HANDOUT

Rock Blasting Technique - I

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Rock Drilling Method

Lesson 5

Rock Drilling

- Rock drilling, in the field of blasting, is the first operation carried out and its purpose is to Open holes, with the adequate geometry and distribution within the rock masses, where the explosive charges will be placed along with their initiating devices.

The first Pit Viper 351 was launched in 2000 and used at the Morenci copper mine in Arizona.

The Pit Viper 235 was launched at MINExpo 2008.

The new Pit Viper 311.

The systems of rock drilling that have been developed and classified according to their order of present day applicability are:

- - ***Mechanical:*** Percussion, rotary, rotary-percussion.
- - ***Themzal:*** Flame, plasma, hot fluid, Freezing.
- - ***Hydraulic:*** Jet, erosion, cavitation.
- - ***Sonic:*** High frequency vibration.
- - ***Chemical:*** microblast, dissolution.
- - ***Electrical:*** Electric arc, magnetic induction.
- - ***Seismic:*** Laser ray.
- - ***Nuclear:*** Fusion, fission.

Types of Drilling Operations Used in Rock Breakage

- ***Manual drilling.*** This is carried out with light equipment that is hand held by the drillers. It is used in small operations where, due to the size, other machinery cannot be used or its cost is not justified.
- ***Mechanized drilling.*** The drilling equipment is mounted upon rigs with which the Operator can control all drilling Parameters from a comfortable position. These structures or chasis can themselves be mounted on wheels or tracks and either be self-propelled or towable.

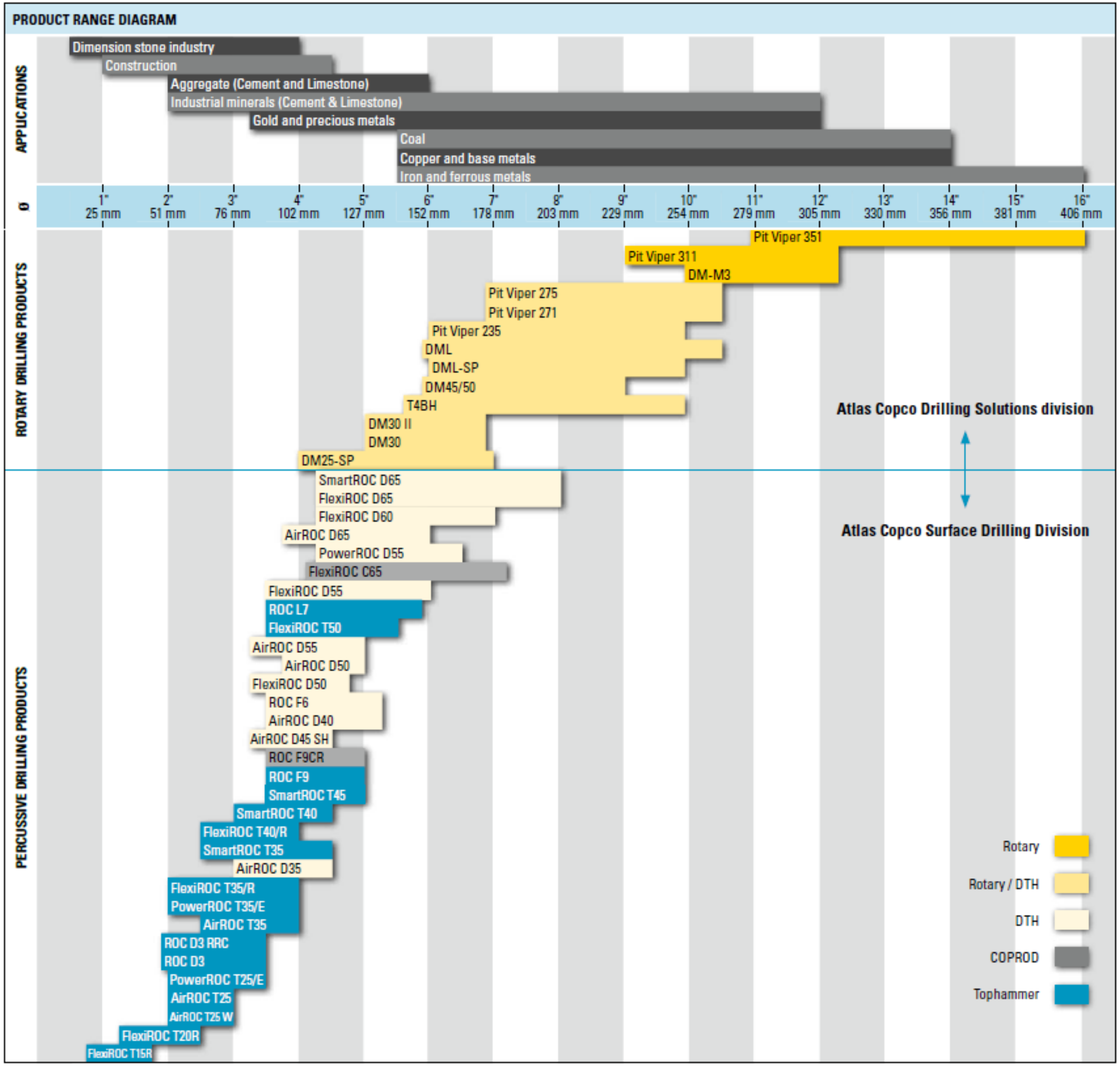
The types of work, in surface as well as in underground operations, can be classified in the followings groups:

- ***Bench drilling.*** This is the best method for rock blasting as a free face is available for the projection of material and it allows work to be systemized. It is used in surface projects as well as in underground operations, usually with vertical blastholes, although horizontal holes can be drilled on occasion.
- ***Drilling fordrifting and tunnelling.*** An initial cavity or cut must be opened towards which the rest of the fragmented rock from the other charges is directed. Blasthole drilling can be carried out with hand held drills, but the trend is towards total mechanization, using jumbos with one or various booms.

- ***Production drilling.*** This term is used in mining operations, fundamentally underground, to describe the labors of ore extraction. The equipment and methods used vary with the exploitation systems, having the common factor of little available space in the drifts for blasthole drilling.
- ***Drilling for raises.*** In many underground and civil engineering projects it is necessary to Open raises. Although there is a tendency to apply the Raise Boring method, still today the long blasthole method is used as well as other special drilling systems combined with blasting.
- ***Drilling rocks with overburden.*** The drilling of rock masses which are covered with beds of unconsolidated materials calls for special drilling methods with casing. This method is also used in underwater operations.
- ***Rock supports.*** In many underground operations and sometimes in surface ones it is necessary to support the rocks by means of bolting or cementing cables, in which drilling is the first phase.

Fields of Application for The Different Drilling Methods

- ***Rotary-percussive methods.*** These are the most frequently used in all types of rocks, the top hammer as well as the down-the-hole hammer.
- ***Rotary methods.*** These are subdivided into two groups, depending upon if the penetration is carried out by crushing, with tricones or by cut with drag bits. The first system is used in medium to hard rocks, and the second in soft rocks.



Rotary drilling with tricone bits is the most cost efficient method for large hole diameters.

Rock Properties That Affect Drilling

The principal physical rock properties that have influence upon penetration mechanisms and, as a consequence, on choice of the drilling method are:

1. Hardness,
2. Strength,
3. Elasticity,
4. Plasticity,
5. Abrasiveness,
6. Texture,
7. Structure,
8. Characteristics of breakage.

1. Hardness

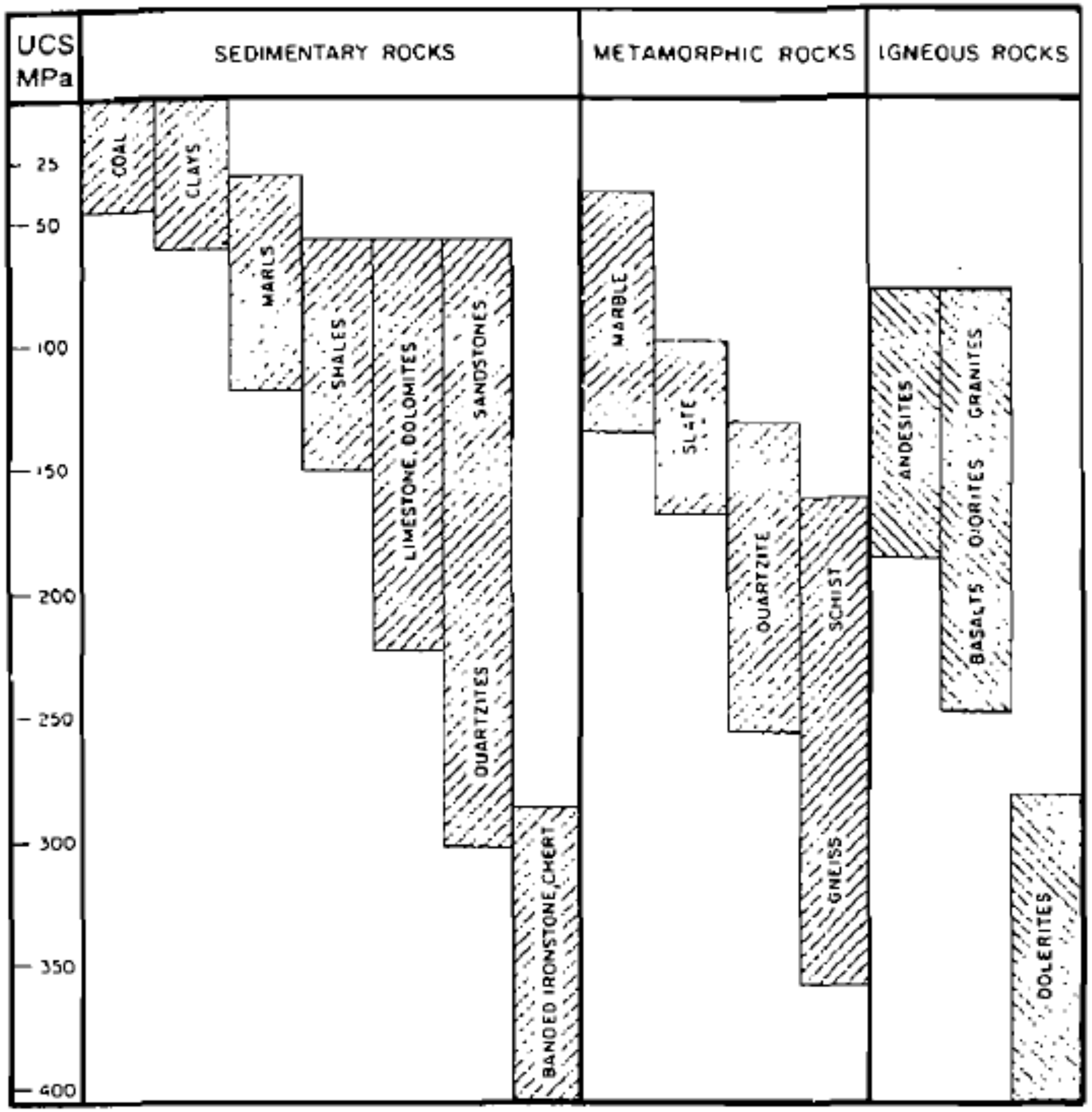
- Hardness is considered to be the resistance of a surface layer to be penetrated by another body of harder consistency.
- In rock, it is a function of the hardness and composition of its mineral grains, the porosity, degree of humidity, etc.
- The hardness of rocks is the principal type of resistance that must be overcome during drilling, because once the bit has penetrated, the rest of the operation is easier.

Classification	Mohs' scale of hardness	Compressive strength (MPa)
Very hard	+7	+200
Hard	6-7	120-200
Medium hard	4.5-6	60-120
Medium soft	3-4.5	30-60
Soft	2-3	10-30
Very soft	1-2	–10

2. Strength

Mechanical strength of a rock is the property of opposing destruction by an external force, either static or dynamic.

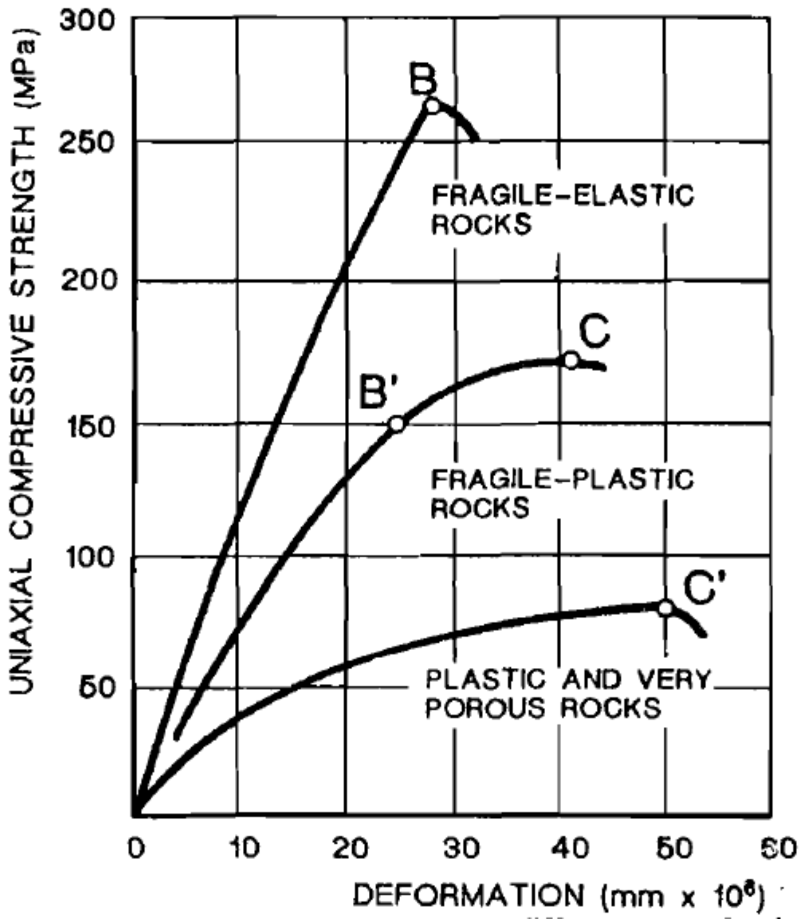
The rocks give maximum resistance to compression, normally, as the tensile strength is not more than 10 or 15% of the compressive strength. This is due to the fragility of rocks, to the large quantity of local defects and irregularities that exist and to the small cohesion between the particles of which they are constituted.



NOTE UCS = Uniaxial Compressive Strength

3. Elasticity

- The majority of rock minerals have an elastic-fragile behavior, which obeys the Law of Hooke, and are destroyed when the strains exceed the limit of elasticity.
- Depending upon the nature of deformation, as function of the Stresses produced by static charges, three groups of rocks are taken into consideration: 1) The elastic-fragile or those which obey the Law of Hooke, 2) The plastic-fragile, that have plastic deformation before destruction, 3) The highly-plastic or very porous, in which the elastic deformation is insignificant.



4. Plasticity

- The plasticity depends upon the mineral composition of the rocks and diminishes with an increase in quartz content, feldspar and other hard minerals. The humid clays and some homogeneous rocks have plastic properties.
- The plasticity of the stony rocks (granites, schistoses, crystallines and sandstones) becomes noticeable especially at high temperatures.

5. Abrasiveness

- Abrasiveness is the capacity of the rocks to wear away the contact surface of another body that is harder, in the rubbing or abrasive process during movement.
- The factors that enhance abrasive capacities of rocks are the following:
  a. The hardness of the grains of the rock. The rocks that contain quartz grains are highly abrasive.
  b. The shape of the grains. Those that are angular are more abrasive than the round ones.
  c. The size of the grains.
  d. The porosity of the rock. It gives rough contact surfaces with local stress concentrations.
  e. The heterogeneity. Polymineral rocks, although these are equally hard, are more abrasive because they leave rough surfaces with hard grains as, for exarnple, quartz grains in a granite.
- This property has great influence upon the life of drill steel and bits.

The mean amounts of quartz for different types of rock are indicated

Rock type	Quartz content %
Amphibolite	0-5
Anorthosite	0
Diabase	0-5
Diorite	10-20
Gabbro	0
Gneiss	15-50
Granite	20-35
Greywacke	10-25
Limestone	0-5
Marble	0
Mica gneiss	0-30
Mica schist	15-35
Norite	0
Pegmatite	15-30
Phyllite	10-25
Quartzite	60-100
Sandstone	25-90
Shale	0-20
Slate	10-35
Taconite	0-10

6. Texture

- **The texture of a rock refers to the structure of the grains of minerals that constitute it. The size of the grains are an indication, as well as their shape, porosity etc. All these aspects have significative influence on drilling performance.**
- **When the grains have a lenticular shape, as in a schist, drilling is more difficult than when they are round, as in a sandstone.**
- **The type of material that makes up the rock matrix and unites the mineral grains also has an important influence.**

7. Structure

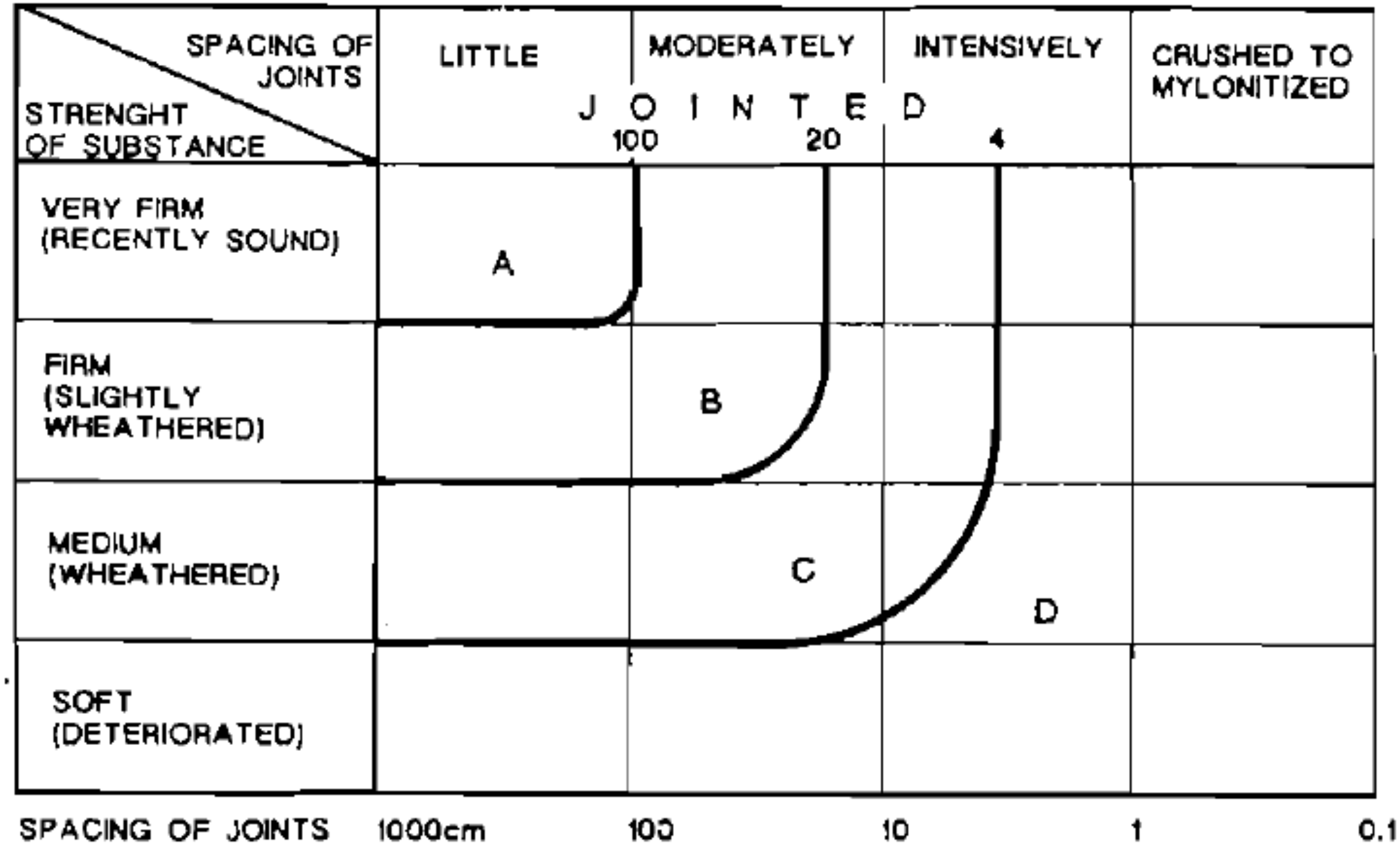
- The stmctural properties of the rock masses, such as schistosity, bedding planes, joints, diabases and faults, as well as their dip and strike affect the allignment of the blastholes, the drilling performance and the stability of the blasthole walls

Properties of rock types according to origin-based classification

Rock type		Specific gravity (m^3)	Grain size (mm)	Swell factor	Compressive strength (MPa*)
Intru-sive INGENOUS	Diorite	2.65-2.85	1.5-3	1.5	170-300
	Gabbro	2.85-3.2	2	1.6	260-350
	Granite	2.7	0.1-2	1.6	200-350
Extrusive	Andesite	2.7	0.1	1.6	300-400
	Basalt	2.8	0.1	1.5	250-400
	Rhyolite	2.7	0.1	1.5	120
	Trachyte	2.7	0.1	1.5	330
SEDIMEN-TARY	Congomerate	2.6	2	1.5	140
	Sandstone	2.5	0.1-1	1.5	160-255
	Shale	2.7	1	1.35	70
	Dolomite	2.7	1-2	1.6	150
	Limestone	2.6	1-2	1.55	120
	Limerock	1.5-2.6	1-2	1-1.6	30-100
METAMOR-PHIC	Gneiss	2.7	2	1.5	140-300
	Marble	2.7	0.1-2	1.6	100-200
	Quartzite	2.7	0.1-1	1.55	160-220
	Schist	2.7	0.1-1	1.6	60-400
	Serpentine	2.6	–	1.4	30-150
	Slate	2.7	0.1	1.5	150

1 MPa = 1 MN/m^2 = 10 kg/cm^2 = 142.2 psi

Classification of the rock masses

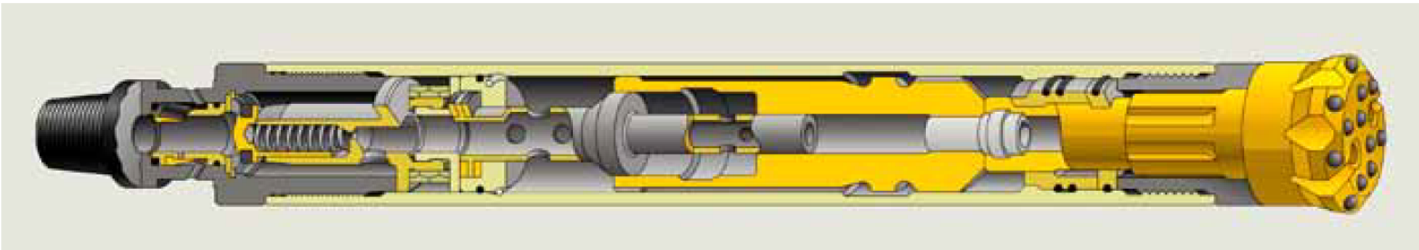


A) STRONG ROCK
B) MEDIUM ROCK
C) WEAK ROCK
D) VERY WEAK ROCK

Rotary Percussive Drilling

Top hammer. In these drills, two of the basic actions, rotation and percussion, are produced outside the blasthole, and are transmitted by the shank adaptor and the drill steel to the dnll bit. The hamrners can be driven hydraulically or pneumatically.

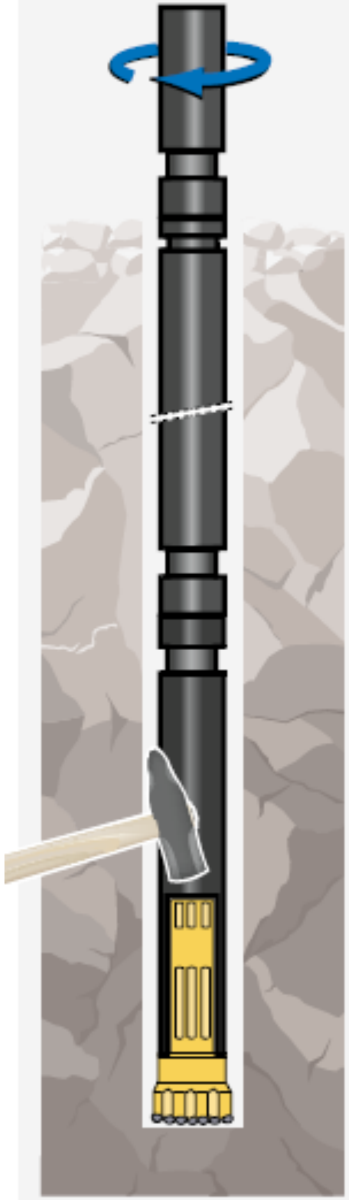
The first drill made by Atlas "pneumatic rock drill No. 16" had a weight of 280 kg (617 lb) and was heavy and difficult to handle - at least two men were needed to move it.



Secoroc COP64 Gold downhole hammer.

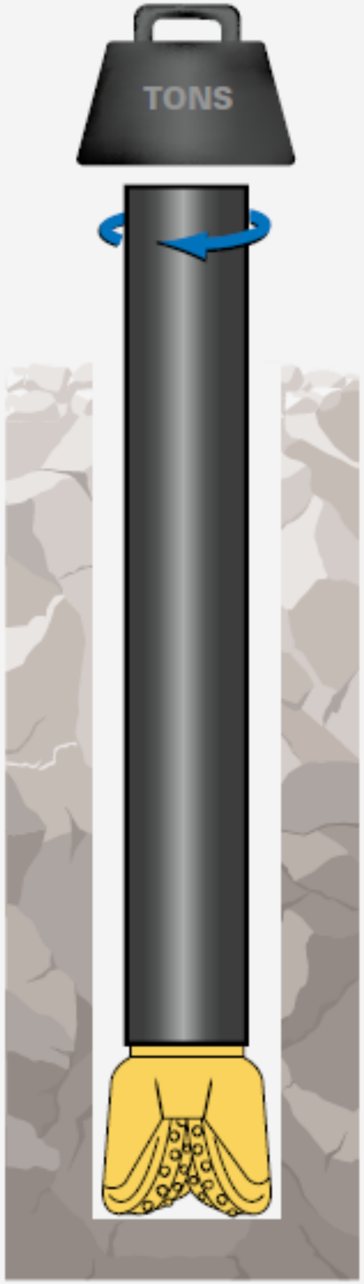
Down the hole hammer. The percussion is delivered directly to the drill bit, whereas the rotation is performed outside the hole. The piston is driven pneumatically, while the rotation can be hydraulic or pneumatic.

Down-The-Hole method



Principle:
The hammer is situated down the hole in direct contact with the drill bit. The hammer piston strikes the drill bit, resulting in an efficient transmission of the impact energy and insignificant power losses with the hole depth. The method is widely used for drilling long holes, not only for blasting, but also for water wells, shallow gas and oil wells, and for geo-thermal wells. In mining it is also developed for sampling using the reverse circulation technique (RC drilling).

Rotary drilling method



Principle:
Rotation is provided by a hydraulic or electric motor driven gearbox, called a rotary head, that moves up and down the tower via a feed system, generating the pulldown required to give sufficient weight on the bit. Flushing of drill cuttings between the wall of the hole and the drill rods is normally done with compressed air.

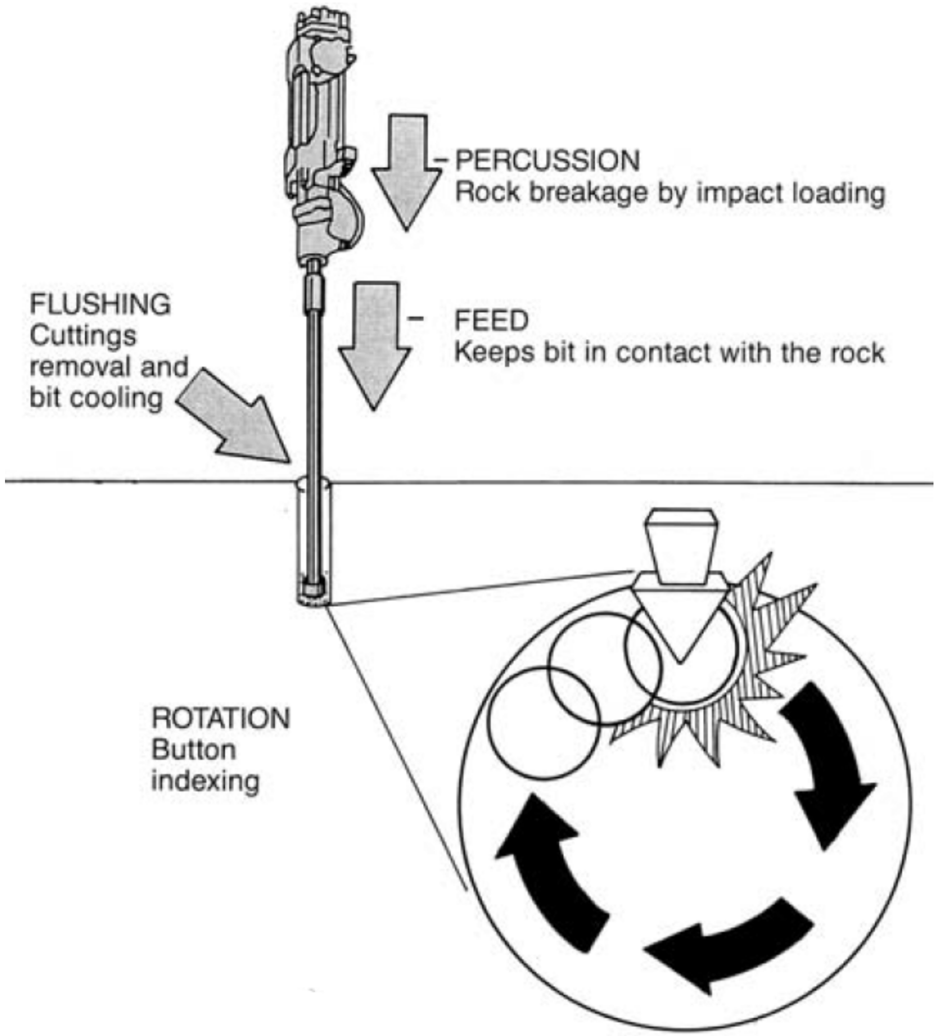
The main advantages of rotary percussive drilling are:

- It can be applied to any type of rock, from soft to hard.
- Wide range of diameters;
- Versatile equipment, it adapts well to different operations and is very Mobile;
- Only requires one Operator;
- Easy, quick maintenance, and
- The capital cost is not high

Rotary percussion drilling is based upon the combination of the following:

- ***Percussion.*** The impacts produced by repeated blows of the piston generate shock waves that are transmitted to the bit through the drill steel (in top harnmer) or directly upon it (down the hole).
- ***Rotation.*** With this movement, the bit is turned so that the impacts are produced on the rock in different positions.
- ***Feed, or thrust load.*** In order to maintain the contact of the dnll bit with the rock, a thrust load or feed force is applied to the drill siring.
- ***Flushing.*** Flushing removes the drill cuttings from the blasthole.

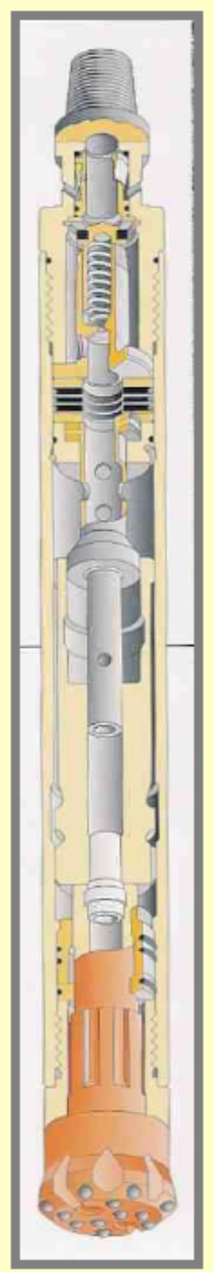
- Percussion output power in percussive drilling is produced by the rock drill's impact energy and frequency.
- Pneumatic drilling has a typical impact frequency of between 1,600 - 3,400 hits per minute; hydraulic drilling, 2,000 - 4,500 hits per minute.



Percussion Drill Rigs

Percussion drill can be air – or hydraulic – operated and are generally limited to hole diameter of 5 inches or less.

Percussion drill use button or cross (X-type drill bits in which the cutting tool is made of hard tungsten carbide. Wing angle and button configurations are designed to accommodate soft to hard formations and come in a variety of configurations.



- DTH hammers, with the piston in the hole, tend to drill straighter holes at greater depth as compared to OTH drifters. The air-driven piston hammer causes the bit to rapidly impact the rock while the bit is slowly turned. DTH hammers are efficient in hard-rock types. With the hammer in the hole, drill-pipe vibrations are eliminated

Steel tooth bit selection

- **Soft formation bits,** The Type S, regular circulation steel tooth bit is designed for optimum performance in formations of low compressive strength, such as soft sand rock, calcite, shale and clay. These formations quite often contain abrasive materials such as sharp sand and may be interspersed with layers of medium and hard formations.
- **Medium formation bits,** The Type M and regular circulation steel tooth rack bits are designed for abrasive and non-abrasive medium formations. Note that this design differs from the “softer” types principally in the progressive strengthening of the teeth and change in bit geometry to provide more chipping-crushing action. These bits have more closely spaced teeth with a large included angle and more gage surface to resist the wear in harder and more abrasive formations.
- **Hard formation bits,** Type H, regular circulation steel tooth rock bits are designed to drill hard formations which contain amounts of abrasive materials.

S Series

M Series

H Series

Steel tooth Tricone rock bit type vs. rock hardness

Rock UCS (PSI)	Steeltooth Tricone bit series			Rock Type
0				
	S series			Unconsolidated Sands
2,000				Limestone, Siltstone
				Clay Stone, Mudstone
4,000				
		M series		Marl, Chalky Limestone
6,000				
				Soft Shales
8,000				
				Consolidated Sandstones
			H series	
10,000				
				Soft Marble, Dolomite
12,000				
				Tuff, Soft Schist
14,000				

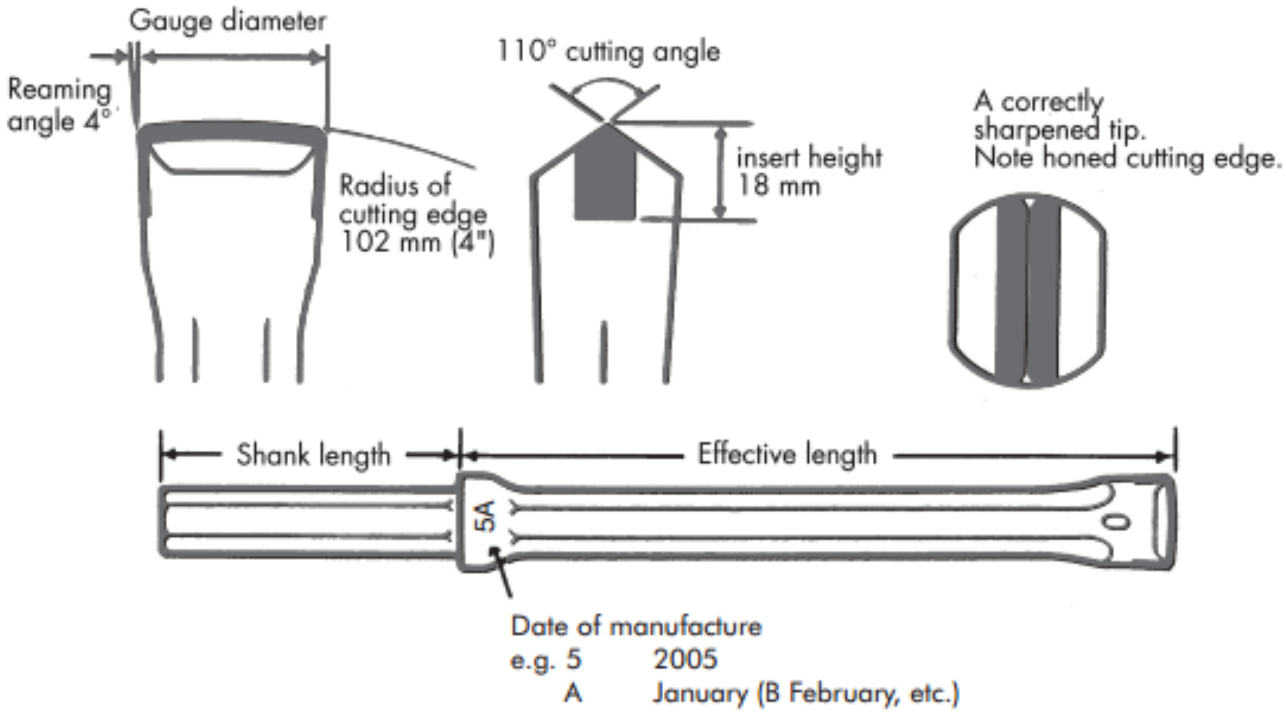
Rock UCS hardness (Unconfined Compressive Strength) is only one factor contributing to the "drillability" of any rock. Other factors influencing drillability are fracture toughness, shear strength, Young's modulus of elasticity, Poisson's ratio of stress vs. strain & internal angle of friction. Any particular bit may be used in harder or softer rock than this chart indicates.

When to change a bit

- At the end of a Tricone bits life the cutting structure becomes ineffective either through breakage or wear, resulting in reduced penetration rate.

Rock Drilling Equipment

- Integral Drill Steel



BITS

CROSS

7° x 22

	mm	in	Part no.
D =	32	1¼"	4202-0332
	35	1⅜"	4202-0335
	38	1½"	4202-0338
	41	1⅝"	4202-0341
	45	1¾"	4202-0345
	48	1⅞"	4202-0348
	51	2"	4202-0351

BUTTON

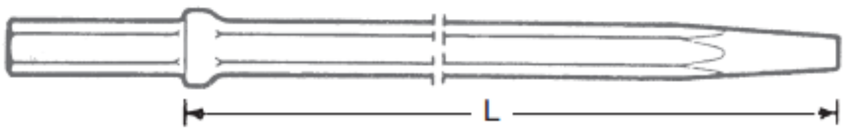
	mm	in	Part no.
D =	32	1¼"	4702-0932
	35	1⅜"	4702-0935
	38	1½"	4702-0938
	41	1⅝"	4702-0941
	45	1¾"	4702-0945

DRILL RODS

22 mm (⅞") HEXAGON BODY

82.5 x 22 mm (3¼" x ⅞") HEXAGON SHANK

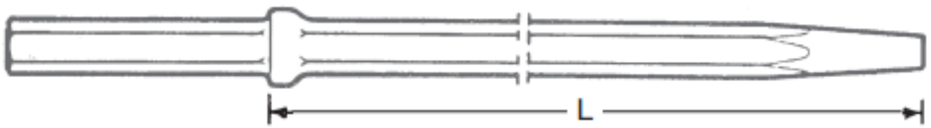
7° x 22



	mm	ft	Part no.
L =	600	2'	5033-0206
	915	3'	5033-0209
	1220	4'	5033-0212
	1830	6'	5033-0218
	2435	8'	5033-0224
	3050	10'	5033-0231

108 x 22 mm (4¼" x ⅞") HEXAGON SHANK

7° x 22

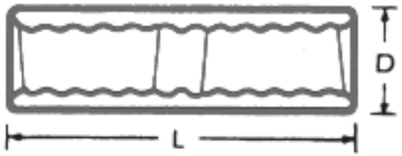


	mm	ft	Part no.
L =	600	2'	5034-0206
	915	3'	5034-0209
	1220	4'	5034-0212
	1830	6'	5034-0218
	2145	7'	5034-0221
	2435	8'	5034-0224
	3050	10'	5034-0231

COUPLING

SEMI-BRIDGE

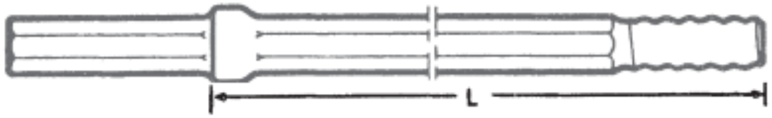
R25



D =	35	1¾"	5525-0001
L =	159	6¼"	

SHANKED RODS

108 x 22 mm (4¼" x ⅞") HEXAGON SHANK



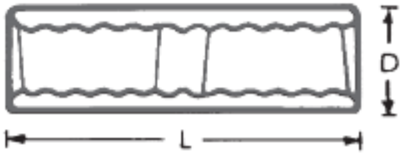
	EFFECTIVE LENGTH MM	FT/INS	CATALOGUE NUMBER
L =	610	2'	5425-2203-06
	1220	4'	5425-2203-12
	1830	6'	5425-2203-18
	2440	8'	5425-2203-24

108 x 25 mm (4¼" x 1") HEXAGON SHANK

L =	610	2'	5425-2503-06
	1220	4'	5425-2503-12
	1830	6'	5425-2503-18
	2440	8'	5425-2503-24
	3050	10'	5425-2503-31

COUPLING

SEMI-BRIDGE



D = 35	1⅜"	**5525-0001**
L = 159	6¼"	

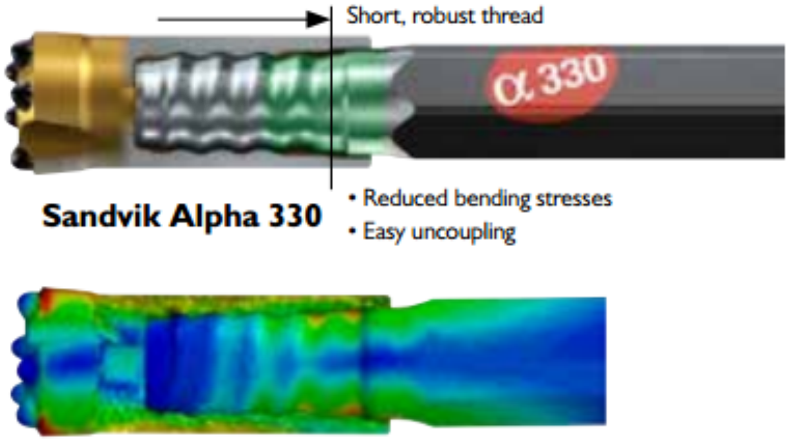
EXTENSION RODS

25 mm (1") HEXAGON

FLUSHING HOLE SIZE 9 mm (11/32")

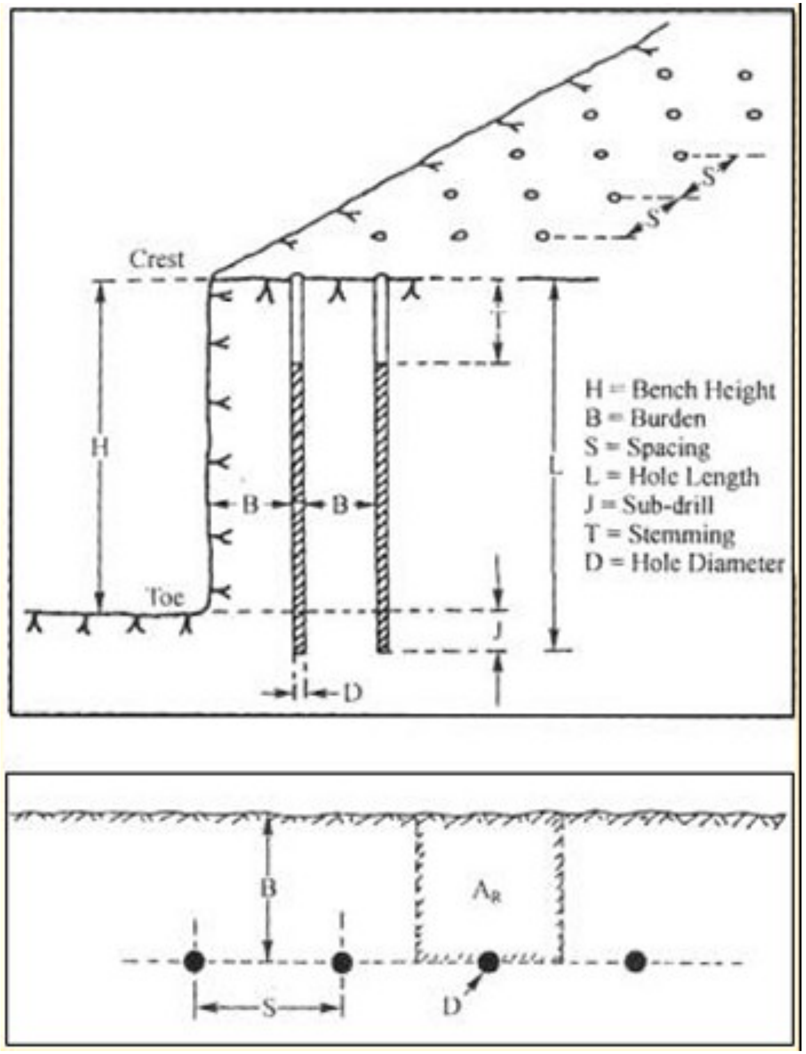
L = 610	2'	**5725-2506**
915	3'	**5725-2509**
1220	4'	**5725-2512**
1525	5'	**5725-2515**
1830	6'	**5725-2518**
3050	10'	**5725-2531**
3660	12'	**5725-2536**

Rock Blasting Technique – Mining Engineering Department



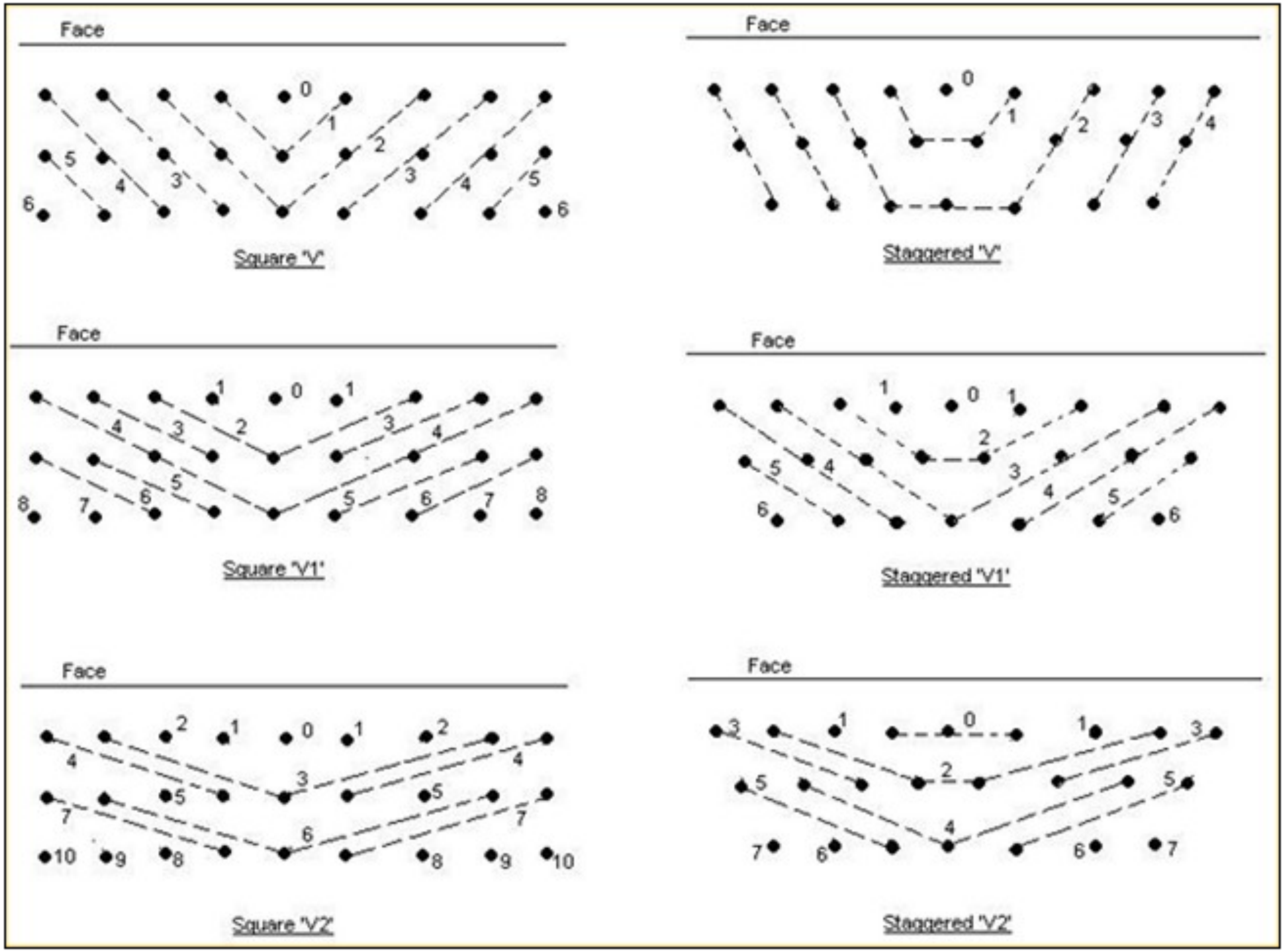
Advanced analysis have been used to simulate and locate critical bending stresses of various designs to arrive at an optimally dimensioned rod / bit connection.

Blasthole Patterns



Bench Blast Pattern in Quarry / Open Pit

Blastholes / Initiation patterns for shots fired to an open face



Square 'V'

Staggered 'V'

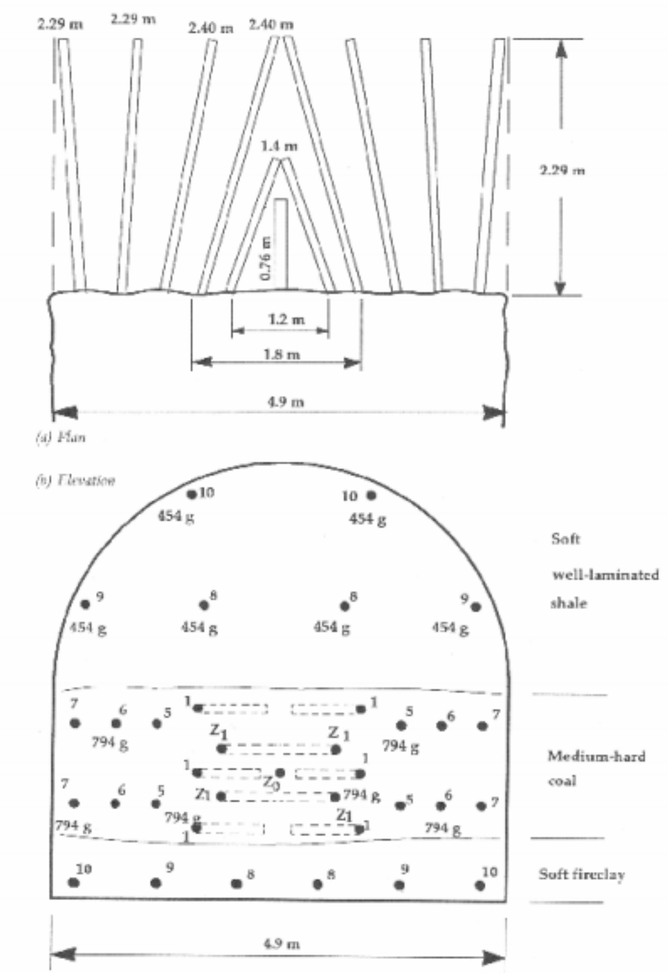
Square 'V1'

Staggered 'V1'

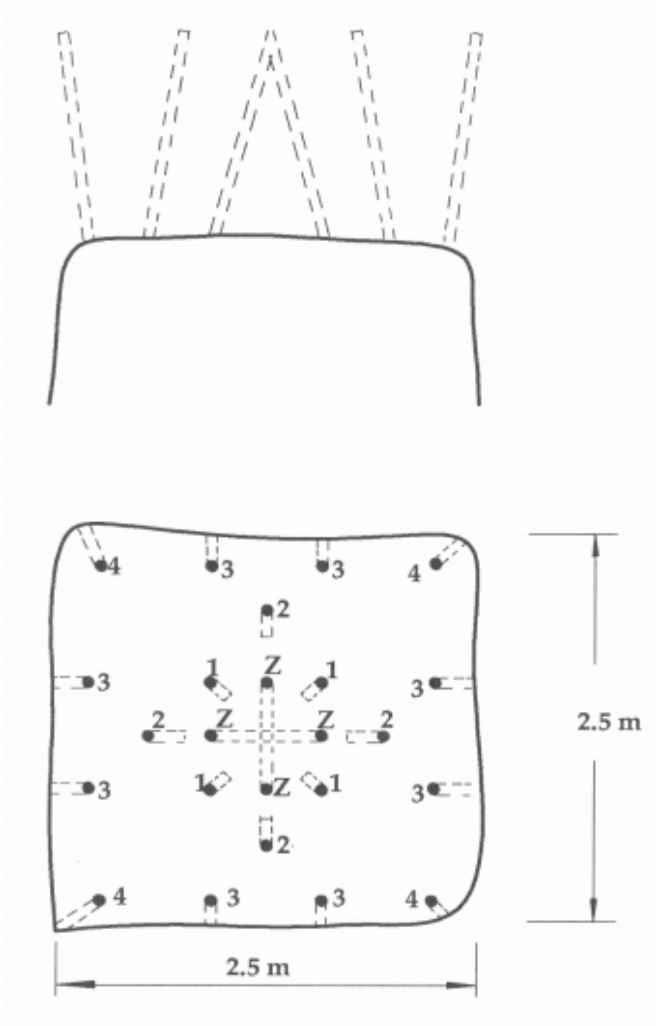
Square 'V2'

Staggered 'V2'

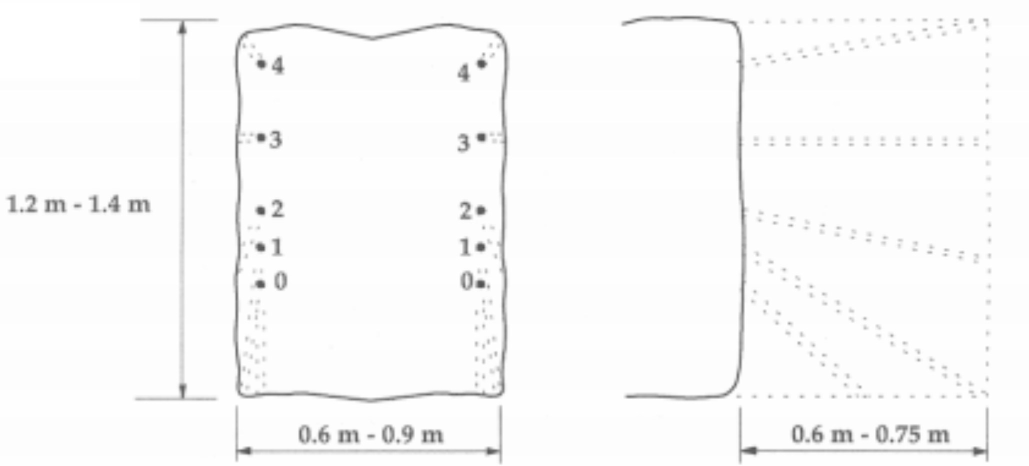
UNDERGROUND BLASTING



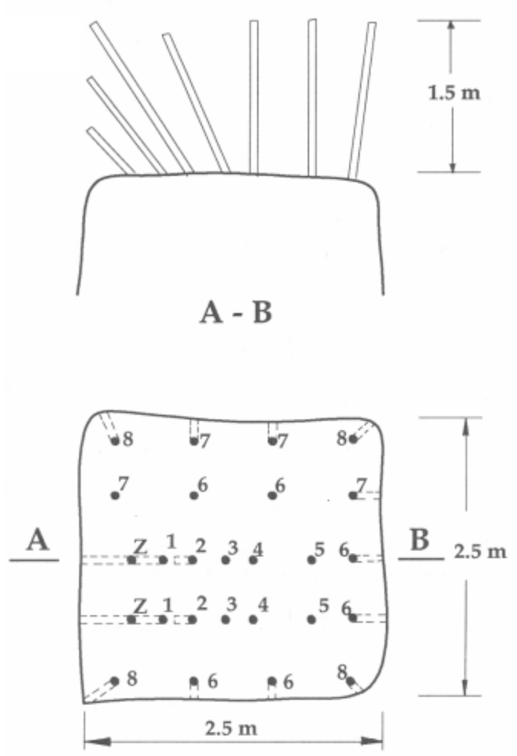
Wedge cut (after ICI)



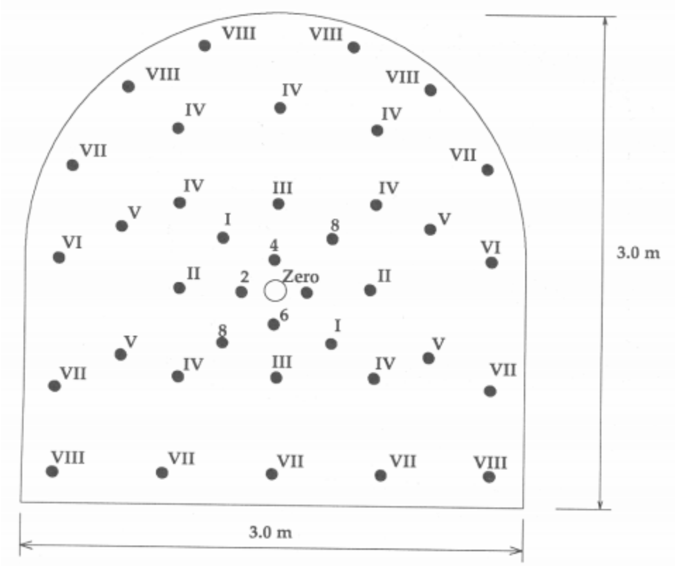
Pyramid or diamond cut (after ICI)



Drag cut



Fan cut



Arabic numerals: short delay periods
Roman numerals: half-second periods

Burn cut (after ICI)