A chlorite–corundum rock from Mount Painter, South Australia

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Summary. A rock from the Mt. Painter area, South Australia, consists essentially of corundophilite (anal., X-ray) and corundum, with accessory boehmite, sapphirine, cordierite, muscovite, and rutile. The rock probably crystallized at 500 to 700° C under 20 000 lb/in.^{2} pressure, boehmite being formed by retrogressive metamorphism at 120 to 280° C.

THIS paper is primarily a description of a single rock specimen collected by Sir Douglas Mawson presumably from the Corundum Mine locality, Mt. Painter area, northern Flinders, South Australia, and now located in the collection of the Department of Geology, Adelaide University (No. 10193). Rocks with which it is associated *in situ* have been mentioned by Mawson (1916, 1923) and include a variety of metamorphic schistose types characterized by the presence of one or more of the minerals corundum, cordierite, sillimanite, spinel, monazite. Study of a corundum-rich variety in the Geophysical Laboratory of the Carnegie Institute, Washington, revealed the presence of sapphirine (Schreyer and Yoder, 1961).

In hand specimen, the rock has an even, coarse texture, and consists of about equal quantities of sky-blue corundum and books of pale green chlorite.

In thin section: *Corundum* ($\sim$ 34 %) is patchily coloured, sky-blue and pleochroic in part and elsewhere colourless. *Boehmite* ($\sim$ 9 %) occupies cracks in some corundum grains and mantles others; it appears to be an alteration product of the corundum. *Chlorite* ($\sim$ 44 %) is colourless under the microscope. Flakes are 2–3 mm in diameter and very strained; the consequent undulose extinction renders the determination of optic axial angle difficult, but a range of $2V_\gamma$ of 0 to 23° (by combined U-stage measurement and optic figure observation) is thought to be correct. $\alpha = \beta = 1{\cdot}584$, $\gamma = 1{\cdot}596$ (Na light). γ is perpendicular to the marked basal cleavage. *Sapphirine* ($\sim$ 9 %) is similar in general appearance to corundum. Some grains are colourless, others are faintly tinted blue-green but more uniformly than the corundum; $2V_\alpha$ 60 61°. *Cordierite* (~ 4 %) interstitial; $2V_\alpha$ 75°. *Muscovite* (~ 4 %) interstitial; $2V_\alpha$ 43°. *Rutile* (~ 4 %) scattered yellow-green-brown grains up to 0·5 mm diameter.

All the above minerals have been isolated and their identity confirmed by a combination of specific gravity, optical properties, and X-ray diffraction. Grains of rutile (~ 100 mesh) display a wide range of colour from pale yellow through red-brown to very dark brown; well-formed stumpy prismatic crystals are common.

TABLE I. Composition of chlorite from Mt. Painter. (Sample dried at 110° C; analyst R. L. Oliver)

			Atoms to 36 (O, OH)	
SiO_2	26·21	Si	4·857	8
Al_2O_3	29·50	Al	3·143	
		Al	3·295	11·849
TiO_2	tr.	Ti	—	
Fe_2O_3	1·04	Fe^{+3}	0·156	
FeO	1·28	Fe^{+2}	0·200	
MnO	0·02	Mn	—	
MgO	29·41	Mg	8·131	
CaO	tr.	Ca	—	
Na_2O	0·11	Na	0·045	
K_2O	0·05	K	0·022	
H_2O	12·98	(OH)	16·061	
	100·60			

Composition of the chlorite. Separation of the chlorite for analysis was difficult because of fine-grained boehmite contamination, and crushing to < 260 mesh was necessary to free the contaminant. The proximity of the S.G. of boehmite (3·0) to that of a magnesium-rich chlorite (ca. 2·7) was an added problem and the final specimen is perhaps no better than 98 % pure. Only 0·24 g were eventually available for analysis, and a combination was used of the micro methods described by Riley and Williams (1959), and classical gravimetric techniques using proportionately reduced quantities. Total H_2O was determined as loss on ignition; effects of oxidation have been ignored.

The analysis is shown in table I, and X-ray powder data in table II. The figure for FeO is possibly too low, relative to Fe_2O_3, but not enough material was available to prove this. The X-ray data are near those quoted by Brown (1961; table VI. 9, no. 1) for a sheridanite but the Mt. Painter mineral has a higher Al content and on the basis of Hey's (1954) classification, although close to sheridanite, it would be classified as *corundophilite* (see fig. 1); and the refractive indices are perhaps more akin to those of corundophilite than to those of sheridanite (see Deer, Howie, and Zussman, 1962).

Petrogenesis. Both the chlorite analysis and the composition of associated minerals indicate crystallization in an extremely aluminium–magnesium–water rich environment. The composition of the rock in the $MgO–Al_2O_3–SiO_2–H_2O$ tetrahedron might, in the absence of a complete rock analysis, be plotted somewhere between sapphirine and the H_2O corner of the tetrahedron (fig. 2). A point for the Mt. Painter corundophilite is shown between those for clinochlore and amesite.

TABLE II. Chlorite from Mt. Painter. *d* spacings and intensities obtained with an 11·46-cm powder camera using Co-*K*α (λ 1·7902 Å); calc. spacings for a cell with *a* 5·313 Å, *b* 9·203 Å, *c* 14·280 Å, and *β* 97·1°.

hkl	$d_{calc.}$	$d_{obs.}$	*I*
001	14·170	13·87	m 56*
002	7·085	7·14	s 100*
003	4·723	4·73	s 90*
020	4·602	4·59	vw
004	3·542	3·56	s 96*
005	2·834	2·836	m 40*
131	2·579	2·580	w
$20\bar{2}$	2·577		
$13\bar{2}$	2·536	2·535	m
201	2·536		
132	2·434	2·435	mw
$20\bar{3}$	2·436		
$13\bar{3}$	2·376	2·376	w
202	2·376		
133	2·253	2·253	w
$20\bar{4}$	2·253		
134	2·063	2·060	vvw
$20\bar{5}$	2·061		
007	2·025	2·027	w
$13\bar{5}$	1·999	1·999	mw
204	2·000		
135	1·879	1·879	w
$20\bar{6}$	1·879		
$13\bar{6}$	1·821	1·821	vw
205	1·821		
$22\bar{6}$	1·739	1·737	vvw
$13\bar{7}$	1·660	1·657	vvw
206	1·660		
137	1·563	1·563	w
$20\bar{8}$	1·563		
060	1·534	1·535	m
$33\bar{1}$	1·534		
062	1·499	1·500	w
331	1·499		
063	1·459	1·460	vvw
0.0.10	1·417	1·417	w
$13\bar{9}$	1·393	1·391	mw
208	1·393		
$26\bar{2}$	1·317	1·318	w
$2.0.\overline{10}$	1·318		
066	1·289	1·288	vw
$2.0.\overline{11}$	1·218	1·218	vw
0.0.12	1·181	1·181	vw

* Relative intensities from a diffractometer trace using a Philips high-angle goniometer, oriented smear mount 3 cm long and 1° slits. This chart gave a spacing of 14·17 Å for 001.

Yoder (1952), in his investigation of the $MgO–Al_2O_3–SiO_2–H_2O$ system, prepared clinochlore (with a leuchtenbergite ≡ sheridanite X-ray pattern) at temperatures between 520 and 680° C at pressures from 2000 to 30 000 lb/in.^{2} Roy and Roy (1955), studying the same system, demonstrate that high pressures (ca. 23 000 lb/in.^{2}) very greatly enhance the formation of clinochlore (at 535° C). With descending temperature it first becomes stable at 700° C and 20 000 lb/in.^{2} The authors state that above 800° C at 10 000 lb/in.^{2} only anhydrous minerals are stable. Support for this is given by Nelson and Roy (1958) who maintain that the equilibrium stability temperature for the chlorites appears

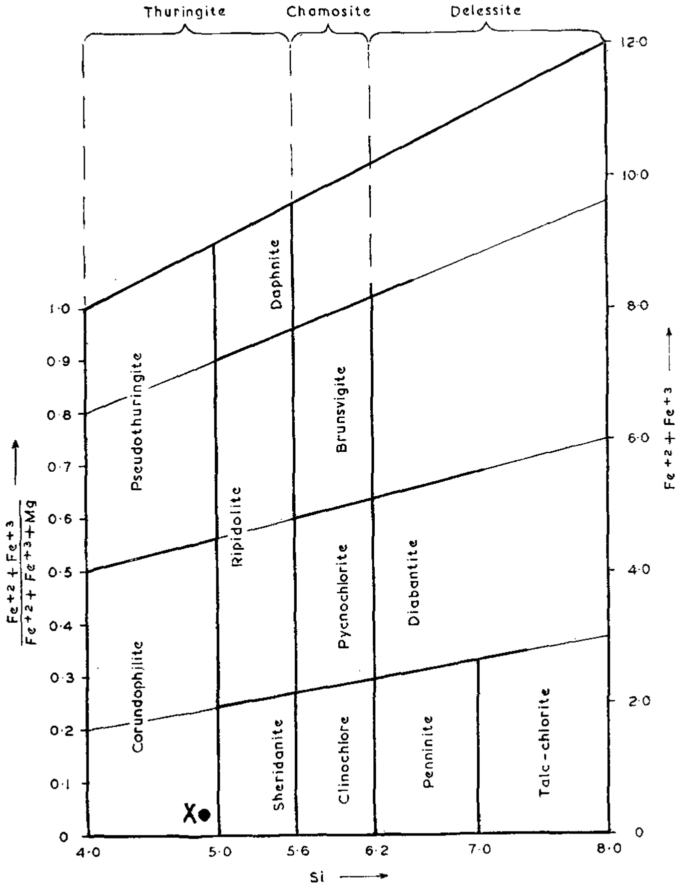

FIG. 1. Nomenclature of the chlorites (after Hey, 1954). The point at *X* shows the composition of the Mt. Painter chlorite.

to reach a maximum at the composition of clinochlore (710° C at 20 000 lb/in.^{2}), and to decrease slightly (~ 20° C) towards both pennine and amesite. A minimum temperature of 400° C for the assemblage amesite–corundum is suggested in fig. 4 of Nelson and Roy (1958). At temperatures of 520° C and 690° C, in the same figure, the pair cordierite corundum is stable. Segnit (1963) investigated the synthesis of clinochlore and found that between 10 and 20 kilobars aluminous serpentine (= 7 Å clinochlore) was obtained below 600° C and clinochlore above 780° C, but these pressures, corresponding to a depth of 40 to 60 Km, are probably greater than those that prevailed during the formation of the Mt. Painter rocks.

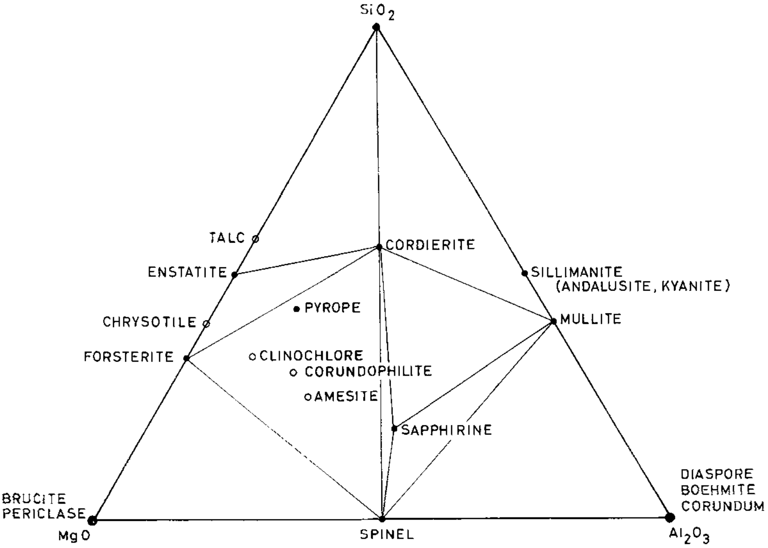

Fig. 2. Mol % composition diagram showing some of the phases in the SiO_2–MgO–Al_2O_3–H_2O system: ● anhydrous phases; o hydrous phases, above the plane of the paper. The corundophilite shown on the diagram is the plot of the Mt. Painter example described herein.

Reference has been made to the corundum–cordierite pair, an association plentiful in some of the Mt. Painter rocks occurring with the corundum–chlorite rock. Tilley (1924) in his investigations at Comrie, Scotland, considered this pair as stable in what is now regarded as the pyroxene hornfels facies (Turner and Verhoogen, 1960), though Yoder (1952) demurs. Schreyer and Yoder (1961) refer to the forbidden corundum–cordierite join at liquidus temperatures in the MgO–Al_2O_3–SiO_2 and FeO–Al_2O_3–SiO_2 systems. Roy and Roy in 1955, however, had found that at high pressure and below 800° C the pair is stable in preference to spinel–mullite. In the same paper, Roy and Roy put a lower stability limit on cordierite, in the presence of excess water, of 500° C.

Limited information is available on the stability relations of sapphirine. Segnit (1957) describes it in hypersthene-bearing gneisses from Antarctica, and Turner and Verhoogen (1960, p. 556) discuss rocks containing sapphirine in their consideration of the hornblende granulite facies.

Conclusions. Combined data suggest that the corundum–chlorite rock from Mt. Painter crystallized at temperatures between 500° C and 700° C under pressures of at least 20 000 lb/in.^{2} The principal minerals, corundophilite, corundum, and sapphirine were probably in equilibrium at the time of formation, there being a similar number of components to thus satisfy the Mineralogical Phase Rule (MgO, SiO_2, and Al_2O_3), H_2O being mobile. Other minerals in the general area, such as spinel, cordierite, sillimanite, may reflect slightly different *PT* conditions or a varied chemical rock composition. Retrogressive metamorphism has facilitated the subsequent development of boehmite at temperatures between 120° C and 280° C (see Roy, 1954).

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