Granitoid Rocks

Reading:

Winter (2001) Chapter 18

Granitoids

“Granitoids” (*sensu lato*): loosely applies to a wide range of felsic plutonic rocks

This lecture focuses on non-continental arc intrusives

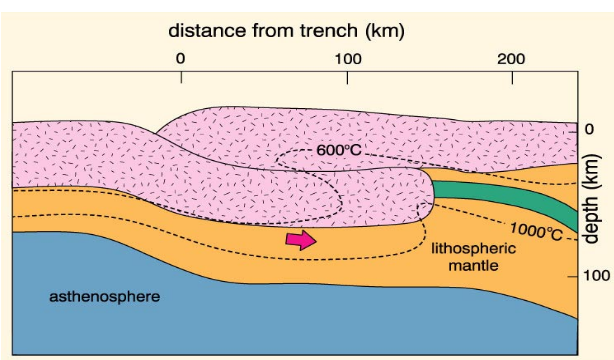
Associated volcanics are common and have same origin, but are typically eroded away

Common Features

- Most large granitoid bodies occur in areas where the continental crust was thickened by orogeny
- Formed by either continental arc subduction or collision of sialic masses.
- Many granites, however, may post-date the thickening event by tens of millions of years.

Anatexis?

- Because the crust normally is solid, some thermal disturbance is required to form granitoids
- Most workers believe that the majority of granitoids are derived by crustal anatexis, but that the mantle may also be involved in the process.
- The mantle contribution may range from being a source of heat for crustal anatexis to being the source of material as well.



The effect of subducting a slab of continental crust. The dip of the subducted plate shallows as subduction ceases and the isotherms “relax” (return to a steady-state value). Thickened crust, whether created by underthrusting (as shown) or by folding or flow, leads to sialic crust at depths and temperatures sufficient to cause partial melting. Winter (2001)

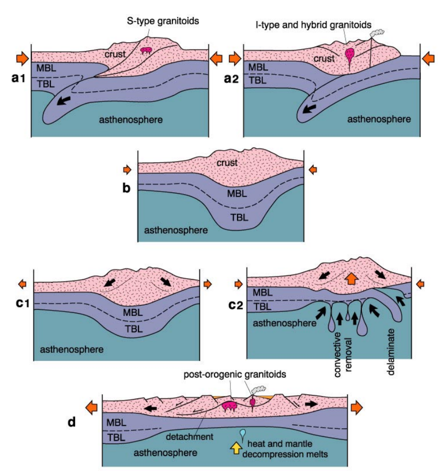
Subduction thickens crust by continental collision (a1) or compression of the continental arc (a2).

Both thicken crust and mechanical and thermal boundary layers (“MBL” and “TBL”) (b)

Then, either compression ceases (c1) or the thick dense thermal boundary layer is removed by delamination or convective erosion (c2).

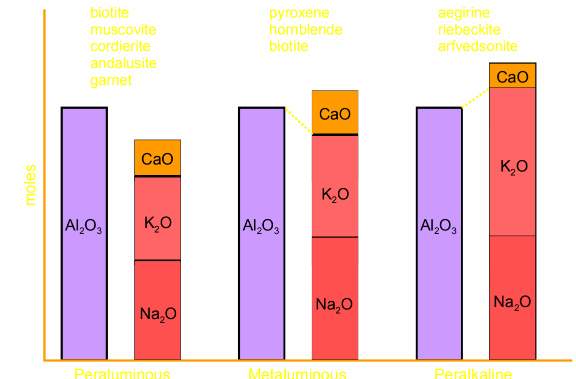
The result is extension and collapse of the crust, thinning of the lithosphere, and rise of hot asthenosphere (d).

Increased heat flux plus decompression melting of the rising asthenosphere results in bimodal post-orogenic magmatism with both mafic mantle and silicic crustal melts. Winter (2001)



Granitoid Classification

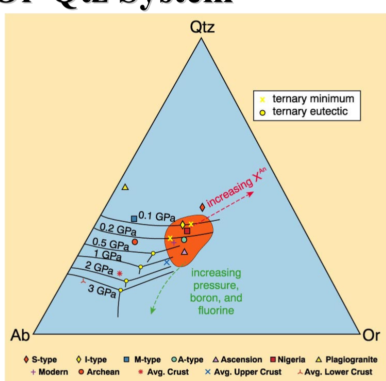
- Aluminum ratios
- SIAM classification
  - Sedimentary source
  - Anorogenic
  - Mantle source
  - Igneous source



Alumina saturation classes based on the *molar* proportions of $Al_2O_3/(CaO+Na_2O+K_2O)$ ("A/CNK") after Shand (1927). Common non-quartzo-feldspathic minerals for each type are included. After Clarke (1992). Granitoid Rocks. Chapman Hall.

Ab-Or-Qtz System

Ternary cotectic curves and eutectic minima from 0.1 to 3 GPa. Locus of most granite compositions in orange and plotted positions of the norms from analyses. Note the effects of increasing pressure and the An, B, and F contents on the position of the thermal minima. From Winter (2001).



SIAM Characteristics

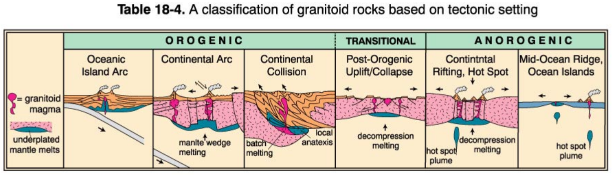
Table 18-3. The S-I-A-M Classification of Granitoids

Type	SiO_2	K_2O/Na_2O	Ca, Sr	A/(C+N+K)*	Fe^{3+}/Fe^{2+}	Cr, Ni	$\delta^{18}O$	$^{87}Sr/^{86}Sr$	Misc	Petrogenesis
M	46-70%	low	high	low	low	low	< 9‰	< 0.705	Low Rb, Th, U Low LIL and HFS	Subduction zone or ocean-intraplate Mantle-derived
I	53-76%	low	high in mafic rocks	low: metal-uminous to peraluminous	moderate	low	< 9‰	< 0.705	high LIL/HFS med. Rb, Th, U hornblende magnetite	Subduction zone Infracrustal Mafic to intermed. igneous source
S	65-74%	high	low	high metaluminous	low	high	> 9‰	> 0.707	variable LIL/HFS high Rb, Th, U biotite, cordierite Als, Grt, Ilmenite	Subduction zone Supracrustal sedimentary source
A	high → 77%	Na_2O high	low	var peralkaline	var	low	var	var	low LIL/HFS high Fe/Mg high Ga/Al High REE, Zr High F, Cl	Anorogenic Stable craton Rift zone

* *molar* $Al_2O_3/(CaO+Na_2O+K_2O)$ Data from White and Chappell (1983), Clarke (1992), Whalen (1985)

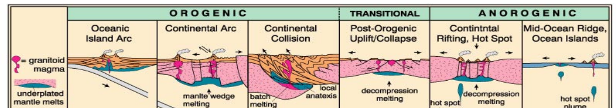
Tectonic Setting

Table 18-4. A classification of granitoid rocks based on tectonic setting



A Classification of Granitoid Rocks Based on Tectonic Setting. After Pitcher (1983) in K. J. Hsü (ed.), *Mountain Building Processes*, Academic Press, London; Pitcher (1993), *The Nature and Origin of Granite*, Blackie, London; and Barbarin (1990) *Geol. Journal*, 25, 227-238. Diagram from Winter (2001)

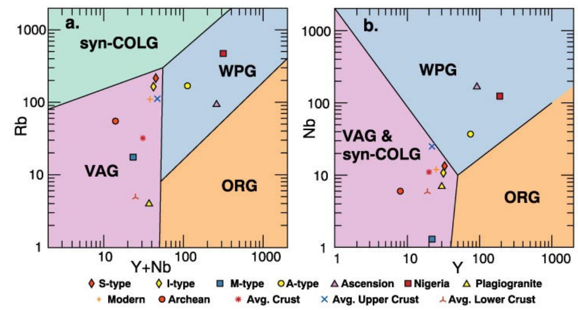
Table 18-4. A classification of granitoid rocks based on tectonic setting



	OROGENIC			TRANSITIONAL	ANOROGENIC	
	Oceanic Island Arc	Continental Arc	Continental Collision	Post-Orogenic Uplift/Collapse	Contintntal Rifting, Hot Spot	Mid-Ocean Ridge, Ocean Islands
Examples	Bougainville, Solomon Islands, Papua New Guinea	Mesozoic Cordilleran batholiths of west Americas Gander Terrane	Manaslu and Lhotse of Nepal, Amorican Massif of Brittany	Late Caledonian Plutons of Britain, Basin and Range, late Variscan, early Northern Proterozoic	Nigerian ring complexes, Oslo rift, British Tertiary Igneous Province, Yellowstone hotspot	Oman and Troodos ophiolites; Iceland, Ascension, and Reunion Island intrusives
Geo-chemistry	Calc-alkaline > thol. M-type & I-M hybrid Metaluminous	Calc-alkaline I-type > S-type Met-Al to sl. Per-Al	Calc-alkaline S-type Peraluminous	Calc-alkaline I-type S-type (A-type) Metalum. to Peralum	Alkaline A-type Peralkaline	Tholeiitic M-type Metaluminous
Rock types	qtz-diorite in mature arcs	tonalite & granodior. > granite or gabbro	migmatites & leucogranite	bimodal granodiorite + diroite-gabbro	Granite, syenite + diorite-gabbro.	Plagiogranite
Associated Minerals	Hbl > Bt	Hbl, Bt	Bt, Ms, Hbl, Grt, Als, Crd	Hbl > Bt	Hbl, Bt, aegirine fayalite, Rbk, arfved.	Hbl
Associated Volcanism	Island-arc basalt to andesite	Andesite and dacite in great volume	often lacking	basalt and rhyolite	alkali lavas, tuffs, and caldera infill	MORB and ocean island basalt
Classification Barbarin (1990)	T_{IA} tholeiite island arc	H_{CA} hybrid calc-alkaline	C_{ST} C_{CA} C_{CI} continental types	H_{LO} hybrid late orogenic	A alkaline	T_{OR} tholeiite ocean ridge
Pearce et al. (1984)	VAG (volcanic arc granites)		COLG (collision granites)		WPG and ORG (within plate and ocean ridge granites)	
Maniar & Piccoli (1989)	IAG island arc granite	CAG contin. arc granite	CCG cont. collision gran.	POG post-orogenic gran.	RRG CEUG rift & aborted/hotspot	OP ocean plagiogranite
Origin	Partial melting of mantle-derived mafic underplate	PM of mantle-derived mafic underplate + crustal contribution	Partial melting of recycled crustal material	Partial melting of lower crust+ mantle and mid-crust contrib	Partial melting of mantle and/or lower crust (anhydrous)	Partial melting of mantle and frac-tional crystallization
Melting Mechanism	Subduction energy: transfer of fluids and dissolved species from slab to wedge. Melting of wedge, transfer of heat upward		Tectonic thickening plus radiogenic crustal hea	Crustal heat plus mantle heat (rising asthen. + magmas)	Hot spot and/or adiabatic mantle rise	

After Pitcher (1983, 1993), Barbarin (1990)

Discrimination Diagrams



Granitoid discrimination diagrams used by Pearce *et al*. (1984, *J. Petrol.*, 25, 956-983) with the granitoids of Table 18-2 plotted. From Winter (2001)

Spider Diagrams

MORB-normalized spider diagrams for the analyses in Table 18-2 . From Winter (2001)