ENCE 3610 Soil Mechanics

Lecture 1
Introduction and Overview of Engineering Geology
University of Tennessee at Chattanooga
Don C. Warrington, P.E., PhD., Instructor

Outline of Presentation

- Definition and Overview of Geotechnical Engineering
- Basic Engineering Geology
  - Rock formation and decomposition
  - Geological formations
  - Strike and Dip calculations
  - Rock Quality Designation (RQD) Test
  - Nature of soil deposits

Sources of Graphics (Not Comprehensive)

- Verruijt, A., *Soil Mechanics*. Delft, The Netherlands: VSSD, 2012. (We actually use the online version)
- Naresh C. Samtani and Edward A. Nowatzki, *Soils and Foundations Reference Manual*, Vols. 1 and 2. Washington, DC: National Highway Institute, Department of Transportation, 2006.
- *NAVFAC DM 7.1: Soil Mechanics*. UFC 3-220-10. Naval Facilities Engineering Command, Alexandria, Virginia, 2022.
  - NAVFAC DM 7.01, *Soil Mechanics*. Naval Facilities Engineering Command, Alexandria, Virginia, 1986. (the older version, we are in the process of phasing these out when necessary)
- Tsytovich, N.A. *Soil Mechanics*. Mir Publishers, 1976.
- FM 5-410, *Military Soils Engineering*. Washington, DC: Department of the Army, 1997.

Types of Civil Engineering

- Structural Engineering
- Engineering Mechanics
- Transportation Engineering
- Environmental Engineering
- Coastal Engineering
- Geotechnical Engineering

Definition of Geotechnical Engineering

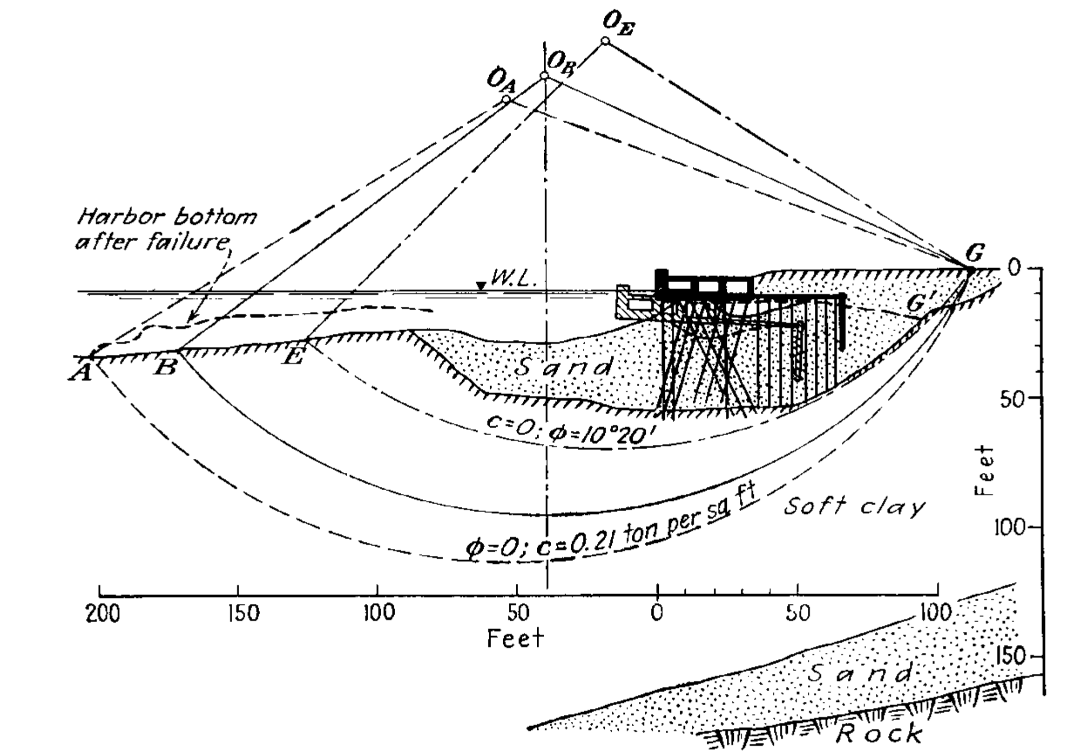
"The branch of Civil Engineering that deals with the properties of soils and rocks and their capability of supporting structures placed on, next to or under them."

Overview of Geotechnical Engineering

- Characteristics
  - Works in a complex environment
  - Requires a higher degree of judgement than other branches of engineering
  - More than one “acceptable” solution to any problem
  - The integrity of the structure above is dependent upon the quality of the foundation below

- Development
- The slowest branch of civil engineering to develop a theoretical basis that could be used in practical design
- Design of foundations traditionally was conservative and the result of trial and error
- Larger structures and catastrophic failures led to the investigation of the causes of failure and the establishment of theory which in turn would lead to design methods that resulted in workable foundations

Gothenburg Harbour Failure
5 March 1916



- Soft clay deposit, 150' deep
- 50' was dredged out and replaced by sand fill; piles were driven to stabilize the quay
- Several hundred feet of wall slid seaward as shown

Appointment of Swedish Commission

- In 1913, the Swedish State Railroad Administration appointed a special Geotechnical Commission – the first so titled – to study these types of failures and to recommend a solution
- Its chairman, Wolmar Fellenius, developed the basic methods for analysing rotational failures of slopes which, with improvement, we use today

Karl Terzaghi

- The “father of geotechnical engineering”
- Developed both the theory and practice of the analysis of soils and the design of foundations
  - Consolidation theory
  - Bearing Capacity of Shallow Foundations
  - Design of retaining walls and cellular cofferdams
- Wrote some of the first textbooks on soil mechanics and foundations design
  - *Soil Mechanics in Engineering Practice* (1948)
  - *Theoretical Soil Mechanics* (1943)

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

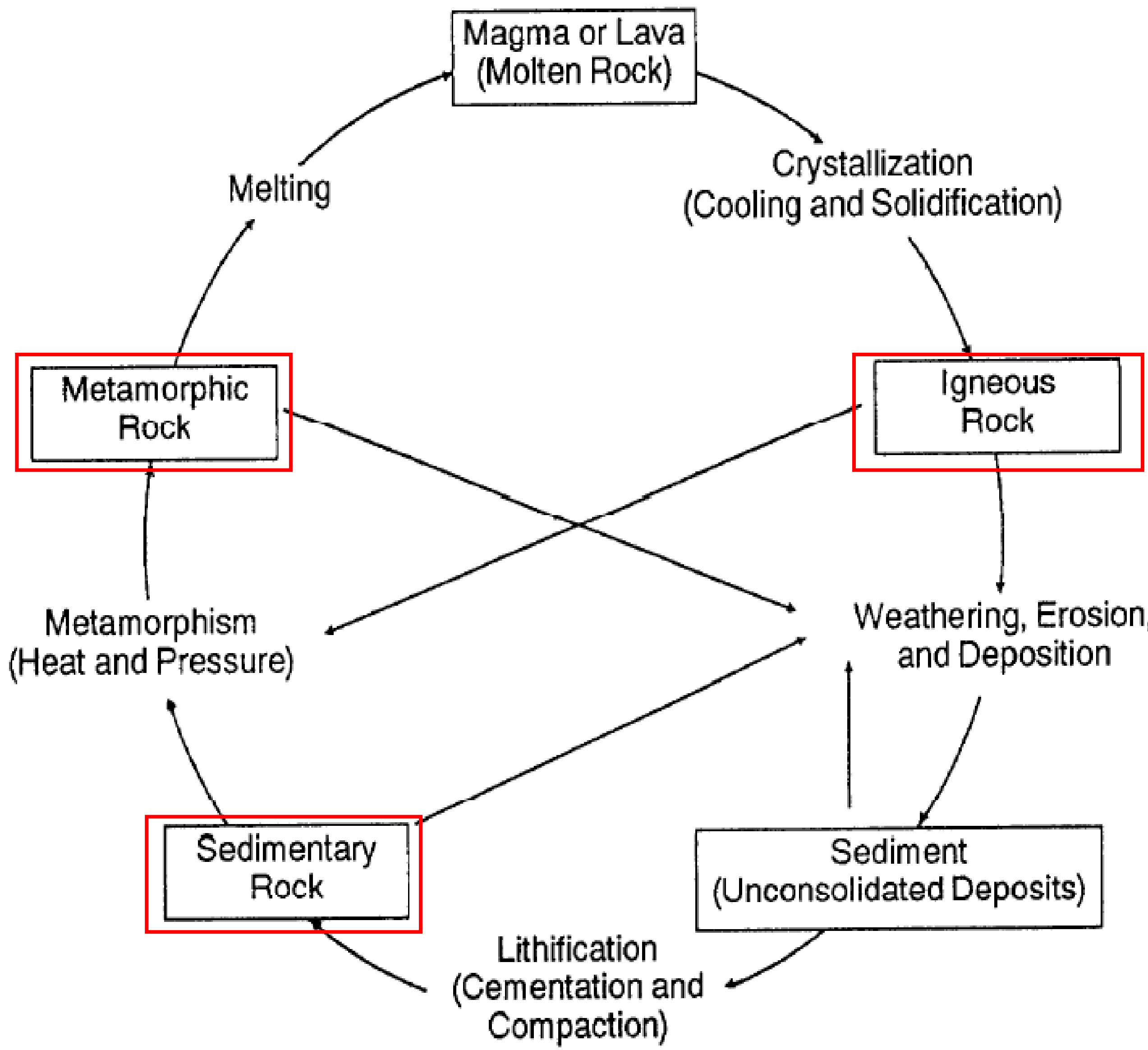
Rock (and Soil) Forming Minerals

- 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

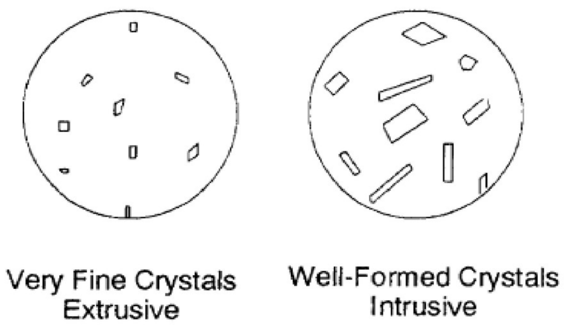
- **Calcite**
  - Calcite is a soft, usually colorless to white mineral distinguished by a rapid bubbling or fizzing reaction when it comes in contact with dilute hydrochloric acid (HCl).
  - Calcite is the major component of sea shells and coral skeletons and often occurs as a well formed, glassy to 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.

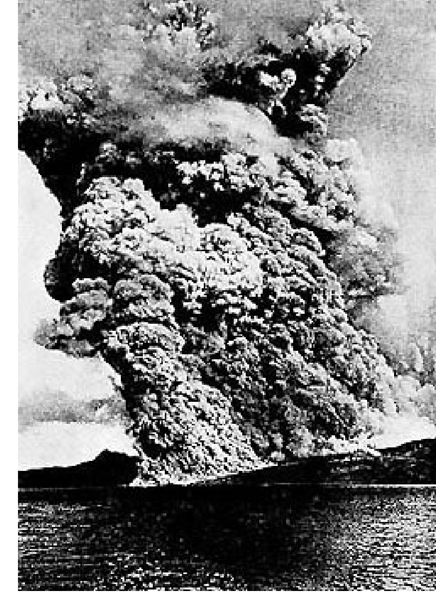
Types of Rocks and The Rock Cycle



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).





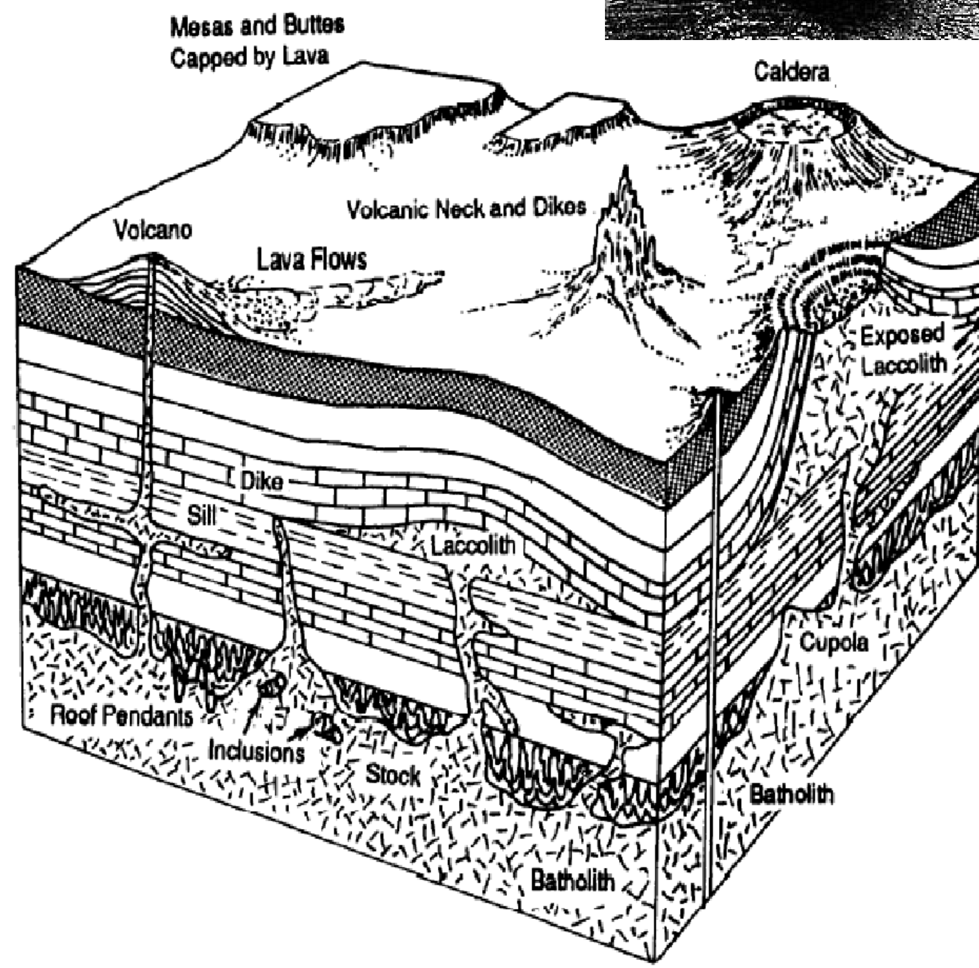
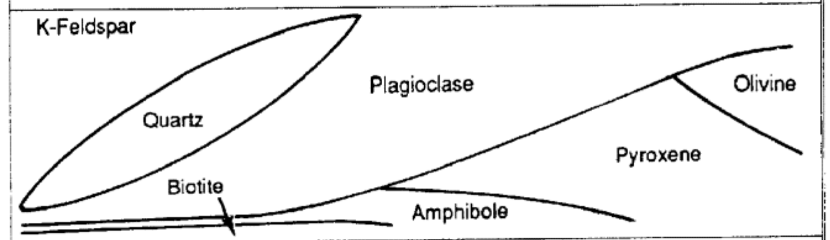


Figure 1-5. Intrusive and extrusive rock bodies.

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

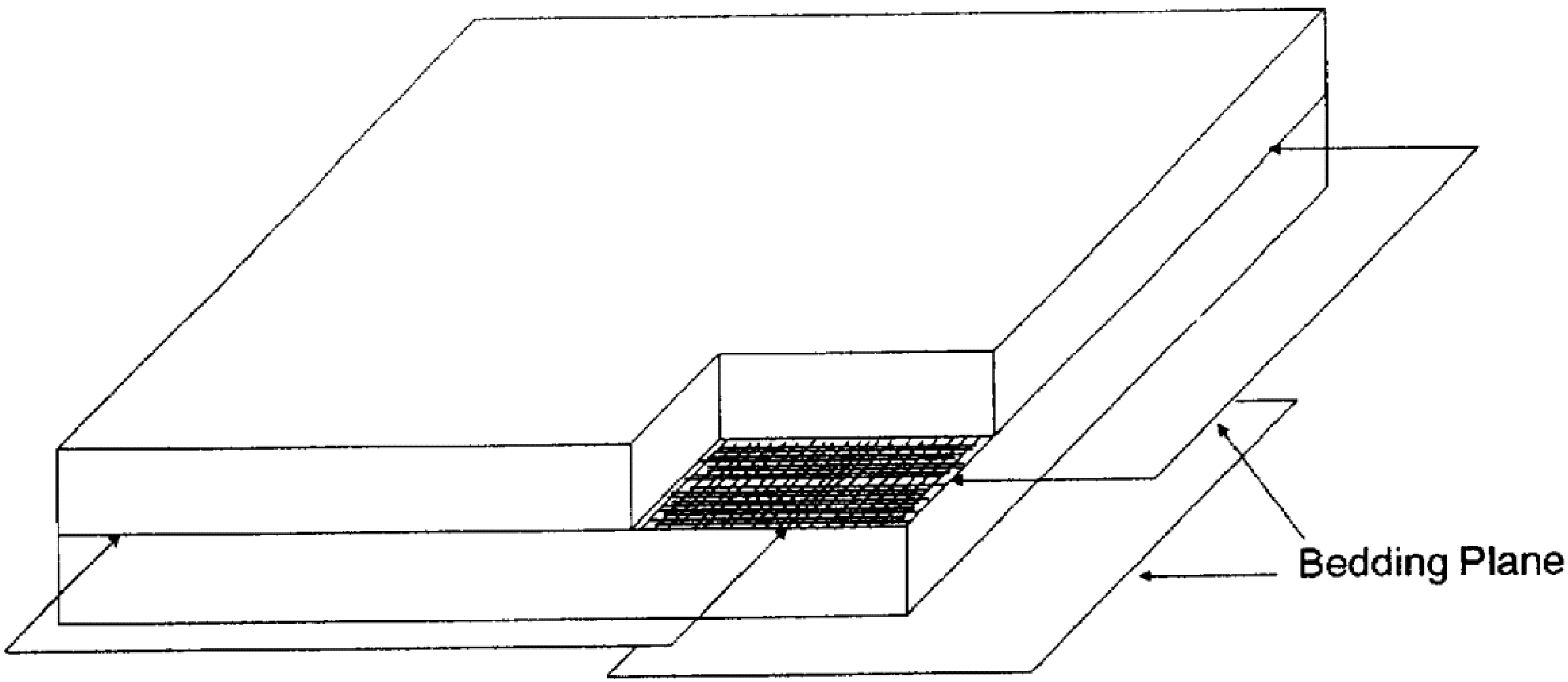


Figure 1-7. Bedding planes.

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

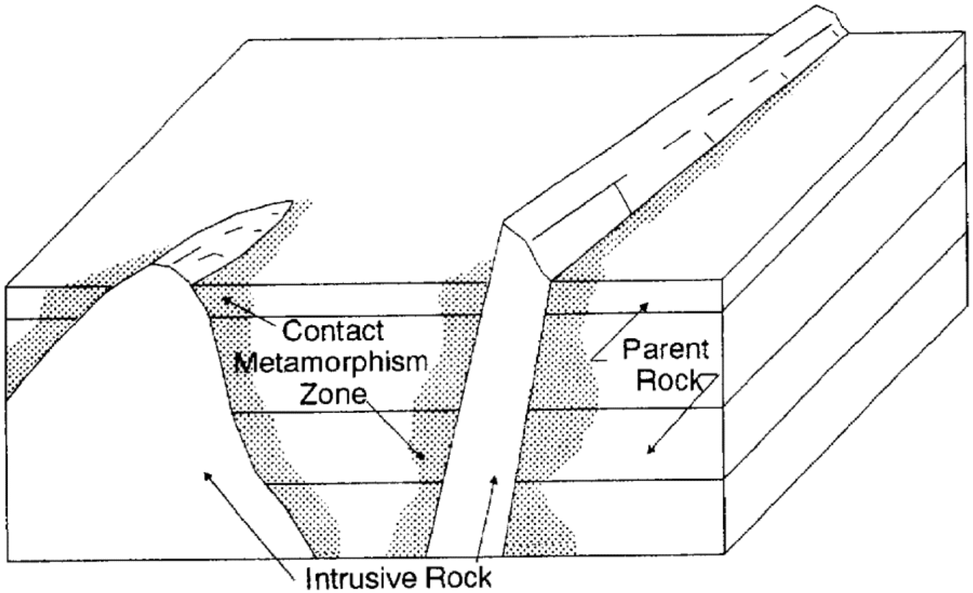


Figure 1-8. Contact metamorphism zone.

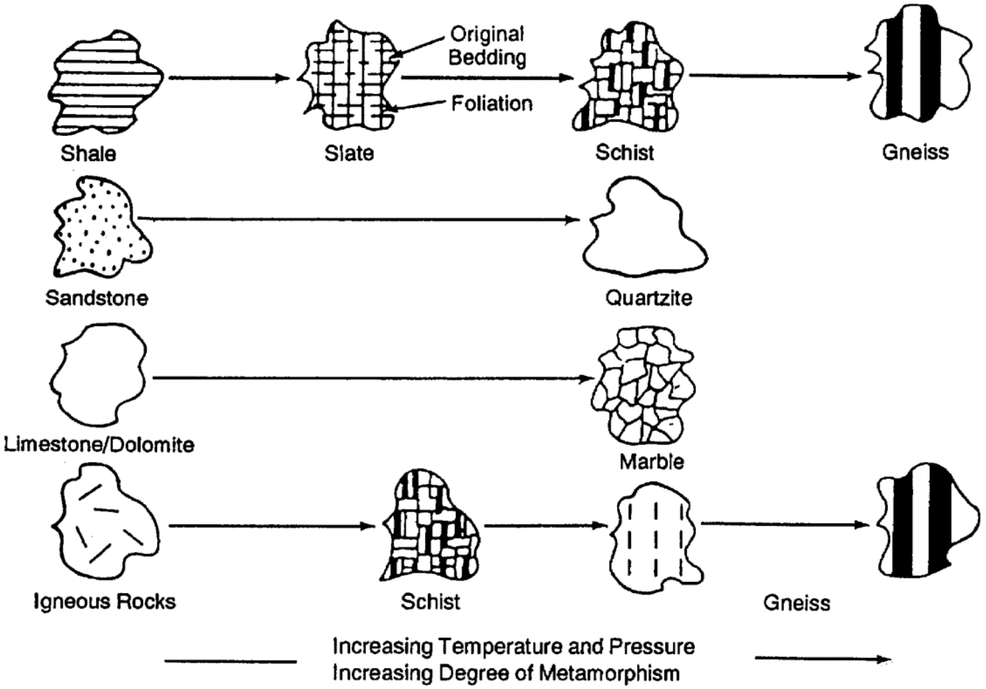


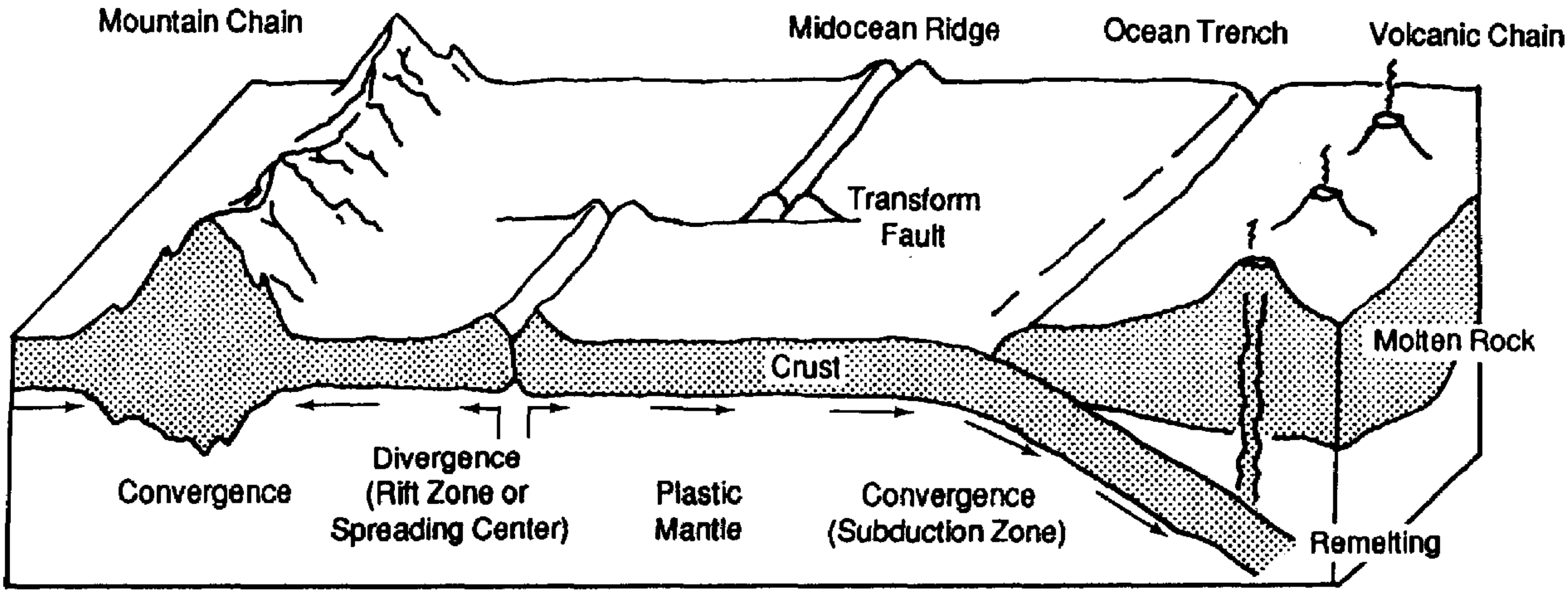
Figure 1-12. Metamorphism of existing rocks.

Overview of Identification of Rocks

Table 1-5. Identification of geologic materials.

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

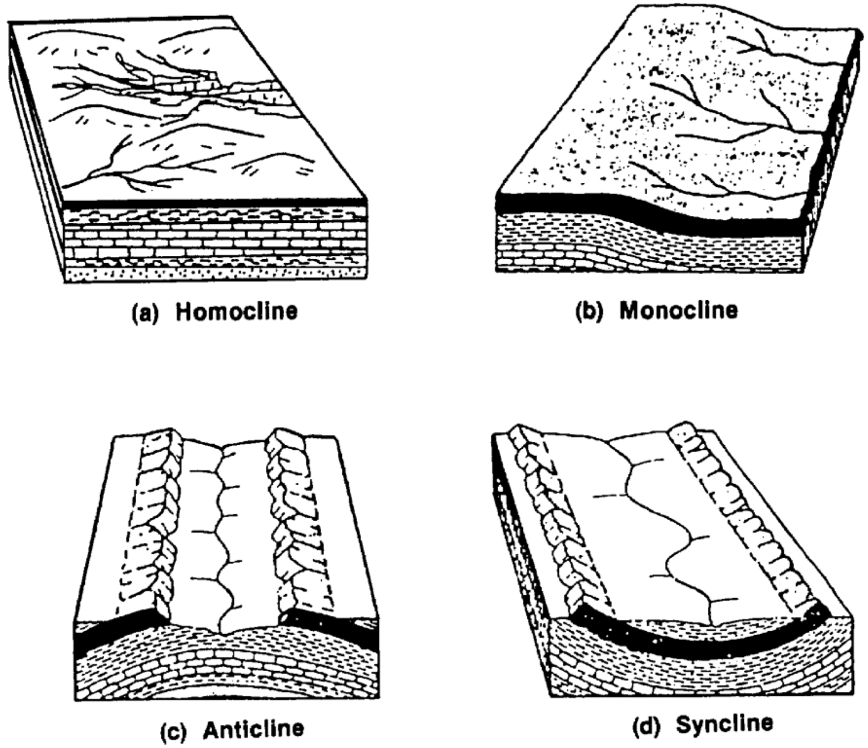


Figure 2-5. Common types of folds.

Faults

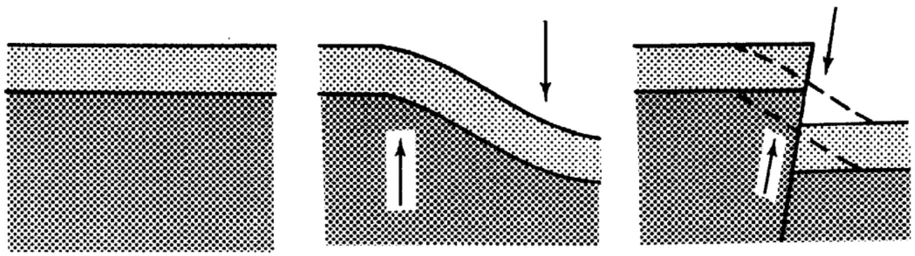


Figure 2-8. Faulting.

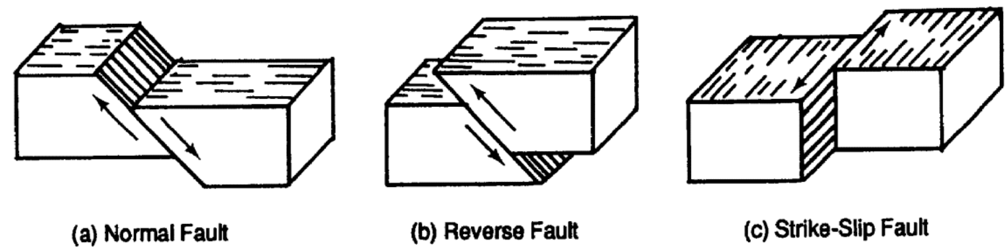


Figure 2-12. Types of faults.

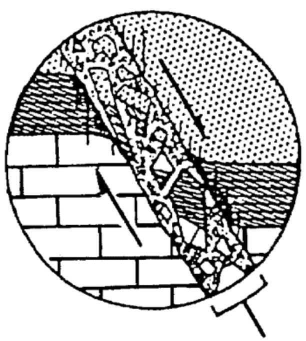


Figure 2-9. Fault zone.

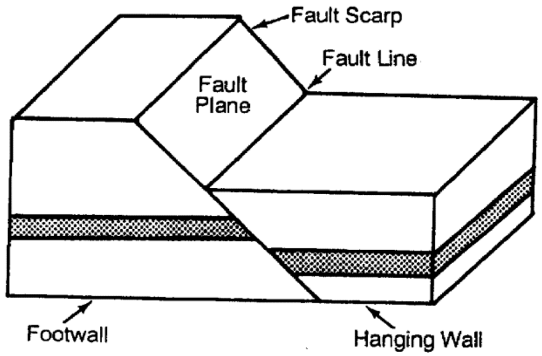


Figure 2-11. Fault terminology.

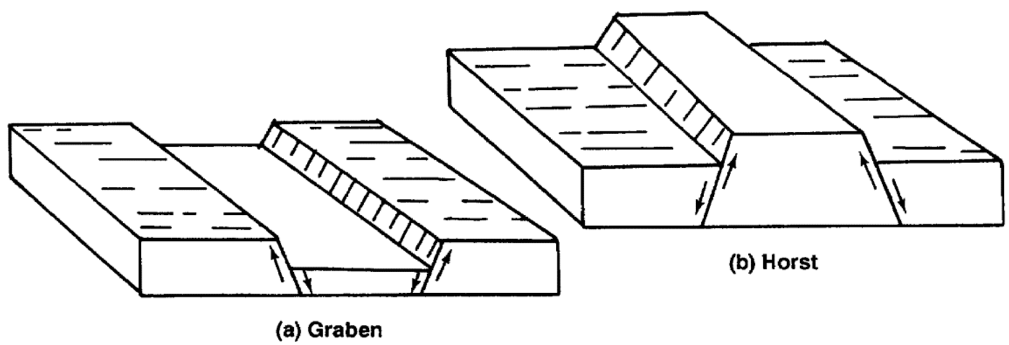


Figure 2-13. Graben and horst faulting.

Strike and Dip

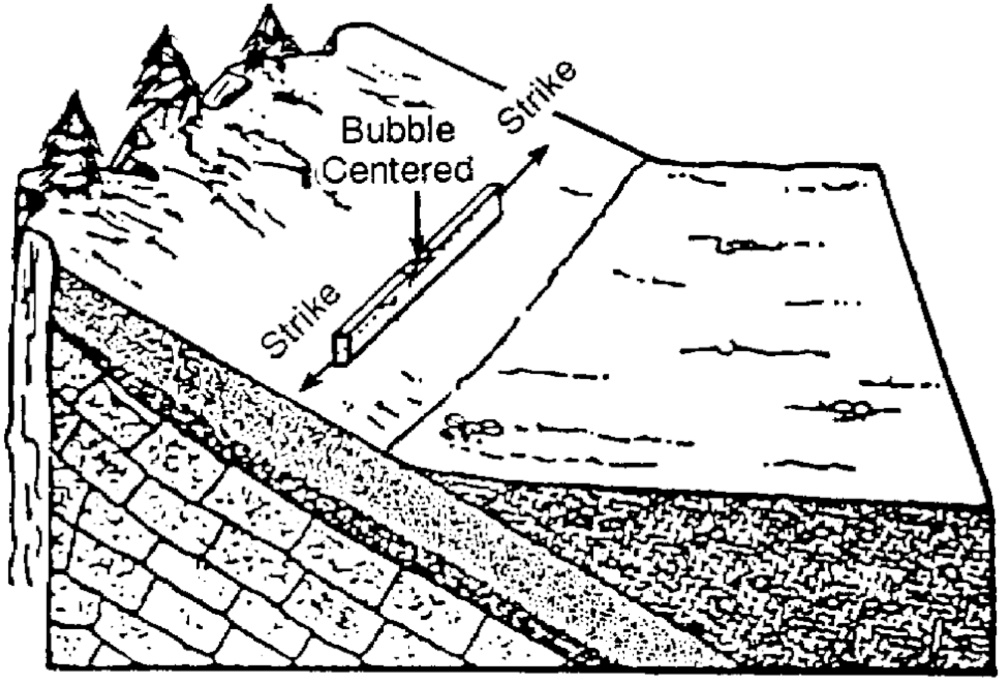


Figure 2-15. Strike.

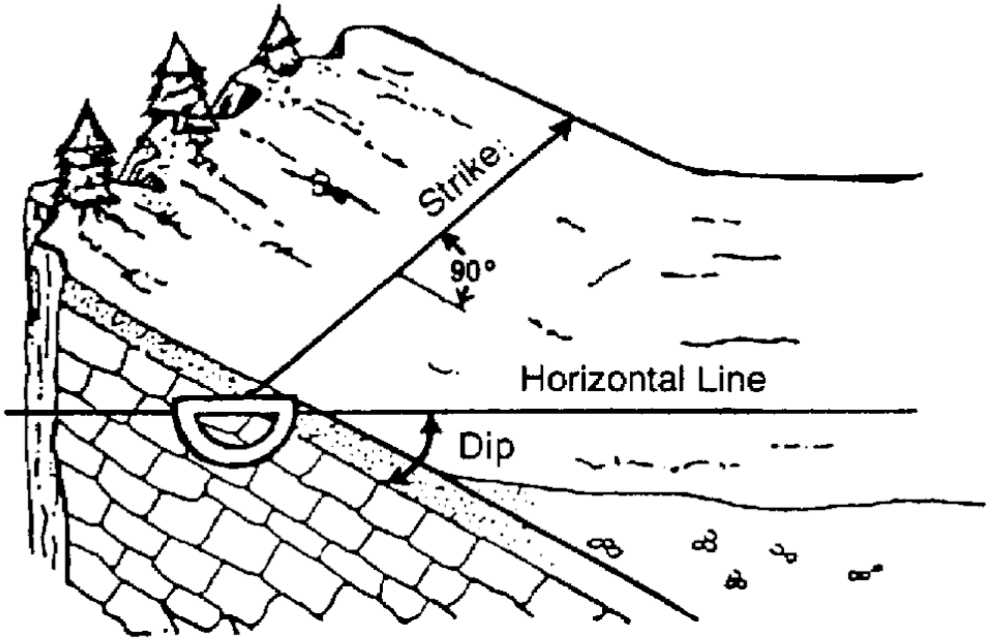


Figure 2-16. Dip.

Measuring Strike and Dip
Symbols for Strike and Dip

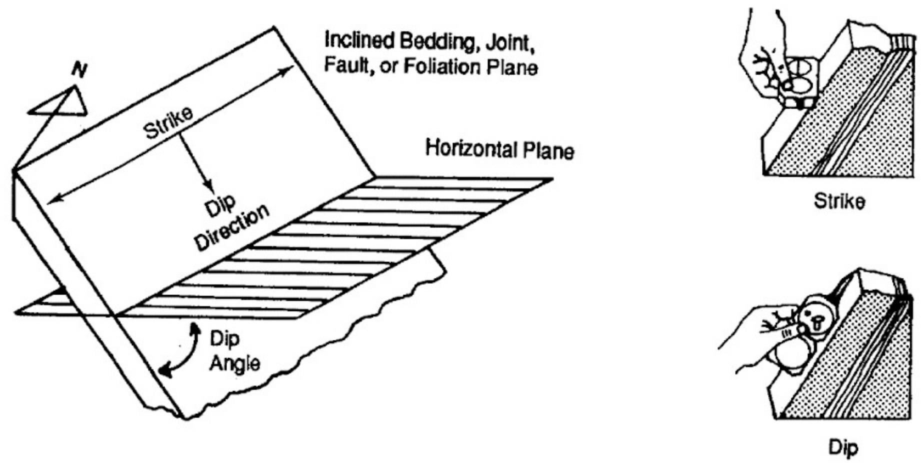


Figure 2-17. Measuring strike and dip with a Brunton compass.

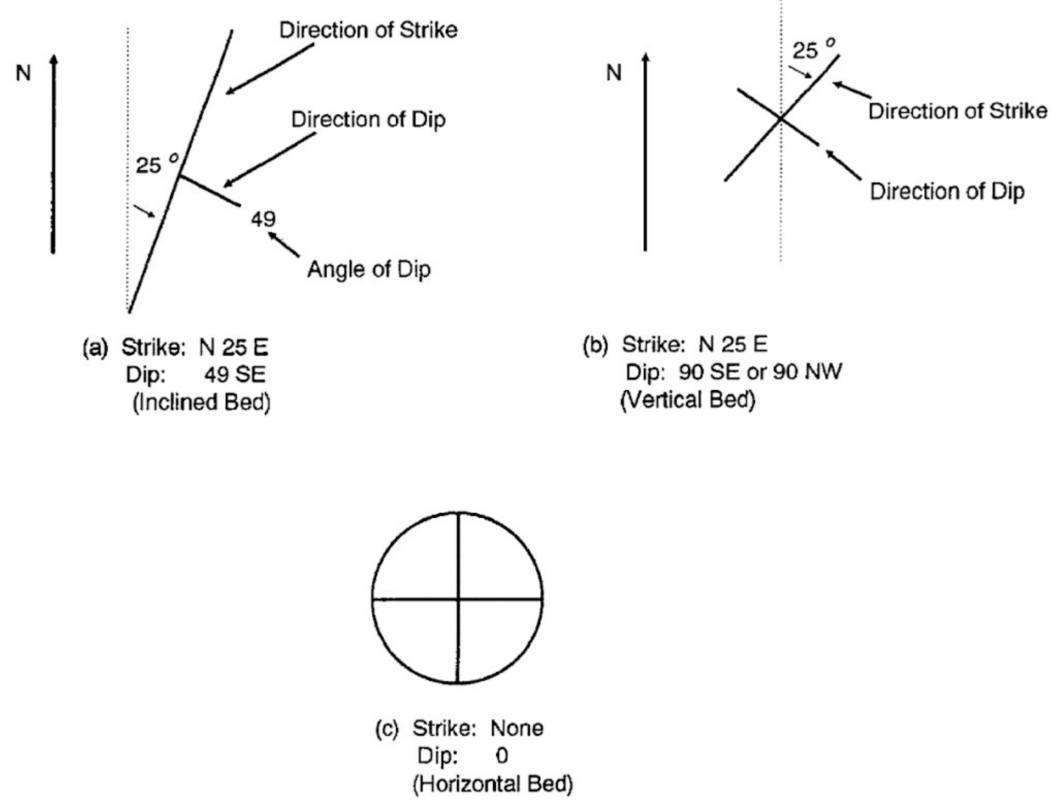


Figure 2-18. Strike and dip symbols.

Note orientation of strike and dip relative to cardinal directions!

Application to Geologic Maps

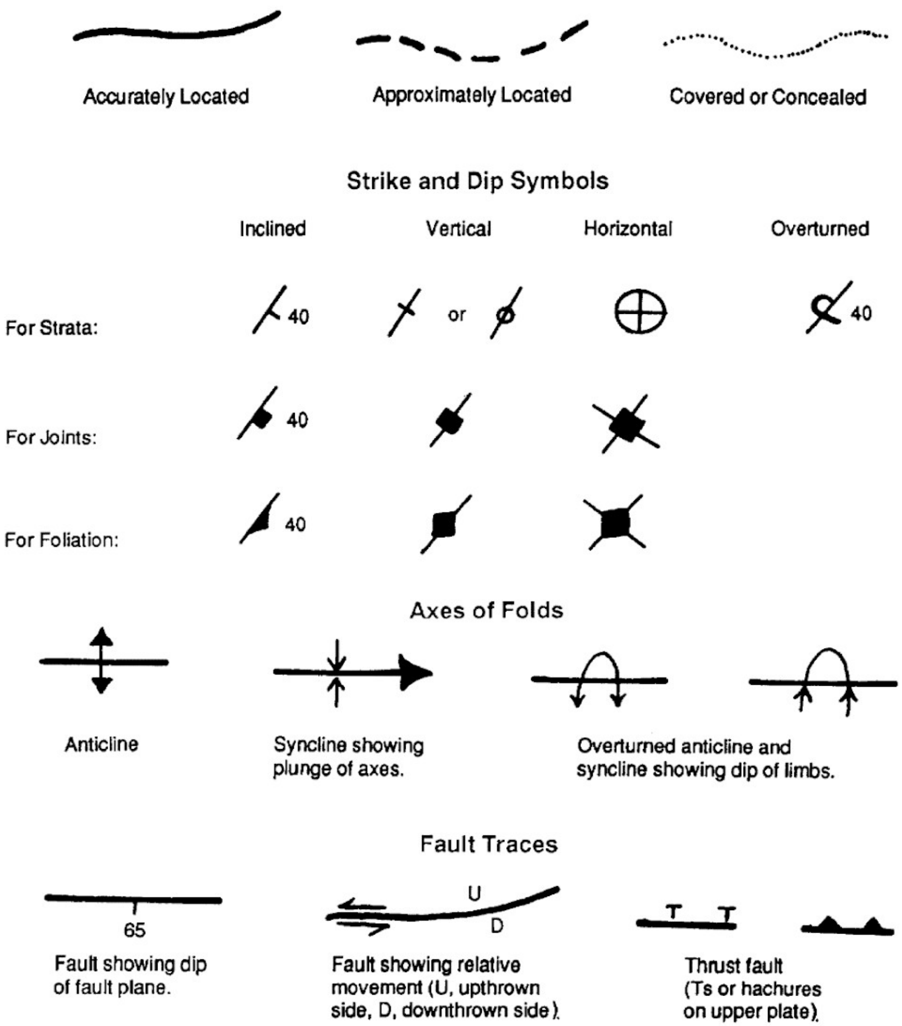


Figure 2-21. Geologic map symbols.

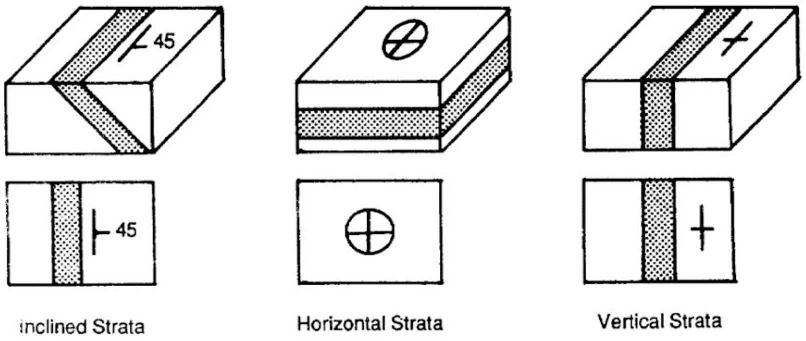


Figure 2-22. Placement of strike and dip symbols on a geologic map.

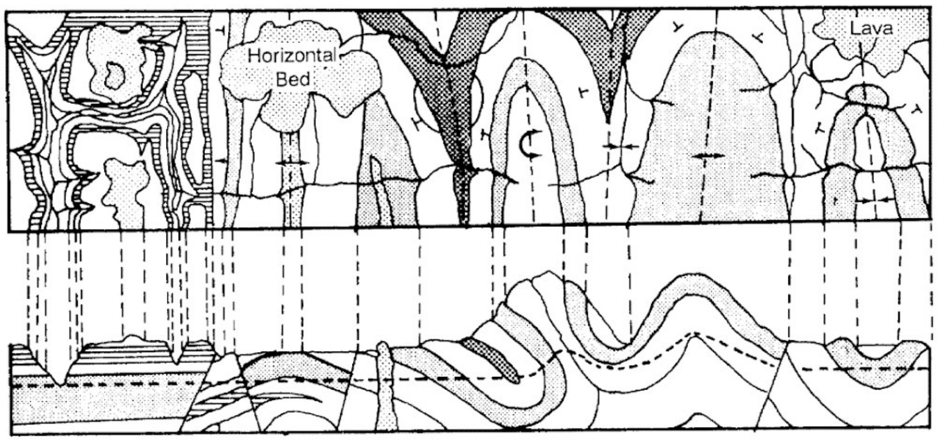


Figure 2-23. Geologic map and cross section.

Application of Strike and Dip

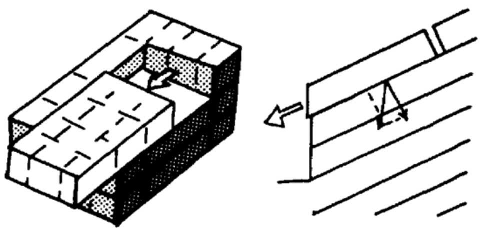


Figure 2-34. Rock slide on inclined bedding plane.

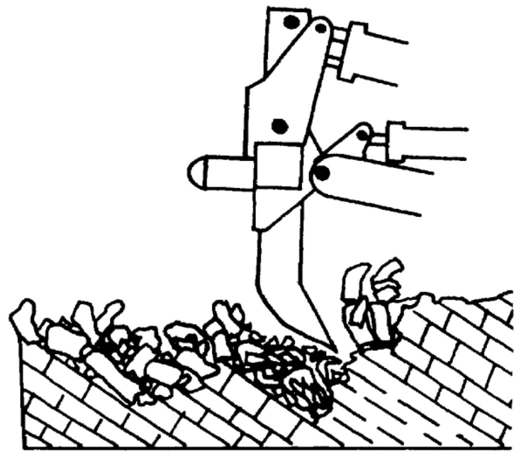


Figure 2-32. Ripping in the direction of dip.

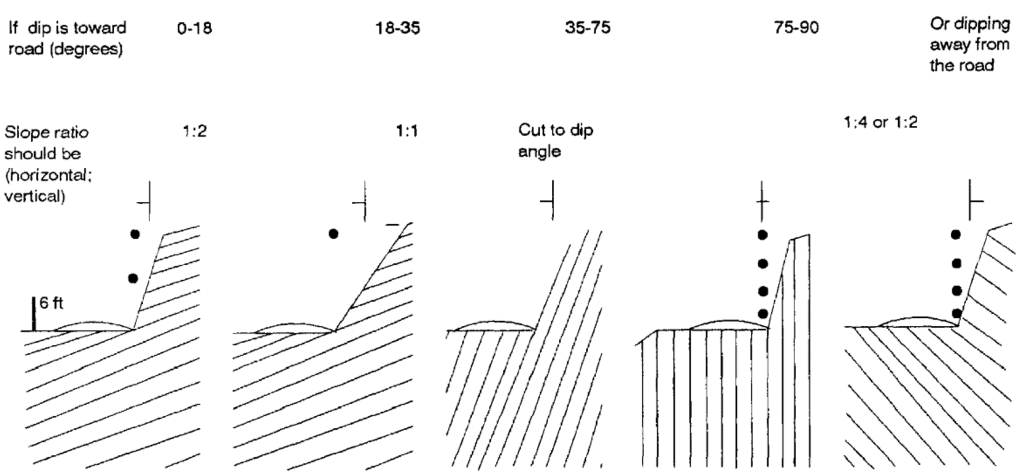
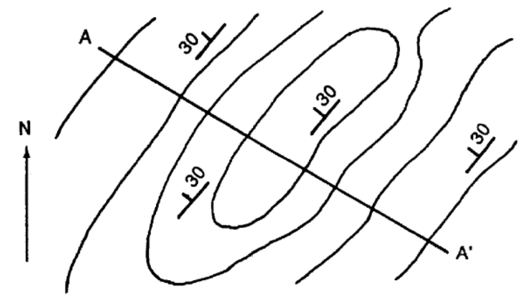
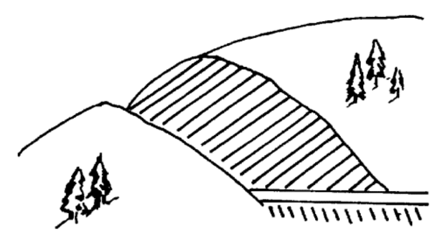


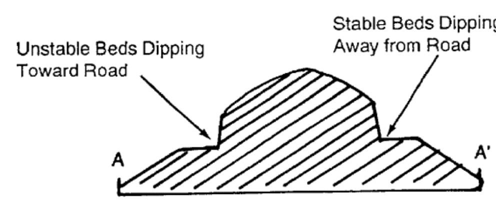
Figure 2-35. Rules of thumb for inclined sedimentary rock cuts.



(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 $\geq$ 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

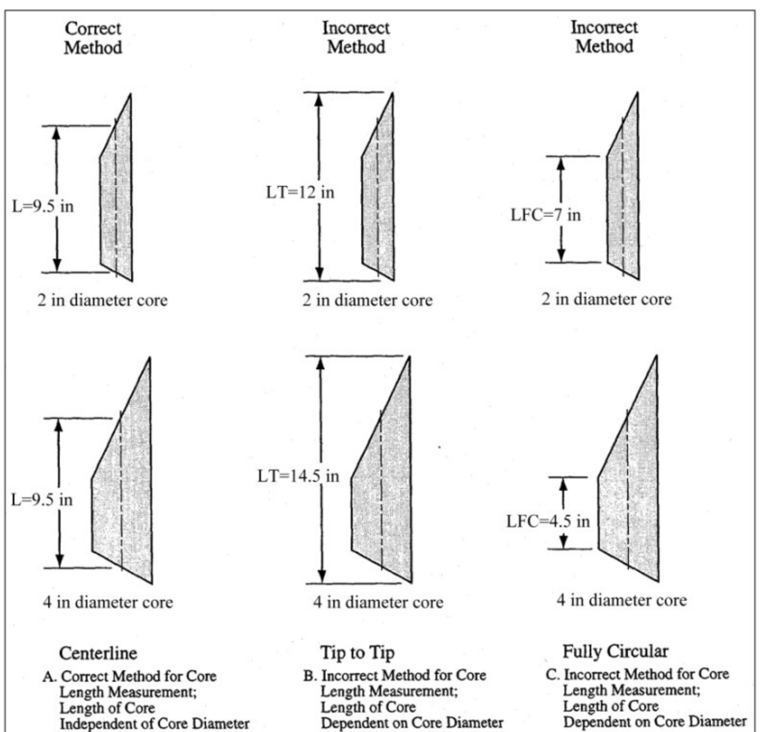
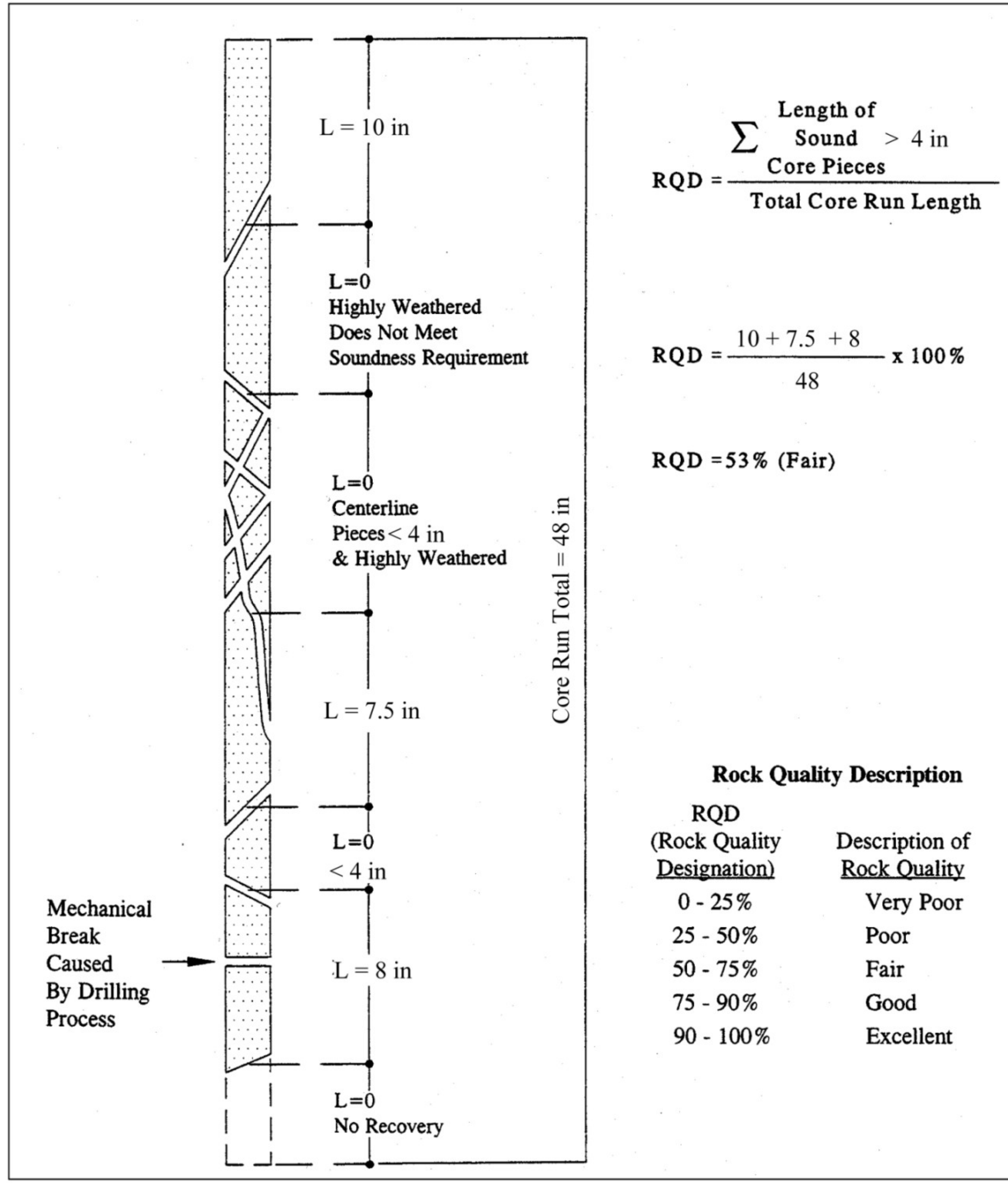


Figure 3-18. Length measurements for core RQD determination (FHWA, 1997).



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

Basic Soil Types

- Sedimentary Soils
  - Soils which are weathered in place
    - Residual
    - Organic

- Transported Soils
  - Soils which are transported and deposited in a new location
    - Alluvial
    - Aeolian
    - Glacial
    - Marine
    - Colluvial
    - Pyroclastic

Sedimentary Soils

- Residual Soils: Material formed by disintegration of underlying parent rock or partially indurated material.
  - Sands
    - Residual sands and fragments of gravel size formed by solution and leaching of cementing material, leaving the more resistant particles; commonly quartz.
  - Clays
    - Residual clays formed by decomposition of silicate rocks, disintegration of shales, and solution of carbonates in limestone.
- Organic Soils: Accumulation of highly organic material formed in place by the growth and subsequent decay of plant life
  - Peat. A somewhat fibrous aggregate of decayed and decaying vegetation matter having a dark colour and odour of decay.
  - Muck. Peat deposits which have advanced in stage of decomposition to such extent that the botanical character is no longer evident.
- Very compressible. Entirely unsuitable for supporting building foundations.

Transported Soils: Alluvial Soils

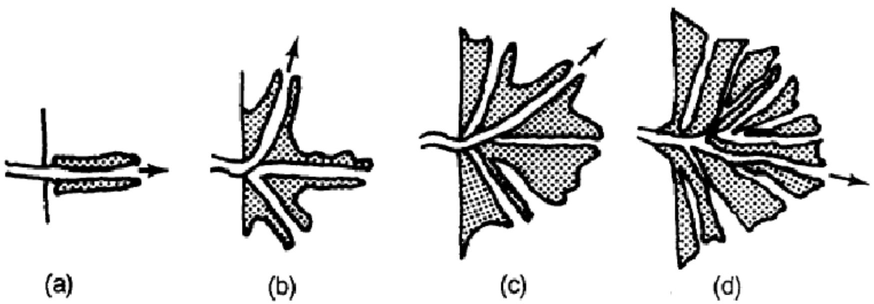


Figure 3-14. Growth of a simple delta.

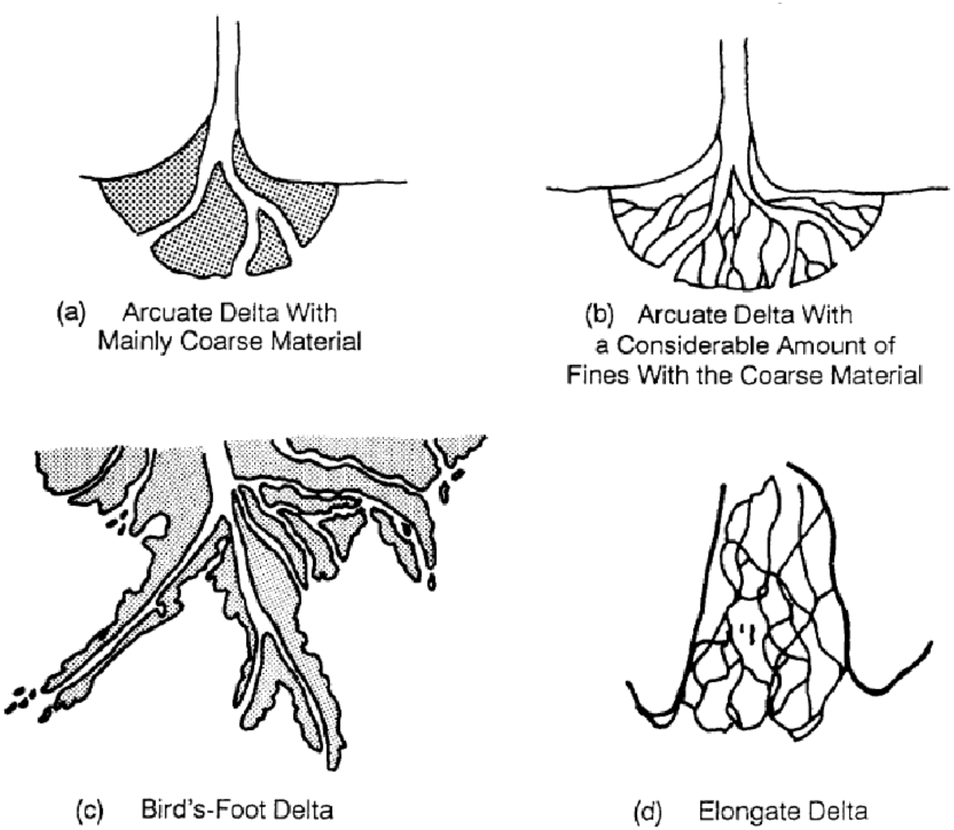


Figure 3-15. Arcuate, bird's-foot, and elongate deltas.

Table 3-2. Fluvial surficial features.

Feature	Description
Point Bar	A low, crescent-shaped mound located at the inside of many bends in rivers or streams.
Channel Bar	A low, streamlined mound in braided streams or just downstream from point bars and on the opposite bank.
Floodplain	A flat valley floor, leveled by back and forth erosion of the river or stream between the valley walls.
Alluvial Terrace	A platform or flat surface higher than the floodplain and generally close to the valley walls. It is all that remains of what was a floodplain many years before.
Oxbow Lake	A horseshoe-shaped, abandoned section of a stream or river channel still containing water.
Clay Plug	A clay-filled, abandoned section of a stream or river at the ends of horseshoe-shaped oxbow lakes.
Natural Levee	Wide, low mounds (5 to 15 feet high), paralleling the river along both banks with sloping sides away from the river.
Backswamp	A swampy, level portion of a floodplain with very poor drainage and a high water table.
Delta	Natural land extension into a body of water, visible as a low, almost level, land mass protruding into the body of water.
Alluvial Fan	A cone-shaped mound formed against a valley wall, appearing fan-shaped from above.
Lake Bed Deposit	A layer formed from the settling of sediments to the bottom of lakes. The layers are thick at the center of the lake bed and thin near the lake margins.

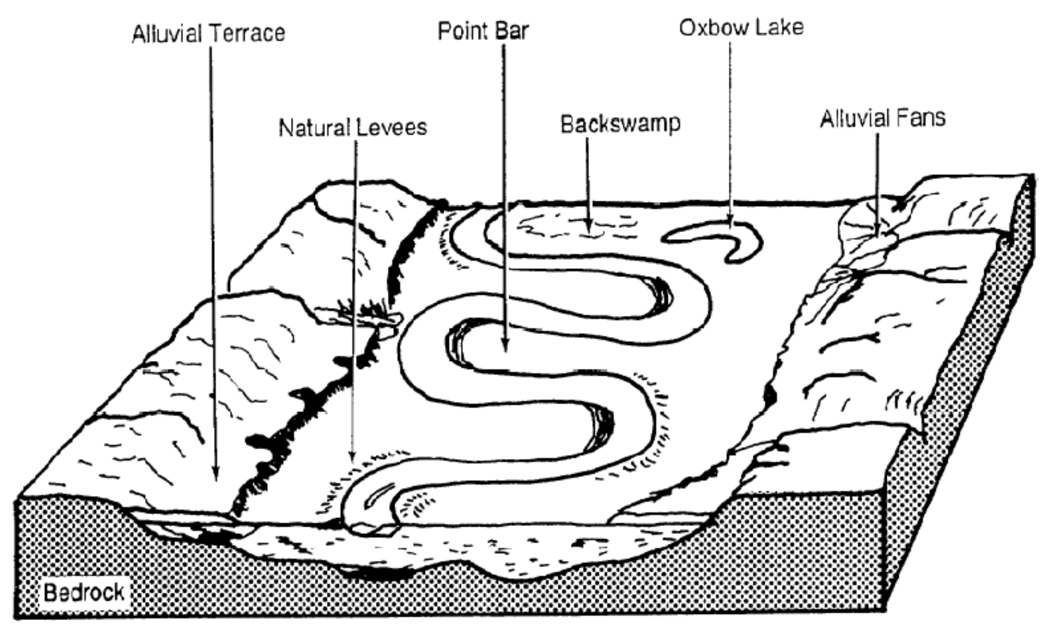


Figure 3-19. Major floodplain features.

Transported Soils: Alluvial Soils

- Other examples
  - Alluvial fans: water transported deposits in relatively dry places
  - Piedmont deposits

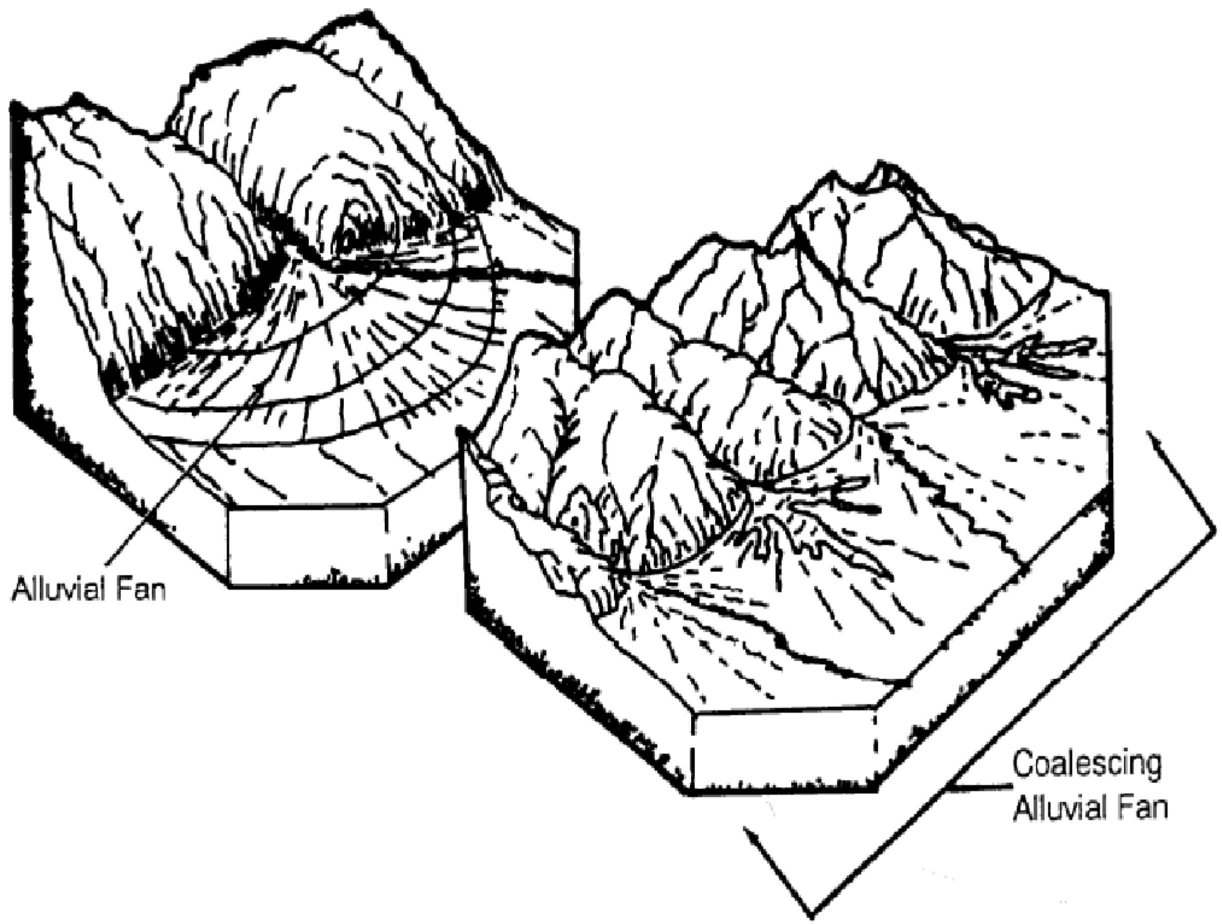


Figure 3-16. Alluvial fan and coalescing alluvial fans.

Transported Soils: Aeolian Soils

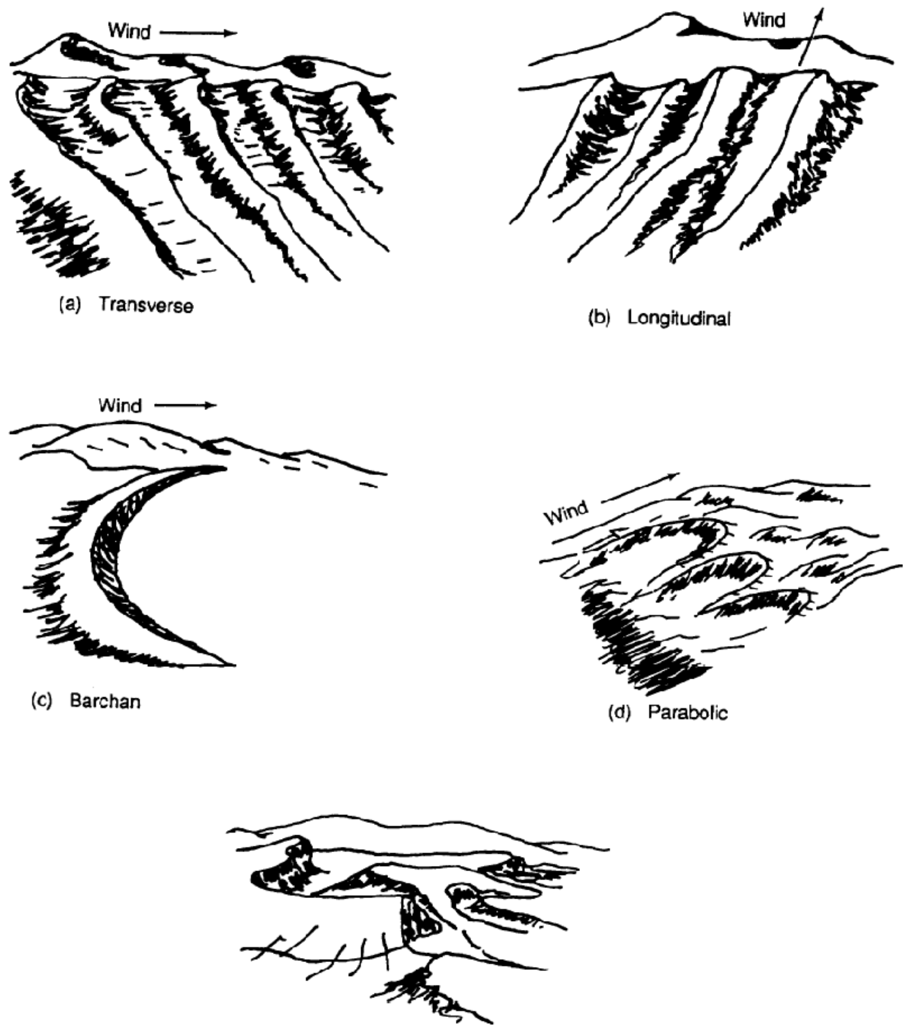


Figure 3-33. Sand dune types.

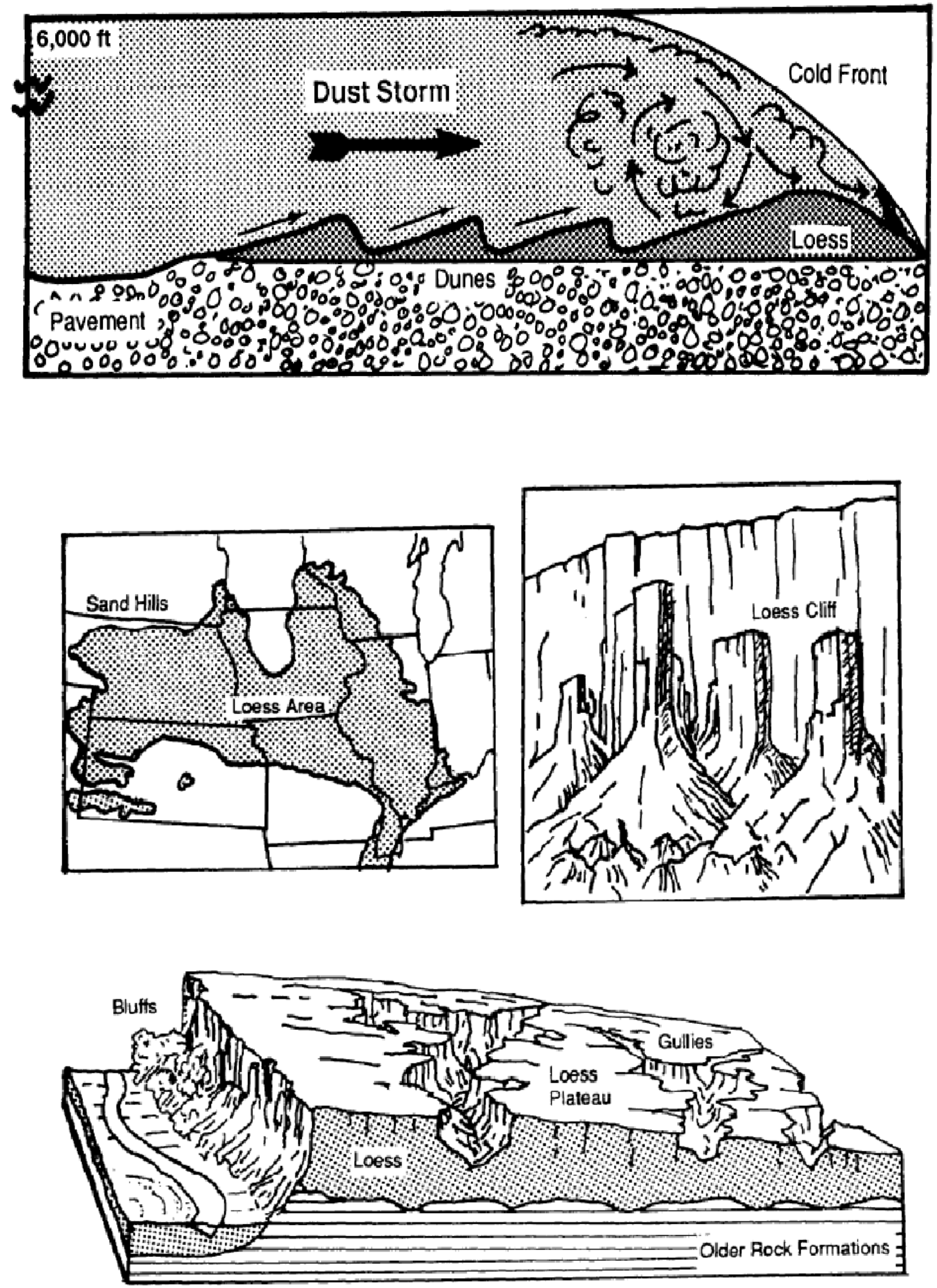


Figure 3-34. Loess landforms.

Transported Soils: Glacial Soils

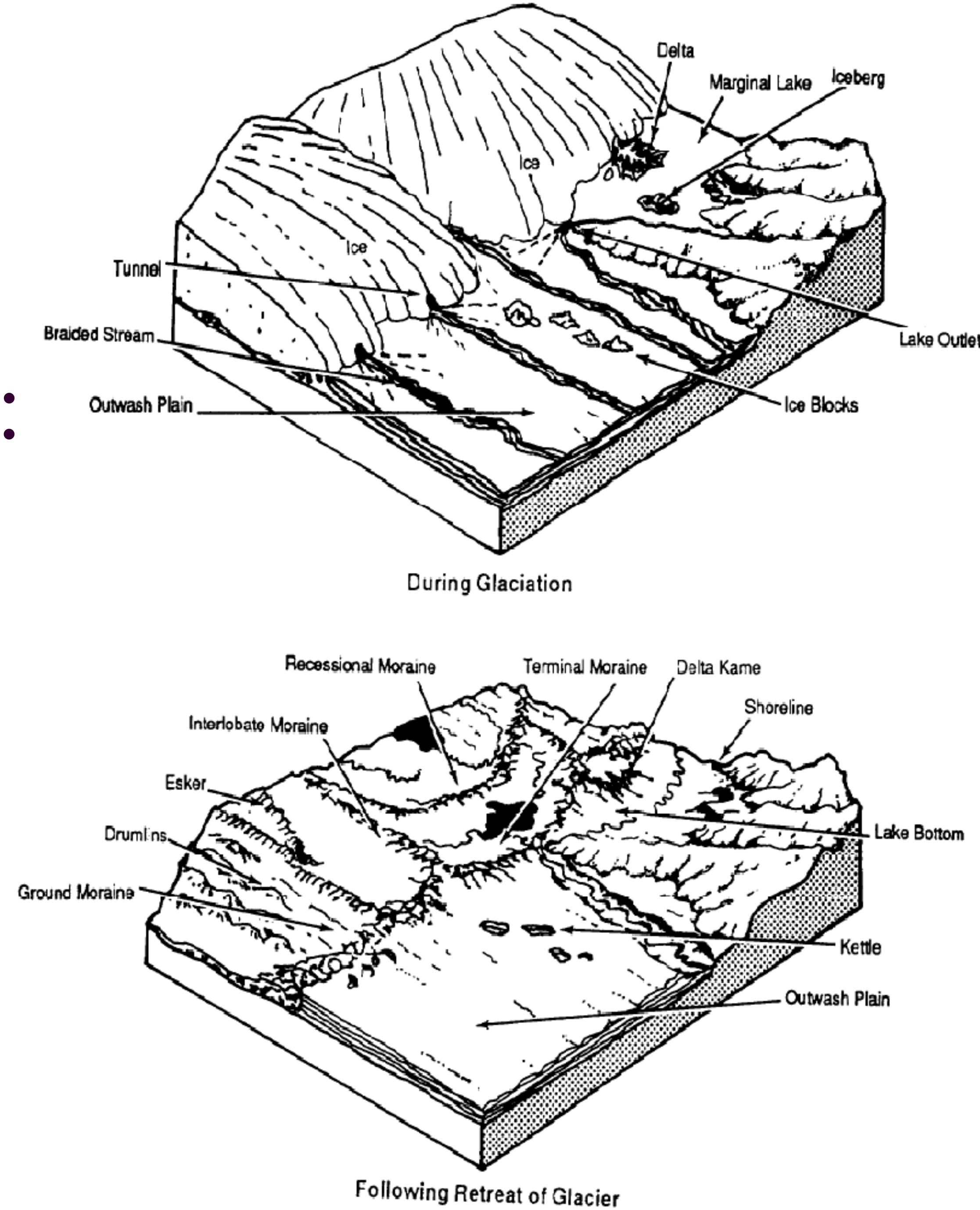


Figure 3-22. Continental glaciation.

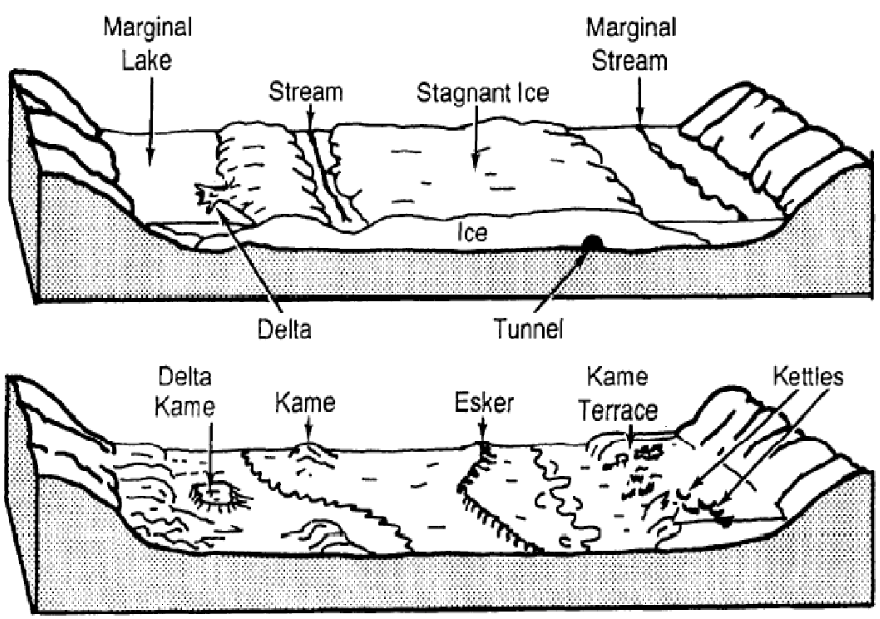


Figure 3-25. Valley deposits from melting ice.

Transported Soils

- Marine Soils: Material transported and deposited by ocean waves and currents in shore and offshore areas.
  - Shore deposits
    - Deposits of sands and/or gravels formed by the transporting, destructive, and sorting action of waves on the shoreline.
  - Marine clays
    - Organic and inorganic deposits of fine-grained material.
- Colluvial Soils: Material transported and deposited by gravity.
  - Talus
    - Deposits created by gradual accumulation of unsorted rock fragments and debris at base of cliffs.
  - Hillwash
    - Fine colluvium consisting of clayey sand, sand silt, or clay.

Soil Cohesion

- Cohesionless Soils
  - Generally are granular or coarse grained
  - Particles do not naturally adhere to each other
  - Have higher permeability

Cohesive Soils

Generally are fine grained

Particles have natural adhesion to each other due to presence of clay minerals

Have low permeability

Structure of Clay Minerals

- Atoms of clay minerals form sheets
  - Silica tetrahedral sheets
  - Alumina octahedral sheets
  - Sheets can layer in different ways, forming different types of clay minerals
  - Clay minerals tend to form flat, platelike shapes

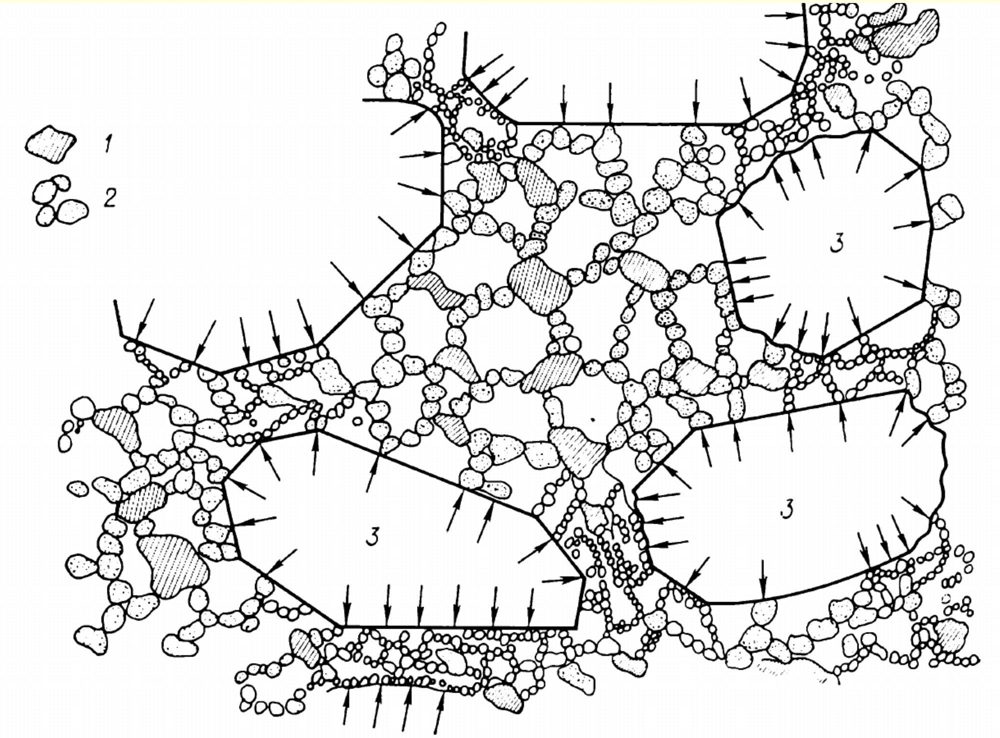


Fig. 4. Structure of clay
1—clay particles; 2—compacted colloids; 3—sand grains

Types of Clay Minerals

- Kaolinite
  - One sheet alumina, one silica
  - Relatively low unit surface area (10 m^2/g)
  - Most prevalent clay mineral
- Halloysite
  - One sheet alumina, one silica, sheet of water in between
  - Properties affected by presence or removal of water sheet
  - Reverts to kaolinite when water is removed
- Illite
  - One silica, one alumina, one silica sheet, bonded with potassium
  - More plastic than kaolinite
  - Most prevalent in marine deposits
- Montmorillonite
  - Same as illite except no potassium; iron or magnesium replace the alumina
  - Very prone to expansion with changes in water content due to weak bonding and larger unit surface area (800 m^2/g)

Principal Soil Deposits in Terms of Origin

Table 1-1 Principal Soil Deposits in Terms of Origin

Major Division	**Principal Soil Deposits**	**Pertinent Engineering Characteristics**
Organic: Accumulation of highly organic material formed in place by the growth and subsequent decay of plant life	*Peats*: Somewhat fibrous aggregate of decayed and decaying vegetation matter having a dark color and odor of decay	Very compressible; entirely unsuitable for supporting building foundations
	Mucks: Peat deposits which have advanced in stage of decomposition to such extent that the botanical character is no longer evident	
Pyroclastic: Material ejected from volcanoes and transported by gravity, wind and air	*Ejecta*: Loose deposits of volcanic ash, lapilli, bombs, etc.	Typically, shard-like particles of *silt* size with larger volcanic debris; weathering and redeposition produce high plasticity, compressible *clay*; unusual and difficult foundation conditions
	Pumice: Highly porous volcanic rock that is frequently associated with lava flows and mud flows, or may be mixed with nonvolcanic sediments	
Residual: Material formed by disintegration of underlying parent rock or partially indurated material	Residual sands and fragments of gravel-sized material formed by dissolution and leaching of cementing material, leaving behind the more resistant particles, commonly quartz	Generally favorable foundation conditions
	Residual clays formed by the decomposition of silicate rocks, disintegration of shales, and solution of carbonates in limestone; with few exceptions, becomes more compact, rockier and less weathered with increasing depth; at intermediate stage may reflect composition, structure and stratification of parent rock	Variable properties requiring detailed investigation; deposits present favorable foundation conditions except in humid and tropical climates, where depth and rate of weathering are very great
	Transported soils: See Table 1-2	

Principal Soil Deposits in Terms of Occurrence

Table 1-2 Principal Soil Deposits by Mode of Occurrence

Major Division	Principal Soil Deposits	Pertinent Engineering Characteristics
Aeolian: Material transported and deposited by wind.	*Loess*: A calcareous unstratified deposit of silts or sandy or clayey silt traversed by a network of tubes formed by root fibers now decayed	Relatively uniform deposits characterized by ability to stand in vertical cuts; collapsible structure; deep weathering or saturation can modify characteristics
	Dune sands: Mounds, ridges, and hills of uniform fine sand characteristically exhibiting rounded grains	Very uniform grain size; may exist in relatively loose condition
Alluvial: Materials transported and deposited by running water.	*Floodplain:* Low-lying stream or river deposits that are subject to inundation by floodwaters	
	Point bar: Alternating deposits of arcuate ridges and swales (lows) formed on the inside or convex bank of mitigating river bends; ridge deposits consist primarily of silt and sand, swales are clay filled	Generally favorable foundation conditions; however, detailed investigations are necessary to locate discontinuities; flow slides may be a problem along riverbanks; soils are quite pervious
	Channel fill: Deposits laid down in abandoned meander loops isolated when rivers shorten their courses; composed primarily of clay; however, silty and sandy soils are found at the upstream and downstream ends	Fine-grained soils are usually compressible; portions may be very heterogeneous; silty soils generally present favorable foundation conditions
	Backswamp: The prolonged accumulation of floodwater sediments in flood basins bordering a river; materials are generally clays but tend to become siltier near riverbank	Relatively uniform in a horizontal direction; clays are usually subjected to seasonal volume changes
	Terrace: Relatively narrow, flat-surfaced, river-flanking remnants of floodplain deposits formed by entrenchment of rivers and associated processes	Usually drained and oxidized; generally favorable foundation conditions
	Estuarine: Mixed deposits of marine and alluvial origin laid down in widened channels at mouths of rivers and influenced by tide of body of water into which they are deposited	Generally fine grained and compressible; many local variations in soil conditions
	Lacustrine: Material deposited within lakes (other than those associated with glaciation) by waves, currents, and organo-chemical processes; deposits consist of unstratified organic clay or clay in central portions of the lake and typically grade to *stratified* silts and sands in peripheral zones	Usually very uniform in horizontal direction; fine-grained soils generally compressible
	Deltaic: Deposits formed at the mouths of rivers, which result in extension of the shoreline	Generally fine-grained and compressible; many local variations in soil condition
	Piedmont: Alluvial deposits at foot of hills or mountains; extensive plains or alluvial fans	Generally favorable foundation conditions

Principal Soil Deposits in Terms of Occurrence

Table 1-2 (cont.) Principal Soil Deposits by Mode of Occurrence

Major Division	Principal Soil Deposits	Pertinent Engineering Characteristics
Colluvial: Material transported and deposited by gravity	*Talus*: Deposits created by gradual accumulation of unsorted rock fragments and debris at base of cliffs	Previous movement indicates possible future difficulties; generally unstable foundation conditions
	Hillwash: Fine colluvium consisting of clayey sand, sand silt, or clay	
	Landslide deposits: Considerable masses of soil or rock that have slipped down, more or less as units, from their former position on steep slopes	
Glacial: Material transported and deposited by glaciers, or by meltwater from the glacier.	*Glacial till*: An accumulation of debris, deposited beneath, at the side (lateral moraines), or at the lower limit of a glacier (terminal moraine); material lowered to ground surface in an irregular sheet by a melting glacier is known as a ground moraine.	Consists of material from *boulder* and *gravel* to clay; deposits are unstratified; present generally favorable foundation conditions but rapid changes in conditions are common.
	Glacio-fluvial deposits: Coarse and fine-grained material deposited by streams of meltwater from glaciers; material deposited on ground surface beyond terminal edge of a glacier is known as an outwash plain; gravel ridges known as kames and eskers; depressions known as kettles can be filled with peat	Many local variations; generally present favorable foundation conditions
	Glacio-lacustrine deposits: Material deposited within lakes by meltwater from glaciers; consisting of clay in central portions of lake and alternate layers of silty clay or silt and clay (varved clay) in peripheral zones	Very uniform in the horizontal direction
Marine: Material transported and deposited by ocean waves and currents in shores and offshore areas.	*Shore deposits*: Deposits of sands and/or gravels formed by the transporting, destructive, and sorting action of waves on the shoreline	Relatively uniform and of moderate to high density
	Marine clays: Organic and inorganic deposits of fine-grained material	Generally, very uniform, compressible and usually very sensitive to remolding

Questions?