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.

Evidence for Anaatexis

Backscattered electron image of a zircon from the Strontian Granite, Scotland. The grain has a rounded, un-zoned core (dark) that is an inherited high-temperature non-melted crystal from the pre-granite source. The core is surrounded by a zoned epitaxial igneous overgrowth rim, crystallized from the cooling granite. From Paterson *et al*. (1992), *Trans. Royal. Soc. Edinburgh.* 83, 459-471.

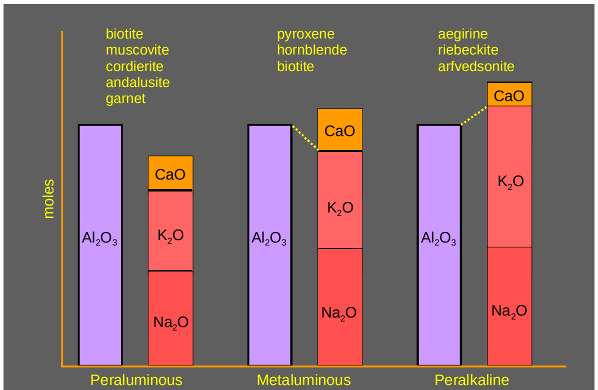
Inclusions

Table 18-1. The Various Types of Enclaves

Name	Nature	Margin	Shape	Features
Xenolith	piece of country rocks	sharp to gradual	angular to ovoid	contact metamorphic texture and minerals
Xenocryst	isolated foreign crystal	sharp	angular	corroded reaction rim
Surmicaceous Enclave	residue of melting (restite)	sharp, biotite rim	lenticular	metamorphic texture micas, Al-rich minerals
Schlieren	disrupted enclave	gradual	oblate	coplanar orientation
Felsic Micro-granular Enclave	disrupted fine-grained margin	sharp to gradual	ovoid	fine-granied igneous texture
Mafic Micro-granular Enclave	Blob of coeval mafic magma	mostly sharp	ovoid	fine-granied igneous texture
Cumulate Enclave (Autolith)	disrupted cumulate	mostly gradual	ovoid	coarse-grained cumulate texture

After Didier and Barbarin (1991, p. 20).

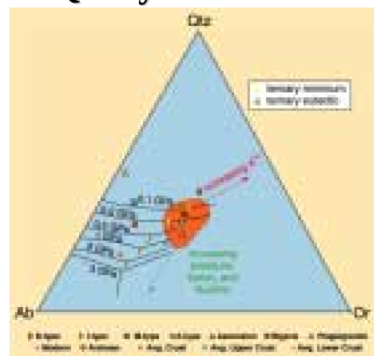
Didier, J. and Barbarin (1991) The different type of enclaves in granites: Nomenclature. In J. Didier and B. Barbarin (1991) (eds.), *Enclaves in Granite Petrology*. Elsevier. Amsterdam, pp. 19-23.



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.

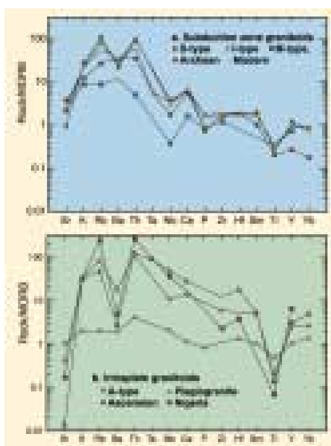
Ab-Or-Qtz System

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).



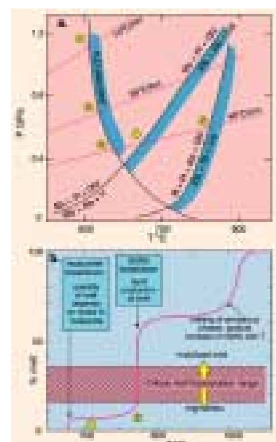
Spider Diagrams

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



Crustal Melting

a. **Simplified P-T phase diagram**
b. **Quantity of melt generated during the melting of muscovite-biotite-bearing crustal source rocks, after Clarke (1992) *Granitoid Rocks*. Chapman Hall, London; and Vielzeuf and Holloway (1988) *Contrib. Mineral. Petrol.*, 98, 257-276.**
c. **Shaded areas in (a) indicate melt generation. Figures from Winter (2001)**



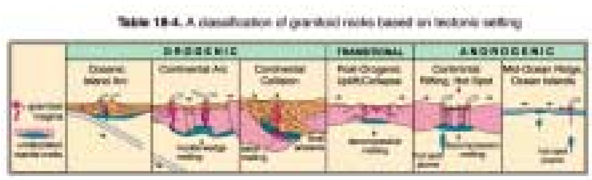
SIAM Characteristics

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

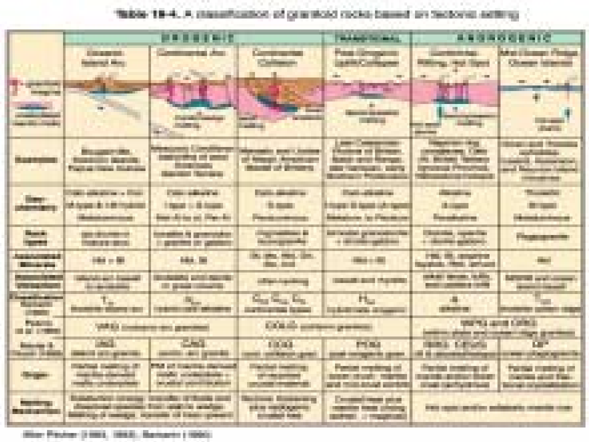
Type	SiO_2	K_2O/Na_2O	Ca, Sr	A/(C+N+K)*	Fe^{3+}/Fe^{2+}	Cr, Ni	$\delta^{18}O$	$^{87}Sr/^{86}Sr$	Misc	Petrogenesis
M	46-70%	low	high	low	low	low	< 9‰	< 0.705	Low Rb, Th, U Low LIL and HFS	Subduction zone or ocean-intraplate Mantle-derived
I	53-76%	low	high in mafic rocks	low: metal-uminous to peraluminous	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

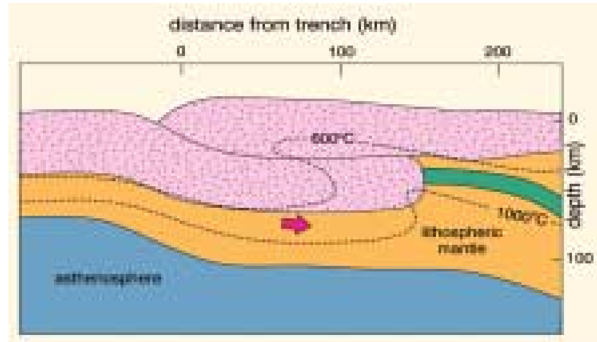
* *molar* $Al_2O_3/(CaO+Na_2O+K_2O)$ Data from White and Chappell (1983), Clarke (1992), Whalen (1985)

Tectonic Setting



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)





The effect of subducting a slab of continental crust. The dip of the subducted plate shallow 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)

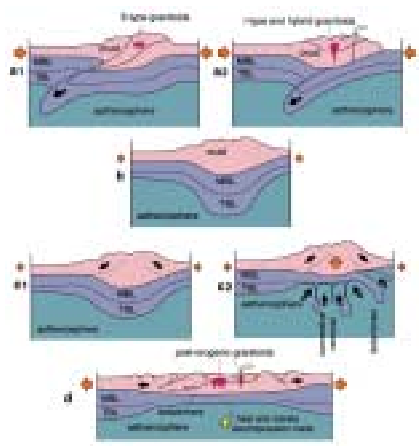
Subduction thickens crust by continental collision (a1) or compression of the continental arc (a2).

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

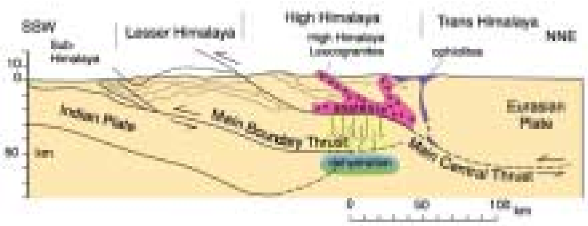
Then, either compression ceases (c1) or the thick dense thermal boundary layer is removed by delamination or convective erosion (c2).

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)

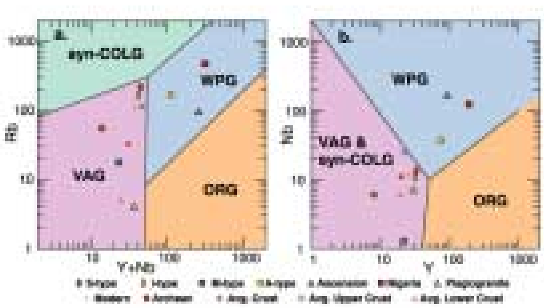


Himalaya Cross Section



Schematic cross section of the Himalayas showing the dehydration and partial melting zones that produced the leucogranites. After France-Lanord and Le Fort (1988) *Trans. Roy. Soc. Edinburgh*, 79, 183-195. From Winter (2001)

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)