Chapter 5

Quarry Supervisor and Operations

Topics

To hear audio, click on the box.

Overview

Pits and quarries provide the natural materials used for fills, base courses, and surfacing of roads and airfields. The Quarry Supervisor plays a critical role in analyzing and identifying the material needed for the specific task and selecting sites for pit or quarry operations which involve the removal and extraction of these materials. This chapter describes the various responsibilities of the Quarry Supervisor.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the responsibilities of the Quarry Supervisor concerning analysis and identification of common rock, pit, and quarry site selection, and preparing for and performing pit and quarry operations.

Prerequisites

None

This course map shows all of the chapters in Equipment Operator (EO) Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Well Drilling Supervisor and Operations	↑	EO ADVANCED
Asphalt Plant Supervisor and Operations		
Concrete Batch Plant Supervisor and Operations		
Crusher Supervisor and Operations		
Quarry Supervisor and Operations		
Project Supervisor		
Crane Crew Supervisor		
Air Detachment Equipment Supervisor		
Transportation Supervisor		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 QUARRY SUPERVISOR RESPONSIBILITIES

Pit and quarry operations in the Naval Construction Force (NCF) are normally managed by Alfa Company. The Operations Chief of Alfa Company is usually responsible for the pit and quarry operations and normally assigns a Quarry Supervisor to direct the operations of the pit and quarry.

The selected Quarry Supervisor must possess a Navy Enlisted Classification (NEC) 5708 and serve as Head Blaster, responsible for the safety and supervision of a blasting crew per COMFIRSTNCDINST 8023.2. Blasting crew personnel must be qualified and certified blasting technicians from the following rates: Equipment Operator, Construction Mechanic, Construction Electrician, Steelworker, and Engineering Aid.

1.1.0 Pits and Quarries

Material requirements and tasking for construction projects as well as rock crushing operations directly determine the operation of the pit and quarry. The size of the crew assigned to support the pit and quarry operation is dictated by the availability of the equipment and material required for a construction task. At a minimum, a blasting crew consists of four personnel: one head blaster, one assistant blaster, and two crew members. The minimum number of personnel at the quarry site should be consistent with safe operation.

Pits and quarries are classified according to the type of material they contain and the methods used to excavate and process the material (*Table 5-1*).

Table 5-1 Pit and quarry classifications.

Type	*Material*	*Primary Use*	*Operation*
Borrow pit	Soil, sand, and gravel	Subgrades, bases course, or fill	Medium and light mechanical
Gravel pit	Gravel, coarse sand, and clay	Base course, surfacing, or fill	Medium and light mechanical
Alluvial pit	Clean gravel and sand	Aggregate for concrete and mixes	Heavy mechanical crushing, screening, and washing
Dump pit	Mine spoil, slag, and overburden	Recycling, surfacing, or aggregate	Heavy mechanical, crushing, screening, and washing
Hard-rock quarry	Aggregate	Base course, surfacing, or aggregate for concrete and mixes	Heavy mechanical crushing, screening, and washing and drilling and blasting
Medium-rock quarry	Aggregate	Base course, surfacing, or fill	Heavy mechanical crushing, screening, and washing and drilling and blasting
Soft-rock quarry	Cement material	Base course and surfacing of roads and airfields	Medium and light mechanical

1.1.1 Pits

Pits are excavations made at the earth's surface in unconsolidated materials, such as clay, sand, and gravel. They are sites from which suitable construction materials are obtained in quantity, being removed or extracted from the surface without the use of blasting. Pits fall into two categories: borrow or gravel.

- A borrow pit is a site where material suitable for fill, surfacing, or blending can be removed with earthmoving equipment. Borrow pits should be worked dry.
- A gravel pit is a source of coarse-grained soil consisting predominantly of gravel-sized particles. Pit run gravel is used extensively for surfacing secondary roads; as a base course for pavement in roads, taxiways, and runways; and as ***aggregate*** in concrete and bituminous construction. The three types of gravel pits are alluvial, bank or hill, and miscellaneous.
    - Alluvial gravel pits are named for the origin of the deposit. The gravel or sandy gravel obtained from alluvial pits is often very clean and free of clay and humus, making it particularly desirable. This type of pit may be worked either wet or dry.
    - Bank or hill gravel pits produce clayey gravel or clayey, sandy gravel. This type of material is desirable for surfacing because of its binding qualities.
    - Miscellaneous gravel pits are sometimes referred to as dumps. These pits may consist of mine tailings, slag, cinder, or similar material. This type of material is used as aggregate, for surfacing, and occasionally for fill and railroad ballast.

1.1.2 Quarries

Quarries are sites where large, open excavations are made for the purpose of extracting or removing rock in its natural state by drilling, cutting, and blasting. In some cases, it may be possible to remove and break up rock by use of dozer rippers and bull pricks (jack hammer attachment). The primary types of rocks obtained from quarries are igneous and metamorphic, such as granite, diorite, gneiss, quartzite, and certain shales. Since it is seldom used in its in-place state, quarry rock is processed with mobile equipment that crushes, screens, and washes.

1.2.0 Analysis of Common Rock

The crust of the earth is made of rock. Rocks are aggregates of minerals, and are naturally occurring and inorganically formed substances. Rock type serves as a guide in determining the engineering characteristics of a site. Geologists classify rocks into three groups: igneous, sedimentary, and metamorphic.

1.2.1 Igneous Rocks

Igneous rocks are formed by the cooling and solidification of magma. There are two different types: extrusive and intrusive.

- Extrusive igneous rocks are formed when magma is thrown out of volcanoes or pushed slowly up through cracks in the earth's crust. As the molten rock reaches the surface, it usually spreads out and cools rapidly, which may result in small crystals. Recently extruded lavas may contain long hollow tubes or tunnels.

- Intrusive igneous rocks are formed from deeply buried magmas that cool very slowly within the crust of the earth, thus forming larger crystals. There are three main types of intrusive masses: stocks, sills, and dikes.
    - Stocks are smaller masses of a few square kilometers in surface.
    - Sills are tabular masses intruded between rock layers.
    - Dikes fill cracks or fractures, cutting across such layered structures

The following are common igneous rocks and their properties.

Granite – Granite is an intrusive igneous rock with an even texture commonly found in ***batholiths***. Any light colored, coarse to medium grain rock may be called granite. Granite is gray, pink, or red, with crushing strength ranging from 15,000 to 30,000 pounds per square inch (psi). Granite is found in all parts of the world and forms a large part of the continental masses. Unweathered granites are strong and durable rocks suitable for bridge piers, sea walls, and foundations of buildings. Its chief defect lies in the fact that when heated and chilled, the ***quartz*** and ***feldspar*** grains expand or contract at different rates, sometimes causing the rock surface to crumble or peel.

Diorites – Diorites are a family of rocks that resemble dark granite and are most often found in sills, dikes, and small stocks. Unweathered diorites are strong and durable and have an average compressive strength of 28,000 pounds per square inch.

Gabbro – Grabbro is a dark gray, green, or black granular rock similar in appearance to diorites. Like granite, gabbro is found in batholiths, but it also forms small stocks, dikes, sills, and volcanic necks. Gabbro, which is a durable construction material for all purposes, has a high degree of compressive strength (average is 26,000 pounds per square inch), and low absorbability. Gabbro is chiefly used for road materials.

Felsites – Felsites are a group of very dense, fine-grained extrusive igneous rocks. They have dull, stony textures and are composed of quartz and feldspars. Colors range from light or medium gray to pink, brown, yellow, purplish, and light green. Weathering causes felsite to become brown and rusty and to crumble, eventually breaking down completely to become clay. Felsites are generally used as concrete aggregate.

Basalts – Basalts are a group of very dense fine-grained igneous rocks whose colors range from black to dark gray to green to purplish. All basalts contain a great deal of lime, magnesium, and iron. They are a fine-grained equivalent of gabbro and are closely related to the esites.

When fresh and unweathered, all intrusive rocks have high crushing and shearing strengths and, unless fractured too small, are satisfactory for all types of engineering construction operations. They often provide an excellent source of concrete aggregates and other types of construction materials.

Extrusive igneous rocks require extensive examination before their engineering characteristics can be determined. Many lavas are as satisfactory as intrusive rock, but the pyroclastic material may be unreliable.

1.2.2 Sedimentary Rocks

Most sedimentary rocks result either directly or indirectly from weathering. They consist of hardened or cemented layers of sand, clay, and lime. The two major types of sedimentary rocks are chemical sediments and clastic sediments.

- Chemical sediments are formed by material that has been transported in solution and later precipitated. Limestone and dolomite are the most widespread of the chemically precipitated rocks, and the dense varieties of these carbonate rocks have high crushing and shearing strength. Their principal defects are solution cavities formed during past geologic time. Other chemically precipitated sediments (chert, flint, rock salt, anhydrite, coquina, caliche, and soft coral) are unsatisfactory for most engineering purposes due to their solubility, chemical reactivity, or low physical strength.
- Clastic sediments are formed by mechanical transportation (wind, water, glacial action, and so forth) and deposition. These sediments may be cemented to form firm rock by a variety of materials, the most important being oxides, carbonates, and silica.

The following are common sedimentary rocks and their properties.

Limestone – Any rock that contains more than 50 percent calcium carbonate in the form of calcite is considered limestone. When pure, limestones are white, but they are usually colored gray to black by carbon, or stained buff, yellow, red, or brown by iron oxides. As a building stone, limestone is used in both inner and outer walls, floors, foundations, bridges, and a variety of other structures. Crushed limestone is used in the manufacture of Portland cement.

Dolomite – Although similar in appearance and usage to limestone, dolomite is a calcium magnesium carbonate of varying proportions.

Chert and Flint – These are siliceous sediments usually found in limestone and shale. They are very hard and difficult to drill. Chert can be used as a satisfactory road material.

Rock Salt and Anhydrite – Rock salt and anhydrite are very abundant, very soft, and soluble in water. Rock salt deposits are of no value as a construction material.

Conglomerates – Conglomerates are composed of cemented gravel of varying sizes. Breccia (conglomerates composed of cemented angular fragments) may be used for road material if properly graded or crushed to size. It is usually susceptible to rapid weathering and consequent weakness.

Till – Till consists of a heterogeneous group of materials that have been deposited by glaciers. Till is an excellent source of material for earth dams and embankments, but usually not suitable for concrete and bituminous aggregates.

Sandstone – Sandstone consists of small grains (1/16 millimeter to 2 millimeters) that have been cemented together to form rock. The color of sandstone depends on the nature of the cement. Iron oxides give the red, yellow, and brown shades. Sandstone that splits easily into even slabs is known as flagstone. Flagstone is commonly used as a decorative building material.

Siltstone – Siltstone is similar to sandstone, but composed mainly of cemented particles that are between 1/256 and 1/16 millimeter in diameter.

Clays and Shales – Clays and shales are made up of clay minerals, various oxides, silica, fine particles of ordinary minerals, and a greater or lesser amount of colloidal and organic material.

The shearing resistance, crushing strength, and hardness of clastic sediments depend for the most part on the degree of consolidation and cementation.

1.2.3 Metamorphic Rocks

Metamorphic rocks are the result of profound changes in both igneous and sedimentary rock. There are two principal types of metamorphism: igneous and dynamic.

- Igneous metamorphism is caused by direct contact with hot igneous rocks and the water, steam, and other gasses that come from them.
- Dynamic metamorphism is caused by movement of the crust and the action of water, resulting in rock changes that go further than mere compaction and cementation.

The following are common metamorphic rocks and their properties.

Gneiss – Gneiss is a banded rock of granite composition containing quartz, feldspar, and ***mica***. Its banded structure enables the rock to be split into more or less parallel surfaces, allowing its use in the construction of tough walls and some road surfaces.

Schists – Schist has a much finer texture than gneiss and possesses a well marked ***cleavage***. Unlike gneisses, its bands are mineralogically alike, causing treacherous rock slips in quarries, rock cuts, and tunnels if unsupported on steep or vertical faces.

Slate – Slate is a fine-grained, hard, and dense rock which was formed by the metamorphism of shale. It splits easily into thin layers which cut across bedding planes. The most important feature of slate is its cleavage, which makes it valuable for roofing. Although not recommended, it can be used as a road material if absolutely necessary.

Quartzite – For the most part, quartzite is metamorphosed sandstone. The grains of feldspar, hematite, chlorite, muscovite, and other minerals are present as impurities and give the rock a pink, brownish, or red brick color. Although similar in appearance to grainy limestones, quartzites are much harder. Quartzite is not used as building stone due to shattering during jointing, but when crushed, becomes an excellent material for concrete work, railroad ballast, and road work.

Marble – Marble is the result of the metamorphism of limestone and dolomite. When crushed and used as an aggregate, marble has the same value as limestone.

It is impossible to generalize the engineering properties of metamorphosed rocks. Most gneisses are hard and tough and have high crushing and shearing strengths. Most schists are highly ***anisotropic*** and attention must be given to their cleavage orientation. Also, many schists are very soft and unusable for high unit loading.

Table 5-2 shows how these common rocks can be used.

Table 5-2 Use of aggregate for military construction.

Classification	Rock Type	Use of Aggregates		Use as a Base Course or Subcourse
		Concrete	Asphalt	
Igneous	Granite Gabbro-Diorite Basalt Felsite	Fair – Good Excellent Excellent Poor*	Fair – Good** Excellent Excellent Fair	Good Excellent Excellent Fair – Good
Sedimentary	Conglomerate (Breccia) Sandstone Shale Limestone Dolomite Chert	Poor Poor – Fair Poor Fair – Good Good Poor*	Poor Poor – Fair Poor Good – Poor*	Poor Fair – Good Poor Good – Poor – Fair
Metamorphic	Gneiss Schist Slate Quartzite Mable	Good Poor – Fair Poor Good Fair	Good Poor – Fair Poor Fair – Poor Fair	Good Poor – Fair Poor Fair – Good Fair
*Reacts (alkali aggregate) **Antistripping agents should be used.				

1.3.0 Identification of Common Rock

Properties of rock are used to help select rocks and aggregates for construction. These rock properties are as follows: toughness, hardness, durability, crushed shape, chemical stability, surface character, and density.

1.3.1 Toughness

Toughness is the mechanical strength, or resistance to crushing or breaking. In the field this property may be established by attempting to break the rock with a hammer.

1.3.2 Hardness

Hardness is the resistance of a rock to scratching or abrasion. This property is important in determining the suitability of aggregate for construction. Hardness can be measured using the Moh's scale (*Table 5-3*). The harder the material, the higher its number on the scale. Any material will scratch another of equal or lesser hardness. In the field, hardness may be measured using the common expedients shown in *Table 5-2;* for example, when you are able to scratch a rock with a knife blade, the rock has a hardness of 5.0 or less. A rock which you can scratch with a copper coin has a hardness of 3.0 or less.

Table 5-3 – Moh's 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	

Aggregates for general construction should have a hardness of 5 to 7 and should be difficult or impossible to scratch with a knife. Material with a hardness greater than 7 should be avoided since it cause excessive wear to crushers, screens, and drilling equipment. Material with a hardness of less than 5 may be used if other sources of aggregate prove uneconomical.

1.3.3 Durability

Durability is the resistance of the material to slaking or disintegration due to alternating cycles of wetting and drying or freezing and thawing. Estimate durability in the field by observing the effects of weathering on natural exposures of rock.

1.3.4 Crushed Shape

Crushed shape refers to the irregular, bulky, blocky, and elongated fragments made when rock breaks. Irregular and blocky broken rocks provide the best aggregates for construction because their particles compact well and interlock to resist displacement and to distribute loads. They are of nearly equal strength in all directions.

Elongated pieces (slabs, distribute loads plates or sheets, flakes, or chips), shown in *Figure 5-1*, are weak and do not compact or interlock.

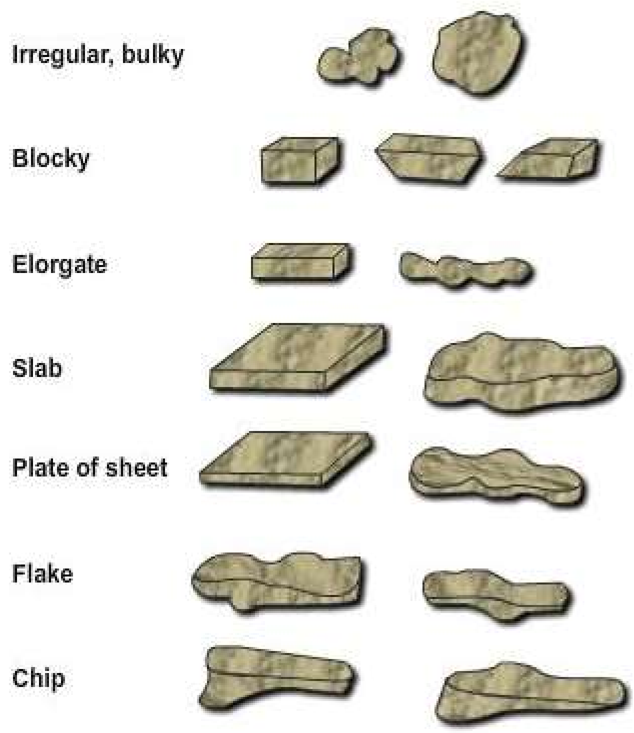

Figure 5-1 – Crushed shapes of rock.

1.3.5 Chemical Stability

Chemical stability is the resistance of the material to a reaction with the alkali material in Portland cements. Several rock types contain impure forms of silica that react with alkalies in cement to form a gel. The gel absorbs water and expands, which causes cracks or disintegration in the hardened concrete. Estimate this potential alkali aggregate reaction in the field by identifying the rock and comparing it to known reactive types or by investigating structures in which the aggregate has previously been used.

1.3.6 Surface Character

Surface character is determined by the bonding characteristics of the surface of broken rock. Excessively smooth, slick, nonabsorbent aggregate surfaces bond poorly with cementing materials and shift readily under loads. Excessively rough, jagged, or absorbent surfaces are likewise undesired because they resist compaction or placement and require excessive amounts of cementing material. In addition, if the absorption ability of the aggregate is greater than about 1 percent, the water that is likely to be trapped in the pores will cause destruction of the aggregate particles during freeze-thaw cycles.

1.3.7 Density

Density is the material weight per unit volume. Estimate density in the field by hoisting a rock sample and using *Table 5-4*. Density affects excavation and hauling costs and may influence the selection of rocks (such as riprap, jetty stone, or lightweight aggregate) for special requirements. Among rocks of the same type, density is often a good indicator of the toughness and durability to be expected.

Table 5-4 – Field-estimating rock density.

Description	Density (gr/cm^3)
Very dense	≥3.0
Dense	≥2.8 to <3.0
Moderately dense	≥2.6 to <2.8
Low density	≥2.4 to <2.6
Very low density	≥2.4

Table 5-5 shows the properties of igneous, sedimentary, and metamorphic rocks.

Table 5-5 – Engineering properties of rocks.

	Rock Type	Toughness	Hardness	Durability	Crushed Shape	Chemical Stability	Surface Character	Density (gr/cm^3)	Pounds/ Cubic Foot	Tons/Cubic Yard	Cubic Feet/Ton
Igneous	Granite	Good – Very Good (1.2 – 2.1)	Good	Good	Good	Excellent	Good – Fair	2.65	165	2.2.3	11.8
	Gabbro-Diorite	Excellent (1.6 – 2.1)	Excellent	Excellent	Good	Excellent	Excellent	2.96 - 2.92	183.5	2.48	10.6
	Basalt	Excellent (2.3)	Excellent	Excellent	Fair	Excellent	Excellent	2.86 - 2.96	178	2.41	10.6
	Felsite	Excellent (2.0)	Good	Good	Fair	Questionable	Fair	2.66	166	2.24	–
	Obsidian	Poor (–)	Good	Good	Very Good	Questionable	Very poor	2.3 - 2.4	–	–	–
	Pumice	Very poor (–)	Very poor	Poor	Good	Questionable	Poor	<1.0	–	–	–
	Scoria	Poor (–)	Poor	Poor	Good	Good	Poor	Variable	–	–	–
Sedimentary	Tuff	Poor (–)	Poor	Poor	Good	Questionable	Good	Variable	–	–	–
	Conglomerate (Breccia)	Poor (1.0)	Poor	Poor	Fair	Variable	Good	2.68 - 2.57	163.5	2.21	–
	Sandstone	Variable (1.0)	Variable	Variable	Good	Good	Good	2.54	159	2.14	13.2
	Shale	Poor (1.0)	Poor	Poor	Poor	Questionable	Fair – Good	1.8 - 2.5	134	182	11.4
	Limestone or Dolomite	Good (1.0)	Good	Fair – Good	Good	Good	Good	2.66 - 2.70	167.5	2.26	11.9
	Chert	Good (1.5)	Excellent	Poor	Poor	Poor	Fair	2.50	156	2.11	–
Metamorphic	Gneiss	Good (1.0)	Good	Good	Good	Excellent	Good	2.74	171	2.31	11.9
	Schist	Good (–)	Good	Fair	Poor – Good	Excellent	Poor – Fair	2.85	178	2.40	11.9
	Slate	Good (1.2)	Good	Fair	Poor	Excellent	Good	2.72	–	–	11.4
	Quartzite	Excellent (1.9)	Excellent	Excellent	Fair	Excellent	Good – Fair	2.69	168	2.27	12.1
	Mable	Good (1.0)	Fair	Good	Good	Good	Good	2.63	164	2.22	–

1.4.0 Site Selection

Before a pit or quarry is located, the site must be investigated to establish that suitable construction materials are available in adequate amounts and that the excavation can be worked efficiently with available equipment. Using existing pits and quarries is preferable for the following reasons:

- The quantity and quality of materials can easily be determined.
- Good haul and access roads are probably already built.
- Less effort can be spent on removal of overburden.

- Facilities such as ramps, hoppers, bins, power, and water are generally available.

The chosen site should be as close as possible to the construction project and convenient to good routes of transportation to allow more efficient hauling by decreasing the length of haul roads. Pit and quarry haulage is usually accomplished with equipment such as dump trucks and scrapers.

1.4.1 Information Sources

When locating the best site for pit or quarry material, use the following sources to collect preliminary information.

Intelligence Reports – Intelligence reports contain a wealth of information. Satellite imagery, as well as high- and low-altitude photography, will assist in locating soil types, rock formations, and existing pits and quarries. It is essential to obtain as much information as possible on landforms, soil types and thicknesses, bedrock types and structures, and groundwater conditions (including potential environmental impact and concerns). If time and resources permit, develop long-range plans before entering an area.

Geologic Maps – Geologic maps are good aids when locating pits and quarries. They often contain information on existing pits and quarries and mining districts. Geologic maps may provide information on surface geology and may indicate the angles of strike and dip. Preliminary haul road locations, elevations, vegetation, drainage, and surface limitations may also be gained by using geologic maps. Although geologic maps are generally available for most areas of the world, they may not be readily available in all areas.

Satellite Imagery – Perhaps the greatest aid comes from using satellite imagery such as a geographic information system (GIS). A GIS offers flexibility and speed because it is geographically referenced data and computer-based. A GIS-identified location of natural outcrops and surface features allows complex analyses and manipulation of information.

Topographic Maps – Topographic maps are the most common source for preliminary information and planning. They may also be used with other sources of information such as a GIS and geologic maps. Topographic maps indicate existing pit and quarry locations, streams, roads, railway beds, cuts, cliffs, and routes of communication as well as other important tactical information. Close inspection and interpretation of topographic patterns (such as the steepness of slopes and stream patterns) will often provide clues to the relative nature of rocks, the depth of weathering, soil, and drainage.

Local Inhabitants – When gathering information, do not overlook the benefits of local inhabitants, particularly surveyors, engineers, miners, and contractors. They may provide useful information about the local geology or engineering problems that may be encountered. The local courthouse, library, and drilling and mining records also provide useful information. Coordinate with Army and civilian environmental offices to ensure that there are no environmental concerns adversely affected by the proposed pit or quarry location. These offices can help in determining wetlands, identifying endangered species or habitats, and answering any questions about other protected areas. The United States Geological Survey (USGS) is an additional source of useful information.

1.4.2 Rock Structures

The sources described above may locate various types of rock structures, including strike and dip, folds, faults, and joints.

- Strike and dip, shown in *Figures 5-2* and *5-3*, are the orientation of planar features and are determined by the attitude of the rock. Strike is the trend of the line of intersection formed between the horizontal plane and the bedding plane being measured. The dip is the inclination of the bedding plane (the acute angle between the bedding plane and a horizontal plane). It is a vertical angle measured at right angles from the strike line.

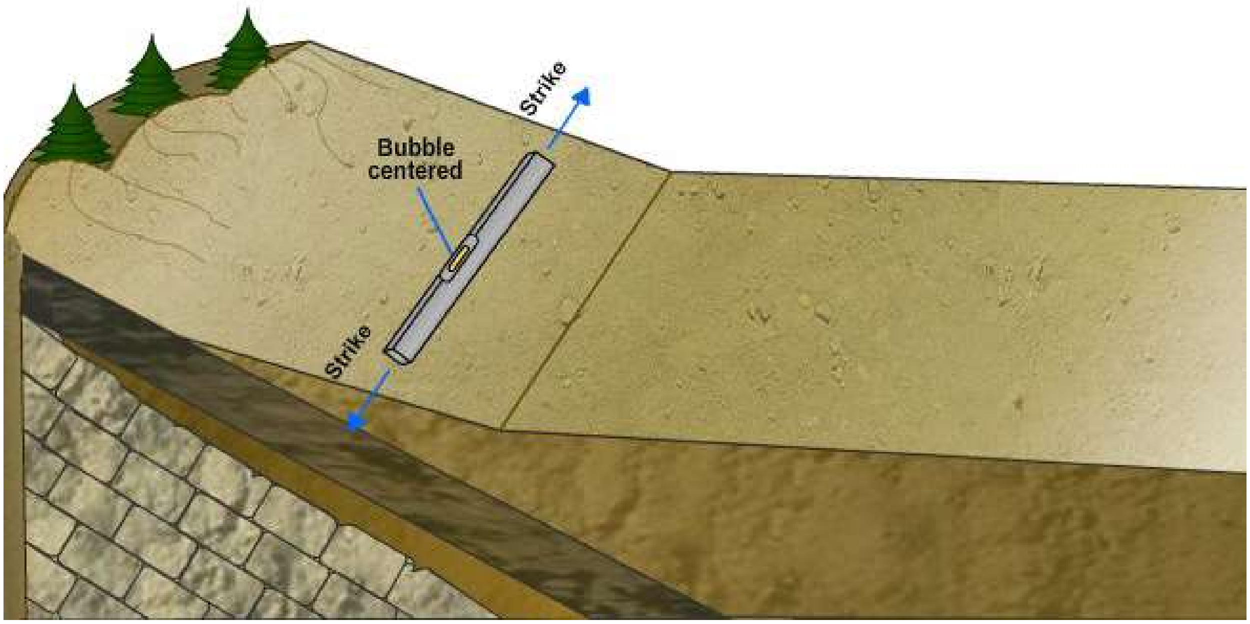

Figure 5-2 – Strike.

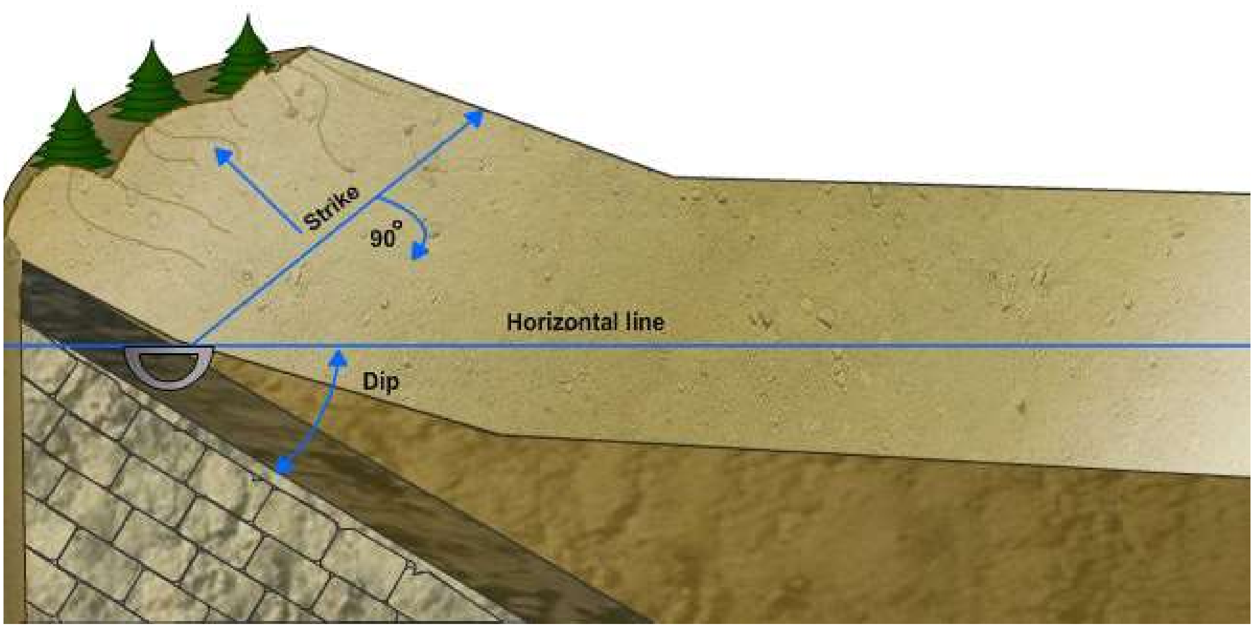

Figure 5-3 – Dip.

- Folds are undulating surface expressions of the forces of bending and crumpling. Folding is the most common type of deformation. There are several basic types of folds, as shown in *Figures 5-4* and *5-5*, such as homocline, monocline, anticline, syncline, plunging, dome, and basin.

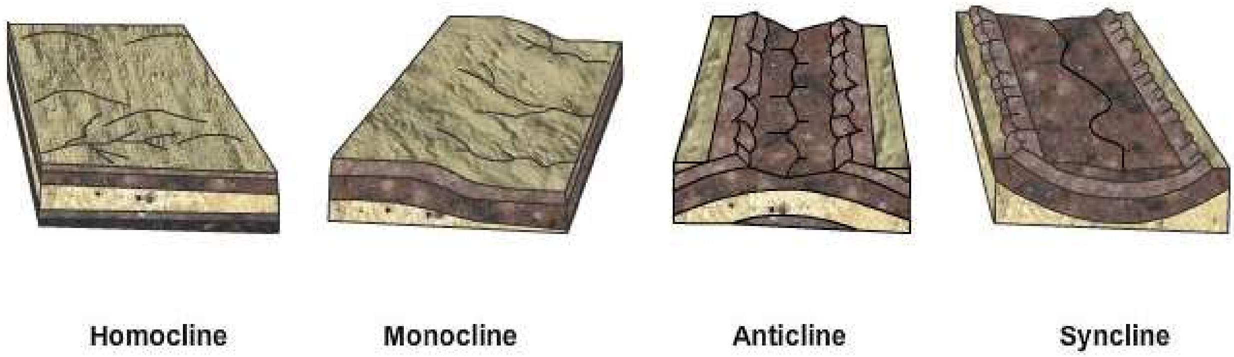

Figure 5-4 – Common types of folds.

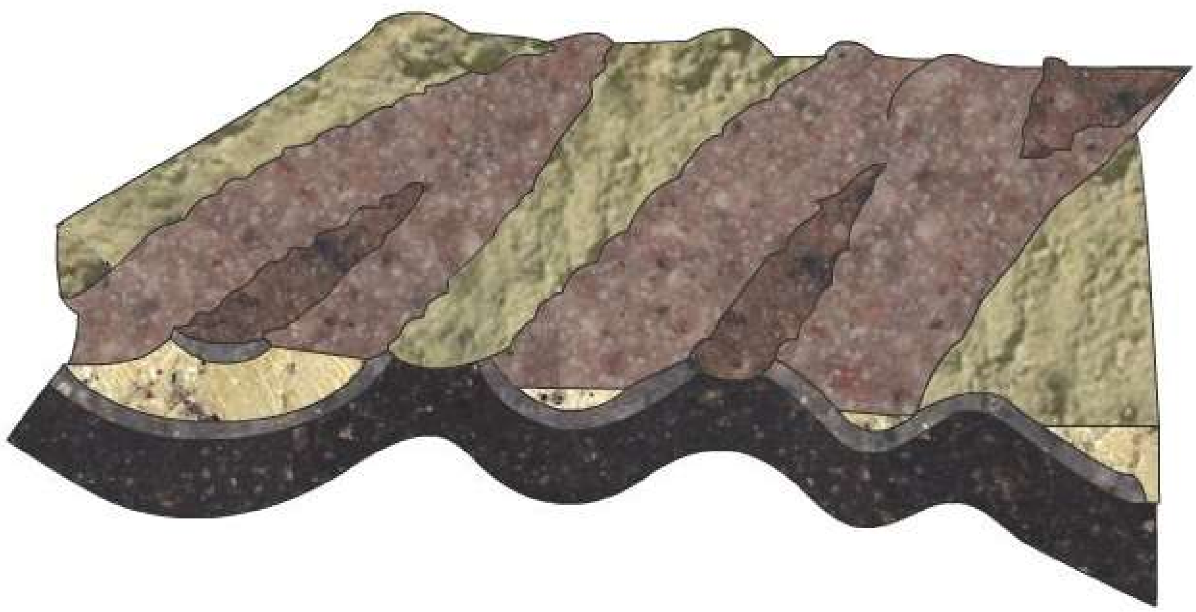

Figure 5-5 – Topographic expression of plunging folds.

- Faults (*Figure 5-6*) are fractures that cause displacement of the rock parallel to the fracture plane. Faults are commonly recognized on rock outcrop surfaces by the relative displacement of strata on opposite sides of the fault plane. Faults are identifiable on aerial photographs by long linear traces on the ground surface and by the offset of linear features such as strata, streams, fences, and roads.

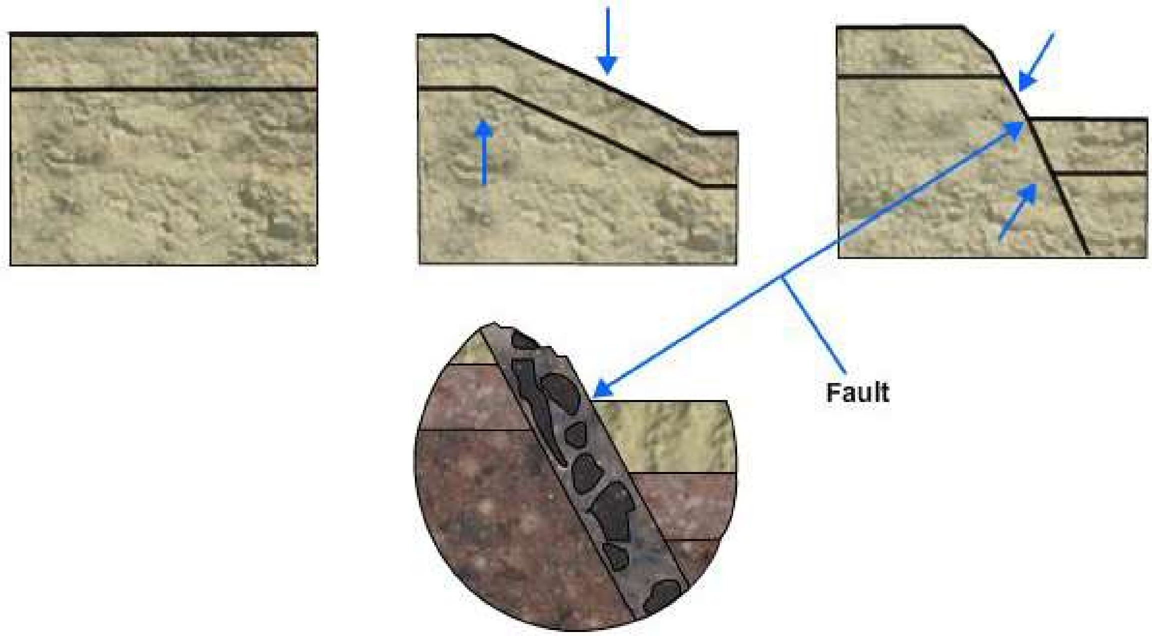

Figure 5-6 – Faulting and fault zone.

- Joints (*Figure 5-7*) are rock masses that fracture in such a way that there is little or no displacement parallel to the fractured surface. Joints influence the way the rock mass behaves when subjected to the stresses of construction. Strike and dip are used to measure the attitude of joints. Joints may result from a number of processes, including deformation, expansion, and contraction.

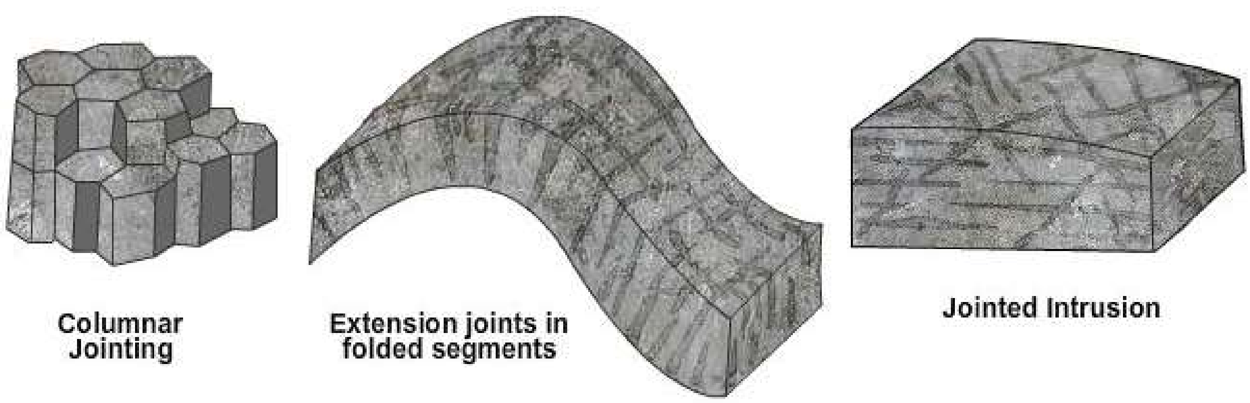

Figure 5-7 – Jointing in sedimentary and igneous rocks.

1.5.0 Pit or Quarry Preparation

Preparation of a new site should start immediately after the site location has been selected. Preparatory work includes making an operations plan, clearing the site, removing overburden, draining the site, building roads, loading ramps, and installing processing equipment.

1.5.1 Operations Plan

The operations plan is prepared before any earth is moved. The plan includes the limits of the site to be developed, methods of excavation, equipment to be used, number of personnel required, and locations of roads, structures, and support equipment. Traffic control and drainage plans are also established.

1.5.2 Clearing the Site

When the site is located in a wooded area, the first operation is to clear all timber, standing or fallen. If camouflage is necessary, trees or brush outside the designated cleared area should not be removed.

Construction equipment operations are usually the most rapid and efficient means of clearing a site. Use of the equipment is limited only by unusually large trees and stumps-terrain which hinder its maneuverability and maintenance requirements. The construction equipment used includes bulldozers, winches, power saws, rippers, motor graders, and scrapers. In addition, hand tools are used in certain clearing operations.

You may dispose of brush by burning it on the site; however, check to see if a burn permit is required. Stockpile timber of suitable dimensions at the perimeter of the site, saving it for possible use in the construction of loading ramps. All stumps, roots, boulders, vegetation, and rubbish must be excavated and moved clear of the site.

1.5.3 Overburden

Overburden is usually removed from a pit or quarry site by a continuous process of stripping. The methods and equipment used in removing overburden are dependent upon the type of excavation planned, the depth of overburden, and the distance the overburden must be moved. It may be advantageous to leave the overburden in place at military quarry sites and blast it with the rock to provide binder for road building materials. Removal is coordinated with excavation to provide a continuously cleared area. Dump the spoil in a remote area to avoid double handling. On hillside locations, place the spoil in banks located on the downhill side outside the working area.

Remember that all overburden is not necessarily waste. Some of the overburden is suitable for filling building access roads, and leveling stockpile and equipment sites.

In excavating aggregates for concrete, bituminous mixtures, or base courses, the overburden must be removed while the aggregates are processed. Frozen material is loosened either with a ripper or explosives. Keep overburden cleared at least 50 feet back from the top of the face of a quarry or pit to prevent rock and other material from falling on personnel working near the top of the face. Also, clear overburden far enough back from the top so the equipment being used to clear the overburden does not interfere with drilling operations.

1.5.4 Drainage

Adequate drainage is essential to the operation of a pit or quarry. Alluvial gravel pits may be worked wet or dry, depending on water levels. Borrow pits and quarries are normally worked dry.

Install drainage facilities as early as possible so the site will be dry when work starts. The means of drainage depends primarily upon the location and the amount of water to be eliminated. Hillside locations are easy to drain by an interceptor ditch made along the uphill side with a scraper, dozer, or grader. When the floor of a site is below ground level, both surface and seepage water must be disposed of. When open ditches cannot be dug to take advantage of gravity flow, direct all water to a sump hole. Maintain a slight slope on the site floor at all times to permit water to drain away from the working face of the site.

1.5.5 Roads

Construction of access roads should start as soon as the operations plan is completed so they are ready for use when the pit and quarry equipment arrives. The access roads should be designed for all-weather operation under the heaviest loads anticipated. The roads should follow the shortest and easiest routes that satisfy the traffic control plan. To speed up hauling, you must avoid sharp curves and keep grades as low as possible. Ten percent grade (10-foot drop or climb every 100 feet) is the maximum grade for truck operations, whereas tractors and graders can climb 20-percent grades for short distances. Except for the loop at the loading site, access roads should provide for one-way traffic--one route to enter and another to haul out. Leave enough space between haul roads and borrow pits to avoid traffic hazards.

1.5.6 Chute Loading Ramps

A chute loading ramp is an expedient means of loading excavated material into trucks with earth-moving equipment at sites where loaders and clamshells are unavailable. An elementary type of loading is the plain chute shown in *Figure 5-8*. Each ramp must be able to support the heaviest equipment used, plus an impact factor of 50 percent, and approximately 20 ton of materials.

Figure 5-8 – Plain chute loading ramp.

1.6.0 Pit Operations

Sand, gravel, and other construction materials are extracted from pits with scrapers that can move huge volumes of material in a relatively short period of time. The material is removed from the floor of the pit in successive thin layers over its entire width.

During excavation, scrapers should be carefully spotted to maintain an even downgrade and prevent cutting holes below the general level of the pit floor. When the pit is longer than 100 feet in the direction of loading, the scraper spots should be staggered along the length of the cut as well as across the width of the zone. *Figure 5-9* depicts the layout and development of a scraper pit, with lines A-A and B-B showing the limits of the pit. Lines A-A and B-B divide the area into three zones for current excavating, stripping, and clearing. Zone 1 is being excavated at the same time Zone 2 is being stripped and Zone 3 is being cleared. Three scrapers in staggered formation load downhill in Zone 1, and a dozer strips downhill in Zone 2.

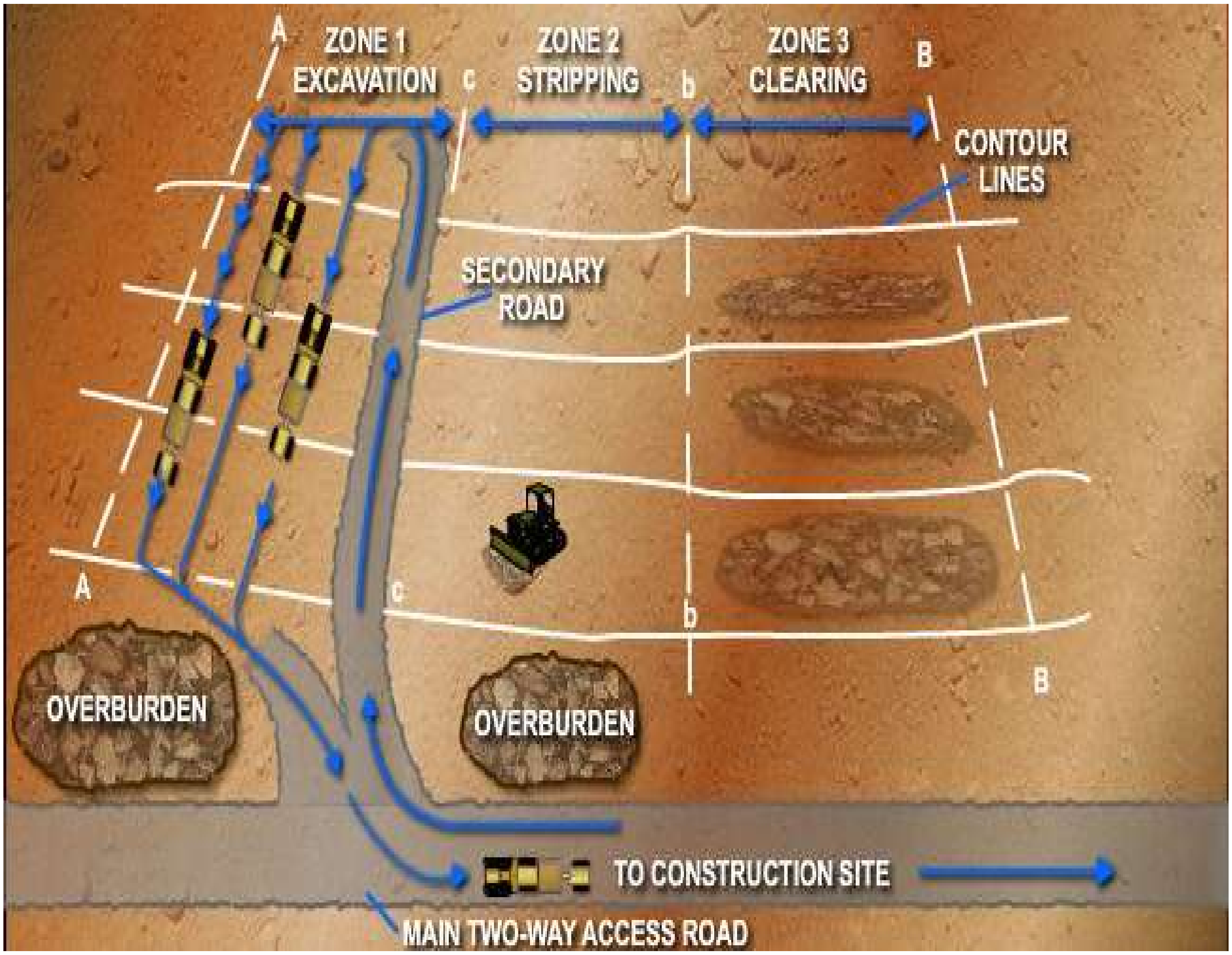

Figure 5-9 – Layout and development of a scraper pit.

In consolidated gravel or soft rock, when scrapers assisted by pusher tractors (push cat) will not pick up a heaping load within 150 feet, a ripper should be used to loosen the material, thereby increasing the loading efficiency of the scrapers. Rippers should be operated downhill, and an entire zone should be ripped at one time while the scrapers are hauling from another zone.

A dragline is the most practical piece of construction equipment for underwater digging and is particularly adapted to submerged gravel pit operations. Draglines can efficiently recover sand, gravel, laterite, or coral from beaches, the beds of streams, and the bottoms of lakes and lagoons. They are also used to stockpile material for other loading equipment. A dragline is slower and less accurate than power shovels, so they are not generally used to load trucks. *Figure 5-10* depicts the layout and development of a pit being excavated with a dragline.

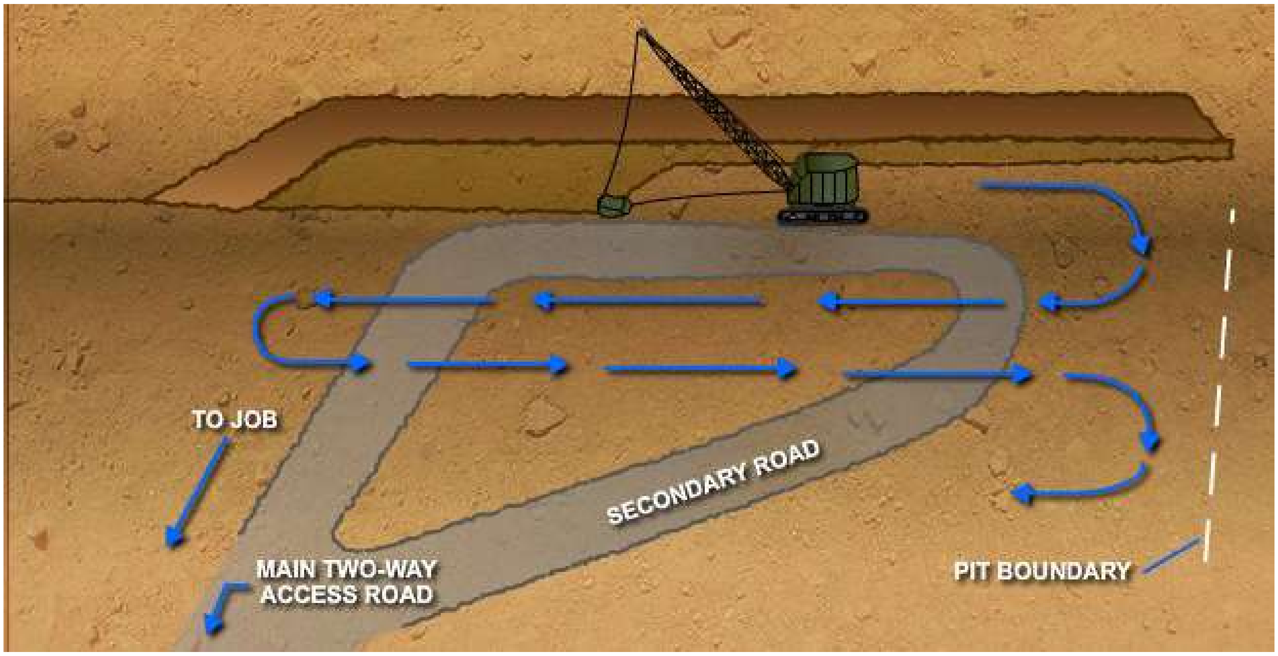

Figure 5-10 – Layout and development of a pit using a dragline.

Clamshells are capable of excavating loose sand, gravel, and crushed stone at, above, or below ground level. The clamshell can be raised and loads dumped at heights equal to the distance from the tip of the boom to the ground, minus the length of the clamshell bucket, to allow adequate clearance for the bucket when it is opening.

Material removed from pits can seldom be used in its in-place state. In most cases, pit material must be processed (crushed and screened) to meet job specifications, but before the material can be processed, it must be loaded and delivered to the processing equipment. Loading and delivery may require additional handling equipment such as front-end loaders equipped with either a rollback bucket or 4-in-1 bucket, and conveyers that may be used singly or in a series to load vehicles, construction equipment, or hoppers from stockpiled material. Bucket loaders may also be used. They consist of a power-driven endless chain to which buckets are attached so material is loaded on the downward travel. Handling equipment is used to load stockpiled material into overhead hoppers and trucks.

The production of any pit material that requires crushing and screening depends on the capacity of the processing equipment used.

1.7.0 Quarry Operations

Quarry operations involve not only extracting the material (rock), but also crushing and screening it in order to make it suitable for construction use.

1.7.1 Quarry Features

Figure 5-11 shows various quarry features. These features are described below.

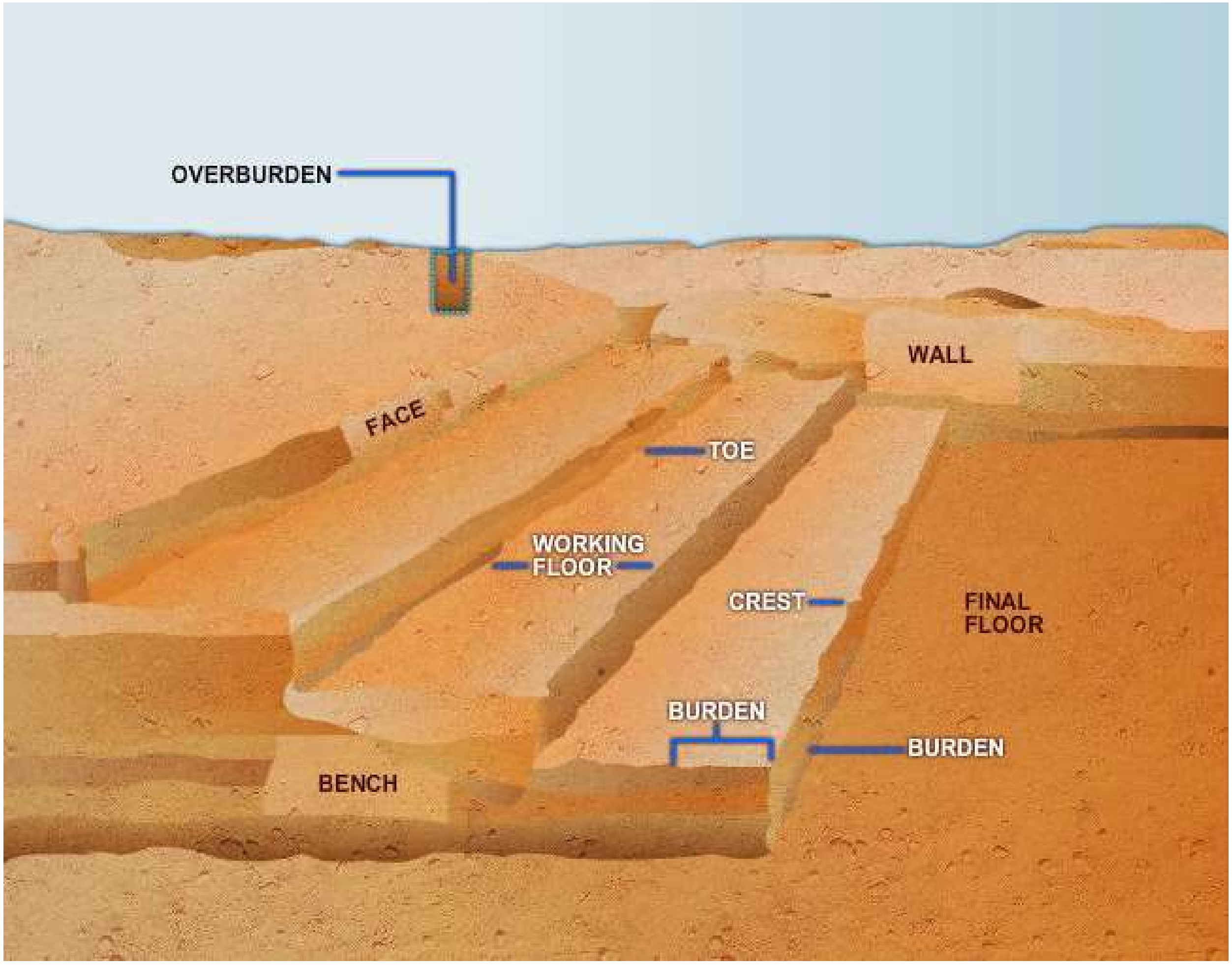

Figure 5-11 – Quarry features.

Overburden – Overburden is the waste material that often overlies pit or quarry sites. Deposits within the waste materials are called spoil and must be removed before excavation of the construction materials lying below. Overburden refers to loose material but locally it may include solid rock lying above the desired material.

Burden – Burden is the construction material on the face of a quarry.

Floor – The floor of the quarry is the inside bottom surface that marks the lower limit of excavation.

Working Floor – Often quarries contain one or more working floors at various levels above the final quarry floor.

Wall – A quarry wall is a more or less vertical surface that marks the lateral limit of excavation.

Face – The face of a quarry is a rock surface (usually vertical) from which rock is to be excavated.

Crest and Toe – The top of the face is called the crest, and the bottom is called the toe.

Bench – A bench is a step-like mass of rock behind a face and below a working floor. Notice that each bench has a face, toe, and crest.

A single-bench quarry, as shown in *Figure 5-12*, has the entire floor on one level. The height of the bench will depend on the reach of the equipment available. In the NCF, the recommended bench height is 10 feet; however, depending on the drilling equipment available, type of rock, magnitude of operation, and experience of the operating personnel, bench heights can range from 8 to 40 feet.

Figure 5-12 – Single-bench quarry.

Military quarries are usually of the single-bench type. This type offers greater safety and efficient operation. All operations are on one level, a greater amount of rock is shot at one blast, and less equipment is needed in the overall process. In addition, this type of quarry requires less training for the operating crews.

Blast trial shots are made in both existing and new quarries before installing equipment for two reasons. The first is to avoid possible damage to installed equipment, and the second, in the case of new quarries, is that the trial shots will provide necessary ballast for the construction of access roads and foundations to place equipment upon.

WARNING

Blasting must be supervised and controlled directly by a qualified blaster. Also, all personnel working around blasting should wear hard hats, safety goggles, dust respirators, earplugs, and hard toe safety shoes.

A multiple-bench quarry, as shown in *Figure 5-13*, has a series of ledges or terraces resembling steps. The highest bench is blasted and worked first. Then successive lower levels are simultaneously developed as the work progresses and as each bench is required.

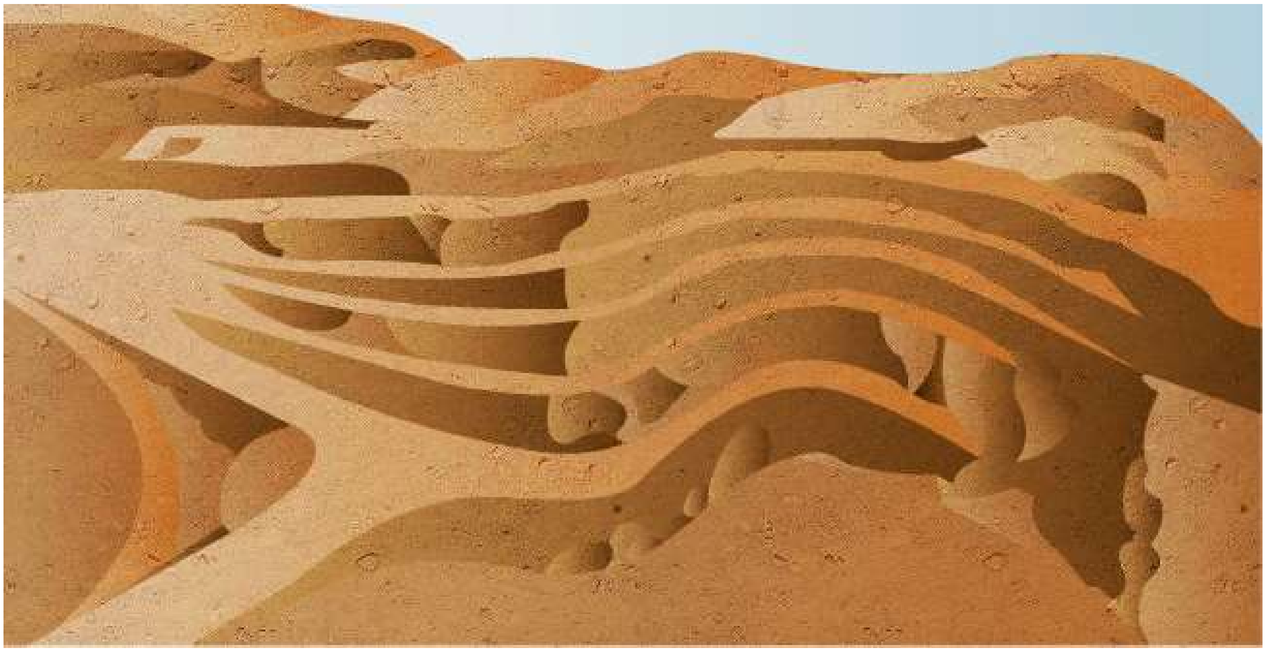

Figure 5-13 – Multiple-bench quarry.

Quarries are developed by the multiple-bench method when the face is too high for single shots, horizontal seams or separations are present, or deep and narrow deposits exist. This method of development permits equipment to be used simultaneously at more than one level. All benches must be made wide enough to allow the use of equipment to remove blasted rock (50 feet minimum). Multiple-bench quarries make possible greater continuity of operation than single-bench quarries.

NOTE

When you are developing a multiple-bench quarry, blasting must be confined to only one bench at a time. Simultaneous blasting at several levels is NOT permitted under any circumstances.

1.7.2 Types of Quarries

There are three basic types of quarries: hillside, subsurface, and terrain. The intended use of the quarry will dictate the type to develop.

- A hillside quarry, like the one shown in *Figure 5-14*, is constructed in rock that is part of the structural geology of a hill. These quarries have the advantage of natural drainage and gravity affecting the material flow from the quarry face. The disadvantages of a hillside quarry are the difficulty of removing the overburden, the grade or steepness of haul roads, the high visibility of operations, the noise radiating from the site, the vulnerability to severe weather, and the necessity of bench operations.

Figure 5-14 – Hillside quarry.

- A subsurface quarry, like the one shown in *Figure 5-15*, is opened below the level of the surrounding terrain. Two disadvantages of this type of quarry are the removal of material below grade and the disposition of the material above grade, disadvantages that apply to both overburden and construction aggregate. Another disadvantage is that this type of quarry will not naturally drain. Advantages include being masked from view, containing the noise, and providing some protection from severe weather.

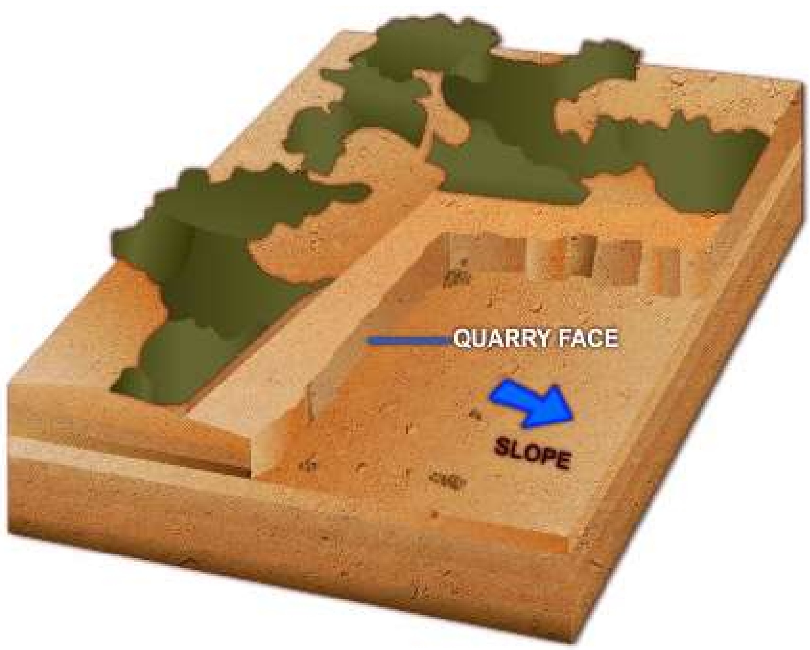

Figure 5-15 – Quarry face on slightly inclined strata showing underlying stratum used as quarry floor and slope away from quarry face.

- A terrain quarry is a temporary operation in which the existing terrain is lowered or leveled (such as the excavation of a roadway through a rock formation).

1.7.3 Determining the Direction of the Quarry Face

Before determining the layout of the quarry, it is necessary to determine the quarry face.

Steeply Inclined and Folded Strata – The quarry face must be oriented perpendicular to the strike in these types of strata, as shown in *Figure 5-16*. If the rock is worked in this manner, a vertical or near vertical face will result. If the face is oriented parallel to the strike, an overhanging or sloping face with an extended toe will result. These conditions are hazardous and inefficient.

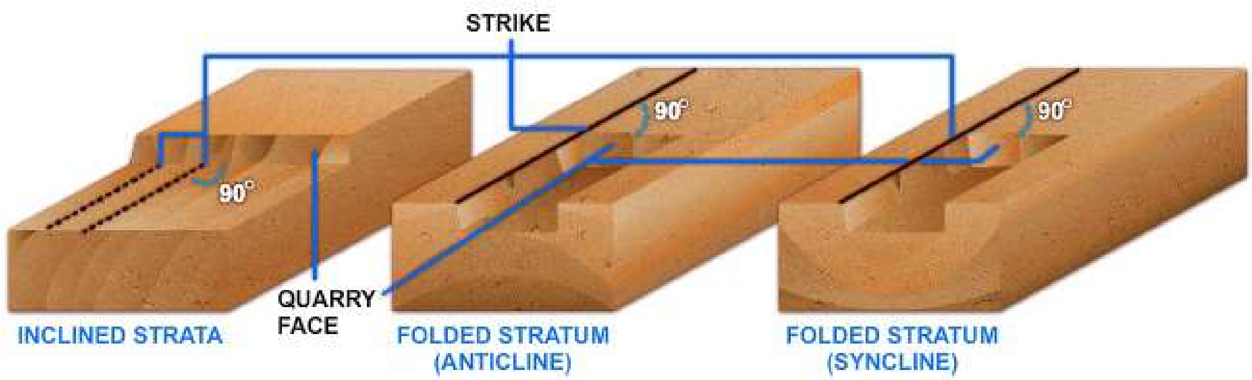

Figure 5-16 – Determining the direction of the quarry face.

Level and Slightly Inclined Strata and Massive Rock Formations – Where conditions of level strata or massive rock formations exist, the direction of the quarry face may be determined by other factors. If the strata at the proposed quarry site are slightly inclined, the quarry face should be worked up the grade so that the floor of the quarry will slope away from the face (*Figure 5-17*).

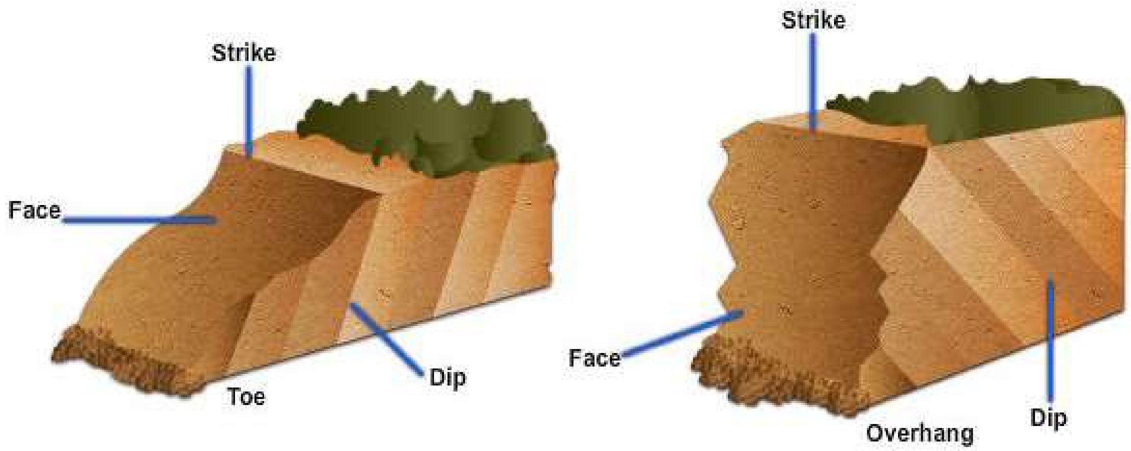

Figure 5-17 – Disadvantage of the opening face parallel to the strike.

1.7.4 Quarry Layout

The layout of a quarry should provide a gravity flow of material from the face to the crusher, from the crusher to the storage bin, and from the bin to the hauling equipment, as illustrated in *Figure 5-18*. A quarry laid out in this manner assures that a maximum quantity of rock can be processed with a minimum of labor and equipment. In quarries laid out on the gravity-flow principle, the drainage problem is practically eliminated.

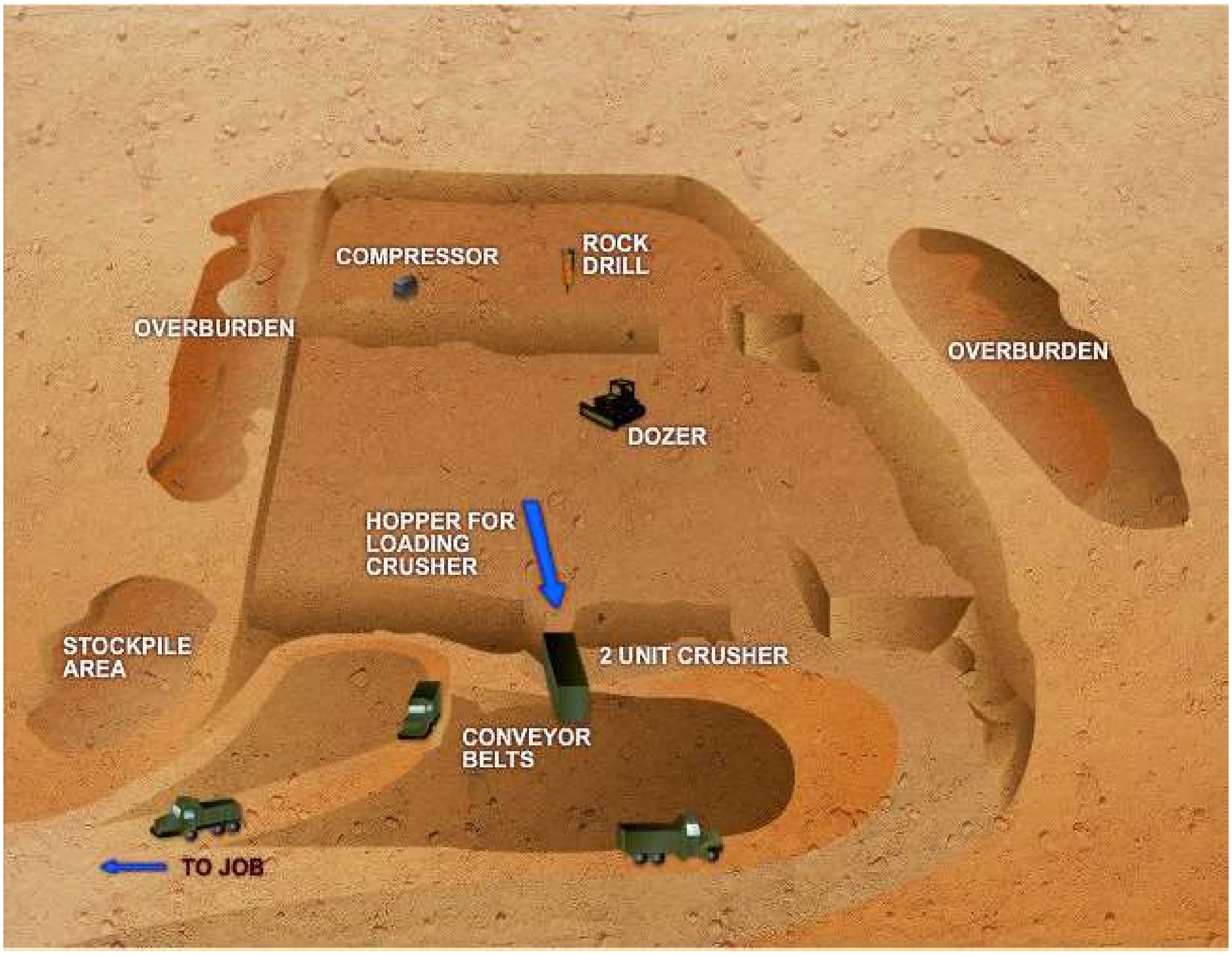

Figure 5-18 – Typical quarry layout.

1.8.0 Quarry Equipment

Civil engineer support equipment (CESE) is available in the NCF Table of Allowance to enable construction units to meet their own aggregate production requirements. Quarry equipment is subject to exceptionally hard wear due to the abrasive action of rock and rock dust; therefore, the operator's maintenance procedures contained in the manufacturer's maintenance and service manuals must be strictly followed.

The equipment used in hard-rock quarries consists of bulldozers, air compressors, rock drills, drill steel and bits, loading and hauling equipment, and miscellaneous tools. The Quarry Supervisor must ensure that operator's maintenance is performed and that all cutting edges, end bits, teeth and shanks, dozer tracks, tires, blades, and so forth are checked daily for wear, adjustments, and cracks.

1.8.1 Wearfacing

Equipment used in quarry operations should be wearfaced. Wearfacing greatly extends the usable life of construction equipment, ensures efficient operation with less downtime, and greatly reduces the need for spare parts. Guidelines for wearfacing equipment parts and accessories are outlined in the *NCF Welding Materials Handbook,* NAVFAC P-433.

Wearfacing is commonly known in the NCF as hardfacing. The purpose of hardfacing is to insulate many working parts of equipment from the destructive forces that cause metal wear. The selection of a hardfacing alloy for a certain application is based on the capacity of the alloy to withstand or resist impact and abrasion. Impact refers to a blow or series of blows on a surface that result in a fracture or gradual deterioration. Abrasion is the grinding action that results when one surface slides, rolls, or rubs against another. Under high compressive loads, this action can result in gouging.

Alloys that resist abrasion well are poor in withstanding impact, whereas those that withstand impact well are poor in resisting abrasion; however, there are many alloys whose hardfacing properties fall between two extremes. These alloys offer some protection against abrasion and withstand impact fairly well. The hardfaced welding procedures, the type material the part is manufactured from, and the primary and alternate electrodes to perform the hardfacing procedures are all outlined in NAVFAC P-433. Hardfacing operations must be approved by the Maintenance Supervisor.

1.8.2 Maintenance

Often, maintenance is put off to a later date because of production. This may satisfy the immediate production demands of the unit, but it is not good for the equipment and creates a lax attitude toward scheduled maintenance. When this occurs, a precedent is set that leads to putting maintenance second to production. Should this happen, it is not long before production rates decline because of equipment breakdowns.

1.9.0 Safety Items

According to the Quarry and Blasting Standard Operating Procedures featured in *Quarry Operations*, Navy Technical Reference Publications (NTRP) 4-04.2.12, the following items are required at the quarry site:

- First aid kit
- Dry chemical fire extinguishers (2)
- CO_2 fire extinguishers (2)
- Blasting flags
- Road signs
- Warning siren
- Binoculars

1.10.0 Blasting Operations

Blasting operations are performed under the direct supervision and control of a qualified blaster who carries the NEC-5708. All other quarry personnel assigned must follow written and oral instructions, carry out assigned duties, and observe all safety precautions.

Limiting the number of personnel handling explosives lessens the risk of accidents. This means one or two blasters have a definite assignment to conduct several of the tasks involved in loading and firing a blast. These tasks include the following: carrying explosives and detonators, opening cases, priming, loading, stemming, connecting blasting circuits, and firing. The entire quarry crew must know exactly what the blaster's duties are. When such a system is observed, everything is accomplished in a precise and orderly manner with no haphazard assumption of the various tasks to be performed.

1.10.1 Responsibilities

Before conducting blasting operations, the Head Blaster, acting as Quarry Safety Officer, has the following responsibilities.

- Advise the following agencies of anticipated operations:
  - Fire department
  - Medical department
  - Others as necessary
- Ensure that all required equipment is operational and located in an area at a calculated safe distance from the blast site and that supplies are available and correctly stored.
- Ensure that fire protection and emergency equipment is immediately available (within 5 minutes).
- Ensure that "caution" signs are appropriately posted according to local policies.
- Conduct a task-oriented explosive safety briefing.
- Conduct a radio check to enter the appropriate net, receive instructions from ranger control, and be assigned/understand the stand-by frequency.

Summary

This chapter discussed the responsibilities of the Quarry Supervisor, including analyzing and identifying properties of common rock used as construction materials. In addition, it described the various resources a Quarry Supervisor can use to locate suitable pit and quarry sites. This chapter also discussed how to prepare for and conduct pit and quarry operations with the most efficient equipment.

Review Questions (Select the Correct Response)

1. In an NMCB, what company is responsible for the management of pit and quarry operations?

   A. Alfa
   B. Bravo
   C. Charlie
   D. Headquarters

2. At a minimum, how many people are on a blasting crew?

   A. 5
   B. 4
   C. 3
   D. 2

3. How are pits and quarries classified?

   A. By the type of material they contain and their location
   B. By their location and the methods used to excavate and process the material
   C. By the type of material they contain and methods used to excavate and process the material
   D. By the type of material they contain and their size

4. Material suitable for fill, surfacing, or blending can be removed at which type of pit?

   A. Borrow
   B. Gravel
   C. Alluvial
   D. Bank or hill

5. **(True or False)** A borrow pit is a source of coarse-grained soil consisting predominantly of gravel-sized particles.

   A. True
   B. False

6. Which type of pit may be worked either wet or dry?

   A. Borrow
   B. Alluvial gravel
   C. Bank or hill gravel
   D. Dump

7. Which type of pit may consist of mine tailings, slag, cinder, or similar material?

   A. Borrow
   B. Alluvial gravel
   C. Bank or hill gravel
   D. Dump

8. What types of rocks are primarily obtained from quarries?

   A. Igneous and sedimentary
   B. Metamorphic and sedimentary
   C. Igneous and metamorphic
   D. Igneous and limestone

9. Geologists classify rocks into what three groups?

   A. Sedimentary, metamorphic, and shale
   B. Igneous, silica, and brick
   C. Metamorphic, alluvial, and brick
   D. Igneous, sedimentary, and metamorphic

10. Which rocks are formed by the cooling and solidification of magma?

   A. Igneous
   B. Sedimentary
   C. Metamorphic
   D. Limestone

11. What is the crushing strength of granite, in psi?

   A. 15,000 to 50,000
   B. 15,000 to 40,000
   C. 15,000 to 35,000
   D. 15,000 to 30,000

12. Which igneous rock is chiefly used for road materials?

   A. Granite
   B. Diorites
   C. Gabbro
   D. Felsites

13. **(True or False)** Intrusive igneous rock provides an excellent source of concrete aggregates and other types of construction materials.

   A. True
   B. False

14. Which rocks consist of hardened or cemented layers of sand, clay, and lime?

A. Igneous
B. Sedimentary
C. Metamorphic
D. Intrusive

15. Any rock that contains more than 50 percent calcium carbonate in the form of calcite is considered _______.

A. limestone
B. dolomite
C. chert
D. flint

16. Which sedimentary rock is used in the manufacture of Portland cement?

A. Limestone
B. Rock salt
C. Anhydrite
D. Till

17. Which sedimentary rock is an excellent source of material for earth dams and embankments?

A. Limestone
B. Rock salt
C. Anhydrite
D. Till

18. What metamorphic rock can be use in the construction of tough walls and some road surfaces?

A. Gneiss
B. Schist
C. Slate
D. Quartzite

19. What metamorphic rock is very soft and unusable for high unit loading?

A. Gneiss
B. Schist
C. Slate
D. Quartzite

20. **(True or False)** Hardness is the mechanical strength, or the resistance to crushing or breaking.

A. True
B. False

21. Aggregates for general construction should have a hardness of _______.

A. 7 to 9
B. 5 to 7
C. 7 to 5
D. 5 to 3

22. **(True or False)** Elongated pieces provide the best aggregates for construction because their particles compact well and interlock.

A. True
B. False

23. What is the advantage of using existing pits and quarries?

A. The quantity and quality of materials can easily be determined.
B. Less effort can be spent on removal of overburden.
C. Facilities such as ramps, hoppers, bins, power, and water are generally available.
D. All the above

24. What source is most commonly used for preliminary information and planning?

A. Intelligence reports
B. Geologic maps
C. Satellite imagery
D. Topographic maps

25. What should you check before burning brush on a proposed pit or quarry site?

A. Weather
B. Type of fire extinguisher
C. Requirement for a smoke permit
D. Requirement for a burn permit

26. Overburden should be kept cleared at least ______ feet back from the top of the face of a quarry.

A. 50
B. 40
C. 25
D. 10

27. What is the maximum percent grade for a haul road designed for use by truck operations in a quarry?

A. 20
B. 15
C. 10
D. 5

28. A chute loading ramp should be constructed to support a minimum of how many tons of material?

A. 20
B. 15
C. 10
D. 5

29. When a pusher-assisted scraper cannot load within 150 feet, what equipment should you use?

A. An additional scraper
B. An extra pusher
C. A ripper tractor
D. A closed-faced

30. What factor determines the layout of a quarry where the rocks formation is jointed?

A. Method of development
B. Depth of overburden
C. Direction of rock formation
D. Lay of the strata

31. In the NCF, what is the recommended bench height in a quarry, in feet?

A. 25
B. 20
C. 15
D. 10

32. What person is responsible for ensuring that operator maintenance is performed on quarry equipment?

A. Operations Chief
B. Maintenance Supervisor
C. Maintenance field crew
D. Quarry Supervisor

33. What NAFAV publication provides guidelines for wearfacing equipment parts?

A. P-404
B. P-433
C. P-405
D. P-300

34. **(True or False)** Putting off maintenance to satisfy immediate production demands sets a good precedence and increase the life of the equipment.

A. True
B. False

35. What is the NEC of a qualified blaster?

A. 5710
B. 5709
C. 5708
D. 5707

Terms Introduced in this Chapter

Aggregate	A mineral material, such as sands, graved shells, slag, or broken stone or combinations thereof with which cement or bituminous material is mixed to form a mortar or concrete. Fine aggregate is material that will pass a 1/4-inch screen. Coarse aggregate is material that will not pass a 1/4-inch screen.
Anisotropic	Having properties that differ according to the direction of measurement. Example: The crystal has an anisotropic structure, as it is stronger along its length than laterally.
Batholiths	A large emplacement of igneous intrusive rock that forms from cooled magma deep in the earth's crust
Cleavage	The capacity of a rock to split along certain parallel surfaces more easily than along others.
Feldspar	A general name for a group of abundant rock-forming minerals, the names and compositions of which are as follows: orthoclase, microcline, anorthoclase, plagioclase, oilgoclase, andesine, labradorite, bytownite, cesian, and hyalophane. The name is often combined with the names of those rocks that contain it, such as feldspar-porphyry or feldspar-basalt. The term feldspar applies not merely to one, but to all members of a group of minerals composed of aluminum silicates carrying principally sodium, calcium, or potassium. Feldspars are light in color (pink, green, white, and gray), have a glassy or satiny luster, and have a good cleavage in two directions, almost at right angles to each other. Feldspars cannot be scratched with a knife. Most feldspars occur in igneous rocks. Feldspar pebbles may be distinguished from quartz pebbles by the good cleavage.
Mica	The name of a group of several minerals that are unusual because they split into thin, flat, flexible, or elastic sheets. This type of splitting is the result of having one perfect cleavage. Mica is composed of aluminum silicates of many elements. Muscovite, or common white mica, is transparent and colorless. It can be seen as tiny, flat shining flakes in sandstones, siltstones, and shales and as small crystals in boulders of metamorphic and igneous rocks. Biotite (black mica) may be seen in some tertiary and quaternary sands. The color of biotite is caused by iron. Phlogopite mica is yellowish brown, has a copper-like luster on the cleavage surface, and often is mistaken for flakes of gold.

Quartz

The most common of all minerals, is composed of silicon and oxygen (SiO_2) and is found in many different varieties. When pure, it is colorless, but it also assumes various shades of yellow, pink, purple, brown, green, blue, or gray. One of the hardest of minerals, it will easily scratch window glass. It has no good cleavage and has a glassy to greasy luster. There are two main types of quartz: the coarse lycrystalline and the fine or cryptocrystalline forms. The crystals of the first type are six-sided prisms with pyramids capping one or both ends. Well-formed, colorless quartz crystals of this type are found in geodes and as linings on the inside of some fossils. Quartz crystals with a bluish cast are found in some granites. Nearly all sands and sandstones are composed of tiny worn particles of crystalline quartz. The second main type of quartz is called cryptocrystalline because the crystals are so small that they cannot be seen without a microscope. One of the best-known varieties in this group is flint or chert. Chert is dull gray, brown, or black. It breaks with a shell-like fracture, and the edges of the broken pieces are sharp. Chalcedony is a cryptocrystalline quartz with a waxy luster that forms banded layers or globular masses. Agate is a many-colored form of Chalcedony that has been deposited in cavities or veins.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

NCF Welding Materials Handbook, NAVFAC P-433, Naval Facilities Engineering Command, Alexandria, VA, 1991.

Quarry Operations 1, U.S. Army Subcourse EN5463, U.S. Army Engineer School, Fort Belvoir, VA, 1989.

Quarry Operations Volume 1, Navy Technical Reference Publications (NTRP) 4-04.2.12, Department of the Army Headquarters, Washington, DC.

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