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On scorzalite from the Angarf-Sud pegmatite, Zenaga Plain, Anti-Atlas, Morocco

André-Mathieu Fransolet*

With 2 tables

Abstract: Scorzalite occurs frequently but not abundantly in the phosphate minerals from the Angarf-Sud Precambrian pegmatite outcropping in Zenaga Plain, Anti-Atlas, Morocco.

Scorzalite is characterized by a determination of the ratio Fe^{2+}/Mg. The value obtained for the ratio $Fe^{2+}/(Fe^{2+} + Mg)$ is 0.54. The unit cell dimensions are also given.

In the Angarf-Sud pegmatite, the phosphate nodules are zoned. A core of gray triphylite, widely replaced by green alluaudite, is fringed by reddish fine-grained apatite. The more important secondary phosphate minerals are: melonjosephite, barbosalite, tavorite, lipscombite, mitridatite, and rockbridgeite. If muscovite occurs in this assemblage, it is systematically accompanied by scorzalite and fringed by apatite.

Scorzalite replaces muscovite and is inserted in its cleavage.

It seems that scorzalite forms under a low oxygen fugacity, more or less simultaneously with Mg-triphylite. The solution, rich in P, Fe^{2+} and with a little Mg, reacts with mica which provides Al; SiO_2 and K are released. It is not necessary to evoke a metasomatic process to explain the presence of Al.

Introduction

Minerals of the lazulite $MgAl_2(PO_4)_2(OH)_2$ – scorzalite $FeAl_2(PO_4)_2(OH)_2$ isomorphous series described by Pecora & Fahey (1950), occur rather frequently in pegmatites but they are scarcely abundant.

Systematic study of phosphates from Precambrian pegmatites injected in micaschists and gneiss in Zenaga Plain, Anti-Atlas, Morocco, has revealed the occurrence of a mineral belonging to this series in the Angarf-Sud pegmatite.

This pegmatite, one of the most important of this pegmatitic area described by Bouladon, Jouravsky & Morin (1950) and by Morin (1952) is in particular characterized by a large mass of still visible phosphates, situated at the western border of the quartz core.

The aim of this paper is to characterize the phosphate of the lazulite-scorzalite series found in this pegmatite and to suggest a genetic process.

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* Université de Liège, Institut de Minéralogie, Place du 20 août, 9, B-4000 Liège, Belgique

Identification problem

Phosphate mineral nodules from the Angarf-Sud pegmatite show a clear zonality. In the center a magnesium-rich triphylite (Fransolet, 1974) is developed, deeply corroded by a dark-green ferric iron – and calcium – bearing alluaudite. This assemblage is fringed, with sharp contact, by a rim of reddish apatite, characterized by a conchoidal fracture, stained and stippled by hematite.

The phosphate mineral of the lazulite-scorzalite series occurs in irregular lenses, sky-blue to light-blue, within muscovite, near the apatite. The high iron content found in all phosphate minerals so far identified indicates that this blue phosphate is scorzalite rather than lazulite. Other associated minerals include melonjosephite (Fransolet, 1973), barbosalite (Cech et al., 1972), rockbridgeite, lipscombite, mitridatite, and tavorite (Fransolet, 1974). However, since the triphylite contains MgO 3.73%, the presence of lazulite is possible.

The fine-grained aspect of scorzalite and its intimate association with apatite, hematite, pyrite, muscovite, and sometimes mitridatite made its identification difficult.

Optical data

The fine-grained nature of the scorzalite made impossible the accurate measurement of optical constants in the conventional manner.

Study of thin sections has, however, allowed some fragmentary data. The mineral is biaxial negative, with $2V \simeq 60^{\circ}$. Dispersion $r < v$ is perceptible. The intense pleochroism is X', colorless to light pinkish and Z', sky-blue.

Chemical composition

A qualitative analysis by electron microprobe shows abundant P, Al, Fe, and Mg. The absence of Ca and Mn has been carefully controlled. So, veinlets of fine-grained apatite have been observed in a parallel direction to a residual lamellar structure.

Semi-quantitative analyses have shown that Fe is more abundant than Mg. Partial chemical determinations of iron and magnesium have been obtained using 90 mg amount of mineral purified by gravity and hand-picking.

It has provided the following results (analyst: J.M. Speetjens): FeO = 12.96% and MgO = 6.20 %.

Having used a fusion to attack scorzalite, the distinction between Fe^{2+} and Fe^{3+} has not been made and total iron is indicated as FeO. These data lead to the ratio $Fe^{2+}/(Fe^{2+} + Mg) = 0.54$.

The theoretical composition for $(Fe_{0.54}Mg_{0.46})Al_2(PO_4)_2(OH)_2$ with Fe^{2+}: Mg = 1.17 is : FeO 12.15, MgO 5.81, Al_2O_3 31.93, P_2O_5 44.47, H_2O 5.64, total 100.00. The contents of FeO and MgO can be compared to those obtained by partial analysis.

As a conclusion, it can be said that after determination of FeO et MgO, the blue phosphate mineral from the Angarf-Sud pegmatite is *magnesian scorzalite*, with composition as given above, close to the middle of the lazulite-scorzalite series. It is similar to Corrego Frio scorzalite (Pecora et al., 1950), although containing a little more magnesium.

Crystallographical properties

The diffractogram of the analysed scorzalite, corrected with an internal standard of lead nitrate, is given in Table 1. The indices determined from the powder data are based on these of Campbell (1962), which are in agreement with the space group $P2_1/c$ determined by Lindberg & Christ (1959).

Table 1. X-ray powder pattern of scorzalite from Angarf-Sud, Anti-Atlas, Morocco.

I/I_0	$d(Å)_{obs}$	$d(Å)_{calc}$	hkl
15	6.175	6.163	100
20	4.738	4.744	$11\bar{1}$
20	4.710	4.708	110
5	3.635	3.648	020
		3.623	$10\bar{2}$
100	3.247	3.245	$11\bar{2}$
90	3.210	3.211	111
65	3.151	3.150	$12\bar{1}$
45	3.084	3.081	200
35	2.556	2.554	121
5	2.349	2.348	102
15	2.265	2.262	130
10	2.225	2.223	211
10	2.054	2.054	300
15	2.011	2.011	131
15	2.006	2.003	013
20	1.990	1.988	$12\bar{3}$
15	1.975	1.973	$32\bar{2}$
10	1.826	1.824	040
15	1.810	1.811	$20\bar{4}$
5	1.787	1.786	$40\bar{2}$
10	1.624	1.625	$24\bar{1}$
10	1.605	1.604	$42\bar{2}$
10	1.583	1.582	033
25	1.575	1.575	042
20	1.570	1.570	240
15	1.563	1.562	004
15	1.541	1.541	400
5	1.414	1.414	$33\bar{4}$
5	1.392	1.392	312

The unit cell dimensions calculation with the *Fortran* program for leastsquares refinement (Cox, 1967) has given the data reproduced in Table 2, where are also mentioned the data of Lindberg & Christ (1959).

Table 2. Crystallographical parameters.

	Lindberg & Christ, 1969		This report
	Lazulite, Minas Gerais, Brazil $Fe^{2+}/(Fe^{2+} + Mg) = 0.125$	Scorzalite, Victory, South Dakota $Fe^{2+}/(Fe^{2+} + Mg) = 0.765$	Scorzalite, Angarf-Sud, Morocco $Fe^{2+}/(Fe^{2+} + Mg) = 0.54$
a(A)	7.16	7.15	7.145 ± 0.002
b	7.28	7.31	7.297 ± 0.003
c	7.24	7.25	7.246 ± 0.003
β	120°40'	120°35'	120°24' ± 2'

In Table 2, *a* and *c* seem to vary a little into the lazulite-scorzalite series whereas *b* should vary a great deal; but the precision of given data does not allow to locate the position of the Tazenakht mineral in this series.

Genetical problem

Description of the paragenesis of scorzalite from the Angarf-Sud pegmatite

Scorzalite from the Angarf-Sud pegmatite is always observed intimately associated with muscovite. This muscovite, generally located on the border of phosphate mineral nodules, is also isolated in alluaudite. The muscovite flakes reach a length of 1 to 2 cm and are sometimes bent. A more or less thick rim of reddish apatite systematically separates mica from the other phosphate minerals. The chemical analysis and the measure of axial ratio *c*/*a* of this apatite indicates that it is a fluorapatite, poor in Mn and Fe. Under the microscope, the apatite appears very fine-grained to weakly fibrous with waving extinctions. Its red colour is due to a pigmentation of hematite. This oxide can form fine veinlets.

Hematite lamellaes cut through fractured pyrite cubes. Scorzalite shows a mosaic of fine lengthened grains which insert themselves between muscovite cleavages.

Some quartz long grains also emphasize residual lamellar structure. Scorzalite moreover contains sharp pyrite cubes and hematite chaplets which extend themselves in muscovite cleavages. Mitridatite veinlets are also inserted between separated cleavages, forming lenses or suddenly divide with anastomosis and cut through scorzalite and mica flakes. The contact between muscovite or scorzalite with apatite is very confused, stippled with hematite and sometimes chlorite, mixed with quartz and mitridatite.

Discussion

From microscopic observations, it clearly appears that scorzalite replaces muscovite and that this replacement results from a reaction between mica and a complex phosphorus-bearing solution.

In order to make an assumption about the genesis of this phosphate mineral, it is useful to first analyze the complexity degree of this solution before proposing conditions of formation of scorzalite.

Among the phosphate minerals present in Angarf-Sud pegmatite, scorzalite is the only one with a high-Al content. Presence of Fe and Mg in the reacting solution has an easy explanation: a magnesia-rich triphylite (Fransolet, 1974) exists in the center of the phosphate nodules. So *phosphorus, iron,* and *magnesium* are introduced elements but in this paragenetic relationship, on the contrary, *aluminum* is not introduced. During replacement, muscovite provides the aluminum necessary for the growth of scorzalite.

Such a behaviour of P, Fe, Mg and Al has already been demonstrated by Geijer (1964) in his detailed study on paragenetic relationships Al_2SiO_5 – lazulite – rutile.

Whereas *manganese* is rather low in triphylite and in alluaudite, whereas it looks like a minor element in fluorapatite and has not been detected by microprobe in scorzalite, the high calcium content in the environment of this mineral is noteworthy.

Pecora & Fahey (1950) have demonstrated that the calcium lazulite described by Watson (1921) is not valid and that the significant percentages of CaO were probably observed on samples. In his description of a first scorzalite occurrence in Russia Lugovskoi (1965) proposes special conditions required for the formation of this mineral in the studied albitized pegmatite, i.e. an enrichment of aluminum and a low content of Ca. These conditions seem too restrictive. Even if calcium indeed does not appear in the lazulite structure, it might be present in the surrounding rocks. Geijer (1964) finds apatite in particular and woodhouseite sometimes in the assemblages Al_2SiO_5 – lazulite – rutile.

In the Angarf-Sud pegmatite the abundance of *calcium* shown by the development of fine-grained apatite, sometimes even into muscovite cleavages, does not seem to have prevented the reaction between (Ca, PO_4, Fe, Mg) solution and mica to form scorzalite.

Although *fluorine* has not been either determined in the mica or detected in the scorzalite, the role of this element in the reactions is not to be neglected, as pointed out by Geijer (1964). It is difficult to determine whether fluorine has behaved as mineralizing agent or as catalyzing one. In this case, fluorine eventually has facilated destruction of muscovite and departure of released silica.

At the end of this study a hypothetical reaction could be mentioned:

$$\underset{\text{muscovite}}{K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O} + \underset{\text{solution}}{(3FeO, 3P_2O_5 \cdot 2H_2O)} \longrightarrow$$

$$\underset{\text{scorzalite}}{3(FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot H_2O)} + \underset{\text{quartz}}{6\,SiO_2} + 2\,K(OH),$$

this reaction taking place possibly in the presence of large amounts of calcium, which will form apatite.

After having studied the role of chemical elements during replacement of muscovite by scorzalite, an assumption is suggested about physico-chemical conditions of this replacement.

Scorzalite formation should be rather precocious in the genesis of the Angarf-Sud pegmatite phosphate minerals.

In fact, in the Mg-triphylite – Ca-alluaudite – melonjosephite – apatite sequence which characterizes the zonality of phosphates nodules (Fransolet, 1974), the ratio Fe^{3+}/Fe^{2+} trends to an evolution from 0 to 1. Moreover in this sequence magnesium decreases rapidly. Although the ratio Fe^{3+}/Fe^{2+} has not been established in scorzalite, the percentage of ferric iron is considered to be low, based on analyses of Pecora & Fahey (1950). So, it could be assumed that the formation of scorzalite occurs approximately simultaneous with the triphylite one. In the opposite case, for scorzalite formation which requires a low oxygen fugacity, it should have been needed a variation in Eh and pH conditions with a magnesium recurrence. The presence of unaltered pyrite cubes in the blue phosphate mineral further reinforces this attempt.

Following Fersman (1931), triphylite formation take place during the G phase i.e. in the temperature interval from 600° to 500°C. This range of temperature could be the one of scorzalite formation, which is also in agreement with Geijer's opinions (1964).

As a conclusion scorzalite form the Angarf-Sud pegmatite should have been formed under a low oxygen fugacity, between 600° and 500°C, due to an introduction of iron and magnesium by a phosphate solution corroding muscovite, which has yielded aluminum.

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