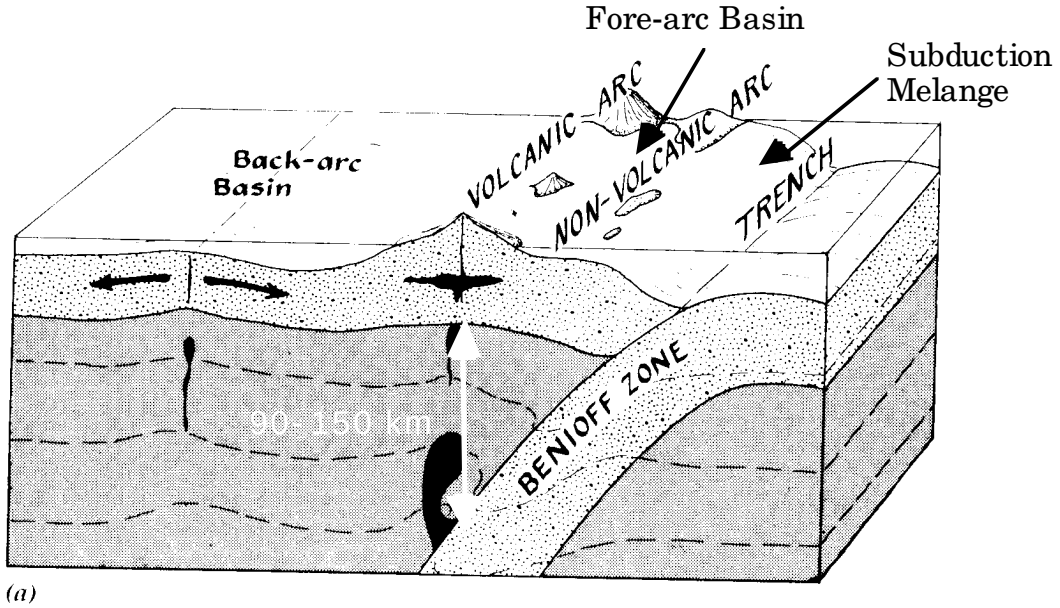
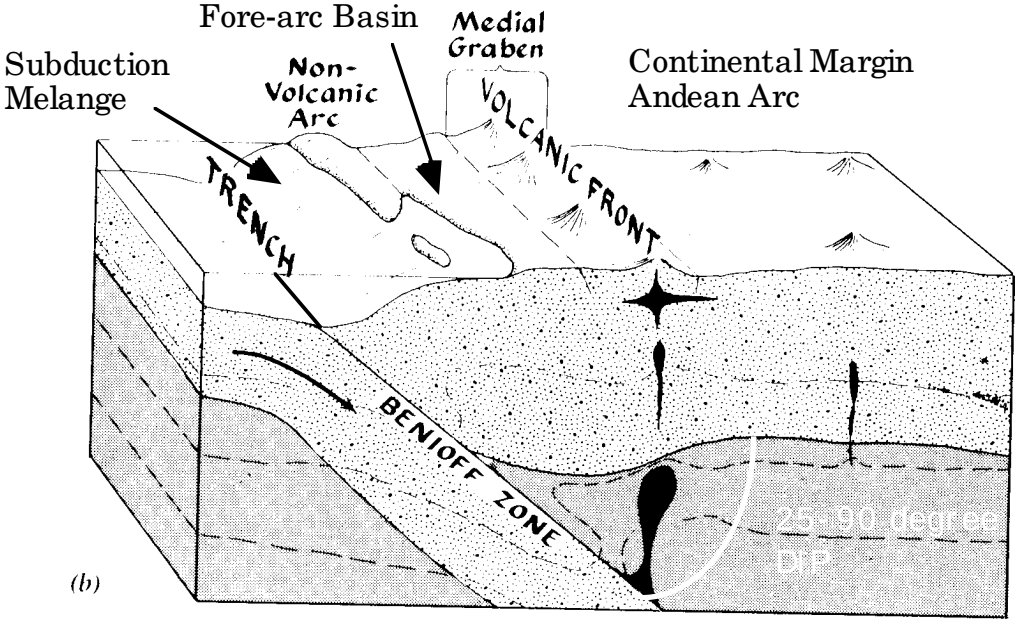
ARC VOLCANISM AND GRANITE BATHOLITHS

Benioff (1954) was first to note the presence of seismic zones associated with deep sea trenches that appear to dip below the island arc. Earthquakes as deep as 400 km. Mantle is too hot to fail brittlely at this depth, thus earthquakes must be within colder material that has been thrust in from shallower depths.



(a)



(b)

ARC VOLCANISM AND GRANITE BATHOLITHS

Coates (1962) associated dehydration in underthrust slab with partial melting mantle above to form Aleutian island arc.

3 Volcanic Series Associated with Island Arcs:

1. Arc Tholeiite

a. Young volcanic arcs, oldest, closest to trench.
b. Moderate-strong Fe-enrichment, Weak Si, Na, K-enrichment.
c. Mostly **Basaltic-andesite**.

2. Calc-alkaline Suite

a. More mature arcs, farther from trench, overlie arc tholeiites.
b. Little or no Fe-enrichment, Strong Si, Na, K-enrichment.
c. Complete series: Basalt, **Andesite**, Dacite, Rhyolite.

3. Alkaline Suite (Shoshonites)

a. Youngest series, erupts farthest from trench, not in all arcs.
b. Generally potassic (shoshonite: $K_2O > Na_2O$), may be sodic.
c. All mafic (**basalt**, basaltic-andesite), no SiO_2 enrichment.

Island Arc Volcanics vs MORB

	MORB	**Arc Tholeiite**	**Calc-alkaline**	**Shoshonite**
Avg. SiO2	50%	55%	60%	52%
Dominant Rx	Basalt	Basaltic Andesite	Andesite	Shoshonite
Avg. K2O	<0.25%	< 0.5%	1.5%	4.5%
K2O/Na2O	< 0.1	< 0.4	< 0.8	1.1-1.3
TiO2	0.6-2.5%	0.6%	0.8%	0.7%
LREE/HREE	< 1.0	< 1.0	2-4	4-6
Phenoxtls:	Olivine Plagioclase Augite	Olivine Plagioclase Pigeonite	Hypersthene Plagioclase Hornblende	Olivine Augite

Arc Tholeiites: Tonga-Kermadec, South Sandwich Islands, Izu-Bonin
CalcAlkaline: Marianas, Japan, Fiji, Java-Sumatra
Shoshonite: Fiji

How Do Island Arc Magmas Form ?

Hypothesis 1: SLAB Melting

Early idea, still supported by many
Problem: Low geotherms make it difficult to exceed melting T
Problem: Experimental melts of Slab don't match lavas.

Hypothesis 2: Mantle Wedge Melting

OK for arc Tholeiites but can't explain enrichments in K_2O, SiO_2.
If dry, solidus too high for peridotite to melt.

Hypothesis 3: Mantle Wedge Melt with Slab Component

H_2O lowers solidus of peridotite.
High P_{H2O} melts SiO2 saturated.
High fO_2 early magnetite fractionation.
Alkalis, SiO2 mobile in hot, H_2O-rich fluids.
Generally favored by most petrologists.

ARC MAGMATISM CAUSES

1. Melting caused by reduction in solidus T - H_2O from subducting slab.
   Dehydration reactions with Depth:
   a. Hornblende --> Eclogite + H_2O (80-100 km)
   b. Serpentine --> Talc + Bruceite + H_2O (100-120 km)
   c. Talc --> Enstatite + SiO_2 + H_2O (120-150 km)

2. Change in melting relations at high P_{H2O} :
   >> Melts may be Si-Saturated.

3. Water Dissociates, increasing P_{O2} **:** $2 * H_2O \rightarrow O_2 (g) + 4 * H (g)$

   >> Early magnetite fractionation supresses Fe-enrichment.

4. Arc magmas rich in Alkalis, SiO_2 (mobile in H_2O solutions), poor in Ti Nb Ta Hf (Immobile in H_2O solutions).

CONTINENTAL MARGIN ARCS -- ANDEAN ARCS

1. Continental crust acts as density filler: primitive melts must fractionate to lower density (lower FeO) before they can rise into low density continental crust.

2. During fractionation, rising magma will assimilate crustal material, increasing K_2O, SiO_2, and other lithophilic elements.

3. Partial melting of lower crust (andesitic in composition) creates large volumes of more felsic magma; rhyolites & granites more common.

4. Batholiths more common in continental arcs, e.g. Sierra Nevada Batholith in California, Coast Range Batholith in British Columbia, Coastal batholith in Peru.

Depth of origin: shallow H_2O-saturated melting of lower crust/upper mantle creates magmas which will freeze (intersect solidus) before reaching surface.

Continental margin arcs vs island arcs

	Andean Arcs	**Island Arcs**
SiO_2	56-75 wt%	50-66 wt%
FeO/MgO	> 2.0	< 2.0
K_2O/Na_2O	0.6 to 1.1	< 0.8

GRANITES

Mostly derived from fusion of lower crust found only in old Andean Arcs or very mature island arcs e.g. Japan with well developed basement.

I-type granites: subduction related
Melting of older arc volcanics or greywackes derived from them.

S-type granites: Anorogenic, related to continent-continent collisions
Melting of shales, alumina-rich sediments.

	I-type Granites	**S-type Granites**
Oxygen fugacity	high fO2	low fO2
Cause of fO2	H20 dissociation	Graphite (C)
Dominant Alkali	Na2O	K2O
Initial $^{87}Sr/^{86}Sr$	Low < 0.710	High > 0.710
Molar Al/(Na+K)	Low < 1.0	High >> 1.0
Accessory Phases	Sphene, Magnetite	Ilmenite, Garnet
	Hornblende, Biotite	Muscovite, Cordierite
Ore Deposits	Cu, Mo, Au, Ag	Sn, W