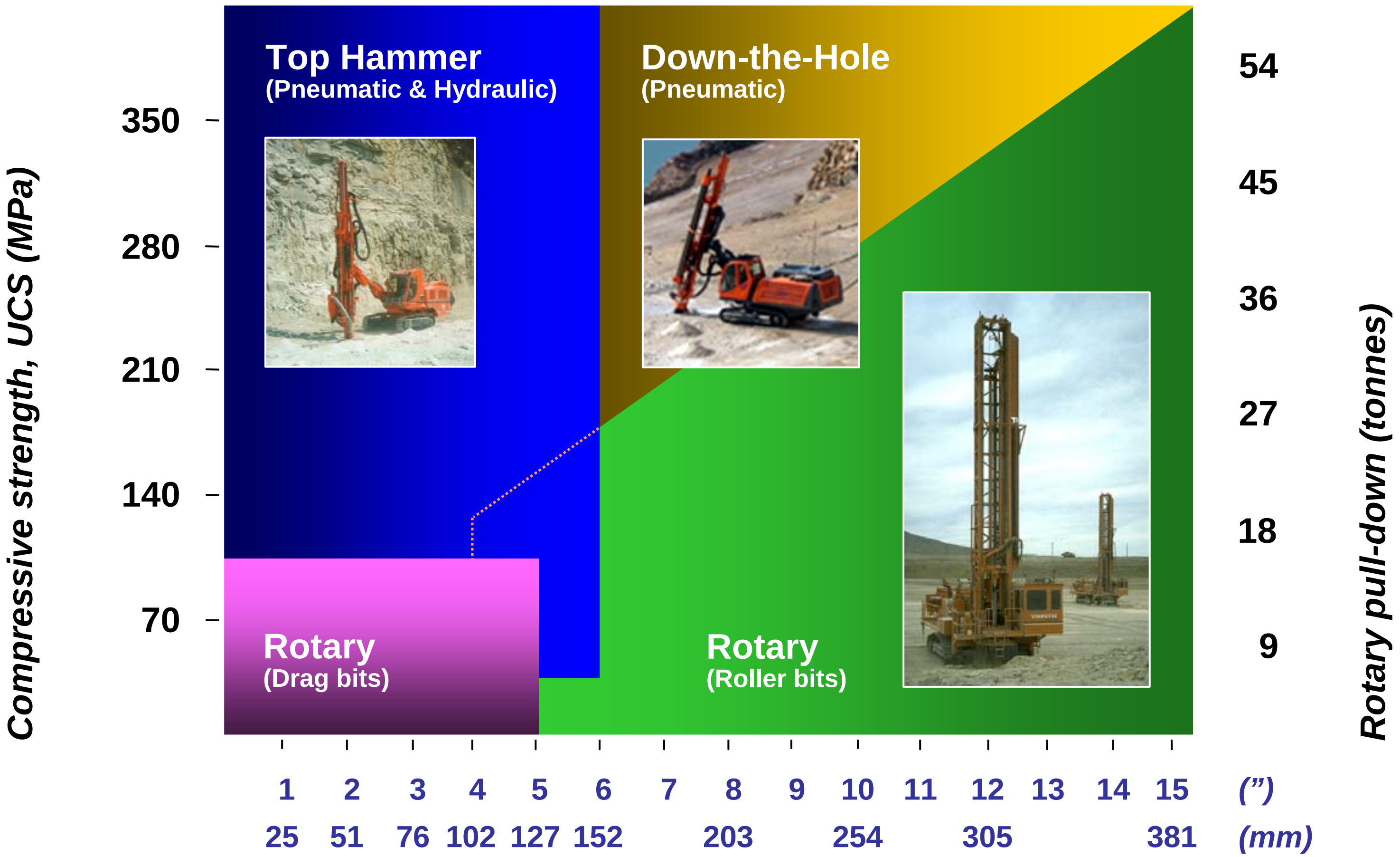
Drilling Management

Drilling Management

Equipment type selection



Drilling Management

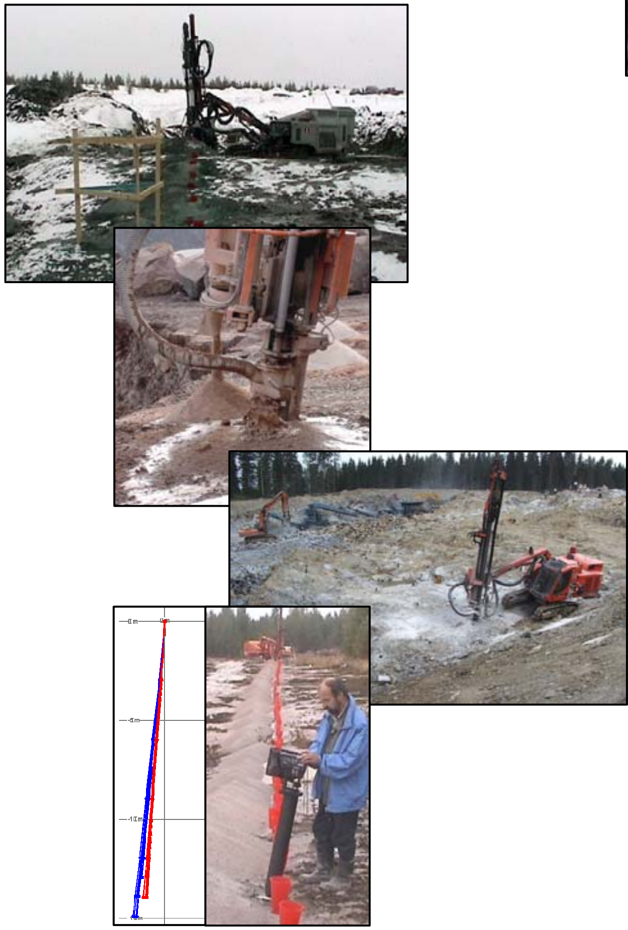
Drilling operational items and objectives

- *drill patterns as per blasting supervisors specs*
- *site preparation and procedures for:*
  - *removal or drilling through prior sub-drill zone*
  - *marking of collaring positions*
  - *drill-hole alignment*
  - *minimizing drill-hole deflection*
  - *drill-hole depth control*
- *selection of percussion power level and other drilling parameters*
- *selection of drill steel, bit regrinding procedures and consumption followup*
- *scheduled equipment service and maintenance*
- *production reporting and work documentation for Quality Assurance*
  - *shift, weekly reports, …*
  - *drilling deviation reports*
- *for contractors - rapid rig relocation to new jobsites*

Prior bench level sub-drill zone removed

Drilling Management

Site preparation



Drill-hole positioning, alignment and levelling

Drilling through overburden with foam flushing

Drilling after removing overburden

Drill-hole monitoring & documentation

Water tank for special drilling conditions

Bit regrinding

Field service

Refueling

Utility wagon

Drilling Management

Good drilling practices

Setup & Collaring

- lock oscillation cylinders, use rear jack (not lift rig), firmly push feed-pin into ground and keep retaining centralizer closed while drilling
- if the marked collaring point is in a bad spot (sloping surface, sinkholes, etc.) - it is then better to collar on the side and adjust feed alignment to correspond to the targeted drill-hole bottom
- have a plentiful supply and use shothole plugs to avoid rocks falling into shotholes

Drilling

- avoid drilling with hot couplings - adjust feed pressure or bit RPMs or change bit model
- change drill rods before threads are totally worn out - use thread wear gauges
- ensure that sufficient flushing is available - especially when drilling with large bits
- check that drilling is carried out with optimum bit RPMs with regard to button wear rates
- if the drill string bends while drilling - align feed to drill string so as to reduce the adverse effects of excessive drill string bending on hole straightness
- avoid excessive rattling against the hole-bottom and retaining centralizer when loosening threads (typically only 10 - 20 seconds)

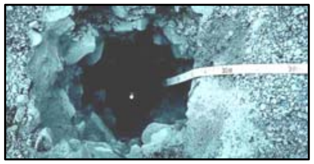
Drill steel selection

- select bit type according to rock mass conditions e.g. retrac in broken ground, big front flushing hole(s) in weathered rock/mud seams, spherical buttons in hard and abrasive rock types, etc.
- select bits, drill rods/guide tubes according to service life or hole straightness requirements

Bit regrinding

- avoid excessive loss of bit diameter when regrinding - especially when using hand held grinders
- in non-abrasive rocks such as limestone, dolomite, etc. it can be advantageous to adopt frequent “touch-up” regrinds at the rig in stead of traditional regrinding procedures to remove snakeskin on button wearflats and wearflat edges

Drill-hole deviation



- excessive drill-hole deviation reduces drill steel life - typically caused by bit deflection when drilling through shears and mud seams
- rod breakage is reduced when using rods with loose couplings when compared to MF rods
- lower a flashlight to check drill-hole deflection depth as a rough rating of hole straightness

Drilling Management

Drilling in difficult (rock mass) conditions

Prior sub-drill zone

- *stabilize drill-hole walls in the prior sub-drill zone with water added to the flushing air*
- *drill through the prior sub-drill zone with reduced percussion power and feed force. Adjust the flushing flow to a minimum so as to reduce return-air erosion around the collaring point*
- *if drill-hole walls tend to collapse - stabilise walls with additives such as Quik-Trol, EZ-Mud, ...*

Very jointed rock

- *use straight hole drill steel selection guidelines to minimise drill string deflection*
- *use retrac type bits and back-hammering to ease drill string extraction*
- *use power extractor if required to retrieve drill string*
- *adjust drilling parameter settings frequently to match drilling in varying geological conditions*

Soft or weathered rock

- *increase bit RPMs or use X-bits to increase bit resistance to indentation. This improves the percussion energy transfer efficiency ratio and reduces the feed force requirement - and reduces the problem of opening tight threads*

Mud seams and shears

- *use bits with big front flushing hole(s) to reduce the occurrence of bits getting stuck and the anti-jamming mechanism triggering in too often*
- *flushing control automatics recommended - it retracts the drill string when the flush flow is close to zero (adjustable set-point)*
- *do not retract the drill string too fast when drilling in mud so as to avoid the collapse of holes by this “vacuum” effect*
- *avoid high return-air velocities by reducing the flushing flow when drilling in water filled holes so as to avoid the added water erosion effect on drill-hole walls and the collaring point*

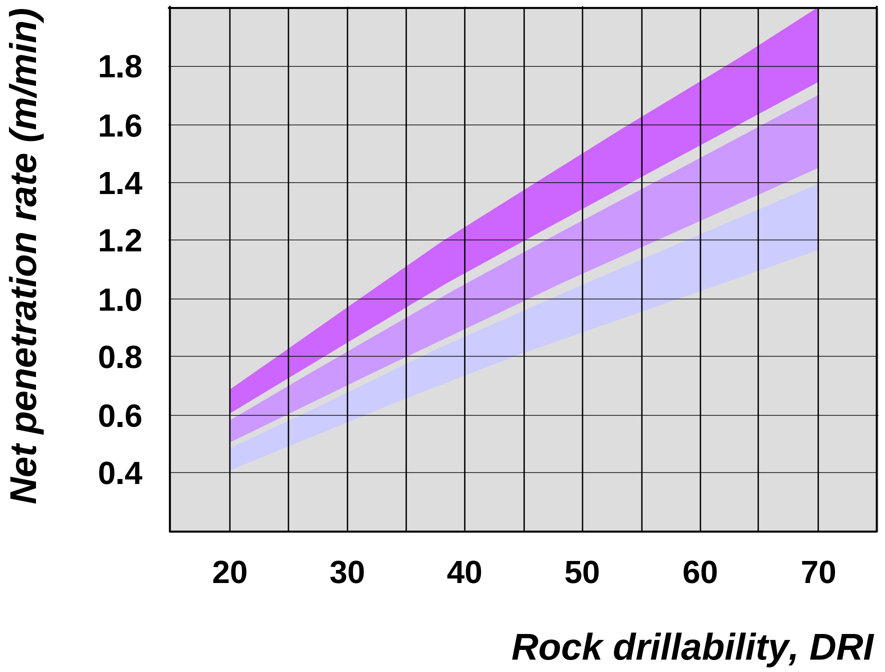
Dust prevention

- *use ZeroDust™ to avoid releasing dust into the air when the dust collector empties. ZeroDust™ also reduces the amount of airborne dust after blasting.*

Drilling Management

TH - predicting net penetration rates (m/min)

- *rock mass drillability, DRI*
- *percussion power level in rod(s)*
- *bit diameter*
  - *hole wall confinement of gauge buttons*
- *goodness of hole-bottom chipping*
  - *bit face design and insert types*
  - *drilling parameter settings (RPM, feed)*
- *flushing medium and return flow velocity*



HL510/HLX5T	**51 mm**	**2”**
HL600	**64 mm**	**2.5”**
HL710/800T	**76 mm**	**3”**
HL1500/1560T	**102 mm**	**4”**

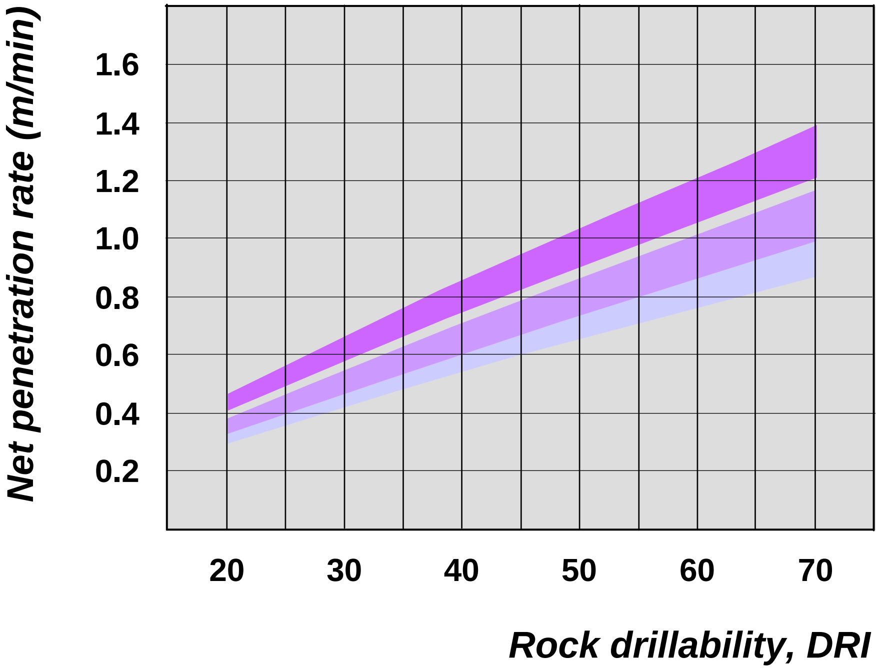
HL510/HLX5T	**64 mm**	**2.5”**
HL600	**76 mm**	**3”**
HL710/800T	**89 mm**	**3.5”**
HL1000	**89 mm**	**3.5”**
HL1500/1560T	**115 mm**	**4.5”**

HL510/HLX5T	**76 mm**	**3”**
HL600	**89 mm**	**3.5”**
HL710/800T	**102 mm**	**4”**
HL1000	**115 mm**	**4.5”**
HL1500/1560T	**127 mm**	**5”**

Drilling Management

DTH - predicting net penetration rates (m/min)

- *rock mass drillability, DRI*
- *percussion power of hammer*
- *bit diameter*
  - *hole wall confinement of gauge buttons*
- *goodness of hole-bottom chipping*
  - *bit face design and insert types*
  - *drilling parameter settings (RPM, feed)*
- *flushing and return flow velocity*



M50 / M55	**140 mm**	**5.5”**
M60 / M65	**165 mm**	**6.5”**

M30	**89 mm**	**3.5”**
M40	**115 mm**	**4.5”**
M60 / M65	**203 mm**	**8”**

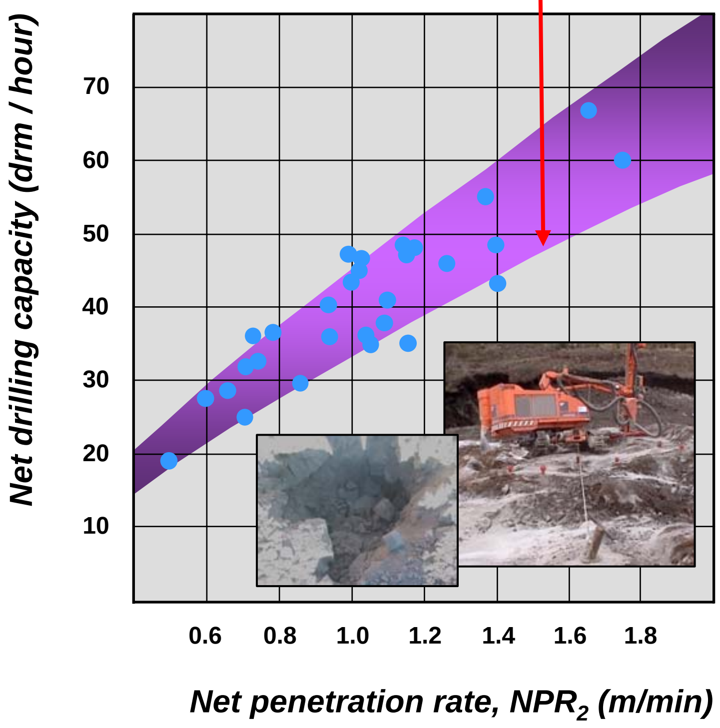
M85	**251 mm**	**9 7/8”**

Drilling Management

Gross drilling capacities (drm/shift)

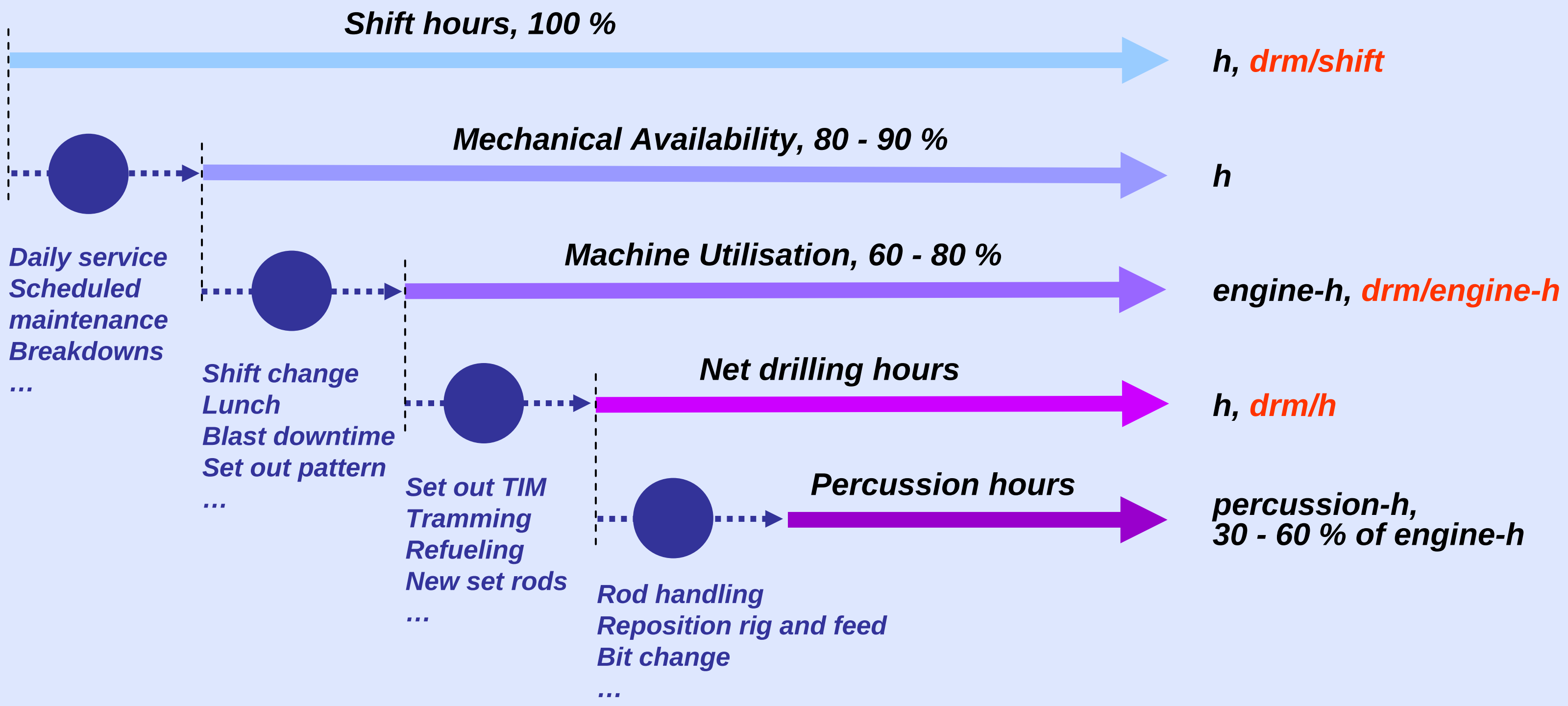
- *rig setup and feed alignment time per drill-hole*
- *collaring time through overburden or sub-drill zone*
- *drill-hole wall stabilisation time (if required)*
- *rod handling times (unit time and rod count)*
- *net penetration loss rate percentage i.e.*
  - *rods and couplings* *6.1 % per rod*
  - *MF rods* *3.6 % per rod*
  - *tubes* *2.6 % per tube*
- *effect of percussion power levels on:*
  - *net penetration rates*
  - *drill steel service life*
  - *drill-hole straightness*
- *rig tramming times between benches, refueling, etc.*
- *effect of operator work environment on effective work hours per shift*
- *rig availability, service availability, service and maintenance intervals*

Poor net drilling capacities for:
- **very broken rock**
- **terrain benches - winching**
- **very low or very high benches**
- **very poor collaring conditions**



Drilling Management

Typical breakdown of long term rig usage and capacities

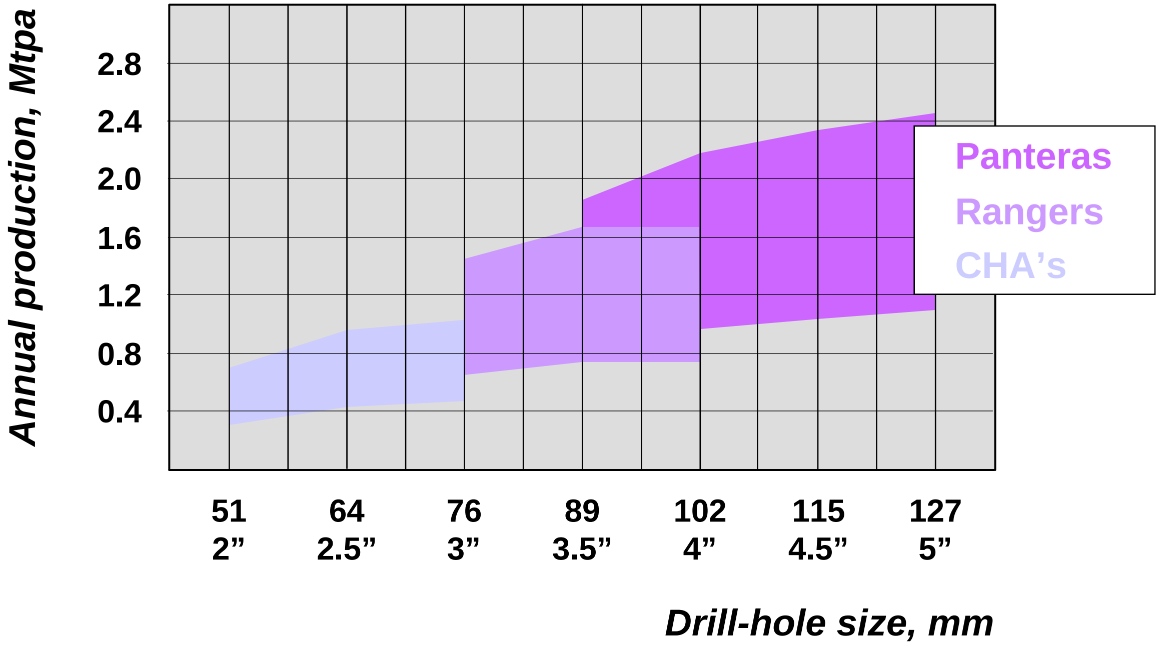


Gross drilling capacity = Shift hours x Net drilling capacity x Machine Utilisation %

Drilling Management

TH - annual drill rig production capacities

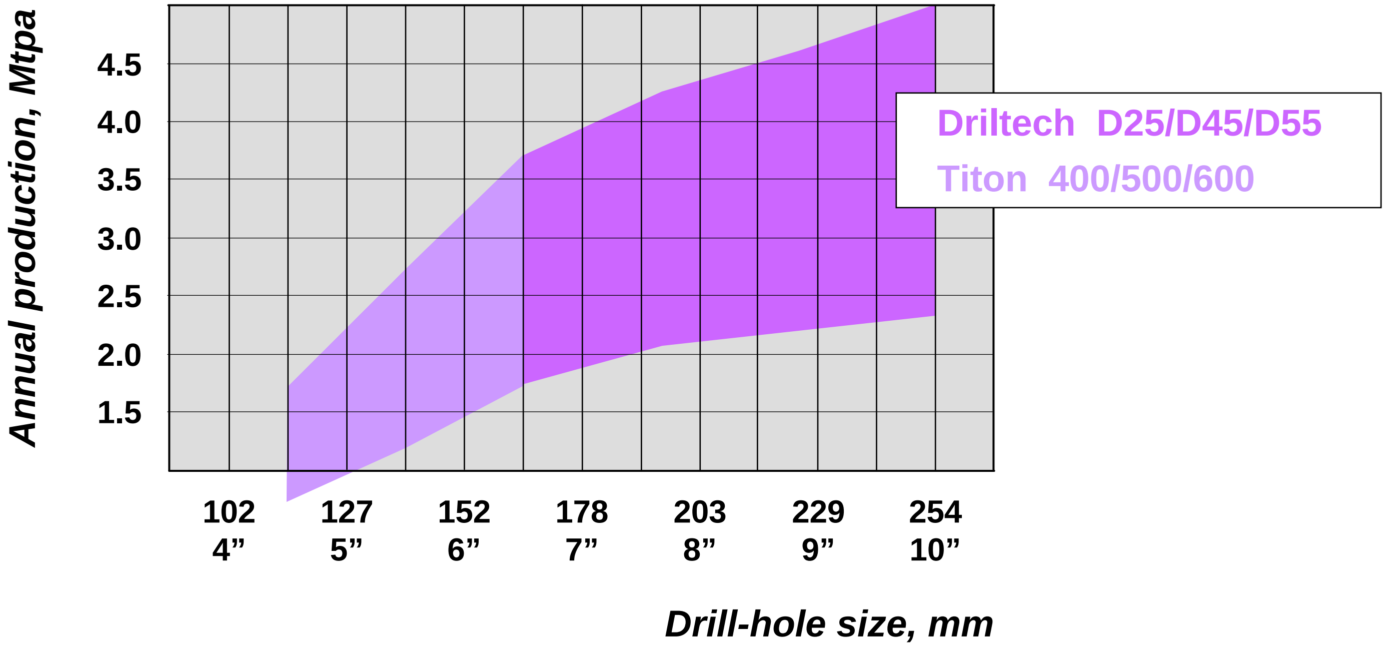
- *shifts per year* *225* *= 5 d/w · 45 w/a*
- *shift hours per year* *1800* *= 8 h/d · 5 d/w · 45 w/a*
- *engine hours per year* *1224* *= 1800 · 68 % utilisation*
- *rock density, t/m³* *2.7*



Drilling Management

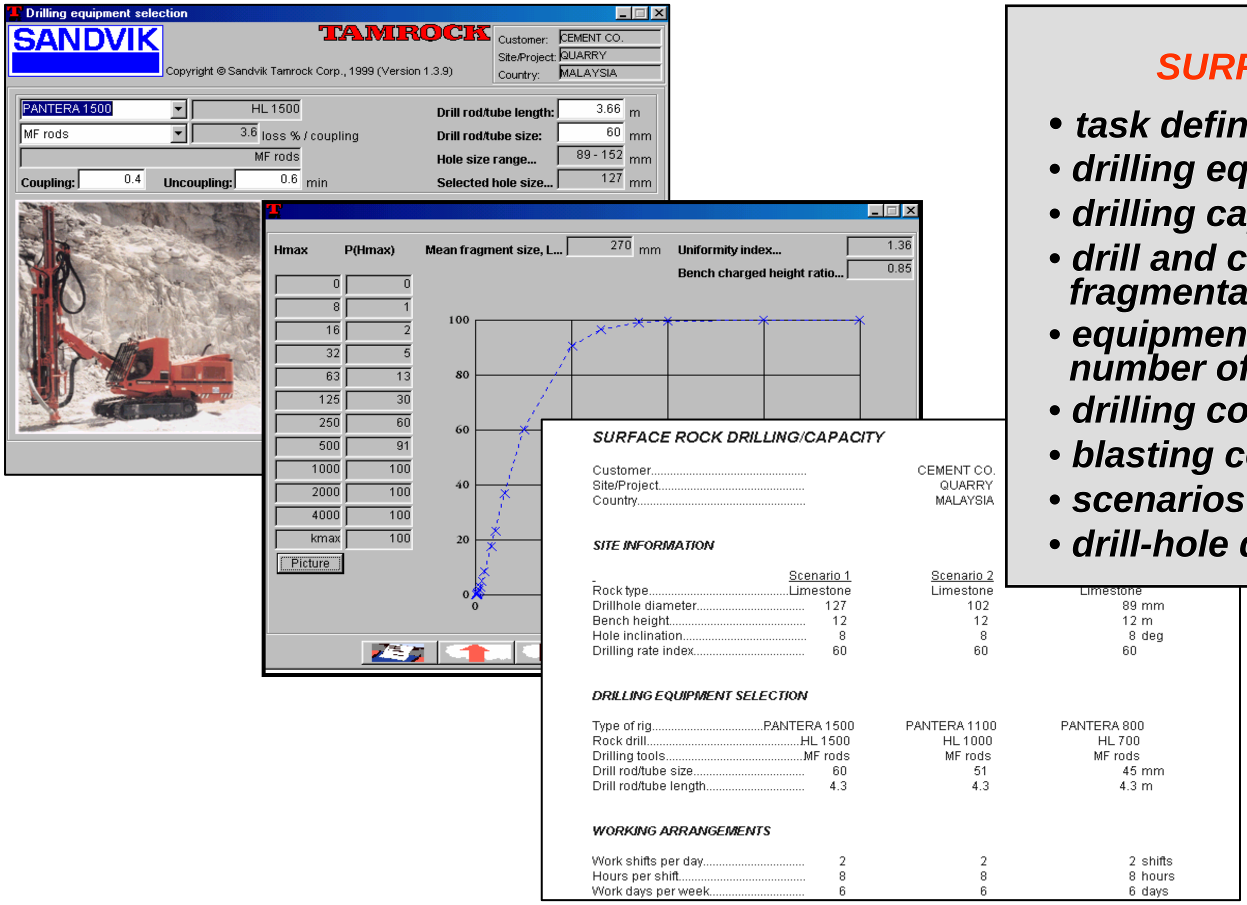
DTH - annual drill rig production capacities

• *shifts per year*	*225*	*= 5 d/w · 45 w/a*
• *shift hours per year*	*1800*	*= 8 h/d · 5 d/w · 45 w/a*
• *engine hours per year*	*1224*	*= 1800 · 68 % utilisation*
• *rock density, t/m³*	*2.7*	



Drilling Management

Simulation tools / study programs



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Customer: CEMENT CO.
Site/Project: QUARRY
Country: MALAYSIA

PANTERA 1500
HL 1500
MF rods
3.6 loss % / coupling
MF rods
Coupling: 0.4
Uncoupling: 0.6 min
Drill rod/tube length: 3.66 m
Drill rod/tube size: 60 mm
Hole size range... 89 - 152 mm
Selected hole size... 127 mm

Mean fragment size, L... 270 mm
Uniformity index... 1.36
Bench charged height ratio... 0.85

Hmax	P(Hmax)
0	0
8	1
16	2
32	5
63	13
125	30
250	60
500	91
1000	100
2000	100
4000	100
kmax	100

SURFACE ROCK DRILLING/CAPACITY

Customer.. CEMENT CO.
Site/Project.. QUARRY
Country.. MALAYSIA

SITE INFORMATION

-	Scenario 1	Scenario 2	
Rock type..	Limestone	Limestone	Limestone
Drillhole diameter..	127	102	89 mm
Bench height..	12	12	12 m
Hole inclination..	8	8	8 deg
Drilling rate index..	60	60	60

DRILLING EQUIPMENT SELECTION

Type of rig..	PANTERA 1500	PANTERA 1100	PANTERA 800
Rock drill..	HL 1500	HL 1000	HL 700
Drilling tools..	MF rods	MF rods	MF rods
Drill rod/tube size..	60	51	45 mm
Drill rod/tube length..	4.3	4.3	4.3 m

WORKING ARRANGEMENTS

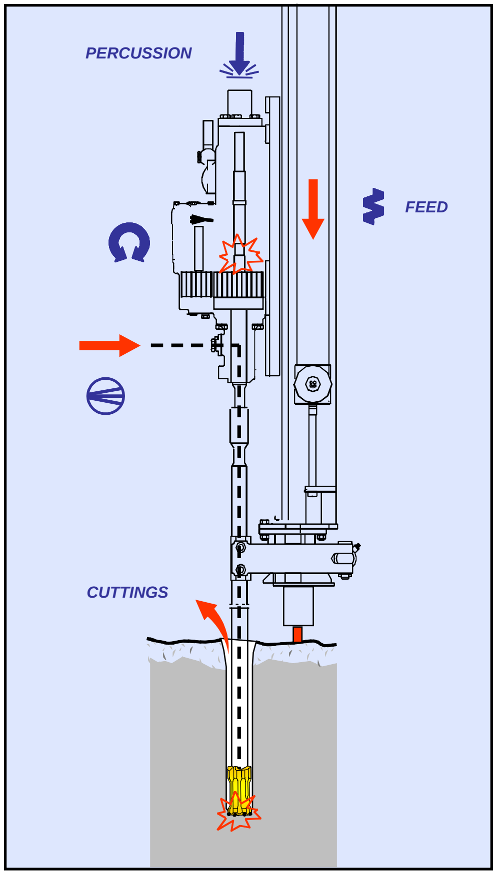
Work shifts per day..	2	2	2 shifts
Hours per shift..	8	8	8 hours
Work days per week..	6	6	6 days

SURFACE STUDY PROGRAM

- ***task definition / site information***
- ***drilling equipment / tools selection***
- ***drilling capacities***
- ***drill and charge patterns versus shotrock fragmentation and boulder count***
- ***equipment performance and required number of units***
- ***drilling costs***
- ***blasting costs***
- ***scenarios (optimisation)***
- ***drill-hole deviation***

Drilling Management

Mechanics of percussive drilling



Percussive drilling

Drilling powered by impact induced stress waves

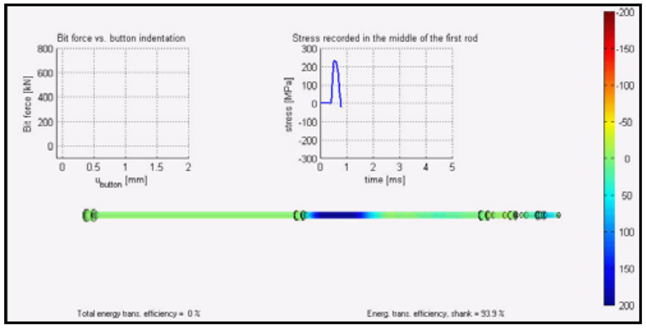
- *Down-the-hole, DTH*
  Stress waves transmitted directly through bit into rock
- *Tophammer*
  Stress waves transmitted through drill string into rock

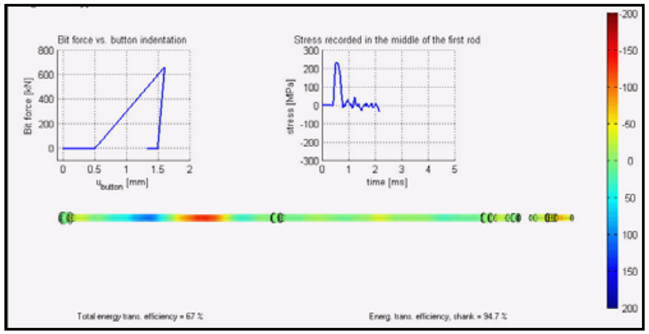
Basic functions

percussion	- *reciprocating piston to produce stress waves*
feed	- *provide bit-rock contact during impact*
rotation	- *provide bit indexing*
flushing	- *cuttings removal from hole bottom*
foam flushing	- *drill-hole wall stabilisation*

Drilling Management

The energy transfer chain in tophammer drilling





Work of hydraulic circuit during one piston stroke: $W_{hydraulic} = \int Q\,p\,dt$

Work transmitted to drill string by one piston strike: $W_{kinetic} = \frac{1}{2} \cdot m\,v_p^2$

Work of one bit indentation: $W_{rock} = \int F\,du$

Energy transfer efficiency*: $\eta = W_{rock} / W_{kinetic}$

Feed force required to maintain bit-rock contact: $F_{feed} = f \cdot \Sigma\,\Delta mv$

** includes losses in shank, drill string and bit*

Drilling Management

About stress wave energy transmission

Stress wave energy transfer efficiency can be divided into:

- *energy transmission through the drill string*
  - *optimum when the cross section through the drill string is constant*
  - *length of stress wave*
  - *weight of bit*
- *energy transmission to rock*
  - *bit indentation resistance of rock – k_1*
  - *bit-rock contact*

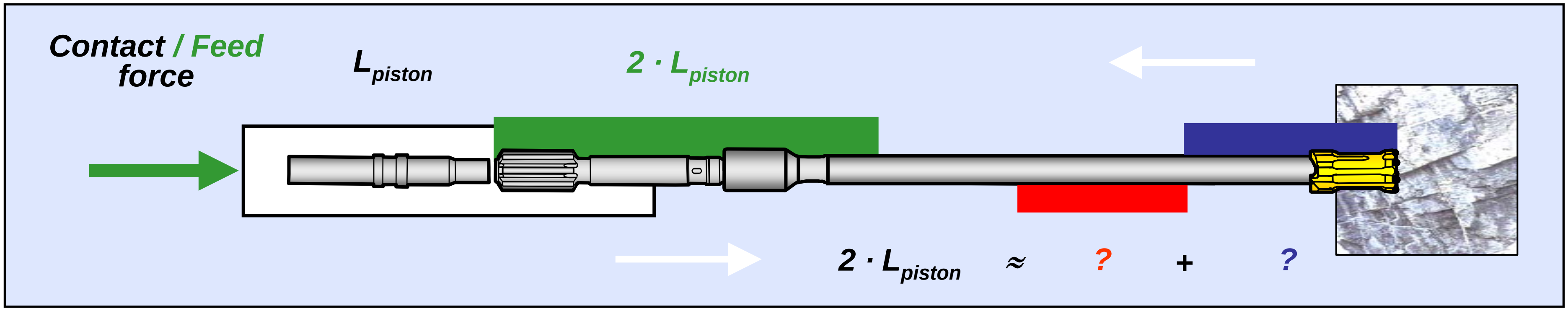
The most critical issue in controlling stress waves is to avoid high tensile reflection waves.

Tensile stresses are transmitted through couplings by the thread surfaces - not through the bottom or shoulder contact as in the case for compressive waves.

High surface stresses combined with micro-sliding result in high coupling temperatures and heavy wear of threads.

Drilling Management

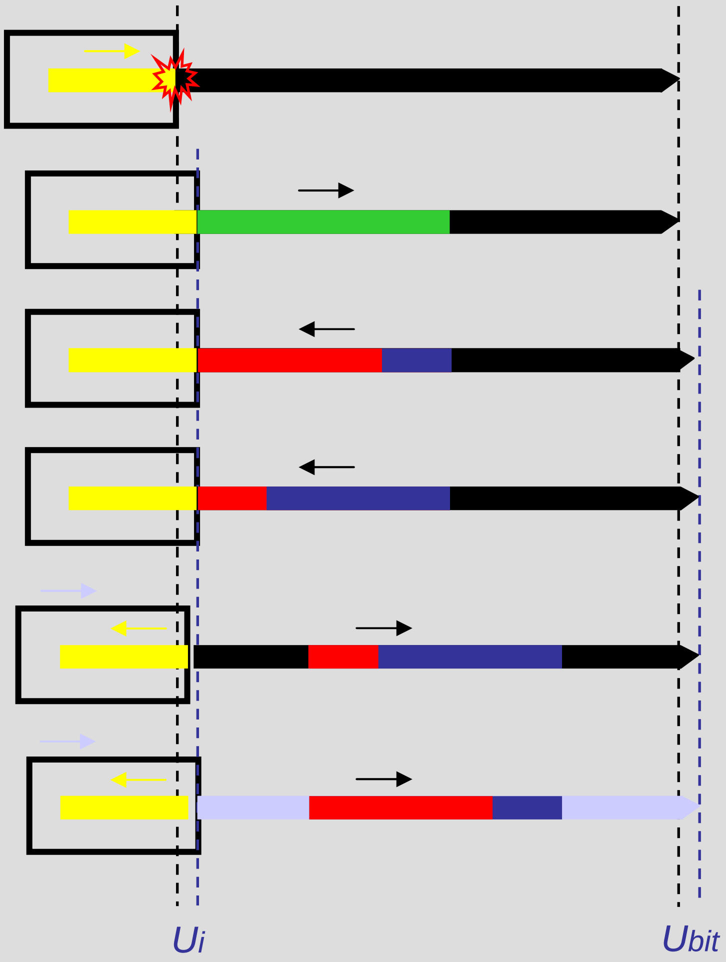
Energy transfer efficiency and bit-rock contact



- no contact / free-end => incident compressive wave totally reflected as a tensile wave from bit-rock interface
  => no feed force applied
  => no energy transfer to rock
- poor contact / underfeed => reflected tensile wave from bit-rock interface of high amplitude and duration
  => applied feed force too low
  => low energy transfer to rock
  => additional drilling occurs with the re-reflected tensile waves from bit-rock interface
- optimum contact => max energy transfer from bit to rock
- high contact / overfeed => reflected compressive wave from bit-rock of high amplitude and duration
  => applied feed force too high
  => reduced energy transfer to rock

Drilling Management

Feed force levels / rock drill



Piston strikes shank

Incident stress wave travels down drill string

__Underfeed__: Bit indentation and reflection of incident stress wave takes place

__Overfeed__: Bit indentation and reflection of incident stress wave takes place

__Underfeed__: Re-reflected tensile wave pulls shank forwards - creating first a gap and thereby moving strike point forwards and loosening threads

__Overfeed__: Re-reflected compressive wave pushes shank and rock drill backwards - creating jerky rock drill movements and tightening threads

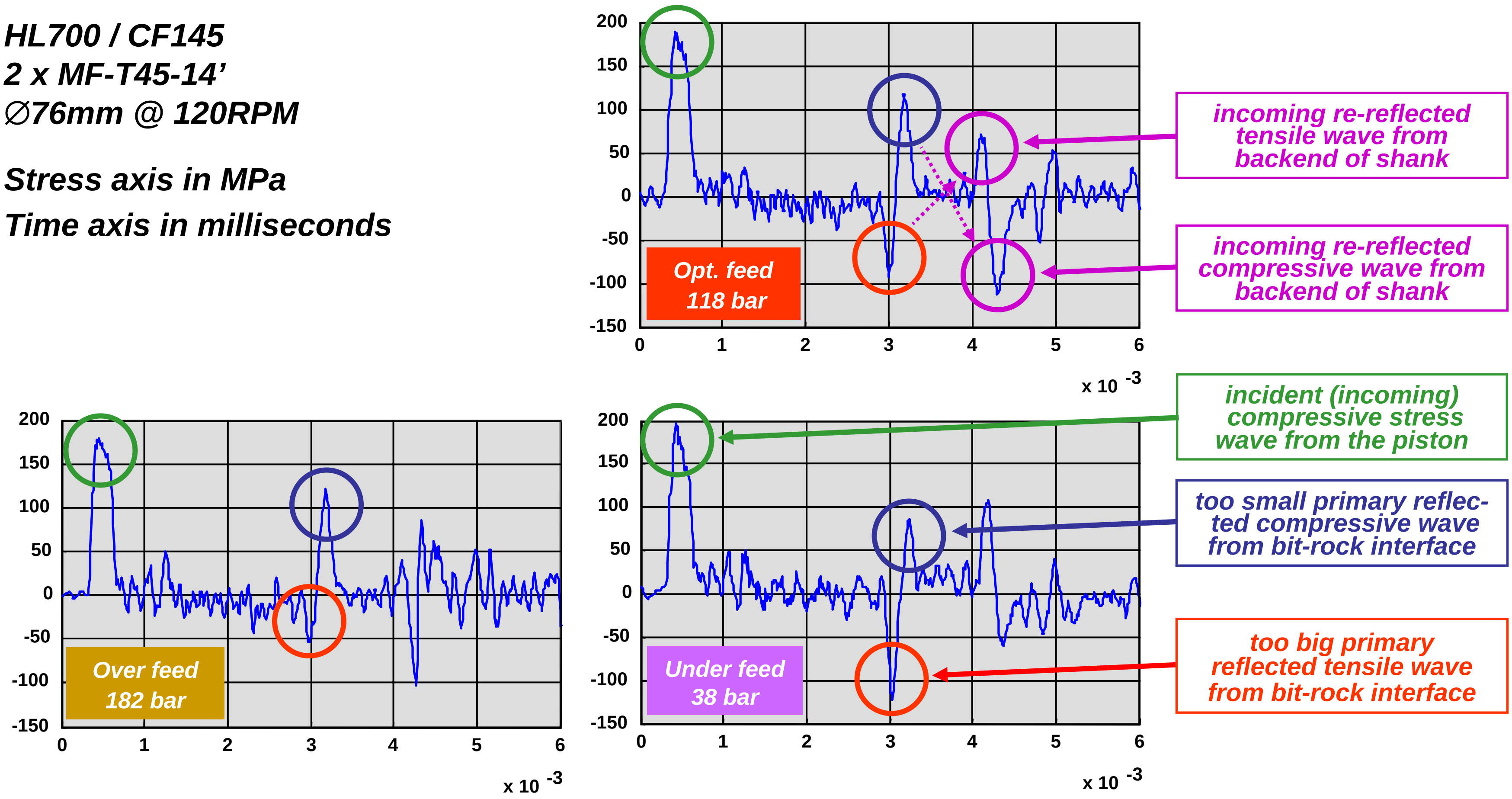
Drilling Management

Reflected stress wave response in rods to feed force levels

HL700 / CF145
2 x MF-T45-14’
∅76mm @ 120RPM

Stress axis in MPa

Time axis in milliseconds



incoming re-reflected tensile wave from backend of shank

incoming re-reflected compressive wave from backend of shank

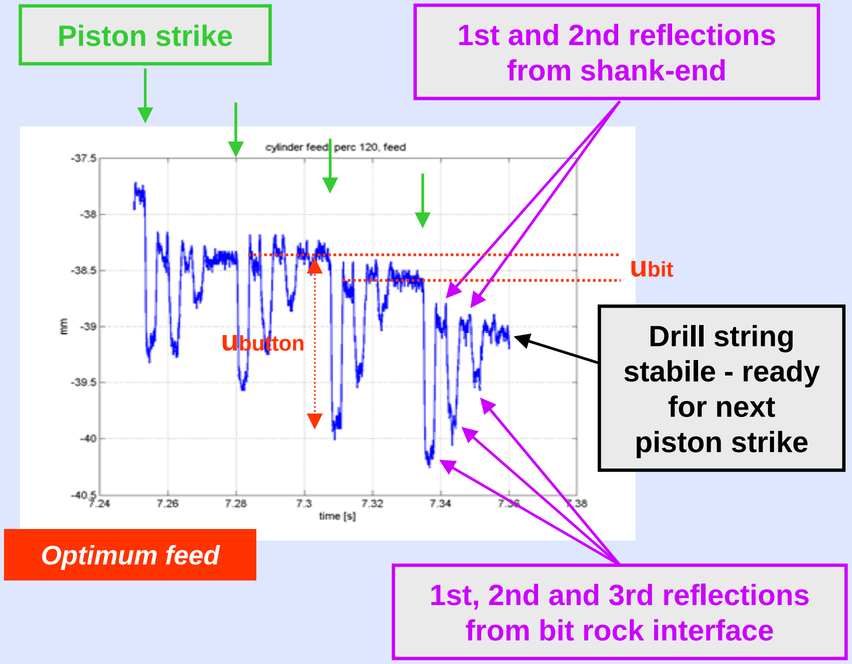
incident (incoming) compressive stress wave from the piston

too small primary reflected compressive wave from bit-rock interface

too big primary reflected tensile wave from bit-rock interface

Drilling Management

Displacement of 1st coupling while drilling



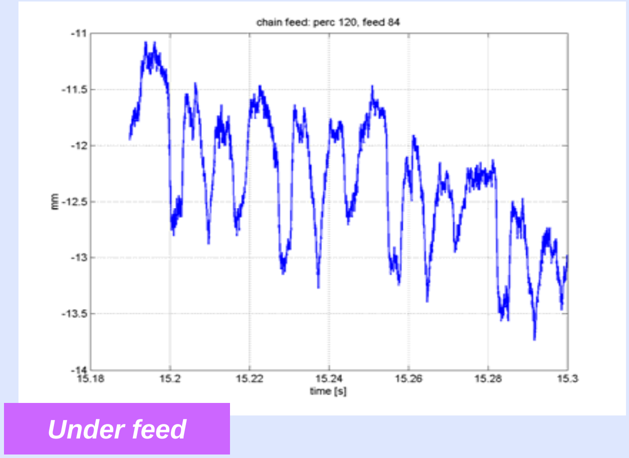
Piston strike

1st and 2nd reflections from shank-end

Drill string stabile - ready for next piston strike

1st, 2nd and 3rd reflections from bit rock interface

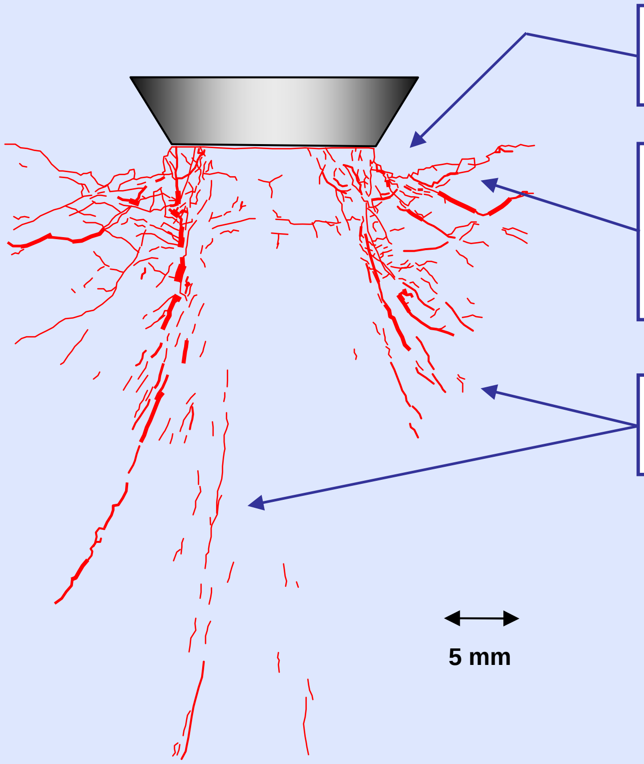
Optimum feed



Under feed

Drilling Management

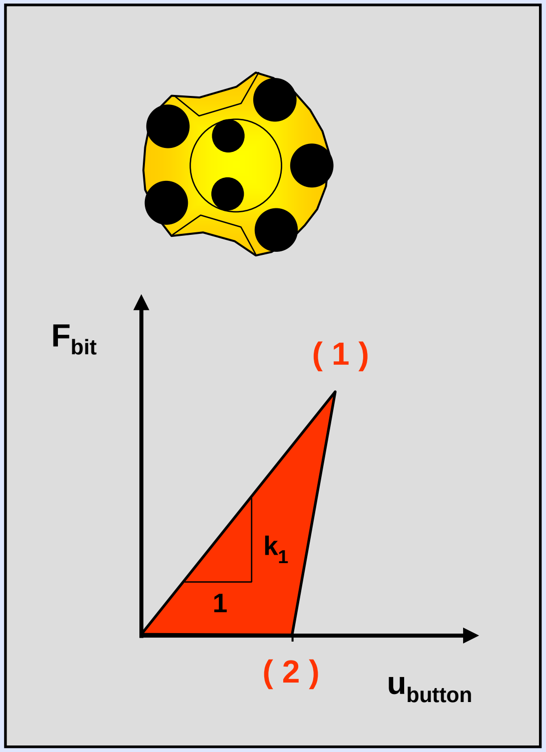
Button indentation, chip formation and bit force



Chipping around the button footprint area

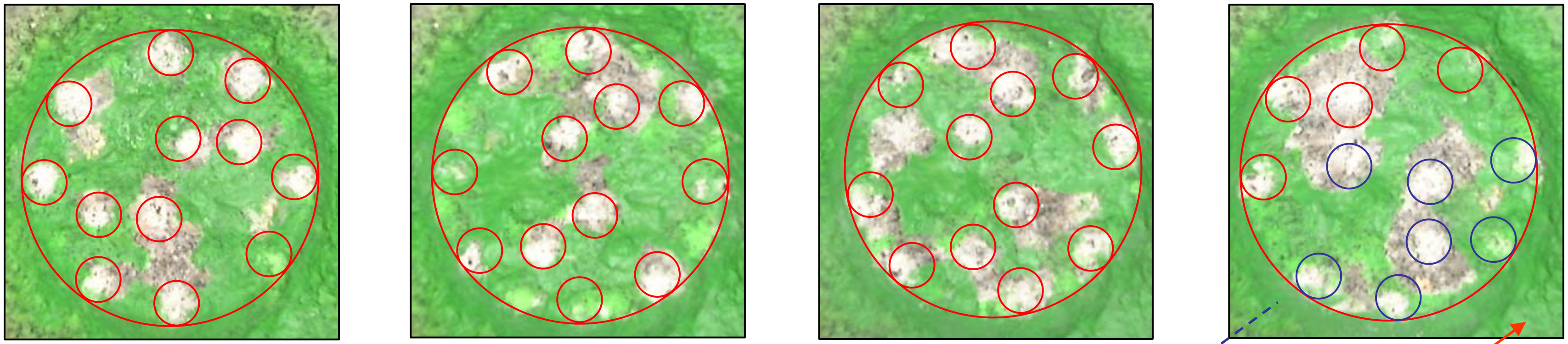
Off-loading fractures at (2) which create cuttings by chip spalling

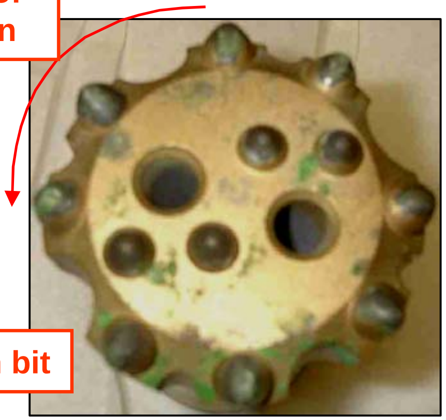
On-loading fractures created at (1)



Drilling Management

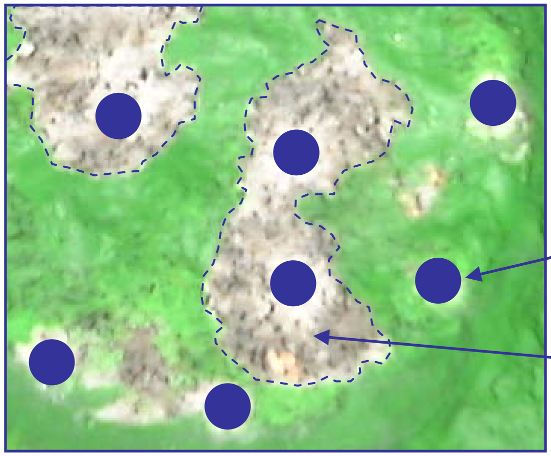
Chip formation by bit indentation and indexing





Direction of bit rotation

Ø76mm bit



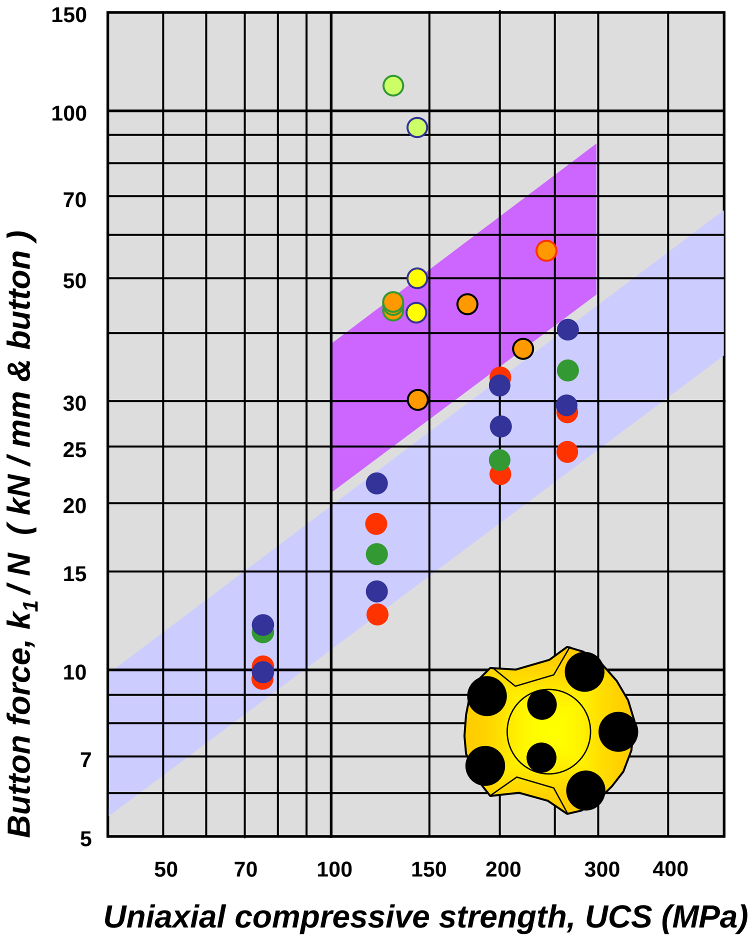
Applied spray paint between bit impacts

Button footprint area

Chipping around the button footprint areas

Drilling Management

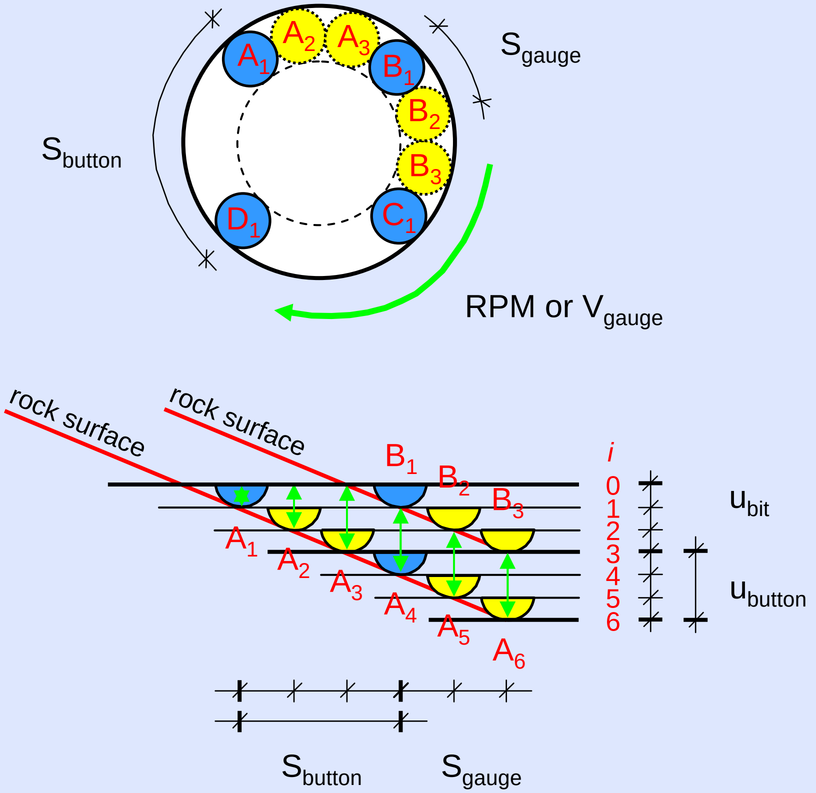
Button force versus rock strength, UCS

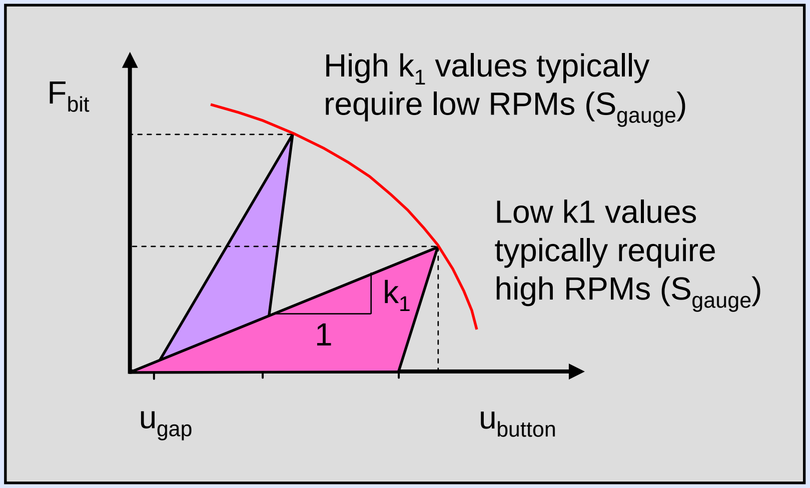


- ● ***dynamic, Ø11mm spherical buttons***
- ● ***dynamic, Ø10mm spherical buttons***
- ● ***dynamic, Ø9mm spherical buttons***
- ● ***static, Ø9mm spherical buttons***
- ● ***static, Ø11mm spherical buttons***
- ● ***static, Ø12mm spherical buttons***

Drilling Management

Effect of button indentation and bit force on bit RPM's



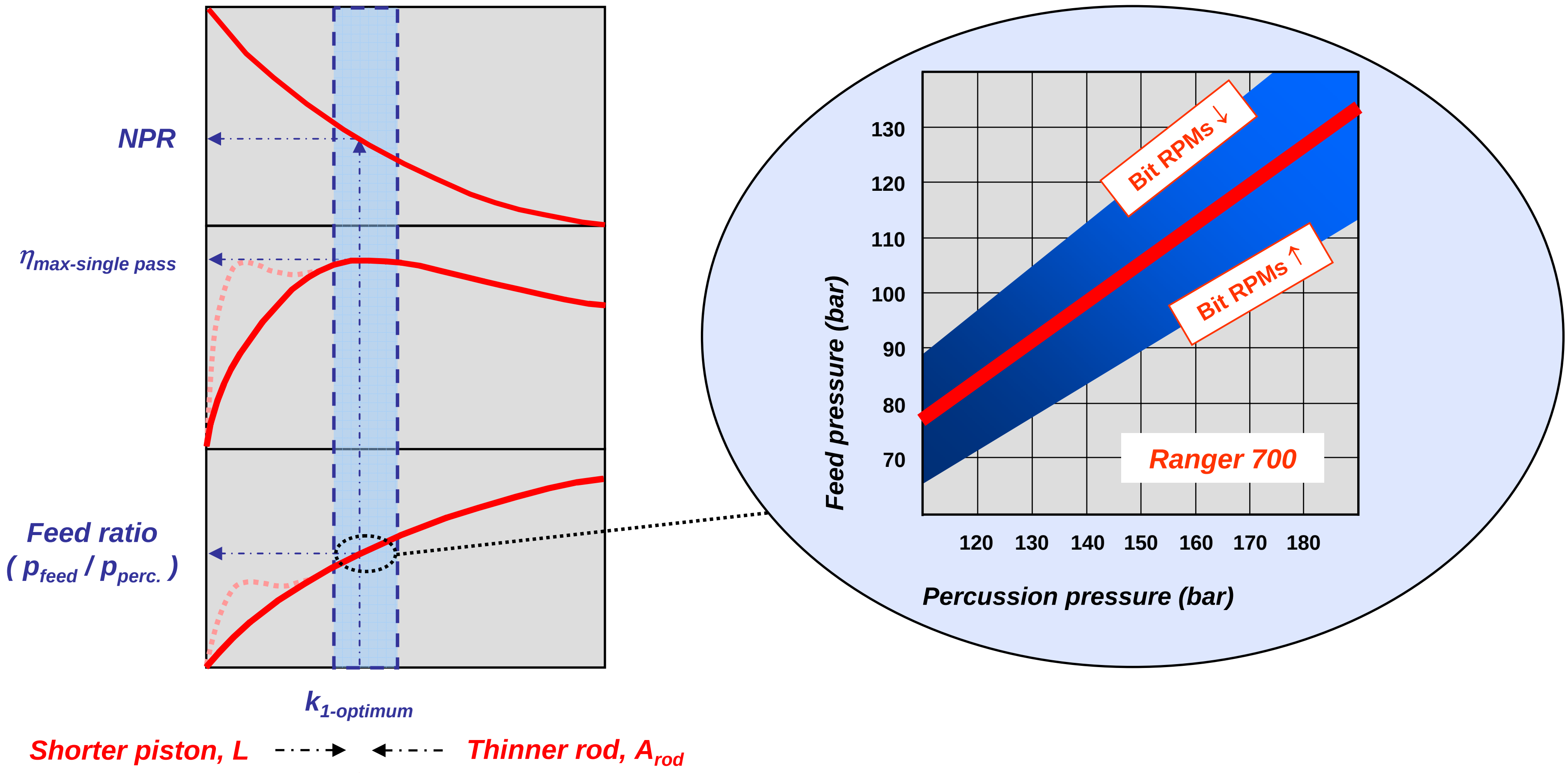


$$\Sigma i = S_{button} / S_{gauge}$$

$$\approx u_{button} / u_{bit}$$

Drilling Management

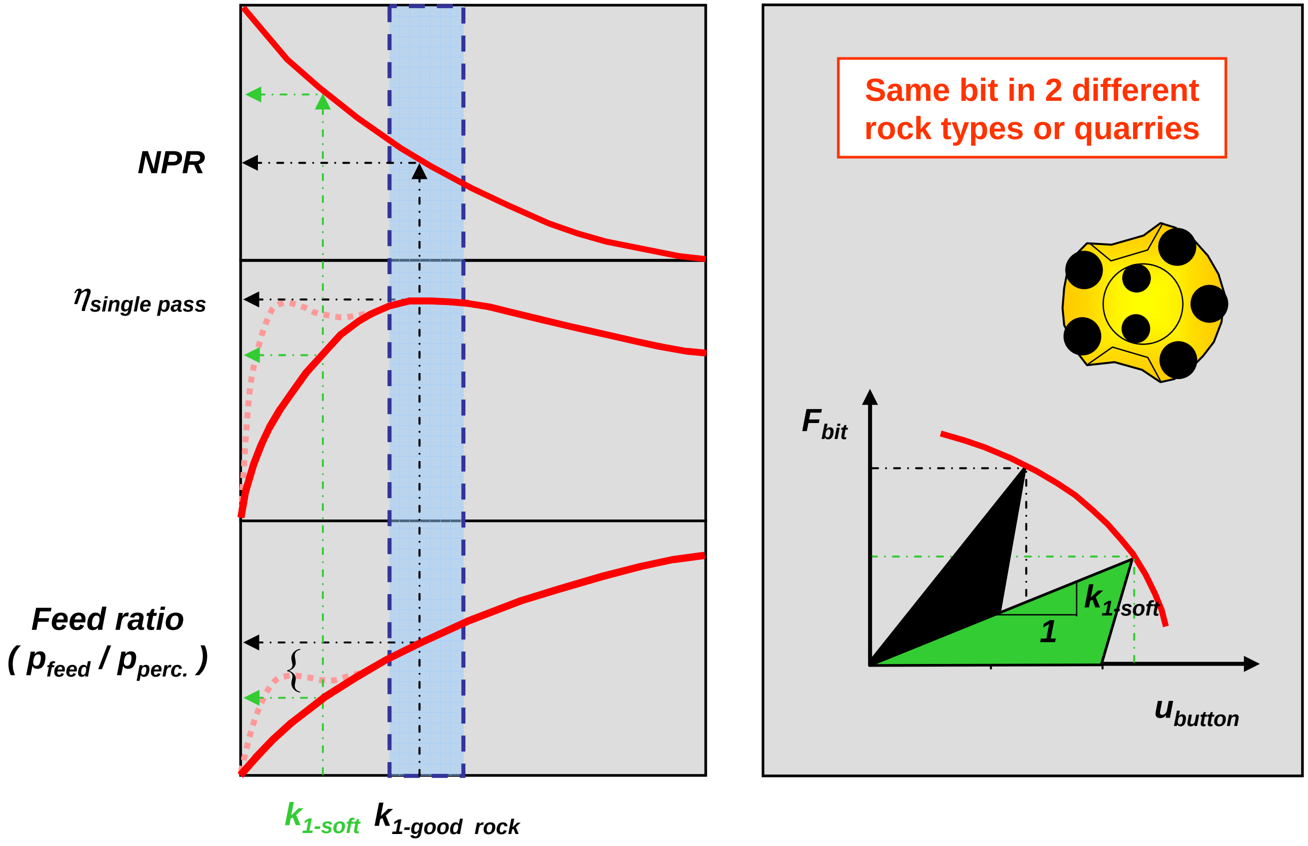
Energy transfer efficiencies and feed force requirements



The basic parameters (L, A_{rod}) + bit mass determine the transfer efficiency curve and the $k_{1\text{-optimum}}$ value for a given percussive system

Drilling Management

Matching site drilling to transfer efficiency curve

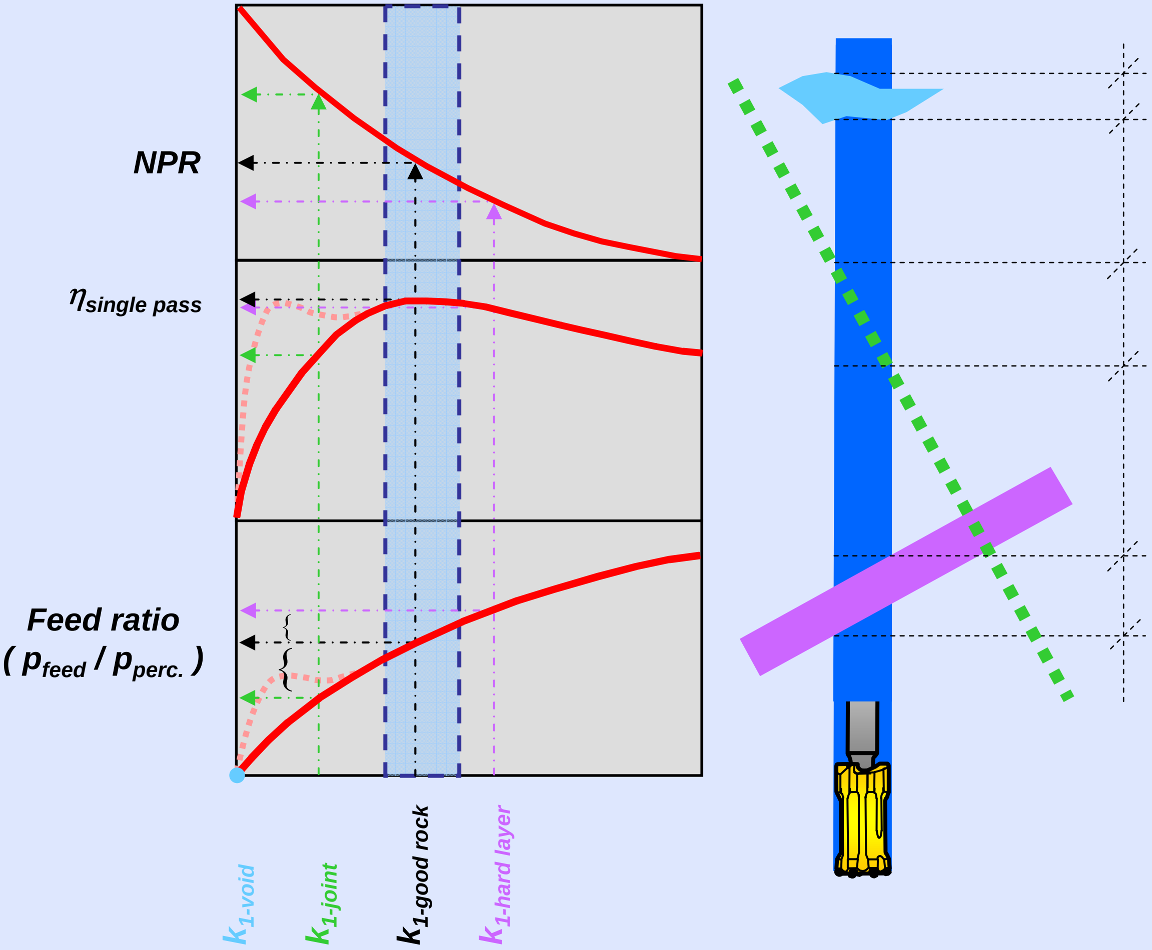


Rock hardness → ← *$p_{percussion}$ (u_{bit})*

Button count and size →
(and bit size)

Drilling Management

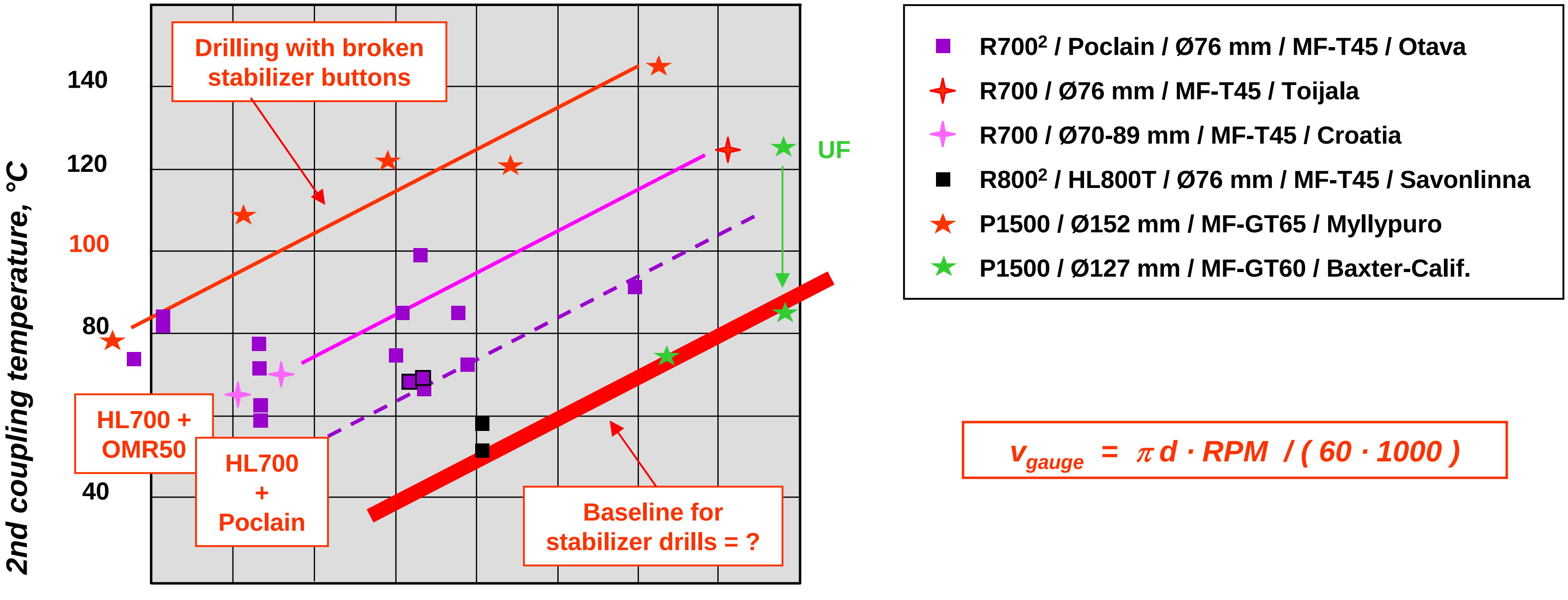
Drilling in variable rock mass



Situation =>	Actual feed conditions
$k_{1\text{-void}} \approx 0$	Total overfeed (feed speed control)
$k_{1\text{-good rock}}$	OK (feed ratio set here)
$k_{1\text{-joint}} < k_{1\text{-good rock}}$	Overfeed
$k_{1\text{-good rock}}$	OK
$k_{1\text{-hard layer}} > k_{1\text{-good rock}}$	Underfeed

Drilling Management

Ranger 700 and 800 / Pantera 1500

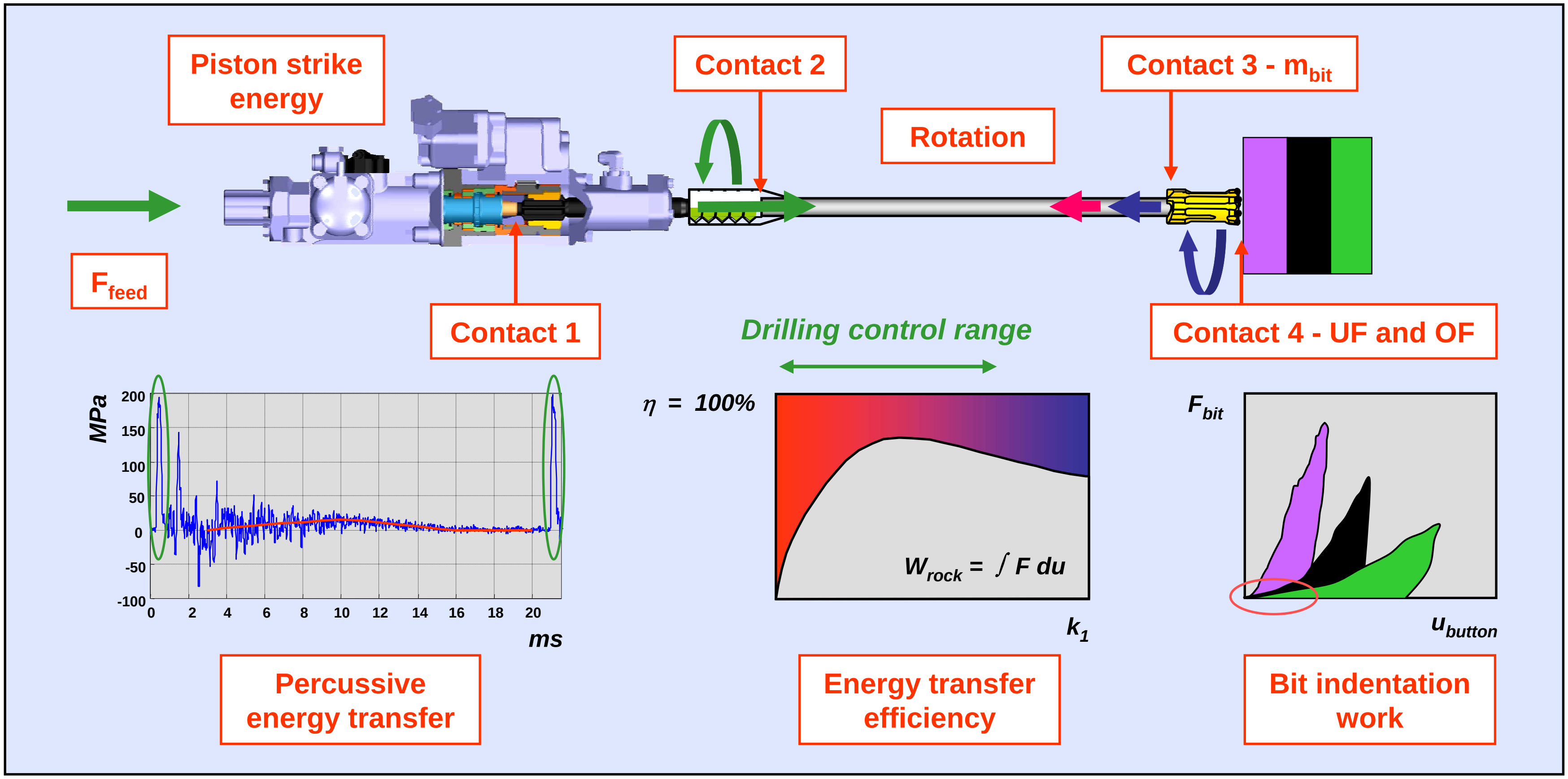


$$v_{gauge} = \pi d \cdot RPM \ / \ (60 \cdot 1000)$$

0,26	0,31	0,37	0,42	0,47	0,52	0,58	0,63	v_{gauge} (m/s)
66	79	92	105	118	132	145	158	*RPM for Ø76mm*
56	67	79	90	101	112	125	135	*RPM for Ø89mm*
49	59	69	78	88	98	108	118	*RPM for Ø102mm*
39	47	55	63	71	79	87	95	*RPM for Ø127mm*
33	39	46	53	59	66	72	79	*RPM for Ø152mm*

Drilling Management

Summary of percussion dynamics and drilling controls



Piston strike energy

Contact 2

Contact 3 - m_{bit}

Rotation

F_{feed}

Contact 1

Contact 4 - UF and OF

Drilling control range

Percussive energy transfer

Energy transfer efficiency

Bit indentation work

Drilling Management

Some topics in percussive rock drilling R & D

Rock mass characterisation and breakage mechanisms

- *drillability of intact rock and rock mass*
- *bit indentation and multi-pass rock chipping*
- *abrasivity of intact rock and rock mass*

Percussion power generation and transmission

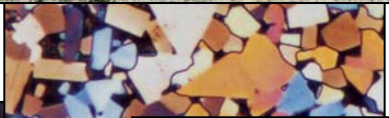
- *models for wear and failure resistance of cemented carbide inserts*
- *simulation models for bit, drill string and thread performance*
- *simulation models for rock drill and feed system performance*
- *hydraulic fluids - mineral oils, bio-degradeable oils, water, air*
- *drilling control systems*

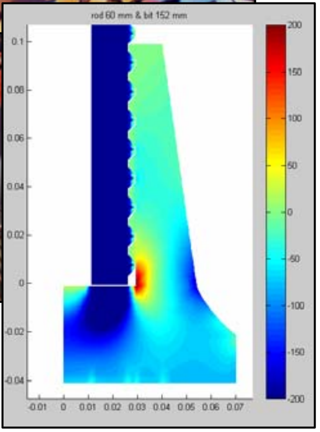
Drill rig design and engineering

- *simulation models for rig stability and booms*
- *dust and noise suppression systems*
- *safety and work environmental issues*
- *instrumentation and condition monitoring*
- *remote control and automation*
- *reliability*

Drilling applications

- *prediction models for overall drilling equipment performance and costs*
- *prediction and simulation models for rock excavation processes*

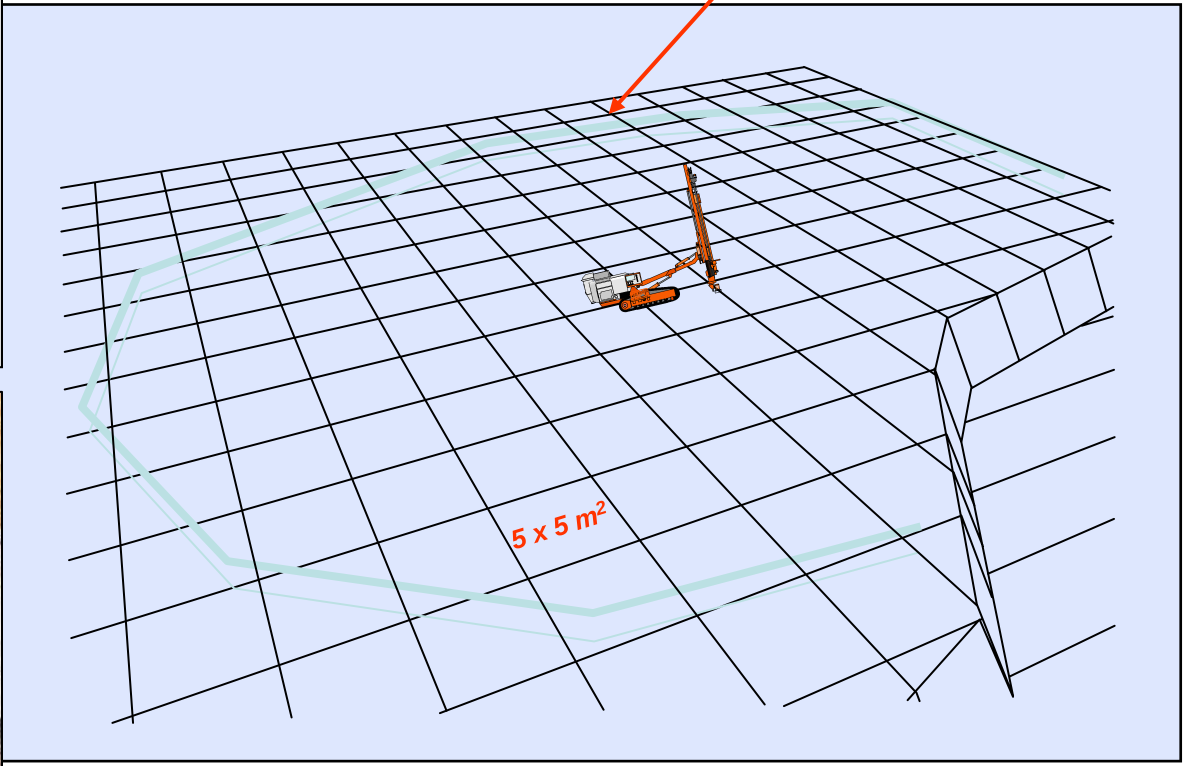




Drilling Management

Drilling noise levels

Standard	*ISO 4872*
Pressure	*L_{WA} dB(A)*
Commando 100	*125.7*
Commando 300	*123.8*
CHA 660	*124.2*
Ranger 700	*126*
Pantera 1500	*127*



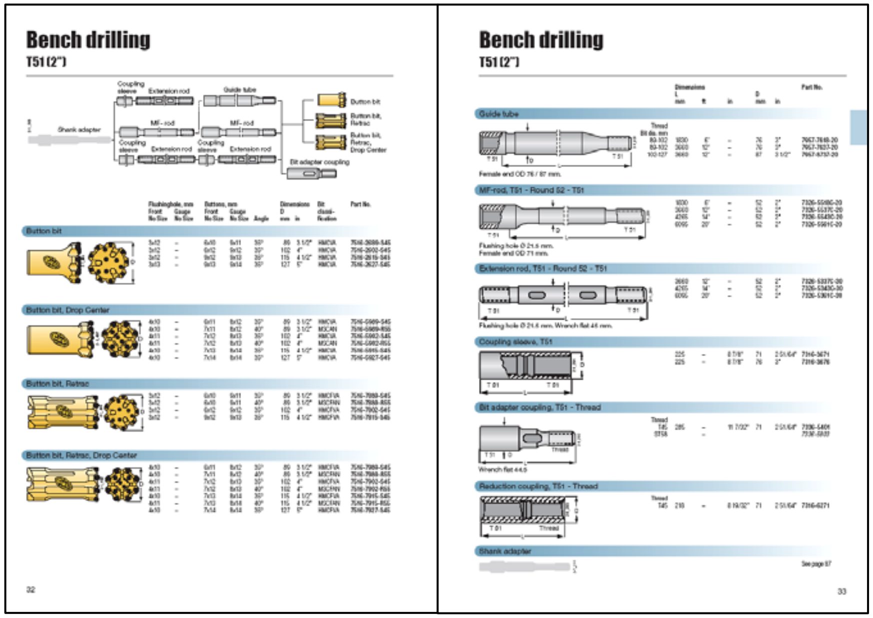
85 dB(A) boundary for CHA 660

Feed casing reduces noise levels by approx. 9 dB(A)

Drilling Management

Selecting drilling tools

- bit face and skirt design
- button shape, size and cemented carbide grade
- drill string components
- grinding equipment and its location at jobsite



Bench drilling

T51 (2")

Button bit

Button bit, Drop Center

Button bit, Retrac

Button bit, Retrac, Drop Center

Bench drilling

T51 (2")

Guide tube

Female end OD 76 / 87 mm.

MF-rod, T51 - Round 52 - T51

Flushing hole Ø 21.5 mm.
Female end OD 71 mm.

Extension rod, T51 - Round 52 - T51

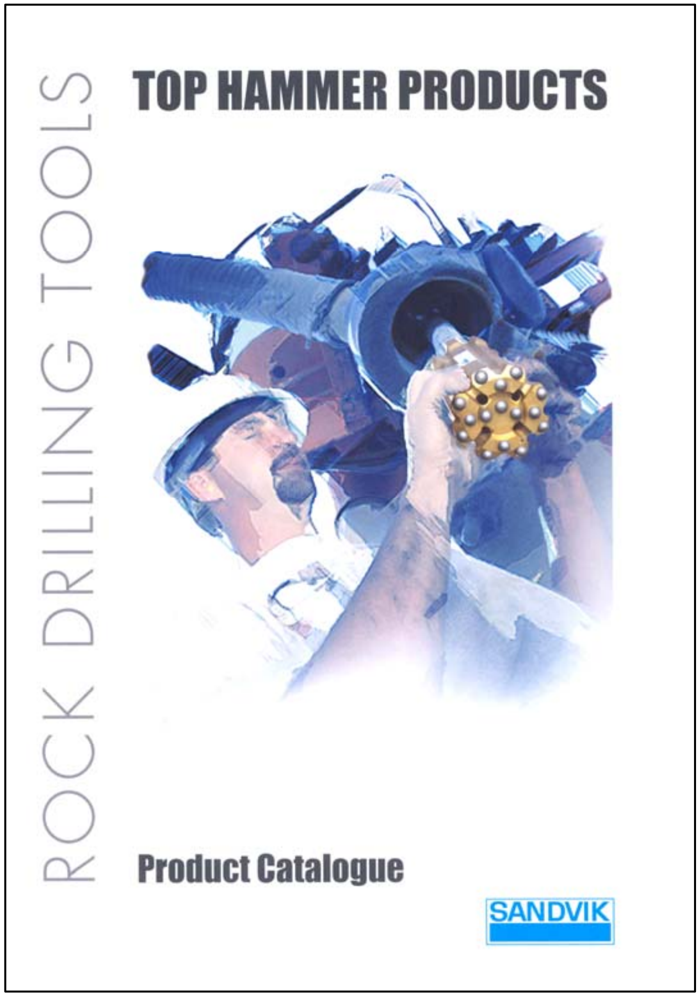
Flushing hole Ø 21.5 mm. Wrench flat 46 mm.

Coupling sleeve, T51

Bit adapter coupling, T51 - Thread

Reduction coupling, T51 - Thread

Shank adapter



ROCK DRILLING TOOLS

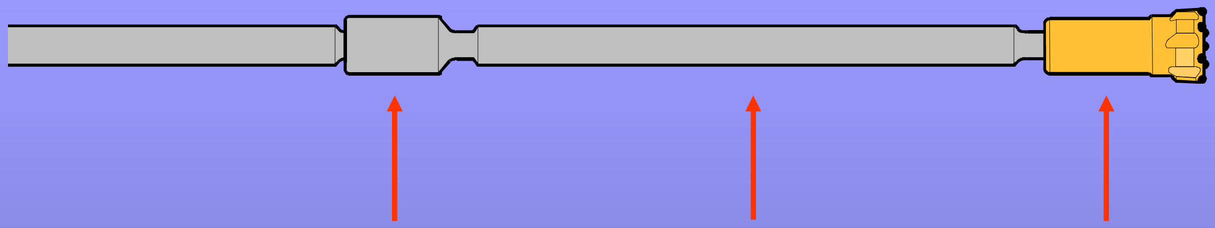
TOP HAMMER PRODUCTS

Product Catalogue

SANDVIK

Drilling Management

Optimum bit / rod diameter relationship



Thread	Cross section coupling	Cross section	Optimum bit size
R32	∅44	∅32	∅51
T35	∅48	∅39	∅57
T38	∅55	∅39	∅64
T45	∅63	∅46	∅76
T51	∅71	∅52	∅89
GT60	∅82	∅60	∅92
GT60	∅85	∅60	∅102

Drilling Management

Optimum bit / guide or pilot (lead) tube relationship

Thread	Cross section coupling	Cross section	Optimum bit size
T38	Ø55	Ø56	Ø64
T45	Ø63	Ø65	Ø76
T51	Ø71	Ø76	Ø89
GT60	Ø85	Ø87	Ø102
GT60	Ø85	Ø102	Ø115

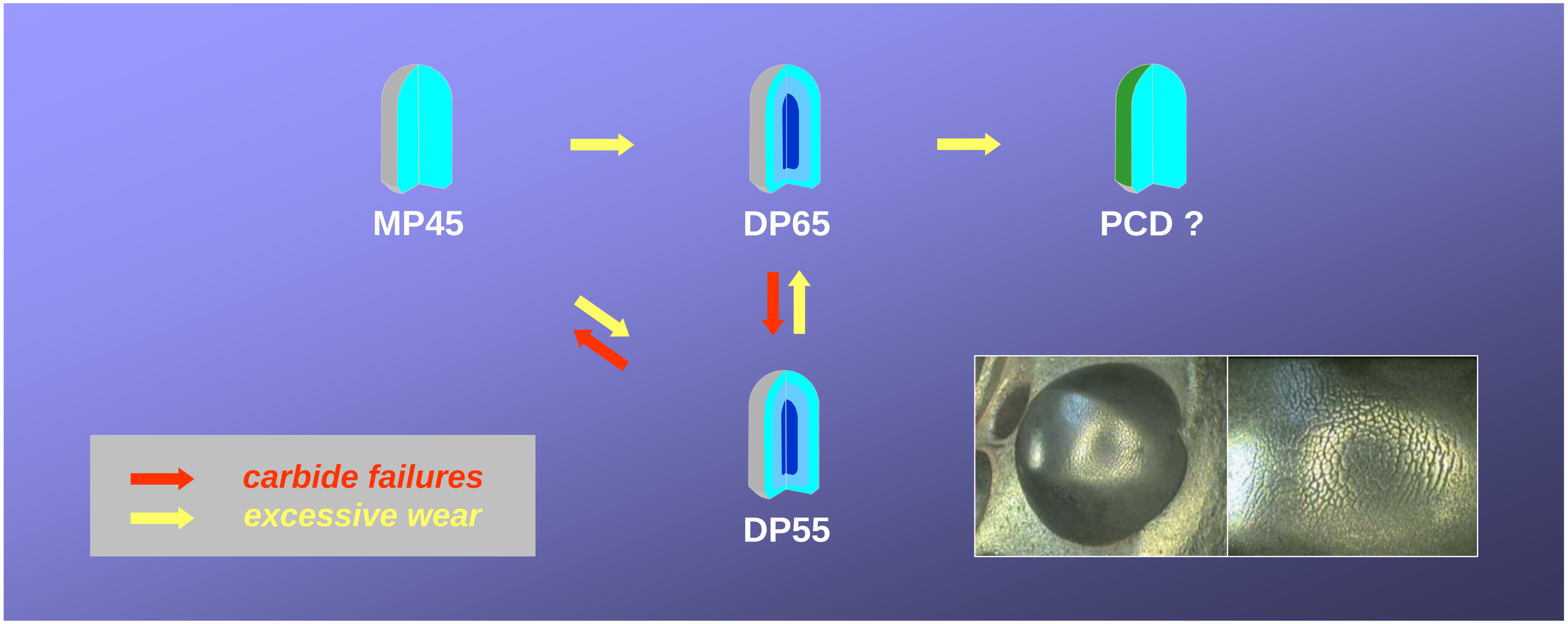
Drilling Management

Guidelines for selecting cemented carbide grades

- ***avoid excessive button wear (rapid wearflat development)***

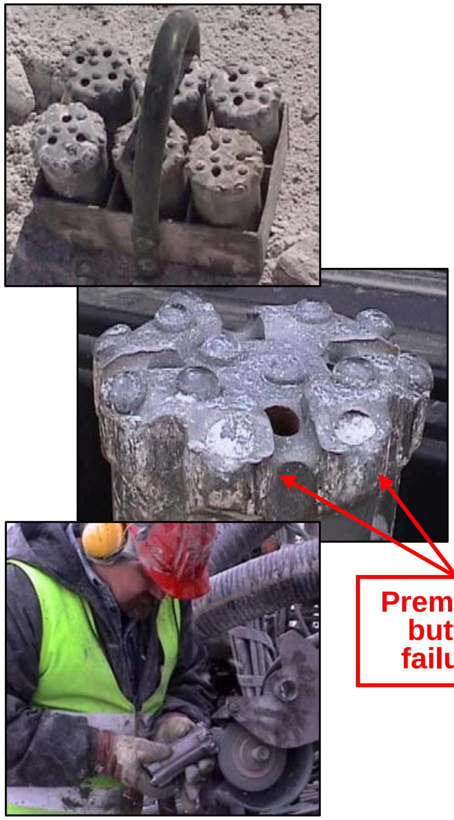
  => select a more wear resistant carbide grade
- ***avoid button failures (due to snakeskin development or too aggressive button shapes)***

  => select a less wear resistant or tougher carbide grade or spherical buttons

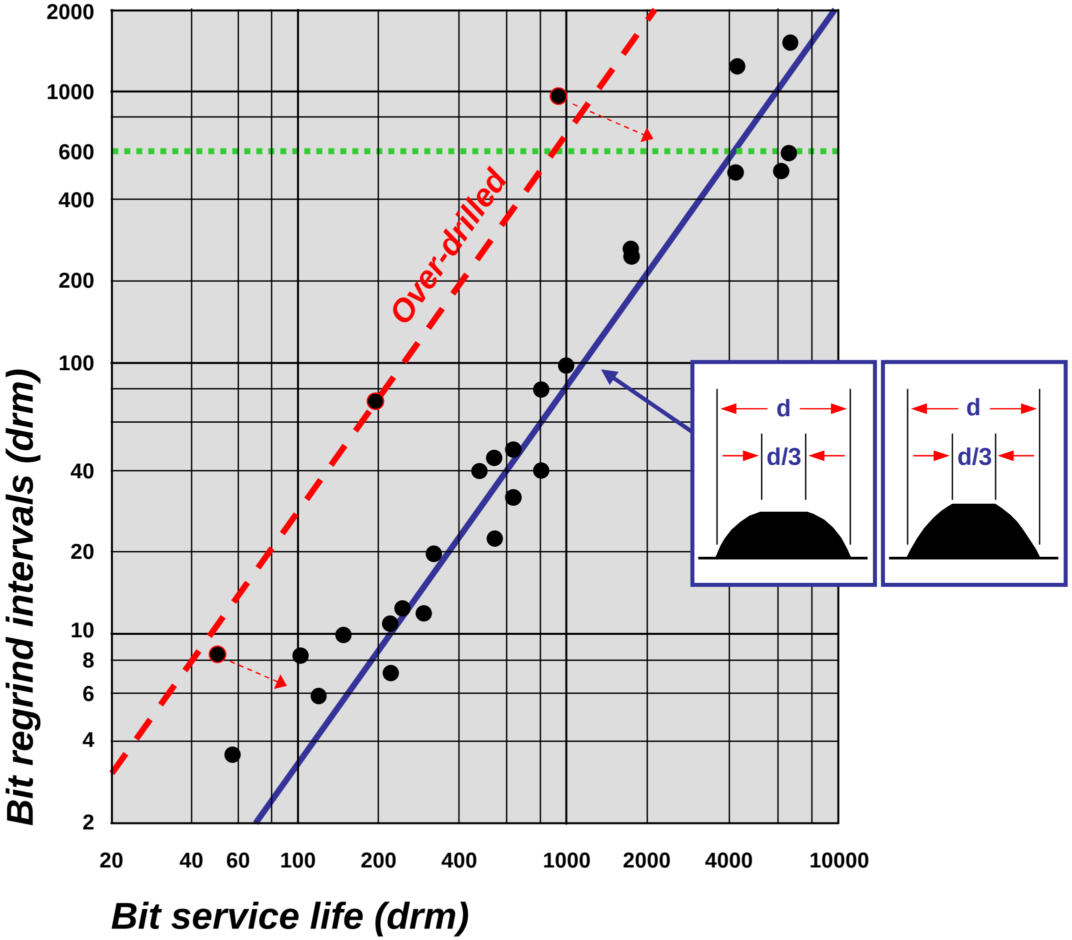


Drilling Management

Bit regrind intervals, bit service life and over-drilling

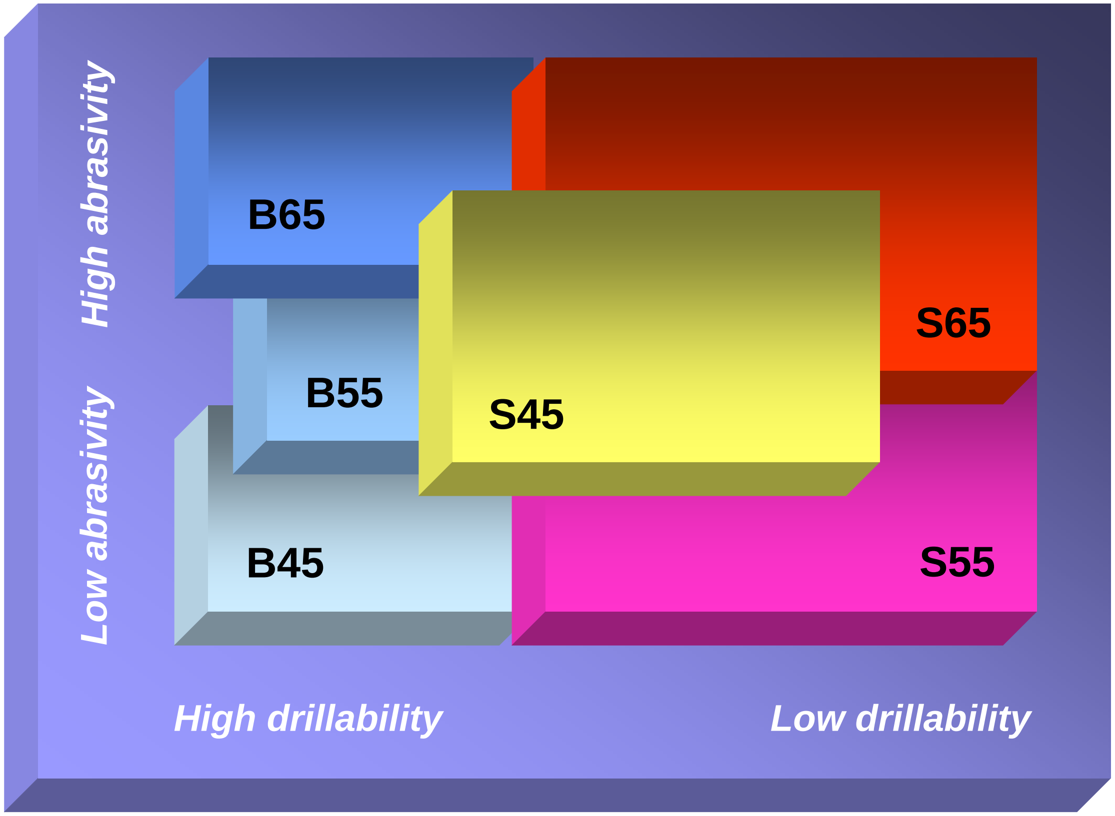


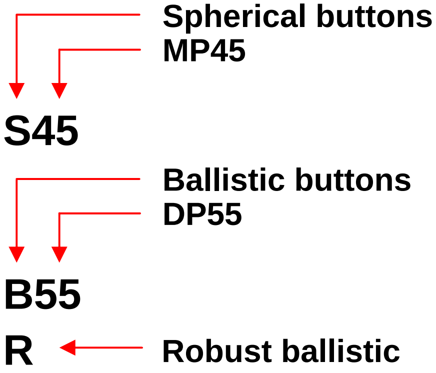
Premature button failures



Drilling Management

Selecting button shapes and cemented carbide grades



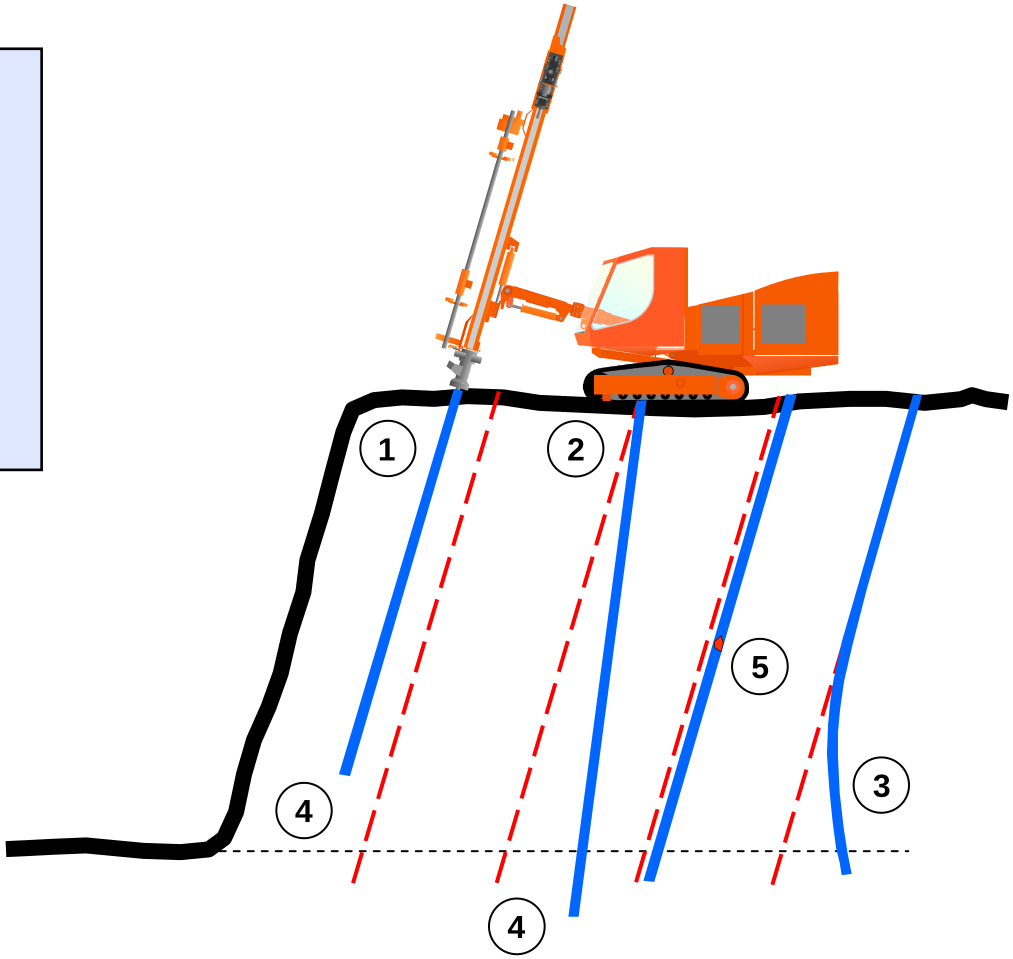


Drilling Management

Accurate drilling gives effective blasting

Sources of drilling error

1. Marking and collaring errors
2. Inclination and directional errors
3. Deflection errors
4. Hole depth errors
5. Undergauge, omitted or lost holes

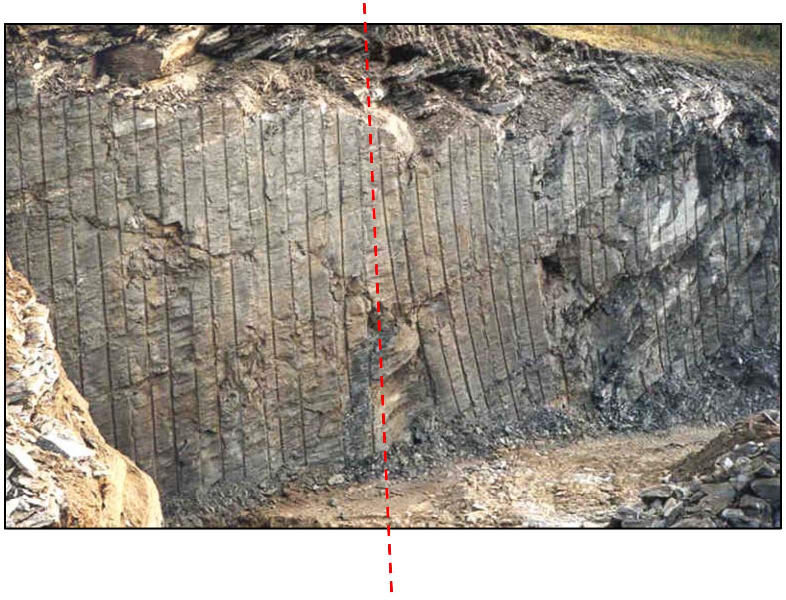


Drilling Management

Examples of drill-hole deviation

Directional error
Ø89 mm retrac bit
/ T45 in granite

Deflection caused by
gravitational sagging of drill
steel in inclined holes in syenite

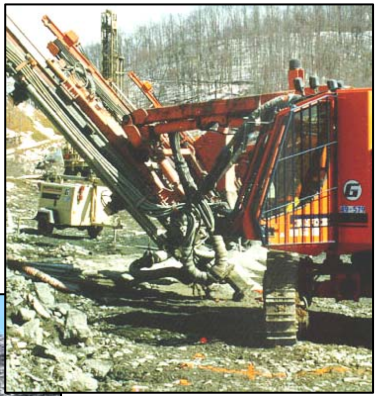


Deflection with and
without pilot tube for
Ø89 mm DC retrac bit
/ T51 in micaschist

Drilling Management

I-26 Mars Hill Highway Project, North Carolina

D & B excavation volume	*13.7 mill. m^3*
Contractor for presplitting	*Gilbert Southern Corp.*
Equipment for presplitting	*3 x Ranger 700*
Bench height	*7.6 m with 40° inclined walls*
Drill steel	*Ø76mm retrac / T45*
Target accuracy at hole bottom	*152 mm at 10.0 m or 15.2 mm/m*
Rock type	*biotite-granite gneiss*



Drilling Management

Lafarge Bath Operations, Ontario

Annual production	*1.6 mill. tonnes*
Rock type	*limestone*

Current program - Pantera 1500

Bench height	*32 m*
Bit	*Ø115 mm guide XDC*
Drill steel	*Sandvik 60 + pilot tube*
Hole-bottom deflection	*< 1.5 %*
Gross drilling capacity	*67 drm/h*
Drill pattern	*4.5 x 4.8* m^2 *(staggered)*
Sub-drill	*0 m (blast to fault line)*
Stemming	*2.8 m*
No. of decks	*3*
Stem between decks	*1.8 m*
Deck delays	*25 milliseconds*
Charge per shothole	*236 kg*
Explosives	*ANFO (0.95 & 0.85* g/cm^3*)*
Powder factor	*0.34* kg/bm^3

Drilling Management

Marking and collaring position error control

Marking collaring positions

1a. Use tape, optical squares or alignment lasers for measuring out drill-hole collaring positions.

1b. Use GPS or theodolites to determine collaring positions - an advantage when drilling from undulating terrain.

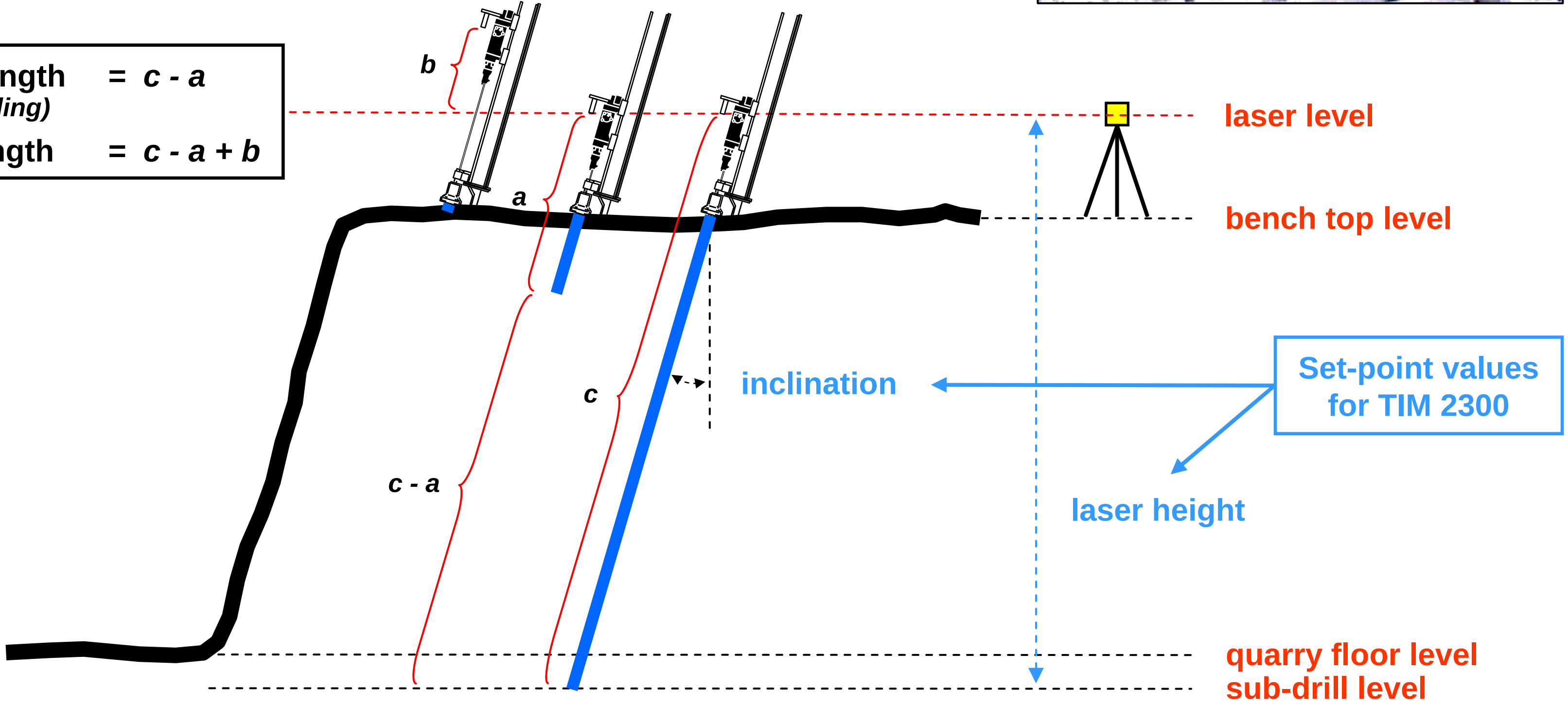
2. Collaring positions should be marked using painted lines - not movable objects such as rocks, shothole plugs, etc.

3. Use GPS guided feed collar positioning device.

Drilling Management

Hole depth error control

Remaining drill length = *c - a*
(at 1st laser level reading)
Total drill hole length = *c - a + b*



laser level

bench top level

inclination

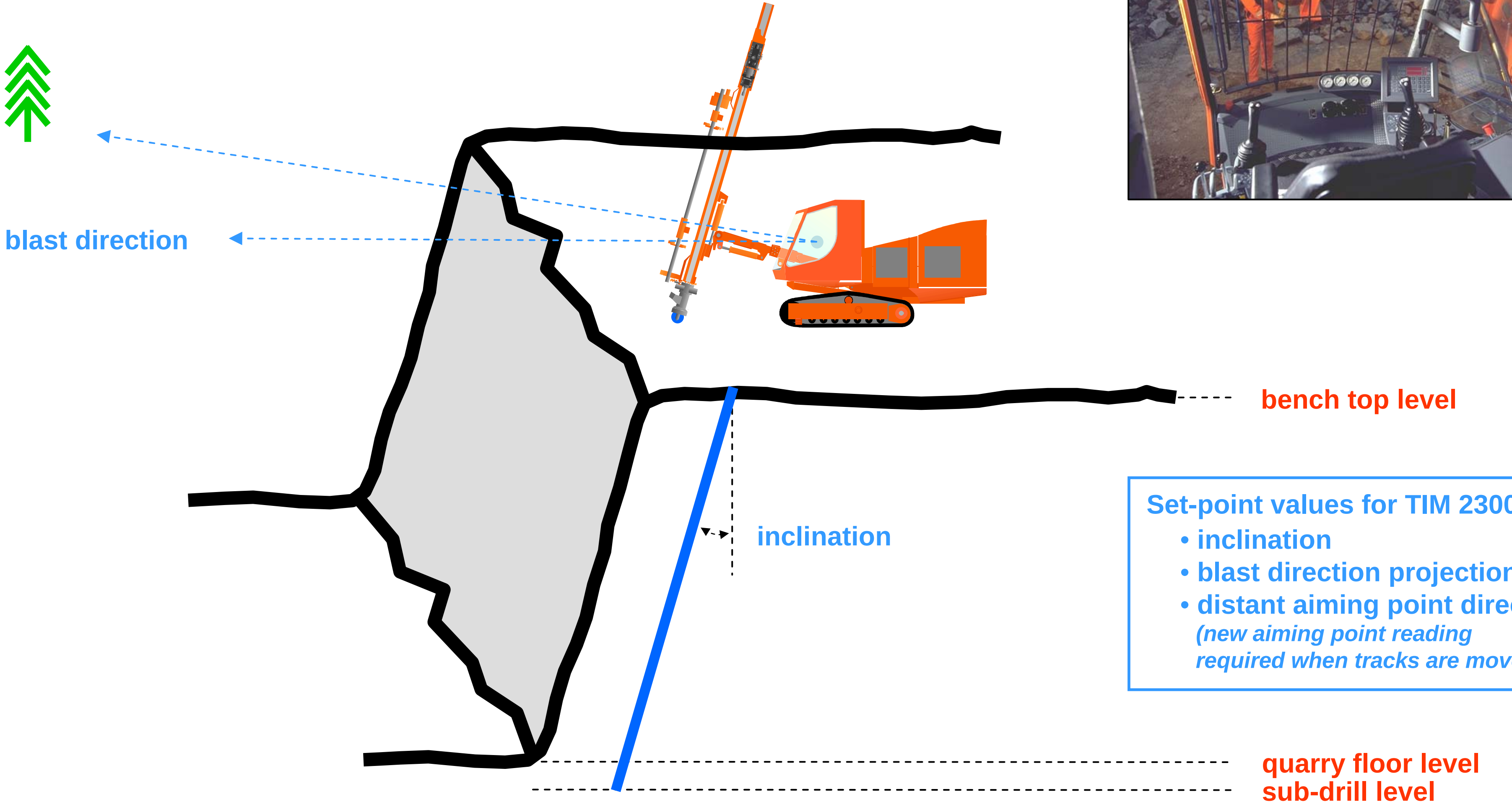
Set-point values for TIM 2300

laser height

quarry floor level
sub-drill level

Drilling Management

Inclination and directional error control

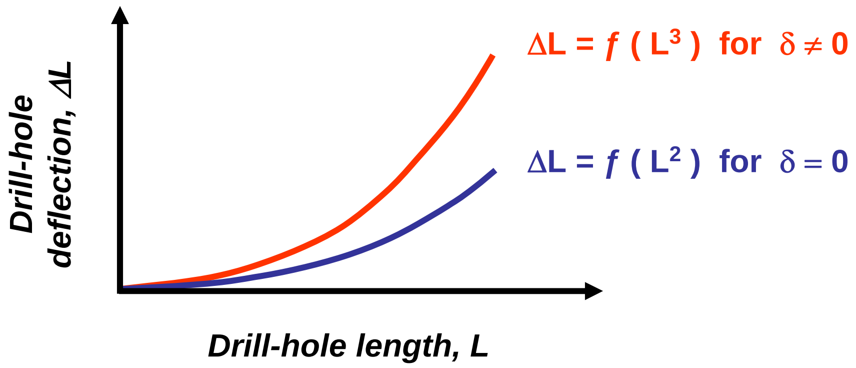


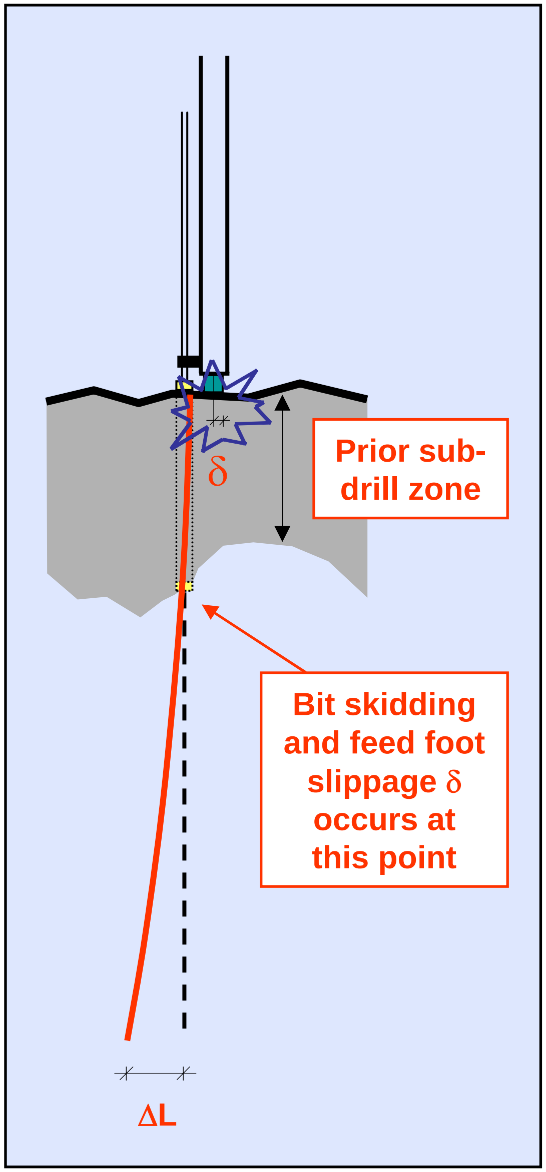
Set-point values for TIM 2300
- inclination
- blast direction projection
- distant aiming point direction
  (new aiming point reading required when tracks are moved)

Drilling Management

Drill-hole deflection error control

- ***select bits less influenced by rock mass discontinuities***
- ***reduce drill string deflection by using guide tubes, etc.***
- ***reduce drill string bending by using less feed force***
- ***reduce feed foot slippage while drilling - since this will cause a misalignment of the feed and lead to excessive drill string bending (occurs typically when drilling through sub-drill zones from prior bench levels)***
- ***avoid gravitational effects which lead to drill string sagging when drilling inclined shot-holes (> 15°)***
- ***avoid inpit operations with excessive bench heights***



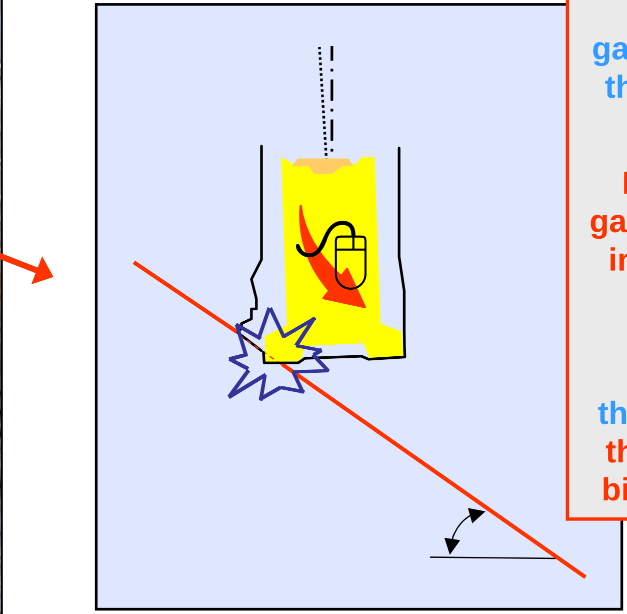


Prior sub-drill zone

Bit skidding and feed foot slippage δ occurs at this point

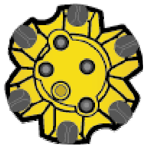
Drilling Management

How bit face designs enhance drill-hole straightness



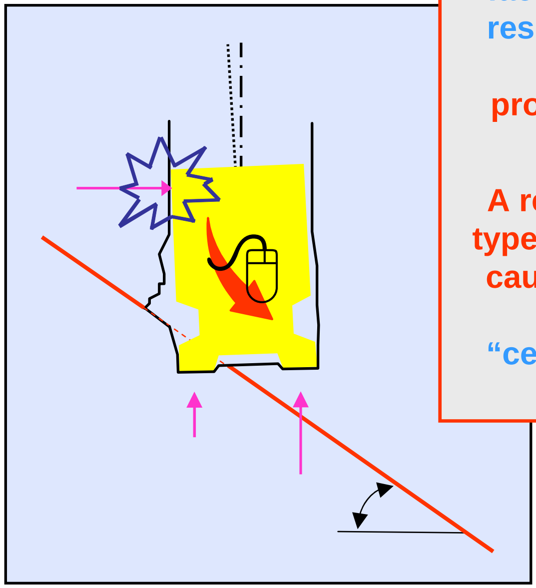
When the bit starts to drill through the fracture surface on the hole bottom - the gauge buttons tend to skid off this surface and thus deflect the bit.

More aggressively shaped gauge inserts (ballistic / chisel inserts) and bit face profiles (drop center) reduce this skidding by allowing the gauge buttons to “cut” through the fracture surface - thus resulting in less overall bit and drill string deflection.



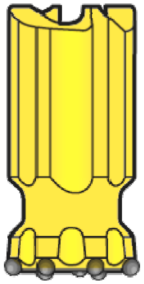
Drilling Management

How bit skirt designs enhance drill-hole straightness



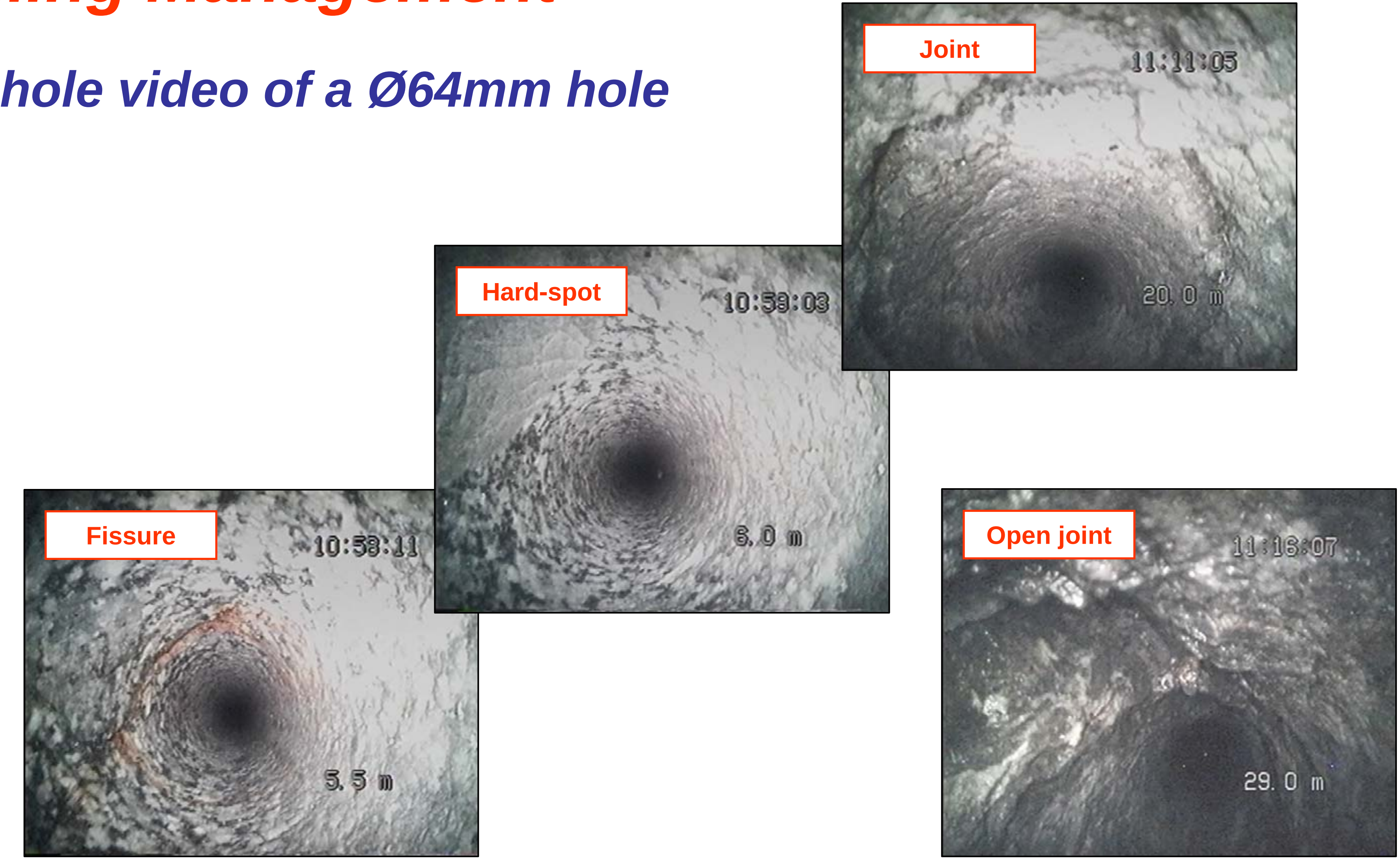
When the bit is drilling through the fracture surface - uneven bit face loading conditions arise; resulting in bit and drill string deflections - which are proportional to the bit impact force.

A rear bit skirt support (retrac type bits) reduces bit deflection caused by the uneven bit face loading conditions by “centralizing” the bit with this rear support.



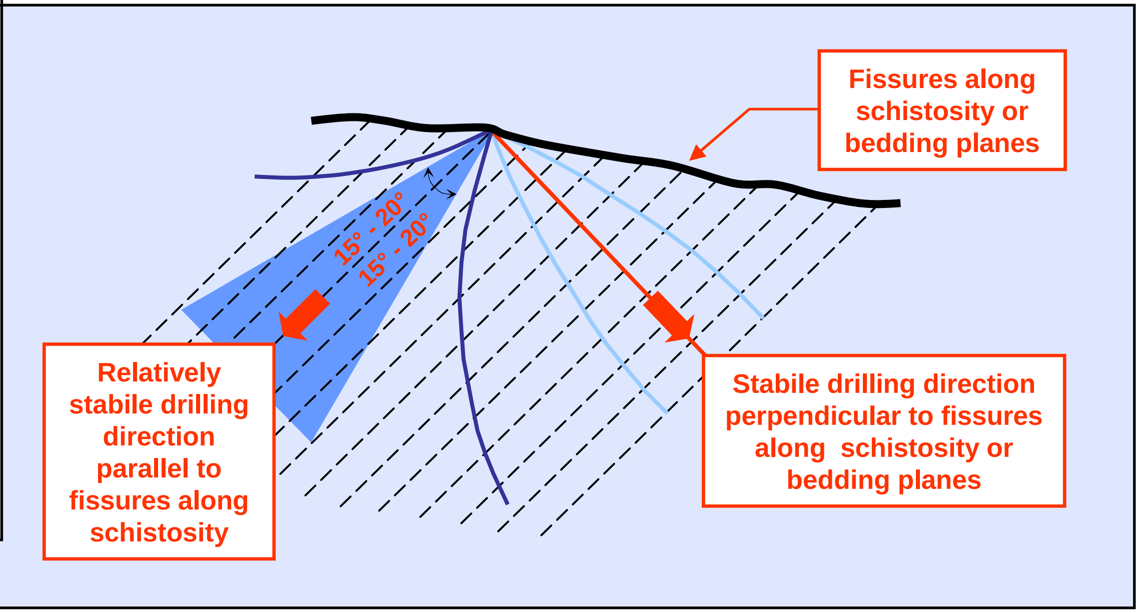
Drilling Management

Inhole video of a Ø64mm hole



Drilling Management

Drill-hole deflection trendlines in schistose rock



Fissures along schistosity or bedding planes

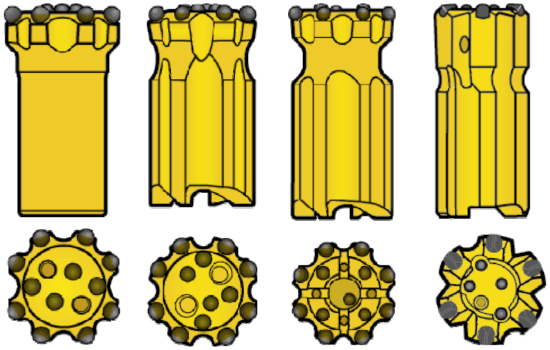
Relatively stabile drilling direction parallel to fissures along schistosity

Stabile drilling direction perpendicular to fissures along schistosity or bedding planes

Drilling Management

Selecting straight-hole drilling tools

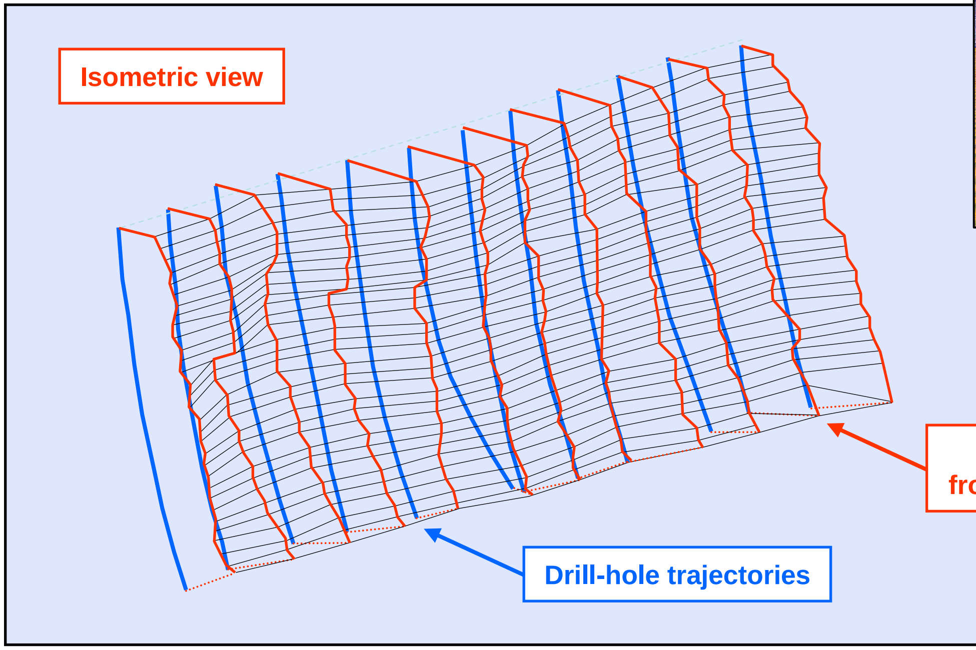
- ***optimum bit / rod diameter relationship***
- ***insert types / bit face and skirt***
  - *spherical / ballistic / chisel inserts*
  - *normal bits*
  - *retrac bits*
  - *drop center bits*
  - *guide bits*
- ***additional drill string components***
  - *guide tubes / pilot (lead) tubes*



Drilling Management

Documention of drilling and charging prior to blasting

- ***actual distribution** of explosives in the rock mass - indicating local variations of powder factor*
- ***risk of flyrock** from bench face and top*
- ***risk of flashover initiation** between shotholes*
- ***risk of dead pressing** of explosives*



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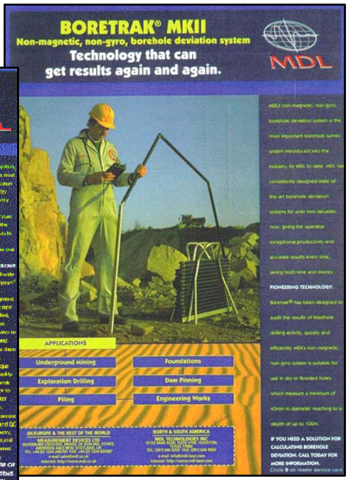


BORETRAK® MKII

Non-magnetic, non-gyro, borehole deviation system

Technology that can get results again and again.

MDL

APPLICATIONS

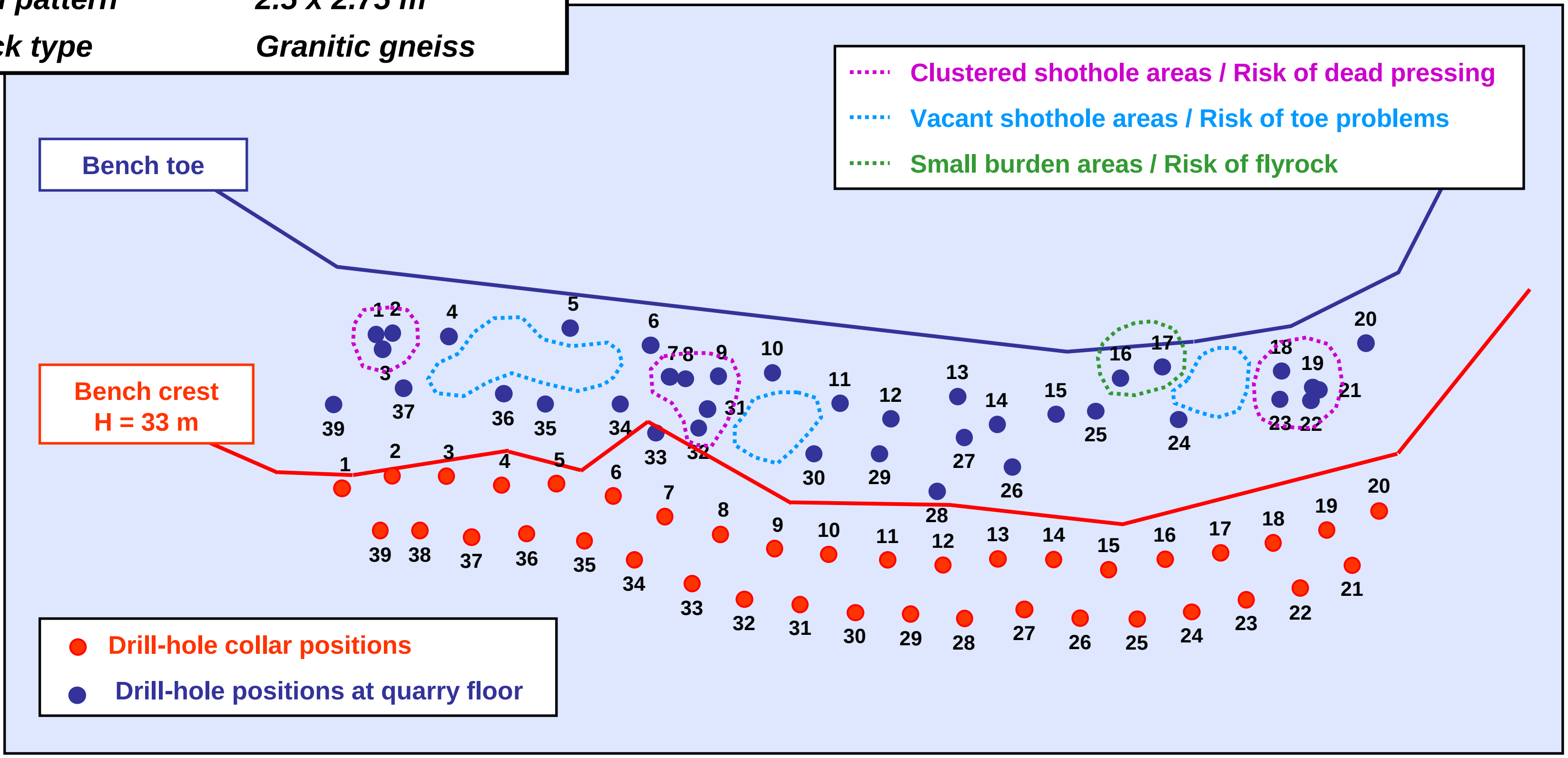
Underground Mining	Foundations
Exploration Drilling	Dam Pinning
Piling	Engineering Works

IF YOU NEED A SOLUTION FOR CALCULATING BOREHOLE DEVIATION, CALL TODAY FOR MORE INFORMATION.

Drilling Management

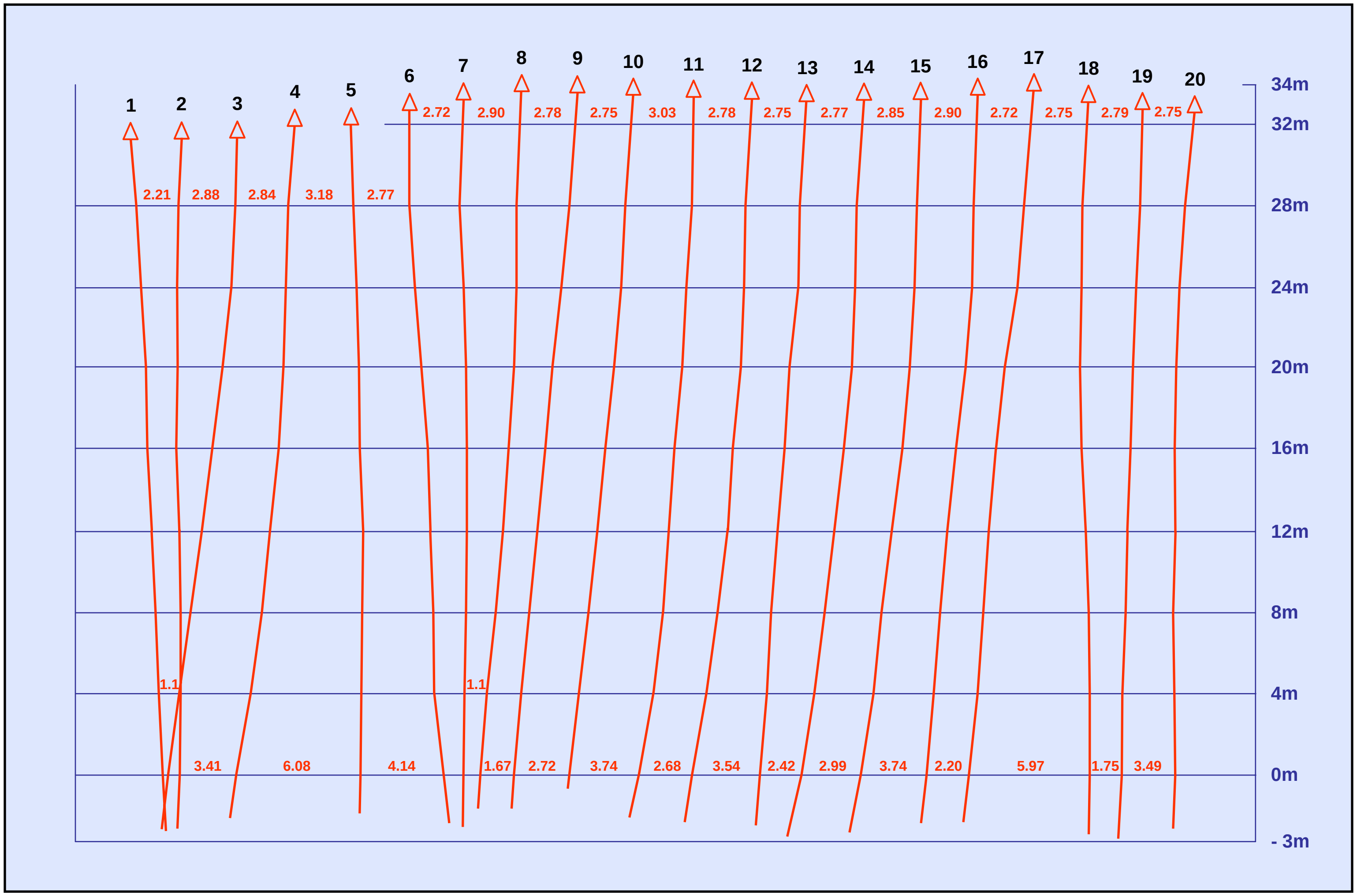
Drill pattern at quarry floor

Bench height	***33 m***
Hole inclination	***14°***
Drill steel	***Ø76 mm retrac / T45***
Drill pattern	***2.5 x 2.75 m^2***
Rock type	***Granitic gneiss***



Drilling Management

Vertical projection of Row 1



Drilling Management

Summary of H = 33m bench drill-hole deviation errors

Target inclination	14.0°
Average inclination	14.4°
Standard deviation	1.4°
Target azimuth	0.0°
Average azimuth	-7.6°
Standard deviation	7.7°

Bench height, H (m)	Drill-hole length, L (m)	Inclin. and directional errors, ΔL_{I+D} (mm)	Deflection errors, ΔL_{def} (mm)	Total deviation errors, ΔL_{total} (mm)	Deviation $\Delta L_{total} / L$ (%)
9	9.3	440 (140)	120	420	4.5
13	13.4	640 (210)	240	650	4.9
17	17.6	840 (275)	400	900	5.1
21	21.7	1040 (340)	610	1190	5.5
33	34.1	1630 (530)	1470	2270	6.7

(…) values where the systematic azimuth error has been excluded

Drilling Management

Summary of drill-hole deviation prediction

Prediction of overall drill-hole deviation magnitude

- **collaring errors** $\Delta L_C \sim d$
- **inclination + direction errors** $\Delta L_{I+D} = k_{I+D} \cdot L$
  $k_{I+D} = 20 - 60$ (mm/m) or 1.1° - 3.5°
- **deflection errors** $\Delta L_{def} = k_{def} \cdot L^2$
- **total errors** $\Delta L_{total} = (\Delta L_{I+D}^{\,2} + \Delta L_{def}^{\,2})^{1/2}$

Straight-hole drilling components

• driller	- marking, collaring position and feed foot slippage adjustment and feed control
• drill rig	- inclination and directional control, hole depth, drilling control systems, collaring procedures
• drill steel	- bit skidding while collaring, sagging and deflection control
• management	- quality and cost of shotrock production, blasting safety and documentation

Drilling Management

Prediction of deviation errors

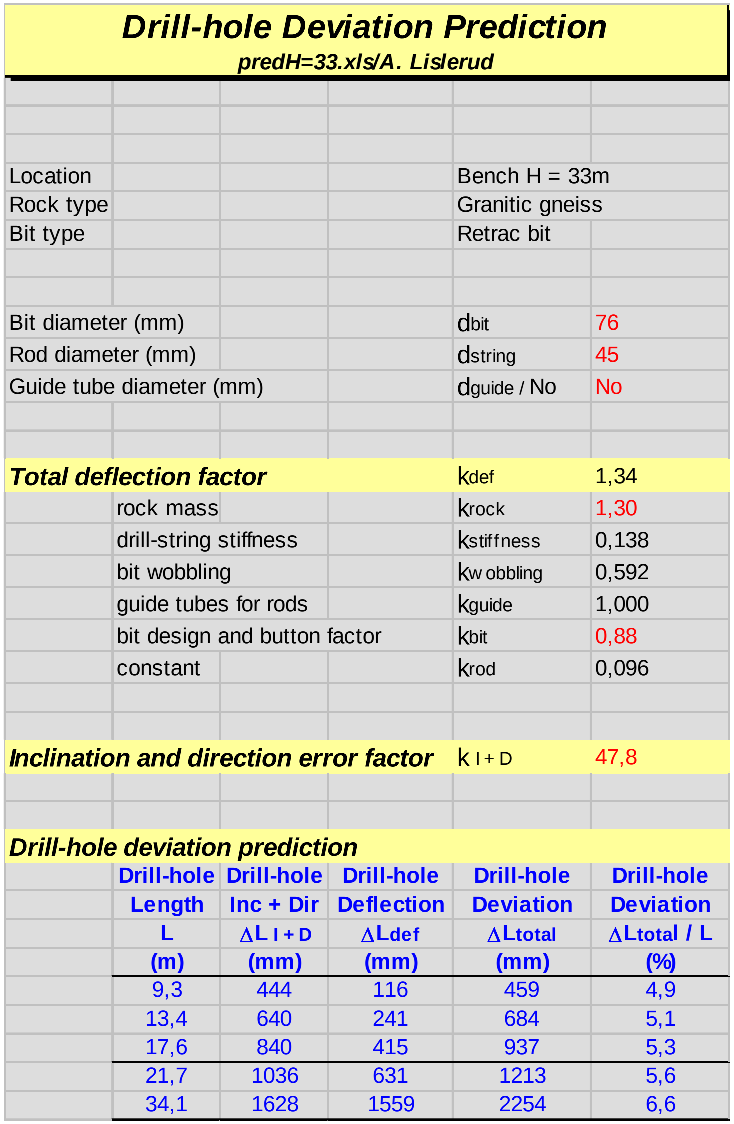
- *direction of deviation can not be "predicted"*
- *magnitude of deviation can be predicted*

Rock mass factor, k_{rock}

massive rock mass	0.33
moderately fractured	1.0
fractured	2.0
mixed strata conditions	3.0

Bit design and button factor, k_{bit}

normal bits & sph. buttons	1.0
normal bits & ball. buttons	0.70
normal X-bits	0.70
retrac bits & sph. buttons	0.88
retrac bits & ball. buttons	0.62
retrac X-bits	0.62
guide bits	0.38



Drill-hole Deviation Prediction

predH=33.xls/A. Lislerud

Location	Bench H = 33m
Rock type	Granitic gneiss
Bit type	Retrac bit

Bit diameter (mm)	d_{bit}	76
Rod diameter (mm)	d_{string}	45
Guide tube diameter (mm)	d_{guide} / No	No

Total deflection factor	k_{def}	1,34
rock mass	k_{rock}	1,30
drill-string stiffness	$k_{stiffness}$	0,138
bit wobbling	$k_{wobbling}$	0,592
guide tubes for rods	k_{guide}	1,000
bit design and button factor	k_{bit}	0,88
constant	k_{rod}	0,096
Inclination and direction error factor	k_{I+D}	47,8

Drill-hole deviation prediction

Drill-hole Length L (m)	Drill-hole Inc + Dir ΔL_{I+D} (mm)	Drill-hole Deflection ΔL_{def} (mm)	Drill-hole Deviation ΔL_{total} (mm)	Drill-hole Deviation ΔL_{total} / L (%)
9,3	444	116	459	4,9
13,4	640	241	684	5,1
17,6	840	415	937	5,3
21,7	1036	631	1213	5,6
34,1	1628	1559	2254	6,6

Drilling Management

How drilling errors affect down-stream operations

Drilling	• reduced drill steel life
Blasting	• danger of poor explosives performance in neighbouring shotholes due to deflagration or deadpressing • danger of flyrock due to poor control of front row burden
Load and Haul	• poor loading conditions on “new floors” with reduced loading capacities due to toes and quarry floor humps and locally choked (tight) blasts
Good practice	• max. drill-hole deviation up to 2-3 %