University of Tennessee at Chattanooga
ENCE 3610L

Overview of Rock and Soil Formation
Rock Quality Designation Test

Soils and Rocks

Definition of “Rock” and “Soil”

- Rock
  - Naturally occurring material composed of mineral particles so firmly bonded together that relatively great effort is required to separate the particles (i.e., blasting or heavy crushing forces).
  - Generally cemented
  - Lower porosity than soils
  - Properties much more variable due to weathering
  - Often discontinuous
  - More complex stress histories

- Soil
  - Naturally occurring mineral particles which are readily separated into relatively small pieces, and in which the mass may contain air, water, or organic materials (derived from decay of vegetation)
  - Rarely cemented
  - Higher porosity
  - Less variable due to weathering and decay
  - Generally Continuous
  - More predictable stress histories

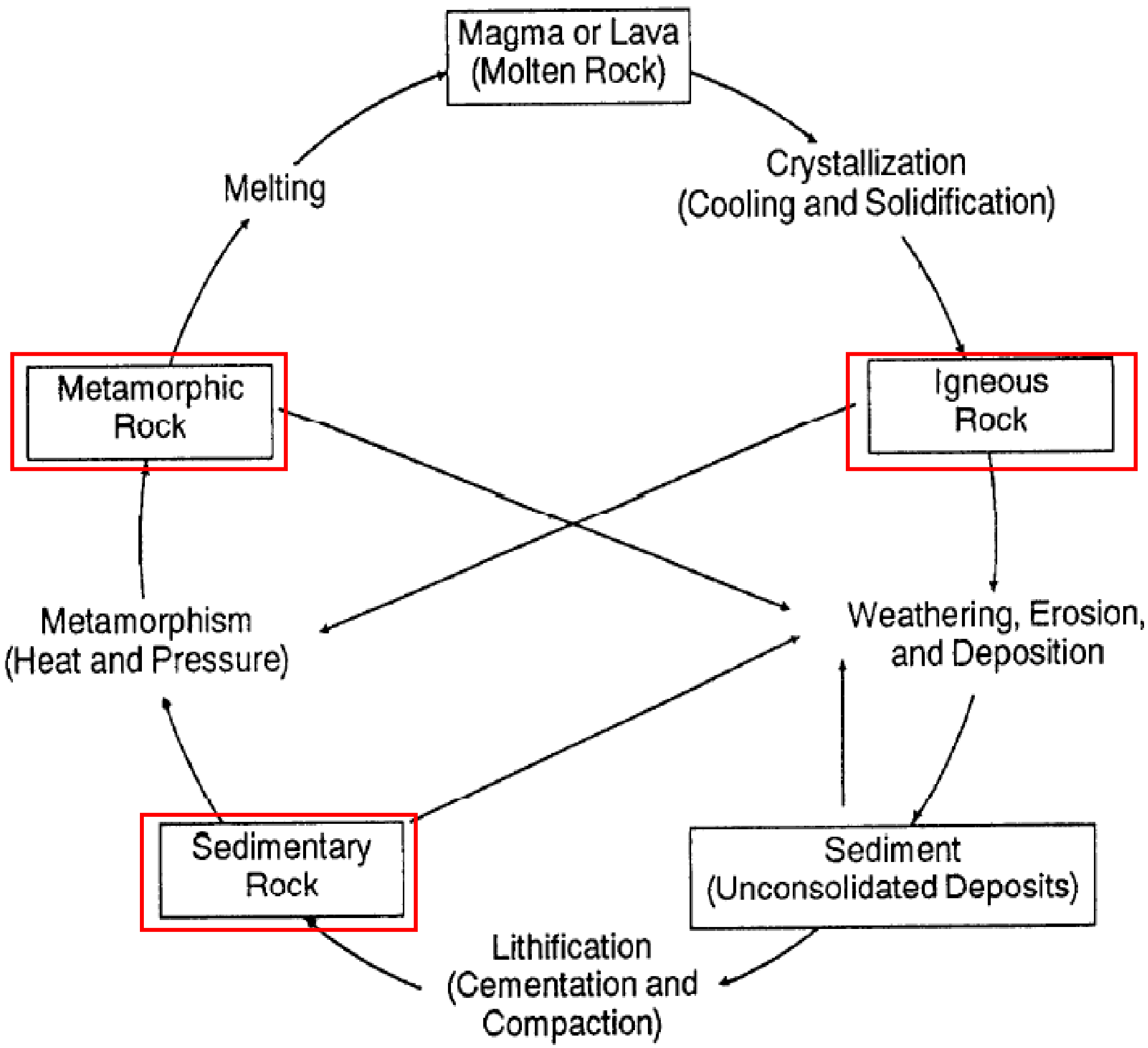
Rock (and Soil) Forming Minerals

- Feldspars
  - Crystalline feldspars are major components of most igneous rocks, gneisses, and schists. In the presence of air and water, the feldspars weather to clay minerals, soluble salts, and colloidal silica.
  - Feldspars form very hard, blocky, opaque crystals with a pearly or porcelain-like luster and a nearly rectangular cross section. Crystals tend to cleave in two directions along flat, shiny, nearly perpendicular surfaces.
  - Plagioclase varieties often have fine parallel grooves (striations) on one cleavage surface.
  - Orthoclase varieties are usually pink, reddish, ivory, or pale gray.
  - Where more than one variety is present, color differences are normally distinct.
- Quartz
  - Quartz (silicon dioxide) is an extremely hard, transparent to translucent mineral with a glassy or waxy luster. Colorless to white or smoky-gray varieties are most common, but impurities may produce many other colors.
  - Like man-made glass, quartz has a conchoidal (shell-like) fracture, often imperfectly developed. It forms pointed, six-sided prismatic crystals on occasion but occurs most often as irregular grains intergrown with other minerals in igneous and metamorphic rocks; as rounded or angular grains in sedimentary rocks (particularly sandstones); and as a microcrystalline sedimentary rock or cementing agent.
  - Veins of milky white quartz, often quite large, fill cracks in many igneous and metamorphic rocks.
  - Unlike nearly all other minerals, quartz is virtually unaffected by chemical weathering.

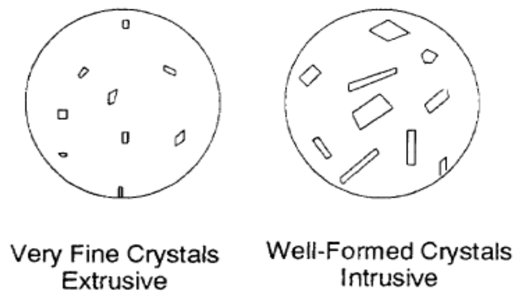
Rocks (and Soil) Forming Minerals

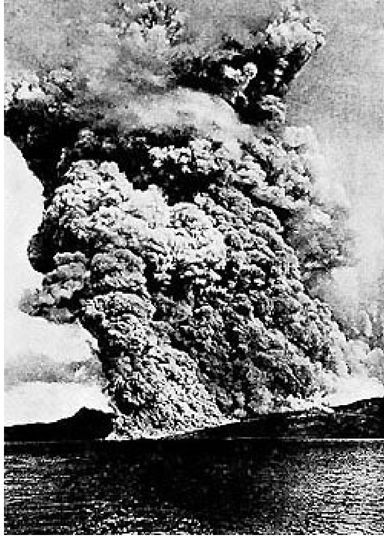
- **Calcite**
  - Calcite is a soft, usually colorless to white mineral distinguished by a rapid bubbling or fizzing reaction when it comes in contact with dilute hydrochloric acid (HCl).
  - Calcite is the major component of sea shells and coral skeletons and often occurs as a well formed, glassy to dull, blocky crystals.
  - As a rock-forming mineral, it usually occurs as fine to coarse crystals in marble, loose to compacted granules in ordinary limestone, and as a cementing agent in many sedimentary rocks.
  - Calcite veins, or crack fillings, are common in igneous and other rocks.
  - Calcite weathers chiefly by solution in acidic waters or water containing dissolved carbon dioxide.
- Dolomite
  - Dolomite is similar to calcite in appearance and occurrence but is slightly harder and more resistant to solutioning. It is distinguished by a slow bubbling or fizzing reaction when it comes in contact with dilute HCl.
  - Usually the reaction can be observed only if the mineral is first powdered (as by scraping it with a knife).
  - Coarse dolomite crystals often have curved sides and a pinkish color.
  - Calcite and dolomite frequently occur together, often in intimate mixtures.
- Mica
  - Micas form soft, extremely thin, transparent to translucent, elastic sheets and flakes with a bright glassy or pearly luster.
  - “Books” of easily separated sheets frequently occur.
  - The biotite variety is usually brown or black, while muscovite is yellowish, white, or silvery gray.
  - Micas are very common in granitic rocks, gneisses, and schists. Micas weather slowly to clay minerals.

Types of Rocks and The Rock Cycle



Igneous Rocks





- Igneous rocks are solidified from hot molten rock material that originated deep within the earth.
- This occurred either from magma in the subsurface or from lava extruded onto the earth's surface during volcanic eruptions.
- Igneous rocks owe their variations in physical and chemical characteristics to differences in chemical composition of the original magma and to the physical conditions under which the lava solidified.
- The groups forming the subdivisions from which all igneous rocks are classified are—
  - Intrusive igneous rocks (cooled from magma beneath the earth's surface).
  - Extrusive igneous rocks (cooled from magma on the earth's surface).

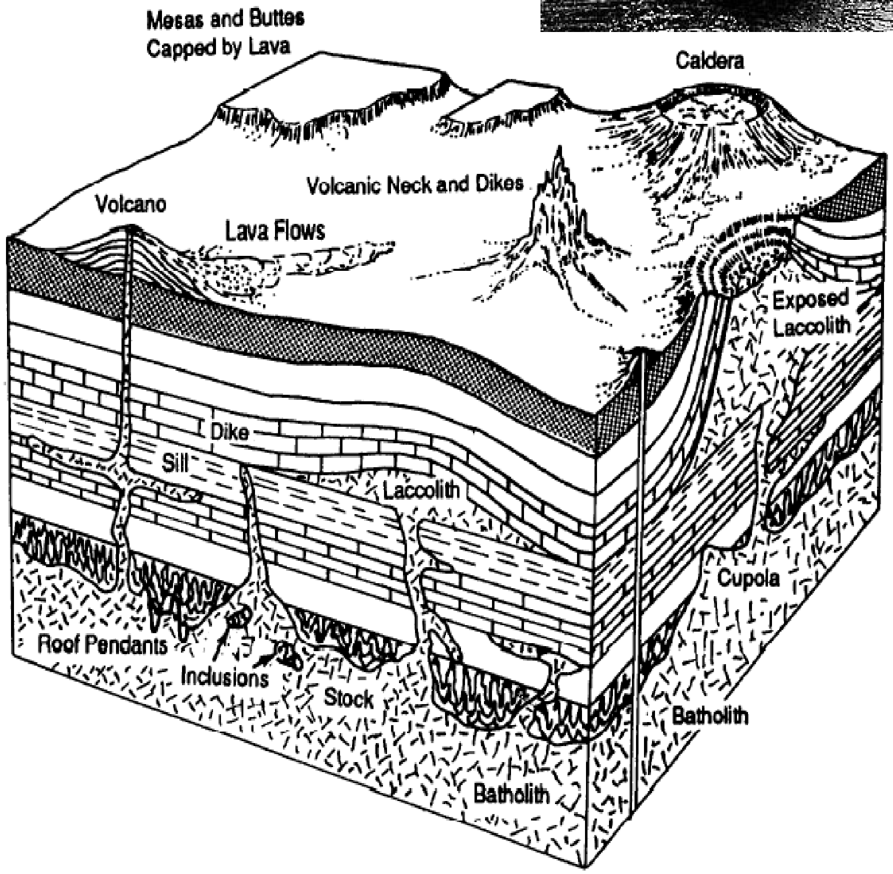
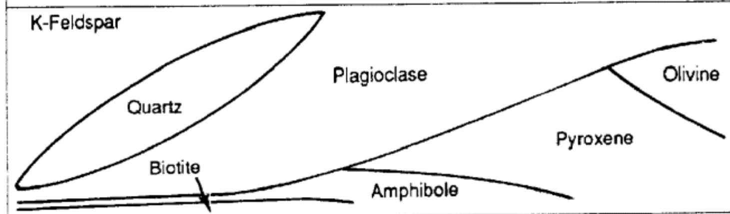


Figure 1-5. Intrusive and extrusive rock bodies.

Classification of Igneous Rocks

- Igneous rocks are classified primarily on the basis of—
  - Texture.
  - Color (or mineral content).
- The intrusive igneous rocks generally have a distinctive texture of coarse interlocking crystals of different minerals. Under certain conditions, deep-seated intrusions form "pegmatites" (rocks with very large crystals).
- The extrusive (volcanic) igneous rocks, however, show great variation in texture. Very fine-grained rocks maybe classified as having stony, glassy, scoriaceous, or fragmental texture.

Typical Mineral



Origin	Dominant Texture*		Color: Light	Color: Dark
Intrusive	Coarse-grained (distinguishable grains)		Granite	Gabbro-diorite
Extrusive	Very fine (indistinguishable)	Stony	Felsite	Basalt
		Glassy	Obsidian	
		Scoriaceous	Pumice	Scoria
		Fragmental	Volcanic ash, cinder, bombs, and blocks	
Intrusive/extrusive	Contrasting grain size		Porphyritic rocks	

*Rocks containing many scattered larger crystals are called "porphyritic," such as porphyritic granite and porphyritic basalt.

Sedimentary Rocks

- Sedimentary rocks, also called stratified rocks, are composed of chemical precipitates, biological accumulations, or elastic particles.
- Chemical precipitates are derived from the decomposition of existing igneous, sedimentary, and metamorphic rock masses.
- Dissolved salts are then transported from the original position and eventually become insoluble, forming "precipitates"; or, throughevaporation of the water medium, they become deposits of "evaporites."
- A relatively small proportion of the sedimentary rock mass is organic sediment contributed by the activities of plants and animals.

- Clastic sediments
  - These are derived from the disintegration of existing rock masses. The disintegrated rock is transported from its original position as solid particles.
  - Rock particles dropped from suspension in air, water, orice produce deposits of "elastic" sediments.
  - Volcanically ejected material that is transported by wind or water and then deposited forms another class of layered rocks called "pyroclastics."
  - Most pyroclastic deposits occur in the vicinity of a volcanic region, but fine particles can be transported by the wind and deposited thousands of milesfrom the source.
- Organic sediments
  - Sedimentary rocks which form when organic materials accumulate and become indurated

Classification of Sedimentary Rocks

- Classified according to:
  - Grain size.
  - Composition.
- They can be described as either clastic or nonclastic
  - The clastic rocks are composed of discrete particles, or grains.
  - The nonclastic rocks are composed of interlocking crystals or are in earthy masses.

Group		Dominant Composition		Rock Type
Clastic	Coarse-grained	Rock fragments larger than 2 mm	Rounded	Conglomerate
			Angular	Breccia
		Mineral grains (chiefly quartz) $\frac{1}{16}$ mm to 2 mm)		Sandstone
	Fine-grained	Clay and silt-sized particles (smaller than $\frac{1}{16}$ mm)		Shale
Nonclastic	Inorganic	Dolomite Microcrystalline silica		Dolomite Chert
	Organic/inorganic	Calcite		Limestone
	Organic	Carbonaceous plant debris		Coal

Bedding Planes in Sedimentary Rocks

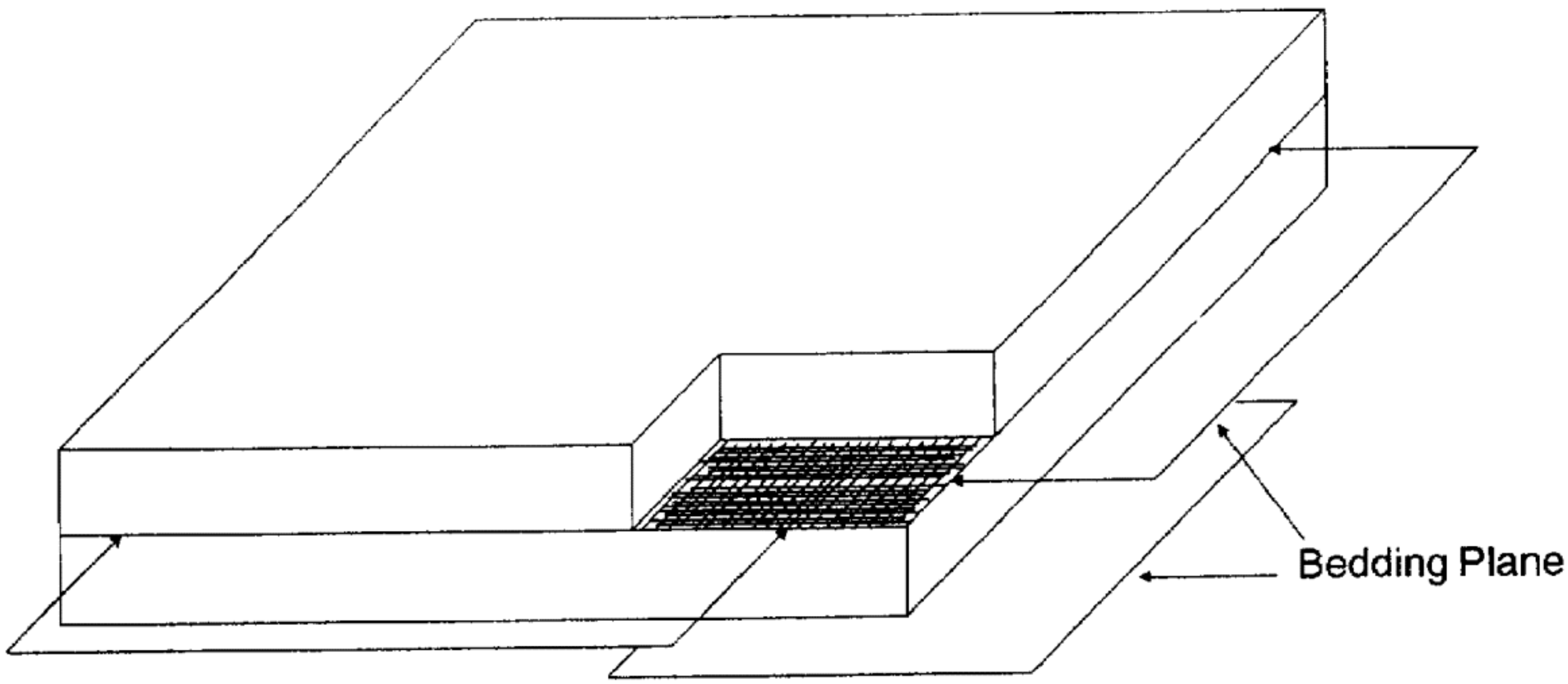


Figure 1-7. Bedding planes.

Metamorphic Rocks

- Definition
  - Rocks that may be either igneous or sedimentary rocks that have been altered physically and sometimes chemically by the application of intense heat and pressure at some time in their geological history
- Metamorphic rocks are classified primarily by—
  - Mineral content.
  - Fabric imparted by the agents of metamorphism.
- They are readily divided into two descriptive groups known as—
  - Foliated. Foliated metamorphic rocks display a pronounced banded structure as a result of the reformational pressures to which they have been subjected. Banding surfaces can result in rock failure under load (similar effect as bedding planes.)
  - Nonfoliated. The nonfoliated, or massive, metamorphic rocks exhibit no directional structural features.

Table 1-4. Classification of metamorphic rocks.

Structure	Characteristics	Rock Type
Foliated	Very fine-grained; cleaves readily into thin sheets or plates	Slate
	Fine- to coarse-grained; thin semiparallel layers of platy minerals; splits into flakes between layers	Schist
	Fine- to coarse-grained; streaks or bands of differing mineralogic composition; breaks into bulky pieces	Gneiss
Nonfoliated	Mostly fused quartz grains	Quartzite
	Mostly calcite or dolomite	Marble

Metamorphism of Rocks

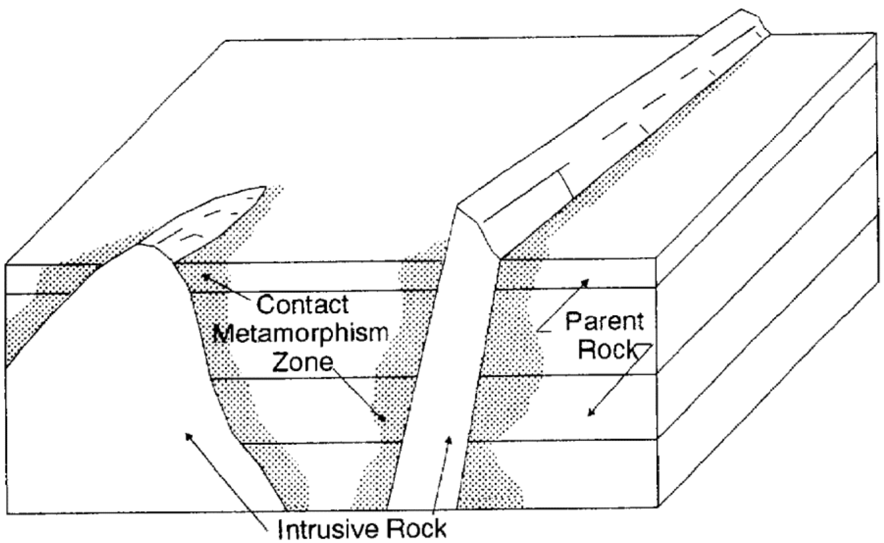


Figure 1-8. Contact metamorphism zone.

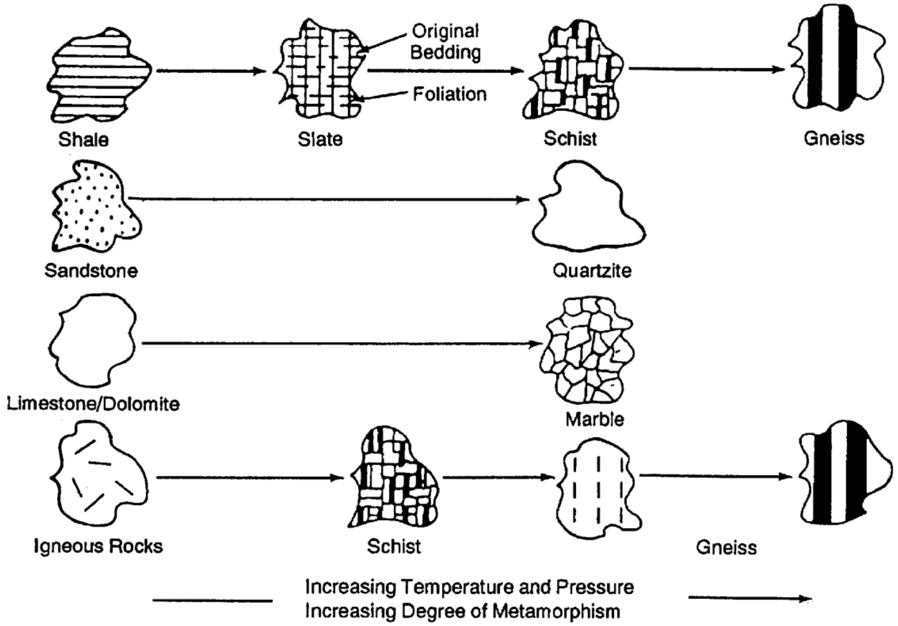


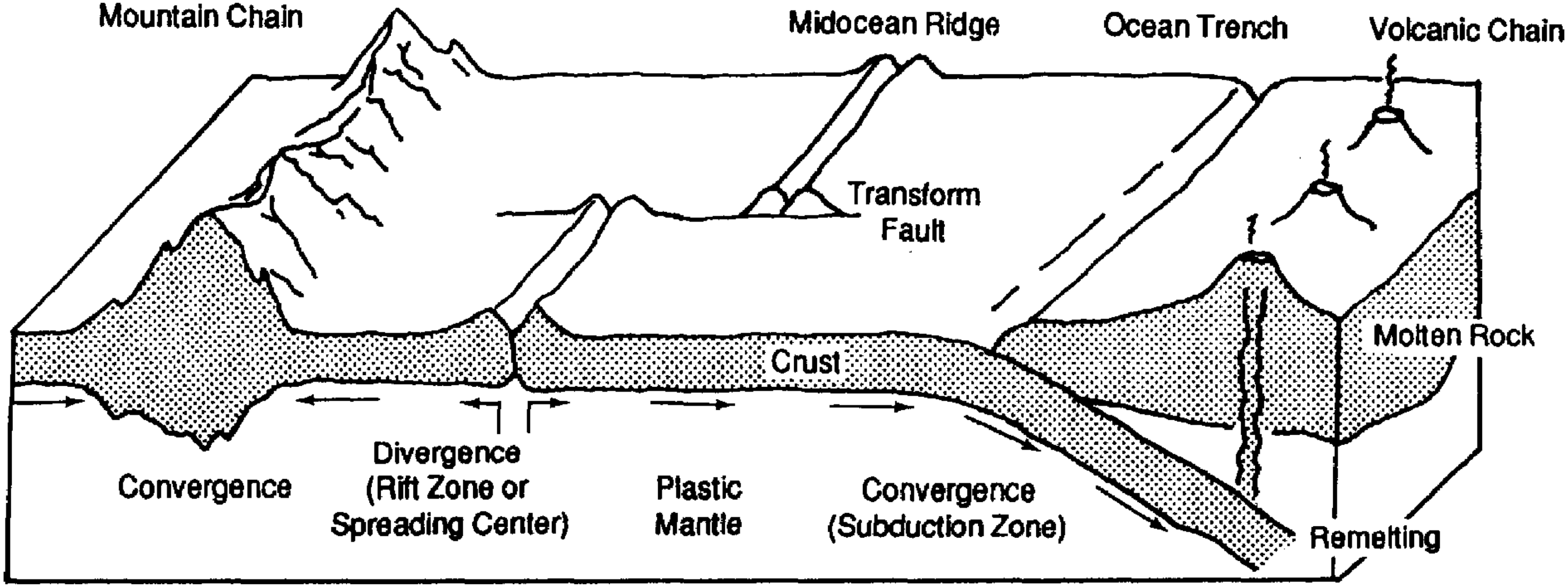
Figure 1-12. Metamorphism of existing rocks.

Overview of Identification of Rocks

Table 1-5. Identification of geologic materials.

Foliated			Very fine-grained; splits along thin planes		Slate
			Metallic reflection; splits into slabs and flakes or thin semitransparent sheets		Schist
			Contains streaks or bands of light and dark minerals; breaks to bulky, angular fragments		Gneiss
Very Fine-Grained	Frothy		Light colored; lightweight; easily crushed		Pumice
			Dark colored; cindery		Scoria
	Glassy		Light colored; massive; extremely hard		Quartz
			Dark colored; may have some gas bubbles		Obsidian
	Stony	Soft	No acid reaction	Earthy; clay odor; platy	Shale
				May have small pieces of glass; low density	Tuff
			Acid reaction	Sugary appearance	Marble
				Dull and massive	Limestone
		Hard	Waxy; very hard; weathers to soft white		Chert
			Dull; may contain some gas bubbles or visible crystals	Light colored	Felsite
				Dark colored	Basalt
			Sandy; mostly one mineral (quartz)	Gritty sandpaper feel	Sandstone
				Sugary; not gritty	Quartzite
Coarse-Grained	Hard		Sandy; mostly one mineral (quartz)	Gritty sandpaper feel	Sandstone
				Sugary; not gritty	Quartzite
			Mixed minerals; salt-and-pepper appearance	Light colored	Granite
				Dark colored	Gabbro-diorite
			Fragmental; appearance of broken concrete		Conglomerate
	Soft		Fragmental; may contain small pieces of glass	Low density	Tuff
			Acid reaction	Sugary appearance	Marble
				Shell fragments	Limestone

Structural Geology



Folds

- A rock body that dips uniformly in one direction (at least locally) is called a homocline
- A rock body that exhibits local steplike slopes in otherwise flat or gently inclined rock layers is called a monocline.
  - Monoclines are common in plateau areas where beds may locally assume beds on opposite sides of the fold may differ by hundreds or thousands of feet.
- Anticlines are upfolds, and synclines are downfolds. They are the most common of all fold types and are typically found together in a series of fold undulations.
  - Differential weathering of the rocks composing synclines and anticlines tends to produce linear valleys and ridges.
- Folds that dip back into the ground at one or both ends are said to be plunging .
  - Plunging anticline and plunging syncline folds are common.
- Upfolds that plunge in all directions are called domes.
- Folds that are bowed toward their centers are called basins.
- Domes and basins normally exhibit roughly circular outcrop patterns on geologic maps.

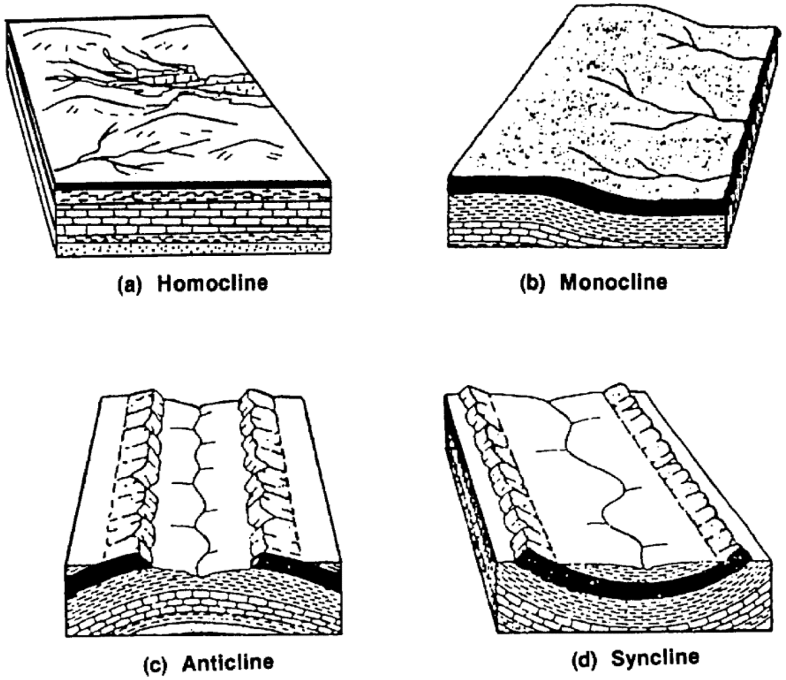


Figure 2-5. Common types of folds.

Faults

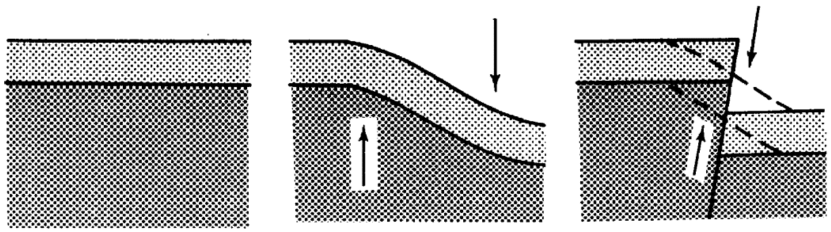


Figure 2-8. Faulting.

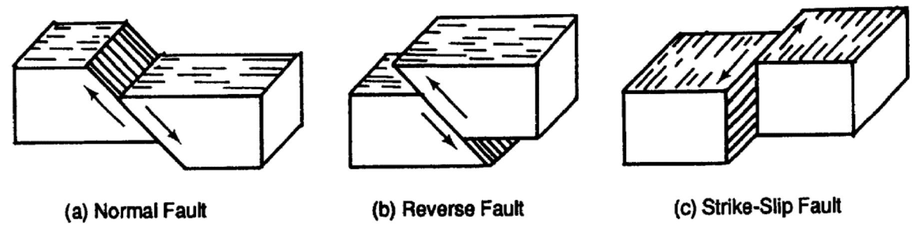


Figure 2-12. Types of faults.

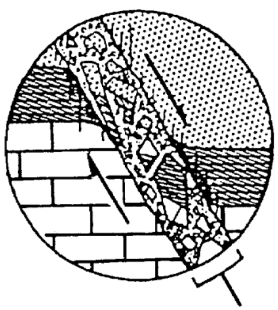


Figure 2-9. Fault zone.

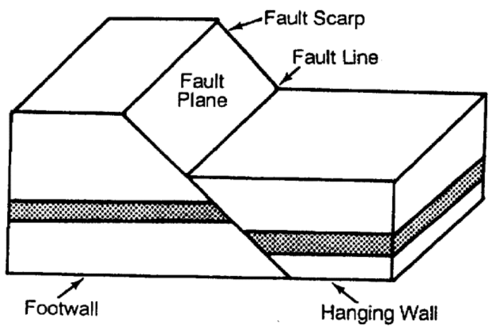


Figure 2-11. Fault terminology.

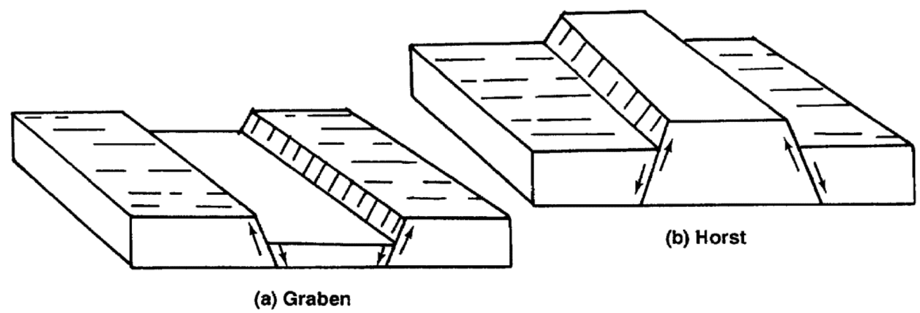


Figure 2-13. Graben and horst faulting.

Strike and Dip

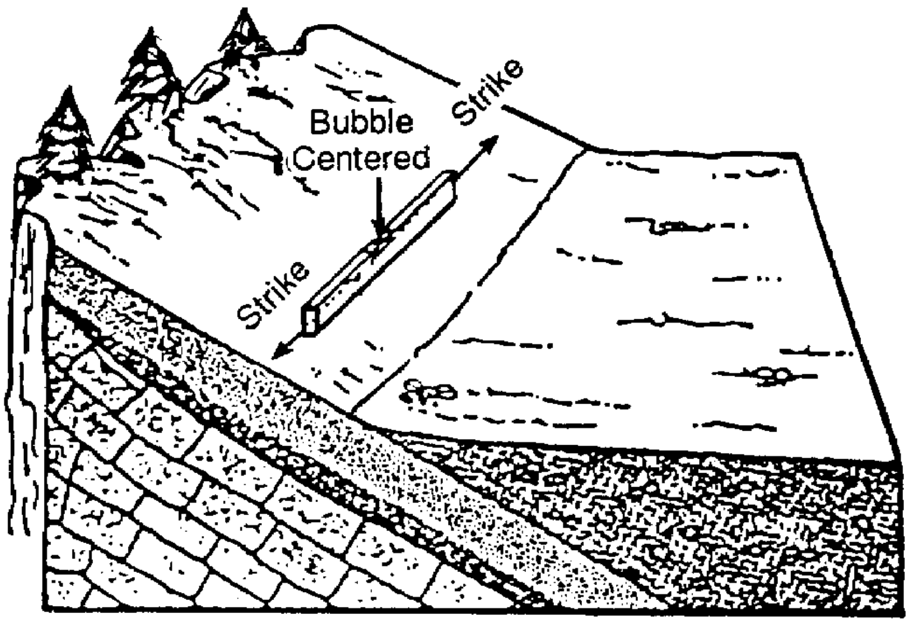


Figure 2-15. Strike.

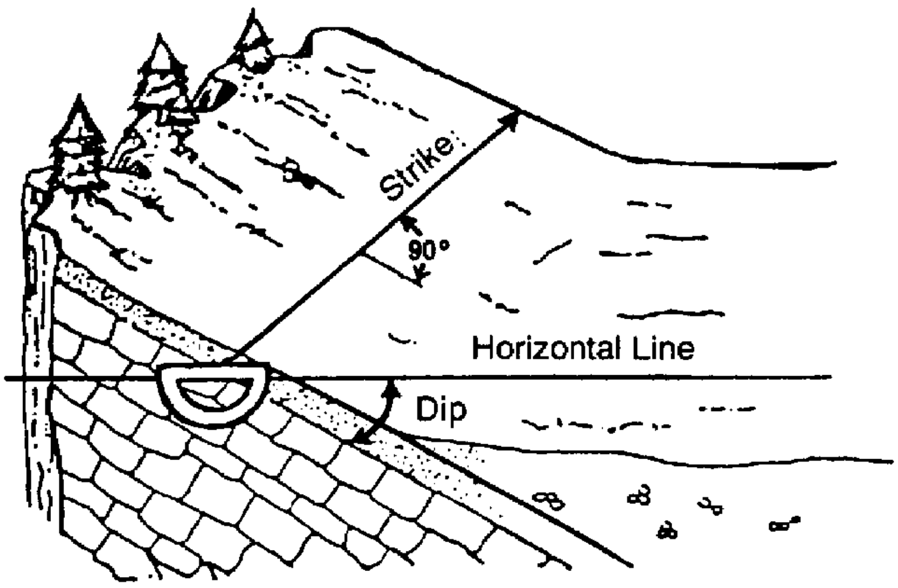


Figure 2-16. Dip.

Measuring Strike and Dip
Symbols for Strike and Dip

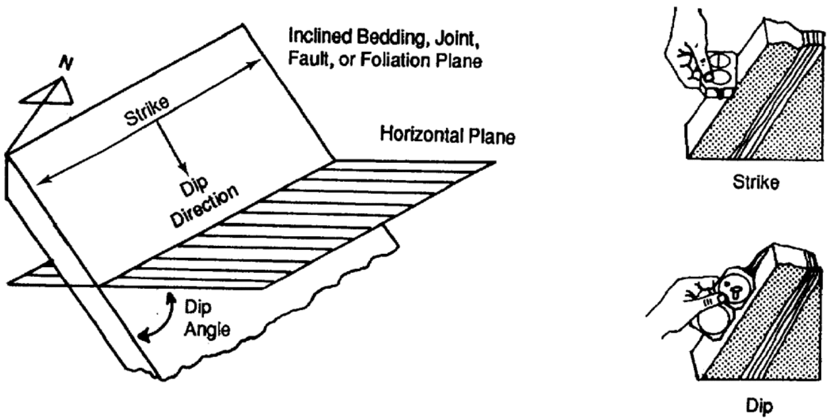


Figure 2-17. Measuring strike and dip with a Brunton compass.

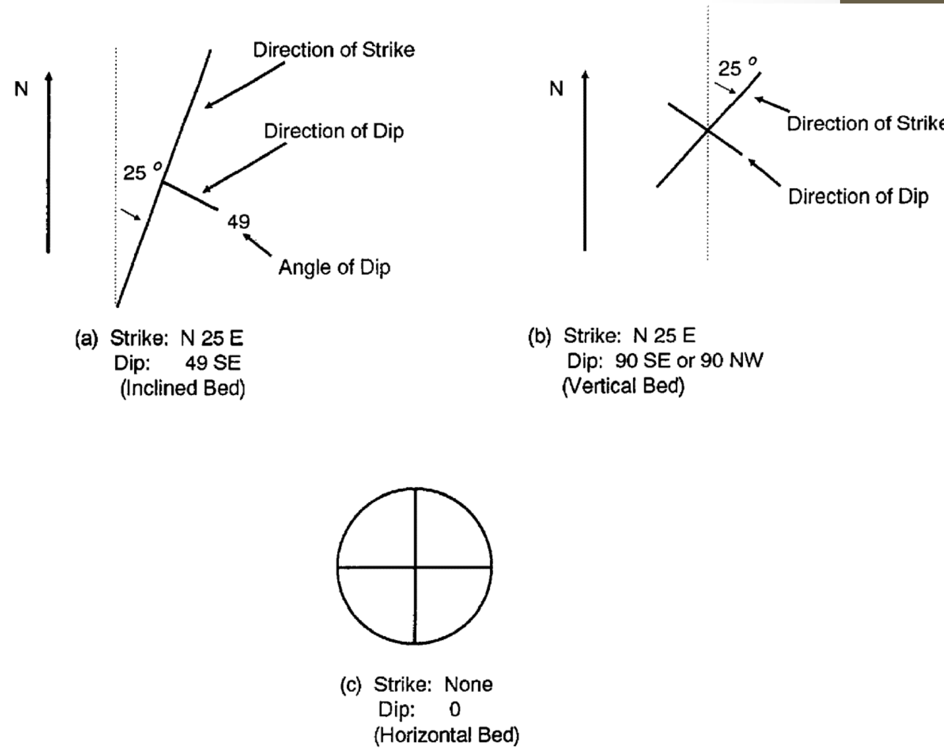


Figure 2-18. Strike and dip symbols.

Note orientation of strike and dip relative to cardinal directions!

Application to Geologic Maps

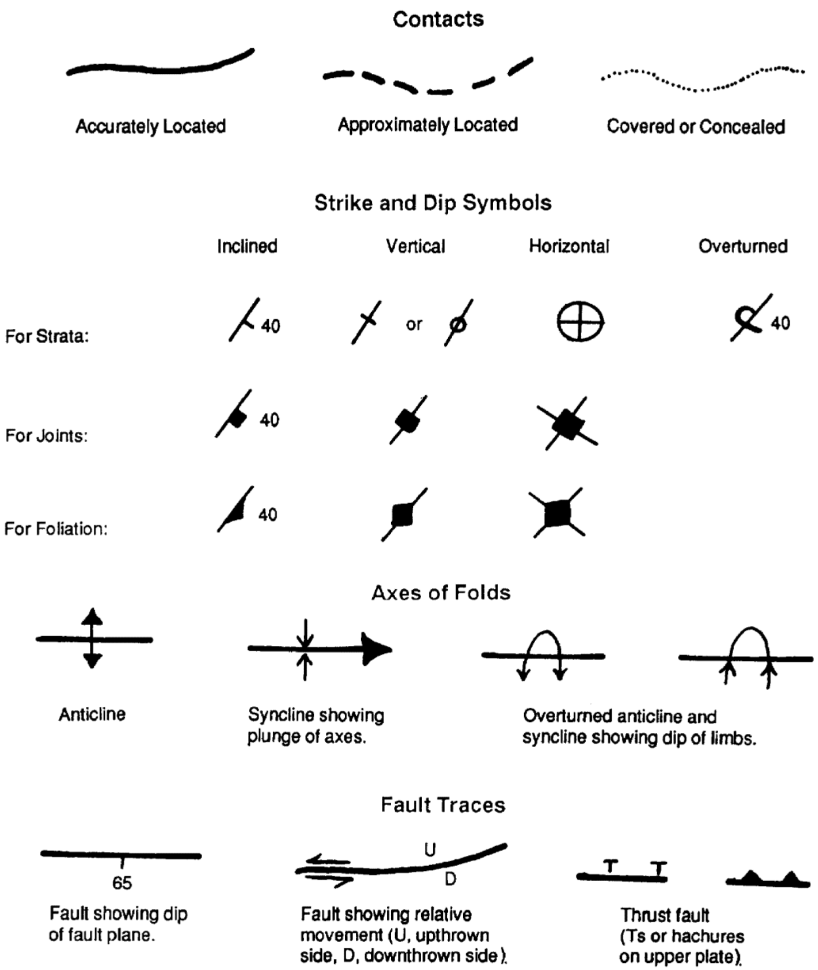


Figure 2-21. Geologic map symbols.

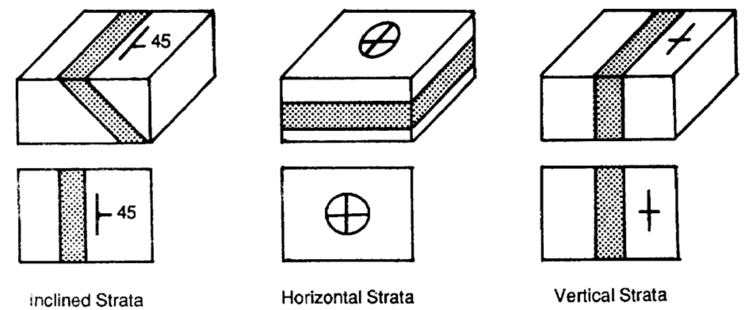


Figure 2-22. Placement of strike and dip symbols on a geologic map.

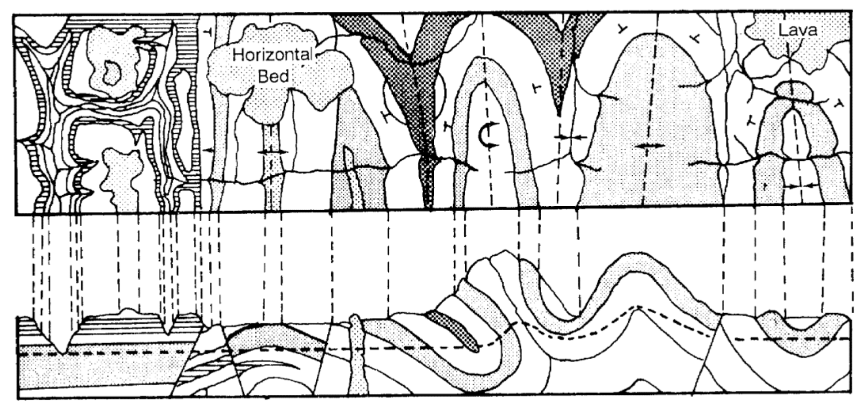


Figure 2-23. Geologic map and cross section.

Application of Strike and Dip

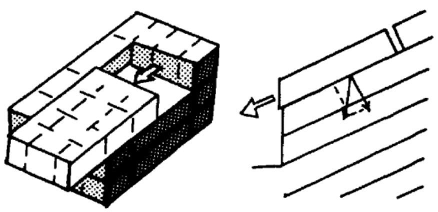


Figure 2-34. Rock slide on inclined bedding plane.

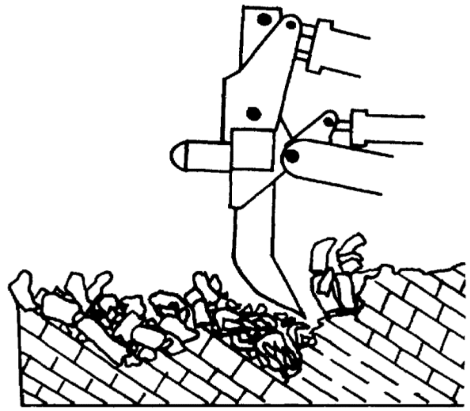


Figure 2-32. Ripping in the direction of dip.

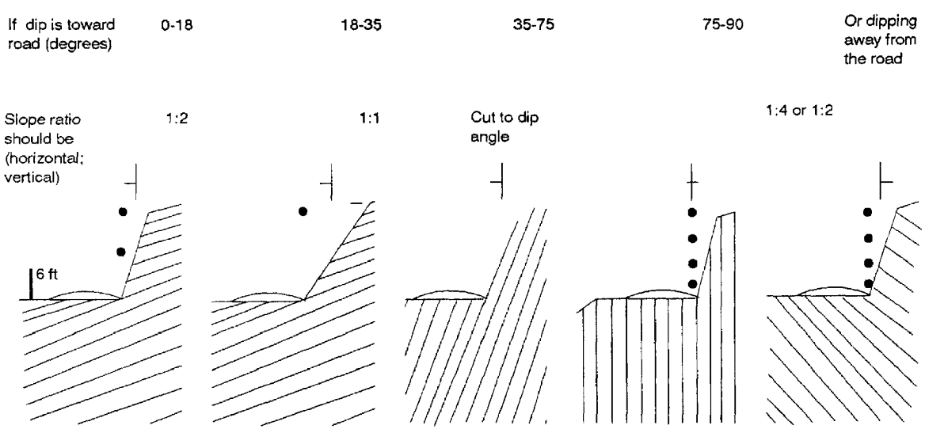
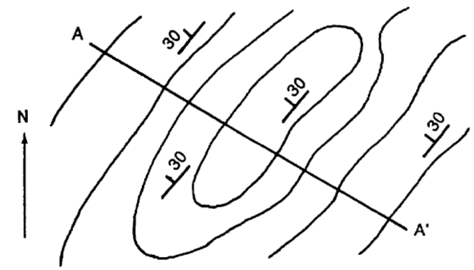
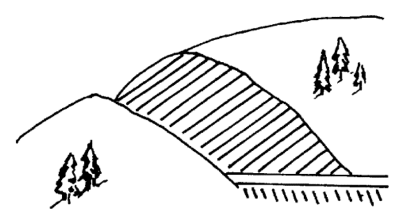


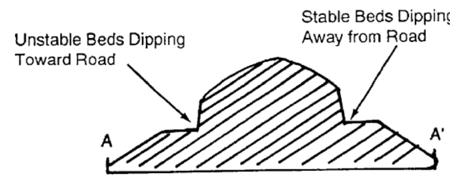
Figure 2-35. Rules of thumb for inclined sedimentary rock cuts.



(a) Map view, illustrating strike and dip symbols. The best road alignment, based on the structural geology, is NW-SE, perpendicular to the strike.



(b) Through cut in the hill, illustrating rock dipping along the road. This is the most naturally stable road alignment.



(c) Cross section of same hill with side hill cuts oriented parallel to strike direction, illustrating unstable orientation where rock beds dip toward the road and a more stable orientation where the rock beds dip away from the road.

Figure 2-36. Road cut alignment.

Weathering of Rocks to Soil

- Weathering is the physical or chemical breakdown of rock
- Physical Weathering
  - Unloading of overburden compressive stresses
  - Frost Action
  - Organism Growth
  - Temperature Changes
  - Crystal Growth
  - Abrasion
- Chemical Weathering
  - Oxidation
  - Hydration
  - Hydrolysis
  - Carbonation
  - Solution
    - Especially significant in the erosion of limestone and the formation of Karst Topography and sinkholes

Rock Samples

Rock Quality Designation (RQD)

- Based on a modified core recovery procedure
  - L_i = length of a given recovered piece ≥ 4”
  - L_t = total length of core sample

$$RQD = \frac{\sum L_i}{L_t}$$

RQD%	VELOCITY INDEX	ROCK MASS QUALITY
90 - 100	0.80 - 1.00	Excellent
75 - 90	0.60 - 0.80	Good
50 - 75	0.40 - 0.60	Fair
25 - 50	0.20 - 0.40	Poor
0 - 25	0 - 0.20	Very Poor

RQD Example

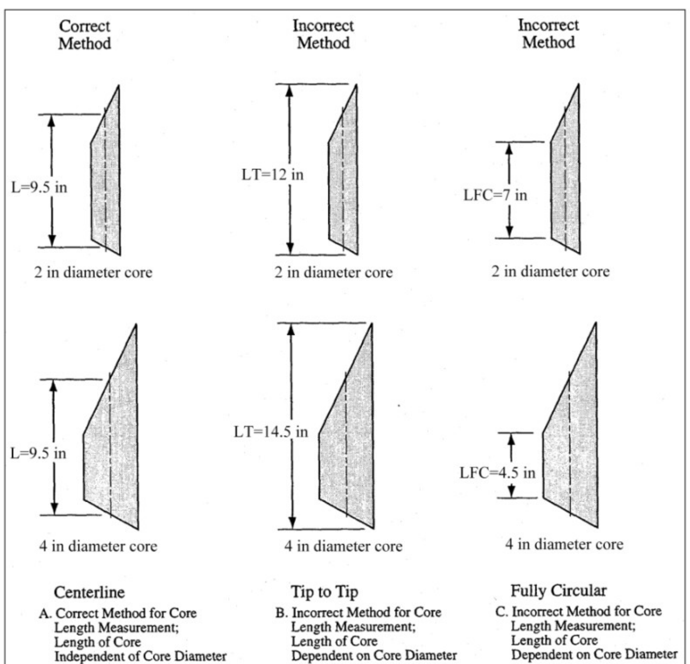
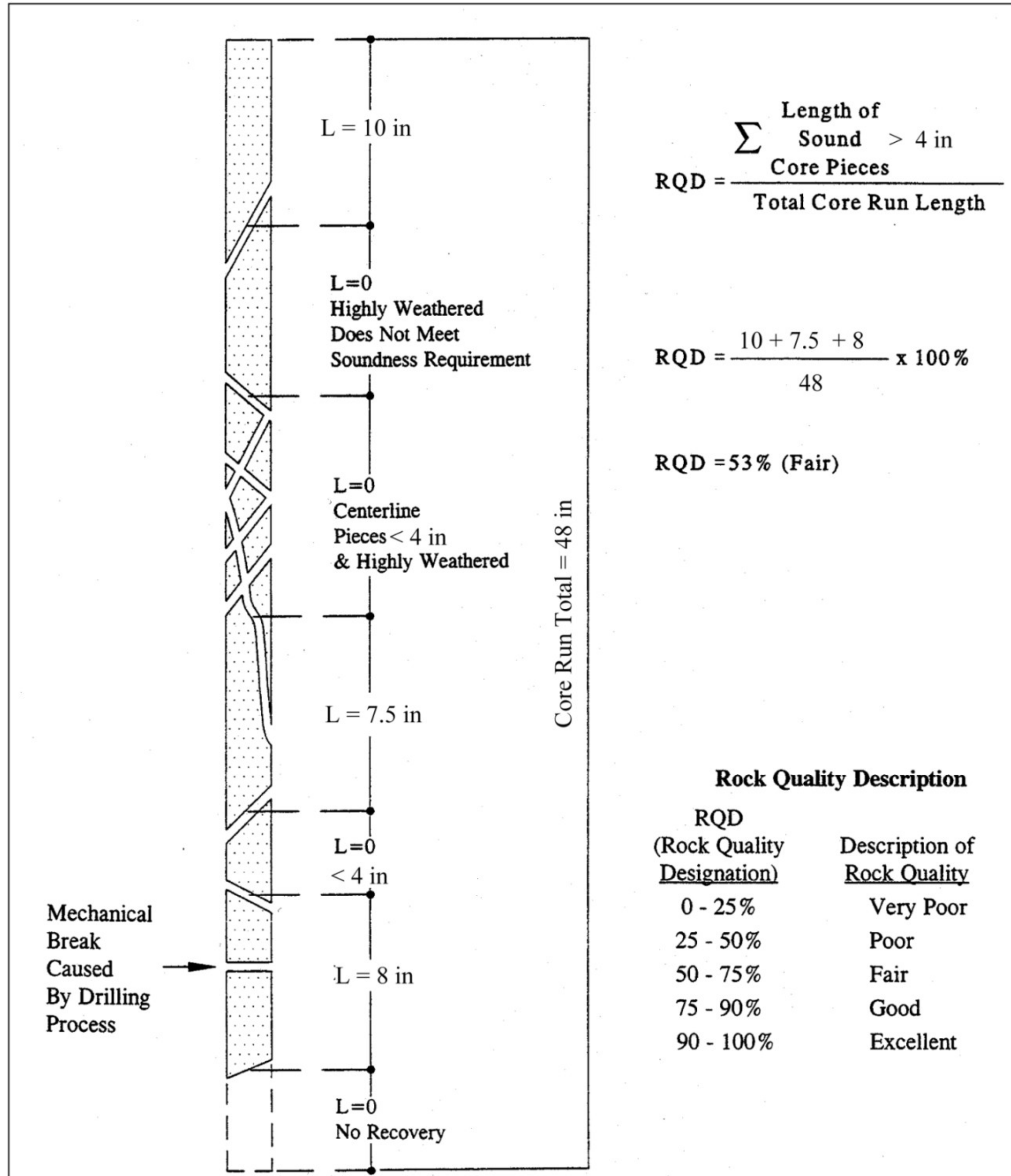


Figure 3-18. Length measurements for core RQD determination (FHWA, 1997).



igure 3-17. Modified core recovery as an index of rock mass quality (FHWA, 1997).

Objective of RQD Test

- Determine the Rock Quality Designation (RQD) for all of the rock samples presented.
- Make some determination as to the type of rock