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Department of Geology, National Museum of Wales, Cardiff CF1 3NP

J. M. HORAK

Department of Geology, University College, Cardiff CF1 1XL

W. GIBBONS

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## Chromium-rich kyanite in an eclogite from the Rouergue area, French Massif Central

A CHROMIUM-RICH kyanite with a maximum content of 7% Cr<sub>2</sub>O<sub>3</sub> occurs in an eclogite from the leptyno-amphibolic group of Eastern Rouergue, French Massif Central. The leptyno-amphibolic group is a bimodal formation with relict eclogitic parageneses (Nicollet and Leyreloup, 1978) which represents the trace of an ancient suture zone (Bodinier *et al.*, 1985). The studied eclogite sample (Rd 749) comprises a lens 1 m long within a matrix of both amphibolites and metagreywackes. The matrix has suffered the later barrovian type metamorphism related to Variscan thrusting (Burg *et al.*, 1984). In this paper we present mineralogical and chemical data on the high-chromian kyanite in order to discuss the kyanite-forming reaction and inferred *P-T* conditions, with special references to other Cr-kyanite occurrences. Representative microprobe analyses (Table I) have been carried out with a wavelength dispersive Camebax instrument in the University of Montpellier (France).

In the eclogite Rd 749, the high-pressure stage is characterized by the association garnet (gro 24, py 47, alm 28)-omphacite (jad 25)-epidote-kyanite-quartz. The most striking occurrence of garnet is the development of garnet coronas around omphacite, thus giving the eclogite a peculiar

honeycomb texture (Lasnier, 1970). Numerous idiomorphic kyanite inclusions (< 0.05 mm) are present in the garnet core whether coronitic textures develop or not. No significant R<sup>3+</sup> ⇌ Al<sup>3+</sup> substitution has been observed in these kyanite grains. Also in the garnet core is a smaller number of large kyanite crystals (up to 0.2 mm); these have been found to be chromian kyanite and show strong blue pleochroism. The crystals (fig. 1) invariably contain inclusions of Cr-rich rutile (0.47% < Cr<sub>2</sub>O<sub>3</sub> < 0.68%). A marked zonation in Cr<sub>2</sub>O<sub>3</sub> content is measured in the kyanite, from core (up to 6.99%) to rim (up to 1.1%), the 6.99% maximum being reached around the Cr-rutile inclusions. Fe<sub>2</sub>O<sub>3</sub> (up to 0.58%) is the other trivalent ion, with no relation to the Cr<sub>2</sub>O<sub>3</sub> content. The increase in Cr<sub>2</sub>O<sub>3</sub> content is positively correlated with the blue colour intensity (an observation also made by Sobolev *et al.*, 1968) and it does not seem necessary to imply any other chemical control as charge transfer process (Smith and Strens, 1976) or TiO<sub>2</sub> content (Neiva, 1984).

From a general point of view, the occurrence of kyanite inclusions, both chromian and Cr-free, appears as a major feature of the Rd 749 eclogite. In addition a magnesio-hornblende aggregate is

Table I. Electron microprobe analyses of Cr-kyanite, Mg-hornblende, garnet and omphacite.

	1	2	3	4	5
SiO <sub>2</sub>	36.78	52.24	39.70	54.12	54.13
Al <sub>2</sub> O <sub>3</sub>	56.14	8.87	22.63	7.81	7.54
FeO <sup>t</sup>	0.58	4.24	19.82	3.94	3.37
MnO	—	—	0.48	0.05	0.01
MgO	—	17.08	9.84	12.17	12.02
CaO	0.02	13.79	7.94	18.21	18.18
Na <sub>2</sub> O	—	1.38	—	3.25	3.46
K <sub>2</sub> O	—	0.05	—	—	—
TiO <sub>2</sub>	0.02	0.30	—	0.07	0.15
Cr <sub>2</sub> O <sub>3</sub>	6.99	—	—	—	0.55
ZnO	—	—	—	—	—
<b>Total</b>	<b>100.53</b>	<b>97.95</b>	<b>100.41</b>	<b>99.62</b>	<b>99.5</b>
Number of ions in the formula based upon					
	5 oxy	23 oxy	24 oxy	6 oxy	
Si	1.013	7.248	5.965	1.931	1.955
Al	1.819	1.451	4.009	0.332	0.321
Fe <sub>2</sub>	—	0.492	2.445	0.119	0.102
Fe <sub>3</sub>	0.012	—	0.046	—	—
Mn	—	—	0.061	0.002	0.003
Mg	—	3.532	2.204	0.654	0.647
Ca	—	2.050	1.278	0.704	0.704
Na	—	0.371	—	0.227	0.242
K	—	0.009	—	—	—
Ti	—	0.031	—	0.002	0.002
Cr	0.152	—	—	—	0.016
Zn	—	—	—	—	—
<b>Total</b>	<b>2.996</b>	<b>15.184</b>	<b>16.008</b>	<b>3.971</b>	<b>3.992</b>

n°1 : Cr-kyanite included in garnet; FeO total (FeO<sup>t</sup>) as Fe<sub>2</sub>O<sub>3</sub>

n°2 : magnesio-hornblende in garnet

n°3 : garnet (rim)

n°4 : omphacite included in garnet (n°3)

n°5 : Cr-omphacite in the matrix, without garnet corona.

contained in kyanite-free garnet cores. This amphibole is not found elsewhere within the partially retrogressed omphacitic matrix where omphacite presents a small but significant 0.5% Cr<sub>2</sub>O<sub>3</sub> content. Paradoxically, omphacite with garnet corona is Cr<sub>2</sub>O<sub>3</sub> free.

The retrogression products from the eclogitic paragenesis will not be described in detail, but we particularly mention: (i) andesine-edenitic hornblende symplectites around garnet; (ii) andesine-clinopyroxene<sub>II</sub> (jad 23 to 9.5) symplectites around omphacite. Locally, a secondary Cr-free kyanite generation of kyanite occurs as randomly oriented

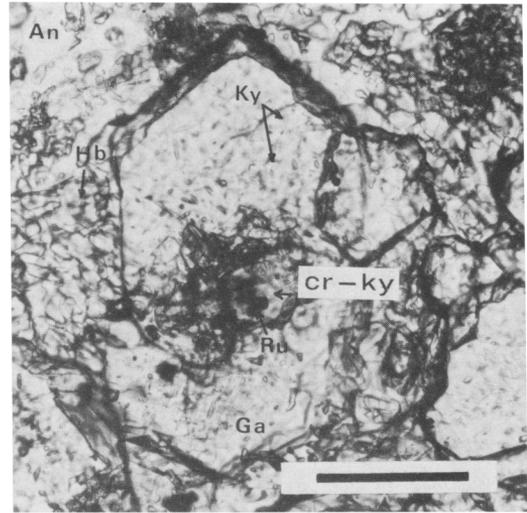


FIG. 1. Photomicrograph showing Cr-kyanite (cr-ky) and Cr-rutile (ru) both included in garnet core (ga). Numerous Cr-free kyanite (ky) can also be observed. Edenitic hornblende (hb) and andesine (an) are the retrograde phases (one nicol, bar scale = 0.4 mm).

tabular crystals in andesine-biotite symplectitic dots.

Chromian kyanite has been found in various rock types, such as trondjemites (up to 0.4%; Neiva, 1984), metacherts in whiteschists (up to 2.88%; Cooper, 1980) or grosopydite xenoliths in kimberlites (up to 12.86%; Sobolev *et al.*, 1968). According to these examples the Cr content of kyanite is not just related to the Cr content of the host rock, but also indicate high-pressure conditions of crystallization ( $P > 10$  kbar; Cooper, 1980; Sobolev *et al.*, 1968). This assumption is supported by the experimental results of Seifert and Langer (1970) who synthesized chromian kyanite with 24 and 31% moles Cr<sub>2</sub>SiO<sub>5</sub> at 20 and 30 kbar respectively. The Rd 749 eclogite in Eastern Rouergue shows the highest Cr<sub>2</sub>O<sub>3</sub> content so far recorded in eclogitic rocks, setting aside the 12.86% maximum reached in grosopydites from the Yakutia area (Sobolev *et al.*, 1968).

Yakutia grosopydites show close mineralogical analogies with the Rd 749 eclogite: numerous kyanite inclusions are observed in garnet; maximum chromium content is reached in blue kyanite included in garnet.

Both in Yakutia and Eastern Rouergue the restricted occurrence of high-chromian kyanite in the garnet core suggests that the chromian-kyanite-forming reaction represents an earlier stage in the eclogitization process, closely associated

with garnet blastesis. Coronitic garnet growths are classically observed in metagabbros (Lasnier, 1970), and involve reactions between both magmatic plagioclase and ferromagnesian phase. More particularly, kyanite, Mg-hornblende, and garnet have already been described between orthopyroxene and magmatic plagioclase in a meta-orthite from the Rouergue area (Nicollet, 1982). By analogy with this reaction type, we suggest that chromium-free kyanite and Mg-hornblende of the Rd 749 eclogite are the breakdown products of a primary gabbroic stage during the eclogitization event. The nucleation of Cr-kyanite around Cr-rutile could be related to the same process. Pressure-temperature estimates based upon jadeite content in omphacite (minimum pressure; Holland, 1980) and Fe-Mg cationic exchange between garnet and clinopyroxene (thermometer of Ellis and Green, 1979) yield  $P = 14.5$  kbar and  $T = 760$  °C for the high-pressure stage.

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Laboratoire de Pétrologie des Zones Profondes, USTL, Place E. Bataillon, 34060 Montpellier, France

Laboratoire de Pétrologie, USTL, Place E. Bataillon, 34060 Montpellier, France

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C. P. DELOR

A. F. LEYRELOUP

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## Comments on 'Priderite stability in the system $K_2MgTi_7O_{16}$ -BaMgTi<sub>7</sub>O<sub>16</sub>'

IN a recent contribution to this journal Dubeau and Edgar (1985) investigated solid solution behaviour and stability relations of the hollandite phase along the join  $K_2MgTi_7O_{16}$ -BaMgTi<sub>7</sub>O<sub>16</sub> (KP-BP) in order to obtain a better understanding of the petrogenesis of the naturally occurring titanate hollandite, priderite  $(K,Ba)_x(Mg,Fe,Ti)_8O_{16}$  (Norrish, 1951). They found that rutile coexists with hollandite in all bulk compositions with 50 wt. % or more of BP, and suggested that it was stabilized as a consequence of oxygen deficiencies in the hollandite structure, viz.  $(Ba,K)MgTi_{7-x}O_{16-x}$ . They also recognized the possibility that

tunnel site vacancies in the hollandite structure might somehow offer an alternative explanation.

These proposals deserve further discussion. Titanate hollandites with Ba as the major or only tunnel cation typically display superlattice periodicity due to ordering of vacant and occupied tunnel sites (Bursill and Grzanic, 1980; Mijlhoff *et al.*, 1985; Kesson and White, 1986). [ $K_{2x}Mg_xTi_{8-x}O_{16}$  hollandites may also exhibit superlattice ordering if some of their tunnel sites are vacant and  $x < 1.0$  (e.g. Beyeler and Schuler, 1980).]

The stoichiometry of  $Ba_xMg_xTi_{8-x}O_{16}$  hollandites ranges from  $x = 1.33$  to 1.14 (Roth, 1981) with