ENCE 361 Soil Mechanics

University of Tennessee at Chattanooga
Spring 2010

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http://www.vulcanhammer.net/utc

Catalogue Description

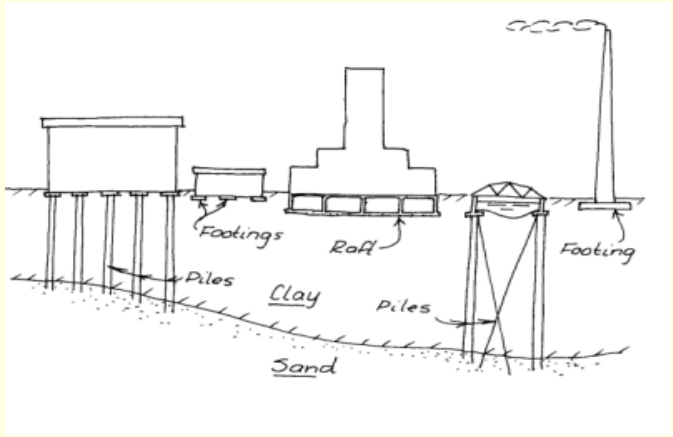
- Geologic overview
- Soil composition
- Soil type and structure
- Index properties
- Classification
- Site investigation
- Subsurface flow
- Flow nets
- Drainage
- Subsurface stresses
- Settlement
- Shear strength
- Slope stability

Textbook and Reference Books

- Textbook
  - Das, Braja M. *Principles of Geotechnical Engineering*. Sixth Edition. Stamford, CT: Cengage Learning, 2006
  - EM 1110-2-1906, *Laboratory Soils Testing*. Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1986.

- Reference Works
  - NAVFAC DM 7.01, *Soil Mechanics*. Naval Facilities Engineering Command, Alexandria, Virginia, 1986.
  - Sabatini, P.J., Bachus, R.C., Mayne, P.W., Schneider, J.A., and Zettler, T.E. *Evaluation of Soil and Rock Properties.* FHWA Geotechnical Engineering Circular #5. FHWA-IF-02-034. Washington, DC: Federal Highway Administration.
  - U.S. Army. *Military Soils Engineering.* Field Manual FM 5-410, Change 1. Washington, DC: U.S. Army, 1992.

Line Drawing Credit



Dr. Bengt Broms
Foundation Design
http://www.geoforum.com/

Evaluation

- Homework: Seven (7) assignments @ 4% each = 28%
- One (1) Mid-Term Examination: 14%
- Three (3) unannounced quizzes @ 4% each: 12%
- Six (6) Laboratory Reports @ 5% each: 30%
- Final Examination: 16%

Class Notebook

- You are required to keep and assemble a three-ring (or other suitable binding) notebook with the following divisions in it:
  - Homework
  - Quizzes
  - Tests
  - Laboratory Experiment Reports
  - Class Notes (Optional)
- You will turn this notebook in at the final exam. It will be inspected and returned to you.

Appearance of Work

- All homework and tests must be on engineering paper.
- Homework and tests must conform to format given in syllabus. Failure to do so will result in reduced credit.
- Each time you use an equation, write down what it is: don't just put a bunch of numbers on the page and expect anyone to know what you did. This too will result in reduced credit.

Honour System

- You are encouraged to work homework with someone but your turned in work must be your own work.
- You are studying now so that you may enter and practice the engineering profession later. The engineering profession is highly regarded by the public because those who practice it do so with ethical and social consciousness. The same is expected of students in this course. Any direct copying of homework, tests or exams will be considered a violation of the honour code and a course grade of “F” will be given.

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 or under them."

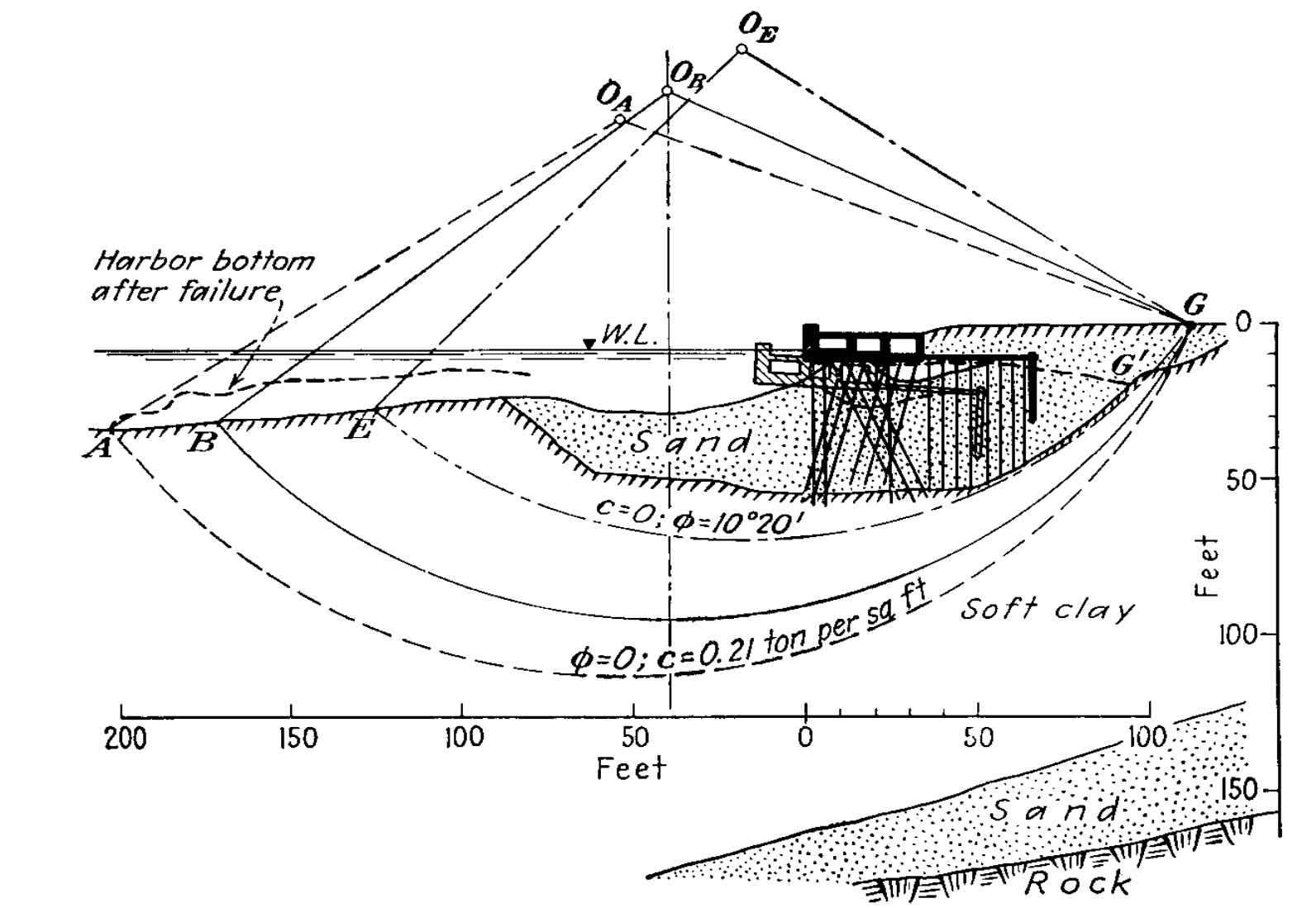
Characteristics of Geotechnical Engineering

- 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

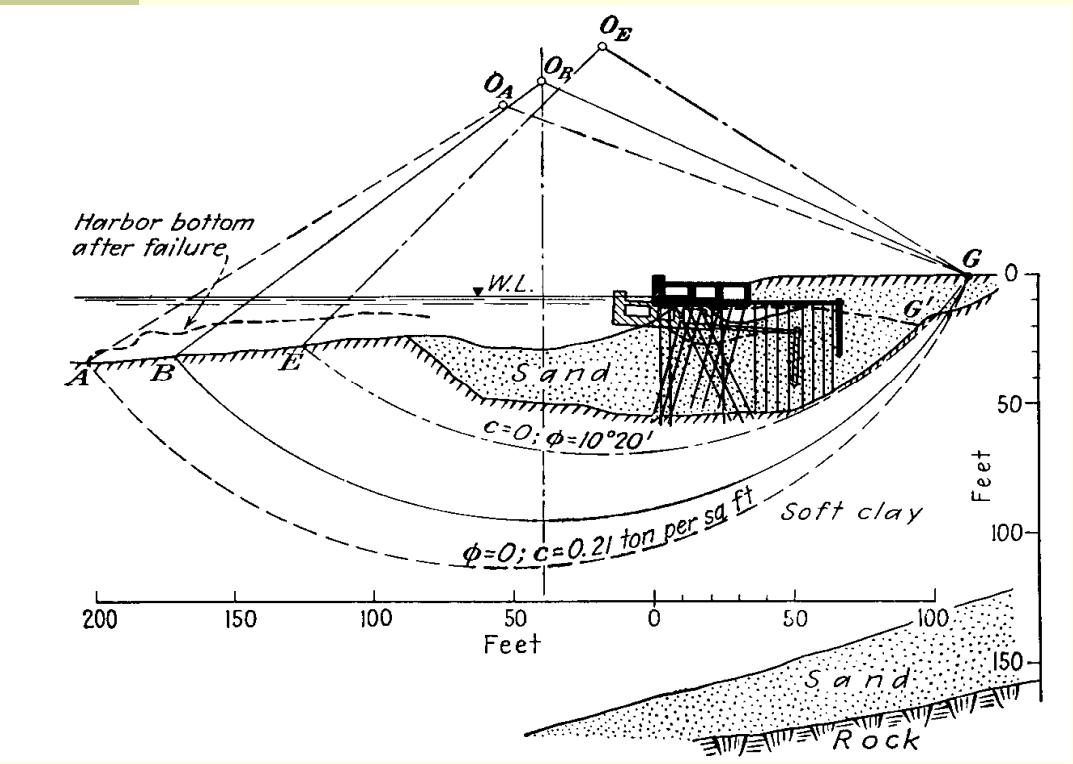
Development of Geotechnical Engineering

- 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



Gothenburg Harbour Failure 5 March 1916



- Soft clay deposit, 150' deep
- 50' was dredged out and replaced by sand fill; piles were driven to stabilise 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

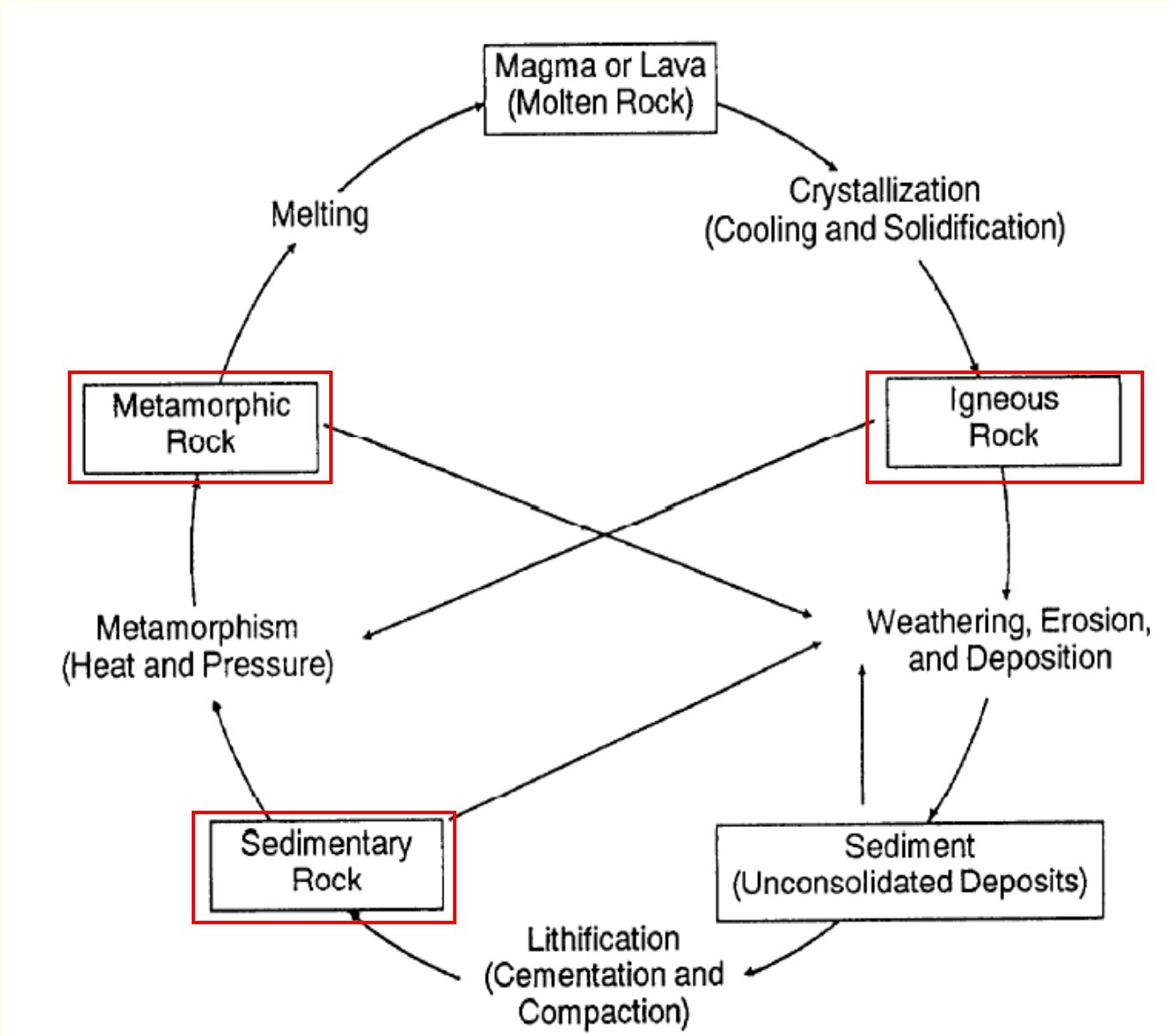
- The “father of geotechnical engineering”
- Developed both the theory and practice of the analysis of soils and the design of foundations
  - Consolidation theory
  - Bearing Capacity of Shallow Foundations
  - Design of retaining walls and cellular cofferdams
- Wrote some of the first textbooks on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

Soils and Rocks

Definition of “Soil” and “Rock”

- 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).
- 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).

Types of Rocks and The Rock Cycle



Igneous Rocks

- Definition
  - Rocks formed by the solidification of molten material, either by intrusion at depth in the earth's crust or by extrusion at the earth's surface.

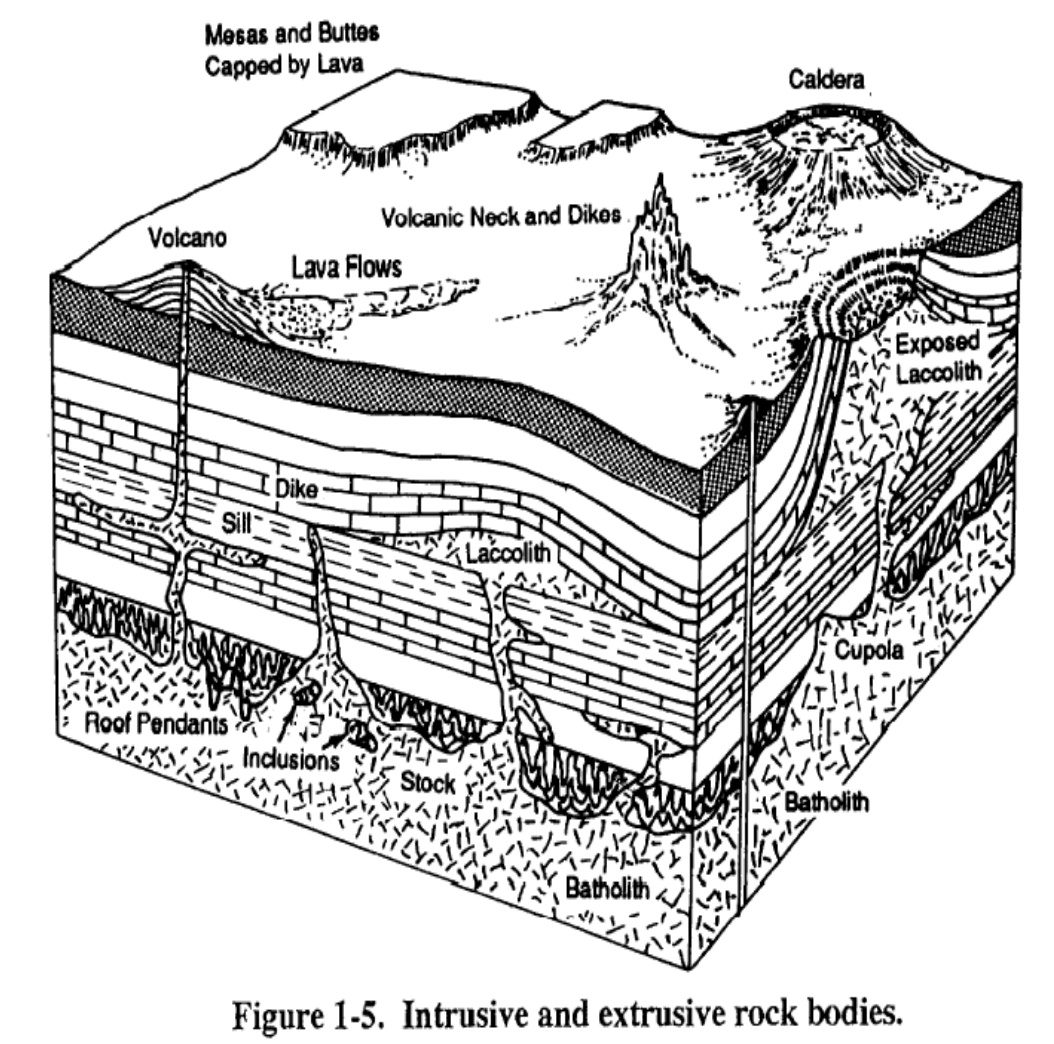
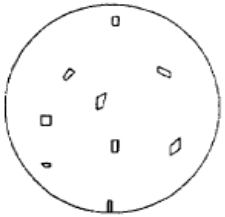


Figure 1-5. Intrusive and extrusive rock bodies.



Very Fine Crystals
Extrusive

Well-Formed Crystals
Intrusive

Table 1-2. Classification of igneous rocks.

Origin	Dominant Texture*		Typical Mineral: K-Feldspar, Quartz, Plagioclase, Biotite, Pyroxene, Olivine, Amphibole	
			Color	
			Light	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

- Definition
  - Rocks formed by deposition, usually under water, of products derived by the disaggregation of pre-existing rocks.
- Types
  - Shales ← clay and silt particles
  - Sandstones
  - Limestone (Karst topography)
  - Dolstone (marl, chalk)
- Importance of Weathering

Table 1-3. Classification of sedimentary rocks.

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

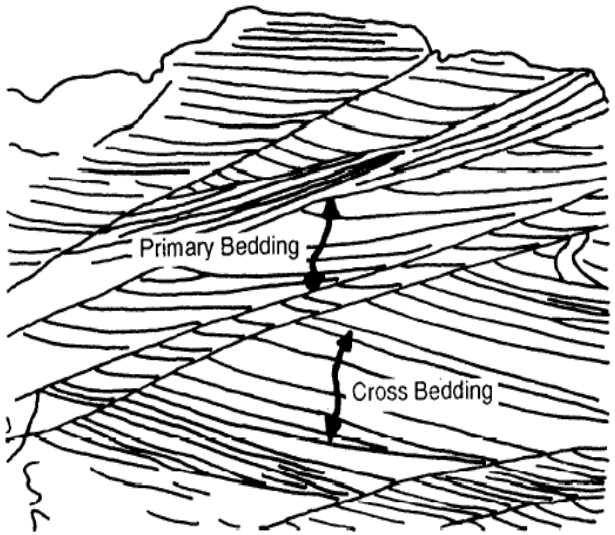


Figure 1-11. Cross bedding in sandstone.

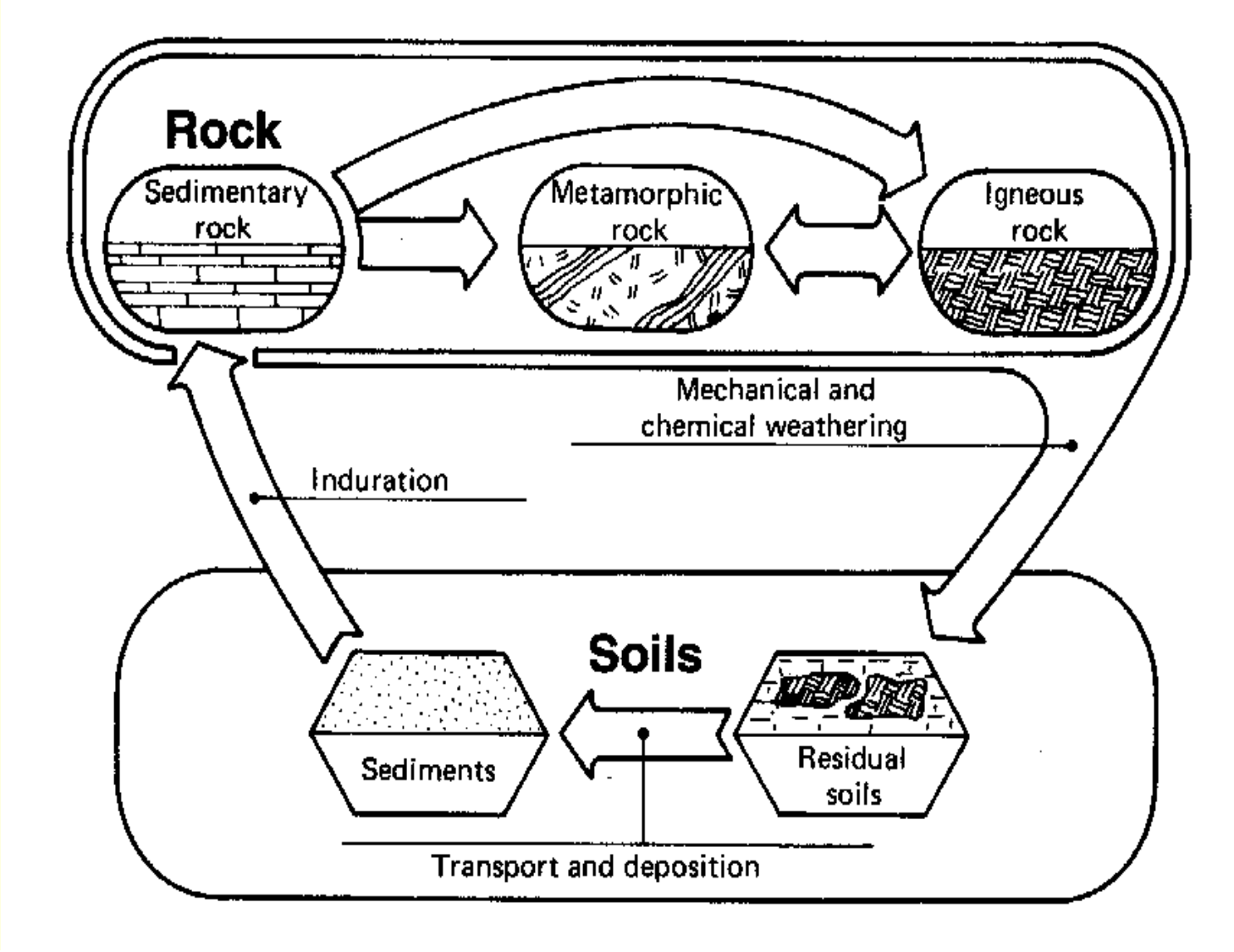
Metamorphic Rocks

- 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

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

From Rock to Soil



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

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

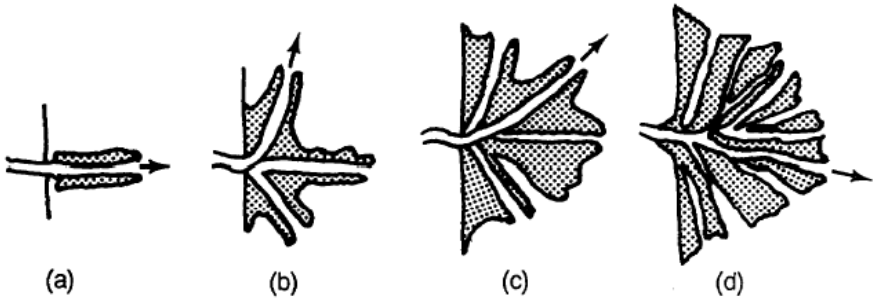


Figure 3-14. Growth of a simple delta.

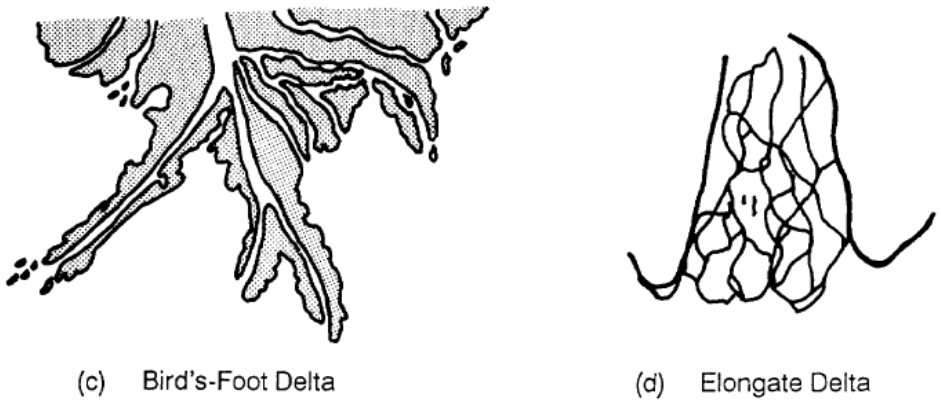


Figure 3-15. Arcuate, bird's-foot, and elongate deltas.

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.

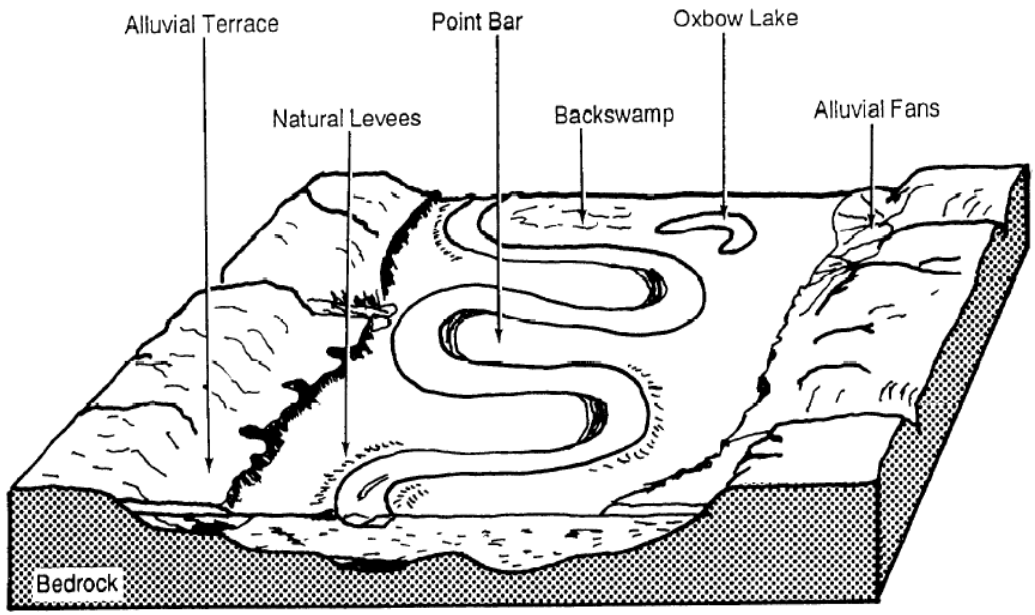


Figure 3-19. Major floodplain features.

Transported Soils: Alluvial Soils

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

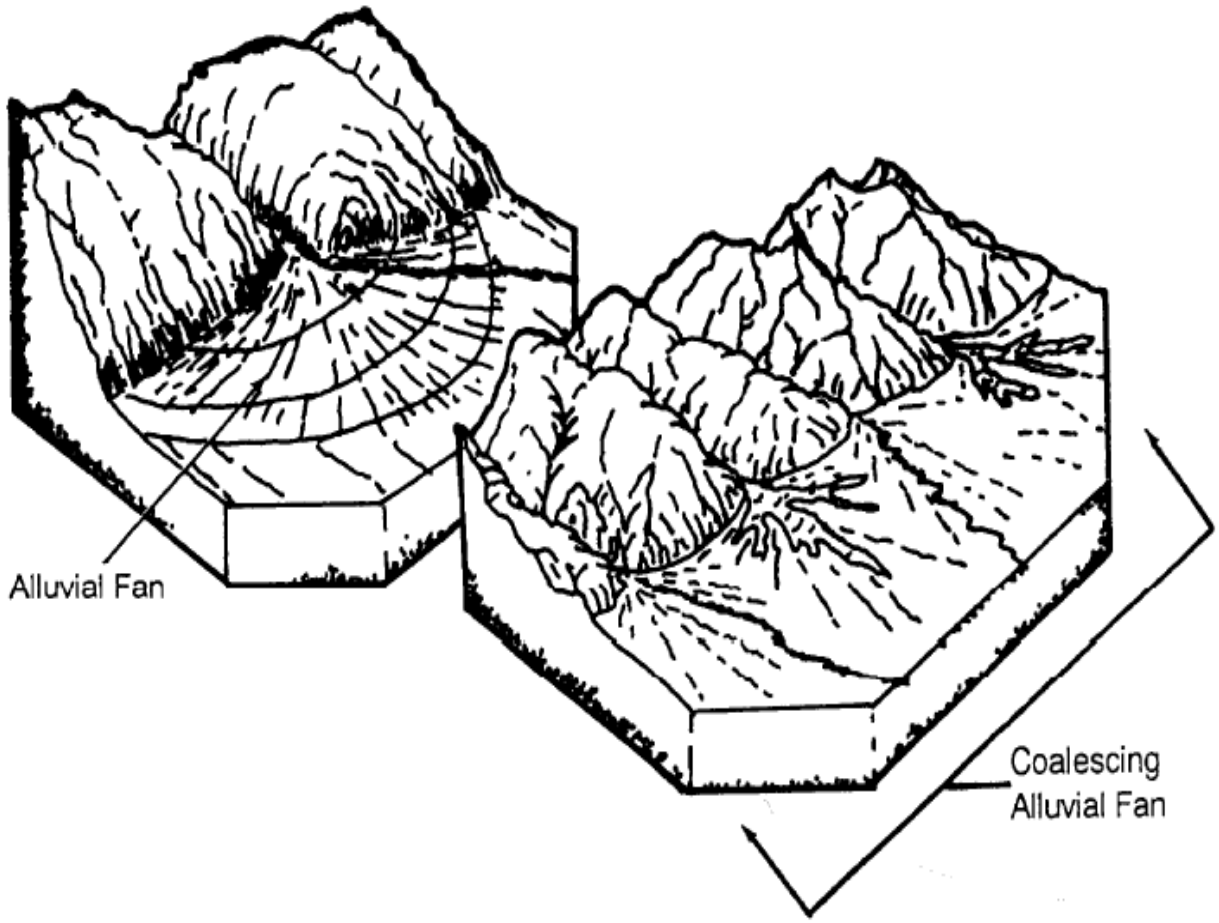


Figure 3-16. Alluvial fan and coalescing alluvial fans.

Transported Soils: Aeolian Soils

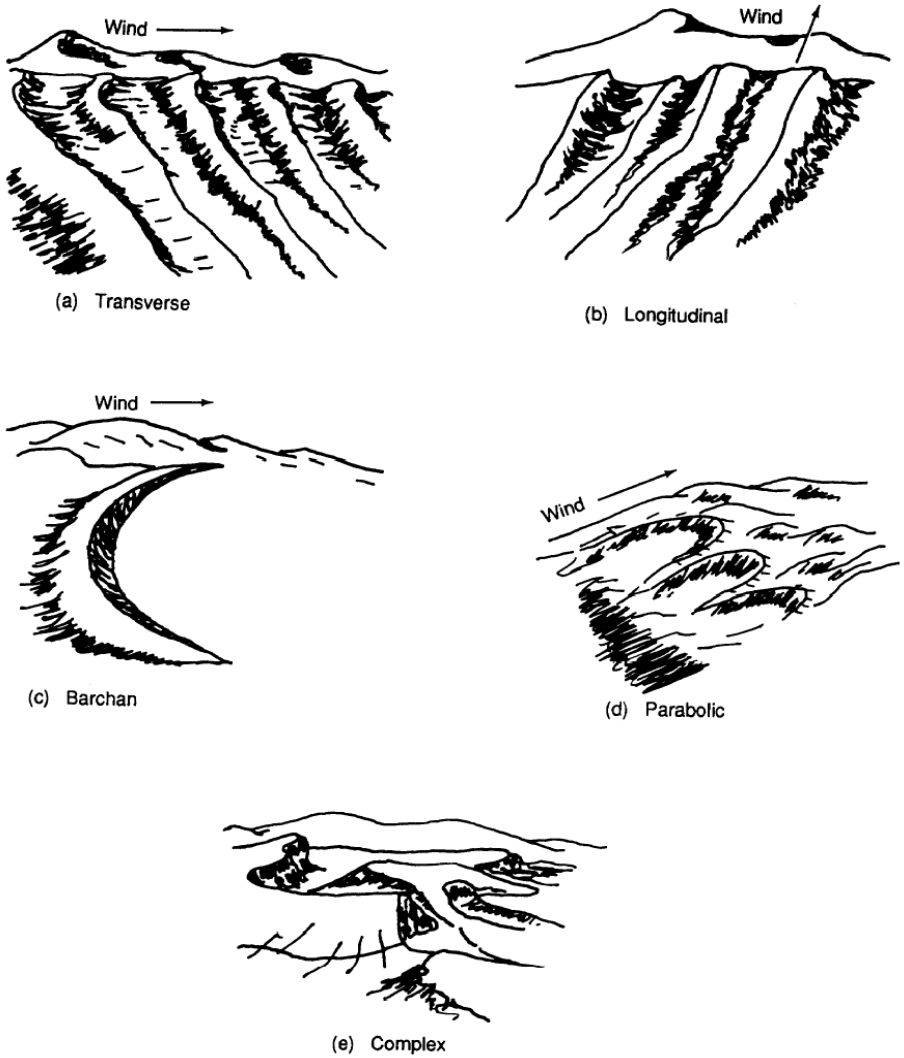
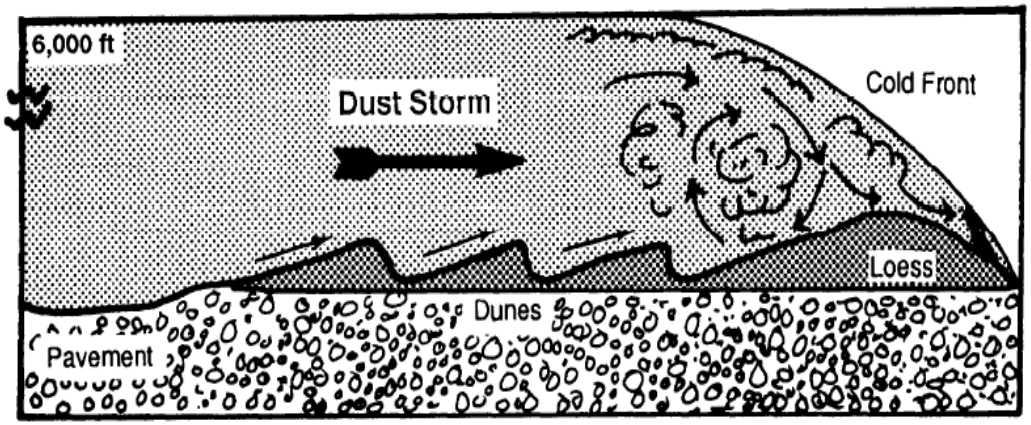
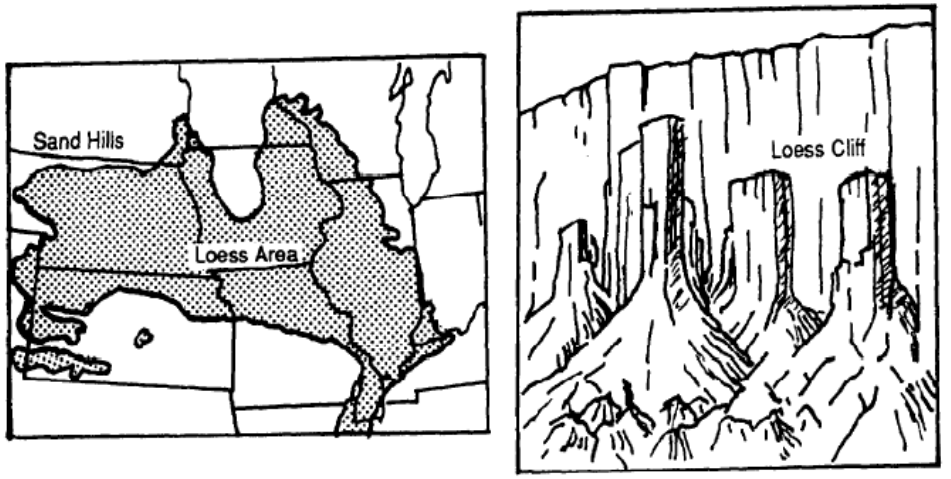


Figure 3-33. Sand dune types.





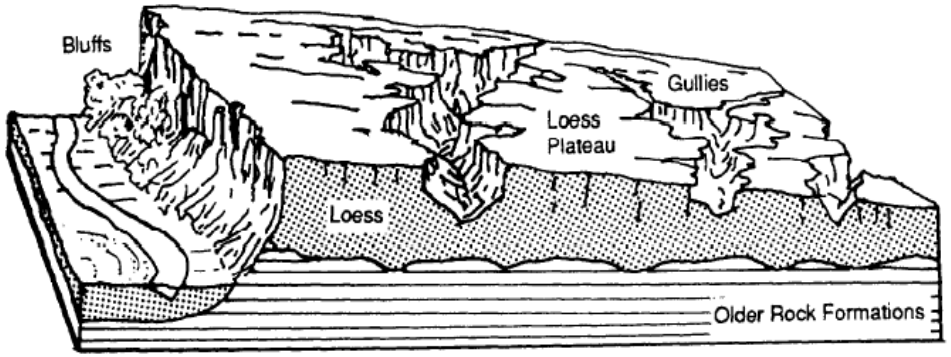


Figure 3-34. Loess landforms.

Transported Soils: Glacial Soils

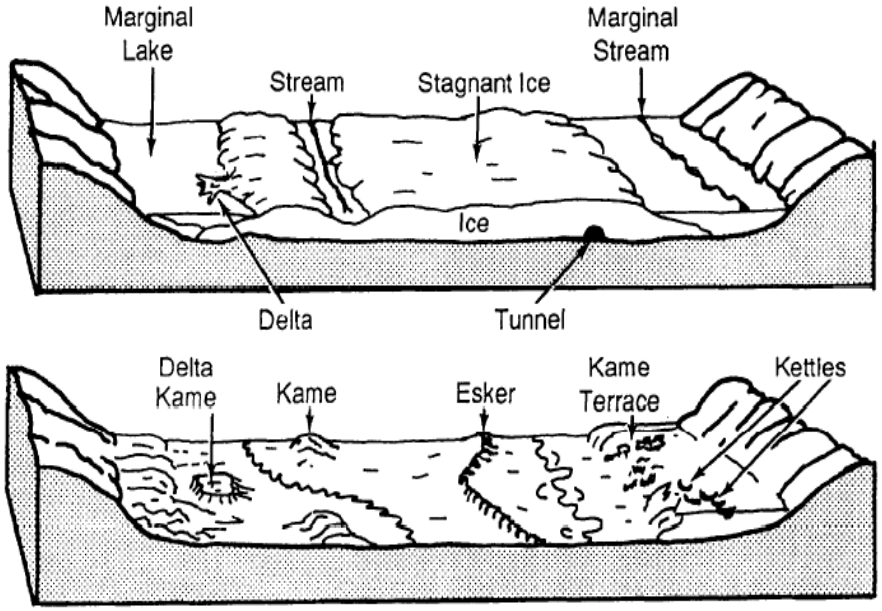
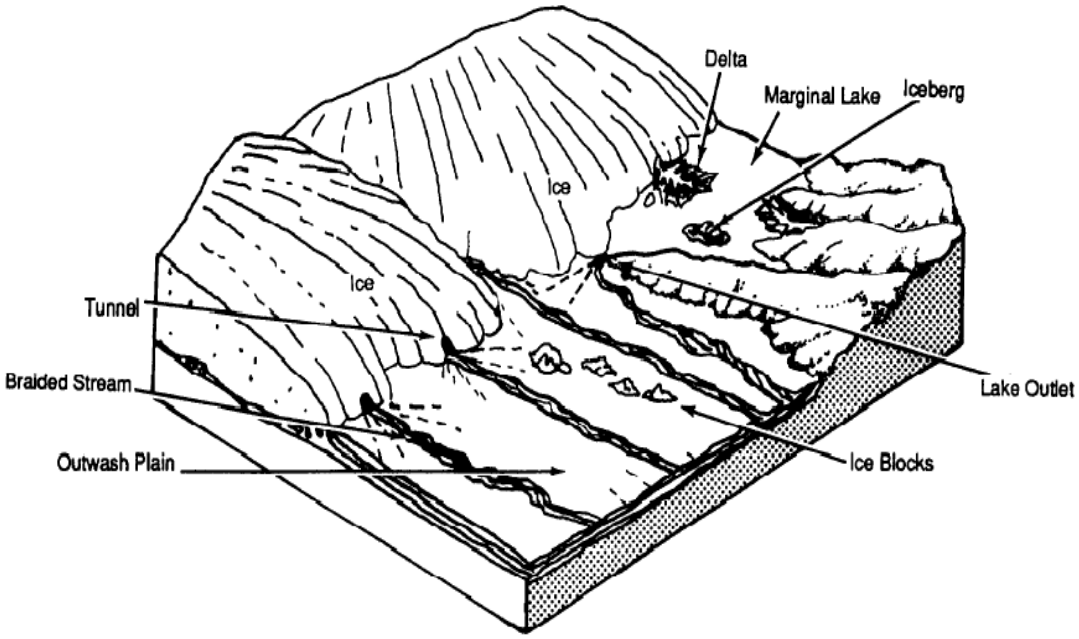
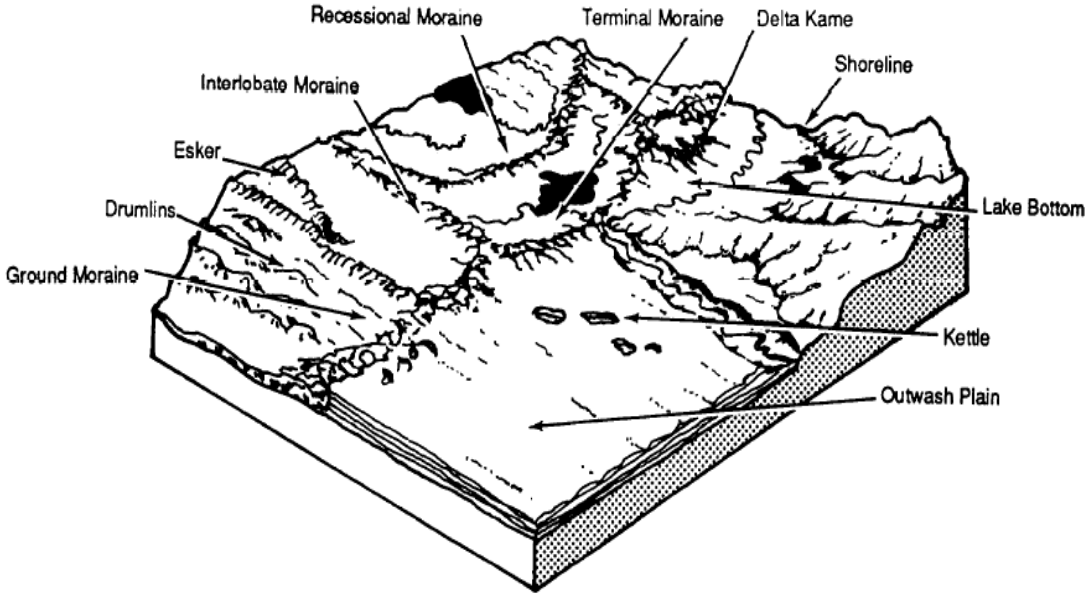


Figure 3-25. Valley deposits from melting ice.



During Glaciation



Following Retreat of Glacier

Figure 3-22. Continental glaciation.

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.

Particle or Grain Sizes

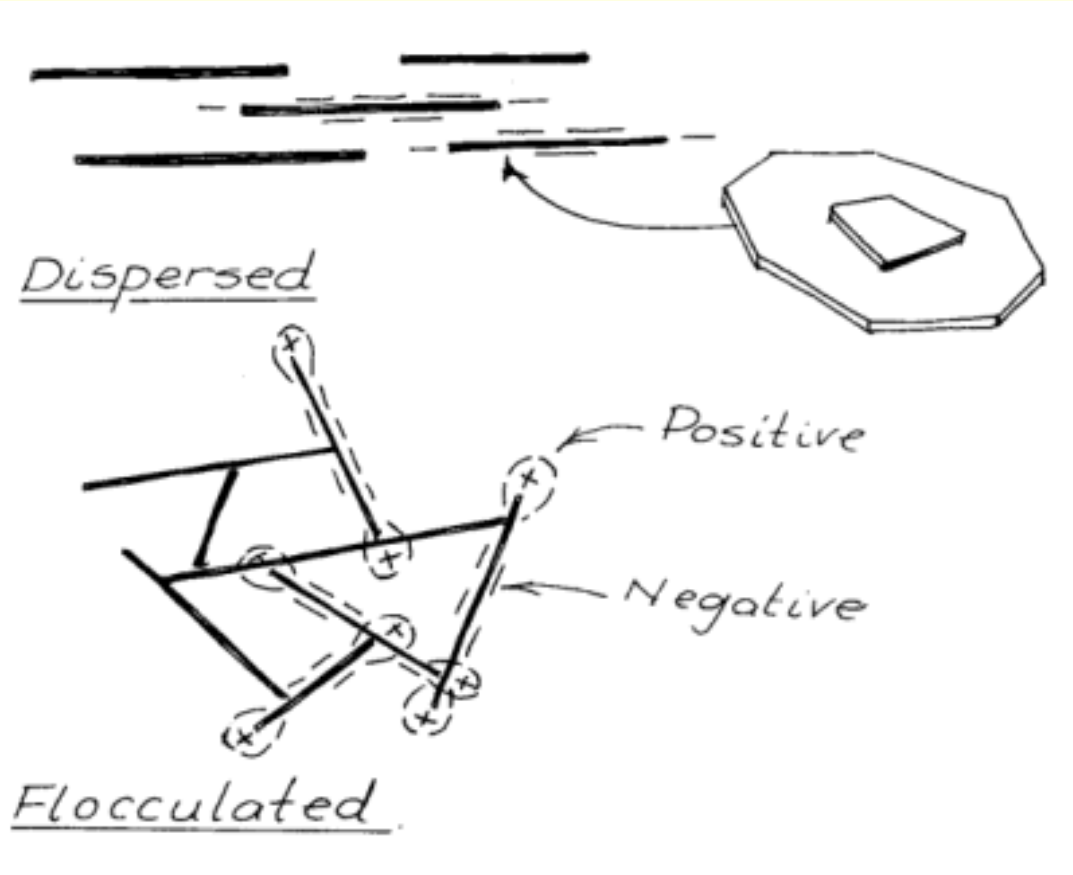
Soil type	min.	max.
clay		0.002 mm
silt	0.002 mm	0.063 mm
sand	0.063 mm	2 mm
gravel	2 mm	63 mm

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



Types of Clay Minerals

- Kaolinite
  - One sheet alumina, one silica
  - 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

Questions?

Homework Set 1 on Blackboard—due 20 January 2010