Compact chlorite associated with lizardite from New South Wales, Australia

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Summary. Segregations of compact chlorite from ultramafic belts in New South Wales have been examined using chemical, X-ray, differential thermal, and electron-probe techniques. The chlorites vary from pennine to sheridanite. Some segregations occupy the central zone in metasomatic sequences of altered chromite, chlorite, and lizardite; but others may have formed at junctions of serpentinite and rodingite.

SEGREGATIONS of compact chlorite associated with serpentinite and chromite in the Coolac Serpentine Belt (Golding, 1966) in south-eastern New South Wales are similar in some respects to pseudophite (Benson, 1913) from Nundle, in the Great Serpentine Belt of north-eastern New South Wales, and to the compact chlorite, pseudophite or 'Styrian Jade', from Bernstein, Austria (Campbell Smith, 1924), which has also been termed aluminous serpentine (Webster, 1962). The mode of occurrence of the Nundle and Bernstein materials was not stated and no genesis was suggested.

Petrographic, chemical, X-ray, and differential thermal techniques have been used to compare compact chlorite and associated material from the Nundle and Coolac localities, and further detail for some specimens was obtained by means of an electron-probe analyser. This data, reported below, permits some comment on the genesis of the chlorites.

Nundle specimens. Fragments of pseudophite were recorded by Benson (1913) from Oakenville Creek, near Hanging Rock, Nundle. At this locality an isolated outcrop of serpentinite was recently excavated to recover 'precious serpentine' and is represented by a small pit. Much of the original material has been removed and the remaining serpentinite is poorly exposed. The nearest well-exposed rock mass, a few metres from the pit, is a fine-grained rodingite containing equal amounts of pale brown to colourless garnet and a pale green chlorite in micron-wide flakes. The relationship of this rodingite to the excavated material, however, is not apparent. Patches of a similar garnet–chlorite rock occurred in some of the compact chlorite described by Campbell Smith (1924).

Specimens of chlorite and serpentinite, several centimetres thick, were obtained from the rubble in the pit. The chlorite (specimen 1-a) is massive, greyish-green, resinous, and translucent, with a hardness of 2½. A thin section reveals colourless, optically positive, micron-wide flakes with a prevailing orientation. Sporadic patches of similar but somewhat coarser chlorite, and accessory chromite in clusters of corroded, opaque grains, are present. The chlorite composition,

$$(Mg_{48}Fe_{0\cdot4}Al_{0\cdot8})(Si_{3\cdot2}Al_{0\cdot8})O_{10}(OH)_8,$$

was calculated from the chemical analysis (table I) and confirmed by the position and intensity of the 001 reflections on the diffractogram. The physical properties and chemical analysis are similar to those for pseudophite from the same locality (Benson, 1913), to those for compact chlorite from Bernstein (Campbell Smith, 1924), and to those for pseudophite from Hungary (Vavrineez, 1929). In two analyses of pseudophite given by Benson minor constituents include 0·08 and 0·04 % of Cr_2O_3, 0·03 and 0·23 % of NiO+CoO and 0·22 and 0·07 % of MnO.

The chlorite (specimen 1-a) merges into harder and less resinous material (specimen 1-b) a diffractogram of which reveals similar chlorite admixed with lizardite and subordinate clinochrysotile. Specimen 1-b, in turn, abuts dark green, blocky serpentinite (specimen 1-c) having a dull lustre and a hardness about 4. A thin section of specimen 1-c shows predominant nearly isotropic material with a fibrous texture enclosing subordinate patches displaying a somewhat higher birefringence, together with a few narrow cross-fibred and parallel-banded veinlets. A diffractogram of specimen 1-c indicates lizardite and subordinate clinochrysotile but no chlorite. Differential thermal curves of these three materials (1-a to 1-c) are compared in fig. 1.

Specimens from the Coolac Belt. At the Kangaroo West chromite mine in the Honeysuckle Range, the country rock is serpentinized harzburgite and the excavation walls are of sheared serpentinite. Specimens on the dumps suggest that the excavated lens of massive chrome ore was separated from the serpentinite walls by a discontinuous selvage, up to 8 cm thick, of compact chlorite, in places merging into nodular chromitite. The compact chlorite (specimen 2-a) is bluish-green but otherwise megascopically and microscopically similar to the Nundle chlorite. The chlorite composition $(Mg_{4\cdot6}Fe_{0\cdot1}Al_{1\cdot3})(Si_{2\cdot7}Al_{1\cdot3})O_{10}(OH)_8$ was calculated from the chemical analysis (table I). A differential thermal curve is similar to that of the Nundle chlorite except that the major exothermic peak at 861° C for the Nundle chlorite occurs at 890° C for this chlorite.

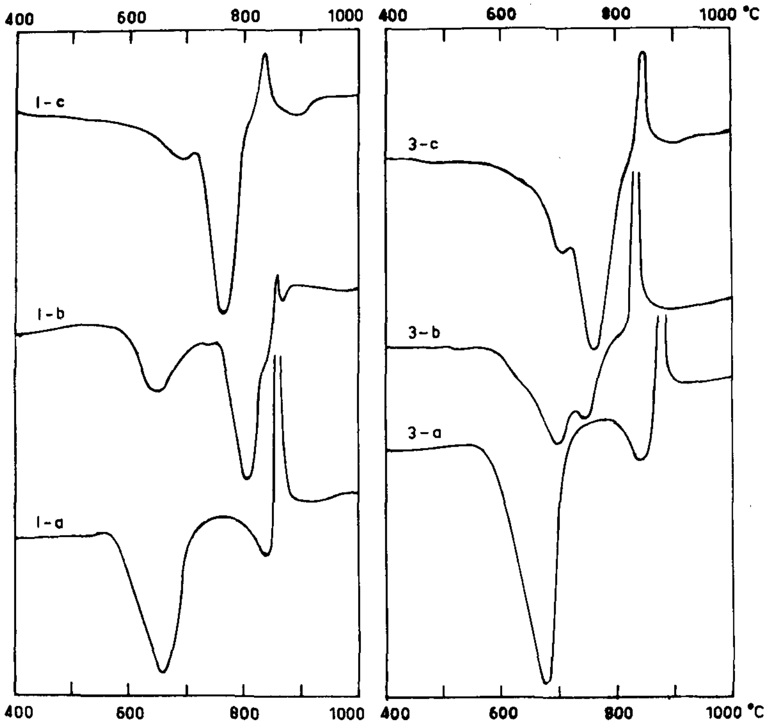

FIG. 1. Differential thermal analysis curves of chlorites and associated serpentinites from Nundle (1-a to 1-c) and from the Mooney Mooney Range (3-a to 3-c). 1-a. Chlorite. 1-b. Chlorite, lizardite, and subordinate clinochrysotile. 1-c. Lizardite with subordinate clinochrysotile. 3-a. Chlorite. 3-b. Lizardite. 3-c. Lizardite with minor clinochrysotile.

The nodular chromitite (specimen 2-b) contains 50 % of matrix, which varies from a harder yellowish-green lizardite to a softer bluish-green mixture of lizardite and chlorite, as indicated by diffractograms. The chromite is altered to porous secondary products, which are shown by electron-probe scans to be depleted in aluminium as compared with unaltered relict chromite in the cores of some nodules. The matrix in thin section reveals preponderant, well-defined serpentine mesh-texture in much of which the mesh rims polarize with anomalous blue colour. Subordinate portions of the matrix are fibrous and polarize with anomalous brown colours. Electron-probe scans over the softer matrix materials indicate the presence of chromium only for a shell about 100μ thick surrounding the chromite nodules.

The Granite Hills chromite mine in the Mooney Mooney Range is excavated in antigorite serpentinite. Talc- and carbonate-bearing serpentinites and rodingite occur in the vicinity. A specimen selected

TABLE I. Analyses of compact chlorites

	SiO_2	Al_2O_3	FeO	MgO	H_2O	Totals
1-a	32·56	16·36	4·65	33·13	12·46	99·16
2-a	27·60	26·38	2·03	31·67	13·47	101·15

1-a. Hanging Rock, Nundle, north-eastern New South Wales.
2-a. Kangaroo West mine, Honeysuckle Range, south-eastern New South Wales.

for examination consists of a block of chrome ore flanked by a selvage 5 mm wide of bluish-grey compact chlorite which in turn abuts hard, apple-green serpentine. The chromite is increasingly altered toward the chlorite selvage. Thin sections of the chlorite and serpentine suggest a relict, disrupted serpentine mesh-texture in both, but the chlorite consists largely of minute flakes polarizing with anomalous blue colours. The approximate composition of the chlorite (specimen 3-a), as indicated by a diffractogram, is $(Mg_5Al)(Si_3Al)O_{10}(OH)_8$. Diffractograms of the serpentine show it to vary from lizardite (specimen 3-b, 2 mm from the chlorite) to lizardite mixed with a trace of clinochrysotile (specimen 3-c, one centimetre from the chlorite). Differential thermal curves for the three specimens (3-a to 3-c) are compared in fig. 1.

Electron-probe scans over the chromite, continued across the chlorite and serpentine of the Granite Hills specimen indicate: Iron and chromium enrichment but aluminium and lesser magnesium depletion in the altered as compared with the primary chromite; the presence of a little chromium in the chlorite only over 150μ abutting the chromite; the progressive depletion of aluminium in the chlorite towards the serpentine; and the presence within the serpentine of iron- and aluminium-enriched patches (fig. 2), which increase in frequency toward the chlorite.

From fig. 2 and other electron-probe scans it is estimated that the iron- and aluminium-enriched patches contain 3 % of FeO as compared with 2 % in both the chlorite and in the remaining lizardite; 10 % of Al_2O_3 as compared with 18 % in the chlorite and 3 % in the remaining lizardite; and 35 % of SiO_2 as compared with 30 % in the chlorite and 40 % in the remaining lizardite. MgO remains constant at about 40 % for the three materials.

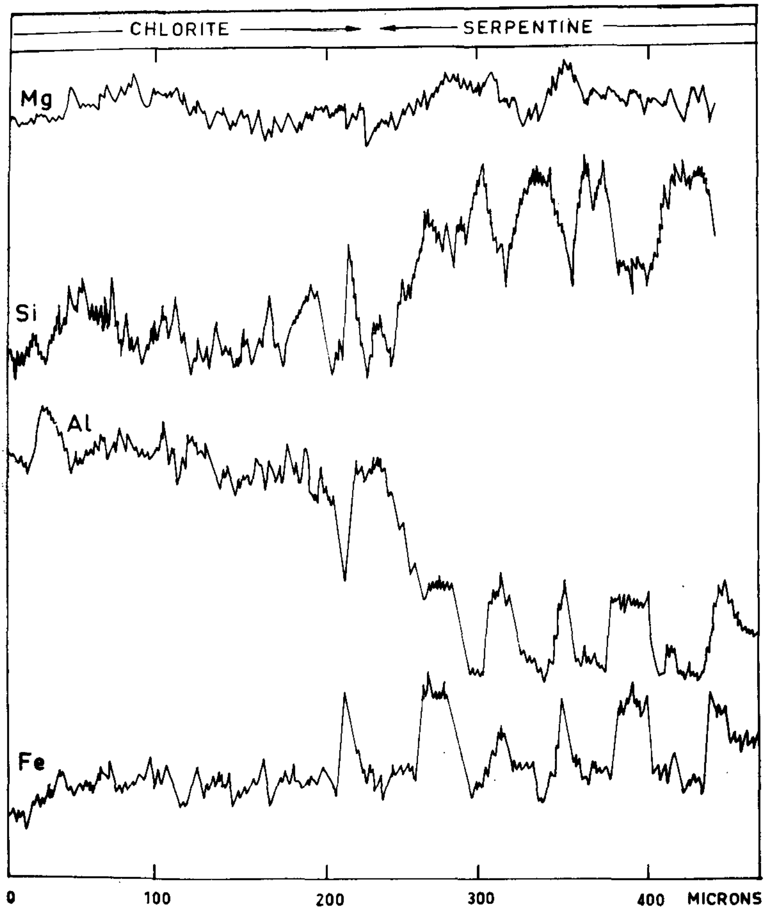

FIG. 2. *Qualitative electron-probe scans across a chlorite–serpentinite junction.* Specimen 3. Granite Hills mine, Mooney Mooney Range.

Conclusions. The compact chlorites are characterized by a low content of heavy metals and the general absence of chromium. The content of magnesium and aluminium, however, varies widely and the chlorite compositions range over the pennine, clinochlore, and sheridanite fields of Hey (1954). The chlorite segregations sharply abut or merge into lizardite or lizardite-rich serpentinite some of which contains iron- and aluminium-enriched patches.

In the specimens from the Coolac Belt the disposition of the chlorite segregations with respect to the associated materials, the progressive changes within and between adjacent materials, and the relict serpentine mesh-textures jointly indicate that these chlorites are metasomatic zonal segregations that formed at pre-existing junctions of chromite and serpentinite. The chloritization of the serpentinite was influenced by the availability of aluminium released from chromite during chromite alteration. The ratio of lizardite to clinochrysotile in the associated serpentinite probably increased during this metasomatism. These occurrences may be genetically related in a broad way to some other associations of chlorite and chromite that occur in the same ultramafic belt and elsewhere (Miller, 1953; Brindley and von Knorring, 1954; Thayer, 1956), but which include better crystallized and chromium-bearing chlorites, and chlorites derived from pyroxenes and amphiboles.

The presence of accessory chromite in the Nundle pseudophite and its association with lizardite suggests that this chlorite also derived from pre-existing serpentinite or peridotite as a result of alumina metasomatism, but the source of the aluminium is not evident. While some degree of replacement of pre-existing chromite by chlorite and the tectonic removal of pre-existing juxtaposed chrome ore are both possible, the presence of associated rodingite suggests a genetic affinity of this chlorite segregation with those occurring at junctions of serpentinite with rodingitic or similar rock masses elsewhere (Shirozu, 1958; Seki and Kuriyagawa, 1962; Vuagnat, 1965; Coleman, 1966).

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