

Keys for Identification of Common Minerals in Thin Section

The attached tables provide a concise summary of the properties of a range of common minerals. Within the tables, minerals are arranged by colour so as to help with identification. If a mineral commonly has a range of colours, it will appear once for each colour.

To identify an unknown mineral, start by answering the following questions:

- (1) **What colour is the mineral?**
- (2) **What is the relief of the mineral?**
- (3) **Do you think you are looking at an igneous, metamorphic or sedimentary rock?**

Go to the chart, and scan the properties. Within each colour group, minerals are arranged in order of increasing refractive index (which more or less corresponds to relief). This should at once limit you to only a few minerals. By looking at the chart, see which properties might help you distinguish between the possibilities. Then, look at the mineral again, and check these further details.

Characteristic Features:

(i) **Name:** names listed here may be strict mineral names (e.g., andalusite), or group names (e.g., chlorite), or distinctive variety names (e.g., titanian augite). These tables contain a personal selection of some of the more common minerals. Remember that there are nearly 4000 minerals, although 95% of these are rare or very rare. The minerals in here probably make up 95% of medium and coarse-grained rocks in the crust.

(ii) **IMS:** this gives a simple assessment of whether the mineral is common in igneous (I), metamorphic (M) or sedimentary (S) rocks. These are not infallible guides - in particular many igneous and metamorphic minerals can occur occasionally in sediments. Bear this in mind, even if minerals are not marked as being common in sediments.

(iii) **Colour in TS etc:** the range of colours for each mineral is given, together with a description of any pleochroism. Note that these are colours seen in thin-section, not hand-specimen. The latter will always be much darker and more intense than thin section colours.

(iv) **RI:** the total range of refractive index shown by the mineral with this colour is shown: This covers any range due to compositional variation by solid solution, as well as the two or three refractive indices of anisotropic minerals.

(v) **Relief :** is described verbally, followed by a sign indicating whether the relief is positive or negative (ie greater or less than the mounting medium of the thin-section - 1.54). Minerals with refractive indices close to 1.54 have low relief, those with much higher or lower refractive indexes will have high relief.

(vi) **Extinction:** angles are only given where minerals usually show a linear feature such as a cleavage and/or long crystal faces. For plagioclase feldspars (stippled) the extinction angles given are those determined by the Michel-Levy method (see a textbook for details).

(vi) **Int. Figure:** this gives details of the interference figure. Any numbers given refer to the value of $2V$ (normally a range is given), followed by the optic sign. For uniaxial minerals the word "Uni" is given, followed by the sign. Your course may or may not have covered interference figures. If not, ignore this section!

(vii) **Birefringence:** Birefringence is described verbally, In some cases the maximum is given as a colour, in other cases you will need to cross-refer to an interference colour chart.

(viii) **Twinning etc.:** a few Characteristic Features about twinning, or other internal features of crystals may be given. If no twinning is mentioned, then the phenomenon is not common in thin section, but this does not mean that it NEVER occurs.

(ix) **Characteristic Features:** general tips on appearance, occurrence and distinguishing features. May include indication of whether the mineral is length fast or slow - again a feature not covered in all courses - but a useful and easily-determined property.

Mineral	IMS	Colour in TS etc.	RI	Relief	Extinction	Int. Figure	Birefr.	Twinning etc.	Characteristic Features
COLOURLESS									
fluorite	IS	colourless, blueish or purple	1.43	v. high -			ISOTROPIC		Late mineral in granites - often purple due to radiation damage. Also a cement in sandstones. High -ve relief, colour and isotropy distinctive.
analcime	I	colourless	1.49	mod -		-	vv weak		Usually in groundmass of dolerites and basalts filling spaces between plagioclase crystals. Colourless and nearly isotropic distinctive.
"orthoclase"	IMS	colourless	1.52-1.53	v.low -		70, -ve	low: up to grey	Carlsbad (2 halves)	Often turbid. May show patchy or thready perthitic texture.
microcline	IMS	colourless	1.52-1.53	v.low -		80, -ve	low: up to grey	cross-hatch	Twinning very distinctive.
albite (plagioclase)	IM	colourless	1.52-1.54	v.low +-	-20 to -12 (Michel-Levy)	70-80, +ve	low : up to cream	Albite twins along length, also Carlsbad + others	Common in low-grade meta. rocks with chlorite-muscovite-actinolite etc), and often clear and untwinned - can be very hard to identify. In igneous rocks usually twinned, as rims on more calcic plagioclase, or on perthite, or as a late replacement of other feldspars.
oligoclase (plagioclase)	IM	colourless	1.53-1.55	v.low +-	-12 to 12 (Michel-Levy)	70-90, -ve or +ve	low: up to white	Albite twins along length, also Carlsbad + others	In igneous rocks often with biotite and K-feldspar. Also in low-med grade meta rocks. Crystals in igneous rocks often rectangular laths. Often zoned: usually An-rich cores and Ab-rich rims. An-rich cores may alter more easily to sericite - a fine-grained turbid mica. Twinning distinctive - otherwise process of elimination.
nepheline	I	colourless	1.53-1.55	v.low +-	0	Uni -ve	low: up to dk grey		Euhedral xls blocky: hexagons or rectangles, but only seen in lavas. Elsewhere anhedral. Often cloudy. May have highly birefr. alteration. Mostly in igneous rocks - v. scarce elsewhere.
cordierite	M	colourless.	1.53-1.57	v.low - low +-		40-80, mostly -ve	low : up to white	sometimes radiating hexagonal, striped, or untwinned.	Mostly found in low-pressure metapelites (eg hornfels). One of the hardest minerals to identify - often looks like quartz or plagioclase. Twinning may look like plag twinning in coarse grained rocks. Often has "blebby" inclusions. May have yellow pleochroic haloes around zircons etc. Tends to alter to darker coloured crud than plagioclase.
andesine (plagioclase)	IM	colourless	1.54 -1.56	v.low +	12-28 (Michel-Levy)	70-90, -ve or +ve	low : up to pale grey	Albite twins along length, also Carlsbad + others	In igneous rocks, often with hornblende, also in med-high grade meta rocks. Crystals in igneous rocks often rectangular laths. Often zoned: usually An-rich cores and Ab-rich rims. An-rich cores may alter more easily to sericite - a fine-grained turbid mica. Twinning distinctive - otherwise process of elimination.
quartz	IMS	colourless	1.54-1.55	v.low +		Uni +ve	low : up to cream	rare	Usually irregular grains. Clear and unaltered. May show strained extinction.
labradorite (plagioclase)	IM	colourless	1.55-1.57	low +	28-39 (Michel-Levy)	70-90, -ve or +ve	low : up to white	Albite twins along length, also Carlsbad + others	In igneous rocks often with clinopyroxene and/or olivine. Also in high-grade meta rocks. Crystals in igneous rocks often rectangular laths. Often zoned: usually An-rich cores and Ab-rich rims. An-rich cores may alter more easily to sericite - a fine-grained turbid mica. Twinning distinctive - otherwise process of elimination.
calcite	IMS	colourless	1.55-1.65	low to mod +		Uni -ve	extreme. Pinky-buff	rhombic lamellae	Relief usually changes as stage rotated. Hard to tell apart from other carbonates in thin section unless stained.
bytownite (plagioclase)	IM	colourless	1.56-1.58	low +	40-52 (Michel-Levy)	80-90 -ve	low : up to cream	Albite twins along length, also Carlsbad + others	In igneous rocks often with clinopyroxene and/or olivine. Also in high grade meta rocks. Crystals in igneous rocks often rectangular laths. Often zoned: usually An-rich cores and Ab-rich rims. An-rich cores may alter more easily to sericite - a fine-grained turbid mica. Twinning distinctive - otherwise process of elimination.
muscovite	IMS	colourless.	1.56-1.61	low +	0	30-40, -ve	high: up to up. II order		flakes with 1 perfect cleavage. Habit and birefringence distinctive. In aluminous granites + many metamorphic rocks.
anorthite (plagioclase)	M	colourless	1.57-1.59	low +	52+ (Michel-Levy)	80-90 -ve	low : up to cream/yellow	Albite twins along length, also Carlsbad + others	Anorthite commoner in very high grade metamorphic rocks than in igneous rocks. Often zoned. Twinning distinctive.
tremolite (amphibole)	M	colourless	1.60-1.64	med +	ca.20	80-88, -ve	mod to high: up to mid II order.		Crystals usually elongate. Only found in carbonate-rich metamorphic rocks (eg marbles). End sections show 2 cleavages at 120 degrees, Long sections show 1 cleavage along length, Length slow.
anthophyllite (orthoamphibole)	M	colourless	1.60-1.67	med +	0	70-90, +ve	mod: up to low II order		In Mg-rich meta rocks, esp. low-grade metabasites - often with talc. Like actinolite, but parallel extinction. Length slow. Amphibole cleavages on end sections: 120 deg.

Mineral	IMS	Colour in TS etc	RI	Relief	Extinction	Int. Figure	Birefr.	Twinning etc.	Characteristic Features
COLOURLESS (continued)									
actinolite (amphibole)	M	colourless to pale green	1.60-1.70	med. +	10-20	75-80, -ve	mod-high: up to mid II order		Crystals usually elongate. Lo-grade meta. rocks - esp. basic igneous rocks, or sediments containing basaltic detritus. End sections show 2 cleavages at 120 degrees, Long sections show 1 cleavage along length. Length slow.
apatite	IM	colourless.	1.63-1.65	mod +	0	Uni -ve	low - grey		Usually as tiny elongate crystals with round or hexagonal outline. Shape, and birefringence distinctive. Length fast usually.
andalusite	M	colourless or v. pale pink (pleochroic)	1.63-1.66	mod-high +	0	70-90, -ve	low: up to white.		Restricted to low-P metapelites. Crystals usually elongate, with nearly square X-section. "chiasolite" variety has cross-like inclusions in end sections. Habit, low birefringence and straight extinction distinctive. Length fast.
olivine	I	colourless	1.63-1.87 (Fe rich higher)	mod-high+	0	Mg rich: 80-90 +ve, Fe rich 50-90 -ve	high: up to up. II order, or III in Fe-rich ones.		Crystals often equant or rounded/granular with curving cracks and alteration to colourless serpentine, or yellow or green clays. Commonest in basic and ultrabasic igneous rocks; also in meta marbles. Fe olivines rare, in granitic and syenitic rocks. Association, shape, lack of colour and cleavage, and birefringence distinctive.
sillimanite	M	colourless	1.65-1.68	high +	0	20-30, +ve	mod: up to mid II order.		Crystals usually finely acicular ("fibrolite") - elongate. Restricted to high-grade metapelites. Length slow. Higher birefringence and relief than andalusite. "Fibrolite" especially associated with biotite.
orthopyroxene	IM	colourless or pale green-red pleochroism	1.65-1.73	mod-high +	0	50-90 -ve (very Mg-rich ones +ve)	low-mod: up to I order red.		Commonest in basic and ultrabasic rocks, plus high-grade meta rocks (esp metabasites). End sections show 2 cleavages at ca. 90, otherwise 1 along crystals. Length fast. Px cleavages, pleochroism, and low birefringence diagnostic.
diopside-augite clinopyroxene	IM	colourless or pale brownish or greenish	1.66-1.76	high +	35-50	50-70, +ve	Mod -high: up to up. II order	Not uncommon. Also sector zoning.	Much solid soln and variation in properties. Almost always present in basic igneous rocks. Also in meta marbles, and in high grade metabasites. Association, birefringence and px cleavages (90 deg.) distinctive.
spinel	IM	colourless, or brown, green or black.	1.71- 1.8+	high +			ISOTROPIC		Transparent spinels mainly in meta rocks: colourless ones in marbles, coloured ones in high-grade metapelites. Deep brown Cr-rich ones in basic and ultrabasic rocks. Equant grains, isotropic. May resemble garnet in TS, but rarer, and octahedral habit often seen.
kyanite	M	colourless.	1.71-1.73	high +	up to 30, but often near 0	ca. 85, -ve	low: up to I order yellow	Not uncommon.	Moderate to high grade metapelites. Length slow. 2 cleavages at 85 often seen in long grains. May show marginal alteration to fine-grained muscovite etc. High relief, low-birefringence, association and cleavages distinctive.
epidote	IM	colourless to yellow-green; may be weakly pleochroic	1.71-1.79	high +	usually 0	60-90, -ve	high: up to III order; sometimes anomalous blue.		In low grade metamorphic rocks, esp. metabasalts, and as accessory mineral in granitic rocks. Often shows distinctively bright birefringence colours with patchy colour distribution. Frequently shows faint yellow tint (distinctive) in PPL.
garnet	IM	colourless to pinkish	1.74-1.81 for most colourless garnets	v. high +			ISOTROPIC		In wide range of meta rocks including marbles. Crystals rounded or equant - if well-formed may have 6 or 8 sides in thin section. May have zones or trails rich in inclusions of quartz, biotite etc, which may show S or Z shapes. Shape, isotropy, and relief distinctive.
titanite	IM	colourless or pale brown.	1.85-2.11	v. high +		17-40, +ve	extreme - pinky buff colours	Occasional.	In intermediate and acid igneous rocks, and in many metabasites. Crystals common - often diamond-shaped rhombic X-sections seen. Extreme relief and birefringence distinctive. Low birefringent grains often don't extinguish properly and instead go from dull anomalous orange to dull blue.
zircon	IM	colourless (usually)	1.92-2.01	v. high +	0	Uni +ve	High: up to III order		crystals usually tiny or small. Often included in biotite - may produce pleochroic haloes. Birefr. Lower than titanite. In sediments rare detrital grains in quartzites and other v. mature sediments.

Name	IMS	Colour in TS etc.	RI	Relief	Extinction	Int. Figure	Birefr.	Twinning etc.	Characteristic Features
GREEN									
biotite	IM	pale to deep greenish brown, or brown. Pleochroism moderate to strong.	1.54-1.64	mod +	0 to cleavage	0-25	High - partly masked by deep colour		Perfect mica cleavage in most sections.. Darkest when cleavage E-W. Basal sections have no cleavage, low birefringence and little or no pleochroism. Very common in igneous and meta rocks: rare in seds - easily altered to chlorites & clays.
chlorite	IM	usually pale green and weakly or non-pleochroic	1.57-1.68 (usually 1.57-1.60)	low-mod +. Rarely higher.	0-10 to cleavage	Often hard to obtain.	v.low-low: up to grey. Usually anomalous blue, purple, or brown.		Very common in low grade metamorphic rocks, often with muscovite. Also as alteration product, esp. of biotite, in many rocks. Looks like a mica, but rather low relief, pale green colour and low or anomalous birefringence distinctive.
actinolite (amphibole)	M	pale bluish green - colourless. More Fe-rich ones more green. May be weakly pleochroic.	1.61-1.65	mod +	10-20	80-85, -ve	mod: up to mid II order	Not uncommon.	Very common in low-grade metamorphic rocks. Elongate crystals, weak colour and pleochroism distinguishes from hornblende; epidote is more yellowish and has higher relief. Length slow.
"hornblende" (amphibole)	IM	greenish to greenish brown or bluish green. Markedly pleochroic.	1.61-1.7+	mod-high +	10-30	50-80, -ve	mod: up to mid II order. May be masked by colour.	Not uncommon.	Colour and pleochroism usually quite intense. Common in intermediate igneous rocks, and in med. grade meta rocks, esp. metabasites. Colour of meta. hornblendes often correlated with grade: from bluish green to green to brownish with increasing grade. 2 cleavages at 120 deg on ends of xls; 1 on longer side sections.
clinopyroxene	IM	Pale green-deep green and weakly or non-pleochroic	1.66-1.76	mod-high +	variable	mostly 20-50.	mod-high: up to up. II order.	Not uncommon.	Deeply coloured varieties (usually Na-rich) in alkaline rocks. Extinction angles higher, and birefringence lower than aegirine. Paler green varieties in igneous rocks, and in metamorphic rocks, may be Fe-rich or Cr-rich.
orthopyroxene	IM	pale green to pink pleochroism	1.67-1.73	mod-high +	0	90-70, +ve or -ve	low: up to I order red		Pleochroic ones usually -ve.
spinel	IM	green, brown or black. Never pleochroic.	1.71- 1.8+	high +		-	ISOTROPIC		Transparent spinels mainly in meta rocks: colourless ones in marbles, coloured ones in high-grade metapelites. Deep brown Cr-rich ones in basic and ultrabasic rocks. Equant grains, isotropic. May resemble garnet in TS, but octahedral habit often seen.
epidote	IM	greenish yellow - colourless and weakly pleochroic.	1.71-1.79	high +	usually 0	60-90, -ve	high: up to III order; sometimes anomalous blue.		In low grade metamorphic rocks, esp. metabasalts, and as accessory mineral in granitic rocks. Often shows distinctively bright birefringence colours with patchy colour distribution
aegirine (clinopyroxene)	I	green, with yellowish or brownish tints. Weakly to strongly pleochroic.	1.74-1.83	high-v. high	0-6	80-90, -ve	High: up to III or IV order.		Often acicular crystals, or rims on other green pyroxenes. High birefringence and low extinction angle distinctive. Length fast (cf amphiboles)

Name	IMS	Colour in TS etc.	RI	Relief	Extinction	Int. Figure	Birefr.	Twinning etc.	Characteristic Features
YELLOW									
tourmaline	IM	yellow to brown or blue pleochroic	1.61-1.70	mod-high +	0	Uni -ve	mod-high: up to up II order.		Accessory mineral in some B-rich meta rocks.. Pleochroic and darkest when N-S. Xls elongate with curved triangular x-sections. Often colour zoned. Length fast.
epidote	IM	yellowish green - colourless and weakly pleochroic.	1.71-1.79	high +	usually 0	60-90, -ve	high: up to III order; sometimes anomalous blue.		In low grade metamorphic rocks, esp. metabasalts, and as accessory mineral in granitic rocks. Often shows distinctively bright birefringence colours with patchy colour distribution
staurolite	M	pale yellow or brownish yellow; weakly pleochroic	1.74-1.76	high +	0	80-90 +ve	low : up to I yellow	Common, but rarely visible in thin-section.	Restricted to metapelites. Usually as porphyroblasts, often with many quartz inclusions. Colour, relief and low birefringence distinctive.
rutile	IM	deep golden yellow; to brown or black; may be opaque.	2.60-2.90	extreme +	0	Uni, +	extreme, but masked by colour		Mainly seen in coarse-grained high-pressure metamorphic rocks (eg eclogites, or kyanite-bearing). Also in other igneous and metamorphic rocks but often as tiny grains, or opaque. Extreme relief, intense colour and parallel extinction distinctive.

Name	IMS	Colour in TS etc.	RI	Relief	Extinction	Int. Figure	Birefr.	Twinning etc.	Characteristic Features
BROWN									
biotite	IM	pale to deep brown, or greenish brown. Strongly pleochroic.	1.54-1.64	mod +	0	0-25	high: partly masked by deep colour.		Perfect mica cleavage in most sections.. Basal sections have no cleavage, low birefringence and little or no pleochroism. Very common in igneous and meta rocks: rare in sediments - easily altered to chlorites and clays.
tourmaline	IM	brown and blue or yellow; markedly pleochroic.	1.61-1.70	mod-high+	0	Uni -ve	mod-high: up to up II order.		Pleochroic and darkest when N-S. Xls elongate or radiating, with curved triangular x-sections. Often colour zoned. Length fast.
brown amphibole	IM	Usually deep brown - greenish brown and strongly pleochroic	1.61-1.76	mod-high +	0-30	50-80, -ve	mod- high: up to III order masked by deep colour	Not uncommon.	Wide range of compositions: Ti-rich ones in alkaline igneous rocks; Fe3+ - rich ones in andesites and basalts. High grade metamorphic amphiboles often brown. Usually less pleochroic than biotite and shows amphibole cleavages and habit: 2 cleavages at 120 deg on ends of xls; 1 on longer side sections.
augite, titanian (clinopyroxene)	I	pale purplish brown; may be very weakly pleochroic	1.69-1.74	high +	40-45	ca. 60, +ve	mod: II order; sometimes anomalous colours.	Not uncommon; sector zoning common.	A major mineral in alkaline basaltic rocks. Deep coloured varieties often fail to extinguish properly and show anomalous bluish or reddish colours instead.
spinel	IM	colourless - brown, green or black. Never pleochroic.	1.71- 1.8+	high +			ISOTROPIC		Transparent spinels mainly in meta rocks: colourless ones in marbles, coloured ones in high-grade metapelites. Deep brown Cr-rich ones in basic and ultrabasic rocks. Equant grains, isotropic. May resemble garnet in TS, but octahedral habit often seen.
garnet (melanite)	I	pale yellowish-brown to deep brown (often colour zoned). Never pleochroic.	1.85-1.89	v. high +			ISOTROPIC		Restricted to undersaturated rocks eg nepheline syenites, carbonatites and related rocks.
titanite	IM	pale brown to colourless. Rarely shows weak pleochroism.	1.89-2.05	v. high +		17-40, +	extreme - pinky buff colours	Occasional.	In intermediate and acid igneous rocks, and in many metabasites. Crystals common - often diamond-shaped rhombic X-sections seen. Extreme relief and birefringence distinctive. Low birefringent grains often don't extinguish properly and instead go from dull anomalous orange to dull blue.
rutile	IM	brown to black, or deep golden yellow; may be almost opaque.	2.60-2.90	extreme +	0	Uni, +	extreme, but masked by colour		Mainly seen in coarse-grained high-pressure metamorphic rocks (eg eclogites, or kyanite-bearing). Also in other igneous and metamorphic rocks but often as tiny grains, or opaque. Extreme relief, colour and parallel extinction distinctive.
PURPLE, LILAC or BLUE									
fluorite	IS	bluish to purple or colourless.	1.43	v. high -			ISOTROPIC		Often shows purple patches or zones due to radiation damage. 3 good cleavages may be seen at 60 deg, or 2 at 70 deg. As a late mineral in granites; also a cement in sandstones, or in voids in limestone. High -ve relief, colour and isotropy distinctive.
glaucofan - (amphibole)	M	blue to grey-blue or lavender; weakly to strongly pleochroic	1.60-1.67	mod +	0-6	0-50 -ve.	mod: up to low II order		Restricted to high P, low-T metamorphic rocks. Zoning common. Colour completely distinctive. Length slow. Pale colours may be best seen examining TS by hand. Xls may have rims of more greenish actinolite or hornblende.
tourmaline	IM	blue to brownish-yellow, and markedly pleochroic	1.61-1.70	mod-high+	0	Uni -ve	mod-high: up to up II order. May be masked by colour.		Pleochroic and darkest when N-S. Xls elongate or radiating, with curved triangular x-sections. Often colour zoned. Length fast. In granites and metapelites.
Na amphiboles	I	inky blue-black to muddy brown; markedly pleochroic	1.61-1.71	mod - high +	usually < 30 to long cleavage	variable -ve or +ve.	Low-mod: but masked by intense colour.		Usually in igneous rocks: includes riebeckite and arfvedsonite amphiboles. Often poikilitic plates rather than euhedral xls. Intense inky blue colours completely distinctive.

Name	IMS	Colour in TS etc.	RI	Relief	Extinction	Int. Figure	Birefr.	Twinning etc.	Characteristic Features
RED or PINK									
garnet	IM	pinkish to colourless. Never pleochroic.	1.74-1.82 for red garnets	v. high +			ISOTROPIC		Pink garnets in metabasites and metapelites. Crystals rounded or equant - if well-formed may have 6 or 8 sides in thin section. May have zones or trails rich in inclusions of quartz, biotite etc, which may show S or Z shapes. Shape, isotropy, and relief distinctive.
orthopyroxene	IM	pale green-pink pleochroism	1.67-1.73	mod-high +	0	90-70, +ve or -ve	low: up to I order yellow or red.		Pleochroic ones usually biaxial -ve. Pleochroism invisible to red-green colour blind persons. In tholeiitic basalts, andesites and plutonic equivalents, and in high-grade metabasites, or rarely pelites.
hematite	IM	may be deep blood-red, or opaque.	2.9-3.2	v. high +	hard to see,	hard to see	hard to see		Normally opaque in TS - grains may be deep red on thin edges. Mainly in schists, and as secondary mineral in many other rocks.
andalusite	M	v. pale pink to colourless (pleochroic)	1.63-1.66	mod-high +	0	70-90, -ve	low: up to white.		Restricted to low-P metapelites. Crystals usually elongate, with nearly square X-section. "chiastolite" variety has cross-like inclusions in end sections. Habit, low birefringence and straight extinction distinctive. Length fast.
ALTERATION PRODUCTS									
"sericite"	IMS	turbid pale greyish or pale brownish					high: II-III order		Fine grained mica replacing other aluminosilicates, esp. feldspars. Often in particular zones in plagioclases. Coarsens into muscovite-like flakes with high birefringence.
"iddingsite"	I	deep yellow to yellow-brown					high: II-III order		Deep yellow -brown highly birefringent replacement of olivine, esp. in lavas. May be overgrown by later fresh olivine.
"serpentine"	IM	colourless					low: up to grey or white		Replaces olivine., often as network of veins or cracks. Association, very low relief and flaky, net-like or fibrous grey birefringence distinctive.
"uralite"	IM	pale green					mod: up to mid II order		name given to fibrous pale green amphibole usually replacing pyroxene in altered igneous rocks. The overall shape of the igneous grains is preserved during replacement.
"leucoxene"	IM	very intense turbid grey or greyish brown					extreme, but hard to see due to fine grain size.		Always pseudomorphs Fe-Ti oxides, especially ilmenite. Occurs in altered dolerites and gabbros.
"limonite"	IMS	deep brown, nearly opaque	-	-	-	-	-	-	Usually fine-grained very dark brown crud or stain around other Fe minerals, or filling cracks.