FM 5-410

Military Soils Engineering

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HEADQUARTERS, DEPARTMENT OF THE ARMY

Field Manual 5-410

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Preface

SCOPE

Construction in the theater of operations is normally limited to roads, airfields, and structures necessary for military operations. This manual emphasizes the soils engineering aspects of road and airfield construction. The references give detailed information on other soils engineering topics that are discussed in general terms. This manual provides a discussion of the formation and characteristics of soil and the system used by the United States (US) Army to classify soils. It also gives an overview of classification systems used by other agencies. It describes the compaction of soils and quality control, settlement and shearing resistance of soils, the movement of water through soils, frost action, and the bearing capacity of soils that serve as foundations, slopes, embankments, dikes, dams, and earth-retaining structures. This manual also describes the geologic factors that affect the properties and occurrences of natural mineral/soil construction materials used to build dams, tunnels, roads, airfields, and bridges. Theater-of-operations construction methods are emphasized throughout the manual.

PURPOSE

This manual supplies engineer officers and noncommissioned officers with doctrinal tenets and technical facts concerning the use and management of soils during military construction. It also provides guidance in evaluating soil conditions, predicting soil behavior under varying conditions, and solving soil problems related to military operations. Military commanders should incorporate geologic information with other pertinent data when planning military operations, to include standing operating procedures.

The proponent of this publication is the US Army Engineer School. Submit changes for improving this publication on DA Form 2028 and forward it to: Commandant, US Army Engineer School, ATTN: ATSE-TD-D, Fort Leonard Wood, MO 65473-6650.

Unless otherwise stated, masculine nouns and pronouns do not refer exclusively to men.

CHAPTER 1

Rocks and Minerals

The crust of the earth is made up of rock; rock, in turn, is composed of minerals. The geologist classifies rocks by determining their modes of formation and their mineral content in addition to examining certain chemical and physical properties. Military engineers use a simpler diagnostic method that is discussed below. Rock classification is necessary because particular rock types have been recognized as having certain properties or as behaving in somewhat predictable ways. The rock type implies information on many properties that serves as a guide in determining the geological and engineering characteristics of a site. This implied information includes—

- A range of rock strength.
- Possible or expected fracture systems.
- The probability of encountering bedding planes.
- Weak zones.
- Other discontinuities.
- Ease or difficulty of rock excavation.
- Permeability.
- Value as a construction material.
- Trafficability.

This chapter describes procedures for field identification and classification of rocks and minerals. It also explains some of the processes by which rocks are formed. The primary objective of identifying rock materials and evaluating their physical properties is to be able to recommend the most appropriate aggregate type for a given military construction mission.

Section I. Minerals

PHYSICAL PROPERTIES

Rocks are aggregates of minerals. To understand the physical properties of rocks, it is necessary to understand what minerals are. A mineral is a naturally occurring, inorganically formed substance having an ordered internal arrangement of atoms. It is a compound and can be expressed by a chemical formula. If the mineral's internal framework of atoms is expressed externally, it forms a crystal. A mineral's characteristic physical properties are controlled by its composition and atomic structure, and these properties are valuable aids in rapid field identification. Properties that can be determined by simple field tests are introduced here to aid in the identification of minerals and indirectly in the identification of rocks. These properties are—

- Hardness.
- Crystal form.
- Cleavage.
- Fracture.
- Luster and color.
- Streak.
- Specific gravity.

Hardness

The hardness of a mineral is a measure of its ability to resist abrasion or scratching by other minerals or by an object of known hardness. A simple scale based on empirical tests has been developed and is called the Mohs

Hardness Scale. The scale consists of 10 minerals arranged in increasing hardness with 1 being the softest. The 10 minerals selected to form the scale of comparison are listed in *Table 1-1.* Hardness kits containing most of the reference minerals are available, but equivalent objects can be substituted for expediency. Objects with higher values on Mobs' scale are capable of scratching objects with lower values. For example, a rock specimen that can be scratched by a copper coin but not by the fingernail is said to have a hardness of about 3. Military engineers describe a rock as either hard or soft. A rock specimen with a hardness of 5 or more is considered hard. The hardness test should be performed on a fresh (unweathered) surface of the specimen.

Table 1-1. The Mohs Hardness Scale.

Mineral	Relative Hardness	Equivalent Objects
Diamond	10	
Corundum	9	
Topaz	8	
Quartz	7	Porcelain (7)
Feldspar	6	Steel file (6.5)
Apatite	5	Window glass (5.5) Knife blade or nail (5)
Fluorite	4	
Calcite	3	Copper coin (3.5)
Gypsum	2	Fingernail (2)
Talc	1	

Crystal Form

Most, but not all, minerals form crystals. The form, or habit, of the crystals can be diagnostic of the mineral and can help to identify it. The minerals galena (a lead ore) and halite (rock salt) commonly crystallize as cubes. Crystals of garnet (a silicate mineral) commonly have 12 or 24 equidimensional faces. Some minerals typically display long needle-like crystals. Minerals showing no crystal form are said to be amorphous. *Figure 1-1* illustrates two of the many crystal forms.

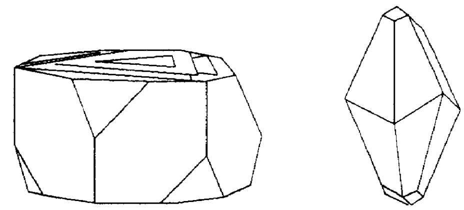

Figure 1-1. Crystal forms.

Cleavage

Cleavage is the tendency of a mineral to split or separate along preferred planes when broken. It is fairly consistent from sample to sample for a given mineral and is a valuable aid in the mineral's identification. Cleavage is described by noting the direction, the degree of perfection, and (for two or more cleavage directions) the angle of intersection of cleavage planes. Some minerals have one cleavage direction; others have two or more directions with varying degrees of perfection. *Figure 1-2* illustrates a mineral with one cleavage direction (mica) and one with three directions (calcite). Some minerals, such as quartz, form crystals but do not cleave.

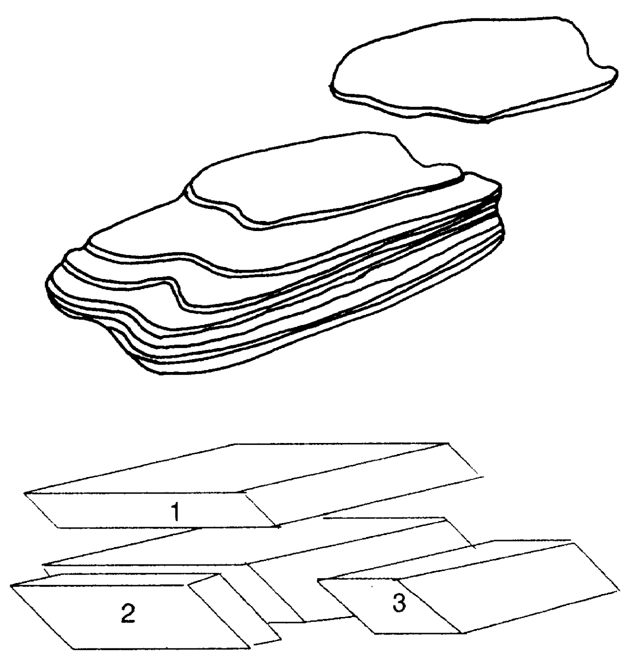

Figure 1-2. Cleavage.