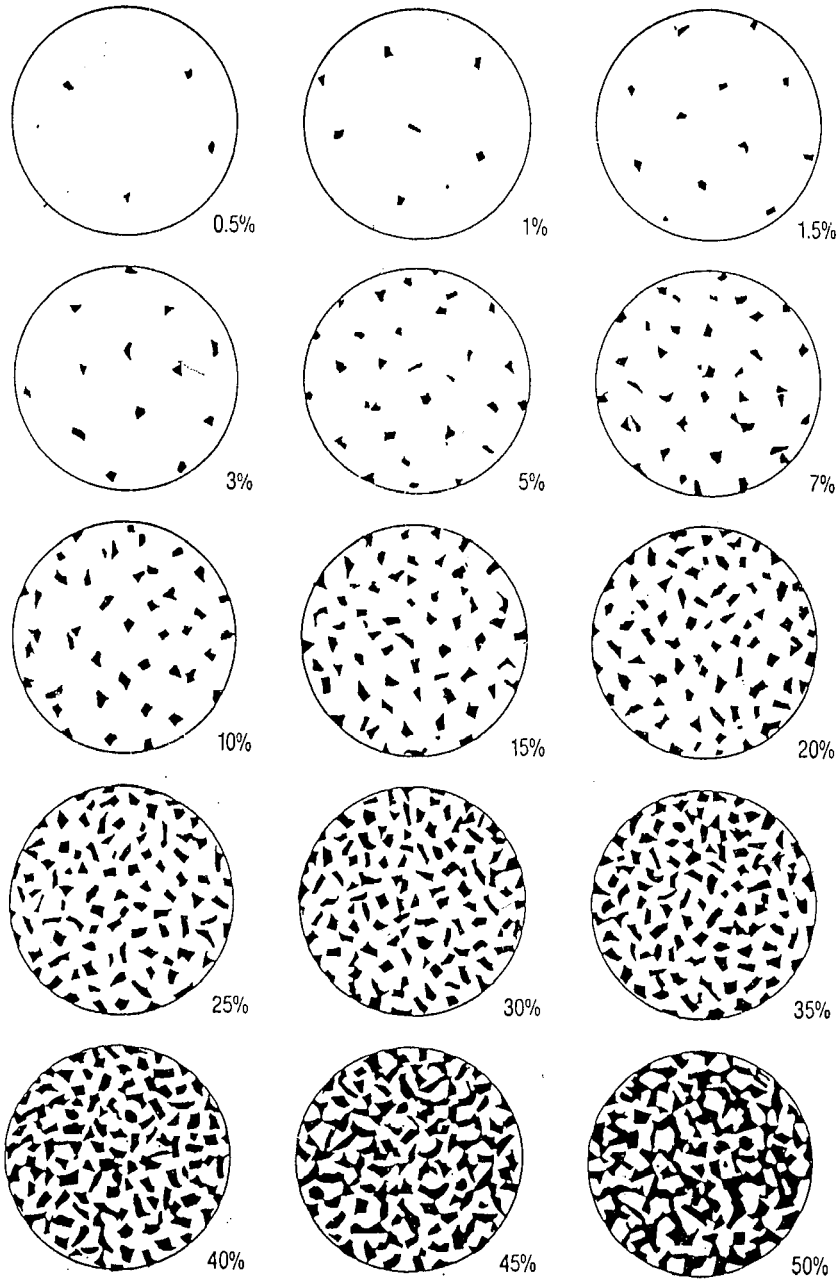
APPENDIX 3. Percentage Diagrams For Estimating Compositon By Volume*



*To convert the results to weight percentages, multiply each volume percentage by the specific gravity of that mineral and recalculate the resulting numbers so that they sum to 100.

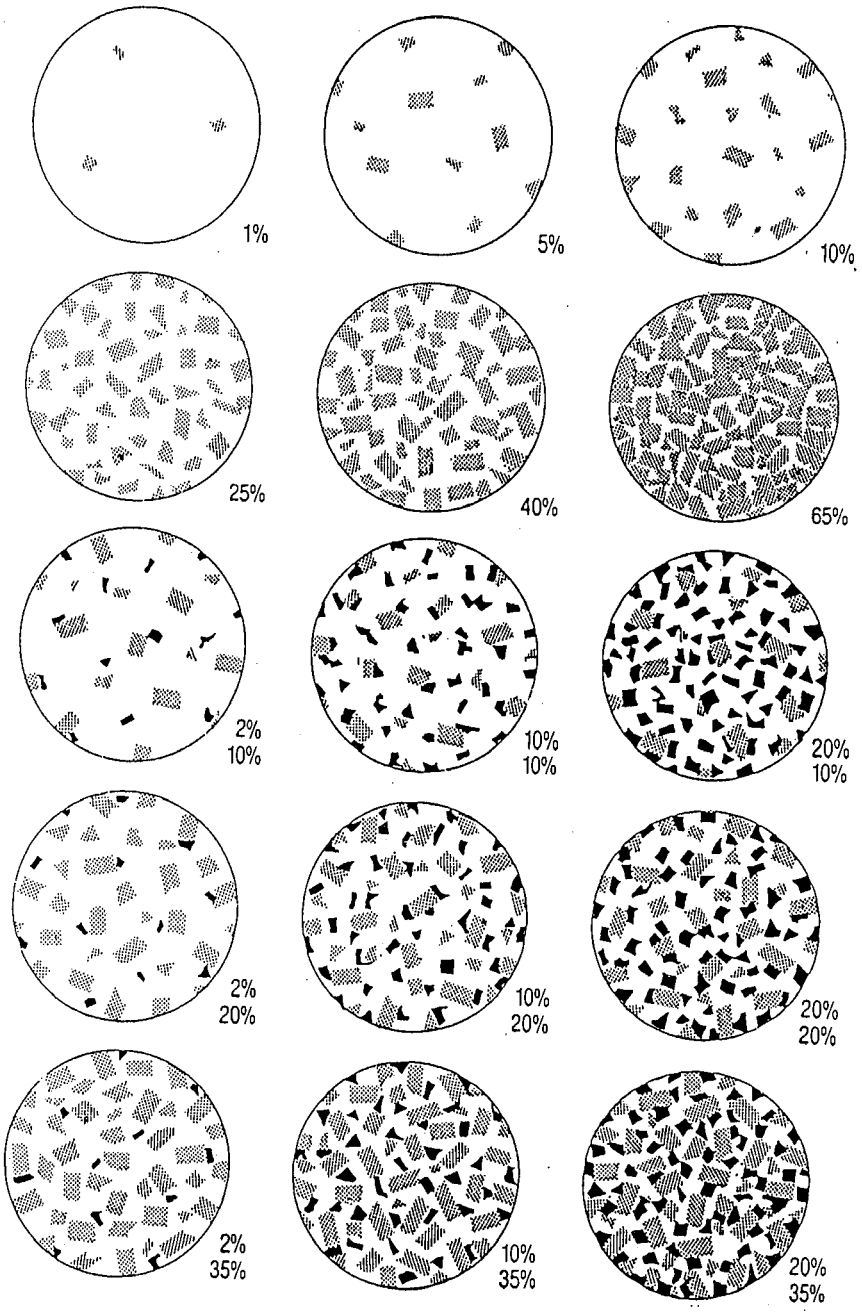


Table 2–1 Common Rock Names, with IUGS Recommended Terms in Bold Print

Name	Approximate Meaning	Name	Approximate Meaning
Adakite	Mg-rich andesite	Katungite	K-rich olivine melilitite
Adamellite	Quartz Monzonite	Keratophyre	Albitized felsic volcanic
Alaskite	Leuco-(alkali feldspar) granite	**Kersantite**	Biotite-plag. lamprophyre (Tbl. 19-6)
Alnöite	Melilite lamprophyre (Tbl. 19-6)	**Kimberlite**	Volatile-rich ultramafic (Tbl. 19-1)
Alvekite	Med.- to fine-grained calcite carbonatite	**Komatiite**	Ultramafic volcanic (mostly Archean)
Andesite	Figs. 2-3 and 2-4	**Kugdite**	Olivine melilitolite
Ankaramite	Olivine basalt	Ladogalite	Mafic alkali feldspar syenite.
Anorthosite	Fig. 2-2	**Lamproite**	A group of K-, Mg-, volatile-rich volcanics (Tbl. 19-1)
Aplite	Granitoid with fine sugary texture		
Basalt	Figs. 2-3 and 2-4	**Lamprophyre**	A diverse group of dark, porphyritic, mafic ultramafic K-rich hypabyssal rocks (Tbl.
Basanite	Olivine tephrite (Tbl. 19-1)		
Beforsite	Dolomite carbonatite	**Larvikite**	Augite syenite-monzonite
Benmoreite	Trachyte (Fig. 14-2)	**Latite**	Fig. 2-3
Boninite	Mg-rich andesite	**Leucitite**	Volcanic rock that is nearly all leucite
Camptonite	Hornblende lamprophyre (Tbl. 19-6)	**Lherzolite**	Fig. 2-2
Cancalite	Enstatite sanidine phlogopite lamproite (Tbl. 19-5)	**Limburgite**	Volcanic = pyroxene + olivine + opaques in glassy groundmass
Carbonatite	> 50% carbonate	**Liparite**	Rhyolite
Cedricite	Diopside leucite lamproite (Tbl. 19-5)	Luxulianite	Porphyritic granite with tourmaline
Charnockite	Orthopyroxene granite	Madupite	Lamproite with poikilitic phlogopite groun mass (Tbl. 19-5)
Comendite	Peralkaline rhyolite		
Cortlandite	Pyroxene-olivine hornblendite	Mafurite	Alkaline ultramafic volcanic
Dacite	Figs. 2-3 and 2-4	Malchite	Lamprophyre
Diabase	Medium-grained basalt/gabbro	**Malignite**	Aegirine-augite nepheline syenite
Diorite	Fig. 2-2	Mamilite	Leucite-richterite lamproite (Tbl. 19-5)
Dolerite	Medium-grained basalt/gabbro	**Mangerite**	Hypersthene monzonite
Dunite	Fig. 2-2	Marianite	Mg-rich andesite
Enderbite	Hypersthene tonalite	Marienbergite	Natrolite phonolite
Essexite	Nepheline monzo-gabbro/diorite	Masafuerite	Picrite basalt
Felsite	Microcrystalline granitoid	**Meimechite**	Ultramafic volcanic
Fenite	Alkali feldspar-rich metasomatic rock associated with carbonatites	**Melilitite**	Ultramafic melilite-clinopyroxene volcanic (Tbl. 19-1)
Fergusite	Pseudolucite (foid)ite	**Melilitolite**	Plutonic melilitite
Fitzroyite	Leucite-phlog. lamproite (Tbl. 19-5)	**Melteigite**	Mafic ijolite
(Foid)ite	Fig. 2-3 Replace "foid" with the actual	Miagite	Orbicular gabbro
(Foid)olite	Fig. 2-2 feldspathoid name	**Miaskite**	Felsic biotite.-nepheline monzosyenite
Fourchite	Mafic analcime lamprophyre	**Minette**	Biotitic lamprophyre (Tbl. 19-6)
Fortunite	Glassy olivine lamproite (Tbl. 19-5)	**Missourite**	Mafic type of leucite (foid)ite
Foyaite	Nepheline syenite	**Monchiquite**	Feldspar-free lamprophyre (Tbl. 19-6)
Gabbro	Fig. 2-2	**Monzonite**	Fig. 2-2
Glimmerite	Biotite-rich ultramafic	**Monzonorite**	Orthoclase-bearing hypersthene gabbro
Granite	Fig. 2-2	**Mugearite**	Mafic sodic trachyandesite (Fig. 14-2)
Granitoid	Felsic Plutonic (granite-like) rock	**Natrocarbonatite**	Rare sodic carbonatite volcanic
Granodiorite	Fig. 2-2	Nelsonite	Ilmenite-apatite dike rock
Granophyre	Porphyritic granite with granophyric texture	**Nephelinite**	Nepheline-bearing basalt (Tbl. 19-1)
Grazinite	Phonolitic nephelinite	**Nephilinolite**	Plutonic nephelinite (a foidite)
Grennaite	Nepheline syenite	Nordmarkite	Quartz-bearing alkali feldspar syenite
Harrisite	Troctolite	**Norite**	Orthopyroxene gabbro
Harzburgite	Fig. 2-2	**Obsidian**	Volcanic glass (typically silicic)
Hawaiite	Sodic trachybasalt (Fig. 14-2)	Oceanite	Picrite
Hornblendite	Ultramafic rock >90% hornblende	Odinite	Lamprophyre
Hyaloclastite	Pyroclastic rock = angular glass fragments	**Opdalite**	Hypersthene granodiorite
Icelandite	Al-poor, Fe-rich andesite	Orbite	Lamprophyre
Ignimbrite	Applied to welded tuffs	Orendite	Di-sanidine-phlog. lamproite (Tbl. 19-5)
Ijolite	Clinopyroxene nephelinite (Tbl. 19-1)	Orvietite	Volcanic near the tephri-phonolite – phono tephrite border (Fig. 2-4)
Italite	Glass-bearing leucititolite		
Jacupirangite	Alkaline pyroxenite	Oachitite	Ultramafic lamprophyre
Jotunite	Hypersthene monzonorite	**Pantellerite**	Peralkaline rhyolite (Tbl. 19-1)
Jumillite	Olivine madupitic lamproite (Tbl. 19-5)	**Pegmatite**	Very coarse-grained igneous rock
Kalsilitite	Kalsilite-rich mafic volcanic (Tbl. 19-1)	**Peridotite**	Fig. 2-2
Kamafugite	Collective term for the group: KAtungite-MA Furite-Ugandite	Perlite	Volcanic glass that exhibite fine concentric cracking

Table 2–1 *Continued*

Name	Approximate Meaning	Name	Approximate Meaning
Phonolite	Figs. 2-3 and 2-4	Tachylite	Basaltic glass
Phono-tephrite	**Fig. 2-3**	Tahitite	Haüyne tephri-phonolite
Picrite	Olivine-rich basalt (Fig. 14-2)	**Tephrite**	Fig. 2-3 and Tbl. 19-1
Picrobasalt	Fig. 2-4	**Tephri-phonolite**	Fig. 2-3
Pitchstone	Hydrous volcanic glass	**Teschenite**	Analcime gabbro
Plagioclasite	Anorthosite	**Theralite**	Nepheline gabbro
Plagiogranite	Leucotonalite	**Tholeiite**	Tholeiitic basalt or magma series (Sec. 8.7)
Polzenite	Melilite lamprophyre (Tbl. 19-6)	**Tonalite**	Fig. 2-2
Pyroxenite	Fig. 2-2	**Trachyte**	**Figs. 2-3 and 2-4**
Quartzolite	Fig. 2-2	**Troctolite**	Olivine-rich gabbro (Fig. 2-2)
Rauhaugite	Coarse dolomitic carbonatite (Tbl. 19-2)	**Trohdhjemite**	Leuco-tonalite
Reticulite	Broken-up pumice	**Uncompahgrite**	Pyroxene melilitolite
Rhyolite	Figs. 2-3 and 2-4.	**Urtite**	Felsic nephilinolite (Tbl. 19-1)
Sannaite	Na-amph-augite lamprophyre (Tbl. 19-6)	**Verite**	Glassy ol-di-phlog. lamproite (Tbl. 19-5)
Sanukite	Mg-rich andesite	Vicolite	See orvietite
Scoria	Highly vesiculated basalt	**Vogesite**	Hbl-di-orthocl. lamprophyre (Tbl. 19-6)
Shonkinite	Alkaline plutonic with Kfs, foid, and augite	**Websterite**	Fig. 2-2
Shoshonite	K-rich basalt (Tbl. 19-1)	**Wehrlite**	Fig. 2-2
Sövite	Coarse calcite carbonatite (Tbl. 19-2)	Woldigite	Di-leucite-richterite madupidic lamproite (Table 19-5)
Spessartite	Hbl-di-plag. lamprophyre (Tbl. 19-6)		
Spilite	Altered albitized basalt	Wyomingite	Di-leucite-phlog. lamproite (Tbl. 19-5)
Syenite	Fig. 2-2		

Glossary or LeMaitre (1989). For the sake of brevity, I have included only the root IUGS terms, such as *granite*, *andesite*, or *trachyte*, and not compound terms such as *alkali-feldspar granite*, or *basaltic trachy-andesite*, etc.

2.5 PYROCLASTIC ROCKS

The initial IUGS classification did not cover pyroclastic rocks, but they were covered in a later installment (Schmid, 1981). As mentioned previously, if the chemical composition is available these rocks could be classified compositionally in the same manner as any volcanics, but they commonly contain significant impurities, and only those for which the foreign material is minimal can a name be applied with confidence. Pyroclastics are thus commonly classified on the basis of the *type* of fragmental material (collectively called **pyroclasts**) or on the *size* of the fragments (in addition to a chemical or modal name if possible). If the type of material is to be the basis, the volume percent of glass, rock fragments, and crystal fragments is determined and the name derived from Fig-

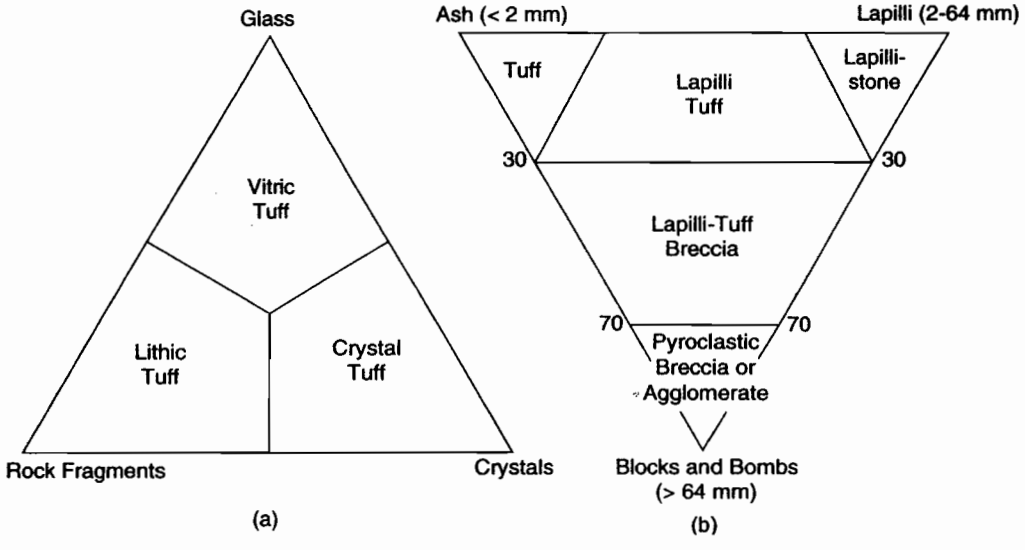
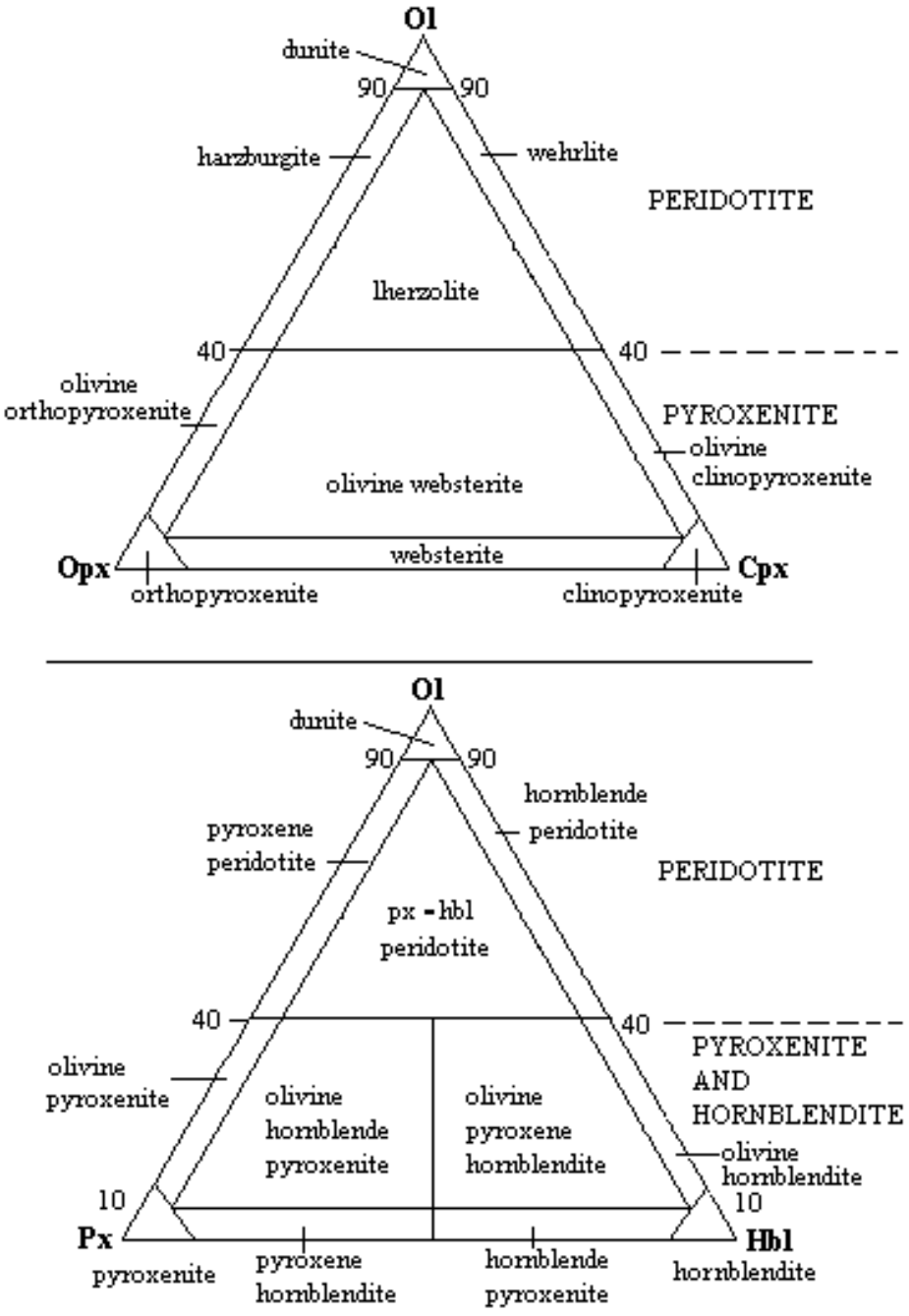


Figure 2–5 Classification of the pyroclastic rocks. **(a)** Based on type of material. After Pettijohn (1975) and Schmid (1981). **(b)** Based on the size of the material. After Fisher (1966). Copyright © with permission from Elsevier Science.

CLASSIFICATION SCHEMES FOR PERIDOTITIC ROCKS



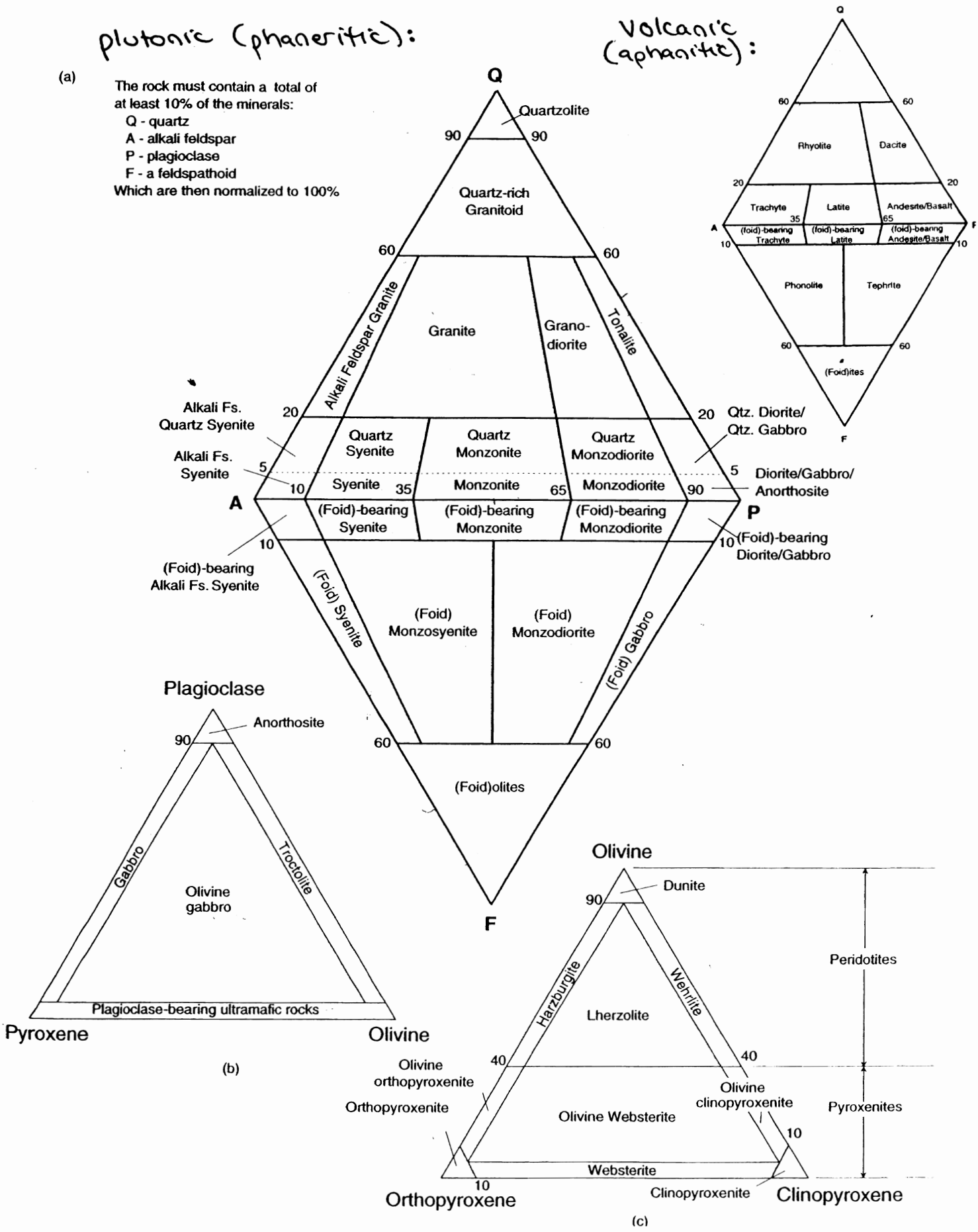


Figure 2–2 A classification of the phaneritic igneous rocks. **(a)** Phaneritic rocks with more than 10% (quartz + feldspar + feldspathoids). **(b)** Gabbroic rocks. **(c)** Ultramafic rocks. After IUGS (see references at the end of the chapter).

from Winter (2001)

Table 3–1 Common Igneous Textural Terms

Crystallinity	
Holocrystalline	Consisting entirely of crystals (default term, not commonly used).
Hypocrystalline	Containing both crystals and glass.
Holohyaline, Vitric	Consisting entirely of glass.
Grain Size	
Aphanitic	Most minerals are too fine-grained to see with the naked eye.
Phaneritic	The minerals are coarse enough to see with the naked eye.
Cryptocrystalline	Too fine-grained to distinguish the minerals microscopically.
Fine grained	Average crystal diameter is less than 1 mm.
Medium grained	Average crystal diameter is 1–5 mm.
Coarse grained	Average crystal diameter is greater than 5 mm.
Pegmatitic	Very coarse grained.
Aplitic	Fine- to medium-grained xenomorphic and equigranular (looks sugary).
Equigranular	Grains are all approximately the same size.
Inequigranular	Grains vary considerably in size.
Porphyritic Textures	
Porphyritic	Approximately bimodal size distribution (usually requires a great difference).
Megaporphyritic	Porphyritic texture that can be seen in hand specimen (rarely used).
Microporphyritic	Porphyritic texture that is visible only under the microscope.
Phyric (-phyric)	An adjective (or suffix) referring to porphyritic texture.
Phenocryst	Large crystal set in a fine matrix.
Microphenocryst	Microscopic crystals that are still larger than the remainder of the groundmass.
Megacryst	An unusually large crystal, either a phenocryst or a xenocryst.
Poikilitic	The host phenocryst (oikocryst) contains many inclusions of other minerals.
Oikocryst	The host phenocryst in poikilitic texture.
Groundmass	The glassy or finer grained element in the porphyritic texture (matrix, mesostasis).
Cumulophyric	Phenocrysts of the same or different minerals occur in clusters (Figure 3–11a).
Glomeroporphyritic	Synonymous with cumulophyric (used by some to specify that only one mineral is involved).
Hiatial porphyritic	There is a pronounced difference in size between the phyric and groundmass phases (the default term: rarely used).
Seriate	There is a continuous gradation in size.
Aphyric	Non-porphyritic (no phenocrysts).
Form of Individual Grains	
Euhedral (idiomorphic)	Completely bounded by crystal faces.
Subhedral (subidiomorphic)	Crystal faces only partially developed.
Anhedral (allotriomorphic)	Crystal faces are entirely absent.
Crystal habits: equaint, prismatic, columnar, accicular, fibrous, tabular, platy, micaceous, lath-shaped, etc. (see any mineralogy text).	
Corroded (embayed)	Subhedral or anhedral forms produced by partial melting (resorption) of phenocrysts by the melt.
Forms of Grains in the Rock as a Whole	
Panidiomorphic	Most of the grains are euhedral (rare).
Hypidiomorphic	Consisting predominantly of subhedral grains (common in many granitic rocks).
Allotriomorphic	Most of the grains are anhedral. Common.
Sutured	Characterized by articulation along highly irregular inter-penetrating boundaries. Common in recrystallized deformed rocks.
Mosaic	A texture of polygonal equigranular crystals.
Intergrowths	
Host (Oikocryst)	The large mineral that includes others in poikilitic texture.
Guest	The included mineral in poikilitic texture.
Poikilitic	One large crystal contains several small discrete crystals of another mineral. Refers to growth phenomena, not exsolution or replacement.
Graphic	An intergrowth in which the guest shows angular wedge-like forms. Usually occurs with quartz in microcline (Figure 3–9b).
Micrographic	Graphic texture visible only under the microscope.
Granophyric	A texture of certain porphyritic rocks in which the groundmass minerals (usually quartz and alkali feldspar) penetrate each other as feathery irregular intergrowths. Resembles micrographic texture, but is more irregular.
Exsolution lamellae	Lamellar bands of a phase exsolved from a host phase (Figure 3–9a).
Perthitic	Irregular veins, patches, lenses, etc., of sodic plagioclase in an alkali feldspar host.Usually results from exsolution (Figure 3–18a).
Antiperthitic	Exsolution lamellae of alkali feldspar in a plagioclase host. Usually much thinner than perthite.
Symplectite	A replacement texture in which a mineral is replaced by an intergrowth of one or more minerals.
Myrmekite	A secondary texture consisting of irregular "wormy" blebs or rods of quartz in a plagioclase host adjacent to alkali feldspar grains (Figure 3–21).
Spherulitic	A radial intergrowth of fibrous minerals. Commonly alkali feldspar and quartz in devitrified silicic volcanics.
Axiolitic	Similar to spherulitic, but the fibers occur in a layer and are oriented normal to its walls.

(*continued*)

Table 3–1 *Continued*

Variolitic	Spherulitic structures consisting of divergent plagioclase fibers in certain basalts.
Coalescent	Anhedral textures developed by simultaneous growth of two mineral grains in contact.
Textures of Mafic Igneous Rocks	
Ophitic	Large pyroxene grains enclose small random plagioclase laths (Figure 3–8).
Subophitic	The plagioclase laths are larger and only partially enclosed by the pyroxene.
Nesophitic	Plagioclase is larger yet and the pyroxenes are interstitial.
Intergranular	Small discrete grains of pyroxene, olivine, etc., fill the interstices in a random network of larger plagioclase laths (Figure 3–15).
Intersertal	Glass, cryptocrystalline material, or alteration products occupy the spaces between plagioclase laths.
Hyalo-ophitic	An intersertal texture in which a larger amount of glass is present and less pyroxene.
Hyalopilitic	Still more glass is present and plagioclase occurs only as tiny random microlites.
Diktytaxitic	Texture of certain basalts containing abundant angular interstitial gas cavities between the plagioclase laths.
Cumulate	Interstitial growth of a mineral between earlier ones which are all in contact and give the distinct impression that they accumulated at the bottom of a magma chamber (Figure 3–14).
Orthocumulate	Cumulate texture with other minerals occupying the interstitial areas (Figure 3–14b).
Adcumulate	Cumulate texture in which the early cumulate minerals grow to fill the pore space (Figure 3–14c).
Mesocumulate	Intermediate between ortho- and adcumulate.
Replacement Textures	
Pseudomorph	One or more minerals replace another, retaining the form of the original mineral.
Symplectite	A replacement texture in which a mineral is replaced by an intergrowth of one or more minerals.
Other forms include replacement of rims, cores, or patches of one mineral by another. Common processes include:	
Uralitization	Replacement of pyroxene by amphibole (Figure 3–21a).
Saussuritization	Replacement of plagioclase by epidote.
Biotitization	Replacement of pyroxene or amphibole by biotite.
Chloritization	Replacement of any mafic mineral by chlorite (Figure 3–20b).
Seritization	Replacement of feldspar or feldspathoids by fine white micas.
Miscellaneous Terms	
Interstitial	One mineral fills the interstices between earlier crystallized grains (Figure 3–7).
Crystallites	Minute, inchoate crystals in earliest stages of formation. They are isotropic and cannot be identified under the microscope.
Microlites	Tiny needle- or lath-like crystals of which at least some properties are microscopically determinable.
Felty	Consisting of random microlites (Figure 3–13b).
Pilotaxitic	Like felty.
Trachytic	Consisting of (feldspar) microlites aligned due to flow (Figure 3–12a).
Embayed	Having embayments due to reaction with the melt (resorption) (Figure 3–2).
Skeletal	Crystals which grew as, or have been corroded to, a skeletal framework with a high proportion of internal voids (Figure 3–4).
Sieve	Crystals are filled with channelways (appearing as holes) due to resorption (Figure 3–11a).
Epitactic	Oriented nucleation of one mineral on another of a different kind.
Rapakivi	Overgrowths of plagioclase on alkali feldspar.
Vesicular	Contains gas bubbles.
Scoriaceous	Highly vesicular.
Pumiceous	Frothy vesicular structure characteristic of pumice.
Diktytaxitic	Containing vesicles into which microphenocrysts protrude.
Miarolitic	Gas cavities present in certain plutonic rocks into which euhedral minerals protrude.
Pipe vesicles	Tube-like elongate vesicles that result from rising gases.
Vesicular pipes	Cylindrical bodies highly charged with vesicles.
Amygdaloidal	Vesicles completely or partially filled with secondary minerals.
Lithophysae	Large ovoid structures representing gas bubbles in devitrified rhyolitic glass.
Flow	A parallel structure developed as the result of flow.
Foliation	Planar parallelism.
Banding	Alternating planar layers.
Lineation	Linear parallelism.
Xenolith	An inclusion of country rock.
Xenocryst	A single-crystal foreign inclusion.
Perlitic	Concentric fracture pattern resulting from contraction of some volcanic glasses upon cooling.
Pyroclastic	Comprised of fragments.
Ocelli	Ovoid blobs created by liquid immiscibility, mingled magmas, or filled vesicles.
Orbicules	Ovoid masses of radiating crystals, commonly concentrically banded, found in some granites.
Spinifex	Centimeter-scale sub-parallel to dendritic growth of olivine crystals in some quenched ultramafics.
Pyroclastic Terms	
See Section 2.5.	
Pyroclastic Glass textures	
Pele's tears	Glassy lapilli.
Pele's hair	Hair-like strands of glass.
Fiamme	Compressed pumice fragments in a tuff.