, 2004), the oldest unit exposed in the Chagai Arc. Volcanic rocks abundantly occur in younger stratigraphic units including the Paleocene Juzzak Formation, Eocene Saindak Formation, Oligocene Amlaf Formation, Miocene Buz Mashi Koh Formation, and Pliocene-Pleistocene Koh-i-Sultan Formation (Siddiqui, 2004). The Late Cretaceous-Paleocene volcanism is dominated by basalts and basaltic andesites. In comparison, Eocene and younger volcanism is dominantly andesitic to dacitic with minor basalts.

Detailed major, trace, and rare-earth geochemistry classifies the temporal volcanism in the Chagai Arc into three groups; 1) Late Cretaceous-Paleocene, 2) Eocene, and 3) Oligocene and younger. Trace element characteristics like LILE and LREE enrichment and HFSE and HREE depletion relative to mid-oceanic ridge basalts (MORB), positive anomalies for LILE (K, Sr, and Ba) and marked negative anomalies for Nb (in mantle normalized trace-element patterns) are common to all the three groups, conforming to their origin in subduction-related settings. However, there are distinct geochemical differences between the three groups, suggesting temporal changes in their tectonic setting of origin. The Late Cretaceous-Paleocene volcanic rocks are typical low-K island-arc tholeiites formed in an intra-oceanic island-arc setting. The Eocene volcanic rocks are transitional from low-K tholeiites to calc-alkaline and suggest formation in a transitional island-arc/continental-margin setting. The Oligocene and younger rocks are typically calc-alkaline (with some trachy-andesite alkaline facies in the Miocene rocks) formed in a mature continental-margin setting.

The information from geochemistry and tectonic setting of origin from the Chagai volcanic rocks enables revising the tectonic models for the evolution of the southern margin of the Afghan block. Whereas previous workers (Sillitoe, 1978; Arthurton and others, 1979, 1982; Kazmi and Jan, 1997) considered the modern-day continental-margin setting to have been maintained since the Late Cretaceous, our study suggests a two-stage evolution. We propose that the Chagai Arc formed as an intra-oceanic island arc in the Neotethys (coeval with the better known Kohistan island arc to the NE in the Western Himalayas), which collided with the Eurasian margin (Central Afghan block) in the latest Palaeocene. Through a transitional evolution during the Eocene, the arc evolved into a mature Andean-type continental margin by Oligocene and continues as such to the present day.

The northern margin of the E-W oriented Chagai arc is covered by superficial sediments of the Sistan basin at Pakistan-Afghan border, which conceal the contact between the Chagai arc and the Central Afghanistan block. Indirect information about this contact zone is available from the Kandahar region of

SE Afghanistan, which occupies the NW side of the Chaman Fault analogous to the Chagai Arc at Naushki, Baluchistan. Two tectonic blocks are recognized in the Kandahar region to the immediate NW of the Chaman Fault; 1) Spin-Boldak, and 2) Kandahar (Debon and others, 1986). The abundance of continental-margin intrusive and volcanic rocks in the Kandahar Block led previous workers to suggest equivalence with the Chagai Arc. However, the presence of Precambrian basement rocks in the Kandahar block negates this possibility. A better candidate for a NE extension of the Chagai arc is the Spin Boldak block, which hosts temporally and compositionally equivalent rocks and, like the Chagai arc, is built on an oceanic basement rather than a continental basement (Debon and others, 1986). We propose that the late Paleocene Kandahar suture zone (Benham and others, 2009), separating the Spin Boldak block from the Kandahar block, extends SW and separates the Chagai arc from the Central Afghan block, a situation analogous to the Kohistan-Karakoram suture separating Kohistan arc from the Karakoram block in the NW Himalayas (Heuberger and others, 2007).

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Cite as: Khan, M.A., Siddiqui, R.H. and Jan, M.Q., 2010, Temporal evolution of Cretaceous to Pleistocene magmatism in the Chagai Arc, Balochistan, Pakistan, *in* Leech, M.L., and others, eds., Proceedings for the 25th Himalaya-Karakoram-Tibet Workshop: U.S. Geological Survey, Open-File Report 2010-1099, 2 p. [http://pubs.usgs.gov/of/2010/1099/khan/].