Acta Mineralogica—Petrographica, Szeged, XXIII/1, 71—76, 1977

MINERALOGICAL AND CHEMICAL STUDIES ON ANTHOPHYLLITE-ACTINOLITE SCHIST FROM WADI UM KABU, SOUTH EASTERN DESERT, EGYPT

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ABSTRACT

The present work deals with the mineralogy and chemistry of an amphibole schist from Wadi Um Kabu lying in the south Eastern Desert of Egypt. The detailed mineralogical investigation including optical and X-ray diffraction studies revealed this schist to be composed of anthophyllite, actinolite, goethite and calcite. Chemical analysis showed the studied schist to be enriched in MgO content (28.79%), but contains certain amounts of FeO (5.29%), CaO (5.42%) and Al_2O_3 (3.57%). It is concluded that the original monoclinic actinolite was transformed to orthorhombic anthophyllite during a thermal metamorphic pulse and in an atmosphere of CO_2 and H_2O, while the exuded Ca and Fe formed the two minerals calcite and goethite.

Thus the schists of Wadi Um Kabu were the place of differential mobilization of certain elements particularly Ca and Fe during thermal metamorphism. This mostly happened under amphibolite facies of metamorphism. The studied amphibole schist sheet lying between muscovite-talc schists can be envisaged as an original basic intrusive body that was subjected later to metamorphism giving rise to the present amphibolite rock.

INTRODUCTION

Wadi Um Kabu is an eastern tributary of the larger and well known Wadi Gemal lying in the southern parts of the Eastern Desert of Egypt *(Fig. 1)*. Wadi Um Kabu consists of a series of diorite gneisses beside schists of various types, the most important of which is the muscovite-talc schist. Sometimes these schists are associated with the so-called actinolite schist variety, the subject of the present study. For details of the field occurrence of these gneisses and schists, see EL SOKKARY [1960].

Other actinolite schist occurrences are reported in literature though not studied in detail. BASTA and ZAKI [1961] described an actinolite-biotite schist from Wadi Sikait area in the south Eastern Desert. EL SHAZLY and HASSAN [1972] mentioned the presence of actinolite bands associated with talc schists in Wadi Sikait–Wadi El Gemal area.

The Um Kabu actinolite schist is subjected here to detailed mineralogical and chemical studies. The mineralogical work includes megascopic description of the hand specimens, specific gravity determination, optical characters under the microscope, X-ray diffraction and chemical mineral tests. A complete chemical analysis of the actinolite schist is given as compared with other analyses quoted from literature. On this basis a discussion of the possible genesis and metamorphic history of the particular type of schist under study is given.

Admittedly, the various types of schists of the basement rocks of Egypt are among the least studied rocks particularly from mineralogical and chemical points of view. The present work is a contribution to the mineralogy and chemistry of certain members of these schistose formations occurring within the basement rocks of Egypt.

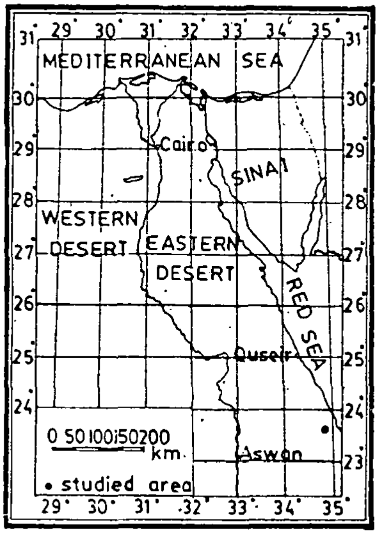

Fig. 1. Map showing the location of Wadi Um Kabu area

MINERALOGICAL INVESTIGATIONS

The field term actinolite schist refers to a rock that is composed of aggregates of long prismatic needle-shaped crystals which may be greater than 3 cm in length, with acicular habit and pale greenish color. Associated with some yellowish brown ferruginous material, mostly goethite, which may be an alteration product of the green amphibole. Some specimens develop minor muscovite and talc components. Average specific gravity on three hand specimens is found to be 3.06. Specimens of almost pure actinolite schist are chosen for more detailed studies.

Under the microscope, the amphibole shows prismatic crystals ranging in color from pale to dark greenish shades, possibly reflecting variable quantities of iron, weakly pleochroic from pale greenish to somewhat dark greenish but certain varieties may show relatively stronger absorption than others, with two perfect sets of cleavage and the presence of cross fractures. Statistical measurement of extinction angle on 50 grains revealed that about 50% of them show straight extinction while 50% give extinction angle ranging from 10–24°, crystals are sometimes strained but the phenomenon is not strong. Interference colors are yellow of the second order indicating moderate birefringence. Occasionally with tiny opaque or transparent inclusions.

The fact that with respect to the extinction angle, the grains fall into two groups of almost equal proportions: a group with straight extinction angle and the other with oblique angles ranging from 10–24°, indicates that the amphibole schist under study may be composed of a mixture of two varieties: one probably anthophyllite and the other is actinolite. Few grains of yellowish mineral occasionally with anomalous birefringence are observed, they mostly represent goethite flakes and constitute a minor fraction of the total grains.

A sample of the amphibole schist is powdered to pass 150 mesh size. It is subjected to X-ray diffraction using a Philips chart recorder diffractometer adapted to work with Cu radiation, wavelength 1.5418 Å, Ni filter, current 26 mA, voltage 36 kV and scale 16.64. Table 1 gives the partial diffraction pattern of the sample as compared with corresponding data for standard (ASTM) anthophyllite, actinolite and goethite.

TABLE 1

Partial diffraction pattern of the amphibole schist sample as compared with standard anthophyllite, actinolite and goethite

Sample		Anthophyllite[1]		Actinolite[2]		Goethite[3]	
*d*Å	I/I_0	*d*Å	I/I_0	*d*Å	I/I_0	*d*Å	I/I_0
9.41	88	9.30	25				
9.12	10	8.90	30	9.06	40		
8.42	88	8.26	55	8.42	70		
7.14	14	7.48	7				
5.10	3	5.04	13	5.12	30		
4.75	8	4.90	9	4.88	50		
4.60	13	4.62	13				
4.53	5	4.50	25	4.52	50		
4.21	22	4.13	20			4.21	100
3.88	4	3.90	13	3.87	50		
3.55	9	3.65	35				
3.39	1	3.36	30	3.38	70		
3.28	10	3.24	60	3.27	60		
3.12	100	3.05	100	3.11	80		
2.95	2	2.87	20	2.94	60		
2.81	24	2.84	40				
2.71	5	2.74	20	2.71	100		
2.70	2	2.68	30			2.69	80
2.60	2	2.59	30	2.59	50		
2.54	2	2.54	40	2.53	60		
2.45	1	2.43	13			2.44	70
2.38	2						
2.34	2	2.32	20	2.33	40		
2.32	2	2.29	20	2.27	20		
2.29	1	2.25	13				
2.17	2	2.17	9	2.16	40		
2.12	1	2.14	30				
2.02	1	2.07	9	2.04	30		
2.01	2	2.06	9	2.01	30		
2.00	2	1.99	15				
1.89	5	1.88	11				
1.87	3	1.84	20	1.86	20		
1.81	2	1.73	30				
1.65	2	1.69	13	1.65	40		
1.64	1	1.64	9				
1.62	3	1.62	30				
1.61	2						
1.59	1	1.58	20	1.58	40		
1.56	1						
1.44	2			1.43	40		

1: ASTM Card No. 9—455.
2: ASTM Card No. 7—336.
3: ASTM Card No. 8—97.

It is concluded from Table 1 that the amphibole schist sample is essentially composed of the following main minerals: anthophyllite, actinolite and goethite. On the basis of the diffraction pattern alone, it looks that anthophyllite is more abundant followed by actinolite while goethite is a minor constituent. However, it is to be noted that the *d* spacings of the ASTM anthophyllite are not exactly matching the corresponding lines of the investigated sample. This may be attributed to certain chemical differences between the sample anthophyllite and the ASTM anthophyllite, a matter which will affect though to a limited extent the dimensions of the unit cell of each mineral.

Two chemical mineral tests are done in order to check the presence of goethite and any traces of carbonates. In the first experiment the sample powder is boiled in HCl (1:1) for about one hour, the filtrate is tested by potassium ferrocyanide when the Prussian blue color characteristic for Fe is obtained. Thus acid leachable iron is present in the form of an independent mineral that is soluble in HCl and takes the ferric state, this mineral is mostly goethite. In the second experiment, the sample powder is tested by adding few drops of HCl and observing the reaction by a hand lens. Weak effervescence is observed from few grains. Traces of carbonates possibly as calcite are therefore present associating the amphiboles.

To sum up, these mineralogical investigations revealed that the pure amphibole schist under study is composed of: anthophyllite, actinolite, goethite and traces of carbonates as calcite. The latter two components, namely goethite and calcite, may represent alteration products of the actinolite.

CHEMICAL ANALYSIS

Table 2 exposes the complete chemical analysis in weight per cent of the oxides of the amphibole schist sample compared with the corresponding analyses of anthophyllite and actinolite as given by DEER *et al.* [1972].

TABLE 2

Chemical analysis (wt.% of the oxides) of the amphibole schist sample compared with other analyses of anthophyllite and actinolite

	Amphibole schist	Anthophyllite	Actinolite
SiO_2	51.35	58.48	51.40
Al_2O_3	3.57	0.57	3.88
Fe_2O_3	0.29	0.58	3.90
FeO	5.29	7.85	14.91
MnO	0.50	0.27	0.33
MgO	28.79	29.25	11.22
CaO	5.42	0.14	10.17
Na_2O	0.34	0.08	1.67
K_2O	0.18	0.02	0.09
TiO_2	0.01	0.03	0.74
P_2O_5	0.05	—*	—*
H_2O^+	3.44	2.60	1.90
H_2O^-	0.21	0.20	0.04
Total	99.44	100.07	100.25

*: Not reported.

As it is clear from Table 2, the most characteristic feature of this amphibole schist is its enrichment in MgO content that equals 28.79%. Nevertheless, the amphibole is not precisely an anthophyllite on account of the presence of relatively considerable amount of CaO that equals 5.42%. The substitutions of FeO (5.29%) and CaO (5.42%) for MgO in the analysed amphibole are not quite extensive (causing no pronounced decrease in the MgO content) to produce a true ferroactinolite. There is also moderate substitution of Al_2O_3 mostly in place of SiO_2 that reaches 3.57%. It is to be noted that the Fe_2O_3 content (0.29%) of the amphibole schist sample is too low particularly if it is taken into consideration that the sample contains free goethite phase visible by the naked eye in hand specimens.

The above chemical considerations indicate clearly that the amphibole schist sample under study is composed neither of anthophyllite alone nor actinolite alone, rather it is composed of a mixture of the two minerals with more anthophyllite due to enrichment in MgO in accordance with the results of X-ray diffraction.

GENETIC DISCUSSION

Results of microscopic investigation together with X-ray diffraction analysis and chemical analysis revealed that the amphibole schist under study is composed mineralogically of anthophyllite, actinolite, goethite and calcite. Anthophyllite may be more abundant than actinolite. The two minor minerals goethite and calcite are alteration products of the actinolite.

It seems that the monoclinic calcic amphibole actinolite has undergone a transformation reaction during a thermal event by means of which it lost part of its Fe and Ca (causing relative enrichment in MgO) and converted to orthorhombic anthophyllite. The extra Fe and Ca are exuded and formed the two minerals goethite and calcite, respectively. This transformation happened during a thermal metamorphic event and in an atmosphere of H_2O and CO_2. On the basis of this study, it is possible to say that the present anthophyllite-actinolite schist was subjected at least two metamorphic cycles: one that produced the original actinolite schist and the other that caused partial transformation of actinolite to anthophyllite.

The above paragenetic sequence receives the following evidence from the field [El Sokkary, 1960]. The talc-muscovite schists interveined by the actinolite schist of Um Kabu contain sporadic and abundant crystals of ferriferous calcite that attains very big sizes. The latter mineral can be considered to form small scattered pockets within the host schists. This attests that the ferriferous calcite is later than the actinolite schist and is formed during a metasomatic process accompanying a thermal event.

It appears that the schists of Wadi Um Kabu were the place of certain chemical mobility under thermal metamorphic environments. The main elements that were mostly affected by differential mobilization in the present case are Ca and Fe. If however the mentioned ferriferous calcite proved to be Mg-bearing, it would be possible to say that the element Mg has suffered as well from limited mobility. This case of differential mobility of elements has resulted in a sort of metamorphic differentiation of the original amphibole schist to give amphibole-calcite-goethite association.

Fairbridge [1972] mentioned that the process of metamorphic differentiation is essentially one of redistribution of elements: Ti, Fe, Mg and Ca segregated from Si, Al, and Na with little change of bulk composition. Differential solubility under conditions of heterogeneous pressure in foliated rocks plays an important role.

The amphibole schist sheet lying between muscovite-talc schists can be visualized as an original basic intrusive body taking the form of a sill that was subjected later to metamorphism giving rise to the present amphibolite rock or anthophyllite-actinolite schist.

The grade of metamorphism of this amphibole schist rock lies within the amphibolite facies. TURNER and VERHOOGEN [1960] pointed out to the cummingtonite (or anthophyllite)-tremolite assemblage (the closest to the present anthophyllite-actinolite assemblage) to belong to the almandine-amphibolite facies. WINKLER [1967] stated that orthorhombic amphiboles i.e. anthophyllite and the Al-bearing gedrite are formed at the beginning of the hornblende-hornfels facies. Since anthophyllite is an important constituent of the present anthophyllite-actinolite assemblage, therefore this assemblage is mostly formed in the hornblende-hornfels facies or the amphibolite facies.

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Manuscript received, August 10, 1977

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