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Description of Drill-hole GN042V Core from the Jabiluka Unconformity-type Uranium Deposit, Northern Territory, Australia

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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INTRODUCTION

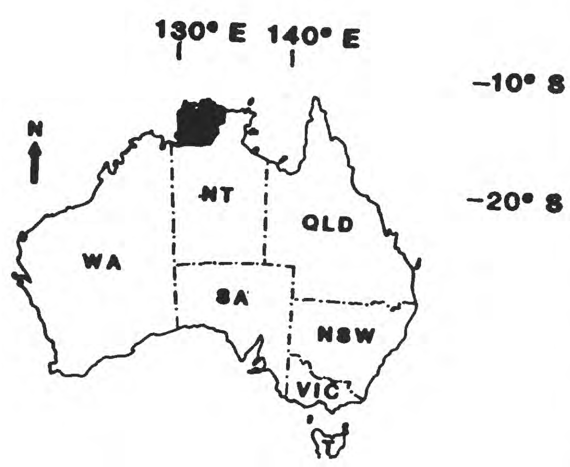
The Jabiluka uranium deposit is one of four known unconformity-type deposits in the Alligator Rivers Uranium Field in the Northern Territory, Australia (fig. 1). The deposits are hosted by metasedimentary rocks of the Lower Proterozoic Cahill Formation, near a regional unconformity separating the Cahill from the sedimentary rocks of the Middle Proterozoic Kombolgie Formation.

The pelitic schists that contain the ore were multiply folded and metamorphosed to amphibolite facies during a 1800 m.y. event (Needham and Stuart-Smith, 1976). At many localities, including Jabiluka and the other unconformity-type deposits, chloritic alteration has affected the rocks, which now have predominantly greenschist facies mineral assemblages. Nutt and Grauch (1983) described the regional and mine geology at Jabiluka; that paper was the first in a series of open-file reports on Jabiluka (Nutt, 1983; Nutt, 1984).

The deposit at Jabiluka consists of two orebodies: Jabiluka 1, the first discovery in 1971, and Jabiluka 2, much the larger of the two orebodies. Ore occurs as disseminations, breccia matrix, and veins in a chloritized and brecciated sequence of quartz-chlorite±muscovite±sericite±graphite schists. Core from Jabiluka is well foliated parallel to compositional layering and, in a few places, two foliations are observed. Small-scale isoclinal folds and crenulations occur throughout the core.

Drill-hole GN042V is located outside the Jabiluka deposit, near the western boundary of Jabiluka 1 (fig. 2). This shallow drill hole penetrated 130 meters of sandstone, quartz-chlorite±muscovite±sericite schist, garnetite, and amphibolite (diabase?).

This report on the core from drill-hole GN042V consists of a stratigraphic section from 80 to 130 m (fig. 3), rock descriptions, and selected thin-section descriptions (table 1). Because only six samples were collected, descriptions are brief. Nutt (1983, 1984) described rocks and minerals encountered in drill-holes T129V and V111V. Comparison of the three drill holes emphasizes the differences between the rocks in the orebodies and the rocks outside of the deposit at the location of drill-hole GN042V.



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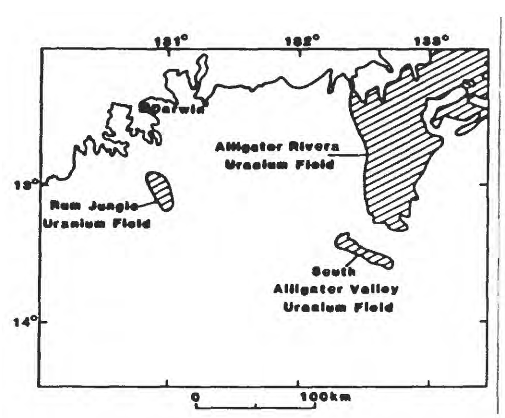

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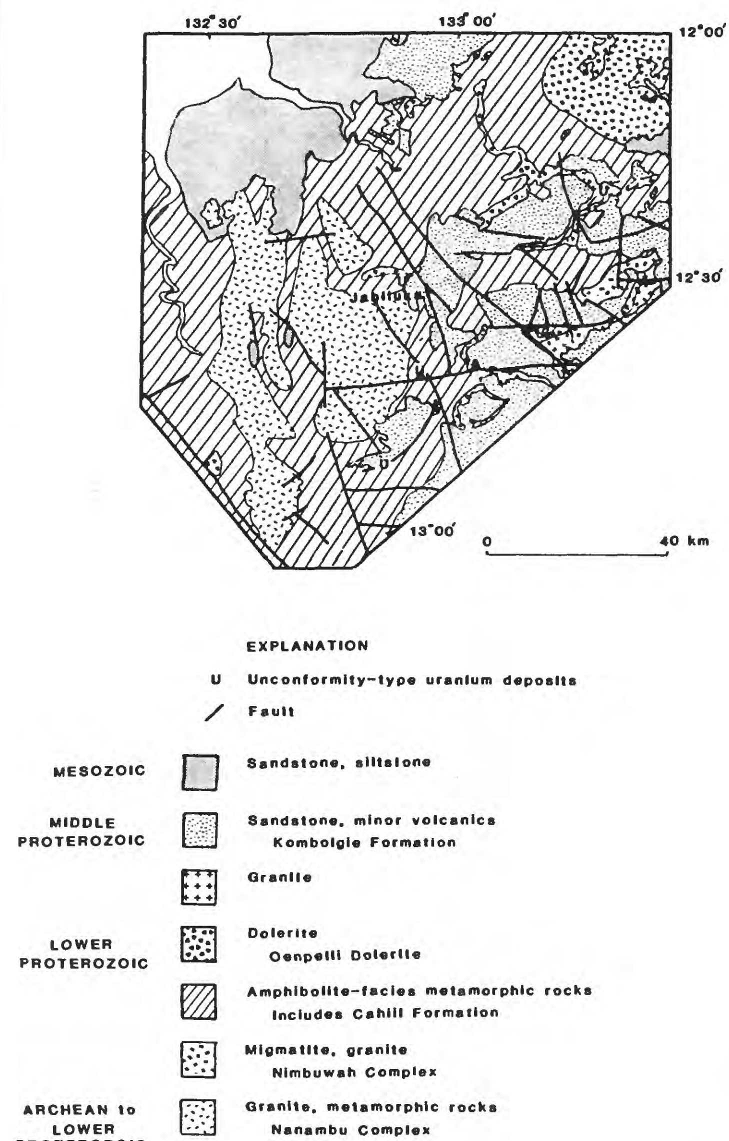

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Figure 1. Locality maps of a) the Pine Creek geosyncline, Northern Territory, Australia and b) the Alligator Rivers Uranium Field; and c) geologic map of Alligator Rivers Uranium Field and the localities of the four known unconformity-type deposits.

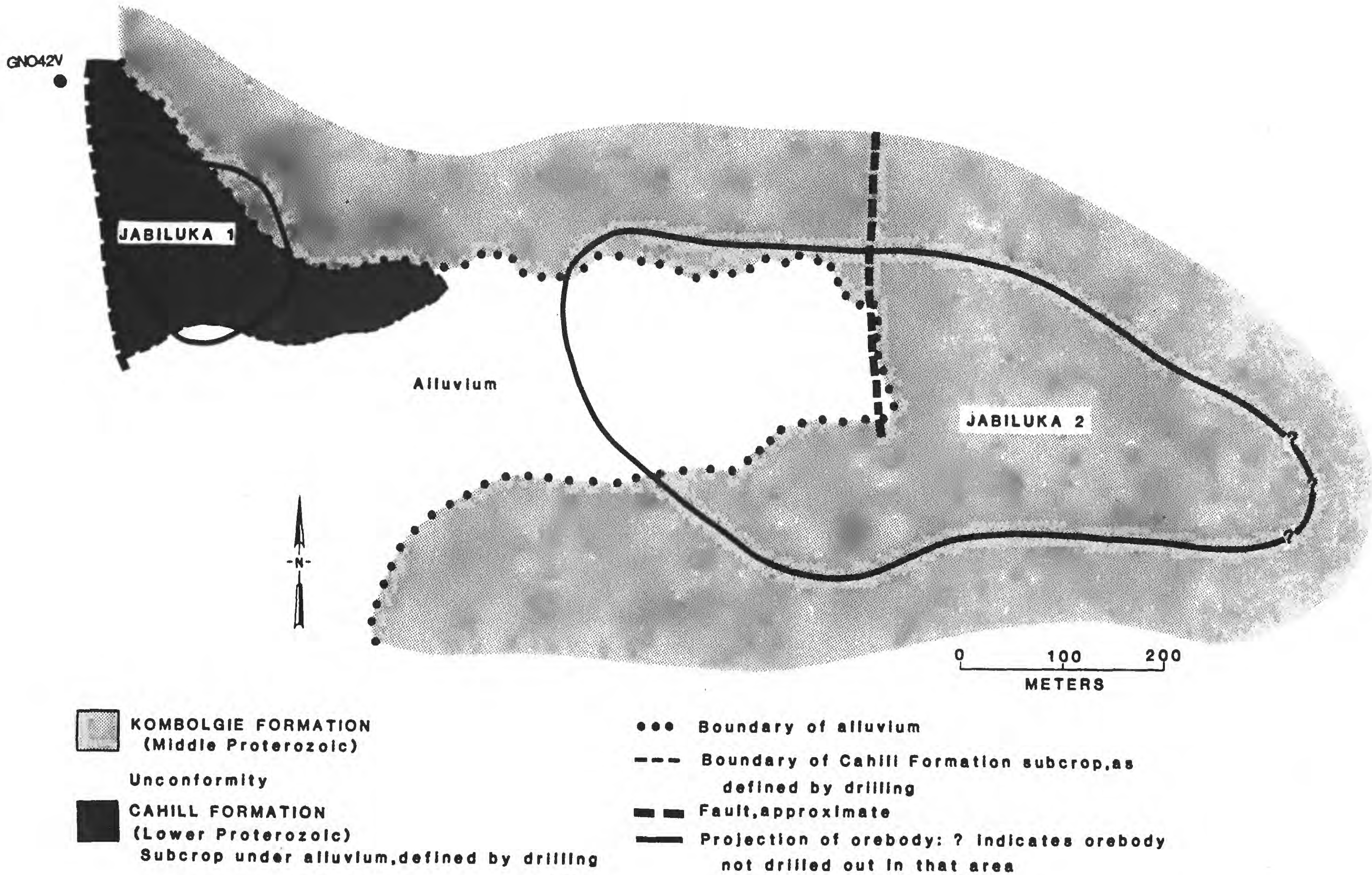

Figure 2. Location map of drill-hole GNO42V and geologic map of the area that contains the Jabiluka orebodies. Geologic map is modified from data provided by Pancontinental Mining Limited.

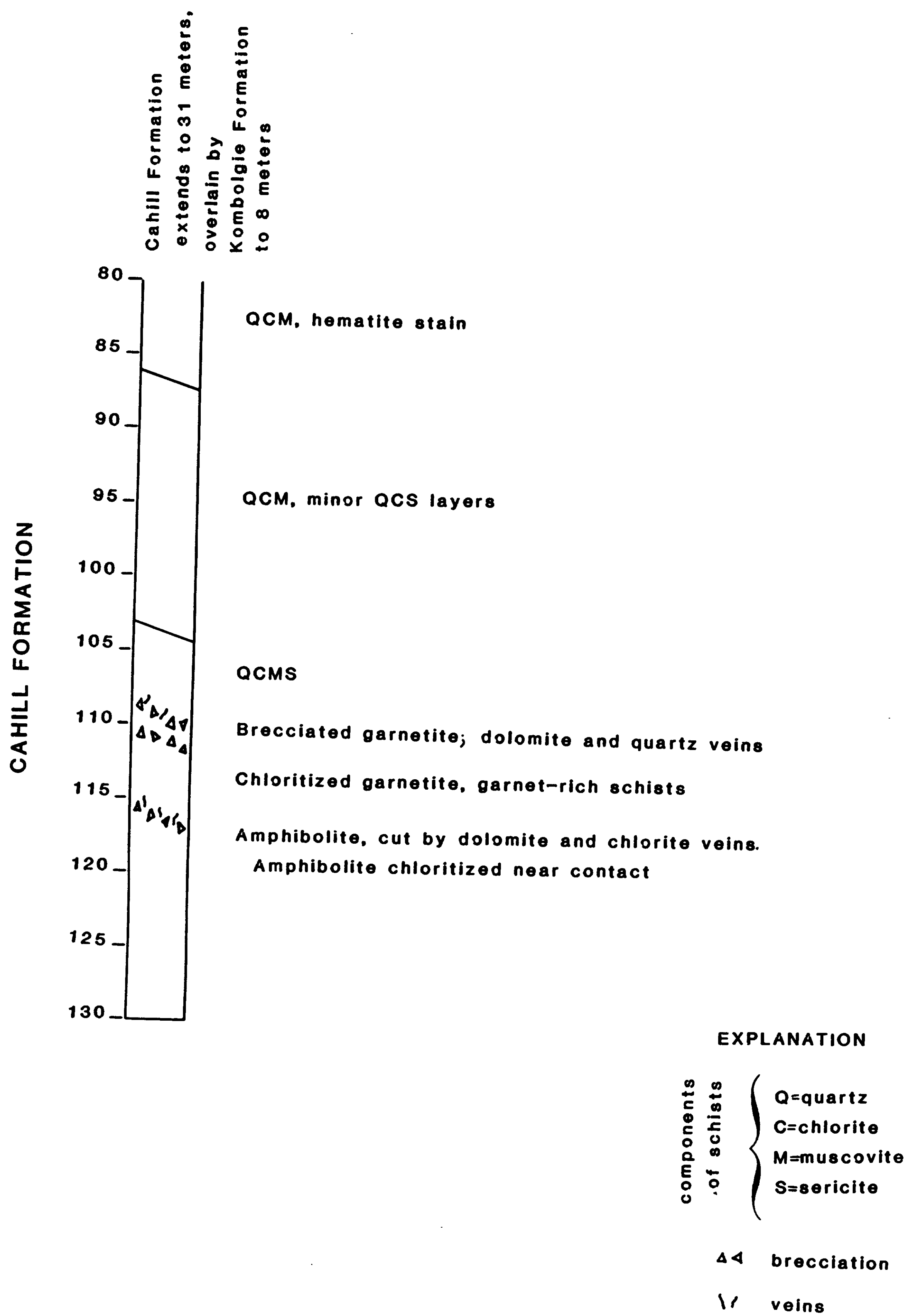

Figure 3. Stratigraphic column of drill-hole GN042V from 80 to 130 meters.

Table 1.--Descriptions of selected thin-section samples

Abbreviations used in column headed "rock type" are: Q=quartz, C=chlorite, M=muscovite, S=sericite, G=garnet. Other abbreviations used in the table are: chl=chlorite, gn=green, bwn=brown, lt=light, yw=yellow, undiff=undifferentiated, w/=with, ✓=present, --=not present. Mineral abundances are estimated.

Sample number= depth in meters	Rock type	Texture	Breccia matrix	Pseudomorphs	Major Minerals					Matrix Minerals		
					quartz	chlorite	muscovite	garnet	others	chlorite	septe-chlorite	sericite
106.6	QCSM schist	Foliated	--	--	✓	In part replaced by bright gn to yw-gn chl	✓	--	--	Gn to bwn undiff., 10-15% of the rock	--	25-30% of the rock
110.2	Garnetite	Massive	--	Chl after garnet	--	--	--	✓	--	--	--	--
	QCG ±M±S schist	Foliated	--	Chl after garnet	✓	✓	✓	✓	--	--	--	✓
113	GQMC	Massive	--	Chl after garnet	✓	✓	✓	✓	--	--	--	--
	CQMG schist	Foliated	--	Chl after garnet	✓	✓	✓	2-10%	--	--	--	--
116	Chloritized amphibolite (diabase?)	Massive to slightly foliated	--	Chl after amphibole, sericite after plagioclase?	✓	✓	--	--	Sericite ≤ 20%	--	--	--
118	Chloritized amphibolite (diabase?)	Massive to slightly foliated	--	Chl after amphibole, sericite after plagioclase?	✓	✓	--	--	Sericite ≤ 20%	--	--	--
119.8	Amphibolite (diabase?)	Crystalline	--	Sericite after plagioclase?	✓	--	--	--	Hornblende, sericite, plagioclase, chloritized biotite	--	--	--

Table 1.--Continued

	Accessory Minerals						Veins					Comments
	TiO_2 phase	tourmaline	apatite	pyrite	others	Dravite	quartz	chlorite	septechlorite	carbonate	others	
106.6	--	--	✓	--	Zircon	--	--	--	--	--	--	Pleochroic bright green to yellow green chlorite with anomalous blue birefringence and in some places radial extinction replaces coarse chlorite.
110.2	✓	--	--	--	Coarse chl, quartz	--	--	Lt-gn ~1 mm thick	--	--	--	Halos around veins consist of chlorite pseudomorphs after garnet. Coarse chlorite grains cut foliation of the schists. Veins and layers of coarse chlorite connect to form network in garnetite.
	✓	--	✓	--	--	--	--	--	--	--	Sericite	Irregularly-shaped zones of garnet-rich rock are in the schists. Apatite forms about 3 percent of one schist layer. Garnets are included in quartz and apatite grains.
113	--	--	--	--	--	--	--	Lt-gn, w/dolomite	--	Dolomite	Pockets of muscovite	Rock consist of as much as 80 percent garnet. Where veins cut garnet-rich rock, the rock is altered to quartz-muscovite ± garnet ± chlorite schists. Chlorite pseudomorphs after garnet occur in rocks altered by veins.
	✓	--	✓	✓	--	--	--	--	--	--		Garnet grains are included in quartz.
116	✓	--	✓	--	--	--		Lt-gn to gn-bwn	--	✓	Pods of quartz w/ TiO_2, rutile needles	A zone of massive light-green chlorite with abnormal blue birefringence is cut by quartz and dolomite (in part silicified) veins. The chlorite occurs in radial clumps and in places shows comb structure.
118	✓	--	✓	✓	Hematite	--	~1 mm thick	(1) mixed with sericite (2) gn chl (3) bright gn chl in pods	--	Dolomite ≤ 3mm	--	Veins of quartz and dolomite are parallel to each other. Thin quartz veins cut dolomite veins. Bright green chlorite has abnormal blue birefrigence.
119.8	✓	--	--	✓	--	--	--	--	--	--	--	Coarse hornblendes are commonly composed of mosaics of finer grained hornblende grains.

Table 1.--Continued

The study of unconformity-type deposits--a new type of uranium deposit typified by deposits discovered in the past 15 years in Australia and Canada--is part of the U.S. Geological Survey uranium program that was partially supported by the U.S. Department of Energy National Uranium Resource Evaluation (NURE) program. During a three week stay at the Jabiluka camp, Pancontinental Mining Limited kindly gave R. I. Grauch and me access to Jabiluka core and made their geological and geophysical data available for inclusion in our reports. Data and interpretations from the study of Jabiluka should aid in defining characteristics and setting of these world class deposits and guide exploration for similar deposits in the United States.

ROCK TYPES

GN042V penetrated some rocks that are not typical of those found within the Jabiluka orebodies (figs. 3 and 4). The upper part of the hole consists of Kombolgie Formation sandstone and Cahill Formation quartz-chlorite± muscovite±sericite schists that are found throughout drill holes in the Jabiluka deposit. However, underlying the schists are garnetite, which was not encountered in any other drill hole, and amphibolite. Because GN042V was a shallow hole (130 m deep) and because a unique rock type, garnetite, was encountered, no correlation was attempted between the rocks of GN042V and the units in the Jabiluka stratigraphic section (fig. 4).

Quartz-chlorite±muscovite±sericite schists

The quartz-chlorite±muscovite±sericite schists of the Cahill Formation that occur in the upper part of GN042V are similar to schists found in the Jabiluka orebodies (Nutt and Grauch, 1983; Nutt, 1983; and Nutt, 1984). Table 2 shows the composition of a sample typical of the more quartz-rich schists. Subhedral to anhedral quartz and coarse-grained subhedral chlorite and muscovite are in a fine-grained (<0.1 mm) matrix of chlorite ± sericite. Locally, quartz veins cut the rocks and traces of hematite stain the schists. The contact between the schist and the underlying garnetite is brecciated and cut by quartz veins.

Garnet-rich rocks

Pink garnet-rich rocks extensively cut by chlorite veins occur in a 7-m-thick sequence interlayered with green quartz-chlorite±muscovite±sericite± garnet±apatite schist (fig 5). The pink rock, which appears cryptocrystalline in hand specimen, has a composition ranging from massive garnetite with as much as 98 percent garnet to finely layered garnet-quartz±chlorite±muscovite schist (fig. 6). The densely packed garnets are euhedral to subhedral and have a narrow size range of 15 to 50 μm. The chemical composition of the garnetite reflects the high garnet content and is markedly different from the composition of the schist (table 2). Garnetite layers, about 1 cm thick in the samples collected, pinch and swell and have irregular contacts with schists. Within the massive garnetite layers the garnets are so densely packed that no laminations can be detected, but where interlayered with quartz, laminations are observed. Semiquantatative microprobe analyses show that the garnets are an iron- and manganese-rich variety (table 3). Garnets within a thin-section show little variation in composition, but composition does vary between samples.

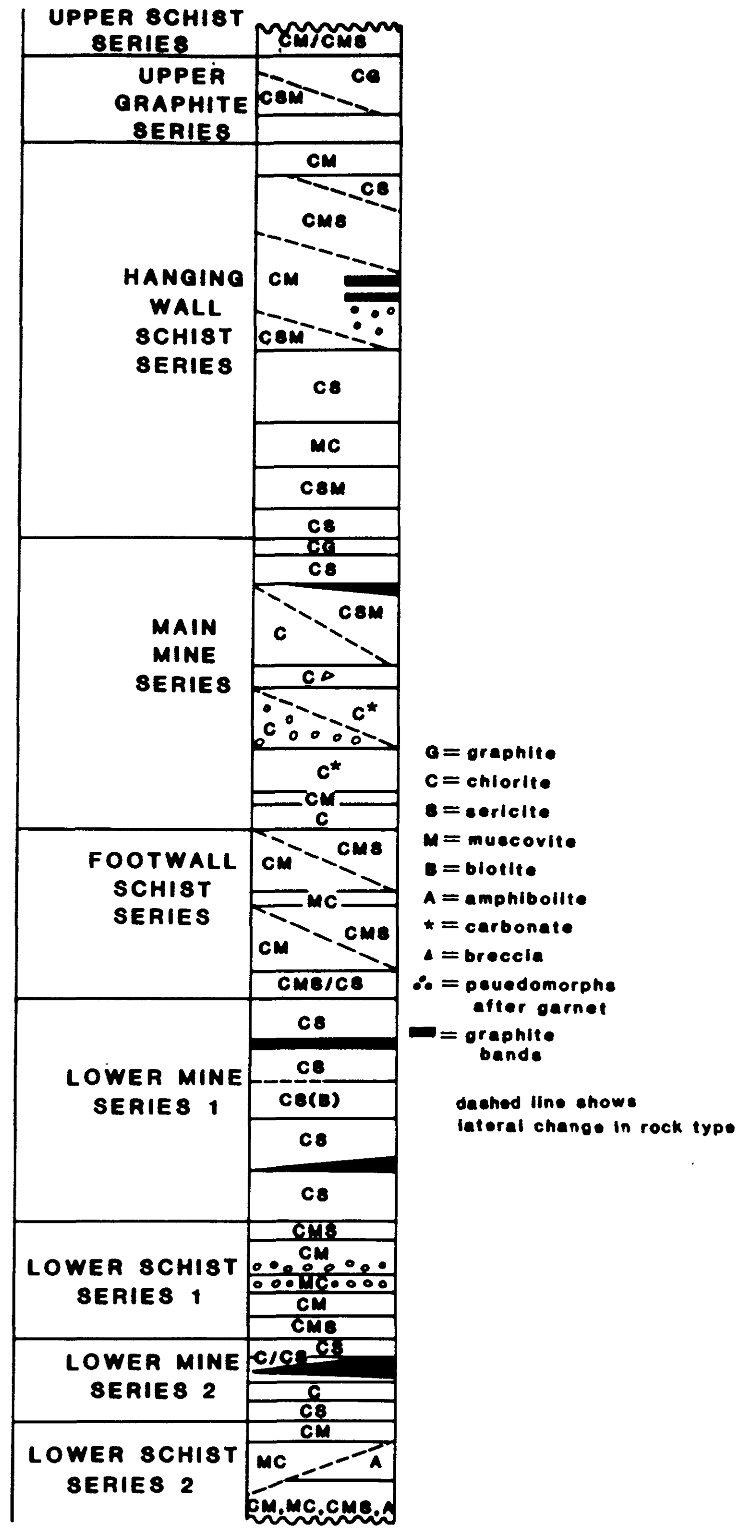

Figure 4. Generalized stratigraphic column of the ore-bearing Cahill Formation at Jabiluka; modified from information supplied by Pancontinental Mining Limited.

Table 2.--Chemical analyses

	GN042V-106.6 QCSM schist[1]	GN042V-110.2 garnetite	GN042V-119.8 amphibolite
SiO_2	76.00	62.00	48.90
Al_2O_3	10.40	16.20	14.80
FeO	2.99	7.75	8.59
Fe_2O_3 calculated	0.77	1.30	1.85
MgO	3.70	3.85	9.04
CaO	0.16	0.49	9.93
Na_2O	<0.15	<0.15	1.16
K_2O	1.94	2.56	2.04
TiO_2	0.38	0.71	0.80
P_2O_5	0.10	0.18	0.09
MnO	0.60	1.38	0.21
[2]LOI	3.51	3.60	1.32
[3]Total	100.55	100.02	98.73

[1]Quartz-chlorite-sericite-muscovite schist

[2]Loss on ignition

[3]Less than value not included in total

All elements except Fe determined by X-ray spectroscopy at U.S. Geological Survey laboratory. Analysed by J. Taggart. FeO determined by classical titration methods at U.S. Geological Survey. Analyzed by H. Neiman and T. Peacock.

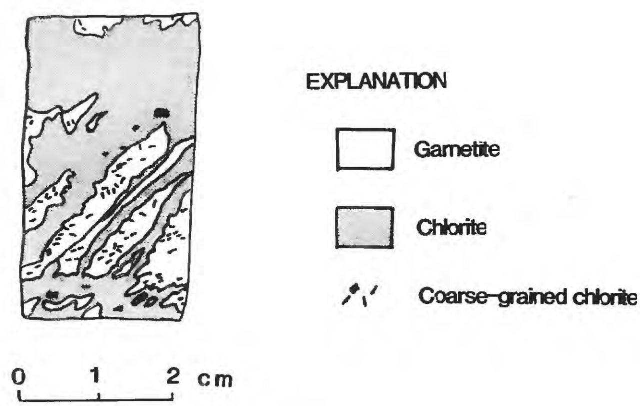

Figure 5. Sketch of a thin-section chip of garnetite. Sample GN042V-113.

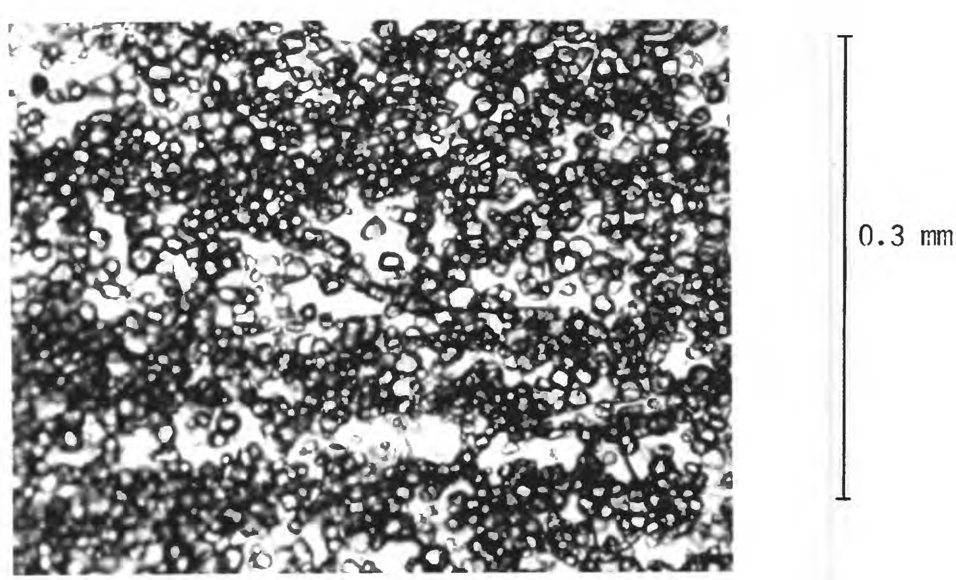

Figure 6. Photomicrograph of garnetite thin section. Sample GN042V-110.

Table 3.--Semiquantitative microprobe analyses of garnets. Analyses are the average composition of 7 to 10 grains (because of small grain size, only one analysis per grain). NASA synthetic basaltic glass standard and Magic data reduction used in analyses. Analyses shown as weight percent of oxides.

Sample Number	GN042V-110.2 (10 grains)	GN042V-113 (7 grains)
SiO_2	38	38
Al_2O_3	21	22
MgO	3	3
CaO	2	2
MnO	9	15
FeO	28	21
TiO_2	tr	tr
Total	101	101
Number of cations on the basis of 24 oxygens		
Si	6.0	6.0
Al	--	--
Al	3.9	4.1
Ti	--	--
Fe^{+3}*	0.1	--
Fe^{+2}	3.7	2.8
Ca	0.3	0.3
Mg	0.7	0.7
Mn	1.2	2.0
End members (mol %) approximated		
Almandine	63	48
Spessartine	20	35
Pyrope	12	12
Andradite and Grossular	5	5

*calculated

Within garnetite layers, chlorite occurs as fine-grained pseudomorphs after garnet and as subhedral coarse grains as large as 2 mm in length that are both disseminated and concentrated in lenses and layers. Chlorite layers are connected by chlorite veins, producing a network of green chlorite in the pink garnetite. The disseminated coarse-grained chlorites, which in places contain garnet inclusions, show no consistent orientation to the general foliation of the core. Pods of coarse-grained muscovite also occur locally in the garnetite.

Cross-cutting veins of chlorite ± dolomite and, rarely, sericite dramatically change the mineralogy of the garnetite. Alteration halos around the veins are composed of quartz-muscovite-chlorite schists; only the presence of fine-grained chlorite pseudomorphs after garnet indicates that the unaltered rock was garnet-rich. The extensive alteration suggests that any correlative garnetite unit within the highly altered orebodies would probably not be distinguishable from any other quartz-muscovite-chlorite schist.

Schist layers interlayered with garnetite are thin (about 1 cm thick), lenticular, and discontinuous. In the few samples examined petrographically, schist layers are composed of coarse-grained chlorite and muscovite and finer grained quartz, sericite, garnet, and apatite. In one sample, apatite forms about 3 percent of a schistose layer. Garnet grains are included in quartz and apatite, and sericitized coarse chlorite grains contain chlorite pseudomorphs after garnet.

Amphibolite

The last 14 m of drill-hole GN042V penetrate an amphibolite that underlies the garnetite. Near the upper contact the rock is faintly foliated, but a sample collected 5 m below the contact is massive and has a crystalline texture. The amphibolite is composed of hornblende, sericite, quartz, plagioclase (because of sericitic alteration the plagioclase was not observed petrographically, but was identified by X-ray diffraction), chloritized biotite, apatite, and a TiO_2 phase; the chemical composition is shown on table 2. The crystalline texture, massive structure, mineralogy, and chemical composition of this amphibolite suggest it is an altered diabase, probably correlative to dolerites described by geologists mapping in the Alligator Rivers uranium field (Needham and others, 1980; Needham and Stuart-Smith, 1980). Some textures suggest recrystallization, such as coarse grains of hornblende containing ragged hornblende inclusions and clusters of small hornblende grains that appear to have formed from coarse grains. Because drilling ended after penetrating 14 m of the amphibolite, the thickness of the intrusive is unknown.

The amphibolite is separated from the overlying garnetite sequence by a brecciated and chloritized contact. Dolomite, quartz, and chlorite veins cut the rocks near the contact and are most abundant in the upper part of the amphibolite. Alteration of the upper 3-4 m of the amphibolite produced a faintly foliated chloritic rock composed of chlorite pseudomorphs after amphibole.

COMMENT

The origin of these rocks is enigmatic, in part because the section is so short and the lateral extent is unknown. Elsewhere, garnetite intervals are found in skarns and coticules. Coticules are laminated garnet-quartz metamorphic rocks that are typified by fine grain size, lack of variability in grain size, dense packing of the garnets, and Mn-rich garnet composition (Kim, 1974). Skarns, in contrast, commonly have variable and coarse grain size and contain garnets that are typically calcium-rich. In dolomite and magnesite skarns, the mineralogy consists of such phases as olivine, clinopyroxene, spinel, magnetite, and calcite (Zharikov, 1970).

The proximity of the garnetite to an intrusive body (the meta-diabase) suggests that the rock formed during contact metamorphism of a carbonate sequence, but the rock composition and the garnet grain size, as well as the presence of laminations and the lack of variation in grain size, are more characteristic of coticules than skarns. Typically, coticules contain spessartine garnet, but the almandine-spessartine compositions reported from the Jabiluka garnets are well within the range reported from coticule samples from New England (Kim, 1974). Unfortunately, the widespread alteration at Jabiluka and the lack of outcrop obscure the lateral extent of the Jabiluka garnetite and make a definitive identification of coticule difficult.

Although variations among coticule localities suggest multiple origins, most workers agree that these rocks, which occur in meta-sedimentary sequences, are metamorphosed siliceous and manganese-rich sediments (Clifford, 1960; Schiller and Taylor, 1965; Kim, 1974; Kramm, 1976). When compared with the composition of the schistose rocks at Jabiluka, the garnetite is enriched in iron and manganese.

The alteration of garnetite to quartz-muscovite-chlorite schist suggests that garnetite may have originally made up a greater percentage of the 7-m-thick sequence in drill-hole GN042V. In the highly altered Jabiluka orebodies, any garnetite layers probably were obliterated, although rare fine-grained garnets inclusions in quartz grains may be remnants of garnet-rich rocks.

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