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Geology, Petrographic Characteristics and Tectonic Structure of Paleoproterozoic basement of Kabul Block (North Eastern Afghanistan), Initial Findings

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Abstract – The Paleoproterozoic basement of Kabul Block is a cratonic basement in north eastern Afghanistan. Precambrian Kabul Block including metamorphic rocks only takes place at the base of the study area. The Neo-Proterozoic Welayati formation overlies the Paleo-Proterozoic Sherdarwaza formation with a tectonic contact, and they both overlay Khair Khana formation. In the region, Alghoi meta granitoid intruded into both Khair Khana and Sherdarwaza formations.

The Khair Khana formation contains of granulites, granitic gneisses ve amphibolites. The mineral assemblages of granulites are *plagioclase + quartz + K-feldspar + orthopyroxene + clinopyroxene (diopside/augite).* Granitic gneisses are observed as hornblende gneiss, garnet-biotite gneiss and pyroxene-gneiss. Hornblende-gneisses include *hornblende + quartz + K-feldspar* mineral assemblage, garnet-biotite gneisses are evident with *plagioclase + quartz + K-feldspar + biotite (red) + garnet* mineral assemblage, and pyroxene gneisses include *quartz + plagioclase + biotite + clinopyroxene* mineral assemblage. Amphibolites consist of *hornblende + plagioclase + quartz ± zoisite ± sphene ± ilmenite ± apatite* mineral assemblage. The Sherdarwaza formation contains marbles, amphibolites, biotite gneisses, micaschists and migmatites. Marbles consist of *calcites ± quartz ± apatite*. In amphibolites, *harnblende + plagioclase + quartz ± epidote ± zoisite ± garnet* mineral assemblage are observed. Biotite gneisses include *plagioclase + quartz + microcline + biotite ± sphene ± apatite ± zircon* mineral assemblage. Micachists consist of *quartz + plagioclase + microcline + biotite ± sphene ± apatite* mineral assemblage. Migmatites include *plagioclase + quartz + microcline +biotite ± sphene ± apatite* mineral assemblage. Alghoi meta granitoid is generally observed as stocks and small masses, and sometimes it shows foliation. It consists mainly of meta granites. The meta granites that show granular texture include *plagioclase + quartz + K-feldspar + biotite + hornblende*. The Welayeti formation contains quartzite, kyanite-garnet-staurolite schist, garnet-mica schist, kyanite-garnet-mica schist and garnet-muscovite schist. Quartzite include *quartz* ± muscovite ± biotite. They are observed *hornblende + quartz + plagioclase ± garnet ± epidote ± zoisite ± rutile* ± magnetite in amphibolites. Kyanite-garnet-staurolite schists are evident with *staurolite + kyanite + garnet + mica + biotite + quartz + plagioclase ± apatite ± epidote ± ilmenite ± monazite* mineral assemblage. Garnet-mica schists and kyanite-garnet-mica schists include *quartz + plagioclase + biotite + muscovite + kyanite + garnet ± chlorite ± apatite ± tourmaline ± sphene ± rutile*. In garnet-muscovite schists, *muscovite + quartz + plagioclase + garnet ± tourmaline ± apatite ± zircon* are observed.

The granulites in Kabul Block are together with granite gneisses, and they can be separated under one formation. Granulites show different mineral compositions, Usually, they are without garnet, in some cases they include garnet. The amount of plagioclase is higher in them according to other rocks. In some cases, the composition of granulites is very similar to that of quartz mangarites that indicates high temperature and pressure of the metamorphism process and shows that this block is related to a segment of Columbia and Rodinia supercontinents during Paleoproterozoic collisional events.

Keywords *– Kabul Block, Metamorphites, Afghanistan*

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I. INTRODUCTION

The Kabul Block is a tectonic block located in the northeast of Afghanistan (Fig. 1). There is little information about the basement rocks and their geologic characteristics in the Kabul Block. Also, there are some old information based on large-scale and non-detailed geological maps such as 1:100000, 1: 500 000 and 1: 1 000 000 [1], [2]. The studies carried out so far in the region and its immediate vicinity can be summarized in chronological order as follows. Ref.[3] introduced the Kabul Stratigraphic Chart. In this diagram, the Kabul Series is

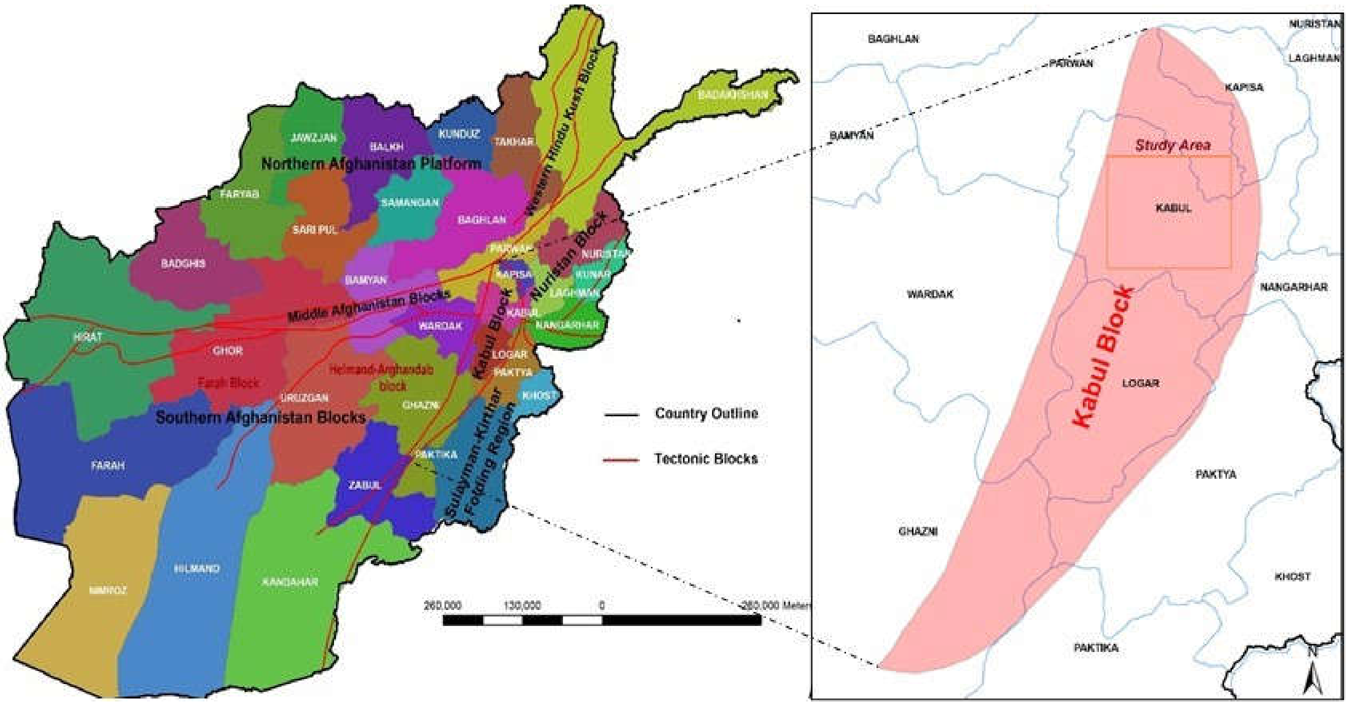

Fig. 1. The study area which is located in the Kabul block in the north-eastern part of Afghanistan

observed above the Khingel Series, which is a carbonate complex.

Ref.[4] in his work titled "Basic Features of Afghan Tectonics" said that the Kabul Block and the Western Hindu-Kush are the two main tectonic blocks in Afghanistan and defined these blocks. Ref. [5] between 1958 and 1961, mapped the area around Kabul. Ref. [6] made partly 1:100000 scale geological maps of Kabul block. Ref. [7] compiled maps of the central and southern parts of Afghanistan at a scale of 1:1000000 and 1: 500000.

Ref. [8] investigated the geological structure and general petrographic features of the Kabul region. Ref. [5] made a detailed study on the biostratigraphy of sedimentary rocks in the Kabul region and developed the study of Manisa. Ref. [9] studied the geological structure and mineral resources of the northern part of the Kabul Block.

Ref. [10] conducted a study on the stratigraphic and tectonic features of the Kabul region. In this study, the interior parts of the Kabul tectonic region were investigated.

Ref. [11], in his study, states that the region gathered around Afghanistan is a collision area consisting of continental blocks derived from Gondwanaland.

Ref. [12] stated that the Kabul Block is composed of the lower Welayati formation and the overlying Sherdarwaza formation, and the Sherdarwaza formation with thickness of about 5.5 km is predominantly composed of marble, amphibolite, quartzitic gneiss and migmatite.

Ref. [13] stated that the Kabul Block collided with the Eurasian Plate during the Late Cretaceous - Early Paleogene.

Ref. [14] suggests that the Indian Plate and the Afghan Block collision during the Pliocene.

Ref. [15] assessed non-fuel mineral resources of Afghanistan.

Ref.[16] defined the gneisses of the Paghman Mountains in the Kabul region as a new series under the Paghman Series.

Ref. [17] stated the Kabul Block is prolonged crustal part that cuts over the Afghan Central Blocks, connecting the Indian and Eurasian continents. After the granulite facies metamorphism, amphibolite facies metamorphism develops. The granulite facies metamorphism took place at a temperature of 850 ^{o}C and a pressure of 7 kbar.

Ref. [18] stated that the Welayeti formation consists of micaschist and quartzite with amphibolite lenses. It unconformably overlies the Neo Archaean Sherdarwaza formation. This formation has undergone a metamorphism progressing from a temperature of 525 ^{o}C and a pressure of 6.2 kbar to a temperature of 650 ^{o}C and a pressure of 9 kbar.

Ref. [19] worked in the Kabul Block, which consists of Sherdarwaza and Welayati formations. According to these researchers, The Sherdarwaza formation consists of migmatites and gneisses.

II. Materials and Method

Within the scope of the field studies, 1/25000 scaled geological maps of an area of 155 km^2 and 1/10000 scaled maps of an area of 120 km^2 were created. Tarauni brand type compass was used during the studies. During the fieldwork performed at all locations, GPS was used to ensure that the points were accurately mapped. The lithologies outcropping in the study area were identified and 300 rock samples were taken for petrographic studies. Considering the top-bottom relationships of the lithologies in the study area, the stratigraphic colon section of the region was revealed. In order to fully understand the geological development of the units, the structural and tectonic elements reflecting the formation mechanisms of the rocks, and their planar and linear structures were measured and recorded on the map.

Among them, 50 samples were selected for petrographic and mineralogical studies. Thin sections were made and assessed using the Nikon and Leica type microscopes at Konya Technical University and Kabul Polytechnic University.

III. Tectonic Evolution and Structural Features of The Region

Afghanistan is located in the tectonically active Alpine-Himalayan orogenic belt in Central Asia, which was formed by the collision between the Indian and Arabian plates and the Eurasian plate in the Late Paleogene [20], (Fig. 2). As the Eurasian continent emerged 65 million years ago, multiple periods of deformation shattered the crust in and around Afghanistan.

Afghanistan consists of a complex assemblage of areas (regions), mostly originating from Gondwana, that was added to the southern margin of Eurasia before and during the collision of the Indo-Eurasian plates [21], [22]. These areas are divided into three separate tectonic zones (Fig. 3). **Afghan-Tajik Platform** in the north consists of fixed blocks, and since the Paleozoic, these blocks have been part of the Eurasian continent [23]. **The Katawaz Basin** which is a major bending basin in the southeast represents the northwestern continental margin of the Indian plate [14]. Among them are the **Afghan Center Blocks** that is NE-SW extension tectonic blocks. The blocks collided with Eurasia during the Mesozoic and Early Cenozoic.

The Afghan Center Blocks contain three separate blocks: the Kabul Block, the Helmand Block, and the Farah Block (Fig. 3). However, the status of the Kabul Block is controversial. Ref. [13] and [14] stated that the Kabul Block represents a detached crustal piece of the Indian subcontinent added to the Afghan Center Blocks in the Paleocene. Against this, accoding to [24] and [25], the Kabul Block belong to Afghan Center Blocks.

The collision of the Indian and Eurasian Plates is caused by the separation of small blocks from India, and the formation of magmatic arcs before the continental collision [13], [14] [21], [26]. Afghanistan's tectonic evolution is related to the closing of the Paleozoic and Mesozoic Tethys. In Fig. 4, the tectonic map of Afghanistan and the western Himalaya-Karakoram-Hindu Kush region is shown.

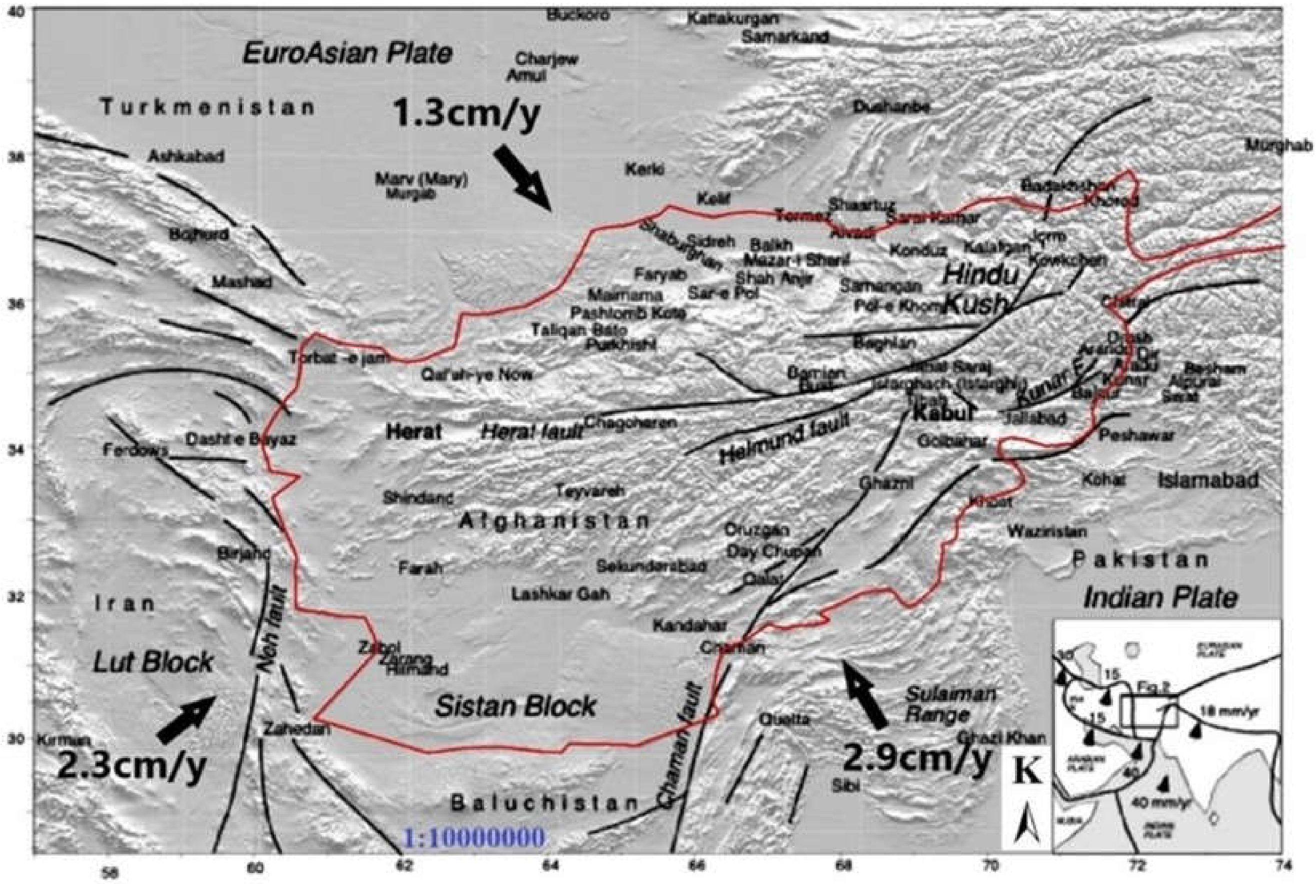

Fig.2. Afghanistan's location and tectonic activities in the Alpine-Himalayan orogenic belt [27]. Vectors show relative plate movements and velocities between Indian, Eurasian, and Arabian plates [28]

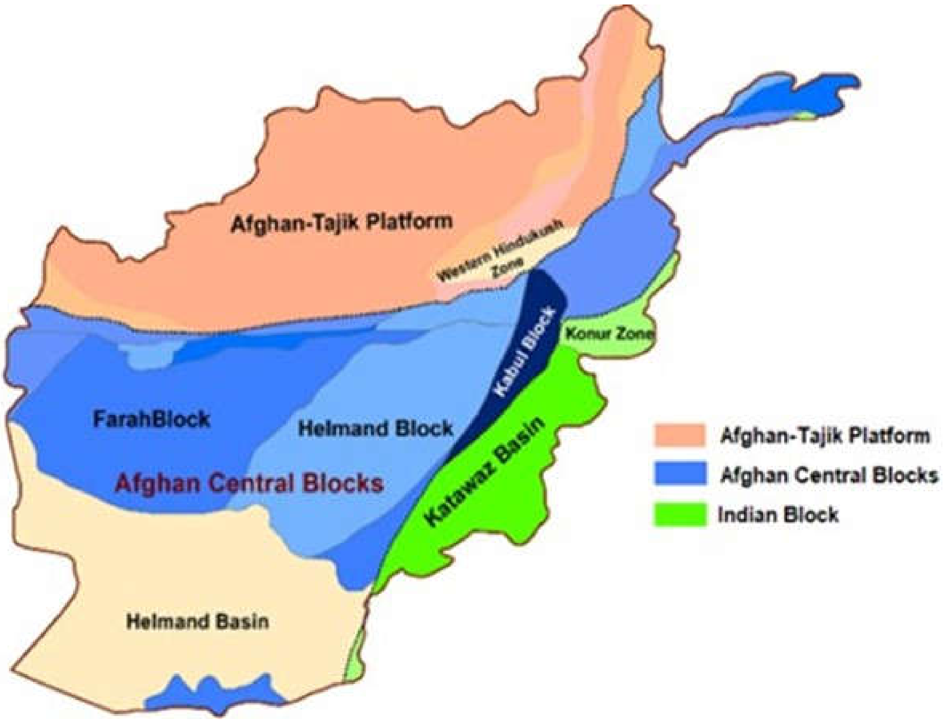

Fig. 3. Tectonic outlines of Afghanistan according to [16], [22]

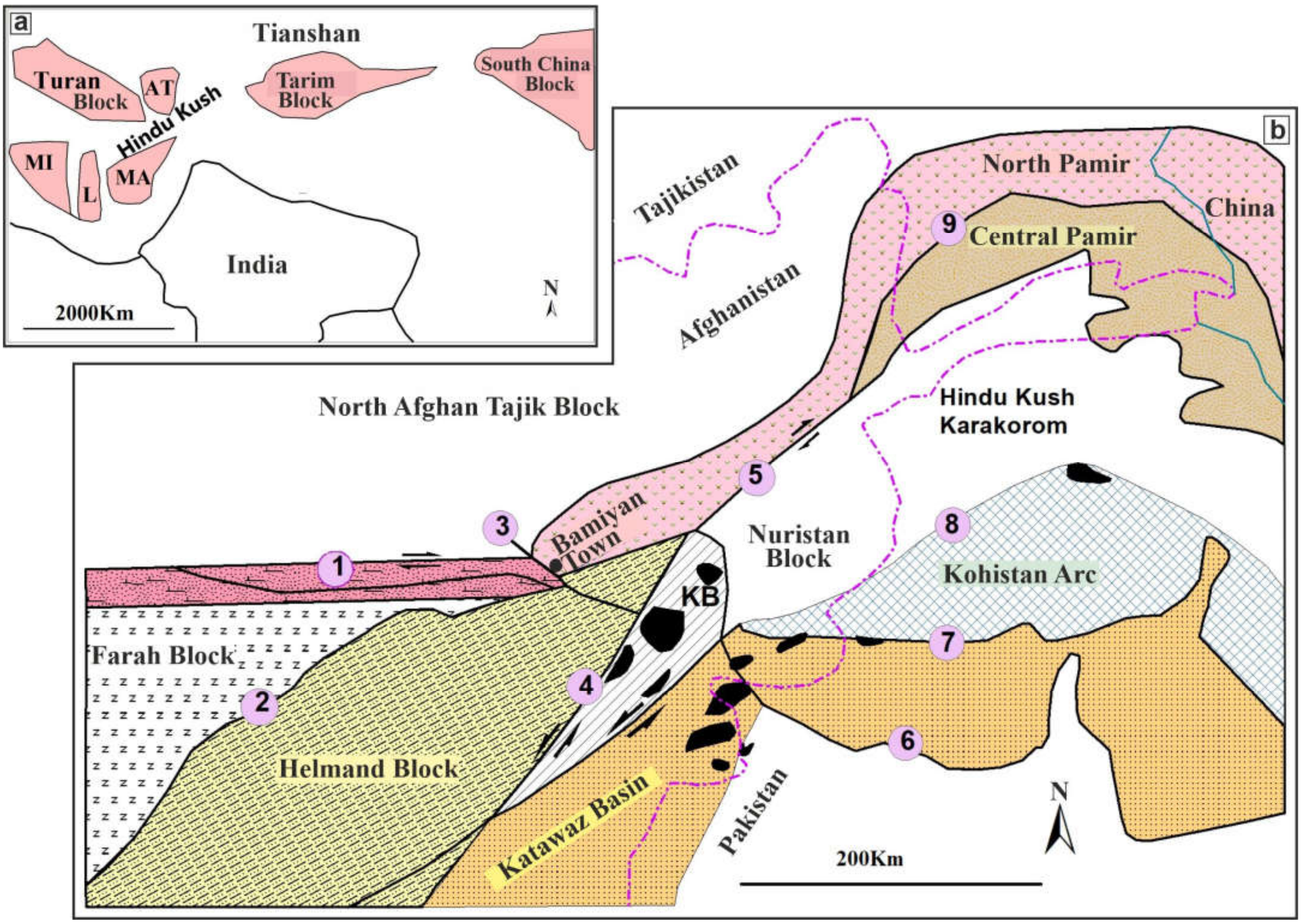

Fig. 4. (a) Current location of Precambrian blocks in South Asia (AT- Afghan-Tajik block, MA-Central Afghan Blocks, MI- Central Iranian Block, L-Lut Block, South China Block, Turan Block, [29]. (b) Tectonic map of Afghanistan - Western Himalaya - Hindu Kush region [11], [13], [26], [30], [31]. The black areas in the Kabul Block (NW) are ophiolite formations. 1-Harirod Fault (Paleozoic Suture), 2-Helmand Fault (Mesozoic Suture), 3-Bamiyan-Shibar Fault, 4-Chaman Fault, 5-Panjshir Fault, 6-Main Boundary Thrust, 7-Foundation Central Thrust (Indus-Tsangpo Suture), 8-Shyok Suture, 9-Mesozoic Suture

The tectonic zones in Afghanistan include **the North Afghan Tajik Block, the Afghan Central Blocks (Farah and Helmand Blocks)** and **Katawaz Basin** (Fig. 3 and 4). The North Afghan Tajik Block is located north of the Harirod-Panjshir fault system (Fig. 4b). The Afghan Center Blocks are located west of the Chaman Fault (Fig. 4b). They were previously part of Gondwanaland. However, they separated from Gondwanaland before the Indian subcontinent was annexed to the southern margin of Eurasia [11], [14], [21], [22]. The Kabul Block was formed at the triple junction of these three regions. According to [24], The Kabul Block is the easternmost part of the Afghan Center Blocks [24]. Against this, according to [13], [14], The Kabul Block is the separate region added to the Afghan Center Blocks before the collision of Eurasia and India. The Kabul Block is a tectonic block between the Indian and Eurasian continents (Fig. 5a). Kabul, Farah and Helmand Blocks forms the Afghan Central Blocks.

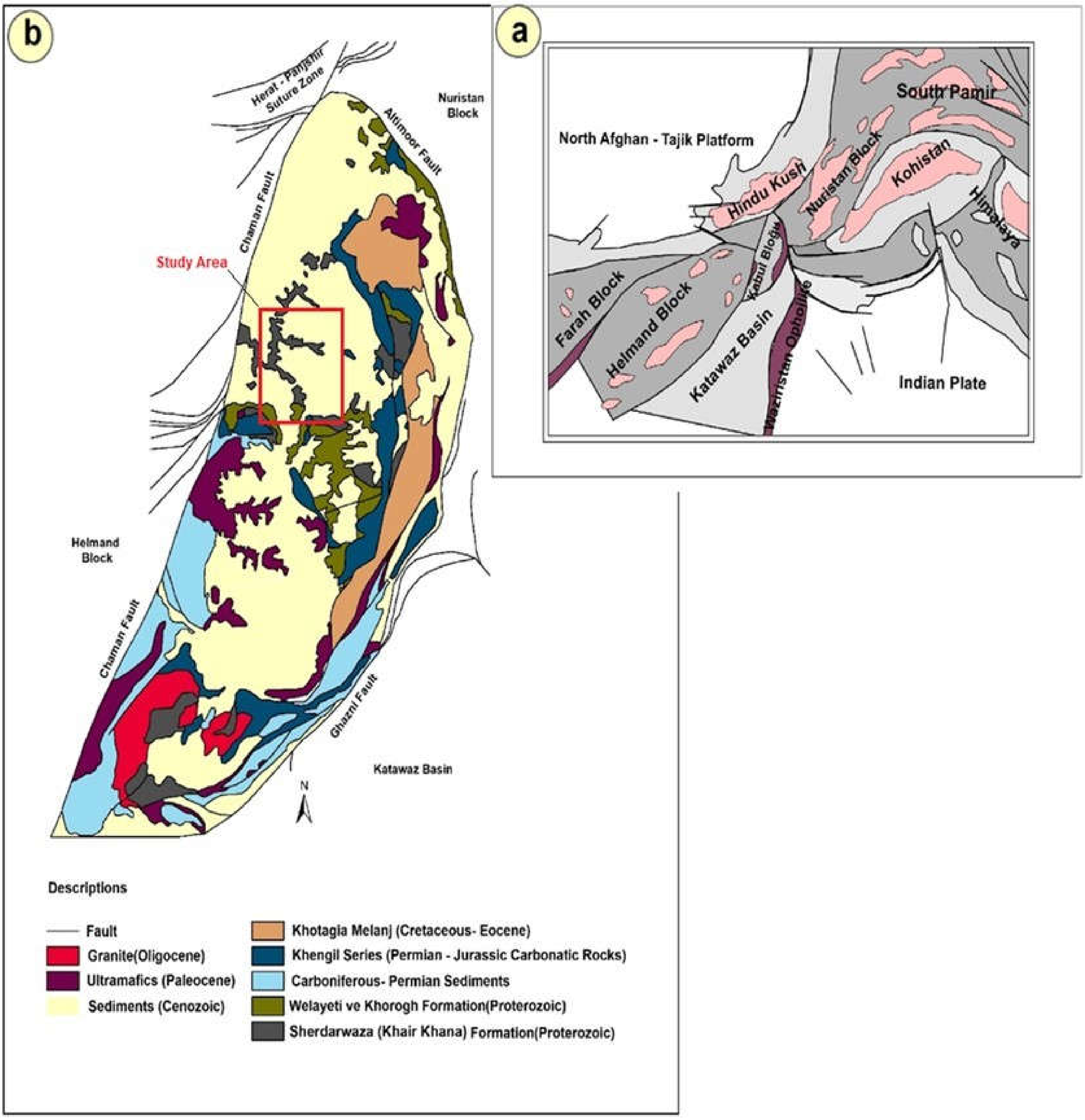

Fig. 5. (a) Tectonic map of the Afghanistan region [32], (b) The geological map of the Kabul Block according to [1], [2]

The Kabul Block is approximately 200 km long and up to 50 km wide (Fig 5a and b). The Kabul block is bounded to the east by the Chaman fault and to the northeast by the Altimoor fault. The Ghazni fault is observed in the southeast of the Kabul block (Fig. 5b). The Herat-Panjshir Suture Zone is observed in the north of the Kabul block.

IV. RESULTS

A. Geological Properties of Kabul Block

In the basement of the Kabul Block, base rocks are shown (Fig. 5b), and Kabul block has an east-west oriented dome structure [12], [24]. Late Paleozoic (Carboniferous-Permian) low-grade metamorphites and Cenozoic volcano-sedimentary succession are observed on the Kabul block [5], [24], [25]. Late Paleozoic aged metamorphites consist of phyllites, metashales, marbles and metaconglomerates. Upper Permian-Triassic aged the Khengil Series consists of conglomerates, limestones and tuffs [5]. The Kotagai melange consisting of peridotites overlies the Jurassic volcano-sedimentary units (Fig. 5b), and Kotagai melange thrusts the eastern and western edges of the Kabul block [6], [25]. The eastern ultramafic thrust layer is reported to belong to the Khost ophiolite complex [13]. The ultramafic rocks in the south and west of the block emerged in the form of clips by thrusting on the unmetamorphized sedimentary cover [13]. Ref. [13] named these ultramafic rocks as the Kabul ophiolite complex. Kabul Block is cut by Eocene-Oligocene aged granitic rocks. These granitic rocks were formed as a result of the collision of the Indian and Eurasian plates [33]. The Kabul block is mostly covered by Cenozoic aged sedimentary rocks [25].

It is assumed that the basement rocks that emerged on the hills around the city of Kabul are the result of a dome-like structure [12], [24]. The basement rocks of the Kabul Block are composed of Proterozoic metamorphites [25]. From bottom to top and in decreasing degree of metamorphism, these are, Khair Khana, Sherdarwaza, Kharog and Welayati formations (Fig. 5b).

According to [17], granulite facies rocks are observed in She Darwaza formation in Khair Khana. These rocks are surrounded by quartz-feldspathic rocks, schists and migmatites [17]. Ref. [10] described granulites from Khair Khana for the first time as Proterozoic orthogneisses. Ref. [12] say that these are xenoliths of a probably Archaean aged formation.

The Sherdarwaza formation is mostly represented by quartzite, amphibolite and marble interbedded migmatites, schists and gneisses. Syenitic and dioritic metamagmatites are observed in the Shedarwaza formation [17].

It is thought that the 0.93 - 0.64 Ga Neoproterozoic ages obtained by K-Ar and Ar-Ar dating [24], [19] of biotite from migmatite and schists correspond to the metamorphism of the Sherdarwaza and Khair Khana formations. In addition, Paleoproterozoic U-Pb zircon ages in the range of 1.8-2.3 Ga were obtained from gneiss and migmatites [16], [19], [34]. According to [19], granulite and amphibolite facies metamorphisms are of Paleoproterozoic and Neo-proterozoic ages.

The Kharog formation consists of meta-quartzite, crystalline schists, gneisses, amphibolites and marbles [25]. The extent and distribution of the Kharog formation have not been fully understood in the studies carried out so far. This formation was defined according to stratigraphic relationships in the Kharog Mountains south of Kabul. The Kharog formation overlies the Sherdarwaza formation with a distinct non-angular unconformity [17].

According [18], the lower boundary of the Welayati formation is in tectonic contact with the Sherdarwaza (Kharog?) formation. The Welayati formation consists of garnet amphibolites and various crystalline schists including biotite schists, staurolite-garnet-biotite schists, muscovite-kyanite-garnet schists and quartzites [25]. According to [18], this formation consists of schist at the base, amphibolite in the middle, and amphibolite-schist alternation at the top.

The identification of the Rodinia and Colombia supercontinents has helped to interpret geodynamic processes on Earth throughout geological time [35], [36], [37], [38], [39], [40], [41], [42], [43], [44]. From the cratonic remains of these supercontinents we can understand sedimentary, magmatic and tectonic processes.

The Kabul block and the Afghan Central Blocks are small continental parts. The block of Cain was separated from Gondwana during the opening of Neotethys. Later collided with Eurasia in the Late Cretaceous - Early Paleogene [13], [14], [45].

We studied in Archean and Proterozoic aged four basement units of the Kabul Block. These are Khair Khana, Sherdarwaza, Welayati formations and Alghoi meta granitoid (Fig. 6, 7, 8).

A.1. Khair Khana formation

It was first named by [12]. Some researchers have defined the Khair Khana formation and the Sherdarwaza formation as a single formation. However, these formations differ from each other in terms of age and lithological features. The Khair Khana formation is older than the Sherdarwaza formation and no quartzite is observed in the Khair Khana formation and meta-carbonates are also very common. The age of the Khair Khana formation was stated by [12] as Archean. The thickness of the formation is 2700 m. Spreading areas of this formations: Khawja Rawash mountains, Paymunar mountains, Kasaba mountains, Khair Khana mountains and Alghoi mountain. The Khair Khana mountains lie in an E-W direction while the Alghoi mountains lie in a N-S direction. This formation consists of granulite, granite-gneisses, marble, calc-silicate rocks, amphibole gneisses and amphibolite. Granite masses have been identified in this region.

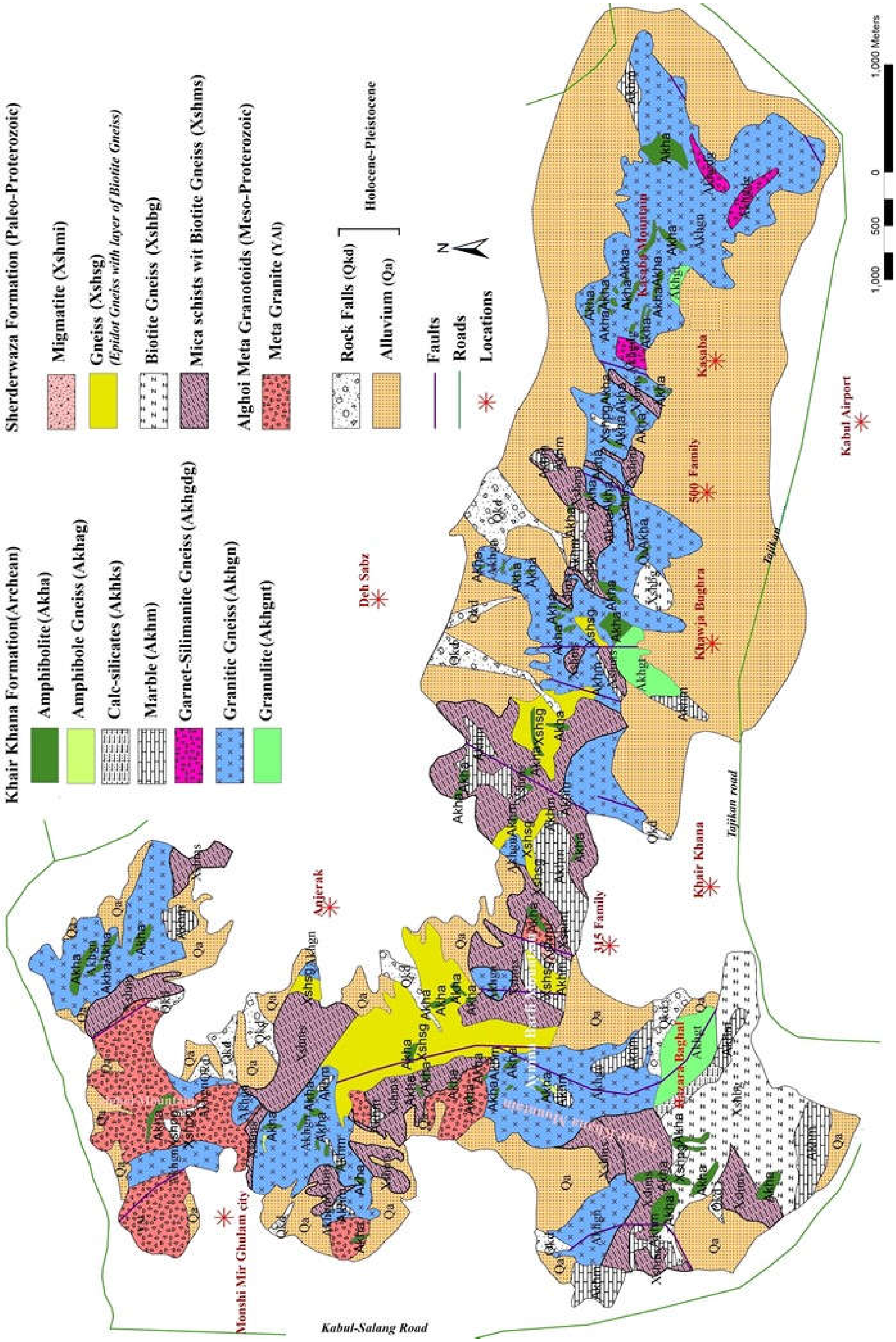

Fig.6. Geological map of the northern part of the study area (north of Kabul)

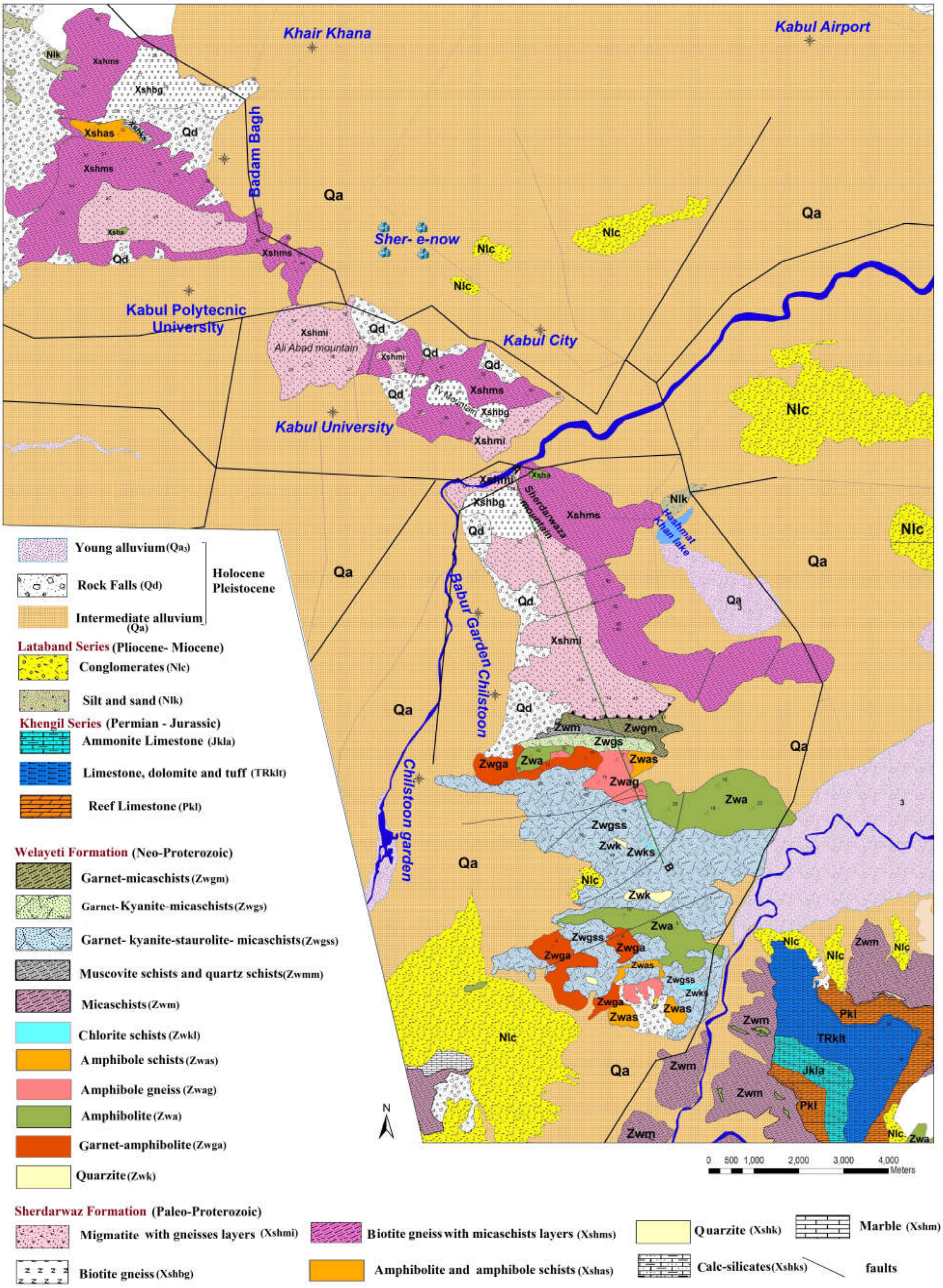

Fig. 7. Geological map of the southern part of the study area (south of Kabul)

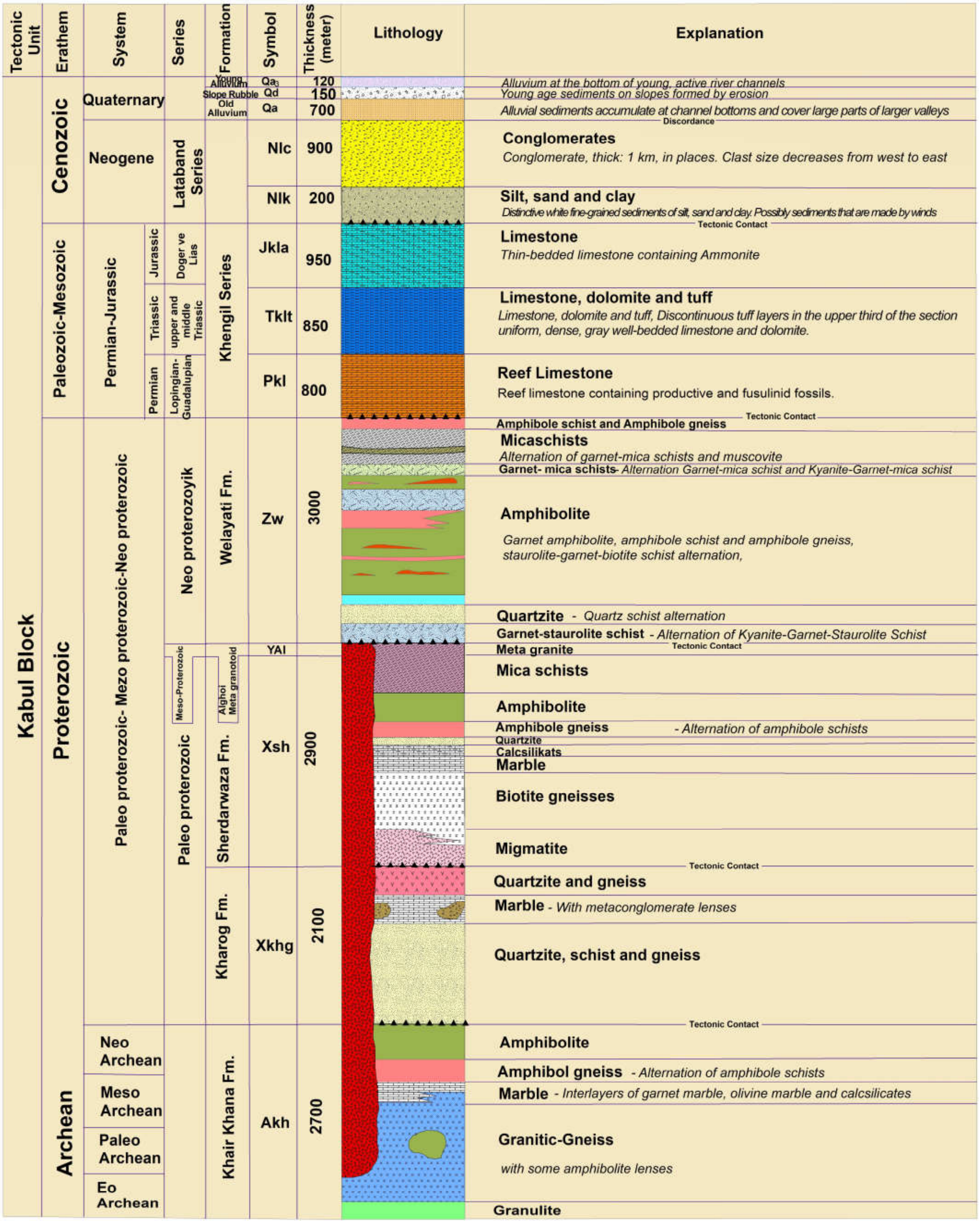

Fig. 8. General stratigraphic column of Kabul Block

Granulite

They are medium-grained, brownish-altered and rather hard rocks. Pyroxenes (clinopyroxene and orthopyroxene) are prominent in the granulite observed in the Khair Khana mountains. In addition, some feldspar minerals are in the form of prophyroblasts (Fig. 9 a, and b). Other granulites were observed in the 500-Family mountains (Kotal-e-Dekapak). Orthopyroxene and clinopyroxenes are observed in these rocks, and are mostly prismatic. Under the microscope, its colour ranges from pale orange to pale green. The amount of clinopyroxene is higher than orthopyroxene and they form small-sized minerals. Minor minerals observed here are magnetite, apatite and sphene. Granulites have a granonematoblastic texture and their structure is foliated (Fig 9 c, d, e and f). Granulites are medium to coarse-grained. As a mineralogical composition, it contains plagioclase (30-40%), quartz (25-30%) and K-feldspar (10-15%), orthopyroxene (<10%) and clinopyroxene (<10%). Orthopyroxenes occur as sub-idioblastic to xenoblastic prismatic grains of approximately 0.8 – 1.9 mm in diameter (Fig 9a and b). Plagioclases have hypo-idomorphic forms that usually have a thin polysynthetic, in which antiperthitic and myrmekitic texture are observed. Potassium feldspars are mostly xenomorphic forms, with a perthitic structure. Orthopyroxenes consist of hypo-idomorphic granules that have an elongated prismatic shape. Monoclinic pyroxenes are augite. In some granulites, amphiboles have developed which have a greenish-brown colour.

Granitic -Gneiss

Granite gneisses in the Khair khana Formation have a very wide distribution and can be called the basement rocks of the Khair khana Formation. Paragneisses are observed in contact with marbles and schists in all sections from the Alghoi Mountains to the Khawjeh Rawash Mountains (Fig. 10 and 11).

Hornblend Gneiss

The composition of these granitic gneisses includes hornblende (10-20%), quartz (15-20%), and feldspar (25-40%). Feldspar is widely observed in it, and in some places, pyroxene relicts are also present among the plagioclases. These rocks have granoblastic texture and massive and rarely foliation structure (Fig.10 c, d and Fig. 11 a, b).

Garnet – Biotite Gneiss

Small garnet porphyroblasts are seen in this type of granitic gneisses. The amount of garnet reaches approximately 5%. These gneisses are commonly found in the Kasaba mountains. The amount of plagioclase is 48%, quartz is 25%, potassium feldspar is 11% and biotite is 11% (Fig. 10 a, b and Fig. 11c). These rocks are massive in structure and lepidogranoblastic in texture.

Pyroxene Gneiss

These gneisses contain both clinopyroxene and orthopyroxene, and these pyroxenes have sometimes been converted to chlorite. In addition, microcline, plagioclase and quartz are observed in these rocks. The structure of these rocks is foliated and, in some cases, a massive structure is seen. The structure is granolepidoblastic. These gneisses contain: quartz (10-20%), plagioclase (20-40%), biotite (10-20%) and pyroxene (5-10%) (Fig. 11 d, e and f)

Marble

Marbles consisting of calcite are very common in the area related to the Khair Khana formation. In appearance, Khair khana marbles are in two different colors, white and light green. Other minerals observed in it are muscovite, garnet, phlogopite and olivine. Marbles are coarse-grained.

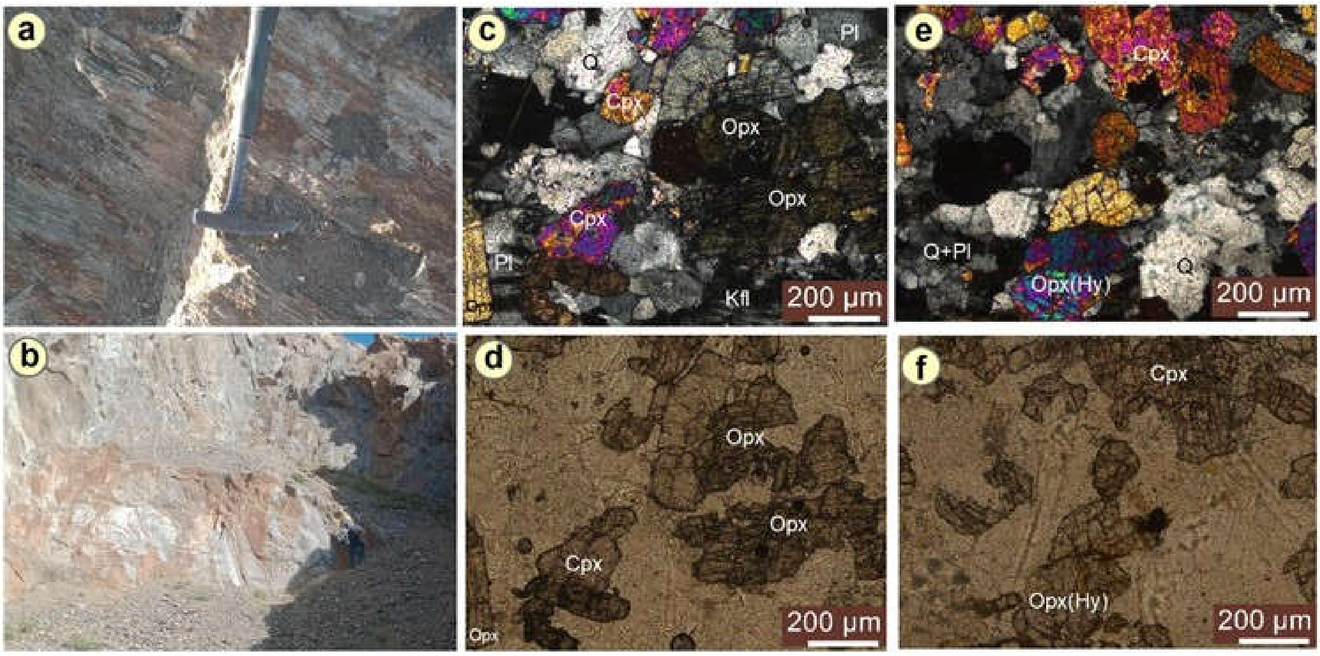

Fig. 9. Granulites of the Khair khana formation, **a**) Granulites with light brown alternating color and foliated structure in places. **b**) Brown altered colored and massive granulites belonging to the Khair khana formation. Location: Khair Khana mountains. c, d, e, f) the microscopic view of granulites, Q: Quartz, Pl: Plagioclase, Kfl. Potassium feldspar Cpx: Clinopyroxene, Opx: Orthoproxene. c, e) // nicol, d, f) / nicol

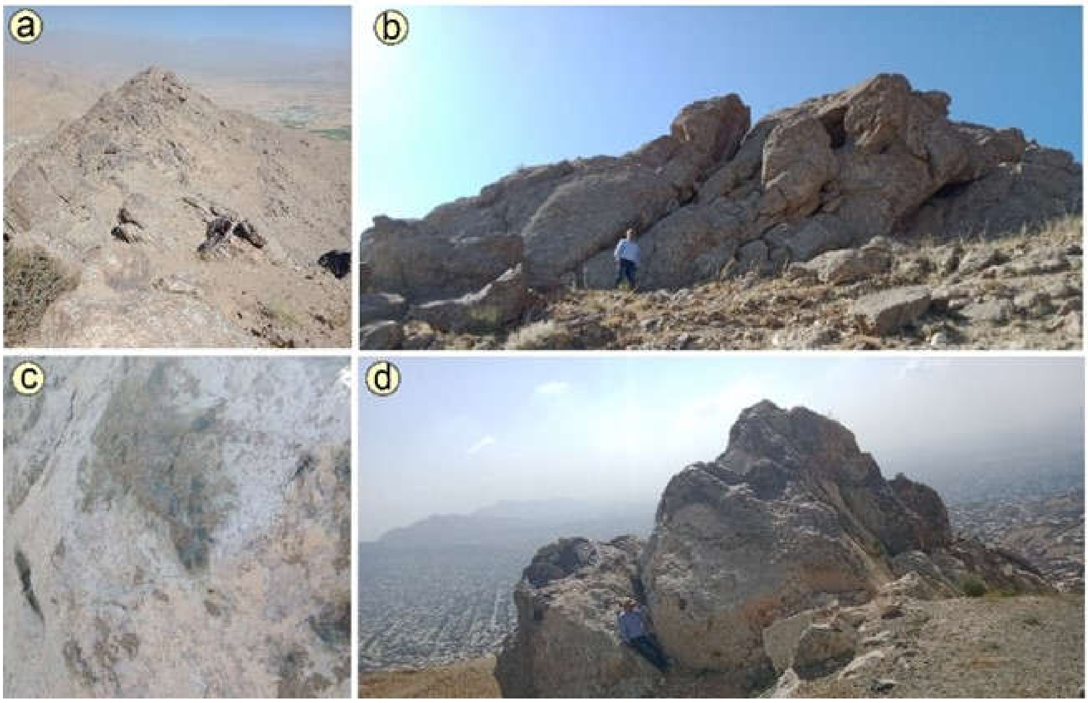

Fig.10. Granite gneisses. Location:kasaba and khair khana Mountains a: Longitudinal view, b: Transverse view c, d) Light gray granite gneisses. These gneisses contain abundant plagioclase contains hornblende and is seen in dark green color. Location: Khair Khana mountains

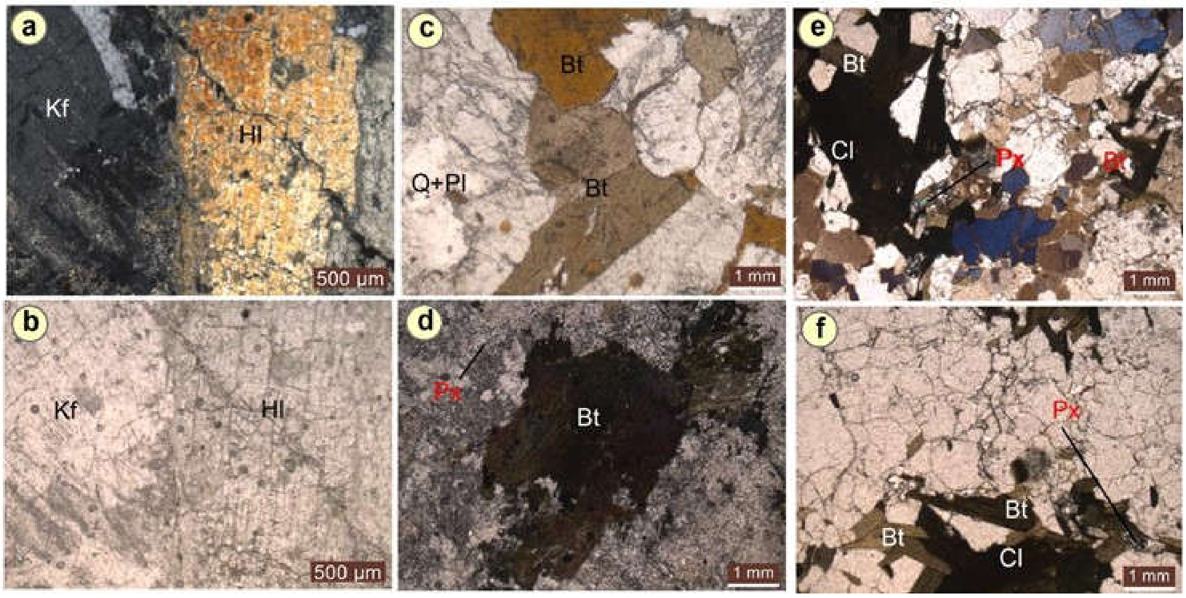

Fig.11. Microscopic view granitic gneiss in study area, a, b) hornblende gneiss, c) garnet biotite gneiss, d, e, f) pyroxene gneiss, a, f) /nicol, a, c, e, d) // nicol. Q: Quartz, Pl: Plagioclase, Cpx: Clinopyroxene, Bt: Biotite, Hl: Hornblende, Px: pyroxene, Cl: Chlorite, Kf: potassium feldspar

Amphibolites and Amphibole Gneiss

The distribution of amphibole-gneisses within the Khair Khana formation is quite low while amphibolites are quite common (Fig. 12a, b and c). Amphibolites are generally found in the form of lenses between granitic gneisses. Especially amphibolites and epidote-amphibolites are quite common. Amphibolite contains small amounts of quartz, but also commonly hornblende and plagioclase. Quartz is 1 - 5%. More than 10% quartz was observed in some samples. Amphibolites are dark green - black in color and fine - medium grained (Fig. 12a, b and c). The main component of amphibolites is hornblende (65-90%), varying from dark green to light green to yellowish green. It contains sphene, ilmenite and apatite as secondary minerals. Especially in amphibolites, sphene is quite common. It is mostly massive and has a granonematoblastic texture (Fig. 12a and d).

Amphibole gneisses have a distinct folate structure and are granonematoblastic in texture. They contain more than 85% hornblende in their composition. They also contain quartz minerals. These are mostly in the form of xenoblasts. Plagioclases are generally subhedral and have abundant inclusions (Fig. 12d, e and f).

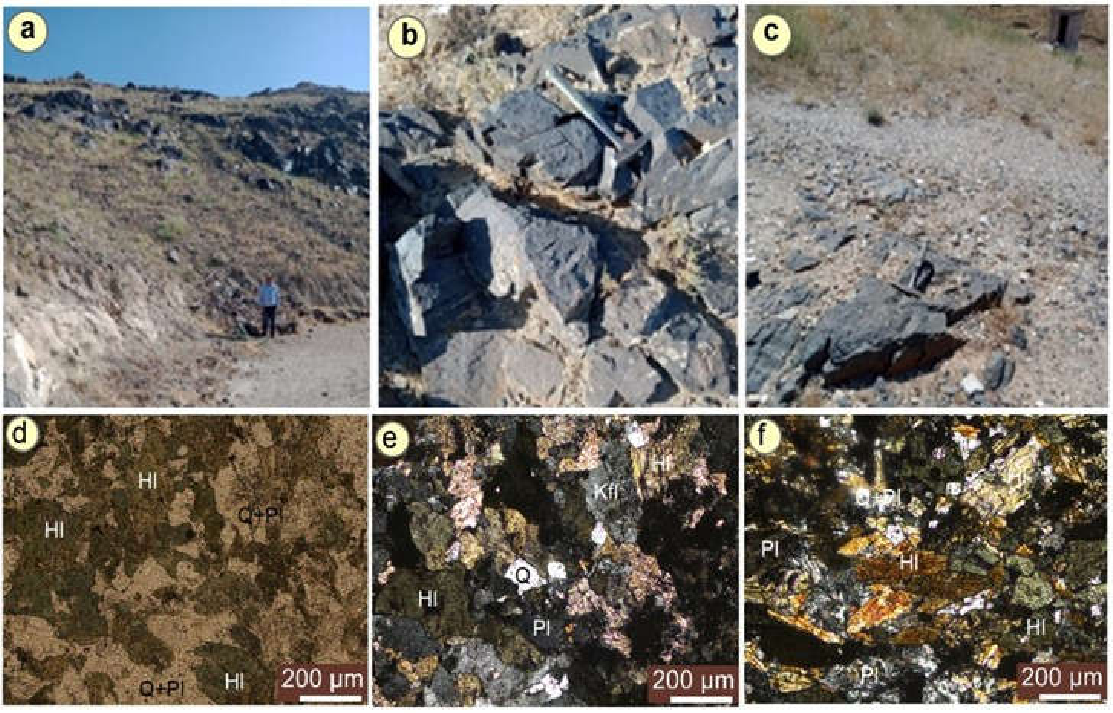

Fig.12. Amphibolite and amphibole gneisses observed in the Khair Khane formation. a, b) Amphibolites observed in the kasaba mountains, c) Amphibole gneisses observed in the Shakar Dara mountains. d, e, f) Microscopic view amphibolite and amphibole gneisses in study area. Q: Quartz, Pl: Plagioclase, Hl: Hornblende

A.2. Sherdarwaza formation

The Sherdarwaza formation is observed in the western part of the Khair Khana mountains, behind the Polytechnic University, Aliabad Mountain, Asmayee mountain Sherdarwaza mountain, Zanburkshah mountain, east of the Kasaba mountains, and north of the Kabul block. It was first named by [12]. The age of this formation was stated as Paleo-Proterozoic by [12]. The thickness of this formation is 2900 meters. Granite, granodiorite, and meta-granites were observed in the formation. According to field observations, the dispersion of marbles in this formation is considerably less than in the Khair Khana formation. The main lithologies in this formation are as a below

Quartzites

In the lower levels of the Sherdarwaza formation, they are in thin layers varying from 0.5 meters to 5 meters in thickness. Their thickness reaches up to 20 meters.

Amphibolites

They are observed at all levels of the Sherdarwaza formation. It is in levels of several meters, sometimes from 10-20 meters to 150 meters, and more in thickness. Garnet porphyroblasts are observed in it. It is observed as massive and foliated. Amphibolites are found in the forms of amphibolites, amphibole gneiss and garnet amphibolites. Amphibolites are composed of up to 90% of hornblende, plagioclase up to 25% of quartz to 15%, and epidote and zoisite are also found in them. Garnets in amphibolites are generally in the form of porphyroblasts (Fig. 13).

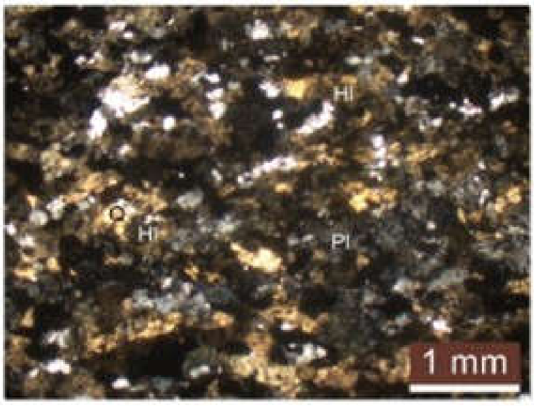

Fig. 13. Amphibole gneisses observed in the Sherdarwaza formation. // Nicol, Q: Quartz, Pl: Plagioclase, Hl: Hornblende

Marbles

They are white-yellow, cream, green-colored, and thick-bedded in the lower levels of the Sherdarwaza formation. Their thickness varies from a few meters to 50 meters. Their texture is granoblastic and their structure is massive, their composition is 75 to 99 percent of calcites and also in their composition serpentine (chrysotile) is observed at 3 to 4 percent and in some cases, apatite is also observed.

Biotite Gneisses

Biotite gneiss is widely observed within the Sherdarwaza formation. It is observed in the north of the Kabul Technical Institute, on Television Mountain, and Khair Khana. These biotite gneisses often contain more than 30% mica with a grain size large enough to be seen with the naked eye. The most common minerals of these gneisses are quartz and mica.

These gneisses are widely distributed within the Sherdarwaza formation, with thicknesses generally varying between 3 meters and 20-40 meters, and reaching up to 100 meters in some places.

Biotite gneiss usually contains biotite, but in some parts, garnet and muscovite are also found in their composition. Quartz (10-20), plagioclase (20-30), microcline (<10%), and also biotite (<10%) are observed in the composition of theses gneisses. These rocks have granoblastic and granolepidoblastic textures and show foliated structures. The secondary minerals in these gneisses are sphene, apatite, and zircon (Fig 14).

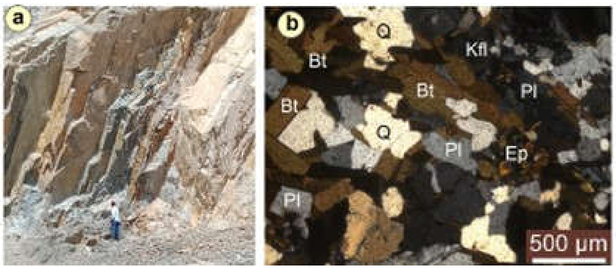

Fig. 14. Biotite gneisses observed in the Sherdarwaza formation. a: field photo, b: microscopic view, Q: Quartz, Bt: Biotite, Pl: Plagioclase, Ep: Epidot, Kfl: Potassium feldspar

Micachists

Schists related to Sherdarwaza formation are usually observed intermittently with biotite gneisses. These rocks have granolepidoblastic texture and show foliated structure. Mica schists usually contain biotite, and also in the composition of these schists: Quartz (20-30), plagioclase (5-10), microcline (<5%) and also biotite (10-20%) are observed (Fig. 15).

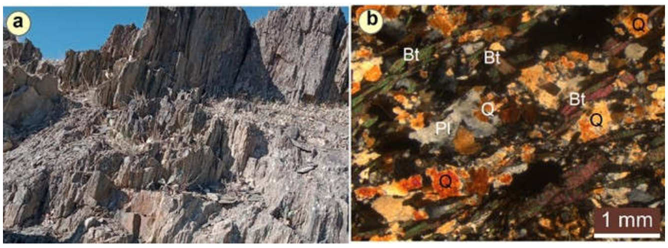

Fig. 15. Mica schists observed in the Sherdarwaza formation. a: field photo, b: microscopic view

Migmatite

Migmatites are observed in the Sakhi Pass valley, north of Kabul Polytechnic University, on Sherdarwaza Mountain near Takhnikam Institute. It was formed by the partial anatexis of gneisses. In migmatites, flebitic structure and folded structure are commonly observed (Fig. 16).

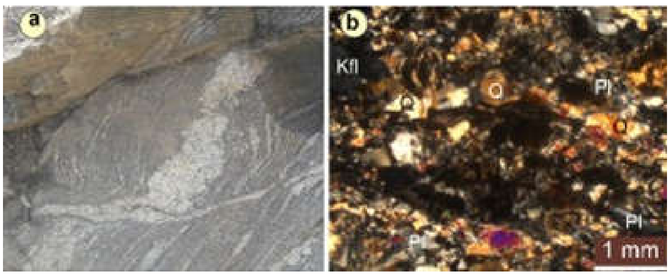

Fig. 16. Migmatite observed in the Sherdarwaza formation. a: field photo, b: microscopic view, Q: Quartz, Bt: Biotite , Pl: Plagioclase, Ep: Epidot, Kfl: Potassium feldspar

A.3. Alghoi Granitoids

Granitoids and granite formations were encountered in the study area, the largest of which was observed in the northern part of the region. These granitoids are observed in the Alghoi mountains and the Khair khana mountains It is also seen in Sherdarwaza and Afshar mountains. Some granite masses are also found in the Sherdarwaza formation and their dimensions vary, usually, from 10 to 100 square meter masses. These granites, which are surrounded by metamorphic in contact, contain coarse quartz, k-feldspar, plagioclase, biotite, and hornblende. Their contacts with the host rocks are conformable (Fig. 17).

These granites are dated as Archean by [12] but, based on field studies and their location among neighbouring rocks, their age can be determined as Mesoproterozoic (Fig. 17).

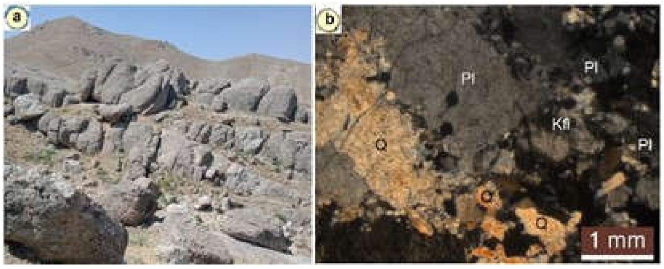

Fig. 17. Granite observed in the Sherdarwaza formation. a, field photo. b, microscopic view, Q: Quartz, Pl: Plagioclase, Kfl: potassium feldspar

A.4. Welayati formation

This formation is observed in the southern part of the study area. It was first named by [12]. This formation is widely observed in the mountains between the Kabul and Logar rivers. It is mostly seen in the Chehelston mountains, the Taraki mountains and the Siahbini mountains. In addition, the Welayati formation is observed in the Shakh-e-berentai mountains, where carbonate rocks belonging to the Khingel formation are observed. The age of this formation was stated as Neo-Proterozoic by [17]. The thickness of the formation is 3000 meters.

The Welayati formation consists of the lower part, which is generally composed of quartzites and their intercalation with schists and amphibolites (micaschist, garnet schist, quartzite, chlorite schist, amphibolite, amphibole schist, amphibole gneiss) and the upper part, which is commonly composed of schists (granite-staurolite schist, micaschist) be divided two sections. The Welayati formation, seen in the south and northeast of Kabul, overlies the Sherdarwaza formation harmoniously. The Welayati formation consists of garnet amphibolites and various crystalline schists including biotite schists, staurolite-garnet-biotite schists, muscovite-kyanite-garnet schists, and muscovite quartzites [25]. According to [17], this formation consists of schist at the base, amphibolite in the middle, and amphibolite-schist alternation at the top. Thus, the Welayati formation is divided into two parts: the lower part, which is generally composed of quartzites and alternating with schists and amphibolites, and the upper part, which consists of schists (Fig. 18 a, b and c).

The following lithologies are observed in the Welayati formation: Quartzite, amphibolites (amphibolite, garnet amphibolite) and amphibole gneisses, schists (garnet-staurolite schist, garnet-kyanite schist, mica schist, garnet-muscovite schist).

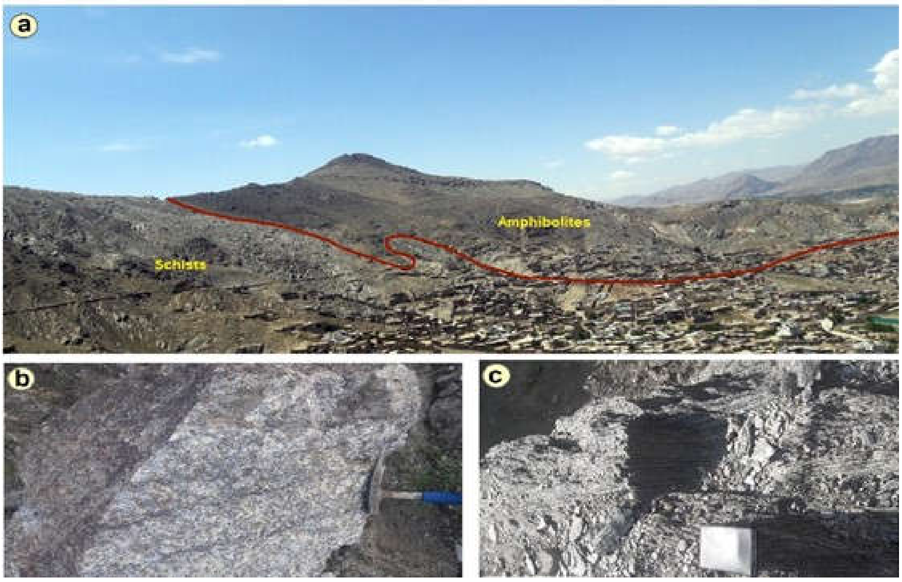

Fig. 18. a) Amphibolites and schists observed in the Welayeti formation, a) Amphibolite, b) Garnet-staurolite-schists, c) Micaschists. Location: Chehelston mountains

Amphibolite

Amphibolites are very common in the formation, and observed in the Chehelston Mountains as garnet amphibolites and amphibolschists. It is in contact with amphibolite schists (Fig. 18). The amphibolites associated with this formation can be divided into three groups. These are; amphibolites, garnet amphibolites and amphibole gneiss.

Garnet is not observed in some amphibolites. The mineral assemblage is amphibole dominated by plagioclase, quartz and opaque phases at the lower level. In some places, amphibole is partially replaced by chlorite or epidote.

These amphibolites make up 90% of Hornblende, including quartz and plagioclase, and are among the rare minerals like, epidote, rutile and magnetite observed.

Plagioclase forms lenticular or long xenoblastic grains. Quartz crystals have a very fine uniformity that seen in the matrix and inclusions. These amphibolites have a foliated structure and their texture is nematoblastic.

Garnet Amphibolite

Garnet-amphibolite samples are significantly coarser-grained than normal amphibolite ones. Garnets are usually observed as sub-idioblastic and hexagonal octagonal porphyroblasts. The garnet in amphibolite is highly eroded and has been partially replaced by chlorite and sometimes calcite. It contains abundant quartz and small feldspar inclusions showing poor alignment. Hornblende values go up to 80% and are mostly seen in prismatic form.

Amphibole Gneiss

The distinction between amphibolite and amphibole gneiss is made by the relative abundance of quartz and amphibole, with more quartz-rich called amphibole gneiss.

Schists

It is commonly observed in the Welayati formation. It is compatible with quartzites. In this formation, kyanite garnet staurolite schist, garnet-mica schist, kyanite garnet micaschist, garnet muscovite schist, chlorite schist, and mica-quartz schist were observed (Fig 19. c and d).

Kyanite garnet-staurolite schists are grey in colour and garnet porphyroblasts are very prominent. These schists are quite common in the formation.

Kyanite-Garnet-Staurolite Schist

Mica can be seen in field samples and brown garnet grains can also be seen. These rocks have a foliated structure and a granolipidoblast texture.

Staurolites are distinctly yellow in color and prismatic in shape and sometimes contain quartz and plagioclase inclusions (Fig.). in these schists, their ratio is up to 15%. They are usually seen as porphyroblasts. Generally, the presence of staurolite is seen together with kyanite.

Garnets are colourless to pale brownish yellow. These appear as xenoblastic sub-idioblastic and prismatic crystals. These garnets are observed as very large porphyroblasts. kyanite usually occurs in these schists as sub-idioblastic and prismatic crystals.

The Kyanite-Garnet-Staurolite Schist specimens are characterized by the presence of garnet and staurolite porphyroblasts, white mica and minor biotite (Fig 19. a and b).

The main minerals are quartz with accessory amounts of apatite, ilmenite and monazite. It is seen that porphyroblasts composed of plagioclase and biotite grow inordinately in foliation. Epidote is found in the inclusion phase of garnets and usually replaces plagioclase.

Garnet-Mica Schist and Kyanite-Garnet-Mica Schist

The matrix of the garnet-mica schist consists of quartz and plagioclase with minor amounts of apatite and tourmaline. Biotite occurs in green to dark green colours, most of them seen as prismatic and sup-idoblasts. In some cases, biotite has changed to chlorite. Feldspars are seen as plagioclase. Quartz, muscovite, biotite, garnet, sphene, rutile and opaque mineral inclusions are seen in plagioclase. Garnets are pale brownish yellow (Fig 19-c, d, e and f).

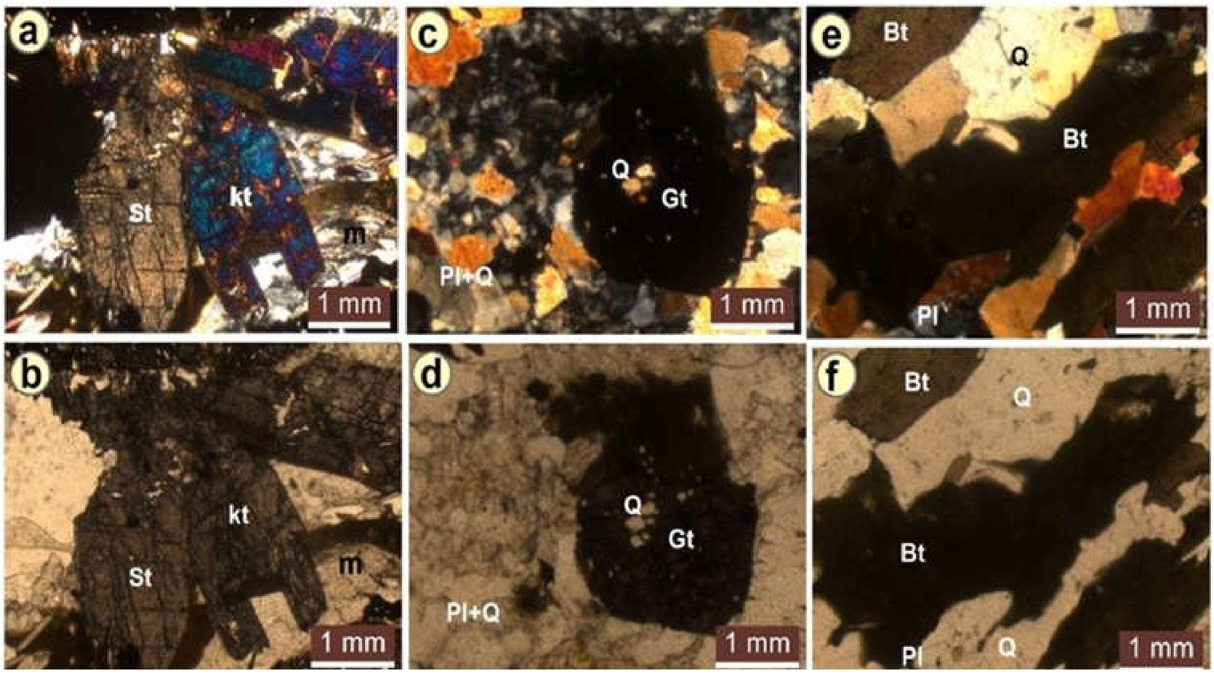

Fig 19. The microscopic view of different schist ralted to Welayeti formation, garnet perfiroblsts and kyanite and staurolite are seen, a, b) kyanite-garnet-staurolite mica schist, c, d) garnet mica schist, e, f) mica schist, a, c, e) //nicol, b, d, f) / nicol. St: staourolite, Gt: garnet, Pl: plagioclase, Q: quartz, Bt: biotite, kt: kyanite

These appear as xenoblastic sub-idioblastic and prismatic crystals. These garnets are sometimes very abundant and are observed as very large porphyroblasts. Garnet porphyroblasts are bordered by biotite, quartz chlorite and feldspar. Rutile seen as inclusions in both garnet and is often interbedded with or bordered by ilmenite.

Garnet-Muscovite Schist

Biotite is not seen in these schists, they contain up to 90% muscovite, quartz and plagioclase are also observed in their composition, garnet porphyroblasts are observed in the form of fabric, the spaces of which are usually filled with muscovite. These rocks have foliated structure and granolepidoblastic texture. Prismatic - short prismatic crystals consisting of tourmaline, apatite and zircon are observed.

V. DISCUSSION

Ref. [12] stated that the Kabul Block is composed of the lower Welayati formation and the overlying Sherdarwaza formation, and the Sherdarwaza formation with a thickness of about 5.5 km is predominantly composed of marble, amphibolite, quartzite, gneiss and migmatite. However, field and laboratory studies show that Sherdarwaza formation also has schist layers in its composition and is usually seen together with biotite-gneiss layers. In most cases, the schist structure has been preserved in biotite-gneiss layers and also granite masses with different dimensions up to 40 meters can be seen in this formation, which indicates the granitization process. Most of this granite is in contact with magmatites, which indicates that these granites are palingenetic formation and locally formed under the anatexis process.

Ref. [19] and [18] in their study on Kabul block stated that this Block is an elongate crustal fragment which cuts across the Afghan Central Blocks, adjoining the Indian and Eurasian continents. The granulite-facies assemblages are overprinted by a younger amphibolite-facies event that is characterized by the growth of garnet at the expense of the granulite-facies phases, but here we can also point out that granulite in Kabul Block are together with granite gneisses and it can be separated under one formation, granulites have been mineralized with different mineral composition, in some cases they are without garnet. The amount of plagioclase is higher in them. In the vast majority of them, orthopyroxenes are observed. Granulites is usually seen alternately with green and light layers. In some cases, the composition of granulites is very similar to that of quartz mangarites.

VI. CONCLUSION

Precambrian aged Kabul Block including metamorphic rocks take places at the base of the study area. The Neo-Proterozoic Welayati formation overlies the Paleo-Proterozoic Sherdarwaza formation with a tectonic contact, and they both overlay Khair Khana formation. In the region, Alghoi meta granitoid intruded into both Khair Khana and Sherdarwaza formations. Therefore, metamorphic rocks in the study area are divided in to four formations which are Khair Khana formation, Sherdarwaza formation, Alghoi meta granitoid and Welayeti formation. The Khair Khana formation consists of granulite, granitic gneiss, marble, amphibolite and amphibole gneiss. The Sherdarwaza formation consists of migmatite, biotite gneiss, marble, quartzite, amphibole gneiss, amphibolite and micashist. The Welayati formation consists of the lower part, which is generally composed of quartzites and their intercalation with schists and amphibolites (micaschist, garnet schist, quartzite, chlorite schist, amphibolite, amphibole schist, amphibole gneiss) and the upper part, which is commonly composed of schists (granite-staurolite schist, micaschist) be divided two sections. Algoi metagranitoid is composed of metagranites. The presence of granulites and granitic gneisses in Khair khana formation indicates the oldest formation in the study area. It shows the formation of granulite facies in the Kable Block, which is located under high temperature and pressure of the metamorphism process and also shows that this block is related to a segment of Columbia and Rodinia supercontinents during Paleo-Proterozoic collisional events. On the other hand, migmatites indicate the melting process in the form of anataxis, which shows that the area has undergone the process of ultra-metamorphism and the granitization process has taken place.

Authors' Contributions

The authors' contributions to the paper are equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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