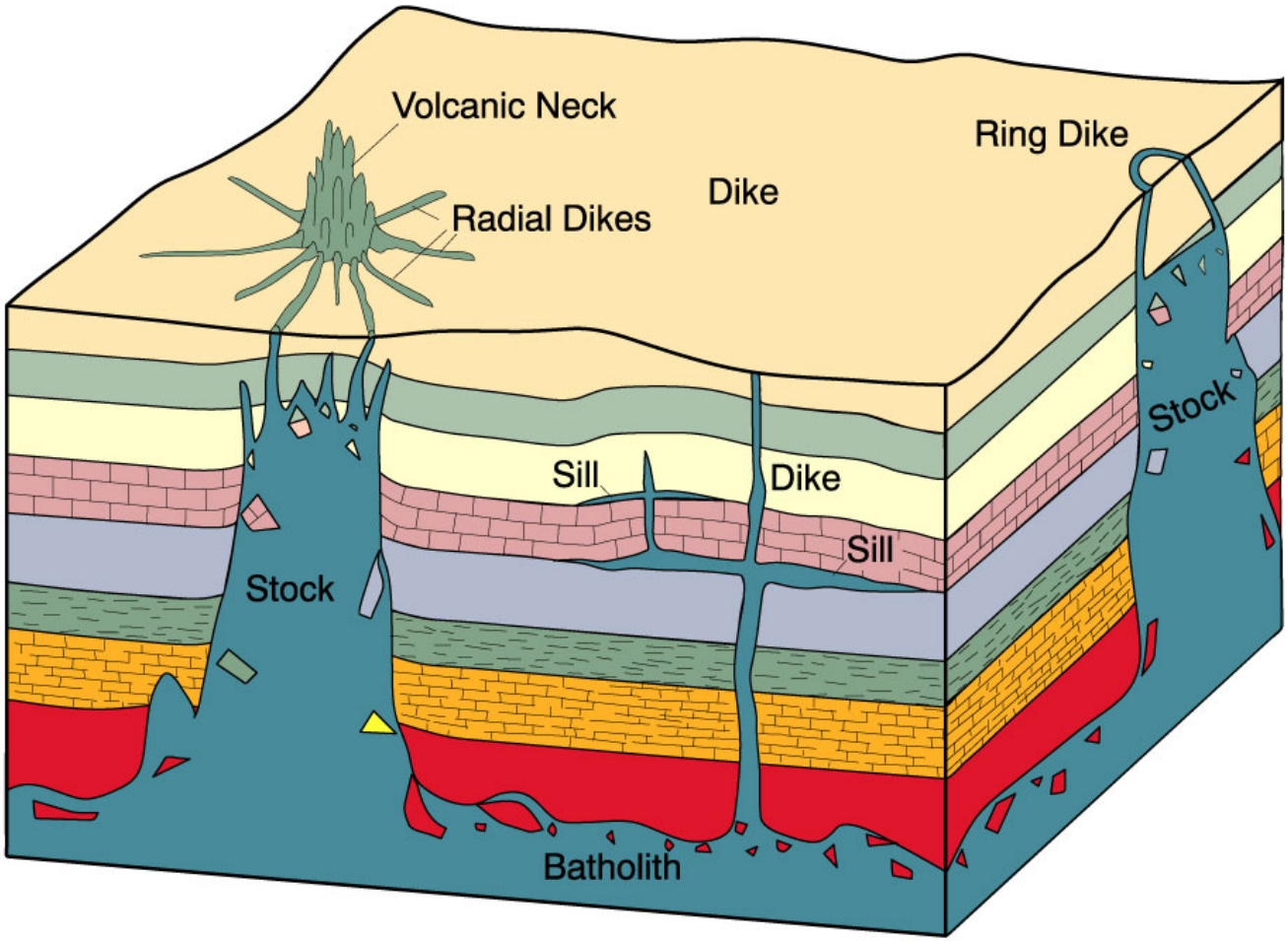
Announcements

Homework 2 due today

Reading: p.219-241 LMI

The many shapes and sizes of igneous intrusions



"plutons"

Concordant and discordant intrusions

Note scale in future slides!

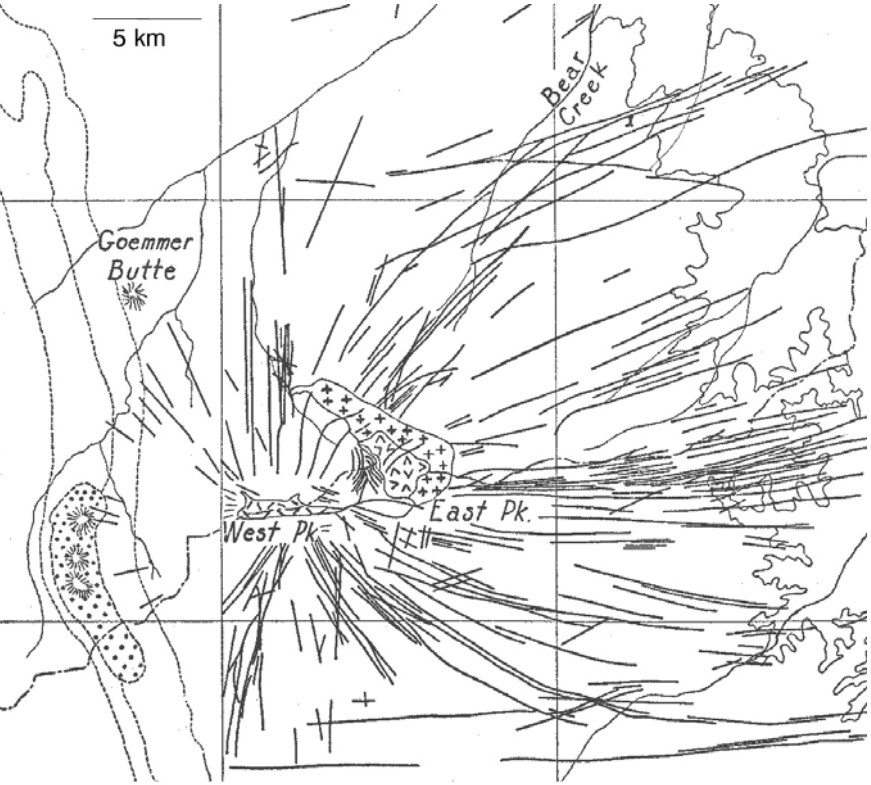
From Winter, Intro to Igneous and Metamorphic Petrology

Igneous Structures: Sill

- Concordant or discordant?
- Scale?

- Sill in Antarctica

Igneous Structures: Dikes



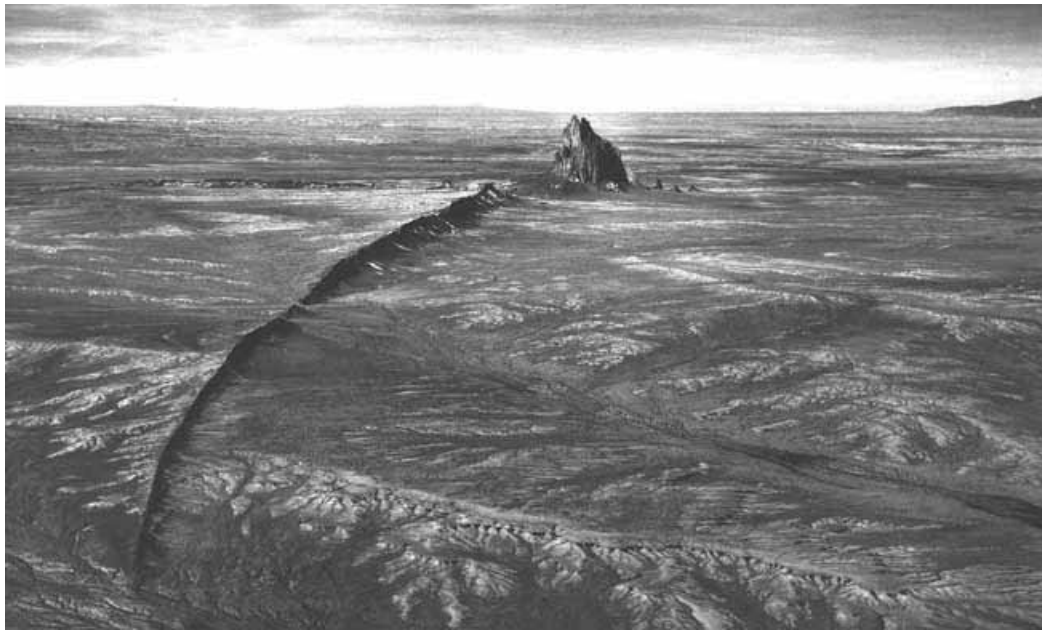


Figure 4-22. **a.** Radial dike swarm around Spanish Peaks, Colorado. After Knopf (1936), *Geol. Soc. Amer. Bull.*, **47**, 1727-1784. **b.** Eroded remnant of a volcanic neck with radial dikes. Ship Rock, New Mexico. From John Shelton © (1966) *Geology Illustrated*. W. H. Freeman. San Francisco.

Structures and Field Relationships

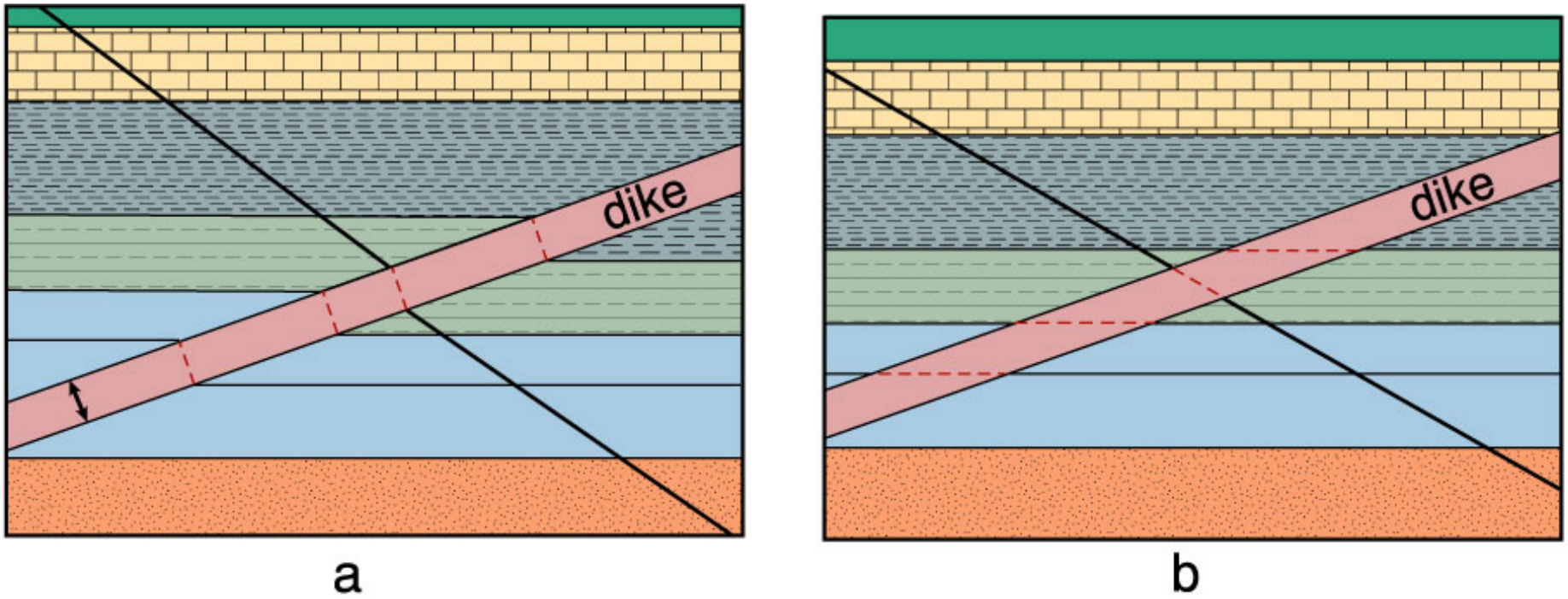


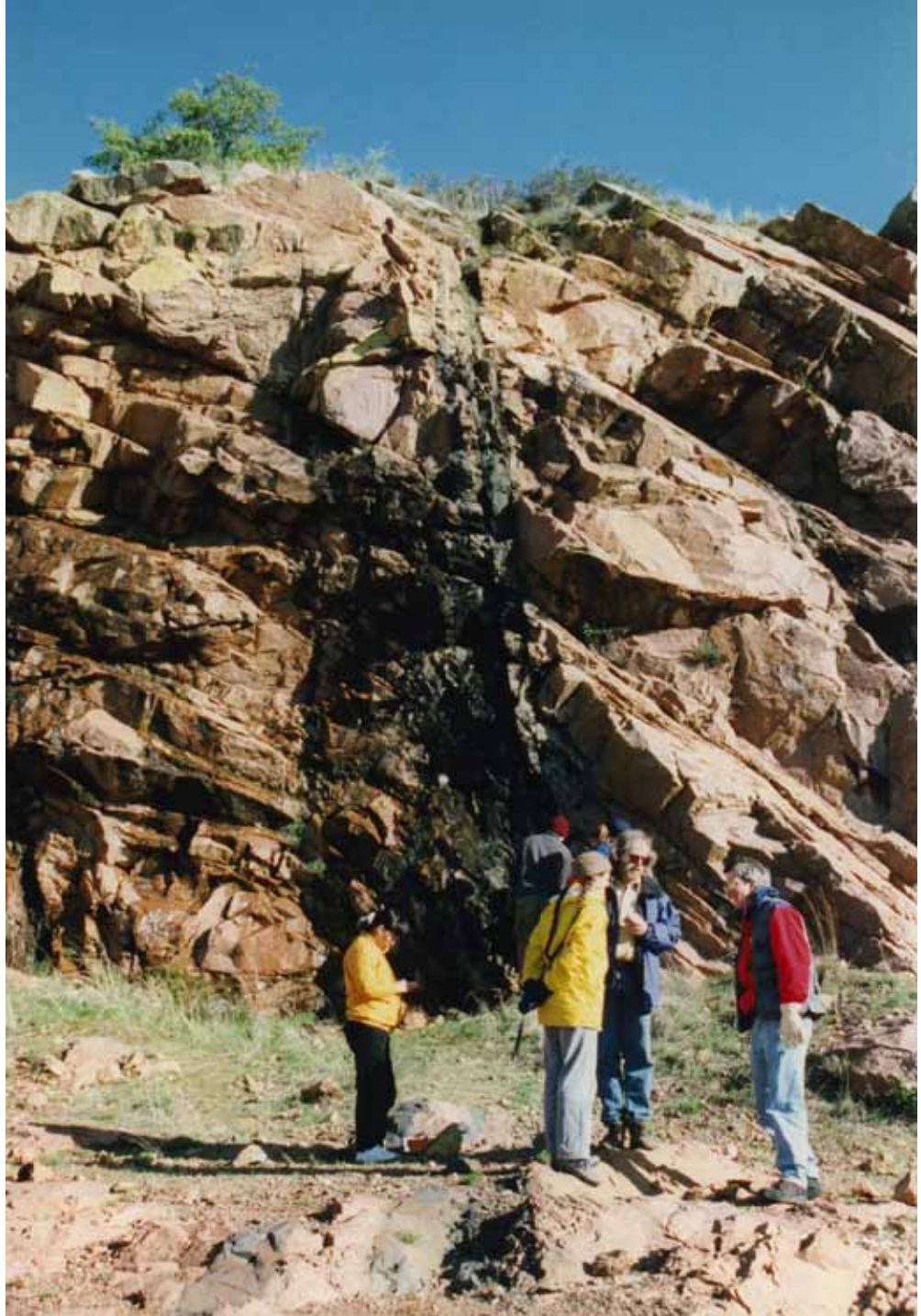
Figure 4-25. Types of tabular igneous bodies in bedded strata based on method of emplacement. **a.** Simple dilation (arrows) associated with injection. **b.** No dilation associated with replacement or stoping.

Concordant or discordant?

Structures and field relationships

Diabase dike in granite, SW Oklahoma

Scale?



Late-stage veining

- Which came first- dark or light veins?

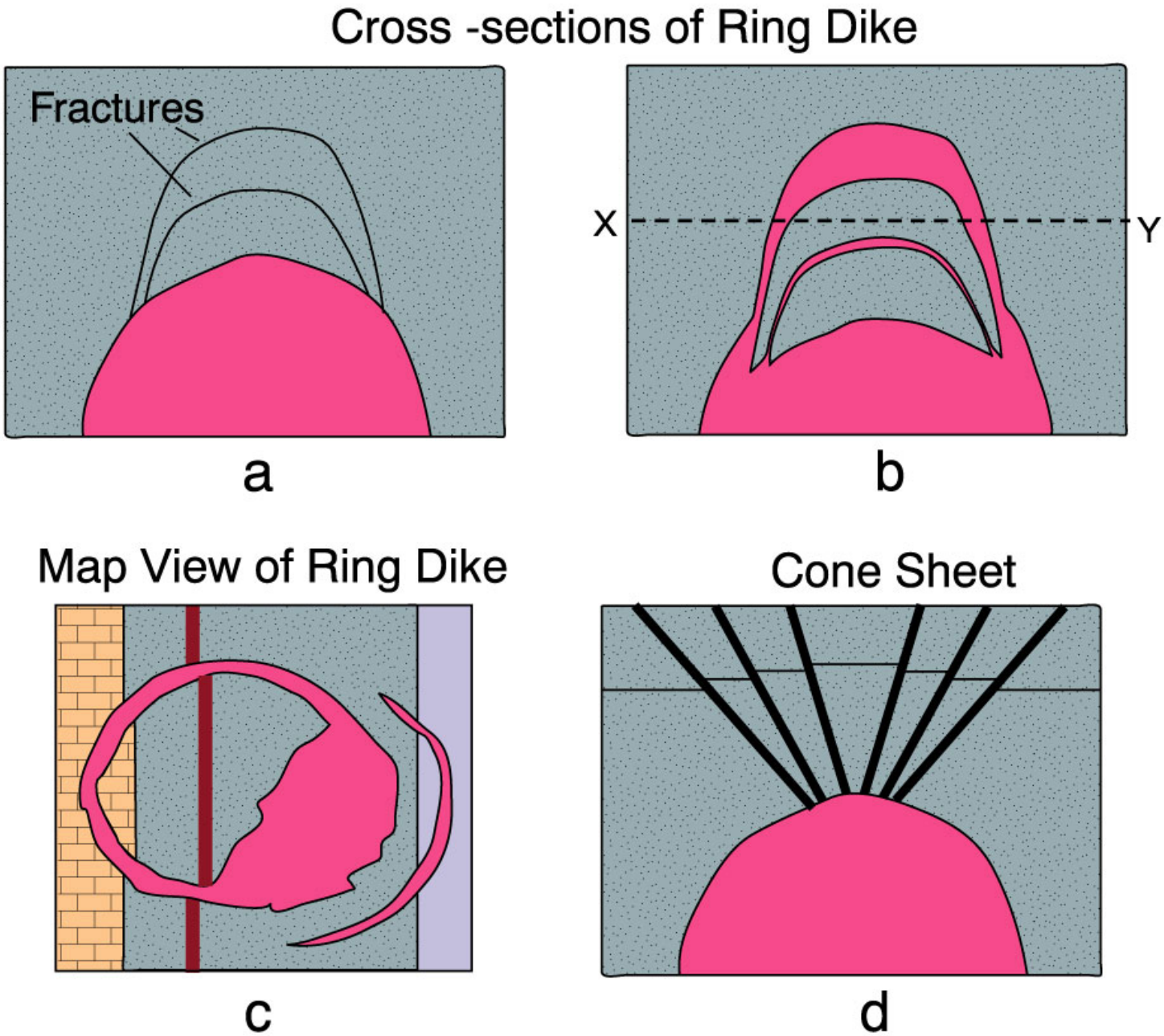


Figure 4-23. The formation of ring dikes and cone sheets. **a.** Cross section of a rising pluton causing fracture and stoping of roof blocks. **b.** Cylindrical blocks drop into less dense magma below, resulting in ring dikes. **c.** Hypothetical map view of a ring dike with N-S striking country rock strata as might result from erosion to a level approximating X-Y in (**b**). **d.** Upward pressure of a pluton lifts the roof as conical blocks in this cross section. Magma follows the fractures, producing cone sheets. Original horizontal bedding plane shows offsets in the conical blocks. (a), (b), and (d) after Billings (1972), *Structural Geology***.** Prentice-Hall, Inc. (c) after Compton (1985), *Geology in the Field.* © Wiley. New York.

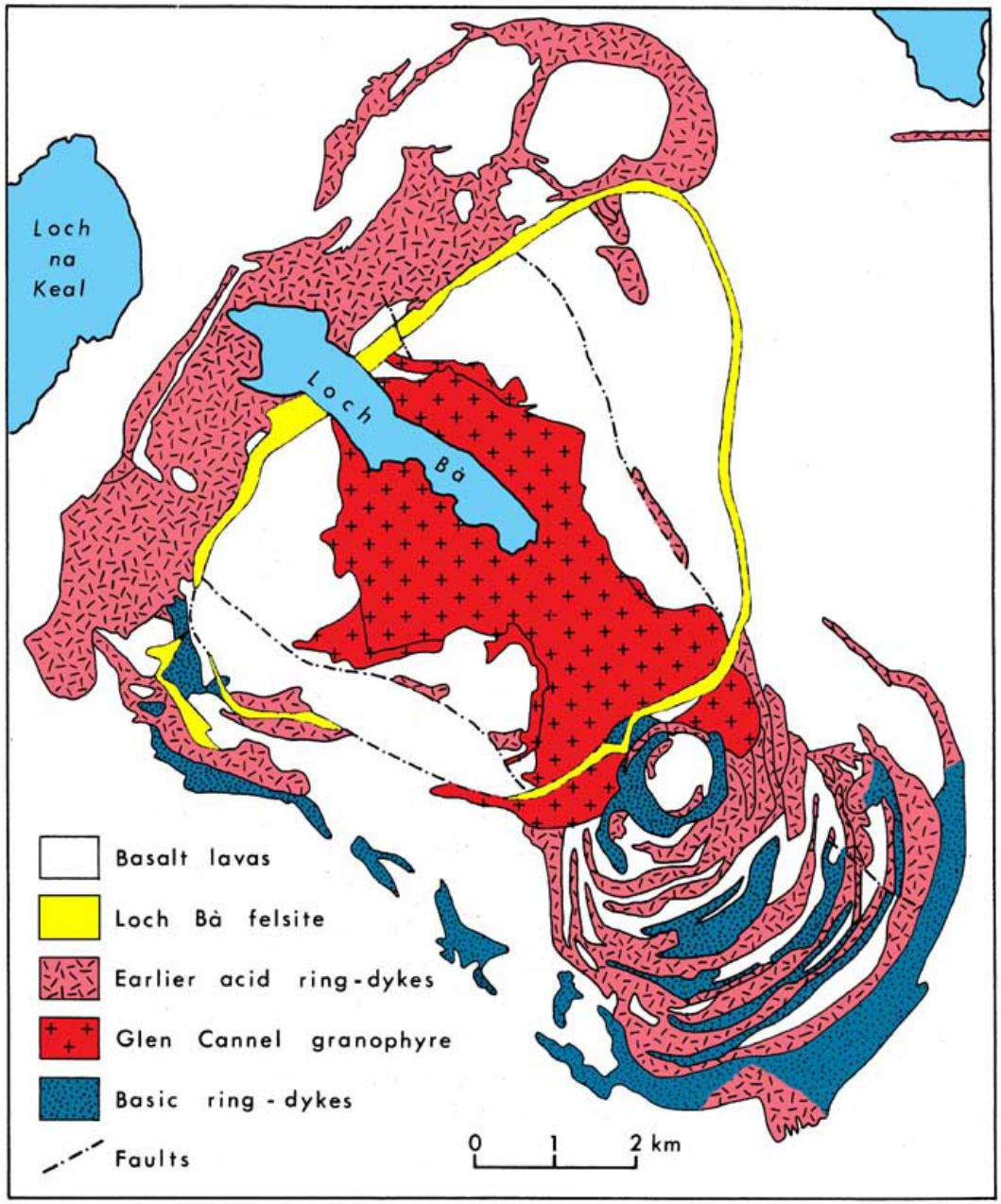


Figure 4-24. a. Map of ring dikes, Island of Mull, Scotland. After Bailey *et al*. (1924), *Tertiary and post-tertiary geology of Mull, Loch Aline and Oban*. Geol. Surv. Scot. Mull Memoir. Copyright British Geological Survey.

What would map view look like if eroded deeper?

Scale?

Structures and Field Relationships

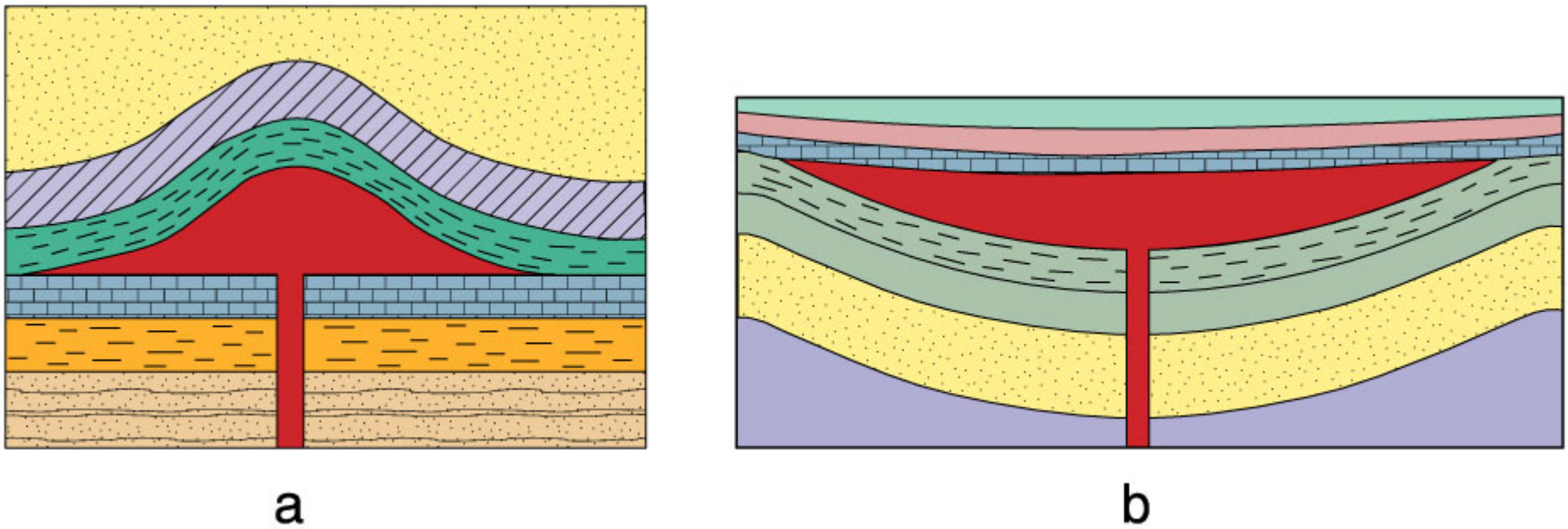
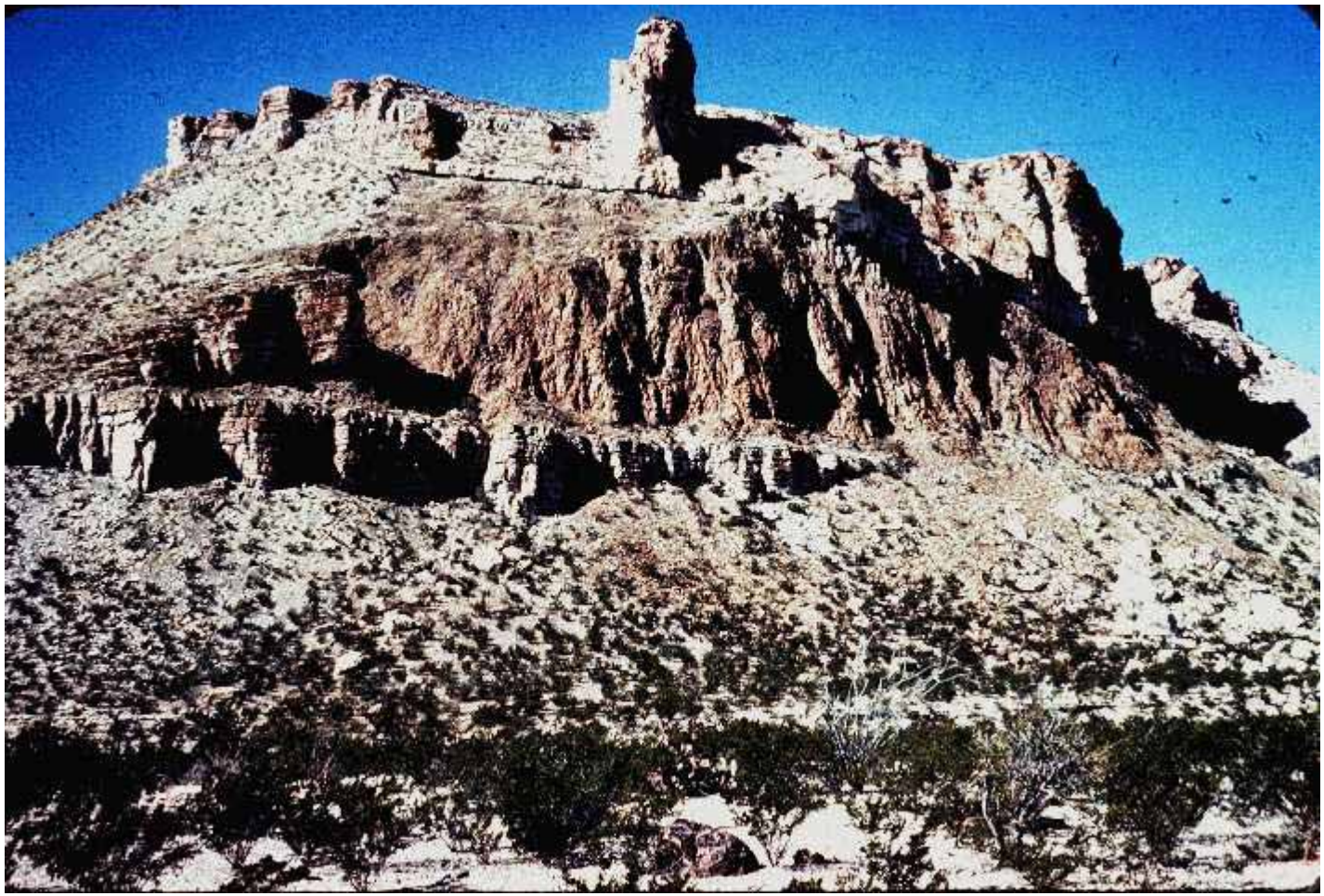


Figure 4-26. Shapes of two concordant plutons. **a.** Laccolith with flat floor and arched roof. **b.** Lopolith intruded into a structural basin. The scale is not the same for these two plutons, a lopolith is generally much larger.

Igneous Structures: Laccolith



Scale?

Vegetation at bottom of picture

Igneous Structures: Lopolith

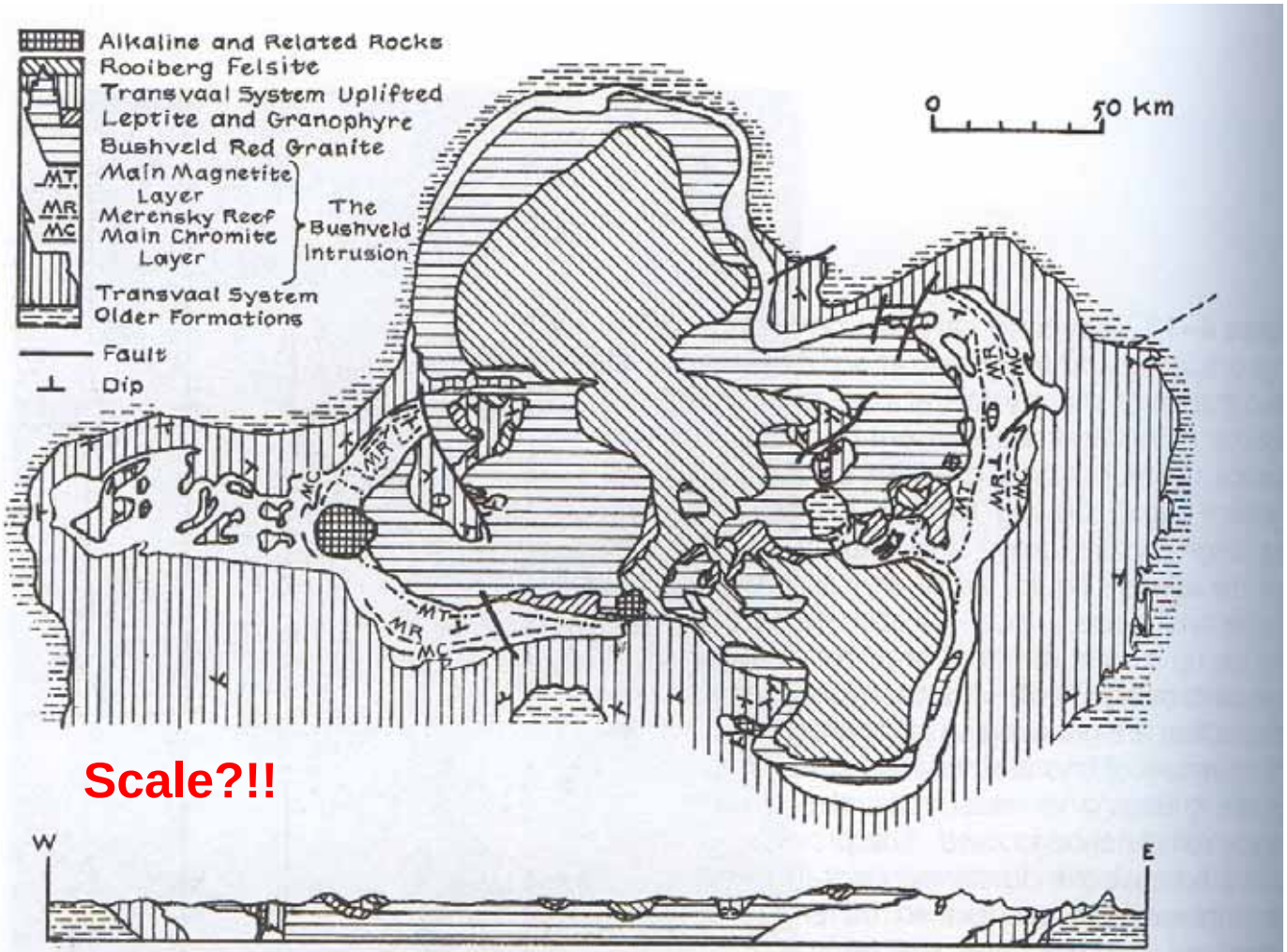


Figure 6–12 Simplified map and cross section of the Bushveld intrusion of South Africa. (Based mainly on a compilation by J. Willemse.)

Igneous Layering

- Rhythmic bedding
- Can also have simple compositional zoning

Batholiths

- Example: Coast Mountains Batholith (north of Vancouver)
- Consists of plutons of different ages
- Scale: 100's km
- Another example of a batholith?

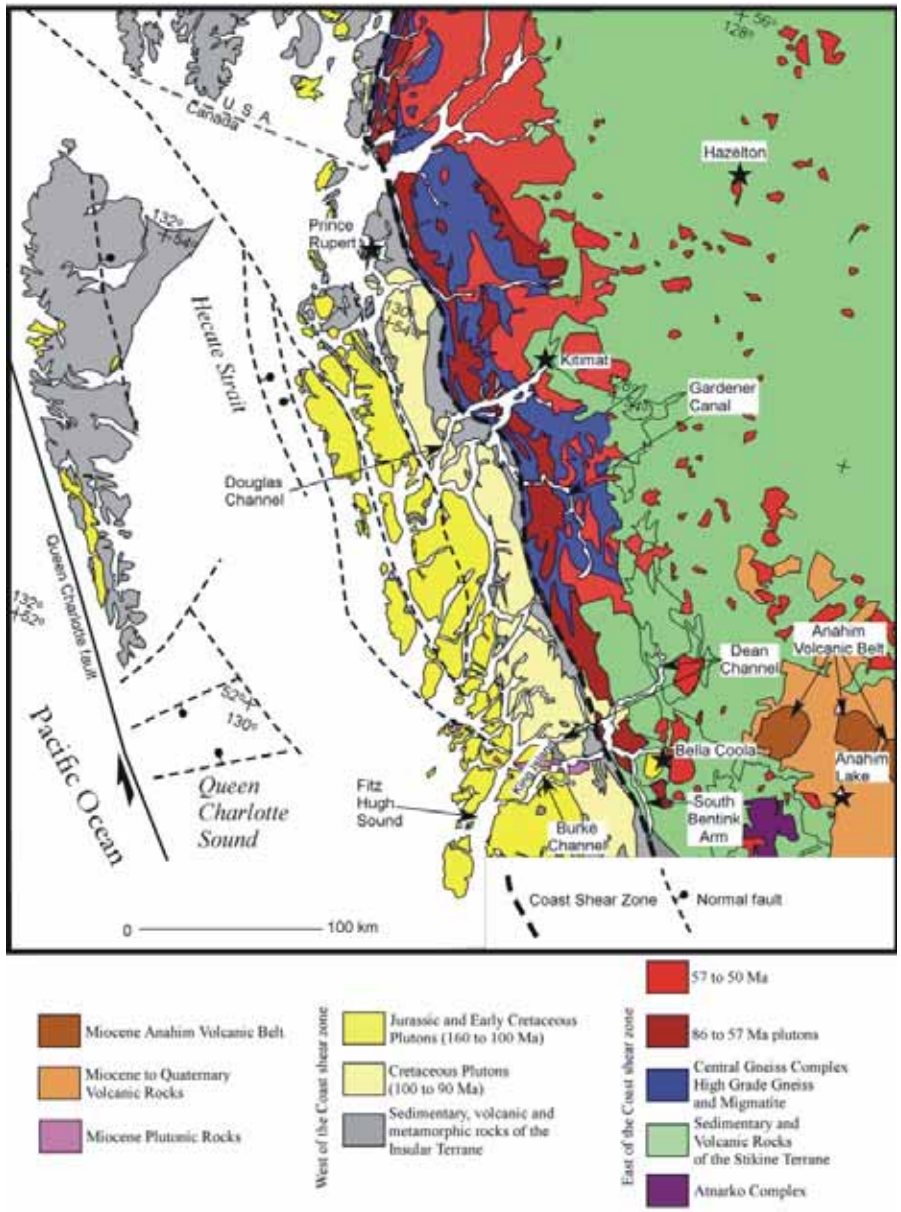


Figure 2. Geologic map containing the proposed study area. Active source seismic experiment layout shown on figure 11. Passive experiment layout shown on Figure 12.

Structures and Field Relationships

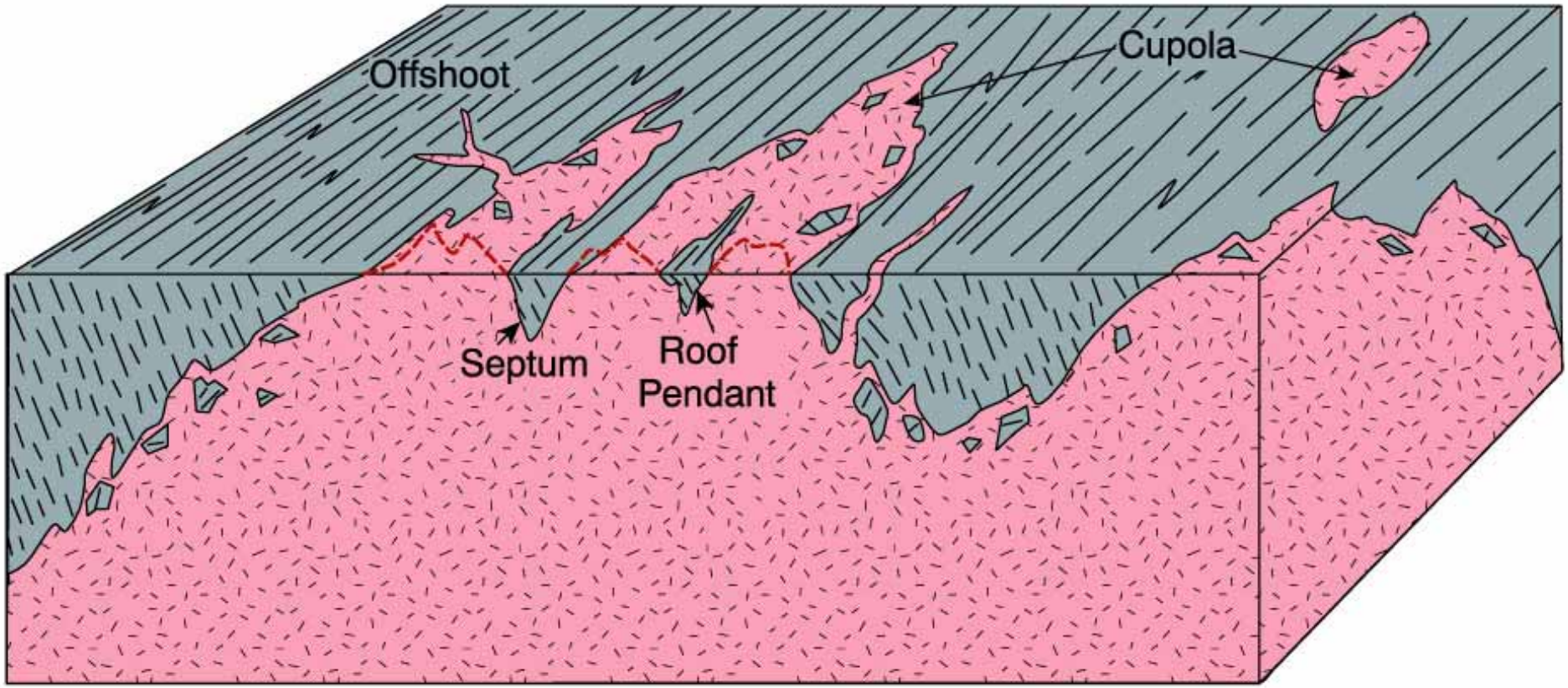
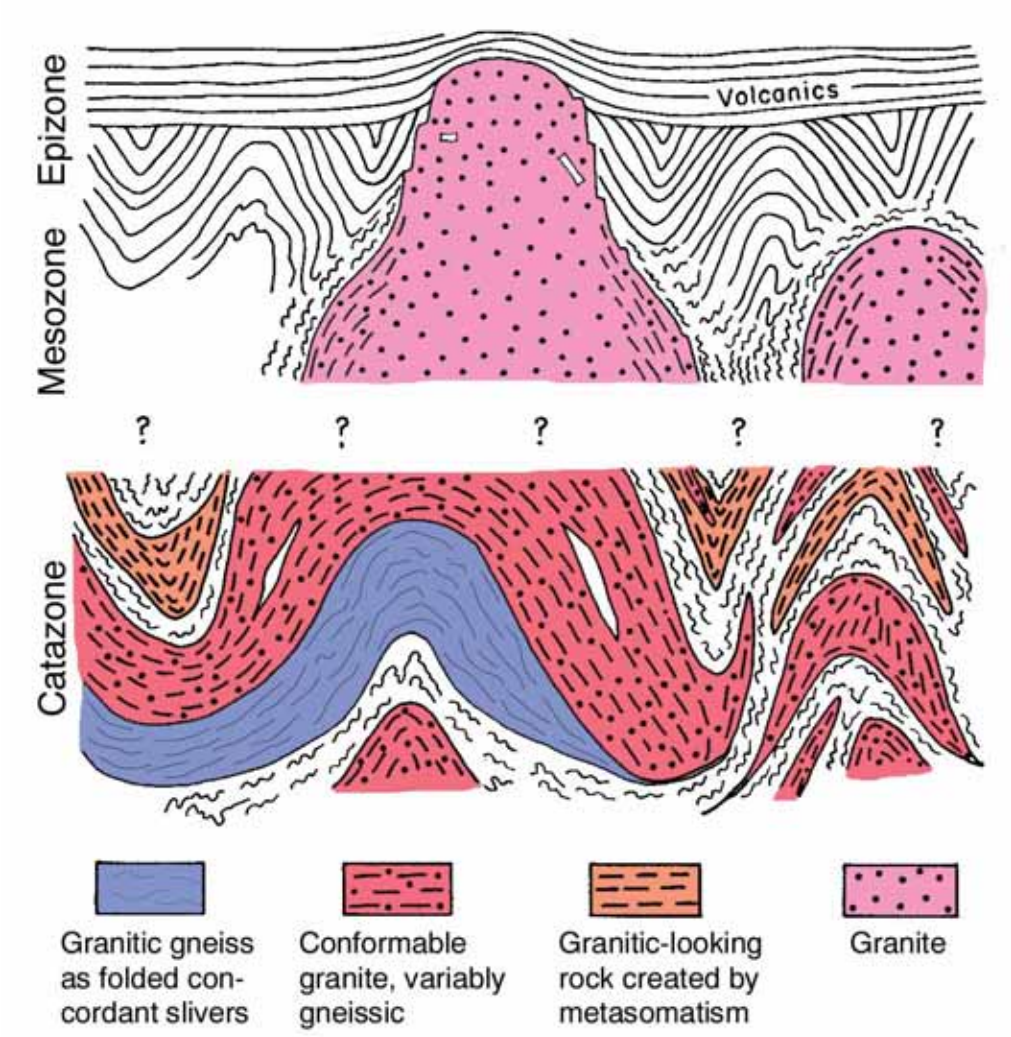


Figure 4-30. Block diagram several kilometers across, illustrating some relationships with the country rock near the top of a barely exposed pluton in the epizone. The original upper contact above the surface is approximated by the dashed line on the front plane. From Lahee (1961), *Field Geology*. © McGraw Hill. New York.

Stocks and generic plutons



<10 km

CR<300°C

5-20 km

CR=300-500°C

>10 km

CR=450-600°C

Figure 4-31. a. General characteristics of plutons in the epizone, mesozone, and catazone. From Buddington (1959), *Geol. Soc. Amer. Bull.*, **70**, 671-747.

Structures and Field Relationships

Dating?

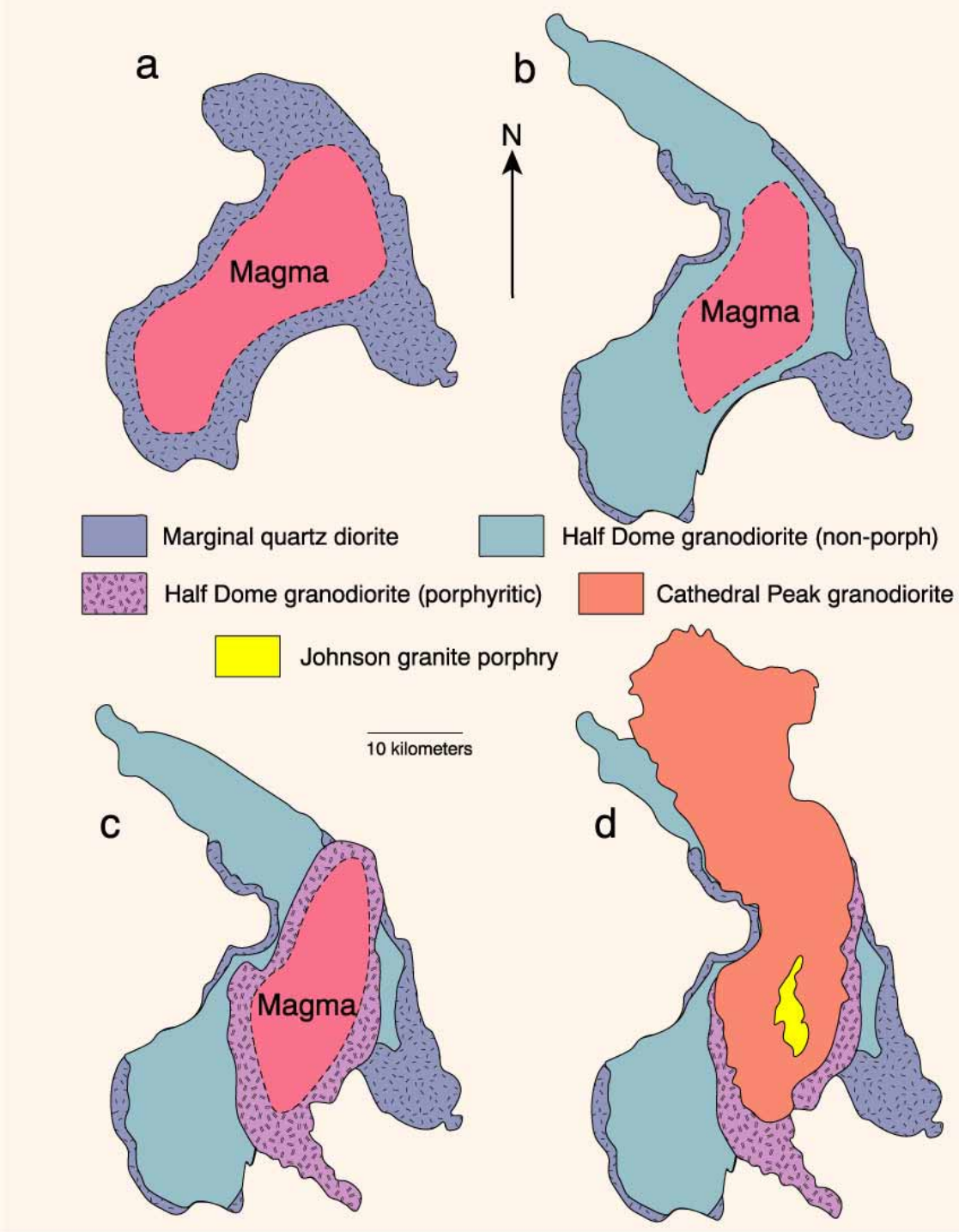


Figure 4-32. Developmental sequence of intrusions composing the Tuolumne Intrusive Series (after Bateman and Chappell, 1979), *Geol. Soc. Amer. Bull.*, **90**, 465-482. **a.** Original intrusion and solidification of marginal quartz diorite. **b.** Surge of magma followed by solidification of Half Dome Granodiorite. **c.** Second surge of magma followed by solidification of porphyritic facies of Half Dome Granodiorite. **d.** Third surge of magma followed by solidification of Cathedral Peak Granodiorite and final emplacement of Johnson Granite Porphry.

Gradational border zones

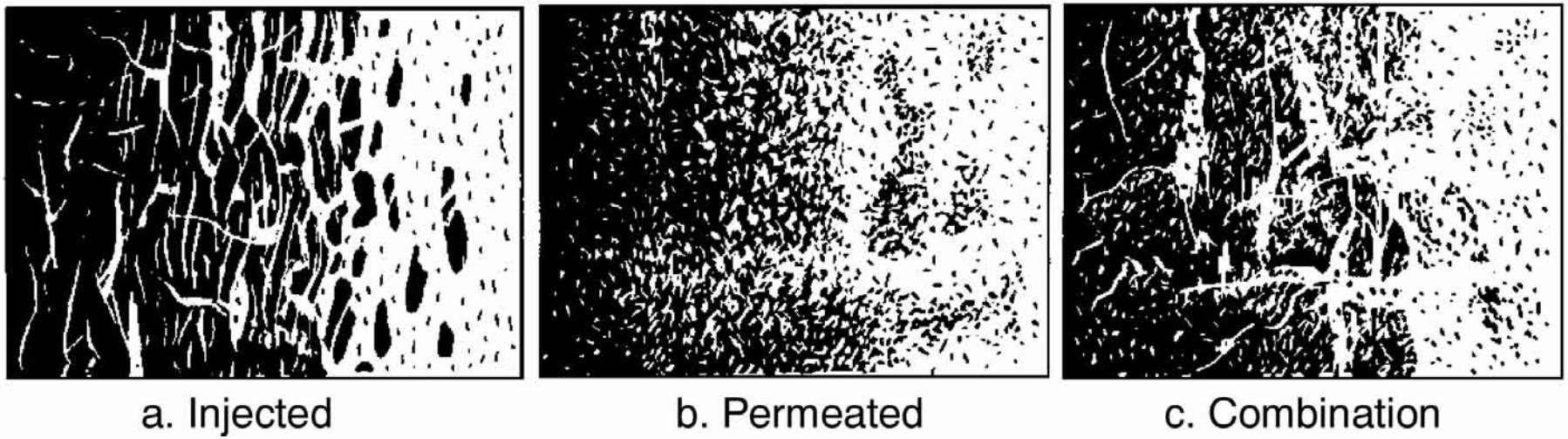


Figure 4-27. Gradational border zones between homogeneous igneous rock (light) and country rock (dark). After Compton (1962), *Manual of Field Geology*. © R. Compton.

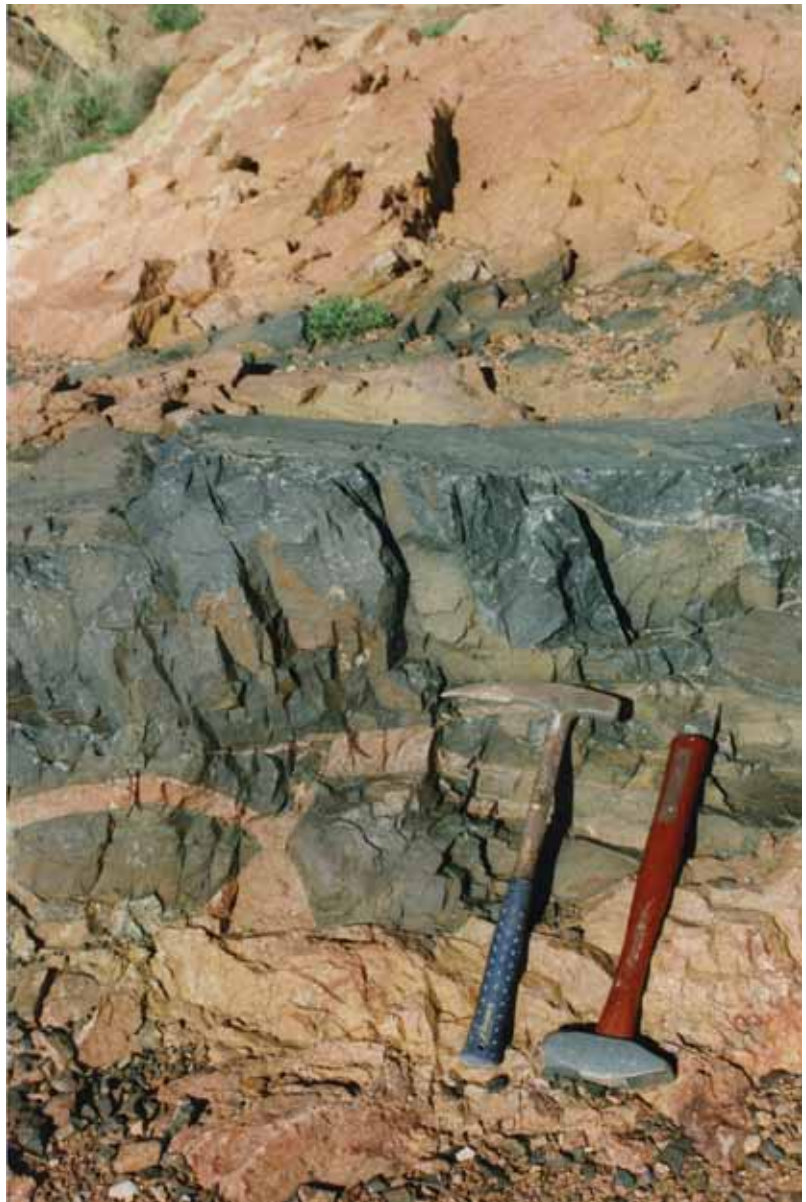
Structures and Field Relationships

Figure 4-28. Marginal foliations developed within a pluton as a result of differential motion across the contact. From Lahee (1961), *Field Geology*. © McGraw Hill. New York.

Flow banding and mafic clots

Complicated intrusive contacts

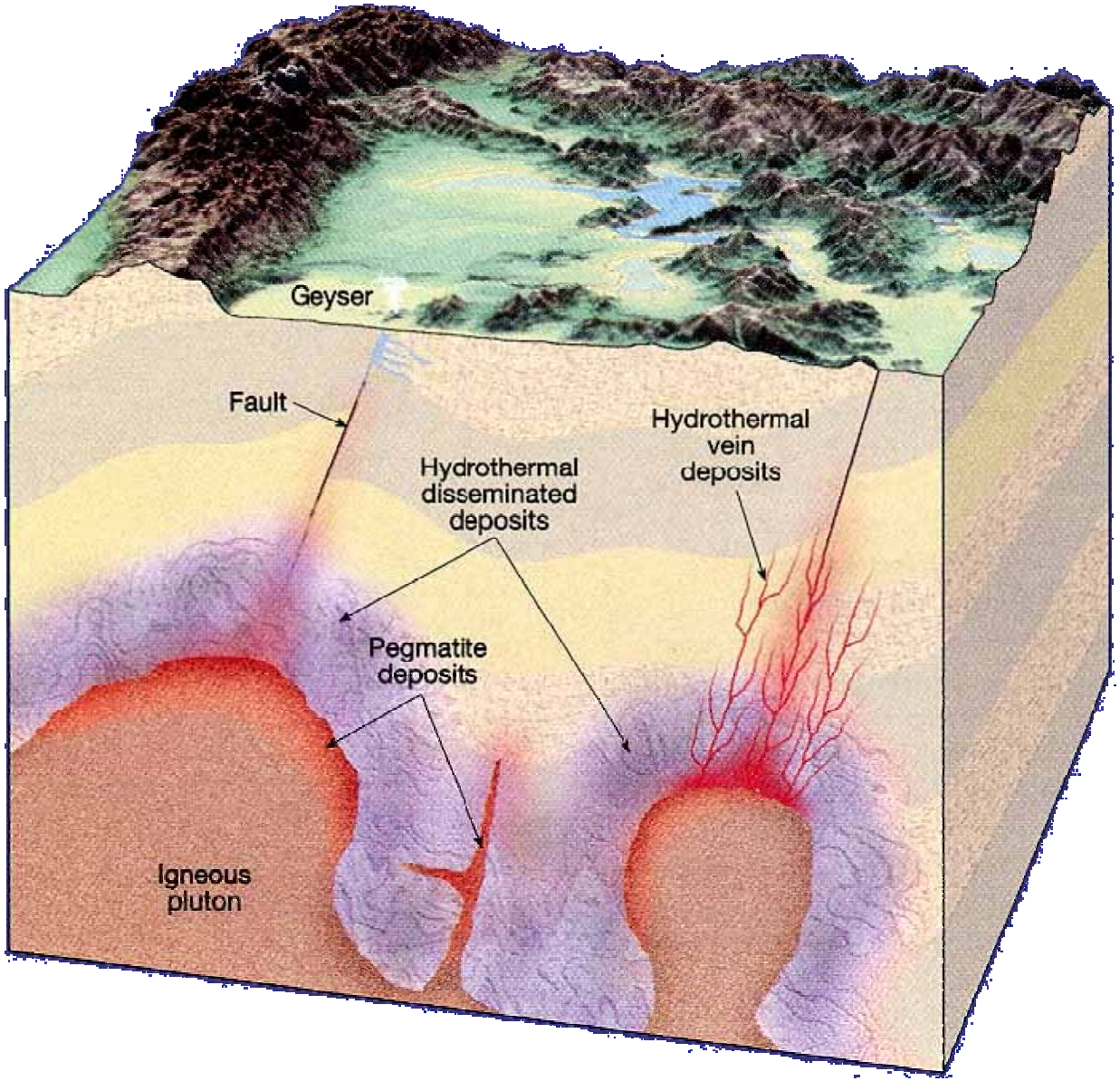
- Diabase dike injected into shallow granitic pluton
- Was the pluton solid or was it still partially melt during dike emplacement?
- Magma mixing



Assimilation of country rock

- If we don’t see xenoliths, does that mean it didn’t happen?

What is a pegmatite?



8 cm tourmaline crystals from pegmatite

5 mm gold from a hydrothermal deposit

- Concentrate incompatible elements
- Complex: varied mineralogy
  - May display concentric zonation

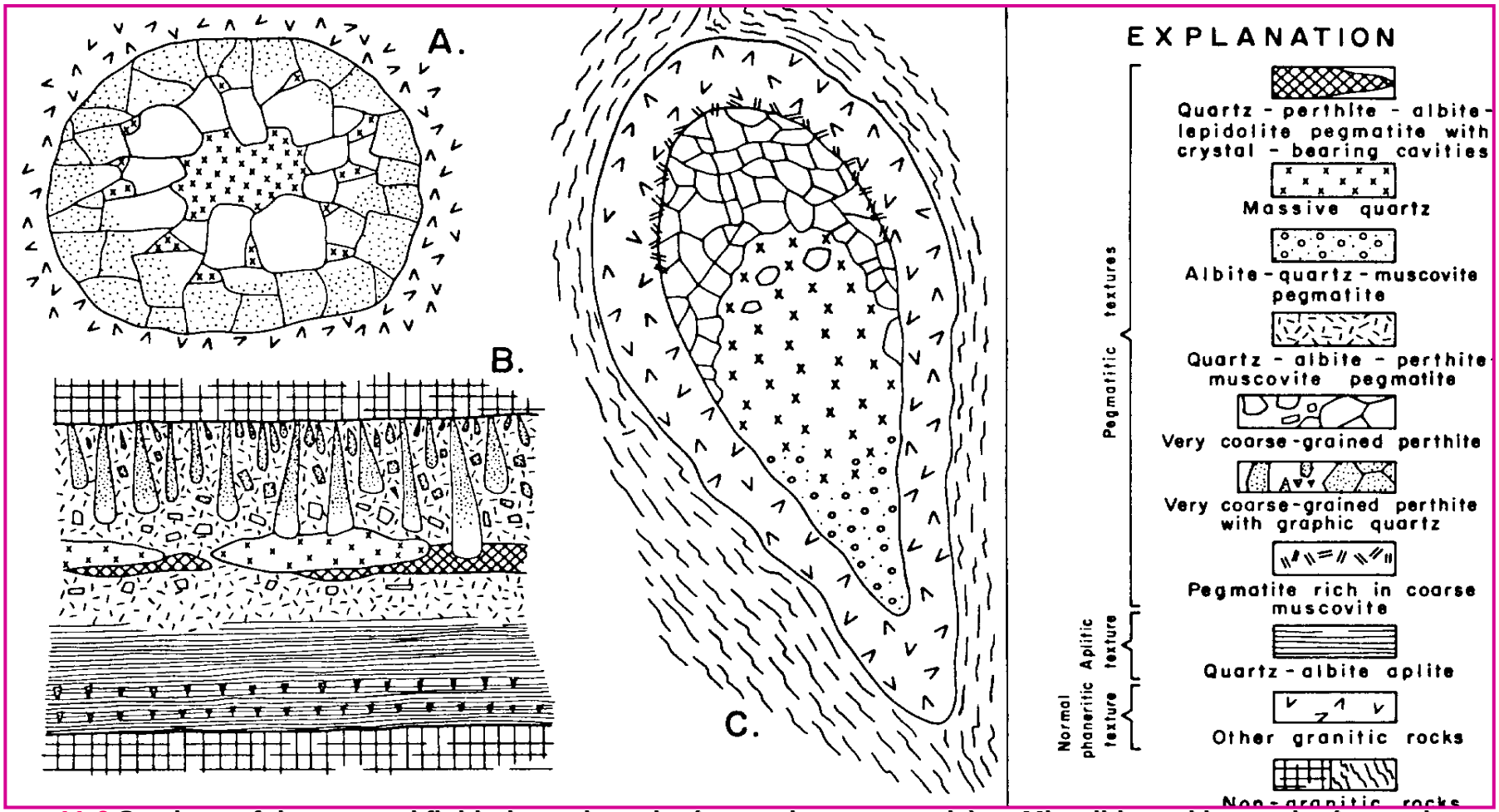
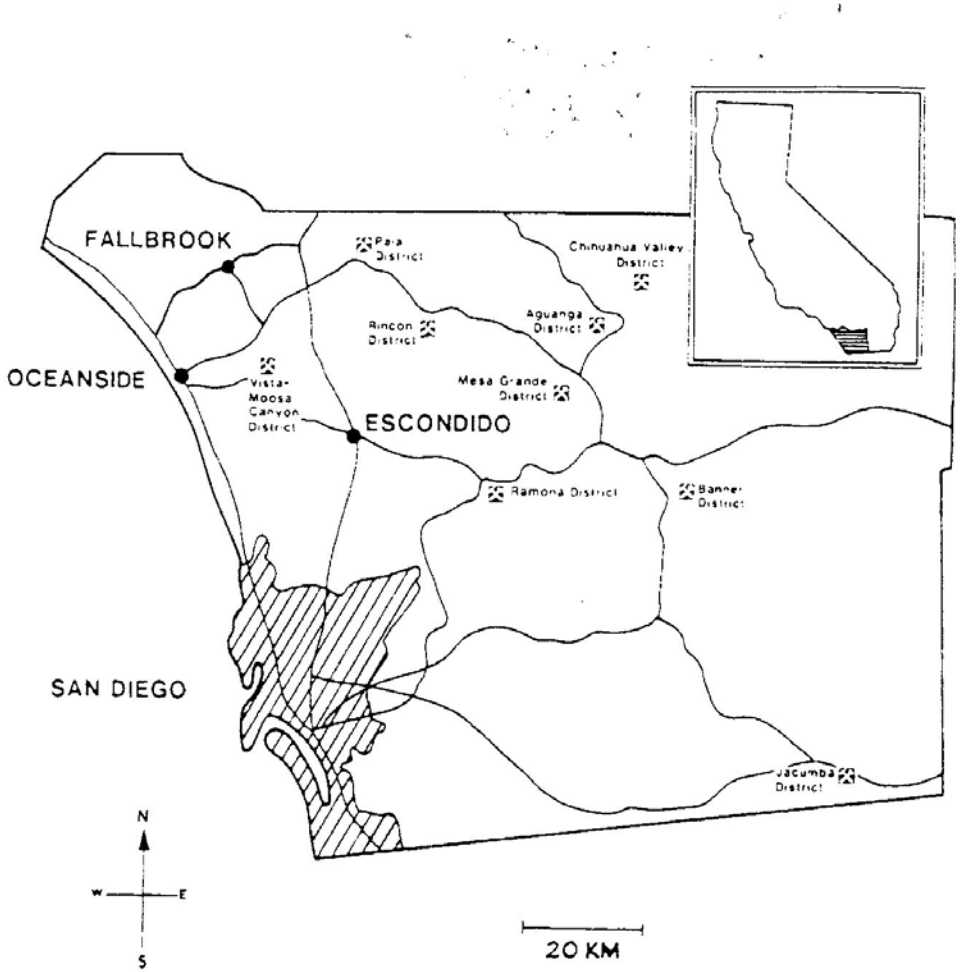


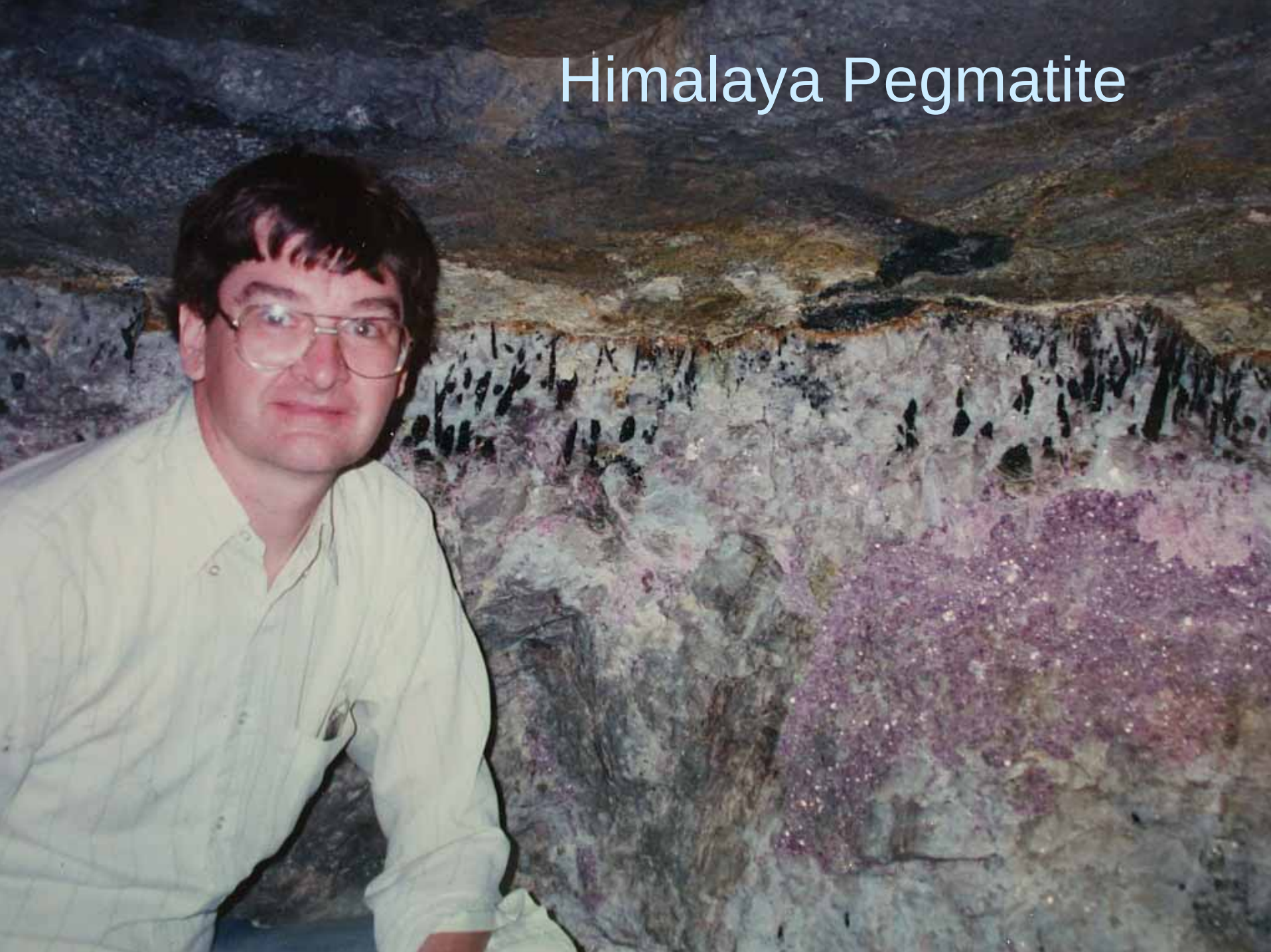
Figure 11-6 Sections of three zoned fluid-phase deposits (not at the same scale). **a.** Miarolitic pod in granite (several cm across). **b.** Asymmetric zoned pegmatite dike with aplitic base (several tens of cm across). **c.** Asymmetric zoned pegmatite with granitoid outer portion (several meters across). From Jahns and Burnham (1969). *Econ. Geol.*, 64, 843-864.

Famous pegmatite localities

- Minas Gerais, Brazil
- Afghanistan
- Virginia/North Carolina
- Pala, California region

Pala, California




Himalaya Pegmatite

Quartz

Large Brazilian crystals in Muséum National d'Histoire Naturelle

Smoky Quartz from Yuzhnyj, Southern Ural Mountains, Russia (over 200 kg)

http://www.rockshop.cz/giantgallery.htm

Feldspar

Potassium feldspar (variety amazonite) at the Ipe Mine, Minas Gerais, Brazil

Photo courtesy of Brenden Laurs

Mica crystals in the Ipe Mine, Minas Gerais, Brazil

$X_2Y_{4-6}Z_8O_{20}(OH,F)_4$

Photo courtesy of Brenden Laurs

Beryl crystals in the Ipe Mine, Minas Gerais, Brazil

$Be_3Al_2Si_6O_{18}$

Minerals from San Diego/Pala

Kunzite

Minerals from San Diego/Pala

Tourmaline

Topaz ($Al_2SiO_4(OH,F)_2$), smoky quartz on albite

Field trip planning

- See web site
- Discuss food, travel, things to bring