# Atlas of Igneous Rocks and Their Textures

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ELBS

LOW-PRICED EDITION

# Mutual relations of crystals (ans amorphus material)

The various pattern of crystal arrangement which can exist are conventely introduces under the following headings: equigranular textures; inequigranular textures; orientes textures; intergrowth textures; radiate textures; overgrowth textures; banded textures; and cavity textures. Particular textures may be belong to more than one of these categories and some also belong to the categories of **crystalinity**, **granularity** and **crystal shape**. Thus certain of the textures introduced in this section have already been mentioned and reference is made to photographs of them in previous sections.

## EQUIGRANULAR TEXTURES

Depending on the general shape of crystals, three textures can be distinguished in which crystals of the principal minerals in a rock are roughly uniform grain size:

| **name** | **synonymous** | **definition** |
|---|---|---|
| euhedral granular | panidiomorphic granular | bulk of crystals are euhedral and of uniform size |
| subhedral granular | hypidiomorphic granular | bulk of crystals are subhedral and of uniform size |
| anhedral granular | allotriomorhic granular (granitic and granitoid textures apply to siliceous rock only) | bulk of the crystals are anhedral and of uniform size |

Boundaries between these categories are not sharply defined and consequently the terms applied very subjectively. Furthermore a rock may not fit neatly into a single category, thus one in which ~ 50% anhedral might best be described as having a mixed euhedral and anhedral granular texture.

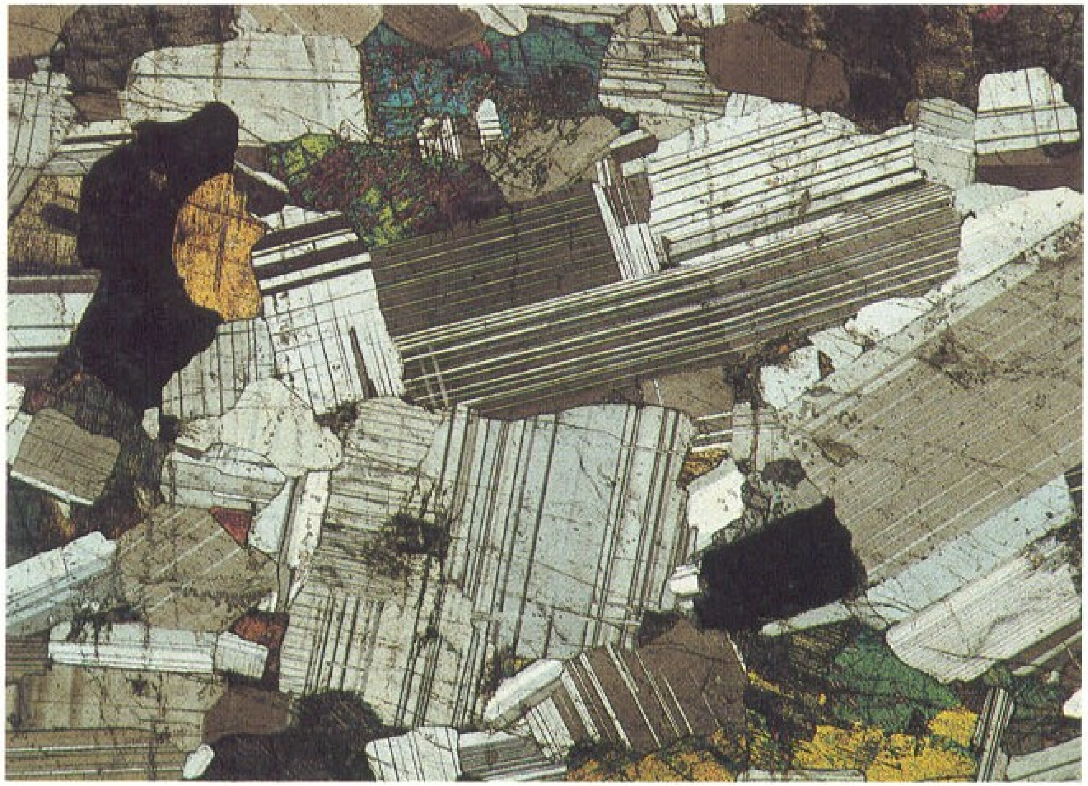
# Euhedral granular hornblendite

## 39 Euhedral granular hornblendite

Rocks possessing truly euhedral granular textures are very rare. The one in this figure is a good example of a more common situation in which only some of the crystals of the principal mineral, hornblende, are euhedral and some strictly are subhedral. In contrast to **40**, there are a higher proportion of crystals with faces and the term 'euhedral granular' is therefore suggested as most appropriate. It should be appreciated, however, that another petrologist might prefer 'subhedral granular'.

*Hornblendite from Ardsheal Hill, Scotland; magnification ×7, XPL.*

# Subhedral granular gabbro

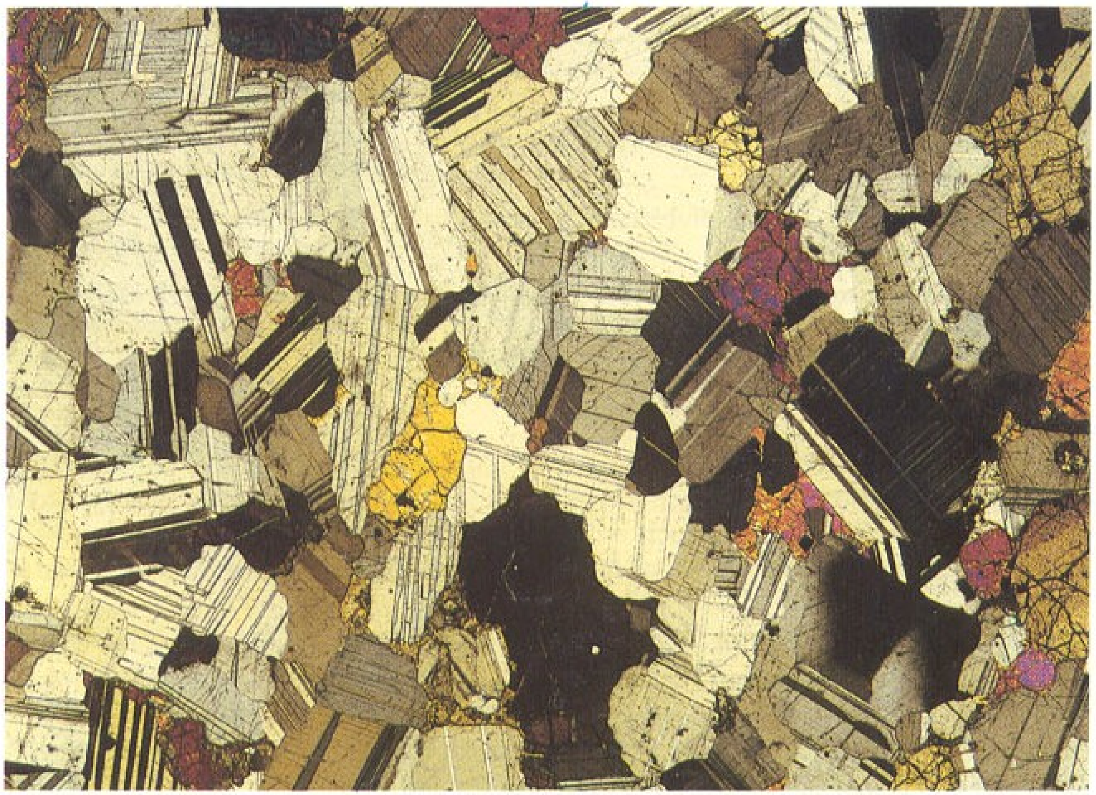


**40 Subhedral granular gabbro**

The stout prismatic plagioclase feldspar crystals which dominate this rock are mostly subhedral. The anhedral interstitial crystals are of orthopyroxene, augite and magnetite.

*Gabbro from Middle Zone of the Skaergaard intrusion, East Greenland; magnification × 20, XPL.*

# Anhedral granular troctolite



**41 (Anhedral) granular troctolite**

Only a few of the plagioclases in this equigranular rock possess a face and none of the olivines do. The crystals are therefore predominantly anhedral and the 'mosaic' texture is granular.

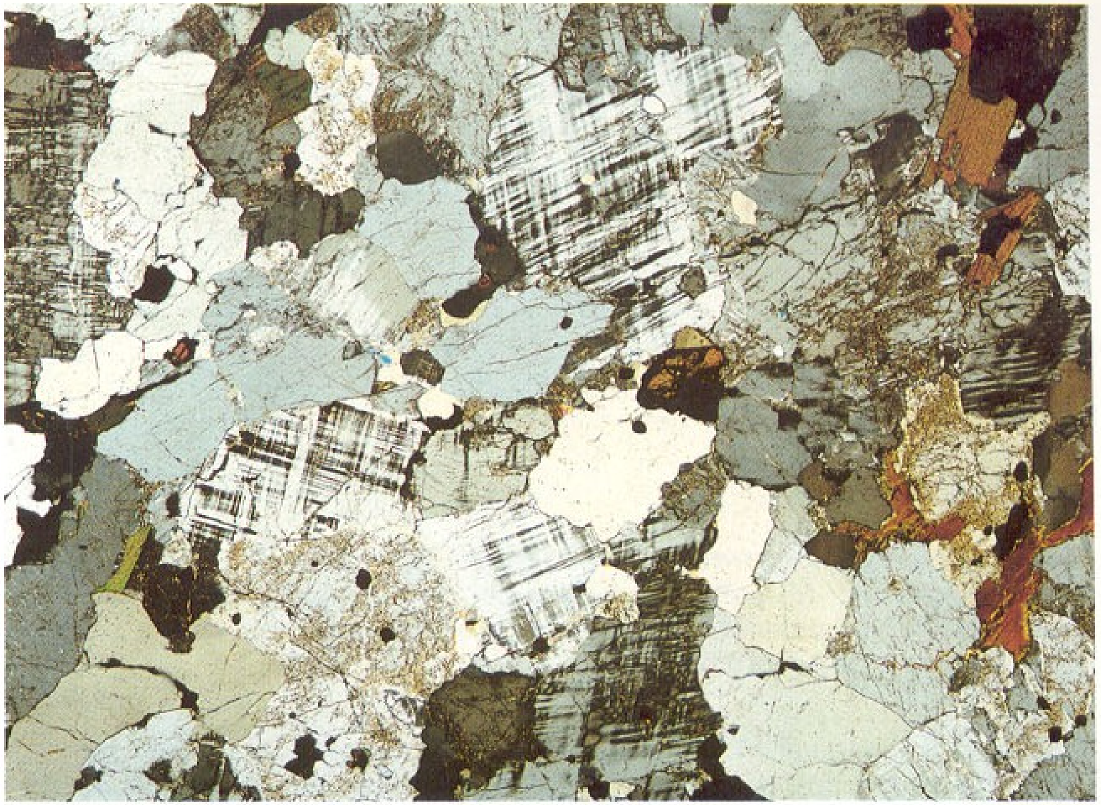
*Troctolite from Garbh Bheinn intrusion, Skye, Scotland; magnification × 17, XPL.*

# Granular granite

## 42 Granular granite

Excepting the scarce biotite crystals, the quartz, microcline and albite crystals which make up the bulk of the rock are anhedral and have slightly interdigitating boundaries (i.e. *consertal texture* – see p. 45).

*Granite from Madagascar; magnification × 13, XPL.*

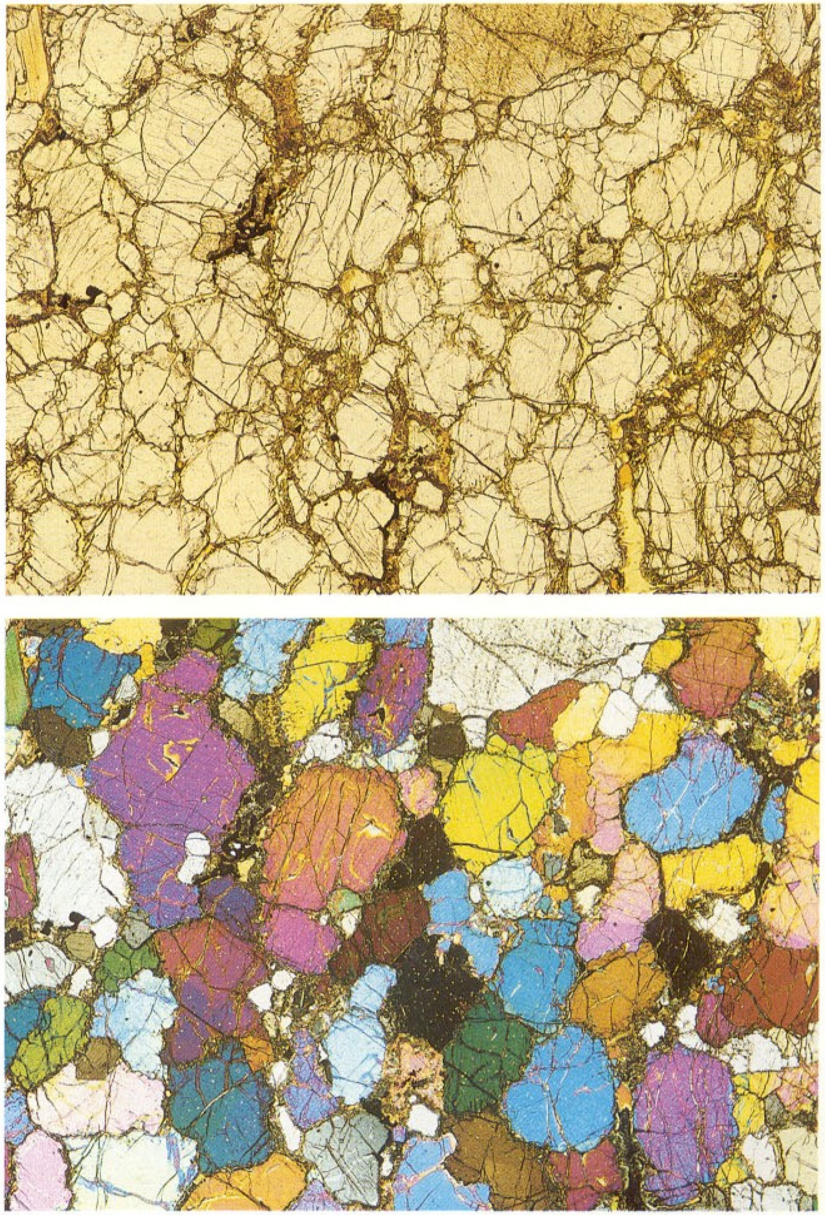


# Granular lherzolite

## 43 Granular lherzolite

The crystals of olivine (colourless in PPL), and pyroxenes (pale brown in PPL) which make up 95% of this rock, lack any crystal faces.

*Lherzolite xenolith from the Matsoku kimberlite pipe, Lesotho; magnification × 16, PPL and XPL.*

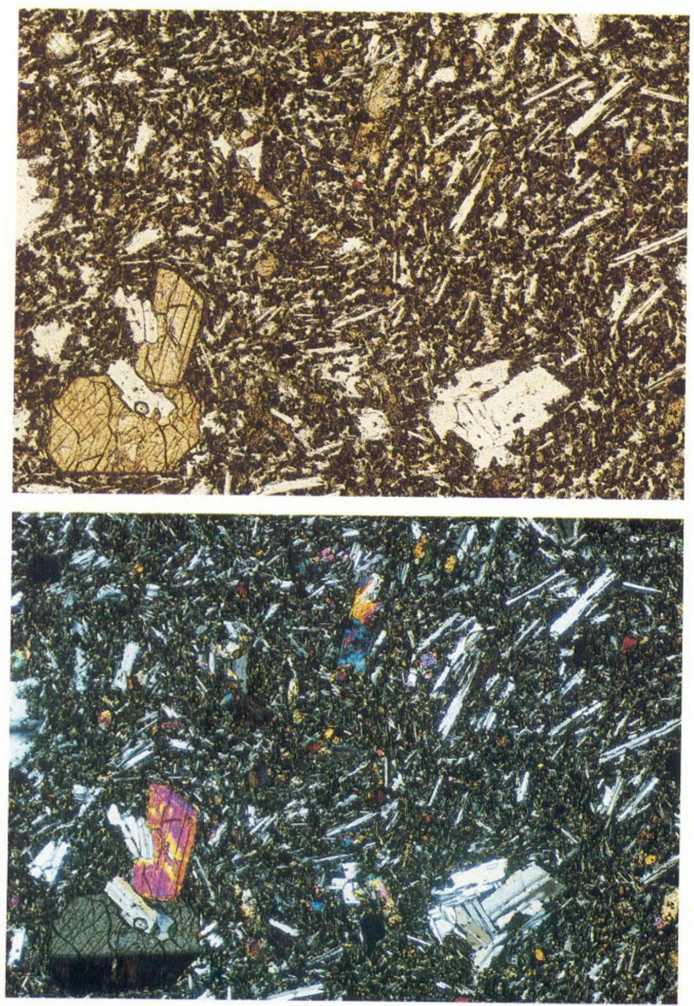


## Inequigranular textures

This category includes seven kinds of texture: (a) seriate; (b) porphyritic; (c) glomerophyritic; (d) poikilitic; (e) ophitic; (f) subophitic; and (g) interstitial (intersertal and intergranualr). It is not uncommon for a single thin section to display more one of these textures.

***Seriate texture***

Crystals of the principal minerals show a continous range of sizes.



**44 Seriate-textured basalt**

This basalt, consisting of just plagioclase, augite and a small proportion of magnetite, shows a range in sizes of plagioclase and augite crystals from <0.01–0.5 mm.

*Basalt from Island of Mauritius; magnification × 43, PPL and XPL.*

*See 22 and 137 for other seriate-textured rocks.*

***Porhyritic texture***

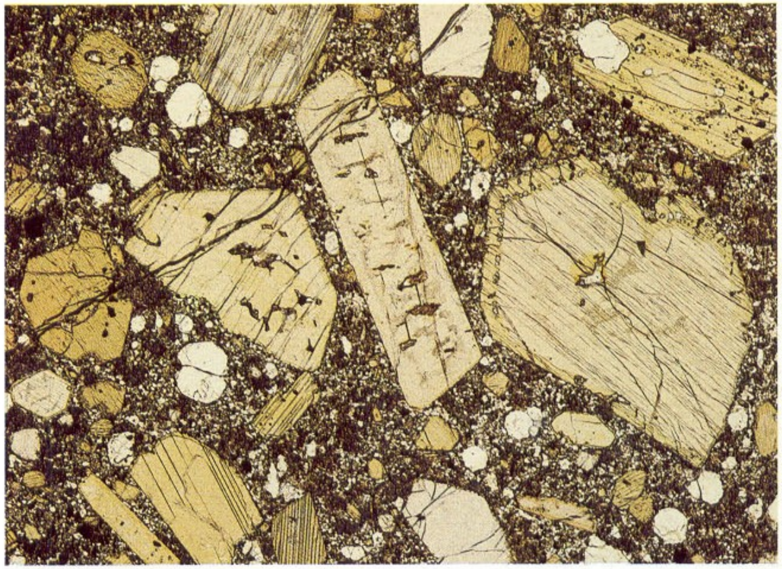
Relatively large crystals (phenocrysts) are surrounded by finer-grained crystals of the groundmass.

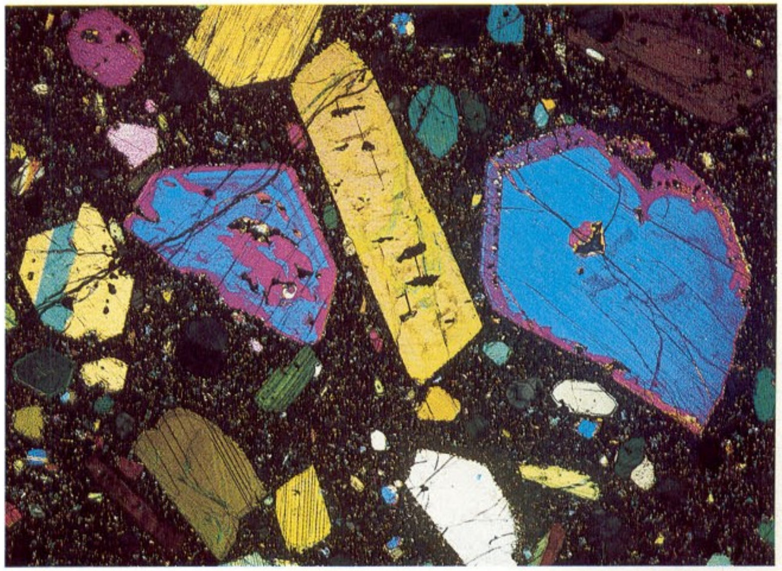
**45 Augite-olivine-leucite-phyric melilitite**

Augite (greyish-green and green in PPL) is present in three generations in this sample – large euhedral phenocrysts, subhedral microphenocrysts and minute groundmass crystals. The leucite occurs as colourless, equant euhedral microphenocrysts, most easily identified by their very low birefringence in the XPL picture, and the olivine as faint-grey, euhedral, columnar microphenocrysts. Note the complicated zoning pattern in one of the augite phenocrysts, the prominent marginal zoning and the line of small inclusions of groundmass crystals in another. Melilite is confined to the fine-grained granular groundmass and cannot easily be seen in these photographs.

*Melilitite from Malawa, Celebes; magnification × 11, PPL and XPL.*

*Many more examples of porphyritic texture may be found by leafing through the book.*

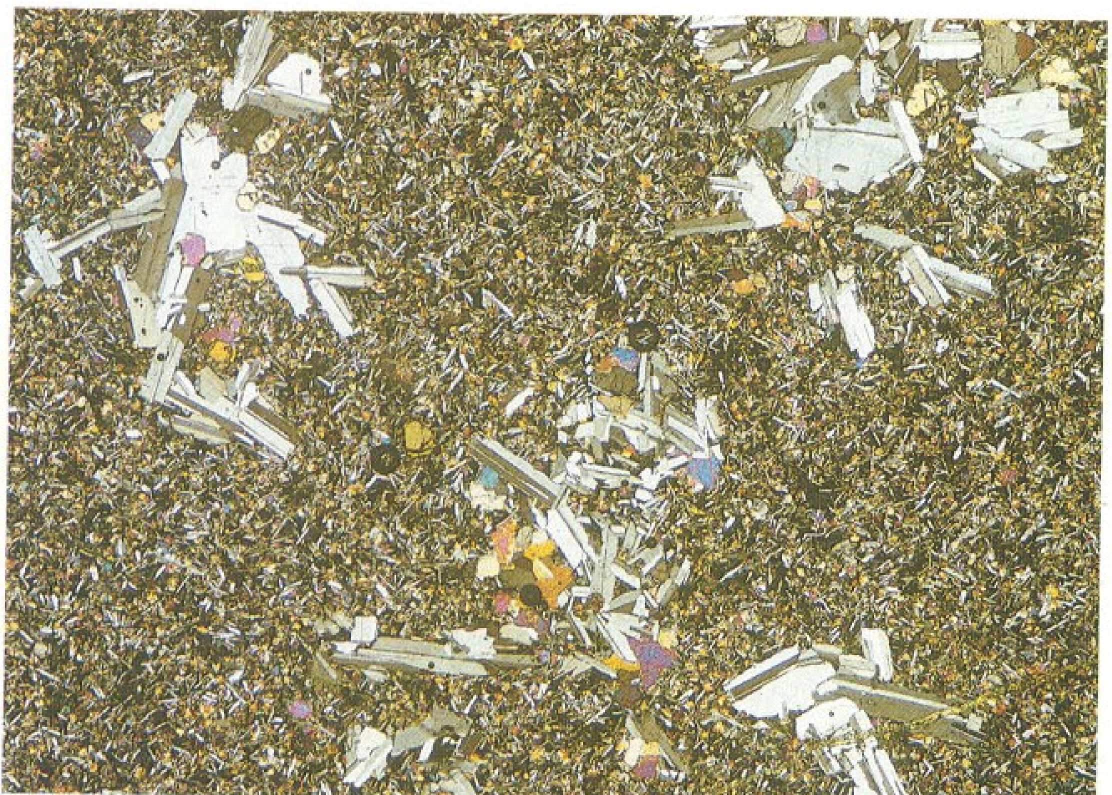




***Glomeroporphyritic texture***

A variety of porphyritic in which the phenocrysts are bunched, or clustered, in aggregates or clots called *glomerocrysts*. (A minority of petrologists maintain taht the term applies only to monomoneralic clots and for polymineralic clots they use the term *cumulophyric texture*.) *Glomerophyric* is usually be reserved for clusters of equant crystals (Johannsen, 1931). (*Synneous texture* also describes crystal clots but includes the genetic implications that crystals swam together and therefore best avoided.

## Glomeroporphyritic tholeiitic basalt

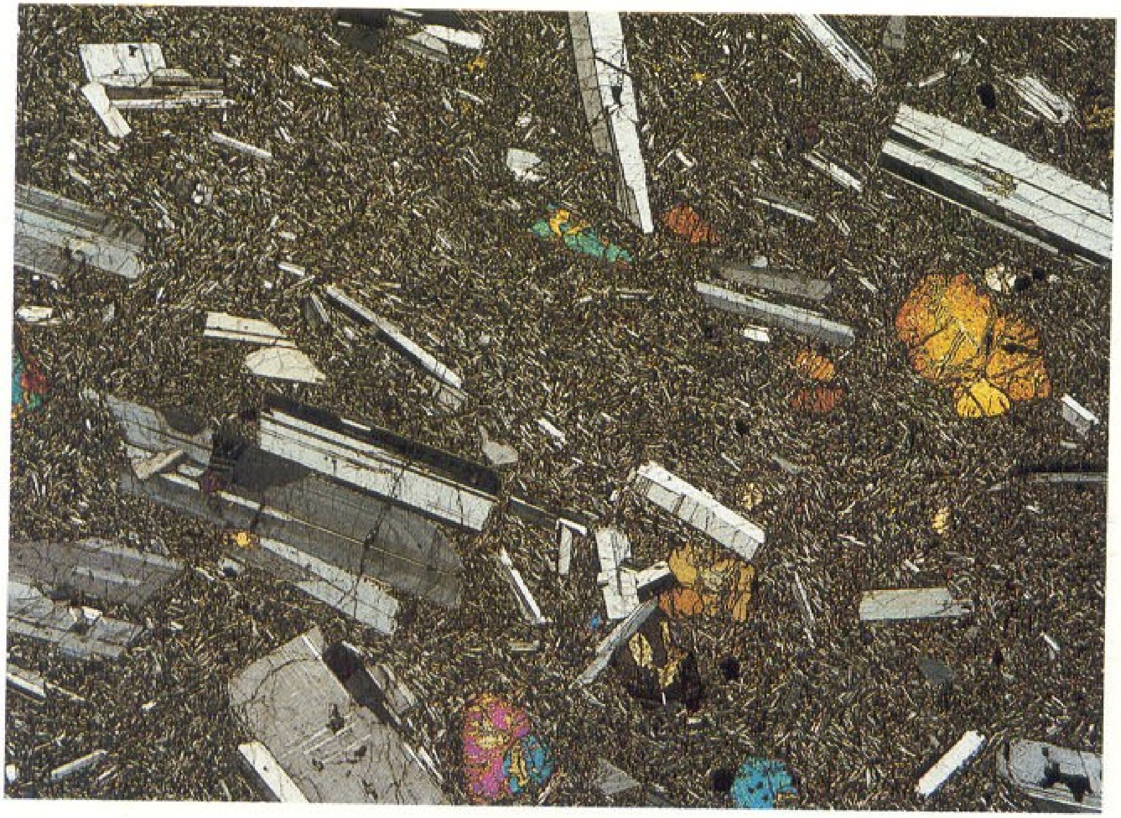


**46 Glomeroporphyritic tholeiitic basalt**

The photograph shows crystal clots of different sizes composed of plagioclase, augite and olivine crystals, enclosed by fine-grained intergranular- and intersertal textured groundmass.

*Basalt from unknown locality; magnification × 11, XPL.*

# Glomeroporhyritic hawaiite



## 47 Glomeroporphyritic hawaiite

Discrete phenocrysts of plagioclase and olivine, and clots consisting of a few crystals of the same minerals, are set in a fine-grained groundmass, in places showing slight alignment of plagioclase needles. Some plagioclases in individual clots are aligned – this arrangement is common in plagioclase glomerocrysts.

*Hawaiite from plateau lavas of North Skye, Scotland; magnification × 11, XPL.*

*Additional views of glomeroporphyritic texture may be seen in* ***122***, ***127***, ***154*** *and* ***158***.

***Poikilitic texture***

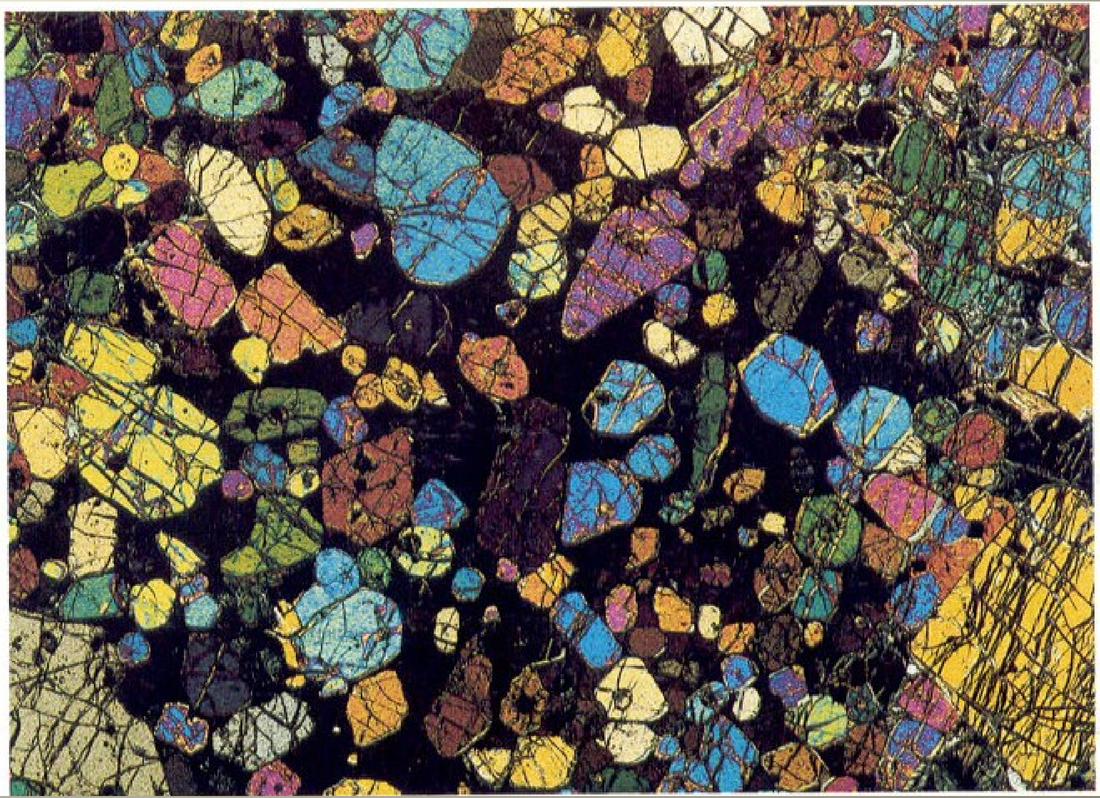
Relatively large crystlas of one mineral enclose numerous smaller crystals on one, or more, other minerals which are randomly oriented and generally, but not necesarily, uniformly distributed. The host crystal is known as an *oikocrysts* (or *enslosing crystal*) and enclosed crystal as *chadacrysts*. Although *chadacrysts* are generally equant, or nearly so, they need not be uniform in size; sometimes they display progressive change in size from the interior to the margin of an oikocrysts, indicating differences in extant of chodocrysts growth at the time of enclosure. It is not customary to apply *poikilitic texture* to the arrangement in which scarce minute crystals of accessory minerals are embeded in a crystal, nor to that in which the encloding mineral is approximately the same size as that included.

# Poikilitic enclousure of olivine crystals by augite

**48 Poikilitic enclosure of olivine crystals by augite**

In this photograph approximately 100 crystals of olivine of fairly uniform size are enclosed by a single augite crystal (at extinction).

*Peridotite from Quarsut, West Greenland; magnification ×22, XPL.*



# Plagioclase chadacrysts enclosed by augite

**49 Plagioclase chadacrysts enclosed by augite**

Part of a single augite crystal (yellow colour), exceeding 30mm in size, is shown here enclosing plagioclase crystals, some of which form clots. The orange crystal at upper right is olivine and the crystal almost at extinction is another augite crystal.

*Gabbro from North Skye, Scotland; magnification × 7, XPL.*

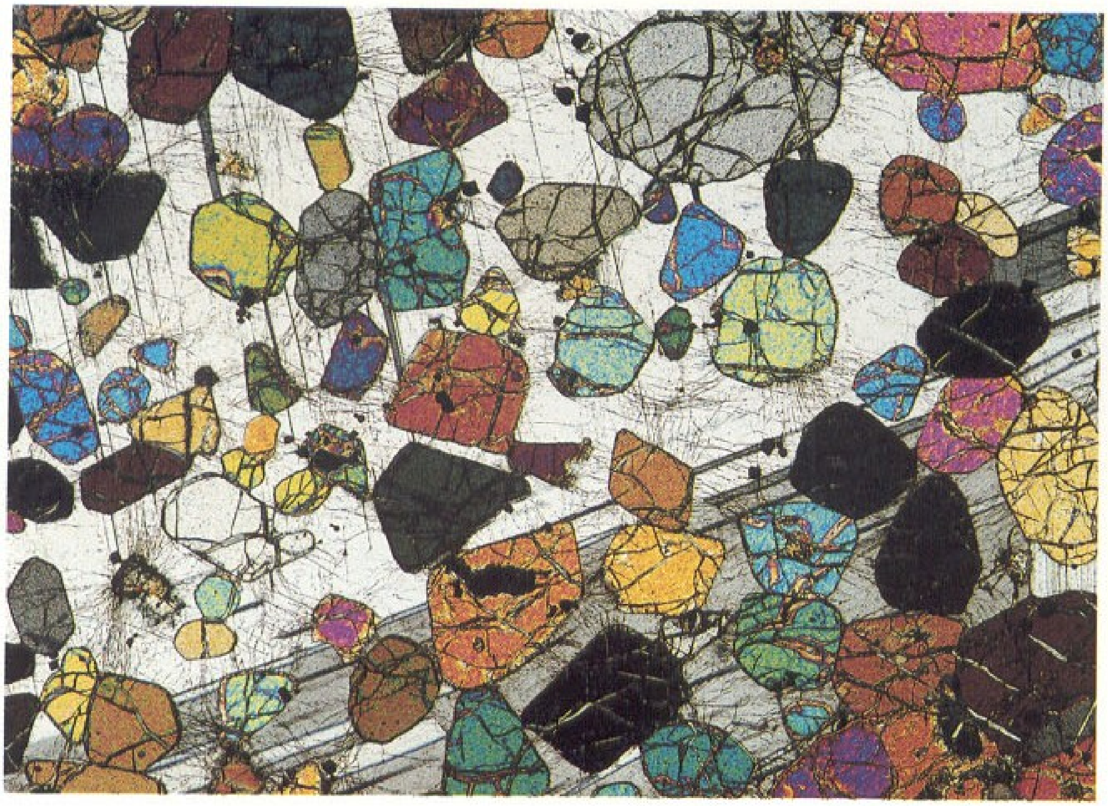
# Olivine gabbro containing poikilitic domains

**50 Olivine gabbro containing poikilitic domains**

Large plagioclases, enclosing or partially enclosing, round olivines at their margins provide a framework to this rock, the interstices of which are occupied by large augites also enclosing round olivines and small stubby crystals of plagioclase.

*Olivine gabbro from Middle Border Group of the Skaergaard intrusion, East Greenland; magnification × 12, XPL.*

# Olivines enclosed by plagioclase oikocryst



**51 Olivines enclosed by plagioclase oikocryst**

Subhedral, equant olivine crystals here are enclosed in a single large plagioclase crystal.

*Feldspar peridotite from Rhum, Scotland; magnification ×21, XPL.*

*Additional views of poikilitic texture may be found in* ***111, 114*** *and* ***167****.*

***Ophitic texture***

This is variant of *poikilitic texture* in which the randomly arranged chadacrysts are elongated and are wholly, or partly, enclosed by the oikocrysts. The commonest occurrence is of bladed crystals of plagioclase surrounded by sebequant augite crystals in dolerite (sometimes refferd to as *doleritic texture*); however the texture is not confined to dolerites, nor to plagioclase and augite as the participating minerals.

Some petrologists distinguish the arrangement in which the elongate chadacrysts are completely enclosed (*poikilophitic texture*) from that in which they are partially enclosed and therefore penetrate the oikocrysts (*subophitic texture*). *Poikilophitic texture* could also be used when oikocrysts surround elongate chadacrysts of one mineral and equant chadacrysts of another.

Fine-and medium-grained rocks made up of many small oikocrysts have a patchy appearance, sometimes described as *ophimottled.*

# Ophitic-textured alkali olivine dolerite

**52 Ophitic-textured alkali olivine dolerite**

Two large anhedral crystals of augite enclose numerous, randomly arranged lath-shaped plagioclases. Note that many of the plagioclases are associated in groups. The larger augite crystal has a variable colour due to a chemical zoning (see p. 61).

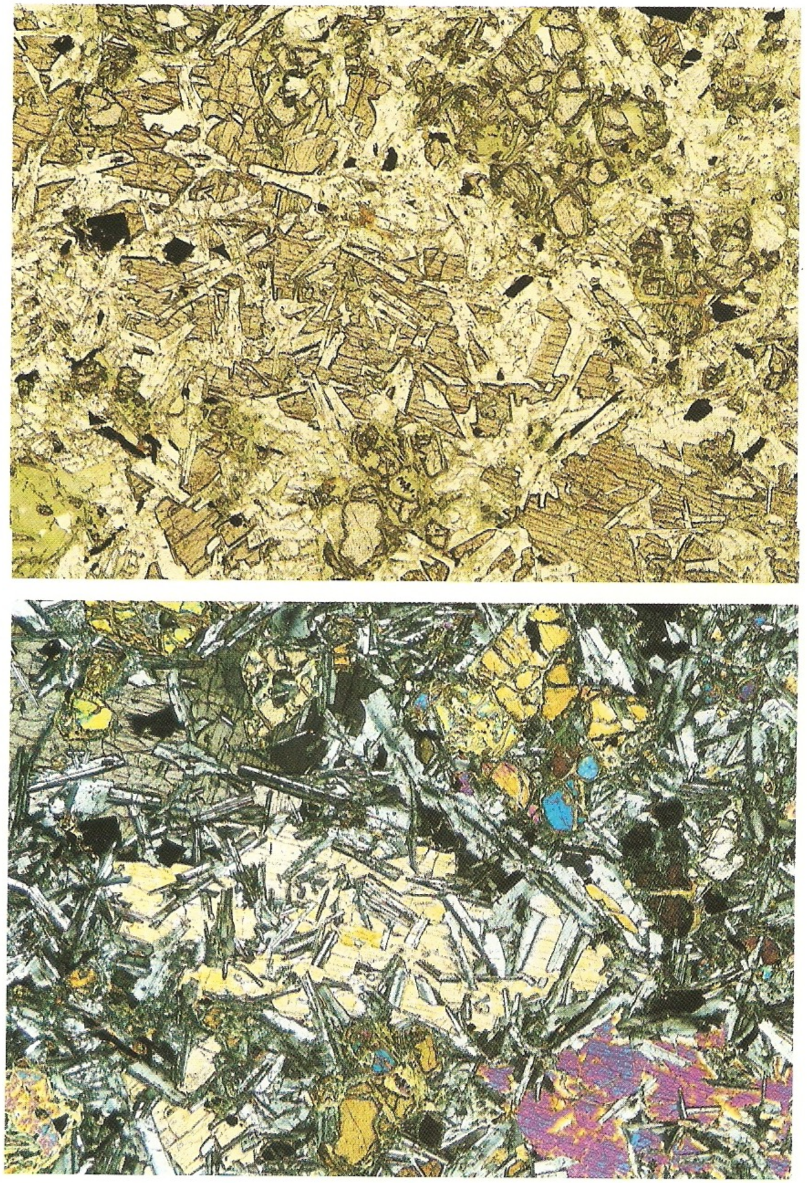
*Olivine dolerite from Shiant Isles still, Scotland; magnification × 11, XPL.*

# Subophitic texture in olivine dolerite

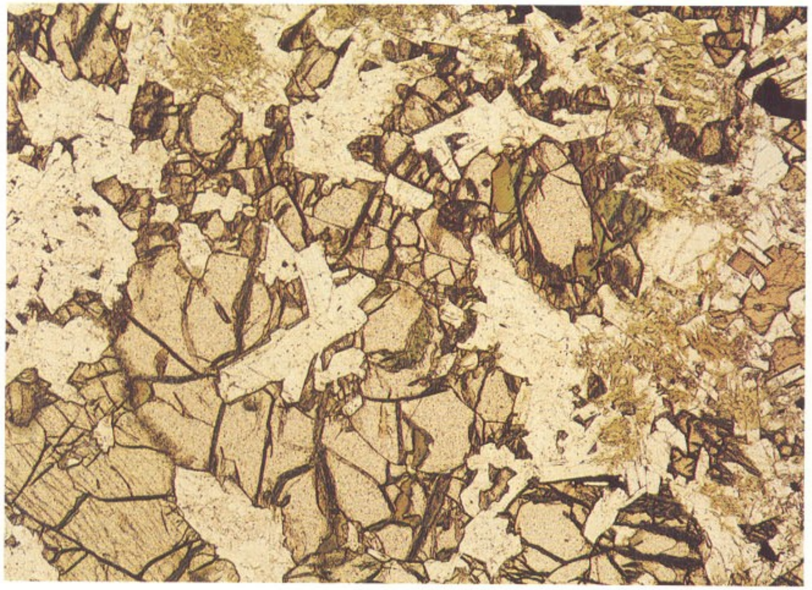
**53 Subophitic texture in olivine dolerite**

The photographs show plagioclase laths embedded in several augite crystals; whereas some of the plagioclases are wholly embedded, others penetrate beyond the augite crystals. The other mafic mineral present is olivine which is partially altered to a green clay-like mineral and is distinguished from the augite by its colour in the PPL view.

*Olivine dolerite from unknown British source; magnification × 27, PPL and XPL.*



# Subophitic alkali olivine dolerite



**54 Subophitic alkali olivine dolerite**

In this view plagioclase laths are embedded in olivine rather than pyroxene. One olivine crystal is at extinction in the XPL photograph and another shows orange interference colour. The other mafic mineral in the pictures is augite showing a purple interference colour.

*Olivine dolerite from Shiant Isles sill, Scotland; magnification × 26, PPL and XPL.*

*See **121**, **126**, **128** and **164** for additional examples of subophitic texture; **121** is particularly interesting because here the pyroxene is subophitically enclosed by plagioclase, and in **164** pyroxene is subophitically enclosed by kalsilite.*

# Poikilophitic texture in olivine gabbro

**55 Poikilophitic texture in olivine gabbro**

For the texture shown here the term poikilophitic is preferable to ophitic because (a) the large augite encloses some equant olivines in addition to plagioclases, and (b) many of the plagioclases are not markedly elongate.

*Olivine gabbro from Lower Zone a of the Skaergaard intrusion, East Greenland; magnification × 10, XPL.*

Ophiomottled texture in olivine basalt

**56 Ophimottled texture in olivine basalt**

Approximately fifty augite crystals are shown here enclosing bladed plagioclases and giving the rock a mottled or speckled appearance.

*Olivine basalt from Isle of Mull, Scotland; magnification ×14, XPL.*

# Feldspar-olivine-phyric ophiomottled basalt

**57 Feldspar-olivine-phyric ophimottled basalt**

Phenocrysts of plagioclase and olivine, some in clots, are set in fine-grained ophimottled groundmass.

*Olivine basalt from Skye, Scotland; magnification × 12, XPL.*

***Interstitial textures***

Two varieties are recognized on the basis of the material occupying the angular spaces between feldspar laths:

1. *Intersertal texture* – glass or hypocrystalline material wholly, or partly, occupies the wedge-shaped interstices between plagioclase laths. The glass may be fresh or have been altered to plagonite, chlorite, analcite or clay minerals, or it may have devitrified. If a patch of glass is sufficiently large and continuous to enclose a number of plagioclases, some petrologists would describe the texture as hyalophitic. (See also *hyalopilitic texture*).
2. *Intergranular texture* – the spaces beween plagioclase laths are occupied by one, or more, grains of pyroxene ( olivine and opaque minerals). Unlike ophitic texture, adjacent interstices are not in optical continuity and hence are discrete small crystals. The feldspar may be in diverse, subradial or subparallel arrangement (see also *pilotaxitic* and *felty* textures).

As shown by some of the photographs illustrating these textures, a single thin section may contain both types of interstitial texture in separate, but contiguous, textural domains.

# Intersertal (hialophitic) texture in thoeliitic basalt

**58 Intersertal (hyalophitic) texture in tholeiitic basalt**

Certain parts of this photograph show lath-shaped plagioclases enclosed in pools of devitrified, deep-brown glass. Other plagioclases are surrounded by augite in a subophitic manner.

*Oceanic tholeiite from Leg 34 of the Deep Sea Drilling Project; magnification ×65, PPL.*

# Intersertal texture in alkali dolerite

**59 Intersertal texture in alkali dolerite**

The intersertal texture in this dolerite consists of plagioclase crystals embedded in analcite (colourless in PPL and isotropic in XPL). Other plagioclases are partially enclosed by pyroxene in a subophitic manner. A crystal of olivine can be seen at the right-hand edge of the view in PPL.

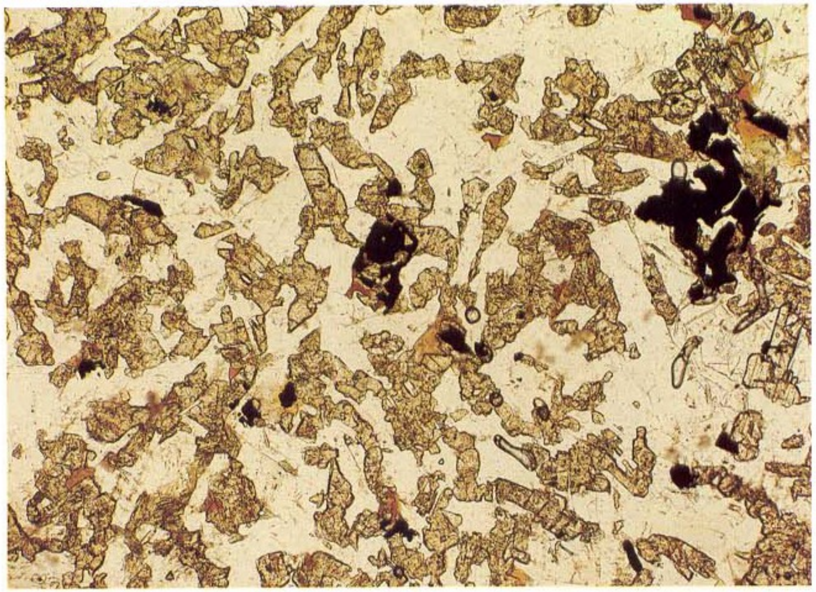
*Alkali dolerite from Howford Bridge sill, Ayrshire, Scotland; magnification × 23, PPL and XPL.*
*See also* ***126*** *and* ***127****.*

# Intergranular dolerite

**60 Intergranular dolerite**

Anhedral equant crystals of augite and pigeonite occupy the spaces between plagioclase crystals in this sample.

*Dolerite from near the lower margin of Palisades sill, New Jersey, USA; magnification × 60, PPL and XPL.*



# Intergranular olivine gabbro

**61 Intergranular olivine gabbro**

In this example of intergranular texture the rock is coarse-grained and the plagioclases have a subparallel arrangement. Note that the interstitial augites are anhedral against the euhedral plagioclases.

*Olivine gabbro from Lower Zone b of the Skaergaard intrusion, East Greenland; magnification × 15, XPL.*

# Tholeitiic basalt with two types of interstitial texture

**62 Tholeiitic basalt with two types of interstitial texture**

In this photograph patches between some of the plagioclases are occupied by brown glass (partly devitrified) and between others by clots of small augite crystals without any glass present, i.e. domains of both intersertal and intergranular texture are present.

*Tholeiitic basalt from Ubekendt Ejland, West Greenland; magnification × 27, PPL and XPL.*

# Intersertal, intergranular and subophitic textures in dolerite

**63 Intersertal, intergranular and subophitic textures in dolerite**

All three of these textures co-exist in this rock.

*Dolerite from Whin sill, Northumberland, England; magnification × 26, PPL and XPL.*

Intersertal, intergranular and subophitic textures in dolerite (continued).

## ORIENTED, ALIGNED AND DIRECTED TEXTURES

Sevral classes of this textural type exist: (a) trachytic texture; (b) trachytoid texture; (c) parallel-growth texture; (d) comb texture; and (e) orbicular texture.

***Trachytic texture***

A subparallel arrangement of microcrystalline lath-shaped feldspars in the ground-mass of a holocrystalline or hypocrystalline rock.

Note well the therm is not restricted in use to rock of trachyte composition.

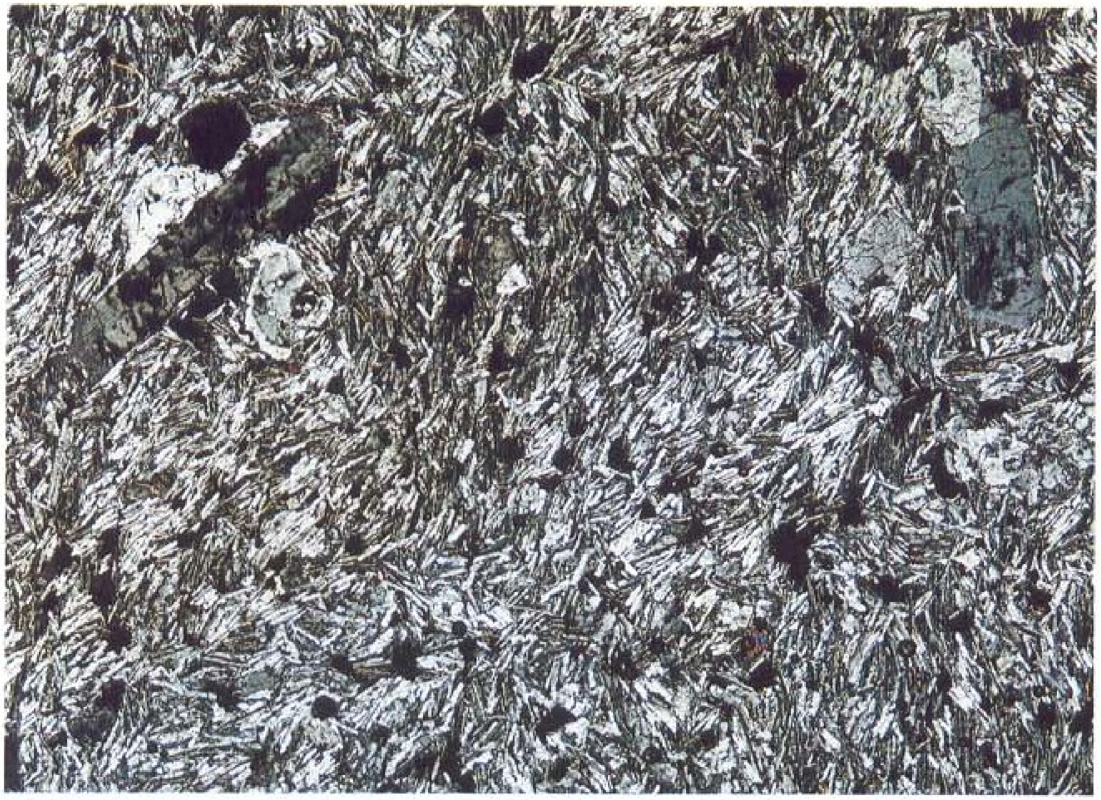
Some petrologists subdivide trachytic texture with microlite-sized feldspars into *pilotaxitic texture* and *hyalopilitic texture*, depending on whether the material between the feldspars is crystalline or glassy. Stristly, however, the microlites in these textures may be more or less aligned. (For a pilotaxitic texture in which the microlites are essentially randomly arranged the term *felty texture* exists.)

***Trachytoid texture***

A subparallel arrangement of tabular, bladed or prismatic crystals which are visiable to the naked eye (Holmes, 1921). While the term is usually applied to crystals feldspar, Johansen (1931) states that in may equally well be used for oriented crystals of any other mineral.

The term *flow* and *fluxion texture* are sometimes used as synonyms for trachytic and trachytiod textures, however they should be avoided of their genetic implications.

# Trachytic texture in a trachyte

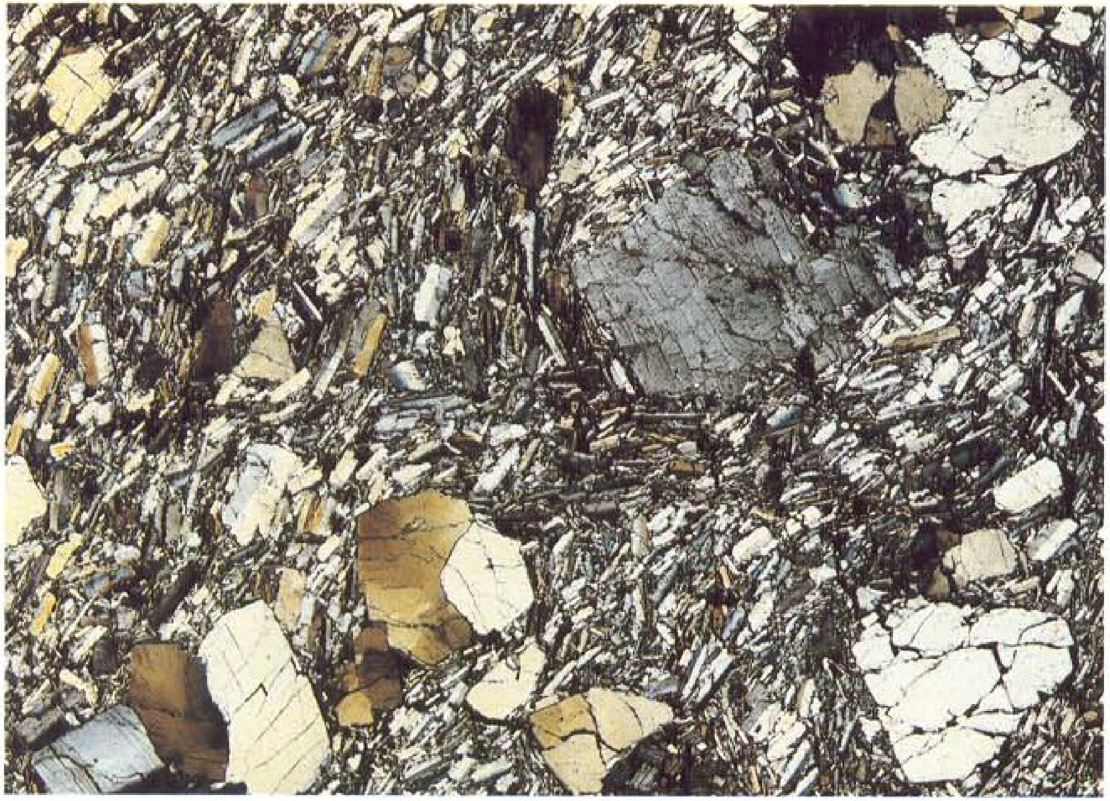


**64 Trachytic texture in a trachyte**

This rock illustrates trachytic texture with no glass between the small, aligned alkali feldspars (i.e. pilotaxitic variety). Note that, rather than there being a single universal alignment direction, there are several domains in the photograph, each having its own preferred direction of feldspar alignment.

*Trachyte from unknown Czechoslovakian locality; magnification × 16, XPL.*

# Trachytic texture in trachyte

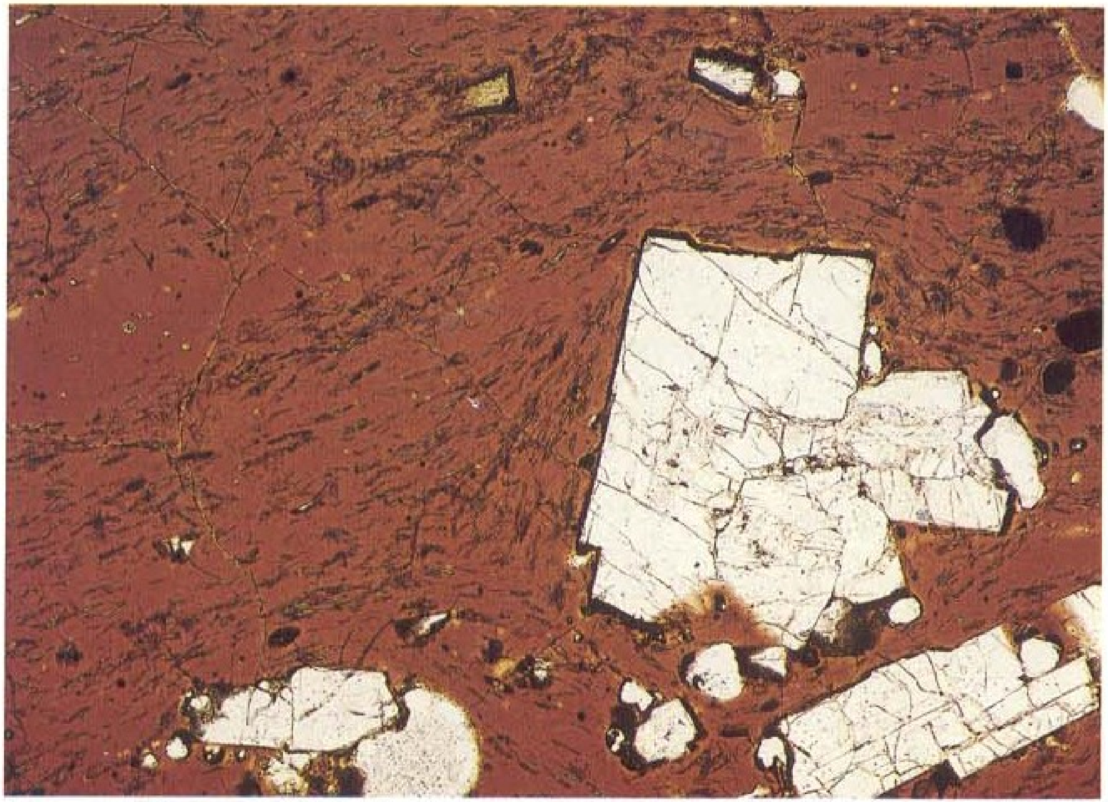


**65 Trachytic texture in trachyte**

The somewhat stumpy groundmass alkali feldspars in this rock display a subparallel alignment which is particularly noticeable where they follow the outline of the phenocrysts.

*Trachyte from unknown German locality; magnification ×15, XPL.*

# Hyalopilitic texture in rhyolitic pitchstone



**66 Hyalopilitic texture in rhyolitic pitchstone**

The feldspar microlites in this glassy rock have a preferred elongation direction from lower left to upper right; near the feldspar phenocrysts and opaque crystals the orientation of the microlites follows the outline of these crystals. Note the tendency for the microlites to be arranged in bands.

*Pitchstone from Ischia, Bay of Naples; magnification × 20, PPL.*

Trachytoid diorite

**67 Trachytoid diorite**

This medium-grained rock contains aligned columnar plagioclases. The cloudy appearance to the plagioclases results from very small inclusions of iron ore and mica.

*Diorite from Comrie, Scotland; magnification × 16, PPL.*

# Trachytoid gabbro

## 68 Trachytoid gabbro

This trachytoid texture consists of platy plagioclases, here seen edge on, stacked upon one another. Note that when this rock is sectioned parallel to the plane of the flattening, the crystal alignment would not be evident.

*Gabbro from Lower Zone b of the Skaergaard intrusion, East Greenland; magnification × 12, XPL.*

# Olivines in trachytoid arrangement in olivine dolerite

**69 Olivines in trachytoid arrangement in olivine dolerite**

In this view, large columnar phenocrysts of olivine, some of skeletal type, are aligned, and embedded in inter-granular-textured plagioclase and augite.

*Olivine dolerite from Isle of Skye, Scotland; magnification ×21, XPL.*

***Parallel-growth texture***

A single elongate skeletal crystal which in thin section appears to consist of a clot of crystals having the same elongation direction and the same optical orientation. In rocks trachytoid texture it is not uncommon for neighbouring parallel-growth crystals to be alignated.

***Comb texture ( comb layering)***

Elongate, possibly curved, branching crystals sharing the same direction of elongation. The crystals typically form a band, layer, or fringe with the elongation direction of the crystals inclined at 60-90 to the plane of the layering. (Synonyms are Willow-Lake layering and crescumulate layering, though the latter is a genetic term and, hence, shoud be avoided.

***Orbicular texture ( Orbicular layering)***

In connection with the group of textures being considered here, note that in some orbicules the concentric shells have elongate crystals *aligned* radially about the centre of the orbicule.

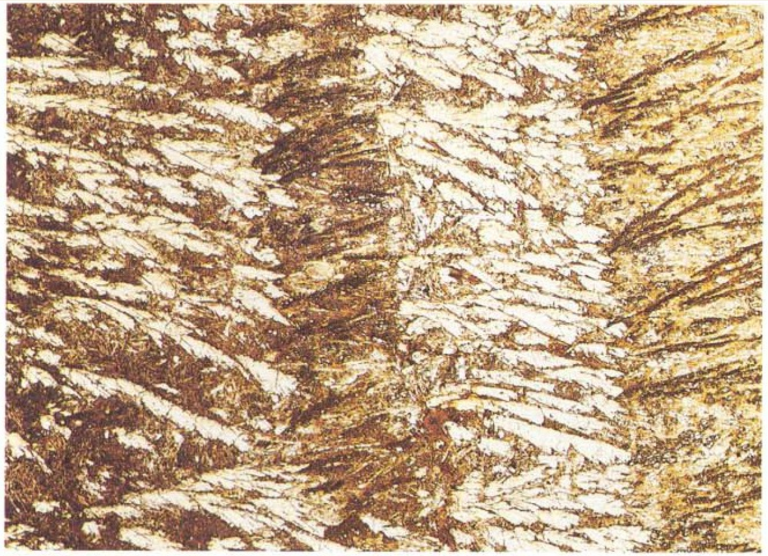
# Pyroxene comb layer in a thin lampropyre (fourchite) dyke

**70 Pyroxene comb layer in a thin lamprophyre (fourchite) dyke**

Long branching augite crystals are aligned at right angles to the boundary between the comb-layered rock (below) and pyroxene-phyric rock (above). The V of the branching widens in the direction of growth, which is away from the dyke wall. (See also **35**.)

*Lamprophyre dyke from Fiskaenesset area, South-west Greenland; magnification × 8, XPL.*

# Comb layers in dolerite dyke



**71 Comb layers in dolerite dyke**

Two types of comb-textured layer are present in these photographs: the first and third bands from the right consist of elongate branching olivine (now largely serpentinized) and plagioclase crystals; the second and fourth bands are pyroxenite dominated by complex, elongate, branching augite crystals with scarce plagioclase crystals in between. The margin of the dyke lies to the left. (See also **34**.)

*Dolerite from North-west Skye, Scotland; magnification ×8, PPL and XPL.*

Comb layers in dolerite dyke (continued)

# INTERGROWTH TEXTURES

In thin section the junction between two crystals may appear as a stright line, a simple curve, or a complex curve; in the third case the crystals interdigitate or interlock, possibly so intimately that they appear[1] to be embedded in one another. These interpenetrative patterns are all examples of *intergrowth textures*. Usually the crystals concerned are anhedral but one or both my be skeletal, dendritic or radiate. Seven varietes are distinguished here: (a) consertal texture; (b) micrographic texture; (c) granophyric texture; (d) myrmekitic texture; (e) intrafasciculate texture; lamellar and blebby intergrowths; and (g) symplectite texture.

[1] The appearence of an interdigitating boundary between two crystals, A and B, depends on the extent of interpenetration and the direction in which the boundary is sectioned; some intersections may show the crystals meeteng in a complex curve; others may crystal A enclosed in B; others may show the converse; and yet others may show each enclosing the other.

***Consertal texture***

The boundary between two crystals involves interdigitations, ane hance appears to be notched or serrated in section (iddings, 1909; Niggli, 1954).

***Micrographic texture (or graphic, if visiable with the naked eye)***

A regular intergrowth of two minerals producing the appearance of cuneiform, semitic or runic writing. The best-known instance is of quartz and alkali feldspar, the quartz appearing as isolated wedges and rods in the feldspar. (a micrographic intergrowth pf quartz and alkali feldspar is also known as micropegmatitic texture.)

***Granophyric texture***

A variety of micrographic intergrowth of quartz and alkali feldspar which is either crudely radiate or is less regular than micrographic texture.

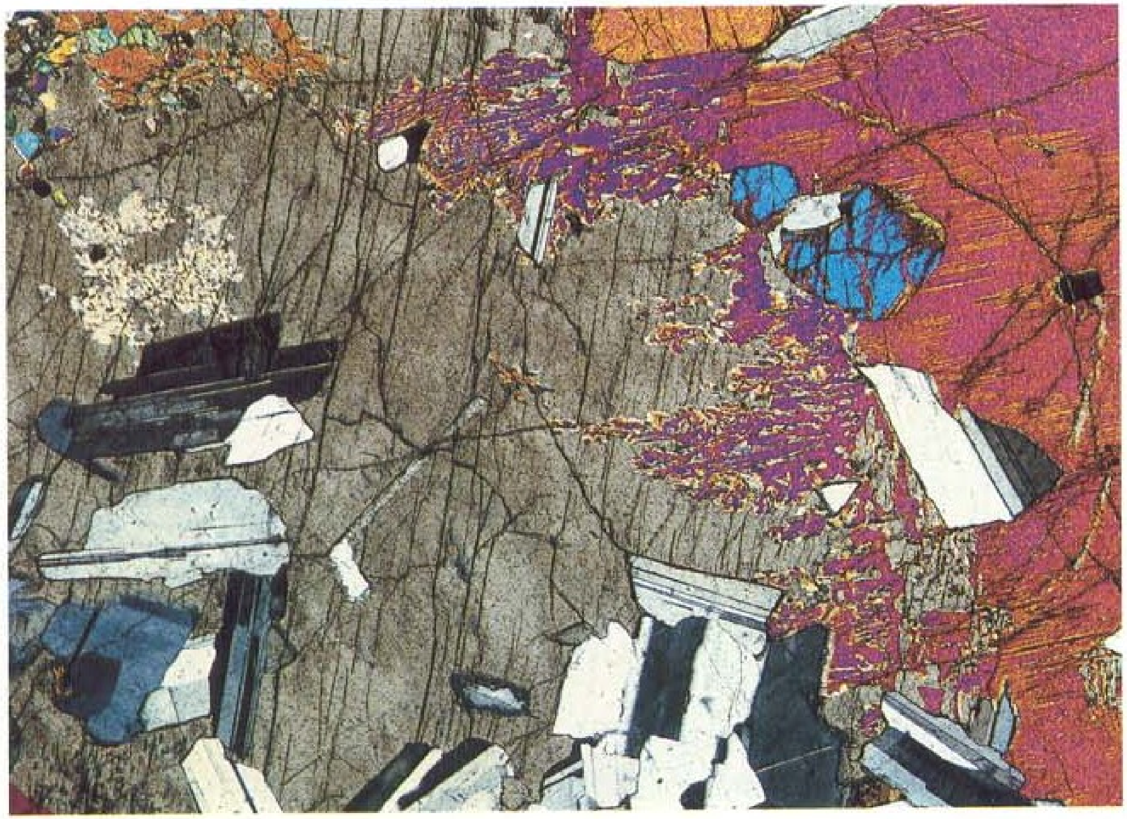
# Consertal texture in granodiorite

**72 Consertal texture in granodiorite**

This photograph of a quartz-rich portion of the rock shows several quartz crystals with intergrown boundaries. (See also **42**.)

*Granodiorite from unknown source; magnification* × 43, *XPL.*

# Consertal intergrowth texture in gabbro



**73 Consertal intergrowth texture in gabbro**

This picture illustrates an extreme example of intergrown boundaries between crystals; the participating crystals are all augites (purple, pale yellow, grey and orange).

*Gabbro from Lower Zone a of the Skaergaard intrusion, East Greenland; magnification × 25, XPL.*

# Graphic granite

## 74 Graphic granite

Photograph of a polished hand specimen of graphic-textured granite in which the dark material is smoky quartz and the light material is alkali feldspar.

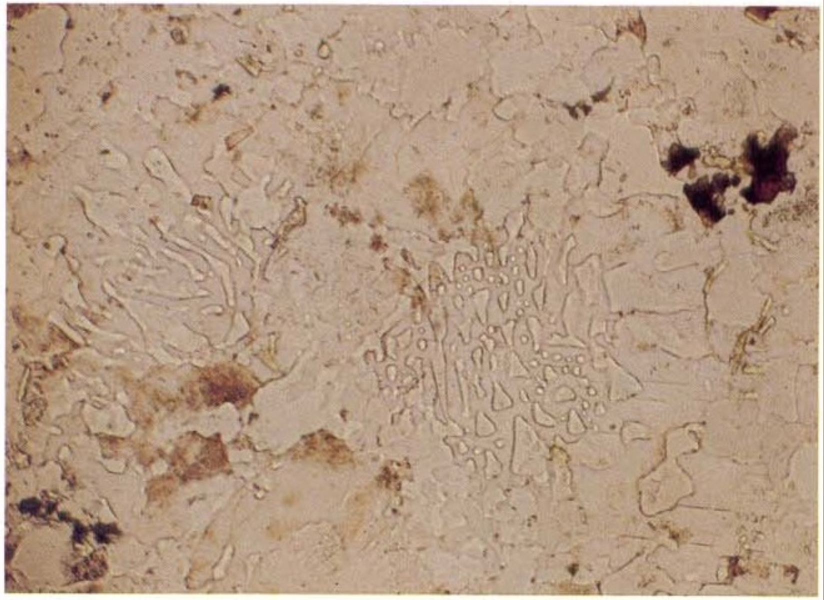
*Graphic granite from unknown locality; magnification × 3.*

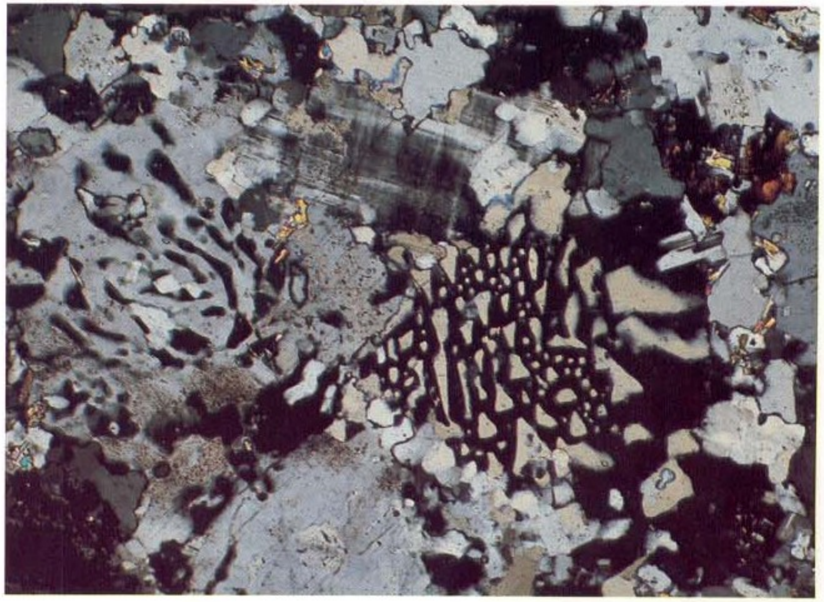
# Micrographic texture in aplite

### 75 Micrographic texture in aplite

Two of the crystals in this view show an intimate micrographic intergrowth of quartz and alkali feldspar. In one (middle right of XPL photograph), the alkali feldspar is at extinction, and in the other (middle left) the quartz is at extinction. (The PPL photograph is deliberately defocussed to show the Becke line in the higher-relief mineral (quartz) when the objective lens is 'raised'.)

*Micro-granite from Worcester, Massachusetts, USA; magnification × 60, PPL and XPL.*





# Micrographic and granophyric textures in microgranite

**76 Micrographic and granophyric textures in microgranite**

The photographs show several units of intergrown quartz and alkali feldspar; most are of micrographic type but some have a radiate arrangement (granophyric texture) at their margins. In the Scottish Hebridean igneous province, rocks like this one were formerly known as *granophyres* in allusion to their distinctive textures.

*Microgranite from Eastern Red Hills of Skye, Scotland; magnification × 20, PPL and XPL.*

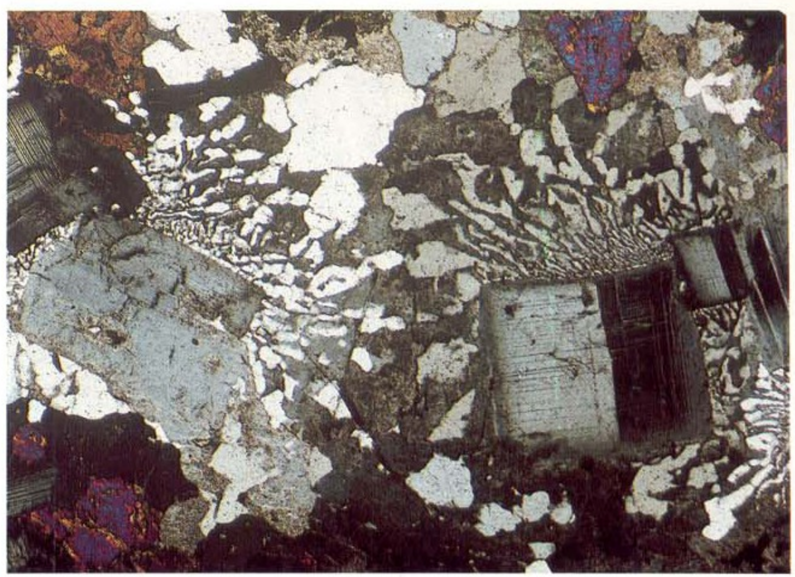
# Granopyric texture

**77 Granophyric texture**

In this rock, radiate intergrowths of quartz and alkali feldspar are arranged about euhedral, equant plagioclase crystals.

*Microgranite from Skaergaard intrusion, East Greenland; magnification × 37, PPL and XPL.*

Granophyric texture (continued)



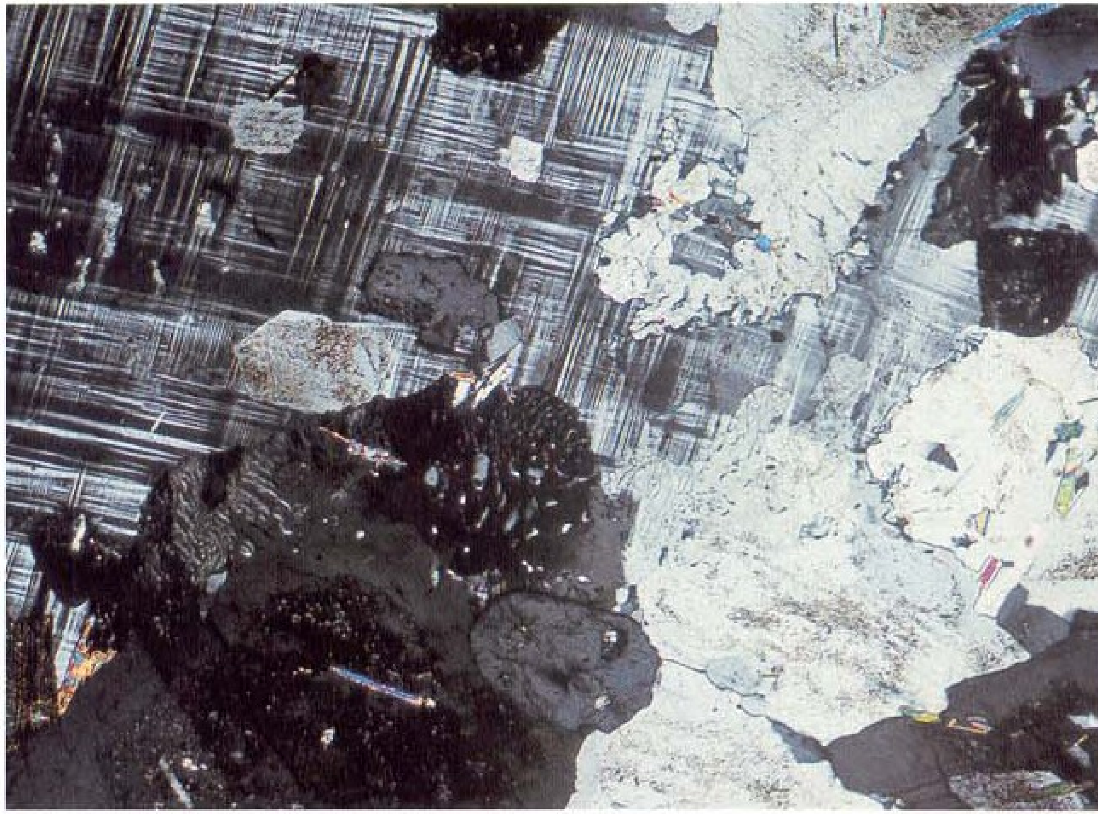
***Mirmekitic texture***

Patches of plagioclase intergrown with vermicular quartz. The intergrowth is often wart-like in shape and is commonly to be found at the margin of a plagioclase crystal, where it penetrates an alkali feldspar crystal. The texture could be regarded as a variety of symplectite texture.

**78 Myrmekitic texture in granite**

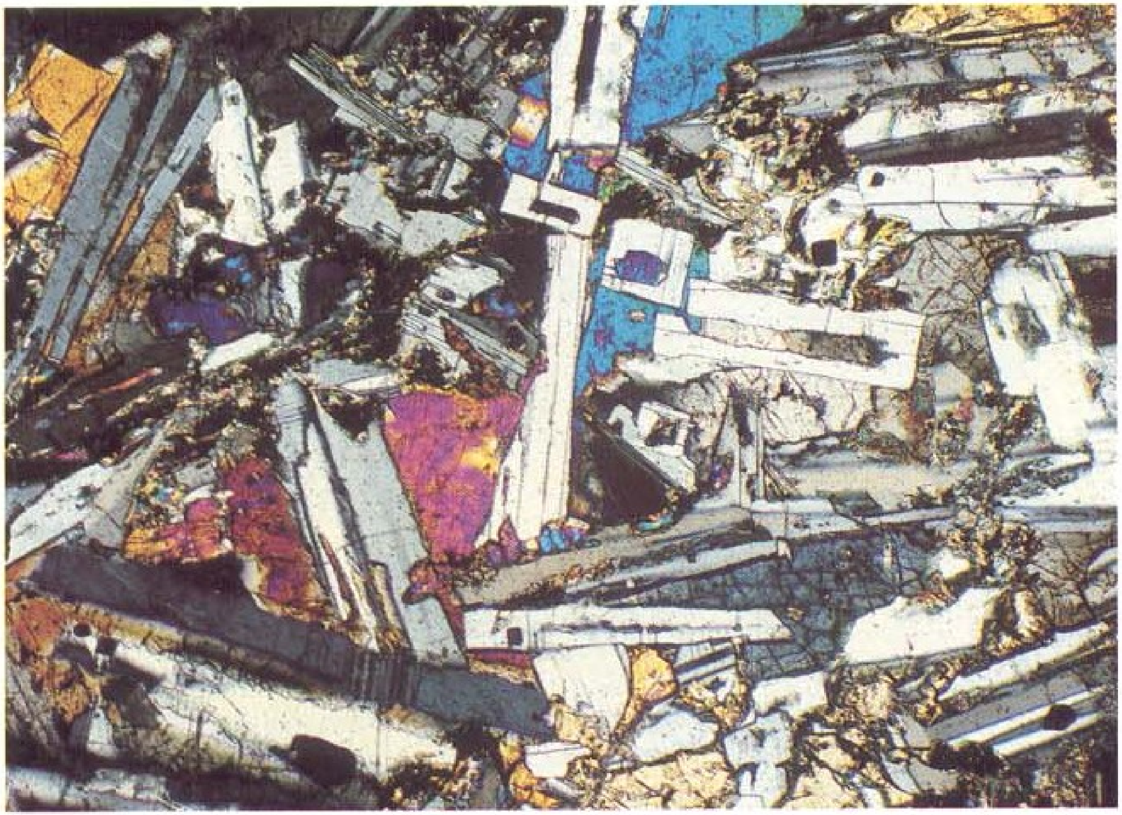
Much of the lower part of this photograph is occupied by an intergrowth of quartz and plagioclase: this forms embayments in the microcline crystal which occupies most of the upper part of the field of view.

*Granite from Rubislaw quarry, Aberdeen, Scotland; magnification × 30, XPL.*



***Intrafasciculate texture***
Hollow, columnar plagioclase crystals filled with pyroxene.

## Interfasciculate texture in dolerite



**79 Intrafasciculate texture in dolerite**

This medium-grained rock has an intergrowth texture in which the gaps in the columnar plagioclase crystals are occupied by augite.

*Dolerite from Garbh Bheinn intrusion, Isle of Skye, Scotland; magnification × 72, XPL.*

***Lamellar and bleb-like intergrowths***

Parallel lamellae, or trains of blebs, of one mineral, and all of the same optical orientation, are enclosed in a single host crystal of another mineral. Well-known examples involve lamellae or blebs of sodium-rich feldspar in a host of potassium-rich feldspar (*perthitic texture*)*;* the converse (antiperthitic texture); and lamellae or blebs of one pyroxene in a host of another (e.g. Augite in orthopyroxene or *vice versa*, and pigeonite in augite or *vice versa*). Other examples include: ilmenite lamellae in (ulvöspinel-magnetite)solid solution crystals; metallic iron rods, and blebs in lunar plagioclases; plagioclase lamellae in pyroxene; and chrome-magnetite lamellae in olivine. Careful examination may reveal lamellae of more than one orientation and scale and sometimes even fine lamellae within coarse lamellae,i.e. multiple generations of lamellae.

Lamellar and bleb-like intergrowths are often attributed to exsolution of the lamellae and blebs from the host crystal (i.e. solid-state reaction) and the genetic term *exsolution texture* is often therefore applied to them. However, laboratory experiments in which antiperthite formed from a melt as a result of co-crystallization of two feldspars, and others in which ilmenite lamellae formed in pyroxene during co-crystalizzation of the two phases from the melt, highlight the danger of uncritical use of the term *exsolution texture*.

# Microperthitic textures

## 80 Microperthitic textures

Three examples of perthites are represented here.
The first photograph shows fairly broad sinuous lamellae of albite traversing the tartan twinning of a microcline crystal.

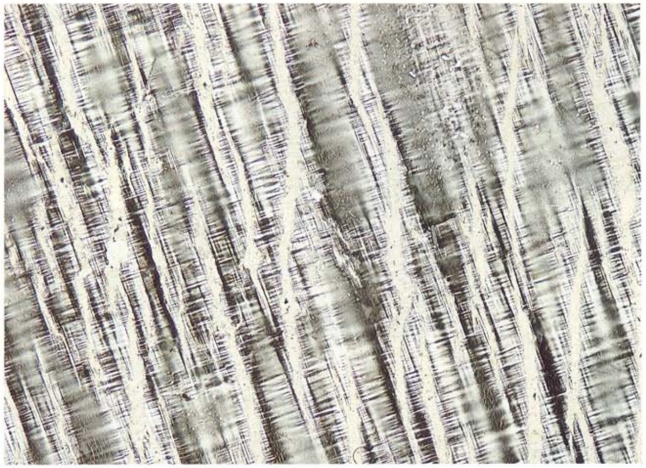
*Specimen from pegmatite, Topsham, Maine, USA; magnification × 16, XPL.*

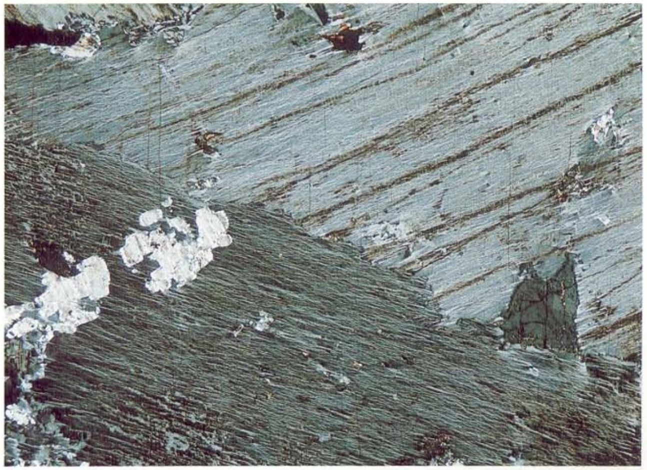
The second photograph shows narrow albite lamellae forming a braided pattern in an orthoclase host (upper centre).

*Specimen from granite, Ratagan, Scotland; magnification × 34, XPL.*

The third photograph shows two large areas of the field of view with different orientations of crystals consisting of an intimate intergrowth of a potassium-rich feldspar and a sodium-rich feldspar. In each case the darker grey colour represents the potassium-rich feldspar. The proportions of the two materials are approximately equal so that neither is clearly the host – in this case the feldspar intergrowth is known as a *mesoperthite*.

*Specimen of nepheline syenite from Langesund fjord, Norway; magnification × 32, XPL.*





Antiperthitic texture in tonalitic gneiss

**81 Antiperthitic texture in tonalitic gneiss**

The poorly aligned, bleb-like inclusions in the plagioclases in this rock are potassium-rich feldspar of intermediate structural state (i.e. orthoclase). It is likely that the texture formed in this rock during prolonged high-grade regional metamorphism rather than during crystallization of magma.

*Tonalitic gneiss from Scourie, North-west Scotland; magnification × 20, XPL.*

Lammellar intergrowths of two pyroxenes in gabbro

**82 Lamellar intergrowths of two pyroxenes in gabbro**

The host crystal to the lamellae is an orthopyroxene (close to extinction); it contains two kinds of lamellae – relatively broad and continuous ones of augite, and narrower discontinuous ones of augite, inclined to the broad variety.

*Gabbro from Bushveld intrusion, South Africa; magnification × 9, XPL.*

Bleb-like intergrowth of augite in orthopyroxene in olivine gabbro

**83 Bleb-like intergrowth of augite in orthopyroxene in olivine gabbro**

In this sample blebs of augite are embedded in an orthopyroxene host, forming an 'emulsion-like' texture. Though the blebs are irregular in shape they have a common elongation direction and the same optical orientation.

*Olivine gabbro from Lower Zone b of the Skaergaard intrusion, East Greenland; magnification × 27, XPL.*

**Symplectite texture**
An intimate interwrowth of two minerals in which one mineral has a vermicular (wormlike) habit.

Symplectite of iron ore and orthopyroxene

**84 Symplectite of iron ore and orthopyroxene**

Iron ore (probably ilmenite) and a small crystal of orthopyroxene are intimately intergrown in a vermicular fashion in the spaces between plagioclase, augite and ilmenite crystals.

*Olivine gabbro from Lower Zone b of the Skaergaard intrusion, East Greenland; magnification × 72, PPL.*

# Fayalite-quartz symplectite

**85 Fayalite-quartz symplectite**

Between the opaque mineral (ilmenite) and the silicate minerals in this rock, there exists a complex boundary consisting of a narrow rim of fayalite immediately adjacent to the opaque mineral, which in places abuts onto a symplectite intergrowth of fayalite and quartz. The fayalite in the intergrowth and that which rims the ilmenite have the same optical orientation.

*Ferrogabbro from Upper Zone b of Skaergaard intrusion, East Greenland; magnification × 32, PPL and XPL.*

Fayalite-quartz symplectite (continued)

## Radiate textures

Radiate textures are those in which elongate crystals diverge from a common nucleus. They are most frequently found in fine-grained rocks, but not exclusively; for example Fig. 34, 35, 36, 70 and 71 show large branching pyroxene, plagioclase and olivine crystals in fan-shaped radiate arrangements. A remarkably large number of terms exists to describe the various patterns, including: fan, plume, spray, bow-tie, spherical, sheaf-like, radiate, radial, axiolitic, spheeulitic and variolitic. All except the last three (which are defined and illustrates here), are of self-evident meaning.

**Spherulitic texture**

Spherulites are approximately apheroidal bodies in a rock: they are composed of an aggregate of fibrous crystals of one or more minerals radiating from a nucleus, with glass or crystals in between. The acicural crystals may be either single, simple fibres or each may brenches alon its length; any branches may or may not share the same optical orientations as their parents. The most common occurence of spherulitic texture is a radiate aggregate of acicular alkali feldspars with glass between them, though quartz or other minerals may be present, resulting in an intergrpwth texture. Should the spherulite have a hollow centre it is known as a hollow spherulite, and if it comprises a series of concentric, partially hollow shells, the term lithophysa is used.

Axiolithes differ from spherulites in that radiating fibres extend from either end of a linear nucleus (i.e. from a small acicular crystal) rather than a point. They could be regarded as a variety of overgtowth texture, as indeed could those sherulites which grow about visible crystal s rather than on submicroscopic nuclei (e.g. Fig. 88).

# Plagioclase spherulite in dolerite

**86 Plagioclase spherulite in dolerite**

This spherulite comprises approximately twenty elongate crystals of plagioclase, each having a different optical orientation. It is an 'open' spherulite, in the sense that there is much space between individual plagioclase crystals; the spaces are occupied by coarse augite, columnar plagioclases not related to the spherulite, and smaller spherulites.

*Dolerite from Garbh Bheinn intrusion, Skye, Scotland; magnification × 32, PPL and XPL.*

*See **126** for a similar example.*

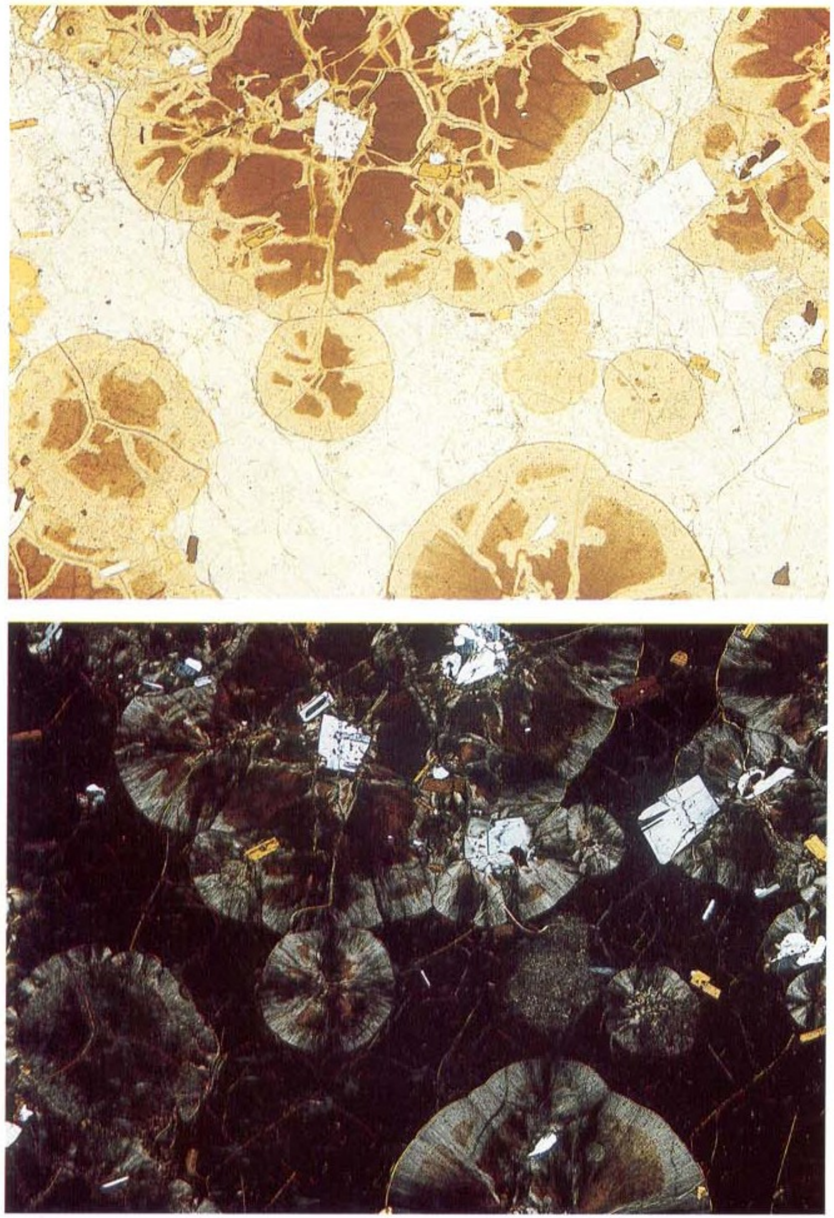
# Spherulite in rhyolite

**87 Spherulite in rhyolite**

The spherulite at the centre of this photograph consists of a dense mass of very fine intergrown needles of both quartz and alkali feldspar radiating from a common nucleus. Above and below, the spherulite abuts onto others, whereas to left and right there is glass.

*Rhyolite from Hlinik, Hungary; magnification × 27, XPL.*

# Compound spherulites in rhyolite



**88 Compound spherulites in rhyolite**

Both single and compound, or clumped, spherulites are surrounded by glass in this photograph. The spherulites enclose microphenocrysts of plagioclase and biotite. The colour variation in the spherulites is caused by variations in density of fibres.

*Rhyolite from Glashutte, Hungary; magnification* × 12, *PPL and XPL.*

***Variolitic texture***

A fan-like arrangement of divergent, often branching, fibres; ussually the fibres are olagioclase and the space between is occupied by glass or granules of pyroxene, olivine or iron ore. This texture differs from spherulitic in that no discrete spherical bodies are identifiable; in fact, each fan as seen in thin section is a slice through a conical bundle of acicular crystals.

# Variolitic olivine dolerite

## 89 Variolitic olivine dolerite

The olivine phenocrysts in this sample are set in a groundmass consisting of many fans of diverging plagioclase needles with augite crystals in the interstices. Note how all the fans diverge from lower right to upper left, indicating progressive solidification in this direction. Note also the branching character of some of the plagioclase fibres.

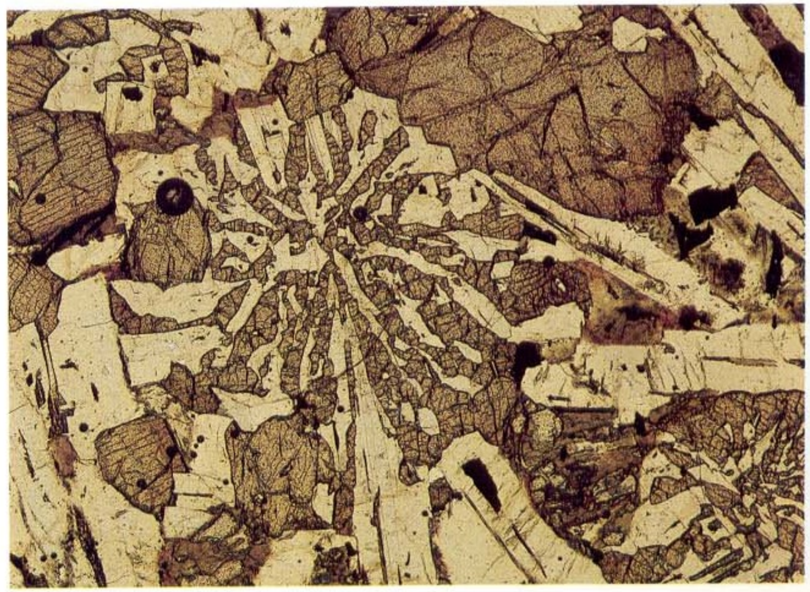
*Olivine dolerite from Skye, Scotland; magnification × 27, PPL and XPL.*

# Radiate intergrowth of plagioclase and augite in dolerite

**90 Radiate intergrowth of plagioclase and augite in dolerite**

This unusual radiate texture occupying the centre of the view consists of two, mutually perpendicular, columnar, plagioclase crystals, the elongate gaps in which have a radiate distribution; these gaps are occupied by a *single* augite crystal, rather than by many crystals. This kind of radiate texture differs from a spherulite; it is more akin to skeletal growth (p. 20).

*Dolerite from Ingia intrusion, West Greenland; magnification × 27, PPL and XPL.*



Radiate intergrowth of plagioclase and augite in dolerite (continued)

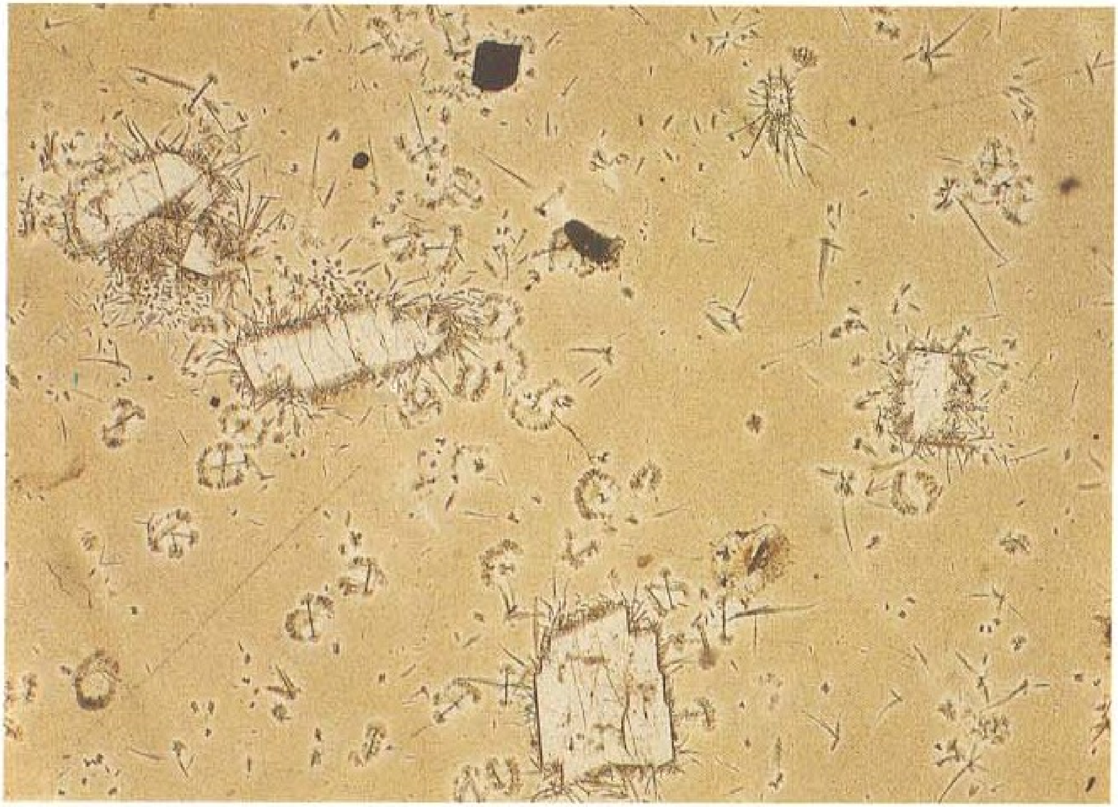
**Overgrowth textures**

This term applies to textures in which a single crystal has been overgrowth either by material of same composition, or by material of the same mineral species but different solid-solution composition, or by an unrelated mineral. There are three types: (a) skeletal and dendritic overgrowths; (b) corona texture; and (c) crystal zoning.

***Skeletal or dendritic overgrowths***

Porphyritic rocks with a glassy or very fine-grained groundmass may show delicate fibres or plates extending from the corners or edges of the phenocrysts. The overgrowth and the phenocryst need not be the same mineral.

Overgrowth textures in rhyolitic pitchstone



**91 Overgrowth textures in rhyolitic pitchstone**

The faces of the phenocrysts of alkali feldspar and magnetite in this glassy rock have acted as locations for nucleation of dendritic overgrowths of (?) alkali feldspar. Dendritic crystallites are also present in the glassy groundmass.

*Pitchstone from Arran, Scotland; magnification × 31, PPL.*

***Corona texture***

A crystal of one mineral is surrounded by a rim, or a ‘mantle’, of one or more crystals of another mineral, e.g. olivine surrounded by orthopyroxene, or biotite surrounding hornblende. Such relationships are often presumed to result from incomplete reaction of the inner mineral with melt or fluid to produce the outer one and for this reason the equivalent genetic terms *reaction rim* and *reaction corona* are frequently used. The special term *Rapakivi texture* is used to describe an overgrowth by sodis plagioclase on large, usually round, potassium-feldspar crystal, and *kelyphitic texture* is used for a microcrystalline overgrowth of fibrous pyroxene or hornblende on olivine or garnet.

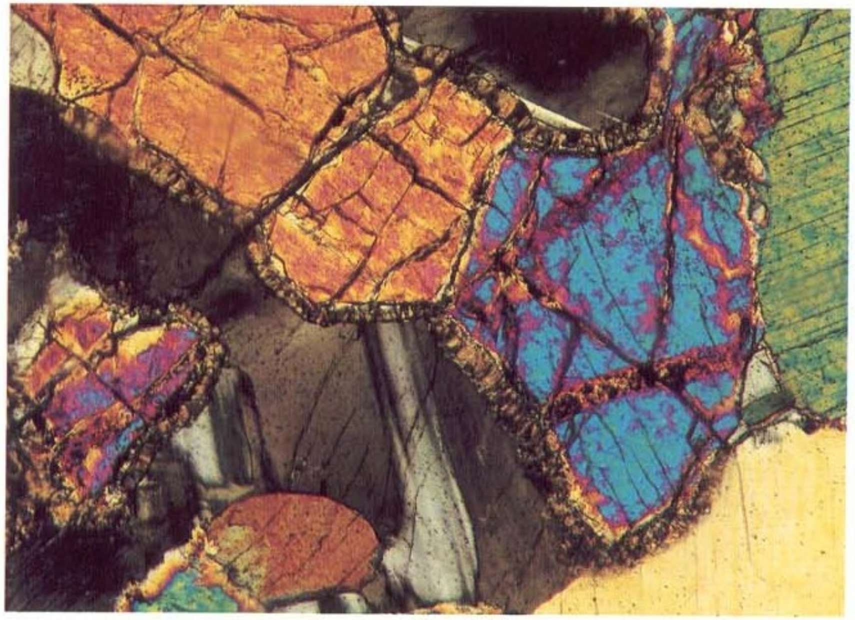
# Corona texture

## 92 Corona texture

In the centre of the photographs a twinned and zoned augite crystal is mantled by green hornblende of non-uniform width.

*Quartz diorite from Mull of Galloway, Scotland; magnification × 43, PPL and XPL.*

# Corona texture



## 93 Corona texture

Between olivine and plagioclase crystals in this rock there is a 0.02–0.06 mm wide corona which consists of either one or two zones: (1) radially oriented, fibrous, brown hornblende; or (2) colourless pyroxene (see middle of photograph) surrounded by radially oriented, fibrous, brown hornblende. Analysis of the pyroxene suggests that it is a submicroscopic intergrowth of augite and orthopyroxene.

*Olivine gabbro from Thessaloniki, North Greece; magnification × 100, PPL and XPL.*

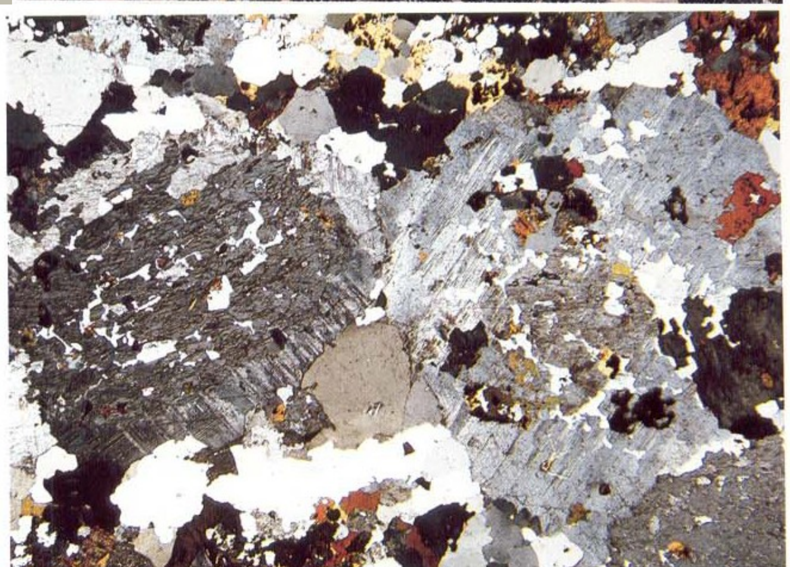
# Rapakivi texture

**94 Rapikivi texture**

The texture is of large, round potassic feldspars, some of which are mantled by sodic plagioclase rims, others have no plagioclase rims. In the first photograph, which is of a polished hand specimen, the plagioclase rims have a greenish colour contrasting with the pink potassic feldspar. The second photograph is of a thin section of the same rock.

*Granite from Eastern Finland; magnification* × 2 *(first photo);* × 3, *XPL (second photo).*

Rapakivi texture (continued)



***Crystal zoning***

One or more concentric bands in a single crystal are picked out by lines of inclusions (Fig 95) or by gradual or abrupt changes in solid-solution composition of the crystal. As regards the latter type of zoning, a large number of patterns are possible, the commoner ones being illustrated graphically and named below, using plagioclase as an example.

*Normal versus reserve zoning*

These terms specify the general trend of solid-solution composition from core to rim. 'Normal' indicates high temperature component→ low-temperature component (e.g. An-rich plagioclase → Ab-rich plagioclase, see Fig C) and ' reverse' indicates the opposite.

*Continuous[1] versus discontinuous[1] zoning*

These terms indicate respectively a gradual or an abrupt change in composition. Fig C shows examples of *continuous normal zoning* and Fig D an example of *discontinuous normal zoning*. Continuous and discontinuous zoning may alternate (Fig E).

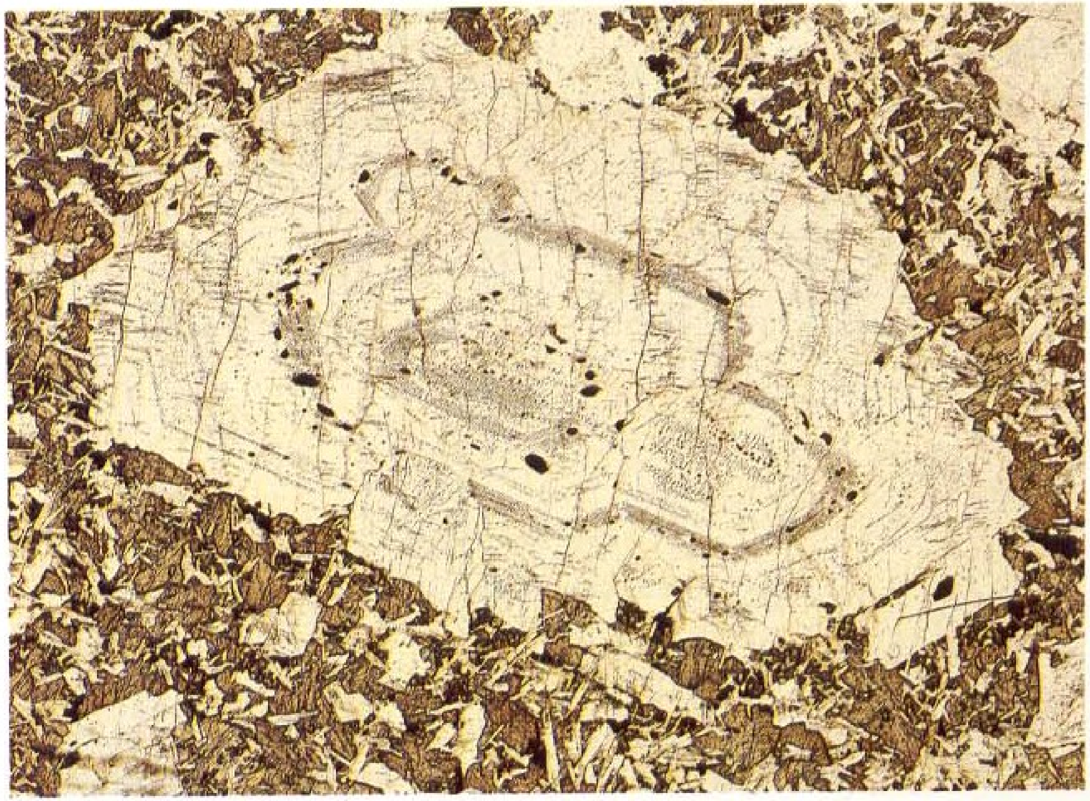
[1] *These terms are not the same as* continuous reaction *and* discontinuous reaction *of crystals with melt.*

# Zonal arrangement of melt inclusions in plagioclase

**95 Zonal arrangement of melt inclusions in plagioclase**

Several stages in the growth of this plagioclase crystal can be picked out by the bands of minute melt inclusions. (See also **45**.)

*Feldspar-phyric dolerite from Isle of Skye, Scotland; magnification × 9, PPL.*



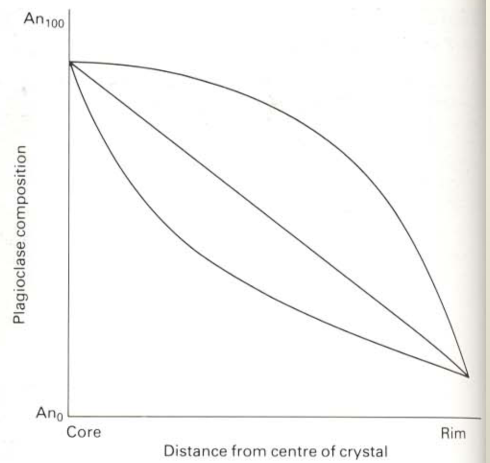



Fig. C Three examples of continuous normal zoning represented on a sketch graph.

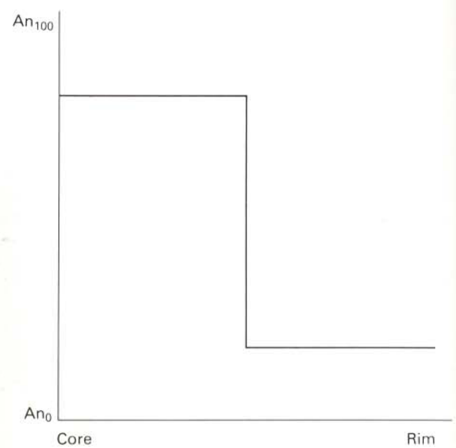



Fig. D Discontinuous normal zoning

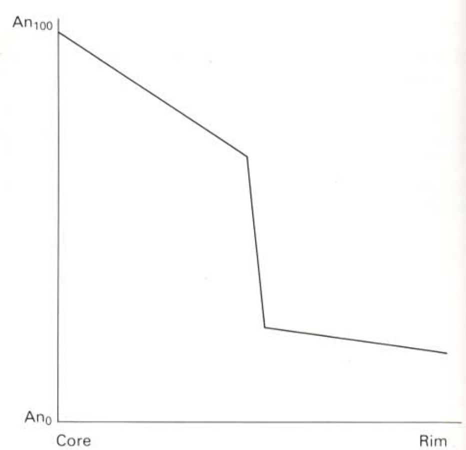



Fig. E combined continuous and discontinuous normal zoning

# Zoned plagioclase

## 96 Zoned plagioclase

The central plagioclase phenocryst in this photograph is discontinuously zoned, having a homogeneous core mantled by a more sodic rim; the rim has continuous normal zoning resulting in variation of the extinction position on rotation of the microscope stage. The crystal is thus partly discontinuously and partly continuously zoned.

*Dolerite from Isle of Skye, Scotland; magnification × 43, XPL.*

***Multiple zoning***

This term used for crystals having repeated discontinuous zones. If the zones show a rhythmic repetition of width, the pattern is known as a oscillatory zoning. The overall compositional trend of the multiple zoning may be normal or reverse or even (in which there is no general trend from core to rim). Individual zones may be of uniform or variable composition, such that the zoning pattern on a composition-distance graph is square wave, step-like, saw-tooth, curved saw-tooth, or some combination of these (see Fig H-J). However, these are details which only very careful and lengthy optical examination or electron-probe microanalyses would reveal.

The reader should appreciate that the sketches in Fig C-J are all idealized and that in real crystals the oscillations will be less uniform; furthermore multiple or oscillatory zoning may only occupy part of a crystal, the remainder perhaps being homogenous or continuously zoned.

Fig F
Multiple, even zoning

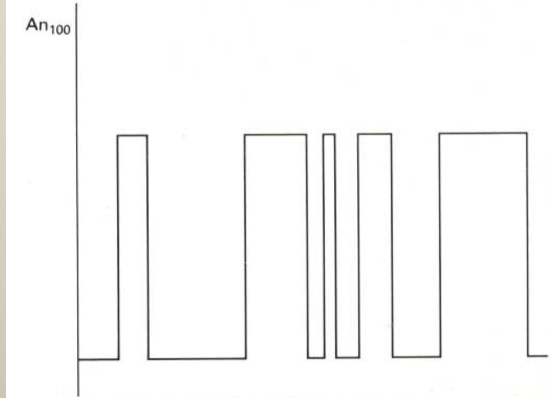



Fig G
Oscillatory, even zoning

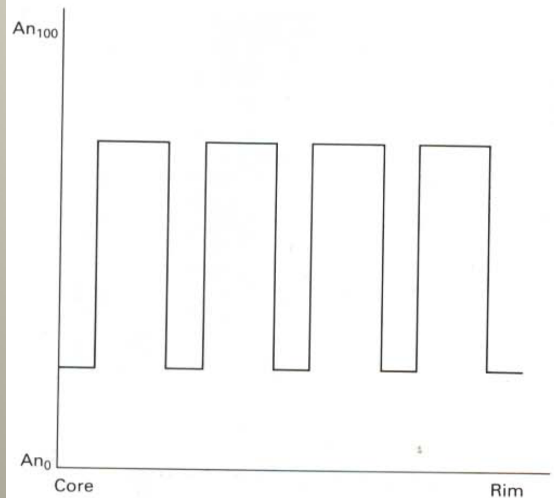



Fig H
Oscillatory, normal zoning: step-like

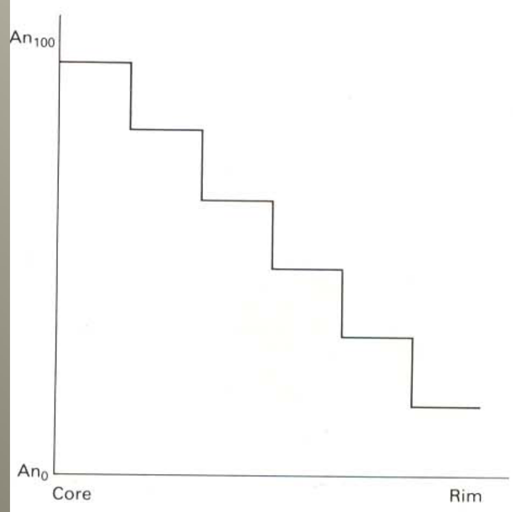



Fig I
Oscillatory, normal zoning: saw-tooth

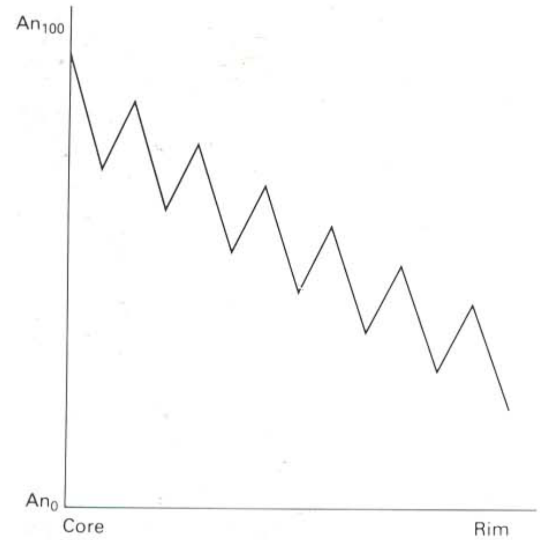
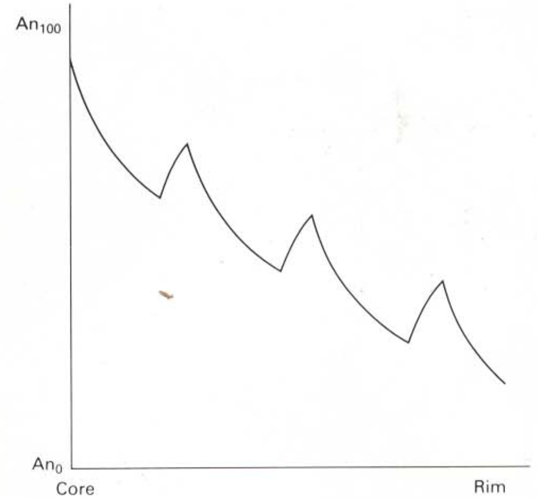



Fig J
Oscillatory, normal zoning: curved saw-tooth



***Convolute zoning***

This is a varierty of multiple zoning in which some of the zones are erratic and have non-uniform thickness.

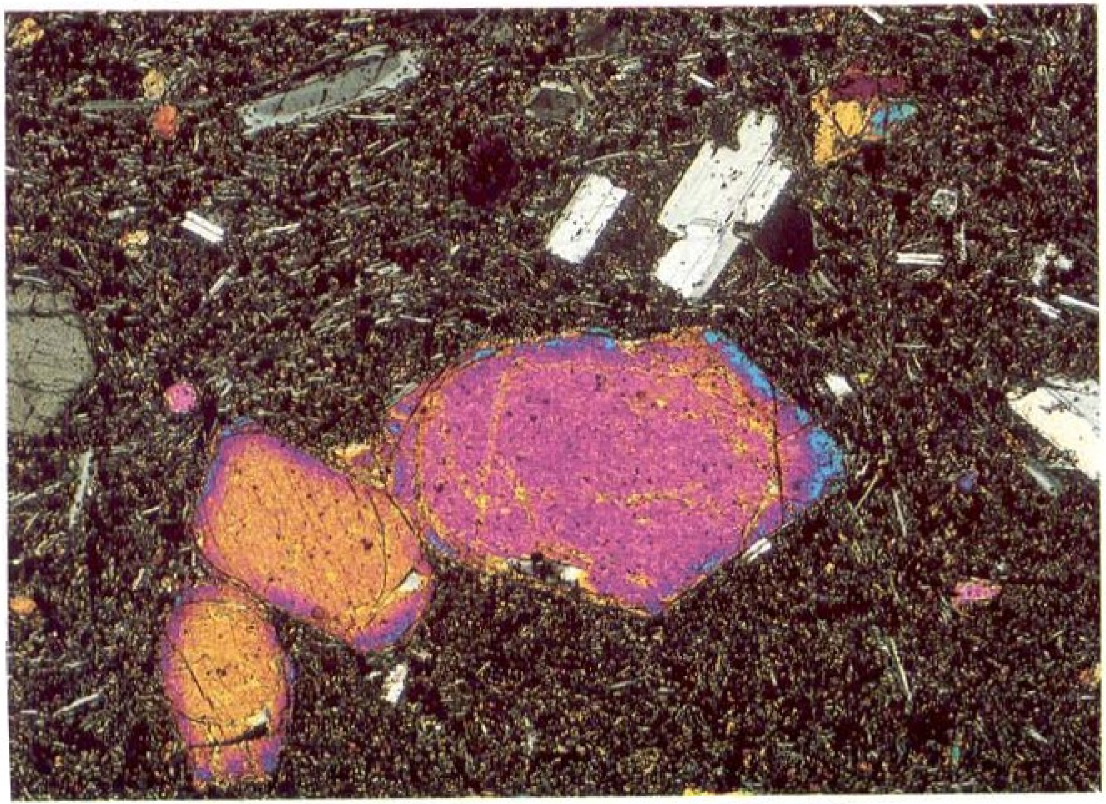
Zoned plagioclases

**97 Zoned plagioclases**

This photograph illustrates several styles of zoning in the two plagioclases comprising the glomerocryst. Combinations of discontinuous, oscillatory and convolute zoning are present, together with zoning picked out by a band of melt inclusions near the margins of both crystals.

*Porphyritic andesite from Hakone volcano, Japan; magnification × 24, XPL.*

# Zoned olivines



## 98 Zoned olivines

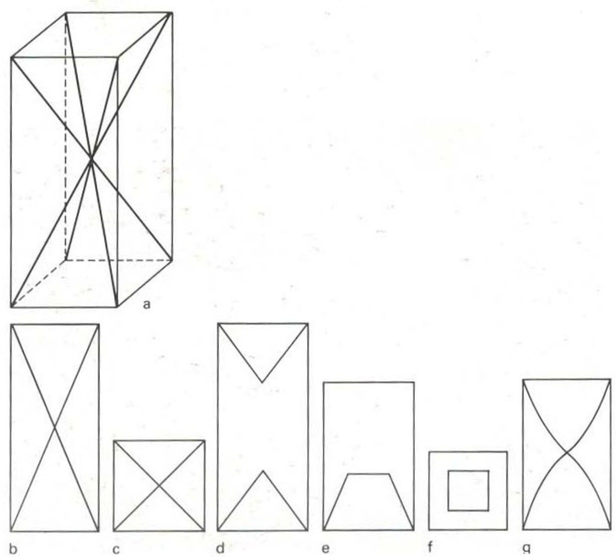
Zoning is not confined to feldspar crystals. Here, each of the three olivine phenocrysts in the cluster has a homogeneous core surrounded by a continuously normal-zoned mantle, as indicated by the variation in interference colours.

*Ankaramite from Mauna Kea, Hawaii; magnification* × 43, *XPL.*

***Sector (or hourglass) zoning***

As seen in thin section, this ideally takes the form of four triangular segments (sectors) with a common apex (Fig K-b). Opposite sectors are chemically identical, whereas adjacent ones differ in composition (though possibly only slightly) and hence in optical properties. Each sector may be homogenous or show continuous or discontinuous or oscillatory, normal ore reverse or even zoning. In there dimensions the sectors are pyramid shaped (Fig K-a), and depending on the orientation of the crystal with respect to the plane of a thin section, a variety of patterns may be seen in thin section (Fig K-b to f). If the sector boundaries are curved, the pattern can resemble that of an hourglass (Fig K-g). Sector zoning is a common feature of pyroxenes in alkali-rich basic and ultrabasic rocks. It has also been in plagioclases in a few quickly cooled basalts.

*Fig. K Schematic representations of sector zoning*



# Sector-zoned augite

**99 Sector-zoned augite**

The picture shows a simple sector-zoned augite phenocryst containing elongate melt inclusions; the crystals partially enclosed by two of the sectors are olivines.

*Essexite from Crawfordjohn, Scotland; magnification × 40, XPL.*

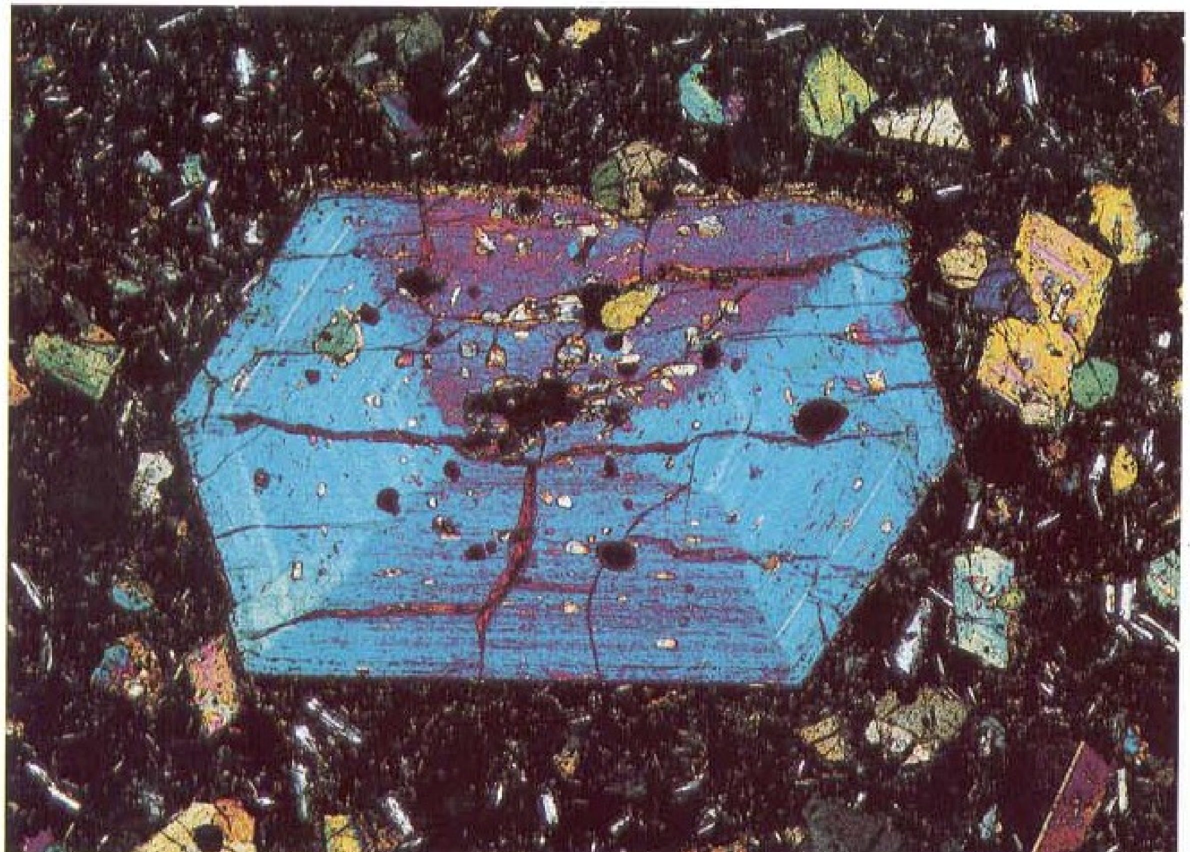
# Sector-zoned pyroxene

**100 Sector-zoned pyroxenes**

Two sector-zoned titanaugite crystals are illustrated in these photographs; that on the left is complicated by forming at one end a graphic intergrowth with nepheline and leucite; the other crystal has an intriguing figure-8-shaped core, with a discontinuous, sector-zoned mantle.

*Melanocratic nepheline microsyenite from Vogelsberg, West Germany; magnification × 7, PPL and XPL.*

Oscillatory- and sector-zoned, inclusion-beraing pyroxene

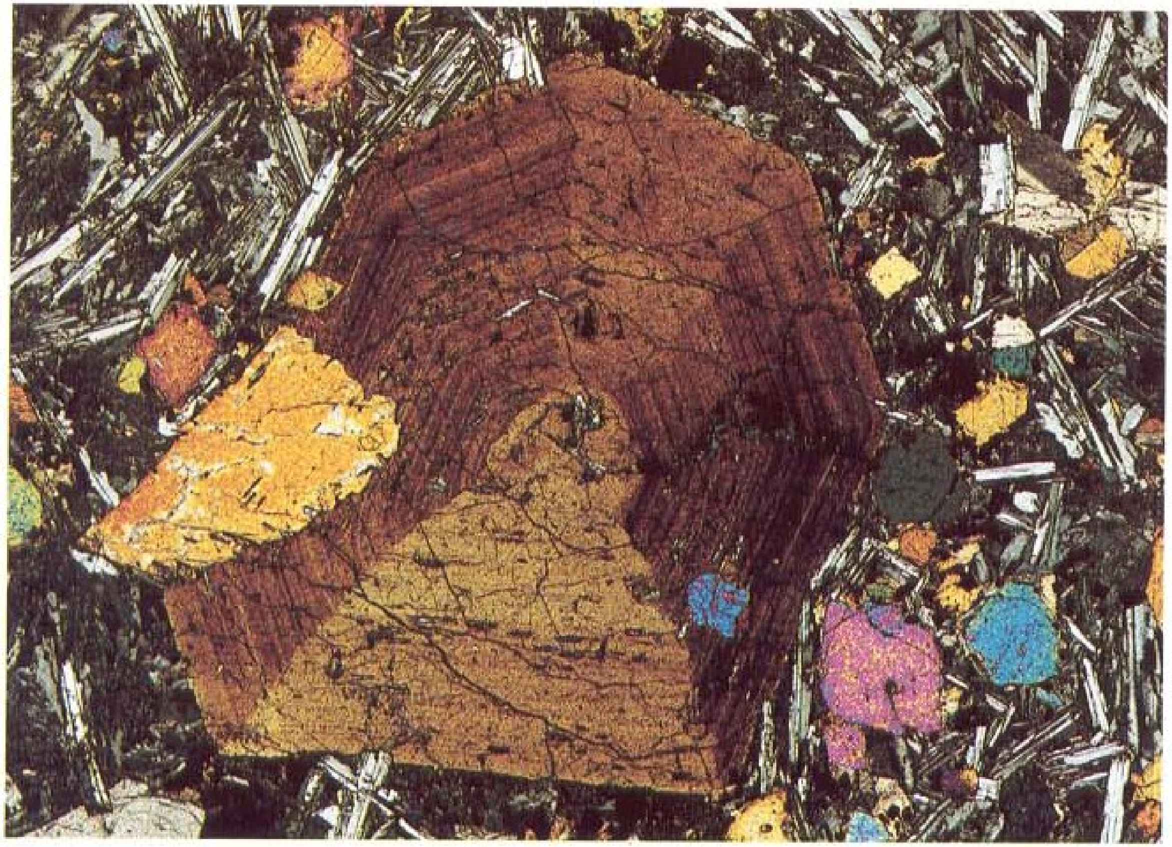


**101 Oscillatory- and sector-zoned, inclusio bearing pyroxene**

The augite phenocryst occupying most of this photog is sector-zoned and each sector displays oscillatory zon Inclusions of nepheline, augite and magnetite are ranged in trains parallel to the oscillatory zones.

*Tephrite from Monte Vulturi, Malfi, Italy; magnifica ×27, XPL.*

# Oscillatory- and sector-zoned pyroxene



**102 Oscillatory- and sector-zoned pyroxene**

Unlike the pyroxenes in **99 and 100**, this sector-zon pyroxene has some sectors bounded by more than face, e.g. the sector on the right is terminated by faces, and that on the left by three faces. The crystal closes plagioclase laths, an olivine (blue colour) and pyroxene crystal (orange colour).

*Essexite from Crawfordjohn, Scotland; magnification × XPL.*

## BANDED TEXTURES (BANDING)

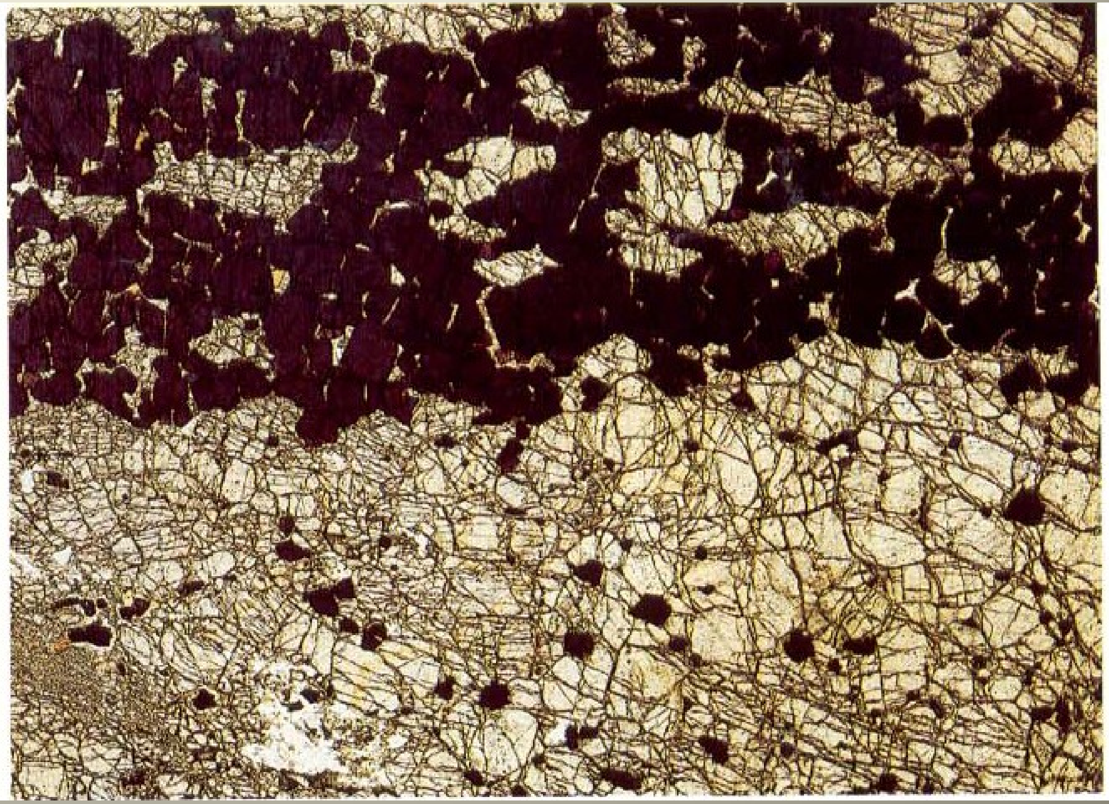
Textures of this involve two, or more, narrow (up to a few centimeters), subparallel bands in a rock which are distinguishable by difference in textures, and/or colour and/or mineral proportions. The term *layering* is also used by petrologists; while it includes banded texture, it is also used for larger scale stratifications. An example of banded texture due to textural differences in illustrated in Images-5, and 103 and 104 shoe examples resulting from extreme differences in mineral proportions.

# Olivine and chrome-spinel banding (or layering)

## 103 Olivine and chrome-spinel banding (or layering)

The photograph shows two bands, one rich in olivine, with scarce disseminated chrome-spinel crystals, and the other rich in equant chrome-spinel crystals with scarce interstitial olivine.

*Banded dunite-chromitite from Skye, Scotland; magnification × 11, PPL.*



# Anorthosite-chromitite banding (or layering)

**104 Anorthosite-chromitite banding (or layering)**

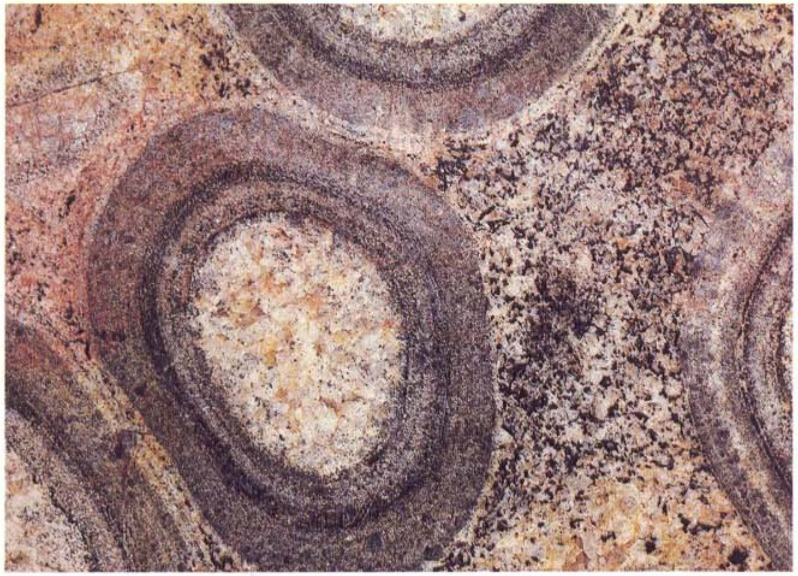
This hand-specimen photograph shows alternating bands of anorthosite (white) and chromitite (black). The yellowish-brown crystals in the anorthosite are enstatite and the black particles are single crystals and glomerocrysts of chromite.

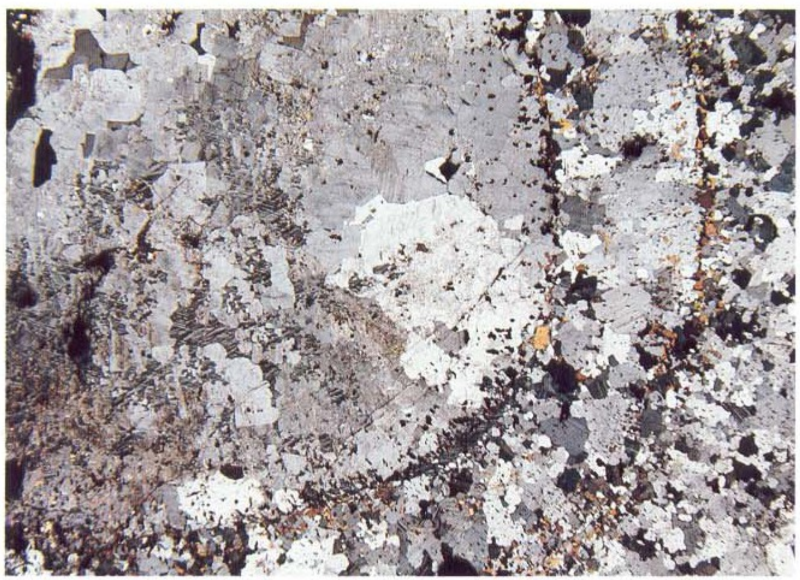
*Banded anorthosite-chromitite from Critical Zone of the Bushveld intrusion, South Africa; magnification × 2.*

***Comb layering, orbicular texture, ocellar texture and eutaxitic***

*Comb layering* and *orbicular texture* are particularly exotic kinds of banding. In the latter, ‘orbs’ consist of concentric shells of rhythmically alternating mineral constitution. Within the shells the texture may either be granular or elongate crystals may be radially arranged. ‘Orbs’ may be reach a few tens of centimetres in diameter. A further variety of banded texture, *eutaxitic*, occurs in some tuffs and ignimbrites and consists of a regular alignment of flattened glassy fragments.

# Anorthosite-chromitite banding (or layering)





**105 Orbicular monzodiorite**

The first photograph shows the texture in a hand specimen. The arrangement of the concentric darker bands about the lighter coloured, homogeneous nuclei is well displayed. The second photograph shows the core and a few inner bands of one orbicule in thin section. The bands can be seen to differ from one another in their contents of biotite and alkali feldspar, and in their grain size.

*Monzodiorite from the Island of Suuri Lintusaari, Ruoko-lahti, S.E. Finland; magnification × 1 (first photo) × 3, and XPL (second photo).*

**Cavity textures**

These are a collection of textures witch feature either holes in the rock or likely former holes which are now partly or completely filled with crystals.

***Vesicular texture***

Round, ovoid, or elongate irregular holes (vesicles) formed by expansion of gas, in a magma.

***Amygdaloidal texture***

Former vesicles are here occupied, or partially occupied, by late-stage magmatic and/or post-magmatic minerals, such as carbonate, zeolites, quartz, chalcedony, analcite, chlorite, and/or, rarely, glasses of fine groundmass. The filled holes are known as amygdales or amygdules.

## Cavity textures - continuation

***Ocellar texture***

Certain spherical or ellipsoidal leucocratic patches enclosed in a more mafic host are known as ocelli (singular ocellus). Unlike amygdales, the minerals filling an ocellus can normally all be found in the host rock; they may include any of: nepheline, analcime, zeolites, calcite, leucite, potassium feldspar, sodium feldspar, quartz, chlorite, biotite, hornblende and pyroxene or even glass, and the minerals are commonly distributed in a zonal arrangement (Fig 109a). Often, platy and acicular crystals in the host bordering an ocellus are tengentially arranged (Fig 109b) but sometimes project into the ocellus. Ocelli are normally less than 5 mm in diameter but may reach 2 cm. Their origin has been ascribed on the one hand to separation of droplets of immiscible liquid from magma, and on the other hand to seepage of residual liquid or fluid into vesicles.

***Miarolitic texture***

These are irregularly shaped cavities (druses) in plutonic and hypabyssal rocks into which euhedral crystals of the rock project.

***Lythophysa (or satone-ball)***

This is term given to a sphere consisting of concentric shells with hollow interspaces.

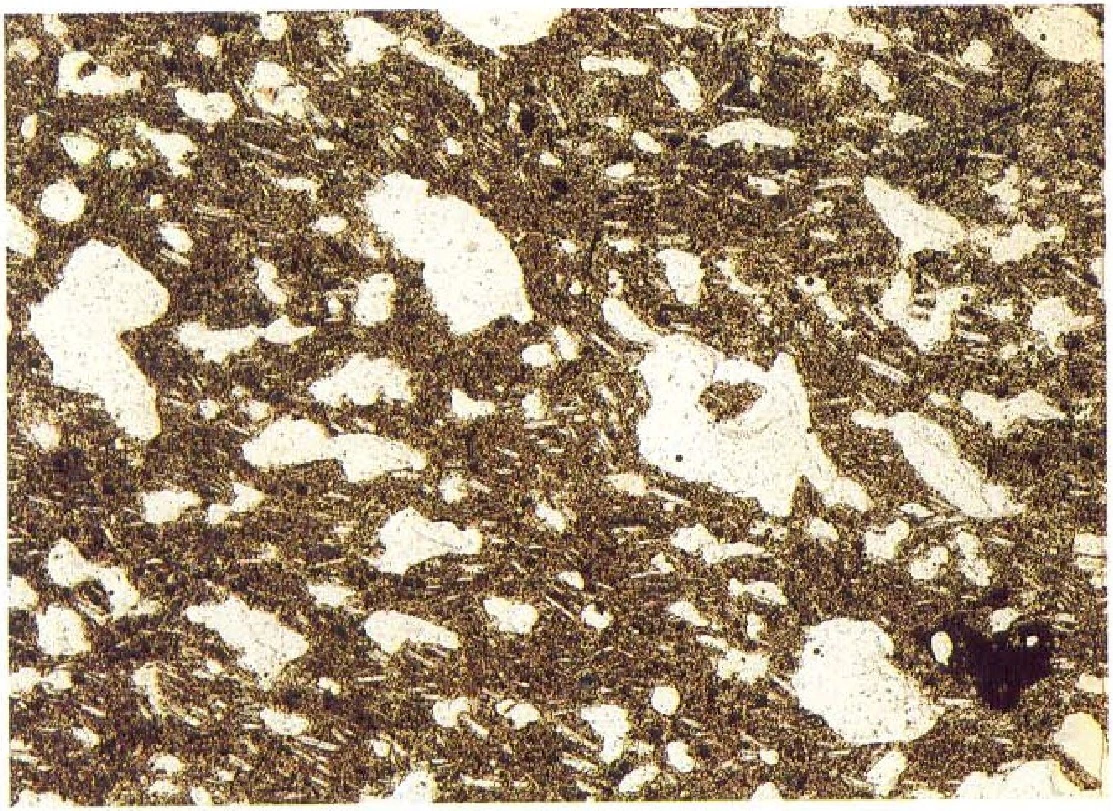
# Vesicular feldspar-phyric basalt

## 106 Vesicular feldspar-phyric basalt

Large subspherical gas cavities are randomly distributed in this volcanic rock. Note the two vesicles at the top left which have coalesced.

*Basalt from Mount Fuji, Japan; magnification × 7, PPL and XPL.*

# Vesicular trachyte



## 107 Vesicular trachyte

Irregularly shaped, elongate vesicles are streaked out through this trachyte; the columnar feldspars show a weak alignment in the same direction.

*Trachyte from the Auvergne, France; magnification ×12, PPL.*

# Amygdaloidal basalt

**108 Amygdaloidal basalt**

The original vesicles in this volcanic rock are now filled with an aggregate of small calcite crystals; calcite is also present as pseudomorphs after olivine in the groundmass. Pyroxene and glass in the rock are altered to clay minerals.

*Basalt from Matlock, Derbyshire, England; magnification ×11, PPL and XPL.*
*124 shows another amygdaloidal rock.*

# Ocellar texture

## 109 Ocellar texture

The upper photograph shows three ocelli in an olivine dolerite sill. Each ocellus is outlined by a more or less complete veneer of tiny magnetite crystals. At the base of the two largest ocelli the groundmass outside the ocelli extends across the magnetite veneer, except that olivine is absent inside the ocelli. The remainder of each ocellus comprises clear zeolite, turbid, very fine-grained zeolite and scarce magnetite. The left-hand ocellus also contains three elongate pyroxenes on the left side.

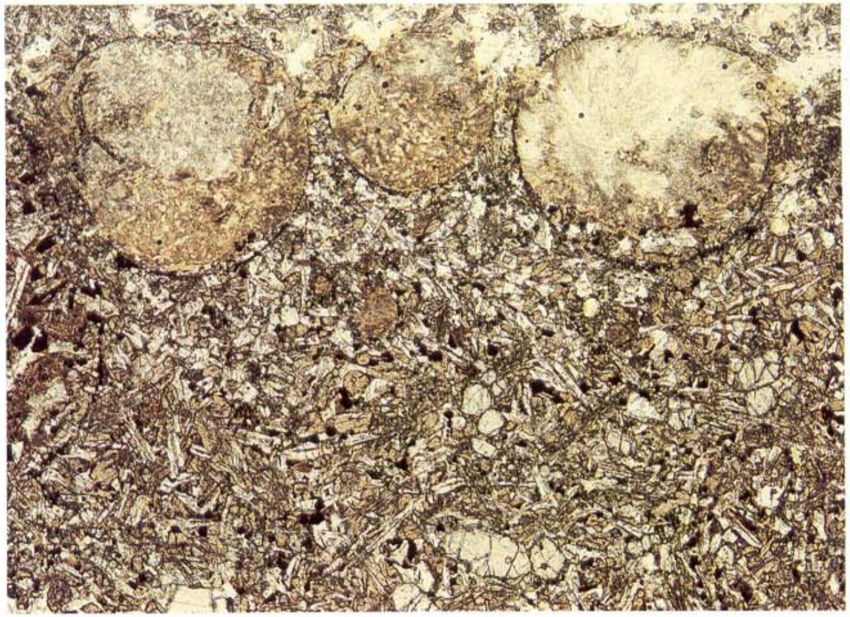
*Non-porphyritic facies of an olivine dolerite sill, Igdlorssuit, Ubekendt Ejland, West Greenland; magnification × 12, PPL.*

The second picture shows two ocelli, occupied by calcite, alkali feldspar, chlorite and fine-grained patches of clay (possibly altered glass). Laths of biotite are arranged tangentially about each ocellus.

*Minette from Westmorland, England; magnification × 16, PPL.*

The third photograph shows miarolitic (or drusy) cavity in granite. The slightly angular cavity shown in this hand specimen is occupied by crystals of alkali feldspar, quartz and biotite, some up to seven times larger than crystals of the same minerals in the rest of the granite.

*Granite from Beinn an Dhubaich, Skye, Scotland; magnification × 1.5.*



# Miarolitic (or drusy) cavity in granite