Advanced Structural Geology, Fall 2022

Cleavage, Foliation, Lineation

Ramón Arrowsmith

ramon.arrowsmith@asu.edu

School of Earth and Space Exploration

Arizona State University

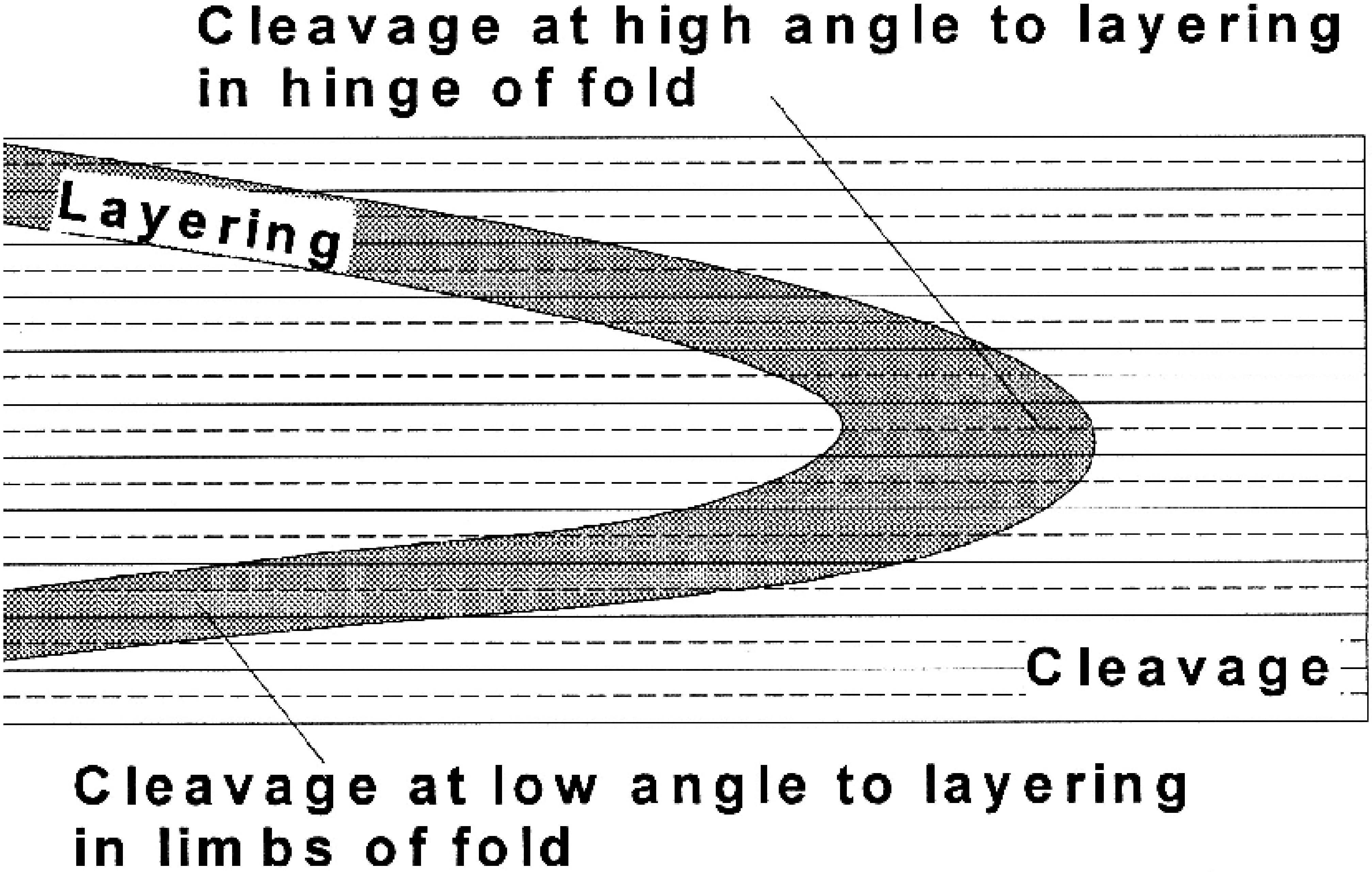
Cleavage, Foliation, Lineation

- Rock fabric: Total sum of grain shape, grain size, and grain configuration in a rock.
- Foliation is a planar fabric
  - Cleavage is a common kind of foliation
- Lineation is a linear fabric

Note that most of the graphics in this lecture come from Davis, Reynolds, Kluth textbook

Cleavage

- **Rock cleavage: Broadly refers to spaced, aligned, planar to curviplanar surfaces that tend to be associated with folds and oriented parallel to or fan-shaped relative to the axial surfaces. Commonly penetrative and form without apparent loss of cohesion.**


Cleavage at high angle to layering in hinge of fold
Layering
Cleavage
Cleavage at low angle to layering in limbs of fold

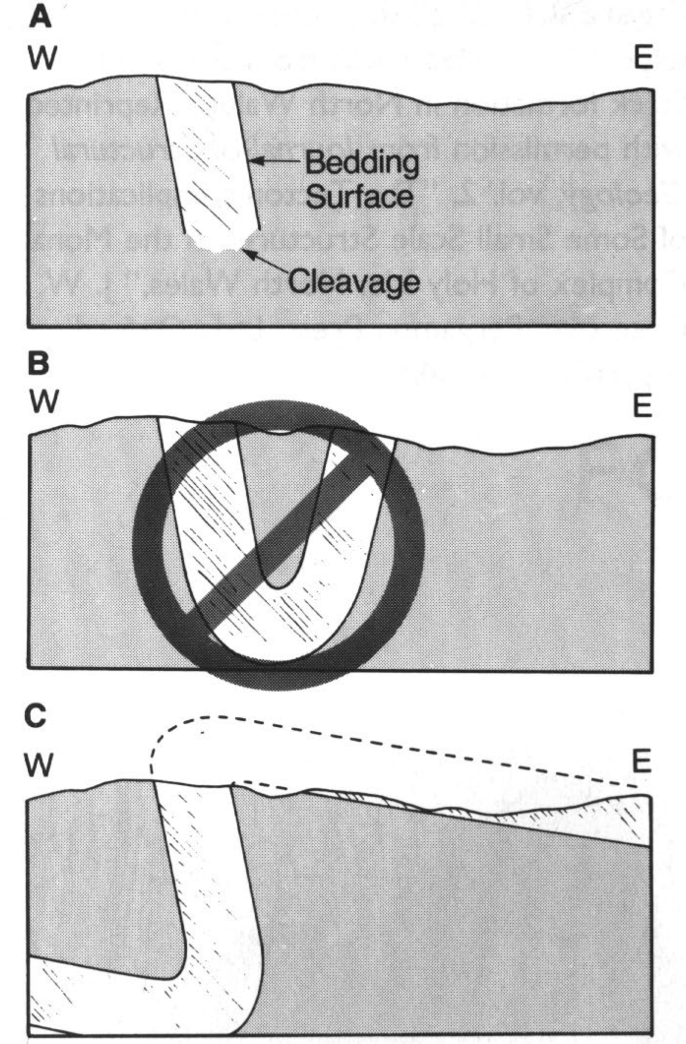


Figure 8.5 Use of the orientations of bedding and cleavage to construct the form of the fold with which the bedding and cleavage are associated. (*A*) The outcrop relationships. (*B*) Misfit between the cleavage orientation and the interpreted fold form. (*C*) A good fit!

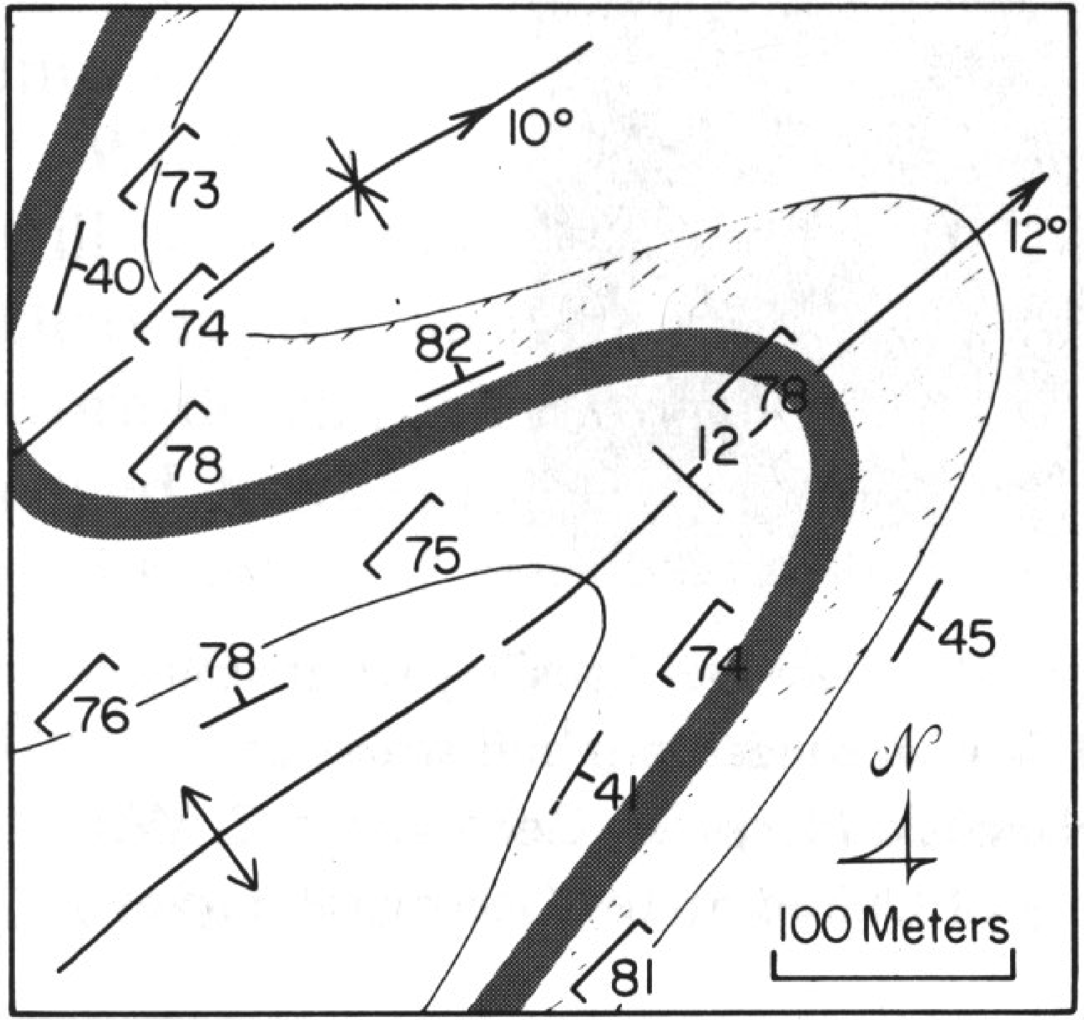


Figure 8.7 Geologic map expression of the relationship(s) between cleavage and folded bedding.

Foliation

- "…mesoscopically penetrative parallel alignment of planar fabric elements in a rock, usually in a metamorphic rock"
  - Can be primary (igneous or sedimentary)

Primary foliation in a volcanic rock

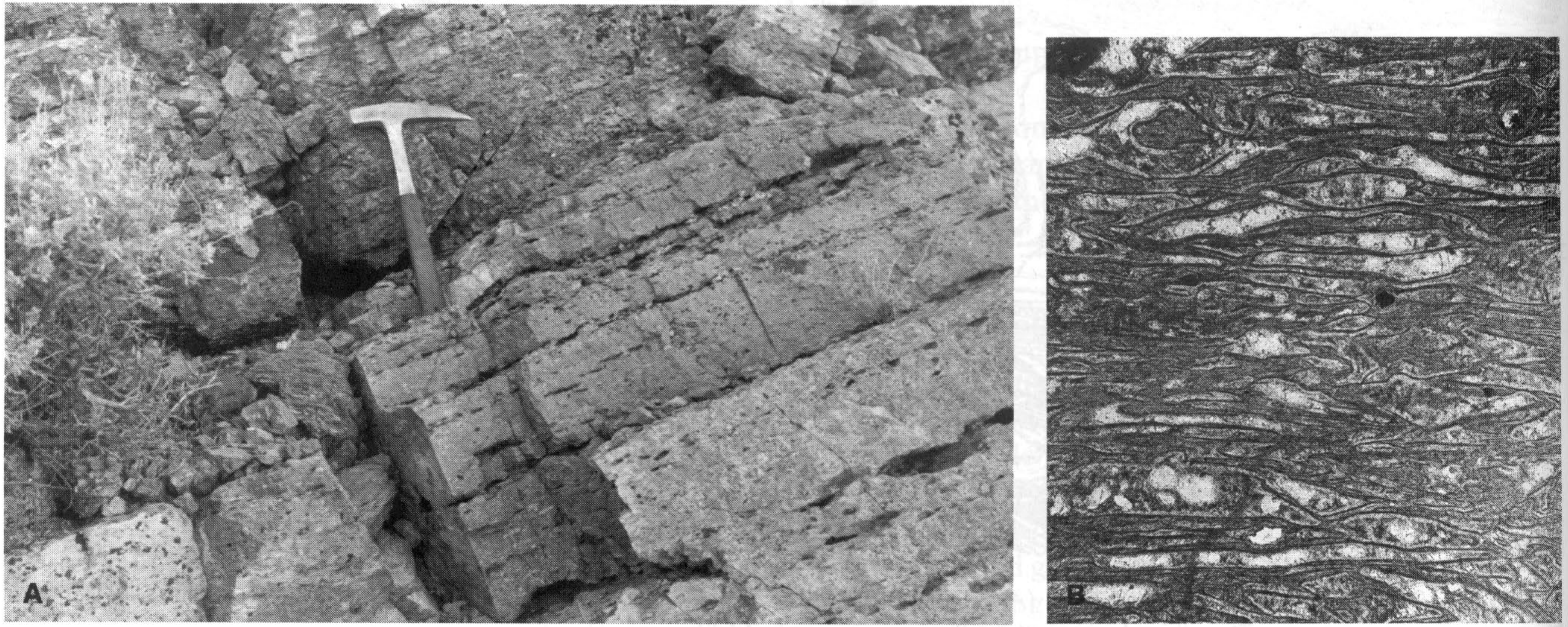
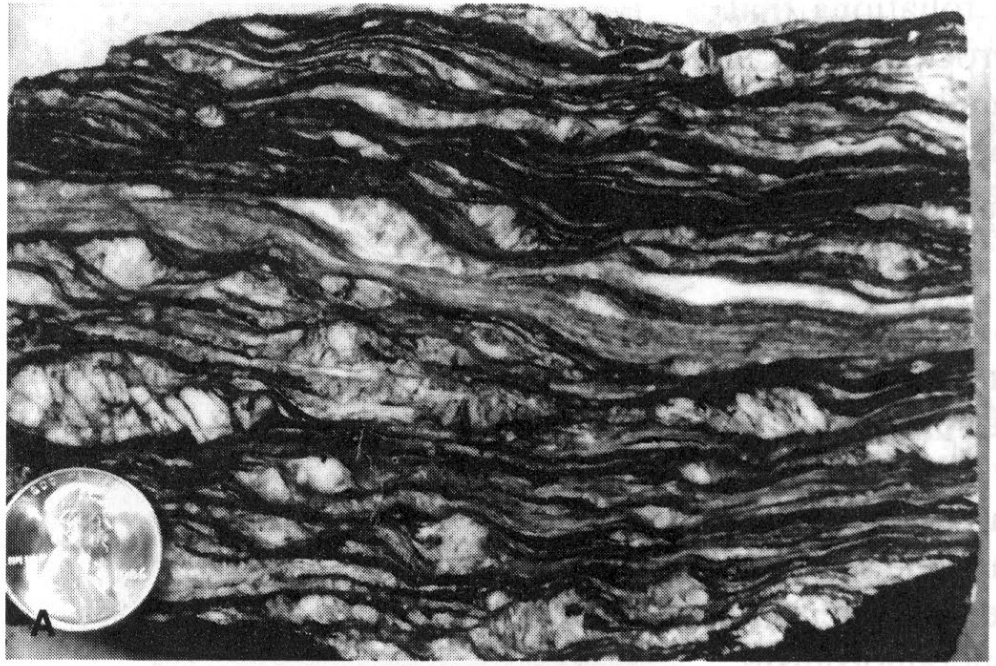
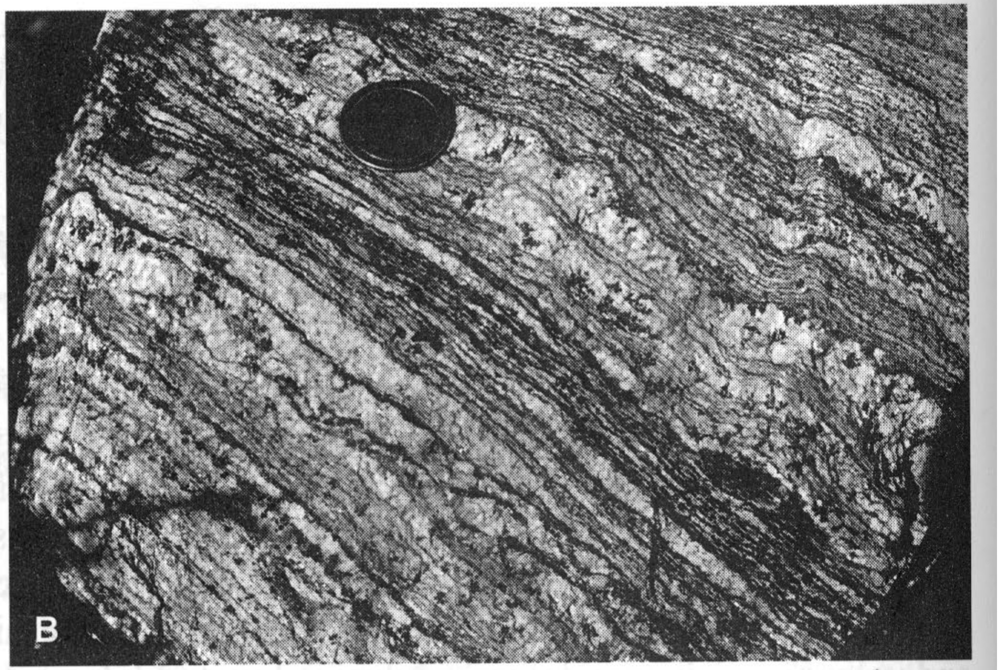


Figure 8.49 (*A*) Eutaxitic structure within a Tertiary ash flow sheet in Nevada. Lower right half of outcrop is composed of densely welded tuff. Partings in the tuff follow concentrations of pumice lapilli, which have been preferentially weathered out. (Photograph by P. W. Lipman. Courtesy of United States Geological Survey.) (*B*) Photomicrograph of primary igneous foliation in rhyolite from the Creede caldera, San Juan Mountains, Colorado. (Photograph by J. C. Ratte. Courtesy of United States Geological Survey.)





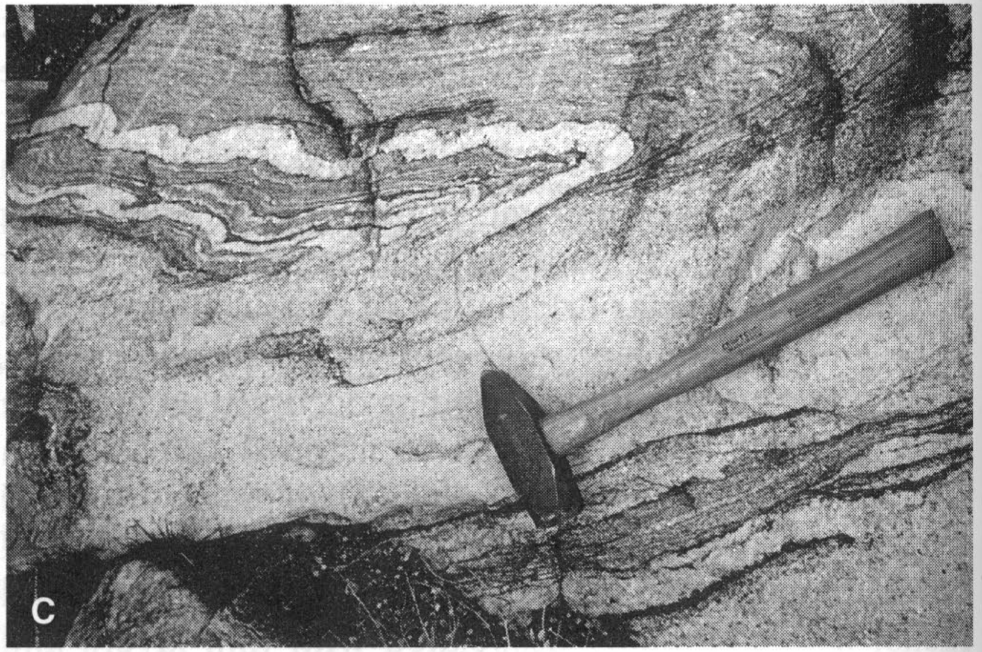
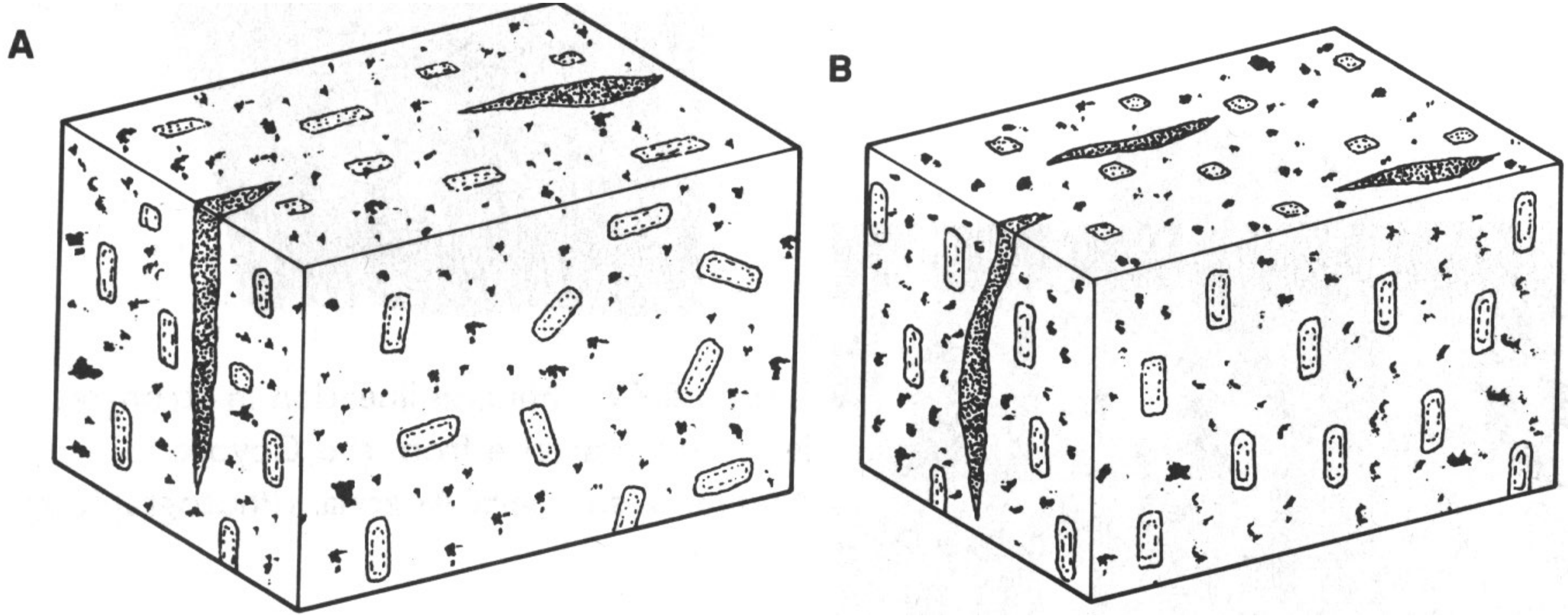


Figure 8.52 (*A*) Mylonitic granitic gneiss, with gneissic foliation defined by feldspar porphyroclasts (white) and "ribbons" of quartz with mica. (Photograph by Carol Simpson.) (*B*) Banded granitic gneiss. (*C*) Banded gneiss and migmatite. The original rock was Precambrian, but it acquired a strongly foliated fabric during Cretaceous regional metamorphism and intrusion. Harquavar Mountains, western Arizona. (Photographs by S. J. Reynolds.)

Lineation

- **"…subparallel to parallel alignment of elongate, linear fabric elements in a rock body, commonly penetrative at the outcrop and/or hand sample scales of observation"**
  - **Can be primary (igneous or sedimentary)**
  - **Includes slickenlines**



Lineation vs. foliation

Figure 8.60 These feldspar drawings by Evans B. Mayo illustrate the fabrics I saw in a granite outcrop in Norway. Both rocks appear to be foliated, yet one is and one is not. (*A*) This drawing shows a granite that contains foliation defined by feldspars, but no lineation. (*B*) This drawing shows a granite that contains lineation defined by feldspars, but no foliation.

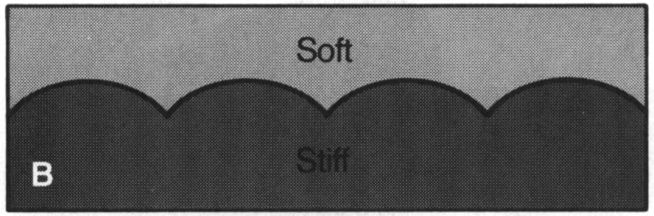
Lineation

Figure 8.65 Cigar-shaped stretched pebble, enjoyed by Stan Keith in the Tortolita Mountains, southern Arizona. (Photograph by G. H. Davis.)

Figure 8.66 This rod occurs in a strongly deformed outcrop of Devonian Excellsior Phyllite in the central Andes of Peru. The landscape within this general outcrop area was strewn with rods, many of them streamlined like bombs. (Photograph by G. H. Davis.)

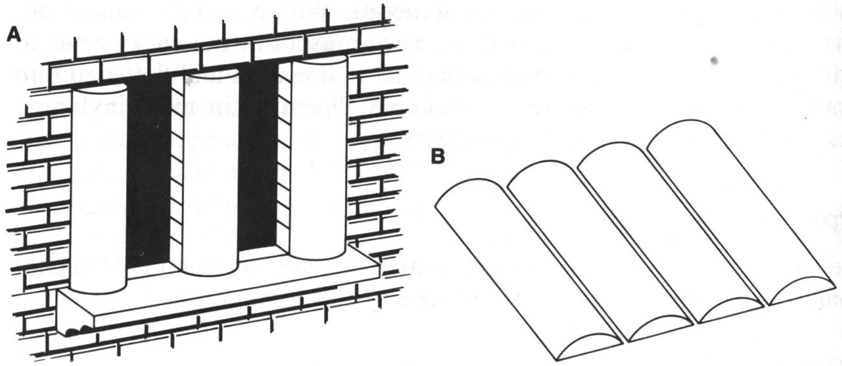
Mullions

Figure 8.67 Architectural mullions (*A*) adorning a Gothic church and (*B*) lined up on the ground in a way resembles geologic mullions.



(*B*) Mullions form preferentially at the interface between mechanically soft vs. mechanically stiff rocks. Buckling instability due to layer parallel compression produces the cuspate–lobate pattern.

Structural Ge



Boudins—French for Sausage; another form of lineation

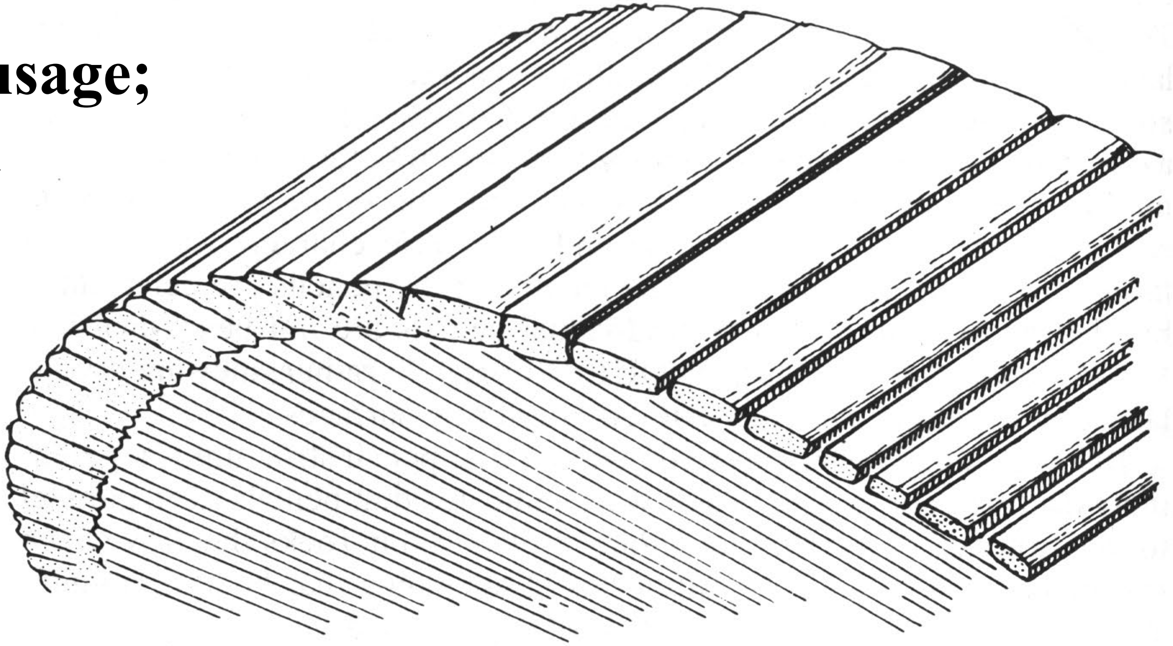
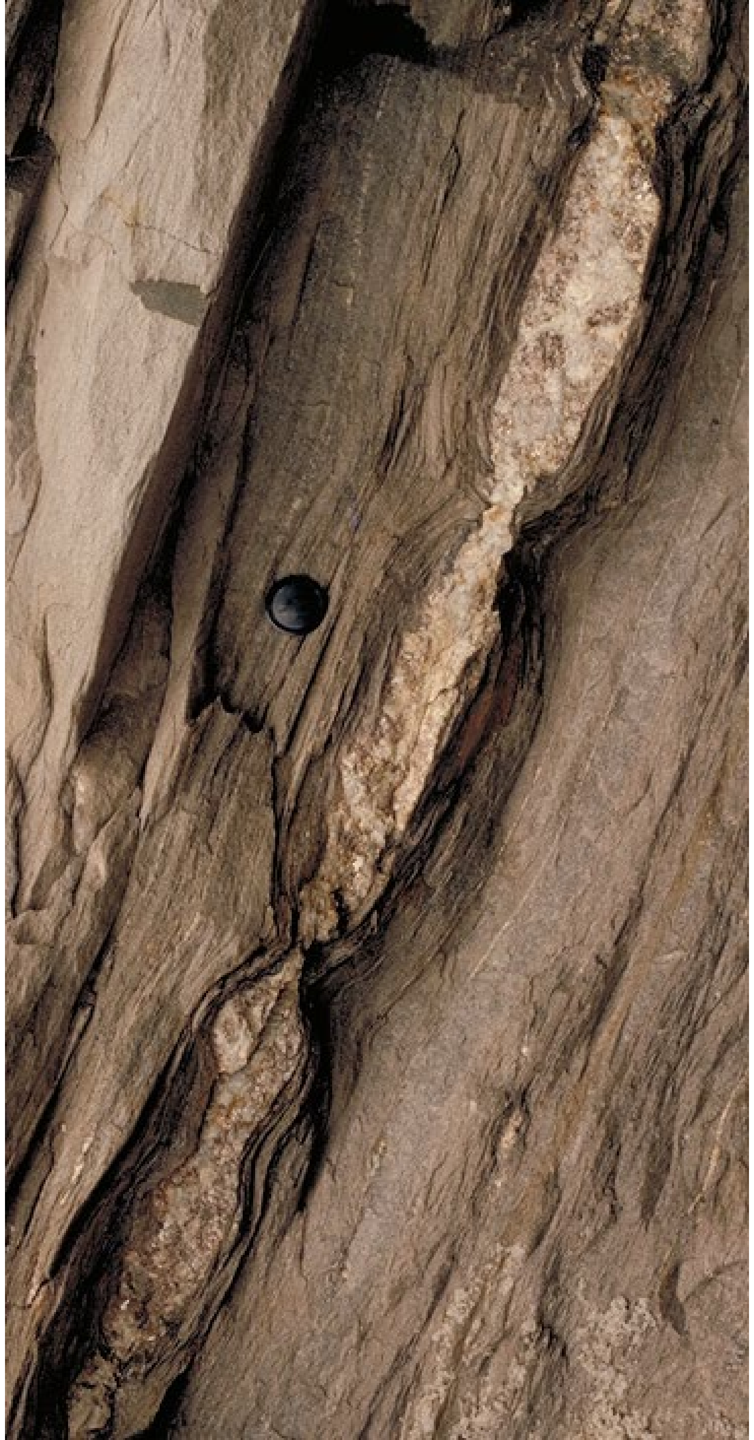


Figure 8.70 Boudins on the flank of a fold. [From *Introduction to Small-Scale Geological Structures* by G. Wilson. Published with permission of George Allen & Unwin (Publishers) Ltd., London, copyright © 1982.]



More Boudins

Why do we care?

- Tectonites
- Sense of shear

→Structures can relate small scale deformation to large scale context

Figure 8.80 A thick viscous pancake batter, plus the right equipment, can result in early-morning experimental production of stretching fabrics (L-tectonites), flattening fabrics (S-tectonites), and combo fabrics (LS-tectonites). I prefer the S variety.

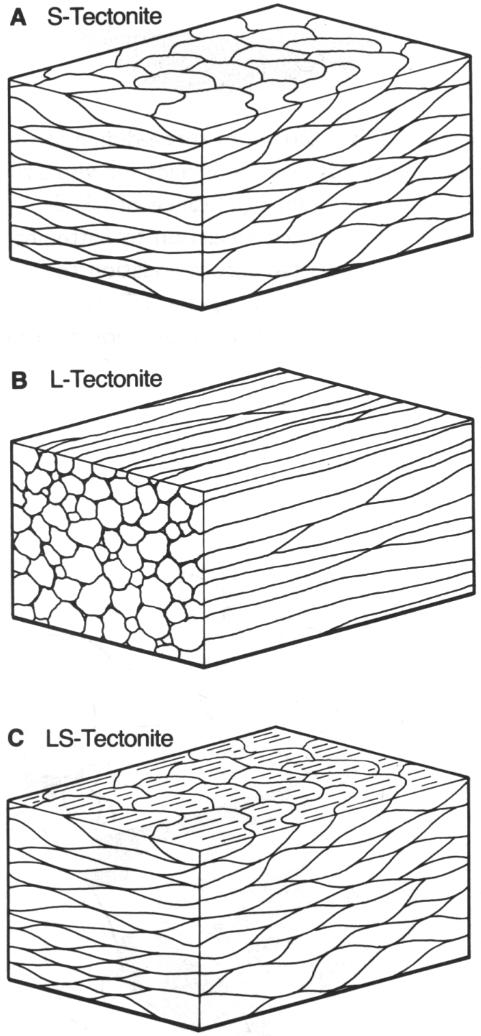


Figure 8.78 Schematic portrayal of S-, L-, and LS-tectonites. (*A*) S-tectonites are marked by a single, penetrative foliation. (*B*) L-tectonites are marked by pervasive lineation, but no foliation. (*C*) LS-tectonites are marked both by foliation and lineation. The lineation in LS-tectonite lies in the plane of foliation.

Predominantly flattening
--single foliation

Predominantly constriction
--single lineation

Mixed
--lineation contained in the foliation

Plane strain—all deformation only in the S_1-S_3 plane, $S_2 = 1$

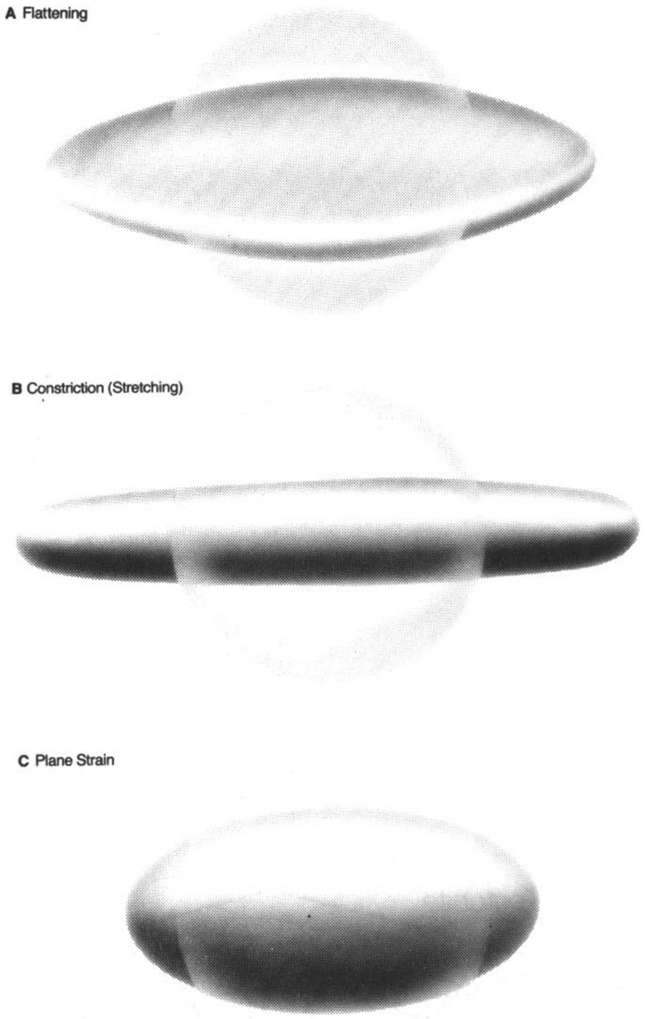


Figure 8.79 Shapes of three-dimensional strain ellipsoids provide images for visualizing the idealized strain significance of (*A*) S-tectonites (an accommodation to flattening), (*B*) L-tectonites (an accommodation to unidirectional stretching), and (*C*) LS-tectonites (commonly an expression of plane strain).

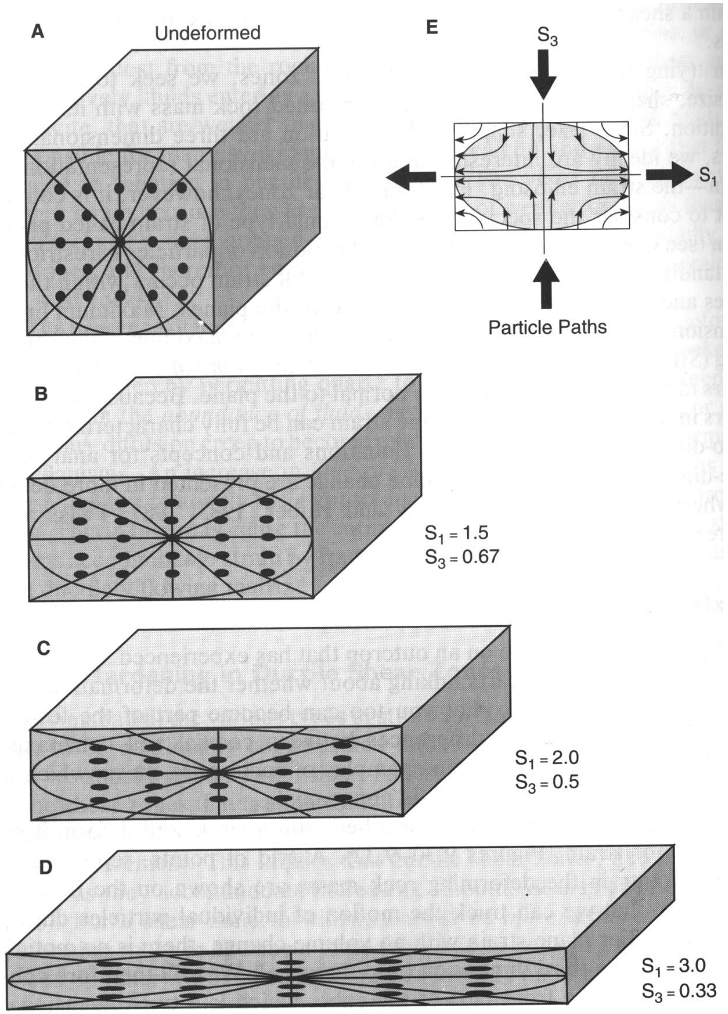


Figure 9.31 Pure shear of a cube. (*A–D*) Cube is converted to progressively flatter, boxlike shapes by vertical shortening and horizontal extension. The successive diagrams, from top to bottom, represent progressive increments of deformation and increasing amounts of strain. S_1 and S_3, the principal finite stretches, are shown for each stage. Note that they are reciprocals of one another. (*E*) Overall displacement paths for particles during deformation [Part E modified from Twiss and Moores (1992)].

Sense of Shear

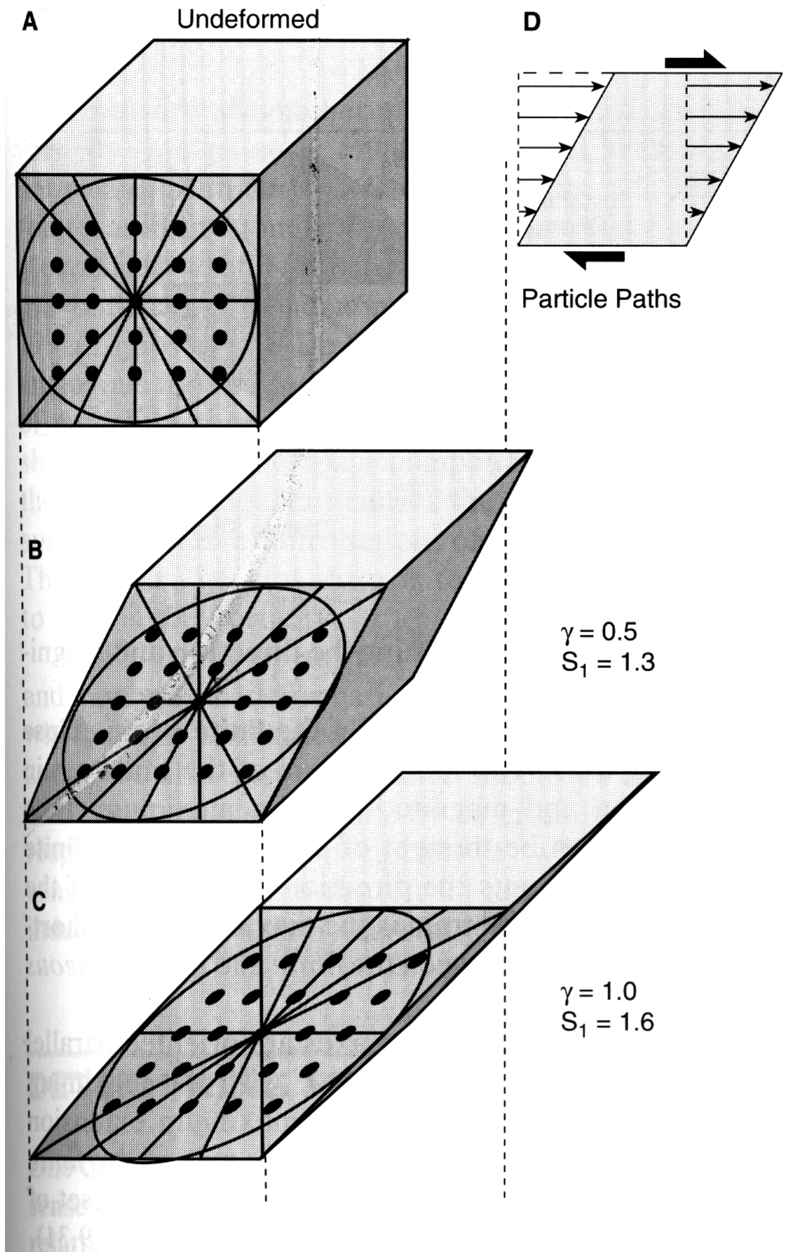


Figure 9.32 Simple shear of a cube. (*A–C*) Cube is converted to progressively more angular, rhomblike shapes by dextral simple shearing. The successive diagrams represent progressive increments of simple shear and increasing amounts of strain. Shear strain (γ) and S_1 are shown for each stage. (*D*) Overall displacement paths for particles during deformation [Part D modified from Twiss and Moores (1992)].

- Identify sense of shear plane: perpendicular to the foliation and containing the lineation

Sense of shear

S-C fabric: S surface = schistosity,
C surface = "cisaillement" (high shear strain) shear bands

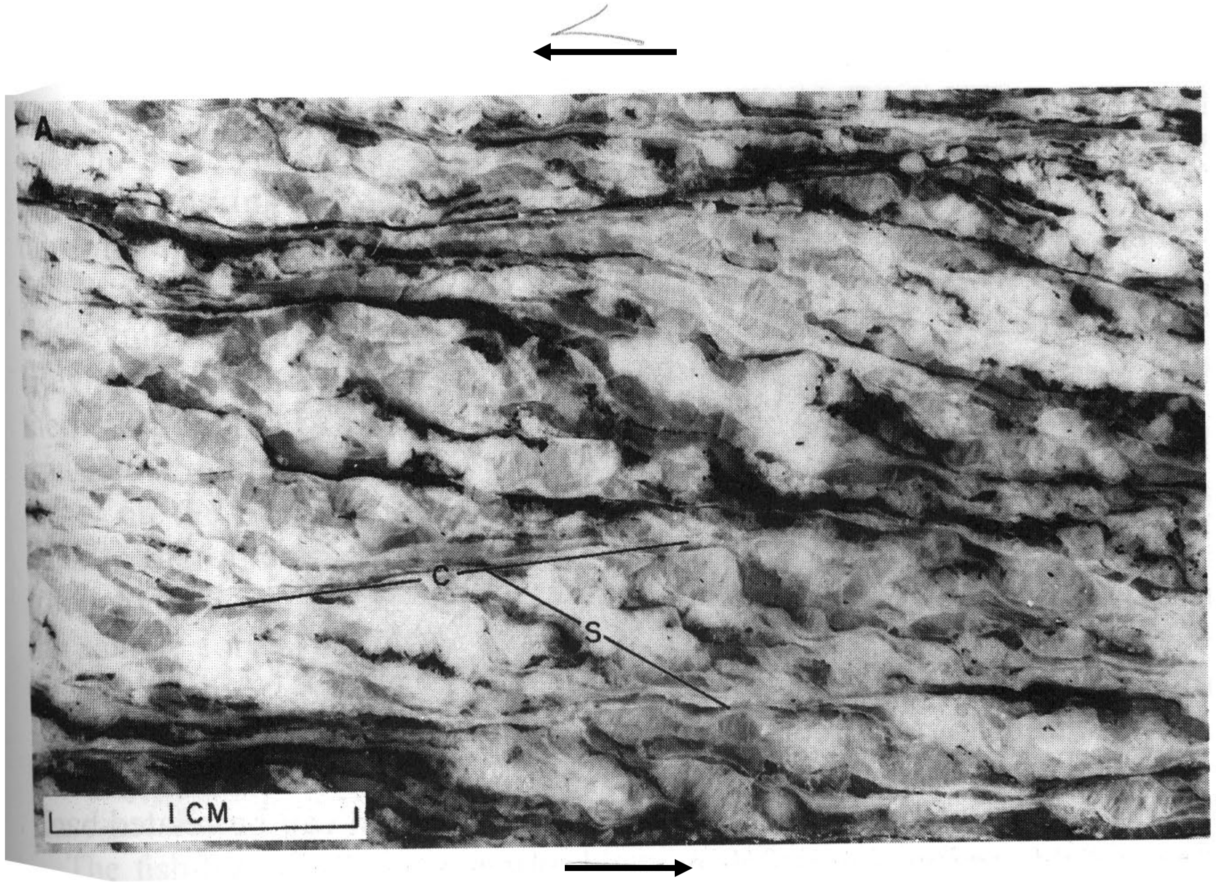
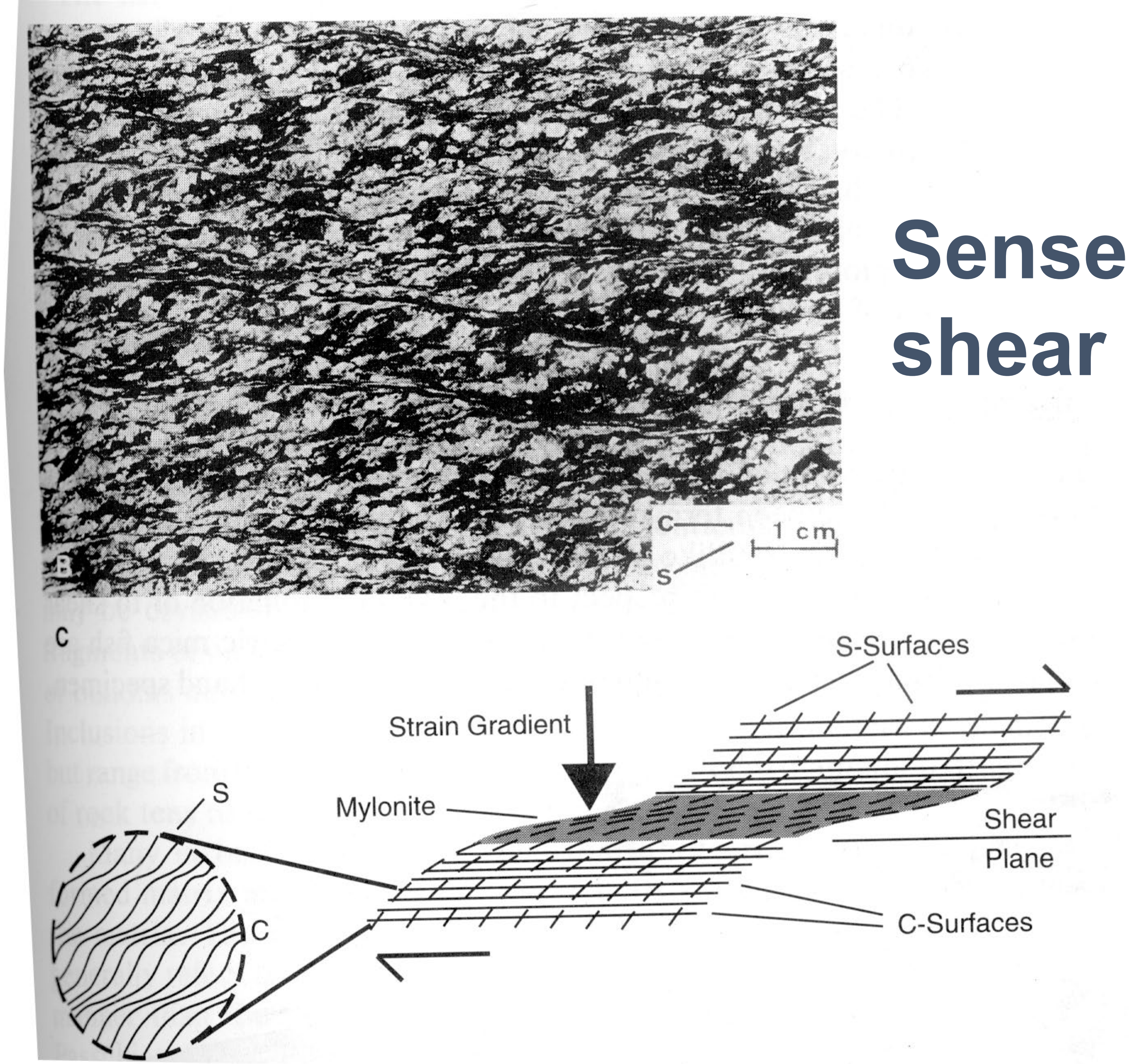


Figure 9.44 S-C fabrics. (*A*) S-C fabric in polished slab of Tertiary granodiorite, South Mountains, Arizona. Sense of shear is sinistral. (Photograph by S. J. Reynolds.) (*B*) S-C fabric in late Cretaceous pluton within the Santa Rosa mylonite zone, southern California. Sense of shear is dextral. [From Simpson and Schmid (1983). Published with permission of the Geological Society of America and the authors.] (*C*) S-C fabrics mimic the sigmoidal foliation patterns in the host shear zone. [From Hanmer and Passchier (1991). Courtesy of the Geological Survey of Canada.]



Sense of shear