Chapter 3
ROCK

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Limestone of the Glen Rose Formation, Cretaceous Age, seen in a highway cut near Austin, Texas

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3.1 Formations

Formations are geologic units that have been mapped by extensive studies by geologists using field work, aerial photography, boring information, and other sources. Formations are generally identified by their geologic age and usually have a fairly consistent set of attributes in a local area. For this reason it is quite useful for the engineer to understand the geologic formations in a local area, since test-boring data can be extended between borings if the engineer knows the geology and the properties of the formations. Most formations consist of rock of various sorts. Geologists tend to call every formation a rock, even if it is soft clay shale, unless it is a surface deposit that has been weathered into something that can grow vegetation.

Some formations consist of very hard rocks that are normally quite good support for foundations and other earth-related structures. However, they can be very difficult and costly to excavate. Rock can include igneous deposits such as granite or sedimentary deposits such as limestone or shale. Igneous rocks are those that are formed from molten rock (lava or magma). Sedimentary rocks are formed when mineral precipitates, or shells of marine organisms are deposited in water and are hardened by pressure or cementation over long time periods. Metamorphic rock is another major rock type. These rocks are formed from any of the igneous or sedimentary rocks by transformation from heat and pressure. Of course within each of these types of rocks there are quite large variations in strength and excavation difficulty. Some of the more difficult rock formations to evaluate for foundation construction purposes can be those of layers of limestone or sandstone intermingled with layers of clay or clay-shale.

A useful engineering definition of rock is a material that will not "slake" when partially submerged in water. This indicates a virtually irreversible cementation, which will allow the rock to retain its structure throughout its use. Another way of determining rock is if it has a brittle fracture or if a small flat piece can be broken with a detectible "snap." The definition of shale is especially confusing at times. Shale is generally considered to be a material meeting the rock tests named above but also is thinly layered or "fissile." Shale can weather into clay, and frequently there is a change in the profile with depth, with weathered clay-like materials near the surface and the more rock-like shale at deeper depths.

3.2 Geology

Geology is the science of the origin, formation, and description of materials of the earth. Geologists have separated various formations and rock units into time periods ranging back to nearly the origin of the earth up to the present time. Figure 3.1 is a representative time scale of geologic units.

FIGURE 3.1
GENERALIZED GEOLOGICAL SEQUENCE
(oldest at bottom)

GROUP	SYSTEM		APPROXIMATE AGE (YEARS)
Recent	Quaternary	Present Day	Present – 10,000
Cenozoic		Pleistocene	10,000 – 1.6 Million
	Tertiary	Pliocene Miocene Oligocene Eocene	1.6 – 65 Million
Mesozoic	Cretaceous Jurassic Triassic		65 – 250 Million
Paleozoic	Permian Carboniferous Devonian Silurian Ordovician Cambrian		250 – 570 Million
Precambrian			Origins of Earth to Cambrian

Any of the rock units shown on the time scale could be exposed near the ground surface at any particular locality depending on the erosional or faulting history of the area. Frequently, regardless of what ancient formation exists at a fairly shallow depth, there are recent deposits overlying the material. Recent deposits could be as old as 1.6 million years or as young as yesterday. These are typically deposits due to water action. Deposition of soil derived from erosion sources often includes river or creek alluvium (alluvium means water-deposited), side bank deposits or deltas, such as the Mississippi River Delta, or wide areas of water-borne deposits called terrace or sheet deposits. Sometimes colluvium, which is material that has fallen from a slope or bluff by gravity, may be found covering older deposits.

Geotechnical engineering is mainly concerned with the engineering properties (strength, compressibility, shrink-swell, permeability) of the upper layers of the Earth's crust ranging from a few feet to perhaps several hundred feet, depending on the type of deposit and the nature of the proposed foundation.

3.3 Faults

Faults are fractures in rock formations caused by relative movements of the Earth's crust. Some faults are famous, such as the San Andreas Fault in California, because their movements result in frequent earthquakes. An earthquake occurs when stresses build up in rock, and the stresses are suddenly relieved by slippage, creating a large acceleration and movement of the surrounding area. The stress build-up results from large plate movements of the Earth's crust, deep molten rock movements, or area subsidence. Faults can be of various types. They can be "strike-slip" movement from side to side or "thrusting" faults in which a sloping layer is forced under or over an adjacent layer. Active faults that tend to move with a sudden acceleration from time to time are of great interest to foundation and structural designers since they produce earthquakes, which can destroy or severely damage structures. If earthquakes occur within the ocean, tsunamis may result, which can be more damaging than earthquakes and result in greater loss of life.

In many areas there are numerous faults that are not active, meaning that they have not moved or caused earthquake-type accelerations for very long periods of time. Sometimes, for foundation design, even these "dormant" faults can cause problems because there may be a rock formation outcropping near the surface immediately adjacent to a clay formation. This will cause two different types of materials to be next to each other at the ground surface, which could cause the reaction of a foundation to be very different in different parts.

Faults can be clean breaks, which are very narrow, or they can have a wide zone of ground-up and mixed-up material. Often faults are sources of springs, and many major springs around the world are located at a fault zone because aquifers have been brought to the surface and fractured open. Figure 3.2 illustrates various kinds of faults.

3.4 Rock as a Foundation Support

Rock is an excellent material for supporting foundations because of the high strength and consequent high bearing values that can be assigned to this material. Naturally, the higher the bearing value of a material, the smaller a foundation can be to distribute the loads of the structure to the earth. Rock strength comes in many grades, ranging from rock that is only somewhat stronger than a hard clay up to material that may be stronger than concrete. To apply standardized permissible bearing values to rock, the rock materials must be classified carefully. Table 3.1, showing presumptive bearing values for rock and soil, is taken from the 2012 IBC. The 2012 IRC has a similar listing in Table R401.4.1.

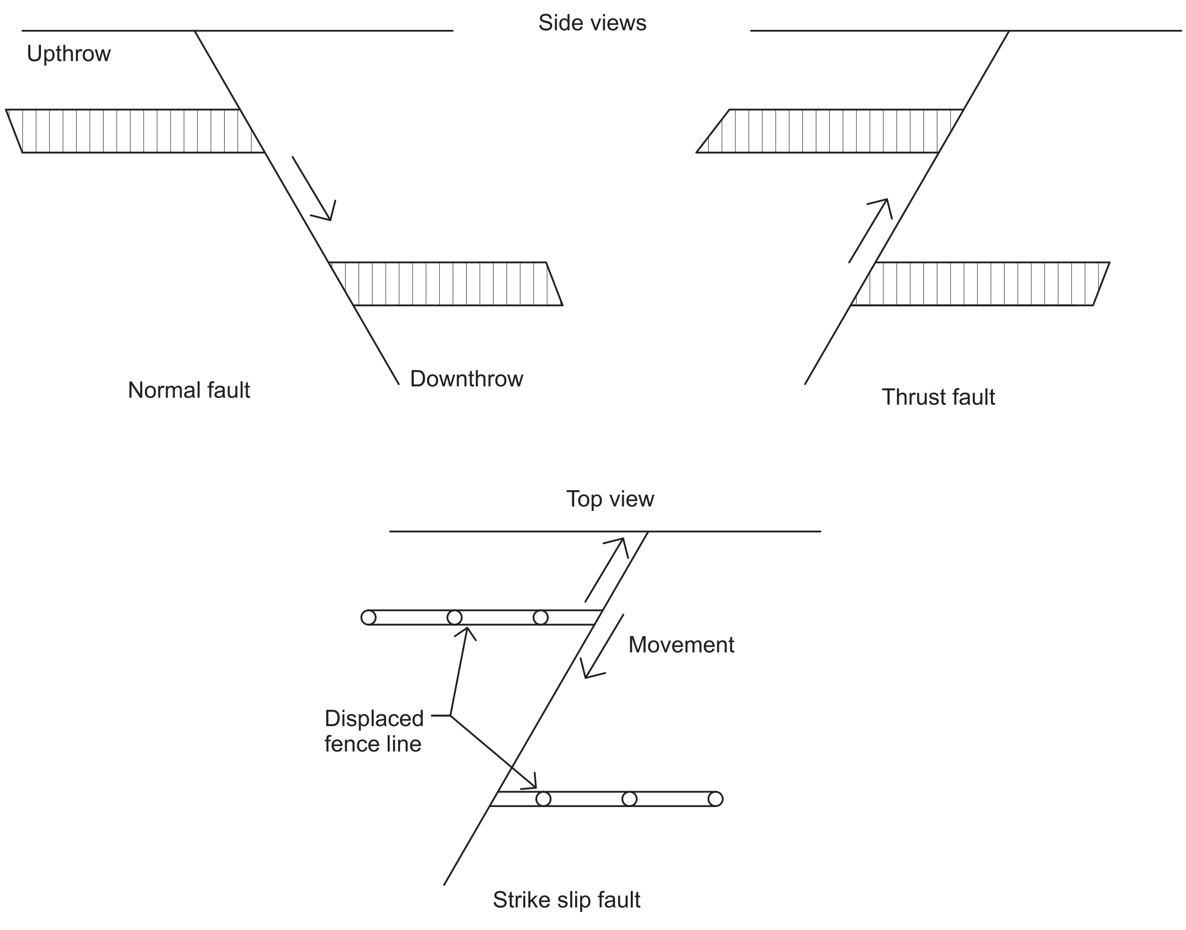

FIGURE 3.2
TYPES OF FAULTS

TABLE 3.1
ALLOWABLE FOUNDATION AND LATERAL PRESSURE
(TABLE 1806.2, 2012 IBC)

CLASS MATERIALS	ALLOWABLE FOUNDATION PRESSURE (PSF)[D]	LATERAL BEARING (PSF/F BELOW NATURAL GRADE)[D]	LATERAL SLIDING	
			COEFFICIENT OF FRICTION[A]	COHESION (PSF)[B]
1. Crystalline bedrock	12,000	1,200	0.70	---
2. Sedimentary and foliated rock	4,000	400	0.35	---
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	---
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	---
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500	100	---	130

For S1: 1 pound per square foot = 0.0479 kPa, 1 pound per square foot per foot = 0.157 kPa/m.
a. Coefficient to be multiplied by the dead load.
b. Cohesion value to be multiplied by the contact area, as limited by Section 1806.3.2.
c. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.
d. An increase of one-third is permitted when using the alternate load combinations in Section 1605.3.2 that include wind or earthquake loads.

It is also important for the designer and the inspector to be certain that a foundation with high bearing pressures is not established on a thin layer of rock, which may have a softer material below it and therefore would be subject to a punching failure. The presumptive bearing values given in Table 3.1 above are conservative numbers, provided the rock or soil classification is reasonably accurate. To determine more precise and possibly higher bearing values for rock formations, a geotechnical investigation is necessary in which cores of the rock are obtained, lab testing is utilized, and some theoretical calculations are done to determine what the rock will safely carry. Higher safety factors are used for rock allowable-bearing pressures than for soil because of the uncertain effect of fractures or joints in rock.

3.5 TEST QUESTIONS

MULTIPLE CHOICE

1. Sedimentary deposits are those that are formed from (select one):
    a. molten rock (lava or magma)
    b. water deposits
    c. fill placed by trucks

2. Geology is the science of (select one):
    a. mapping streets and towns in a locality
    b. finding the best highway route
    c. the origin, formation, and description of materials of the Earth
    d. evolution

3. Select the correct statement (select one):
    a. The Cretaceous Age is older than the Jurassic Age
    b. In normal geologic sequence the oldest formations are at the top of the profile
    c. Recent deposits can be as old as 1.6 million years
    d. Thrusting faults move from side to side

4. Sudden movements of faults (select two):
    a. may result in earthquakes
    a. cause chickens to stop laying eggs
    a. may cause tsunamis
    a. are the result of tornados

5. Faults which have not been active for very long periods of time (select one):
    a. never pose problems with regard to foundation design
    b. may spontaneously collapse
    c. could cause two different soil materials to be present at the ground surface

6. The presumptive allowable foundation pressures shown in in the building code (select one):
    a. can never be exceeded even with the use of a geotechnical study of the site
    b. are safe to use if the bearing material is identified correctly
    c. may not be safe to use

7. Formations are generally identified by (select one):
    a. age
    b. color
    c. the presence of springs

8. Alluvium means soils deposited (select one):
    a. by volcanic ash
    b. from erosion
    c. from airborne dust

9. Higher safety factors are used for rock allowable bearing pressures than for soil because of the uncertain effect of (select one):
    a. core holes
    b. acids generated by tree roots
    c. joints and fractures
    a. concrete interaction with rock

10. Table 1806.2 of the IBC permits allowable foundation pressures of (select one):
    a. 4,000 psf for crystalline bedrock
    b. 400 psf for sedimentary rock
    c. 3,000 psf for sandy gravel or gravel