Periodic Table of the Elements

chemistry.org

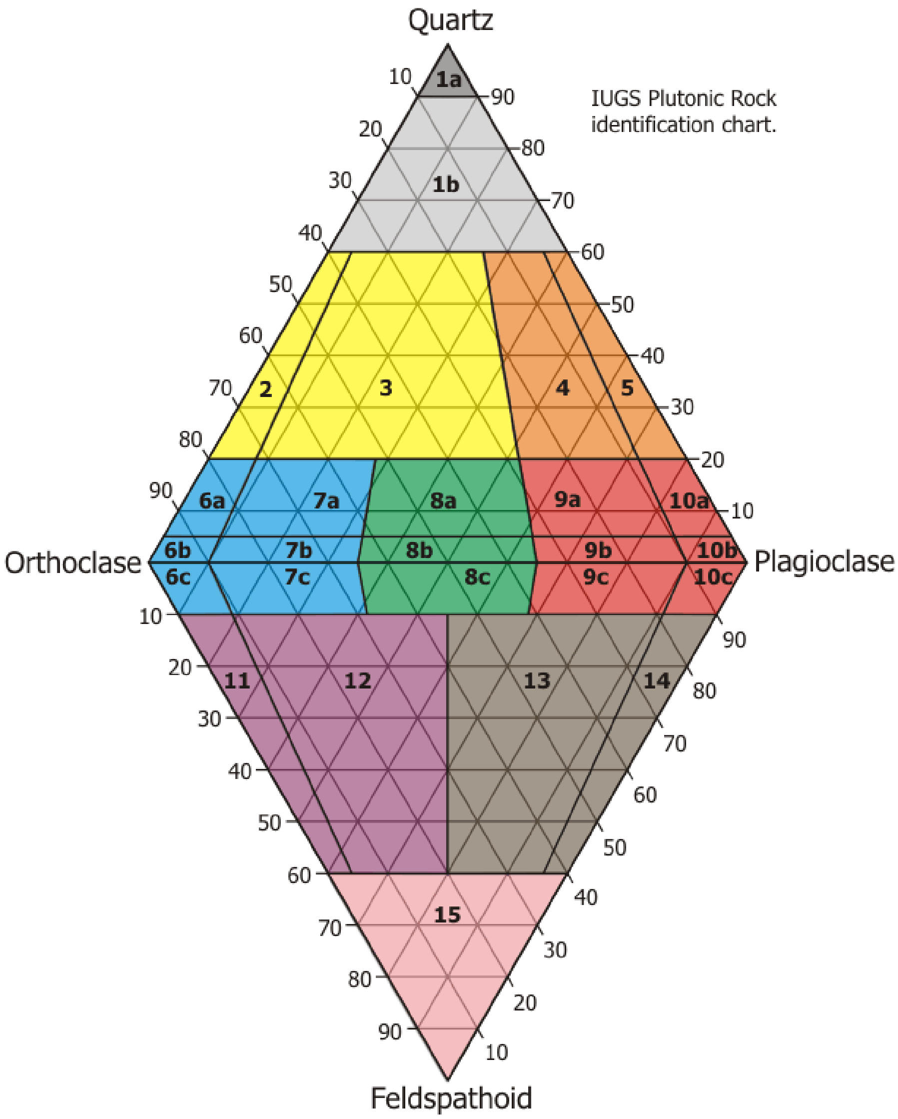
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.6	33 As 74.92	34 Se 79.00	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57-71 *	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103 #	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Uun (281)	111 Uuu (272)	112 Uub (285)		114 Uuq (289)				

* Lanthanide Series	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.3	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
# Actinide Series	89 Ac (227)	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Courtesy of the American Chemical Society

Periodic Table of the Elements

Key:
Atomic Number
SYMBOL
Atomic Weight



1a. Silexite
1b. Quartz-rich Granitoid
2. Alkali-Feldspar Granite
3. Granite
4. Granodiorite
5. Tonalite
6a. Alkali-Feldspar Quartz Syenite
6b. Alkali-Feldspar Syenite
6c. Foid-bearing Alkali-Feldspar Syenite
7a. Quartz Syenite
7b. Syenite
7c. Foid-bearing Syenite
8a. Quartz Monzonite
8b. Monzonite
8c. Foid-bearing Monzonite
9a. Quartz Monzodiorite
Quartz Monzogabbro
9b. Monzodiorite
Monzogabbro
9c. Foid-bearing Monzodiorite
Foid-bearing Monzogabbro
10a. Quartz Diorite
Quartz Gabbro
Quartz Anorthosite
10b. Diorite
Gabbro
Anorthosite
10c. Foid-bearing Diorite
Foid-bearing Gabbro
11. Foid Syenite
12. Foid Monzosyenite
13. Foid Monzodiorite
Foid Monzogabbro
14. Foid Diorite
Foid Gabbro
15. Foidolites

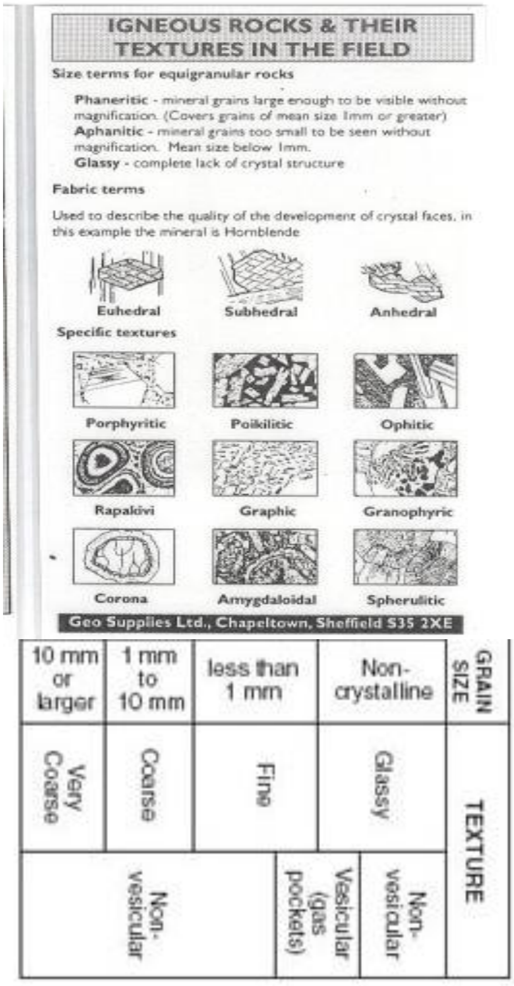
Classification of

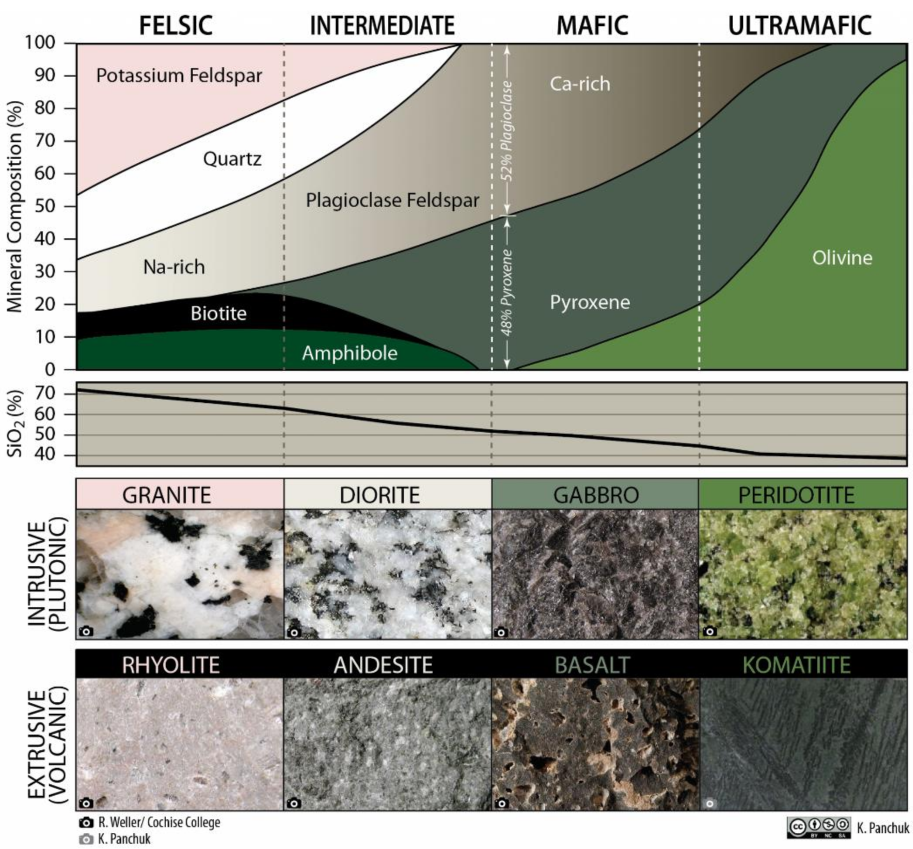
IGNEOUS ROCKS

COMPOSITION

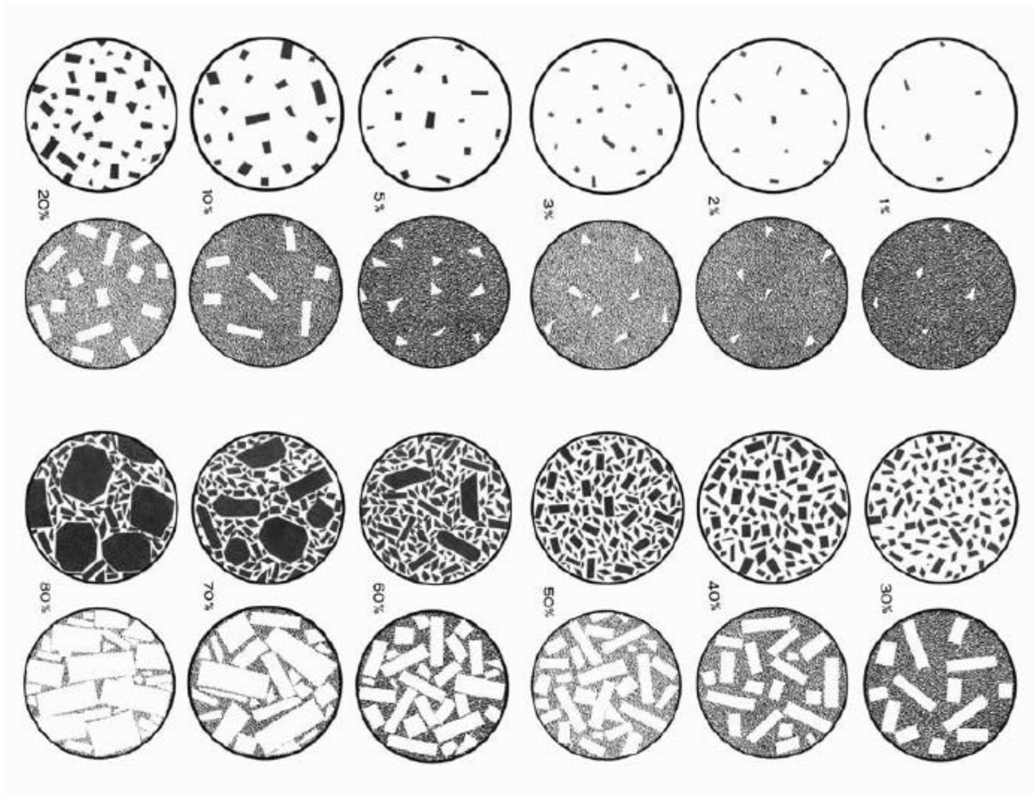
Match the texture with the composition of the rock to identify it.

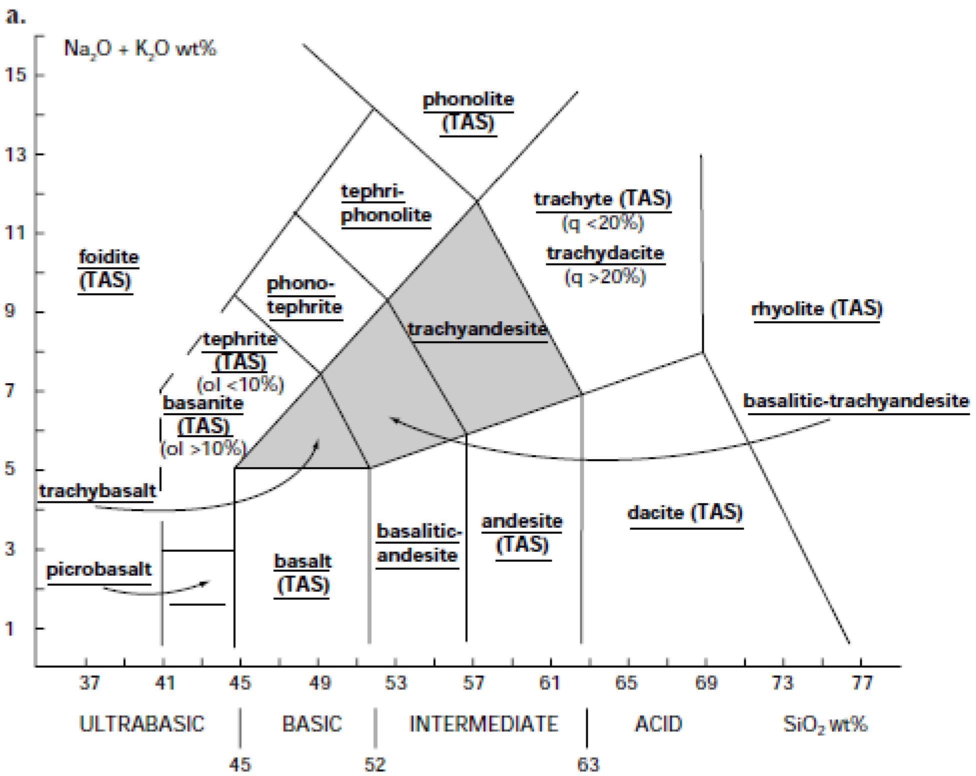
TEXTURE	Felsic (>10% quartz, >50% feldspar, <15% mafic minerals)	Intermediate (>10% quartz, >50% plagioclase, >10% orthoclase, <50% mafic minerals)	Mafic (20-85% plagioclase, 15-50% pyroxene, >35% olivine)	Ultramafic (Olivine & pyroxene)
Phaneritic (coarse grained)	Granite	Diorite	Gabbro	Peridotite
Aphanitic (fine grained)	Rhyolite	Andesite	Basalt	
Porphyritic (large crystals in a fine matrix)	Porphyritic Rhyolite	Porphyritic Andesite	Porphyritic Basalt	
Vesicular (bubbly or frothy)	Pumice		Scoria	
Glassy	Obsidian			
Pyroclastic (fragmental)	Rhyolitic Tuff or Volcanic Breccia	Andesitic Tuff or Volcanic Breccia	Basaltic Tuff or Volcanic Breccia	



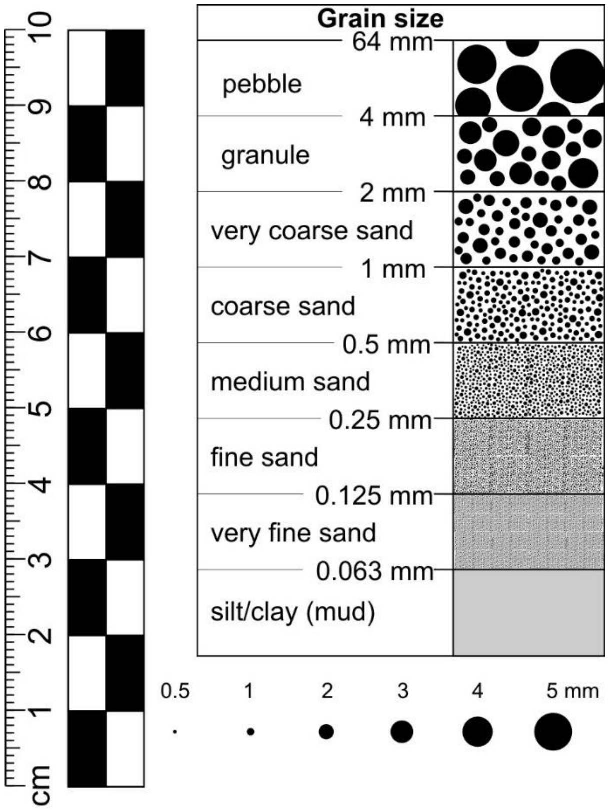


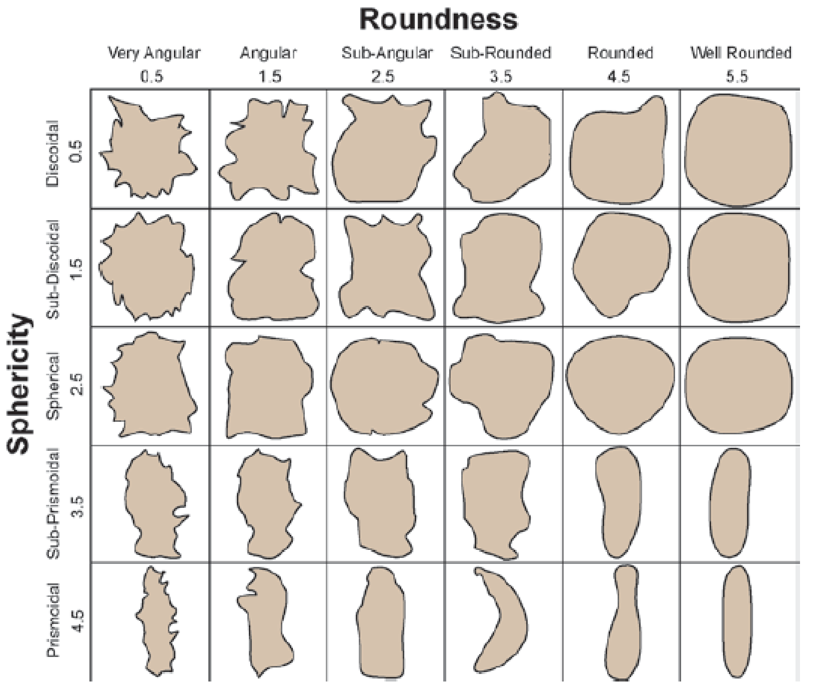
REFERENCE:
Philpotts, A.R., 1989, Petrography of Igneous and Metamorphic Rocks: Upper Saddle River, NJ, Prentice Hall, 178 p.



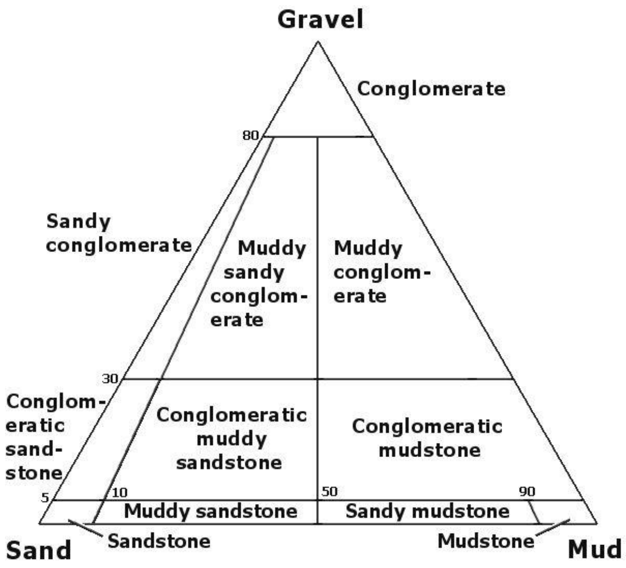


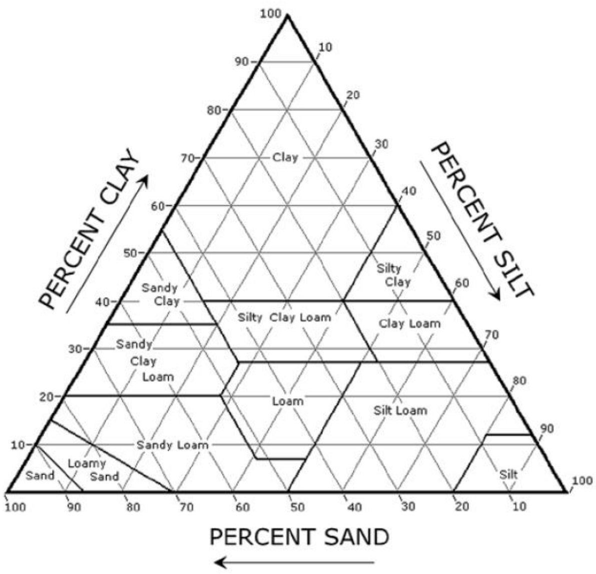
Further subdivisions of shaded fields	trachybasalt	basaltic-trachyandesite	trachyandesite
$Na_2O - 2.0 \geq K_2O$	hawaiite	mugearite	benmoreite
$Na_2O - 2.0 \leq K_2O$	potassic-trachybasalt	shoshonite	latite (TAS)

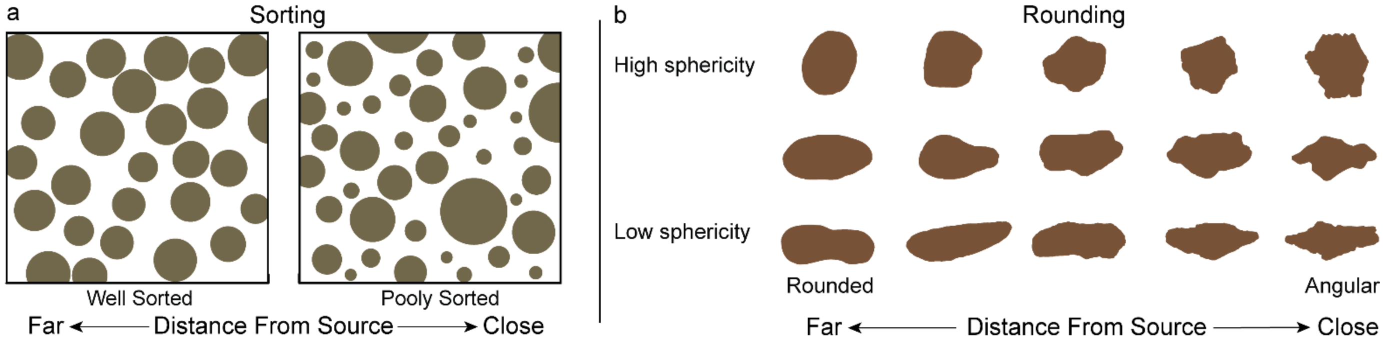


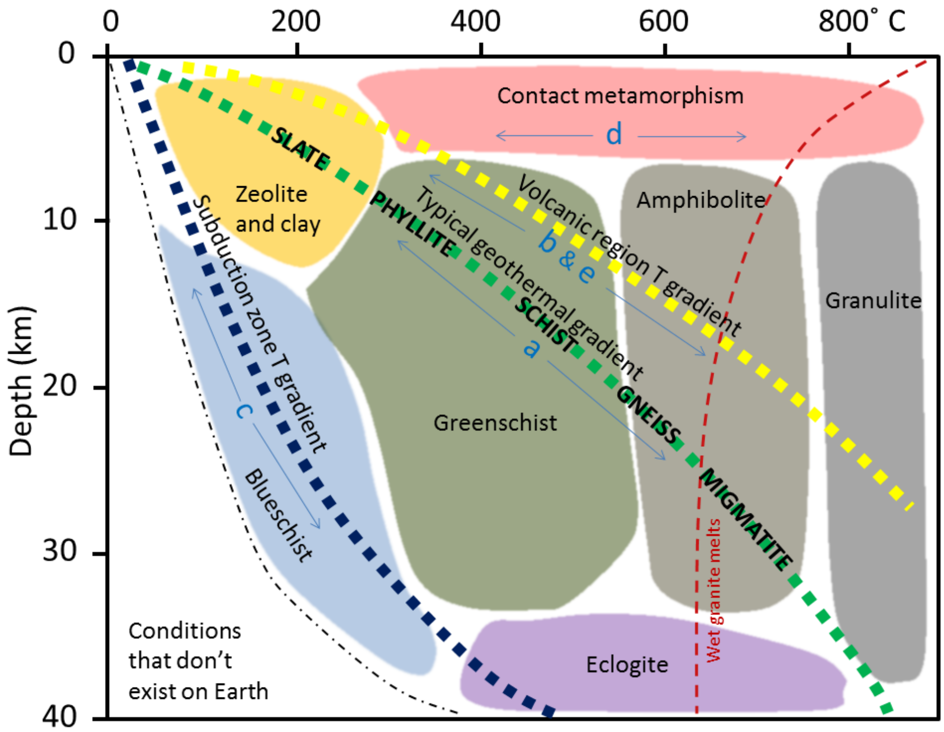


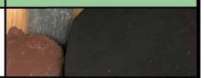
Roundness and Sphericity chart. (AGI graphic, adapted from various sources).









Texture	Grain Size	Composition	Metamorphic Type	Comments	Rock name	Map symbol	Picture
Foliated – Minerals are aligned	Fine	Mica, Quartz, Feldspar, Garnet, Amphibole, Pyroxene	Regional (Heat and pressure increase)	Metamorphism of shale breaks along slaty cleavage	Slate		
	Fine to medium			Shiny, micas barely visible breaks along wavy surfaces	Phyllite		
				Mica visible with bumps of silicate minerals*	Schist		
Foliated – Banded	Medium to coarse			Minerals segregated into light and dark bands	Gneiss		
				Mixed igneous and metamorphic textures	Migmatite		
Nonfoliated	Fine	Carbon	Regional	Metamorphism of bituminous coal	Anthracite coal		
	Fine	Various minerals	Contact (heating)	Various rocks changed by heating by magma/lava	Hornfels		
	Fine to coarse	Quartz	Regional or contact	Metamorphism of quartz sandstone	Quartzite		
	Fine to coarse	Calcite and/or dolomite		Metamorphism of limestone or dolostone	Marble		
	Coarse	Various minerals	Regional	Pebbles will be distorted or stretched	Meta-conglomerate		
	Coarse	Basalt	Regional	>75% amphibole and feldspar	Amphibolite		
	Coarse	Basalt	Regional	Subduction metamorphism garnet and pyroxene	Eclogite		
	Fine	Ultramafic	Regional	Serpentine minerals	Serpentinite		

Not shown are greenstone, mylonite, metasandstone, blueschist, talc schist, jadeitite, augen gneiss, granulite and many more.
* Silicate minerals typically include garnet, andalusite, sillimanite, kyanite, staurolite, and cordierite.

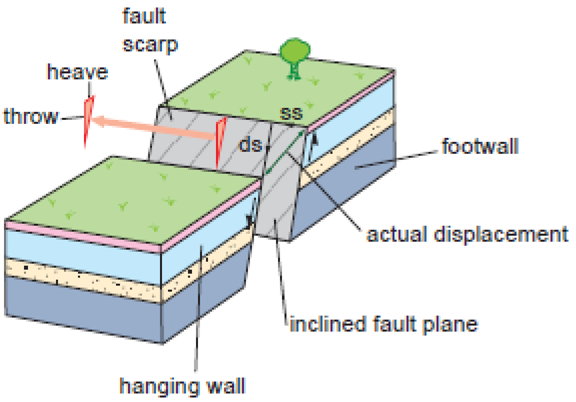


Figure A8.1 Diagram of an oblique-slip fault, annotated with terms for its main components. The actual displacement (green arrows) can be divided into two components: dip-slip component (ds) and strike-slip component (ss).

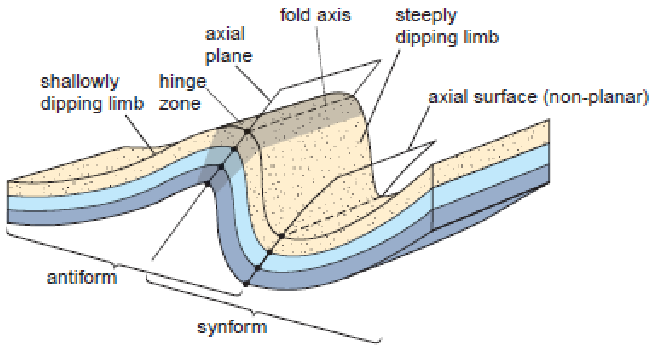


Figure A8.2 Diagram of a typical fold pair, labelled with terms for the main parts of fold structures. The terms antiform and synform describe the form of the folds. If the sequence is right-way up (i.e. the stippled layer is younger than the pale blue layer), then the antiform is an anticline, and the synform is a syncline.

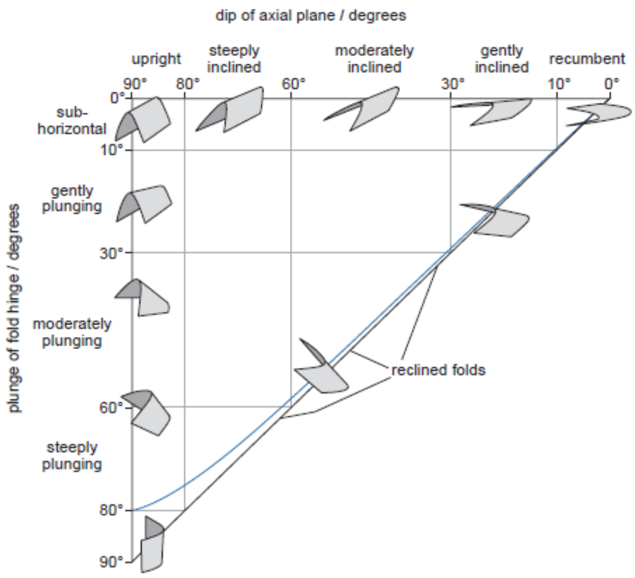


Figure A8.4 Classification of fold types using a combination of the dip of the axial plane and the plunge of hinge line.

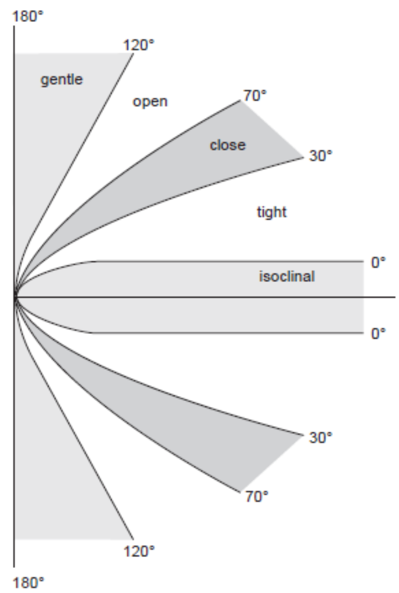


Figure A8.3 Schematic illustration of different types of fold tightness, defined according to the angle between the two fold limbs (the interlimb angle). (Based on Fleuty 1964.)

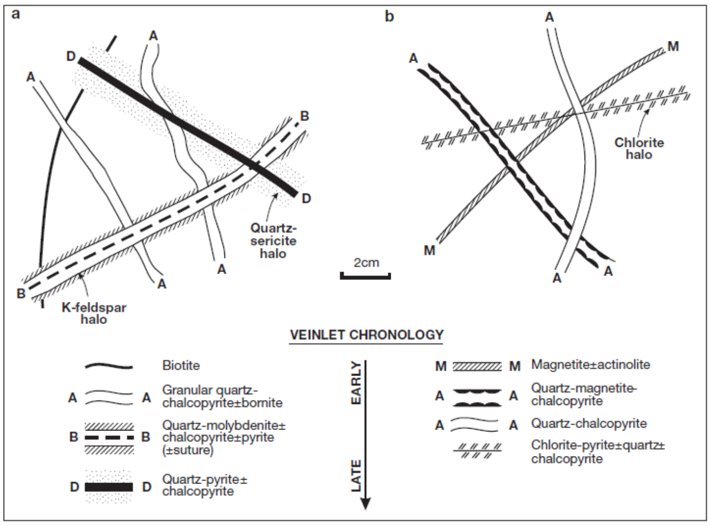


FIG. 13. Schematic chronology of typical veinlet sequences in a. porphyry Cu-Mo deposits and b. porphyry Cu-Au deposits associated with calc-alkaline intrusions. Porphyry Cu-Au deposits hosted by alkaline intrusions are typically veinlet poor (Barr et al., 1976; Lang et al., 1995; Sillitoe, 2000, 2002). Background alteration between veinlets is mainly potassic, which is likely to contain more K-feldspar in the Mo-rich than the Au-rich porphyry Cu stockworks. Note the common absence of B- and D-type veinlets from Au-rich porphyry Cu stockworks and M-, magnetite-bearing A-, and chlorite-rich veinlets from Mo-rich porphyry Cu stockworks. Veinlet nomenclature follows Gustafson and Hunt (1975; A, B, and D types) and Arancibia and Clark (1996; M type).

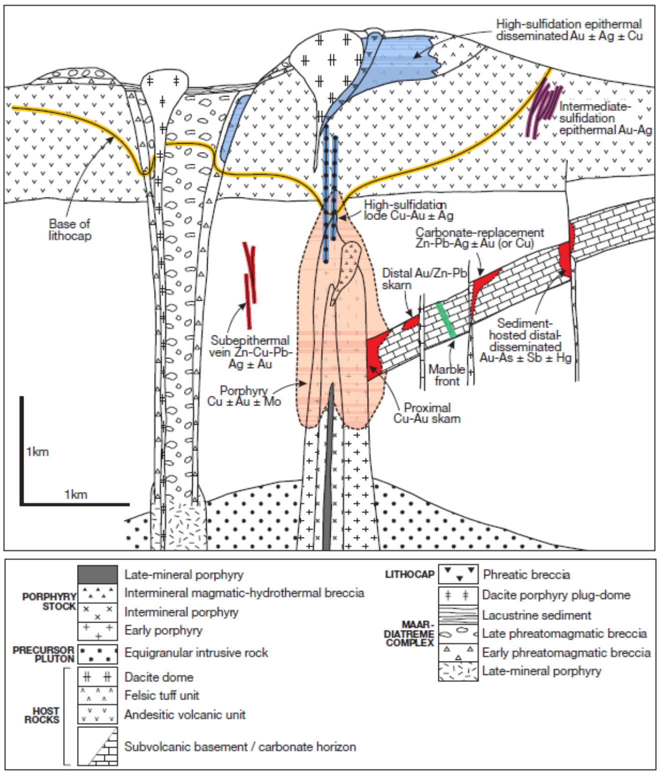


FIG. 6. Anatomy of a telescoped porphyry Cu system showing spatial interrelationships of a centrally located porphyry Cu ± Au ± Mo deposit in a multiphase porphyry stock and its immediate host rocks; peripheral proximal and distal skarn, carbonate-replacement (chimney-manto), and sediment-hosted (distal-disseminated) deposits in a carbonate unit and subepithermal veins in noncarbonate rocks; and overlying high- and intermediate-sulfidation epithermal deposits in and alongside the lithocap environment. The legend explains the temporal sequence of rock types, with the porphyry stock predating maar-diatreme emplacement, which in turn overlaps lithocap development and phreatic brecciation. Only uncommonly do individual systems contain several of the deposit types illustrated, as discussed in the text (see Table 3). Notwithstanding the assertion that cartoons of this sort (including Fig. 10) add little to the understanding of porphyry Cu genesis (Seedorff and Einaudi, 2004), they embody the relationships observed in the field and, hence, aid the explorationist. Modified from Sillitoe (1995b, 1999b, 2000).

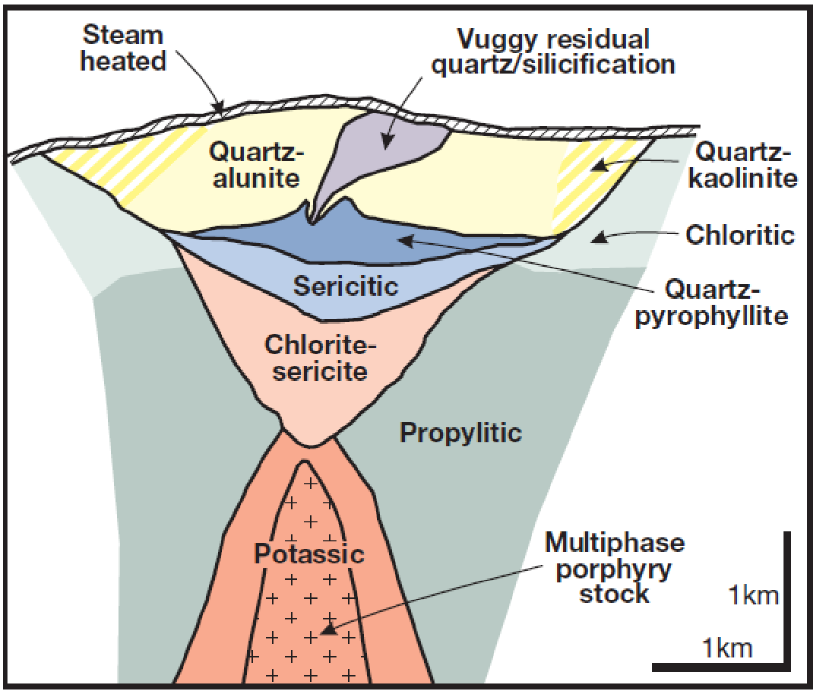
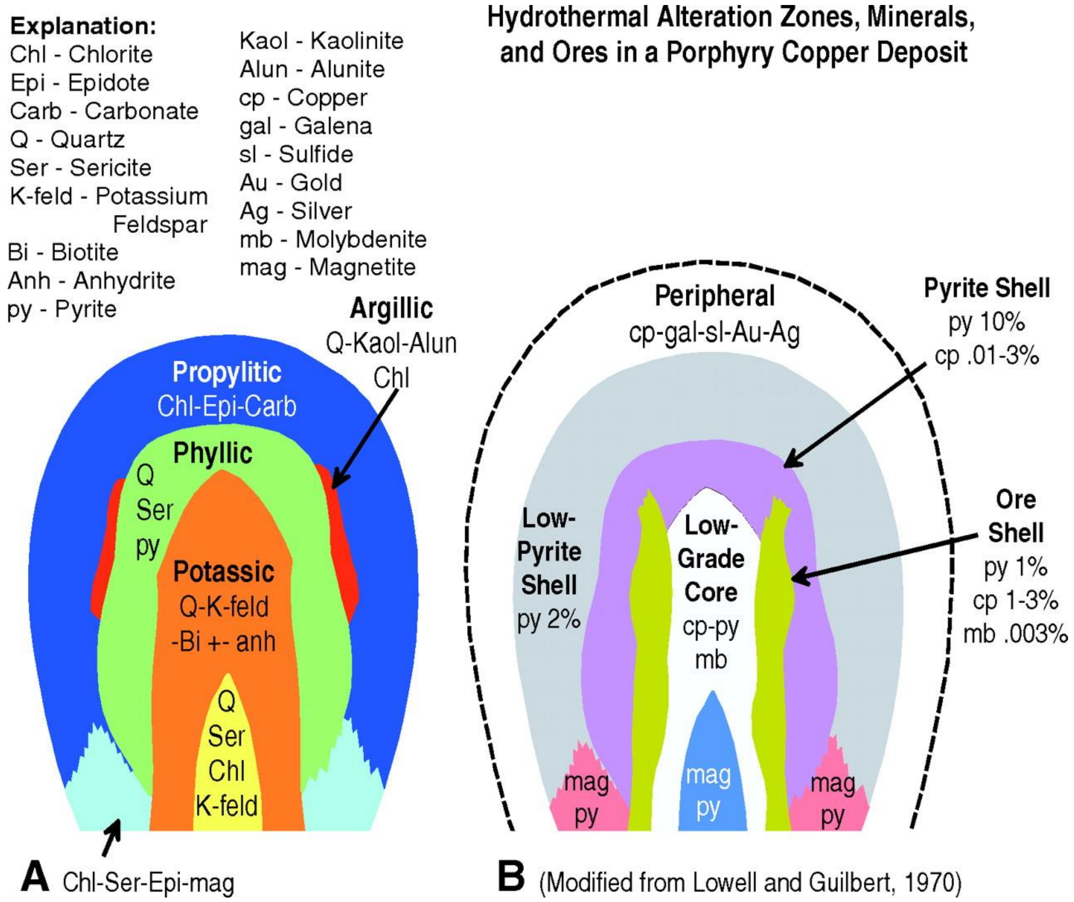
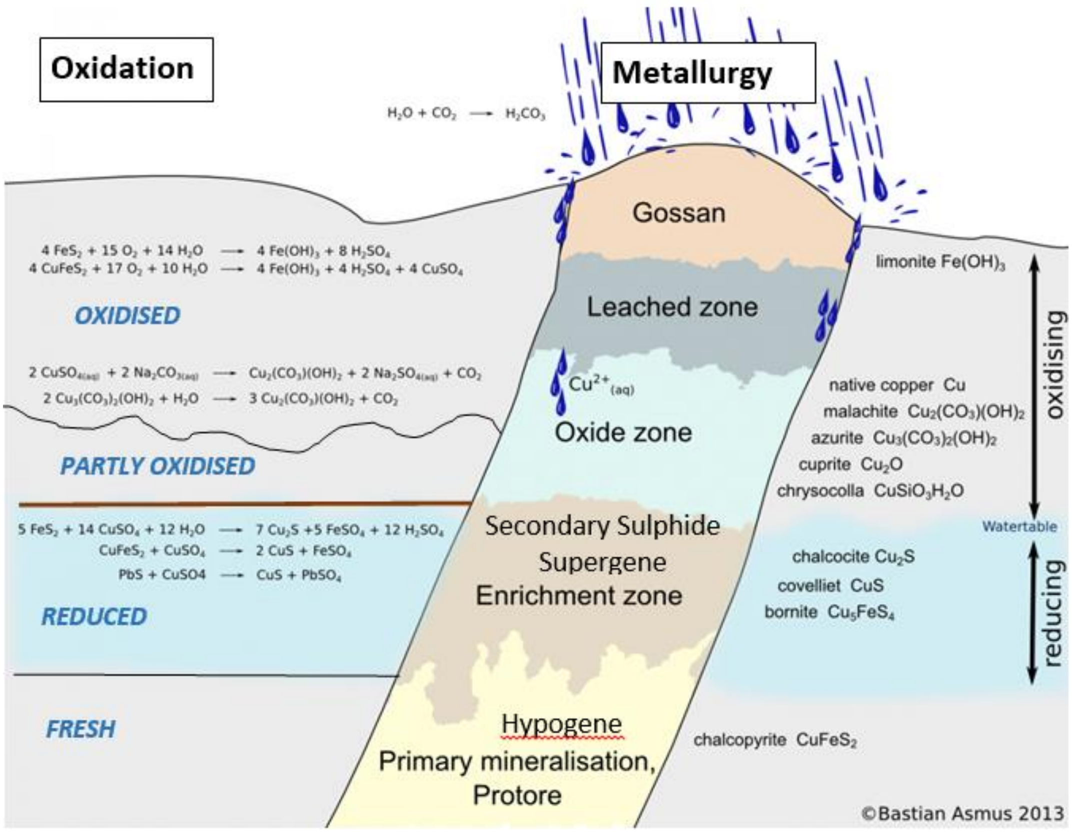


FIG. 11. Generalized alteration-mineralization zoning pattern for a non-telescoped porphyry Cu system, emphasizing the appreciable, commonly barren gap that exists between the lithocap and underlying porphyry stock. Legend as in Figure 10.


Explanation:
Chl - Chlorite
Epi - Epidote
Carb - Carbonate
Q - Quartz
Ser - Sericite
K-feld - Potassium Feldspar
Bi - Biotite
Anh - Anhydrite
py - Pyrite
Kaol - Kaolinite
Alun - Alunite
cp - Copper
gal - Galena
sl - Sulfide
Au - Gold
Ag - Silver
mb - Molybdenite
mag - Magnetite
Hydrothermal Alteration Zones, Minerals, and Ores in a Porphyry Copper Deposit
Argillic
Q-Kaol-Alun Chl
Propylitic
Chl-Epi-Carb
Phyllic
Q Ser py
Potassic
Q-K-feld -Bi +- anh
Q Ser Chl K-feld
A
Chl-Ser-Epi-mag
Peripheral
cp-gal-sl-Au-Ag
Pyrite Shell
py 10%
cp .01-3%
Low-Pyrite Shell
py 2%
Low-Grade Core
cp-py mb
Ore Shell
py 1%
cp 1-3%
mb .003%
mag py
mag py
mag py
B
(Modified from Lowell and Guilbert, 1970)


Oxidation
Metallurgy
$H_2O + CO_2 \rightarrow H_2CO_3$
$4 FeS_2 + 15 O_2 + 14 H_2O \rightarrow 4 Fe(OH)_3 + 8 H_2SO_4$
$4 CuFeS_2 + 17 O_2 + 10 H_2O \rightarrow 4 Fe(OH)_3 + 4 H_2SO_4 + 4 CuSO_4$
OXIDISED
$2 CuSO_{4(aq)} + 2 Na_2CO_{3(aq)} \rightarrow Cu_2(CO_3)(OH)_2 + 2 Na_2SO_{4(aq)} + CO_2$
$2 Cu_3(CO_3)_2(OH)_2 + H_2O \rightarrow 3 Cu_2(CO_3)(OH)_2 + CO_2$
PARTLY OXIDISED
$5 FeS_2 + 14 CuSO_4 + 12 H_2O \rightarrow 7 Cu_2S + 5 FeSO_4 + 12 H_2SO_4$
$CuFeS_2 + CuSO_4 \rightarrow 2 CuS + FeSO_4$
PbS + CuSO4 → $CuS + PbSO_4$
REDUCED
FRESH
Gossan
Leached zone
$Cu^{2+}_{(aq)}$
Oxide zone
Secondary Sulphide Supergene Enrichment zone
Hypogene Primary mineralisation, Protore
limonite $Fe(OH)_3$
native copper Cu
malachite $Cu_2(CO_3)(OH)_2$
azurite $Cu_3(CO_3)_2(OH)_2$
cuprite Cu_2O
chrysocolla $CuSiO_3H_2O$
oxidising
Watertable
chalcocite Cu_2S
covelliet CuS
bornite Cu_5FeS_4
reducing
chalcopyrite $CuFeS_2$
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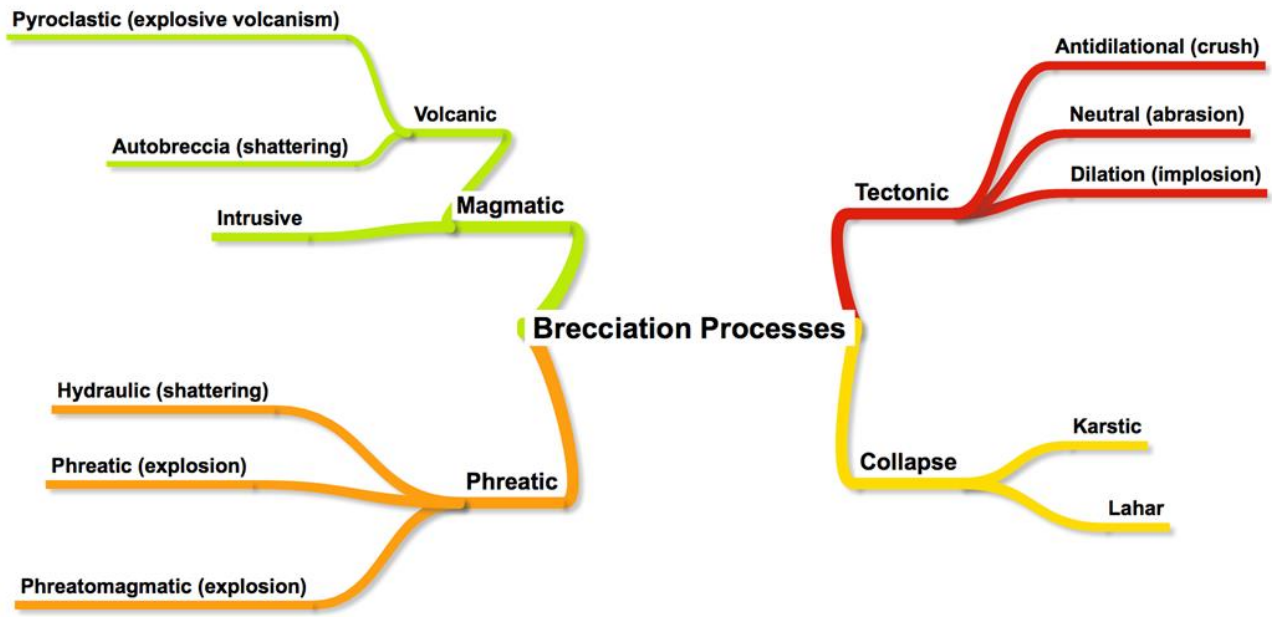

CLASSIFICATION OF IGNEOUS ROCKS

← LIGHT COLOURED DARK COLOURED →

TEXTURE	Mineral composition	With free quartz (Acid)		Quartz rare or absent (Intermediate) < 40 % dark minerals		Quartz rare or absent (Basic) > 40 % dark minerals	Quartz absent (Ultrabasic)	
		Orthoclase > Plagioclase (Alkaline)	Plagioclase > Orthoclase (Calcic)	Orthoclase > Plagioclase (Alkaline)	Plagioclase > Orthoclase (Calcic)	Plagioclase > Orthoclase (Calcic)	No feldspar	
FRAGMENTAL		Tuff , Breccia , Ash , Cinders		Scoria				
GLASSY		Obsidian (glass) , Pumice (frothy glass)				Basic glass or Basaltic obsidian		
FINE GRAINED	Non-porphyritic	Rhyolite	Dacite	Trachyte	Andesite	Basalt		Extrusive
	Porphyritic	Quartz orthoclase porphyry Porphyritic rhyolite	Quartz plagioclase porphyry Porphyritic dacite	Orthoclase porphyry Porphyritic trachyte	Plagioclase porphyry Porphyritic andesite	Porphyritic basalt		
MEDIUM GRAINED	Generally non-porphyritic	Aplite Microgranite	Micro-granodiorite	Microsyenite	Microdiorite	Dolerite	Peridotite	Intrusive
COARSE GRAINED	Generally non-porphyritic	Granite & Pegmatite (Adamellite)	Granodiorite	Syenite	Diorite	Gabbro		

Felsite : A term applied to fine-grained, non-porphyritic, light coloured and low S.G. rocks; viz rhyolite, dacite, trachyte. Fine-grained darker and heavier rocks may be andesites or basalts.

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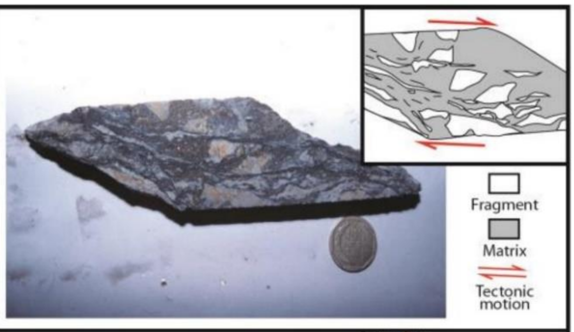
a. Tectonic Breccia

Characteristics:

- grain reduction
- fragments preferred orientation
- frequently monogenic

Process of formation

- Fault activity with comminution and grain reduction



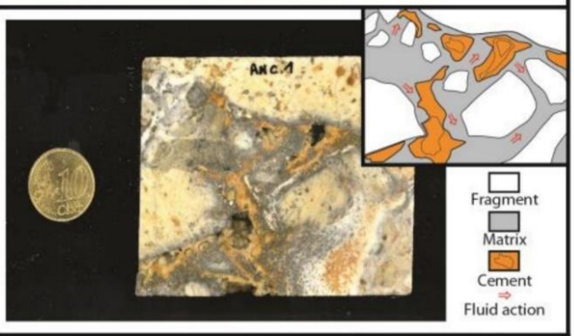
b. Hydrothermal Breccia

Characteristics:

- rounded monogenic fragments
- matrix-supported breccia
- occurrence of matrix and final cement

Process of formation

- Hydrothermal fluid emplacement



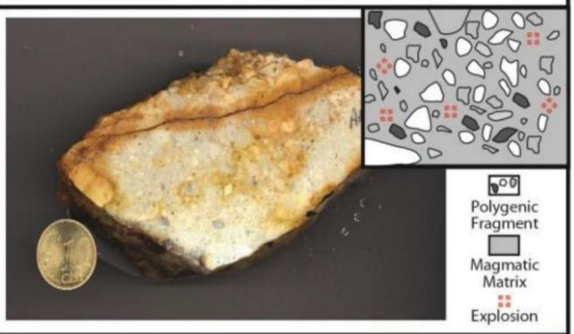
c. Magmatic Breccia

Characteristics:

- rounded polygenic fragments
- matrix-supported breccia
- No cement, magmatic matrix

Process of formation

- Explosion link with magmatic activity



d. Collapse Breccia

Characteristics:

- systematic cement
- grain-supported breccia
- polygenic or monogenic

Process of formation

- Collpase of the fragments and subsequent cementation

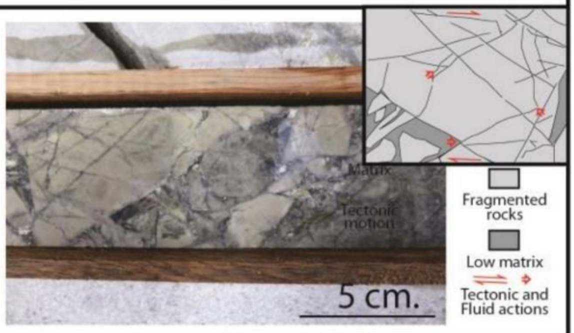
e. Crackle Breccia

Characteristics:

- monogenic
- low matrix

Process of formation

- Beginning of fragmentation due to tectonics or fluid overpressure



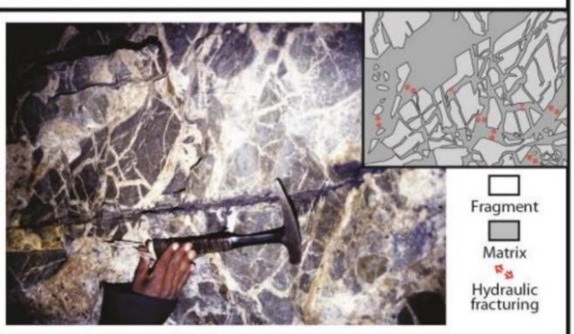
f. Hydraulic Breccia

Characteristics:

- jigsaw geometry
- monogenic character
- matrix-supported breccia

Process of formation

- Cracking by fluid overpressure



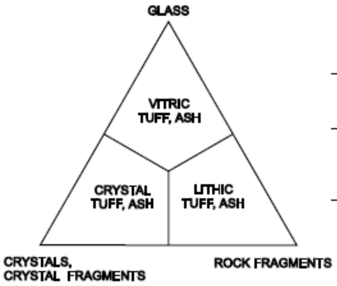


Fig 1- Subdivision of tuffs and ashes according to their composition.

TABLE 1

Granulometric classification of pyroclasts and of unimodal, well-sorted pyroclastic deposits.

Clast size (mm)	Pyroclast	Pyroclastic deposit	
		Mainly unconsolidated: tephra	Mainly consolidated: pyroclastic rock
	Bomb, block	Agglomerate, bed of blocks or bomb, block tephra	Agglomerate, pyroclastic breccia
64 mm			
	Lapillus	Layer, bed of lapilli or lapilli tephra	Lapilli tuff
2 mm			
1/16 mm	Coarse ash grain	Coarse ash	Coarse (ash) tuff
	Fine ash grain (dust grain)	Fine ash (dust)	Fine (ash) tuff (dust tuff)

TABLE 2

Terms for mixed pyroclastic-epiclastic rocks.

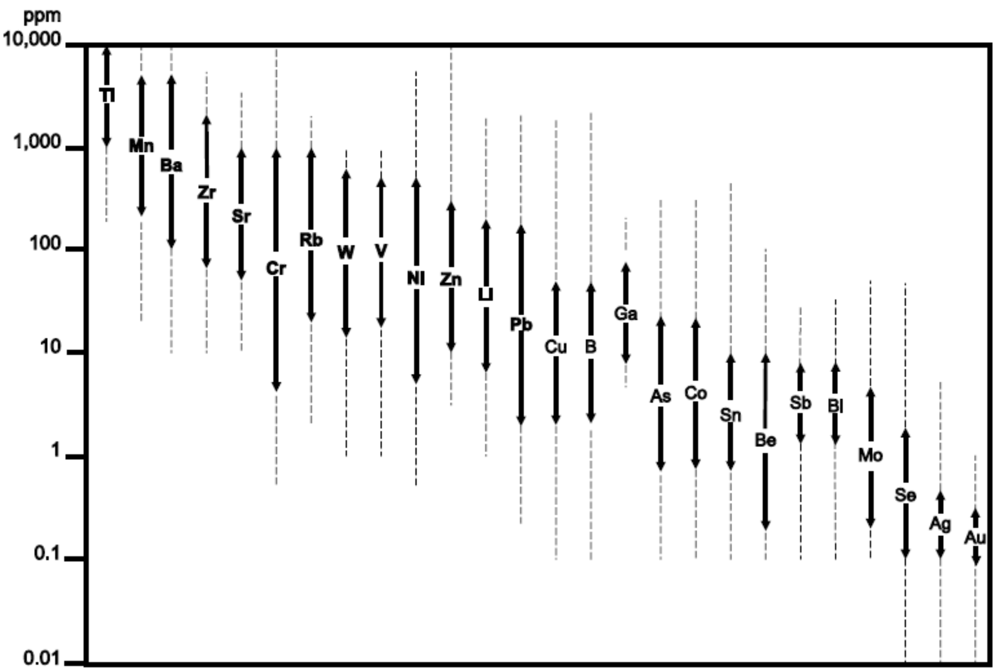
Pyroclastic*		Tuffites (mixed pyroclastic-epiclastic)	Epiclastic (volcanic and/or nonvolcanic)	Av. clast size (mm)
Agglomerate, agglutinate pyroclastic breccia		Tuffaceous conglomerate, tuffaceous breccia	Conglomerate, breccia	64
Lapilli tuff	coarse	Tuffaceous sandstone	Sandstone	2
(Ash) tuff	fine	Tuffaceous siltstone	Siltstone	1/16
		Tuffaceous mudstone, shale	Mudstone, shale	1/256
100	75	25		0% by volume

← Pyroclasts

→ Volcanic + nonvolcanic epiclasts (+ minor amounts of biogenic, chemical sedimentary and authigenic constituents)

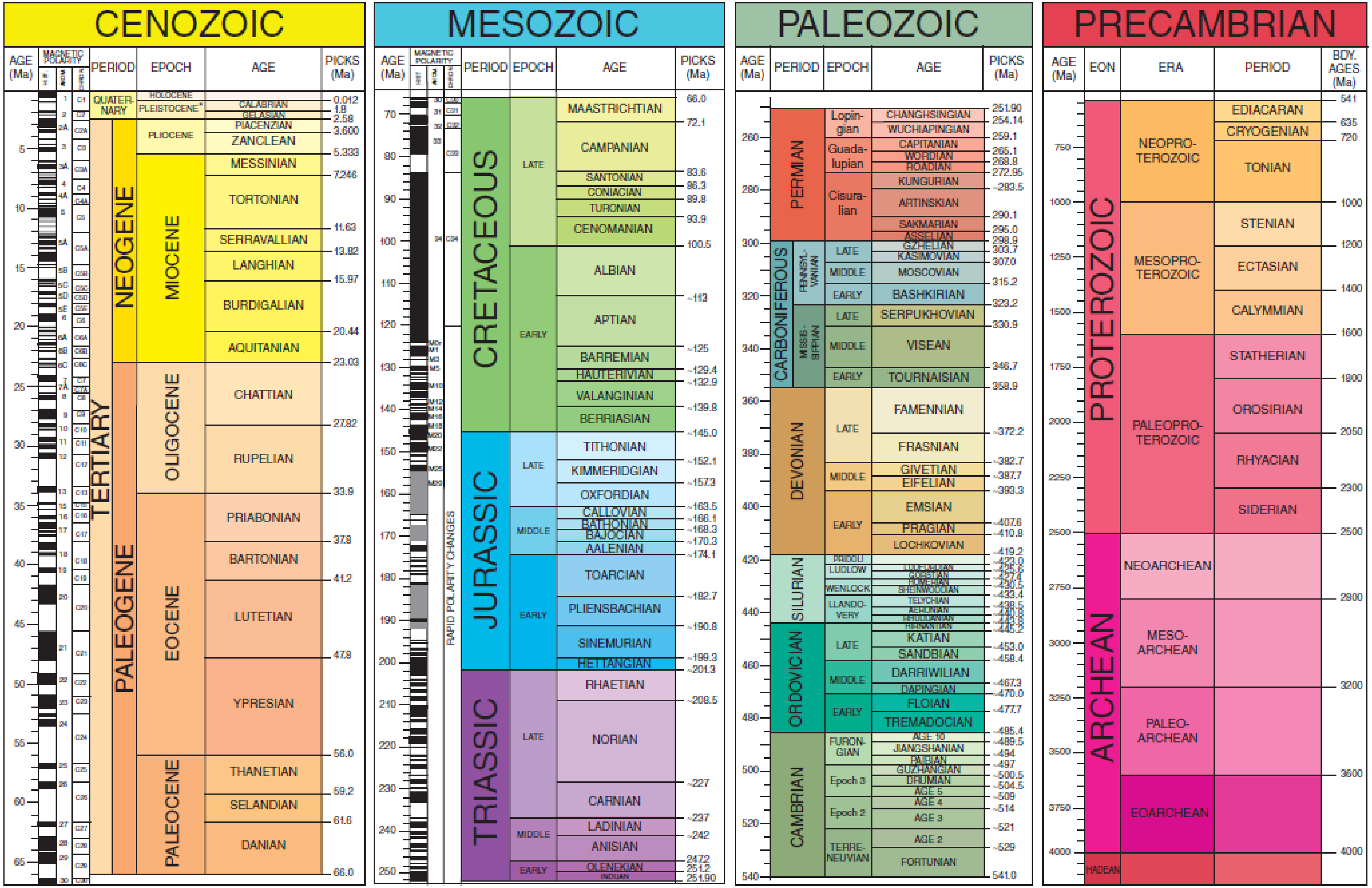
* Terms according to Table 1.

3.3. RANGE OF ABUNDANCE OF TRACE ELEMENTS IN SOILS[1]



Range of common values shown by a solid line, with unusual values shown by a dashed line.

GSA GEOLOGIC TIME SCALE v. 5.0



Walker, J.D., Geissman, J.W., Bowring, S.A., and Babcock, L.E., compilers, 2018, Geologic Time Scale v. 5.0: Geological Society of America, https://doi.org/10.1130/2018.CTS005R3C.

*The Pleistocene is divided into four ages, but only two are shown here. What is shown as Calabrian is actually three ages—Calabrian from 1.80 to 0.781 Ma, Middle from 0.781 to 0.126 Ma, and Late from 0.126 to 0.0117 Ma.

The Cenozoic, Mesozoic, and Paleozoic are the Eras of the Phanerozoic Eon. Names of units and age boundaries usually follow the Gradstein et al. (2012), Cohen et al. (2012), and Cohen et al. (2013, updated) compilations. Numerical age estimates and picks of boundaries usually follow the Cohen et al. (2013, updated) compilation. The numbered epochs and ages of the Cambrian are provisional. A "~" before a numerical age estimate typically indicates an associated error of ±0.4 to over 1.6 Ma.

REFERENCES CITED

Cohen, K.M., Finney, S., and Gibbard, P.L., 2012, International Chronostratigraphic Chart: International Commission on Stratigraphy, www.stratigraphy.org (accessed May 2012). (Chart reproduced for the 34th International Geological Congress, Brisbane, Australia, 5–10 August 2012.)

Cohen, K.M., Finney, S.C., Gibbard, P.L., and Fan, J.-X., 2013, The ICS International Chronostratigraphic Chart: Episodes v. 36, no. 3, p. 199–204 (updated 2017, v. 2, http://www.stratigraphy.org/index.php/ics-chart-timescale; accessed May 2018).

Gradstein, F.M, Ogg, J.G., Schmitz, M.D., et al., 2012, The Geologic Time Scale 2012: Boston, USA, Elsevier, https://doi.org/10.1016/B978-0-444-59425-9.00004-4.

Previous versions of the time scale and previously published papers about the time scale and its evolution are posted to http://www.geosociety.org/timescale.

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