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Halogen-bearing minerals from Airport Hill, Visakhapatnam, India

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Abstract

Coexisting biotite, hastingsite and apatite in a granulitic charnockite from Eastern Ghats, India, contain large amounts of chlorine and fluorine. The chlorine content in biotite is one of the highest ever recorded in this mineral. The hastingsite composition is quite similar to that of other chlorhastingsites reported elsewhere, except that it contains fluorine. The apatite crystals contain rare earth elements in addition to halogens.

Introduction

Halogens in some minerals of high grade metamorphic rocks have been reported by Leelanandam (1969a, b) and Blattner (1980). An understanding of the occurrence and distribution of these minerals in Precambrian terrains appears to be critical as fluids containing chlorine and fluorine are recognized to have contributed significantly to the evolution of early crust (Collerson and Fryer, 1978). In the course of a petrochemical study of a suite of granulite facies rocks from Eastern Ghats, Southern India, we have discovered a sample with fluorine and chlorine-rich minerals. The halogen-bearing minerals include biotite, hastingsite and apatite, and this report deals primarily with their occurrence and composition.

Geological setting

Garnet–sillimanite gneisses, quartzites, calc–granulites (khondalites), and garnet–biotite granites (leptynites) constitute the major lithological units in the hill ranges near Visakhapatnam, Andhra Pradesh, India. They, together with hypersthene-bearing granitoids (charnockites), form the Precambrian basement complex of the Eastern Ghats. Pyroxene granulite sills and dikes are common in the charnockites, leptynites and khondalites.

The charnockites near Visakhapatnam form a prominent hill, Δ 136′, and are being extensively quarried. Two kinds of charnockites are recognized in the area (Sriramadas and Rao, 1979): (1) a medium-grained tonalitic type and (2) a coarse-grained granodiorite variety giving K–Ar ages 2.6 Ga and 2.0 Ga respectively. The coarse-grained garnet–biotite–hypersthene granodioritic charnockites occasionally contain allanite, and are believed to be of palingenetic origin (Rao and Babu, 1978). These are formed from the tonalitic charnockites, mostly along the NW–SE shear zone related to cross-folding in the Eastern Ghats. Biotite is a common mineral in the palingenetic charnockites. Hornblende and apatite occur in minor amounts in these rocks. The rock containing halogen-bearing minerals, described here, belongs to the younger granodioritic charnockitic group.

Petrography

Quartz, plagioclase ($An_{53.1}Ab_{45.4}Or_{1.5}$), potash feldspar ($An_{1.9}Ab_{9.4}Or_{88.7}$), garnet, biotite, hastingsite, hypersthene (En_{44}), apatite and monazite are the minerals identified in polished thin section.

In thin section, the rock displays mortar texture with augen of potash feldspar and garnet crystals (Fig. 1). The potash feldspar grains are perthitic and exhibit well-developed Carlsbad twinning. These crystals show dimensional orientation elongated parallel to the twin plane, which in general is aligned parallel to the rock foliation defined by some matrix minerals. Biotite flakes display a strong preferred orientation. Small prisms of hast-

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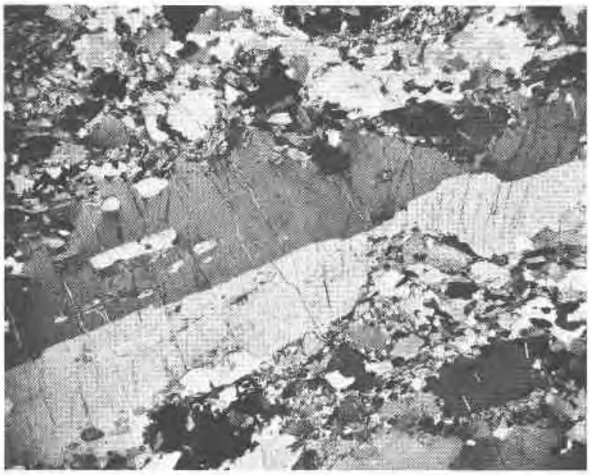

Fig. 1. Photomicrograph displaying mortar texture. Note the potash feldspar augen with well developed carlsbad twinning. Crossed nicols ×5.

ingsite and apatite crystals are found interspersed within biotite foliation (Fig. 2). Apatite occurs also as inclusions in biotite crystals. A few relict grains of hypersthene and two monazite grains were noted in thin section. The monazite occurs as inclusions in biotite.

The relict character of hypersthene grains suggests some element of retrogression in the sample. It is inferred that initially the rock was a hypersthene–garnet-bearing charnockite with few or no hydrous phases, but a subsequent hydration event (associated with cross-folding) produced large amounts of biotite and hornblende. The fluid responsible for this retrogression must have been very rich in chlorine and fluorine.

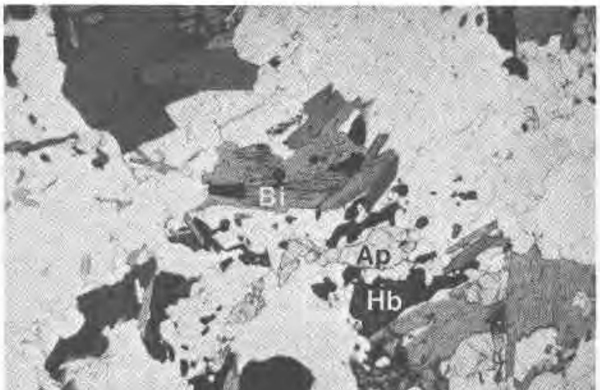

Fig. 2. Photomicrograph showing the coexisting biotite (Bi), hornblende (Hb), apatite (Ap) and garnet (Ga) plane polarized light ×38.

Method of analysis

The apatite, biotite and hastingsite grains in the polished thin section were analyzed with a MAC elecron probe equipped with a KEVEX energy dispersive spectrometer. Accelerating voltage was 20 kV with a specimen current of 10 nA measured on a kaersutite standard. Counting time was 100 seconds. The analytical raw data were corrected for background, non-resolution and matrix effects via MAGIC V (Colby, 1980). For apatite the microprobe standards were a natural analyzed kaersutite (Fe), apatite from Durango, Mexico (Cl, P, Ca), REE 2 (Nd, Sm, Yb, Lu), REE 3 (La, Ce, Pr), REE 4 (Er), (Drake and Weill, 1972) and synthetic phlogopite (F). For biotite and hornblende the standards were kaersutite (Na, Ca), chromite (Cr), biotite (Mg, Al, Si, K, Ti, Mn, Fe), halite (Cl) and synthetic phlogopite (F). The analyses for fluorine were obtained using an ETEC-SEM equipped with a wavelength dispersive spectrometer. Although duplicate analyses of standards of known composition confirmed

Table 1. Microprobe analyses of biotite and hastingsite

	Biotite[1]	Hastingsite[2]
SiO_2	37.47	35.60
TiO_2	5.03	1.36
Al_2O_3	12.18	13.57
Cr_2O_3	0.22	0.18
Fe as FeO	21.16	28.18
MnO	0.01	0.00
MgO	11.08	3.98
CaO	0.02	8.86
Na_2O	0.00	0.64
K_2O	9.63	2.48
Cl	2.07	4.18
F	2.60	1.00
	101.47	100.03
O ≡ F, Cl	1.56	1.36
Total	99.91	98.67

Forumlae* on the basis of 24 oxygens.

	Biotite	Biotite (sum)	Hastingsite	Hastingsite (sum)
Si	5.976	8.000	5.576	8.000
Al^{iv}	2.024		2.224	
Al^{vi}	0.268	6.112	0.342	5.300
Ti	0.599		0.165	
Cr	0.025		0.023	
Fe	2.825		3.811	
Mg	2.636		0.959	
K	1.952	1.952	0.511	2.246
Na	—		0.200	
Ca	—		1.535	
Cl	0.567	1.877	1.145	2.411
F	1.310		0.511	
OH	—		0.755	

[1]Average of 4 analysis, [2]Average of 7 analysis.
Accuracy of fluorine (F) is ± 15%.
*1% water was assumed in hastingsite.

Table 2. Microprobe analysis of apatite

	Wt. %	No. of ions on the basis of 26(O, OH, F, Cl)		
P_2O_5	40.43	P	5.896	
CaO	53.07	Ca	9.794	10.172
FeO	0.57	Fe	0.081	
La_2O_3	0.40	La	0.025	
Ce_2O_3	0.93	Ce	0.059	
Pr_2O_3	0.10	Pr	0.012	
Nd_2O_3	0.68	Nd	0.083	
Sm_2O_3	0.24	Sm	0.029	
Yb_2O_3	0.81	Yb	0.089	
Cl	0.84	Cl	0.244	1.878
F	3.00	F	1.634	
	101.07			
O ≡ F, Cl	1.44			
Total	99.63			

Average of 3 analysis.
Total Fe expressed as FeO; accuracy for fluorine (F) is ± 15%.

the values given (accuracy: ±15%), the values for fluorine should be considered as semi-quantitative due to a certain amount of instability in the system.

Mineral compositions

Biotite

The biotite contains no Na, traces of Mn and Ca, and high Ti, Cl, and F (Table 1). The chlorine content is the highest recorded to date in biotites from either granulite facies rocks or other environments. The Fe–Mg contents are closely comparable to those of chlorine-rich biotites reported by Leelanandam (1970) from Kondapalli, which is located about 250 km south of the present investigation.

Hastingsite

The amphibole contains no Mn, low Na and high K and Cl (Table 1). Referring the amphibole analysis to the nomenclature given Leake (1978) showed that when Cl in amphibole formula is ≥1.00, the prefix chlor is applicable. The amphibole formula also contains K > 0.50. Based on this, the hastingsite could be termed chlorpotassium hastingsite.

Chlorine-bearing hastingsites have been reported from other localities by Krutov (1936), Jacobson (1975), Dick and Robinson (1979) and Sharma (1981). Krutov reported a chlorine-rich potassium hastingsite (dashkesanite) from Skarns associated with gabbro porphyrite in Transcaucasia, and Jacobson (1975) analyzed chlorhastingsites in an ultrabasic intrusion from St. Paul's rocks in equatorial Atlantic. Dick and Robinson (1979) noted chlorine-rich hastingsite in a sphalerite-bearing skarn in Yukon. Recently, Sharma (1981) reported a chlorpotassium hastingsite occurring in a metamorphosed calcareous sediment from Rajasthan, India. Like the present occurrence, the chlorpotassium hastingsite from Rajasthan also crystallized under granulite facies conditions. Except for the presence of fluorine, the chlorpotassium hastingsite from Visakhapatnam is close in composition to dashkesanite from Transcaucasia and St. Paul's rocks of equatorial Atlantic, both analyzed by Jacobson (1975). The St. Paul's chlorhastingsites are richer in Mg presumably because of their ultrabasic host rocks. The chlorpotassium hastingsite from Rajasthan is poor in Na but rich in K. Among the reported occurrences, the chlorine-bearing hastingsite from Yukon contains lowest amounts of Cl (1.15–3.09).

Apatite

The apatite contains Cl, F and rare earth elements (Table 2). The rare earth elements account for 3.10 per cent, making it one of the highest rare earth-bearing apatites recorded. Rare earth elements partially replacing Ca in apatites of alkaline igneous rocks in the Kola Peninsula have been reported (see Deer *et al.*, 1963). The fluorine content is higher than the chlorine and this appears to be the case for all halogen-bearing apatites reported by other workers (Blattner, 1980; Roegge *et al.* 1974).

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