JOINTS

- I Main Topics
  - A Scientific method
  - B Why are joints important?
  - C Observations of joints
  - D Formulation and testing of hypotheses: The origin of joints
- II Scientific method (See Fig. 1.1)
- III Why are fractures important?
  - A Most common geologic structures on earth (joints in particular)
  - B Exceedingly important in heat & fluid flow (all sorts of fluids)
  - C Earthquake faults are fractures
  - D Important in determining geologic & engineering rock strength
  - E Main types of fractures: Joints, dikes, faults, and pressure solution surfaces (See Fig. 24.1 for some examples)
- IV Observations of joints
  - A **Geometry**
    - 1 **Thin relative to their in-plane dimensions**
    - 2 **Bounded in extent**
    - 3 **Relatively planar** (how do we know?)
    - 4 Shape of an "isolated" joint
      - a Massive rocks: joints are probably elliptical or circular
      - b Layered rocks: joints are probably rectangular
  - B Composition: Joints can be mineralized or unmineralized
  - C Kinematics
    - 1 Cut adjacent material; joints are younger than materials they cut
    - 2 Relative (not absolute) displacement of originally neighboring points is perpendicular to the joint
  - D Surface textures of joints (See Fig. 24.2)
    - 1 Plumose structure
    - 2 Hackles
    - 3 Ribs
    - 4 **These are virtually identical to surface textures of opening mode fractures produced in engineering tests**

- E Occurrences of joints
  - 1 Sedimentary rocks (Bedded, porous)
    - a Bedding-perpendicular joints
    - b Mud cracks (Desiccation or shrinkage cracks)
    - c Exfoliation joints
    - d Stylolites as "anti-cracks" in carbonate rocks
  - 2 Volcanic rocks (Discontinuous, bedded, highly variable)
    - Cooling fractures/columnar joints
  - 3 Plutonic rocks (low porosity, isotropic crystalline rock)
    - a Exfoliation joints
    - b Radiating joints in stocks
    - c Cooling-related (??) joints in Sierra Nevada, California
  - 4 Metamorphic rocks (low porosity, anisotropic crystalline rock)
    Fractures along cleavage planes (e.g. shales)
- F Joint sets (joints rarely occur alone)
  - 1 Based on "similar" orientation and "similar" age
  - 2 Field evidence for relative age of joints
    - a T-intersections
    - b Curved approaches
    - c Mineralogy
  - 3 Systematic joints (joint traces are straight)
    Interpretation: Difference in far-field principal stresses (σ_1 - σ_2) is small relative to driving stress (σ_n^{remote} - σ_n^{joint})
  - 4 Nonsystematic joints (joint traces are irregular)
    Interpretation: Joints interact. Perturbing stresses associated with joints is large relative to difference in far-field principal stresses
  - 5 Mechanical significance of joint sets: widespread fracture failure of rock mass

V Formulation and testing of hypotheses: The origin of joints

- A Competing hypotheses: opening mode origin vs. shear mode origin
- B Field observations
  - 1 Joints can form at depth (they are encountered in mines and deep drill holes, so they can't be entirely surficial phenomena)
  - 2 Stresses at depth are characteristically large and compressive

C Laboratory observations of shear fractures

1 Laboratory compression tests produce "conjugate shear fractures"

2 The conjugate shear fractures form at essentially the same time

3 Shear fractures form at ~30° to maximum principal stress

4 Aligned opening mode cracks precede shear fractures

D Implications of detailed field and laboratory observations

Observations/Evidence	Opening origin	Shear origin
Relative displacement of joint walls	Favors	Disfavors
Surface textures	Favors	Disfavors
Single sets of joints are common	Favors	Disfavors

1 Opening-mode origin is favored over shear mode origin

2 Material heterogeneity (e.g., cockle shells in mud flats, fluid inclusions in grains, etc.) is important in the origin of joints

3 Body geometry (e.g., pre-existing "sharp points" [e.g., edges of older joints], bird footprint indentations in mudflats, etc.) is important in the origin of joints

4 Unresolved issue: how do joints open at depth where compressive stresses are large? (σ_n' = effective stress = σ_n - P)

E Terminology

1 Opening mode (dilatant fractures) is preferred

2 ~~"Extension fractures"~~ ? (cooling volcanic rocks contract)

3 ~~"Tension fractures"~~ ? (joints can form in response to fluid pressure)

Key Additional References

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Lawn, B.R., and Wilshaw, T.R., 1975, Fracture of brittle solids: Cambridge University Press, 204 p.

Olson, J., and Pollard, D.D., 1989, Inferring paleostress from natural fracture patterns: a new method: Geology, v. 17, p. 345-348.

Pollard, D.D., and Aydin, A., 1988, Progress in understanding jointing over the past century: Geological Society of America Bulletin, v. 100, p. 1181-1204.

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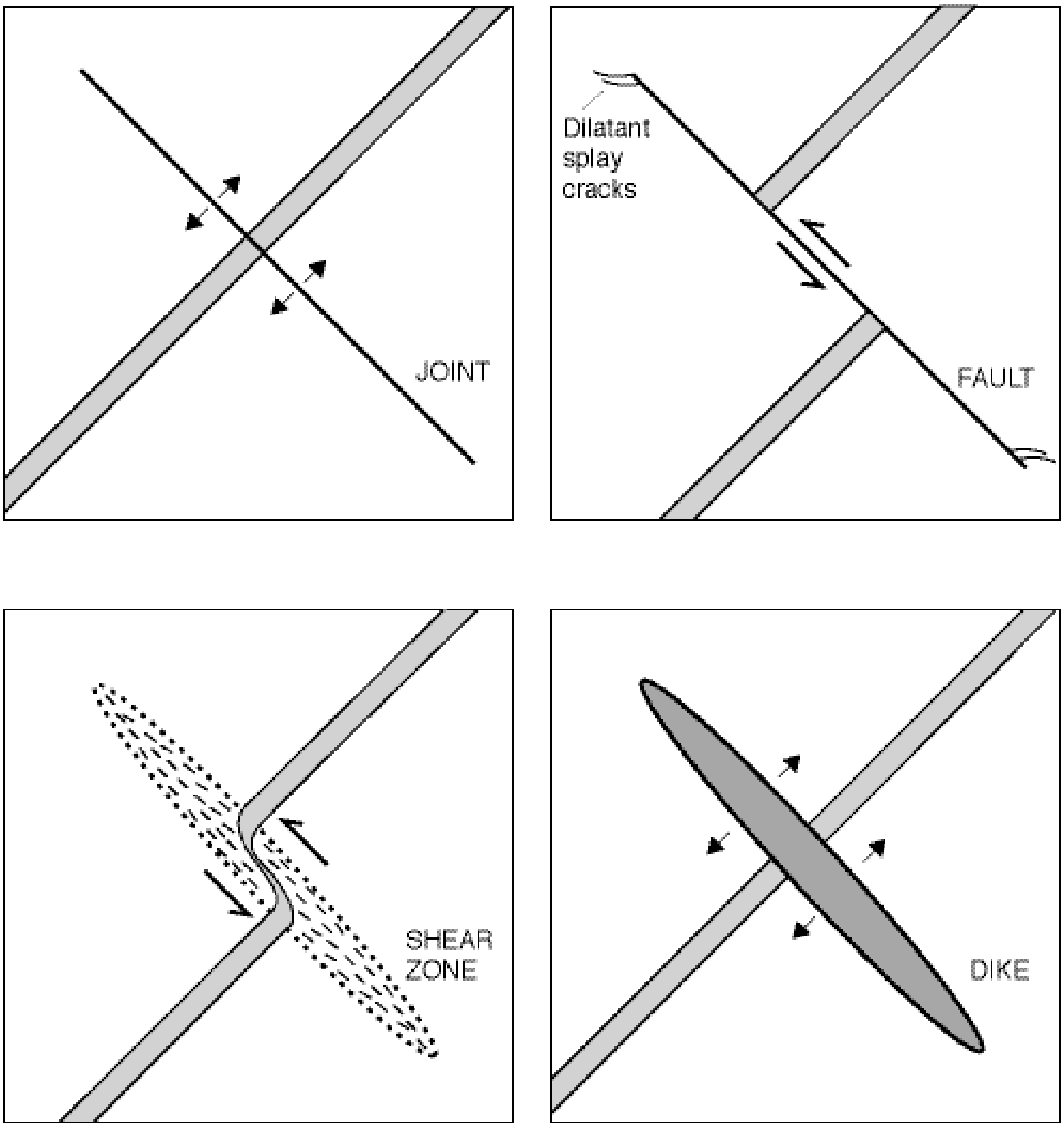
Fig. 28.1

FOUR PLANAR GEOLOGIC STRUCTURES



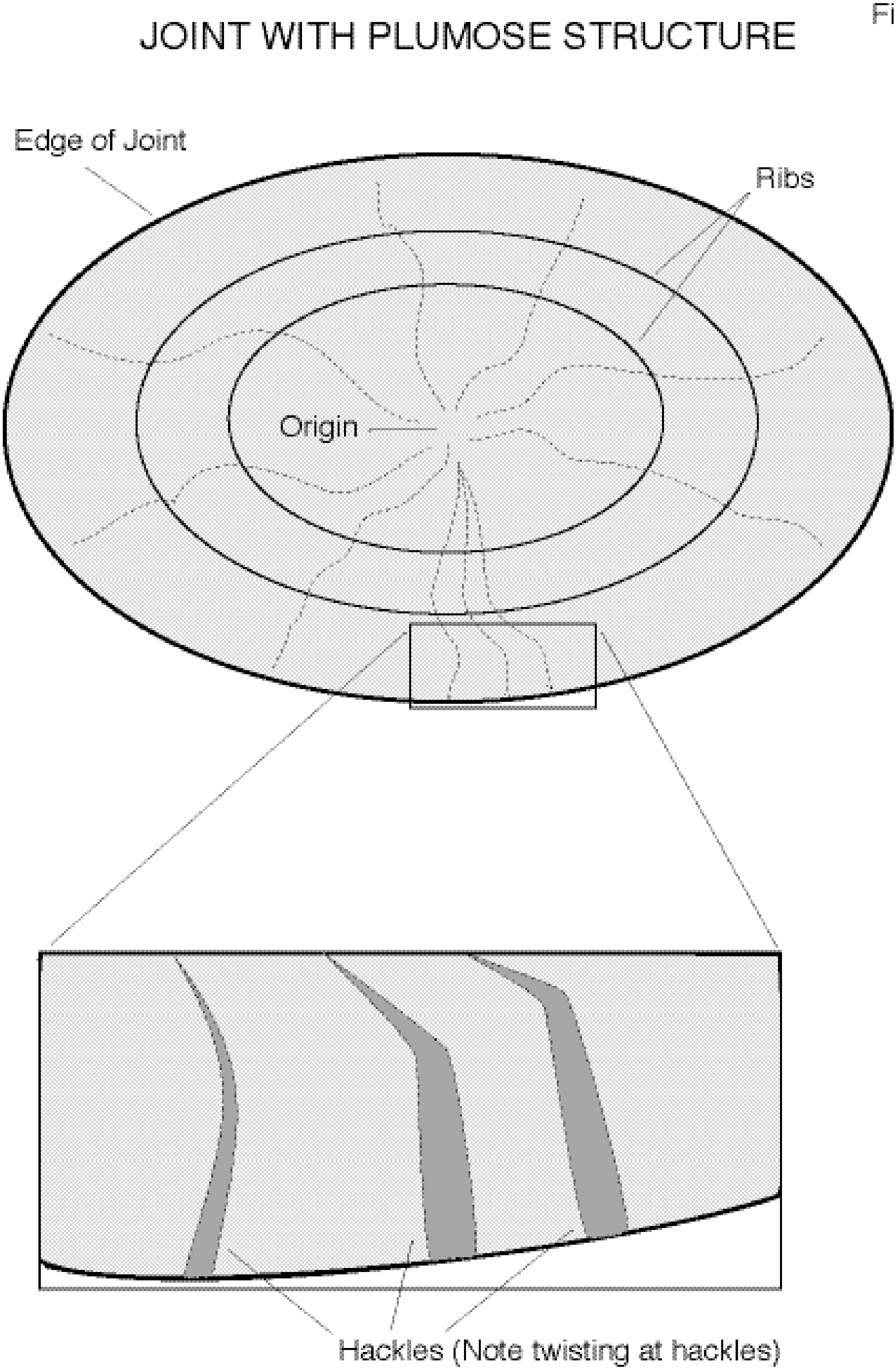
For joints and dikes (opening mode fractures) the relative displacement of originally neighboring points on opposing walls is perpendicular to the fracture

For shear zones and faults, the relative displacement of neighboring points is parallel to the feature

Deformation (displacement) is discontinuous across a fault

Deformation (displacement) is continuous across a shear zone

Fig. 28.2


JOINT WITH PLUMOSE STRUCTURE
Edge of Joint
Ribs
Origin
Hackles (Note twisting at hackles)