Chapter 4

CLASSIFICATION OF ROCKS AND DESCRIPTION OF PHYSICAL PROPERTIES OF ROCK

Introduction

Uniformity of definitions, descriptors, and identification of rock units is important to maintain continuity in geologic logs, drawings, and reports from a project with multiple drilling sessions, different loggers and mappers. Also important is the recording of all significant observable parameters when logging or mapping. This chapter presents a system for the identification and classification of rocks and includes standard terminology and descriptive criteria for physical properties of engineering significance. The standards presented in this chapter may be expanded or modified to fit project requirements.

Rock Classification

Numerous systems are in use for field and petrographic classification of rocks. Many classifications require detailed petrographic laboratory tests and thin sections, while others require limited petrographic examination and field tests. The Bureau of Reclamation (Reclamation) has adopted a classification system which is modified from R.B. Travis [1]. While not based entirely on field tests or field identification of minerals, many of the classification categories are sufficiently broad that field identification is possible. Even where differences in the mineral constituents cannot be determined precisely in the field, differences usually are not significant enough to affect the engineering properties of the rock if classified somewhat incorrectly by lithologic name. Detailed mineralogical identification and petrographic classification can be performed on hand samples or core samples submitted to a petrographic laboratory.

If samples are submitted to a petrographic laboratory, the petrographic classification generally will coincide with the classification according to Travis. The petrographic igneous rock classifications are somewhat more precise and include specialty rock types based upon mineral composition, texture, and occurrence. For example, a lamprophyric dike composed of green hornblende phenocrysts or clinopyroxene in the groundmass could be classified as spessartite, whereas a lamprophyre containing biotite with or without clinopyroxene could be classified as a kersantite. Sedimentary rock classifications generally include grain size, type of cement or matrix, mineral composition in order of increasing amounts greater than 15 percent, and the rock type, such as medium-grained, calcite-cemented, feldspathic-quartzose sandstone, and coarse- to fine-grained, lithic-feldspathic-quartzose gray-wacke with an argillaceous-ferruginous-calcareous matrix. Metamorphic rock classifications include specific rock types based upon crystal size, diagnostic accessory minerals, mineralogical composition in increasing amounts greater than 15 percent, and structure. Two examples of metamorphic rock descriptions are medium-grained, hornblende-biotite schist, or fine- to medium-grained, garnetiferous, muscovite-chlorite-feldspar-quartz gneiss. The above classification can be abbreviated by the deletion of mineral names from the left to right as desired. The mineral type immediately preceding the rock name is the most diagnostic.

The term "quartzite” is restricted to a metamorphic rock only. The sedimentary sandstone equivalent is termed a "quartz cemented quartzose sandstone."

Samples submitted to a petrographic laboratory should be representative of the in-place rock unit. For example, if a granitic gneiss is sampled but only the granite portion submitted, the rock will be petrographically classified as a granite since the gneissic portion cannot be observed or substantiated by the thin section and hand specimen. Petrographic classifications can be related to the engineering properties of rock units and are important.

Geologic rock unit names should be simple, and general rock names should be based on either field identification, existing literature, or detailed petrographic examination, as well as engineering properties. Overclassification is distracting and unnecessary. For example, use "hornblende schist" or "amphibolite" instead of "sericite-chlorite-calcite-hornblende schist." The term "granite" may be used as the rock name and conveys more to the designer than the petrographically correct term "nepheline-syenite porphyry." Detailed mineralogical descriptions may be provided in reports when describing the various rock units and may be required to correlate between observations, but mineralogical classifications are not desirable as a rock unit name unless the mineral constituents or fabric are significant to engineering properties.

The classification for igneous, sedimentary, metamorphic, and pyroclastic rocks is shown on figures 4-1, 4-2, 4-3, and 4-4, respectively. These figures are condensed and modified slightly from Travis' classifications, but the more detailed original classifications of Travis are acceptable. Figure 4-5 or appropriate American Geological Institute (AGI) data sheets are suggested for use when estimating composition percentages in classification.

Description of Rock

Adequate descriptors, a uniform format, and standard terminology must be used for all geologic investigations to properly describe rock foundation conditions. These

COLOR		LIGHT →							DARK		
QUARTZ		> 10 %	< 10 %	> 10 %	< 10 %	> 10 %		< 10 %		CHIEFLY PYROXENE AND/OR OLIVINE	SPECIAL TYPES
FELDSPAR		POTASSIUM FELDSPAR > 2/3 TOTAL FELDSPAR		POTASSIUM FELDSPAR 1/3-2/3 TOTAL FELDSPAR		PLAGIOCLASE > 2/3 TOTAL FELDSPAR					
						K-SPAR > 10 % TOTAL	SODIC PLAGIOCLASE		CALCIC PLAGIOCLASE		
CHIEF ACCESSORY MINERALS		HORNBLENDE BIOTITE MUSCOVITE		HORNBLENDE BIOTITE PYROXENE		HORNBLENDE, BIOTITE, PYROXENE			PYROXENE OLIVINE	SERPENTINE IRON ORE	
Fine to coarse > 0.1 mm	EQUIGRANULAR Batholiths, lopoliths, stocks, large laccoliths, thick dikes and sills.	GRANITE	SYENITE	QUARTZ MONZONITE	MONZONITE	GRANODIORITE	QUARTZ DIORITE	DIORITE	GABBRO	PERIDOTITE	PEGMATITIE - Very coarse grained, normally silicic, rock (or small irregular mass). APLITE - Fine-grained rock having sugary texture. LAMPROPHYRE - Dark rock with high percentage FeMg materials as phenocrysts and in ground mass.
PORPHYRITIC *	FINE TO COARSE GRAIN GROUND MASS Laccoliths, dikes, sills, plugs, small stocks, margins, of larger masses.	GRANITE PORPHYRY	SYENITE PORPHYRY	QUARTZ MONZONITE PORPHYRY	MONZONITE PORPHYRY	GRANODIORITE PORPHYRY	QUARTZ DIORITE PORPHYRY	DIORITE PORPHYRY	GABBRO PORPHYRY	PERIDOTITE PORPHYRY	
	APHANITIC GROUND MASS Dikes, sills, laccoliths, surface flows, margins of larger masses, welded tuffs.	RHYOLITE PORPHYRY	TRACHYTE PORPHYRY	QUARTZ LATITE PORPHYRY	LATITE PORPHYRY	DACITE PORPHYRY		ANDESITE PORPHYRY	BASALT PORPHYRY	RARE	* TRAP - dark-colored aphanitic rock, * FELSITE - light-colored aphanitic rock.
APHANITIC < 0.1 MM	MICROCRYSTALLINE Dikes, sills, surface flows, margins of larger masses, welded tuffs.	RHYOLITE	TRACHYTE	QUARTZ LATITE	LATITE	DACITE		ANDESITE	BASALT		
	GLASSY Surface flows, margins of dikes and sills, welded tuffs.	OBSIDIAN - dark colored PITCHSTONE - resinous VITROPHYRE - porphyritic PERLITE - concentric fractures PUMICE - light colored, finely vesicular SCORIA - dark colored, coarsely vesicular			Normally it is not possible to determine the compositon of these rocks. They are customarily designated by the names at the left. Basic glass is rare so rocks named, except scoria, will normally be silicic. If the approximate composition (by close association) can be determined, the name may be prefixed by the name of the appropriate aphanitic rock, for example, "trachyte obsidian" or "latite vitrophyre". In general, scoria is basic; basic obsidian is called "tachylite"; and spherulite tachylite is "variolite".						* These are somewhat vague terms and generally should not be used.

* The names in these rows should be used if there are >50% phenocrysts. If there are < 50% phenocrysts, the adjective "porphyritic" should be used, for example, "porphyritic granite".

Figure 4-1.—Field classification of igneous rocks (modified after R.B. Travis [1955]).

TEXTURE →	GRAIN SIZE <0.0625 mm			GRAIN SIZE 0.0625 - 2 mm						GRAIN SIZE >2 mm	
	CRYSTALLINE, CLASTIC, AMORPHOUS, BIOCLASTIC, ETC.			CLASTIC						CLASTIC	
COMPOSITION OF MAJOR FRACTION →	CLAY MINERALS or Clay-size Materials	Composition as indicated in left column	CHIEFLY CALCITE OR DOLOMITE	CHIEFLY QUARTZ	QUARTZ with 10-25% FELDSPAR	QUARTZ with >10% ROCK FRAGMENTS	QUARTZ with > 25% FELDSPAR	QUARTZ FELDSPAR ROCK FRAGMENTS	PYROCLASTICS	CHIEFLY ONE CONSTITUENT Homogeneous breccias and conglomerates	SEVERAL CONSTITUENTS Mixed breccias and conglomerates
COMPOSITION OF MINOR FRACTION: <10 % MINOR FRACTION			LIMESTONE, DOLOMITE, ETC.	QUARTZOSE SANDSTONE	FELDSPATHIC SANDSTONE	LITHIC SANDSTONE	ARKOSE	GRAYWACKE	Refer to Figure II-4-4 for classification of Pyroclastics	Name consists of chief constituent and size, as QUARTZ COBBLE CONGLOMERATE, LIMESTONE PEBBLE BRECCIA, ETC.	Name consists of "mixed" and size, as MIXED BOULDER BRECCIA. Name may include composition as ANDESITE-CHERT-ARKOSE CONGLOMERATE
CLAY MINERALS or Clay-size materials	CLAYSTONE, SILTSTONE - nonfissile SHALE - fissile ARGILLITE - highly indurated BENTONITE - sodium montmorillinite		ARGILLACEOUS LIMESTONE, MARL, ETC.	ARGILLACEOUS QUARTZOSE SANDSTONE	ARGILLACEOUS FELDSPATHIC SANDSTONE	ARGILLACEOUS LITHIC SANDSTONE	ARGILLACEOUS ARKOSE	ARGILLACEOUS GRAYWACKE		ARGILLACEOUS (SIZE) CONGLOMERATE	ARGILLACEOUS MIXED CONGLOMERATE, GLACIAL TILL, FANGLOMERATE
SILICA OPAL CHALCEDONY QUARTZ CHERT	SILICEOUS SHALE, SILCEOUS CLAYSTONE, ETC.	DIATOMITE, RADIOLARITE, SILICEOUS OOLITE, OOLITE CHERT,	SILICEOUS LIMESTONE, CHERTY LIMESTONE, ETC.	SILICEOUS QUARTZOSE SANDSTONE	SILICEOUS FELDSPATHIC SANDSTONE	SILICEOUS LITHIC SANDSTONE	SILICEOUS ARKOSE	SILICEOUS GRAYWACKE		SILICEOUS (SIZE) CONGLOMERATE	SILICEOUS MIXED (SIZE) CONGLOMERATE
CALCITE OR DOLOMITE	CALCAREOUS SHALE, ETC.	LIMESTONE DOLOMITE CLASTIC LIMESTONE CALICHE - lime-rich deposit formed near surface OOLITE LIMESTONE FOSSILIFEROUS LIMESTONE CHALK		CALCAREOUS QUARTZOSE SANDSTONE	CALCAREOUS FELDSPATHIC SANDSTONE	CALCAREOUS LITHIC SANDSTONE	CALCAREOUS ARKOSE	CALCAREOUS GRAYWACKE		CALCAREOUS (SIZE) CONGLOMERATE	CALCAREOUS MIXED (SIZE) CONGLOMERATE

Rocks including significant quantities of iron, carbon, or miscellaneous salts follow the above format. For example: ferruginous quartzose sandstone, coal, carbonaceous shale, gypsum, phosphatic limestone.

Figure 4-2.—Field classification of sedimentary rocks (modified after R.B. Travis [1955]).

COLOR	CHIEF MINERALS	ACCESSORY MINERALS	NONDIRECTIONAL STRUCTURE (MASSIVE OR GRANULOSE)		DIRECTIONAL STRUCTURE (LINEATED OR FOLIATED)					
			CONTACT METAMORPHISM		MECHANICAL METAMORPHISM	REGIONAL METAMORPHISM HIGHLY FOLIATED ←→ LESS FOLIATED				PLUTONIC METAMORPHISM
			FINE	FINE TO COARSE	CATACLASTIC	SLATY	PHYLLITIC	SCHISTOSE	GNEISSOSE	MIGMATITIC
						APHANITIC	FINE	FINE TO COARSE		
LIGHTER ↑	FELDSPAR	ACTINOLITE ALBITE ANDALUSITE ANTHOPHYLLITE BIOTITE CHIASTOLITE CHLORITE CHLORITIOD CORDIERITE DIOPSIDE ENSTATITE EPIDOTE GARNET GLAUCOPHANE GRAPHITE KYANITE MUSCOVITE OLIVINE PYROPHYLLITE PHLOGOPITE SCAPOLITE SERICITE SERPENTINE SILLIMANITE STAUROLITE TOURMALINE TREMOLITE WOLLASTONITE	HORNFELS	METAQUARTZITE	These rocks are formed by crushing with only minor recrystallization CATACLASITE Nondirectional MYLONITE Foliated, aphanitic PHYLLONITE Foliated, fine grain, resembles a phyllite. FLASER GRANITE, FLASER DIORITE, FLASER CONGLOMERATE ETC. - Flaser structure, lenses and layers of original or relatively unaltered granular minerals surrounded by matrix of highly sheared and crushed material. AUGEN GNEISS - Augen structure	SLATE	PHYLLITE	SCHIST (AMPHIBOLITE)	GNEISS	These rocks have a gneissose, streaked, or irregular structure produced by intimate mixing of metamorphic and magmatic materials. When they can be recognized as "mixed rock", they are called migmatite gneiss. They may originate by injection (injection migmatite, injection gneiss, or lit-par-lit gneiss), or by differential fusion. Many so-called migmatites probably originate by partial granitization or by metamorphic differentiation. But at great depth these processes apparently do not differ substantially from the igneous processes forming migmatite, so the products are usually indistinguishable. Migmatities are named by prefixing the rock name of the granitic material to the appropriate root as "granite mignatite", "monzonite injection mignatite", etc.
	QUARTZ									
↓	MICA			AMPHIBOLITE						
DARKER	HORNBLENDE								AUGEN GNEISS	
	CHLORITE									
	ACTINOLITE									
	TREMOLITE							GNEISSIC SCHIST		
LIGHTER ↑	TALC			SOAPSTONE				SCHISTOSE GNEISS		
	CALCITE AND/OR DOLOMITE			MARBLE						
↓	CALC-SILICATES			SKARN						
DARKER	SERPENTINE			SERPENTINITE				SERPENTINITE		

Naming a metamorphic rock consists chiefly of prefixing the structural term with mineral names or an appropriate rock name. The rock name indicates either the original rock, if recognizable, or the new mineral composition. The prefix "meta", as "Metagabbro", "metasandstone", "metatuff", etc., is applied to rocks that have undergone considerable recrystallization but have largely retained their original fabric. Most of the minerals listed as accessories are genetically important and if present should be included in the rock name regardless of their quantity.

Figure 4-3.—Field classification of metamorphic rocks (modified after R.B. Travis [1955]).

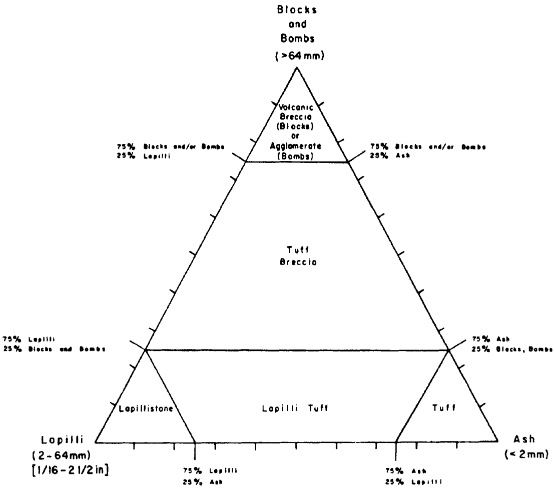

Figure 4-4.—Field classification of pyroclastic rocks. Blocks are angular to subangular clasts > 64 millimeters (mm); bombs are rounded to subrounded clasts > 64 mm. Determine percent of each size present (ash, lapilli, blocks, and bombs) and list in decreasing order after rock name. Preceed rock name with the term "welded" for pyroclastic rocks which retained enough heat to fuse after deposition. Rock names for such deposits are usually selected from the lower right portion of the classification diagram above. (Modified from Fisher, 1966 [2] and Williams and McBirney, 1979 [3]).

paragraphs provide descriptors for those physical characteristics of rock that are used in logs of exploration, in narratives of reports, and on preconstruction geologic maps and cross sections, as well as construction or "as-built" drawings. The alphanumeric descriptors provided may be used in data-field entries of computer generated

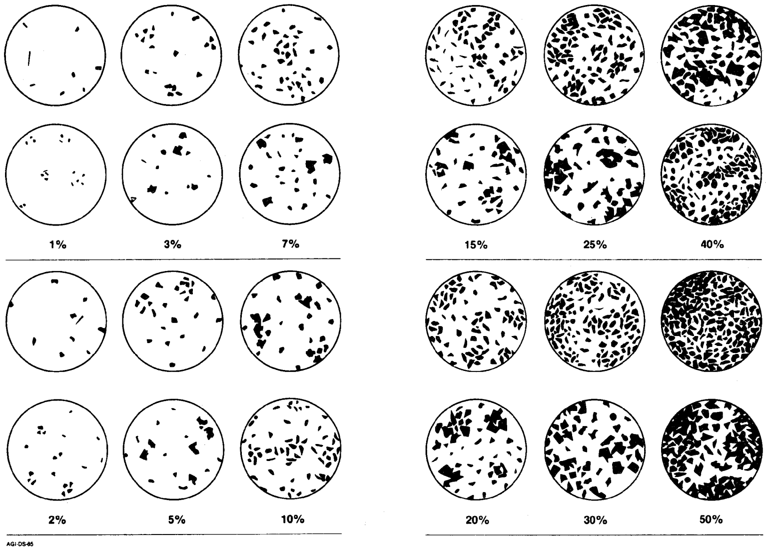

Figure 4-5.—Charts for estimating percentage of composition of rocks and sediments.[4]

logs. Chapter 5 establishes descriptors for the physical characteristics of discontinuities in rock required for engineering geologic studies.

All descriptors should be defined and included in a legend when submitting data for design and/or records of construction. An example of a legend and explanation is figure 4-6, Reclamation standard drawing 40-D-6493, may be used for geologic reports and specifications where the standard descriptors and terminology established for rock are used during data collection.

Format for Descriptions of Rock

Engineering geology rock descriptions should include generalized lithologic and physical characteristics using qualitative and quantitative descriptors. A general format for describing rock in exploration logs and legends on general note drawings is:

- Rock unit (member or formation) name
- Lithology with lithologic descriptors
    - composition (mineralogy)
    - grain/particle size
    - texture
    - color
- Bedding/foliation/flow texture
- Weathering
- Hardness/strength
- Contacts
- Discontinuities (includes fracture indexes)
- Permeability data (as available from testing)
- Moisture conditions

Example descriptions are presented in a later section.

Rock Unit Names and Identification

Rock unit names not only are required for identification purposes but may also provide indicators of depositional environment and geologic history, geotechnical characteristics, and correlations with other areas. A simple descriptive name and map symbol should be assigned to provide other users with possible engineering characteristics of the rock type. The rock unit names may be stratigraphic, lithologic, genetic, or a combination of these, such as Navajo Sandstone (Jn), Tertiary shale (Tsh), Jurassic chlorite schist (Jcs), Precambrian granite (Pcgr), or metasediments (ms). Bedrock units of similar physical properties should be delineated and identified as to their engineering significance as early as possible during each geologic study. Planning study maps and other large-scale drawings may require geologic formations or groups of engineering geologic units with descriptions of their engineering significance in accompanying discussions.

Units should be differentiated by engineering properties and not necessarily formal stratigraphic units where differences are significant. Although stratigraphic names are not required, units should be correlated to stratigraphic names in the data report or by an illustration, such as a stratigraphic column. Stratigraphic names and ages (formation, member) may be used as the rock unit name.

For engineering studies, each particular stratigraphic unit may require further subdivisions to identify engineering parameters. Examples of important engineering properties are:

- Susceptibility to weathering or presence of alteration

WEATHERING

FRESH (W1): Body of rock is not oxidized or discolored; fracture surfaces are not oxidized or discolored*; no separation of grain boundaries; no change of texture and no solutioning. Hammer rings when crystalline rocks are struck.

SLIGHTLY WEATHERED TO FRESH (W2):**

SLIGHTLY WEATHERED (W3): Discoloration or oxidation is limited to surface of, or short distance from fractures; some feldspar crystals are dull; fracture surfaces have minor to complete discoloration or oxidation; no visible separation of grain boundaries; texture preserved and minor leaching of soluble minerals may be present. Hammer rings when crystalline rocks are struck, body of rock is not weakened by weathering.

MODERATELY TO SLIGHTLY WEATHERED (W4):**

MODERATELY WEATHERED (W5): Discoloration or oxidation extends from fractures, usually throughout body of rock; ferromagnesian minerals are "rusty," feldspar crystals are "cloudy;" all fracture surfaces are discolored or oxidized; partial opening of grain boundaries visible; texture generally preserved but soluble minerals may be mostly leached. Hammer does not ring when rock is struck, body of rock is slightly weakened.

INTENSLEY TO MODERATELY WEATHERED (W6):**

INTENSELY WEATHERED (W7): Body of rock is discolored or oxidized throughout; all feldspars and ferromagnesian minerals are altered to clay to some extent. All fracture surfaces are discolored or oxidized, surfaces friable; partial separation of grain boundaries, rock is friable; in situ disaggregation of granitics common in semi-arid regions; texture altered and leaching of soluble minerals may be complete. Rock has dull sound when struck with hammer; rock is weakened, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness.

VERY INTENSELY WEATHERED (W8):**

DECOMPOSED (W9): Body of rock is discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and ferromagnesian minerals are completely altered to clay; complete separation of grain boundaries (disaggregated), partial or complete remnant rock structure may be preserved, but resembles a soil.

NOTE: Weathering categories are established primarily for crystalline rocks and those with ferromagnesian minerals, weathering in various sedimentary rocks will not always fit the categories established - weathering categories may be modified for particular site conditions or alteration such as hydrothermal alteration. Where modified criteria are established, they are identified and described.

* Characteristics of fracture surfaces do not include directional weathering along shears or faults and their associated fracture zones; for example a shear that carries weathering to great depths in a fresh rock mass would not require the whole rock mass to be classified as weathered.

** Combination descriptors are used where equal distribution of both weathering characteristics are present over significant intervals or where characteristics noted are "in between" the diagnostic characteristics.

DURABILITY INDEX

DURABILITY DESCRIPTOR	DESCRIPTIVE CRITERIA
DIØ	Rock specimen or exposure remains intact with no deleterious cracking after exposure longer than 1 year.
DI1	Rock specimen or exposure develops hairline cracking on surfaces within 1 month, but no disaggregation within 1 year of exposure.
DI2	Rock specimen or exposure develops hairline cracking on surfaces within 1 week, and/or disaggregation within 1 month of exposure.
DI3	Specimen or exposure may develop hairline cracks in 1 day and displays pronounced separation of bedding and/or disaggregation within 1 week of exposure.
DI4	Specimen or exposure displays pronounced cracking and disaggregation within 1 day (24 hours) of exposure. Generally ravels and degrades to small fragments.

COLOR

The Munsell color system (Geologic Society of America Rock Color Chart) was used. This system defines wet color by its hue, value, and chroma. Color symbols (i.e., 5 YR 5/6 may be included).

SEDIMENTARY AND PYROCLASTIC ROCK PARTICLE SIZES

Size in mm	Sedimentary (Rounded, subrounded, subangular): Particle or fragment	Sedimentary: Lithified product	Pyroclastic: Fragment	Pyroclastic: Lithified product
	Boulder	Boulder conglomerate	Block* or Bomb**	Volcanic breccia* or Volcanic agglomerate**
256				
	Cobble	Cobble conglomerate		
64				
	Pebble	Pebble conglomerate	Lapilli	Lapillistone and Lapilli tuff
4				
	Granule	Granule conglomerate		
2				
1	Very coarse sand Coarse sand	Sandstone	Coarse ash	Coarse tuff
0.5				
	Medium sand	(Very coarse, coarse, medium, fine, or very fine)		
0.25				
	Fine sand			
0.125				
	Very fine sand			
0.0625				
	Silt	Siltstone/ Shale	Fine ash	Fine tuff
0.00391				
	Clay	Claystone/ Shale		

* Broken from previous igneous rock, block shaped (angular to subangular).
** Solidified from plastic material while in flight, rounded clasts.

IGNEOUS AND METAMORPHIC ROCK TEXTURE

TEXTURE DESCRIPTOR	AVERAGE GRAIN DIAMETER
VERY COARSE GRAINED OR PEGMATITIC	>10 mm [>3/8 in]
COARSE GRAINED	5-10 mm [3/16 - 3/8 in]
MEDIUM GRAINED	1-5 mm [1/32 - 3/16 in]
FINE GRAINED	0.1-1 mm [0.004 - 1/32 in]
APHANITIC (Cannot be seen with the unaided eye)	<0.1 mm [<0.004 in]

ADDITIONAL TEXTURAL ADJECTIVES

PIT (pitted) - Pinhole to 0.03 ft [3/8 in] (<1 to 10 mm) openings.

VUG (vuggy) - Small openings (usually lined with crystals) ranging in diameter from 0.03 ft [3/8 in] to 0.33 ft [4 in] (10 to 100 mm).

CAVITY - An opening larger than 0.33 ft [4 in] (100 mm), size descriptions are required, and adjectives such as small, large, etc., may be used.

HONEYCOMBED - If numerous enough that only thin walls separate individual pits or vugs, this term further describes the preceding nomenclature to indicate cell-like form.

VESICLE (vesicular) - Small openings in volcanic rocks of variable shape and size formed by entrapped gas bubbles during solidification.

BEDDING FOLIATION OR FLOW TEXTURE

DESCRIPTORS	THICKNESS/SPACING
MASSIVE	Greater than 10 ft (>3 m)
VERY THICKLY (bedded, foliated, or banded)	3 to 10 ft (1 to 3 m)
THICKLY	1 to 3 ft (300 mm to 1 m)
MODERATELY	0.3 to 1 ft (100 to 300 mm)
THINLY	0.1 to 0.3 ft (30 to 100 mm)
VERY THINLY	0.03 [3/8 in] to 0.1 ft (10 to 30 mm)
LAMINATED (Intensely foliated or banded)	Less than 0.03 ft [3/8 in] (<10 mm)

BEDROCK HARDNESS / STRENGTH

EXTREMELY HARD (H1): Core, fragment or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.

VERY HARD (H2): Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.

HARD (H3): Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.

MODERATELY HARD (H4): Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow.

MODERATELY SOFT (H5): Can be grooved 1/16 inch (2 mm) deep by knife or sharp pick with (moderate or heavy) pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.

SOFT (H6): Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.

VERY SOFT (H7): Can be readily indented, groved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

Note: Bedrock units softer than H7, Very Soft, are described using USCS (soils) consistency descriptors.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR DESIGNS & SPECIFICATIONS
STANDARD DESCRIPTORS AND DESCRIPTIVE CRITERIA FOR ROCK

GEOLOGY NOMENCLATURE COMM. TECHNICAL APPROVAL
DRAWN SUBMITTED
CHECKED APPROVED
CHIEF, DIVISION OF GEOLOGY

DENVER, COLORADO OCTOBER 1, 1984 40-D-6493

Figure 4-6.—Descriptor legend and explanation example.

- Dominant discontinuity characteristics
  - Hardness and/or strength
  - Deformability
  - Deletereous minerals or beds (such as swelling susceptibility, sulfates, or clays)

For example, a Tertiary shale unit, Tsh, may be differentiated as Tsh_1 or Tsh_2 if unit 2 contains bentonite interbeds and unit 1 does not, and Tsh_c could be used as a unit name for the bentonite beds. A chlorite schist unit, Cs, may be differentiated as Cs_A or Cs_B where unit A contains higher percentages of chlorite or talc and is significantly softer (different deformation properties) than unit B. A metasediment unit, ms, may be further differentiated on more detailed maps and logs as ms_{sh} (shale) or ms_{ls} (limestone). All differentiated units should be assigned distinctive map symbols and should be described on the General Geologic Legend, Explanation, and Notes drawings.

Descriptors and Descriptive Criteria for Physical Characteristics of Rock

Lithologic Descriptors (Composition, Grain Size, and Texture).—Provide a brief lithologic description of the rock unit. This includes a general description of mineralogy, induration, cementation, crystal and grain sizes and shapes, textural adjectives, and color. Lithologic descriptors are especially important for the description of engineering geology subunits when rock unit names are not specific. Examples of rock unit names that are not specific are metasediments, Tertiary intrusives, or Quaternary volcanics.

1. Composition.—Use standard adjectives such as sandy, silty, calcareous, etc. Detailed mineral comp osition generally is not necessary or desirable unless useful in correlating units or indicating pertinent engineering physical properties. Note unique features such as fossils, large crystals, inclusions, concretions, and nodules which may be used as markers for correlations and interpretations.

2. Crystal or particle sizes and shapes.— Describe the typical crystal or grain shapes and provide a description of sizes present in the rock unit based on the following standards:

- Igneous and metamorphic rocks.—Table 4-1 is recommended for descriptions of crystal sizes in igneous and metamorphic rocks. Crystal sizes given in millimeters (mm) are preferred rather than fractional inch (in) equivalents.

Table 4-1.—Igneous and metamorphic rock grain size descriptors

Descriptor	Average crystal diameter
Very coarse-grained or pegmatitic	> 10 mm (3/8 in)
Coarse-grained	5-10 mm (3/16 - 3/8 in)
Medium-grained	1-5 mm (1/32 - 3/16 in)
Fine-grained	0.1-1 mm (0.04 - 1/32 in)
Aphanitic (cannot be seen with the unaided eye	<0.1 mm (<0.04 in)

- Sedimentary and pyroclastic rocks.—Terminology for particle sizes and their lithified products which form sedimentary and pyroclastic rocks is provided in table 4-2. The size

Table 4-2.—Sedimentary and pyroclastic rock particle-size descriptors (AGI Glossary)

USGS (soils only) Particle size	Size in mm (inches)	Sedimentary (epiclastic) Rounded, subrounded, subangular: Particle or fragment	Sedimentary (epiclastic): Lithified product	Volcanic (pyroclastic): Frag-ment	Volcanic (pyroclastic): Lithified product*
Boulder		Boulder	Boulder conglomerate	Block+	Volcanic breccia+
	300 (12)				
	256 (10)				
Cobble		Cobble	Cobble conglomerate	Bomb	Agglo-merate
	75 (3)				
	64 (2.5)				
Coarse gravel	32 (1.3)	Pebble	Pebble conglomerate	Lapilli	Lapilli tuff
	20 (0.8)				
Fine gravel	4.75 (0.19)				
	4 (0.16)				
Coarse sand		Granule	Granule conglomerate	Coarse ash	Coarse tuff
	2 (0.08)				
Medium sand	1 (0.04)	Very coarse sand	Sandstone (Very coarse, coarse, medium fine, or very fine)		
	0.5 (0.02)	Coarse sand			
	0.42	Medium sand			
	0.25				
Fine sand	0.125	Fine sand		Fine ash	Fine tuff
	0.074	Very fine sand			
Fines Non-plastic Silt	0.0625	Silt	Siltstone Shale		
	0.00391	Clay	Claystone Shale		
Plastic Clay					

+ Broken from previous igneous rock block shaped (angular to subangular). Solidified from plastic material while in flight, rounded clasts.

* Refer to figure 4-4.

limits do not correspond to the Unified Soil Classification System for soil particle size but are used for the field description and petrographic classification of rocks. These limits are the accepted sizes in geologic literature and are used by petrographic laboratories.

3. Textural adjectives.—Texture describes the arrangements of minerals, grains, or voids. These microstructural features can affect the engineering properties of the rock mass. Use simple, standard, textural adjectives or phrases such as porphyritic, vesicular, scoriaceous, pegmatitic, granular, well developed grains, dense, fissile, slaty, or amorphous. Use of terms such as holohyaline, hypidiomorphic granular, and crystaloblastic is inappropriate.

Textural terms which identify solutioning, leaching, or voids in bedrock are useful for describing primary texture, weathering, alteration, permeability, and density.

The terminology which follows defines sizes of voids, or holes in bedrock. However, when describing pits, vugs, cavities, or vesicles, a complete description which includes the typical diameter, or the "mostly" range, and the maximum size observed is required. For example:

". . . randomly oriented, elliptically shaped vugs range mostly from 0.03 to 0.06 foot (ft) in diameter, maximum size 0.2 foot; decreases in size away from quartz-calcite vein; about 15 percent contain calcite crystals. . ."

or

". . . cavity, 3.3 ft wide by 16.4 ft long by 2.3 ft high, striking N 45°W, dipping 85°SW was. . .."

• **Pit (pitted).—**Pinhole to 0.03 ft [**d** in] (<1 to 10 mm) openings.

• **Vug (vuggy).—**Small opening (usually lined with crystals) ranging in diameter from 0.03 ft [**d** in] to 0.33 ft [4 in] (10 to 100 mm).

• **Cavity.—**An opening larger than 0.33 ft [4 in] (100 mm), size descriptions are required, and adjectives such as small, or large, may be used, if defined.

• **Honeycombed.—**Individual pits or vugs are so numerous that they are separated only by thin walls; this term is used to describe a cell-like form.

• **Vesicle (vesicular).—**Small openings in volcanic rocks of variable shape formed by entrapped gas bubbles during solidification.

4. Color.—As a minimum, provide the color of wet altered and unaltered or fresh rock. Reporting color for both wet and dry material is recommended since the colors may differ significantly and cause confusion. The Munsell Color System, as used in the Geologic Society of America Rock Color Chart [5], is used to provide standard color names and assist in correlation. The chart also provides uniform and identifiable colors to others. Color designators are optional unless necessary for clarity, e.g., light brown (5YR 5/6). Terms such as banded, streaked, mottled, speckled, and stained may be used to further describe color. Also describe colors of bands, etc.

Bedding, Foliation, and Flow Texture.—These features give the rock anisotropic properties or represent potential failure surfaces. Continuity and thickness of these features influence rock mass properties and cannot always be tested in the laboratory. Descriptors in table 4-3 are used to identify these thicknesses.

Table 4-3.—Bedding, foliation, or flow texture descriptors

Descriptors	Thickness/spacing
Massive	Greater than 10 ft (3 meters [m])
Very thickly, bedded, foliated, or banded	3 to 10 ft (1 to 3 m)
Thickly	1 to 3 ft (300 mm to 1 m)
Moderately	0.3 to 1 ft (100 to 300 mm)
Thinly	0.1 to 0.3 ft (30 to 100 mm)
Very thinly	0.03 [3/8 in] to 0.1 ft (10 to 30 mm)
Laminated (intensely foliated or banded)	Less than 0.03 ft [3/8 in] (<10 mm)

Weathering and Alteration.—

1. Weathering.—Weathering, the process of chemical or mechanical degradation of rock, can significantly affect the engineering properties of the rock and rock mass. For engineering geology descriptions, the term "weathering" includes both chemical disintegration (decomposition) and mechanical disaggregation as agents of alteration.

Weathering effects generally decrease with depth, although zones of differential weathering can occur and may modify a simple layered sequence of weathering.

Examples are: (1) differential weathering within a single rock unit, apparently due to relatively higher permeability along fractures; (2) differential weathering due to compositional or textural differences; (3) differential weathering of contact zones associated with thermal effects such as interflow zones within volcanics; (4) directional weathering along permeable joints, faults, shears, or contacts which act as conduits along which weathering agents penetrate more deeply into the rock mass; and (5) topographic effects.

Weathering does not correlate directly with specific geotechnical properties used for many rock mass classifications. However, weathering is important because it may be the primary criterion for determining depth of excavation, cut slope design, method and ease of excavation, and use of excavated materials. Porosity, absorption, compressibility, shear and compressive strengths, density, and resistance to erosion are the major engineering parameters influenced by weathering. Weathering generally is indicated by changes in the color and texture of the body of the rock, color, and condition of fracture fillings and surfaces, grain boundary conditions, and physical properties such as hardness.

Weathering is reported using descriptors presented in table 4-4, which divides weathering into categories that reflect definable physical changes due to chemical and mechanical processes. This table summarizes general descriptions which are intended to cover ranges in bedrock conditions. Weathering tables are generally applicable to all rock types; however, they are easier to apply to crystalline rocks and rocks that contain ferromagnesian minerals. Weathering in many sedimentary rocks will not always conform to the criteria established in table 4-4, and weathering categories may have to be modified for particular site conditions. However, the basic horizontal categories and descriptors presented can be used. Site-specific conditions, such as fracture openness, filling, and degree and depth of penetration of oxidation from fracture surfaces, should be identified and described.

2. Alteration.—Chemical alteration effects are distinct from chemical and mechanical degradation (weathering), such as hydrothermal alteration, may not fit into the horizontal suite of weathering categories portrayed in table 4-4. Oxides may or may not be present. Alteration is site-specific, may be either deleterious or beneficial, and may affect some rock units and not others at a particular site. For those situations where the alteration does not relate well to the weathering categories, adjusting the description within the framework of table 4-4 may be necessary. Many of the general characteristics may not change, but the degree of discoloration and oxidation in the body of the rock and on fracture surfaces could be very different. Appropriate descriptors, such as moderately altered or intensely altered, may be assigned for each alteration category. Alteration products, depths of alteration, and minerals should be described.

3. Slaking.—Slaking is another type of disintegration which affects engineering properties of rock. Terminology and descriptive criteria to identify this deleterious property are difficult to standardize because some materials air slake, many water slake, and some only slake after one or more wet-dry cycles. The Durability Index (DI) is a simplified method for describing slaking. Criteria for the index are based

Table 4-4.—Weathering descriptors

Descriptors		Diagnostic features					
		Chemical weathering—Discoloration and/or oxidation		Mechanical weathering - Grain boundary conditions (disaggregation) primarily for granitics and some coarse-grained sediments	Texture and solutioning		
Alpha-numeric descriptor	Descriptive term	Body of rock	Fracture surfaces†		Texture	Solutioning	General characteristics (strength, excavation, etc.)§
W1	Fresh.	No discoloration, not oxidized.	No discoloration or oxidation.	No separation, intact (tight).	No change.	No solutioning.	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as siltstones or shales.
W2	Slightly weathered to fresh.*						
W3	Sllightly weathered.	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull.	Minor to complete discoloration or oxidation of most surfaces.	No visible separation, intact (tight).	Preserved.	Minor leaching of some soluble minerals may be noted.	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered.*						
W5	Moderately weathered.	Discoloration or oxidation extends from fractures, usually throughout; Fe-Mg minerals are "rusty," feldspar crystals are "cloudy."	All fracture surfaces are discolored or oxidized.	Partial separation of boundaries visible.	Generally preserved.	Soluble minerals may be mostly leached.	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstone or shales.
W6	Intensely to moderately weathered.*						
W7	Intensely weathered.	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation, see grain boundary conditions.	All fracture surfaces are discolored or oxidized, surfaces friable.	Partial separation, rock is friable; in semiarid conditions granitics are disaggregated.	Texture altered by chemical disintegration (hydration, argillation).	Leaching of soluble minerals may be complete.	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered.						
W9	Decomposed.	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay.		Complete separation of grain boundaries (disaggregated).	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete.		Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes."

Note: This chart and its horizontal categories are more readily applied to rocks with feldspars and mafic minerals. Weathering in various sedimentary rocks, particularly limestones and poorly indurated sediments, will not always fit the categories established. This chart and weathering categories may have to be modified for particular site conditions or alteration such as hydrothermal effects; however, the basic framework and similar descriptors are to be used.

* Combination descriptors are permissible where equal distribution of both weathering characteristics are present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, dual descriptors should not be used where significant, identifiable zones can be delineated. When given as a range, only two adjacent terms may be combined (i.e., decomposed to lightly weathered or moderately weathered to fresh) are not acceptable.

† Does not include directional weathering along shears or faults and their associated features. For example, a shear zone that carried weathering to great depths into a fresh rock mass would not require the rock mass to be classified as weathered.

§ These are generalizations and should not be used as diagnostic features for weathering or excavation classification. These characteristics vary to a large extent based on naturally weak materials or cementation and type of excavation.

on time exposed and effects noted in the field (see table 4-5). These simplified criteria do not specify whether the specimen or exposure is wetted, dried, or subjected to cyclic wetting and drying, and/or freeze-thaw. When reporting slaking or durability, a complete description includes the test exposure conditions. For example, the material could be classified as having "characteristics of DI 3 upon drying." Slaking is not the same as the effects of bedding separation or disaggregation produced by stress relief.

Table 4-5.—Durability index descriptors

Alpha-numeric descriptor	Criteria
DI0	Rock specimen or exposure remains intact with no deleterious cracking after exposure longer than 1 year.
DI1	Rock specimen or exposure develops hairline cracking on surfaces within 1 month, but no disaggregation within 1 year of exposure.
DI2	Rock specimen or exposure develops hairline cracking on surfaces within 1 week and/or disaggregation within 1 month of exposure.
DI3	Specimen or exposure may develop hairline cracks in 1 day and displays pronounced separation of bedding and/or disaggregation within 1 week of exposure.
DI4	Specimen or exposure displays pronounced cracking and disaggregation within 1 day (24 hours) of exposure. Generally ravels and degrades to small fragments.

A field test suitable for evaluating the degree and rate of slaking for materials, primarily clayey materials and altered volcanics, is described below. The slaking test evaluates the disaggregation of an intact specimen in water and reflects the fabric of the material, internal stresses, and character of the interparticle bonds.

To evaluate slaking behavior, immerse two intact specimens (pieces of core or rock fragments consisting of a few cubic inches or centimeters) in water. One piece should be at natural water content (wrapped jar sample) and one piece from an air-dried sample. Test results should be photographed with labels to identify specimens and exposure times.

Results of the evaluation should be reported for each specimen. Describe the behavior of the specimens as follows:

a. Volume changes.—The volume of the material reduced to individual particles should be estimated and compared to the initial volume of material. The degree of disaggregation is described using the following descriptive criteria:

None	No discernable disaggregation
Slight	Less than 5 percent of the volume disaggregated
Moderate	Between 5 and 25 percent of the volume disaggregated
Intense	More than 25 percent but less than the total volume disaggregated
Complete	No intact piece of the material remains

b. Rate of slaking.—The following descriptors are used to identify the time to slake:

Slow slaking	Action continues for several hours
Moderate slaking	Action completed within 1 hour
Rapid slaking	Action completed within 2 minutes
Sudden slaking	Complete reaction, action completed instantaneously

[Generally, slaking applies to rock; disaggregation applies to soils.]

4. Character of material.—The character of the remaining pieces of material after the test is completed is described as follows:

No change	Material remains intact
Plates remain	Remaining material present as platy fragments of generally uniform thickness
Flakes remain	Remaining material present as flaky or wedge-shaped fragments
Blocks remain	Blocky fragments remain
Grains remain	Remaining material chiefly present as sand-size grains
No fragments	Remaining material entirely disaggregated to clay-size particles

Hardness—Strength.—Hardness can be related to intact rock strength as a qualitative indication of density and/or resistance to breaking or crushing. Strength is a necessary engineering parameter for design that frequently is not assessed, but plays a role in engineering design and construction, such as tunnel support requirements, bit wear for drilling or tunnel boring machine (TBM) operations, allowable bearing pressures, excavation methods, and support.

The hardness and strength of intact rock is a function of the individual rock type but may be modified by weathering or alteration. Hardness and strength are described for each geologic unit when they are functions of the rock type and also for zones of alteration or weathering when there are various degrees of hardness and/or strength due to different degrees of weathering or chemical alteration. When evaluating strengths, it is important to note whether the core or rock fragments break around, along, or through grains; or along or across incipient fractures, bedding, or foliation.

Hardness and especially strength are difficult characteristics to assess with field tests. Two field tests can be used; one is a measure of the ability to scratch the surface of a specimen with a knife, and the other is the resistance to fracturing by a hammer blow. Results from both tests should be reported. The diameter and length of core or the fragment size will influence the estimation of strength and should be kept in mind when correlating strengths. A 5- to 8-inch (130- to 200-mm) length of N-size core or rock fragment, if available, should be used for hardness determinations to preclude erroneously reporting point, rather than average hardness, and to evaluate the tendency to break along incipient fractures and textural or structural features when struck with a rock pick. Standards (heavy, moderate, and light hammer blow) should be calibrated with other geologists mapping or logging core for a particular project. Descriptors used for rock hardness/strength are shown on table 4-6.

Table 4-6.—Rock hardness/strength descriptors

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely hard	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately hard	Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow
H5	Moderately soft	Can be grooved 1/16 inch (2 mm) deep by knife or sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

Any bedrock unit softer than H7, very soft, is to be described using USBR 5000 consistency descriptors.

Note: Although "sharp pick" is included in these definitions, descriptions of ability to be scratched, grooved, or gouged by a knife is the preferred criteria

A few empirical and quantitative field techniques which are quick, easy, and inexpensive are available to provide strength estimates. Quantitative strength estimates can be obtained from the point load test. A lightweight and portable testing device is used to break a piece of core (with a minimum length at least 1.5 times the diameter) between two loading points. If a new fracture does not run from one loading point to the other upon completion of the test, or if the points sink into the rock surface causing excessive deformation or crushing, the test should not be recorded. Raw data are given with the reduced data (equations to empirically convert load data to compressive strengths are usually supplied with the equipment). The Schmidt (*L*) hammer may also be used for estimating rock strengths; refer to Field Index Tests in chapter 5. Each of these tests can be used to calibrate the manual index (empirical) properties described in table 4-6, and a range of compressive strengths can be assigned. Depending on the scope of the study and structure being considered, laboratory testing may be required and used to confirm the field test data.

Discontinuities.—Describe all discontinuities such as joints, fractures, shear/faults, and shear/fault zones, and significant contacts. These descriptions should include all observable characteristics such as orientation, spacing, continuity, openness, surface conditions, and fillings.
Appropriate terminology, descriptive criteria and descriptors, and examples pertaining to discontinuities are presented in chapter 5.

Contacts.—Contacts between various rock units or rock/soil units must be described. In addition to providing a geologic classification, describe the engineering characteristics such as the planarity or irregularity and other descriptors used for discontinuities.

Descriptors applicable to the geologic classification of contacts are:

- Conformable
- Unconformable
- Welded—contact between two lithologic units, one of which is igneous, that has not been disrupted tectonically
- Concordant (intrusive rocks)
- Discordant (intrusive rocks)

Descriptors pertinent to engineering classification of contacts are:

- Jointed—contact not welded, cemented, or healed—a fracture
- Intact
- Healed (by secondary process)
- Sharp
- Gradational
- Sheared
- Altered (baked or mineralized)
- Solutioned

If jointed or sheared, additional discontinuity descriptors such as thickness of fillings, openness, moisture, and roughness, should be provided also (see discontinuity descriptors in chapter 5).

Permeability Data.—Permeability (hydraulic conductivity) is an important physical characteristic that must be described. Suggested methods for testing, terminology, and descriptors are available in the *Earth Manual* and *Ground Water Manual*. Numerical values for hydraulic conductivity (K) can be determined using any of several methods. These values may be shown on drill hole logs. For narrative discussions or summary descriptions, the numerical value and descriptors may be used. Descriptors to be used—such as low, moderate—are those shown on figure 4-7. Whether permeability is primary (through intact rock) or secondary (through fractures) should be indicated.

Example Descriptions

The examples which follow are in representative formats for describing bedrock in the physical conditions column of drill hole logs and on a legend, explanation, and notes drawing.

Core Log Narrative

Several examples of descriptions for core logs are presented. These examples illustrate format and the use of the lithologic descriptors but do not include a description of discontinuities.

Log with Alphanumeric Descriptors and English Units.—

> . . . 12.6 to 103.6: Amphibolite Schist (JKam). Fine-grained (0.5 to 1 mm); subschistose to massive; greenish-black (5G 2/1) with numerous blebs and stringers of white calcite to 0.02 ft thick with solution pits and vugs to 0.03 ft, mostly 0.01 ft, aligned subparallel to foliation; very thinly foliated, foliation dips 65° to 85°, steepening with depth. Moderately to slightly weathered (W4), iron oxide staining on all discontinuities. Hard (H3), can be scratched with knife with heavy pressure, core breaks parallel to foliation with heavy hammer blow. Slightly fractured (FD3),. . ..

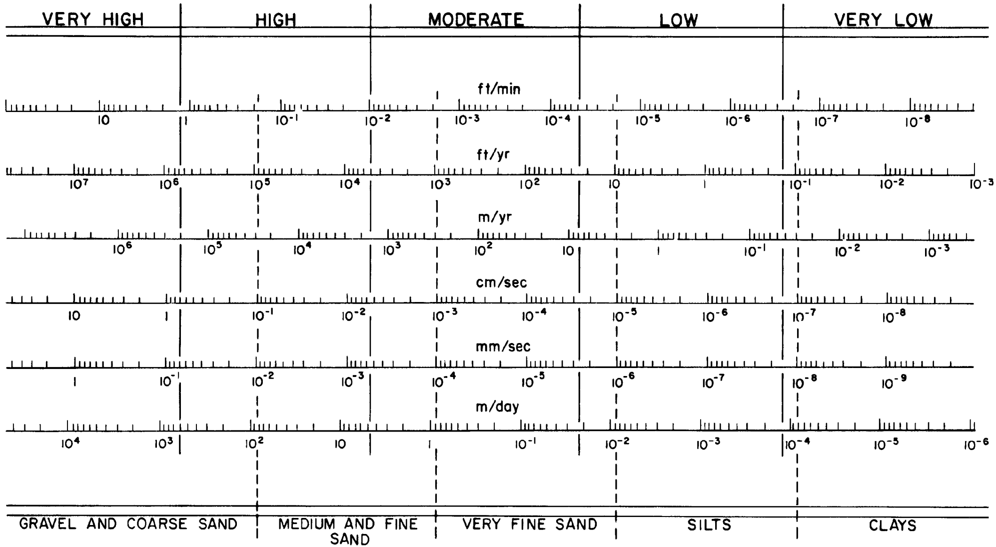

Figure 4-7.—Permeability conversion chart.

Log with Alphanumeric Descriptors Using Metric Units.—

103.60 to 183.22: Sandstone (TU_{sa}). Ferruginous quartzose sandstone. Medium-grained (0.25 to 0.5 mm), well sorted, subrounded to rounded quartz grains are well cemented by silica; hematite occurs as minor cement agent and as thin coating on grains. Moderate reddish-brown (10R 6/6). Moderately bedded, beds 250 to 310 mm thick, bedding dips 15° to 29°, averages 18°. Slightly weathered. Hard, cannot be scratched with knife, core breaks with heavy hammer blow across bedding and through grains. Moderately fractured. Core recovered. . ..

172.41-176.30: Claystone (TU_{c2}). Calcareous montmorillonitic clay with 20 percent subangular, fine sand-size quartz fragments. Strong reaction with hydrochloric acid (HCl), grayish pink (5R 8/2). Moderately to rapidly slaking when dropped in water. Very thinly bedded to laminated with bed thickness from 8 to 20 mm. Very intensely weathered. Very soft, can be gouged with fingernail, friable, core breaks with manual pressure, smaller fragments can be crushed with fingers. . . Upper contact is parallel to bedding, conformable, gradational, and intact; lower contact is unconformable, sharp and jointed but tight; dips 35° . . ..

Legend

The example which follows could be typical of a rock unit description on a general legend, explanation, and note drawing. The object is to describe as many physical properties as possible which apply to the entire rock unit at the site. If individual subunits can be differentiated, they could be assigned corresponding symbols and described below the undifferentiated description. Those characteristics in the subunits which are similar or are included in the undifferentiated unit do not need to be repeated for each subunit.

Amphibolite Schist - Undifferentiated.—Mineralogy variable but generally consists of greater than 30 percent amphibole. Contains varying percentages of feldspar, quartz, and epidote in numerous, thin, white and light green (5G 7/4), discontinuous stringers and blebs. Texture ranges from fine grained and schistose to medium grained and subschistose. Overall, color ranges from greenish black (5G 2/1) to olive black (5Y 2/1). Thinly foliated; foliation dips steeply 75° to 85° NE. Weathering is variable but generally moderately weathered to depths of 75 ft, slightly weathered to 120 ft, and fresh below. Where oxidized, moderate reddish-brown (10R 4/6), frequently with dendritic patterns of oxides on discontinuities. Hard, fresh rock can be scratched slightly with heavy knife pressure; fresh N-size core breaks along foliation with moderate to heavy hammer blow. Foliation joints are variably spaced and discontinuous, spaced more closely where weathered. Joint sets are prominent but discontinuous. (Joint sets are identified in the specifications paragraphs). Commonly altered 0.1 to 6 ft along contacts of dikes and larger shears with epidote and quartz ("altered amphibolite" on logs of exploration). When altered, harder than amphibolite. Based on drill hole permeability testing, hydraulic conductivity is very low to low, with values ranging from 0.09 to 130 feet per year (ft/yr) averages 1.5 ft/yr in slightly weathered and fresh rock.

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