FIELD OCCURRENCE OF PLUTONIC IGNEOUS ROCKS

I. Basic Definitions

DIKE: Discordant, tabular intrusion, 
Length >> Thickness 
Cross-cuts pre-existing layers, fabric.

SILL: Concordant tabular intrusion, 
Length >> Thickness 
Intruded Parallel to pre-existing fabric, layers.

LOPOLITH: Funnel-shaped intrusion, Mafic magma; >10-20km across

LACCOLITH: Shallow, mushroom-shaped intrusion of silicic magma. 
Flat-lying sediments below, domes sediments above.

PLUTON: General term for any large (kilometer scale) body of intrusive igneous rock. Includes both mafic and silicic intrusions.

BATHOLITH: A large intrusive complex, 100's or 1000's of km in extent, composed of dozens of individual plutons. Individual plutons within the batholith may span a large range in ages (100-200 m.y.) and compositions (mafic-silicic).

STOCKS & PLUGS: Small, subequant intrusions 
Intermediate to silicic magma <100 km2 in size. 
Generally applied to shallow subvolcanic intrusions.

DIKE SWARM: Subparallel dikes which occur in large numbers. 
Commonly basaltic, they form in tensional environments. Some dike swarms were feeders for flood basalt provinces.

RADIAL DIKES: Dikes which radiate from a central intrusion (plug or stock) like the spokes of a wheel. Subvolcanic.

RING DIKES: Dikes which form concentric rings or partial rings about the locus of an intrusion (plug). Generally form above a central stock or plug. Ring dikes accommodate sinking movement of roof rocks above the plug.
II. The Space Problem

- How do magmas displace pre-existing rock to make room for themselves?
- Granitic batholiths may require 20,000 to 50,000 km$^3$ of space.

**PASSIVE INTRUSION versus FORCEFUL INTRUSION.**

**PASSIVE INTRUSION:** Magma flows passively into void space created by external process or force (tension or gravity).

**Stoping:** Collapse of blocks into magma chamber from sides or roof. Magma wells up to fill “void” left by sinking blocks. Common in shallow or intermediate depth intrusions.

**Extension:** Movement of magma into fractures or voids formed by extension of the crust in response to regional tensional stress. Scale may vary from small (dikes) to large (batholiths).

**FORCEFUL INTRUSION:** Magma forced into zones of weakness in pre-existing rocks by lithostatic pressure.

**Lifting:** Country rock may be lifted or tilted by intrusion of magma. Characteristic of shallow intrusions.

**Shouldering Aside:** Country rock is pushed out of the way and deformed by intrusion of magma. Characteristic of intermediate or shallow intrusions. May require regional extension for very large intrusions.

**Plastic Flow:** Deep within the crust, country rocks may behave as a plastic and “flow” around diapirs of rising granitic magma. Country rocks are always high grade, highly deformed migmatites.
III. How Do We Know Plutonic Rocks Formed From Liquid Magma?

Unlike volcanic rocks, plutonic igneous rocks cannot be observed in the process of formation. Therefore, we must infer how these rocks formed based on field and laboratory studies.

**Field Evidence for Magmatic Origin of Plutonic Igneous Rocks:**

1. Chilled margins in the plutonic rock (shallow or intermediate depths only).
2. Baked contacts in adjacent sedimentary rocks (shallow) or contact metamorphism of adjacent wallrock (intermediate depths).
3. Discordant contacts which truncate sedimentary layering or other pre-existing fabric.
4. Rotated fragments of wallrock within the pluton.
5. Xenoliths or schlieren within the pluton, which cannot be derived from the adjacent wallrock.
6. Satellite dikes or apophyses which root in the main pluton and penetrate the adjacent wallrock.
7. Dilational offset of pre-existing layers by a tabular intrusion.

**Experimental Evidence for Magmatic Origin of Plutonic Rocks:**

8. Textures of plutonic igneous rocks can be duplicated in the laboratory by melting rocks of the appropriate composition and letting them cool.
9. The crystallization order observed in plutonic rocks consistent with experimental phase relations on analogous compositions.
IV. Depth Zones in Granitic Plutons

Epizonal Plutons (0-10 km):

a. Passive intrusion (stoping of roof-rock),
b. Contacts discordant with country rocks,
c. Chilled margins against hornfelsed or baked contacts,
d. No structure or foliation,
e. Rare inclusions,
f. Vapor-phase crystallization common,
g. No coeval regional metamorphism in country rocks.

Mesozonal Plutons (7-16 km):

a. Forceful intrusion
b. Contacts may concordant or discordant with country rocks
c. Chilled contacts rare
d. Contact metamorphic aureoles common
e. May be foliated near contacts
f. Mafic inclusions common near margins
g. No vapor phase crystallization
h. Coeval greenschist to amphibolite facies metamorphism

Catazonal Plutons (> 12 km):

a. Forceful intrusion with plastic flow of country rock
b. Contacts with country rocks concordant
c. No chilled margins
d. Broad zone of regional contact migmatite
e. May be foliated internally
f. Inclusions common
g. No vapor phase crystallization
h. Coeval garnet amphibolite facies metamorphism
i. Migmatite formation