SOUTH AUSTRALIA

DEPARTMENT OF MINES AND ENERGY

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COWELL JADE PETROGRAPHIC

DESCRIPTIONS AND CHEMICAL ANALYSIS - DATA

Submitted by

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Petrography Map Sheet 6230

AMDEL RPT.	TS NO.	RS NO.	ROCK TYPE	LOCATION	O/C NO.	PLAN NO.	COMMENT
GS2405/81	30969	303	Thulite	ML 5255			
GS3146/80	42889	304	Semi-Nephrite	Miltalie			Miltalie nephrite deposit
	42890	305	Semi-Nephrite	Miltalie			Miltalie nephrite deposit
	42891	306	Quartzite	Miltalie			Miltalie nephrite deposit
GS2477/83	44821	320	Calc-Silicate	Regional			
	44822	321	Amphibolite	Regional			
	44823	322	?Gneiss	Regional			
	44824	323	Calc-Silicate	Regional			
	44825	324	Calc-Silicate	Regional			
	44826	325	Nephrite	ML 4577	83		Analysis
	44828	326	Schist	ML 4386			
	44829	327	Granodiorite Gneiss	Regional			
	44830	328	Aplite Dyke	Regional			
	44836	329	Semi-Nephrite	ML 4217	32	88-86	Analysis
	44837	330	Tremolite/Dolomite	ML 4217	32	88-86	
GS2476/83	44803	331	Calc-Silicate	Regional			
	44804	332	Tremolite Schist	(ML4525)			
	44805	333	Calc-Silicate	Regional			
	44806	334	Schist	Regional			
	44807	335	Granodiorite Gneiss	Regional			
	44808	336	Calc-Silicate	Regional			
	44809	337	Schist	Regional			
	44810	338	Amphibolite	Regional			
	44811	339	Granodiorite Gneiss	Regional			
	44812	340	Granodiorite Gneiss	Regional			
	44817	341	Chert	Regional			
GS5231/83	39682	343	Semi-Nephrite	ML 4783	52	88-90	Analysis
	39689	344	Semi-Nephrite	ML 4381	35	88-86	Analysis
	39690	345	Dolomite	ML 4381	35	88-86	
	39691	346	Semi-Nephrite	ML 4381	35	88-86	Analysis
	39692	347	Foliated Nephrite	ML 4217	24	88-84	Analysis
	39693	348	Foliated Semi-Nephrite	ML 4217	24	88-84	Analysis
	39694	349	Foliated Nephrite	ML 4783	52	88-90	Analysis
	39695	350	Semi-Nephrite	ML 4783	52	88-90	Analysis
	39696	351	Semi-Nephrite	ML 4783	52	88-90	Analysis

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AMDEL RPT.	TS NO.	RS NO.	ROCK TYPE	LOCATION	O/C NO.	PLAN NO.	COMMENT
GS5930/84	40866	352	Tremolite	(ML4522)	112		Analysis
	40868	353	Tremolite Schist	ML 4533	75		Analysis
GS6238/84	41460	354	Calc-Silicate	Regional			
	41461	355	Granite	Regional			
	41463	356	Granodiorite Gneiss	Regional		88-89	Analysis
	41465	357	Calc-Silicate	ML 4381		35/36	Not located on outcrop plan 89-86
	41466	358	Altered Intrusive	ML 4381		35/36	Not located on outcrop plan 89-86
	41467	359	Calc-Silicate	ML 4381		35/36	Not located on outcrop plan 89-86
	41468	360	Semi-Nephrite	ML 4578	51	88-90	Analysis
	41469	361	Calc-Silicate	(ML 4522)		88-89	
	41464	362	Sericite Schist	ML 4339			
		387	Nephrite	ML 4217	24		Analysis only
		405		(ML 4534)	76	89-182	No sample description available
		406		(ML 4534)	76	89-182	No sample description available
		407		(ML 4534)	76	89-182	No sample description available
		408		(ML 4534)	76	89-182	No sample description available
		409		(ML 4534)	76	89-182	No sample description available
		410		(ML 4534)	76	89-182	No sample description available
		411		(ML 4534)	76	89-182	No sample description available
		412		(ML 4534)	76	89-182	No sample description available
		413	Nephrite	ML 4217	32		Analysis only; Not located
GS 2622/87		414		(ML 4568)		89-181	XRD Analysis only
		415		ML 4783	52		Not located, plan 88-90
GS6795#5G	48685	416	Semi-Nephrite	ML 4783	52	88-90	
	48686	417	Tremolite	ML 4783	52	88-90	
	48687	418	Altered Intrusive	ML 4783	52	88-90	
	48699	419	Granitic Gneiss	ML 4217	32		
	48700	420	?Semi-Nephrite	ML 4217	32		Analysis; Not located
	48703	421	Tremolite Schist	ML 4217	114	89-184	Analysis
		422	Amphibolitic Gneiss	(ML 4554)	76		Analysis only
GS6795#5G	48705	423	Chlorite-Tremolite Schist	(ML 4524)	53		Not located
		424		(ML 4524)	53		Not located; No sample description

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Petrography Map Sheet 6230 (Cont'd)

AMDEL RPT. TS NO.	RS NO.	ROCK TYPE	LOCATION	O/C NO.	PLAN NO.	COMMENT
GS2622/87	425		(ML 4524)	53		Not located; No sample description
	428		(ML 4524)	53		No sample description available
	429		(ML 4524)	116	89-181	
	431		ML 4783	52		
	432		ML 4217	32		
	433		ML 4217	32		
	434		ML 4217	32		
	435		ML 4217	32		
	436		ML 4217	32		
	437		ML 4217	32		
	438		ML 4217	32		
	489		(ML 4568)		99-100	
	490		(ML 4568)		99-100	
	491		(ML 4568)		99-100	89-181See also 89-183; No sample description available
	492		(ML 4524)	116	89-181	See also 89-185; No sample description available

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AMDEL RPT.	TS NO.	RS NO.	ROCK TYPE	LOCATION	O/C NO.	PLAN NO.	COMMENT
GS3146/80	42887	24	Nephrite	ML 4132	69		Not located
	42888	25	Nephrite	ML 4132	69		Not located
GS3786/81	31695	77	Talc	ML 4576			
	31696	78	Talc	ML 4576			
GS2477/83	44827	79	Gneiss	Regional			
	44831	80	Gneiss	Regional			
	44832	81	Granodiorite Gneiss	Regional			
	44833	82	Granodiorite Gneiss	Regional			
	44834	83	Granodiorite Gneiss	Regional			
	44835	84	Granodiorite Gneiss	Regional			
GS2476/83	44814	85	Calc-Silicate	Regional			
	44815	86	Gneiss	Regional			
	44816	87	Chert	Regional			
	44818	88	Granodiorite Gneiss	(MC 4966)			
	44819	89	Gneiss	ML 4634	15	88-83	
	44820	90	Calc-Silicate	ML 4634	15	88-83	Surface sample prior to expanded mine operation
	44813	91	Calc-Silicate	ML 4217			
GS5231/83	39683	92	Altered Intrusive	(ML 4597)	14	88-82	
	39684	93	Altered Intrusive	(ML 4597)	14	88-82	
	39685	94	Granodiorite Gneiss	(ML 4597)	14	88-82	
	39686	95	Tremolite	(ML 4597)	14	88-82	Analysis
	39687	96	Semi-Nephrite	(ML 4597)	14	88-82	Analysis
	39688	97	Granodiorite Gneiss	(ML 4597)	14	88-82	
	39697	98	Altered Intrusive	ML 4132	69	88-93	
	39698	99	Nephrite	ML 4132	69	88-93	Analysis
GS5930/84	40845	100	Calc-Silicate	(ML 4597)	14	88-82	
	40846	101	Altered Intrusive	(ML 4597)	14	88-82	
	40847	102	Gneiss	Regional			
	40848	103	Calc-Silicate	(ML 4668)	88		
	40849	104	Gneiss	Regional			
	40851	106	?Pegmatite	Regional			Analysis
	40852	107	Sericite Schist	Regional			
	40853	108	Sericite Schist	Regional			

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Petrography Map Sheet 6231 (Cont'd)

AMDEL RPT.	TS NO.	RS NO.	ROCK TYPE	LOCATION	O/C NO.	PLAN NO.	COMMENT
GS5930/84	40854	109	Gneissic Granite	Regional			
	40855	1210	Granodiorite Gneiss	Regional			
	40856	111	Amphibolite	Regional			
	40857	112	Semi-Nephrite	ML 4129	1		Analysis
	40858	113	Semi-Nephrite	ML 4129	92		Analysis
	40862	117	Quartzite	Regional			
	40863	118	Migmatite	Regional			
	40864	119	Granodiorite Gneiss	Regional			
	40865	120	Tremolite	ML 4338	115	88-431	Analysis
	40867	121	Sericite Schist	Regional			
	40869	122	Semi-Nephrite	ML 4132	70		Analysis
	40870	123	Amphibolite	Regional			
	40871	124	Nephrite	ML 4131			Analysis
	40872	125	Tremolite	(MC 733)			Analysis
	40873	126	Calc-Silicate	(MC 733)			
	40874	127	?Quartzite	Regional			
	40875	128	Granodiorite Gneiss	Regional			
	40876	129	Hornblende Gneiss	Regional			
	40877	130	Dolerite	Regional			
	40878	131	Gneiss	Regional			
	40879	132	Sericite Schist	Regional			
	40880	133	Iron Formation	Regional			
	40881	134	Calc-Silicate	Regional			
	40882	135	Garnet Gneiss	Regional			
	40883	136	Garnet Gneiss	Regional			
	40884	137	Tremolite	Regional			Analysis
	40885	138	Gneiss	Regional			
	40886	139	Gneiss	Regional			
	40887	140	Calc-Silicate	Regional			
	40888	141	Dolomite	Regional			
	40889	142	Dolerite	Regional			
	40890	143	Dolerite	Regional			
	40891	144	Granitic Gneiss	Regional			
	40892	145	Altered Intrusive	Regional			Analysis
	40893	146	Quartzite	Regional			
	40894	147	Semi-Nephrite	Regional	113		Analysis
	40895	148	Granite	Regional			
	40896	149	Calc-Silicate	Regional			

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Petrography Map Sheet 6231 (Cont'd)

AMDEL RPT.	TS NO.	RS NO.	ROCK TYPE	LOCATION	O/C NO.	PLAN NO.	COMMENT
GS6238/84	41462	150	Altered Intrusive	ML 4132	69		Analysis; Not located
GS4653/85		192		ML 4576			XRD Analysis only
		195		ML 4130	55		Not located; No sample description
		196		ML 4130	55		No sample description available
		197		ML 4130	55		No sample description available
		198		ML 4130	55		No sample description available
		199		ML 4130	55		No sample description available
GS6795#5G	48684	200	Granodiorite Gneiss	ML 4217		89-177	
	48688	201	Gneiss	ML 4415			
	48689	202	Gneiss	ML 4415	107	88-430	
		203		ML 4130	55	88-429	No sample description available
GS6795#5G	48691	204	Iron Formation	ML 4130	55	88-429	
	48692	205	Serpentinised Marble	ML 4130	55	88-429	
	48693	206	Iron Formation	ML 4130	55	88-429	
	48694	207	Chlorotoid Schist	ML 4338	115	88-431	
	48695	208	Gneiss	ML 4130	56	88-429	
	48696	209	Tremolite	ML 4130	56	88-429	
	48697	210	Semi-Nephrite	ML 4130	56	88-429	
	48698	211	Semi-Nephrite	ML 4130	57	88-429	
	48701	212	Tremolite Schist	ML 4217	21	88-423	Analysis
	48702	213	Tremolite Schist	ML 4217	21	88-423	Analysis
	48704	214	Chloritic Dolomite	ML 4217	27		Analysis
		215					
		216		ML 4532	9-12	88-422	No sample description available
		217		ML 4532	9-12	88-422	No sample description available
		218		ML 4532	9-12	88-422	No sample description available
		269	Iron Formation	Regional			Same as 6231 RS133; No sample description
		270		ML 4532	11		Not located; No sample description

DESCRIPTION OF PINK MINERAL

Sample: 6230 RS 303; TSC30969 E00001

Location:
Near Cowell in the Cleve Metamorphics

Hand Specimen:
The rock appears coarse grained and has crystals or aggregates 5-10 mm in size which vary in colour from a pale rose pink to pinkish-cream. Some of these appear sub-rectangular to almost square in section. They are separated by zones of translucent pale grey quartz. Identification of the pink mineral was requested.

X-ray Diffraction:
Material was collected from an area of a specimen where a concentration of the pink mineral was present. It was hand-picked to remove as much quartz as possible, powdered and used to produce an X-ray powder diffractometer scan which was interpreted.

The main mineral was found to be clinozoisite. Additional diffraction peaks were present which were interpreted as possibly due to a proportion of admixed zoisite, but this cannot be asserted with confidence.

Thin Section:
The area sectioned contains about equal proportions of quartz and a mineral belonging to the epidote group. There is a minute trace of sericite.

The zones which are pale pink in the hand specimen are composed of intergrown crystals of clinozoisite, many of them between 0.5 and 1 mm long, and in many places there are radiating aggregates of these crystals some of which are almost fibrous. The optical properties vary slightly, in some zones the mineral shows very low anomalous interference covers with greys and ultra-blues but there are other zones showing higher polarization covers possibly indicating the presence of a little iron in the mineral. In some of the fibrous and radiating aggregates, the mineral apparently has straight extinction and it is possible that there is zoisite present as well as the clinozoisite identified by X-ray diffraction as the dominant epidote-group mineral. When the section is examined under very low magnification it is clear that the clinozoisite and other epidote-group minerals which may be present have pseudomorphically replaced some sub-rectangular crystals which, in the area sectioned, vary in size from 4-8 mm. These could well have been crystals of feldspar but, as there are no internal relict textures, this would be very difficult to confirm with certainty. There is one elongate zone about 6 mm long and 1 mm thick in which the mineral has higher polarization colours and could more accurately be classified as epidote. This is intergrown with a trace of chlorite and it could be interpreted as showing poorly preserved relict micaceous texture. It is possible that this was once a very large flake of biotite which was replaced by an epidote-group mineral containing slightly more iron than that which probably replaced the feldspar. There are two metamict ?zircon grains in this elongate aggregate of epidote.

Interstices between the sub-rectangular aggregates of clinozoisite and ?zoisite contain mainly quartz which varies in grain size up to about 4 mm but some of this has been strained and granulated. There is one area containing a little plagioclase intergrown with the quartz and this has

also been granulated. In this area there is no clear evidence of a relationship between the epidote-group mineral and the plagioclase.

Conclusion:

The pink mineral is a member of the epidote group and predominantly clinozoisite with possibly some intergrown zoisite. This member of the epidote group has replaced relatively large crystals which were probably feldspar (?plagioclase) but this cannot be proved with certainty.

Thulite is reported to be a pink variety of zoisite, however, as this mineral is probably a mixture of clinozoisite and zoisite it would be reasonable to classify it as thulite.

Sample: 6230 RS 304; TS42889

Location: Jade deposit on Section 12, Hd Miltalie.

Rock Name:
Nephrite jade

Hand Specimen:
A massive, medium to dark green coloured rock which has a much paler green colour along some weathered surfaces. The rock also contains smaller dark green patches up to several millimetres in size which have a slightly more coarsely crystalline character.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Amphibole	98
Biotite/phlogopite	Trace-1
Opaques and semi-opaques	1

This is an essentially monomineralic rock comprised of amphibole which forms crystals up to 0.3 mm long with a slightly prismatic character and an interlocking nature. Locally, the rock contains patches of more coarsely crystalline amphibole up to several millimetres in size. Within these patches the amphibole has a somewhat prismatic character and forms crystals up to 1 mm long. All of the amphibole crystals have a somewhat random orientation.

Minor biotite is present as small, fibrous flakes located interstitially between the coarser amphibole crystals. The biotite has a very pale brown, weakly pleochroic colour and could, in fact, be phlogopite. Minor opaques and translucent, semi-opaque material are disseminated through the rock as anhedral grains and granular aggregates up to 0.1 mm in size.

This sample of nephrite jade consists of interlocking amphibole crystals generally about 0.15 mm in length, although it does contain coarser-grained patches of amphibole up to several millimetres in size.

Sample: 6230 RS 305; TS42890

Location: Jade deposit on Section 12, Hd Miltalie.

Rock Name:
Nephrite jade

Hand Specimen:
A massive, medium to dark green coloured rock.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Amphibole	80
Phlogopite	20
Opaques	Trace-1

This rock is comprised mainly of prismatic amphibole crystals which exhibit a moderately well developed nematoblastic foliation, although a significant proportion of the amphibole crystals exhibit a somewhat random orientation to produce an interlocking texture. Most of the amphibole crystals are about 0.1-0.3 mm in length but the rock contains some much larger crystals up to about 1.5 mm long. The amphibole is a clear, non-pleochroic variety.

The interstitial regions between the larger amphibole crystals are filled with a very pale brown, weakly pleochroic phyllosilicate which is believed to be phlogopite, although the optical distinction of phlogopite from biotite is difficult. The pale brown weakly pleochroic colour as well as the very small 2V of this phyllosilicate suggests phlogopite.

Minor opaques are disseminated through the rock as anhedral grains up to 0.1 mm in size.

This is a jade sample containing a significant proportion of a phyllosilicate believed to be phlogopite.

Sample: 6230 RS 306; TS42891

Location: Jade deposit on Section 12, Hd Miltalie.

Rock Name:
Amphibole-veined quartzite

Hand Specimen:
A massive, medium-grey coloured rock containing some paler greenish-grey coloured patches and discontinuous bands and veinlets.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Quartz	65
Amphibole	35
Limonite	1
Opaques	Trace

This sample is comprised of an intensely deformed quartz mosaic veined with fibrous amphibole. The quartz mosaic has a typical grain size between 0.3 and 0.5 mm and the quartz itself is extensively deformed showing undulose extinction as well as vague, deformational lamellae which generally have a slightly bent character. Most of the quartz mosaic is comprised of somewhat lenticular quartz grains which have a subparallel orientation defining a foliation direction. Locally, the quartz exhibits slightly sutured grains margins, but for the most part the grain margins have a somewhat straight, unsutured character.

Fibrous amphibole occurs mainly as vein-like structures with the amphibole fibres oriented transversely. The amphibole is a clear, non-pleochroic variety and at least locally forms somewhat larger, prismatic to acicular crystals. Limonite tends to be concentrated in the amphibole-rich bands as irregular patches up to 0.3 mm in size, although minor limonite also occurs as interstitial fillings within the granular quartz. Traces of opaques are disseminated through the rock as anhedral grains and granular aggregates up to 0.1 mm in size.

This is a quartz-rich rock with a highly deformed, recrystallized texture containing fibrous amphibole veins and patches.

2. PETROGRAPHY

Sample: 6230 RS 320; TS44821

Applicant's No.: DJF 1

Rock Name:
Epidote-quartz schist

Hand Specimen:
This is a fine-grained, greyish-green coloured metamorphic rock which shows a weak fabric on the broken surface. On the cut surface the sample shows prominent compositional banding with a subparallel to parallel schistosity.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	45
Epidote	35
?Plagioclase	10
Biotite	6
Chlorite	2
Opaques	2
Muscovite	trace

In thin section this rock shows a prominent compositional banding that is a consequence of variations in the relative proportions of quartz and epidote.

The quartz occurs in two grain sizes. The coarser-grained quartz forms lenticular granoblastic aggregates with an individual average grain size of 0.04 to 0.08 mm in diameter. Grain contacts are straight to gently-curved with most grains showing undulose extinction. These coarser quartz aggregates are parallel with the main fabric and in places, there is a suggestion that they represent attenuated veins. The finer-grained quartz forms mosaics with an average grain size of 0.01 mm. It is probable that there is some untwinned feldspar associated with these fine mosaics. Staining of the cut slab with sodium cobaltinitrite shows that the feldspar is probably plagioclase but the exact composition is uncertain.

The epidote ranges in grain size up to 0.1 mm in diameter, but for the most part is of the order of 0.01 to 0.04 mm. It is generally concentrated into bands which also contain fine quartz mosaics. In addition it forms stringers within the quartz-rich bands.

Micaceous minerals are present in minor amounts. Green pleochroic biotite is evident, as is chlorite and there are small amounts of muscovite. The biotite flakes are orientated parallel to the compositional banding and are of the order of 0.05 mm in length.

Minor, generally amorphous opaque material is also present.

This is an epidote-quartz schist that was probably formed through low-grade metamorphism of a clay-rich sandstone. There is evidence to suggest that an early veining of this rock has been attenuated during a subsequent deformation.

Sample: 6230 RS 321; TS44822

Applicant's No.: DJF 2

Rock Name:
Amphibolite

Hand Specimen:
This is a dark green coloured metamorphic rock which has a prominent foliation. It is medium to fine-grained. There are several elongate felsic patches which form stringers in the foliation and these probably represent attenuated folding.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Hornblende	55
Plagioclase (unaltered)	15
Epidote/sericite (after plagioclase)	28
Quartz	1
Opaques	1

This rock has an equigranular granoblastic texture and consists dominantly of amphibole and plagioclase, or the alteration products of plagioclase. The prominent foliation noted in hand specimen is a consequence of the preferred orientation of elongate amphibole grains.

The amphibole grains range up to 2 mm in length but are usually of the order of 0.5 mm. They show pale green to olive-green pleochroism and an amphibole cleavage well developed. Hornblende is the probable composition. Alteration of the hornblende to ?chlorite is rare and tends to occur along cracks or fissures.

The plagioclase is of a similar grain size to the hornblende and is elongated in the foliation. Unaltered plagioclase shows multiple lamellar twinning, however, for the most part the plagioclase has been extensively saussuritised and sericitised. The fine secondary epidote and sericite aggregates predominate over the unaltered plagioclase.

The elongate felsic stringers noted in hand specimen can be seen to consist of altered plagioclase. In one instance a chain of altered plagioclase grains clearly defines a relict fold hinge. This suggests an earlier segregation of the plagioclase followed by two subsequent deformation events: one which results in folding and the other which attenuates that folding.

Quartz is a minor constituent occurring as discrete equant grains. It is also present as thin veins both oblique and parallel to the foliation.

Blocky to anhedral opaque grains are another minor constituent. These are approximately 0.2 mm in diameter. There is possibly some rutile present.

The rock is a well-foliated amphibolite that was formed through low to middle amphibolite-grade metamorphism of either a basic igneous rock or a sandy marl. There is evidence to suggest two deformation events followed by a younger low-grade alteration.

Sample: 6230 RS 322; TS44823

Applicant's No: DJF 3

Rock Name:
Altered, folded, sericitic-muscovite-biotite-plagioclase-quartz schist

Hand Specimen:
This is a folded schistose rock with a prominent compositional banding due to the interlayering of micaceous material and quartzo-feldspathic material. The rock appears to be moderately altered in hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	30
Plagioclase	20
Sericite and fine muscovite	20
Coarse muscovite	10
Biotite	10
Opaques "primary"	2
"secondary"	5
Chlorite	3
Zircon	trace
Apatite	trace

The compositional banding observed in hand specimen is clearly evident in the thin section. Quartz and plagioclase bands are interlayered with biotite and muscovite bands, and some sericite and fine muscovite bands. The rock as a whole is extensively altered with a moderate amount of secondary opaques (ferruginisation).

Quartz occurs as equant to elongate grains that range up to 4 mm in length. The coarser relict grains show strongly undulose extinction and considerable sub-grain developments. One such grain can be seen to be folded around a fold hinge. The finer-grained quartz also shows undulose extinction but the grains tend to be more equant in outline.

The plagioclase commonly occurs as strongly cracked grains with abundant secondary opaque material along the cracks. Multiple lamellar twinning is present but a high proportion of the plagioclase is untwinned. There may be some cordierite present that has herein been termed plagioclase, but positive identification of the cordierite was not possible.

Both muscovite and biotite appear to be the early metamorphic micas which parallel the folded fabric. The biotite ranges up to 1 mm in length and there is a minor amount of chloritisation. The muscovite occurs both interstratified with the biotite and as discrete grains.

Associated with the micaceous bands are sericitic bands. Some fine muscovite and biotite was also present. The sericite is secondary in origin and probably replaced an earlier metastable metamorphic phase, possibly an alumino silicate.

The primary opaques are generally irregular in outline and range up to 0.5 mm in length. They appear to be more prevalent as relicts within the sericitic bands. The secondary opaques are mainly fine-grained to

amorphous and occur along cracks and fissures. Chlorite can also be seen in late-stage cracks and fissures as well as replacing the biotite and muscovite.

Zircon is present in trace amounts and there is rare apatite.

The rock is an altered, folded, sericite-muscovite-biotite-plagioclase-quartz schist. It was probably formed through low amphibolite facies metamorphism of a pelitic sediment. The rock has subsequently been folded and a low grade alteration superimposed.

Sample: 6230 RS 323; TS44824

Applicant's No.: DJF 4

Rock Name:
Clinozoisite-amphibole schist

Hand Specimen:
This is a banded green to pale green coloured metamorphic rock. The cut surface shows interlayered dark green and pale green bands with thin felsic veins. The felsic veins are discontinuous, consistent with attenuation of early-formed folds. Some relict fold hinges are evident in hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Amphibole (?edenite)	60
Clinozoisite	25
Sericite (minor muscovite)	5
Fine clays	5
Zircon/monazite	1
Opaques (goethite)	1
Sphene	trace
Chlorite	trace
Calcite	trace

The prominent colour banding noted in hand specimen appears in thin section to be due to thin clinozoisite-rich bands in an otherwise amphibole-rich rock.

The amphibole is generally colourless and its optical properties imply an edenite composition although the possibility of cummingtonite cannot be excluded.

The amphibole occurs in a variety of morphologies that may relate to differing metamorphic episodes. The early-formed amphibole appears as coarse elongate grains which range up to 5 mm in length. These grains are typically poikilitic and appear to enclose clinozoisite, which may be after early-formed plagioclase. Rare inclusions of plagioclase are evident. Recrystallisation of the amphibole results in a finer, more elongate aggregate of grains with an average grain size of 0.3 mm. These elongate grains give the rock its prominent schistosity. Associated euhedral prismatic amphibole is also prominent and this appears to be forming in the poikilitic coarse grains as well as in the more clearly recrystallised zones.

The clinozoisite-rich bands consist of aggregates of clinozoisite and fine amphibole with variable amounts of chlorite, sericite and fine clays. The clinozoisite occurs as granular anhedral aggregates that are interstitial to the amphibole. The average grain size of the clinozoisite is generally less than 0.1 mm. Sericite and fine clays appear to be sedondary products after plagioclase and the chlorite may be a result of alteration of a minor mica or amphibole phase.

Accessory phases observed are zircon and/or monazite, and sphene. Opaques are also present tending to be anhedral to blocky in outline after pyrite. In one corner of the thin section there is some prominent secondary ferruginisation. Traces of secondary calcite occur as interstitial infillings

in some places.

The rock is a clinozoisite-amphibole schist that may have been formed through middle amphibolite grade metamorphism of a basic igneous rock.

Sample: 6230 RS 324; TS44825

Applicant's No.: DJF 5

Rock Name:
Amphibole-epidote-quartz schist

Hand Specimen:
This is a well layered metamorphic rock consisting of generally thick pale green to cream coloured bands up to several centimetres in thickness, interlayered with thin dark green bands. There are also several patches of darker green material and in one instance there appears to be boudinaging of the layering about one such patch.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	35
Epidote	35
Amphibole	24
Chlorite	5
Opaques	1
Zircon	trace
Sphene	trace

The compositional banding noted in hand specimen can be seen to be due to a crude alternation of quartz-rich and epidote amphibole-rich bands. There is a subparallel foliation evident, which is a consequence of the parallel alignment of the elongate quartz and amphibole grains, and to a lesser extent epidote grains.

Quartz occurs as elongate grains which show undulose to strongly undulose extinction and sub-grain developments. The grains range up to 1.5 mm in length but are typically of the order of 0.5 mm or so in length. Within the quartz-rich bands epidote and amphibole are also present. Grain margins to the quartz are cuspate or serrated in most instances. Adjacent to the amphibole grains there are sometimes projections of radiating fibres into the quartz. These are considered to represent late growth of fibrous amphibole.

The epidote forms colourless aggregates of high relief and high maximum birefringence. Grains are usually equant to elongate in outline and of the order of 0.5 mm in diameter, although some of the epidote ranges up to 5 mm. It is probable that there is some zoisite or clinozoisite present in addition to the more dominant epidote. In places the epidote appears to be forming at the expense of amphibole.

Two or even three generations of amphibole growth may be present in this thin section. Early-formed coarse-grained knots of pleochroic pale green amphibole are a minor constituent. These grains form the cores of boudins noted in hand specimen. They are up to 4 mm in diameter and show well-developed amphibole cleavage. It is possible that the amphibole in this case is actinolitic in composition.

The second amphibole development is weakly pleochroic and colourless to

pale green in colour. It is finer-grained, of the order of 0.5 mm in length, with the amphibole cleavage not as well developed. The composition in this case is possibly in the actinolite-tremolite range. Rare inclusions of zircon show pleochroic haloes. This secondary amphibole commonly forms aggregates and intergrowths with the epidote, and in places interfingering epidote and amphibole is observed. As noted above, late-stage fibrous amphibole has developed in the quartz and this may represent a third stage of amphibole development.

Minor amounts of chlorite are present and these appear to be forming at the expense of the amphibole. Irregular to blocky opaques are also present. There are traces of sphene and zircon.

The rock is an amphibole-epidote-quartz schist that was possibly formed by low to middle amphibolite grade metamorphism of a pelitic sandstone rich in calcium and magnesium.

Sample: 6230 RS 325; TS44826

Applicant's No.: DJF 6

Rock Name:
Tremolite rock (jade-nephrite)

Hand Specimen:
This is a fine-grained, massive dark green-coloured rock which contains disseminated coarser-grained pale green crystals. The rock has a thin crust of weathering which appears to show a ghost fabric.

Thin Section:
A visual estimate of the constituents presents gives the following:

	%
Tremolite - fine	85
- coarse	10
Biotite/chlorite	4
Opaques	1
Apatite	trace

This rock is dominated by fine aggregates of tremolite with an average grain size of 0.02 mm. The tremolite is partly fibrous, occurring as bundles of fibres in random interlocking orientation. Some radial textures are observed.

Approximately 10% of the rock consists of aggregates and discrete crystals of coarser-grained tremolite. These are the coarse pale green crystals noted in hand specimen. The tremolite in this case generally occurs as bladed crystals with, in places, euhedral cleavage fragments, and they range up to 2 mm in length.

The aggregates of coarse tremolite also contain biotite in places. The biotite appears as small randomly orientated flakes of the order of 0.2 mm in length. Chloritisation of the biotite is prominent in places. The coarse-grained tremolite also appears to have been chloritised in several instances.

Irregular elongate opaque grains are found in the coarse-grained aggregates. These range up to 0.1 mm in length. Thin irregular cracks through the rock also contain late-stage amorphous opaque development. The weathered skin noted in hand specimen can be seen to be marked by an intense ferruginisation of the otherwise fine tremolite aggregates.

One prominent grain of apatite has been observed with a grain size of 0.2 mm. Other smaller less conspicuous grains of apatite are present.

This is a tremolite rock most probably formed through amphibolite facies metamorphism of a dolomitic limestone. The rock could be jade (nephrite).

Sample: 6230 RS 326; TS44828

Applicant's No.: DJF 8

Rock Name:
Chloritic plagioclase-muscovite-sericite schist

Hand Specimen:
This is a pale green coloured schistose metamorphic rock which has a prominent crenulation or microfolding. Several dark grey porphyroblasts up to 1 cm in length are evident on a cut surface.

Thin Section:
A visual estimate of the constituents presents gives the following:

	%
Muscovite and sericite	50
?Chlorite	25
Plagioclase	20
Quartz	5
Zircon	trace
Opaques	trace

This rock is dominated by aggregates of fine-grained muscovite and sericite. The microfolding or crenulation noted in hand specimen is emphasised by the presence of folded feldspar-rich bands that are of the order of 1 mm in thickness or less. Coarse-grained muscovite flakes also reflect the deformation.

The aggregates of fine muscovite and sericite have a grain size which ranges up to 0.02 mm. These aggregates are, for the most part, formed by the flake-like mica with high birefringence. Intergrown material of similar relief but with low maximum birefringence may be a chlorite.

The coarser-grained muscovite flakes range up to 2 mm in length. These are folded about the axes of the crenulation. Material of similar relief is often intergrown with the muscovite or is found in juxtaposition with it. This micaceous mineral has anomalous interference colours and most probably represent some form of chlorite, formed through retrogradation of the muscovite.

Feldspar is a prominent constituent forming bands deformed by the folding. Multiply lamellar twinning is evident, but many grains are untwinned. The grain size ranges up to 3 mm. The plagioclase is of andesine composition. In places it has been altered to sericite or replaced by well-formed muscovite and ?chlorite.

Quartz is a minor constituent of the rock and is found in the feldspar-rich bands as irregular grains with strongly undulose extinction.

Equant to elongate grains of zircon and/or ?monazite are present in trace amounts. These sometimes show growth zoning. Traces of opaques are also present.

This is a chloritic plagioclase-muscovite-sericite schist that was probably formed through a low amphibolite-grade metamorphism of pelitic sediment. Two stages of deformation are evident and there is some retrograde metamorphism.

Sample: 6230 RS 327; TS44829

Applicant's No.: DJF 9

Rock Name:
Granodioritic gneiss

Hand Specimen:
This is a dark grey coloured quartzo-feldspathic gneiss which is generally medium-grained and has a moderate proportion of mafic minerals. Lenticular, slightly coarser-grained, aggregates of quartzo-feldspathic material lie parallel with the prominent metamorphic fabric.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	35
Quartz	30
Biotite	20
Potassium feldspar	5
Muscovite and sericite	4
Apatite	3
Opaques (including sphene)	2
Zircon	1
Colourless phyllosilicates	trace

The gneissic fabric noted in hand specimen can be seen to be due to a general parallel alignment of elongate quartz and feldspar crystals with flakes of biotite also in a similar alignment. The biotite forms semi- to discontinuous zones through the rock.

Both multiply twinned and untwinned plagioclase are present and the composition is oligoclase. The plagioclase grains are usually of the order of 0.5 to 1 mm in diameter, and tend to be more equant in outline than the quartz. Myrmekitic intergrowths with quartz are evident. There is a minor amount of potassium feldspar present, notably microcline and microcline perthite. Alteration of the plagioclase to fine muscovite and sericite is common, but variable. A low birefringent colourless phyllosilicate also appears to be an alteration product of the feldspars.

Quartz tends to be coarser-grained, and occurs as more elongate grains up to 3 mm in length, but generally less than or equal to 1 mm. The quartz shows undulose to strongly undulose extinction with the coarser more equant grains having considerable sub-grain developments. Grain margins are commonly simple curves, however, along a number of margins recrystallisation is evident and in these cases serrated or cuspate grain boundaries can be seen.

The biotite is olive-green to green-brown in colour. The flakes generally show a parallel alignment and range up to 1.5 mm in length. In some cases, particularly where in contact with plagioclase, there is a thin rim or zone of muscovite surrounding the biotite. Opaques also occur in thin rims surrounding biotite, and these include fine granular exsolved sphene.

Apatite is a common accessory phase and it usually occurs in association with the biotite, or in biotite-rich areas. The apatite grains are elongate with round terminations, and are between 0.1 to 0.5 mm in length.

The opaques also occur in association with the biotite. Thin anhedral grains are the most prominent. Zoned round elongate grains of zircon are common; some of the zircon grains are rimmed by secondary opaques.

The muscovite and sericite are late-stage development. They tend to form at the expense of plagioclase, although some may be after biotite. Trace amounts of a colourless phyllosilicate are conspicuous.

The rock is a granodioritic gneiss and may have had an igneous precursor.

Sample: 6230 RS 328; TS44830

Applicant's No.: DJF 10

Rock Name:
Granitic gneiss

Hand Specimen:
This is a medium-grained, granitic gneiss which has red discontinuous bands of feldspar interleaved with dark micaceous bands. Some of the feldspathic bands may have originally been continuous, implying attenuation of early formed isoclinal folds.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Microcline	30
Plagioclase	24
Quartz	20
Biotite	15
Opaques	5
Muscovite and sericite	5
Zircon	1
Apatite	trace
Rutile	trace

The gneissic texture noted in hand specimen can be seen to be due to a parallel alignment of elongate feldspars and quartz coupled with the parallel schistosity arising from the alignment of biotite.

Feldspar is the dominant component of this rock. Microcline and microcline perthite are more prevalent than plagioclase. The microcline shows cross-hatched twinning and often contains perthitic exsolution features. The grains tend to be more equant than elongate and range up to 2 mm in diameter. Included blebs of quartz and serrated grain margins are a common feature.

Both untwinned and multiply twinned plagioclase are present. It is of an oligoclase composition and is generally finer-grained than the potassium feldspar though grains do range up to 2 mm. Myrmekitic intergrowths of plagioclase with quartz can be seen. The plagioclase is variably altered to sericite and fine clays.

The quartz shows several stages of recrystallisation. Coarse grains have strongly undulose extinction, considerable sub-grain developments and range up to 1.5 mm in length. Through cataclastic deformation the grains break down to finer mosaics with serrated and cuspate grain margins. Equant recrystallised quartz shows mildly undulose extinction and has curved grain margins. In some places there are zones of fine quartz mosaics interstitial to coarser grains. These areas may represent zones of more intense deformation.

The biotite is olive-green to green-brown in colour. It ranges up to 1 mm in length and forms thin stringers through the rock. In a number of instances, the biotite is rimmed by fine anhedral opaques with a grain size ranging up to 0.05 mm in length. Secondary fine muscovite also forms around the margins of biotite grains.

The accessory phases observed are zircon, apatite and rutile. The zircon grains are commonly zoned and range up to 0.2 mm in length. The apatite is a trace constituent with elongate grains up to 0.1 mm.

The rock is a granitic gneiss that probably has an igneous precursor.

Sample: 6230 RS 329; TS44836

Applicant's No.: DJF 16

Rock Name:
Tremolite rock

Hand Specimen:
This is a massive pale green coloured rock which is composed of finely crystalline material. There are some sugary recrystallised overgrowths present.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
?Tremolite	98
Opaques	2
Apatite	trace

This rock is dominated by massive aggregates of a fine-grained amphibole. Under high magnification the amphibole appears to occur in fibrous aggregates with individual fibre bundles of the order of 0.02 mm in length. These fibrous bundles of amphibole form together ghost coarser domains which are of the order of 3 to 5 mm in diameter. Optical continuity is evident within each domain and some show ghost multiple lamellar twinning.

Coarser-grained amphibole, most probably tremolite in composition occurs as elongate crystals up to 0.6 mm in length. It is also probable that the finer-grained amphibole noted above is tremolite in composition.

There is a small amount of fine-grained opaque phases present. One end of the thin section shows the effects of a local ferruginisation. Overall there appears to be a slight clouding of the amphibole which may be a consequence of minute dust-like inclusions.

Several grains of apatite are present. These are round and elongate in outline ranging up to 0.2 mm in length.

This is a tremolite rock that was probably formed through amphibolite grade metamorphism of a siliceous dolomitic marble. There is evidence to suggest at least two phases of recrystallisation have occurred.

Sample: 6230 RS 330; TS44837

Applicant's No.: DJF 17

Rock Name:
Banded tremolite rock with minor dolomite-opal bands

Hand Specimen:
This is a poorly banded white and pale green coloured rock which is mostly massive and fine-grained. One surface of the hand specimen is very porous and this presumably represents a weathering crust.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Amphibole bands:	
Tremolite	90-95
Opaques	5
Sericite and calcite in porous bands	5
Carbonate siliceous band:	
Dolomite	50
Opaline silica	45
?Chalcedony	5

This rock is composed of three distinct bands. Two are dominated by amphibole comprised of distinctly different grain sizes whilst the third is a thin 1 to 3 mm band consisting of dolomite and opaline silica.

The coarse-grained amphibole band consists of tremolite which occurs mostly as elongate crystals up to 2 mm in length. Most of the tremolite is porous with minor secondary infills of calcite and/or sericite.

The finer-grained amphibole band consists of aggregates of fibrous tremolite with an average grain size of the order of 0.05 mm in length. There is a crude general alignment of the fibrous tremolite which parallels the overall banding. Some patches of coarser tremolite are present with elongate crystals ranging up to 1 mm in length. In these coarser-grained patches the individual grain margins are sometimes emphasised by the presence of interstitial dust-like opaques. Elsewhere fine opaque material is present.

Along one margin of the rock there is a band which consists of well-formed crystal outlines of dolomite set in a microcrystalline matrix. These relict dolomite crystals range up to 1 mm in length, but internal recrystallisation of the dolomite has resulted in finer granoblastic aggregates bound by the relict euhedral outline. Individual equant grains are of the order of 0.5 mm in diameter. Interstitial to the dolomite there is massive opaline silica which appears colourless and is almost isotropic. Some developments of ?chalcedony occur as round-shaped inclusions in the opaline silica. It is probable that the opaline silica and ?chalcedony is a secondary infill to the dolomite.

This is a banded tremolite rock with minor dolomite opal bands and was probably formed through amphibolite grade metamorphism of an impure dolomitic limestone.

2. PETROGRAPHY

Sample: 6230 RS 331; TS44803

Applicant's No.: E 6

Rock Name:
Retrogressively-altered diopside (?) granulite

Hand Specimen:
A crudely banded and weakly foliated inequigranular mottled green-white rock of metamorphic derivation.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Pyroxene (diopside)	∿40
Tremolite-actinolite	∿40
Talc	∿15
Epidote	2-3
Quartz	2-3
Biotite (and ?sericite)	<1
Opaques (iron oxide)	trace

A complex metamorphic history involving at least two phases has developed this rock from a protolith rich in lime and magnesia (?dolomite). Coarse granuloblastic diopside appears to have been the first metamorphic product. Individual crystals are coarse, being up to 4 or 5 mm diameter, and are grouped in clusters several centimetres across. These groups or metamorphic segregations, are surrounded by partially nematoblastic prisms of tremolite-actinolite in which individual crystals are up to 2 mm long. These have enwrapped the pyroxene segregations with a variable layer up to 1 cm thick. The two minerals together form a band 4 to 5 cm thick which is enclosed in thinner bands of more typically gneissic texture.

The thinner gneissic layers also give the impression that they were originally a mixture of pyroxene and amphibole, but appear to have been exposed to more considerable hydrothermal alteration, possibly in conjunction with minor shearing and crushing of the coarser minerals. These now show only vague pseudomorphous outlines of coarse crystals and consist of a microcrystalline mesh of talc, epidote and rare quartz-rich layers (?introduced). Some of the layers show a degree of schistose foliation which is apparently attributable to the presence of fine flakes of biotite and ?sericite, which may also be present among some of the more finely intermeshed mineral mixtures.

The rock is almost certainly a regional metasediment of high amphibolite to granulite facies, possibly produced from a slightly siliceous magnesian limestone. It appears to have been lightly sheared and retrogressively-altered accompanied by minor hydrothermal changes.

Sample: 6230 RS 332; TS44804

Applicant's No.: E 16

Rock Name:
Tremolite-andesine amphibolite

Hand Specimen:
A coarse-grained weakly foliated schistose rock consisting of bladed dull green amphibole and feldspar.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Tremolite-actinolite	∿50
Plagioclase (andesine)	20-30
Sericite	20
Titanite (sphene)	1-2

Nematoblastic prisms of tremolite-actinolite of very varied sizes up to 10 mm long, are scattered in poorly-defined wavy layers in a minor matrix of granuloblastic feldspars. The tremolite-actinolite is a very pale pleochroic yellow-green ferroan variety, with occasional polysynthetic twin lamellae. Many of these crystals are aligned with their long axes parallel to the layering, but the rock is only very superficially foliated. Elongate polygonal crystals of plagioclase are scattered among many of the amphibole layers, and in places they are concentrated into almost pure feldspar bands, alternating with the amphibole. The coarser crystals of feldspar, which are generally associated with the coarser amphiboles, are copiously twinned and their composition is estimated as a calcic andesine (Ab_{52}). Patches of densely turbid sericite (and ?clay mineral) occur scattered among the more felsic bands in particular. In places, this sericitic alteration is invading the adjacent feldspars, but it appears to have formed from a different but more amenable component, which has been totally replaced. Possibly this was a potassic feldspar. Some of the feldspathic bands also contain inclusions of a prismatic to granular mineral of high refractive index which is almost certainly titanite. The granules all are less than 0.1 mm and form clusters and trains along former grain boundaries and have apparently been recrystallised in conjunction with alteration of the feldspars.

The rock is an amphibolite facies equivalent of a shaly calc-magnesian sediment such as a dolomitic marl.

Sample: 6230 RS 333; TS44805

Applicant's No.: E 19

Rock Name:
Clinozoisite-tremolite amphibolite

Hand Specimen:
A massive fine-grained mottled green and white rock.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Clinozoisite	∿60
Tremolite-actinolite	30
Calcite	3-5
Titanite (sphene)	1-2
Feldspar	<1

This is a massive metamorphic rock in which broad irregular clusters of almost equant prismatic clinozoisite set in calcite forming groups up to 1 cm diameter, are irregularly dispersed in a finer matrix of tremolite-actinolite and clinozoisite. The clinozoisite is very abundant and is by far the most dominant component. It has the form of idioblastic to subidioblastic crystals up to 0.5 mm diameter set among the massive calcite which fills the intercrystalline interstices. It is virtually colourless even in hand specimen, and is very iron-deficient. Away from the calcite it passes into an almost pure granuloblastic clinozoisite of similar general grain size.

Quite abruptly the relatively pure clinozoisite gives way to segregations of a generally finer grained intergrowth of tremolite-actinolite and clinozoisite. Much of the tremolite-actinolite is an exceedingly fine mesh of acicular crystals which wind randomly around the granules of clinozoisite. Many of these areas also contain finely granulated titanite, several crystals showing the typical wedge-shaped form, but actually consisting of microcrystalline composites. A very few crystals of feldspar (?plagioclase) are present as sparse void fillings among the other crystals.

The rock is classified as an amphibolite facies equivalent of a lime-dominant calc-magnesian sediment such as a dolomitic limestone or marl. Clinozoisite being a rather unusual mineral but prominent in this rock, its identity was checked by X-ray diffraction analysis as it is readily confused with other members of the epidote group.

Sample: 6230 RS 334; TS44806

Applicant's No.: E 24

Rock Name:
Tremolite-labradorite amphibolite

Hand Specimen:
A strongly foliated medium-grained dark grey amphibolitic rock.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Tremolite-actinolite	>80
Plagioclase (labradorite)	5
Pyroxene (?diopside)	5-8
?Titanite (sphene)	1-2
?Epidote (saussurite)	2-3

Nematoblastic aligned subidioblastic tremolite-actinolite crystals up to 2 mm long and 1 mm wide are the dominant component of this rock. There is a considerable parallelism of the long axes of the amphibole, and as a result a marked foliated and lineated texture within the rock. Thin bands of ?diopside pyroxene are interlaminated with the tremolite-actinolite. The crystals are of irregular polygonal forms, and are smaller but more equidimensional than the amphibole. They are virtually colourless, but are quite poikiloblastic and contain an abundance of pyroxene and feldspar crystals up to 0.2 mm diameter. Their form and manner of inclusion in the diopside is quite random and suggests that the diopside is of later formation and has enveloped the other minerals. The feldspars are scattered randomly but uniformly throughout the amphibole, usually occupying sites at the junction of crystals. The crystals average 0.3 mm diameter, and the multiple twinning indicates that they are of labradorite(Ab_{50}) composition. They tend to have clear transparent cores but most crystals have a fringe of turbid ?saussuritic and/or sericitic alteration. A few minor masses of fine granular ?titanite are also present within well altered feldspathic crystals.

The rock is a typical amphibolite facies equivalent of a marl or lime-rich shale.

Sample: 6230 RS 335; TS44807

Applicant's No.: E 26

Rock Name:
Sheared microgranodiorite gneiss

Hand Specimen:
A massive grey-green medium-grained metamorphic rock with a rather contorted foliation.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	∿50
Plagioclase (oligoclase)	20-30
Biotite	3-5
Sericite	15-20
Chlorite	3
Leucoxene	<1
Limonite	1-2

Xenoblastic crystals of feldspar and quartz up to 2 mm diameter are the principal part of this rock. Most of these crystals, however, show considerable strain and their boundaries are commonly occupied by a finer mass of cherty recrystallised quartz, or fissures filled with a fine mesh of phyllosilicates. The feldspar has an apparent composition corresponding to oligoclase, but most of the crystals are heavily included with scattered flakes of clay mineral and sericite.

Flakes of biotite are the coarsest mica present, but most of these flakes are bent and distorted with ragged variously altered margins merging into broad intermeshed masses of sericite which occupy most of the fissures. Several biotite masses contain clumps of opaque earthy leucoxene scattered around their margins, as though it has been exsolved during alteration. The sericite is very prominent and is even visible in the hand specimen as a system of fine random intergranular fissure fillings. In section it is so fine-grained that individual flakes are indistinguishable. It is most abundant within the fissure pattern mentioned and appears to be a product of minor tectonism and limited hydrothermal alteration. Small clusters of chlorite and chlorite/sericite mixtures also occur among the quartz grains. These appear to be more prevalent in the vicinity of biotite. Grains of limonite appear to be replacing iron oxides.

The rock is evidently sheared and altered and seems most likely to have been derived from a microgranodiorite or gneiss of equivalent composition.

Sample: 6230 RS 336; TS44808

Applicant's No.: E 39

Rock Name:
Quartz-epidote rock

Hand Specimen:
A massive pale grey-brown metamorphic rock which shows an abundance of fine fractures and shearing.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	30-40
Epidote	50-60
Titanite (?leucoxene)	2-3
Hematite	<1

This is a massive sheared and recrystallised metamorphic rock in which very vaguely defined bands of almost pure epidote alternate with bands containing a greater proportion of quartz. The quartz is clear and transparent and consists of veinlets and areas of fine to medium-grained granuloblastic texture. Odd grains are, however, dispersed among the epidote, and have a form which is constrained by the epidote.

The epidote varies texturally from fine to medium-grained granuloblastic mosaics to radial prismatic to almost acicular clusters of quite elongate (up to 1 mm) prisms. The form of these crystals is more idioblastic against the quartz, and several have sharply defined wedge-shaped outlines. The epidote is virtually colourless both in section and in hand specimen, suggesting that it is deficient in iron; its optical properties could coincide either with zoisite or epidote, so since it was a major component its identity as epidote was confirmed by X-ray diffraction.

The quartz-rich areas and bands contain a sparse scattering of almost opaque finely granulated titanite. Many of these have the typical wedge-shaped form of titanite, but actually consist of microcrystalline composites. These are white and almost earthy in oblique illumination so may be leucoxene or similar titanian oxide.

The rock is classified as an amphibolite facies metamorphic equivalent of a lime-rich siltstone or sandy marl.

Sample: 6230 RS 337; TS44809

Applicant's No. : E 46

Rock Name:
Chloritised quartzo-feldspathic gneiss

Hand Specimen:
A fine to medium-grained pale grey-green metamorphic rock with a weak foliation, and very poorly-defined compositional lamination. Some quartzo-feldspathic veining or segregation is observed at one end of the specimen.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	20-30
Plagioclase (oligoclase)	5-10
Muscovite (sericite)	40-50
Chlorite	15
Limonite	1-2
Opaques (iron oxide)	1-2

An originally medium-grained texture of aligned mica flakes up to 1 mm wide is set amongst granuloblastic mosaic of quartz and feldspars of similar dimensions in this rock. Faint relict layering of a former gneissic to schistose rock can still be seen although the alteration has obscured much of the detail. Virtually all the former feldspars are now converted to a mesh of fine flakes of muscovite (sericite), and the quartz crystals while still clear are fractured and cracked, the crevices being filled with further fine mica and traces of limonitic staining. Biotite was the principal original mica, but is now entirely chloritised, although the form and laminar structure can still be seen. The margin of each crystal is now outlined by a rim of fine granular iron oxides exsolved during the alteration process.

A small (1 × 2 cm) area of fairly pure quartz and feldspar has been segregated at one end of the sample. It is generally coarser-grained (?ptygmatic pegmatite), but can be seen in section to be partly sericitised although some areas of unaltered oligoclase are present.

A few masses of goethitic limonite are scattered throughout the rock, many of them showing clear pseudomorphous outlines after clusters of pyritohedra. Such sulphides may have been a component of the former gneissic metamorphic or else have formed at an early stage of the alteration.

The rock is an extensively hydrothermally-altered gneiss of originally granitoid composition.

Sample: 6230 RS 338; TS44810

Applicant's No.: E 51

Rock Name:
Sericitised amphibolite

Hand Specimen:
A medium-grained dark greenish-grey massive rock with a weakly defined lineation of amphibole.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	15
Sericite (?muscovite)	25-30
Amphibole (hornblende)	40-50
Epidote	10-15
Opaques (iron oxide)	3-5

Prisms of bright green to yellow pleochroic hornblende from 0.5 to 1.0 mm long are the principal part of this rock. The crystals are generally more equant than in some other amphibolites of this series, and there is only a minor parallelism of the long axes which imparts the weak lineation, together with a slight compositional layering. Slightly finer-grained granoblastic quartz and originally also feldspars are scattered among the amphibole, often in parallel layers alternating with more ferromagnesian-rich bands. The feldspars are now entirely converted to masses of fine sericite, which in places, is partially recrystallised to muscovite. Knots and clusters of fine to medium-grained granular epidote are disseminated throughout. These seem generally to follow the junctions of hornblende-rich areas with former feldspathic concentrations. Although there is some coarser granules among the epidote, suggesting a minor degree of recrystallisation, most of it is very fine and disseminated along the intergranular boundaries. This seems to indicate that, at least in part, it was a product of the sericitisation alteration process.

Clusters of granular to skeletal iron oxide opaques (?magnetite) occur disseminated throughout, having shapes suggesting that they were originally intergrown with other minerals. Most are now surrounded with granular epidote and to a lesser extent the sericitised feldspars.

The rock is a para-amphibolite derived from a sediment such as a sandy dolomitic marl, which has suffered hydrolytic alteration probably in conjunction with minor retrogressive metamorphism.

Sample: 6230 RS 339; TS44811

Applicant's No.: E 57

Rock Name:
Granodioritic gneiss

Hand Specimen:
A medium-grained pink-brown gneissic rock of dominantly quartzo-feldspathic composition foliated by thin sparse micaceous layers.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	20-30
Plagioclase (oligoclase)	40-50
Microcline	20
Biotite	1-2
Muscovite	2
Sericite	3-5
Leucoxene	<1
Limonite	1
Zircon	trace

The texture of this rock is generally granoblastic, but very inequigranular. A few xenoblasts of quartz and the feldspars are up to 1 mm diameter, but these are enveloped in a much finer, similarly xenoblastic, but almost cherty grain-sized intergrowths of quartz and feldspar. A few rare flakes of biotite and muscovite are disseminated throughout but most are concentrated along the micaceous bands which rarely exceed 1 mm in width, although there are a few knots of sericite which are up to 5 mm diameter. The micaceous bands contain relict flakes of muscovite and biotite up to 0.5 mm, but these pass into masses of sericite which envelope and appear to be partly forming from them. The biotite in particular is grossly altered and surrounded with limonite staining derived from the exsolved iron oxide. A few possibly pseudomorphous areas of ?goethite limonite may represent former sulphides, but much of the limonite has dispersed through the rock and now stains the intergranular boundaries and fissures.

Two feldspars are present in the rock. The more abundant is a coarser, multiple-twinned plagioclase which is of a composition corresponding to oligoclase. These crystals tend to be enwrapped to a greater or lesser degree by the potassic microcline, which appears to be filling veinlets between the larger components, possibly indicating that it was of later formation.

The rock shows some signs of shearing and recent retrogressive hydrothermal alteration and recrystallisation which has obscured any evidence of its origin; it seems most likely, however, to represent a metasediment such as a siliceous claystone or siltstone.

Sample: 6230 RS 340; TS44812

Applicant's No.: E 62

Rock Name:
Contorted granodioritic gneiss

Hand Specimen:
A medium-grained pink and grey laminated gneissic rock of alternating quartzo-feldspathic and micaceous layers, which has been sharply folded and contorted.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	30
Plagioclase (oligoclase)	30-40
Microcline (+ ?orthoclase)	20
Biotite	2-3
Muscovite	3-5
Chlorite	1
Sericite	~10
Opaques (limonite)	1
Apatite	trace
Zircon	trace

This is in many respects a very similar rock to the previous sample; it has, however, been obtained from a zone of flexure, and shows massive folding and distortion of the gneissic banding. The mineralogical constituents are almost identical, except that sericite is more abundant as it appears to be concentrated in the fold axes. The quartz and feldspars are much as in sample E 57, except that the coarsest crystals are up to 2 mm diameter and are separated by a lesser proportion of fine crystals. A few of the plagioclase feldspars are slightly clouded and spotted with flecks of sericite, but the microcline is comparatively clear. The composition of the plagioclase is again near oligoclase, but is perhaps marginally more calcic.

The micaceous bands consist of broad flakes of biotite and muscovite dispersed among irregular masses of fine sericite, and show various signs of alteration. Much of the biotite is partially or completely chloritised and frequently rimmed with limonite from exsolved iron oxides. The micaceous bands have obviously been a line of least resistance for tectonic fractures and shearing of various kinds which have shredded the flakes and have become channels for oxidising solutions which have stained the micas with limonite. The opaques present are fairly sparse, but appear to be entirely goethite now, and may have been derived by alteration of a minor sulphide content.

The rock is a sheared, contorted, and retrogressively-altered gneiss, which has probably been derived from a metasediment such as a siliceous claystone.

Sample: 6230 RS 341; TS44817

Applicant's No.: E 74

Rock Name:
Epidositic chert

Hand Specimen:
A fine-grained massive yellow-green cherty rock, with a faint sub-parallel colour mottling visible on the cut surface.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	∿50
Epidote	∿50
Opaques (?leucoxene)	<1

A very fine-grained cherty texture similar to the previous sample is also a feature of this rock, except that it consists of a virtually equal mixture of quartz and epidote. Both minerals are essentially fine-grained with no crystals coarser than 0.1 mm, and most are in the size range less than 20 microns. The quartz has formed a granuloblastic mosaic which encloses the more rounded granular epidotes. In a few places, the epidote granules are tending to coalesce into slightly coarser recrystallised bands, but this is still quite insignificant. The colour mottling seen in hand specimen is resolved in section as a minor compositional fluctuation in the proportions of the quartz and the epidote.

Angular patches of almost pure granuloblastic quartz are scattered randomly through the fine quartz-epidote matrix. These are composites of slightly coarser quartz crystals. Their angular form, but general alignment with the banding, suggests that they may represent siliceous pyroclastic fragments or devitrified shards. The abundance of fine epidote is also taken by most authorities as an indication that the sediment is of dominantly tuffaceous derivation. The lack of any except the slightest trace of opaques is possibly against this interpretation, as only a few white earthy granules of leucoxene are visible. As for sample E 72, there is a mesh of random fine veinlets throughout the rock. Most contain quartz, but some also contain recrystallised epidote. The rock is concluded to be a metasediment of quartz and epidote derived from a rock such as a ?tuffaceous siltstone.

2. PETROGRAPHY

Sample: 6230 RS 343; TSC39682

Applicant's No:
E52/30

Rock Name:
Tremolite rock (jade)

Hand Specimen:
This is a fine-grained, pale creamy-green coloured rock that is generally massive. The weathered surfaces are more buff-coloured and on the cut surface there appears to be some colour mottling.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	90
Opaques	8
Calcite	2
Apatite	Trace

This rock is dominated by massive aggregates of fine-grained tremolite. The tremolite is elongate in nature with an average grain size of 0.01 mm for the fine-grained aggregates. These elongate grains are generally in random orientation although there are several small domains which show a preferential orientation.

There are patches and discrete areas of coarser grains of tremolite with individual elongate grains ranging up to 1 mm in length. Within the coarser patches the tremolite is generally in random orientation. The colour mottling noticed in hand specimen appears to correspond with these coarser tremolite aggregates. In one corner of the thin section secondary calcite occurs interstitial to the coarser tremolite enveloping the ragged terminations.

The opaques are variably distributed throughout the rock. They mostly occur as very fine, dust-like inclusions in the tremolite and appear to be preferentially concentrated into zones or patches. Apatite is present in trace amounts. It occurs as ovoid grains which range in size up to 0.25 mm in length.

This is a tremolite rock or jade that was produced from middle amphibolite-grade metamorphism of a siliceous dolomitic marble. The texturally distinct tremolite varieties suggest two crystallization episodes.

Sample: 6230 RS 344; TSC39689

Applicant's No:
DJF 18

Rock Name:
Calcite-bearing tremolite rock (or jade)

Hand Specimen:
This is a pale green-coloured rock which is generally massive although a weakly-developed cleavage is evident. On the cut surface there is an apparent compositional banding which has been folded.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	70-75
Calcite	25-30
Apatite	Trace

This rock consists of tremolite and calcite which exhibit a variety of morphologies and relative times of formation.

Tremolite is the primary phase, occurring as fine-grained aggregates with an average grain size of approximately 0.01 mm. For the most part the tremolite is in random orientation although in patches slightly coarser, ?recrystallized tremolite shows a parallel orientation. Secondary calcite occurs interstitial to this fine tremolite and is of a similar grain size.

Clots consisting of coarser-grained aggregates of tremolite are also prominent with the elongate grains ranging up to 0.5 mm in length. These grains tend to be in random orientation with calcite infilling the interstices.

Tremolite also occurs as thin veins, up to 0.2 mm in thickness, consisting of fibrous tremolite aligned perpendicular to the vein direction. Single grain lengths fill the width of each individual grain.

The calcite also forms veins. These consist of granoblastic aggregates of elongate calcite with a range in grain size up to 0.7 mm. The veins show open fold hinges as noted in hand specimen, and in places there has been attenuation of the limbs. Other more diffuse bands rich in calcite, with lesser tremolite, also exhibit similar style folds. In these compositional bands the tremolite is fibrous and parallels the axial plane of the folds. It is this axial planar feature which gives the rock its indistinct cleavage noted in hand specimen.

Traces of apatite occur as round and irregular-shaped grains ranging up to 0.5 mm in length. They are disseminated throughout the specimen.

This is a calcite-bearing tremolite-rich rock or jade that shows at least three stages of tremolite development and two stages of calcite development. The rock shows broad open-style folding with an axial planar cleavage developed.

Sample: 6230 RS 345; TSC39690

Applicant's No:
DJF 19

Rock Name:
Chlorite-bearing dolomitic marble

Hand Specimen:
This is an off-white to pale green-coloured, coarse-grained rock with a gneissic fabric that is best expressed on the cut surface. On a foliation surface flakes of mica are prominent and there is some pyrite also.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Dolomite	60
Calcite	20
Chlorite (including biotite)	17
Tremolite	5
Opaques	3
Spinel	Trace

This rock is dominated by coarse granoblastic aggregates of dolomite with lesser interstitial mica and secondary calcite. The relict core dolomite grains range up to 3 mm in length, with partial to complete recrystallization resulting in finer aggregates of interstitial dolomite. Most of the coarser grains show multiple lamellar twinning and some have interpenetrating twins. Grain margins are irregular, sutured, or cuspate for the coarser grain sizes with the recrystallized finer grains showing more equant shapes with curved margins. The gneissic fabric noted in hand specimen is due to partial alignment of the elongate dolomite grains. The mica occurs interstitial to the coarser dolomite, either as discrete flakes or as clusters of flakes. Individual flakes are commonly in the size range 0.1 to 0.5 mm in length. The mica tends to lie with the long axes in subparallel orientation, emphasizing the gneissic fabric and some flakes are kinked. Biotite is the primary micaceous phase with the chlorite derived by alteration, and chlorite now forms the dominant micaceous phase.

Tremolite occurs as colourless, elongate to equant grains, 0.1 to 0.5 mm in length. The grain margins are slightly ragged in places and this is a retrograde metamorphic effect.

Calcite occurs both interstitially to the dolomite and as veins. The interstitial calcite is probably a secondary development, introduced at the time of cataclastic deformation. The calcite ranges in size up to 0.5 mm and occurs both as discrete grains and as aggregates. Vein calcite is of variable grain size and follows cracks or fissures in the dolomite, at a high angle to the metamorphic fabric.

The opaques range in size up to 0.3 mm and exhibit variable morphologies. Some are blocky and consist of pyrite. Others are more irregular and finer in grain size. In places the fine opaques occur along the cleavage traces of the mica. Rare subidiomorphic pale green spinel is also present.

This is a dolomitic marble which has secondary calcite and chlorite developments. Prograde metamorphism has reached amphibolite facies as evidenced by the presence of tremolite and ?spinel. Retrograde metamorphism and probably accompanying cataclastic deformation has formed the chlorite and finer interstitial dolomite aggregates.

Sample: 6230 RS 346; TSC39691

Applicant's No:
DJF 20

Rock Name:
Massive tremolite rock(or jade)

Hand Specimen:
This is a very fine-grained, generally massive rock which appears to have a pale green outer skin with an inner dark green core. There is an indistinct cleavage and on the cut surface some colour mottling within each colour band is evident.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	∿95
?Opaques	∿5

The rock dominantly consists of massive aggregates of very fine-grained tremolite which has an average grain size of less than 0.01 mm. This fine tremolite tends to show partial optical continuity within coarser, ghost domains which are of the order of 2 to 3 mm in diameter. These ghost domains are sometimes rimmed by fine dust-like material and it is these domains which are the colour mottling observed in hand specimen.

Coarser-grained tremolite is present as discrete grains or aggregates with a range in grain size up to 0.8 mm in length. Tremolite also occurs in veins or fissure developments, up to 0.1 mm in thickness. These veins consist of fibrous tremolite, either with single crystals forming the width of the vein, or with several crystals forming radiating aggregates within the vein.

Fine dust-like inclusions occur in the tremolite and also along cracks through the sample, mimicking relict domainal structures. This material is extremely fine-grained and tentatively termed opaques. They are probably ferruginous in composition.

This is a very fine-grained tremolite rock or jade, which was probably formed through amphibolite-grade metamorphism of a siliceous dolomitic marble. ?Relict domainal structures suggest that an earlier coarser-grained material has been altered or replaced by fine tremolite.

Sample: 6230 RS 347; TSC39692

Applicant's No:
DJF 21

Rock Name:
Foliated tremolite rock (or jade)

Hand Specimen:
This is a fine-grained, pale green-coloured rock that has a weakly-developed schistosity in hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	∿95
Opaques	∿5
?Apatite	Trace

This rock consists predominantly of tremolite and has a well-developed metamorphic fabric. Relict augen of coarser fibrous tremolite range up to 1.5 mm in length and lie with their long axes in the foliation direction. Within these augen the fibrous tremolite may be orientated at a high angle to the foliation, with single tremolite fibres forming the width of the augen. Interstitial recrystallized tremolite has an average grain size of less than 0.04 mm for fine-grained mats, ranging up to 0.1 mm for more massive aggregates. Much of this finer tremolite is fibrous, being aligned in the foliation direction, and wrapping around the relict coarser material.

The foliation is emphasized by subparallel cracks or wispy fissures which contain very fine secondary opaque phases, ?goethite or limonite. Irregular coarser patches of opaques and/or clays are also evident.

There are one or two coarse grains of ?apatite.

This is a well-foliated rock consisting predominantly of tremolite in a variety of grain sizes. It is a tremolite rock or jade.

Sample: 6230 RS 348; TSC39693

Applicant's No:
DJF 22

Rock Name:
Foliated tremolite rock (or jade)

Hand Specimen:
This is a fine-grained, pale green-coloured rock which appears to have an indistinct cleavage in hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	90
Opaques	∿5
Clays (?chlorite)	5

This rock predominantly consists of fibrous tremolite in a variety of grain sizes. Fine-grained mats of tremolite are the most abundant form with an internal grain size of the order of 0.01 mm. These mats appear to form optically continuous domains which are elongate in outline and give the rock its fabric. The domains are in part highlighted by fine opaque phases around the margins.

The fine tremolite grades into coarser, fibrous aggregates in places. Individual grains within these aggregates may range up to 1.5 mm in length and tend to lie with their long axes parallel to the fabric. Other aggregates contain more crystalline tremolite in random to radial orientation with a range in grain sizes up to 0.4 mm.

In places the tremolite is clouded by inclusions of dust-like material, or has been partially altered to clay. There may be some chlorite developed in these areas. Discrete anhedral opaque grains are also present averaging 0.1 mm in grain size.

This is a foliated tremolite rock or jade that appears to have formed through middle amphibolite-grade metamorphism of a siliceous dolomitic marble.

Sample: 6230 RS 349; TSC39694

Applicant's No:
DJF 23

Rock Name:
Foliated tremolite rock (or jade)

Hand Specimen:
This is a fine-grained, pale green-coloured rock which has an indistinct cleavage. On the cut surface some colour mottling is evident.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
Opaques/clays	5
Apatite	Trace
Zircon	Trace

This rock dominantly consists of fine-grained mats of fibrous tremolite with an average grain size of 0.04 mm. The fibrous tremolite shows parallel alignment and in places there appears to be crenulation of this alignment, resulting in a crenulated schistosity. The fine mats are in optical continuity, forming domains which range in size up to 5 mm. It is these domains which give the rock its colour mottling as noted in hand specimen.

Coarse-grained tremolite is present both as discrete grains and as aggregates. These grains are partly euhedral in outline and range in length up to 1.5 mm. Some of the grains show well-developed amphibole cleavage. In places the coarse grains are ragged in outline and partial recrystallization to finer-grained more fibrous tremolite is evident.

Opaques occur as fine wispy material parallel with the foliation. This material is probably goethitic in nature. Clouding of the tremolite is also evident in places and this is possibly fine opaque material or clays.

Apatite occurs as discrete elongate colourless grains which range up to 0.3 mm in length.

This is a foliated tremolite rock or jade, with a superimposed crenulation of that schistosity. The rock was probably formed through middle amphibolite-grade metamorphism of a siliceous dolomitic marble.

Sample: 6230 RS 350; TSC39695

Applicant's No:
DJF 24

Rock Name:
Tremolite rock (or jade)

Hand Specimen:
This is a green to pale green-coloured rock which for the most part is massive and fine-grained. On the broken surface there is evidence for recrystallization with a saccharoidal texture.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	90-95
Opaques	5
Apatite	∿1

This rock consists of fibrous mats of fine tremolite which for the most part form coarse relict domains of earlier grains. These domains range up to 4 mm in diameter and appear to give the rock the saccharoidal texture noted in hand specimen. Within each domain the fibrous tremolite has an average grain size of 0.01 mm and is usually in a parallel orientation. This orientation is oblique to relict ?twinned textures. In some domains the fine tremolite schistosity has been crenulated or kinked.

Aggregates and discrete coarser grains of tremolite are also present. These are elongate in outline, ranging in length up to 1.5 mm. Some of the coarser tremolite has ragged grain margins implying partial recrystallization to the finer tremolite. Others have a prismatic outline with a common grain size being between 0.1 and 0.5 mm. This more prismatic tremolite in places appears to be coeval with the crenulations or kinking and represents later recrystallization.

Opaques occur along cracks through the sample and are probably fine iron oxides. There are patches where the wispy opaque stringers are more prominent and appear to be replacing the tremolite. Apatite occurs as equant to elongate colourless grains of moderate relief with a range in grain size up to 0.5 mm.

This is a tremolite rock or jade that appears to show several stages of tremolite development. Earlier relict domains appear to have recrystallized into optically continuous fibrous mats of tremolite. These have subsequently been crenulated or kinked and there is some prismatic tremolite developed ?along the axial plane of these crenulations or kinks.

Sample: 6230 RS 351; TSC39696

Applicant's No:
DJF 25

Rock Name:
Epidote/clinozoisite-bearing tremolite rock (or jade)

Hand Specimen:
This is a fine-grained rock with a prominent cleavage and where fresh is dark green in colour. The rock has an orange-brown weathering skin.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	80
Epidote/clinozoisite	10
?Chlorite	5
Opaques	5
Apatite	Trace

This rock is dominated by fibrous mats of tremolite with scattered relict augen of coarser tremolite in a parallel orientation. The finer-grained tremolite also tends to lie in parallel orientation, giving the rock a prominent fabric equivalent to the cleavage noted in hand specimen. The average grain size for the fine tremolite is of the order of 0.01 to 0.04 mm. Relict augen structures range in size up to 4 mm in length. They consist of coarser tremolite showing variable recrystallization to finer tremolite. In most augen the coarser fibrous tremolite is orientated at a high angle to the foliation and long axes of the augen, whilst the finer tremolite tends to show kink bands or crenulations. Discrete coarser tremolite grains are also present, being elongate in shape and of the order of 1 mm in length.

Granular aggregates of turbid, high relief material occur as elongate clusters, also parallel to the foliation. These aggregates are probably epidote or clinozoisite originally, with partial alteration to chlorite and/or clays. Discrete epidote grains, pale green in colour, occur in some of these aggregates, with an average grain size of 0.05 mm. There is one patch of subhedral clinozoisite, consisting of colourless elongate grains of high relief, that are up to 0.4 mm in length. This clinozoisite is orientated in the foliation.

Opaques generally occur as fine-grained irregular masses or stringers around the margins or along the cleavage traces of relict coarse ?tremolite grains. The opaques also form along cracks as younger developments.

Apatite is prominent in trace amounts, occurring as elongate grains which range up to 0.2 mm in length.

This is an epidote/clinozoisite-bearing rock or jade that has a prominent foliation and relict augen textures. Some of the fine fibrous tremolite mats show a secondary crenulation of this foliation.

Sample: 6230 RS 352; TSC40866

Applicant's No.
DJF 49

Rock Name:
Coarse-grained tremolite rock

Hand Specimen:
This is a massive dark green coloured rock with a 1 to 4 mm thick orange-brown weathering skin. On the broken surface there is a sugary overgrowth texture.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
?Actinolite	1
Epidote	3
Clays and iron staining	1
Apatite	trace
Zircon	trace

This sample is comprised mostly of tremolite in a variety of morphologies and grain sizes. The early-formed tremolite is coarse-grained crystals ranging up to 4 mm in diameter. This coarse tremolite is generally colourless to very pale green in colour and has ragged grain margins due its breakdown into finer tremolite. Some euhedral amphibole crystals are also present, showing prismatic amphibole outlines and typical 60°-120° cleavage. This amphibole is colourless and of slightly higher relief, but is still probably of a tremolite composition. The secondary tremolite is generally finer-grained aggregates of fibrous amphibole with a range in grain sizes, grading down from the coarser early-formed tremolite.

There are minor but prominent patches of darker, higher relief material which in the centre can be seen to consist of fine granular epidote. The epidote has an average grain size of 0.02 mm and is surrounded by a thin rim of darker coloured fibrous amphibole which may be actinolitic in composition. Some alteration is associated with the epidote and fine clays can be seen. The fine clays and iron staining are also evident along cracks and fissures through the sample, clouding the adjacent amphibole. Trace amounts of apatite and ?zircon can be seen.

This is a tremolite rock or jade, which is atypical in that it contains abundant coarse tremolite developments which are recrystallised into the more typical fine tremolite aggregates.

Sample: 6230 RS 353; TSC40868

Applicant's No.
DJF 51

Rock Name:
Crenulated tremolite rock

Hand Specimen:
This is a green to pale green coloured, medium to fine-grained rock which has a prominent foliation. On the cut surface crenulation of that foliation is evident.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
Clays (and iron staining)	5
Apatite	trace

This sample consists mostly of fine fibrous tremolite which lies in parallel alignment giving rise to the prominent foliation noted in hand specimen. This foliation has been crenulated, and within the axial planes of the crenulations there is a moderate development of a second generation schistosity. The extent of this second deformation is variable in that in some domains the second generation schistosity is more dominant, whilst in others the crenulation is more or less insignificant and a planar earlier fabric dominates.

Coarse tremolite ranges in grain size up to 3 mm in length. Most are orientated with their long axes and cleavage traces parallel to the early schistosity. Some are elongated in the early schistosity but have their cleavage lying in the second generation schistosity. Others do not appear to show either of the above characteristics and are unstrained irregular crystals.

Trace amounts of apatite are present. There are numerous cracks and fissures through the sample which appear to contain fine clays and/or ferruginous material.

This is a crenulated tremolite rock which shows evidence for two fabric-forming events. The second deformation is not as intense as the first and results in a schistosity that it is not uniformly developed over the scale of this thin section.

3. PETROGRAPHY

Sample 6230 RS354; TSC41460; Applicant's No. DJF54

Rock Name:
Tremolite-Bearing Diopside Rock (or Calc-Silicate)

Hand Specimen:
This is a pale green to cream coloured, coarsely crystalline rock which is generally massive and consists dominantly of pyroxene occurring as well cleaved coarse crystals. There are patches and aggregates of a darker green, fibrous amphibole phase which is also coarse grained, although not as coarse as the pyroxene.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Diopside	65
Tremolite/Actinolite	25
Epidote	7
Apatite	2
Sphene	1
Zircon	Trace
?Biotite	Trace
Dolomite	Trace

This sample dominantly consists of coarse aggregates of diopside which show recrystallisation into finer granoblastic aggregates. The diopside ranges in grain size to at least 7 mm in diameter in this thin section. Many grains show multiple twinning with some twin lamellae bent or curved due to deformation. The finer grained diopside ranges down to less than or equal to 0.1 mm in diameter, occurring as equant grains with curved to straight grain margins.

Replacement of the diopside by elongate prismatic amphibole is common and probably represents retrograde metamorphism. The amphibole is mostly colourless with very weak pale green pleochroism in a few cases. It is most probably of tremolite composition with possibly some extension towards the actinolite end member. The amphibole exhibits a wide range in grain sizes, with individual elongate grains ranging up to 3 mm in length in some of the coarser aggregates. Finer grained more fibrous tremolite occurs interstitial to and replacing the diopside.

Epidote is another retrograde metamorphic phase. It occurs as clouded, anhedral grains which range up to 2.2 mm in diameter, although most are of the order of 1 mm or so. The epidote appears to post date the diopside but can be seen to have formed prior to the development to the tremolite/actinolite.

Apatite and Sphene are prominent prograde accessory phases. The apatite occurs as round elongate to equant grains which range up to 0.5 mm in diameter. Sphene occurs as prismatic to anhedral grains which range up to 2 mm in length, mostly being less than 1 mm. Traces of zircon are also present.

Dolomite is present as a secondary phase occurring as late stage infills associated with cracks. The grain size of the dolomite is quite variable. Some grain margins within this sample have red-brown biotite developed and there are fine opaques along many grain margins.

This is a tremolite-bearing dioxide rock that was probably formed through middle amphibolite facies metamorphism of an impure sandy limestone. Retrograde metamorphism and associated fluids give rise to the epidote and amphiboles.

Sample 6230 RS 355; TSC41461; Applicant's No. DJF55

Rock Name:
Adamellite

Hand Specimen:
This is a medium grained, pale pink coloured, quartzo feldspathic rock. It has a weak foliation as seen in the alignment of darker coloured micaceous phases.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	30
Quartz	25
Potassium Feldspar	25
Biotite	5
Muscovite	5
Opaques	3
Zircon	Trace
Apatite	Trace
Sericite	5
Epidote	2

This is an even grained rock consisting mostly of granular aggregates of quartz and feldspar with lesser biotite, muscovite, and opaques. The plagioclase is slightly coarser grained, appearing as rectangular and anhedral grains ranging up to 1.5 mm in length. It is of an oligoclase to andesine composition and most grains show multiple lamellar twinning. There are some myrmekitic intergrowths with quartz. Alteration of the plagioclase is common with sericite and fine epidote formed in many grains. In some cases the plagioclase is extensively altered giving rise to well developed muscovite.

Microcline perthite and perthite are the potassium feldspars. These range in grain size up to 1.8 mm for some rectangular grains, with most occurring as more equant to anhedral grains averaging 0.5 mm in diameter. The potassium feldspar is not altered to the same extent as the plagioclase.

Quartz occurs in a range of grain sizes due to variable recrystallisation. Coarser remnant quartz grains are up to 1.5 mm in length and these show strongly undulous extinction and considerable subgrained development. The finer grained quartz shows undulous to strongly undulous extinction and curved to sutured grain margins, with very irregular grain outlines.

Biotite appears to be the primary micaceous phase, occurring as elongate to equant grains up to 0.5 mm in length. It is olive green to green-brown in colour, with some replacement by muscovite. Most of the muscovite is of a secondary nature, developed at the expense of plagioclase. Some coarser aggregates have individual flakes up to 1.5 mm in length, however most is less than or equal to 0.5 mm. The alignment of the micaceous phases seen in hand specimen is not as prominent on the micro scale, although there is some crude alignment of the biotite.

The opaques occur as blocky to anhedral grains up to 0.5 mm in diameter. The more irregularly shaped grains appear to show secondary remobilisation of the opaque phases. Zircon and apatite are primary phases which occur in accessory amounts, The zircons are typically elongate round grains. Some irregular high relief grains which are up to 0.3 mm in length may be monazite or xenotime.

Epidote is a minor but prominent secondary phase. It occurs as fine granular aggregates together with the sericite replacing plagioclase. Thin epidote veins are also present, consisting of elongate single epidote crystals up to 0.5 mm in length. There is reddish-brown coloured material developed along grain margins which is probably hydrous iron oxide phases.

This is an even grained adamellite that appears to have suffered a mild deformation resulting in the alignment of some of the micas. Secondary alteration in particular of the plagioclase gives rise to epidote and sericite, and there is some late stage epidote veining.

Sample 6230; RS 356; TSC41463; Applicant's No. DJF57

Rock Name:
Biotite Quartzofeldspathic Gneiss (or Granodioritic Gneiss)

Hand Specimen:
This is a grey to dark grey coloured, medium grained, quartzofeldspathic gneiss. Coarse 1 to 3 mm thick feldspathic veins and pods are elongated in the main foliation. On a foliation surface there appears to be an abundance of mica.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	40
Quartz	25
Potassium Feldspar	15
Biotite	15
Muscovite	3
Sericite	3
Opaques	2
Zircon	Trace

This rock has an inequigranular granoblastic texture consisting of coarser relict feldspar and quartz grains which are elongate in nature and have a subparallel alignment. Biotite is a prominent constituent and is preferentially concentrated into discontinuous stringers which together with the alignment of the quartzofeldspathic material give the rock its gneissic texture.

Both twinned and untwinned plagioclase are present and in one large elongate plagioclase grain, 4.5 mm in length, the twin lamellae are curved due to the deformation. Most of the plagioclase is finer than this grain, generally being less than or equal to 1.5 mm in length. The plagioclase is of an oligoclase composition. Some antiperthitic exsolution features are present and myrmekitic intergrowths with quartz can also be seen. Alteration to clays and sericite is evident in some plagioclase grains.

Microcline perthite and perthite are the potassium feldspars in this rock. The potassium feldspars range up to 2.5 mm in length in the feldspathic rich veins or seggregations noted in hand specimen. Elsewhere the feldspar is less than or equal to 1 mm. Quartz is similarly coarser grained in the veins or seggregations, with relict grains ranging up to 2 mm in length. Strongly undulous extinction, subgrain developments, and cuspate to curved grain margins typify the quartz throughout the rock. Within the host gneiss the quartz occurs as both core grains of similar size to the feldspars, and also as recrystallised interstitial fine aggregates.

The biotite is brown to greenish-fawn in colour with individual flakes ranging up to 1.5 mm in length. Fine grained, granular opaques occur as inclusions within the biotite or around its margins. Patches of sericite and fine muscovite occur together with the biotite, and in places these form stringers subparallel with the foliation, extending along quartz and feldspar grain margins. The larger sericite aggregates mimic the feldspar grain morphologies, implying that the micas have replaced an earlier prograde metamorphic phase.

The opaques occur as discrete anhedral grains in addition to those associated with the biotite. Individual grain sizes range up to 0.5 mm in diameter. Zircon is a prominent accessory phase, with many grains coated by opaques. Zonation of the coarser grains can also be seen.

This is a biotite bearing quartzofeldspathic gneiss which if of a granodioritic composition.

Sample 6230 RS 357; TSC41465; Jade Outcrop 34

Rock Name:
Banded Tremolite Clinozoisite Rock

Hand Specimen:
This rock is comprised of two distinct bands. One is pink to pale purple in colour and is generally massive, whilst the other is green in colour and has fibrous aggregates.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Clinozoisite	60-65
Tremolite	25-30
?Epidote	5-10
Calcite	5
Sphene	Trace

The two distinct colour bands noted in hand specimen correspond to markedly different mineralogies. The pink to pale purple band consists of massive aggregates of clinozoisite with lesser interstitial secondary tremolite. The clinozoisite is essentially colourless in thin section and is an early formed phase occurring as radiating clusters of elongate to prismatic crystals, up to 4 mm in length. More rectangular to equant crystals show multiple twinning and are approximately 0.5 to 1.5 mm in length. The clinozoisite is clouded by fine inclusions in places and appears to partly replaced or altered to a more birefringent phase which may be epidote.

Thin veins of fibrous tremolite permeate through the early formed clinozoisite. Aggregates of fibrous and prismatic tremolite occur interstitially through the clinozoisite and appear to have formed at its expense. Sphene occurs as an accessory phase within the clinozoisite with coarse aggregates of partly prismatic grains ranging in grain size up to 1 mm. Finer anhedral sphene is also present, with an average grain size of $\leq$0.1 mm.

The green coloured band noted in hand specimen consists dominantly of tremolite. Early formed, massive, coarse grained tremolite ranges up to 4.5 mm in length. This can be seen to be partially recrystallised giving rise to finer grained, more fibrous tremolite. The coarser grained tremolite is clouded by fine inclusions or alteration products, including secondary calcite. Near the boundary between the tremolite and the clinozoisite band there is a thin band of subhedral clinozoisite or epidote, with an average grain size of the order of 0.3 to 0.5 mm. There is interstitial fibrous tremolite and abundant secondary calcite associated with this ?epidote. Calcite also occurs in the veins through the clinozoisite bands, and these veins are up to 0.3 mm in thickness.

This is a banded tremolite clinozoisite rock that was probably formed through low to amphibolite facies metamorphism of a siliceous dolomitic limestone or a marl. Retrogradation and recrystallisation of an early coarse grained assemblage can be seen.

Sample 6230 RS 358; TSC41466; Jade Outcrop 34

Rock Name:
Hydrothermally Altered Plagioclase Rock

Hand Specimen:
This is a mottled pale green, dark green, and purple coloured rock. On the cut surface there is an indistinct banding which is cut by the colour mottling.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Seriticised Plagioclase	60-65
Tremolite/Actinolite	15-20
Epidote	10-15
Sphene	2
Apatite	2
Zircon	1
Calcite	Trace

The primary mineralogy of this sample has been extensively altered or replaced. The rock is dominated by aggregates of sericite and/or fine muscovite which appear to have replaced plagioclase. In places relict rims to original plagioclase grains can be seen and some of these show multiple lamellar twinning.

There are irregular vein-like developments of tremolite/actinolite and epidote, which are probably the dark green and purple coloured mottling noted in hand specimen. The tremolite/actinolite is pale green in colour and weakly pleochroic, hence the partly actinolitic designation. This amphibole occurs as elongate, prismatic grains which in places are fibrous, and range up to 0.6 mm in length. More equant anhedral amphibole grains occur in granular aggregates within the cores of some of these vein-like developments. In many cases essentially unaltered plagioclase occurs together with the tremolite/actinolite with the amphibole appearing to be replacing the plagioclase.

Epidote occurs in veins and irregular aggregates. The veins are up to 0.2 mm in thickness and these thin veins cut across the tremolite/actinolite development. The irregular epidote aggregates are coarser and more diffuse, often occurring together with tremolite. Individual grains range up to 0.6 mm in diameter and have ragged grain margins.

Sphene, apatite, and zircon are prominent accessory phases. Sphene occurs both as coarser more prismatic grains, up to 0.25 mm in length, and as finer anhedral grains. The sphene appears to be preferentially concentrated in the tremolite/actinolite and epidote developments. Apatite occurs as round to elongate grains, in part subhedral. The apatite ranges up to 0.25 mm in length and is found both as discrete single grains, as aggregates of two or three grains, and in semi-continuous stringers. The zircon occurs mostly as round elongate grains, some of which have subhedral overgrowths.

Calcite is present in trace amounts, and appears as a late stage phase infilling interstices within tremolite/actinolite.

This is a hydrothermally altered plagioclase rock with prominent secondary development of tremolite/actinolite and epidote.

Sample 6230 RS 359; TSC41467; Jade Outcrop 34

Rock Name:
Tremolite Clinozoisite Rock

Hand Specimen:
This is a massive pale green coloured rock with some irregular pale pink coloured veins. The rock has a sugary texture implying metamorphic recrystallisation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Clinozoisite	50-55
Tremolite	35-40
?Epidote	5
Calcite	5

This sample is dominated by coarse grained aggregates of a colourless, epidote group mineral which shows anomalous interference colours and is probably clinozoisite. The subhedral lath shape clinozoisite crystals range up to 4.5 mm in length, with most showing multiple lamellar twinning. The clinozoisite crystals are generally in a random orientation. In places there is minor recrystallisation of the clinozoisite giving rise to a more birefringent variety which may be epidote. Thin veins of secondary ?epidote cut through the early formed clinozoisite. Most clinozoisite grains are clouded by fine dust like inclusions which may represent the early stages of replacement or alteration.

The other main constituent of this rock is tremolite, which occurs in radiating aggregates of fibrous crystals. The fibrous crystals range up to 2 mm in length and can be seen to be replacing the clinozoisite, with radiating clusters and discrete prismatic crystals penetrating the massive clinozoisite aggregates.

Calcite is a late stage development. It occurs in veins and aggregates throughout the clinozoisite and appears to have partly replaced tremolite. in thin veins. Within the tremolite rich patches the calcite infills any interstices, and forms irregular vein like developments.

This is a tremolite clinozoisite rock that was probably formed through prograde middle to low amphibolite facies metamorphism of a marl, followed by hydrothermal alteration giving rise to the tremolite.

E00053

Sample 6230 RS 360; TSC41468; Jade Outcrop 32

Rock Name:
Tremolite Rock

Hand Specimen:
This is a pale green coloured, fine grained rock which appears to have an indistinct foliation on the weathered surface.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	
Fine	90-95
Coarse	5-10
Apatite	1
?Epidote	Trace
Zircon	Trace

This sample is dominated by tremolite which exhibits a variety of grain sizes. Fine grained aggregates of fibrous tremolite are abundant and occur in a type of domainal texture. Each domain is several millimetres in diameter and has internal optical continuity whilst consisting of fine grained fibrous aggregates. This fine fibrous tremolite is of the order of 0.02 mm in length. In places there is a subparallel to parallel alignment of the fibrous tremolite giving rise to the indistinct foliation noted in hand specimen. This foliation is better developed in some areas and can be seen to have been crenulated.

Coarser grained elongate tremolite grains are a minor constituent, ranging up to 1 mm in length. These occur as subhedral discrete grains or granular aggregates. In places they appear to be relict core grains, not recrystallised into the domainal fine grained aggregates noted above. The weakly developed foliation can be seen to wrap around these relict coarser tremolite grains.

Apatite is a prominent accessory phase, occurring as round to elongate grains which range up to 0.5 mm in length. Traces of zircon are present and there are rare, high relief, colourless grains which may be epidote.

This is a fine grained tremolite rock which has appears to have formed through middle amphibolite facies metamorphism of a siliceous dolomitic limestone. Early prograde coarse grained tremolite has been recrystallised into finer fibrous aggregates which in places show a parallel alignment giving rise to an indistinct foliation. There has been subsequent crenulation of that foliation.

Sample 6230 RS 361; TSC41469; Jade Outcrop 90

Rock Name:
Clinozoisite Quartz Rock

Hand Specimen:
This is a coarse to medium grained rock consisting of coarse pale pink coloured aggregates, with finer interstitial colourless and pale green aggregates. The rock is generally massive with no obvious foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	55-60
Clinozoisite	30-35
?Epidote	5-10
Opaques	Trace
Apatite	Trace
Sphene	Trace

This rock principally consists of granular intergrowths of quartz and epidote group minerals. The quartz is the early formed component and shows variable extenstive recrystallisation. Coarse relict grains of quartz range up to 4 mm in length and show strongly undulous extinction, considerable subgrain developments, and cuspate grain margins. Finer grained aggregates and mosaics of quartz are a consequence of recrystallisation of the coarser material and occur interstitially to and surrounding that material.

In places there are clouded finer grains associated with the quartz which may have originally been plagioclase. However, most of this primary phase(s) associated with the quartz has been altered to or replaced by epidote group minerals.

A colourless to clouded coarse grained phase with low to anomalous interference colours is most probably clinozoisite. In place this occurs as radiating aggregates of fibrous to prismatic crystals, which range up to 3 mm in length. Elsewhere this material is not as well developed and forms granular aggregates after the primary phases it has replaced. The clinozoisite appears to be the pale pink coloured material noted in hand specimen.

A colourless to clouded very pale green phase of similar relief to the clinozoisite has a higher birefringence than that mineral and is possibly epidote. This is the pale green material noted in hand specimen. The epidote occurs as rectangular aggregates of fine elongate crystals and has a noticeably different morphology to the clinozoisite.

Irregularly shaped opaques, subhedral to anhedral sphene, and round to elongate apatite are all present in accessory amounts. The opaques appear to be late stage or remobilised. The sphene tends to be preferentially associated with the clinozoisite and epidote. The apatite generally occurs as fine inclusions within the quartz.

This is a clinozoisite quartz rock that appears to have formed through hydrothermal alteration of a granitoid or gneissic precursor. It is similar to sample 6230 RS 303 described in report GS 2405/81.

6230 RS 362

E00055

Sample ~~6231 RS 151;~~ TSC41464; Applicant's No. DJF 60

Rock Name:
Folded Gneissic Sericitic Schist

Hand Specimen:
This is a reddish-brown to grey coloured rock with a prominent gneissic texture. On the cut surface ?quartzofeldspathic seggregations emphasise the main fabric and relict limbs of folds are evident with attenuated hinge zones. The rock appears to be highly weathered.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Sericite	65
Muscovite	10
Biotite	10
Chlorite	10
Quartz	10
Opaques	5
Zircon	Trace

This sample dominantly consists of sericite with lesser biotite, muscovite, and quartz. The attenuated folded fabric noted in hand specimen is clearly evident in thin section. There is an early foliation represented by a parallel alignment of biotite, elongate quartz, and sericite rich seggregations. These have been folded and attenuated, with fold flexures seen in the biotite rich bands and sericite aggregates. The sericite aggregates appear as quartzofeldspathic bands in hand specimen. The sericite is clearly a retrograde metamorphic or hydrothermal development, probably after feldspar or an aluminosilicate. In places it grades into fine muscovite and there is evidence to suggest that the well developed muscovite has in part broken down to form some sericite.

The quartz occurs both as aggregates and single grains which range up to 1 mm in length. The grains and aggregates are elongated in the fabric or form discontinuous stringers which may be boudinaged bands. Undulous to strongly undulous extinction, some subgrain developments, and curved to cuspate grain boundaries typify the quartz.

The biotite is preferentially concentrated into bands which emphasise the folded fabric. It is green-brown in colour, is often altered to chlorite, and has opaque inclusions or rims. The flakes range up to 0.3 mm in length. Muscovite occurs together with the biotite replacing it in parts, and being of a similar grain size.

The opaques are irregular in outline and range up to 0.2 mm in diameter. Late stage ferruginisation gives rise to the abundant iron stained cracks and alteration of the primary opaques. Zircon is a prominent accessory phase.

This is a gneissic sericitic schist which has suffered at least two deformations. The high sericite content is a consequence of alteration of an original gneissic rock which may have contained an aluminosilicate phase or been rich in plagioclase.

E00056

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT BK NO:
DME NO:
DISK NO: 8

6230 RS 364 DDH 15, 7.13 m Thin section C 43740

RETROGRESSED CALC-SILICATE

Hand specimen: Distinct leopard-skin texture with off-white quartzofeldspathic zones 1-3 mm across with irregularly-shaped and disseminated aggregates of darker green chlorite and actinolite. Appears similar to retrogressed diopside of outcrop #15, but in this case is altered quartz + feldspar.

Thin section:

Original assemblage of quartz, K-feldspar, albite and actinolite has been extensively modified by sericitisation and formation of secondary actinolite, chlorite, epidote and unidentified titanate.

Estimated mineral abundances (%) are:

Sericitised K-feldspar	40
Quartz and albite	33
Actinolite	20
Epidote and titanate	6
Chlorite	1

K-feldspar is extensively sericitised whereas albite is less altered; quartz and untwinned albite difficult to distinguish. Granular with an average size of 0.2 mm which is probably a secondary grain size. Early-phase actinolite forms larger poikiloblastic porphyroblasts to over 1 mm across, but are substantially replaced by finer granular aggregates and aligned fibrous aggregates.

Tremolite fibres are aligned defining a schistosity which is also parallel with a poor to fair dimensional alignment of quartz and feldspar. Schistosity is apparently a retrogressive feature of unknown age.

Primary assemblage	Alteration assemblage
Quartz	Sericite
Plagioclase	Actinolite fibres
K-feldspar	Chlorite
Actinolite	Epidote and semi-opaque
	Titanate

Comment: Rock is probably a retrogressed calc-silicate band, 0.54 m thick within massive and schistose chlorite + tremolite rocks. However, its assemblage and massive fabric are also in keeping with a source of altered leucogranite.

6230 RS 365 DDH 15, 9.80 m Thin section C.43741

CHLORITE + FELDSPAR ROCK

Hand specimen: Massive, dark grey green and fine-grained chlorite-rich rock with a vein to 5 mm wide of dark green-black chlorite and milky white feldspar. Vein is probably an altered and contaminated leucogranite or aplite.

Thin section: Sample is a massive chlorite + sericitised feldspar rock with a pronounced dusting of fine-grained epidote and unidentified titanate.

Estimated mineral abundances (%) are:

Chlorite	45
Sericitised feldspar	40
Epidote and titanate	14
Apatite	trace - 1%

Feldspar is the only early phase but it has been intensely sericitised and also has some cores of chlorite aggregates. Feldspar is coarsest within the interpreted vein, ranging up to 2 mm across, but is also present throughout the sample.

Chlorite has two forms. Firstly, as large flakes to 1.5 mm across with epidote and titanate as thin stringers along chlorite cleavages - this chlorite probably forms from retrogression of an earlier phase, probably amphibole. Secondly and more commonly, chlorite forms blocky sheaves with slightly radiating cleavage traces, with blocky crystals averaging 0.25 mm across. Pleochroism is very pale green to very pale brown, and with very low birefringence.

Epidote and a semi-opaque titanate are abundant as stringers and a high-relief dusting; distinct grains are rare. Both phases are rare within the coarse-grained feldspar-rich vein. Yellow spotting in hand specimen is from epidote-rich aggregates.

Comment: Chlorite + feldspar rock or highly altered leucogranite. Feldspar is the only relict primary phase. Alteration has produced abundant chlorite with epidote and titanate.

6230 RS 366 DDH 15, 13.38 m Thin section C 43742

SEMI-NEPHRITE

Hand specimen: Fine-grained tremolite grading to semi-nephrite, but with a pronounced S_4 foliation. Colour is greyish green (10 GY 5/2 to 6/2) grading to pale green (10 G 6/2).

Thin section: Semi-nephrite containing two tremolite schistosities and minor tremolite porphyroblasts.

Estimated mineral abundances (%) are:

Tremolite schistosity	99
Tremolite porphyroblasts	<1
Apatite	trace

Two schistosities are equally well developed and at about 25° to each other. Both consist of fine-grained well-aligned tremolite with an average length of only 0.02 mm and with length:breadth

ratios averaging 4:1. Both schistosities have identical characteristics, forming an interlocking but aligned network.

Rare coarse tremolite porphyroblasts are to 0.5 mm across and predate the schistosities.

Comment: Sample is sufficiently fine-grained to be classified as semi-nephrite. Both schistosities may have been generated during D_4.

6230 RS 367 DDH 15, 13.38 m Thin section C 43743

SEMI-NEPHRITE

Hand specimen: Fine-grained tremolite grading to semi-nephrite; colour is greyish green - about 10 GY 5/2 to 6/2. An S_4 foliation is weakly developed.

Thin section: Fine-grained tremolite but consisting of irregularly distributed areas of different grain size of fine-grained tremolite.

Estimated mineral abundances (%) are:

Tremolite matrix	>99
Tremolite porphyroblasts	trace
Tremolite veins	trace

Matrix tremolite has two forms, both of which are fine-grained and very similar, differing only in grain size. Each type is separated into broad patches and irregular zones which do not appear to form any discernible pattern.

Finest-grained zones contain equant to poorly-elongate tremolite with a length:breadth ratio averaging only about 2:1. Average length is less than 0.01 mm.

Coarser zones, which still have an average fibre length of only 0.1 mm, again show the same range in shape and elongation. Maximum fibre length is 0.2 mm.

Both zones exhibit a poor alignment defining a schistosity.

Tremolite veins, apparently formed as open fractures at the time of schistosity development, consist of tremolite fibres oriented at a high angle to the vein wall. In places, tremolite schistosity in the matrix is semicontinuous with tremolite fibres within the veins.

Comment: Semi-nephrite with two distinct grain sizes and a poorly-developed S_4 schistosity. All of the tremolite may have developed during D_4.

6230 RS 368 DDH 15, 14.18 m Thin section C 43744

CLINOZOISITE ROCK

Hand specimen: Banded light yellow and dark green rock with irregular slightly-wavy banding 1-3 mm thick. Age of banding not definitely known but is possibly S_3 as it is mylonitic and predates S_4 jointing.

Thin section: Banded epidote/clinozoisite rock with bands 1-3 mm thick which consist almost entirely of a granular mosaic of fine-grained epidote/clinozoisite.

Estimated mineral abundances (%) are:

Epidote/clinozoisite	90
Chlorite	9
Titanate	1

Banding is probably of deformational origin and is paralleled by a chlorite schistosity. Chlorite is concentrated in these mylonitic bands and exhibits a good alignment. Clinozoisite bands contain granular mosaics with no alignment but with grain size variations. Fine-grained bands have an average size of 0.05-0.1 mm while coarser bands have grains up to 0.5 mm.

Chlorite is elongate, has very low grey birefringence and always contains elongate inclusions and stringers of semi-opaque ?titanate parallel to the cleavages.

Comment: Mylonitic banding, foliation and retrogressive assemblage probably produced during D_3. No primary phase remains.

6230 RS 369 DDH 15, 15.61 m Thin section C 43745

CLINOZOISITE ROCK

Hand specimen: Sample is identical with the previous sample, RS 368, but with the addition of dark green-black chlorite-lined joints almost at right angles to the mylonitic banding. Chlorite bands are less than 1 mm wide, subparallel, aligned parallel with the drill core and classified as S_4 joints. Fractures show slight offset across the $?S_3$ mylonitic banding.

Thin section: Sample is very similar to RS 368 but fabric is slightly more mylonitic. Finer-grained granulated zones are more abundant but finer-grained than in RS 368 with an average grain size of only 0.02 mm. Coarser zones average about 0.2 mm.

S_3 mylonitic assemblage	S_4 assemblage
epidote/clinozoisite	chlorite
chlorite	?adularia
titanate	ferrug. staining

Schistosity is defined by bands of aligned chlorite and stringers of semi-opaque titanate.

S_4 joints are predominantly infilled by aligned chlorite. Chlorite fibres and sheaves are aligned not along the joint, not in the S_3 schistosity but at about 45° to each. S_4 joints exhibit displacement and discontinuity across the mylonitic foliation.

?Adularia is also present within S_4 joints as grains with minute ?sericite inclusions, and range up to 0.8 mm long.

RS 370 DDH 15, 16.40 m Thin section C 43746

TREMOLITE SCHIST
(Retrogressed tremolite + diopside + phlogopite rock)

Hand specimen: Dominantly dark green and probably chloritic with lesser white tremolite forming a diffuse compositional banding, across which is developed a strongly-developed tremolite schistosity. A milky white vein of tremolite, about 3 mm thick, cuts across compositional banding and is subparallel to the schistosity.

Thin section: Compositional banding of hand specimen is too coarse and diffuse for thin section examination but appears to consist of slight concentrations of early-phase coarse-grained tremolite, phlogopite and diopside. Across the banding and largely obliterating it is a pronounced fine-grained tremolite schistosity.

Estimated mineral abundances (%) are:

primary phases		schistosity phases	
Phlogopite (chloritised)	8	Tremolite (fibrous)	80
Tremolite (coarse grained)	7	Sphene & opaques	trace
Diopside	5		

Large, clear, colourless tremolite up to 1 mm across is clearly a pre-schistosity phase with overgrowths of fine-grained, aligned, fibrous tremolite. Phlogopite forms equant blocky grains with cleavage often oriented at high angles to the schistosity and with not even a dimensional alignment in the later schistosity. Most phlogopite has been partly chloritised. Basal sections show darker yellow-brown pleochroism and with minute inclusions of acicular ?rutile. Diopside is minor, is strongly granulated and drawn out in the superimposed schistosity.

Tremolite schistosity is defined by fine-grained, well-aligned, colourless to very pale green fibres which wrap around earlier coarser phases as well as forming overgrowths.

Comments: Banding is probably S_1 or S_2 and represents an assemblage consisting of at least diopside + tremolite + phlogopite. Cross-cutting schistosity may be S_4 and is dominated by tremolite fibres.

RS 371 DDH 15, 18.75 m Thin section C 43747

EPIDOTISED GRANITE

Hand specimen: Sample is from the altered and contaminated margin of a feldspar-rich intrusive. White, milky feldspar forms a background to a superimposed light, olive-green, mylonitic schistosity composed of bands of epidote. Cross-cutting the mylonitic schistosity and banding are several veins parallel to the core axis i.e. S_4 joints and veins. The widest is 3 mm and composed of light olive green epidote whereas the others are dark greenish black and composed of chlorite and/or actinolite.

Thin section: The granite is pervasively altered with bands and disseminated epidote and pronounced recrystallisation with reduction of primary grain size. Cross-cutting S_4 veins consist entirely of either epidote or actinolite, and represent about 15% of the total sample.

Estimated mineral abundances (%) for the host altered granite are:

Feldspar	50
Epidote	35
Quartz	14
Sphene	1

All feldspars are either extensively epidotised or sericitsed and have undergone extensive partial recrystallisation reducing primary grain size of about 2 mm down to no more than 0.5 mm.

Quartz is clear and forms finer-grained aggregates apparently interstitial to feldspar. Epidote varies from large irregular grains to 1 mm across in feldspar-rich bands, to very fine grains in epidote-rich mylonitic bands where the average grain size is only about 0.05 mm and grains are often elongate in the schistosity.

Actinolite forms distinct radiating aggregates up to 2 mm across which are concentrated along very thin S_4 fractures, where the S_4 fractures are only 0.02-0.04 mm wide. A few aggregates are disseminated through the altered granite and not obviously directly related to an S_4 fracture.

Comment: Age of granite intrusion and epidotisation is not known but may be about D_3 - a known time of retrogression and mylonitisation. During D_4, radiating clusters of actinolite and bands of granular epidote formed along S_4 fractures.

RS 372 DDH 16, 10.05 m Thin section C 43748

TREMOLITE + CHLORITE SCHIST with primary PHLOGOPITE; minor nephrite

Hand specimen: Irregular mottled texture with dark green to black speckled chlorite and paler green very fine-grained tremolite.

Thin section: Dominantly a retrogressive assemblage containing chloritised phlogopite porphyroblasts in a fine-grained partly-schistose matrix of chlorite and tremolite. Tremolite-rich portions of the matrix produce the paler green zones of hand specimen, dark green zones are of chlorite-rich portions of the matrix, while speckled appearance is from phlogopite porphyroblasts.

Estimated mineral abundances (%) are:

Primary phlogopite (partly retrogressed)	15
Matrix tremolite	40
Matrix chlorite	45
Epidote	trace

The only definite primary phase is phlogopite which forms blocky grains not aligned in the superimposed schistosity. About 50% of the phlogopite has been chloritised in distinct narrow bands parallel to the cleavage, producing marked contrasts between bands of:

- high birefringence, pale brown pleochroism of phlogopite
- low birefringence, colourless chlorite.

Tremolite mats are up to 4.5 mm across and suggest another primary phase of ?dolomite or ?diopside.

Tremolite matrix has a variable texture ranging from extremely fine-grained equant matrix with a grain size of no more than 0.01 mm (i.e. nephritic), to a coarser schistosity wrappng around phlogopite. Chlorite-rich portions of the matrix are apparently completely retrogressed phlogopite or another primary phase.

RS 373 DDH 16, 10.63 m Thin section C 43749

SEMI-NEPHRITE

Hand specimen: Dark green semi-nephrite with Munsell colour of about dusky yellowish green 10 GY 3/4. Also contains thin dark streaks 1-3 mm long of iron-staining or elongate stringers of ?chlorite.

Thin section: Three generations of tremolite are evident of which only one may be a primary phase. Phlogopite shows only minor chloritisation and may also be a primary phase.

Estimated mineral abundances (%) are:

Tremolite mats	35
Tremolite prisms	30
Tremolite matrix	25
Chlorite	5
Phlogopite	5
Epidote/clinozoisite	trace
Apatite	trace

Tremolite mats range up to 4.5 mm across but consist of very fine-grained parallel and elongate bundles of aligned tremolite fibres, with bundles averaging about 0.03 mm long. The phase being replaced contained two distinct cleavages and was apparently either amphibole or calcite/dolomite.

Matrix tremolite is extremely fine-grained with an average size of only 0.01-0.02 mm. Grain boundaries are irregular and 'grains' probably consist of very-small randomly-oriented fibre bundles.

Tremolite prisms are coarser, ranging up to 0.5 mm across, but are not obviously earlier than matrix or mat tremolite. Coarse tremolite may be the same age as the other tremolite rather than representing a primary phase.

Chlorite forms aggregates containing randomly-oriented sheaves of fibres. Chlorite is colourless and with very low birefringence, and apparently formed at the same time as matrix and mat tremolite.

Comment: Up-hole or hanging wall contact zone of jade lens; sample is 8 cm inside the contact.

Primary phases are perhaps phlogopite + ?dolomite. Replacement phases are tremolite + chlorite + epidote + apatite. Only matrix tremolite is sufficiently fine grained to be classified as nephrite. Overall, sample is more appropriately classified as semi-nephrite.

RS 374 DDH 16, 10.95 m Thin section C 43750

SEMI-NEPHRITE

Sample is very similar to RS 373, but RS 374 is from the central portion of the jade lens. Matrix tremolite is more extensive with lesser tremolite mats. Cleavage traces within tremolite mats however indicate that the former phase may have been diopside. Fibrous rims on coarser tremolite prisms confirm prisms as an earlier phase. Allanite and epidote probably form at same time as matrix and mat tremolite.

Estimated mineral abundances (%) are:

Matrix tremolite	38
Mat tremolite	30
Prism tremolite	25
Chlorite	5
Epidote	1
Allanite	1

Comment: Assemblage is almost entirely retrogressive and phlogopite is absent.

Primary phases may have been diopside + tremolite. Early tremolite is partially replaced whereas diopside? is completely replaced by an assemblage of

tremolite + chlorite + epidote + allanite.

Massive and non-foliated.

6230 RS 375 DDH 16, 11.09 m Thin section C 43751

SEMI-NEPHRITE

Hand specimen: Moderately translucent dusky yellowish green (about 10GY 3/2 to 3/4) nephrite with approximately 10% brown ?phlogopite porphyroblasts. Jade sample is from within 1-2 cm of footwall contact of jade lens but actual contact not recovered in core.

Thin section: Sample is very similar to RS 373 and 374 with lesser mat tremolite but more abundant epidote and phlogopite.

Estimated mineral abundances (%) are:

Tremolite matrix	38
Tremolite prisms	35
Tremolite mats	19
Epidote and clinozoisite	3
Chlorite	2
Phlogopite	1
Allanite	trace

Spots/porphyroblasts in hand specimen are from coarse-grained tremolite, phlogopite and epidote. Tremolite is again massive with no schistosity present.

Epidote forms distinct larger aggregates - to over 1 mm across and where some consist of coarse-grained radiating clusters. Epidote, clinozoisite, allanite and phlogopite often form aggregates some of which are intergrown with tremolite.

Comments: Primary phases are probably ?diopside (now tremolite mats), coarse tremolite and probably phlogopite. Secondary retrogressive assemblage developed during jade formation is: tremolite + chlorite + epidote + clinozoisite + allanite + ?phlogopite.

6230 RS 376 DDH 16, 11.21 m Thin section C 43752

DOLOMITIC MARBLE

Hand specimen: Off-white to yellow, medium-grained dolomitic marble with minor disseminated dark green-black specks of chlorite. A grey band, about 4 mm wide, is apparently much finer grained.

Thin section: Estimated mineral abundances (%) are:

Dolomite	90
Chlorite	6
Tremolite-actinolite	3
Calcite	1
Phlogopite	trace

Dolomite forms a coarse-grained equigranular mosaic with an initial grain size of about 2 mm but which has been reduced considerably by recrystallisation etc. Grey band of hand specimen is obviously deformational and contains the finest dolomite - averaging 0.03 mm.

Chlorite can occur in large flakes and is probably after phlogopite as relict phlogopite shows at least 40% alteration to chlorite. Chlorite is pale brown with an anomalous blue birefingence.

Comment: Sample of dolomitic marble is from within 10 cm of a jade lens yet petrographically, it is typical of dolomitic marble from throughout the jade Province.

6230 RS 377 DDH 16, 11.71 m Thin section C 43753

CLINOZOISITE & PHLOGOPITE ROCK

Hand specimen: Weakly foliated rock with pale olive 'augen' (about 10Y 6/2) up to 4 mm long in a darker, weakly foliated matrix. Matrix is light olive grey (5Y 5/2) and contains about 10% dark chlorite or phlogopite.

Thin section: Specimen is dominated by clinozoisite much of which, along with phlogopite, shows a dimensional alignment defining the schistosity evident in hand specimens. The clinozoisite + phlogopite schistosity wraps around 'augens' of almost pure clinozoisite - these are more readily apparent in hand specimen.

Estimated mineral abundances (%) are:

Clinozoisite	80
Phlogopite (slightly chloritised)	19
?Titanate	1

Clinozoisite is colourless to pale brown and non pleochoic, exhibits anomalous blue birefringence and is often elongate and aligned defining a schistosity. Maximum length is 0.4 mm. Clinozoisite in contact with phlogopite aggregates is often subhedral.

Phlogopite has two forms. Larger coarser flakes are aligned parallel with clinozoisite but are still no more than 0.5 mm long. Most phlogopite is in fine-grained aggregates which are apparently interstitial to clinozoisite.

An unidentified dusting ?titanate forms the only other phase present.

Comment: An unusual assemblage with a pre-S_4 phlogopite + clinozoisite schistosity.

6230 RS 378 DDH 16, 12.09 m Thin section C 43754

CHLORITE BRECCIA

Hand specimen: Breccia with dark green-black clasts of fine-grained chlorite set in an unusually brown fine-grained matrix of unknown composition.

Thin section: Dark green clasts, evident in hand specimen, are chlorite-rich but also contain disseminated tremolite and are extremely fine-grained with an average size of no more than 0.01 mm. Matrix areas are distinctly coarser but still average no more than 0.03 mm and consist of tremolite, phlogopite and clinozoisite with only minor chlorite.

Estimated mineral abundances (%) are:

CLASTS (85%)		MATRIX (15%)	
Chlorite	75	Tremolite	45
Tremolite	25	Phlogopite + chlorite	45
Apatite	trace	Clinozoisite	10

Clasts are very fine grained and dominated by colourless, low birefringent chlorite less than 0.01 mm. Small tremolite grains, rarely reaching 0.02 mm, tend to be randomly oriented or only slightly aligned. Also present are minor disseminated slender tremolite needles to 0.3 mm long with high length:breadth ratios and which appear to form fairly late.

Matrix consists of ragged colourless clinozoisite, pale brown phlogopite, tufts of fibrous tremolite and occassional larger tremolite needles. Average grain size is about 0.03 mm with clinozoisite slightly coarser than the other phases.

Comment: Age of formation of clasts and matrix not known but trend is the same as for other outcrops i.e. an early chlorite-rich phase is followed by a more-tremolite-rich phase.

6230 RS 379 DDH 16, 14.42 m Thin section C 43755

ALTERED INTRUSIVE

Hand specimen is from the contact zone of a microcline + quartz intrusive into chlorite-rich rocks. Yellowish colour indicates epidote is present.

Thin section: Extensively altered and recrystallised granite with formation of abundant secondary epidote and acicular actinolite as well as accessory opaques, titanate and apatite. Epidote is concentrated into schistose bands whereas actinolite forms very characteristic radiating clusters along grain boundaries and fracture planes.

Estimated mineral abundances (%) are:

Primary quartz and feldspar	73
Secondary epidote	15
Secondary actinolite	10
Secondary apatite	trace-1
Secondary titanate	trace-1
Secondary opaques	trace

Primary feldspar is to in excess of 5 mm across but has been extensively sericitised and recrystallised. Some sections now consist of a fine-grained deformation/recrystallised band where the average grain size is only 0.01-0.02 mm. Grain boundaries are irregular and often lined by alteration products, particularly actinolite.

Epidote is predominantly concentrated into bands which often do not parallel actinolite bands. Alignment of epidote varies from along the band to a good alignment at about 30° to the band. Colour is pale brown to yellow brown, is non-pleochroic and has anomalous blue-yellow birefringence.

Actinolite forms radiating clusters or sheaves up to 2 mm long which are concentrated in fractures or along grain boundaries of primary fledspar. These contain actinolite needles which penetrate well into neighbouring feldspar.

Comment: As for other altered granite samples, epidote formation is followed by actinolite.

SAMPLE: 6230 RS416: TSC48685

Rock Name:
Nephritic Tremolite

Hand Specimen:
A very fine-grained and massive, greenish-grey rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	99
(?)Apatite	Tr-1
Opaques and semi-opaques	Tr-1

This is essentially a monominerallic rock comprised of fibrous tremolite forming a felted intergrowth. Much of the tremolite has a very fine grain size below 0.03 mm but larger fibrous textured tremolite crystals ranging up to 0.4 mm in length are intergrown with the finer tremolite. Approximately 30% of the sample consists of the larger tremolite crystals with most of the rest consisting of much finer, nephritic intergrowths.

Minor amounts of a very weakly birefringent mineral form disseminated grains up to 0.2 mm in size. Positive identification of this mineral is difficult but it could be apatite.

The rock is transected by very narrow fractures ranging up to 0.05 mm wide which have a discontinuous character and an essentially random orientation. Some of these fractures are lined or partially lined with opaque material which are most likely opaque, iron or manganese oxides. Some of these fractures also contain minor amounts of translucent, reddish-brown limonitic material.

This is a metamorphic rock comprised almost completely of tremolite much of which exhibits a very fine interlocking texture typical of nephrite.

SAMPLE: 6230 RS417: TSC48686

Rock Name:
Tremolite

Hand Specimen:
A dark greyish-green coloured rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	95
Carbonate	3
Clinopyroxene	1

This essentially a monominerallic rock comprised almost completely of colourless amphibole. The amphibole forms weakly prismatic to acicular or fibrous textured crystals up to 1 mm long. Most of the amphibole tends to form crystals between 0.1 and 0.3 mm in size. The amphibole typically forms a felted to interlocking mosaic.

The rock contains minor amounts of disseminated carbonate as very finely granular aggregates and narrow fracture and vein fillings. The carbonate is intimately intergrown with the tremolite and is thought to be an alteration product of tremolite.

Along one margin of the thin section minor clinopyroxene forms skeletal crystals up to 2 mm wide. These clinopyroxene crystals have highly irregular shapes showing marginal replacement by tremolite.

This is a metamorphic rock comprised almost completely of tremolite. Along one margin of the thin section there is evidence that at least some of the tremolite represents a replacement product of pre-existing clinopyroxene. The tremolite shows some alteration to finely granular carbonate.

SAMPLE: 6230 RS418: TSC48687

Rock Name:
Deformed Feldspar-Quartz Gneiss

Hand Specimen:
A coarse grained rock with a white to greenish-grey colour.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Plagioclase	35
Orthoclase	25
Quartz	20
Amphibole	15
(?)Epidote	3
Sphene	1
Opaques and semi-opaques	Tr

This sample consists mainly of a highly deformed intergrowth of quartz and feldspar. The feldpsar consists of both polysynthetically twinned plagioclase and untwinned potash feldpsar. All of the felsic minerals have strongly recrystallised and deformed appearing textures with granulation along grain margins and the development of sutured grain margins. Some larger plagioclase crystals in particular also exhibit bent and broken twin lamellae.

The amphibole tends to be concentrated along fractures where it forms acicular radiating aggregates up to 1 mm long. The amphibole typically has a pale green, weakly pleochroic colour and is most likely a member of the tremolite/actinolite group. Some irregular patches of amphibole up to about 1 mm wide are present and typically have acicular crystals radiating from their outer margins.

Minor amounts of a reddish-brown mineral form finely granular aggregates up to about 1 mm wide. This mineral has high relief and low birefringence and could be an epidote mineral. Minor sphene forms birefringent disseminated grains and granular aggregates some of which have a somewhat turbid character. Traces of sericite were noted locally as an incipient alteration product of the feldspar. Minor opaques form small disseminated grains.

This is most likely a plutonic igneous rock such as an adamellite which has been subjected to strong deformation producing an intensely deformed and recrystallised texture. Fibrous to acicular amphibole has formed as an essentially postdeformational mineral and tends to be concentrated along fractures.

SAMPLE: 6230 RS419: TSC48699

Rock Name:
Granite Gneiss

Hand Specimen:
A strongly foliated, gneissic rock with a white to grey colour.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Quartz	35
Plagioclase feldspar	30
Potash feldspar	20
Biotite	10
Muscovite	5
Zircon	Tr
Opaques	1

This sample consists mainly of a finely granular quartz and feldspar mosaic with a typical grain size of 0.1 to 0.2 mm intergrown with larger feldspar crystals and finely divided mica flakes. The mica exhibits a well-developed lepidoblastic foliation and tends to be concentrated within discontinuous, undulose stringers intergrown with the finely granular quartz and feldspar. This finely granular matrix has a granulated and slightly recrystallised appearing texture. The larger feldspar crystals have angular broken to irregular shapes and appear to be remnants which locally show some marginal granulation.

The feldspar consists of both plagioclase and potash feldspar including at least some grid-iron twinned microcline. Some of the large plagioclase crystals have a zoned character containing slightly altered cores now comprised mainly of finely divided sericite/clay.

The mica consists of biotite and muscovite both of which form small flakes below 0.15 mm long. The biotite is intensely pleochroic in shades of brown.

Minor opaques are disseminated through the rock as anhedral grains up to 0.1 mm wide. Traces of zircon were noted as small disseminated crystals up to 0.1 mm wide.

This is thought to be a metamorphosed and deformed plutonic igneous rock possibly of adamellitic composition.

SAMPLE: 6230 RS420: TSC48700

Rock Name:
Nephritic Tremolite

Hand Specimen:
A very fine-grained and massive, black rock.

Thin Section:
This is essentially a monominerallic rock comprised almost completely of fibrous tremolite which forms a finely felted mosaic. Within localised regions slightly larger tremolite crystals up to 1 mm in length are present and these usually exhibit a lamellar texture probably due to deformational effects. Minor opaque to translucent iron oxides tend to be concentrated within narrow, undulose fractures which exhibit a vague preferred orientation defining a weakly developed foliation.

SAMPLE: 6230 RS421: TSC48703

Rock Name:
Tremolite Schist

Hand Specimen:
A very fine-grained massive rock with a grey colour.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	98
Epidote	1
Opaques and semi-opaques	Tr-1

This sample consists mainly of very fine, fibrous tremolite which forms an essentially nephritic intergrowth. Much of the fibrous tremolite has a whorled and contorted texture but a vague preferred orientation of the fibrous tremolite defines a foliation direction. Some larger fibrous aggregates of tremolite up to 0.5 mm in size are disseminated through the rock. A few weakly prismatic crystals of tremolite up to 0.3 mm long are also locally present.

Epidote is disseminated through the rock as subidiomorphic crystals and aggregates up to 0.8 mm in size. Some of the epidote tends to form vaguely radiating aggregates. Minor opaques form disseminated grains and aggregates below 0.1 mm wide. Some opaque to translucent iron oxides occur locally as very narrow linings along foliation lamellae.

This is a tremolite-rich rock comprised mainly of fibrous, nephritic textured intergrowths.

SAMPLE: 6230 RS423: TSC48705

Rock Name:
Chlorite-Tremolite Schist

Hand Specimen:
A greyish-green foliated rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Chlorite	70
Tremolite	25
Plagioclase	1
Zircon	Tr
Opaques and semi-opaques	4

This sample consists mainly of a fibrous, chloritic matrix through which elongate prismatic amphibole crystals are disseminated. A well-developed foliation is defined by a preferred orientation of the amphibole crystals as well as a preferred orientation of much of the chlorite. A vague mineralogical banding is also defined by a tendency for the amphibole to be concentrated in discontinuous weakly developed bands.

The chlorite is a fibrous variety with a pale green, weakly pleochroic colour and low anomalous birefringence. The amphibole is a colourless variety and forms elongate, prismatic crystals up to 3 mm in length.

Traces of zircon form small disseminated crystals up to 0.1 mm wide. Opaques are disseminated through the rock as anhedral to euhedral grains and aggregates up to 0.5 mm in size. Some of the tremolite in particular shows incipient alteration to reddish-brown iron oxides.

This is a metamorphic rock with a strongly foliated character comprised mainly of elongate tremolite crystals in a well foliated chloritic matrix.

Sample: 6231 RS 24; TS42887, PS28340

Location: Outcrop 69, Section 113, Hd Minbrie.

Rock Name:
Nephrite jade

Hand Specimen:
A dark green coloured rock with a paler coloured weathering rind which appears to penetrate approximately 1 cm into the rock. For most of this depth the rock has a paler green colour but the outermost 1 mm has a dull white colour. Reddish-brown limonitic staining is also evident on the outermost surface of the very narrow coating.

Thin Section:
In thin section this rock can be seen to consist of very finely divided, somewhat fibrous-appearing, amphibole which forms a felted, interlocking network. The largest amphibole crystals are up to about 0.3 mm long and have an essentially random orientation. Opaques are also disseminated through the rock as anhedral grains up to 0.1 mm in size. There are no obvious textural differences between the darker green coloured areas and the paler coloured rind. The outermost portion of the weathered surface contains concentrations of translucent, reddish-brown iron oxides as discontinuous, somewhat undulose, vein-like structures up to 0.05 mm wide.

Polished Section:
In polished section the narrow, 1 mm wide, white rind can be seen to have a translucent character with brilliant white interal reflections giving a colouration similar to that produced by a finely divided titanium mineral such as leucoxene. It is considered likely that the slight colouration is due to finely divided titanium, but this could not be confirmed with the electron microprobe by detecting higher titanium contents in this region. Careful scanning with the probe failed to detect any titanium in the rock, although small amounts of finely divided titanium could still produce this colouration. It is possible that other factors such as the texture of the rock and its reaction to weathering could also produce these white internal reflections.

Conclusions:
This is a nephrite jade rock with a well developed, felted texture. The white rind could be due to very finly divided titanium although precise confirmation of this was not obtained.

E00081

Sample: 6231 RS 25; TS42888

Location: Outcrop 69, Section 113, Hd Minbrie.

Rock Name:
Nephrite jade

Hand Specimen:
A massive rock with a green colouration ranging from a somewhat dark to a somewhat pale green.

The rock is also transected by some narrow fractures lined with white material. An X-ray diffraction powder photograph of this material gave only an amphibole pattern from the host rock.

Thin Section:
This is an essentially monomineralic rock comprised of fibrous amphibole which exhibits a well developed foliation. Variations in colour observed in the hand specimen appear to be due to different amounts of finely divided, translucent, reddish-brown material which most likely represents very finely divided iron oxides. This material tends to be concentrated along slightly undulose planes oriented parallel to the foliation direction within various regions. Minor opaques and translucent, semi-opaque material (possibly a titanium mineral) are disseminated through the rock as small grains and granular aggregates generally below 0.1 mm in size.

Conclusion:
This is a sample of nephrite jade comprised of somewhat fibrous amphibole with a foliated character whose variation in colour appears to be due to variations in very finely divided iron oxides which produce a slightly translucent brown colour in thin section.

DESCRIPTION OF TALC

Sample: 6231 RS 77; TSC31695

Applicant's No.:
A

Location:
Sample from trench on Mt. Geharty Talc Deposit

Hand Specimen:
A massive, very pale greyish-green rock which is soft and has the physical properties of talc. On a freshly cut surface some variations in colour and grain size are visible and these suggest the presence of bands up to 2 cm thick but they are not very regular and there is no definite evidence to suggest the cause of this apparent banding.

Thin Section:
This rock consists practically entirely of talc and the only impurities which can be detected microscopically are traces of opaque oxide and one minute grain of sphene. Some zones of the talc, however, are very fine-grained and if any other fibrolamellar silicate minerals are present they could only be detected by X-ray diffraction.

Up to about 80% of this sample is composed of moderately coarse-grained micaceous talc and many of the individual crystals are between 0.3 and 0.6 mm in size. In the plane in which this section was cut, this talc shows only a very weakly developed preferred orientation and there is therefore no definite foliation.

At both ends of the section there are bands up to at least 15 mm thick composed of much finer grained talc and there is another zone in the rock where there are thinner streaks and interconnected bands, 2-3 mm thick, of similar very fine-grained talc. On a wet, freshly cut surface of the hand specimen, these finer grained zones appear a darker greyish-green and in the plane of the section they are at a high angle to the direction of suggested very weak or incipient foliation. In most of these finer grained zones there are a few larger, generally elongate crystals of talc which, in a few places, show some evidence of sub-parallel orientation in at least two directions which intersect at a very high angle. The reason for this is not clear and when the rock was examined under very low magnification the pattern formed by the finer grained bands did not give any clue as to their origin.

Throughout most of the areas of coarser grained talc there appears to be very fine-grained dark material along many grain boundaries and cleavage planes but it is possible that some of this dark appearance is due to internal reflection in very thin or tiny voids and is not actual inpurity. There are however, at least a few very thin films of tiny crystals of opaque material along some cleavage planes and grain boundaries. In the thin section, one tiny grain of sphene was found.

Conclusion:
The sample is practically pure talc as far as can be determined by microscopic examination and the only visible impurity is a trace of very fine-grained opaque oxide.

Sample: 6231 RS 78; TSC31696

Applicant's No.:
B

Location:
Sample from trench on Mt. Geharty Talc Deposit

Hand Specimen:
A pale, greyish-green rock which is massive but has the physical properties of talc. A freshly cut surface shows less evidence of banding than in sample A, and there are a few small dark spots which, however, are not opaque impurities. There is a poorly defined, paler-coloured vein a few millimetres thick.

Thin Section:
This sample is also composed entirely or almost entirely of talc and the only impurity detectable by microscopic examination is a trace of very fine-grained opaque material.

It differs from sample A in that throughout most of the section there is a background (or matrix) of very fine-grained talc and this contains generally between 15 and 30% of larger, commonly elongate crystals of talc, 0.4 to 0.8 mm long, which tend to be orientated mainly in two or three directions. Throughout most of the section, many of the flakes are orientated in two directions which intersect at about 90° but in places this angle is smaller and in some zones there are flakes orientated in a third direction, almost bisecting the angle between the two other directions. The directions in which these flakes are orientated are the same throughout practically the whole of the thin section and, although in places the pattern formed shows some similarity to cleavage in carbonate, it is most unlikely that this would have been a single very large crystal of carbonate with cleavage planes in the same direction throughout the whole of the sample. The reason for the orientation of these larger flakes of talc therefore remains undetermined at this stage in the investigation. There are some zones in the rock where there is a much higher proportion of larger flakes of talc and correspondingly less of the intersticial, very fine-grained talc, and in one area several millimetres in size there is practically none of the very fine-grained talc.

Impurities are similar to those in sample A and consist of some very fine-grained dark opaque material along a few cleavage planes and grain boundaries. There is a general turbidity along cleavage planes and grain boundaries in the coarser-grained talc but, as noted previously, at least some of this turbidity could be due to the presence of minute voids and films of air causing internal reflection. No other mineral grains were found in the section and if there is another fibrolamellar silicate intergrown with the talc, this could only be detected by X-ray diffraction.

Conclusion:
The sample is composed entirely or almost entirely of talc and the only impurity visible by microscopic examination is a trace of very fine-grained opaque material. This differs from sample A mainly in grain size and texture.

Sample: 6231 RS 79; TS44827

Applicant's No: DJF 7

Rock Name:
Folded biotite-plagioclase-quartz schist

Hand Specimen:
This is a biotite-rich schist with a pronounced quartzo-feldspathic content. The rock shows M or W folds with an amplitude of 4 or 5 cm and a wavelength of approximately 4 cm. These folds can be seen to be affecting an earlier schistosity marked by the prominent biotite-rich bands. There is also some crenulation of the earlier biotite schistosity which could represent a third deformation event, or form part of the event which produced the larger folds.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	30
Plagioclase	30
Biotite	25
Muscovite and sericite	10
Opaques (goethite)	3
Apatite	2
Zircon	trace
Rutile	trace

This rock has two prominent fabrics that are clearly evident in hand specimen. The earlier fabric has a compositional banding and associated layer parallel schistosity. In thin section this is seen to consist of a crude parallel alignment of elongate quartz and plagioclase-rich bands, interleaved with elongate irregular stringers or zones of biotite in the same orientation. The second fabric consists of a folding of this earlier schistosity/ compositional banding with minor recrystallisation.

The quartz generally occurs as elongate grains of variable sizes ranging up to 3 mm in length; but usually of the order of 1 mm in length. The larger quartz grains show strongly undulose extinction and considerable sub-grain developments. The finer grain sizes tend to be more equant with undulose extinction. Grain margins vary from serrated and cuspate in the coarser-grain size through to curved or straight for the more recrystallised quartz varieties. In some fold hinges large elongate quartz grains can be seen to be warped around the fold axes.

Plagioclase is co-dominant with quartz. Many grains show multiple lamellar twinning, although untwinned plagioclase is evident. The plagioclase tends to be more equant than the quartz and has an average grain size of 0.5 mm in diameter. It is of an oligoclase to andesine composition. Minor amounts of myrmekitic intergrowths with quartz have been observed.

The biotite is green-brown in colour and the flakes range up to 3 mm in length. Crenulation of the coarser flakes is evident in some instances. Most of the biotite is folded around the hinges of the second generation folds, but within these hinges there are usually one or two grains in an axial planar orientation. In places the biotite shows prominent pleochroic haloes around inclusions of zircon.

Muscovite and sericite appear to be late-stage developments. The muscovite flakes are of the order of 0.1 mm in length and these occur in association with the biotite-rich stringers or bands, possibly after the biotite. The muscovite also occurs in association with sericite as an alteration of a previous metamorphic mineral. This mineral could have been a feldspar or possibly an alumino silicate. Alteration of the plagioclase to sericite is evident but not ubiquitous, as there is a high proportion of unaltered plagioclase. The opaques show a variety of form, some are euhedral showing cubic, rectangular and even hexagonal outlines. Others are anhedral and show irregular and elongate outlines. · Some rutile has been observed.

Apatite is a common accessory phase. It occurs as elongate to equant grains and is typically found in association with the biotite. Zircon is also present in trace amounts.

The rock is a folded biotite-plagioclase-quartz schist that was probably formed through low to middle amphibolite facies metamorphism of a pelitic sediment.

Sample: 6231 RS 80; TS44831

Applicant's No.: DJF 11

Rock Name:
Schistose biotite-quartz-plagioclase gneiss

Hand Specimen:
This is a gneissic rock with a high proportion of mica resulting in a very well-developed foliation. Semi to discontinuous quartzo-feldspathic segregations have been boudinaged on a small scale and several augen-like pods can be seen. The main fabric has been folded and a fold hinge can be seen in this hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	30
Quartz	25
Biotite	20
Sericite	15
Chlorite	7
Opaques (including rutile)	2
Zircon and monazite	1

This is a coarse-grained metamorphic rock consisting of bands of plagioclase and quartz, and biotite and sericite. The parallel alignment of the biotite gives the rock the prominent foliation noted in hand specimen. In addition to the biotite-rich bands, there are sympathetic sericite-rich zones which parallel the foliation.

Plagioclase commonly shows multiply lamellar twinning, but untwinned plagioclase is present. The plagioclase is oligoclase in composition and ranges in grain size up to 4 mm. The more elongate grains are aligned parallel to the foliation. Included round blebs of quartz are commonly observed. The plagioclase is little altered with only minor sericitisation.

The quartz occurs in a wide range of grain sizes which probably reflect different stages of recrystallisation. The coarse-grained quartz ranges up to 5 mm in diameter. It shows strongly undulose extinction and in places considerable sub-grain developments. Grain margins are curved to cuspate. The finer-grained quartz tends to have simpler-grained margins but still shows undulose to strongly undulose extinction.

The biotite is green to green-brown in colour and individual flakes range up to 2 mm in length. Chloritisation of the biotite is observed and there may be some replacement by muscovite. Pleochroic haloes around zircon inclusions are present and a high proportion of the biotite is rimmed by fine opaques, or has opaque inclusions along grain margins.

Conspicuous aggregates of sericite occur together with the biotite in bands. Fine-grained muscovite also occurs with the sericite and there appears to be some fine clays and/or chlorite. These sericitic aggregates do not appear to have formed at the expense of plagioclase which is generally little altered. It is probable that the sericite has replaced an earlier metastable metamorphic mineral, possibly an alumino silicate or perhaps

cordierite.

The opaques occur both as discrete anhedral grains and as fine rims and inclusions in the biotite. The discrete grains are elongate to equant in shape, although some are anhedral. They are of the order of 0.1 mm in diameter. The finer opaques associated with the biotite have a grain size of 0.01 mm or less. Some rutile is present.

Zircon occurs in accessory amounts with most grains round in outline and often zoned. The zircon grains are typically 0.1 mm or less in length. Some monazite is present.

The rock is a schistose biotite-quartz-plagioclase gneiss. The nature of its precursor is not clear from the mineralogy but it may be sedimentary in nature.

Sample: 6231 RS 81; TS44832

Applicant's No.: DJF 12A

Rock Name:
Schistose granodioritic gneiss

Hand Specimen:
This is a medium to coarse-grained, grey-green coloured schistose rock. The well developed schistosity can be seen to be crenulated and thin coarse quartzo-feldspathic segregations are also deformed.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	35
Quartz	30
Chlorite	15
Biotite	10
Sericite and muscovite	7
Opaques	2
Apatite	1
Zircon	trace
?Cordierite	trace

This rock has granoblastic aggregates of plagioclase and quartz, with the more elongate grains in a subparallel orientation, thereby giving rise to a gneissic fabric. The biotite is both aligned with this fabric and occurs in random orientation.

Multiple lamellar twinning of the plagioclase is common; however, untwinned plagioclase is also present. The plagioclase is oligoclase to andesine in composition. Grains range up to 2 mm in diameter with most being of the order of 1 mm or less. The margins to the plagioclase grains are typically straight to curved. There is variable minor sericitisation evident.

The quartz shows a wide range of grain sizes with the coarsest being 2 mm in length. The coarser grains tend to be elongate, have strongly undulose extinction and show sub-grain developments. Grain margins are curved to cuspate. The finer-grained quartz has simpler grain margins and shows undulose to strongly undulose extinction. Embayments of plagioclase in quartz and vice versa are common.

The biotite is a green to green-brown colour with flakes ranging up to 2 mm in length. It occurs in stringers with parallel orientation, hence the schistosity, but is also found in aggregates with the flakes in random orientation. The biotite has been extensively altered to chlorite and in many cases the chlorite predominates. Inclusions and rims of fine opaques and some muscovite are common features.

There are patches of aggregates consisting of sericite and fine muscovite. These are usually associated with biotite-rich areas and are formed at the expense of an early metastable metamorphic mineral, and not the plagioclase. In places, possible relict ?cordierite may be present but no cordierite has been positively identified.

Apatite is a common accessory phase. The opaques are also present in accessory amounts and occur both associated with the biotite and as

discrete disseminated grains. Zircon is also present.

This is a granodioritic gneiss that probably has a sedimentary precursor.

Sample: 6231 RS 82; TS44833

Applicant's No.: DJF 12B

Rock Name:
Granodioritic gneiss

Hand Specimen:
This is a grey coloured gneissic rock which has a well flattened compositional banding. On the cut surface folding of the compositional banding can be seen. Coarse-grained feldspathic segregations are prominent and probably represent a veining.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	35
Quartz	28
Biotite	20
Sericite and muscovite	7
Microcline	5
Opaques (some rutile)	3
Zircon	1
Chlorite	1

This rock has a foliated granoblastic texture. The grain size is variable and grains range up to 2.5 mm in diameter, with most being less than or equal to 1 mm. The gneissic texture evident in hand specimen is a consequence of the parallel alignment of elongate quartz and feldspar grains. There is a high proportion of biotite which has a similar orientation.

The plagioclase commonly shows multiple lamellar twinning although untwinned plagioclase is present. It is oligoclase to andesine in composition. Included blebs of quartz are present and there are some prominent myrmekitic developments. The average grain size is of the order of 0.5 mm in diameter. Sericitisation of the plagioclase is variable but generally present in only minor amounts.

Microcline and microcline perthite are also present but represent only a small proportion of the total feldspar content. Staining of the off-cut shows the microcline is preferentially concentrated in discrete bands parallel with the foliation, and these probably represent the veining noted above. Cross-hatched twinning and exsolution features are prominent in the microcline and the potassium feldspar tends to be generally coarser-grained than the plagioclase.

Quartz displays a wide range of grain sizes ranging up to 2.5 mm in length. The coarser-grains show strongly undulose extinction and some have sub-grain developments. Grain margins are cuspate and some are very irregular with embayments of feldspar, or quartz embayed into feldspar. In some places there are fine-grained quartz mosaics and elsewhere aggregates of quartz and feldspar.

The biotite is brown to green-brown in colour. Flakes range up to 1.5 mm in length, but for the most part the biotite is less than or equal to 0.5 mm. There are pleochroic haloes around inclusions of zircon. Some of the biotite has minor rims and intergrowths of muscovite and there are some opaque rims

and inclusions. Small amounts of chloritisation of the biotite is present.

Associated with biotite-rich aggregates or zones are prominent areas consisting of sericite and/or fine muscovite. The sericite/muscovite appears to have replaced an earlier metastable metamorphic mineral, possibly cordierite or an alumino silicate phase.

Discrete flakes of muscovite are also present and commonly occur interstitial to the quartz and feldspar or are associated with biotite.

The opaques show a variety of forms. Some euhedral cubic grains are evident but most are anhedral irregular in outline. The opaques range up to 0.3 mm in length. Some rutile is present.

Zircon is a prominent accessory phase occurring as simple discrete grains sometimes zoned, with a few rare compounded grains evident.

The rock is a granodioritic gneiss with possible igneous precursors, although the high biotite content does imply a sedimentary component.

Sample: 6231 RS 83; TS44834

Applicant's No.: DJF 13

Rock Name:
Granodioritic gneiss

Hand Specimen:
This is a grey coloured quartzo-feldspathic gneiss which has a fine compositional banding consisting of mafic-rich and quartzo-feldspathic-rich bands. Coarser-grained feldspathic-rich bands or veins occur parallel with the compositional banding. Both the veins and compositional banding have been folded or rotated with a second generation feldspathic vein occurring along the fold axis.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	30
Plagioclase	30
Biotite	20
Sericite and muscovite	8
Potassium feldspar	5
Opaques	5
Chlorite	1
Zircon	1

This rock has a well foliated granoblastic texture with elongate quartz and feldspar grains in parallel alignment, consistent with the orientation of the abundant biotite. A very coarse vein of quartz and feldspar is also parallel with the metamorphic fabric.

The quartz occurs in a variety of grain sizes and forms. Relict coarser quartz grains range up to 2 mm in length. These show strongly undulose extinction and considerable sub-grain developments, with many being recrystallised into finer aggregates. Grain margins are typically cuspate and embayments of quartz into feldspar and feldspar into quartz can be seen. Finer-grained quartz mosaics and fine aggregates of quartz and feldspar are present.

The vein quartz is much coarser-grained, ranging up to 1 cm in length, although partial to complete recrystallisation during deformation is observed. Undulose extinction, sub-grain developments and some quartz mosaics can also be seen in the vein quartz.

Plagioclase is the dominant feldspar. Both untwinned and multiply twinned plagioclase is evident. The plagioclase composition is oligoclase to andesine. Grain sizes are commonly less than 0.5 mm, although the plagioclase does range up to 1.5 mm. Myrmekitic intergrowths of quartz in plagioclase are present. Alteration to sericite varies from little or none to moderate amounts.

Microcline and microcline perthite occur as minor constituents throughout the rock, but are more common in the secondary veining.

The biotite is brown to green-brown in colour with individual flakes ranging up to 2 mm in length. It has abundant inclusions and rims of

fine opaque grains. Individual opaques are of the order of 0.02 mm in diameter. Replacement of the biotite by muscovite and alteration to chlorite can be seen. Many biotite flakes are intergrown with thin slivers of muscovite or have muscovite borders.

Associated with the biotite are patches up to 2 mm in diameter which consist of fine aggregates of sericite and fine muscovite, with chlorite present as well. As noted with other related rock types, the sericite/muscovite aggregates probably formed at the expense of an earlier alumino silicate phase or cordierite.

Some discrete aggregates of fine muscovite are also present. These are mostly interstitial to the quartz and feldspar or peripheral to the feldspar.

The coarser-grained opaques are blocky to anhedral in outline, ranging up to 0.7 mm in diameter with most of the order of 0.1 mm. Fine opaques also occur with the biotite as noted above. Some rutile has been observed.

Zircon occurs in accessory amounts. Round outlines are common although some complex forms are present consisting of compound round grains.

The rock is a granodioritic gneiss with a high proportion of biotite. It was probably derived from an igneous precursor although a sedimentary component cannot be excluded.

Sample: 6231 RS 84; TS44835

Applicant's No.: DJF 15

Rock Name:
Granodioritic gneiss

Hand Specimen:
This is a grey coloured, layered, quartzo-feldspathic gneiss. Quartzo-feldspathic-rich bands up to 4 mm in thickness are interlayered with more mafic-rich bands. The cut surface shows broad open folding of the compositional layering and there appears to be a superimposed axial planar fabric.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	40
Quartz	30
Microcline	10
Biotite	10
Muscovite and sericite	5
Opaques	3
Chlorite	2
Zircon	trace
Sphene	trace
Apatite	trace

This rock has an inequigranular granoblastic texture. Equant to elongate remnant core grains of quartz and plagioclase, of the order of 1 mm in length, are mantled by finer recrystallised aggregates of quartz and feldspar together with interstitial biotite. The prominent compositional banding is not as clearly evident on the scale of the thin section, however, a general alignment of elongate grains indicates the earlier-formed fabric. The biotite stringers tend to be subparallel, although follow the outline of the relict core grains. Some secondary growths can be seen and these tend to lie parallel to the fold axis seen in hand specimen.

The plagioclase ranges up to 2 mm in diameter with both multiply twinned and untwinned grains present. Some of the coarser grains have antiperthite exsolution features. Included blebs of quartz are common and some myrmekite is observed. Some of the plagioclase shows extensive alteration to sericite.

Microcline and microcline perthite are present both as discrete grains and as exsolution features in plagioclase.

The quartz ranges in grain size up to 2 mm, althlugh it is mostly of the order of 1 mm or less. The grains tend to be more elongate than the feldspars and are more prevalent as recrystallised finer aggregates. Undulose to strongly undulose extinction is evident and grain margins are cuspate. There are abundant finer aggregates of quartz and some mosaics can be seen.

The biotite is brown to green-brown in colour. It commonly occurs as interstitial grains to the coarser feldspar and ranges in grain size up to 0.6 mm in length, although mostly being of the order of 0.1 mm. Fine muscovite is associated with the biotite as are the accessory phases

zircon, opaques and sphene. Some chloritisation of the biotite is associated with these accessory minerals.

The zircon grains are usually round in outline and some show growth zoning. Apatite is also an accessory phase in this thin section.

The rock is a granodioritic gneiss with a possible igneous precursor.

Sample: 6231 RS 85; TS44814

Applicant's No.: E 66

Rock Name:
Amphibolitised ?pyroxene-granulite

Hand Specimen:
A greenish-grey massive rock consisting of a medium to coarse-grained mesh of fibres and prisms of silicate minerals.

Thin Section:
A visual estimate of the constituents is as follows:

	%
?Tremolite-actinolite	∿50
Pyroxene	5-10
Epidote	∿20
Feldspar	2
Chlorite	20-25
Limonite	<1

A granular texture of pale green to almost colourless fibrous amphibole comprises the principal part of this rock. Crystals are up to 3 mm in length and of generally similar width. In many places the minerals appear to be altering to chlorite, which has replicated to greater or lesser degree the almost fibrous cleavage of the amphibole. Trails of fine granular to short prismatic epidote crystals follow the amphibole intergranular boundaries, and in places merge into turbid saussuritic masses. The epidote is both turbid and stained brown with what appears to be a small proportion of limonite or other exsolved iron oxide. The amphibole appears to have the composition of a weakly ferroan tremolite-actinolite, but has an unusually high birefringence. Its form suggests that it has replaced a more granuloblastic pyroxene mixture such as diopside and/or and orthopyroxene. A few relict grains of untwinned feldspar are scattered among the calc-magnesian silicates, and a few sparse concentrations of chlorite indicate the former possible location of more aluminous silicates. Because of the unusual appearance of the amphibole in this rock, the total components were confirmed by X-ray diffraction analysis. A possible derivation of this rock is from a pyroxene-feldspar granulite which has been retrogressively altered to amphibole and epidote. This may have taken place in conjunction with the formation of the chlorite, but there may also have been a degree of later hydrothermal or even metasomatic processes involved. The composition appears to be too rich in lime and deficient in iron to interpret it as an ortho-amphibolite, hence it is considered more likely to have been derived from a calc-magnesian sediment such as a siliceous dolomite.

Sample: 6231 RS 86; TS44815

Applicant's No.: E 69

Rock Name:
Biotite-feldspar-quartz schist

Hand Specimen:
A fine to medium-grained foliated rock consisting of near-white quartzo-feldspathic layers alternating with thin but abundant micaceous laminations. The rock is extensively folded and crumpled.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	40-50
Feldspars	30-40
Biotite	15-20
Muscovite	<1
Leucoxene (or titanite)	2
Limonite	1-2
Zircon	trace

Strongly aligned laminations of biotite flakes of fairly fine grain size (few exceed 0.5 mm diameter) alternate with broad layers of granuloblastic quartz-feldspar intergrowths up to 5 mm wide which contain a very small proportion of mica. The quartz and feldspars in places show faint relict outlines of former detrital grains of quartzitic composites around which, there are swathes of biotite flakes. Several coarse crystals of quartz and feldspars are present up to 1 mm diameter, which may be relict detrital grains or, less likely, porphyroblasts. They are set in a generally finer to even cherty mosaic of granuloblastic quartz in which the individual crystals rarely exceed 0.2 mm. The feldspars are predominantly soda-lime varieties, and the crystals showing multiple twinning indicate a composition corresponding to oligoclase. Many feldspars are cloudy with ?clay mineral alteration products, and staining tests indicate that potassic metasomatism has taken place along a few fine transverse veinlets sparsely distributed across the rock.

The biotite-rich layers do contain a few rare flakes of muscovite, and small granular inclusions of leucoxene (or titanite) scattered among them. The schisty foliation along these layers is also the weakest direction, and there has been a tendency for the layers to separate and the fissures become filled with limonitic weathering products.

The rock is a schistose metasediment derived from an argillaceous siltstone or lithic arenite.

Sample: 6231 RS 87; TS44816

Applicant's No.: E 72

Rock Name:
Chert

Hand Specimen:
A generally dark green and pale brown banded massive fine-grained siliceous chert, with additional fine quartz veining.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	>90
Chlorite	2-3
Sericite	<1
Limonite	<1

This is a fine to very fine-grained mass of granuloblastic quartz. The laminations seen in hand specimen are revealed microscopically as consisting of varied grain sizes and clarities of almost pure quartz. Some is so fine as to be virtually cryptocrystalline, and others contain crystals up to 0.1 mm. Within the quartz veins the crystals become coarser again, being up to 0.3 mm diameter and much more transparent.

The laminations of the chert are resolved microscopically to contain a multiplicity of ultra-fine layers, some being no more than 0.1 mm thick. Most of the long axes of the quartz crystals are parallel to the laminations, and have recrystallised more completely and more coarsely where there is a paucity of other components. The finer chert layers contain fine chlorite flakes and even rarer traces of sericite. A few sparse bands are quite densely clouded with inclusions, and contain an assortment of quartz or chalcedony grains, which give the impression that they may have replaced feldspars. Some intergranular limonitic staining, and minor void fillings of the same material, are present in these bands and the adjacent quartz veins.

The rock is a chert which has been derived from a siliceous sediment. Many cherts are considered to be derived by silicification or devitrification of glassy lavas or tuffs. The relict laminations in this rock are so fine, and the ferromagnesian contaminants are so sparse that this interpretation seems unlikely. It is therefore suggested that it is a direct oceanic colloidal precipitate, such as are known to form in the vicinity of volcanic sources where additional silica is fed into the water. It may, however, contain a very small proportion of pyroclastic contaminants.

Sample: 6231 RS 88; TS44818

Applicant's No.: E 90

Rock Name:
Sheared granodiorite gneiss

Hand Specimen:
A medium-grained lineated granitoid rock.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	20-30
Plagioclase (oligoclase)	∿60
Muscovite	3
Biotite	1
Chlorite	5-8
Titanite (sphene)	<1
Zircon	trace

This rock has a well-developed boudinage structure in which aligned cylindrical masses of quartz and feldspar of rounded to elliptical cross section are enclosed in very weakly foliated clusters of micaceous minerals. The feldspar is entirely plagioclase with an oligoclase composition (Ab_{80}). Most crystals are xenoblasts of average diameter 0.5 mm, but there is a considerable proportion of smaller crystals (0.1 mm and less) distributed along the coarser crystal boundaries. Most of the quartz is also present as part of this finer mosaic separating the coarser feldspars. A few coarser quartz crystals are, however, present particularly among the micaceous components.

Muscovite flakes up to 0.5 mm diameter, intergrown with variously chloritised biotite of similar dimensions, comprise the micaceous separations between the boudins. The flakes are partially aligned and the clusters elongated with the general structure. Granular masses of titanite occur particularly within the biotite and chlorite-rich zones, and in a few places rounded prisms of zircon are also present.

The rock is classified as a gneiss which has an essentially granodioritic composition. It is an amphibolite facies metamorphic equivalent of an argillaceous siltstone or arenaceous shale.

There is one very fine hydrothermal metasomatic veinlet, which traverses the hand specimen. Some fine pink ?hematitic pigmentation has developed in the feldspars along its length, and staining tests show the presence of potassic feldspar traces which are penetrating the intergranular crevices of the plagioclase.

Sample: 6231 RS 89; TS44819

Applicant's No.: ML 4634/21

Rock Name:
Chloritised quartz-feldspar gneiss (?migmatite)

Hand Specimen:
A massive green rock with a rather crumpled and folded alternate banding of white layers or veins. There is also a very weak foliation parallel to the layering.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Quartz	15-20
Plagioclase (andesine)	∿70
Chlorite	5-10
Muscovite	1-2
Titanite (sphene)	∿1
Opaques (leucoxene)	1

A considerable diversity of grain sizes is a feature of this rock. Broad medium to quite coarse-grained quartzo-feldspathic (?pegmatite) bands occupy the white layers, while relatively fine-grained quartz, feldspars and chlorite make up the foliated green laminations. The finer-grained feldspar is untwinned, but within the coarser ?veins it shows multiple twinning and a series of perthitic-type intergrowths. The composition appears to be that of a sodic andesine (Ab_{65}). Quartz is relatively scarce within these ?veins but is more prevalent in some of the finer bands and micaceous layers. The chlorite is present as knots and layers of fine partially aligned flakes, which in a few places, alternate with patches of muscovite. Much of the chlorite is as ultra-fine inclusions in the more cherty to chalcedonic siliceous bands, and is obviously the cause of coloration in the rock. A few subidiomorphic crystals of titanite are randomly scattered, and there are drawn-out streaks and schlieren of pale cream to brown earthy opaques which follow the laminations, and appear to be a titanian oxide such as leucoxene.

This rock gives the impression that it was a micaceous schist or gneiss which has been hydrothermally chloritised and tectonically distorted during the introduction of the quartzo-feldspathic (?pegmatite) phase. Alternatively it could represent a chloritised metamorphic rock which had already been segregated such as a migmatite.

Sample: 6231 RS 90; TS44820

Applicant's No.: ML 4634/42

Rock Name:
Epidote-chlorite rock

Hand Specimen:
A medium to fine-grained yellowish-green massive rock with a very weakly defined subparallel banding.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Epidote	>80
Chlorite	10-15
Carbonate (?dolomite)	2-3

This rock is almost entirely a mass of subidioblastic pale yellow-green epidote prisms, which are up to 1 mm long and 0.5 mm wide. The crystal terminations tend to be rounded and the intergranular spaces filled with finer to even microcrystalline mesh of chlorite. Some of the chlorite has the form of fine curving swathes of flakes which wind between the epidote prisms; other larger areas consist of small rosettes of radial flakes. Although the chlorite is not very abundant, it is most concentrated along a few subparallel fractures or fissuring directions, which coincide with the banding direction and may be largely responsible for it. Even finer (less than 50 microns) crystallites of carbonate are also disseminated along these chloritic fissures, and to a lesser extent among the epidote. This carbonate appears virtually colourless, and is unaffected by the alizarin red-S agent used for staining calcite. It is assumed that it is dolomite, although siderite or ankerite are also possibilities.

This rock differs markedly from any common metamorphic composition. If the banding is a relict sedimentary texture rather than a metamorphic compositional segregation, then it could be regarded as a metasediment derived from a lime-dominant calc-magnesian marl or dolomitic shale such as for sample E 19. Alternatively, if the granular texture of the epidote is itself a relict, it could be a retrogressively and hydrothermally altered pyroxene granulite, which must itself have been derived from a dolomitic source rock. The genetic evidence in this rock is rather too vague for meaningful interpretation.

The iron content is one of the more unusual features and it seems difficult to interpret without resorting to some volcanogenic contaminant in the original sediment or introduction of one or more elements metasomatically.

Sample: 6231 RS ~~84~~ 91; TS44813

Applicant's No.: E 63

Rock Name:
Epidote amphibolite

Hand Specimen:
A fine to medium-grained massive granular yellow-green rock with faint darker mottling visible on the sawn surface.

Thin Section:
A visual estimate of the constituents is as follows:

	%
Epidote	∿50
Amphibole (tremolite-actinolite)	40-50
Titanite (sphene)	1-2

This rock consists essentially of a fibrous to prismatic amphibole enclosing granular masses of epidote. Most of the amphibole is a random fibrous mesh of very pale green to colourless tremolite-actinolite (nephrite) which winds its way between coarser (up to 1 mm long × 0.5 mm wide) prisms of the same mineral, and the granular masses of epidote.

The epidote itself occurs in trains and bands of quite coarse grain size, which are resolved microscopically as aggregates of granules which virtually never exceed 0.1 mm diameter. In places these aggregates become the dominant component and the rock is virtually monomineralic, except for inclusions of acicular tremolite-actinolite. Alternatively, in other places the amphibole is dominant, and only rare discontinuous trains of finer epidote are present.

The titanite is also rather finely granulated. Although a few crystals show partial development of the typical lozenge-shaped form, these are in some places actually microcrystalline composites. Others appear to be portions of narrow elongate crystals up to 0.5 mm long wedged among the other components and aligned with the lineation direction of the amphibole.

There is a very faint compositional banding visible in thin section alternating between the calc-aluminous epidote-rich layers and the calc-magnesian tremolite-actinolite. There is also a slight tendency for the titanite crystals to lie along definite bands, but they may have been influenced by minor fissures in the rock which appear to be of later origin.

The rock is an amphibolite facies metasediment, derived from a very calcic rock with appreciable alumina and magnesia. While there is no definite evidence that this is not an ortho-amphibolite, it is believed more likely to have been a metasediment from an argillaceous siliceous dolomitic limestone.

Sample: 6231 RS 92; TSC39683

Applicant's No:
E14/17

Rock Name:
Chlorite and muscovite-bearing plagioclase gneiss

Hand Specimen:
This is a coarse-grained feldspathic rock. On the cut surface a prominent foliation is evident due to the concentration of micas into distinct bands. This foliation shows the effects of an open folding or crenulation event.

Thin Section:
A visual estimate of the constituents gives the following:

	%
Plagioclase	55
Chlorite	15
Sericite	15
Muscovite	10
Opaques	4
Zircon and/or monazite	1
?Altered sphene	Trace

This is a plagioclase-rich rock and has a wide range in grain sizes. The plagioclase ranges in size up to 1 cm in diameter. The coarser plagioclase has antiperthitic exsolution features and some show multiple lamellar twinning but most are untwinned. It is an oligoclase in composition although there may be some albite present. There is little or no K-feldspar and there may be some quartz. Grain boundaries are ragged and sub-grain developments common, indicating at least one superimposed cataclastic deformation. The plagioclase grains are commonly clouded by fine alteration products and many have sericite/muscovite and chlorite developed within.

The muscovite also shows a wide range in grain sizes with some flakes up to 3 mm in length. The coarser muscovite flakes appear to be early metamorphic developments at the expense of feldspar and these have small-scale kinks in the cleavage traces. The sericite and finer muscovite are concentrated along zones within the rock which have suffered more intense cataclastic deformation and alteration of the feldspar. These micaceous bands are the crenulated foliation evident in hand specimen.

Associated with the muscovite is a colourless to greyish-coloured micaceous mineral with low maximum birefringence. This is probably chlorite and in places can be seen to be replacing the muscovite. As with the sericite, there are patches of finer-grained chlorite developed.

The opaques are typically irregular in outline and range in size up to 0.5 mm in length. In a number of cases the opaques occur around the margins of, and along the cleavage traces of muscovite or chlorite. These finer-grained opaques have very ragged grain margins. Zircon, and/or monazite , is a prominent accessory, ranging in grain size up to 0.1 mm with some zoned and complex composite grains evident. There are also traces of ?altered sphene.

This is a chlorite and muscovite-bearing plagioclase gneiss that has suffered at least one major cataclastic deformation and a subsequent mild crenulation or folding event.

Sample: 6231 RS 93; TSC39684

Applicant's No:
E14/37

Rock Name:
Chlorite and sericite-rich plagioclase gneiss

Hand Specimen:
This is a well-foliated rock consisting mostly of finer-grained, dark green-coloured micaceous material with coarser, white feldspathic bands or segregations. There are some very coarse clots of feldspar which are up to 5 cm in diameter. The foliation and feldspar segregations show open warps or crenulations, and in places there is some disruption along the axial plane of these warps.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	50
Sericite	20
Chlorite	15
Coarse muscovite	5
Opaques	9
Epidote	1
Goethite	Trace
Sphene	Trace
Zircon	Trace

This sample is similar to 6231 RS 92, in that it consists of plagioclase which has been altered, resulting in chlorite, muscovite and sericite.

Plagioclase in thin section exhibits a continuous spectrum in grain sizes, ranging up to 7 mm in diameter. Most of the plagioclase occurs as elongate grains orientated in the foliation. The plagioclase is essentially an untwinned variety and in places shows extensive alteration to sericite. Grain boundaries are ragged and irregular in outline, with many strain features and sub-grain developments, consistent with at least one major cataclastic deformation.

The chlorite is colourless to pale olive green in colour. Individual flakes range up to 1.5 mm in length. The cleavage planes and margins of the chlorite are enhanced by a preferential concentration of fine-grained opaques. Muscovite commonly occurs together with the chlorite, forming micaceous bands. The muscovite flakes also range up to 1.5 mm in length, but it is usually finer-grained than the chlorite and grades down into sericite. In places there is evidence to suggest that the chlorite is derived at least in part from earlier formed coarse muscovite. The schistosity that arises from the parallel alignment of these micaceous minerals can be seen to be crenulated. There is only very minor amounts of recrystallization in the hinges of these crenulations, giving rise to one or two flakes of muscovite and lesser chlorite parallel to the axial plane.

Sericite occurs as massive aggregates which form bands through the rock parallel to the main foliation. The sericite can be seen to be replacing an earlier feldspathic phase, and at the latest it was developed synchronously with the main schistosity-producing event.

The disruption along the axial planes of the crenulations is represented in thin section by cracks or fissures with opaque phases. In the places,parallel to these fissures there is some epidote veining. The epidote is colourless to very pale yellow-green in colour, elongate in nature, and ranges up to 0.8 mm in length. Apart from the association with chlorite, the opaques also occur as very ragged, disseminated grains, some up to 1 mm in length. Round zircon grains are present in trace amounts and there are minor secondary goethitic developments and possibly some altered sphene.

This is a chlorite and sericite-rich plagioclase gneiss that has suffered at least two main deformations.

Sample: 6231 RS 94; TSC39685

Applicant's No:
E14/45

Rock Name:
Granodioritic gneiss

Hand Specimen:
This is a medium-grained, white-coloured granitoid that is foliated.

Thin Section:
A visual estimate of the constituents gives the following:

	%
Plagioclase	80
Quartz	10
Muscovite	6
Chlorite	2
Sphene	1
Opaques	1
Apatite	Trace
Zircon	Trace

This rock has an inequigranular granoblastic texture. It dominantly consists of plagioclase which ranges up to 2.5 mm in diameter. There has been partial recrystallization of the plagioclase particularly around its grain margins, which has resulted in fine interstitial feldspar with parallel aligned,elongate plagioclase core grains. This alignment, together with the coincident alignment of some of the muscovite gives the rock a prominent foliation in thin section,as noted in hand specimen.

The plagioclase is andesine in composition and exhibits multiple lamellar twinning, antiperthitic exsolution features, and is also untwinned in places. Some of the multiple twinning resembles that seen in cordierite, however no positive identification of cordierite has been made. Grain margins are ragged in places and prominent sub-grain developments can be seen. Clouding of the plagioclase is common, together with some sericitization.

Muscovite occurs interstitial to the plagioclase. Flakes range up to 0.5 mm in length, with most being of the order of 0.1 to 0.2 mm. There is a general alignment of the muscovite, however some of the aggregates have radial arrangements. In places, chlorite can be seen to have developed from muscovite. The interstitial nature of the muscovite indicates a secondary development relative to the plagioclase and some may have been derived from earlier plagioclase.

Quartz is a relatively minor interstitial constituent, being of similar size to the plagioclase. It is distinguished by a general lack of inclusions and alteration. The quartz shows undulose extinction and is often associated with sphene.

Sphene is a prominent accessory phase. Generally ragged in outline with some relict prismatic grains present. Sphene ranges in grain size up to 0.5 mm. Other minerals present in trace amounts are apatite and zircon The apatite has a maximum grain size of 0.15 mm.

This is a medium to coarse-grained granodioritic gneiss that was probably formed through amphibolite grade metamorphism of an igneous rock.

Sample: 6231 RS 95; TSC39686

Applicant's No:
E14/51

Rock Name:
Diopside-bearing tremolite rock(or jade)

Hand Specimen:
On the weathered surfaces this is a fine-grained, massive brown-coloured rock. Variations in grain sizes are evident on the cut surface with material ranging from very fine, up to 0.5 - 1 cm in diameter. The fresh rock is a dark green colour.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	85
Diopside	10
Chlorite (and biotite)	1
Opaques	1
Secondary ferruginization	3

This rock is dominated by tremolite which exhibits a wide range in grain sizes. Relict coarse domains of tremolite, averaging 1 to 1.5 mm in diameter show partial to complete recrystallization to massive, fine-grained tremolite. These fine aggregates have an average internal grain size of 0.1 mm or less. There is a tendency for these fibrous tremolite grains to have a parallel alignment, giving the rock a micro-schistosity, although much of the tremolite is in random orientation.

The diopside occurs in coarse-grained aggregates with an internal grain size ranging up to 5 mm in diameter. The diopside is typically granular in outline and the grains are strongly cracked. Partial replacement of the diopside by tremolite can be seen. Much of the diopside is clouded by fine, dust-like inclusions, probably representing the early stages of alteration.

In places there are some fine aggregates of chlorite, interstitial to the tremolite and some biotite has also been observed with the chlorite.

Minor shearing occurs through the sample and there is rotation of the tremolite needles into the shear zones. In parts, new tremolite formation occurs adjacent to, and within these zones of intense deformation. Secondary ferruginization is also present and has resulted in an intense iron staining of some parts of the rock.

This is a diopside-bearing tremolite rock or jade that was probably formed through amphibolite-grade metamorphism of a siliceous sandy dolomite. There is evidence to suggest at least two stages of metamorphic development with early formed pro-grade diopside retrograding to tremolite.

Sample: 6231 RS 96; TSC39687

Applicant's No:
E14/52

Rock Name:
Dark green coloured massive tremolite rock (or jade)

Hand Specimen:
This is a massive rock of high density, which when fresh is very dark green in colour. The weathered surface is brown in colour and on a cut surface there is an apparent planar fabric.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
Opaques (including dust-inclusions)	5
?Apatite	Trace
Biotite	Rare

This rock consists almost entirely of tremolite. ?Relict coarse domains are emphasized by rims of fine opaque inclusions. These ?relict domains range up to 2 mm in length and have been almost completely recrystallized to aggregates of massive fine tremolite. A few scattered coarse tremolite grains are preserved, ranging up to 1.5 mm in length. Some secondary coarse tremolite is also evident, being of a similar grain size but occurring as radial clusters.

The bulk of the rock consists of fine-grained tremolite with an average grain size less than 0.1 mm. A weak alignment of these fine-grained aggregates, together with the ?relict structures give the rock an indistinct fabric as noted in hand specimen.

There are significant but minor amounts of very fine opaque material mostly concentrated along cracks through the rock which mark the boundaries to possible earlier structures. Traces of apatite and rare biotite have been observed.

This is a dense massive tremolite rock or jade which was probably formed through middle amphibolite-grade metamorphism of a siliceous dolomitic marble.

Sample: 6231 RS 97; TSC39688

Applicant's No:
E14/64

Rock Name:
Chloritized and sericitized granodioritic gneiss

Hand Specimen:
This a pale grey green-coloured rock, medium-grained, with a prominent foliation. Slightly coarser grained, pale pink-coloured feldspathic stringers are parallel to the foliation and range up to 1 cm in thickness.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	60
Quartz	10
Sericite	15
Chlorite	9
Muscovite	5
Opaques	1
Zircon	Trace
Sphene	Trace
?Apatite	Trace

This is an altered foliated granitoid with turbid and sericitized feldspar, and chloritized micas. The foliation noted in hand specimen is due to a parallel alignment of plagioclase and quartz together with muscovite and chlorite.

Both twinned and untwinned plagioclase is present and some antiperthite exsolution features can be seen. Most feldspar grains are turbid and in patches there has been extensive sericitization. The grains are elongate in outline, ranging up to 1.5 mm with an average grain size of the order of 0.5 mm. Grain margins are irregular, sutured and/or serrated with partial recrystallization and sub-grain developments peripheral to the coarser grains.

The quartz shows similar grain margin and partial recrystallization features as the plagioclase. Most grains have undulose to strongly undulose extinction.

Muscovite and chlorite commonly occur together in stringers or wispy aggregates elongated in the foliation. The flakes range up to 0.5 mm in length. Chlorite seems to have formed at the expense of muscovite or possibly an earlier ?biotite. The chlorite shows weak pale grey-green pleochroism.

Lenticular zones of fine massive aggregates of sericite are present, also orientated in the foliation. The sericite appears to have replaced earlier feldspars possibly forming augen-like structures. Muscovite usually occurs together with the sericite and there is some chlorite. The sericite and muscovite are also present as secondary interstitial phases in small aggregates around feldspars.

Opaques occur as very fine-grained inclusions along the cleavage planes and margins to the chlorite. Some secondary iron oxide developments along grain margins are present. Minerals occurring in trace amounts

are zircon, sphene and ?apatite.

This is a chloritized and sericitized granodioritic gneiss that probably has an igneous precursor. There is evidence for at least one major cataclastic deformation.

Sample: 6231 RS 98; TSC39697

Applicant's No:
DJF 26

Rock Name:
Hydrothermally-altered granodiorite

Hand Specimen:
This is a massive coarse-grained granitoid with a weak foliation shown by a tendency for elongate mafic clots to be in parallel alignment.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	65-70
Biotite and chlorite	15-18
Tremolite	5-7
Quartz	?5
Opaques (goethite and rutile)	4
Apatite	1
Zircon	Trace

This rock consists principally of coarse-grained plagioclase with secondary interstitial biotite and chlorite, and late-stage acicular tremolite.

The plagioclase ranges in grain size up to 5 mm in diameter. Many of the grains show multiple lamellar twinning which in places is kinked and a deformation texture results. Some untwinned plagioclase, antiperthitic feldspar, and rare simple twins can be seen. Grain margins are cuspate to ragged and recrystallized finer interstitial aggregates are present. The plagioclase generally has a clouded appearance consistent with the early stages of alteration to ?fine clays.

In places the plagioclase has been partly replaced by acicular aggregates of tremolite. Individual tremolite needles range up to 1 mm in length and show a radial pattern, emanating from a common point usually adjacent to the junctions of several plagioclase grains. It is probable that these tremolite needles are formed from late-stage fluids moving along grain boundaries.

Biotite occurs as massive aggregates of equidimensional flakes that are interstitial to, and in part replacing an earlier feldspar phase. Relict plagioclase does occur in association with the biotite, and tremolite seems to cross-cut the biotite developments. Individual biotite flakes are 0.05 mm in diameter. It is olive green to pale green-brown in colour and there is significant alteration in places to chlorite. Coarser-grained aggregates of biotite are restricted developments, with flakes up to 0.5 mm in length. These aggregates occur in areas of intense recrystallization of the plagioclase, resulting in fine mosaics of plagioclase and ?quartz, together with biotite.

Quartz is generally of limited extent, occurring as secondary interstitial vein-like stringers with undulose extinction. Opaques are irregular to blocky in outline, ranging in size up to 1 mm. Goethite is a common opaque phase, being secondary in origin, infilling or replacing earlier phases. Some rutile is present. Apatite generally occurs as round, elongate grains up to 0.2 mm in length. It appears to be preferentially associated with, or adjacent to the biotite development. Traces of zircon are present.

This is a coarse, even-grained granodioritic rock that has suffered hydrothermal alteration resulting in replacement of plagioclase and ?other feldspar by biotite. Late-stage movement of fluids has resulted in the development of acicular aggregates of tremolite within the plagioclase.

Sample: 6231 RS 99; TSC39698

Applicant's No:
DJF 27

Rock Name:
Dark green and pale green-coloured tremolite rock (or jade)

Hand Specimen:
This is a massive fine-grained rock that has a pale green portion and a dark green portion. There is an indistinct cleavage which is subparallel to the boundary between these two colour bands.

Thin Section:
The thin section was cut mostly of the pale green material with only a small portion of the dark green material present.

A visual estimate of the constituents present gives the following:

	%
Tremolite	∿94
Opaques/ferruginous staining	∿5
Apatite	∿1

This rock consists of fibrous mats of fine-grained tremolite with scattered coarser tremolite aggregates. The fine tremolite has an average grain size of approximately 0.01 to 0.04 mm. There is an indistinct subparallel alignment of the fibrous tremolite which results in the fabric noted in hand specimen.

The coarser grained tremolite ranges up to 1 mm in length, occurring both as elongate and more needle-like grains. The coarse tremolite forms irregular interconnected zones throughout the rock which may be vein-like in origin. Within these coarse aggregates the tremolite is generally in random to radial orientation.

Apatite is a prominent accessory phase occurring as equant to round elongate grains up to 0.4 mm in length. There is conspicuous fine dust-like material occurring along cracks or fissures through the rock and there is also some secondary ferruginization of the tremolite. Fine dust-like inclusions can also be seen within some tremolite aggregates.

The colour bands noted in hand specimen do not appear to be a consequence of any textural or obvious mineralogical differences as seen in this thin section.

This is a massive tremolite rock or jade that appears to have suffered some secondary tremolite development possibly through solution veining.

3. PETROGRAPHY

Sample: 6231 RS 100; TSC40845

Applicant's No.
DJF 28

Rock Name:
Plagioclase veined actinolite rock

Hand Specimen:
This rock consists of two components, a host of coarse-grained, green coloured amphibole which is veined with thin quartzo-feldspathic material resulting in a banded appearance. One end of the hand specimen has a ca 5 cm thick vein of feldspar.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Host:	
Actinolite	85
Epidote	13
Plagioclase	2
Vein:	
Plagioclase	85
Epidote	10
Actinolite/tremolite	5
?Sphene	trace

The host portion of this sample is dominated by actinolite with lesser amounts of epidote. The actinolite is colourless to very pale green and occurs as elongate to braded crystals ranging up to 4 mm in length. Some show typical amphibole 60-120° cleavage and a few grains appear to be curved in a deformation fabric. Generally the elongate actinolite is in random orientation.

The epidote (?clinozoisite) is finer-grained and occurs as colourless aggregates with individual grains ranging up to 1 mm in length. There are some discrete prismatic epidote crystals as well as finer anhedral, granular aggregates. Plagioclase occurs as patches or discrete veinlets within the actinolite, consisting of untwinned granoblastic aggregates with subgrain developments and sutured grain margins. It is possible that there is some quartz associated with the plagioclase.

The prominent feldspathic vein noted in hand specimen can be seen to dominantly consist of coarse-grained plagioclase which has suffered considerable intergranular recrystallisation consistent with a cataclastic deformation. Coarse, relict plagioclase grains range up to 5 mm in diameter and are either twinned or untwinned. Most show antiperthic textures and have considerable subgrain developments, being surrounded by fine granular feldspar with an average grain size less than 0.1 mm. Epidote and partially fibrous actinolite/tremolite occur interstitial to the plagioclase. The epidote occurs both as massive aggregates of fine anhedral grains, and as aggregates and discrete euhedral crystals up to 0.5 mm in length. The

tremolite grades from coarser more massive crystals into fibrous wispy aggregates. There is a trace of sphene.

This is a calc-silicate rock that was probably formed through middle amphibolite facies metamorphism of a siliceous dolomite. It has subsequently suffered at least one cataclastic deformation which post-dates a prominent feldspathic veining event.

Sample: 6231 RS 101; TSC40846

Applicant's No.
DJF 29

Rock Name:
Plagioclase-rich pegmatite

Hand Specimen:
This is a coarse-grained feldspathic rock which is generally massive with no obvious foliation. Quartz is evident in the hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	60-65
Quartz	10-15
Epidote	15
Actinolite	8
Apatite	1
Zircon (?xenotime)	1
Sphene	trace

This sample is similar in composition and texture to the plagioclase vein described in sample 6231 RS 100.

Coarse early-formed plagioclase grains range up to 6 mm in diameter. These show antiperthic textures and are variably twinned. A superimposed cataclastic deformation has resulted in the development of fine granular interstitial feldspar and subgrain to mosaic textures within the remnant coarse core grain. In places there is a seriate texture with grain sizes ranging from 2 to 3 mm downwards. Some of the partly recrystallised grains also show multiple lamellar twinning.

Although not positively identified in thin section it is apparent that there is a small to moderate amount of quartz in this sample. Staining of the hand specimen reveals that quartz is present in ca 10 to 15%.

The epidote and actinolite commonly occurs interstitial to the plagioclase. One coarse patch of intensely altered epidote (?clays) is 5 mm in length but mostly the epidote is found as granular aggregates with a grain size of less than 0.5 mm. In part the epidote can be seen to form at the expense of plagioclase. The actinolite is pale green to colourless in colour, weakly pleochroic and ranges up to 1 mm in length (mostly less than 0.5 mm). Some fibrous amphibole is also present and in places degradation of the amphibole to ?clays is apparent.

Apatite is a prominent accessory phase and there is some zircon and/or ?xenotime, with traces of sphene. Minor secondary ferruginisation along cracks and fissures can be seen in addition to the clay developments.

This is a coarse-grained igneous rock that is dominated by plagioclase with minor amounts of quartz. It has been subjected to a cataclastic deformation and there is some retrograde metamorphic effects in the form of epidote.

Sample: 6231 RS 102; TSC40847

Applicant's No.
DJF 30

Rock Name:
Weathered, crenulated, mica-rich gneissic schist

Hand Specimen:
This is a reddish-brown coloured foliated quartzo-feldspathic rock which appears to be deeply weathered. On the cut surface a gneissic texture is evident with discontinuous bands outlining a crenulated fabric. Some of these bands appear to be attenuated earlier fold hinges.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	25
Plagioclase	20
Muscovite	15
Biotite (chloritised)	10
Opaques	2
Zircon	trace
Secondary:	
Sericite	25
Ferruginous staining	3

This is a medium to coarse-grained gneissic schist consisting principally of quartz and plagioclase with lesser muscovite and biotite. The crenulated and attenuated banding noted in hand specimen can be seen to consist of secondary sericite.

Quartz occurs as irregularly-shaped grains of variable grain size with undulose to strongly undulose extinction. Elongate relic grains, lying in the main foliation range in length up to 5 mm. These coarser grains show considerable subgrain development. The plagioclase is more even in grain size, generally occurring as multiply twinned equant to rectangular grains averaging 0.3 mm in diameter.

Biotite appears to be the earlier formed mica with muscovite generally of a slightly younger nature. Alteration of the biotite to chlorite is common and there is also possible replacement of the biotite by muscovite. Both micas predate the main fabric in this rock and are folded together with the foliation, although there are some random orientations evident.

The sericite occurs as massive aggregates, comprising bands up to 5 mm in thickness. Some relict coarser mica developments also occur in these bands together with partly altered feldspar, and these minerals may give rise to some of the sericite. The presence of essentially unaltered plagioclase in juxtaposition with this folded sericite tends to rule out derivation of the sericite from earlier plagioclase. This implies an unknown alumino silicate source.

Irregularly-shaped opaques are present in minor amounts and there are trace amounts of ziron. Late-stage iron staining is consistent with

near-surface weathering.

This is a gneissic schist with prominent muscovite and biotite. An early-formed foliation has subsequently been crenulated and the development of sericite after an unknown precursor predates this foliation.

Sample: 6231 RS 103; TSC40848

Applicant's No.
DJF 31

Rock Name:
Finely banded calc-silicate gneiss

Hand Specimen:
This is a finely banded rock consisting of alternating green, pale green, and off-white layers generally less than 1 mm in thickness.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase (including sericite and fine clay secondary developments)	45
Quartz	20
Epidote	20
Actinolite/tremolite	15
Apatite	trace
?Sphene	trace
Zircon	trace

The prominent banding seen in hand specimen is not as clearly evident in thin section. There are some semi-continuous stringers of plagioclase and quartz, and epidote, however, much of the amphibole appears to lie with the long axes at an angle to the compositional layering.

The plagioclase shows variable alteration with some completely replaced by sericite and fine clays. The average grain size is 0.2 to 0.3 mm in diameter. Quartz is of a similar grain size with undulose to strongly undulose extinction and some subgrain developments.

Epidote occurs as colourless to very pale green grains of variable size, ranging up to 5 mm in length. It appears to have been formed early and lies in the main fabric. The amphibole on the other hand seems to have formed after the main fabric, and the long axes of the pale green to colourless actinolite/tremolite are at a low angle to the early fabric. Some fibrous amphibole is present, the bladed to elongate grains range up to 8 mm in length.

Much finer-grained accessory phases are apatite and zircon, with a fine prismatic high relief mineral probably being sphene. The sericite and clays are a secondary development after plagioclase and in part possibly epidote. They would constitute 30 to 35% of the rock.

This is a finely banding calc-silicate gneiss which appears to have early-formed quartz and plagioclase and possibly epidote, with secondary actinolite developed during an amphibolite grade metamorphism postdating the main fabric development.

Sample: 6231 RS 104; TSC40849

Applicant's No.
DJF 33

Rock Name:
Weathered, crenulated gneissic schist

Hand Specimen:
This is a well foliated, weathered gneissic schist with prominent micas on the foliation surface.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	20-25
Plagioclase	20-25
Potassium feldspar	10-15
Biotite	15-20
Sillimanite	5-10
Opaques	2
Zircon	trace
Secondary:	
Kaolinite	5-10
Muscovite and sericite	5
Limonite	3

This rock consists of granoblastic aggregates of quartz and feldspar with poorly aligned stringers and zones of biotite, and lesser sillimanite. A low birefringent clay mineral is associated with the biotite and also occurs as distinct veins.

The quartz occurs as irregularly-shaped grains, with curved to mildly sutured grain boundaries. It ranges in grain size up to 1.5 mm although most are less than 1 mm. The potassium feldspar is finely perthitic with some microcline perthite. It is of a similar grain size to the quartz as is the plagioclase. Both multiply twinned and untwinned plagioclase is evident with minor alteration to sericite in places, and some secondary inclusions of biotite and sillimanite.

The biotite is red-brown to greenish-fawn in colour and individual flakes range up to 1.5 mm in length. Much of the biotite is in a subparallel orientation, except in the hinges of minor folds where somewhat random orientations are evident. Sillimanite is intimately associated with the biotite, commonly occurring as aggregates of fine granules (less than 0.02 mm in diameter) or as stringers of fibrous grains parallel with the biotite foliation. In small scale fold hinges the sillimanite grains can also be seen to have been folded.

The opaques are irregular in outline and range up to 0.8 mm in length. In one fold hinge a single opaque grain exhibits the outline of the fold together with sillimanite and biotite. Zircon and/or monazite are present

in trace amounts.

Secondary alteration of the rock has resulted in the development of a very low birefringent clay mineral identified as kaolinite by X-ray diffraction. The kaolinite occurs both as veins and as ?*in situ* alteration of the sillimanite and biotite-rich bands. Limonite staining is associated with the kaolinite in places, possibly resulting from the liberation of iron due to the breakdown of biotite. Muscovite, in part after biotite, and sericite are other secondary phases.

This is a crenulated, sillimanite-bearing, quartz-feldspar-biotite schist that was probably formed through middle amphibolite facies metamorphism of a psammo-pelitic sediment. Two deformations are evident and there has been an intense weathering resulting the formation of kaolinite.

Sample: 6231 RS 106; TSC40851

Applicant's No.
DJF 35

Rock Name:
Hydrothermally-altered calc-silicate

Hand Specimen:
This is a massive, coarsely crystalline rock consisting of pale purple and white coloured segregations. There are trace amounts of a fine-grained blue mineral.

X-ray Diffraction:
Material was collected from each of the three different coloured phases seen in hand specimen. An X-ray powder photograph of the pale blue mineral indicates that this is apatite. X-ray diffraction scan of the white segregations indicates that this is mostly plagioclase, possibly of labradorite or bytownite composition.

Two X-ray diffraction scans of the purple segregations were made. The first indicated that this consists of plagioclase of approximately albite composition, and a mica close to the muscovite pattern, possibly a lithium mica due to the purple coloration. A second scan of another sampling indicates a high muscovite component with accessory albite and prehnite, and possibly some scapolite.

Thin Section:
The thin section was made so as to include both the white and purple coloured segregations. A visual estimate of the constituents present gives the following:

	%
White Segregation:	
Plagioclase	95
Sericite/muscovite	5
Purple Segregation:	
Sericite/muscovite	60
Plagioclase	15
Scapolite	15
Apatite	5
Prehnite	?5

The white coloured segregation consists dominantly of plagioclase. Coarse plagioclase crystals range up to 1 cm in length. There has been a mild to intense cataclastic deformation resulting in considerable recrystallisation of the coarse plagioclase into finer interstitial aggregates and relict coarse grains show subgrain developments and strain shadows. Alteration to fine clays, sericite, and some muscovite is evident, particularly along grain margins where interstitial sericite and muscovite can be seen.

The purple coloured segregation consists mostly of massive aggregates of sericite which appear to have replaced coarse-grained plagioclase. In places ghost multiple lamellar twinning can be seen within

and marginal to the sericitic alteration of the plagioclase. The sericite grades into distinctive flakes of muscovite in some areas, the muscovite occurring as aggregates of flakes with individual flakes up to 0.2 mm in length.

Scapolite is a prominent constituent in this thin section occurring as coarse grains up to 5 mm in diameter. It is associated with plagioclase in finer granoblastic aggregates in one patch, the individual grains sizes being of the order of 0.1 mm. The coarser-grained scapolite shows marked alteration to sericite and muscovite.

Apatite is a prominent constituent, occurring as aggregates or stringers in a vein-like form, or as discrete disseminated grains. Individual grain sizes range up to 0.4 mm.

Prehnite was identified in one of the X-ray diffraction scans. This mineral is not obvious in this thin section, but may be present as fine-grained aggregates associated with the sericite, or as ?coarser, fibrous material associated with the alteration of the scapolite.

This is a plagioclase-rich rock, or calc-silicate that has suffered considerable low temperature hydrothermal alteration giving rise to the sericite, scapolite and prehnite.

Sample: 6231 RS 107; TSC40852

Applicant's No.
DJF 36

Rock Name:
Folded sericite schist

Hand Specimen:
This is a well layered gneissic schist which shows prominent folding on the cut surface.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Sericite	60
Quartz	18
Biotite (including chlorite)	10
Muscovite	5
Opaques	2
Zircon	trace

The layering in this rock is a consequence of preferential concentration of quartz, sericite, and mica into discrete bands. The bands have been folded with small parasitic folds common in the limbs. Sericite is the dominant constituent occurring as massive fine aggregates which grade into muscovite in places. The coarser sericite/fine muscovite is aligned in the early fabric and folded together with the compositional layering.

Quartz occurs as discrete elongate grains or in stringers aligned in the folded foliation. It shows undulose extinction, some subgrain developments, and ranges in grain size up to 1.5 mm in length. Much of the quartz has secondary muscovite and sericite inclusions.

Green to green-brown biotite also occurs aligned in the foliation. Individual flakes range up to 0.5 mm in length. Alteration to chlorite is common and in some of the fold hinges there are coarse ragged biotite/chlorite grains.

The muscovite for the most part appears to be of a secondary nature. Whilst some elongate flakes are aligned with the foliation much of the muscovite is rectangular to square in outline and lies with its cleavage traces at a high angle to this early fabric. This implies a secondary origin as the other constituents, for example sericite, quartz and biotite, are all aligned in the early fabric.

There are minor amounts of blocky to anhedral opaques, and elongate and round zircons can also be seen. Some late stage iron staining is preferentially concentrated along the coarse micaceous bands.

This is a strongly folded sericitic schist that appears to have suffered a main fabric forming deformation, followed by a second folding event. Late-stage development of coarse muscovite may reflect a third deformation/metamorphism.

Sample: 6231 RS 108; TSC40853

Applicant's No.
DJF 37

Rock Name:
Intensely deformed sericitic schist

Hand Specimen:
This is an intensely deformed schistose rock with a protomylonitic texture in hand specimen. Attenuated quartzo-feldspathic bands form discontinuous stringers or lenses in a fine dark coloured matrix.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Sericite	50
Muscovite	10
Quartz	20
Biotite/chlorite	15
Opaques	5
Rutile	trace
Zircon	trace
?Apatite	trace

This sample has a very similar mineralogy to sample 6231 RS 107. The protomylonitic texture is not as clearly evident in the thin section due to the presence of a high proportion of sericite. This sericite occurs as fine massive aggregates which grade into fine muscovite in places, with a subparallel alignment.

The quartz occurs as elongate grains with its long axes parallel to the foliation. Indistinct lensoid aggregates are common and the quartz shows undulose to strongly undulose extinction, with some subgrain developments. It ranges in grain size up to 1.5 mm in length.

Relict biotite also lies in the foliation plane with individual flakes up to 1.5 mm in length. The biotite is extensively replaced by muscovite or altered to chlorite. There are patches of late-stage mica development with small radial clusters of chlorite and muscovite. Some of the biotite/chlorite has abundant inclusions of ?rutile, and in many of the micas the cleavage traces are emphasised by fine opaque inclusions. The opaques also occur as minor discrete anhedral grains less than 0.02 mm in diameter. Traces of zircon, rutile, and ?apatite are also present.

This is a strongly foliated sericitic schist with prominent quartz lenses and augen.

Sample: 6231 RS 109; TSC40854

Applicant's No.
DJF 38

Rock Name:
Granitic gneiss with a prominent hematite-quartz band

Hand Specimen:
This is a coarse-grained, red coloured rock which on the cut surface shows a prominent gneissic fabric and some darker coloured compositional banding.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Granitic Component:	
Quartz	45
Potassium feldspar	40
Plagioclase	8
Opaques	5
Muscovite	2
Apatite	trace
Zircon	trace
Hematite Band:	
Hematite	45
Quartz	40
Muscovite	10
Biotite/chlorite	5

This rock is mostly composed of quartz and potassium feldspar with lesser opaques and muscovite. There is a prominent band through the host granitic gneiss which consists of quartz and opaques. Overall the sample has a granoblastic texture.

Within the granitic band the potassium feldspar is perthite and microcline perthite. It ranges up to 3 mm in diameter. Due to a superimposed cataclastic deformation there is abundant finer quartz and feldspar interstitial to and derived from the coarser grains. Some plagioclase is present, showing multiple twinning and mostly occurring in finer interstitial aggregates.

The quartz is of variable grain size, a consequence of the cataclastic deformation. Relict grains may be up to 4 mm in length, however, most have considerable subgrain developments and strongly undulose extinction. This variable grain size gives the rock a seriate texture.

Muscovite is a minor to trace constituent of the granitic component, occurring interstitial to the quartz and feldspar. It is probably of a secondary nature forming from recrystallisation of sericitised feldspar. Within the quartz-rich band muscovite is more prevalent occurring both as coarse flakes and as fine interstitial material. The coarse flakes range up to 3 mm in length and show deformation kink banding. In

places there are opaque grains with cores of quartz, and interstitial to the quartz and opaques there is a fine rim of muscovite in a form of corona development.

Within the granitic component the opaques occur as anhedral elongate grains up to 4 mm in length. Within the quartz and opaque-rich band they form a semi-continuous interconnected framework with interstitial quartz and muscovite as noted above. Using oblique reflected light it can be seen that the predominant opaque phase is hematite with some limonite, and possibly leucoxene in younger cracks and joints.

There are trace amounts of zircon and apatite. One prominent zircon grain is 0.3 mm in length.

This appears to be a deformed granitic rock with some compositional bands in the form of quartz and hematite.

Sample: 6231 RS 110; TSC40855

Applicant's No.
DJF 39

Rock Name:
Granodiorite gneiss

Hand Specimen:
This is a grey coloured gneiss with a moderate mafic content and prominent megacrysts of feldspar. These feldspar megacrysts have been strung out in the foliation resulting in a partial augen texture.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	30
Quartz	25
Biotite	20
Potassium feldspar	15
Apatite	1
Zircon	1
Opaques	1
Secondary:	
Sericite	5
Muscovite	3
Limonite	1

This rock has an equigranular granoblastic texture. It has a prominent foliation arising from the parallel alignment of elongate quartz and feldspar grains, coincident with the preferential concentration and alignment of biotite.

The prominent megacrysts noted in hand specimen are mostly microcline perthite ranging up to 2 mm in length in this thin section. Some plagioclase also occurs as megacrysts. The plagioclase is both multiply twinned and untwinned and is oligoclase to andesine in composition. Alteration of the plagioclase to sericite and fine clays is variable in extent but common. The plagioclase has an average grain size of 0.3 to 0.5 mm.

Quartz is of variable grain size with undulose to strongly undulose extinction and considerable subgrain developments. Grain margins are curved to mildly serrated and the average grain size is similar to that of plagioclase.

Dark green-brown biotite occurs as flakes in parallel alignment. Individual flakes range up to 1 mm in length. There are minor but prominent amounts of zircon associated with the biotite, and some apatite. Apatite also occurs as discrete single grains in the quartzo-feldspathic material. Replacement of the biotite by muscovite can be seen in places. Blocky to anhedral opaques occur in trace amounts. There is some secondary limonite developed along grain margins in addition to the sericite and fine

clays.

This is a gneissic rock of granodiorite composition with a moderate biotite content. It was probably formed through intense deformation of a clay-rich sediment or alternatively could have been formed from a biotite-rich granitoid.

Sample: 6231 RS 111; TSC40856

Applicant's No.
DJF 40

Rock Name:
Amphibolite

Hand Specimen:
This is a mafic, well-foliated, medium-grained rock which also has a prominent lineation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Hornblende	60
Plagioclase	10
Quartz	5
Epidote	2
Apatite	trace
Opaques	1
Secondary:	
Sericite (and fine clays)	18
Chlorite	4

This rock dominantly consists of aligned elongate hornblende and variably altered plagioclase giving rise to the prominent foliation seen in hand specimen. The main fabric is cut by several thin zones of intense deformation and partial recrystallisation, and there are some quartz-rich zones or veins.

The hornblende is pale green to olive-green in colour. In places it shows a well developed amphibole cleavage. Individual elongate grains range up to 2 mm in length with most being between 0.5 and 1 mm. Grain margins are irregular with inclusions of plagioclase and altered plagioclase and there appears to be some alteration to chlorite.

The plagioclase is commonly strongly altered to sericite and fine clays. Some relict plagioclase does show multiple lamellar twinning. The plagioclase has an average grain size of 0.5 mm in length. Fine granular aggregates of epidote can also be seen to have formed at the expense of plagioclase. There is some coarser epidote, up to 0.5 mm in length, associated with the hornblende.

Minor amounts of quartz occur as discrete grains of similar size to the plagioclase, with undulose extinction. The quartz is also found in thin veins, commonly less than 0.2 mm in thickness. Irregularly-shaped opaques and traces of apatite can also be seen.

This is a well-foliated/lineated amphibolite that was probably formed through middle amphibolite grade metamorphism of a mafic igneous rock or calc-silicate sediment. There has been subsequent low retrograde metamorphism with the development of epidote and sericite, and some late-stage minor shearing.

Sample: 6231 RS 112; TSC40857

Applicant's No.
DJF 41

Rock Name:
Well-foliated, magnetite-bearing, tremolite rock or jade

Hand Specimen:
This is a well-foliated, fine-grained green rock with prominent white spots, approximately 1 mm in diameter, encircling opaque cores. These opaque cores are strongly magnetic.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	90
Opaques (including magnetite)	5
Clays	5
Apatite	trace
Biotite	trace
Zircon	trace

This sample is dominated by fine-grained fibrous tremolite which for the most part has a subparallel alignment, giving rise to the well-foliated nature of the hand specimen. The fine tremolite has an average grain size of less than 0.03 mm. Coarse tremolite knots and veins are also present, with individual coarse fibrous aggregates ranging up to 0.5 mm in length. Some ghost domainal textures are evident, however, most of the fibrous tremolite appears to have crystallised in the schistosity plane thereby obliterating earlier textures. The veins are oblique to the schistosity and appear to have developed in the axial planes of small scale crenulations. These veins consist entirely of coarser tremolite and up to 0.3 mm in width. In one area the veins exhibit a type of ptygmatic folding. Clouding of the tremolite is common in places and this appears to be due to alteration to clays.

Subhedral to euhedral early-formed opaques are a prominent constituent and are probably magnetite. These opaques have remained competent during deformation and the schistosity can be seen to wrap around. Some of the opaques have an envelope of extremely fine-grained alteration products which are probably clays. These clayey envelopes are the white spots noted in hand specimen. Secondary opaque phases are very irregular in outline and some occur along cracks subparallel with the foliation.

Round to elongate grains of apatite occur in accessory amounts. Several patches of poorly formed brown to fawn coloured biotite can be seen, and there are trace amounts of zircon.

This is a foliated tremolite rock that has a moderate magnetite component. The early-formed foliation has been crenulated and in places there are veins of coarser tremolite developed in the axial planes.

Sample: 6231 RS 113; TSC40858

Applicant's No.
DJF 42

Rock Name:
Tremolite rock or jade

Hand Specimen:
This is a fine-grained, dark green coloured rock with prominent circular to ovoid patches of coarser material which range up to 5 mm in diameter. On the weathered surface there appears to be an indistinct foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

		%
Tremolite	- fine	70-75
	- coarse	20-25
Opaques		2
Apatite		1
Zircon		trace

This sample is almost entirely composed of tremolite but in two distinct grain sizes. It occurs as a host of fine-grained colourless amphibole with an average grain size of less than 0.05 mm. The fine material is usually fibrous in nature with generally radiating clusters in random orientation, although in places there is a weak alignment of this fibrous material.

Coarser-grained tremolite comprises the prominent patches seen in hand specimen. Here the tremolite ranges in grain size up to 1 mm in length and the long axes of the tremolite is usually orientated in one of two directions either at approximately 60° or at 90° to adjacent tremolite. The coarse patches also contain fine tremolite aggregates which appears to have formed at the expense of the coarser tremolite, although there is evidence to suggest that the converse has also occurred. Some of the smaller patches of coarser tremolite have a core entirely composed of fine tremolite with a halo of coarse tremolite.

Apatite occurs as discrete elongate, round grains ranging up to 0.2 mm in length. Traces of zircon can also be seen. Opaques and/or fine clays occur as very fine-grained developments along cracks through the sample.

This is a tremolite rock or jade which shows two forms of tremolite development. Possible early-formed coarser tremolite aggregates appear to be degrading into finer tremolite.

Sample: 6231 RS 114; TSC40859

Applicant's No.
DJF 43

Rock Name:
Folded quartzo-feldspathic gneiss

Hand Specimen:
This is a medium- to coarse-grained, layered quartzo-feldspathic gneiss which shows open folding of the layering.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	25-30
Plagioclase	25-30
Potassium feldspar	20-25
Biotite	10-15
Muscovite/sericite	5
Opaques	3
Zircon	2
Apatite	trace

This sample has an equigranular granoblastic texture and consists of bands of biotite-rich and quartzo-feldspathic-rich material giving rise to the layering noted in hand specimen.

Both potassium feldspar and plagioclase are present with the plagioclase being slightly more abundant. Multiply twinned and untwinned plagioclase can be seen with an oligoclase composition evident. The plagioclase ranges in grain size up to 1.5 mm in length. Grain shapes are elongate with curved to irregular grain margins and some myrmekitic intergrowths. There is minor alteration to fine clays and sericite. The potassium feldspar is microcline and microcline perthite. It ranges in grain size up to 3 mm and tends to occur more as coarser elongate grains aligned in the layering.

The quartz is of variable grain size ranging up to 3 mm in length. It shows undulose to strongly undulose extinction, with the coarser grains having subgrain developments and more irregular grain shapes.

The biotite is fawn to red-brown in colour with abundant pleochroic haloes around zircon inclusions. Discrete, zoned zircon grains also occur together with the biotite-rich layers. The biotite flakes commonly lie between 0.3 and 0.6 mm in length. There does not appear to be any realignment of the biotite in the axial planes of the folds. In places fine flakes of muscovite occur interstratified with, and replacing, the biotite. Fine muscovite and sericite rims much of the biotite.

Opaques are irregular in outline and preferentially concentrated with the biotite. Zircon and possibly monazite are prominent accessory phases and there is a trace of apatite.

This is a well layered gneiss of granodioritic composition. The high zircon and biotite content suggests derivation from a sedimentary rock.

Sample: 6231 RS 115; TSC40860

Applicant's No.
DJF 44

Rock Name:
Tremolite rock or jade

Hand Specimen:
This rock has a thin brown weathering skin. On the cut surface it can be seen to be a pale to dark green coloured, very fine-grained rock which is generally massive.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
Fine clays	3
Apatite	2

This sample is composed dominantly of fine-grained tremolite with some relict coarse tremolite and a few scattered grains of apatite. The fine tremolite appears to be optically continuous in domains which range in size up to 6 or 7 mm in diameter. Some of these domains shows a ghost twinning structure. Elsewhere patches of coarse tremolite development can be seen to be partially to almost completely replaced by fine tremolite. This fine tremolite has an average grain size of less than 0.05 mm and commonly occurs as fibrous aggregates mostly in random orientation. In some areas there is a weak alignment of the fibrous tremolite. Apatite occurs as round elongate grains up to 0.3 mm in length. There is some clouding of the tremolite and fine-grained material developed along cracks probably consists of fine clays.

This is a tremolite rock or jade that shows an earlier coarse-grained texture replaced by massive aggregates of fine fibrous tremolite.

Sample: 6231 RS 116; TSC40861

Applicant's No.
DJF 45

Rock Name:
Tremolite rock or jade

Hand Specimen:
This sample has a 1 to 3 mm thick brown weathering skin. On the cut surface the fresh rock can be seen to be very fine-grained and dark green in colour.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
Clays	3
Apatite	2

This sample almost entirely consists of fine-grained tremolite with minor apatite, and dust-like inclusions near the weathering surface. The fine fibrous tremolite has an average grain size of less than 0.05 mm in length. It shows optical continuity in domainal structures which relate to earlier crystalline material. Ghost multiple lamellar twinning is apparent in some of these domains. The domains range up to 5 mm in length. Coarser-grained tremolite, up to 0.5 mm in length, occurs in a vein which has indistinct margins, and a moderate proportion of fine tremolite. Apatite occurs as ovoid-shaped, discrete grains which range up to 0.3 mm in length. The sample has late-stage fine cracks and fissures which appear to be filled with clays. These clays also occur as a clouding of the tremolite in the weathering skin.

This is a fine-grained tremolite rock or jade. Relict domainal structures indicate an early coarse-grained precursor prior to the development of the fine tremolite. Some of the fibrous tremolite shows an indistinct parallel alignment.

Sample: 6231 RS 117; TSC40862

Applicant's No.
DJF 46A

Rock Name:
Weathered diopside quartz rock

Hand Specimen:
This is a deeply weathered sample consisting of coarse-grained quartz with cream coloured ?diopside. The diopside forms coarse radial, columnar structures on one surface of the hand specimen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	40
Diopside	5
Tremolite/actinolite	2
Potassium feldspar	5
Plagioclase	5
Apatite	trace
Zircon	trace
Secondary:	
Clays	30-35
?Chlorite	5-10
Muscovite	3
Calcite	trace

This is a moderately deformed metamorphic rock consisting dominantly of quartz and the alteration products of ?diopside. The original pre-weathering texture appears to have been inequigranular granoblastic aggregates of quartz and diopside. The quartz ranges in grain size up to 3 mm in length. It shows undulose to strongly undulose extinction, considerable subgrain developments and sutured to cuspate grain margins. Most quartz grains are elongate and aligned in the foliation. More equant, generally ovoid grains of feldspar occur together with the quartz. Cross-hatch twinned microcline and multiply twinned plagioclase are both evident, ranging in grain size up to 0.3 mm.

The other main constituent of this rock has been extensively altered to a fine, very low birefringent clay ?kaolinite and in patches radiating fibrous aggregates of chlorite. There are some remnant grains of clinopyroxene, ?diopside, and these suggest that the bulk of the altered material was similar in composition, and approximately similar grain size as the quartz. Associated with the diopside there are some fine tremolite/actinolite aggregates and discrete elongate grains. Other primary phases present in trace amounts are apatite and zircon, with some zoned zircon grains evident.

Apart from the more dominant clays and chlorite, other secondary phases present in minor to trace amounts are muscovite, sericite, and rare late-stage calcite.

This is a diopside quartz rock that was probably formed through middle amphibolite facies metamorphism of a siliceous dolomitic marble. A late-stage weathering/hydrothermal alteration has led to extensive breakdown of the pyroxene.

Sample: 6231 RS 118; TSC40863

Applicant's No.
DJF 46B

Rock Name:
Partly mylonitised, sericitic quartzo-feldspathic gneiss

Hand Specimen:
This is a pale pink coloured quartzo-feldspathic gneiss with medium-grained quartzo-feldspathic rich layers and finer ?micaceous bands.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	30
Sericite	25
Quartz	20
Chlorite	10
Biotite	5-7
Muscovite	5-7
Opaques	2
Zircon	trace

This sample consists of quartz and plagioclase-rich, and sericite and biotite-rich bands. Within and adjacent to the micaceous bands there is a prominent mylonitic texture with the quartz and feldspar considerably strung out in the foliation planes. In the adjacent quartzo-feldspathic bands there is a more granoblastic texture with elongated grains not as intensely deformed.

The quartz occurs both as ribbon-like aggregates and disseminated grains. The ribbons consist of several elongate grains with subgrain developments and undulose extinction, possibly representing original single grains. Elsewhere the quartz is more irregularly-shaped with ragged to curved margins. There are some finer more ovoid quartz grains associated with the plagioclase.

The plagioclase commonly occurs as elongate grains up to 1.5 mm in length. Much of the plagioclase is untwinned and clouded by fine dust-like inclusions, ?clays. There is some twinned plagioclase and also some antiperthitic segregations.

The sericite forms most of the fine micaceous bands noted in hand specimen. It grades into fine muscovite but is mostly less than 0.04 mm in diameter. Where the coarser sericite/fine muscovite is developed it is orientated at a high angle to the mylonitic fabric.

Biotite occurs in stringers together with the sericite. Individual flakes range up to 1.5 mm in length, and many have fine opaque inclusions along the cleavage traces. Alteration to chlorite is common as is replacement by muscovite. Muscovite also occurs in the quartzo-feldspathic bands interstitial and replacing the feldspar.

Zircon is a prominent accessory phase and many of the elongate grains are zoned. The opaques mostly occur as fine inclusions within the micas.

This is a sericitic quartzo-feldspathic gneiss with a mylonitic texture. It was probably derived through intense deformation of a mica-rich granitoid or psammo-pelitic sediment.

Sample: 6231 RS 119; TSC40864

Applicant's No.
DJF 47

Rock Name:
Folded, biotite-rich granodioritic gneiss

Hand Specimen:
This is a grey coloured, coarse-grained, mica-rich gneiss with openly folded quartzo-feldspathic and mica-rich layers.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	25-28
Plagioclase	20-25
Potassium feldspar	15
Biotite	15-20
Muscovite	5-10
Sericite	10
Opaques	1
Zircon	1
Apatite	trace

The layering seen in hand specimen is a consequence of the alignment and concentration of biotite and lesser muscovite, and quartz and feldspar into layers. A layer parallel schistosity is also evident and both the layering and schistosity have subsequently been folded.

The quartz show a wide range of grain sizes up to coarse elongate grains greater than or equal to 5 mm in length. The coarse-grained quartz shows considerable subgrain developments, undulose extinction, and curved to sutured grain margins. Partial to complete recrystallisation has resulted in finer-grained interstitial quartz with some mosaics.

The feldspar is generally finer-grained with microcline and microcline perthite not as prevalent as plagioclase. Grain margins to the feldspars are similarly sutured and together with the quartz they give the rock a granoblastic, inequigranular, amoeboid texture. Both twinned and untwinned plagioclase are present, there is some myrmekite, and some alteration to sericite.

The olive-brown to green-brown biotite lies mostly with its long axes in the foliation/compositional layering, although there is some scatter of orientations about this fold plane. Individual flakes range up to 1.5 mm in length, and there are prominent pleochroic haloes around the abundant zircon inclusions. Muscovite is associated with the biotite, and also occurs aligned with the foliation. Whilst the muscovite appears to have replaced some of the biotite its orientation indicates that this is an early development.

Apatite, zoned zircon, and opaques occur in accessory amounts.

There has been substantial development of sericite, in preference along the micaceous-rich bands. The sericite forms massive aggregates with individual flakes in random orientation within the sericite bands following

the folded fabric. It also occurs as a secondary interstitial phase along grain margins in the quartzo-feldspathic bands.

This is a sericitised, folded, biotite-rich gneiss of granodioritic composition.

Sample: 6231 RS 120; TSC40865

Applicant's No.
DJF 48

Rock Name:
Veined tremolite rock

Hand Specimen:
This is a massive, pale green coloured rock which has a sugary texture. There is a 0.5 to 1 cm thick vein of coarser fibrous material.

X-ray Diffraction:
X-ray diffraction scans of the fibrous vein material and the host indicate that both phases are a monoclinic amphibole probably tremolite.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	95
Clays	5

This sample consists mostly of fine fibrous aggregates of a colourless amphibole which has been identified as tremolite by X-ray diffraction scans. The average grain size is of the order of 0.02 to 0.04 mm, with a gradation of the fine material into coarser amphibole. In places there is a subparallel alignment of the fibrous aggregates, giving the rock an indistinct foliation. As with other tremolite rocks from this province there is a relict domainal texture seen in the fine tremolite.

Coarser euhedral amphibole crystals are a secondary development in the fine host tremolite. These are often prismatic to needle-like in shape and range up to 1.5 mm in length. This amphibole has a marked higher relief than the host tremolite and there may be subtle chemical differences.

The coarser-grained fibrous vein noted in hand specimen also consists of tremolite. Individual grains range up to 5 mm in length, each consisting of very fibrous amphibole. Probably associated finer veins are also evident through the host tremolite. Alteration of the amphibole to pale brown, fine clay material is a late-stage development.

This is a tremolite rock that has coarse veins also consisting of tremolite.

Sample: 6231 RS 121; TSC40867

Applicant's No.
DJF 50

Rock Name:
Intensely deformed sericitic schist

Hand Specimen:
This is a grey-green coloured, strongly foliated rock with a protomylonitic texture. Coarse micas are prominent on the schistosity surface.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Sericite	60
Muscovite	15
Chlorite	15
Biotite	5
Plagioclase	5
Zircon	trace
Opaques	trace
?Epidote	trace
?Altered sphene	trace

The highly deformed nature of this rock is somewhat masked in thin section by a high proportion of sericite. The mylonitic to protomylonitic fabric is expressed by attenuated biotite and chlorite-rich bands, augen of granular ?sphene and opaques, and some very elongate plagioclase aggregates. A second fabric formed at a high angle is expressed by the development of muscovite.

Sericite forms the bulk of this rock grading into fine muscovite in places. Fine massive aggregates have an average grain size of less than 0.04 mm in diameter. The sericite/fine muscovite mimicks the mylonitic fabric in broad terms, however, on the finer scale the fine muscovite lies in a somewhat random orientation. Coarser muscovite, with individual flakes up to 1 mm in length, lie oblique and parallel to the main foliation. Those oblique appear to be subparallel indicating a second deformational phase.

Biotite appears to have been the early-formed mica. It lies in the main fabric with individual flakes up to 1.5 mm in length. Most of the biotite has now been replaced by chlorite. Chlorite also occurs interstitial to plagioclase in a prominent plagioclase-rich augen. Here the chlorite occurs as bundles of flakes in radial arrays. This chlorite appears to be secondary in nature and may be coeval with late-stage veins and coarse-grained patches which consist almost entirely of chlorite.

The plagioclase occurs as aggregates which have an overall augen-shape lying in the foliation planes. Within the augen or lenses the plagioclase ranges in grain size up to 4 mm, although most is less than 2 mm. There has been some recrystallisation of the coarser plagioclase into finer more equant grains. Antiperthitic exsolution features, multiple lamellar twinning, and minor alteration to sericite are common.

The opaques occur as elongate discontinuous aggregates in the foliation,

ranging up to 2 mm in length. Some of these lenticular aggregates appear to be a titania-rich phase possibly after sphene. Zircon is a prominent accessory phase occurring as zoned elongate and round grains. There is some late-stage mylonitic staining and there may be some epidote.

This is a sericitic schist that has suffered one major deformational event with a minor younger fabric also evident.

Sample: 6231 RS 122; TSC40869

Applicant's No.
DJF 52

Rock Name:
Weakly foliated tremolite rock or jade

Hand Specimen:
This sample has a 1 to 4 mm thick red-brown weathering skin which appears to show an indistinct foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	97
Clays	3
?Epidote	trace

The indistinct foliation noted in hand specimen is expressed in thin section by a parallel alignment of elongate coarser tremolite and fibrous tremolite. These coarser remnant grains range up to 2 mm in length and can be seen to be replaced by massive aggregates of fine tremolite. There is a gradation in grain sizes from the coarse tremolite down to the fine massive aggregates of fibrous grains which average 0.01 mm in diameter.

In places there are fine clots of high relief material which may be epidote. The sample has some cracks which appear to be filled with fine clays.

This is a tremolite rock or jade which has remnant coarser tremolite aligned in a foliation. Subsequent recrystallisation give rise to massive aggregates of fine fibrous tremolite.

Sample: 6231 RS 123; TSC40870

Applicant's No.
EAD 134

Rock Name:
Amphibolite

Hand Specimen:
This is a black, medium-grained rock with a prominent foliation and lineation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Hornblende	55-60
Plagioclase	5-10
Quartz	10
Opaques	1
Epidote	trace
Zircon	trace
Secondary sericite and clays	25

A parallel alignment of elongate hornblende gives the rock its prominent foliation/lineation. The hornblende is bright green to olive-brown in colour and ranges in grain size up to 1.5 mm in length. Grain margins are straight to curved, and there are many triple point junctions between adjacent hornblende grains.

The plagioclase is finer-grained and interstitial to the hornblende. It has an average grain size of 0.2 to 0.3 mm. Rare multiply twinned grains can be seen, but most of the plagioclase is altered to sericite and fine clays, and in some instances epidote.

Quartz is of a similar grain size to the plagioclase occurring as elongate to round grains, with curved grain margins and straight to slightly undulose extinction.

The opaques are blocky to irregular in outline. They range up to 0.3 mm in length, with most less than or equal to 0.1 mm. Zircon is present in trace amounts, occurring as inclusions within the hornblende giving rise to pleochroic haloes.

This is a well-foliated amphibolite that was probably formed through middle amphibolite facies metamorphism of a mafic igneous rock or possibly a calcareous sediment. The prograde metamorphism seems to have reached equilibrium as evidenced by the triple point junctions. A subsequent low-grade alteration gives rise to sericite after plagioclase.

Sample: 6231 RS 124; TSC40871

Applicant's No.
EAD 152

Rock Name:
Tremolite rock or jade

Hand Specimen:
This sample has a strongly weathered surface which shows an indistinct foliation. On the cut surface it can be seen a mottled dark green and pale green coloured rock.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite - coarse	35-40
- fine	60-65
Clays	4
Limonite	1
Opaques	trace
Apatite	trace
?Biotite	trace

This sample dominantly consists of tremolite in two distinct grain sizes. The coarse tremolite occurs as euhedral prismatic grains which range up to 3 mm in length. These tend to have a weak alignment in thin section. More irregularly-shaped coarse-grained tremolite occurs in aggregates and veins. Within a specific aggregate or vein the orientation of the cleavage traces is consistent, but not necessarily from one aggregate to the next. The coarse tremolite in the aggregates is distinct from the euhedral prismatic grains in that it appears to be replaced at its margins by finer tremolite giving rise to ragged grain margins.

The fine tremolite consists of massive aggregates of fibrous material, with an average grain size of 0.01 mm in length. Within these aggregates there is a coarse domainal structure consistent with derivation of the fine tremolite from earlier coarser tremolite.

Some brown micaceous material is found in association with the coarse tremolite and this may be biotite. Trace amounts of opaques and apatite can also be seen. Alteration to fine clay material is evident along prominent cracks through the sample. Some limonite occurs in association with this alteration.

This is a tremolite rock or jade which appears to show three stages of tremolite development. Early coarse tremolite recrystallises to fine fibrous aggregates. Euhedral prismatic tremolite is of uncertain age.

Sample: 6231 RS 125; TS40872

Applicant's No.
EAD 155

Rock Name:
Coarse tremolite rock with secondary epidote

Hand Specimen:
This is a coarse-grained green coloured rock which has some prominent bright green epidote segregations and veins. The rock is generally massive.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	80-85
Epidote	5
Opaques	2-5
Clays	8-10
Apatite	trace
Calcite	trace

This sample consists principally of elongate coarse-grained tremolite with prominent secondary epidote. The tremolite ranges in grain size up to 3 mm in length and is generally in random orientation. Within many of the coarser tremolite grains there is a clear colourless core which does not show any obvious cleavage. This core is usually surrounded by clouded, well-cleaved amphibole which is in optical continuity with the core. The clouded material appears to be slightly altered amphibole, ?clouded by fine inclusions of clay phases. In places there may be small amounts of ?plagioclase which have been replaced by amphibole through a metasomatic process.

The pale bright green coloured epidote is clearly secondary in nature, and occurs in discrete zones or veins. Individual grains tend to be elongate and prismatic, ranging in length up to 3 mm. More equant granular aggregates of epidote can also be seen.

Trace amounts of apatite occur as a primary phase ranging in grain size up to 0.2 mm. The opaques, however, are mostly of a secondary nature occurring as very fine granular material probably formed at the same time as the clay. Some limonitic developments are of a minor extent and there are very late-stage calcite grains found interstitial to the tremolite.

This is a tremolite rock with prominent secondary epidote. Early-formed more massive tremolite appears to have partly degraded into more fibrous tremolite with minor clay developed.

Sample: 6231 RS 126; TSC40873

Applicant's No.
EAD 156

Rock Name:
Quartz and opaque-bearing actinolite schist

Hand Specimen:
This is a foliated, generally fine-grained, dark green to black coloured rock with prominent thin quartz veins or bands. On the cut surface warping of the foliation/veining can be seen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Actinolite	55
Quartz	20
Opaques	20
Hornblende	1
Apatite	trace
Clays	3
Limonite	1

The foliated nature of this rock is expressed in thin section by a parallel alignment of elongate amphibole and quartz. A pale green coloured amphibole dominates and occurs both as coarser, relatively clear grains and as finer, clouded fibrous grains. This amphibole is probably actinolite in composition. The coarser clear actinolite ranges in grain size up to 5 mm in diameter for some relict grains which in places show prominent cleavage and rare twinning. Much of this earlier-formed actinolite has recrystallised into finer fibrous material with an average grain length of 0.3 to 0.6 mm. The fibrous amphibole is clouded by fine dust-like inclusions and opaques. The opaques rim many grains and also occur along relict cleavage traces, presumably a relict of the earlier amphibole. These opaques are very irregular in outline. Coarser discrete, blocky opaques are also present and range in grain size up to 0.6 mm in length.

Within the cores of some of the coarse actinolite trace amounts of hornblende can be seen. This hornblende is optically continuous with the surrounding actinolite and this implies a retrogradation of the hornblende to actinolite. Elsewhere trace amounts of discrete hornblende can be seen and these probably represent relict unaltered material.

The quartz occurs as irregularly-shaped elongate grains ranging up to 5 mm in length. It occurs in stringers or veins through the sample, parallel with the foliation. Grain margins are curved to cuspate and most grains show undulose to strongly undulose extinction with subgrain developments. Some of the quartz grains have a thin corona-like rim of actinolite, orientated perpendicular to the grain margins and oblique to the more general foliation shown by juxtaposed actinolite.

Trace amounts of apatite are present. There is prominent orange-brown limonite developed along late-stage cracks through the sample. Some of this also occurs interstitial to the fibrous amphibole together with

fine clays.

This is a quartz and opaque-bearing actinolite schist that was probably derived through amphibolite facies metamorphism of a siliceous dolomitic limestone. Possibly early prograde hornblende has been replaced by actinolite which has subsequently recrystallised into a more fibrous amphibole.

Sample: 6231 RS 127; TSC40874

Applicant's No.
EAD 160

Rock Name:
Biotite-quartz gneiss with pegmatite vein

Hand Specimen:
This is a grey to dark grey coloured quartz-rich gneiss which has a pegmatite-like vein on one side. The pegmatite contains very coarse biotite flakes which are up to 2 to 3 cm in diameter.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Host Gneiss:	
Quartz	75-80
Biotite	10-15
Plagioclase	5
Sericite	5
Muscovite	1
Opaques	trace
Apatite	trace
Zircon	trace
Vein:	
Plagioclase	40-45
Quartz	30-35
Biotite	20-25
Sericite/muscovite	1

The host gneiss in this sample consists mostly of elongate quartz with lesser biotite in a prominent schistosity. The quartz occurs as variably recrystallised coarse grains, with relict grains exceeding 5 mm in length. Undulose to strongly undulose extinction, considerable subgrain developments, and curved to cuspate grain margins typify the quartz.

The biotite is fawn to brown in colour, with individual flakes up to 2 mm in length. Some of the biotite shows curved or kink deformational features. The muscovite is present as a primary metamorphic phase.

The plagioclase is a minor constituent, varying in grain size up to 3 mm. Most grains are clouded or show alteration to sericite and fine muscovite. The sericite also tends to rim some of the biotite. Other constituents present in trace amounts are apatite, zircon, and opaques.

The pegmatite vein consists principally of very coarse-grained plagioclase and biotite with finer interstitial quartz. The plagioclase grains are up to a centimetre or so in length, show multiple lamellar twinning, and

some alteration to sericite and muscovite with minor secondary biotite. The coarse nature of the primary biotite can be seen in hand specimen. The quartz appears to represent recrystallised interstitial material.

This is a biotite-quartz gneiss that was probably derived through middle amphibolite facies metamorphism of a very siliceous sediment or quartzite. The pegmatite vein was developed post-deformation as the biotite does not appear to be preferentially aligned.

Sample: 6231 RS 128; TSC40875

Applicant's No.
EAD 163A

Rock Name:
Granodiorite gneiss

Hand Specimen:
This is a red-coloured, medium to coarse-grained granitoid with a distinct foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	60
Quartz	20-25
Biotite	5-10
Potassium feldspar	5
Muscovite	1
Opaques	1
Zircon	trace
Secondary clays and limonite	3

This sample has an inequigranular granoblastic texture. Coarser core grains of plagioclase are surrounded by generally finer quartz and plagioclase aggregates. The coarser plagioclase ranges in grain size up to 2 mm in length, and is aligned with its long axes in the foliation. It shows multiple lamellar twinning, some myrmekitic intergrowths, and is of an andesine composition. Plagioclase feldspar is a minor constituent with microcline evident as finer interstitial grains.

Some of the quartz is of a similar grain size as the coarse plagioclase and shows prominent subgrain developments. For the most part, however, the quartz is less than or equal to 0.5 mm in diameter. It shows undulose to strongly undulose extinction and curved to cuspate grain margins.

The biotite occurs as discontinuous stringers in the foliation planes. It is fawn to deep green-brown in colour and ranges up to 0.6 mm in length. There is alteration/replacement of the biotite by muscovite and possibly some chlorite.

The opaques are generally very irregular in outline and range up to 1 mm in length. They are of a secondary nature and can be seen encircling biotite and plagioclase. There is also some limonitic developments along grain margins together with some fine clays.

This is a granodioritic gneiss that was probably formed through amphibolite facies metamorphism of a granodiorite.

Sample: 6231 RS 129; TSC40876

Applicant's No.
EAD 163B

Rock Name:
Biotite-bearing amphibolite

Hand Specimen:
This is a well-foliated, medium-grained, dark green to black rock. On the foliation surfaces coarse flakes of mica are prominent.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Hornblende	45
Plagioclase	40
Quartz	5
Biotite (and ?muscovite)	5
Opaques	1
Secondary sericite (fine clays)	4
Limonite	trace

The well-foliated nature of this rock is a consequence of the parallel alignment of elongate hornblende and plagioclase, and biotite. The hornblende is pale green to aqua-green in colour. It has a well developed amphibole cleavage and ranges in grain size up to 1.5 mm in length.

The plagioclase is slightly finer-grained than the hornblende with an average grain size of 0.3 to 0.6 mm. Multiply twinned plagioclase is common and it is of an andesine (to labradorite) composition. Alteration of the plagioclase to sericite and some fine clays is variable but quite extensive in places.

Biotite is a distinctive constituent of this rock, it is pale brown to golden-brown in colour and the flakes are generally aligned in the foliation, with some appearing to be warped. Individual flakes are commonly between 0.5 and 1 mm in length. Some finer biotite occurs interstitial to the hornblende, and appears in part to be replacing it together with some sericite/fine muscovite.

Quartz occurs as discrete grains or grouped into short bands in the foliation. It ranges in grain size up to 1 mm, shows undulose extinction, and curved grain margins.

The opaques are blocky to anhedral in outline with an average grain size of 0.1 mm in diameter. Small amounts of limonitic staining along grain margins are evident.

This is a biotite-bearing amphibolite that was probably formed through middle amphibolite facies metamorphism of a mafic igneous rock or possibly a calcareous iron-rich sediment. The prograde metamorphic assemblage was probably hornblende, plagioclase, opaques, and/or quartz, with secondary metamorphism giving rise to the biotite.

Sample: 6231 RS 130; TSC40877

Applicant's No.
EAD 165

Rock Name:
Altered dolerite

Hand Specimen:
This is a greenish-brown coloured, medium to fine-grained rock which is generally massive with no obvious foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	40
Opaques	8
Hornblende	5
Clinopyroxene	5
Biotite	2

Secondary:

Sericite (and fine clays)	15-20
Limonite	10-15
Chlorite	5-10
Epidote	trace

The primary igneous texture is still evident in thin section, however, much of the primary ferromagnesian phases have been extensively altered. The plagioclase is moderately altered and randomly oriented laths are a prominent igneous feature. Individual plagioclase laths range up to 1 mm in length with most less than or equal to 0.3 mm. Alteration to sericite is variable with unaltered plagioclase evident in some places whilst in others sericite predominates.

Relict primary igneous clinopyroxene crystals can be seen and some early-formed hornblende and ?biotite are present. These phases occur interstitial to and enclosing the plagioclase giving the rock a subophitic texture. The grain size of these ferromagnesian minerals is similar to the finer plagioclase material. Blocky opaques are the other primary phase evident. These are also interstititial to the plagioclase and have an average grain size of 0.1 to 0.15 mm in diameter.

Apart from the sericite the other dominant secondary minerals are chlorite and limonite. The chlorite is formed at the expense of the above ferromagnesian phases and the secondary limonite occurs together with the chlorite, as well as forming thin veins through the sample, and staining most grain margins. Trace amounts of epidote have been observed.

This is a dolerite that has been subjected to an intense weathering resulting in a high proportion of sericite, chlorite, and limonite. Whilst the rock is intensely weathered there is little evidence of deformation and the primary igneous texture is preserved.

Sample: 6231 RS 131; TSC40878

Applicant's No.
EAD 167

Rock Name:
Ferruginised, quartz-sericite-plagioclase schist

Hand Specimen:
This sample has a prominent red coloration in hand specimen. It is a well-foliated, coarse-grained rock.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	25
Quartz	20
Sericite	20
Secondary iron oxides	10
Muscovite	5
Biotite	5
?Kaolinite	5
Zircon	trace

The well-foliated nature of this sample can be seen in the thin section to be a consequence of parallel aligned sericite-rich bands and coarser, more massive plagioclase and quartz-rich bands.

The sericite-rich bands have in part developed at the expense of earlier-formed coarser micas in a similar orientation. Some relict biotite flakes are present, ranging up to 1 mm in length. These are replaced by muscovite and/or sericite, or have been altered to clay material ?kaolinite. Some fine muscovite also occurs together with the sericite, most probably representing a prograde development from that mineral.

The sericite-rich bands also contain abundant opaques, mostly of a secondary or remobilised origin. These appear to be principally iron oxide phases which have a very regular morphology, occurring as interstitial phases infilling any voids or cracks in the sample. The secondary iron oxides are also prominent in the plagioclase and quartz-rich bands, and occur along grain margins or cleavage traces, or in cracks.

The plagioclase ranges in grain size up to 4 mm in length. Both twinned and untwinned plagioclase are present and there is variable alteration to sericite and fine clays. The quartz is very irregular in grain size with remnant coarser grains of a similar size to the plagioclase, however, due to the deformation the quartz has been in part recrystallised into finer interstitial material. The coarser-grained quartz shows subgrain developments, strongly undulose extinction, and cuspate to curved grain margins. Secondary sericite and muscovite occur interstitial to the plagioclase and quartz in these bands.

Zircon is present in accessory amounts. The prominent red coloration noted in hand specimen is a consequence of the abundant secondary iron oxides. Some colourless low birefringent material associated with the

alteration of the early-formed micas and secondary sericite is probably kaolinite.

This is a ferruginised, quartz-sericite-plagioclase schist that was possibly formed through low amphibolite facies metamorphism of a granodioritic rock or sediment of similar composition.

Sample: 6231 RS 132; TSC40879

Applicant's No.
EAD 182

Rock Name:
Folded sericite schist

Hand Specimen:
This is a greenish-grey coloured, fine-grained rock with some coarser feldspathic segregations evident on the cut surface. The rock is weakly foliated with some crenulation of this foliation also evident on the cut surface.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Sericite	60-65
Muscovite	10
Biotite	10
Plagioclase	5-10
Chlorite	2-5
Opaques	1-3

In thin section this can be seen to be a well-foliated sample which has been folded. It dominantly consists of sericite and fine muscovite with lesser relict biotite and plagioclase. The sericite and fine muscovite have an average grain size of less than or equal to 0.02 mm in length.

Plagioclase occurs as disrupted granoblastic aggregates with an average grain size of 0.3 to 0.6 mm in diameter. Interstitial remnant biotite and secondary sericite after plagioclase indicate that the disruption is a consequence of the folding, with the more competent plagioclase behaving in a brittle fashion.

Biotite appears to be the earliest formed mica, occurring as brown to fawn coloured flakes which range up to 1 mm in length. Alteration of the biotite to chlorite and replacement by muscovite is common. Muscovite also forms some coarse aggregates which predate the folding. Biotite can be seen in these aggregates and both micas have an average grain size of 0.1 to 0.2 mm in length. In places, finer chlorite can be seen together with the biotite and muscovite. It occurs in aggregates of flakes with a somewhat radial structure.

Irregularly-shaped elongate opaque grains occur strung out in the primary foliation, and folded together with that fabric. The opaques range up to 0.5 mm in length.

This is a folded sericite schist which appears to have resulted from alteration of a more plagioclase and biotite-rich schistose rock, prior to or during the early deformation. Most of the secondary minerals appear to have been subjected to the second folding episode.

Sample: 6231 RS 133; TSC40880

Applicant's No.
EAD 184

Rock Name:
Garnetiferous amphibole-rich iron formation

Hand Specimen:
This is a banded, dark brown to grey-black coloured rock which is medium to coarse-grained. The hand specimen is magnetic to weakly magnetic.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Silicates:	
Amphibole	30
Garnet	20
Apatite	3
Plagioclase	trace
Quartz	trace
Opaques:	
Magnetite	5-10
Hematite	5-10
Ilmenite	2
Secondary:	
Goethite	15
Clays	10
Sericite	5

The banding noted in hand specimen can be seen in transmitted light to be a consequence of the concentration of garnet and amphibole into diffuse compositional layers. Aggregates of garnet form semi-to discontinuous stringers through the rock. The garnets are a pale pink colour, have equant subhedral to anhedral outlines, and range in size up to 0.6 mm with most lying between 0.1 and 0.3 mm. Alteration/ replacement of the garnet by goethite is present in some areas.

The dominant primary silicate phase is a colourless amphibole. Relict coarse grains may be up to 6 mm in diameter, with some well preserved amphibole 1 mm or so in length. The relict coarser grains consist of more fibrous secondary amphibole and contain abundant inclusions of opaques and garnet. The well preserved amphibole shows rare well developed cleavage and in places multiple twinning. This amphibole is probably of a cummingtonite-grunerite composition. Some finer ?recrystallised material is evident clouded with abundant fine granular opaques as inclusions and along grain margins. Alteration of the amphibole is common, with prominent clays (?kaolinite in some instances), iron-stained clays and sericite.

Apatite is the other notable silicate phase. It occurs as elongate to equant round grains, with an average grain size of 0.1 mm in length. Traces

of plagioclase and quartz can also be seen.

In reflected light the opaques can be seen to principally iron oxides with minor iron titanium phases. Magnetite is the early-formed oxide occurring both as discrete grains and as thin rims to the silicate grains. Individual discrete grains range up to 0.6 mm in diameter, although most are less than or equal to 0.3 mm. Some primary ilmenite is also present and this occurs both as discrete grains and together with the magnetite as combined grains.

Alteration of the magnetite to hematite is common and there are several stages of alteration preserved, from magnetite with rims and thin lamellae of hematite through to hematite pseudomorphs after magnetite with ?ilmenite and magnetite lamellae, i.e. martite. There is also prominent late-stage goethite developed.

The primary mineralogy of this rock appears to have been cummingtonite-grunerite, garnet, magnetite, and apatite. Early remobilisation of the oxides leads to rims of many of the silicate phases with magnetite, and the alteration of these to hematite is evident. Late-stage weathering has resulted in alteration of the amphibole to clays and sericite, and there has been prominent goethite developed.

Sample: 6231 RS 134; TSC40881

Applicant's No.
EAD 187

Rock Name:
Banded diopside actinolite rock

Hand Specimen:
This is a well layered medium-grained metamorphic rock consisting of alternating pale green and dark green compositional layers.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Diopside	∿45
Actinolite	∿45
Sericite	8
Epidote	1
Sphene	1
Plagioclase	trace
Apatite	trace
Zircon	trace

This sample consists of diopside-rich and amphibole-rich interlayers. The amphibole is pale green to pale yellow-green in colour and occurs as elongate grains up to 1.5 mm in length, with most less than or equal to 0.6 mm. A parallel alignment of the elongate amphibole grains gives the rock a prominent foliation.

Euhedral prismatic morphologies and well developed amphibole cleavage are common, although in places fibrous amphibole is developed. The amphibole is probably of an actinolite composition and some grains have pleochroic haloes around inclusions of zircon.

The diopside occurs as anhedral grains ranging up to 2 mm in diameter. It is of a similar colour to the amphibole. Grain margins are very irregular in places and ?secondary inclusions of mainly euhedral amphibole are common.

There are several thin discontinuous bands and patches of sercite and minor epidote. The epidote mostly occurs as fine granular aggregates. These bands and patches tend to be associated more with the diopside than with the amphibole, and most probably originally consist of plagioclase. In places some partly altered multiply twinned plagioclase can still be seen.

Minerals present in accessory amounts include sphene and apatite. The sphene occurs as irregular grains up to 0.6 mm in length, and the apatite occurs as round elongate grains averaging 0.1 mm. Trace amounts of zircon occur mostly as inclusions in the amphibole.

This is a banded diopside actinolite rock or calc-silicate, with some primary plagioclase that has been altered to sericite and epidote. The rock was probably formed through middle amphibolite facies metamorphism of a siliceous dolomitic limestone.

Sample: 6231 RS 135; TSC40882

Applicant's No.
EAD 188

Rock Name:
Garnet-bearing biotite quartzo-feldspathic gneiss

Hand Specimen:
This is a grey coloured medium-grained rock which is foliated. Some coarser quartzo-feldspathic segregations lie in the foliation plane.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	30-35
Quartz	30-35
Biotite	20
Potassium feldspar	10
Sericite (and muscovite)	3
Garnet	1
Zircon	1
Chlorite	trace
Opaques	trace

This rock has an equigranular granoblastic texture consisting dominantly of elongate grains of quartz and feldspar which have a parallel alignment. Together with the alignment of the biotite the quartz and feldspar produce a prominent foliation.

Quartz occurs as irregularly-shaped grains with curved to cuspate grain margins and undulose to strongly undulose extinctions. The generally elongate quartz grains range up to 2 mm in length. The coarse grains show the effects of deformation in the form of subgranular developments and partial recrystallisation into finer material of a more regular shape.

Plagioclase is the dominant feldspar and occurs mostly as untwinned grains up to 2 mm in length. Multiply twinned plagioclase is present, there is some myrmekite, and minor alteration to sericite. The potassium feldspar is generally finer-grained than the plagioclase, with an average grain size of 0.2 to 0.5 mm. It is a cross-hatch twinned microcline with some microcline perthite. The coarser quartzo-feldspathic segregation noted in hand specimen consists of plagioclase and quartz with a range in grain sizes up to 2.5 mm in length.

The biotite is fawn to red-brown in colour and has a subparallel orientation. Individual flakes range up to 1.8 mm in length, although most lie between 0.2 and 0.6 mm. There are abundant pleochroic haloes around zircon inclusions, and inclusions and rims of fine opaques are present in some grains.

Garnet is a minor but notable constituent of this rock, generally associated with the biotite. It is found as equant round grains, often cracked, with an average grain size between 0.3 and 0.6 mm. Alteration and replacement of the garnet by chlorite and sericite is evident.

Zircon is a prominent accessory phase occurring as round, elongate, and

composite grains up to 0.1 mm in length. Some monazite and/or xenotime may also be present grouped here as zircon. The opaques are mostly found as fine granular material associated with the biotite.

Apart from the chlorite and sericite after garnet, and sericite after plagioclase, there are a few fine flakes of muscovite which appear to have replaced biotite.

This is a garnet-bearing biotite-quartz-feldspar gneiss that appears to have been formed through middle to upper amphibolite facies metamorphism of a pelitic quartzo-feldspathic sediment or from a granitoid of slightly aluminous granodioritic composition.

E00162

Sample: 6231 RS 136; TSC40883

Applicant's No.
EAD 189

Rock Name:
Sericitised, garnet-bearing, biotite-plagioclase-quartz gneiss

Hand Specimen:
This is a weathered well-foliated and layered rock which has been crenulated. It is brown to orange-brown in colour.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	45
Plagioclase	15
Biotite	10-15
Opaques	3
Garnet	1
Zircon	trace
Secondary sericite and muscovite	20-25
Chlorite	1

Both the earlier-formed foliation and a secondary fabric associated with the crenulation of the first are well developed in this thin section. Parallel alignment of elongate quartz and biotite outlines both foliations.

The quartz occurs in a range of grain sizes a consequence of the variable recrystallisation. Coarser quartz ranges up to 3 mm with most lying between 1 and 2 mm in length. Abundant subgrain developments, curved to cuspate grain margins, and strongly undulose extinction typify the quartz. The plagioclase is of a similar grain size as the quartz although generally not as coarse. Untwinned and twinned plagioclase are both present and there is variable alteration to sericite.

Biotite is the primary micaceous phase, occurring as fawn to brown flakes up to 1.5 mm in length. The biotite is aligned both in the $?S_2$ and $?S_3$ fabric. Alteration and replacement by fine muscovite and sericite is common, with minor chlorite in places. The sericite also forms crenulated bands through the rock with some associated biotite. This sericite is secondary and may be formed after an earlier primary mica or feldspar, or could represent introduced material parallel to the foliation. Some coarser muscovite is also associated with the sericite.

Opaques occur both as discrete anhedral grains and more commonly as fine granular inclusions and rims to the biotite. Trace amounts of zircon are present and there are some conspicuous equant, strongly cracked grains of garnet in one patch.

This is an altered garnet-bearing biotite-plagioclase-quartz gneiss that has abundant secondary sericite. It was probably formed through a prograde middle to upper amphibolite facies metamorphism of a pelitic quartzo-feldspathic sediment or aluminous granitoid. An early-formed foliation designated S_2 has been crenulated and resulting in a S_3 fabric.

E00163

Sample: 6231 RS 137; TSC40884

Applicant's No.
EAD 193

Rock Name:
Diopside-tremolite rock

Hand Specimen:
On the broken surfaces this rock can be seen to be a medium to coarse-grained, dark green coloured rock with an indistinct foliation. The rock has a 1 to 3 mm thick orange-brown weathering skin.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	80
Diopside	10
Sphene	1
Apatite	1
Epidote	5
Opaques and fine clays	3

This rock consists mostly of tremolite in a variety of morphologies, and in places can be seen to have replaced primary clinopyroxene. The clinopyroxene occurs as colourless grains ranging up to 3 mm in length. The primary grain shape was rectangular, however, due to the replacement by tremolite clinopyroxene is generally ragged to granular with a strongly cracked character. It probably is of a diopside composition with the possibility of extending towards hedenbergite.

Much of the tremolite occurs as fibrous aggregates in coarse domains with optical continuity. Relict clinopyroxene can be seen in the cores of these domains and hence it is probable that the tremolite is a retrograde development after the clinopyroxene. Fibrous tremolite has an average grain size of less than 0.1 mm. Subsequent deformation of the coarse domains gives rise to a foliated texture in places with subparallel alignment of the fibrous tremolite. Partly euhedral, prismatic tremolite crystals are a late-stage development. These crystals range up to 1.5 mm in length and mostly have a random orientation. Patches of clouded darker coloured tremolite appears to be a consequence of secondary alteration with inclusion of fine-grained clay material.

Epidote occurs as irregular granular aggregates with grain sizes up to 1 mm in diameter, although mostly less than 0.5 mm. The epidote appears to have formed after the fibrous tremolite. Apatite and sphene are conspicuous accessory phases. The apatite occurs as round to elongate grains up to 0.3 mm in diameter. The sphene is mostly anhedral in shape, however, there is some prismatic grains up to 0.6 mm in length. Fine-grained opaques and/or clayey material occurs along cracks through the rock. Some grains are rimmed by a thin opaque film.

This is a diopside-tremolite rock that appears to have formed through a prograde upper amphibolite facies metamorphism of a siliceous dolomitic limestone. The prograde metamorphic assemblage appears to have been dominantly diopside. Subsequent retrograde amphibolite facies metamorphism leads to the development of tremolite and a later deformation has given rise to the variably developed foliation.

E00164

Sample: 6231 RS 138; TSC40885

Applicant's No.
EAD 201

Rock Name:
Epidote-bearing hornblende-biotite-quartz-plagioclase gneiss

Hand Specimen:
This is a dark medium-grained with fine leucocratic segregations which have a parallel alignment, giving rise to a prominent foliation. Thin, 1 to 3 mm thick veins cut across this foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	35
Secondary epidote	22
Quartz	15
Biotite	15
Hornblende	10
Opaques	2
Apatite	1
Sphene	trace

The foliated nature of this rock is due to subparallel alignment of elongated biotite and hornblende together with elongate quartz and plagioclase. The primary prograde metamorphic assemblage may have been plagioclase + hornblende ± quartz, however, this has been considerably modified with the development of biotite and later epidote.

The plagioclase is mostly untwinned, ragged grains with abundant secondary fine inclusions of quartz and epidote. Much of the plagioclase is clouded with fine clays. The quartz ranges in grain size up to 1.5 mm in length. The coarser elongate grains show subgrain developments, strongly undulose extinction and curved grain margins.

The hornblende is blue-green to brown-green in colour and relict grains range up to 1 mm in length. Most of the hornblende grains are ragged and have inclusions of biotite and epidote which seem to have formed at the expense of the primary amphibole. The fawn to brown coloured biotite mostly occurs together with the hornblende. Discrete biotite flakes range up to 1 mm in length, with most being less than or equal to 0.5 mm. The coarser biotite flakes have stringers of fine granular sphene which lie in the foliation plane. Elsewhere discrete single grains of sphene can also be seen.

Opaques and apatite tend to be preferentially associated with the biotite and hornblende. The opaques are anhedral in outline with an average grain size of 0.1 mm. Apatite occurs as round to elongate grains up 0.4 mm in length. Some prismatic apatite is present.

Epidote occurs both as irregularly-shaped granular aggregates throughout the host rock, and as coarse-grained veins. The epidote in the host is a late-stage development with some of it replacing hornblende and

and plagioclase. Discrete aggregates of epidote range up to 0.5 mm in length with much of the individual fine granular epidote less than 0.1 mm. The vein epidote is more uniform in grain size with an average of 0.2 to 0.3 mm in length. Clouding of the epidote with fine clay inclusions is a feature of these veins.

This is an epidote-bearing hornblende-biotite-quartz-plagioclase gneiss. It was probably formed through prograde amphibolite facies metamorphism of a basic igneous rock or impure calc-silicate sediment. The former is more likely. Subsequent retrograde metamorphism has led to the development of biotite and more recently epidote with secondary epidote veining.

Sample: 6231 RS 139; TSC40886

Applicant's No.
EAD 213

Rock Name:
Granodioritic gneiss

Hand Specimen:
This is a grey coloured, medium-grained gneissic rock with some coarser quartzo-feldspathic veining.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	45
Quartz	30
Chlorite (including biotite)	13
Sericite/fine muscovite	10
Opaques	2
Zircon	trace

This rock consists of granoblastic aggregates of elongate plagioclase and quartz, which together with the flakes of chlorite and lesser biotite have a parallel orientation, giving rise to the gneissic fabric.

Both multiply twinned and untwinned plagioclase are present with one or two relict grains ranging up to 4 mm in length. Most, however, are of the order of 1 mm or less. In places the plagioclase has been extensively altered to sericite and fine muscovite. There is a preferential concentration of this alteration into specific zones which are subparallel to the foliation. The plagioclase is of an oligoclase composition.

Quartz ranges in grain size up to 3 mm. Undulose to strongly undulose extinction, variable subgrain developments, and curved to mildly cuspate grain margins typify quartz.

The chlorite flakes have an average length of 0.2 to 0.3 mm. It is pale green to colourless, and in places relict biotite occurs with the chlorite implying that the chlorite is a secondary development.

Sericite and fine muscovite are prominent secondary phases. They form at the expense of plagioclase in specific zones. Sericite also occurs along many grain margins and at the junction of several grains.

Opaques and zircon are present in accessory amounts. The opaques range from well-formed blocky grains to irregularly-shaped material. They are generally less than 0.1 mm in diameter. The round to elongate zircon grains are present in trace amounts.

This is a gneissic rock of granodioritic composition that was probably formed through amphibolite facies metamorphism of an igneous precursor, although the derivation from a sediment of a similar composition is also possible.

E00167

Sample: 6231 RS 140; TSC40887

Applicant's No.
EAD 219

Rock Name:
Diopside rock with quartz-sericite veining mantled by actinolite-tremolite

Hand Specimen:
This is a higly veined rock consisting of a pale green, coarse-grained massive host with abundant coarse ?quartzo-feldspathic veins. The veins have a thin rim of dark green material. On the cut surface one end of rock appears to be well foliated.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Host:	
Diopside	90-95
Actinolite-tremolite	5-10
?Epidote	trace
?Clays	0-5
Vein:	
Quartz	55-60
Sericite	30-35
?Amphibole	5-10
Apatite	1
Vein Rim:	
Actinolite-tremolite	100
Zircon	trace

The host material for this rock dominantly consists of granoblastic aggregates of clinopyroxene of a diopside composition. The diopside occurs as equant grains which range up to 2 mm in diameter, with most being of the order of 0.3 to 0.6 mm. A feature of the diopside is its strongly cracked nature with secondary actinolite-tremolite and some fine clays infilling the interstices. Clouding of the grains with fine ?clayey material and intergranular thin rims of clays can also be seen. Minor amounts of epidote are a secondary development.

The main vein material consists of quartz with abundant interstitial sericite and ?amphibole. The quartz ranges in grain size up to 3 mm and the deformed nature of the quartz is evidenced by strongly undulose extinction and variable subgrain development. Grain margins are cuspate to curved with relict triple point junctions evident. Interstitial to the quartz are dominantly sericite developments which are formed at the expense of an earlier phase of a similar grain size to the quartz. In some of the sericite-rich patches relict amphibole can be seen, however, some of the original grains may have been a feldspar. Accessory phases observed in the veins are apatite, biotite, and chlorite. The apatite

grains are up to 0.5 mm in length.

The veins are mantled by aggregates of subhedral actinolite/tremolite. This amphibole is pale green to colourless and rare grains are up to 7 mm in length, with most being less than or equal to 1 mm. Well developed amphibole cleavage is common and some grains have pleochroic haloes around inclusions of zircon. The boundary between the diopside and the amphibole rims is ragged with the amphibole enclosing some of the host diopside.

This is principally a diopside rock which has been veined with quartz and sericite material in turn mantled by actinolite-tremolite. The host rock was probably formed through amphibolite facies metamorphism of a siliceous dolomitic marble. Subsequent veining has resulted in the remobilisation of the calcium magnesian phases leading to the development of actinolite-tremolite rims to essentially quartzo-feldspathic veins which also contain amphibole.

Sample: 6231 RS 141; TSC40888

Applicant's No.
EAD 222

Rock Name:
Garnet-bearing serpentinised olivine calcite dolomite

Hand Specimen:
This is an off-white to grey coloured coarsely crystalline rock with a prominent dark mineral banding.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Dolomite	45
Calcite	25
Serpentine	15
Olivine	5
Opaques	5
?Chlorite	4
Garnet	1

This sample is dominated by granoblastic aggregates of dolomite and calcite, with lesser interstitial olivine and serpentine. The dolomite occurs as coarse anhedral grains up to 4 mm in diameter. Grain margins are curved to cuspate and most grains are twinned. The calcite is generally finer-grained than the dolomite, ranging up to 2 mm in diameter, with a higher proportion less than 1 mm. It is twinned and grain margins are curved. The calcite occurs preferentially together with the serpentine and olivine, and appears to be a secondary development. In places it is interstitial to the dolomite. The association of calcite with olivine and serpentine implies that magnesium is incorporated in the olivine during prograde metamorphism whereby calcite forms rather than dolomite.

Olivine occurs as anhedral round grains which originally were up to 3 or 4 mm in diameter. There has been extensive alteration of the olivine to serpentine, and now only scattered relics of strongly cracked olivine grains remain. Colourless well crystallised flakes of a micaceous mineral occur with the olivine/serpentine-rich bands. Individual flakes are commonly between 1 and 3 mm in length. This mineral has anomalously low interference colours and appears to be a chloritic phase which may have replaced an earlier mica, ?phlogopite. In some patches of serpentine there is more obvious pale green coloured chlorite.

The opaques show a variety of morphologies, with blocky to elongate grains occurring in the host dolomite and calcite. Very irregularly-shaped opaques occur in the serpentine patches, in part occurring as relict rims to the original olivine grains. Some opaques occur interstratified with the dolomite.

Garnet is a conspicuous accessory phase. It is found as granular forms

up to 0.5 mm in diameter and tends to be associated with the ?chlorite and serpentine/olivine-rich bands.

This rock appears to be originally a garnet-bearing olivine-calcite-dolomite that was formed through prograde amphibolite to low granulite facies metamorphism of a mildly siliceous dolomitic limestone. The formation of the olivine which is possibly of a forsterite composition is a prograde metamorphic development, subsequent retrograde metamorphism has led to the formation of serpentine.

E00171

Sample: 6231 RS 142; TSC40889

Applicant's No.
EAD 226

Rock Name:
Altered dolerite

Hand Specimen:
This is a medium to fine-grained mafic rock with randomly orientated white lath-shaped crystals of ?plagioclase. The rock is generally massive with no obvious foliation.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	45
Biotite	20
Hornblende	10
Opaques	10
Sericite/fine clays	10
Secondary iron oxides	5
Epidote	trace

The primary igneous texture of this rock is preserved in the form of randomly orientated laths of plagioclase. The interstitial primary ferromagnesian phases, however, have been extensively altered. Individual plagioclase laths range up to 1 mm in length. They are commonly twinned and have ragged grain margins particularly along the lengths of the laths. The plagioclase is of an andesine labradorite composition. Alteration to sericite and fine clayey material is variable, but quite extensive in places.

The primary ferromagnesian phases now consist of very fine-grained green to brown coloured material which in part resembles biotite, and in part a fine admixture of sericite, clay, and iron oxides. Discrete clearly discernible fine flakes of biotite can be seen and these grade imperceptibly into the adjacent admixture. Green to blue-green coloured hornblende is also present, and appears to be formed earlier than the above admixture. Discrete partly euhedral elongate hornblendes are a rare late-stage development.

The opaques are a prominent primary phase. They range in size up to 2 mm with most being between 0.5 and 1 mm in diameter. Blocky to equant irregular outlines typify the opaques.

Epidote is a secondary phase present in trace amounts.

This is a dolerite that has been subject to an intense weathering giving rise to the high proportion of secondary ferromagnesian phases. It is similar in texture and mineralogy to sample 6231 RS 130.

Sample: 6231 RS 143; TSC40890

Applicant's No.
EAD 230

Rock Name:
Altered dolerite

Hand Specimen:
This is a medium to fine-grained, greenish-black coloured rock which is generally massive.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	45
Sericite (including fine clays)	20
Hornblende	15
Biotite	10
Opaques	10
Clinopyroxene	trace

The primary igneous texture of this rock is evident in the form of randomly orientated laths of plagioclase. Interstitial primary ferromagnesian phases have been extensively altered or replaced, as has the plagioclase. Plagioclase laths range up to 1 mm in length and have ragged margins. Most show multiple lamellar twinning. Alteration to sericite is variable with unaltered plagioclase evident in places, whilst elsewhere sericite and fine clays may dominate.

Some relict clinopyroxene can be seen, however, most of the primary igneous phase has been replaced by hornblende and to a lesser extent biotite. The hornblende is green to green-brown in colour and grain shapes are very irregular although tending to be elongate. The biotite is brown to green-brown in colour with an average grain size of less than 0.1 mm. No well-formed flakes have been seen and it appears that the biotite may be formed after the hornblende with a fine-grained admixture of the two prominent in some places.

The opaques are a primary igneous phase and occur as blocky to irregularly-shaped grains with an average grain size of 0.1 mm. Secondary iron staining is present in minor amounts.

This is a dolerite that has been considerably altered with the randomly orientated igneous plagioclase laths still present, however, the interstitial ferromagnesian has been replaced or altered. The rock is similar in texture and mineralogy to 6231 RS 130 and RS 142.

Sample: 6231 RS 144; TSC40891

Applicant's No.
EAD 232

Rock Name:
Biotite-quartz-feldspar gneiss

Hand Specimen:
This is a medium to coarse-grained, micaceous quartzo-feldspathic gneiss with much coarser quartzo-feldspathic segregations in places forming augen. The rock is pink in colour with black and grey coloured more micaceous bands.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Potassium feldspar	30
Quartz	25
Plagioclase	20
Biotite	15
Muscovite	2
Apatite	1
Zircon	trace
Sericite and fine clays	5
Secondary iron oxides	2

This rock has an equigranular granoblastic texture. The biotite is preferentially concentrated into stringers through the rock and there is a subparallel alignment of elongate quartz and feldspar grains.

Potassium feldspar is more dominant than plagioclase. Microcline, microcline perthite, and perthite are all present. The coarser augen-like grains noted in hand specimen are microcline perthite in composition, and these are simply twinned and range up to 1 cm in length in this thin section. Elsewhere the feldspars are finer-grained, generally being between 0.5 and 1.5 mm in diameter. The plagioclase is more commonly untwinned than twinned. Myrmekitic intergrowths with quartz are present and the plagioclase tends to be clouded with fine alteration products, sericite and fine clays.

Quartz occurs as irregularly-shaped grains with undulose to strongly undulose extinction and a variable subgrain development. It is of a similar grain size to the feldspar.

Biotite is dark green-brown to green-brown in colour. The flakes range up to 1.5 mm in length. Finer-grained muscovite occurs together with the biotite and is of a secondary nature. The muscovite ranges in grain size up to 0.1 mm, generally less than 0.05 mm, and lies oblique to the main foliation.

Apatite is a prominent accessory phase occurring as round to elongate grains between 0.1 and 0.2 mm in diameter. Round to elongate zircon

grains are also present in accessory amounts. There is one aggregate of colourless high relief grains associated with the biotite stringers, and these may be zircon or xenotime. Apart from the secondary sericite and fine clays there is some secondary iron oxides.

This is a biotite-quartz-feldspar gneiss that was probably formed through middle amphibolite facies metamorphism of either a granitoid or an arkosic sediment.

Sample: 6231 RS 145; TSC40892

Applicant's No.
EAD 240

Rock Name:
Chlorite-plagioclase rock

Hand Specimen:
This is a grey-green coloured, medium-grained rock which has a foliation or weak compositional banding.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	60-65
Chlorite	30-35
Opaques	3
Sericite and fine clays	2
?Sphene	trace
Muscovite	trace
Zircon	trace

This rock consists of equigranular granoblastic aggregates of plagioclase with finer interstitial chlorite. The plagioclase has an average grain size of 0.4 to 0.6 mm in diameter, it is both twinned and untwinned, and shows minor alteration to sericite and fine clays. The plagioclase is probably of an oligoclase to albite composition.

Chlorite is interstitial to the plagioclase and in places appears to be slightly younger in origin. It is pale green to colourless in colour, with flakes ranging up to 0.5 mm in length. Some muscovite is associated with the chlorite.

The opaques are generally irregular in outline and fine-grained. Some coarse ?framework structures of opaques are up to 1 mm in diameter, and these now consist of an altered mush of fine granular opaques.

Zircon is a prominent accessory phase occurring mainly as round elongate grains with some euhedral lithologies also present. Small amounts of a variably altered orange-brown coloured high relief phase is probably sphene. The grains are prismatic in places and range up to 0.5 mm in length with some showing twinning.

This is a chlorite-plagioclase rock that may have been formed through metasomatic processes and subsequently deformed.

Sample: 6231 RS 146; TSC40893

Applicant's No.
EAD 250

Rock Name:
Sericitic chloritic quartzite

Hand Specimen:
This is a green coloured, medium-grained rock with a prominent foliation. On the foliation surface coarse flakes of mica can be seen.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Quartz	75
Chlorite (biotite)	15
Sericite and fine muscovite	10
Opaques	trace
Zircon	trace
?Garnet	trace

This rock is dominated by granoblastic elongate aggregates of quartz, with lesser parallel aligned chlorite and fine interstitial sericite. The quartz grains range up to 1.5 mm in length, have undulose to strongly undulose extinction, and considerable subgrain developments. Grain margins are very irregular.

Chlorite occurs as pale green to colourless flakes that have replaced biotite. Relict biotite can be seen in places, however, most has been altered to the chlorite. The flakes are up to 1 mm in length, and often have pleochroic haloes around inclusions of fine zircon.

The sericite is found in the elongate aggregates and stringers interstitial to the quartz. It appears to have formed at the expense of an earlier phase, ?plagioclase, or developed in response to secondary fluid activity.

There are some colourless, high relief grains which are isotropic and therefore probably garnet in composition. The ?garnet ranges up to 4 mm in diameter, and is altered or replaced by chlorite and sericite.

Zircon is present in accessory amounts as are subhedral opaques which are up to 6 mm in diameter.

This is a sericitic chloritic quartzite that appears to have been formed through metamorphism of an impure quartz-rich sediment. The prograde metamorphic assemblage appears to have been quartz + biotite ± garnet, and this has subsequently been retrograded to chlorite with the introduction of sericite.

E00177

Sample: 6231 RS 147; TSC40894

Applicant's No.
EAD 250 Jade outcrop 113

Rock Name:
Tremolite rock or jade

Hand Specimen:
This is a medium to fine-grained, massive, dark green coloured rock. It has a thin orange-brown weathering skin.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Tremolite	90
Opaques	5
Epidote	3
Iron staining	2
Biotite	trace
Zircon	trace

This sample is dominated by tremolite which exhibits a wide range in grain sizes. Coarse sheaves of fibrous tremolite range up to 3 mm in length and have a partial radial structure. Finer radial aggregates of fibrous tremolite occur in domainal pattern in places with each domain ranging up to 3 mm in diameter. Some of these domains have epidote cores. Much finer-grained fibrous tremolite forms the remainder with grain sizes ranging down from 0.2 mm. The tremolite is generally colourless or iron stained, however, in places it has a pale green pleochroism which may indicate a more actinolitic composition for this sample as compared with other tremolite rocks described from the Cowell Province.

Epidote also shows a wide range in grain sizes. Coarse, pale yellow, subhedral to irregular grains are up to 1.5 mm in the cores of the tremolite domains noted above. Elsewhere the epidote occurs in granular aggregates with an average grain size of approximately 0.1 mm. There is a tendency for the tremolite to be greener in colour adjacent to the epidote possibly reflecting a more iron-rich composition. In some instances, brown to fawn coloured biotite occurs adjacent to these epidote aggregates.

The opaques show a variety of morphologies, some are euhedral with most being irregular in outline. The opaques range up to 0.5 mm. Zircon is present in trace amounts. Iron staining is prominent along cracks through the sample.

This is a tremolite rock or jade, that appears to show at least two forms of tremolite development, one of which contains cores of epidote.

Sample: 6231 RS 148; TSC40895

Applicant's No.
EAD 259

Rock Name:
Weakly deformed granite

Hand Specimen:
This is a medium-grained, grey coloured granitoid which on some surfaces appears to be weakly foliated.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Potassium feldspar	30-35
Quartz	25-30
Plagioclase	20-25
Biotite	6
Muscovite	2
Sericite	3
Opaques	2
Zircon and/or monazite	1
Chlorite	1
Apatite	trace

This sample shows the effects of a cataclastic deformation. Relict igneous phenocrysts of simply twinned potassium feldspar are evident in a rock which has a granoblastic texture and weak alignment of biotite flakes.

Potassium feldspar is more dominant than plagioclase, with perthite, microcline perthite, and microcline present. Many simply twinned potassium feldspars can be seen and these range up to 3 mm in length. Both untwinned and twinned plagioclase are present. It is generally finer-grained than the potassium feldspar and is variably altered to sericite and fine clays.

The quartz ranges in grain size up to 2.5 mm. Undulose to strongly undulose extinction and considerable subgrain developments typify the quartz. Grain margins are strongly sutured in places, and simple curved margins are also present. Some finer quartz mosaics are a consequence of the cataclastic deformation.

The biotite is brown to green brown in colour and some show small scale kinks. Individual flakes range up to 0.6 mm in length, and there is minor alteration to chlorite. Fine opaques and muscovite are commonly associated with the biotite. The muscovite ranges from fine interstitial material up to well-formed flakes of similar size to the biotite.

Zircon and/or monazite is a prominent accessory phase. Some of the zircon is euhedral, prismatic with many growth zones. Other grains are anhedral and may be monazite. The opaques are generally irregular in outline and range up to 0.3 mm in length. Traces of fine apatite are also present.

This is a granite which has suffered a mild cataclastic deformation.

E00179

Sample: 6231 RS 149; TSC40896

Applicant's No.
EAD 271

Rock Name:
Tremolite-epidote rock

Hand Specimen:
This is a coarsely crystalline, dark green coloured rock with some finer, cream coloured segregations.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Epidote	50-55
Tremolite	40-45
Clays	5
Sphene	trace
Zircon	trace
?Biotite	trace

This sample principally consists of earlier-formed coarse granular epidote and secondary mostly euhedral amphibole. The epidote is colourless, clouded to pale yellow-green in colour and ranges in grain size up to 3 mm in diameter. The coarser grains are cracked and have prominent secondary interstitial amphibole developed. The amphibole is colourless to very pale green in colour and is probably tremolite in composition, perhaps extending towards actinolite. The grains are commonly euhedral prismatic forms which range up to 2 mm in length. Typical amphibole cleavage is well developed on many grains. In places the tremolite is more fibrous and biotite can be seen to be forming.

There are one or two prominent grains of sphene, up to 1 mm in length. Zircon and opaques are accessory phases.

The clouding of the epidote appears to be a consequence of alteration and fine clays can be seen to be developed. Clayey material also occurs along grain margins.

This is a tremolite-epidote rock that was probably formed through amphibolite facies metamorphism of a siliceous dolomitic marble. The prograde mineralogy was probably epidote with secondary tremolite developed.

Sample 6231 RS 150; TSC41462; Applicant's No. DJF56

Rock Name:
Hydrothermally Altered Diorite

Hand Specimen:
This is a coarse grained grey/white coloured rock which on the cut surface has a finer grained band. The average grain size of the coarser bands either side of this finer band is 3 to 5 mm, with the finer material being between 1 to 2 mm in diameter.

Thin Section:
A visual estimate of the constituents present gives the following:

	%
Plagioclase	60
Biotite	25
Chlorite	10
Quartz	?5
Zircon	Trace
Opaques	Trace

This sample consists of coarse grained plagioclase with prominent interstitial aggregates of finer biotite, and lesser chlorite. The plagioclase ranges in grain size up to 4.5 mm in diameter. These coarser grains appear as remnants with finer grained recrystallised plagioclase at the margins, or as zones or patches within the relict coarse material. Much of the plagioclase exhibits multiple twinning and anti-perthitic exsolution features are common. Inclusions or blebs of ?quartz can also be seen. The plagioclase is probably of an oligoclase to albite composition. Alteration to sericite and fine muscovite together with replacement by biotite and chlorite can be seen.

Biotite occurs as fine aggregates interstitial to or as veins within the plagioclase. The biotite is khaki to olive green in colour and has an average grain size of 0.02 to 0.03 mm, with the range being up to 0.2 mm in length. The chlorite is colourless to very pale green. It is coarser than the biotite and tends to occur peripheral to the biotite aggregates as flakes ranging up to 1 mm in length. The chlorite also occurs within and replacing the plagioclase. Both the biotite and the chlorite are formed after plagioclase probably being introduced by hydrothermal activity.

Quartz is a minor component of the rock occurring as blebs within the plagioclase and thin veinlets around some plagioclase grains or infilling cracks. Zircon is present in trace amounts giving rise to pleochroic haloes in biotite. The opaques are mostly fine grained secondary hydrothermal iron oxide phases.

This rock appears to have primarily consisted of a dioritic composition with remnant plagioclase still evident. The early formed ferromagnesian phases appear to have been replaced by biotite and chlorite probably during a hydrothermal alteration.

6231 RS (151) DDH 17, 6.72 m Thin section C 42254

CHLORITE

Hand specimen: Massive, dark greenish block rock with about 2% disseminated yellowish grey and greyish orange aggregates but only to 1.5 mm across. Rock is soft with Hardness of 2½-3, and is very fine grained.

Thin Section:
Estimated mineral abundances (%) are:

Chlorite	98
Sphene/titanate	2
Apatite	tr

Chlorite forms only as radiating aggregates and sheaves up to 0.2mm across but averaging only 0.1mm across. Sheaves partly interlock and no preferred alingment is evident. Pleochroism is pale green.

Sphene or titanate has ragged irregular shapes but with a few relict crystal outlines, range up to 1 mm across and are the yellowish grey spots seen in hand specimen.

Comments:
Drill hole intersected 1.3 m of massive chlorite, which with chlorite + tremolite, forms hanging wall rocks to jade at outcrop #15.

ICP analyses reveals highest MgO content (24.2%) and TiO_2 (1.15%) of samples from DDH 14-17.

6231 RS 152 DDH 17, 7.86 m Thin section C 42255

TREMOLITE

Hand specimen: Massive tremolite rock exhibiting diffuse banding 2-5mm thick. Rock has speckled appearance with varying size and colour of tremolite aggregates defining banding. Aggregates and sheaves of tremolite range up to 1-2mm across. Colour bands are in shades of grey green (5G 5/2 to 10 G 4/2).

Thin section:
Estimated mineral abundances (%) are:

Tremolite	99
Epidote	trace
Opaques	trace

Tremolite is everywhere fibrous and wispy forming sheaves, rosettes and aggregates ranging up to 1mm across but averaging only 0.3mm across. Parallel alignment of fibres is present but minor, but overall, there is no alignment of aggregates or constituent tremolite. Interstital to tremolite aggregates is very fine-grained tremolite averaging 0.05 mm in length which forms about 15% of the total area. Coarsest tremolite appears to be formed first, followed by fibre sheaves, and then finest-grained matrix tremolite.

Epidote is in trace amounts only and opaques form minute dusting inclusions.

Comments:
Rock is coarse-grained tremolite marginal to jade intersected less than 1 m below in the drillcore. Texture is very similar to that of jade but much coarser grained; colour also matches that of jade.

6231 RS 153 DDH 17, 8.34 m. Thin section C 42256

TREMOLITE + CHLORITE

Hand specimen: Dark greenish black (5GY 2/1) aggregates of ?chlorite are to 30 mm across and consist of fine-grained ?chlorite with a grain size of 1 mm. These aggregates or 'pseudo-breccia' clasts are subordinate to a very fine-grained nephritic tremolite matrix, which is grey green (10 G 4/2), and contains small 0.5 - 3 mm chlorite-rich aggregates and one discontinuous band of sphene. Sphene has same characteristics as RS 151. Rock massive but with a poorly-developed schistosity in both chlorite-rich aggregates and tremolite rich matrix.

Thin section:

Estimated mineral abundances (%) are:

Tremolite matrix		Greenish black aggregates	
Tremolite matrix	58	Chloritised schistose matrix	90
Tremolite schistosity	40	Chloritised actinolite porphyroblasts	10
Chloritised actinolite	1		
Sphene	1		

Greenish black aggregates consist of about 90% fine-grained chlorite and 10% extensively chloritised ?actinolite porphyroblasts. Porphyroblasts are to 0.5 mm across and are aligned across the later $?S_4$ fine-grained chlorite schistosity. Porphyroblasts exhibit pale brown to light green pleochroism and low chlorite birefringence except in rim zones which show birefringence of actinolite. Chlorite schistosity folds the crystal cleavage of chloritised ?actinolite and schistosity is defined by very fine-grained aligned chlorite with an average size of only 0.02mm.

Grey green tremolite-rich zones consists of fine-grained tremolite -actinolite fibres which are aligned and indicating two schistosities. Schistosities show varying extents of development and preservation - being replaced by equant and very fine-grained tremolite-actinolite which form a matrix. Most tremolite-actinolite fibres are only 0.08 mm long.

Within this zone, chloritised actinolite exhibits pale green and green blue pleochroism, and form porphyroblasts about 0.3mm long which have a dimensional alignment in a tremolite-actinolite schistosity but a crystallographic alignment across it. Hence these porphyroblasts predate the schistosity. Rarer porphyroblasts are to 1 mm long and aligned in the schistosity. Yellowish grey specks of the hand specimen are ragged sphene grains to 0.7 mm across with minute opaque inclusions.

Comments:

Order of events is apparently:

- ?actinolite porphyroblasts
- tremolite-actinolite first schistosity
- " " second schistosity and chloritisation producing chlorite schistosity (? S_4)
- late-stage fine-grained equant tremolite-actinolite replacing the schistosites.

Sample is only 0.3 m from contact of jade lens.

6231 RS 154 DDH 17, 8.69 m. Thin section C 42257

NEPHRITE with chlorite

Hand specimen:

Banded with alternating bands 2-10 mm thick of greyish green nephrite/tremolite (5 G 5/2 to 5 G 5/3) and greenish black, speckled chlorite (about 5 GY 2/1).

Thin section:

Estimated mineral abundances (%) are:

Nephrite matrix	85
Chloritised porphyroblasts and aggregates	13
Chloritised actinolite	1-2
Apatite	trace
Pyrite?	trace

Nephrite consists of a very fine-grained mat of wispy tremolite where the mat size is no more than 0.05 mm long. Tremolite aggregates forming the mat are elongate and aligned where a cleavage/schistosity is locally developed. Schistosity slightly wraps around and enclosed chloritised amphibole porphyroblasts and chlorite-rich aggregates up to 1 mm long. Chlorite mostly forms sheaves and rosettes with no alignment with minor chlorite as larger flakes. However, chlorite-rich aggregates exhibit a poor to moderate dimensional alginment in the schistosity. Chloritised amphibole appears to have been cummingtonite with light yellow-green pleochroism but alteration is extensive.

Pyrite is subhedral, 0.9 mm across and partly oxidised producing a marginal Fe-staining in nephrite.

Comments: Sample is of jade from the hanging wall contact, is low grade because of chlorite abundance, and appears to have relicts of chloritised cummingtonite.

E00184

6231 RS155 DDH 17, 9.05 m Thin section C42258

NEPHRITE with chlorite

Hand specimen: Low-quality nephrite with abundant thin (1-3 mm) discontinuous bands of green black chlorite and speckled dark grey ?porphyroblasts. ?Porphyroblasts and chlorite bands constitute about 20-25%. Jade massive with colour about dusky green (5G 3/2) to greenish black (5G 2/2).

Thin section:

Estimated mineral abundances (%) are:

Nephrite matrix	70
Chloritised porphyroblasts and aggregates	29
Coarse-grained relicts of tremolite and ?anthophyllite	trace-1%
Titanate/sphene	trace-1%
Diopside	trace
Apatite	trace

Sample has many similarities with Rs 154 - a dominant nephrite matrix containing large chlorite aggregates and porphyroblasts, as well as a locally-developed cleavage or schistosity within nephrite. Differences to RS 154 are mainly in the extensive replacement textures still preserved:

- large chlorite aggregates exhibiting two generations of chlorite with euhedral actinolite needles.
- remnant diopside and ?anthophyllite
- relict coarse tremolite
- ghost-structures within nephrite
- large fractured actinolite needles within nephrite.

Chlorite aggregates are to 2.5 mm across but the largest individual chlorite is 1 mm. Pleochroism is pale brown to light green with some anomalous reddish brown pleochroism. This chlorite is partially replaced by a mosaic of extremely fine-grained chlorite with an average size of about 0.02 mm and of darker-green pleochroism. Prominent within the finer-grained chlorite are needles of ?actinolite to in excess of 1 mm long which also extend into zones of the earlier chlorite.

Nephrite schistosity is similar to that of RS 154 with better alignment in close proximity to the cleavage, and with goethitic /limonitic staining along the cleavage.

Remnant diopside and ?anthophyllite form as equant grains to 1mm which have been almost completely replaced by matrix nephrite.

Ghost textures are wholly within nephrite matrix; minute dustry inclusions outline former larger grains of 0.3 - 0.4 mm. Shapes vary from equant to irregularly elongate with rare ones suggesting typical amphibole cross-section.

One actinolite needle is 5 mm long, only 0.15 mm wide and is chloritised where fragmented.

Sequence of events may be:

1. Chlrotisation producing first-phase chlorite in aggregates
2. Formation of second-generation matrix chlorite, nephrite matrix and replacement of diopside, ?anthophyllite etc producing 'ghost textures'. Possibly formation of nephrite cleavage/schistosity.
3. Late-stage acicular actinolite, with minor chloritisation where fractured.

Comments: From central portion of low-quality chlorite-rich jade lens.

6231 RS 156. DDH 17, 10.52 m. Thin section C42259

NEPHRITE TREMOLITE

Hand specimen: Dusky green (5G 3/2) to greyish green (10 G 3/2) speckled tremolite rock. Grades from fine-grained and nephritic to coarser-grained aggregates 2-3 mm across of radiating tremolite. Low-grade nephrite of footwall contact. Diffuse banding from colour and grain size variations of tremolite.

Thin section:

Estimated mineral abundances (%) are:

Matrix nephrite	90
Coarse-grained tremolite and ?anthophyllite	9
Chlorite	1

Sample consists of a fine-grained nephrite matrix with relict coarser tremolite and ?anthophyllite, as we-l as aggregates up to 2.5 mm across.

Nephrite matrix consists of small sheaves and fibrous mats only 0.03 - 0.04 mm across and composed of finer tremolite fibres. Grain size grades up to 0.1 - 0.2 mm and elongate crystals interlock.

Coarser tremoliteis in aggregates to 2.5 mm across with parallel and subparallel alignments, as well as being partly replaced by matrix nephrite. Some coarse grains exhibit parallel extinction and very pale green pleochroism and may be anthophyllite.

Comments: Typical of matrix nephrite grading to coarse-grained aggregates of tremolite.

E00186

6231 RS 157 DDH 17, 10.69 m Thin section C 42260

DOLOMITIC MARBLE

Hand specimen: Banded dolomitic marble with alternating bands of:

- light greenish grey (5 G 7/1) medium-grained dolomite with less than 2% disseminated specks of green chlorite or yellow serpentine

- dark greenish grey (5 G 4/1) grading through to greenish black (5 G 2/1) dolomitic marble with more abundant aggregates and thin bands of chlorite and serpentine.

Thin section:

Estimated mineral abundances (%) are:

Dolomite	75
Tremolite poikiloblasts	15
Calcite	7
Opaques	2
Serpentine	trace-1

Banding is defined by mineralogical and grain size variations, as well as by opaque-rich bands.

Distinctive, is the very large, intensely poikiloblastic tremolite which ranges up to 5 mm across. Inclusions are dolomite, calcite and opaques. Poikiloblasts are restricted to dolomite-rich areas and in selected bands, but are randomly oriented.

Dolomite and calcite are granular, equant but with a widely variable grain size ranging from about 0.02 mm to 3 mm.

Serpentine is concentrated in one band which appears yellow in hand specimen and probably forms as replacement of large poikiloblastic olivine. Serpentine forms small diffuse aggregates of only 0.03 - 0.04 mm across but which in semicontinuous optical continuity with nearby aggregates over distances of 1-3 mm.

Opaques form en-echelon trails which cut across large poikiloblastic tremolite; these parallel very fine-grained dolomite bands and both may be related to tension gashes.

Comments: Marble is only 0.2 m from jade lens. Primary assemblage is apparently (coarse-grained) dolomite + tremolite + olivine. Olivine is later serpentinsed, with retrogressive calcite, dolomite, opaques and marked reduction in dolomite grain size.

6231 RS 158 DDH 17, 12.25 m C 42261

DIOPSIDE

Hand specimen: Massive, coarse-grained, off-white to yellowish-grey (5 Y 8/1) diopside rock with a primary grain size of 6-8 mm. Irregular cross-cutting fractures, 1-3 mm thick, apparently consist of retrogressive yellow-green epidote and greenish black chlorite.

Thin section:

Estimated mineral abundances (%) are:

Primary diopside	95
Secondary tremolite	3
" epidote	2
" opaques	trace
" serpentine	trace

Granular diopside rock with equant anhedra ranging up to 8mm across. Deformation and recrystallisation has reduced considerably the grain size so that the average size is only 0.3 mm in some areas. Deformation is evident by curved twins and cleavages, as well as numerous subgrains only in slight optical discontinuity from adjacent subgrains.

Pronounced thin deformation bands extend right across the sample, are only 0.2 - 0.4 mm wide and consist of fine-grained granular epidote, dolomite, dusty opaques and ?serpentine. Prominent brittle fracturing within and across diopside, particularly in large grains, are infilled by fine-grained calcite.

Prominent dark green black fractures in hand specimen is predominantly a vein of poorly-aligned tremolite up to 3 mm wide. Tremolite fibres are to 0.8 mm long and replace diopside. Also present are epidote and a thin, 0.2 mm wide, dolomite vein which is late-stage and central to the tremolite band.

Comments:

Primary mineralogy is 100% very coarse-grained diopside. Brittle fracture and recrystallisation is pronounced, as well as later retrogression to tremolite and epidote. A thin dolomite vein represents the final event.

6231 RS 159 DDH 17, 14.61 m Thin section C42262

DIOPSIDE

Hand specimen: Dominantly a very fine-grained greenish grey (5 G 6/1) rock, massive with disseminated darker green specks of chlorite and/or tremolite. Reflections indicate some of the greenish grey minerals are elongate and up to 3mm long. Appears to be a dolomitic marlbe except for elongate crystals.

Thin section:

Estimated mineral abundances (%) are:

Diopside	95
Chlorite	3
Dolomite	2

Rock consists predominantly of granular diopside with an average size of 0.8 mm but ranging up to 3 mm; many grains are elongate and tend to be acicular with length: breadth ratios exceeding 5:1. Chlorite and dolomite are interstitial to diopside.

Prominent cross fractures, up to 1 mm wide, are lined by dolomite but with minor chlorite and Fe-staining; epidote is absent.

Comment: Acicular diopside is unusual; coarse granular equant crystals of RS 158 are more typical.

E00189

6231 Rs 160 DDH 17, 15.89 m Thin section C42263

TREMOLITE SCHIST (mylonitised diopside)

Hand specimen: Tremolite schist with strong development of a tremolite schistosity which appears to be retrogressed diopside. Diopside relicts from small equant to elongate augen several millimetres across. Colour varies from off-white to light greenish grey (5 GY 8/1 to 5G 8/1) with darker dusky green bands (5 G 3/3) parallel to the schistosity.

Thin section:

Estimated mineral abundances (%) are:

Diopside relicts with tremolite overgrowths	5
Mylonite zone - tremolite	75
- calcite	11
- dolomite	5
- chlorite	4

Rock is a tremolite + calcite schist containing remnants of early phase, coarse-grained diopside with tremolite overgrowths. Dominant feature is the late-stage tremolite schistosity with parallel veins of dolomite.

Schistose tremolite is fine grained; fibres average 0.1 mm in length, have length: breadth ratios of about 4:1 and their alignment is good. In places, the tremolite schistosity shows repeated folding typical of mylonite zones. Calcite bands are also folded and predate at least some of the schistosity development. Dolomite bands are late stage and vary from planar to slightly sigmoidal and probably infill open fractures. Dolomite is as elongate grains perpendicular to vein margins.

Calcite of folded veins however is equant with an average size of 0.3 mm.

Diopside, as early phase relicts to 4 mm across, is equant to slightly elongate and has substantial overgrowths and rims of coarse-grained tremolite. Replacement by coarse-grained tremolite is often to the extent of 50-80%.

Chlorite is very fine grained and interstitial to tremolite forming the schistosity.

Comments: Sequence of events is apparently:

1. Coarse-grained diopside
2. Replacement of diopside by coarse-grained tremolite, ?plus calcite veining.
3. Mylonitisation with extensive development of schistose tremolite, folding of calcite veins, formation of chlorite.
4. Late-stage dolomite infilling open fractures or tension gashes.

6231 RS 161 DDH 17, 16.07 m Thin section C42264

RETROGRADED DIOPSIDE

Hand specimen: Dominantly massive off-white to light greenish grey (5 GY 8/1) diopside but with retrogression along numerous irregularly-distributed hair-line cracks. Retrogressive products are dusky green to greenish black and are probably mostly chlorite. Sample is 0.18 m from a mylonite zone through diopside producing tremolite schist (RS 160).

Thin section:

Estimated mineral abundances (%) are:

primary diopside	40
? sphene	trace
retrogressive chlorite	35
" tremolite	24
" calcite	1

Diopside has been extensively fragmented, recrystallised and retrogressed. Curved twin planes and cleavages are common, as well as subgrain development. New grains are often about 0.4 mm across and these smaller new grains are often in only slight optical discontinuity from neighbouring grains, indicating an earlier average grain size of 4 mm.

Retrogression is extensive with retrogression products of tremolite + chlorite more abundant than primary diopside. Tremolite is mostly randomly oriented except in narrow deformation bands where the alignment is good. In those zones tremolite averages 0.5 mm long and has a length:breadth ratio of 6:1. Chlorite is concentrated in the same areas as tremolite and occurs as isolated flakes as well as in sheaves and radial clusters; average size is less than 0.1 mm.

Comments: Sequence of events is:

1. Formation of coarse-grained diopside
2. Deformation, recrystallisation and retrogression during mylonitisation. Retrogressive assemblage consists of tremolite + chlorite ± calcite.

6231 RS 162 DDH 17, 17.68 m. Thin section C 42265

MASSIVE DIOPSIDE and TREMOLITE SCHIST

Hand specimen: Massive light greenish grey diopside, partially chloritised with dark greenish black chlorite lining irregular fractures, grading to tremolite schist where extensively retrogressed. Tremolite is very fine-grained and resembles nephrite - is slightly translucent and colour is dusky yellowish green (10 GY 3/2).

Thin section: Estimated mineral abundances (%) are:

Diopside zone		Tremolite schist zone	
Diopside	90	Tremolite	95
Secondary chlorite	5	Chlorite	5
" tremolite	5		

Diopside zone has the same characteristics as Rs 161 i.e. primary grain size of around 4 mm but with extensive subgrain development by deformation and recrystallisation, as well as retrogression.

Tremolite schist exhibits a diffuse banding defined by grain-size variations of tremolite. Several generations of tremolite schistosities are present as in Rs 160 and again is indicative of a mylonite zone. In addition, a crenulated schistosity is also present which probably has the same origin.

In places, large areas of elongate tremolite which extend for areas up to 4 mm across, are only in slight optical discontinuity and suggest possible early large tremolite grains of same size as diopside. Schistose tremolite averages 0.15 mm long with length:breadth ratios of 4:1 and is not fine enough to be classed as nephrite.

Dolomite is in late-stage fractures and veins which cut across the tremolite schistosity. Also forms in slightly signoidal ?tension gashes at a low angle to the schistosity.

Comments: Order of events is:

1. Coarse-grained diopside + ? tremolite or
2. Partially retrogressed to coarse-grained tremolite
3. Deformation, recrystallisation and retrogression produces tremolite schist. Retrogressive assemblage is tremolite + chlorite.
4. Late-stage veins of dolomite.

6231 RS 163 DDH 17, 18.20 m. Thin section C 42266

RETROGRADED DIOPSIDE

Hand specimen: Massive, light greenish grey diopside (as in Rs 161 & 162) grading to a pronounced speckled, which consists of irregular mottling of:

- very fine-grained greyish green (5 G 5/2) tremolite resembling nephrite and
- moderate greenish yellow (10 Y 7/3) epidote

Thin section: Estimated mineral abundances (%) are:

Diopside zone		Speckled zone	
Diopside	80	Tremolite	80
Tremolite	18	Epidote	20
Chlorite	2		

Diopside zone has some characteristics as in RS 161 and 162.

Speckled zone contains aggregates of very pale yellow epidote surrounded by tremolite; both are marked by abundant dusty inclusions. Epidote grains are to 2 mm across whereas surrounding tremolite averages 0.4 - 0.5 mm long. Tremolite has fewere inclusions than epidote. Both eipdote and surrounding tremolite are further surrounded and veined by clear tremolite which varies:

- from randomly-oriented, elongate tremolite-actinolite averaging 0.2 - 0.3 mm in length
- to veins consisting of minute tremolite of about 0.2 mm long where tremolite fibres have a sigmoidal shape at a high angle to the vein margin. The pattern is typical of S_4 tremolite schistosity/cleavage in outcrop.

Comments: Sample is of massive diopside with an unusual retrogressive style. Early phase retrogression produces epidote, tremolite overgrowths and abundant dusty inclusions. Second stage retrogression produces further tremolite of several forms; only minute tremolite in narrow cross-cutting veins approaches nephrite.

In the following sample, RS 164, this speckled retrogressive assemblage has been mylonitised.

6231 RS 164 DDH 17, 18.95 m Thin section C 42267

MYLONITISED RETROGRADED DIOPSIDE

Hand specimen: Sample is very similar to Rs 163 but has a mylonitic foliation superimposed - especially on the speckled zone.

Thin section: Coarse-grained, primary diopside on one margin of the thin section is similar to that in Rs 161 - 163 but is more extensively fragmented.

Mylonitisation has produced abundant submicroscopic flour or powder which is colourless, has high relief and is probably diopside and/or epidote. Mylonitisation also produces compositional and grain-size banding on a scale of 0.3 - 0.8 mm.

Largest remnants are of epidote aggregates 2-3 mm across strung out in the mylonitic foliation. Diopside forms smaller relicts. Tremolite, in relict aggregates and bands, tends to be acicular with lengths averaging 0.4 mm and length:breadth ratios of 5:1.

Comments: Mylonitisation is very much a comminution event with no obvious late-stage minerals. Some portions of the sample apparently contained only diopside prior to mylonitisation whereas others contained a mixture of diopside with retrogressive epidote and tremolite. Mylonitisation post-dates development of the speckled fabric in RS 163.

6231 RS 165. DDH 17, 20.05 m. Thin section C 42268

CONTAMINATED LEUCO-GRANITE

Hand specimen: Massive off-white and light grey leucogranite with white feldspar, grey quartz and a primary grian size of 2-3 mm. Abundant irregular fractures contain dusky yellow green and greyish olive epidote and greenish black chlorite. Some of the fractures are elongate and parallel, defining a retrogressive epidote-rich foliation at about 50° to the core axis.

Thin section: A microcline + quartz leucogranite with extensive deformation and recrystallisation, and with probably two periods of alteration. An early phase produced predominantly epidote, and was followed by chlorite and ?actinolite.

Estimated mineral abundances (%) are:

Primary microcline and quartz	70
Secondary epidote	19
chlorite	6
?actinolite	4
sphene	1

Microcline and quartz apparently form the only primary minerals - any mafic phases have been completely altered. Large equant primary grains of 2-3mm have undergone extensive subgrain development producing secondary grains averaging only 0.03 mm across and with diffuse, irregular and sutured grain boundaries.

Epidote or clinozoisite appears as an early alteration phase which may be the same age as subgrain development. Largest grain is 1 mm but most forms in fine-grained epidote ± sphene aggregates to several millimetres across or in epidote-rich bands across the slide. Colourless to pale yellow pleochroism.

Chlorite, with minor quartz, infills late stage fractures as well as around and within epidote-rich zones. Chlorite mostly forms in elongate sheaves oriented at a high angle to the fracture. Prominent within these fracture zones is minute acicular ?actinolite forming felted masses with needles only 0.05 mm long and exhibiting pale green pleochroism. At times, ?actinolite needles are oriented perpendicular to the vein margin and growing into adjacent feldspar. Aligned needles within the vein also, in places, show a crenulation.

Comments: Leuco-granite often grades, when fresh and unaltered, into massive microcline-quartz without a mafic phase present. Alteration phases of epidote, chlorite, ?actinolite and tremolite are only present in the contact zone of leuco-granite and dolomitic marble.

E00195

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME Pet. Rept. 12/84
1:100 000 Sheet 6231

Rept.Bk.No. 85/20
D.M.E. No. 454/82
Disk No. 117

THE GENESIS OF JADE AND HOST ROCKS IN DDH14 AT OUTCROP 15, COWELL JADE PROVINCE SOUTH AUSTRALIA

ABSTRACT

Specimens examined from the Cowell Jade Province illustrate the formation of nephrite jade from metamorphosed carbonate sediments. The jade is produced by a series of episodes of recrystallisation and replacement during the retrograde metamorphism of prograde assemblages. Diopside and epidote are the parental silicates of two parallel series of alteration products. Diopside alters to tremolite which recrystallises as nephrite of progressively finer grain sizes. At the same time the epidote series passes through clinozoisite to zoisite.

The quality of the jade is controlled partly by the composition of the original sediments. Silica content is the major control. At silica contents over 50%, calcium from the carbonate reacts to form the epidote series. At levels of silica below 40%, only magnesium carbonates react, producing olivine in prograde metamorphism and serpentinites and chlorites in the retrograde episodes. The ratio of magnesium to calcium is a secondary control. Specimens of good jade occupy a very restricted field in a ternary plot of composition referred to the critical components SiO_2, CaO and MgO. Specimens from DDH14 tend to contain more calcium than is ideal for high quality jade.

The physical control of quality is the fineness of grain size in the nephrite. The best jade with the darkest colour consists of a finely felted mesh of tufted nephrite. Late stage alteration, probably hydrous, promotes regrowth of coarse grained tremolite and reduces the quality of the jade. Fine grain size is produced by recrystallisation and appears to be independent of tectonic stress. Some local stresses may be related to volume changes during alteration.

INTRODUCTION

Twenty two samples in hand specimen and thin section were received for petrographic examination from Don Flint of the Mineral Resources Branch. The specimens were cut from drill core between 5.89 m and 36.51 m in diamond drill hole 14 at outcrop 15 in the Cowell Jade Province, Eastern Eyre Peninsula. Particular interest was expressed in the textural relationships between minerals as an indication of the alteration history of the rocks.

The investigation is part of a continuing programme of geological mapping and diamond drilling of the Jade Province by Messrs. Flint and Dubowski. Chemical analyses of drill core are listed in AMDEL report AC 4545/84. Drilling logs and reports on geological mapping at outcrop 15 and in the vicinity of outcrops 32 and 36 by the above authors are in preparation.

PETROGRAPHY

Specimen 6231 RS 166, TS C42269, 5.89 m

Rock name. Amphibolitised calc silicate rock.

Hand Specimen

The specimen is banded at right angles to the length of the core. The bands consist of fine grained green minerals, a coarse grained intergrowth of green and black, vitreous minerals, very coarse grained white minerals with black veining, a fine grained black mineral and a large proportion of fine to medium grained grey mineral in close intergrowths with poorly-defined grain boundaries.

Thin section

One end of the thin section is composed of coarse crystals of epidote with interstitial amphibole. The epidote is patchy in composition with colourless and pale yellow, weakly pleochroic areas, probably depending on a low but variable iron content. The amphibole is colourless and occurs as closely intergrown, ragged prisms which are often bent and in places are acicular and fibrous. The mineral is tremolite but grades into nephrite with a decrease in grain size, probably without chemical change. This paragenesis forms the band seen in hand specimen as a coarse green and black intergrowth.

In thin section the nephritic and asbestiform amphibole is seen to have penetrated grain boundaries of the epidote, filled interstitial spaces and to have replaced the epidote itself. The replacement is seen in progressive stages between an initial corrosion of the margins and penetration of the cleavages of an epidote crystal and a final mass of fine nephrite with scattered relict inclusions of epidote. It is clear that the nephrite is a replacement phase and younger than the epidote.

In places the epidote is fine grained and as such is seen to form a band in hand specimen. While some of the fine grained epidote may be due to original metamorphic crystallisation, there are indications in places that one grain size transforms to another. The evidence is slightly unclear but on balance the coarse grained epidote appears to replace the fine grained material. In some coarse crystals faint internal outlines indicate the former presence of finer grains which are seen elsewhere as inclusions in the coarse crystals.

The fine grained epidote is also replaced by nephrite so that, where the two forms of epidote are of different ages, the time sequence is: fine epidote, coarse epidote and nephrite.

The band of fine grained epidote is distinguished by the presence of fine, irregular grains of a pale yellow brown to pinkish-brown, pleochroic sphene. The sphene does not appear to be affected by amphibolitic replacement but some recrystallisation is evident in patches where the epidote has been recrystallised into coarser grains. The sphene is probably contemporary with the fine grained epidote. Most grains show a strong preferred orientation along the band.

Adjacent to the band of fine grained epidote is a band seen in hand specimen as coarse grained white minerals veined by black and grey minerals. This is seen in thin section to consist of a pyroxene partially replaced by an amphibole. The pyroxene is often twinned and is colourless to faintly grey-brown but not detectably pleochroic. It is almost certainly diopsidic but the optical properties are not diagnostic of composition. Similarly the amphibole is almost certainly tremolitic but the composition is more effectively determined by chemical than by optical

methods. The absence of a greenish tint which is often diagnostic of both diopside and tremolite is probably the result of a very low iron content.

The band of coarse grained diopside and tremolite has been invaded at several points by veins of a fine grained nephritic amphibole which extend from the mass of nephrite forming the greater part of the specimen. The nephrite is not confined to the vein system but has penetrated grain boundaries and cleavage planes in the coarser minerals. Both diopside and tremolite are replaced by the nephrite.

The remainder of the specimen consists of a closely interlocked mass of fine grained, ragged, prismatic to acicular nephrite. In a few places irregular remnants of coarser amphibole, sometimes in clusters of grains, appear to be partially replaced by the finer grained nephrite. There is no optical indication of any compositional difference in the coarse and fine phases. It is possible that the coarser crystals may represent an earlier tremolitic amphibole, possibly contemporary with the tremolite replacing diopside in the band just described. The ultimate parental material is not in evidence.

The fabric of the nephrite is generally random and interlocking. The only situation in which a preferred orientation is evident is in the walls of a branched fracture system, partly conformable to the banding but partly discordant to it. Fine and very ragged prisms of nephrite are aligned within the centre of the fracture parallel to its length. Within the walls of the fracture similar prisms extend outwards in a shallow curve from the fracture filling. The forces controlling this fabric are related to the formation of the fractures and fracture fillings and are probably of purely local origin and related to hydrostatic pressures and the movement of solutions.

Comment

The specimen consists essentially of three lithologies. The major lithology consists almost exclusively of nephrite and the two minor lithologies, one characterised by epidote and the other by diopside, are progressively altered towards nephrite. The sequence of alteration in the three lithologies is charted below.

Epidote lithology	Pyroxene lithology	Nephrite lithology
Fine epidote and sphene	Diopside	Tremolite
Coarse epidote and sphene	Tremolite	Coarse nephrite
Nephrite	Nephrite	Fine nephrite

The distinction between lithologies probably owes its origin to differences in composition of the original dolomitic sediments. Although the nephrite is clearly an alteration product, its abundance in some parts of the specimen relative to others may again reflect original differences in the chemical or physical properties of the parental sediments which facilitated the amphibolitisation process.

The petrographic evidence suggests that alteration of the original rocks occurred in more than one stage. Conversion of diopside to tremolite preceded replacement of both by nephrite in the diopsidic lithology and may have preceded it in the nephrite lithology. Recrystallisation of fine epidote to a coarser grain size may have occurred at the same time as the early stage of amphibolitisation but may have been a distinct process.

If the observed differences in lithology reflect original sedimentary compositions, the banded fabric of the specimen may be the product of original bedding. However, the presence of oriented sphene which appears to have been unaffected by the amphibolitisation indicates the probability of a deformational recrystallisation which may have produced a metamorphic differentiation, possibly with no relationship to the bedding of the original sediments.

Contrary to expectations, there is no observable consistent orientation in the products of either of the two episodes of amphibolitic alteration or the episode of recrystallisation affecting the epidote. Only the sphene mentioned above and nephrite developed within and around a late stage fracture system exhibit a preferred orientation. Both of the major episodes of alteration apparently took place in the absence of directional stress. If the development of Cowell jade is the product of regional metamorphism, it must have occurred at a later stage as a retrogressive process after regional stress had abated. The process may have been thermally driven and have involved the

regional migration of hydrothermal solutions down a thermal gradient or the migration of a thermal gradient through water-impregnated country rock.

Specimen 6231 RS 167, TS C42270, 6.24 m

Rock name. Amphibolitised and mobilised calc silicate rock.

Hand specimen

The specimen consists of white, grey, pink and green minerals and shows no consistent fabric. In appearance it is patchy and fractured.

Thin section

The minerals identified in the specimen from 5.89 m are present in that from 6.24 m but in different proportions and a much more random distribution. If a banded fabric ever was present, it has been almost totally disrupted by mobilisation associated with the alteration. The pink mineral is colourless in thin section. It is a zoisite and the colour probably indicates a small manganese content (1600 ppm in the rock). With more manganese it would qualify as a thulite, with enough to constitute a major element it would become piedmontite, a manganoan epidote.

The components of the epidote lithology are present but in scattered patches. Fine grained epidote with greenish patches is rare. Most of the epidote has been recrystallised. It is very coarse grained and highly variable in composition. Even within one grain the composition often varies between a weakly ferruginous epidote and the weakly manganiferous zoisite. Compositional variation is patchy with sharply to weakly defined boundaries. Both simple and complex polysynthetic twinning is common in the zoisite. Coarse zoisite often encloses corroded and fragmentary diopside and has presumably replaced the pyroxene. The epidote and diopside lithologies overlap to a much greater extent in the patchy as compared with the banded specimen. There is a tendency for the zoisite to be concentrated in the walls of a fracture which is also a channel for the introduction of nephrite and the zoisite is clearly a replacement phase, probably developed through the agency of solutions

traversing the fracture. A little finer grained sphene is present as inclusions in patches of epidote. It is not associated with the later zoisite.

The diopsidic lithology is similar to that of the banded specimen except that the initial tremolitic alteration is not as sharply distinct from the subsequent development of nephrite as it is in specimen RS166. Diopside occurs throughout the specimen in both coarse and fine grains. It is strongly altered, particularly in the coarse grains, with amphibole penetrating cleavages and along grain boundaries. The amphibole tends to be fine grained and ragged more often than it occurs as continuous, coarser grains of tremolite.

Nephrite occurs throughout the specimen in linear masses along fractures, in coherent patches and as isolated prisms along pyroxene cleavages. It forms irregular prisms, acicular grains and asbestiform fibres. Orientation of the crystals may be consistent within one mass but there is no regional preferred orientation affecting the whole specimen. In some places bands of nephrite appear to have flowed round blocks of diopside rock which have been isolated, and possibly moved, by the surrounding masses of alteration products.

Fine veins of nephrite cut the zoisite.

Comment

The major difference between the specimen from 6.24 m and that described above from 5.89 m is in the evidence of greater mobility in the former specimen. Not only the nephrite but also a mobilised form of epidote have clearly been introduced along fractures, grain boundaries and cleavage planes. It also appears possible that the structure of the host rock has been disrupted and displaced by the mobile phase. This may be the result of tectonic forces but, if so, they were locally rather than regionally applied. Local pressures are perhaps more likely to have been generated by volume changes consequent upon alteration processes producing hydrated phases.

The time relationships established from the specimen from 5.99 m are supported by the evidence in the specimen from 6.24 m. The zoisite which was not encountered in the specimen higher up the drillhole is younger than the diopside and its

early tremolitic alteration product but is older than at least the latest phase of nephrite development.

Specimen 6231 RS 168, TS C42271, 6.59 m

Rock name. Cowell Jade.

Hand specimen

The specimen consists of three regular bands of dark grey, light grey and greenish-grey. The bands are perpendicular to the length of the core.

Thin section

Although three bands are distinct in hand specimen the rock is seen in thin section to be virtually monomineralic. The difference between the bands is one of grain size alone and the only mineral present of any significance is nephritic tremolite. The green, light grey and dark grey bands consist respectively of medium grained, coarse grained and very fine grained nephrite respectively. The only other minerals present are scattered remnants of partially replaced tremolite and a few very fine grains of a highly birefringent mineral which is probably sphene.

The most abundant lithology is the very fine grained nephrite which forms a closely interlocked, felted mass of fibrous and lamellar grains. Unlike the more coarsely crystalline nephrite, the very fine grained material displays a detectable tendency to a preferred orientation. The orientation is not universal but is fairly prominent when the foliation plane is at 45° to the cross hairs of the microscope. The plane is at about 65° to the length of the core.

The fine grained nephrite invades the coarser material along grain boundaries and has formed a series of embayments along the contact between the two bands.

Comment

The fine, felted nephrite probably represents the true Cowell Jade. It would be a tough, compact but fairly easily worked stone. The evidence of specimen RS168 indicates that the felted nephrite is probably the latest alteration product of the system and should be added to the sequence already established.

It is possibly contemporaneous with the oriented nephrite seen in fractures in other samples.

The petrogenetic history so far established is thus:

1. Dolomite sedimentation with quartz and minor clay.
2. ?Possible metamorphic differentiation and alteration.
3. Epidote and diopside lithologies representing respectively calcium and magnesium rich sediments.
4. Partial amphibolitisation of diopside and recrystallisation of epidote.
5. Formation of zoisite.
6. Alteration of amphibole, diopside and epidote minerals to coarse and medium grained nephrite.
7. Replacement of coarse and medium grained nephrite by fine, felted nephrite with fracturing and imposition of a moderate regional foliation.

Specimen 6231 RS 169, TS C42272, 7.69 m

Rock name. Banded epidote amphibolite.

Hand specimen

The rock is banded in shades of grey. The bands are broad, imprecisely bounded and sub-parallel to the width of the core. A few dark grains are distinct from the matrix which otherwise appears to be fine grained. A preferred orientation is evident in places along the direction of the banding.

Thin section

The rock consists mainly of fine to medium grained nephrite with relict patches of partially replaced tremolite and bands rich in iron bearing epidote and in zoisite.

The nephrite is rarely as fine grained as in specimen RS168. It consists of fibres, needles and ragged feathery flakes in the finer bands and of somewhat ragged prisms in the coarser bands. The coarser material exhibits a higher degree of preferred orientation than the finer and one band in particular consists of closely packed, almost parallel, long, thin prisms.

The relict tremolite occurs as large, ragged, patchy and discontinuous grains which are corroded and invaded by the fine nephrite amphibole.

Iron-bearing epidote occurs as the relatively coarse grained crystals that are visible in hand specimens. They are disposed in a band but are not continuous. In plane polarised light they are pleochroic in shades of pale yellow-green and they exhibit high polarisation colours between crossed polarisers. The crystals are marginally corroded by fine grained nephrite and often are surrounded by a reaction rim of iron-poor epidote.

A finer grained, iron-poor, fragmentary epidote or clinozoisite is distributed through the band of coarse, oriented nephrite.

The orthorhombic zoisite occurs as a lenticular band in one corner of the section. It consists of closely intergrown, relatively well-shaped prisms, often with lamellar twinning. There is some indication that fine grained nephrite replaces zoisite but contacts between coarser nephrite and zoisite appear to be mainly those of an equilibrium assemblage.

Fine, ragged and elongated grains of sphene are associated with the zoisite and clinozoisite.

Comment

Textural and time relationships deduced from the specimen do not differ from those suggested earlier in the investigation except that there is some indication that the early stages of nephritic amphibolitisation may overlap with the recrystallisation and alteration of epidote to zoisite.

Specimen 6231 RS 170, TS C42273, 14.87 m

Rock name. Silicified granitoid gneiss with retrograde alteration.

Hand specimen

The rock is strongly banded in grey and pink. The pink bands are coarse grained and consist partly of feldspar but largely of quartz in lenticular pods. The grey bands are indeterminate in both texture and composition except that thin layers of dark green minerals are seen in places.

Thin section

Quartz occurs in two forms. It is widely distributed as medium grained patches of mosaic grains but also occurs as extremely coarse grains and pods with a replacive relationship to

other constituents. The mosaic quartz grains are separated by moderately complex intergranular sutures and appear to be the product of partial annealing in silica granulated by stress. The very coarse grains embay and surround adjacent minerals and are clearly the product of a late stage silicification.

The feldspars are sometimes polysynthetically twinned and sometimes untwinned but for the most part a sericitic alteration precludes the optical identification of feldspar composition. Much of the darker bands are made up of altered feldspar and quartz.

The green mineral which is seen in hand specimen when concentrated into substantial bands, is seen in thin section to be widely distributed. It is a chlorite with pale green to pale brown pleochroism, anomalous birefringence and a small 2V. It is probably a penninite. In places it is clearly a pseudomorph after a mica, probably biotite.

Minor sphene and opaque minerals and rare zircon and apatite are also present.

Comment

The specimen clearly demonstrates that after the major regional metamorphism had produced a moderately high grade gneiss with a strongly oriented fabric, a second episode of stress granulated the quartz. At the same or at a different time an episode of hydrous alteration sericitised the feldspar, altered the mica to chlorite and introduced additional quartz. More than one such episode may have taken place. This type of petrogenetic history is compatible with the suggested alteration of the dolomitic sediments and amphibolitised calc silicate rocks derived from them.

Specimen 6231 RS 171, TS C42274, 17.48 m

Rock name. Banded calc silicate rock.

Hand specimen

The banding is at an angle to the length of the core and is marked by colour changes in shades of grey and greenish-yellow and by changes of grain size between very fine and coarse.

Thin section

The major mineral constituents are members of the epidote-zoisite group and of the tremolite-nephrite group. An important addition, not encountered in the specimens from higher in the drillhole, appears to be wollastonite.

The epidote minerals include iron-bearing epidote, iron-free clinozoisite and orthorhombic zoisite. The two former phases tend to be closely intergrown in bands with a mosaic structure. The zoisite tends to be patchy and associated with nephrite in alteration assemblages.

Tremolite occurs in relict grains but also in what appears to be a late re-growth of coarse tremolite which post-dates at least some development of nephrite. In two bands across the section the late tremolite is associated with a mineral with most of the optical properties of wollastonite but an anomalous optical orientation. This should be checked by non-optical methods of identification.

A second mineral requiring x-ray diffraction, powder photography or electron probe microanalysis is closely associated with the apparent wollastonite. It occurs as bundles of fibres with a low refractive index and low birefringence. It is possibly antigorite.

Evidence that the apparent wollastonite, possible antigorite and re-grown tremolite are late stage developments is obtained from thin veins containing a mineral with low birefringence and multiple twinning which may be a calcium zeolite akin to scolecite but which again requires confirmation of identification. The veins are sharply defined when crossing bands of epidote and early tremolite, well defined but partly replaced by late acicular nephrite in the nephrite bands but almost completely obliterated in regrown tremolite and totally absent in the apparent wollastonite.

The wide band of nephrite at one end of the section contains several forms of the mineral which probably represent different growth stages. The most prominent structures are radial clusters of long prisms. Interstitial to these fans and rosettes are

short, ragged irregular prisms. Superimposed on both these forms but most prominent in the veins where they are the only nephrite crystals, is a network of acicular crystals.

Sphene and apatite are present in the epidote bands.

Cavities in the band of apparent wollastonite are filled with an isotropic mineral of low refractive index which is almost certainly fluorite. The fluorine may have formed part of the solutions responsible for the latest stage, and undesirable, alteration processes.

Comment

The identity of three phases should be checked by x-ray diffraction, x-ray powder photography or, preferably, by electron probe microanalysis. These are: the probable wollastonite, the possible antigorite and the possible scolecite in the vein system. There is some uncertainty in the optical determination of these minerals.

Regardless of the identity of minerals not seen in other specimens of this suite, there is evidence of a type of alteration not encountered higher up the drillhole. It appears that the trend in which nephrite is formed in finer and finer grain sizes by successive episodes of recrystallisation from, among other minerals, tremolite, can be reversed at a later stage of alteration. Coarse grained, if imperfect, tremolite apparently grows at the expense of finer grained nephrite.

Some of the differences between specimen RS171 and the other specimens are probably the result of a higher calcium content in the original sediment. This is expressed in a high epidote abundance and also by the probable presence of wollastonite, fluorite and a calcium zeolite. Since wollastonite does not accommodate any significant amount of magnesium, the presence of antigorite is possibly explained by magnesium rejected from an original carbonate source or from a tremolitic amphibole when calcium silicates such as wollastonite formed. Both calcium and magnesium appear to be mobile at a late stage.

If the latest episode of alteration tends to produce coarsely recrystallised grains, the best Cowell Jade is not, as appeared from the specimens higher up the drillhole, the most strongly altered as well as the most magnesium rich rock. The

finest jade appears at this stage to be derived from a diopsidic parent but with advanced, not terminal, alteration.

Specimen 6231 RS 172, TS C42275, 17.74 m

Rock name. Amphibolite.

Hand specimen

The specimen is grey and weakly banded by grain size variations but the bands are wide, irregular and poorly defined. A few darker grains or patches indicate rare mineralogical variations.

Thin section

The rock is almost monomineralic, consisting almost entirely of amphibole. Most of this is coarse enough to be defined as tremolite but interstitial fine grained amphibole may be classified as nephrite. The massive, very fine grained nephrite which constitutes the best Cowell Jade is absent.

In the coarser grained bands the tremolite tends to form long, prismatic crystals, often in a radiating cluster. The clusters are fan shaped rather than completely rosette shaped and many grains are randomly oriented. The finer grained bands consist of an interlocking mesh of fine prisms and felted nephrite. No preferred orientation is detectable.

The rare patches of minerals other than amphibole consist of finely fragmented zoisite and clinozoisite and a few patches of possible antigorite. Fragmentation of the epidote suggests the application of some stress, whether tectonic or related to volume changes.

Occasional cavities contain the isotropic mineral which is almost certainly fluorite.

Comment

The dependence of the process forming jade on two major factors, the right composition and the right degree of recrystallisation, is underlined by this specimen. The composition is ideal in that it is almost 100% tremolite. The absence of good quality jade, that is the paucity of fine, felted nephrite, must be entirely due to the absence of the right temperature, pressure or dynamic factors to promote the fine grained recrystallisation of the tremolite. Alternatively, the

fine grained nephrite that is present may be relict material from which coarser blades of tremolite have grown by later replacement. Possibly the presence of fluorite is an indication of late recrystallisation, catalysed by fluorine. On textural evidence some tremolite is older and some younger than the nephrite.

Specimen 6231 RS 173, TS C42276, 22.20 m

Rock name. Serpentinised marble.

Hand specimen

The rock is partly massive and white in colour and partly a greenish-grey colour with a poorly defined fine banding. The bands are formed by subspherical grains of a green colour and form an angle with the length of the core.

Thin section

The matrix of the rock consists of a coarse grained mosaic of calcite and dolomite. Dolomite predominates in the white patch but the two carbonate phases are approximately equal in abundance in the banded part. Grain boundaries are often granulated and granulated patches are common.

The material which is seen as green in hand specimen is colourless to faintly brown in thin section. The grains are subspherical to irregular and of medium grain size. Most of them consist of a very weakly birefringent, fibrous mineral of low refractive index. Some grains are scaly or irregular in internal structure but in most grains the fibres are parallel and form coherent patches, sectors and concentric zones. The regularity of the fibres suggests that the mineral making up the serpentinite is chrysotile rather than the more common antigorite. Optical identification is not entirely reliable in fibrous minerals and non-optical methods are recommended.

Not all the green minerals are serpentinite. A few round grains of a pale green colour are diopside. Equally rare grains of penninite (oxidized chlorite) are also present.

Patches and trails of fine opaque grains are widespread throughout the rock. These are probably ilmenite since some grains carry a reaction rim of sphene.

Comment

The serpentinite is presumably derived from the retrograde alteration of magnesium silicates. It is possible that the original mineral may have been a forsteritic olivine but the only remaining evidence of a parental silicate is of rare diopside. Retention of carbonate minerals rather than total conversion to silicates is possibly the result of a low silica content (12%) in the original sediment.

Specimen 6231 RS 174, TS C42277, 23.15 m

Rock name. Serpentinised and recrystallised marble.

Hand specimen

The rock is more prominently greenish than specimen RS173. The colour is due to a greater abundance of green minerals which are less distinct as individual grains than in RS173. One corner of the specimen appears to be composed of massive green material. An oriented fabric at an angle to the length of the core is distinguishable but more prominent textural features are a dark ovoid patch and a few discontinuous dark bands.

Thin section

Substantial textural differences between specimens RS173 and 174 are evident in thin section and are responsible for the difference in appearance of the hand specimens. The overall texture of RS174 is much finer grained and the green silicate is interstitial rather than forming subspherical grains.

The carbonate component is fine grained, irregularly crystalline and often acicular in form. It has clearly been subjected to a similar recrystallisation as that affecting the tremolite in other specimens. The preferred orientation which is detectable in hand specimen is very weakly displayed in thin section. The fine fabric is randomly oriented with tufted and radiating clusters of acicular grains. Only a rather imperfect alignment of weakly concentrated calcite and dolomite grains forms the oriented fabric.

The dark areas are formed by concentrations of fine grained, interstitial serpentine minerals, dominantly antigorite in this specimen. The mineral is widespread throughout the specimen but is patchily concentrated.

Chlorite is relatively coarse grained and moderately abundant. It occurs as well shaped flakes, almost certainly pseudomorphous after a mica, probably phlogopite. Three varieties are present and single flakes often include more than one of the varieties. The most abundant form is the penninite encountered in specimen RS173. Another abundant form is colourless in plane polarised light but displays an anomalous green polarisation colour between crossed polarisers. A less abundant variety is weakly birefringent in shades of grey. The optical orientation of the penninite is anomalously length slow but the other two varieties are length fast. All three varieties probably represent different stages in the alteration of a phlogopite parent mineral and probably differ little in composition.

Comment

The effect of an additional episode of recrystallisation in specimen RS174 has been structural rather than compositional and reinforces the suggestion that the retention of a carbonate phase is the consequence of an initially low silica content (18%) rather than any difference in applied stress or thermal regime. No significant addition of silica is evident in the mineralogy.

Specimen 6231 RS 175, TS C42278, 24.23 m

Rock name. Amphibolitised diopside rock.

Hand specimen

The specimen is irregularly banded in shades of grey. Pale to medium grey broad bands are consistently oriented at about 40° to the length of the core but the dark grey, narrow bands are partly discordant. Fine, branching fractures are frequently filled with white or green minerals.

Thin section

The brown banding is the result of alternations between coarse grained diopside (white to pale grey) and fine grained nephritic amphibole (medium grey). A second generation of finer grained nephrite (dark grey) is responsible for the finer bands, some of which are discordant to the broad banding. The narrow, branching veins diminish in places to fractures without filling but elsewhere contain carbonate, serpentinite and fine grained diopside. The carbonate veinlets tend to cut the serpentinite

(probably antigorite) but in places the two phases occur in the same fractures. Both calcite and a calcium rich dolomite occur in the veinlets, often in the same fractures. The diopside occurs partly in broader fractures which are older than both other veinlet systems and in which the diopside is altered and partly in narrow fractures which cut both carbonate and serpentinite veinlets.

The diopside tends to be coarse grained but strongly fractured and in places, particularly where substantially replaced, is granulated.

Coarse grained tremolite, encountered in other specimens from the drillhole, is absent from this specimen and the alteration product is a fine and very fine grained nephrite. The nephrite does not form large enough areas to be valuable as jade and is not of the closely felted variety. Relict fragments of diopside are frequently included in masses of nephrite.

Epidote is rare and occurs as occasional coarse, fragmented grains in the diopside bands.

Comment

Apart from minor quantities of calcium bearing carbonates and very rare epidote, there are no specifically calcic minerals in the rock. The calcium content of 18% CaO must be contained, with the 20% MgO in the diopside and nephrite. This represents approximately one calcium atom to one magnesium atom and, since this is the ratio in stoichiometric diopside, apparently indicates the ratio of magnesium to calcium which, in the presence of excess silica, promotes the formation of diopside rather than diopside plus epidote. The abundance of aluminium must also affect the formation of epidote but the 5% Al_2O_3 in the rock has not led to a significant epidote content and the major control is apparently the calcium to magnesium ratio. Conversion of a small amount of diopside to nephrite has not significantly affected the overall Mg:Ca ratio.

Specimen 6231 RS 176, TS C42279, 26.96 m

Rock name. Serpentiniferous marble (ophicalcite).

Hand specimen

Broad bands in shades of green, grey and purple cross the specimen in an orientation perpendicular to the length of the core. The prevalent colour of the matrix is a purple grey but one band consists of a slightly greenish-grey and half the specimen is tinted green by subspherical grains of a jade green and a yellow-green colour.

Thin section

The most abundant component of the rock is a medium grained carbonate which stains strongly with the alizarin red dye and is therefore a calcite low in magnesium content. This accounts for the 30% content of CaO. Dolomite occurs only in the grey band, where it is the only carbonate. Much of the carbonate is acicular.

The second most abundant component is chlorite but two chlorite minerals are present. Chlorite grains are similar to those of specimen RS174 and include normal penninite and the anomalous green-polarising chlorite, often both in one flake. The chlorite is again a probable alteration product of phlogopite and occurs as well shaped flakes. Chlorite grains are yellow-green in hand specimen, colourless in thin section.

Grains of a second green mineral, serpentinite, of darker, less yellow shade, are also present and these too consist of two phases. The serpentinite consists mainly of chrysotile in clusters of well crystallised acicular fibres. These tend to form bands and sectors within a subspherical outline. Less systematically organised antigorite also fills outlines of coarser grains, probably pseudomorphously, in random, felted masses. Some of the patterns of alteration visible in serpentinised grains indicate that the original parent mineral was an olivine, presumably forsterite, rather than diopside. Alteration of diopside tends to proceed inwards along parallel cleavage planes but olivine alters along broad, curving fractures rather than regular cleavage. Traces of such fractures in the serpentinite alteration are thus evidence supporting an olivine

host. This is the only evidence since no trace of the former mineral survives and grain shapes are not on the whole reliable evidence owing to surface corrosion effects.

The grey to purple bands are composed of fine grained, often acicular carbonate with a similarly fine grained silicate of low birefringence. The silicate forms tufted flakes, often with a radial distribution and is probably antigorite.

Carbonate was apparently remobilised at a late stage. Although no discordant veinlets occur in this specimen, some serpentinised grains have been marginally corroded and penetrated along fractures, often along the same fractures through which serpentinisation was initiated.

Comment

The specimen is similar to RS174 in that a silica content of about 18% has led to the probable formation of forsterite rather than diopside, even in a calcium rich system. Subsequent alteration, and in some bands a recrystallisation of coarse grained assemblages to a finer grain size, have produced a low temperature serpentinisation without any evidence of an intermediate temperature pyroxene and amphibole assemblage. This has given rise to an ornamental marble but not to any jade.

Specimen 6231 RS 177, TS C42280, 27.36 m

Rock name. Micaceous ophicalcite.

Hand specimen

A fragmentary and irregularly developed banding in white and green forms an angle with a rather weak preferred orientation in fine grained constituents.

Thin section

The specimen contains coarse grained calcite, fine grained dolomite, much serpentinite and a little mica, probably phlogopite, altering to chlorite.

The calcite occurs as mosaic masses in discontinuous bands and patches in various orientations. It appears in many places to be a late stage product of recrystallisation and minor replacement of serpentinite.

The dolomite occurs in bands of closely interlocked and poorly defined fine grains.

Serpentinite occurs in coherent masses and as a dispersed, interstitial mineral. Rare bands consist of serpentinite in pseudomorphous outlines after earlier minerals, probably olivine but this form is not abundant in the section as a whole.

Chlorite occurs as individual flakes and with the serpentinite in large masses. It is of the colourless type with low birefringence but is visibly of micaceous parentage as stages of the transition between phlogopite and chlorite are traced in different grains and even within one grain in places. The mica is rarely present without some alteration and often forms a nucleus of a grain altered to chlorite round the margins. The very small quantity of mica remaining is reflected in a potash determination of only 600 ppm.

Comment

Despite a silica content almost twice as high as that of the marble from 0.4 m above it, specimen RS180 still contains no nephritic alteration product. The silica limit at which amphibolitic alteration (and a presumed diopside parent) appears is apparently quite sharp and close to 40% SiO_2. An increase in silica below this level simply leads to an increase in the serpentinitic and chloritic alteration products. Calcium is retained in the carbonate phase, together with magnesium in excess of requirements for the silicate phases serpentinite and chlorite.

Specimen 6231 RS 178, TS C42281, 29.29 m.

Rock name. Tremolitic marble with amphibolitised pyroxene.

Hand specimen

The specimen is weakly banded in shades of white and grey. One end is fine grained and carbonate rich but most of the other end consists of coarse white crystals of pyroxene.

Thin section

The finer grained bands of the rock consist of fine to medium grained, closely interlocked calcite and tremolite. Concentrations of both calcite and tremolite vary in patches within the bands. In some bands the tremolite is fine grained enough to make a moderately good jade but there is not enough of this material to be worked separately as jade.

The coarser grained bands consist of large but fragmented and patchy crystals of normal diopside together with a second pyroxene with positive sign, low birefringence and multiple twinning which is distinguished from the diopside by a small (25°-30°) optic axial angle. It appears on this evidence to be a pigeonite, or at least a pigeonitic diopside. The pyroxenes are peripherally replaced by fine grained tremolite which also invades the broken grains along fractures and cleavages.

No epidote was observed but neither were any serpentine phases or chlorite.

Comment

The silica content of this specimen, determined to be 41% SiO_2, just exceeds the critical 40% for the development of the pyroxene-tremolite assemblage with excess calcium remaining as calcite. Despite the excess calcium, which is in an almost 3:2 ratio with magnesium, no epidote minerals have formed. It appears that a silica content of 50% SiO_2 or better is required to form epidote where diopside is competing for the silica. It is possible that the low aluminium content of 3% Al_2O_3 may have inhibited the formation of epidote.

Specimen 6231 RS 179, TS C42282, 31.18 m.

Rock name. Weakly serpentinised marble.

Hand specimen

The specimen consists largely of carbonate, both coarse and fine grained. It is patchy rather than banded, with a tendency for fine grained patches to be greenish in colour owing to the associated serpentinite. A few thin, straight fractures carry fine grained carbonate.

Thin section

Both calcite and dolomite are distributed throughout the specimen but the distribution of the two phases is uneven and calcite rich and dolomite rich patches are common. Dolomite tends to occur in coarse grained crystals with granulated grain boundaries while calcite tends to occur in finer grained mosaics with a random orientation. However, neither carbonate occurs to the total exclusion of the other and both may crystallise in the same habit.

With a silica content of less than 8% it is not surprising that serpentinite is not abundant. It occurs as fine grains of antigorite, usually concentrated in patches and discordant veins. Some antigorite is pseudomorphous after a platy mineral. Since a few ragged relics of chlorite are present, the alteration has probably been in two stages; from phlogopite to chlorite and from chlorite to antigorite. Many of the patches of fragmentary antigorite fill a rounded pseudomorphous outline with fine grained dolomite. The flakes of altered mica, now antigorite, are corroded at the margins by poorly crystallised, fine grained dolomite.

It appears that a dolomitic phase was remobilised and partially replaced magnesian silicates at a very late stage in the alteration history of the rock. A line of fine dolomite often occurs in the middle of a veinlet of antigorite. Fine veinlets of calcite cut the antigorite-dolomite veinlets and constitute the latest mobilisation process to affect the rock.

Comment

The rock is essentially a dolomitic marble, as indicated by the very low silica and a 40% loss on ignition, and its history is one of successive recrystallisation and mobilisation, chiefly of the carbonate phases. The few silicate phases present are magnesian, despite a high CaO determination of 30%. Final alteration processes, probably at relatively low temperatures and in the presence of carbonate in solution, reversed the initial development of silicate phases and partly restored them to magnesian carbonates.

Specimen 6231 RS 180, TS C42283, 31.40 m.

Rock name. Banded diopside-tremolite rock.

Hand specimen

The specimen is divided into two parts along a line approximately perpendicular to the core. About half of the specimen is a dark greenish-grey with relatively coarse grains delineated by reflections from cleavage planes. The other half of the specimen is light grey and appears to be rich in coarse grained carbonate from the reflections from cleavage planes.

This is misleading as it is seen in thin section to be largely fine grained and composed mainly of tremolite with recrystallised calcite as a subsidiary phase.

Thin section

The dark greenish-grey part of the specimen is composed of coarse to very coarse grained diopside with a little interstitial calcite. The light grey part consists of fine to very fine grained tremolite with patches of medium grained calcite forming lenticular mosaics with an oriented disposition.

The diopside occurs as coherent bands of closely packed crystals varying only in grain size from band to band in a continuous fabric. Grains vary from euhedral to anhedral but all are well crystallised. The small amount of calcite fills a few interstitial spaces without any obvious reaction and is presumably at equilibrium with the diopside. Some grains are partially replaced by fine grained tremolite.

The tremolite of the light grey part occurs as irregular, ragged prisms and clusters of wispy acicular or feathery forms in sub-parallel to radiating arrays. Most of the tremolite is not fine grained enough to form a nephrite jade but a finer grained and closely interlocked felt occurs in patches and bands within the main mass. The fine tremolite generally, and the finer grained bands within it in particular, exhibit a preferred orientation at an angle to the compositional boundary between the diopside band and the tremolite band.

Calcite patches are composed of a medium grained mosaic of well crystallised grains in close contact along simple grain boundaries with occasional perfect 120° triple junctions. The calcite has annealed after recrystallisation to form an equilibrium assemblage. The outer margins of the calcite patches do not exhibit strong evidence of reaction with the surrounding tremolite and the two phases are probably close to equilibrium. In places where there is textural evidence of reaction the tremolite appears to have replaced the calcite. Lenses of calcite are oriented both along and perpendicular to the fabric of the tremolite.

There are no relict grains of diopside in the tremolite and the main position in which the two phases are in contact is along the boundary of the two bands. Here there is strong evidence of reaction in which fine grained tremolite has invaded diopside along cleavages and grain boundaries. Some alteration has penetrated beyond the contact and has affected diopside within the main diopside band.

Comment

The persistence of calcite may be the result of a relatively high calcium content (27% CaO) and low magnesium content (16% MgO) despite what appears to be an adequate silica content (43% SiO_2) to convert all the carbonates to silicates. (Compare, for example, with specimen RS175). The absence of an epidote phase in the presence of excess calcium may be attributed to the low aluminium content (<0.5% Al_2O_3).

Specimen 6231 RS 181, C42284, 31.66 m.

Rock name. Cowell Jade.

Hand specimen. None.

Thin section

Nephrite makes up the highest proportion of the rock and includes much of the fine, felted material typical of better quality jade. However, a substantial amount of coarse grained tremolite is also included and an irregular and fragmentary band of fibrous amphibole crosses the specimen at an angle to the length of the core.

The finest nephrite is oriented randomly but slightly coarser grains form thin, discontinuous bands in places. The main oriented fabric is imposed by a system of thin anastomosing planes accentuated by limonite layers and with a general orientation at an angle to the length of the core. The nephrite is somewhat dark in colour and dusty in appearance. The iron content of the specimen (2% Fe_2O_3) is low but may encompass fine inclusions in the amphibole as well as the limonite staining.

Coarse grained inclusions of a colourless, clear amphibole with a highly fibrous structure are scattered throughout the fine grained nephrite and form an almost continuous band at one end of the section. The amphibole is probably tremolite as there is no optical discontinuity between it and the nephrite except for the

clear, dust-free transparency and in places a marginal concentration of black, opaque material which is probably a segregation of material forming the dusty inclusions. In the band of concentrated tremolite the amphibole forms tufted and radiating clusters of fibrous and feathery prisms with a substantial concentration of opaque granules between the clusters. Fan and rosette shaped clusters of the fibrous tremolite are spread from the edge of the band into the felted nephrite. In places the tremolite is altered wholely or in part to chlorite.

The wide but fragmented band of highly fibrous amphibole crossing the middle of the section of an angle to the length of the core is heavily darkened by dusty inclusions. The dense masses of fibrous material are distinguished from the surrounding nephrite by refractive index differences. However, in places the index appears to be higher and in other places lower than the nephrite. The birefringence of the fibres appears to vary from place to place. Some of the fibres are a yellow colour and in places segregations of iron have been oxidised and hydrated to limonite with a fibrous appearance. The polarisation colours displayed are nowhere high enough to identify talc and the fibrous material appears to be amphibolitic. It is probably a composite material including amphiboles such as cummingtonite and anthophyllite, the former possibly altering to the latter by rejection of iron. A check of identification by non-optical methods is recommended.

Rare grains of apatite are present.

Comment

The development of both fibrous tremolite and the fibrous masses of other amphiboles appear to be later stage processes than the formation of felted nephrite. The presence of apatite is possibly diagnositc of late stage, low temperature alteration. Fluorite was sought but not identified.

Specimen 6231 RS 182, TS C42285, 31.7 m.

Rock name. Banded calcium and magnesium silicate rock.

Hand specimen

The specimen is divided into two sections by a plane at an angle to the length of the core. One section contains white material spotted with patches of green and grey minerals, often with a radiating structure. The second section is composed of grey material tinted with green except bordering a fracture where broad zones each side of a leached zone are tinted a purple shade of grey.

Thin section

The white material consists of a combination of an amphibole, a probable member of the chondrodite series and minor fragmented epidote. The green spots consist of coarse grained, fibrous tremolite and the grey spots of fine grained, felted nephrite. The greenish grey material in the second portion of the specimen is fine grained chlorite. The chlorite is coarser in grain size each side of the fracture and has apparently acquired a purplish tint. This is not evident in thin section.

Optical identification of the minerals in the white part of the rock is not entirely definitive and a more reliable identification by electron probe microanalysis is recommended. The amphibole is highly birefringent with high refractive indices and a positive 2V of about 50°. These properties are somewhat anomalous in view of the low iron content of the rock (2.36% Fe_2O_3) but the mineral is probably in the cummingtonite-grunerite series. It is dark with dusty inclusions and may have rejected iron after initial crystallisation. A second mineral present is tabular, even higher in refractive index and birefringence and has a high positive 2V. It appears on these properties to be a member of the norbergite-chondrodite-humite-clinohumite series with a formula of:

$$Mg(OH,F)_2.nMg_2SiO_4$$

where n = 1 to 4.

A third, very minor, constituent of the white material is epidote. This occurs as rare grains which are integral and complete but which are made up of small, lenticular fragments. It appears to have been granulated by stress but there is no preferred orientation in the fabric.

The white material has been invaded by large and small patches containing medium to coarse grains of fibrous tremolite. The tremolite often forms radiating clusters which give the patches of alteration the rosette structure visible in hand specimen.

Other patches contain felted tremolite which is fine enough to justify the designation of nephrite. In some of the larger patches an outer zone of nephrite surrounds the coarser tremolite. The relationship between tremolite and nephrite indicates that at most points the nephrite is the later phase but in a few places there appears to have been a growth of fibrous tremolite which postdates the nephrite.

A few cavities contain an isotropic mineral of low refractive index which is probably fluorite. Some cavities are rimmed by relict granulated epidote and it is possible that the epidote is preferentially replaced by fluorite.

The plane separating the white and grey parts of the specimen is seen in thin section to be irregular due to veining and embayment of the tremolite-nephrite assemblage by fine grained chlorite. The mineral is fine grained close to the contact but increases in grain size substantially away from it and towards the fracture noted in the hand specimen. The immediate walls of the fracture consist of very fine grained chlorite but grain size again increases on the other side of the fracture. A second reduction of grain size occurs adjacent to another band of nephrite and tremolite. The chlorite is optically positive with a low 2V and in coarse grains exhibits a first order orange polarisation colour. Texturally it differs from the chlorite encountered in other specimens which appeared to be pseudomorphous after phlogopite. The chlorite in specimen 182 is fibrous and frequently forms radiating clusters. It is almost certainly a replacement product of tremolite and nephrite.

Comment

The paragenesis is rich in magnesian minerals and minerals in which calcium is subordinate to magnesium. This is probably to a large extent the product of an initially high magnesium content in the parental carbonate sediment, which accounts for the presence of cummingtonite and chondrodite instead of tremolite alone, and for the minimal abundance of epidote.

However, the overall calcium to magnesium atomic ratio is almost identical to that which in specimen RS181 resulted in a dominantly tremolite mineralogy. The other cause of a high magnesium content is an alteration process in which magnesian chlorite replaced both tremolite and nephrite. This imposes another constraint on the conditions promoting the formation of good quality jade. Presumably the alteration process involved substantially an aqueous solution while the recrystallisation of tremolite to nephrite occurs in essentially dry conditions. Indeed the fine grain size of the best quality jade may in itself be an indication of a high viscosity, possibly with the properties of a melt rather than a solution.

The sequence of alteration processes in this specimen appears to be:

1) Magnesium-rich carbonate sediment.
2) High temperature alteration to ?olivine+?clinoenstatite +diopside.
3) Lower temperature alteration to chondrodite+ cummingtonite+tremolite.
4) Partial alteration of tremolite and magnesian silicates to nephrite.
5) Some regrowth of tremolite. Replacement of minor epidote by fluorite.
6) Replacement of all earlier materials by chlorite in a late magnesium metasomatic alteration.

Specimen 6231 RS 183, TS C42286, 31.88 m.
Rock name. Brecciated diopside rock.
Hand specimen

The rock consists of angular fragments of white material in a grey matrix. No grain boundaries are prominent enough to permit the estimation of grain size. A very weak preferred orientation is evident in some lines of fragments at a shallow angle to the width of the core.

Thin section

The rock appears to be essentially monomineralic and as far as may be determined the mineral appears to be diopside. All grains are optically positive but in some the optic axial angle is typically large while in others the pyroxene appears to be

closer to pigeonite. Very few grains exhibit high birefringence but almost all appear to have been sectioned on planes close to perpendicular to the optic axes. A non-optical check on the identification is recommended since such an exact preferred orientation is unusual.

Little or no different in refractive index is evident between the diopside fragments and the finely granulated matrix and it may be assumed that the matrix is at least dominantly fine diopside.

A few coarse grains exhibit an anomalous polarisation colour typical of clinozoisite.

The matrix is almost uniformly low in birefringence and high in refractive index but some patches are slightly lower in refractive index and may be composed of tremolitic alteration products of diopside.

Abundant fine, dusty granules of opaque material make the whole rock, but particularly the matrix, grey and with somewhat obscured detail.

Some breccia fragments are composed of earlier breccia, indicating a complex stress regime.

Comment

The specimen is highly significant in that the severe stress to which the diopside has been subjected has not led to the development of nephrite or to any substantial amphibolitic or other form of alteration. Stress by itself simply granulates the diopside. The formation of Cowell Jade requires another factor or combination of factors and appears not to be the result of regional deformation alone, however intense.

Specimen 6231 RS 184, TS C42287, 33.20 m.

Rock name. Altered calc-silicate mylonite.

Hand specimen

The specimen consists of poorly defined, lenticular areas of grey, pink and white, surrounded by irregular bands of dark grey. Individual grains are not distinguishable. There is a weak preferred orientation at a low angle to the width of the core.

Thin section

The granulation of the rock is intense but the strong alteration, which contrasts with specimen 183, is associated with veins and patches containing hydrous phases.

The coherent fragments may originally have been composed of diopside as are those in specimen RS183 but none of this mineral is recognisable. Tremolite has developed in a flaky, fragmentary mode of occurrence within the granulated material. Large areas of fragments often extinguish together in optical continuity although they are not physically continuous. Some of the tremolite is fine grained enough to be classed as nephrite but most of it is of considerably coarser grain size.

Some epidote minerals occur in patches and veinlets within the granulated masses but most of the epidote, clinozoisite and zoisite occur in the bands of highly recrystallised material between the masses and in discordant veins. Zoisite may be responsible for the pink colour seen in the hand specimen but is particularly common in late veins which cut granular masses and intervening bands alike.

Another mineral which occurs in late veinlets, often associated with zoisite, is a zeolite with polysynethtic twinning, probably scolecite.

Minor quantities of chlorite, often after mica, are formed within the interstitial bands of altered minerals.

Scattered, irregular grains of sphene are widespread but not quantitatively abundant.

Comment

The low magnesium and high aluminium determinations are hard to reconcile with the observed mineralogy but the abundant epidote is reflected in a moderate calcium content. The specimen illustrates clearly that substantial alteration occurs when volatile phases are introduced through discordant structures. In this example the alteration is not of a type which produces good jade. Trace element analyses indicate that the alteration involved the introduction of barium, strontium, rare earths, niobium, zirconium, thorium and very minor uranium.

Specimen 6231 RS 185, TS C42288, 34.04 m.

Rock name. Altered calc silicate mylonite.

Hand specimen

The specimen is predominantly grey and fine grained but lenticular patches and discontinuous bands of brown, dark grey and greenish-yellow are preferentially oriented at a small angle to the width of the core. A thin, meandering veinlet is filled with white and black minerals.

Thin section

The rock is texturally more uniform than specimen RS184. There is little clear distinction between granulated masses and bands of alteration and the grain size of the whole rock is more uniform, owing to a more evenly distributed alteration. However, mineralogical variations are distributed in bands and pods. The fine, discordant veinlets contain quartz and limonite.

Tremolite is present but not abundant. Irregular to lenticular patches and streaky bands contain ragged and feathery grains of tremolite but, despite the higher magnesium than specimen RS184, the epidote minerals are much more abundant than tremolite in specimen RS185.

Fragmented and irregular grains of epidote, clinozoisite and zoisite are scattered throughout the rock and are concentrated into almost continuous bands in some places. The epidote minerals are the most abundant group in the rock.

A mineral not yet encountered in this series of specimens, and the only one in the specimen to form coarse grained crystals, is plagioclase. With a determination of less than 1.5% Na_2O in the rock the plagioclase is probably an anorthite. Extinction angles are not helpful in this regard. The plagioclase occurs both as closely intergrown mosaics of coarse grains, often stressed, fractured and distorted, and as granulated masses, forming bands and lenticles.

A little finely granulated carbonate forms irregular patches and occasional schlieren. The refractive index remains consistently higher than the mounting medium and the carbonate may be magnesite rather than dolomite. This may be partly

responsible for the magnesium level determined by analysis which is higher than can be accounted for by the small amount of tremolite present.

A few grains of highly strained quartz are associated with the plagioclase.

Comment

Both specimens RS184 and 185 are composed of bands varying in mineralogical composition. In these circumstances discrepancies in the relationship of mineral phases to the chemical analyses probably reflect the inhomogeneity of the specimen and the possibility that the thin section is not representative of the whole analysed specimen.

Mineralogically the specimen represents a facies too rich in calcium to form nephrite jade. In any case, what little tremolite is present does not form a fine, nephrite felt because the conditions of alteration are not optimum.

The same trace elements are concentrated in specimens R184 and 185.

Specimen 6231 RS 186, TS C42289, 35.30 m.

Rock name. Altered granitoid.

Hand specimen

The rock is made up of medium to coarse grains with rather poorly defined boundaries. Pink, white, grey and black minerals are distinguishable and some grains are platy in structure. A preferred orientation of grains and a weakly banded fabric is evident.

Thin section

The fabric of the rock is seen to be strongly stressed. Distorted grains, granulated and partly annealed mosaics and oriented bands of platy minerals and comminuted material are common. The mineralogy is of a granitoid which has undergone some chemical alteration as well as physical strain. Alteration products such as epidote and chlorite are similar to those of the former carbonate sediments.

The pink grains are coarse microcline crystals with a complex and often distorted twin pattern. The grains are fractured and patchy with incipient sub-grain development and are closely intergrown with plagioclase.

The plagioclase grains are similarly fractured, fragmented and patchy. They are more abundant than the potash feldspar and the granitoid is granodioritic rather than granitic in its feldspar content. It is richer in quartz than a normal granodiorite. Symmetrical extinction angles are imprecise due to strain but appear to indicate a composition of about a sodic andesine. Evidence of calcium introduction in the moderately abundant epidote suggest that the plagioclase composition may have been metosomatically modified.

Quartz is abundant and forms irregular bands and patches of equigranular mosaics with relatively simple intergranular sutures and occasional 120° triple junctions. It also occurs as scattered and less regularly shaped grains and small patches. Bands of finely comminuted material probably consist largely of quartz but may also include feldspar. The finest of these bands cut other structures and fracture large grains of feldspar. The bands often contain epidote, fine grained mica and chlorite. Sharply defined discordant pods of coarse grained quartz which occur at 14.87 m are not seen in this granitoid specimen.

Three kinds of platy minerals are associated with each other to varying extents. A fine grained, pale brown, pleochroic mica occurs in fragmentary patches and in bands marginal to zones of fine granulation. The mica is a type of biotite and appears to be a product of alteration rather than an original constituent. A pale green, pleochroic chlorite with a low birefringence and anomalous polarisation colours forms bands of well shaped platy crystals. This may be an alteration product of original mica. The third type of platy mineral is a pleochroic blue-green to yellow-brown chlorite with a higher birefringence. This forms relatively coarse grained, well-shaped flakes at discordant angles to the main fabric and is possibly the latest phase to develop in the hydrous alteration episode.

Epidote occurs as fragmented crystals associated with chlorite in the highly granulated bands. It is not highly abundant but indicates a mobility of calcium associated with

magnesium in chlorite which affected the granitoid rocks as well as the carbonates and calc-silicates at a late stage in the history of the rock pile.

Comment

The movement of calcium and magnesium in hydrous solution at a late stage has been noted in several of the specimens examined. It may be said to constitute a calcium-magnesium metasomatism when related to one specific rock specimen but is probably syngenetic in terms of the formation as a whole. Since the granitoid is affected by it and since the alteration post-dates the tectonic granulation of the rock, it is improbable that any genetic association could be sustained between the granitoid and the metasomatic solutions.

Although it is probable that quartz has been introduced to the granitoid, the introduction antedates the tectonic deformation which produced an oriented structure. Since the movement of calcium and magnesium postdates the deformation it is unlikely that the movement of silica was related to the amphibolitisation of calc-silicate rocks and the formation of nephrite jade.

Specimen 6231 RS 187, TS C42290, 36.51 m.

Rock name. Epidotised feldspathic quartzite.

Hand specimen

The specimen is a coarse grained, pink, weakly banded rock with discordant patches and bands of fine grained, dark greenish-grey material.

Thin section

The rock is a plagioclase-rich quartzite with irregular bands and pods of fine-grained epidote.

The quartz includes coarse grains but is largely broken up into medium to fine grains. The visible fabric consists of bands of granulation rather than original sedimentary bedding. Much of the granulation has been annealed and a range of simple to complex grain boundaries indicate a succession of episodes of stress superimposed on the fabric.

Plagioclase exhibits the same range of grain sizes and shapes as the quartz. It probably forms about 1/3 of the original grains to the 2/3 of the quartz.

A few grains of potash feldspar are present but the trace of potassium in the assay is contained mainly in small inclusions of sericite flakes in the plagioclase.

The epidote occurs in fine but varied grain sizes in masses which are discordant to the fabric imposed by the planes of granulation. Some boundaries of the masses are sharply defined but others are diffuse with epidote grains forming interstitial offshoots from the main masses. Within the masses the original constituents of the rock remain in varied proportions with the epidote.

Small, irregular grains and patches of sphene occur in the areas of epidote.

Rare zircon crystals are found in the quartzite.

The pink colouration of the hand specimen is due to iron oxide and small interstitial clusters of often rounded spots of orange to pink oxide are scattered throughout the quartzite. Limonite stains mark many discordant fractures. The epidote appears to have incorporated, and subsequently exsolved, iron to give a patchy colour variation in plane polarised light.

Comment

The Warrow Quartzite of the contact zone has been affected by the same mobile calcium silicate phase as the overlying granitoid and the altered carbonates above that. Apart from higher silica and minimal potash, the assay of the quartzite resembles closely that of the granitoid. It appears likely that the high quartz content of the granitoid is derived from silica mobilised by reciprocal reactions with the Warrow Quartzite. It is possible that the granitoid was the source of the trace elements concentrated in the alteration of adjacent sediments, such as rare earths, zirconium, niobium, thorium and uranium. The elements may have been mobilised during the alteration of the granitoid and stabilised in epidote precipitated from calcium and silica derived from the carbonate sediments.

amdel

E00231

PETROGRAPHY OF SAMPLES FROM THE COWELL JADE PROVINCE

SAMPLE: 6231 RS200: TSC48684

Rock Name:
Gneissic Granodiorite

Hand Specimen:
A foliated, pinkish-grey coloured rock containing some larger quartz and feldspar porphyroblasts.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Plagioclase	45
Quartz	30
Potash feldspar	20
Biotite	5
Sericite	Tr
Apatite	Tr
Opaques	Tr-1

This is a well foliated rock comprised mainly of a granular quartz and feldspar mosaic intergrown with minor amounts of biotite. The foliation is defined mainly by a tendency for the biotite to be concentrated in discontinuous stringers with a parallel orientation and by a tendency for the quartz and feldspar to form lenticular bodies. The feldspar in particular tends to form larger crystals up to about 1 mm in size while the quartz tends to form granoblastic aggregates with a typical grain size of 0.1 to 0.2 mm. The quartz bodies in particular have elongate, lenticular shapes oriented parallel to the foliation direction.

Overall the rock has a deformed appearing character with much of the quartz exhibiting granulated textures with sutured grain margins. Many of the large feldspar grains exhibit marginal granulation.

The biotite forms small flakes up to 0.1 mm in length with an intensely pleochroic, dark brown colour. Minor sericite occurs as an incipient alteration product of plagioclase. Opaques form anhedral disseminated grains up to 0.2 mm wide which tend to be intergrown with the biotite or interstitial to the quartz and feldspar grains within foliation lamellae.

This appears to be a plutonic igneous rock which has been subjected to strong deformational effects producing a foliated and granulated texture.

SAMPLE: 6231 RS201: TSC48688

Rock Name:
Feldspar-Mica Gneiss

Hand Specimen:
This is a strongly banded rock with a brownish-grey colour.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Plagioclase	55
Potash feldspar	20
Muscovite	15
Chlorite	7
Biotite	1
Apatite	Tr
Opaques	2

This is a strongly banded rock comprised mainly of a granoblastic feldspar-rich mosaic intergrown with phyllosilicates which define a well-developed lepidoblastic foliation. The feldspar consists mainly of plagioclase with smaller amounts of potash feldspar and forms crystals with a typical grain size between 0.5 and 1 mm. The mica consists mainly of muscovite/sericite and chlorite, both of which tend to form moderately well-developed flakes concentrated in bands oriented parallel to the lepidoblastic foliation.

The plagioclase generally has a deformed appearing character showing a granulated texture along with deformed twin lamellae. Some of the muscovite is concentrated in bands where it exhibits a very fine, felted character which could also be a deformational feature.

Much of the chlorite forms well-developed flakes up to 0.3 mm long which have a pleochroic green colour and low birefringence. Minor chlorite also occurs as interstitial fillings between the feldspar grains. This chlorite has a slightly different green colour and birefringent character and is thought to be a much later chlorite in the well-developed chlorite flakes which define the foliation direction. The foliated chlorite most likely represents completely altered biotite flakes and locally minor amounts of remnant biotite are included with this chlorite.

Minor apatite forms small disseminated crystals up to 0.2 mm wide. Some opaques are disseminated throught the rock as euhedral to subhedral crystals up to 0.4 mm wide. Opaques also occur as narrow fracture and vein fillings particularly along foliation lamellae. Some opaques form very finely divided intergrowths with chlorite flakes after biotite.

This is a strongly foliated and deformed rock comprised mainly of feldspar and mica. The rock contains two generations of chlorite one of which forms well-developed flakes pseudomorphic after original biotite and another late chlorite which tends to occur interstitially between the feldspar crystals. This later chlorite also tends to form radiating aggregates with a random orientation and is most likely a postdeformational phase.

SAMPLE: 6231 RS202: TSC48689

Rock Name:
Sericitised Feldspar Gneiss

Hand Specimen:
A greenish-grey coloured rock with a banded and foliated character.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Plagioclase	40
Muscovite/sericite	20
Potash feldspar	20
Chlorite	12
Quartz	5
Apatite	Tr
Zircon	Tr
Biotite	Tr
Opaques	3

This sample consists mainly of feldspar (plagioclase and minor potash feldspar) and minor quartz which forms a granular mosaic intergrown with secondary phyllosilicates. The secondary phyllosilicates consist mainly of finely divided muscovite/sericite which tends to be concentrated in bands. Moderate amounts of chlorite are also present as well-developed flakes up to 0.5 mm long which exhibit a preferred orientation parallel to the mineralogical banding.

The sericite-rich bands are separated by feldspar-rich bands in which the feldspar exhibits a deformed, granulated texture. Minor quartz is also present as xenomorphic grains which commonly exhibit granulated margins.

The chlorite is generally a pleochroic green variety with low birefringence. Within localised areas traces of weakly pleochroic brown biotite intergrown with the chlorite indicating that at least some of the chlorite is an alteration product of biotite. The muscovite contains discontinuous stringers oriented parallel to the banding and foliation of a turbid mineral which tends to form a fibrous textured intergrowth. This is thought to represent a finely divided titanium mineral although the fine grain size makes positive identification difficult. Other opaque to translucent iron and titanium oxides form disseminated grains and aggregates up to 0.1 mm wide which are generally intergrown with the chlorite. Traces of apatite and zircon form small disseminated grains up to 0.2 mm wide.

This is a metamorphic rock of probable amphibolite facies grade which has been subjected to strong deformational effects and retrograde alteration with the development of abundant muscovite/sericite and chlorite.

SAMPLE: 6231 RS204: TSC48691

Rock Name:
Amphibolite

Hand Specimen:
A dark grey, strongly foliated and banded rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Amphibole	60
Sericite	20
Epidote	10
Feldspar	10
Carbonate	Tr
Apatite	Tr
Opaques	Tr-1

This is a well foliated and banded rock comprised of amphibole crystals intergrown with altered feldspar. The amphibole crystals tend to have weakly prismatic shapes and exhibit a strong preferred orientation defining a nematoblastic foliation. The altered feldspar forms xenomorphic crystals located between the amphibole crystals and it has been almost completely replaced by sericite and epidote.

Most of the amphibole forms subidiomorphic, prismatic crystals with a pleochroic brownish-green colour. A very small number of larger paler green, weakly pleochroic amphibole crystals are present and are generally surrounded by the darker brown amphibole. These paler coloured crystals have xenomorphic shapes and also tend to contain finely divided carbonate inclusions. They are thought to represent a lower grade, previously existing amphibole which has been largely replaced by the prograde more intensely pleochroic brown amphibole.

Minor remnants of feldspar are disseminated through the rock as intergrowths with the sericite and epidote. Feldspar also occurs as narrow vein fillings up to 0.1 mm wide. This feldspar consists mainly if not exclusively of untwinned potash feldspar. The feldspar shows pervasive replacement of finely divided sericite and very finely granular, turbid epidote.

Traces of apatite form small disseminated crystals up to 0.1 mm wide. Minor opaques are disseminated through the rock as small grains below 0.1 mm wide.

This is an amphibolite facies grade metamorphic rock showing strong retrograde alteration of original feldspar to sericite and epidote.

SAMPLE: 6231 RS205: TSC48692

Rock Name:
Carbonate-bearing Serpentinite

Hand Specimen:
A massive, greyish-green rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Serpentine	60
Carbonate	40
Opaques	Tr

This sample consists mainly of fibrous textured serpentine intergrown with a granular carbonate. The rock has a very uneven distribution of minerals with some areas consisting mainly of serpentine and others consisting mainly of carbonate. The carbonate forms a granoblastic mosaic with a typical grain size between 0.1 and 0.5 mm. Most of the carbonate is colourless although some carbonate has a pale brown, pleochroic appearing colour. Positive identification of the carbonate in this rock would require X-ray diffraction analysis.

The serpentine forms fibrous textured aggregates some of which range up to several millimetres in size. Most of the serpentine patches have xenomorphic shapes and are thought to represent a completely altered mafic mineral. It is possible that the serpentine at least in part could represent altered olivine.

Minor opaques are disseminated through the rock as anhedral grains and aggregates up to 0.2 mm wide.

This is thought to be a magnesian marble containing abundant carbonate (possibly dolomite or siderite) intergrown with serpentine and representing an altered mafic mineral such as olivine.

SAMPLE: 6231 RS206: TSC48693

Rock Name:
Amphibole Schist

Hand Specimen:
A banded rock with a dark brownish-grey colour.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Amphibole	60
Pyroxene	20
Garnet	3
Biotite	2
Apatite	Tr
Opaques	15

This rock consists mainly of amphibole comprised of two quite different generations of amphibole intergrown with smaller amounts of other minerals. Most of the amphibole is a very pale green, weakly pleochroic variety which often contains clinopyroxene cores and is obviously of retrograde origin. Another prograde amphibole forms xenoblastic crystals up to 1 mm in size which tends to be concentrated within bands up to a few millimetres wide. This amphibole exhibits a dark green, intensely pleochroic colour.

The pyroxene forms xenomorphic crystals up to 0.8 mm in size which show moderate to pervasive replacement with the weakly pleochroic green amphibole. Minor garnet occurs locally in the rock as xenoblastic grains and aggregates up to 3 mm wide. The garnet also tends to be concentrated in slightly elongate, lenticular bodies oriented parallel to the foliation direction.

Minor biotite was noted as well-developed flakes up to 1 mm in length which are generally intergrown with the intensely pleochroic hornblende as totally included flakes.

Opaques are disseminated through the rock as anhedral grains and aggregates up to 1 mm wide. Opaques tend to be concentrated along what appear to be remnant grain margins between pyroxene crystals and weakly pleochroic amphibole-rich areas. Opaques also are locally concentrated within discontinuous bands. Traces of apatite were noted as disseminated crystals up to 0.2 mm long.

This is an amphibolite facies grade metamorphic rock with what appears to be a primary mineralogy of clinopyroxene and hornblende in which a significant proportion of the clinopyroxene has been replaced by a secondary weakly pleochroic, pale green amphibole.

SAMPLE: 6231 RS207: TSC48694

Rock Name:
Chloritoid Schist

Hand Specimen:
A pale, brownish-grey coloured rock with a strongly foliated schistose texture.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Muscovite	60
Chloritoid	20
Sillimanite	10
Chlorite	10
Opaques	Tr

This sample consists mainly of finely divided muscovite/sericite which exhibits a foliated and banded texture due to variations in grain size. Some of the better developed muscovite flakes exhibit a lepidoblastic foliation but most of the muscovite forms very fine, felted aggregates with an essentially random orientation.

Chloritoid is disseminated through the rock as idioblastic to subidioblastic porphyroblasts up to 2 mm wide. These porphyroblasts are quite fresh although they show incipient marginal alteration to translucent, reddish-brown iron oxides. Some of the porphyroblasts also have slightly irregular, ragged outer margins.

Intergrown with the muscovite are moderate amounts of fibrous sillimanite. The sillimanite is unevenly distributed through the rock but tends to occur within localised areas as fibrous aggregates with a contorted texture.

Chlorite is disseminated through the rock as flakes and flaky aggregates up to 0.5 mm wide. Within localised areas chlorite is concentrated within discontinuous bands and lenticular bodies. Most of the chlorite has a weakly pleochroic brownish-green colour and, low anomalous birefringence. Some of the chlorite forms moderately well-developed flakes with a slightly more pleochroic character and appears to be a partially chloritised biotite.

Minor opaques are disseminated through the rock as small grains up to 0.1 mm wide.

This is a highly aluminous schist now comprised mainly of muscovite and chloritoid. It is thought that a high proportion of the muscovite/sericite represents an alteration product of original sillimanite since it locally contains remnants of fibrous sillimanite. Chlorite is also disseminated through the rock and at least in part represents a replacement product of original biotite.

SAMPLE: 6231 RS208: TSC48695

Rock Name:
Feldspathic Gneiss

Hand Specimen:
A banded, gneissic rock with a relatively coarse grain size comprised mainly of whitish-grey feldspar.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Potash feldspar	40
Plagioclase feldspar	20
Quartz	10
Amphibole	10
Chlorite	10
Epidote	10
Opaques	Tr

This sample consists mainly of a deformed feldspar-rich mosaic comprised of feldspar crystals ranging up to 5 mm in size. The feldspar consists mainly of untwinned potash feldspar along with smaller amounts of polysynthetically twinned plagioclase. Minor quartz is intergrown with the feldspar as xenoblastic crystals up to 0.5 mm in size. All of the quartz and feldspar has a deformed, granulated appearing texture and within localised areas forms finely granulated mosaics with sutured grain margins. Fracturing along with granulation along fractures is common in both the feldspar and quartz.

Amphibole is disseminated through the rock as radiating acicular aggregates up to 1 mm long. This amphibole is somewhat similar to the amphibole in sample 6230 RS418 (TSC48687) in both its colour and textural features. Epidote is also disseminated through the rock as xenomorphic to subidiomorphic crystals up to 1 mm in size. The epidote typically has a moderate to high birefringence although some epidote with low, anomalous birefringence is present.

Chlorite forms well-developed flakes up to 1.5 mm in size as well as flaky aggregates. Some of the flaky chlorite aggregates contain radiating fibrous textured chlorite with a diameter of about 0.1 mm. The chlorite typically has a very pale green, weakly pleochroic colour and low birefringence.

Minor opaque to translucent iron and titanium oxides form disseminated grains and aggregates up to 0.2 mm wide. Included in this is some turbid, birefringent granular aggregates of a titanium mineral such as leucoxene which are generally intergrown with the chlorite.

This is a strongly deformed feldspar-rich rock believed to contain retrograde epidote, chlorite and amphibole all of which appear to be essentially postdeformational.

SAMPLE: 6231 RS209: TSC48696

Rock Name:
Tremolite (Nephritic) Schist

Hand Specimen:
A greenish-grey coloured rock with a foliated texture.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	99
Opaques and semi-opaques	1

This sample consists mainly of very finely divided tremolitic amphibole which generally forms a strongly felted mosaic. The fine tremolite fibres tend to exhibit a preferred orientation defining a foliation direction. There is a tendency for the tremolite to form patches up to 1 or 2 mm wide within which the tremolite fibres have a preferred orientation producing optically continuous zones. Within these zones despite the optical continuity much of the tremolite forms a very fine, felted intergrowth. It is considered possible that these optically distinguishable domains could represent original tremolite crystals which have been subsequently deformed.

The rock contains a small number of disseminated tremolite crystals ranging up to 0.5 mm in size which are intergrown with the felted tremolite. Some of these crystals have prismatic shapes and are oriented at a high angle to the general foliation direction.

Opaque to translucent iron oxides form discontinuous linings along foliation lamellae. These linings rarely exceed 0.05 mm in width.

This is essentially a monominerallic rock comprised of felted, nephritic tremolite. Despite the felted character of the tremolite it still tends to form large optically distinguishable domains up to 1 to 2 mm in size which could represent original tremolite crystals which have been subsequently deformed to produce the present felted texture.

SAMPLE: 6231 RS210: TSC48697

Rock Name:
Tremolite Schist

Hand Specimen:
A foliated dark grey rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	98
(?)Cordierite	1
Opaques	1

This sample consists mainly of an interlocking mosaic of tremolite crystals with a typical grain size of about 0.3 mm although some coarser grained and finer grained tremolite is present. A pneumatoblastic foliation is defined by a weakly developed preferred orientation of the tremolite which is particularly strong within some areas but quite weak in others. Many of the tremolite crystals have random orientations forming an interlocking network. The rock contains some large tremolite crystals or domains which have been broken down into much finer tremolitic intergrowths.

A small number of xenomorphic crystals up to 0.3 mm in size are disseminated through the rock. These crystals have low birefrigence and have been tentatively identified as cordierite although positive identification would require further analysis. Minor opaque to translucent iron and titanium oxides form small disseminated grains and aggregates up to 0.1 mm wide. Minor translucent, reddish-brown iron oxides also form narrow linings along foliation lamellae.

This is a tremolite-rich schistose rock showing some deformational effects of the tremolite.

SAMPLE: 6231 RS211: TSC48698

Rock Name:
Tremolite Schist

Hand Specimen:
A foliated, dark grey rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	98
(?)Cordierite	1
Carbonate	Tr-1
Opaques	1

This sample consists mainly of weakly prismatic to acicular or fibrous tremolite crystals which form an interlocking mosaic. A very vague foliation is defined by a preferred orientation of some tremolite crystals but a significant proportion of the tremolite crystals have a random orientation. Tremolite crystals up to 3 mm in length are present but most of the tremolite has a much smaller grain size and some forms a fine, felted intergrowth.

A weakly birefringent mineral (possibly cordierite) forms xenomorphic disseminated crystals up to 0.2 mm wide. Opaques are disseminated through the rock as subhedral crystals up to 0.3 mm wide. Opaque to translucent iron oxides also form narrow fillings along some foliation lamellae. Traces of carbonate were noted locally as small inclusions within tremolite crystals.

This is a tremolite schist very similar to sample 6231 RS210 although this sample has a slightly coarser grain size.

SAMPLE: 6231 RS212: TSC48701

Rock Name:
Tremolite Schist

Hand Specimen:
A massive, dark greenish-grey rock.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	98
Chlorite	1
Opaques and semi-opaques	1

This sample consists of finely intergrown fibrous tremolite which tends to exhibit a preferred orientation defining a foliation direction. Most of the tremolite forms a fine felted, nephritic intergrowth but some slightly larger crystals are present. The largest tremolite crystals range up to about 0.5 mm in size and at least some exhibit a strong preferred orientation. As with some previously described fibrous tremolitic rocks this sample also exhibits optically distinguishable domains within which fibrous intergrowths are present. Within some of these domains vague lamellar textures are also present. It is thought these domains represent original larger crystals which have been disintegrated into the finer fibrous intergrowths.

Chlorite is disseminated through the rock as flakes ranging up to 0.5 mm in size. These chlorite flakes have a very pale green colour and low birefringence.

Minor opaque to translucent iron oxides form discontinuous linings along very narrow, undulose foliation lamellae.

This is a tremolite-rich rock which generally has a fibrous, nephritic texture although some domains possibly representing original larger tremolite crystals are present.

SAMPLE: 6231 RS213: TSC48702

Rock Name:
Tremolite Schist

Hand Specimen:
A greenish-grey coloured rock with a vague foliation.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Tremolite	98
Chlorite	Tr-1
Opaques and semi-opaques	1

This sample consists mainly of a felted, nephritic intergrowth of tremolite with some disseminated larger tremolite crystals. The rock has a foliated character defined by a preferred orientation of the fine felted tremolite and by very narrow, undulose foliation lamellae which are defined mainly by linings with opaque to translucent iron oxides.

The larger tremolite crystals range up to 0.5 mm in size and have fibrous to lamellar textures believed to be of deformational origin.

Minor chlorite is disseminated through the rock as small flakes up to 0.5 mm in size.

This is an almost monominerallic rock comprised of tremolite which typically has a felted, nephritic texture.

SAMPLE: 6231 RS214: TSC48704

Rock Name:
Chlorite-Carbonate Rock

Hand Specimen:
A very fine-grained rock with a greenish-grey colour.

Thin Section:
An optical estimate of the constituents gives the following :

	%
Carbonate	50
Chlorite	50
Opaques	1

This sample consists mainly of weakly birefringent phyllosilicate flakes believed to be chlorite intergrown with granular carbonate which is most likely dolomite. The chlorite generally forms a somewhat felted interlocking mosaic comprised of flakes with a maximum size of 0.3 mm although most of the chlorite flakes form a much more finely felted intergrowth. The carbonate generally forms irregular grains and granular aggregates with a maximum size of 0.3 mm. Many of the larger carbonate crystals exhibit lamellar twinning believed to be of deformational origin.

Minor opaques are disseminated through the rock as anhedral to subhedral grains up to 0.1 mm wide.

This is a very fine-grained rock comprised mainly of weakly birefringent chlorite intergrown with granular carbonate.