Canadian Mineralogist
Vol. 21, pp. 661-664 (1983)

CHLORITOID AMPHIBOLITES FROM THE PAMUR AREA, ANDHRA PRADESH, SOUTHERN INDIA

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ABSTRACT

Chloritoid and tremolite–chloritoid amphibolites are reported from a metasedimentary sequence in southeastern India. From optical and X-ray data, chloritoid is identified as the monoclinic variety. These chloritoid-bearing rocks seem to have evolved, under greenschist-facies conditions, from marly sediments containing intercalated aluminous and ferruginous strata.

Keywords: chloritoid, amphibolite, marly sediments, greenschist facies, India, Andhra Pradesh.

SOMMAIRE

On décrit des amphibolites à chloritoïde et à trémolite-chloritoïde d'une séquence métasédimentaire dans le Sud-Est de l'Inde. D'après les propriétés optiques et les données de diffraction X, le chloritoïde est monoclinique. Les roches qui le contiennent résulteraient de l'évolution, dans les conditions génératrices du facies schiste-vert, de sédiments marneux intercalés de strates alumineuses et ferrugineuses.

(Traduit par la Rédaction)

Mots-clés: chloritoïde, amphibolite, sédiments marneux, facies schiste-vert, Inde, Andhra Pradesh.

INTRODUCTION

During the course of our geological investigation of the Pamur area in the Prakasam district, Andhra Pradesh, southern India (79°20′ - 79°25′E, 15°5′ - 15°10′N), four major rock-types were encountered: chlorite schist, granitic gneiss, amphibolite and quartzite (Fig. 1). The rare association chloritoid–hornblende was observed in samples from the amphibolitic map-unit. The object of this note is to describe some of the unusual assemblages in which this association was found.

PETROGRAPHY

The metasedimentary amphibolites are compact dark green rocks with a well-developed schistosity. They can be classified into four types, depending on the dominant mineral present in the rock in addition to hornblende: calcite amphibolite, epidote amphibolite, tremolite amphibolite and chloritoid amphibolite.

The choritoid amphibolite occurs as lenses in a sequence of schistose amphibolite layers. It contains xenoblastic chloritoid grains that cut across the schistosity (Fig. 2), and that must therefore be postkinematic. Quartz, plagioclase, hornblende, opaque minerals (mostly oxides) and epidote also are present. The chloritoid is green, with the pleochroic scheme, *X* green, *Y* light blue, *Z* pale yellow; $2V$ 54–70°, $Z{:}c$ 2–6°; $n\alpha - n\gamma$ 0.005–0.009, $n\beta$ 1.720–1.723. The optic axial plane is normal to (010). A single-crystal X-ray precession photograph gave the following cell-dimensions:

a 9.44(3), b 5.32(3), c 18.42(3) Å,
α 90°, β 101°30(5)′, γ 90°.

The optical and X-ray parameters identify the mineral as monoclinic chloritoid (Halferdahl 1961). Some of the grains are twinned, and some exhibit shadowy strained extinction. The green hornblende in the assemblage is the common type and has inclusions of quartz and opaque phases. Plagioclase is lath-shaped and shows polysynthetic twinning. Some of the quartz grains have relict clastic textures.

Chloritoid and hornblende are also observed in association with fibrous tremolitic–actinolitic amphibole, in assemblages that include quartz, epidote, chlorite and opaque phases. Chloritoid develops from chlorite (Fig. 3) and is similar in optical properties to that described in chloritoid amphibolite. Hornblende is green, with light green to light blue pleochroism, $2V$ 58–62°, $Z{:}c$ 22–25°, $n\gamma - n\alpha$ = 0.025–0.028. Some of the tremolite grains are colorless, whereas a few others are light green, $2V$ 70–80°, $Z{:}c$ 18–20°, $n\gamma - n\alpha$ 0.023–0.025.

CHEMISTRY

Two specimens of chloritoid, one from a chloritoid amphibolite and one from a tremolite–chloritoid amphibolite, have been chemically analyzed (Table 1). The chloritoid from the tremolite–chloritoid amphibolite was found to contain a few quartz inclusions, which could not be separated. These inclusions have probably given a high SiO_2 value and corresponding low values of other constituents. The structural formulae agree with the general chloritoid formula, $X_2Y(OH)_4Al_3O_2(SiO_4)_2$, in which X represents Fe^{3+}, Fe^{2+}, Mg, Mn, Ca, Na and K, and Y represents Al, Fe^{3+} and Ti (Snelling 1957). The

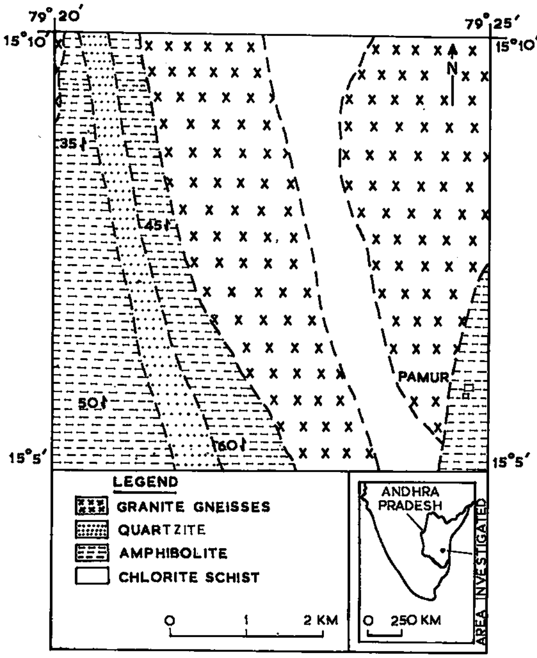

FIG. 1. Geological map of Pamur area, showing the distribution of amphibolite and other associated rocks.

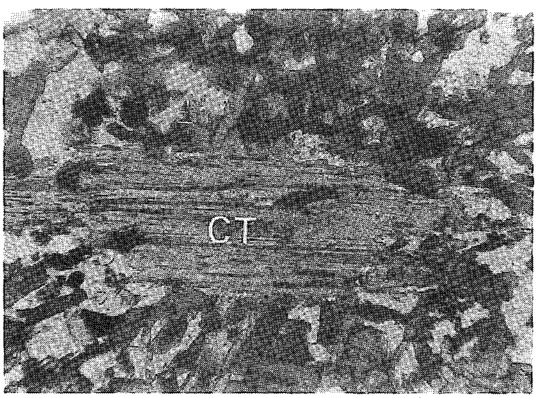

FIG. 2. Development of chloritoid across the schistosity (schistosity in NE direction); inclusions of quartz in chloritoid. ×45, plane light.

analytical results are recalculated to give 2 Si per unit cell, and the resultant formula is very close to the general formula. The calculated molar ratios $MgO/(MgO + FeO)$ and $MgO/(MgO + FeO + 2Fe_2O_3)$ are 15.1, 12.8 and 13.3, 11.3, respectively, which are within the values given by Chinner (1967) for chloritoid.

Two samples of chloritoid-bearing amphibolite and three of chloritoid-free amphibolite have been analyzed. Their chemical and modal compositions are given in Table 2. When plotted on Hoschek's (1967) triangular diagrams (Fig. 4), a clear separation of chloritoid-bearing from chloritoid-free rocks

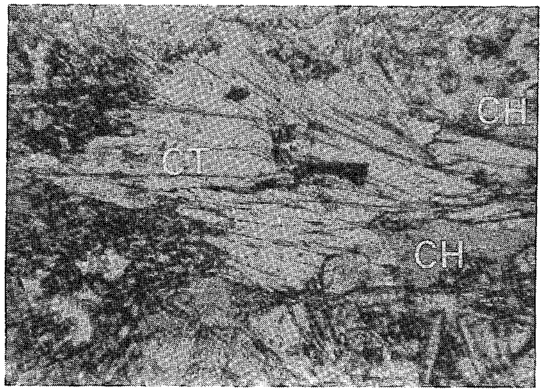

FIG. 3. Development of chloritoid CT from chlorite CH. ×45, plane light.

TABLE 1. CHEMICAL COMPOSITION OF CHLORITOID FROM THE PAMUR AREA

	1	2		1	2
SiO_2 wt.%	25.11	23.85	Si*	2.08	2.00
TiO_2	0.66	0.98	Al	3.00	3.00
Al_2O_3	35.18	35.44	Al	0.44	0.50
Fe_2O_3	9.21	8.88	Ti	0.04	0.06
FeO	19.63	20.07	Fe^{3+}	0.58	0.56
MnO	0.86	0.69	Fe^{2+}	1.36	1.40
MgO	1.96	1.72	Mg	0.24	0.22
CaO	0.82	0.92	Mn	0.06	0.05
Na_2O	0.20	0.38	Ca	0.07	0.08
K_2O	0.14	0.12	Na	0.03	0.06
H_2O	7.08	7.14	K	0.01	0.01
Total	100.85	100.19	OH	3.92	4.00

Structural formula, on the basis of 14(O + OH).
1. $(Fe^{2+},Mg,Mn,Ca,Na,K)_{1.77}(Al,Fe^{3+},Ti)_{1.06}Al_3O_2(SiO_4)_{2.08}(OH)_{3.92}$
2. $(Fe^{2+},Mg,Mn,Ca,Na,K)_{1.94}(Al,Fe^{3+},Ti)_{1.12}Al_3O_2(SiO_4)_2(OH)_4$

* number of cations on the basis of 14(O + OH). 1. Chloritoid from chloritoid amphibolite. 2. Chloritoid from chloritoid-tremolite amphibolite. Analyst: D. Sesha Reddy.

TABLE 2. CHEMICAL AND MODAL COMPOSITION OF SCHISTOSE AMPHIBOLITES FROM THE PAMUR AREA

SiO_2 wt.%	48.56	56.02	53.95	57.14	57.84
TiO_2	1.14	0.94	1.00	0.94	1.30
Al_2O_3	15.04	13.67	12.22	11.13	8.87
Fe_2O_3	4.18	4.08	3.43	3.64	4.01
FeO	8.95	5.55	4.80	4.73	4.92
MnO	0.22	0.24	0.43	0.03	0.42
MgO	9.48	8.33	10.02	9.45	8.37
CaO	8.22	7.53	9.43	8.76	10.16
Na_2O	1.32	1.04	1.83	1.63	1.24
K_2O	0.38	0.42	0.45	0.41	0.20
P_2O_5	0.13	0.12	0.20	0.16	0.25
H_2O	2.56	2.30	2.15	2.02	2.25
Total	100.18	100.24	99.91	100.04	99.83
Quartz	11.2	32.5	22.4	27.7	26.1
Plagioclase	-	2.7	8.5	6.5	3.2
Hornblende	25.1	55.9	67.2	63.5	27.0
Tremolite	44.8	-	-	-	31.0
Chloritoid	14.3	6.3	-	-	-
Epidote	2.1	0.1	-	-	12.7
Chlorite	1.3	-	-	-	-
Opaque phase	1.2	2.5	1.9	2.3	-

1, 2: chloritoid-bearing amphibolite. 3, 4, 5: chloritoid-free amphibolite. Analyst: D. Sesha Reddy.

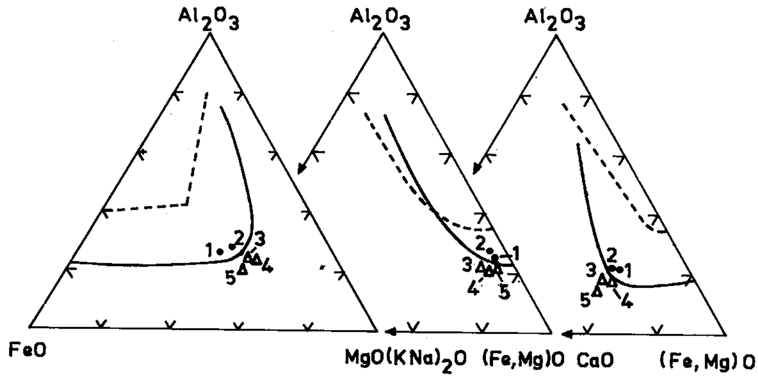

FIG. 4. Triangular diagrams showing chemically analyzed amphibolites (molar basis); dashed lines by Hoschek (1967), solid lines by the authors. Points 1 to 5: legend as given in Table 2.

is observed, with the former lying closer to the Al_2O_3 apex than the latter. However, note that some of these rocks lie outside Hoschek's chloritoid field, a fact that may indicate that Hoschek's line of separation does not apply to amphibolites, but only to assemblages derived from metapelites.

PETROGENESIS

Chloritoid-bearing assemblages in aluminous metapelites are relatively common (*e.g.*, Milne 1949, Williamson 1953, Hoschek 1967). They have also been found in metamorphosed, hydrothermally altered felsic volcanic rocks (*e.g.*, Spitz & Darling 1973, Franklin *et al.* 1975). However, chloritoid–amphibole assemblages appear to be rare. Descriptions of such assemblages could only be found in Thompson (1972) and Fox (1974), and in both cases, the rocks are richer in Al_2O_3 and K_2O and poorer in FeO + Fe_2O_3, CaO, MgO and Na_2O than those at Pamur.

As described earlier, chloritoid-bearing amphibolites occur as lenses in the schistose amphibolites. The protoliths of the schistose amphibolites are considered to be marls. Aluminous and ferruginous sediments admixed with marls as intercalations provided the suitable composition for the formation of chloritoid amphibolites. The mineral assemblages of these amphibolites are in the greenschist facies.

Iron oxides and chlorite might have reacted to give rise to chloritoid thus: 5 hematite + chlorite = 5 magnetite + 2 chloritoid + 2 quartz + $4H_2O$, as observed by Miyashiro (1973). The experimental studies reveal that chloritoid would be stable over the entire pressure range [$P_S = P(H_2O)$] from near zero to the highest value (above 20 kbar) and up to 500–700°C depending on $P(O_2)$. With the participation of the full range of phases and components available, the formation temperature of the chloritoid is likely to be lower than that obtained in experiments. In a reaction that involves the prior existence of dolomite in addition to the mineral assemblages observed, chloritoid formation is likely to have been influenced not only by T, P and $f(O_2)$, but also by $X(CO_2)$.

ACKNOWLEDGEMENTS

The authors thank Dr. B.V. Ramanamurthi and Dr. G.V.N. Apparao, I.I.T., Madras, for help in taking X-ray photographs. We thank Dr. R.F. Martin, Dr. E. Froese and the referees, whose suggestions have improved the quality of the paper. D.S. Reddy greatly acknowledges the financial assistance of the C.S.I.R. (New Delhi).

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Received June 14, 1982, revised manuscript accepted April 1, 1983.