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Mineralogy and Geochemistry of talc deposits in the Khogyani district of the Nangarhar province, Afghanistan

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ABSTRACT

The article consists of two parts. In the first part of the article the geological Structure of the Jalalabad tectonic block is shortly discussed, and the second part covers the geological structure, mineralogy of the country rocks, geochemical characteristics of the talc and its country rock and the genesis of the Khogyani talc deposits in Nangarhar Province have been studied and researched.

The talc deposits under investigation are located approximately 75Km southeast of Jalalabad city in Khogyani district of Nangarhar Province. In order to achieve the aim of the research, in addition to field observations and measurements, numerous samples from talc and its country rocks were collected from the study area. These samples were analyzed, using the lab facilities in the Afghanistan Geological Survey, Isan laboratory in Turkey and Shikozan laboratory in Japan. The samples were analyzed for their petrographic, mineralogical and geochemical characteristics and their trace elements' composition; and bases on these characteristics the quality of the talc has been evaluated.

The results show that Talc formation is genetically related to carbonate rocks especially dolomite marble, resulting from the activity of hydrothermal solution and their subsequent metamorphism. The results also show that all talc samples have a monomineralic composition with talc contents approximately 99.1 percent; the presence of harmful and foreign minerals is often counted as nothing. The structure and texture of the majority of studies samples are similar; the structure is massive and the texture is lepidoblastic, which indicate the high pressure in the process of metamorphism. The petrographic and geochemical analysis (using XRF and XRD) of the collected samples suggest that the quality of Khogyani talc is very high, due to its monomineralic composition, brightness, greasy and some other chemical-physical characteristics.

As talc is genetically linked to the marble, there are some of the good quality marble deposits in the region. In addition to talc and marble, the area is also rich in magnesite' deposits, and in some places their reserves has the mining and industrial potential, therefore the area is also rich and interesting for magnesite' deposits as well.

1. Research aim and Methods

The principle aim of this research is to study the mineralogical, petrographic and geochemical composition of talc rich rocks of the Khogyani area, located in the Nangarhar province, as well as to compare the quality of talc in the study area with other talc in the world.

In order to achieve the aim of the research, various libraries, field and laboratory methods were used. In the library method, different books, research articles and online resources were studied in order to collect information related to the geological structure of the Nangarhar tectonic zone, talc deposits and its economic importance in Afghanistan and the world. To study the mineralogy and geochemistry of the talc and its country rocks, the study areas were visited and necessary field observations and measurements were made; in additions, various talc and country rocks samples have been collected and analyzed for their geochemistry, mineralogy and petrography, using petrographic microscope, XRF and XRD analytical instruments.

2. Talc characteristics and Geology of the area

Talc is one of the minerals that have always been used in various aspects of life and in numerous parts of the industry. The use of this mineral on a large scale depends on a number of properties, which include: softness and lubrication, chemical durability, high brightness in powders, heat resistance, dielectric properties, high absorption capacity and etc. Large amounts of talc are used in tile making and in radio parts; the construction tiles use those talc, which have a high purity. In addition, talc is used in the paper, rubber, paint, cosmetics, baby powder, and pharmaceutical industries. The harmful ingredients in talc include iron, calcium and asbestoses. Based on the above properties and availability of the vast deposit of talc in the country, research on talc is very important and interesting.

If we take a brief look at the geology of Afghanistan, talc has been found in various areas of the eastern Nangarhar province such as Achin, Mamakhil, Agam, Gandomak, Sherzad, Tato, Pachir, Anzeri Tangy, Wazir Tangy; as well as

other provinces such as Parwan, Kabul, Wardak, Baghlan, Laghman and other areas of the country. Many high-quality talc-deposits particularly in the eastern part of the country are being exploited unprofessionally by the smugglers and smuggled out to the neighboring countries [1 and 2].

Since the Khogyani talc deposit and its adjacent talc rich occurrences and showings are located in Nangarhar province and in the tectonic zone of the Jalalabad (Fig. 1), it is necessary to consider the brief evaluation of the geological structure of this tectonic zone.

The Jalalabad tectonic zone is located in the eastern part of Afghanistan and at the southeastern part of the Nuristan tectonic zone (Fig. 1). The zone was first separated by Slavin and Sayed Hashim Mirzad (1969) under the name of Jalalabad zone. Kalchanof and Sayed Hashim Mirzad (1968) in a tectonic map consider and relate this zone to the core of the Alps folding [4].

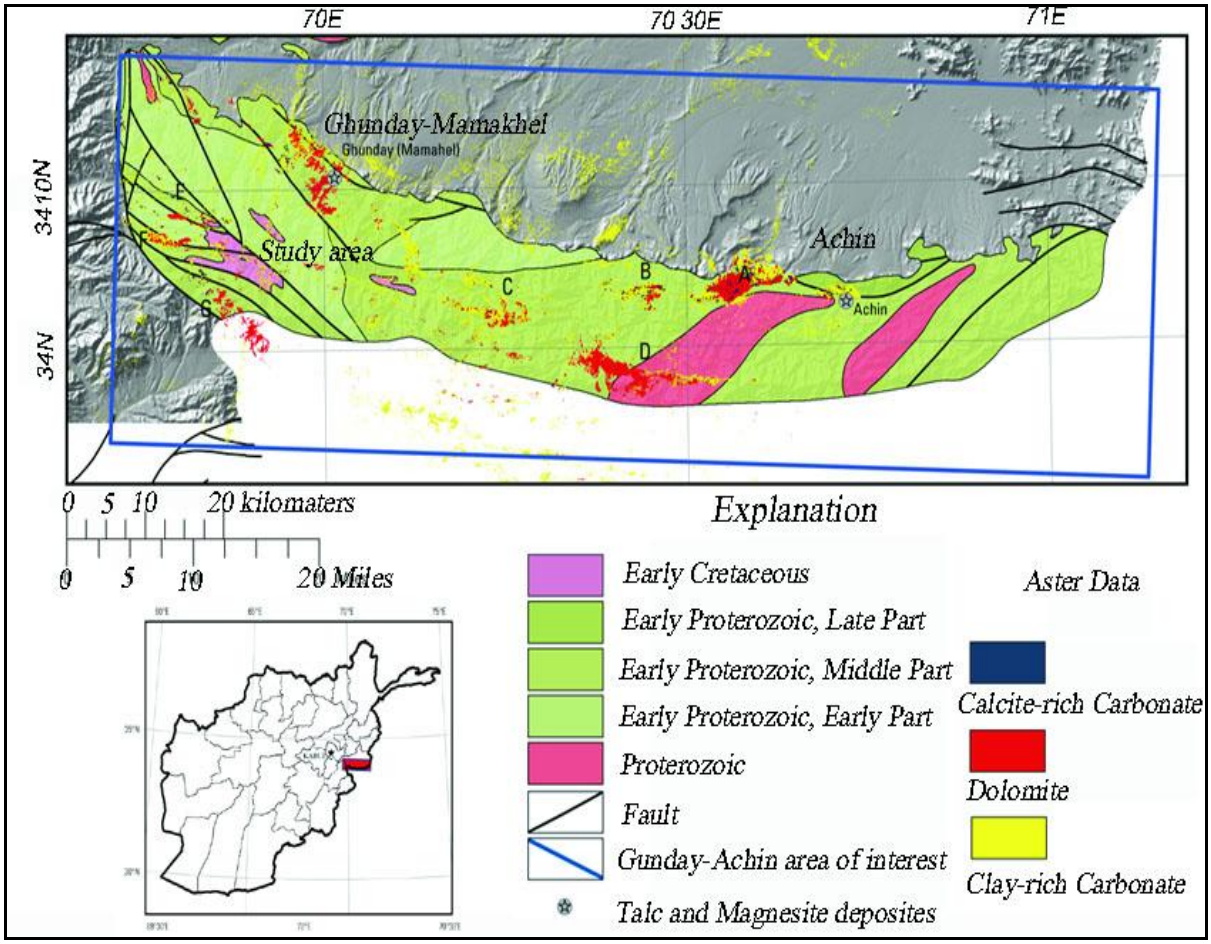

Fig. 1: Geological map of Jalalabad Tectonic Zone (Spinghar Block). [7]

The Jalalabad zone is part of the depth of the former Cimmerian folding; the deposits of this zone are located above the folding and ridges of the former Cimmerian that forms the foundation of the geocyncline [4]. These folding outcropped to the surface of the earth in the mountains. In the eastern part of the zone and in the southeastern part of the Jalalabad city, on the left bank of the Kabul River and on the banks of the Kunar River, the upper Paleozoic and lower Mesozoic sediments are visible in the surface. The central part of the zone is covered by Neogene sediments [4].

The rocks and sediments of the Jalalabad zone ranging from Archean-Proterozoic to quaternary in age (Fig. 2b). The Archean-Proterozoic formations composed of various gneisses, quartzite, amphibolites, and crystalline schists, which containing the beds and layers of the white-grayish marble. The thickness of the marble beds and layers inside the gneisses varies from 300 - 600 meters. The Paleozoic formations are relatively extensive in the Jalalabad zone, which include the Ordovician, Silurian, Devonian, and Carboniferous formations. These formations are composed of quartzite, schists, sandstones, argillites, and limestone. The contact relationship between these formations is not clear in some places. The sediments of the Neogene unconformably overlie the older sediments, and composed of conglomerates, sandstones, and clays. Quaternary sediments have filled the rivers valleys and their thickness is not very high [2] [3] and [9].

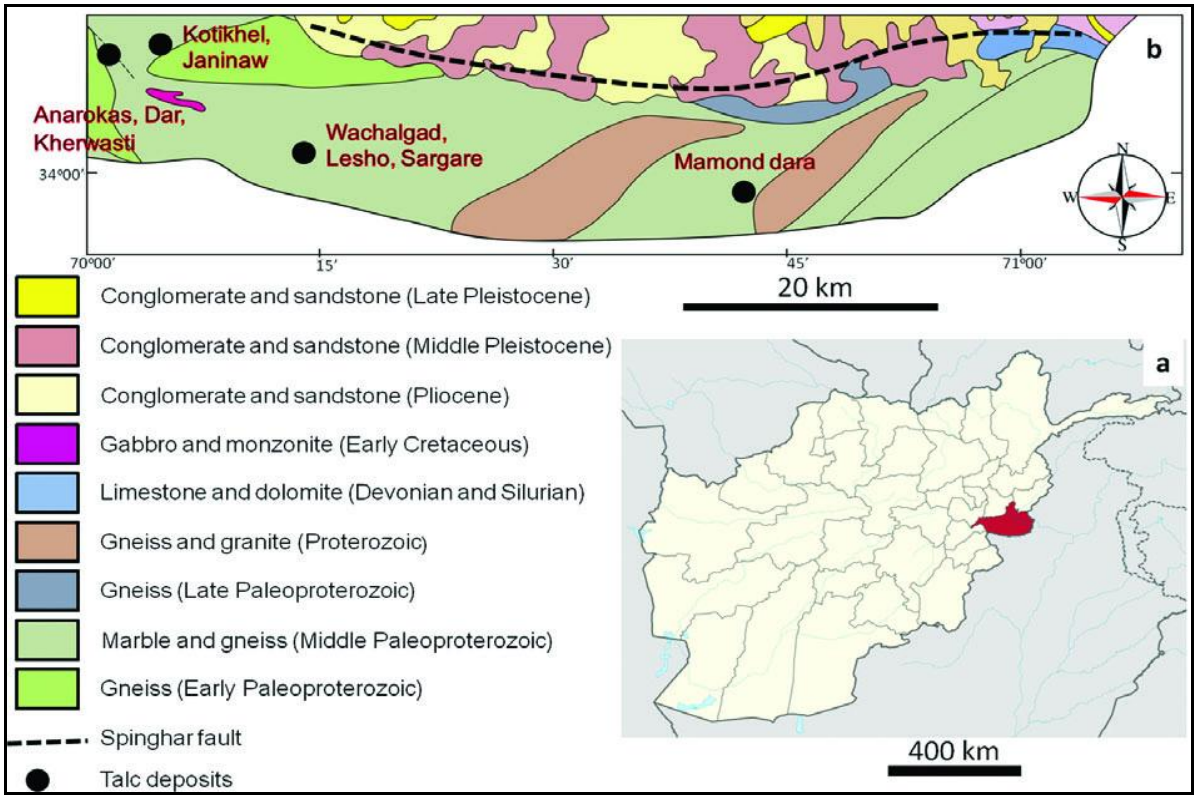

Fig. 2: a- Location of the Nangarhar province in the geographic map of Afghanistan, b- Geological map of Spinghar block and location of talc mining areas within it [13].

In the Jalalabad zone, extensive igneous rocks are existed, which are visible on the surface in the left part of the Kunar River and in the Spinghar mountain ranges. The age and composition of these rocks are different and are divided into different complexes. In terms of composition, magmatic rocks contain granites, gabbro amphibolies, granodiorites, and albitites. These magmatic rocks are spread in different parts of this zone and are interesting in terms of having various mineral deposits.

Tectonically, the Jalalabad zone is associated with the Cimmerian structures, which divided into three structural-formations that relate to the AR-PR, O-T, and N-Q periods. [4]. in the tectonic map (1973), prepared by the Afghanistan Geological Survey (AGS), the following three zones have been divided in this region: the Kunar Tectonic Zone, the Spinghar Tectonic Zone, and the Jalalabad Deep region, which are separated by Kunar and Spinghar faults.

3. Geological characteristics and petrography of the Khogyani talc deposits

The Khogyani talc deposit and occurrences are located in the Khogyani district of the Nangarhar province (Fig. 2a). The talc of this minefield is located in a marble formation, which is cut by semi-concordannt dykes that has a composition of crystalline granitoids. The composition of the marble in this talc area is dolomitic, which is highly replaced by the quartzite and has become a thin beds and layers. In some places the repetitive layers of talc and magnesites can be observed.The presence of magnesite with the thickness of 1- 3 meters in marbles is rarely seen. The magnesite usually located close to the talc rich zones (Fig. 3H). These marbles are usually granular isometric under a microscope with its grains up to 2 mm in size, with schistose structure and granoblastic texture. The country rocks have evolved from serpentinized diabase (dolerite) and amphibolite dykes, chrysotile aggregates and antigorite (see Figs. 6c, d, e and h).

In the Khogyani minefields, the marble beds are 25-100 m thick, the magnesite and talc beds are 1-25m and 15m thick respectively. The magnesite of this region often has massive characteristics that are expressed in blocky and dimension forms but in large beds the magnesites are under intense pressure and cracked. In the folded sides to the southwest, the marble beds are thinner and in some areas are reflected in the form of lenses. The talc within the marble occur as veins, beds, layers and lenses, which forms a clear boundary between magnesite and marble (Figs. 3B, D and H).

The talc zones of Khogyani have a severely broken and displaced beds of marble, within which occur lens-like, vein-like, nest-like talc and amphibolite dykes. In some places amphibolites dykes have the tendency and shapes of the talc bodies, which cut the talc and magnesites beds, resulting the formation of irregular shapes zoning of talc veins (see Figs.3B, D and H and Figs. 6g and h). Within these amphibolites, which are mainly derived from albitite-plagioclase, saussurite amphibolites (up to 0.3 mm in thickness) and alkaline hornblendes occur; in addition saussurite epidote minerals can be observed in the form of prismatic grains thatt grows up to 0.1 mm within the plagioclase.

The Khogyani talc occurrences are placed within the deformed carbonaceous rocks, which has the age of upper Proterozoic (PR2). The mineralized formation in the area is the dolomitic marble which is host to the talc minerals. The host formation conformably overlies the middle Proterozoic aged crystalline schists,, and the rocks of the host formation are generally monoclinic in location and are generally inclined to the south and southwest, with an angle of inclination of 45- 85°. The dolomite marbles, with respect to their structural and

textural characteristics and their composition, are similar to their protolith sedimentary dolomite rich rocks; due to the regional metamorphism, within the light-grayish crystalline schist, the white marble and talc occur, within which the primary beds can be clearly observed. Minerals have grown unevenly throughout the Khogyani talc rich region, especially in the host formation. The amphibolites have magmatic origin; therefore have the characteristics of aphanitic structure.

4. Location of the collected samples

The Khogyani district of Nangarhar province is very interesting in terms of the presence of talc and magnesites deposits and occurrences. On this basis, petrographic and geochemical studies have been carried out on samples collected from the Kadekhil, Khairwast, Gandomak, Alifkhil and Wazir Tangi mining areas of this district.

The Kadekhil minefield is located 50 km southwest of Jalalabad city with coordinates (N: 34 15 19.1, E: 69 56 6.2) (Figs. 3A and B). The Khairwast minefield is located 58 km west of Jalalabad city with coordinates (N: 34 10 36.70, E: 70 00 03) (Figs. 3C and D). The Alifkhil minefield is located 75 km south of Jalalabad city with coordinates (N: 34 02 59.61, E: 70 14 17.41) (Figs. 3E and F), and the Wazir Tangi minefield is located 75 km south of Jalalabad city with coordinates (N: 34 06 50, E: 70 07 15) (Figs. 3G and H).

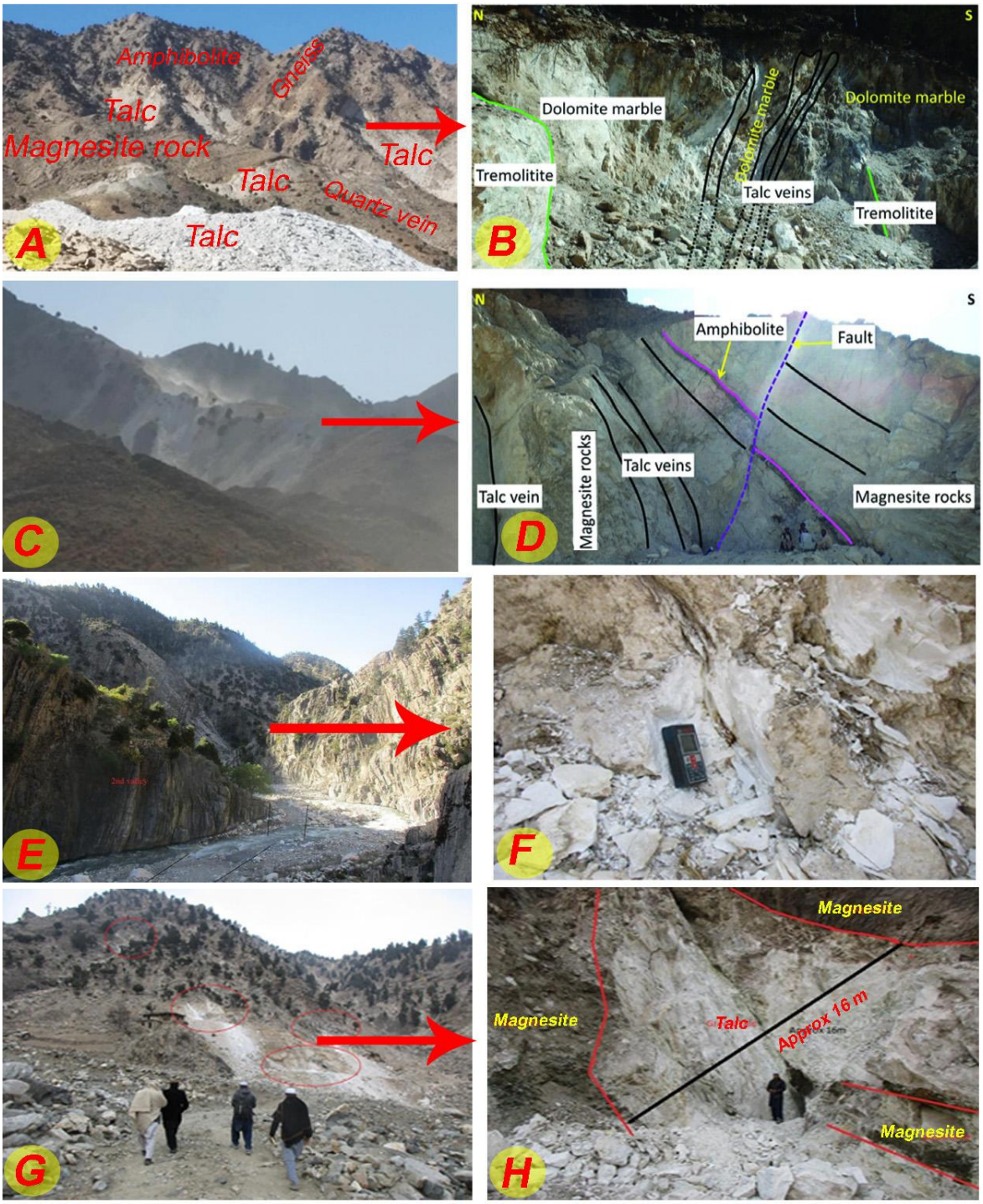

Fig.3. Outcrop photographs of Kadekhil (A & B), Khairwast (C & D), Alifkhil (E&F), and Wazir Tangi (G & H). Photos taken from [13 and 15].

5. The Petrographic description of the samples

The petrographic results, using a polarizing microscope, of the collected samples can be summarized as follow:

QAG.33: its color is greenish, structure is massive and texture is granoblastic. The essential minerals are hornblende (75%), quartz (10%), epidote (10%) and talc (3%). This sample is fine grain granular in which the most abundant mineral is hornblende with 75%, which is replaced by chlorite; the sphene (titanite) occurs as accessory mineral. The name of the rock can be fine grained detrital amphibolites (Figs. 4A and B).

061. Q1: Its color is grayish white and structure is massive and texture is semi-granoblastic. The essential minerals are sodium and potassium feldspar (30%), plagioclase (10%), quartz (30%), biotite (25%), muscovite (2%); and accessory mineral are apatite and zircon. This sample is fine grain biotitic gneiss in which both types of feldspar (sodium & potassium) as well as plagioclase makes 40% of rock constituents. Quartz and biotite are appear very clearly and very less amount of muscovite was also observed. Apatite and zircon crystals are grown in one direction (Figs. 4C and D).

065. Q3: The color is grayish white and structure is massive and texture is semi-granoblastic. The essential minerals of this sample are talc (99%), quartz (0.3%), and carbonate minerals (0.7%). This sample is essentially composed of a single mineral, which is talc with very less amount of carbonate minerals (Figs. 4E and F).

QKH11: The petrographic and geological characteristic of this sample is approximately the same as (065. Q3), however the percentage of talc in sample OKH11 reaches up to 99.5 and has a white color.

QWZ-22: The color is white and has a massive structure and lepidoblastic texture. The essential mineral of this sample are: magnesite (99.4%), quartz (0.3%), and calcite (0.1%). This sample is essentially made of mono-mineral, which is magnesite. The grain size is fine and their shape is granular and radios. Zircon can be observed as accessory mineral in this thin section (Figs. 4G and H).

67Q1: The color is grayish and has massive structure and granoblastic texture. The essential minerals of this sample are: quartz (40%), muscovite (30%), talc (15%), calcite (2%) and biotite (13%). Serpentine can also be seen in lower concentration in this sample. This sample is collected from the contact of talc and marble. The name of the rock can be coarse grain muscovite quartzite (Figs. 4I and J).

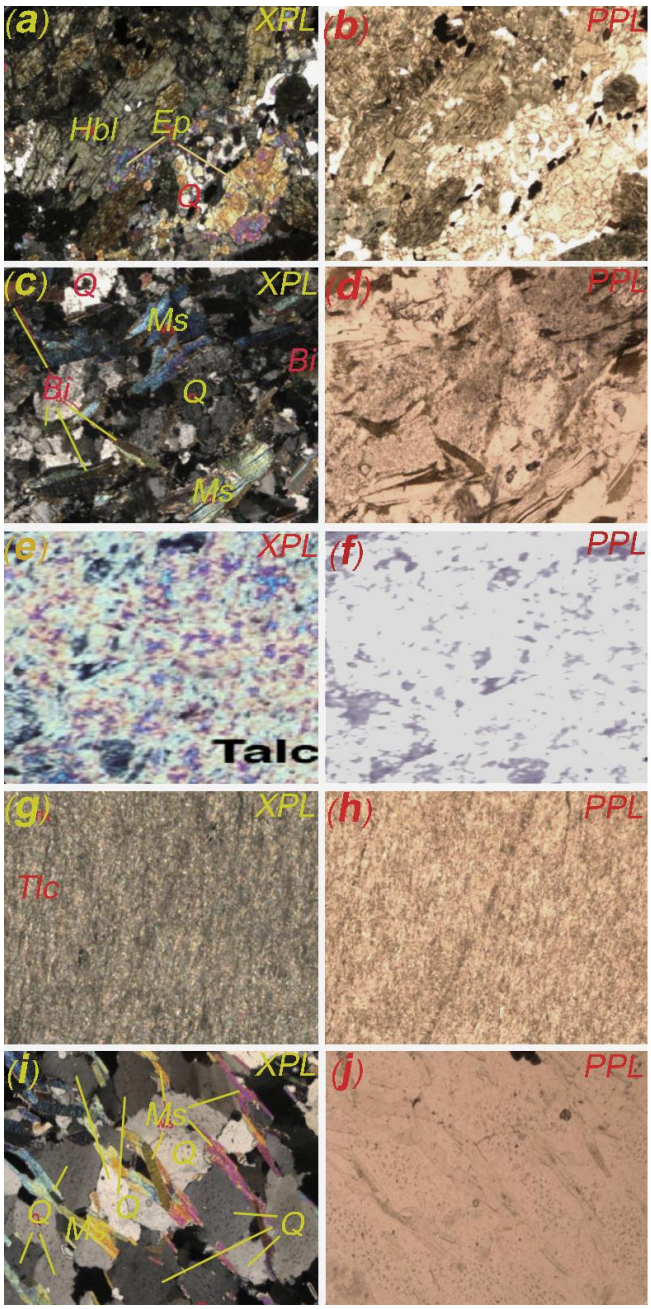

Fig. 4: Plane–polarized (PPL) and crossed polar (XPL) photomicrographs of the collected samples (magnification for all photomicrographs are 40X). Please see the above text for the description of each photo. Abbreviations are; Hbl = hornblende, Q = quartz, Tlc = talc, Ms = muscovite, Bi = biotite and Ep = epidote.

6. The geochemical analysis of the samples

Spectrometer and XRD analyses of various samples show that the SiO_2 concentration in talc samples ranges from 52.9-65.1 percent and in carbonate rocks reaches to 1.6- 33 percent. High MgO levels can be seen in carbonate samples ranging from 18.4- 48.1 percent but in talc samples the MgO levels ranges from 29.4- 34 percent. The amount of TiO_2 and MnO is less than 1 percent in talc and carbonaceous samples. Al_2O_3 and Fe_2O_3 concentration are also usually less than 1 percent in these samples, but in some samples they can be as high as 2.5 percent, the single exception in which these percentages are 12.52 and 3.76 respectively was taken from Wazir Tangi location. The CaO concentrations are less than 1

percent in talc samples but ranges from 18 to 26 percent in carbonate samples.

The results of XRD analysis of some of the samples are shown in Table 1, which shows the components of the essential elements in talc and carbonate samples with (Wt%).

Table 1: The concentration of essential elements in talc and carbonate samples (Wt. %). analyzed by XRD.

Samples	AF07A	AF07B	AF08	AF10	AF13B	AF14	AF15	AF16	AF18A	AF20A	AF20C	AF22B	AF28A	AF28B
Samples types	magnesite	talc	magnesite	talc	talc	Dolomite marble	talc	talc	Dolomite marble	Dolomite marble	Dolomite marble	talc	talc	talc
Area	Khairwast	Khairwast	Khairwast	Khairwast	Kadekhil	Kadekhil	Kadekhil	Kadekhil	Alifkhil Agam	Alifkhil Agam	Alifkhil Agam	Alifkhil Agam	Wazir Tangi	Wazir Tangi
SiO_2	1.56	62.00	27.93	63.66	62.36	33.0	60.31	57.34	12.95	56.07	17.7	62.37	62.41	62.33
TiO_2	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.07	0.04	0.01	0.00	0.00
Al_2O_3	0.03	0.02	0.45	0.13	0.18	0.08	0.48	0.16	0.10	2.48	1.72	0.16	0.04	0.02
Fe_2O_3	0.22	0.06	0.75	0.36	0.37	0.04	1.93	1.05	0.23	0.16	0.24	0.35	0.02	0.05
MnO	0.01	0.00	0.01	0.00	0.02	0.01	0.03	0.06	0.01	0.00	0.00	0.00	0.00	0.00
MgO	46.27	32.23	48.06	33.04	31.79	18.33	30.21	29.36	22.90	31.9	21.29	31.49	32.05	32.03
CaO	0.033	0.13	0.83	0.13	0.14	25.99	0.12	4.19	19.75	1.04	17.96	0.12	0.17	0.12
Na_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
K_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.00	0.01	0.04	0.01	0.01	0.01
P_2O_5	0.01	0.01	0.36	0.01	0.00	0.01	0.00	0.02	0.01	0.02	0.03	0.00	0.02	0.00
LOI	50.64	5.12	18.75	0.52	4.87	18.79	4.95	6.91	41.57	8.47	37.74	4.86	4.92	4.93
Unidentified	-	-	-	-	-	-	20.00	20.00	20.00	20.00	20.00	20.00	-	-
Total (Wt.%)	99.3	99.7	99.8	99.3	99.8	97.3	98.5	99.7	98.9	100	98.9	99.7	99.7	99.6

In addition to the talc and carbonate rocks, the basic elements and components of intrusive and metamorphic rocks are shown in Table 2.

Table 2: The concentration of essential elements in intrusive and metamorphic rocks (ppm); analyzed by XRD.

Samples	AF01A	AF01B	AF02D	AF17	AF19	AF21	AF05C	AF09	AF11	AF12
Samples types	Chlorite rock	Serpentinized peridotite	Dolerite/diabase	Talcy quartz	Quartz-chlorite schist	Actinolite-biotite-gneiss	Altered dolerite	Altered diorite	Actinolite rock	Actinolite rock
Area	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Khairwast	Khairwast	Khairwast	Khairwast
SiO2	30.60	39.54	47.25	79.77	47.88	71.77	43.44	48.30	55.62	57.78
TiO2	4.22	0.52	1.36	0.12	2.70	0.33	1.06	4.38	0.03	0.01
Al2O3	12.32	3.29	14.06	2.64	12.41	13.68	13.31	12.43	1.01	0.23
Fe2O3	5.28	3.24	13.66	0.99	16.42	3.32	12.94	15.04	6.95	0.47
MnO	0.032	0.02	0.17	0.03	0.18	0.03	0.16	0.17	0.12	0.01
MgO	34.05	37.62	8.84	13.95	6.04	0.52	13.76	5.81	19.75	24.10
CaO	1.00	3.19	10.37	0.40	9.06	0.63	6.81	9.59	12.82	13.77
Na2O	0.05	0.01	2.01	0.02	2.19	2.62	1.23	2.19	0.38	0.06
K2O	0.13	0.03	0.45	0.02	0.46	5.27	0.60	1.05	0.64	0.02
P2O5	0.72	0.37	0.15	0.15	0.26	0.07	0.13	0.44	0.07	0.02
LOI	12.07	12.81	0.65	3.24	1.42	0.99	6.33	0.52	1.97	2.3
Total (Wt.%)	10047	100.6	99.0	101	99.1	99.23	99.77	99.9	99.4	99.1

Rare elements are rarely found in talc and magnesites samples; however the presence of rare elements in dolomite marbles and metamorphic rocks is relatively higher than that of talc and magnesite. The presence of rare elements in magnesite rocks has been shown to be high due to the presence of apatite and titanite minerals (Table 3)

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Table 3: Concentration of rare elements in talc and its country rocks (ppm).

Samples	AF01A	AF01B	AF01C	AF06B	AF07B	AF08	AF04	AF05A	AF05C	AF06A	AF03	AF02B	AF02E	AF02E	AF02C	AF02A	AF02D	AF21
Rock types	Chlorite rock	Serpentinized peridotite	Magnesite	Talc	Magnesite	Magnesite	Talc	Magnesite	Altered dolerite	Magnesite	Magnesite	Magnesite	Talc	Talc	Talc	Quartz-chlorite schist	Dolerite/ diabase	Actinolite-biotite gneiss
Area	Khairwast	Khairwast	Khairwast	Khairwast	Khairwast	Khairwast	Kadekhil	Kadekhil	Alifkhil Agam	Alifkhil Agam	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi	Wazir Tangi
La	34.29	6.34	1.05	0.10	0.15	2.6	0.13	0.16	7.52	0.48	0.39	0.31	0.05	0.00	0.04	88.63	10.34	46.79
Ce	67.95	16.15	1.99	0.27	0.54	6.55	0.35	0.48	18.44	1.09	1.18	0.60	0.11	0.00	0.13	180.90	23.87	150.70
Pr	7.56	2.27	0.20	0.02	0.06	0.83	0.04	0.06	2.63	0.11	1.17	0.06	0.01	0.01	0.01	20.61	3.22	16.37
Nd	28.11	10.68	0.72	0.08	0.25	3.64	0.14	0.25	12.55	0.39	0.75	0.22	0.03	0.00	0.07	79.85	14.58	57.58
Sm	4.394	2.66	0.14	0.01	0.05	1.05	0.02	0.04	3.69	0.06	0.17	0.03	0.00	0.00	0.01	13.97	3.67	10.07
Eu	0.68	0.59	0.02	0.004	0.01	0.16	0.01	0.00	1.22	0.02	0.02	0.01	0.00	0.00	0.01	2.541	1.23	1.34
Gd	3.90	2.92	0.13	0.01	0.04	1.43	0.01	0.04	4.74	0.05	0.13	0.03	0.00	0.00	0.01	11.36	4.28	7.66
Tb	0.48	0.39	0.02	0.00	0.00	0.20	0.00	0.00	0.71	0.00	0.01	0.01	0.00	0.00	0.01	1.41	0.63	0.98
Dy	2.97	2.43	0.13	0.00	0.03	1.12	0.01	0.03	4.71	0.04	0.11	0.04	0.00	0.00	0.01	8.43	4.08	6.18
Ho	0.56	0.45	0.03	0.00	0.00	0.19	0.00	0.00	0.94	0.00	0.02	0.01	0.00	0.00	0.01	1.54	0.78	1.15
Er	1.45	1.25	0.09	0.00	0.01	0.46	0.00	0.01	2.66	0.02	0.06	0.04	0.00	0.00	0.01	4.20	2.27	3.27
Tm	0.18	0.15	0.02	0.00	0.00	0.04	0.00	0.00	0.36	0.00	0.00	0.01	0.00	0.00	0.00	0.58	0.31	0.46
Yb	0.96	0.88	0.11	0.00	0.01	0.21	0.00	0.01	2.293	0.01	0.06	0.06	0.00	0.00	0.01	3.50	1.96	2.88
Lu	0.13	0.12	0.02	0.00	0.00	0.03	0.00	0.00	0.32	0.00	0.00	0.01	0.00	0.00	0.00	0.49	0.28	0.41
Total	153.6	47.3	4.7	0.5	1.2	18.5	0.7	1.1	62.8	2.3	4.07	1.44	0.2	0.00	0.33	418	71.5	305.8

The spectrometry results of a number of samples are shown in Table 4; these samples were analyzed and researched at the ISAN laboratory in Turkey.

4. Table. Results of spectrometric analysis (in percent).

Area	Samples	SiO_2	MgO	Al_2O_3	Fe_2O_3	TiO_2	CaO	Na_2O	K_2O	Ability of grease absorption	L.O.I
Alifkhil	QAG1	64.49	28.42	0.97	0.59	0.17	0.04	0.02	0.01	29.50	5.44
Alifkhil	QAG2	66.09	28.24	0.20	0.56	0.01	0.06	0.02	0.01	30	4.80
Alifkhil	QAG3	64.29	28.01	1.27	1.03	0.04	0.21	0.03	0.01	30.40	5.10
Alifkhil	QAG4	65.83	28.05	0.15	0.94	0.01	0.09	0.02	0.01	31.80	4.89
Khairwast	QKH1	65.40	28.48	0.19	0.82	0.01	0.03	0.02	0.01	32.50	5.03
Khairwast	QKH2	66.08	28.27	0.15	0.63	0.03	0.04	0.03	0.01	32.40	4.77
Khairwast	QKH3	63.99	29.13	0.85	0.30	0.01	0.23	0.03	0.01	31.96	5.43
Khairwast	QKH4	65.45	28.41	0.12	0.13	0.01	0.07	0.03	0.01	30.90	4.76
Kadekhil	QGK1	66.20	28.54	0.09	0.39	0.01	0.03	0.02	0.01	30.60	4.70

Kadekhil	QGK2	65.87	28.76	0.07	0.24	0.01	0.04	0.03	0.01	29.60	4.95
Kadekhil	QGK3	65.84	28.89	0.02	0.29	0.01	0.04	0.02	0.01	29.30	4.88
Kadekhil	QGK4	65.50	28.81	0.15	0.15	0.01	0.19	0.04	0.01	29.40	5.13
Wazir Tangi	QWZ1	66.82	28.35	0.05	0.30	0.01	0.04	0.01	0.01	31.50	4.40
Wazir Tangi	QWZ2	66.10	28.18	0.06	0.74	0.01	0.13	0.02	0.01	31.30	4.75
Wazir Tangi	QWZ3	65.83	28.20	0.22	0.69	0.04	0.07	0.03	0.01	29.20	4.94
Wazir Tangi	QWZ4	59.42	29.77	0.59	0.38	0.02	0.32	0.03	0.01	29.30	4.95
Wazir Tangi	QWZ5	66.07	28.29	0.27	0.18	0.02	0.12	0.03	0.01	30.60	5
Wazir Tangi	QWZ6	44.32	28.80	12.52	3.76	0.44	0.14	0.04	0.01	31.20	9.94
Wazir Tangi	QWZ7	66.46	28.94	0.07	0.10	0.01	0.02	0.03	0.01	29.70	4.35

7. Genetic model

On the basis of field observations, petrographic evidence related to structure, texture and mineral composition and geochemical data, we are proposing the similar genetic model for the talc formation in the Nangarhar province as suggested by Tahir, et al (2018). This model is presented in (Fig. 5) and can be described as follow: The hydrothermal fluids entered into existing beddings of the Middle Paleoproterozoic carbonate rocks passing through the Early Paleoproterozoic gneisses. This is consistent with the occurrence of quartz veins in gneiss (Fig. 5B1) and hydrous minerals such as talc, tremolite, and antigorite in host carbonate rocks (Figs.6a, b, c and d). The hydrothermal fluids infiltrated along the gneissosity, and formed some parallel quartz veins. The hydrothermal fluids that reached the magnesite rocks and dolomite marble transformed these rocks into talc. Late Paleoproterozoic granitic intrusion cuts gneiss and quartz veins (Fig. 5B2). The granitic intrusion and diorite and dolerite dikes post-date talc formation and are not involved in the alteration of magnesite rocks and dolomite marble to talc (Fig. 5B3). These mafic units also formed sills following the trend of talc orebodies, magnesite rocks, and dolomite marble (Fig. 3, Fig. 5B4 & Fig. 6). During the Early Cretaceous, these intrusive units may have heated surrounding talc and carbonate rocks which caused the formation of tremolite from talc, and antigorite from magnesite rocks and dolomite marble by contact metamorphism (Figs. 5 & Fig. 6) [13].

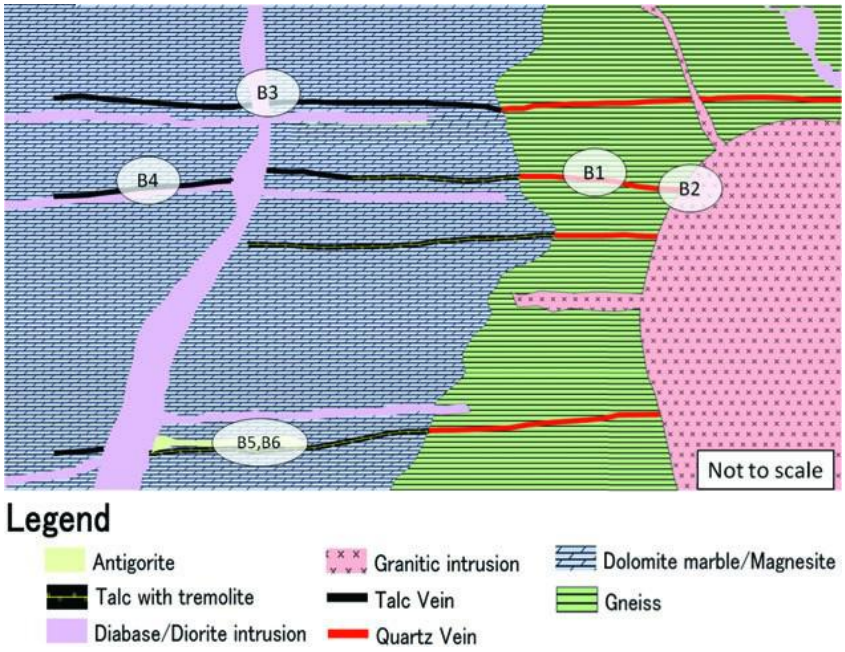

Fig. 5: A genetic model for the talc formation in the Nangarhar province. Please see the above text for the description of B1 to B6 in this figure[13].

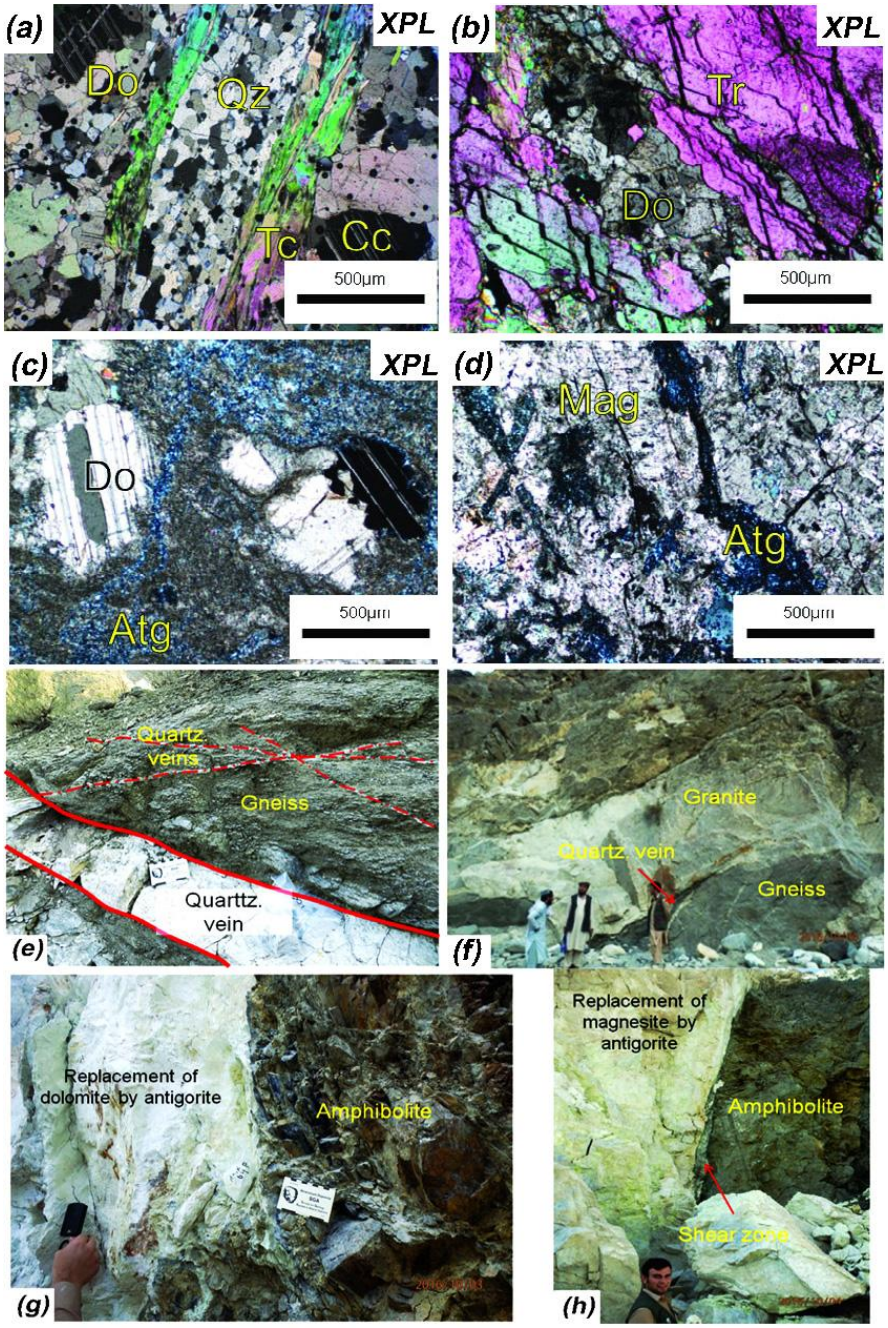

Fig. 6. Photomicrographs and Photographs of (a) dolomite marble, showing the quartz vein in dolomite that formed the talc, (b) tremolitite from Kadekhil showing replacement textures of dolomite by tremolite, (c) antigorite from Kadekhil showing antigorite replacing dolomite, (d) antigorite from Khairwast showing the replacement of magnesite by antigorite. Abbreviations are Do = dolomite, Qz = quartz, Tc = talc, Cc = calcite, Tr = tremolite, Mag = Magnesite and Atg = antigorite [13].

Photographs showing typical field occurrences of talc mineralization in the Spinghar Fault Block. (e) Parallel quartz veins in gneiss showing locally crosscutting relationship, (f) granitic body intruding into the gneiss. The granitic body also cuts the quartz veins, (g) replacement of dolomite marble by antigorite at Kadekhil, (h) replacement of magnesite rocks by antigorite at Khairwast [13].

8. Conclusions and Recommendations

The key findings and conclusions to be drawn from this Khogyani talc-based study can be summarized as follows:

1. The results of the samples taken from the talc of Khogyani area, show that most of the talc samples have monomineralic composition(e.g. amount of talc is up to 99%) and the presence of harmful and foreign minerals is often counted as nothing or very low. The structure and texture of the most specimens are the same, i.e. the structure is massive and the texture is lepidoblastic, which indicates high pressure in the process of metamorphism.
2. The main ore minerals are talc and magnesites and the main wallrock (country rock) minerals in these areas are dolomite, hornblende, quartz, epidote, sodium and potassium feldspar, biotite, muscovite, chlorite, tremolite, antigorite, and the family of amphibole minerals.
3. The formation of Khogyani talc has a genetic link with carbonates rocks (dolomitic marble) which is the result of multi stages; hydrothermal activity and contact and regional metamorphism. In places where the

hydrothermal dolomitic marble vein is present, the talc is formed from the result of contact metamorphism.

4. The above-mentioned hydrothermal fluids in this area intruded into the middle Paleozoic aged gneiss and carbonate rocks, which formed talc and quartz veins as a result. In additions, due to the contact metamorphism, some changes and replacement can be seen, the presence of Antigorite and tremolite minerals are evidence for this.
5. As talc is genetically linked with the carbonate rocks in this area; in addition to the deposits of talc, the deposits of magnesite and good quality marble are also present in the area. In some places these reserves are economically important and mineable; therefore the government is recommended to consider the magnesite and marble reserves as well, when the talc deposits are contracted.
6. The process of these talc deposits is very simple. It is suggested to the government and private companies to set up a large processing factory for these talc and meet the international standards and export them to European countries through Lapis Lazuli route under the mark and brand of Afghanistan; or it should be used properly in domestic industries.
7. In addition to the Ghundy, Mamakhil, Khairwast, Kadekhil, Wazir Tangy and Alifkhil talc deposits and occurrences in Khogyani district, dozens of other talc occurrences have been discovered. In this study, only a handful of samples have been studied, which are not sufficient for a thorough and detailed description of these deposits. Therefore the government is recommended to thoroughly investigate all mineral deposits and calculate the exact reserves of talc and magnesites in these sites. Thus there is a need for large-scale, accurate and comprehensive studies.
8. Powerful and anti-government militants have destabilized the area and every day tons of talc are being extracted unprofessionally and smuggled to Pakistan and other countries [5]. Hence it is suggested to the government to immediately stop the illegal mining and smuggling of talc and other minerals (e.g. chromites, nephrites, talc, asbestoses, gemstones and semi-gemstones) in the Khogyani, Goshta and other districts of the Nangarhar province, the necessary and significant steps should be taken as soon as possible to avoid the smuggling of the country national assets.

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