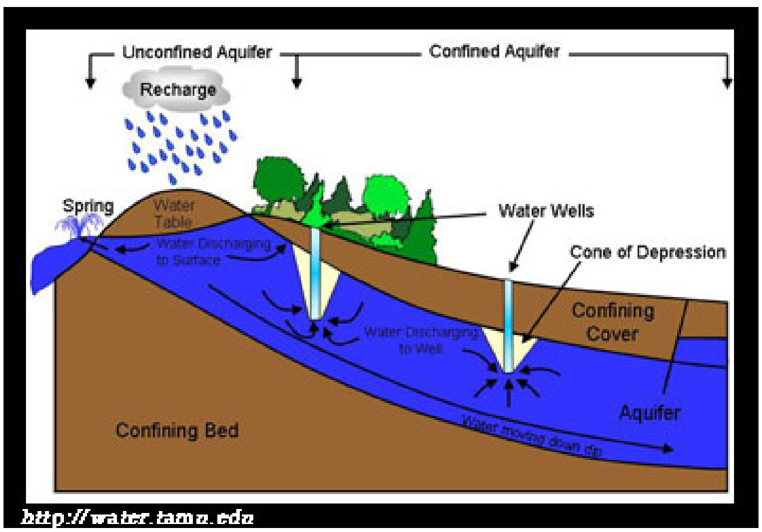
Geology

Introduction

Geology is the science and study of the physical matter and energy that make up the Earth. It includes the study of the composition, structure, properties, and history of the planet's physical material, the processes by which it is formed, moved, and changed, the history of live on Earth, and human interactions with the Earth.

The field of Geology is a major academic discipline, and it is commercially important for mineral and hydrocarbon extraction, as well as for predicting and understanding earthquakes and volcanic eruptions. It is also an important foundation for many other science and engineering disciplines, including evolutionary biology, paleoclimatology, and geotechnical engineering.



The word "geology" is Greek in origin meaning: *geo "earth", and logos "speech."* So the word geology actually means – Earth speech." That is really a very good definition since Geology refers to the story of the Earth.

For the purpose of this course we will confine our discussion to the geotechnical engineering aspects of Geology.

EARTH MATERIALS

The majority of geological data come from research on solid Earth materials. These fall into two categories: rock and unconsolidated material.

Rock

Rocks are divided into three categories: igneous, sedimentary, and metamorphic. The rock cycle is an important concept in geology because it illustrates the relationships between these three types of rock, and magma which comes from volcanoes. The majority of research in geology revolves around the study of rock. Rock provides the primary record of the majority of the geologic history of the Earth.

The "rock cycle"

All rock undergoes a changing process called the "rock cycle." When a rock crystallizes from melt (magma or lava), it is an igneous rock. The rock can be weathered and eroded, and then redeposited and lithified into a sedimentary rock, or be turned into a metamorphic rock due to heat and pressure that change the mineral content of the rock and give it a characteristic fabric. The sedimentary rock can then be subsequently turned into a metamorphic rock due to heat and pressure, and the metamorphic rock can be weathered, eroded, deposited, and lithified, becoming a sedimentary rock. Sedimentary rock may also be re-eroded and redeposited, and metamorphic rock may also undergo additional metamorphism. All three types of rock may be re-melted; then this happens, a new magma is formed, from which an igneous rock may once again crystallize.

In simple terms – all rock forms from lava, or magma. It then crystallizes into igneous rock. Then it "morphs" into sedimentary or metamorphic rock. Easy enough! But this process takes thousands of years!

Igneous Rock

Igneous rocks are formed when molten magma cools and are divided into two main categories: plutonic rock and volcanic rock. Plutonic, or intrusive rocks, result when magma cools and crystallizes slowly with the Earth's crust (example, granite), while volcanic, or extrusive rocks result from magma reaching the surface either as lava or fragmental ejecta (examples, pumice and basalt).

Sedimentary rocks

Sedimentary rocks are formed by deposition of either clastic sediments, organic matter, or chemical precipitates (evaporates), followed by compaction of the particulate matter and cementation during diagenesis. Sedimentary rocks form at or near the Earth's surface. Mud rocks comprise 65% (mudstone, shale, and siltstone); sandstones 20-25%, and carbonate rocks 10-15% (limestone and dolostone).

Metamorphic rocks

Metamorphic rocks are formed by subjecting any rock type (including previously formed metamorphic rock) to different temperature and pressure conditions than those in which the original rock was formed. These temperatures and pressures are always higher than those at the Earth's surface and must be sufficiently high so as to change the original minerals into other mineral types or else into other forms of the same minerals (example: by recrystallisation).

Unconsolidated material

Geologists also study unlithified material, which typically comes from more recent deposits. This is sometimes known as Quaternary geology, after the recent Quaternary Period. This includes the study of sediment and soils, and is important to studies in geomorphology, sedimentology, and paleoclimatology.

Methods of Geology

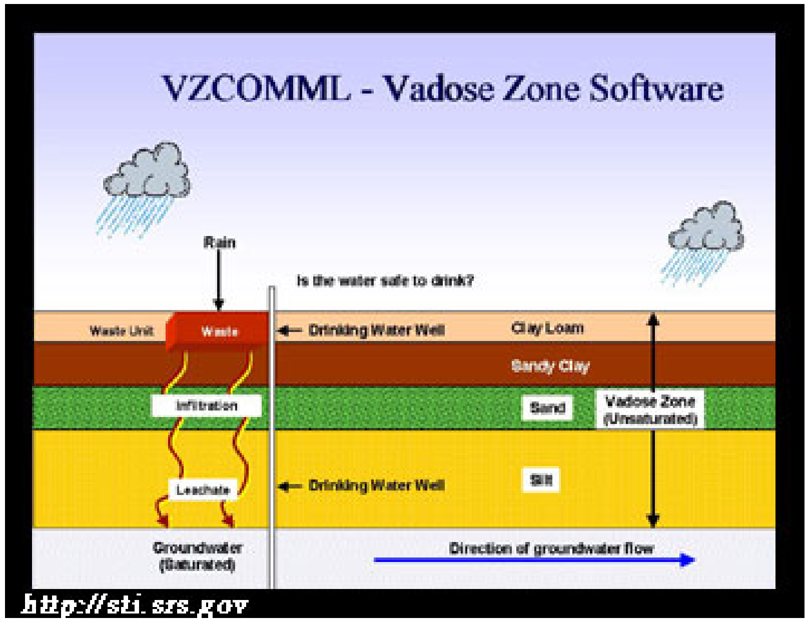
Geologists use a number of field, laboratory, and numerical modeling methods to understand Earth history and the processes that occur on and in the Earth. In typical geological investigations, geologists use primary information related to petrology (the study of rocks), stratigraphy (the study of sedimentary layers), and structural geology (the study of positions of rock units and their deformation). In many cases, geologists also study modern soils, rivers, landscapes, and glaciers; investigate past and current life and biogeochemical pathways, and use geophysical methods in investigate the subsurface. For the purpose of this course we will concentrate on Field methods.

Field methods

Geological field work varies depending on the task at hand. Typical field work may include:

- Geological mapping. Location of major rock units and faults and folds
- Surveying topographic features. Creation of topographic maps and working to understand change across landscapes including patterns of erosion, deposition, river channel changes through migration and avulsion, and hillslope processes.

- Subsurface mapping through geophysical methods. These include shallow seismic surveys, ground penetrating radar, and electrical resistivity tomography. They are used for hydrocarbon exploration, finding groundwater, and locating buried archaeological artifacts.

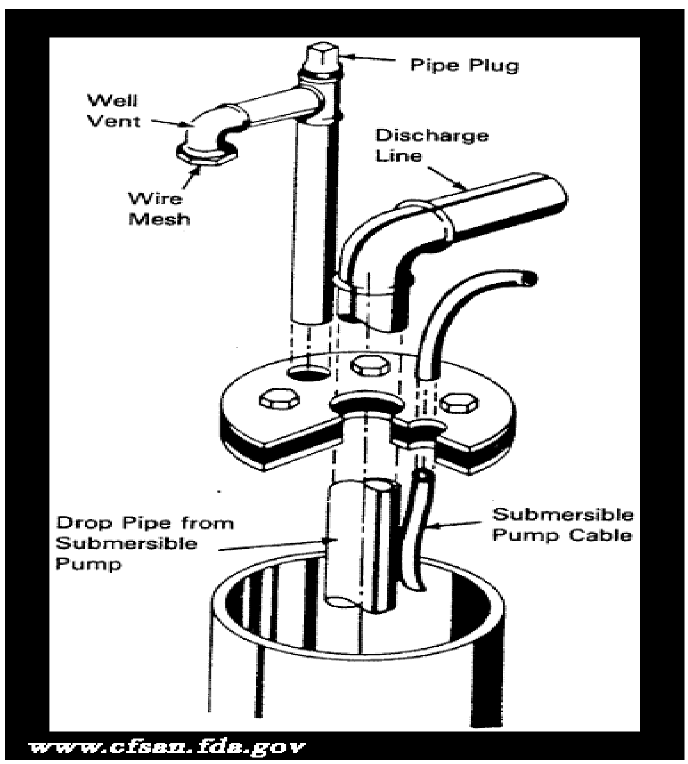


- High-resolution stratigraphy. This includes measuring and describing stratigraphic section of the surface. It also includes well drilling and logging.
- Biogeochemistry and geomicrobiology. This includes collecting samples to determine biochemical pathways, identify new species of organisms, or identify new chemical compounds. Theses allow us to understand early life on Earth and how it functioned and metabolized, and find important compounds for use in pharmaceuticals.
- Paleontology. This includes excavation of fossil material for research into past life and evolution for museums and education.
- Collection of samples for geochronology and thermochronology.

- Glaciology. This is the measurement of characteristics of glaciers and their motion.

GEOTECHNICAL INVESTIGATIONS FOR WELL DRILLING AND PUMP INSTALLATION

Geotechnical investigations are performed by geotechnical engineers or engineering geologists to obtain information on the physical properties of soil and rock around the site, to design earthworks and foundations for proposed structures, and for repair of distress to earthworks and structures caused by subsurface conditions. A geotechnical investigation will include surface exploration and subsurface exploration of the site. Sometimes, geophysical methods are used to obtain data about sites. Subsurface exploration usually involves soil sampling and laboratory tests of the soil samples retrieved.



Surface exploration can include geologic mapping, geophysical methods, and photogrammetry, or it can be as simple as a geotechnical professional walking around on the site to observe the physical conditions of the area.

To obtain information about the soil conditions below the surface, some form of subsurface exploration is required. Methods of observing the soil below the surface, obtaining samples, and determining physical properties of the soils and rocks include test pits, trenching (particularly for locating faults and slide planes), boring, and in situ tests.

Soil Sampling

Borings come in two main varieties, large-diameter and small-diameter. Large borings are rarely used due to safety concerns and expense, but are sometimes used to allow a geologist or engineer to visually and manually examine the soil and rock stratigraphy in-situ. Small diameter borings are frequently used to allow a geologist or engineer to examine soil or rock cuttings from the frilling operation, to retrieve soil samples at depth, and to perform in-place soil tests.

Soil samples are obtained in either “disturbed” or “undisturbed” condition; however, “undisturbed” samples are not truly undisturbed. A disturbed sample is one in which the structure of the soil has been changed sufficiently that tests of structural properties of the soil will not be representative of in-situ conditions, and only properties of the soil grains can be accurately determined. An undisturbed sample is one where the condition of the soil in the sample is close enough to the conditions of the soil in-situ to allow tests of structural properties of the soil to be used to approximate the properties of the soil in-situ.

Soil Samplers

Soil samples are taken using a variety of samplers; some provide only disturbed samples, while others can provide relatively undisturbed samples.

- Shovel. Samples can be obtained by digging out soil from the site. Samples taken this way are disturbed samples.

- Hand/Machine Driven Auger. This sampler typically consists of a short cylinder with a cutting edge attached to a rod and handle. The sampler is advanced by a combination of rotation and downward force. Samples taken this way are disturbed samples.
- Continuous Flight Auger. A method of sampling using an auger as a corkscrew. The auger is screwed into the ground then lifted out. Soil is retained on the blades of the auger and kept for testing. The soil sampled this way is considered disturbed.
- Split-spoon/SPT Sampler. Utilized in the 'Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils' (ASTMD 1586). This sampler is typically a 18-30" long, 2.0" outside diameter (OD) hollow tube split in half lengthwise. A hardened metal drive shoe with a 1.375" opening is attached to the bottom end, and a one-way valve and drill rod adapter at the sampler head. It is driven into the ground with a 140 pound hammer falling 30". The blow counts (hammer strikes) required to advance the sampler a total of 18" are counted and reported. Generally used for non-cohesive soils, samples taken this way are considered disturbed.

- Modified California Sampler. Similar in concept to the SPT sampler, the sampler barrel has a larger diameter and is usually lined with metal tubes to contain samples. Samples from the Modified California Sampler are considered undisturbed if the soil is not excessively soft, does not contain gravel, or is not very dense sand.
- Shelby Tube Sampler. Utilized in the "Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes' (ASTM D 1587). This sampler consists of a thin-walled tube with a cutting edge at the toe. A sampler head attaches the tube to the drill rod, and contains a check valve and pressure vents. Generally used in cohesive soils, this sampler is advanced into the soil layer, generally 6" less than the length of the tube. The vacuum created by the check valve and cohesion of the sample in the tube cause the sample to be retained when the tube is withdrawn. Standard ASTM dimensions are 2" OD, 36" long, 18 gauge thickness; 3" OD, 36" long, 16 gauge thickness; and 5" OD, 54" long, 11 gauge thickness. It should be noted that ASTM allows other diameters as long as they are proportional to the standardized tube designs, and tube length is to be suited for field conditions. Soil sampled in this manner is considered undisturbed.
- Piston samplers. These samplers are thin-walled metal tubes which contain a piston at the tip. The samplers are pushed into the bottom of a borehole, with the piston remaining at the surface of the soil while the tube slides past it. These samplers will return undisturbed samples in soft soils, but are difficult to advance in sands and stiff clays, and can be damaged (compromising the sample) if gravel is encountered. The Livingstone corer, developed by D. A. Livingstone, is a

commonly used piston sampler. A modification of the Livingstone corer with a serrated coring head allows it to be rotated to cut through subsurface vegetable matter such as small roots or buried twigs.

- Pitcher Barrel sampler. This sampler is similar to piston samplers, except that there is no piston. There are pressure-relief holes near the top of the sampler to prevent pressure buildup of water or air above the soil sample.

In-Situ Tests

A standard penetration test (SPT) is an in-situ dynamic penetration test designed to provide information on the properties of soil, while also collecting a disturbed soil sample for grain-size analysis and soil classification.

A cone penetration test (CPT) is performed using an instrumented probe with a conical tip, pushed into the soil hydraulically at a constant rate. A basic CPT instrument reports tip resistance and shear resistance along the cylindrical barrel. CPT data has been correlated to soil properties. Sometimes instruments other than the basic CPT probe are used including:

- CPTu – Piezocone Penetrometer. This probe is advanced using the same equipment as a regular CPT probe, but the probe has an additional instrument which measures the groundwater pressure as the probe is advanced.
- SCPTu – Seimic Piezocone Penetrometer. This probe is advanced using the same equipment as a CPT or CPTu probe, but the probe is also equipped with either

geophones or accelerometers to detect shear waves and/or pressure waves produced by a source at the surface.

- Full Flow Penetrometers – T-bar, Ball, and Plate: These probes are used in extremely soft clay soils (such as sea-floor deposits) and are advanced in the same manner as the CPT. As their names imply, the T-bar is a cylindrical bar attached at right angles to the drill string forming what looks like a T, the ball is a large sphere, and the plate is flat circular plate. In soft clays, soil flows around the probe similar to a viscous fluid. The pressure due to overburden stress and pore water pressure is equal on all sides of the probes (unlike with CPT's), so no correction is necessary, reducing a source of error and increasing accuracy. Especially desired in soft soils due to the very low loads on the measuring sensors. Full flow probes can also be cycled up and down to measure remolded soil resistance. Ultimately the geotechnical professional can use the measured penetration resistance to estimate undrained and remolded shear strengths.

Flat Plate Dilatometer Test (DMT) is a flat plate probe often advanced using CPT rigs, but can also be advanced from conventional drill rigs. A diaphragm on the plate applies a lateral force to the soil materials and measures the strain induced for various levels of applied stress at the desired depth interval.

Laboratory Tests

A wide variety of laboratory tests can be performed on soils to measure a wide variety of soil properties. Some soil properties are intrinsic to the composition of the soil matrix and are not affected by sample disturbance, while other properties depend on the structure of the soil as well as its composition, and can only be effectively tested on relatively undisturbed samples. Some soil tests measure direct properties of the soil, while others measure “index properties” which provide useful information about the soil without directly measuring the property desired.

Atterberg limits

The Atterberg limits define the boundaries of several states of consistency for plastic soils. The results of this test can be used to help predict other engineering properties.

California bearing ratio

A test to determine the aptitude of a soil or aggregate sample as a road sub grade. It is still used as a cheap method to estimate the resilient modulus.

Direct shear test

The direct shear test determines the consolidated, drained strength properties of a sample.

Expansion index test

This test uses a remolded soil sample to determine the Expansion Index (EI), and empirical value required by building design codes, as a water content of 50% for expansive soils, like clays.

Hydraulic conductivity tests

There are several tests available to determine a soil’s hydraulic conductivity. They include the constant head, falling head, and constant flow methods. The soil samples tested can be any type including remolded, undisturbed, and compacted samples.

Odometer test

This can be used to determine consolidation and swelling parameters

Particle-size analysis

This is done to determine the soil gradation.

R-Value test

This test measures the lateral response of a compacted sample of soil or aggregate to a vertically applied pressure under specific conditions. This test is used for pavement design.

Soil compaction tests

These tests are used to determine the maximum unit weight and optimal water content a soil can achieve for a given compaction effort.

Triaxial shear tests

This is a type of test that is used to determine the shear strength properties of a soil. It can also simulate drained and undrained conditions.

Unconfined compression test

This test compresses a soil sample to measure its strength.

Water content

This test provides the water content of the soil, normally expressed as a percentage of the weight of water to the dry weight of the soil.

Applied Geology

There are numerous career opportunities for geologists. Here are just a few ways that geologists affect everyday life.

Economic geology

Economic geologists help locate and manage the Earth’s natural resources, such as petroleum and coal, as well as mineral resources, which include metals such as iron, copper, and uranium.

Petroleum geology

Petroleum geologists study locations of the subsurface of the Earth which can contain extractable hydrocarbons, especially petroleum and natural gas.

Engineering geology

Engineering geology is the application of the geologic principles to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction, operation, and maintenance of engineering works are properly addressed.

Environmental Concerns

Geology and geologic principles can be applied to various environmental problems, such as stream restoration, the restoration of brownfields, and the understanding of the interactions between natural habitat and the geologic environment. Groundwater hydrology, or hydrogeology, is used to locate groundwater, which can often provide a ready supply of uncontaminated water and is especially important in arid regions, and to monitor the spread of contaminants in groundwater wells.

Different tests and sampling are used to tell geologists about past and present temperature, precipitation, and sea level across the globe. These data are our primary source for information on global climate change outside of instrumental data.

Natural Hazards

Geologists and geophysicists study natural hazards in order to enact safe building codes and warning systems that are used to prevent loss of property and life. Natural hazards pertinent to geology include:

- Avalanches
- Earthquakes
- Floods
- Landslides and debris flows
- River channel migration and avulsion
- Liquefaction
- Sinkholes
- Subsidence
- Tsunamis
- Volcanoes