

AN UNUSUAL CARBONATE MINERAL FROM THE SCHISTS OF WADI UM KABU, SOUTH EASTERN DESERT, EGYPT

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ABSTRACT

An unusual carbonate mineral is associated with the schists of Wadi Um Kabu in the South Eastern Desert of Egypt. It is subjected here to detailed mineralogical and chemical studies. It is revealed that the brownish and rhombic carbonate material under study is composed of: dolomite with MgO partly replacing CaO and the mineral retaining the structure of its predecessor ferroan dolomite, calcite, goethite which is amorphous to poorly crystalline and possible brucite.

It is suggested that the former ferroan dolomite was subjected to a thermal metamorphic pulse by means of which major part of Fe and some Ca and Mg were exuded while the original ferroan dolomite is modified in chemical composition to the present dolomite. The expelled elements formed goethite, calcite and brucite, respectively. Both the dolomites and their schistose country rocks underwent differential mobilization of the three cations: Fe, Ca and Mg under thermal metamorphic environment.

INTRODUCTION

The schists of Wadi Um Kabu lying in the South Eastern Desert of Egypt were referred to by EL SOKKARY [1960] and certain members of these schists were studied in some detail from mineralogical and chemical points of view by EL SOKKARY [1977]. These schists particularly the muscovite-talc schist are associated with unusual coarse crystals of a carbonate mineral which is the subject matter of the present investigation.

The schists of the studied area belong to muscovite-talc members which are veined by a great vein composed of anthophyllite-actinolite schist, the succession runs from down upwards as follows:

- 1) Country rock schists of muscovite-talc character.
- 2) Vein of anthophyllite-actinolite schist, grading downwards to graphite mica schist.
- 3) Country rock of muscovite-talc schist.

The whole succession is associated with this unusual carbonate mineral which takes the form of small isolated and scattered pockets.

MINERALOGY

The carbonate mineral under study develops very coarse rhombohedral crystals with varying sizes such as: $5 \times 4 \times 4$ and $3.5 \times 3.5 \times 3.5$ cm, crystal faces are almost complete, in other words crystals are almost euhedral, brown in color, with distinct

cleavage traces. The solid material gives weak reaction with dilute HCl. The powdered material effervesces after a while with dilute HCl and the reaction is not vigorous. This excludes the bulk carbonate mineral under study to be calcite.

A sample of the carbonate mineral was ground to pass 150 mesh size, afterwards it was subjected to X-ray diffraction analysis. The used instrument is a Russian diffractometer working with Cu radiation with wave length 1.5418 Å, Ni filter, current 8 mA, 35 kV. Sample data which are given in Table 1 are compared with the important lines of some standard ASTM minerals.

The diffraction pattern as given in Table 1 shows that the carbonate material under study is composed mainly of dolomite as a principal constituent, with minor calcite, goethite which is poorly crystalline to amorphous and possible brucite $Mg(OH)_2$. Anthophyllite and actinolite are present as impurity from the host country rock carrying the carbonate mineral.

The three principal lines of goethite ($\alpha\text{-FeOOH}$) are: 4.21 (100), 2.69 (80) and 2.44 (70). Only one of them 2.42 (52) is present in the diffraction pattern of the analysed carbonate material. This is interpreted on the basis that the present hydrated iron oxides are poorly crystalline to amorphous.

TABLE 1

Partial diffraction pattern of the carbonate sample under study as compared with standard dolomite and calcite

Sample		Dolomite ⁽¹⁾		Calcite ⁽²⁾		Others
d Å	I/I ₀	d Å	I/I ₀	d Å	I/I ₀	
9.51	31					An ⁽³⁾
6.81	25					?
4.44	42					?
4.06	56	4.02	1	3.86	12	
3.45	29	3.69	2			
3.12	23					Ac ⁽⁴⁾
3.04	21			3.04	100	
2.83	100	2.88	100	2.85	3	
2.62	35	2.66	4			
		2.53	4	2.50	14	
2.42	52					G ⁽⁵⁾
2.40	50	2.40	4			B ⁽⁶⁾
2.28	27			2.29	18	
2.16	63	2.19	12			
2.10	31			2.10	18	
2.06	40	2.06	2			
1.97	40	2.01	7	1.93	5	
1.90	33			1.91	17	
		1.84	2	1.88	17	
1.78	52	1.80	13			B ⁽⁶⁾
1.77	48	1.78	14			
1.70	44					An ⁽³⁾
1.67	38			1.63	4	
1.57	35	1.56	1			
1.53	25	1.54	2			
1.52	25	1.49	1			
1.41	25	1.41	1			
1.38	27	1.39	2			

(1): ASTM Card No. 5—0622.

(2): ASTM Card No. 5—0586.

(3): Anthophyllite ASTM Card No. 9—455.

(4): Actinolite ASTM Card No. 7—336.

(5): Goethite ASTM Card No. 8—97.

(6): Brucite ASTM Card No. 7—239.

It is worthy to note that the diffraction lines of the present identified dolomite do not accord precisely with the standard dolomite lines of the ASTM cards, a matter indicating the presence of certain substitutions in the unit cell. However, this might be explained as follows. The present dolomite with brownish rhombic crystals and shifted diffraction lines has acquired the structure of its predecessor which was ferroan dolomite, the latter was subjected to a thermal metamorphic pulse by means of which major part of its Fe and some of its Ca and Mg were exuded while the original ferroan dolomite is modified in chemical composition to the present dolomite.

This kind of pseudomorphism (dolomite after ferroan dolomite) is discussed by BETEKHTIN [1968] who explained the phenomenon of pseudomorphism as being replacement of crystal by a certain constituent in such a way that the resulting mineral retains not only the external shape but sometimes also the peculiar internal structure of the original mineral.

The mentioned metamorphic pulse has happened in the presence of carbon dioxide (CO₂) and water vapour (H₂O) atmosphere. Thus the exuded Ca formed calcite while the expelled Fe and Mg formed amorphous to poorly crystalline goethite beside possible brucite, respectively. The expelled iron takes at first the ferrous form and then oxidized to give Fe₂O₃ which is subsequently hydrated. DEER *et al.* [1972] mentioned that the commonest alteration product of siderite (FeCO₃) is a hydrous ferric oxide generally goethite often known loosely as limonite. It seems that the alteration of FeCO₃ to goethite is valid whether the former takes the form of an independent mineral like siderite or forms part of a more complex carbonate mineral like dolomite or ankerite.

CHEMISTRY

Table 2 presents complete chemical analysis of the investigated carbonate material from Um Kabu as expressed in weight per cent of the oxides.

TABLE 2
Chemical analysis of the carbonate material under study

Oxide	Wt. %
SiO ₂	16.99
Al ₂ O ₃	2.55
Fe ₂ O ₃	22.41
FeO	2.22
MnO	0.81
MgO	14.26
CaO	8.82
Na ₂ O	1.88
K ₂ O	0.48
TiO ₂	2.17
P ₂ O ₅	0.12
CO ₂	23.56
H ₂ O ⁺	2.94
H ₂ O ⁻	0.38
Total	99.59

Silica and alumina originates mainly from some anthophyllite (hydrated silicate of Mg, Fe) and actinolite (hydrated silicate of Ca, Mg, Fe) impurity associating the carbonate mineral.

It is to be noted that excessive amount of Fe_2O_3 is present up to 22.41% probably as free phase in the form of fine disseminated particles imparting a brownish coloration to the rhombohedral dolomite. On the other hand, a small part of the combined water ($\text{H}_2\text{O}^+ = 2.94\%$) is attributed to anthophyllite-actinolite impurity while the main part should be associated with Fe_2O_3 to make goethite or lepidocrocite constituting about one quarter by weight of the analysed carbonate material. Thus iron oxides are present mainly in the form of hydrated iron oxides. As it is clear from X-ray diffraction, these iron hydroxides are either poorly crystalline or amorphous because the characteristic diffraction lines of both goethite and lepidocrocite are almost wanting. It looks that these iron hydroxides firstly precipitated in a colloidal sooty form and then partly started to change with time to cryptocrystalline character.

Both MnO and TiO_2 are somewhat enriched in this carbonate material, being present up to 0.81% MnO and 2.17% TiO_2 respectively.

The remaining important ions in the analysis of the carbonate material are: Mg, Ca, Fe^{2+} and CO_2 which amount to $\text{MgO} = 14.26\%$, $\text{CaO} = 8.82\%$, $\text{FeO} = 2.22\%$ and $\text{CO}_2 = 23.56\%$. No doubt that the anthophyllite-actinolite impurity contributes, though to a small extent, to the MgO, CaO and FeO contents. Its contribution to the MgO content is greater because the impurity itself contains more anthophyllite, this explains why the MgO content is much higher than the CaO content. However, the bulk of these elements comes from the analysed carbonate material. Thus, this carbonate material is composed mainly of Mg, Ca, some Fe^{2+} and CO_2 which belong to dolomite. To sum up, hand specimen investigation, X-ray diffraction and chemical analysis all tend to prove the investigated carbonate mineral to be dolomite.

The two alkali elements $\text{Na}_2\text{O} = 1.88\%$ and $\text{K}_2\text{O} = 0.48\%$ substitute for Ca in the dolomite structure. This is apparent from the ionic radii of the three cations which are: $\text{Na}^+ = 0.95$, $\text{K}^+ = 1.33$ and $\text{Ca}^{2+} = 0.99 \text{ \AA}$. Because of the close similarity of the ionic radii between univalent sodium and divalent calcium, more Na than K is incorporated in the dolomite trigonal structure.

In order to get a more detailed insight in the composition of this dolomite, the MgO, CaO, FeO and CO_2 (the main constituents of dolomite) contents as given in Table 2 are recalculated to 100 and compared with the corresponding values of normal dolomite CaCO_3 . MgCO_3 [DANA, 1949] as given in Table 3.

TABLE 3
*Recalculated analysis (wt. %) of dolomite
of the studied carbonate sample as compared
with normal dolomite*

Oxide	Calculated dolomite	Normal dolomite
MgO	29.19	21.70
CaO	18.05	30.40
FeO	4.54	—
CO_2	48.23	47.90
Total	100.01	100.00

It is evident from Table 3 that the MgO content of the investigated dolomite is higher while the CaO content is lower than normal dolomite. DANA (*op. cit.*) continues that the carbonates of iron and manganese also frequently enter replacing the magnesium carbonate and grading to ankerite, limited amounts of lime may replace the magnesia and vice versa. It appears in the present case that magnesia is replacing part of the lime.

Concerning the chemistry of dolomites, DEER, *et al.* [1972] say that although the composition is normally fairly close to pure $\text{CaMg}(\text{CO}_3)_2$, many dolomites contain small amounts of Fe^{2+} replacing Mg, giving the mineral a brownish tinge in hand specimen. It is seen from Table 2 and Table 3 that the investigated dolomite contains certain amount of FeO partly replacing MgO.

CONCLUSION

The investigated rhombohedral and brownish carbonate material proved on the basis of megascopic description, X-ray diffraction and chemical analysis to be composed of the following components: dolomite, calcite, goethite and possible brucite. The dolomite has some MgO replacing part of CaO. The goethite is amorphous to poorly crystalline.

It is argued that the present dolomite has acquired the structure of its predecessor which was ferroan dolomite, the latter was subjected to a thermal metamorphic pulse by means of which major part of Fe and some of the Ca and Mg were exuded while the original ferroan dolomite is modified in chemical composition to the present dolomite. The expelled elements formed goethite, calcite and possible brucite, respectively.

This study illustrated the mobility of certain cations like Fe, Ca and Mg during thermal metamorphic environment. It is already shown [EL SOKKARY, 1977] that the schist of Wadi Um Kabu, the country rocks of the present carbonate material, are also the place of differential mobilization of certain elements particularly Ca and Fe during thermal metamorphism. Thus both the schists and their dolomites underwent differential mobilization of the three cations: Fe, Ca and Mg under thermal metamorphism.

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