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Research paper

Supracrustal suite of the Precambrian crystalline crust in the Ghor Province of Central Afghanistan

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ABSTRACT

The Proterozoic pre-Ediacaran metamorphic basement of the southern Tajik (North Afghanistan) continental block and the adjacent Band-e-Bayan zone is exposed in the Ghor Province of Central Afghanistan. It is predominantly composed of the EW-striking supracrustal succession consisting of interbedded felsic schists and gneisses (metapsammites), amphibolites (metabasalts), calcite and dolomite marbles. The metamorphic facies changes from greenschist in the Band-e-Bayan zone to amphibolite facies in the Tajik block. The supracrustal rocks of the Band-e-Bayan zone and Tajik block possess common features suggesting that the former represents a tectonized part of the latter. The geochemical characteristics of metapsammites indicate derivation of the clastic material from a continental arc and, partly from a passive continental margin, whereas the composition of metabasalts suggests their possible formation in a continental rift basin. The tectonic setting of supracrustal unit could be interpreted as a back-arc type basin. We presume that the Tajik microcontinent split off the Gondwana supercontinent along an ancient rift zone during the late Paleozoic.

1. Introduction

The Afghanistan segment of the Alpine-Himalayan orogenic system shows a complex Permian–Quaternary history of successive amalgamation of different microcontinental blocks to the Asian continent (Şengör and Natal'in, 1996; Klett et al., 2006; Kalvoda and Bábek, 2010). The available information on the crystalline crust of these continental blocks in Afghanistan is scarce. The central part of Afghanistan was first systematically mapped by the German Geological Mission in the 60s, compiling a geological map at the scale of 1:500,000 where the Precambrian metamorphic rocks underlying the sedimentary cover were identified (Wittekindt and Weppert, 1973). The Soviet geological mission initiated more detailed geological exploration and mapping activities in the sixties and seventies. The central part of Afghanistan was covered by mapping at a scale of 1:200,000 with some areas at 1:50,000 and 1:10,000 scales (Dronov et al., 1972, 1973). The metamorphosed Precambrian basement rocks mostly overlain by sediments were studied in significant detail. The results have been published in several compilations (Abdullah and Chmyriov, 1977, 1980).

Since 1979, field geological studies have ceased, and the main activities were focused on the systematization of the available information, such as the compilation of a 1:2,000,000 geological map published in 1995 by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) in cooperation with the Department of Mines and Geological Survey of Afghanistan (Atlas of Mineral Resources of the ESCAP Region Series, 1995).

The United States Geological Survey (USGS) in co-operation with the Afghanistan Geological Survey carried out an assessment of the mineral resources of Afghanistan based on the compilation and reinterpretation of existing geological materials (Peters et al., 2007) and prepared a digitized geological map of Afghanistan (Doebrich and Wahl, 2006). This map is based on the one published by Abdullah and Chmyriov (1980), keeping original geological boundaries.

The Tajik (North Afghanistan) block represents the largest lithotectonic domain of Afghan continental collage. The rocks in the crystalline basement are mainly of Precambrian age and are exposed in some areas, while most of the territory is buried under thick

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package of sedimentary cover. There are no detailed studies as yet in relation to the primary composition and tectonic environment of formation of the basement rocks. Furthermore, the southern margin of the Tajik block is embroidered by more than 700 km long highly deformed Band-e-Bayan zone, the origin of which is debated.

The metamorphic basement rocks of the southern margin of the Tajik block and the Band-e-Bayan zone are exposed in the middle part of the Ghor Province of central Afghanistan. Geochemical and petrological studies with a view to understand the evolution of the Proterozoic metamorphic succession were undertaken and the results presented in this paper are based on field observations in the Ghor Province performed in 2008 and 2011 (Fig. 1). The study area was confined to the catchment of the Hari Rod River and its tributaries, from the western border near Jam to the eastern border of the Ghor Province. One hundred and thirty one sites were inspected and sampled, including 48 locations of Precambrian metamorphic rocks (Fig. 2).

2. Geological setting

The study area is located in central Afghanistan at the junction of the Tajik (North Afghanistan) and Farah Rod (also referred to as the Middle Afghanistan) blocks separated by the Band-e-Bayan zone (Fig. 1).

The Band-e-Bayan zone is an elongated narrow crustal block oriented in a W–E direction, bounded on the North by the major Herat Fault (also referred to as the Hari Rod), and the southern border limited by the distribution of the Pre-Mesozoic rocks, which are absent in the south. The nature of the zone has not been well investigated and could be considered as (1) a tectonized margin of the Tajik block, (2) an uplifted northern margin of the Farah Rod block, and (3) an exotic block.

The Precambrian metamorphic rocks are exposed along the southern margin of the Tajik block and in the Band-e-Bayan zone (Fig. 2).

In the Ghor portion of the Tajik block, the metamorphic basement is covered by sedimentary sequences ranging in age from Carboniferous to Quaternary. In the Band-e-Bayan zone the metamorphic basement is covered by sediments ranging in age from the Ediacaran (Vendian) to Quaternary. Most of the Paleozoic paleogeographic reconstructions suggest a peri-Gondwana affinity for the Tajik block (von Raumer et al., 2002; Klett et al., 2006; Kalvoda and Bábek, 2010).

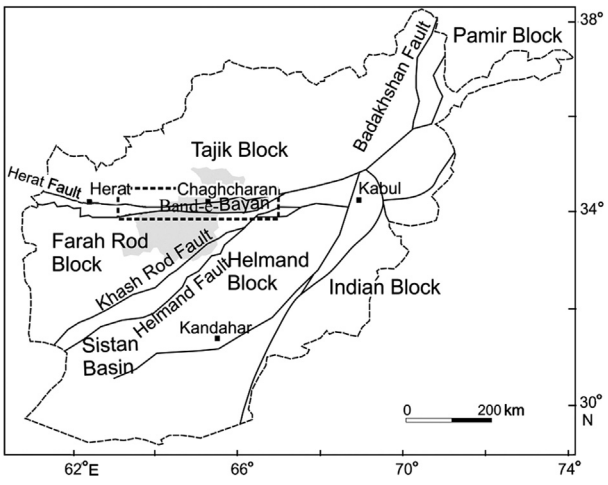

Figure 1. Generalized tectonic framework of Afghanistan (after Peters et al., 2007). Shaded area marks the Ghor Province.

The nature of the Farah Rod block is not well understood. It is composed of a very thick sedimentary pile that can be viewed as an accretionary complex of Mesozoic and Tertiary age. There are no exposures of the Paleozoic sedimentary sequences and the underlying metamorphic basement.

3. Age of the metamorphic basement

No isotope age data are available for the metamorphic rocks from the Tajik block and Band-e-Bayan zone. The basement of the Band-e-Bayan zone is locally overlain by Ediacaran and Cambrian unmetamorphosed sediments which suggesting its Precambrian age (Dronov et al., 1973). Geochronology of similar basement rocks exposed in other crustal blocks of Afghanistan show Paleo- and Mesoproterozoic (Nadimi, 2007) or Neoproterozoic (Saki, 2010) ages.

In previous studies, the metamorphic rocks of the Ghor Province were subdivided into two lithological units: (1) a mafic metavolcanic unit with subordinate metasediments and (2) a metasedimentary unit with rare metavolcanics (Dronov et al., 1973). They were tentatively identified as Mesoproterozoic based on low grade (predominantly greenschist facies) metamorphism (Abdullah and Chmyriov, 1977, 1980). The stratigraphic subdivision of metamorphic rocks is represented slightly differently on the map compiled by the USGS team (Fig. 2). The sequence outcropping in the westernmost part of the Ghor Province is characterized by a higher metamorphic grade (amphibolites facies) and was accordingly attributed to the Paleoproterozoic (unit X*gn*) comprising gneisses, migmatites, amphibolites, quartzites, and marble, while the metamorphic sequence distributed further east was attributed to the Mesoproterozoic (units Y*m* and Y*vl*). The unit Y*m* comprises undifferentiated metamorphic rocks including “greenschist, gneiss, quartzite, marble, amphibolite (metavolcanic lava and sedimentary rocks)”, whereas unit Y*vl* is characterised as “metavolcanic lava and sedimentary rocks” (Doebrich and Wahl, 2006).

4. Petrography

Based on our observations, three lithological groups are defined in the crystalline basement of the Ghor Province, i.e. felsic metasedimentary gneisses, greenschists (primary basic metavolcanics), and marbles. The rocks of all groups are interbedded and form common sequence. Felsic gneisses are predominant both in the Band-e-Bayan zone and the Tajik block. Marbles and greenschists are more common in the Band-e-Bayan zone, while in the north they were observed only in one locality (Loc. G93; Fig. 3C).

Felsic gneisses are subdivided into two subgroups: (1) muscovite gneisses and (2) biotite gneisses. Muscovite gneisses occur in the Band-e-Bayan zone, south of the Herat Fault, while biotite gneisses are distributed to the north of the Herat Fault, along the southern margin of the Tajik block.

The basement rocks of the Band-e-Bayan zone are metamorphosed under greenschist facies as indicated by characteristic mineral assemblage, including muscovite, epidote, chlorite, actinolite. The grade of metamorphism increases to the north and west, reaching amphibolite facies in the Tajik block. The presence of metatexite migmatites suggests partial melting in the western part of the study area. The sequence is folded to predominantly isoclinal folds, striking generally in an E–W direction, parallel to the southern margin of the Tajik block and the Band-e-Bayan zone. The lithologies strike in the same direction and can be traced to tens of kilometres (Fig. 3).

The intrusive rocks that might be attributed to Precambrian are scarce. A few small bodies of intrusive rocks affected by metamorphism were observed in the Tajik block north of the Herat Fault