Chapter 2

GEOLOGIC TERMINOLOGY AND CLASSIFICATIONS FOR GEOLOGIC MATERIALS

Established References for Geological Terminology

Adaptations or refinements of the Bureau of Reclamation (Reclamation) standards presented in this and subsequent chapters may be established to meet specific design requirements or site-specific geologic complexity when justified.

The *Glossary of Geology,* Fourth Edition [1][1], published by the American Geological Institute (AGI), 1997, is accepted by Reclamation as the standard for definitions of geologic words and terms except for the nomenclature, definitions, or usage established in this chapter and chapters 3, 4, and 5.

The North American Stratigraphic Code (NASC) [2] is the accepted system for classifying and naming stratigraphic units. However, Reclamation's engineering geology programs are focused primarily on the engineering properties of geologic units, not on the details of formal stratigraphic classification. Stratigraphic names are not always consistent within the literature, often change from one locality to another, and do not necessarily convey engineering properties or rock types. Use of stratigraphic names in Reclamation documents normally will be informal (lower case) (see NASC for discussion of formal versus informal usage). Exceptions to informal usage are for names previously used formally in the area in discussions of geologic setting or regional geology. Normally,

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[1] Brackets refer to bibliography entries at end of each chapter.

the first use of formal names in a report should include a reference to a geologic map or publication in which the term is defined.

Geologic Classification of Materials

The following definitions of geologic materials more fully satisfy general usage and supersede those in the *Glossary of Geology*. These definitions are for geologic classification of materials. They should not be confused with engineering classifications of materials such as rock and soil or rock and common excavation.

• **Bedrock** is a general term that includes any of the generally indurated or crystalline materials that make up the Earth's crust. Individual stratigraphic units or units significant to engineering geology within bedrock may include poorly or nonindurated materials such as beds, lenses, or intercalations. These may be weak rock units or interbeds consisting of clay, silt, and sand (such as the generally soft and friable St. Peter Sandstone), or clay beds and bentonite partings in siliceous shales of the Morrison Formation.

• **Surficial Deposits** are the relatively younger materials occurring at or near the Earth's surface overlying bedrock. They occur as two major classes: (1) transported deposits generally derived from bedrock materials by water, wind, ice, gravity, and man's intervention and (2) residual deposits formed in place as a result of weathering processes. Surficial deposits may be stratified or unstratified such as soil profiles, basin fill, alluvial or fluvial deposits, landslides, or talus. The material may be partially indurated or cemented by silicates, oxides, carbonates, or other chemicals (caliche or hardpan). This term is often used interchangeably with the imprecisely defined word "overburden." "Overburden" is a mining term meaning, among other things, material overlying a useful material that has to be removed. "Surficial deposit" is the preferred term.

In some localities, where the distinction between bedrock and surficial deposits is not clear, even if assigned a stratigraphic name, a uniform practice should be established and documented and that definition followed for the site or study.

Guidelines for the collection of data pertaining to bedrock and surficial deposits are presented in chapter 6.

Engineering Classification of Geologic Materials

General

Geologic classification of materials as surficial deposits or bedrock is insufficient for engineering purposes. Usually, surficial deposits are described as soil for engineering purposes, and most bedrock is described as rock; however, there are exceptions. Contract documents often classify structure excavations as to their ease of excavation. Also, classification systems for tunneling in geologic materials have been established.

Classification as Soil or Rock

In engineering applications, **soil** may be defined as generally unindurated accumulations of solid particles produced by the physical and/or chemical disintegration of bedrock and which may or may not contain organic matter. Surficial deposits, such as colluvium, alluvium, or residual soil, normally are described using Reclamation Procedure 5005, Determining Unified Soil Classification (Visual Method) [3]. American Society for Testing and Materials (ASTM) Standards D2487-85, Standard Test Method for Classification of Soils for Engineering Purposes or D2488-84, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), which are based on Reclamation 5000 and 5005 [3] also may be used. Instructions for the description and classification of soils are provided in chapter 3. Chapter 11 provides instructions for the logging of soils in geologic explorations. In some cases, partially indurated soils may have rock-like characteristics and may be described as rock.

The United States Department of Agriculture (USDA) Agricultural Soils Classification System is used for drainage and land classification and some detailed Quaternary geology studies, such as for seismotectonic investigations.

Rock as an engineering material is defined as lithified or indurated crystalline or noncrystalline materials. Rock is encountered in masses and as large fragments which have consequences to design and construction differing from those of soil. Field classification of igneous, metamorphic, sedimentary, and pyroclastic rocks are provided in chapter 4. Chapter 4 also presents a suggested description format, standard descriptors, and descriptive criteria for the lithologic and engineering physical properties of rock. Nonindurated materials within bedrock should be described using the Reclamation soil classification standards and soil descriptors presented in chapter 3. Engineering and geological classification and description of discontinuities which may be present in either soil or rock are discussed in chapter 5.

Classification of Excavations

The engineering classification of excavation as either rock excavation or common excavation or the definition of rock in specifications must be evaluated and determined for each contract document and should be based on the physical properties of the materials (induration and other characteristics), quantity and method of excavation, and equipment constraints and size.

Classification of Materials for Tunneling

Classification systems are used for data reports, specifications, and construction monitoring for tunnel designs and construction. When appropriate for design, other load prediction and classification systems may be used such as the Q system developed by the Norwegian Geotechnical Institute (NGI), Rock Mass Rating System Geomechanics Classification (RMR), and Rock Structure Rating (RSR).

The following terms for the classification of rock [4] for tunneling are suggested:

• **Intact rock** contains neither joints nor hairline cracks. If it breaks, it breaks across sound rock. On account of damage to the rock due to blasting, spalls may drop off the roof several hours or days after blasting. This is known as spalling condition. Hard, intact rock may also be encountered in the popping condition (rock burst) involving the spontaneous and violent detachment of rock slabs from sides or roof.

• **Stratified rock** consists of individual strata with little or no resistance against separation along the boundaries between strata. The strata may or may not be weakened by transverse joints. In such rock, the spalling condition is quite common.

• **Moderately jointed rock** contains joints and hairline cracks, but the blocks between joints are locally grown together or so intimately interlocked that vertical walls do not require lateral support. In rocks of this type, both the spalling and the popping condition may be encountered.

• **Blocky and seamy rock** consists of chemically intact or almost intact rock fragments which are entirely separated from each other and imperfectly interlocked. In such rock, vertical walls may require support.

• **Crushed but chemically intact rock** has the character of a crusher run. If most or all of the fragments are as small as fine sand and no recementation has taken place, crushed rock below the water table exhibits the properties of a water-bearing sand.

• **Squeezing rock** slowly advances into the tunnel without perceptible volume increase. Movement is the result of overstressing and plastic failure of the rock mass and not due to swelling.

• **Swelling rock** advances into the tunnel chiefly on account of expansion. The capacity to swell is generally limited to those rocks which contain smectite, a montmorillonite group of clay minerals, with a high swelling capacity.

Although the terms are defined, no distinct boundaries exist between rock categories. Wide variations in the physical properties of rocks classified by these terms and rock loading are often the case.

Table 2-1, Ground behavior for earth tunneling with steel supports, provides ground classifications for different reactions of ground to tunneling operations.

Application and Use of Standard Indexes, Terminology, and Descriptors

This section and subsequent chapters 3, 4, and 5 provide definitions and standard descriptors for physical properties of geologic materials which are of engineering significance. The ability of a foundation to support loads imposed by various structures depends primarily on the deformability and stability of the foundation materials and the groundwater conditions. Description of geologic and some manmade materials (embankments) is one of the geologist's direct contributions to the design process. Judgment and intuition alone are not adequate for the safe and economical design of large complex engineering projects. Preparation of geologic logs, maps and sections, and detailed descriptions of observed material is the least expensive aspect and most continuous record of a subsurface exploration program. It is imperative to develop design data properly because recent advances in soil and rock mechanics have enabled engineers and geologists to analyze more conditions than previously possible. These analyses rely on physical models that are developed through geologic observation and which must be described without ambiguity.

The need for standard geologic terminology, indexes, and descriptors has long been recognized because it is important that design engineers and contractors, as well as geologists, be able to have all the facts and qualitative information as a common basis to arrive at conclusions from any log of exploration, report, or drawing, regardless of the preparer. Geologic terminology,

Table 2-1.—Ground behavior for earth tunneling with steel supports (after Terzaghi, 1977) [4]

Ground classification	Reaction of ground to tunneling operation
HARD	Tunnel heading may be advanced without roof support.
FIRM	Ground in which a roof section of a tunnel can be left unsupported for several days without inducing a perceptible movement of the ground.
RAVELING	Chunks or flakes of soil begin to drop out of roof at some point during the ground-movement period.
SLOW RAVELING	The time required to excavate 5 feet of tunnel and install a rib set and lagging in a small tunnel is about 6 hours. Therefore, if the stand-up time of raveling ground is more than 6 hours, by using ribs and lagging, the steel rib sets may be spaced on 5-foot centers. Such a soil would be classed as slow raveling.
FAST RAVELING	If the stand-up time is less than 6 hours, set spacing must be reduced to 4 feet, 3 feet, or even 2 feet. If the stand-up time is too short for these smaller spacings, liner plates should be used, either with or without rib sets, depending on the tunnel size.
SQUEEZING	Ground slowly advances into tunnel without any signs of fracturing. The loss of ground caused by squeeze and the resulting settlement of the ground surface can be substantial.
SWELLING	Ground slowly advances into the tunnel partly or chiefly because of an increase in the volume of the ground. The volume increase is in response to an increase of water content. In every other respect, swelling ground in a tunnel behaves like a stiff non-squeezing, or slowly squeezing, non-swelling clay.
RUNNING	The removal of lateral support on any surface rising at an angle of more than 34^{E}(to the horizontal) is immediately followed by a running movement of the soil particles. This movement does not stop until the slope of the moving soil becomes roughly equal to 34^{E}• if running ground has a trace of cohesion, then the run is preceded by a brief period of progressive raveling.
VERY SOFT SQUEEZING	Ground advances rapidly into tunnel in a plastic flow.
FLOWING	Ground supporting a tunnel cannot be classified as flowing ground unless water flows or seeps through it toward the tunnel. For this reason, a flowing condition is encountered only in free air tunnels below the watertable or under compressed air when the pressure is not high enough in the tunnel to dry the bottom. A second prerequisite for flowing is low cohesion of soil. Therefore, conditions for flowing ground occur only in inorganic silt, fine silty sand, clean sand or gravel, or sand-and-gravel with some clay binder. Organic silt may behave either as a flowing or as a very soft, squeezing ground.

standard descriptors, and descriptive criteria for physical properties have been established so that geologic data are recorded uniformly, objectively, consistently, and accurately. The application of these indexes, terminology, descriptors, and various manual and visual tests must be applied consistently by all geologists for each particular project. The need to calibrate themselves with others performing similar tests and descriptions is imperative to ensure that data are recorded and interpreted uniformly. The use of these standard descriptors and terminology is not intended to replace the geologist's or engineer's individual judgment. The established standard qualitative and quantitative descriptors will assist newly employed geologists and engineers in understanding Reclamation terminology and procedures, permit better analysis of data, and permit better understanding by other geologists and engineers, and by contractors. Most of the physical dimensions established for the descriptive criteria pertaining to rock and discontinuity characteristics have been established using a 1-3-10-30-100 progression for consistency, ease of memory, conversion from English to metric (30 millimeters [mm] = 0.1 foot [ft]) units, and to conform to many established standards used throughout the world. Their use will improve analysis, design and construction considerations, and specifications preparation. Contractor claims also should be reduced due to consistent and well defined terminology and descriptors.

Alphanumeric values for many physical properties have been established to enable the geotechnical engineer and engineering geologist to readily analyze the geologic data. These alphanumeric descriptors also will assist in compilation of data bases and computer searches when using computer generated logs. For consistency, the lower the alphanumeric value, the more favorable the condition being described. However, alphanumeric codes do not replace a complete description of what is observed. A complete description provides physical dimensions including a range and/or average in size, width, length or other physical property, and/or descriptive information.

It is important to start physical testing of the geologic materials as early as possible in an exploration program; descriptors alone are not sufficient. As data are interpreted, index properties tests can be performed in the field to obtain preliminary strength estimates for representative materials or materials requiring special consideration. The scope of such a program must be tailored to each feature. Tests which are to be considered include point load, Schmidt hammer, sliding tilt, and pocket Torvane or penetrometer tests. These tests are described briefly in chapters 4 and 5. Indexes to be considered include rock hardness, durability (slaking), and Rock Quality Designation (RQD). The type of detailed laboratory studies can be formulated better and the amount of sampling and testing may be reduced if results from field tests are available.

Units of Measurements for Geologic Logs of Exploration, Drawings, and Reports

Metric Units

For metric specifications and studies, metric (International System of Units) should be used from the start of work if possible. Logs of exploration providing depth measurements should be given to tenths or hundredths of meters. All linear measurements such as particle or crystal sizes, ranges or averages in thickness, openness, and spacing, provided in descriptor definitions in chapters 3, 4, and 5, should be expressed in millimeters or meters as appropriate. Pressures should be given in pascals (Pa). Permeability (hydraulic conductivity) should be in centimeters per second (cm/s). In some cases, local usage of other units such as kilogram per square centimeter (kg/cm^2) for pressure or centimeters (cm) may be used.

English Units (U.S. Customary)

For specifications and studies using United States customary or English units (inch-pound), depth measurements should be given in feet and tenths of feet. Ranges in thickness, openness, and spacing, are preferred in tenths or hundredths of a foot, or feet as shown in the descriptor definitions in chapters 4 and 5. Pressure should be in pound-force per square inch (lbf/in^2 or PSI). Permeability should be in feet per year (ft/yr). The exceptions to the use of English units (inch-pound) are for describing particle and grain sizes and age dating. Particle sizes for soils classified using American Society for Testing and Materials/Unified Soil Classification Systems (ASTM/USCS) should be in metric units on all logs of exploration. For description of bedrock, particle and grain sizes are to be in millimeters.

Age Dates

If age dates are abbreviated, the North American Stratigraphic Commission (NASC) recommends *ka* for thousand years and *Ma* for million years, but *my* or *m.y.* (million years) for time intervals (for example, ". . . during a period of 40 my . . .").

Conversion of Metric and English (U.S. Customary) Units

Table 2-2 provides many of the most frequently used metric and English (U.S. Customary) units for geotechnical work.

Table 2-2.—Useful conversion factors—metric and English units (inch-pound)

To convert units in column 1 to units in column 4, multiply column 1 by the factor in column 2.
To convert units in column 4 to units in column 1, multiply column 4 by the factor in column 3.

Column 1	Column 2	Column 3	Column 4
	Length		
inch (in)	2.540 X 10^{1}	3.937 X 10^{-2}	millimeter (mm)
hundredths of feet	3.048 X 10^{2}	3.281 X 10^{-3}	millimeter (mm)
foot (ft)	3.048 X 10^{-1}	3.281	meter (m)
mile (mi)	1.6093	6.2137 X 10^{-1}	kilometer (km)
	Area		
square inch (in^2)	6.4516 X 10^{-4}	1.550 X 10^{-3}	square meter (m^2)
square foot (ft^2)	9.2903 X 10^{-2}	1.0764 X 10^{1}	square meter (m^2)
acre	4.0469 X 10^{-1}	2.4711	hectare
square mile (mi^2)	0.386 X 10^{-2}	259.0	hectares
	Volume		
cubic inch (in^3)	1.6387 X 10^{-2}	6.102 X 10^{-2}	cubic centimeter (cm^2)
cubic feet (ft^3)	2.8317 X 10^{-2}	3.5315 x 10^{1}	cubic meter (m$^{3)}$
cubic yard (yd^3)	7.6455 X 10^{1}	1.3079	cubic meter (ms)
cubic feet (ft^3)	7.4805	1.3368 x 10^{-1}	gallon (gal)
gallon (gal)	3.7854	2.6417 X 10^{-1}	liter (L)
acre-feet (acre-ft)	1.2335 X 10^{3}	8.1071 X 10^{-4}	cubic meter (m^3)
	Flow		
gallon per minute (gal/min)	6.309 X 10^{-2}	1.5850 X 10^{1}	liter per second (L/s)
cubic foot per second (ft^3/s)	4.4883 X 10^{2}	2.228 X 10^{-3}	gallons per minute (gal/min)
	1.9835	5.0417 X 10^{-1}	acre-feet per day (acre-ft/d)
cubic foot per second (ft^3/s)	7.2398 X 10^{2}	1.3813 X 10^{-3}	acre-feet per year (acre-ft/yr)
	2.8317 X 10^{-2}	3.531 X 10^{1}	cubic meters per second (m^3/s)
	8.93 X 10^{5}	1.119 X 10^{-6}	cubic meters per year (m^3/yr)
	Permeability		
k, feet/year	9.651 X 10^{-7}	1.035 X 10^{6}	*k*, centimeter per second (cm/sec)
	Density		
pound-mass per cubic foot (lb/ft^3)	1.6018 X 10^{1}	6.2429 X 10^{-2}	kilogram per cubic meter (kg/m^3)
	Unit Weight		
pound force per cubic foot (lb/ft^3)	0.157	6.366	kilonewton per cubic meter (kN/m^3)
	Pressure		
pounds per square inch (psi)	7.03 X 10^{-2}	1.4223 X 10^{1}	kilogram per square centimeter (kg/cm^3)
	6.8948	0.145	kiloPascal (kPa)
	Force		
ton	8.89644	1.12405 X 10^{-1}	kilonewton (kN)
pound-force	4.4482 X 10^{-3}	224.8096	kilonewton (kN)
	Temperature		
	EC = 5/9 (EF - 32 E)		EF = (9/5 EC) + 32 E
	Grouting		
Metric bag cement per meter	3.0	0.33	U.S. bag cement per foot
Water:cement ratio by volume	0.7	1.4	water:cement ratio by weight
pounds per square inch per foot	0.2296	4.3554	kilogram per square centimeter per meter (kg/cm^2/m)
k, feet/year	0.1	10	Lugeon

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