Atlas of Igneous Rocks and Their Textures

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ELBS

LOW-PRICED EDITION

Atlas of Igneous Rocks and Their Textures

Part 1

The textures of igneous rocks

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Introduction

To English-speaking petrologists *textures* are the geometrical relationships among the component crystals of a rock and any amorphous materials (glass or gas in cavities) that may be present. They comprise the following properties:

1. Crystallinity (degree of crystallization) – i.e. the relative proportions of glass and crystals.
2. Granularity (grain size) – i.e. the absolute and the relative sizes of crystals.
3. Crystal shapes.
4. Mutual relations or arrangement of crystals and any amorphous materials present.

In this part of the book textures in each of these categories are described and illustrated, some in plane-polarized light (PPL), some in cross-polarized light (XPL) and some in both. Some textures exhibit more than one of the above properties and we have indicated where this is so.

Petrography, of which textural relations are a part, is the descriptive and factual side of *petrology*, whereas *petrogenesis* is the interpretive side. Thus genetic terms, such as *cumulate*, *cumulus crystal*, *cumulate texture*, *synneusis texture*, *exsolution texture* and *fluxion texture* should be avoided, as they combine factual description with interpretation; they rob any person reading a petrographic description of unbiased observations and can cast doubt on the objectivity of the petrographer who wrote the description. For this reason, genetic textural terms are not included in this book, there being suitable non-genetic terms available for all of them.

Remarkably few igneous textures have been reproduced in the laboratory and the origins of even fewer could be claimed to be adequately understood. For these reasons, we have made no comment on the origin of most of the textures; readers should consult the texts by Iddings (1909), Holmes (1921), Niggli (1954), Hatch, Wells and Wells (1972) or Cox, Bell and Pankhurst (1979), for discussion of the origin of textures and their implications. However, it should be noted that many textures are open to more than one interpretation and the newcomer to the subject is advised to consider the possible origins and implications for himself before reading one of these texts. He is then likely to interpret the crystallization of a rock more objectively and flexibly than if the 'standard interpretation' is adopted slavishly. This comment is particularly relevant to the interpretation of 'order of crystallization' of minerals in a rock. We have found that both students and teacher can benefit from a two-hour discussion of the subject; the student who is unencumbered by preconceptions can be remarkably inventive and provide his teacher with copious new ideas for consideration.

In studying rocks in thin section we must not forget that only a two-dimensional view is present and hence the true three-dimensional texture has to be deduced from examination of the dispositions of many crystals in the section. In rocks with a strong preferred orientation of crystals, two or more sections of different attitude may be required to reveal the texture adequately.

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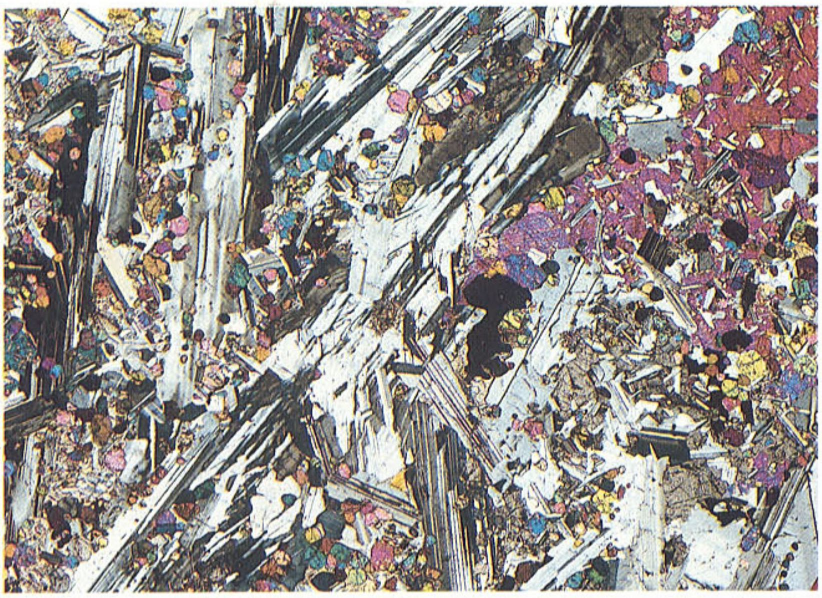
Crystallinity

Igneous rocks range in crystallinity from entirely crystals to entirely glass. Adjectives used to describe these states are shown on the following scale:

100% crystals		*100% glass*
holocrystalline	*hypocrystalline*[1] or *hypohyaline*	*holohyaline*

The adjectives *glassy*, *vitreous* and *hyaline* all indicate that a rock is more or less completely glass.

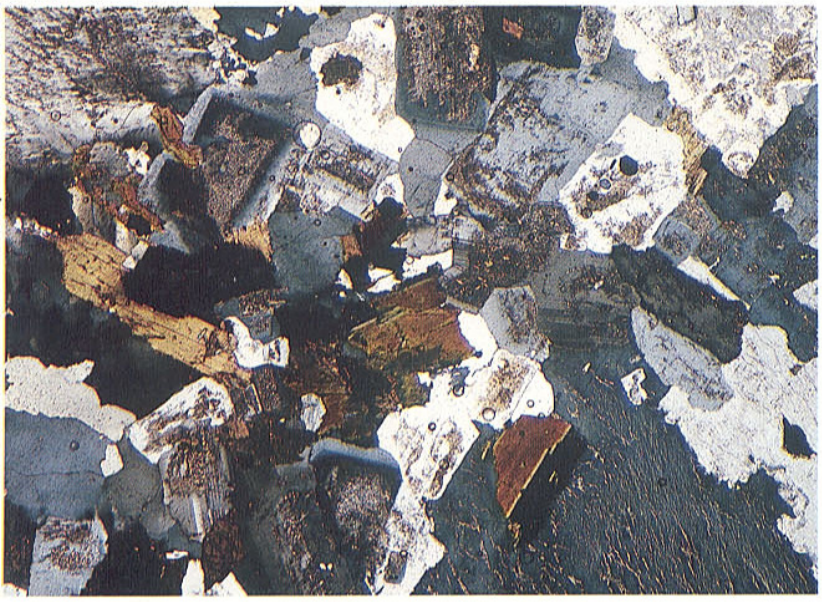
[1] *Hypocrystalline rocks can be described more precisely by stating the relative proportions of crystals to glass.*



1 Holocrystalline anorthositic gabbro

Elongate crystals of plagioclase feldspar, some wrapped round olivine crystals, form a framework in this rock, the interstices of which are filled with smaller plagioclase, olivine and augite crystals. The purplish-blue area at the top right of this photograph is an augite crystal which includes a number of small plagioclase and olivine crystals.

Perpendicular Feldspar gabbro from Middle Border Group of the Skaergaard intrusion, East Greenland; magnification ×7, XPL.



2 Holocrystalline granite

Crystals of biotite, quartz, 'perthitic' potassium-rich feldspar (large crystal bottom right) and zoned sodium-rich feldspar makes up this granite. The speckled appearance in the cores of the plagioclase feldspars is caused by fine inclusions of mica.

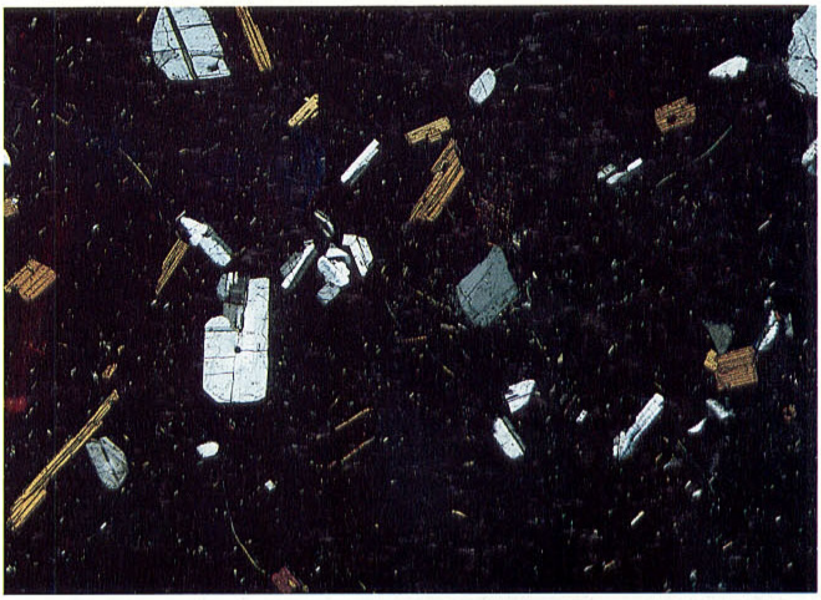
Granite from Ross of Mull, Scotland; magnification ×14, XPL.

Contents

3 Hypocrystalline pitchstone with perlitic cracks

Crystals of plagioclase, biotite and magnetite in this rock are set in glass (black in XPL) which has spherical fractures known as *perlitic cracks*: these appear as circles in thin section.

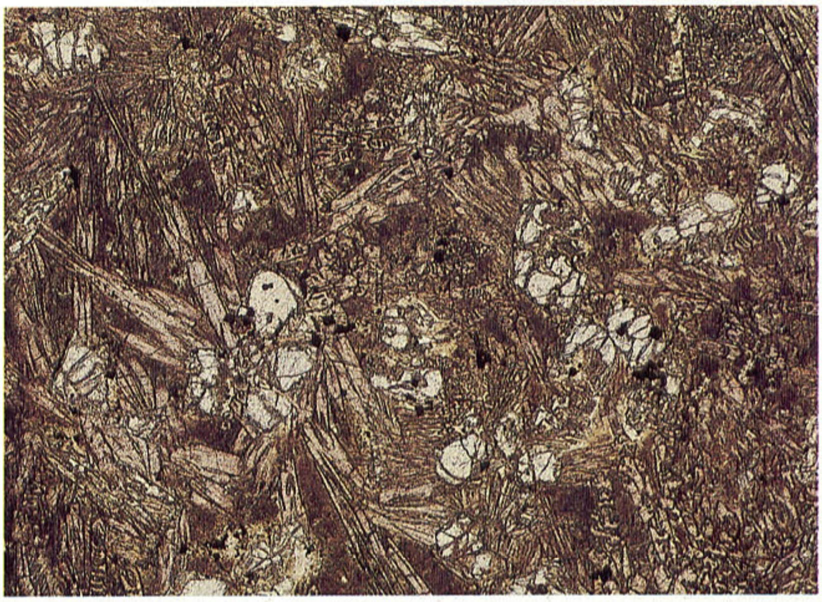
Dacite from Chemnitz, East Germany; magnification ×20, PPL and XPL.



4 Hypocrystalline basalt

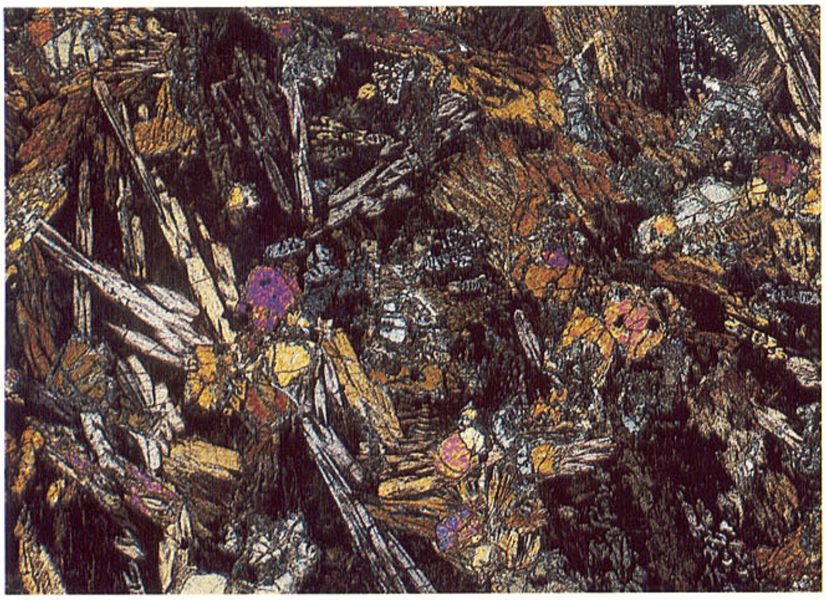
Small olivine phenocrysts (colourless in PPL) and columnar, skeletal titanaugite crystals (pinkish-beige colour in PPL) are enclosed by murky brown glass. No plagioclase has crystallized in this rock. The deeper pink colour around the margin of some of the titanaugites is a narrow mantle of Ti-rich amphibole.

Basalt from Quarsut, West Greenland; magnification ×35, PPL and XPL.

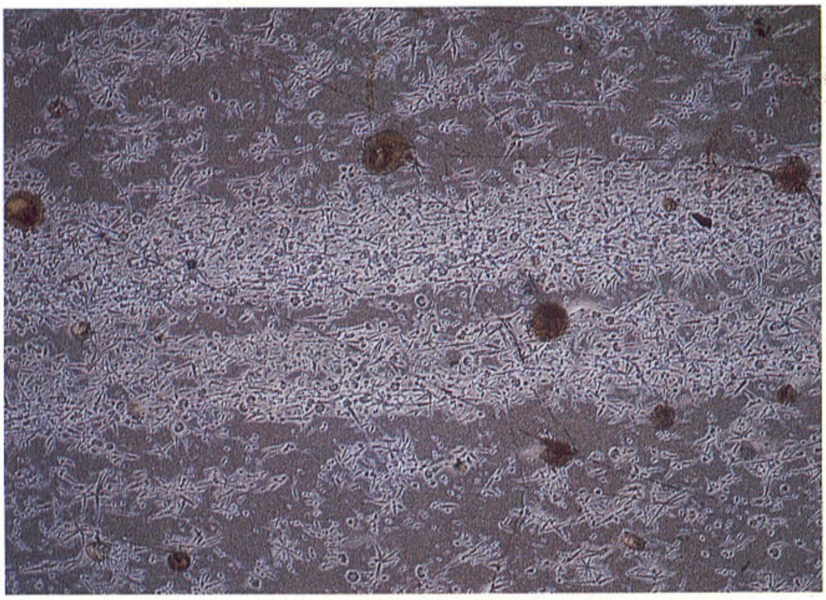


Part 2 Varieties of igneous rocks

(Numbers refer to photographs – not to pages)



Hypocrystalline basalt (continued)



5 Glassy rock

The photograph shows abundant, very small crystals (probably quartz or feldspar) enclosed by glass. Note the banding caused by (a) differences in abundance of crystallites, (b) crystallites in the lighter bands having a slight preferred alignment and (c) differences in colour of the glass. The small brown, isolated round objects are known as 'spherulites' (see *Spherulitic texture*, p. 54). (See also **14**.)

Pitchstone from Arran, Scotland; magnification × 12, PPL.

6 Glassy basalt threads – Pele's hair

These filaments of basalt glass form when particles in a molten lava spray are caught by the wind and drawn out. Pele is a mythical lady, believed by native Hawaiians to reside within the volcano Kilauea. (Contrast 7.)

Specimen from Erta Alé volcano, Ethiopia; magnification × 8, PPL.

Intermediate rocks

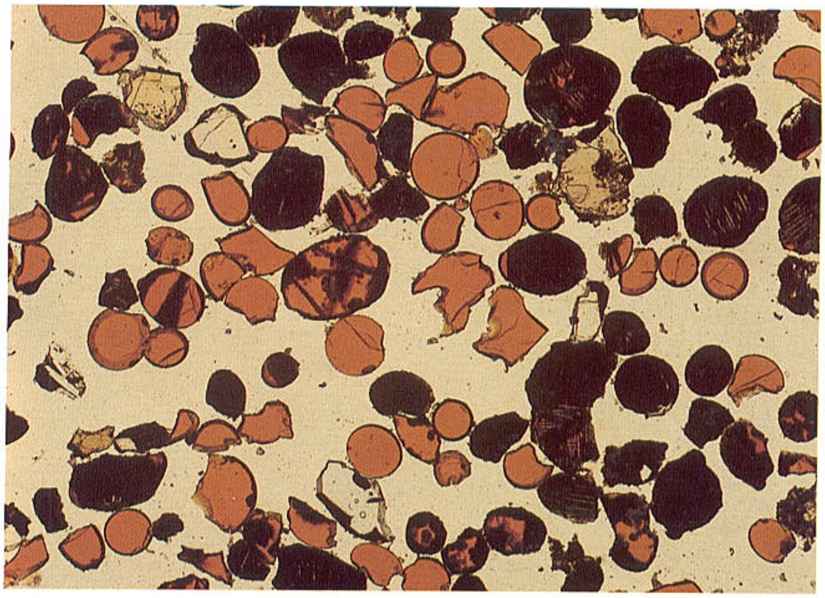
Acid rocks

Alkaline and miscellaneous rocks

7 Glassy particles of mare basalt in lunar soil

Pieces of glass, many of them spherical, are orange-brown or black in colour. Some of the darker ones are partially crystalline. These particles were formed by rapid cooling of droplets of basalt melt; it has been suggested that the droplets formed either in a fire-fountaining lava eruption, or by meteorite impact into a lava lake or into a molten or solid lava flow. (Contrast **6**.) The scarce, irregularly shaped fragments are pyroxene (pale brown) and feldspar (colourless).

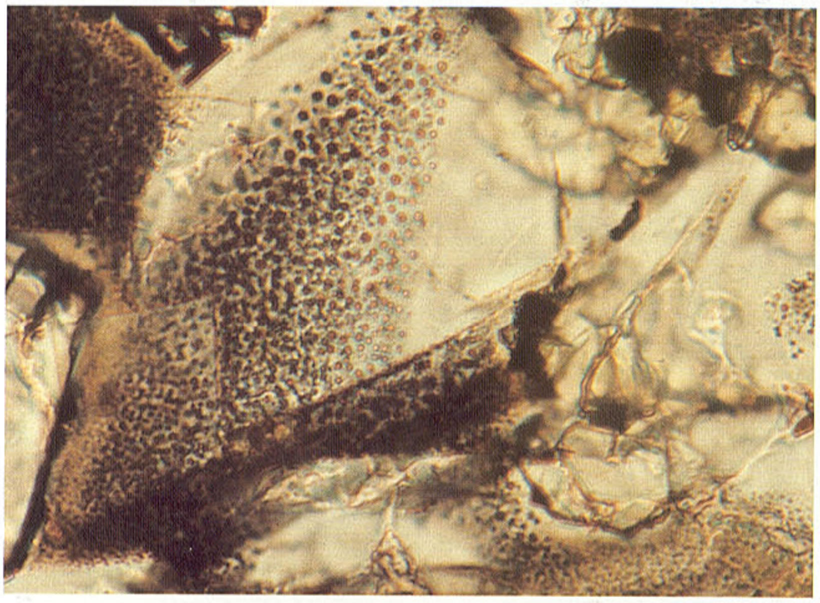
Lunar basalt 74220 from Taurus Littrow Valley collected by Apollo 17 astronauts; magnification × 43, PPL.



7a Liquid Immiscibility

Globules of one glass in another are found in some rocks and these are attributed to immiscibility of the two liquids. In this rock they can only be seen at very high power in thin films of glass between laths of plagioclase.

Specimen from basalt lava, Lava beds National Monument California, U.S.A.: magnification × 600, PPL.



Glass, or devitrified glass, is often an important constituent of the pyroclastic rocks known as *ash-fall tuffs* and *ash-flow tuffs* (or *ignimbrites*). Such rocks typically have *fragmental textures*, i.e. they comprise mixtures of fragments of rocks, crystals and glass, predominantly less than a millimetre in size (**8**–**9**). In an ash-flow deposit the glass fragments may initially be plastic enough to be partly or wholly welded together as the weight of overlying material causes compaction of the constituent fragments; such a rock is known as a *welded tuff* (**8b**). If sufficient heat is available, glassy fragments devitrify.

Preface

The commonest means of studying an igneous rock is to examine it in thin section, either with a petrographic microscope or a hand lens, which permits identification of the minerals present and investigation of their textural relations. From such study the skilled petrographer can interpret details of the history of the magma which crystallized to form the rock.

To become skilled requires many hours of study and training. Much of the training is acquired by patient attention by the teacher to the student. The student needs his observations verified and this can result in the teacher being summoned every minute or so; with a class of ten or more, the student is for long periods unattended, becomes frustrated and loses interest. The remedy is for the student to be able to verify his own observations by comparison with a photograph of a rock of the same type or showing the same feature(s).

The main aim of this book is to provide such a laboratory handbook to assist the student of geology (undergraduate and amateur) beginning to study igneous rocks in thin section. It is hoped that it may also be useful as a reference work for more advanced students and others interested in the natural history of rocks.

The work is divided into two parts – Part 1 is devoted to descriptions and photographs of textures found in igneous rocks and Part 2 consists of photographs of common (and a few not so common) igneous rocks.

We have selected those rocks and textural types which we believe may be encountered in an undergraduate course in geology but have made no attempt to produce a comprehensive coverage of all igneous rocks which have been given individual names because many of these names reflect only minor mineralogical or textural differences.

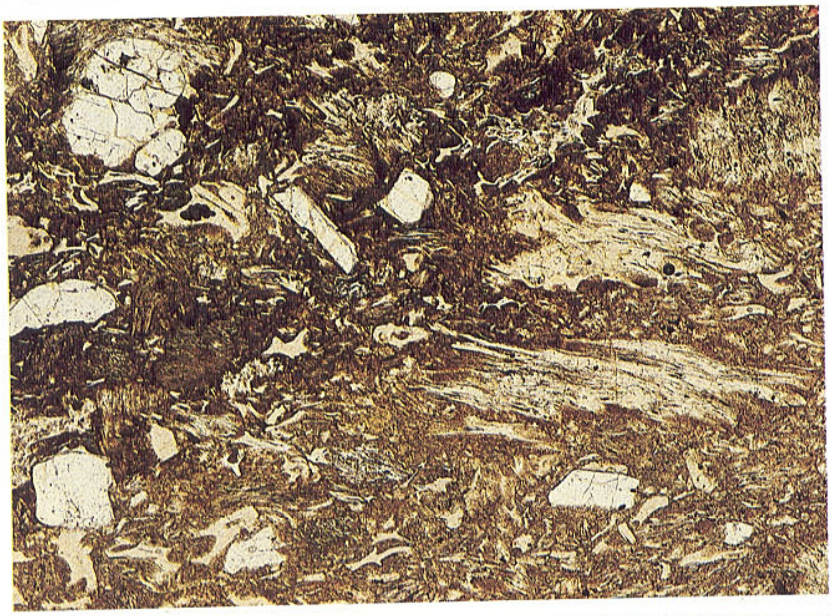
We have tried, as far as possible, to avoid any interpretation of the origin of textures and rocks, although the simple matter of arranging the rocks in some order of presentation is based to some extent on presumed genetic relationships between them.

In a previously published *Atlas of Rock-Forming Minerals* we have illustrated the appearance of the common rock-forming minerals so that here we have not considered it necessary to describe the optical properties in detail. To be able to give a name to the majority of igneous rocks it is only necessary to be familiar with the properties of between twelve and fifteen minerals and we have assumed that the user of this book is already able to recognize these minerals.

Thin sections can be observed under the simplest of microscopes fitted with two pieces of polaroid and a new field of interest is open to the amateur for only a modest financial outlay. Because some amateur geologists may be interested in preparing their own thin sections we have included a brief description of how this may be done.

Many of the photographs show a combination of shapes and colours which have a special beauty of their own, reflecting the fact that while thin section study is of practical importance it can also be of aesthetic satisfaction. A few of the most attractive pictures unashamedly represent the authors' self-indulgence.

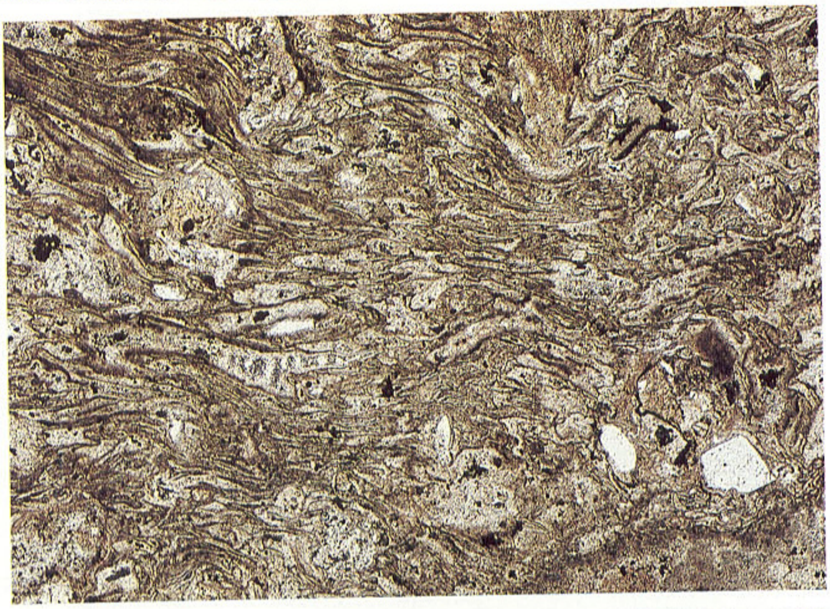
The usual criticism of photomicrographs is that it is very often difficult to determine which feature they are intended to illustrate. For this reason many textbooks are illustrated by drawings in which the required feature may be exaggerated. We have tried to test the usefulness of our photographs by asking our colleagues to identify the mineral assemblage or texture which we have illustrated. We are grateful



8a Glassy unwelded rhyolite tuff

The glassy fragments in this rock, some of which are banded and slightly flattened, are not welded to one another. They and the crystals of quartz and feldspar are embedded in fine glassy particles (ash).

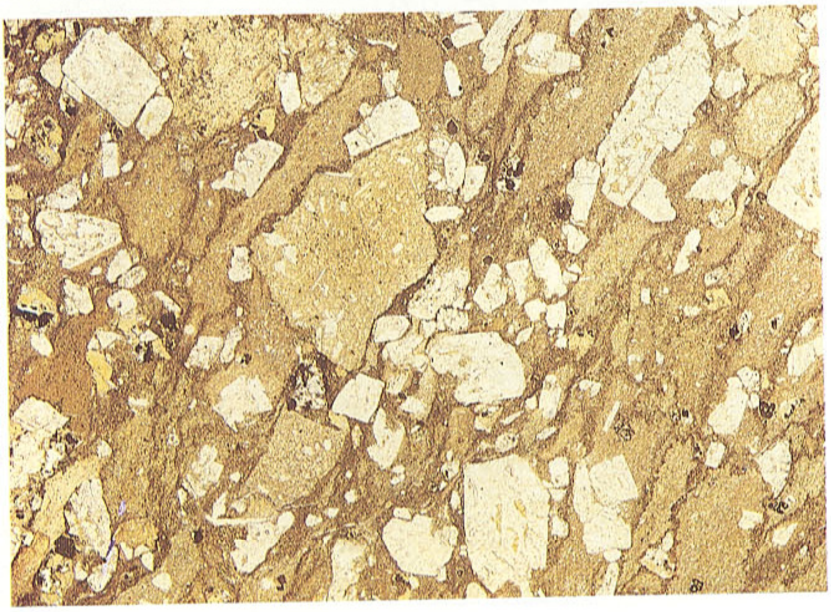
Recent ignimbrite, from Whakatane, North Island, New Zealand; magnification × 46, PPL



8b Glassy welded crystal tuff

The glassy matrix in this rock has an apparent discontinuous lamination caused by extreme compaction and welding of original pumice fragments. The regular alignment of the flattened fragments is known as *eutaxitic texture*.

Welded tuff from Tibchi granite ring-complex, Nigeria; magnification × 36, PPL.



9 Tuff

This fragmental rock consists of crystals of quartz, alkali feldspar and plagioclase of various sizes and shapes, pieces of glassy rhyolite (e.g. centre) and pieces of fine-grained tuff, all enclosed in a fine-grained banded ash matrix which originally may have been glassy. (See also **13**.)

Tuff from Llanellwedd, Wales; magnification × 10, PPL and XPL.

to them for their help in this respect. Most of the photographs were made from thin sections of rocks in the teaching collections of the Geology Departments of Manchester University and St Andrews University. Others were provided by friends and colleagues who made available to us thin sections from their own research collections, and we are most grateful to them for their help in this matter. We are particularly indebted to Dr John Wadsworth and Mr Ian MacKenzie who read and criticized all the descriptions of the textures and rocks. However, any failings in these descriptions are our responsibility alone.

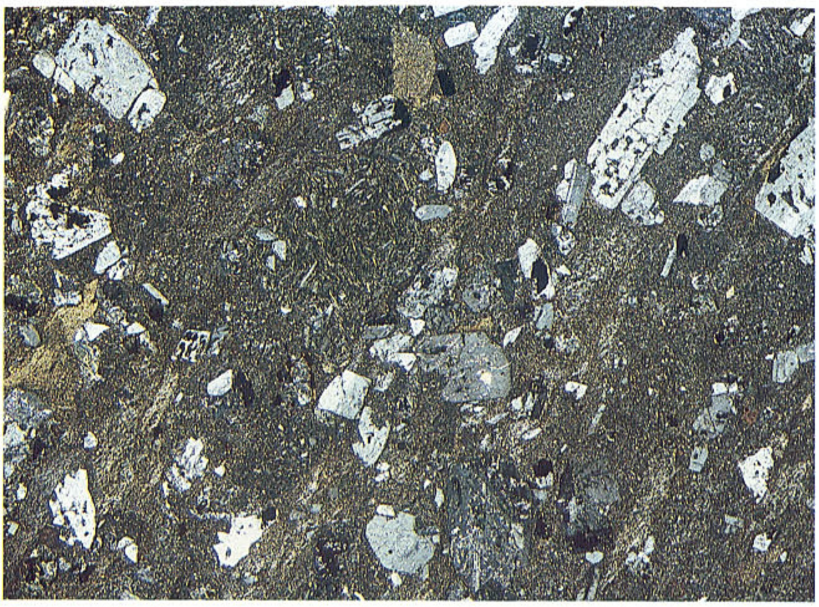
Finally, we caution those using the book not to regard the photographs as representing all the known textures and varieties of igneous rock, or indeed all their guises. These photographs are only an *aid* to recognition of textures and rock types and can never substitute for looking at thin sections under the microscope.

Acknowledgements

We are much indebted to our colleagues and friends who have generously given us thin sections of rocks from which to take photographs: they include the following gentlemen; S. O. Agrell, B. Atkinson, N. Binstead, K. Brooks, F. M. Broadhurst, I.S.E. Carmichael, J. B. Dawson, J. Esson, M. E. Fleet, F. G. F. Gibb, A. Hall, D. L. Hamilton, C. M. B. Henderson, A. M. Hopgood, E. Iki, R. Johnston, I. R. MacKenzie, R. Nesbitt, E. Sapountzis, J. Wadsworth, Rong-shu Zeng and J. Zussman. We have also benefited greatly from having beem able to use the collections of the late Prof. H. I. Drever who was the teacher and friend of both WSM and CHD at St. Andrews University, although 25 years intervened between our time as his students: he and his colleague Mr. R. Johnston were jointly responsible for arousing our interest in igneous rocks early in our careers.

The staff of the publishers have been very patient and helpful and we especially wish to thank them for their consideration and for that quality essential to all publishers – a sense of humour.

Miss Patricia Crook's help both in typing the manuscript and in preparing the index is gratefully acknowledged. We are grateful to Dr Robert Hutchison of the British Museum (Natural History) for permission to photograph thin sections of the Prairie Dog meteorite and the Stannern meteorite, both of which are in the British Museum collections.



Granularity

This property embraces three different concepts: (1) what the aided and unaided eye can or cannot see; (2) absolute crystal sizes (p. 12); and (3) relative crystal sizes (p. 14).

Terms referring to what the aided and unaided eye can or cannot see

Phanerocrystalline (*phaneritic texture* of American petrologists) – all crystals of the principal minerals can be distinguished by the naked eye (see **10**).[1]
Aphanitic – all crystals, other than any phenocrysts present (see p. 14), cannot be distinguished by the naked eye.[2] Two sub-types exist:

(a) *Microcrystalline* – crystals can be identified in thin section with a petrographic microscope (**11**). Crystals only just large enough to show polarization colours (less than 0.01mm) are called *microlites*.
(b) *Cryptocrystalline*[3] – crystals are too small to be identified even with the microscope (**12** and **13**). Globular, rod-like and hair-like crystals which are too small to show polarization colours are known as *crystallites*.

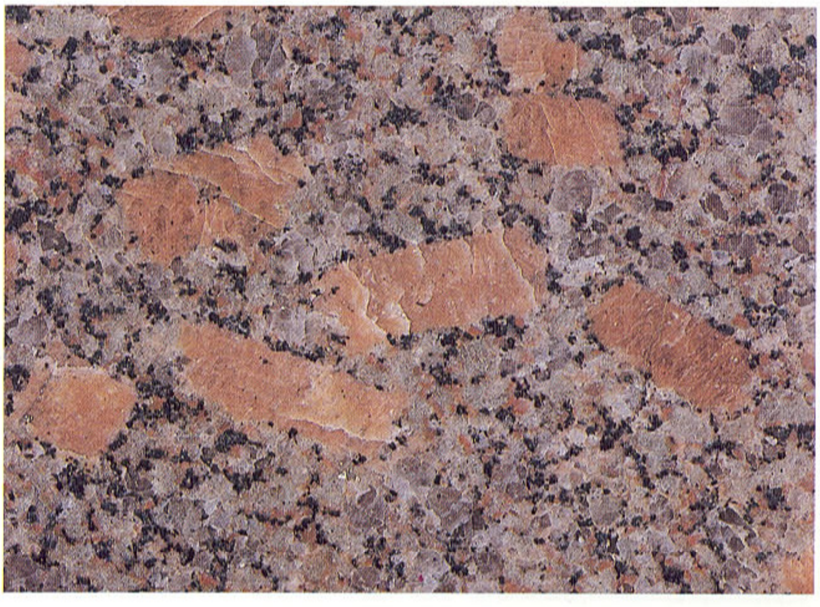
[1]Pegmatitic texture *is a variety of phanerocrystalline in which the crytals are strikingly large, bigger than 1–2 cm, and in rare instances up to many metres.*
[2]*The term* aphyric *is sometimes used for aphanitic rocks which lack phenocrysts* **(eg, 60, 63, 107)**.
[3]Felsitic texture *is sometimes applied to siliceous rocks with ill-defined, almost cryptocrystalline, grey-polarizing areas composed of more or less equigranular aggregates of quartz and alkali feldspar. The name* felsite *is often applied to such rocks, although this is more commonly a field term for fine-grained acid material of uncertain mode off occurrence.*

10 Phanerocrystalline granites

The crystals in the two granites, illustrated here in hand specimen, are clearly visible to the naked eye. Although the rocks contain the same minerals (alkali feldspar, plagioclase feldspar, quartz and biotite) the proportions of the minerals are not the same, and this influences the rock textures. Thus the Shap granite contains two distinct sizes of potassium feldspar crystals (pink), whereas the Eagle Red Granite has only one.

Granite from Shap, England (opposite) and 'Eagle Red' granite, South Africa (next page); both magnifications × 1.

A thin section view of the Shap granite is shown in ***144***

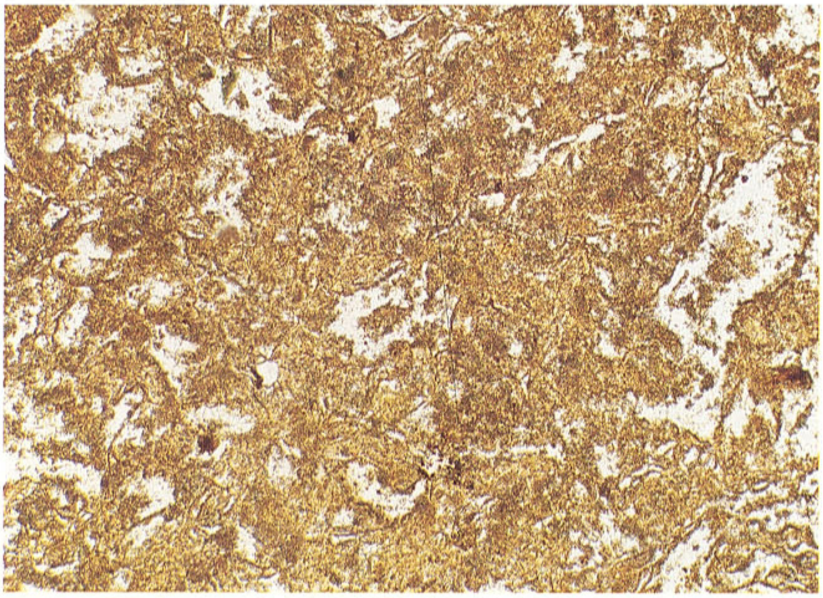


Phanerocrystalline granites (continued)

11 Microcrystalline olivine basalt

This rock consists mainly of plagioclase feldspar, augite and olivine but, without the aid of the microscope, individual crystals would not have been distinguishable. In parts of the photograph the randomly arranged rectangular plagioclases are enclosed by areas showing uniform yellowish interference colours, these are augite crystals.

Olivine basalt from North-west Skye, Scotland; magnification × 11, PPL.

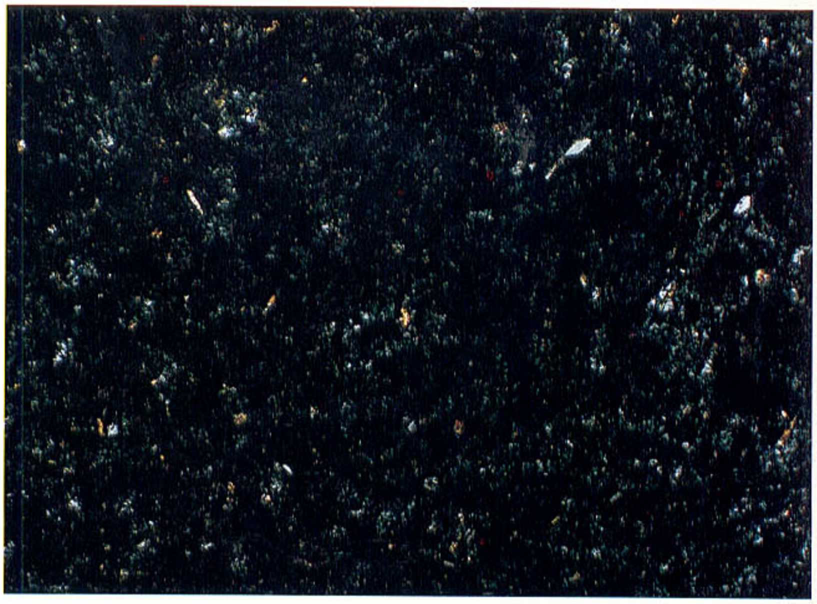


12 Cryptocrystalline rock

Comparison of these two photographs shows that the brown material in the PPL view is birefringent but that the individual crystals are of submicroscopic size. The clear areas in the PPL view are slightly more coarsely crystalline, as can be seen in the XPL view.

Rhyolite from Island of Pantelleria, Italy; magnification × 72, PPL and XPL.

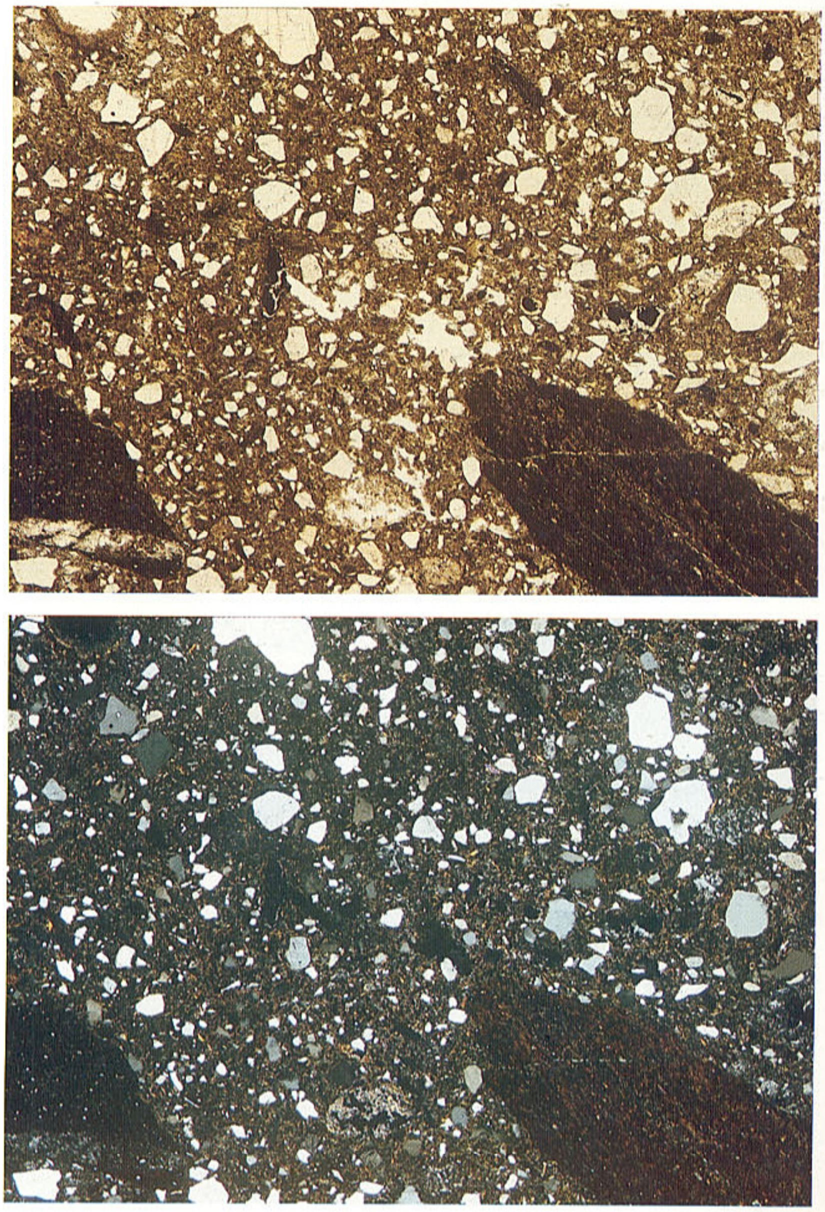
Cryptocrystalline rock (continued)

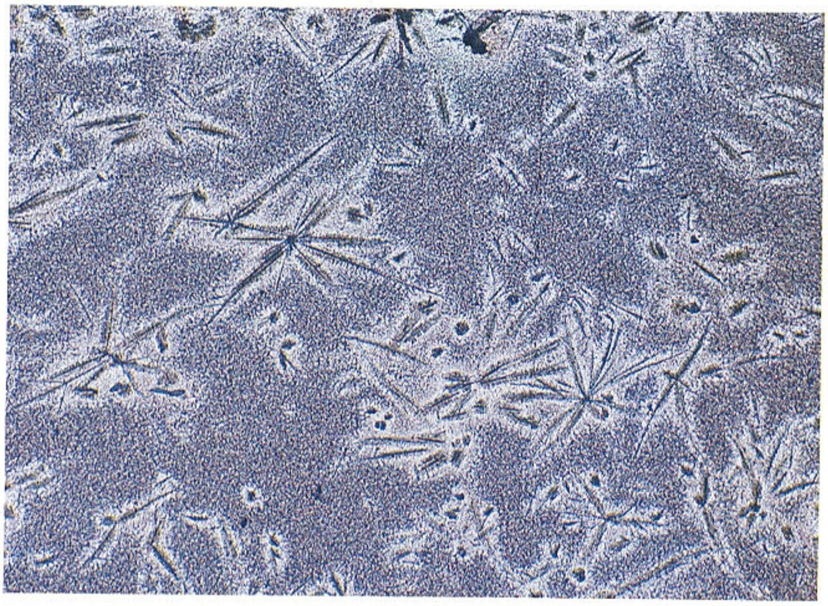


13 Cryptocrystalline matrix in a tuff

Cryptocrystalline texture is common in tuffs (i.e. consolidated ash), as in the matrix of this rock. Here the matrix encloses fragments of shale and quartz crystals. (See also **8** and **9**.)

Tuff from unknown locality; magnification × 16, PPL and XPL.





14 Pitchstone containing crystallites of two sizes

Radiate clusters of crystallites are set here in glass. The bulk of the glass contains even smaller crystallites, causing the grey colour, whereas adjacent to the larger crystallites the smaller ones are absent. This is a higher magnification view of the rock illustrated in **5**.

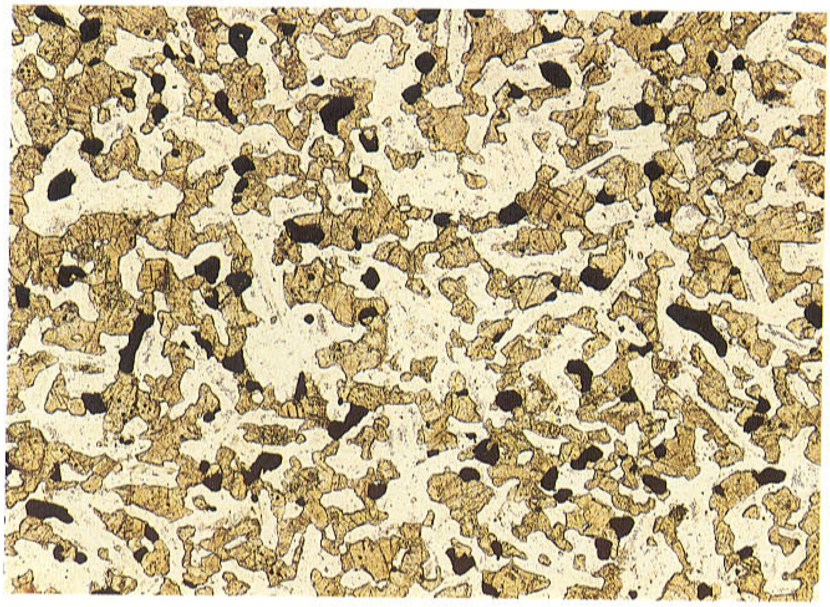
Pitchstone from Arran, Scotland; magnification × 52, PPL.

Terms indicating absolute ranges of grain size

Coarse-grained – crystal diameters >5 mm
Medium-grained – crystal diameters 1–5 mm
Fine-grained – crystal diameters <1 mm[1]

The next six photographs (**15**, **16** and **17**) were all taken at the same magnification (× 27) to indicate how grain size relates to the number of crystals seen in a given field of view (4.2 × 3.1 mm), and hence the extent of the texture visible at that magnification. While the overall texture is recognizable in the fine-grained rock, it is not so in the coarse one and a low-power objective lens would be necessary to examine it adequately. Petrographic microscopes rarely have a sufficiently low-power objective lens for examining the textures of coarse-grained rocks; a hand lens should be used for these, with two sheets of polaroid, if available.

[1] *Some petrologists include another range, <0.05 mm, which they call* very fine-grained.

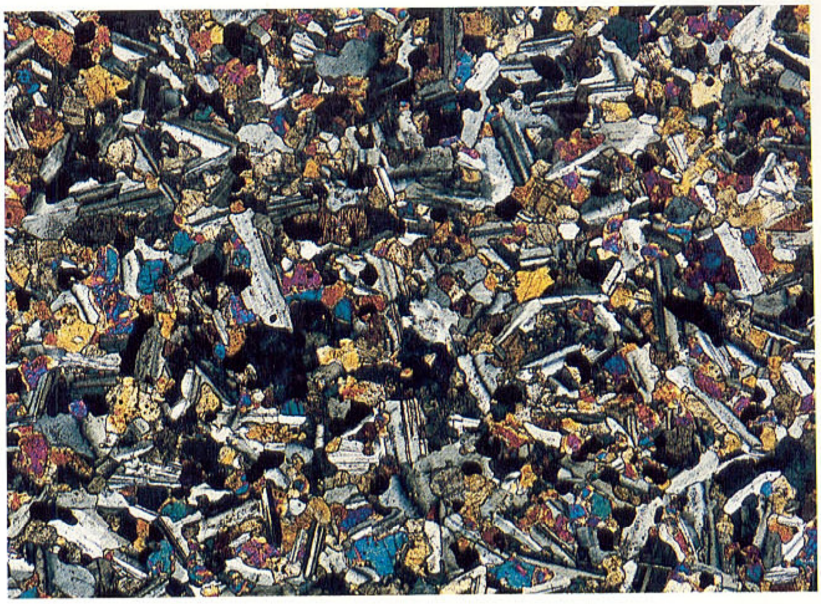


15 Fine-grained gabbro

This rock contains plagioclase, orthopyroxene, augite and magnetite; some of the orthopyroxene crystals (low birefringent mafic mineral) contain narrow lamellae of augite. Although the rock is fine grained, it is called a 'gabbro' because it is from a large intrusion; the fine grain size results from quick cooling at the intrusion margin. Another term that could be used for this rock is *microgabbro* (see p. 78).

Gabbro from chilled margin of the Skaergaard intrusion, East Greenland; magnification × 27, PPL and XPL.

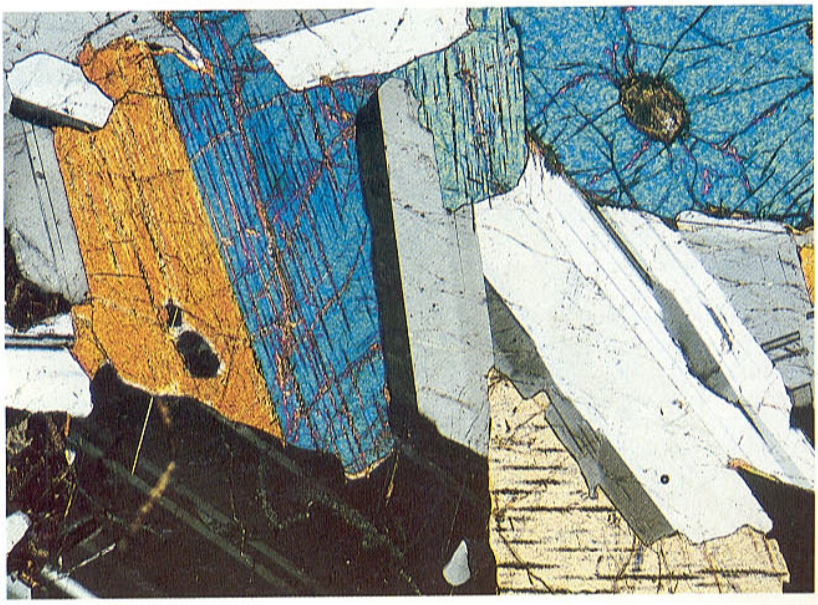
Fine-grained gabbro (continued)

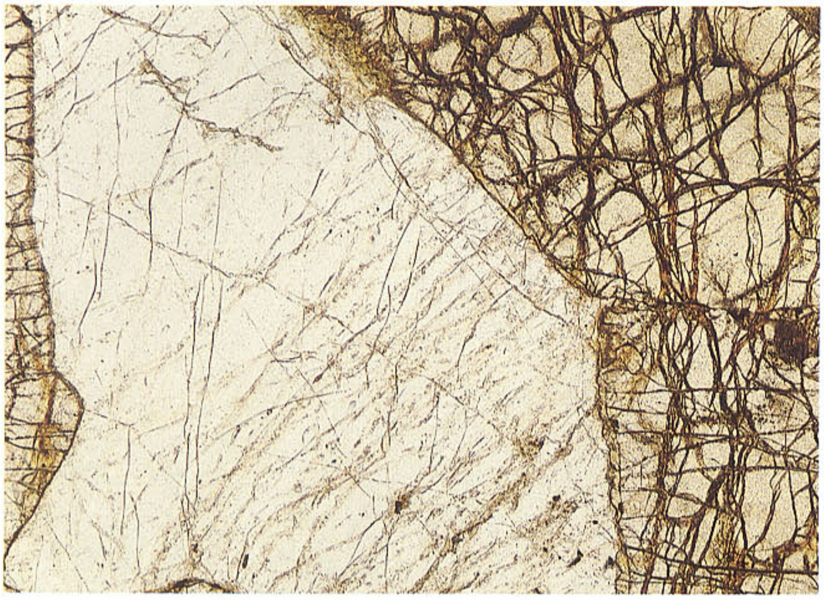


16 Medium-grained olivine gabbro

The spaces between the tabular crystals of plagioclase in this rock are occupied by augite and ilmenite. At the top right of the picture the plagioclase abuts onto an olivine crystal. The augite crystals contain lamellae of orthopyroxene.

Gabbro from Lower Zone b of the Skaergaard intrusion, East Greenland; magnification × 27, PPL and XPL.





17 Coarse-grained olivine gabbro

At this magnification only parts of three large olivines and one plagioclase are visible, such that textural relations are not determinable in this single view.

Gabbro from Rhum, Scotland; magnification × 27, PPL and XPL.

Terms indicating relative size of crystals

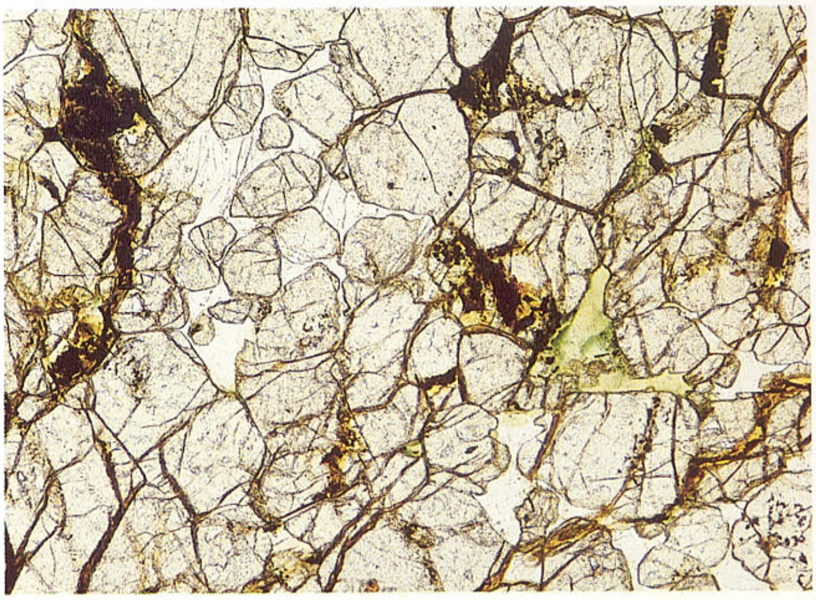
Equigranular – all crystals are of approximately the same size.
Inequigranular – crystals differ substantially in size. A common variety, *porphyritic* texture, involves relatively large crystals (*phenocrysts*[1]) embedded in finer-grained groundmass. (*N.B.* The same mineral may be present as both phenocrysts and groundmass.) In naming a rock with porphyritic texture the minerals present as phenocrysts should be listed and followed by the suffix -phyric, e.g. 'hornblende-pigeonite-phyric andesite'. However, if the groundmass is glassy, the term 'vitrophyre' is used, e.g. an 'olivine vitrophyre' has olivine phenocrysts set in glass; the texture in this case is referred as *vitrophyric* (**3, 142**). *Seriate* texture involves a continuous range in sizes of crystals of the principal minerals; if the crystals show a broken series of sizes, the inequigranular texture is said to be *hiatal*. Caution is necessary in the identification of seriate and hiatal textures, since the dimensions of a crystal in a thin section depend on the attitude of the intersection of the crystal in three dimensions.

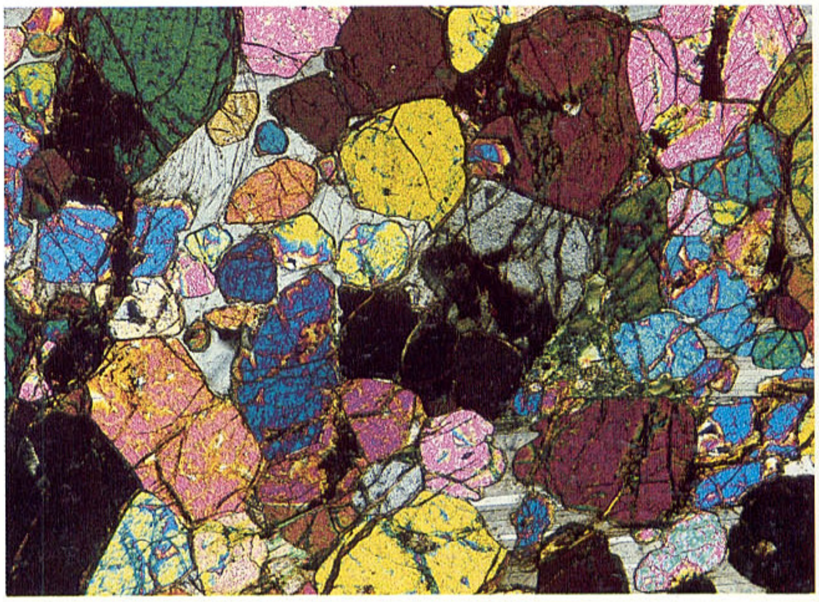
[1] *The prefix* micro- *may be added to* phenocrysts *which have diameters between 0.05 and 0.5 mm (e.g. 'olivine microphenocrysts').*

18 Equigranular peridotite

Uniformly-sized olivine crystals, some of them in clots, form the bulk of this rock, with plagioclase filling the interstices. The black material is microcrystalline haematite formed by oxidation of olivines and the green material is a clay mineral.

Peridotite from the Skaergaard intrusion, East Greenland; magnification × 27, PPL and XPL.
*Additional views of equigranular rocks are shown in **43**, **113**, **117**, **125**, **130** (first photo), **134**, **140** (third photo), **168**.*



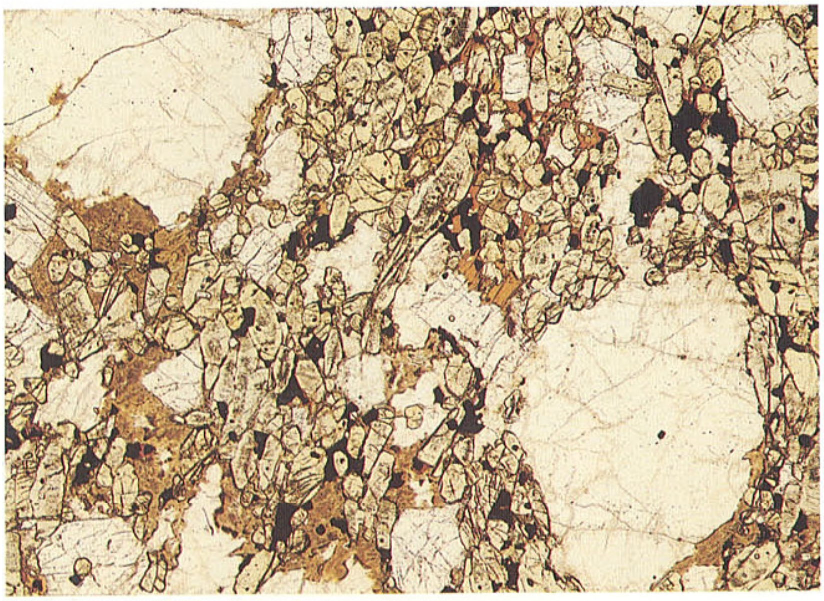


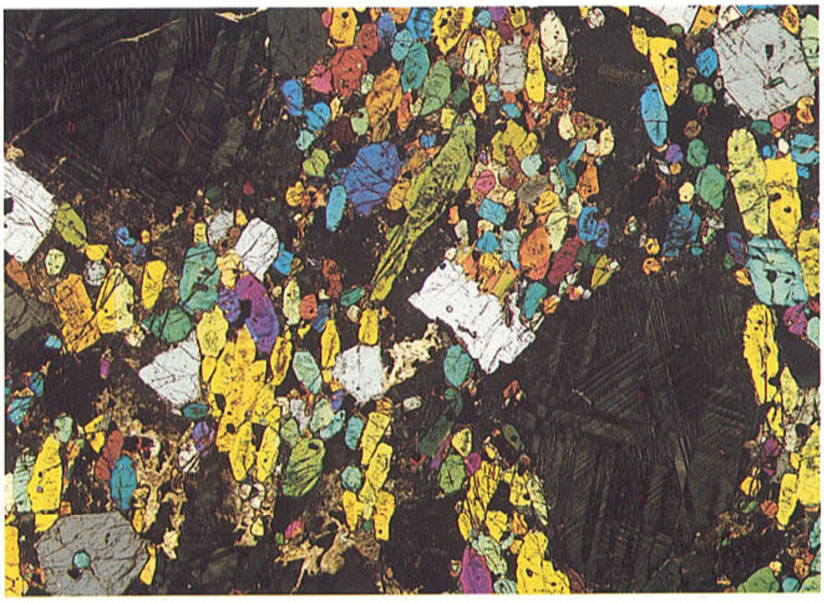
19 Porphyritic andesite

In this rock the phenocrysts (some of them in clots) of plagioclase, hornblende (khaki colour in PPL), augite (pale green in PPL) and magnetite, are surrounded by fine-grained groundmass of plagioclase, magnetite and glass.

Andesite from Siebengebirge, Germany; magnification × 23, PPL and XPL.

Porphyritic andesite (continued)





20 Leucite-phyric micro-ijolite

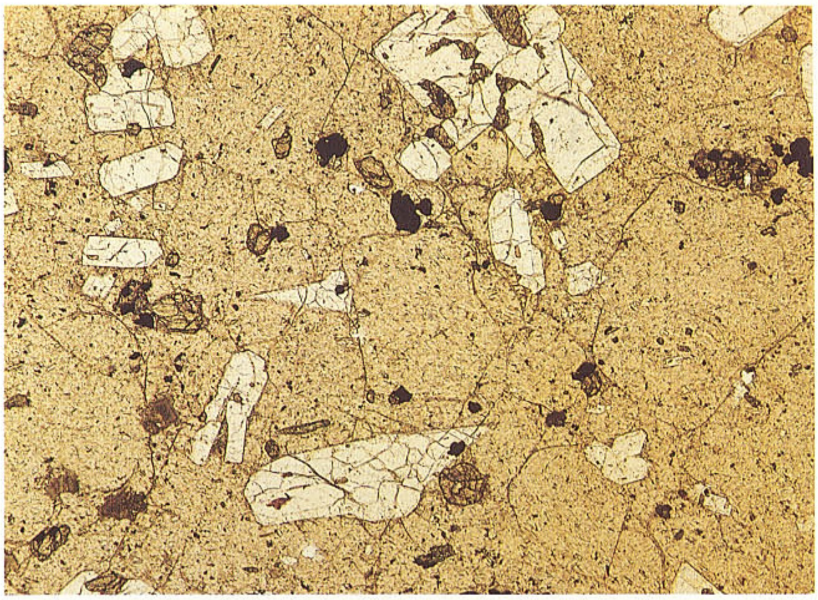
Two, large, shapeless crystals of leucite (very dark and showing multiple twinning in XPL photograph) are here surrounded by an equigranular groundmass consisting of crystals of elongate augite (bright interference colours), equant nepheline (grey in XPL) and interstitial biotite, leucite and magnetite. The amorphous material in the PPL view is a clay mineral.

Micro-ijolite from the Batsberg intrusion, East Greenland; magnification × 11, PPL and XPL.
Many other examples of porphyritic rocks can be seen by leafing through the book.

21 Plagioclase-augite-magnetite vitrophyre

Phenocrysts of the three minerals plagioclase, augite and magnetite, some of them in clots, are set in glass which contains crystallites of plagioclase.

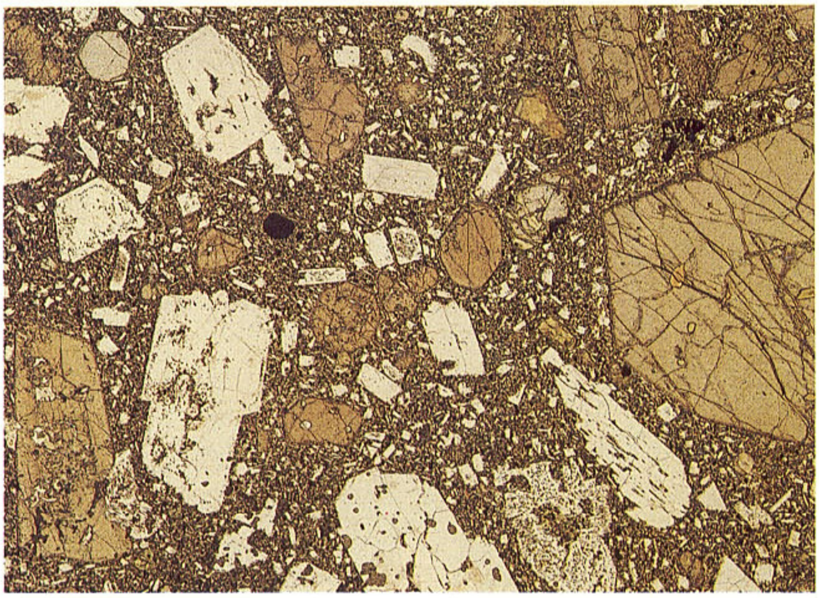
Basalt from Arran, Scotland; magnification × 20, PPL.
*See **132** for another example of vitrophyre.*

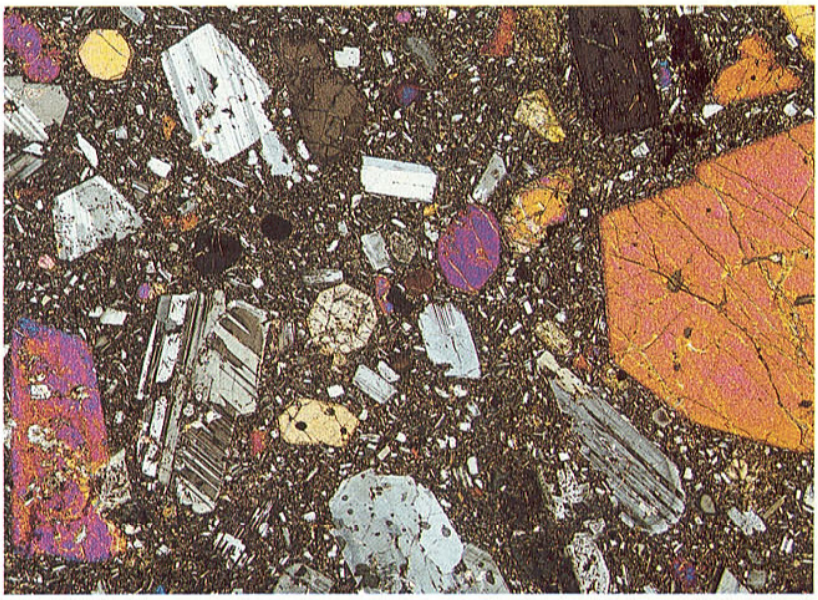


22 Seriate-textured olivine basalt

The crystals of olivine, augite and plagioclase in this basalt all show a wide range of grain size from as small as 0.01 mm up to 4 mm. Note the abundance of groundmass inclusions in some of the crystals, giving them a sponge-like appearance.

Olivine basalt from Arthur's Seat, Edinburgh, Scotland; magnification × 11, PPL and XPL.
*See **44** and **137** for other examples of this texture.*





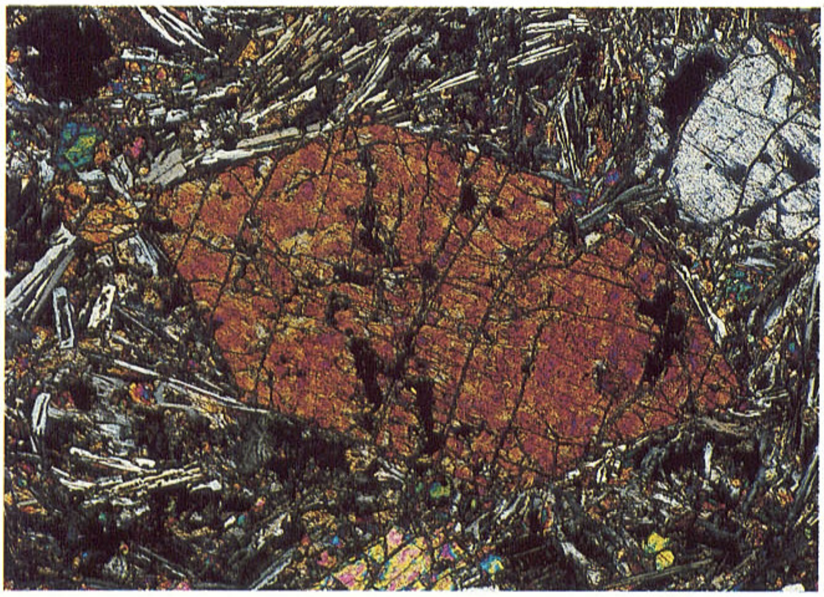
Crystal shapes

Two kinds of term are used to describe crystal shape: (1) those relating to the quality of the development of faces on crystals and (2) those specifying the three-dimensional shapes of individual crystals (p. 19).

Terms indicating the quality of the development of faces on crystals

Regrettably, three sets of words are in use to describe the same ideas, the most commonly used set being that in the first column of the following table.

Preferred terms	Synonymous terms	Synonymous terms	Meaning
Euhedral	Idiomorphic	Automorphic	Crystal completely bounded by its characteristic faces.
Subhedral	Hypidiomorphic	Hypautomorphic	Crystal bounded by only some of its characteristic faces.
Anhedral	Allotriomorphic	Xenomorphic	Crystal lacks any of its characteristic faces.



23 Euhedral olivine in olivine basalt

The photograph shows the characteristic six-sided euhedral shape of olivine in sections through the prism and dome faces. Note the slight enclosure of matrix material by one of the prism faces.

Olivine basalt from Ubekendt Ejland, West Greenland; magnification × 40, XPL.

24 Subhedral olivine in picritic basalt

Some of the faces on this equidimensional olivine crystal are flat, planar ones, whereas others are curved and embayed.

Picritic basalt from Ubekendt Ejland, West Greenland; magnification × 72, XPL.