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Pressure–temperature evolution of Neoproterozoic metamorphism in the Welayati Formation (Kabul Block), Afghanistan

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ABSTRACT

The Welayati Formation, consisting of alternating layers of mica-schist and quartzite with lenses of amphibolite, unconformably overlies the Neoarchean Sherdarwaza Formation of the Kabul Block that underwent Paleoproterozoic granulite-facies and Neoproterozoic amphibolite-facies metamorphic events. To analyze metamorphic history of the Welayati Formation and its relations to the underlying Sherdarwaza Formation, petrographic study and pressure–temperature (P–T) pseudosection modeling were applied to staurolite- and kyanite-bearing mica-schists, which crop out to the south of Kabul City. Prograde metamorphism, identified by inclusion trails and chemical zonation in garnet from the micaschists indicates that the rocks underwent burial from around 6.2 kbar at 525 °C to maximum pressure conditions of around 9.5 kbar at temperatures of around 650 °C. Decompression from peak pressures under isothermal or moderate heating conditions are indicated by formation of biotite and plagioclase porphyroblasts which cross-cut and overgrow the dominant foliation. The lack of sillimanite and/or andalusite suggests that cooling and further decompression occurred in the kyanite stability field. The results of this study indicate a single amphibolite-facies metamorphism that based on P–T conditions and age dating correlates well with the Neoproterozoic metamorphism in the underlying Sherdarwaza Formation. The rocks lack any paragenetic evidence for a preceding granulite-facies overprint or subsequent Paleozoic metamorphism. Owing to the position of the Kabul Block, within the India–Eurasia collision zone, partial replacement of the amphibolite-facies minerals in the micaschist could, in addition to retrogression of the Neoproterozoic metamorphism, relate to deformation associated with the Alpine orogeny.

1. Introduction

The Kabul Block is a tectonic fragment that occurs at the juncture between the Indian and Eurasian continents (Fig. 1a). Along with the Farah and Helmand Blocks, it is part of a series of NE–SW aligned terranes that comprise the Afghan Central Blocks. Thick Phanerozoic sedimentary sequences are prevalent in all of the Afghan Central Blocks (Abdullah and Chmyriov, 1977); however, basement rocks are exposed in the central part of the Kabul Block (Fig. 1b). This is thought to be the result of an apparent dome like structure (Andritzky, 1967; Karapetov et al., 1981). The basement rocks are represented by two, three or four superposed units, called the Khair Khana, Sherdarwaza, Kharog and Welayati Formations (Abdullah and Chmyriov, 1977; Karapetov et al., 1981; Bohannon, 2010). Recent results of extensive geochronological dating by U/Pb SHRIMP (zircon), Ar–Ar (micas) and U/Th (monazite) (Faryad et al., 2015) indicate that the oldest rocks, belonging to the Sherdarwaza (or Khair Khana) Formation(s), consist of migmatites with Neoarchean orthogneiss that show a Paleoproterozoic granulite-facies metamorphism. A subsequent Neoproterozoic amphibolite-facies event is recorded throughout both the Sherdarwaza and overlying Welayati Formation. Detailed petrological study by Collett et al. (2015) confirmed the granulite and subsequent amphibolite-facies events in the Khair Khana or Sherdarwaza Formation. However, the relations and degree of metamorphism in the Welayati Formation remains unclear. This is because of differing interpretation regarding the superposition with other formations and the lack of detailed petrological data.

This paper aims to verify metamorphic characteristics of the Welayati Formation and its relations to the polymetamorphic events recorded in the underlying Sherdarwaza Formation. The most prominent and characteristic rock sequences with coarse-grained garnetiferous mica-schists from the Welayati Formation were selected for this study. The samples come from

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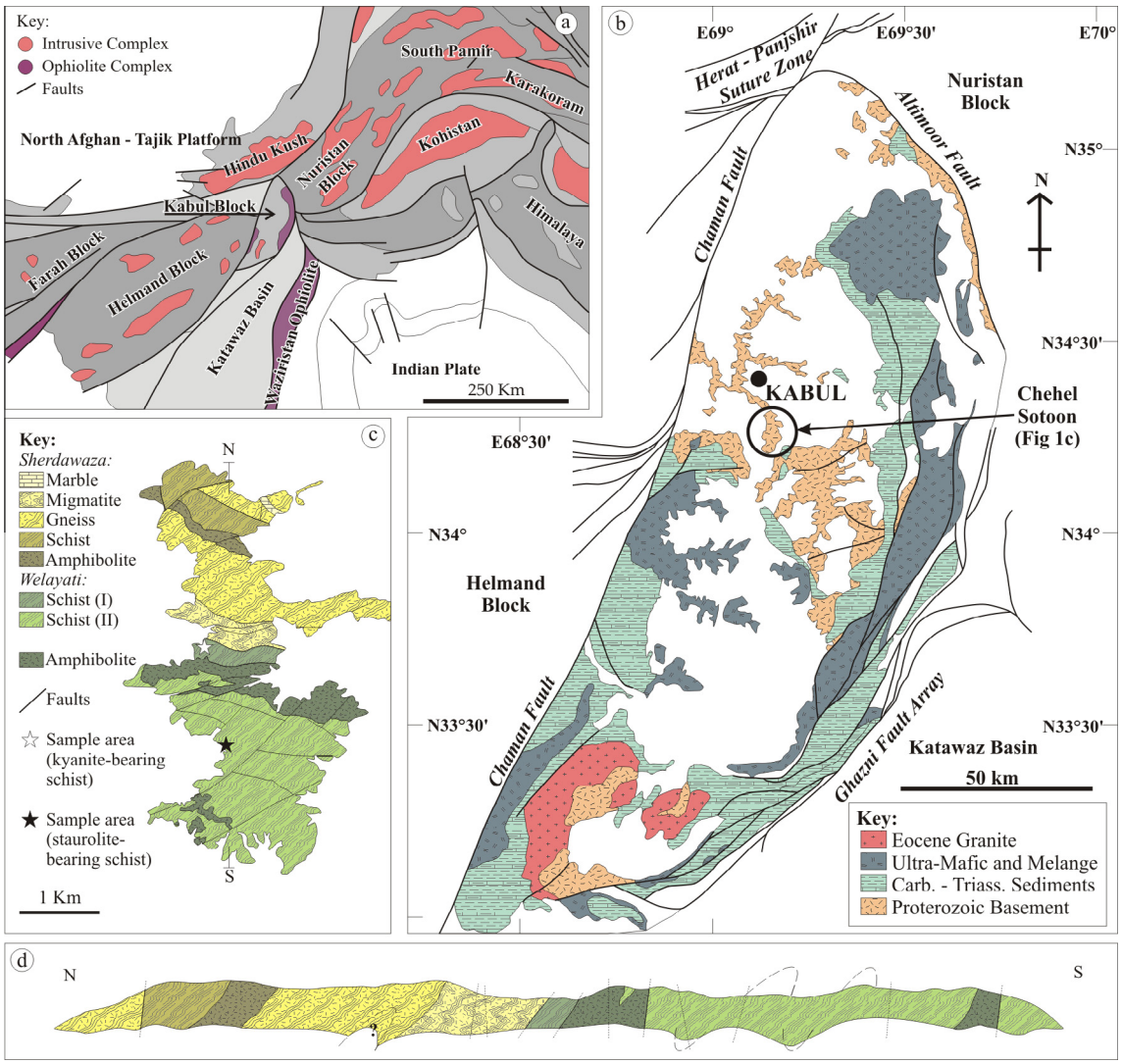

Fig. 1. (a) Tectonic Map of the Afghan region after Stocklin (1977), the Kabul Block is surrounded by the Helmand Block to the west, Hindu Kush Mountains to the North, Nuristan Block to the North-East and Katawaz Basin to the South East. (b) Schematic geological map of the Kabul Block after Kafarsky et al. (1975) and Bohannon and Turner (2005). Proterozoic basement crops out extensively around the Kabul City area. (c) Detailed geological map of the sample area after Karapetov et al. (1981). Welayati micaschist labelled (I) interpreted as belonging to the Kharog Formation by Karapetov et al. (1981); however, here and in geological maps by Kafarsky et al. (1975) and Bohannon (2010) considered part of the Welayati Formation. Stars indicate sample locations of kyanite-bearing schist (white star) and staurolite-bearing schist (black star). (d) Cross-section along boundary of the Sherdarwaza and Welayati Formation adapted from structural data in Karapetov et al. (1981) and cross-section of Andritzky (1967).

the Chehel Sotoon area (Fig. 1b and c) in the southern part of Kabul City, where both the Sherdarwaza and Welayati formations are exposed. We apply phase-equilibria (pseudosection) modeling in combination with mineral textural relations and major element zonation in garnet to constrain pressure–temperature (P–T) evolution for the Welayati mica-schists. The new data presented here adds to the overall understanding of the tectono-thermal evolution of the Kabul Block as well as examining the utility of phase equilibria modeling to understanding petrographical and mineral-chemical observations.

2. Geological background

The Afghan Central Blocks (the Farah, Helmand and Kabul Blocks, Fig. 1a) form a set of NE–SW aligned crustal fragments that adjoin the Indian and Eurasian continental masses. They are separated from the Eurasian continent by the Herat-Panjshir Suture Zone and Hindu Kush Mountains in the north. To the south east the Katawaz Basin (a flexural basin) and Waziristan ophiolite complex represent the join to the Indian Continent (Treloar and Izatt, 1993). The Kabul Block is separated from the other Afghan Central Blocks by the Chaman fault and it is variably described as the easternmost of the Afghan Central Blocks (Andritzky, 1967; Abdullah and Chmyriov, 1977; Şengör, 1984; Faryad et al., 2015) or as a leading edge of India, detached prior to collision with Eurasia (Tapponnier et al., 1981; Treloar and Izatt, 1993).

Although rare within the other Afghan Central Blocks, high-grade basement rocks crop out in the central part of the Kabul Block. They are overlain by un-metamorphosed to low-grade late Paleozoic to Mesozoic sedimentary sequences (Fesefeldt, 1964; Andritzky, 1967; Fischer, 1971; Abdullah and Chmyriov, 1977). Peridotite sheets underlain by Jurassic volcano-sedimentary melange are thrust onto the sedimentary sequences along both the eastern and western margins of the block (Mennessier, 1976; Abdullah and Chmyriov, 1977). The south of the Kabul Block is intruded by a series of plutonic rocks of Eocene age that continue through the Afghan Central Blocks and eastwards to the Nuristan Block. They are related to continental collision subsequent to oceanic subduction between the Indian