Drilling Applications

Arne Lislerud – Bill Hissem

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

Drilling Management

Agenda

- *well planned operations and correctly selected rigs yields low cost drilling*
- *technically good drilling and correctly selected drill steel yields low cost drilling operations*
- *straight hole drilling yields safe and low cost D&B operations*

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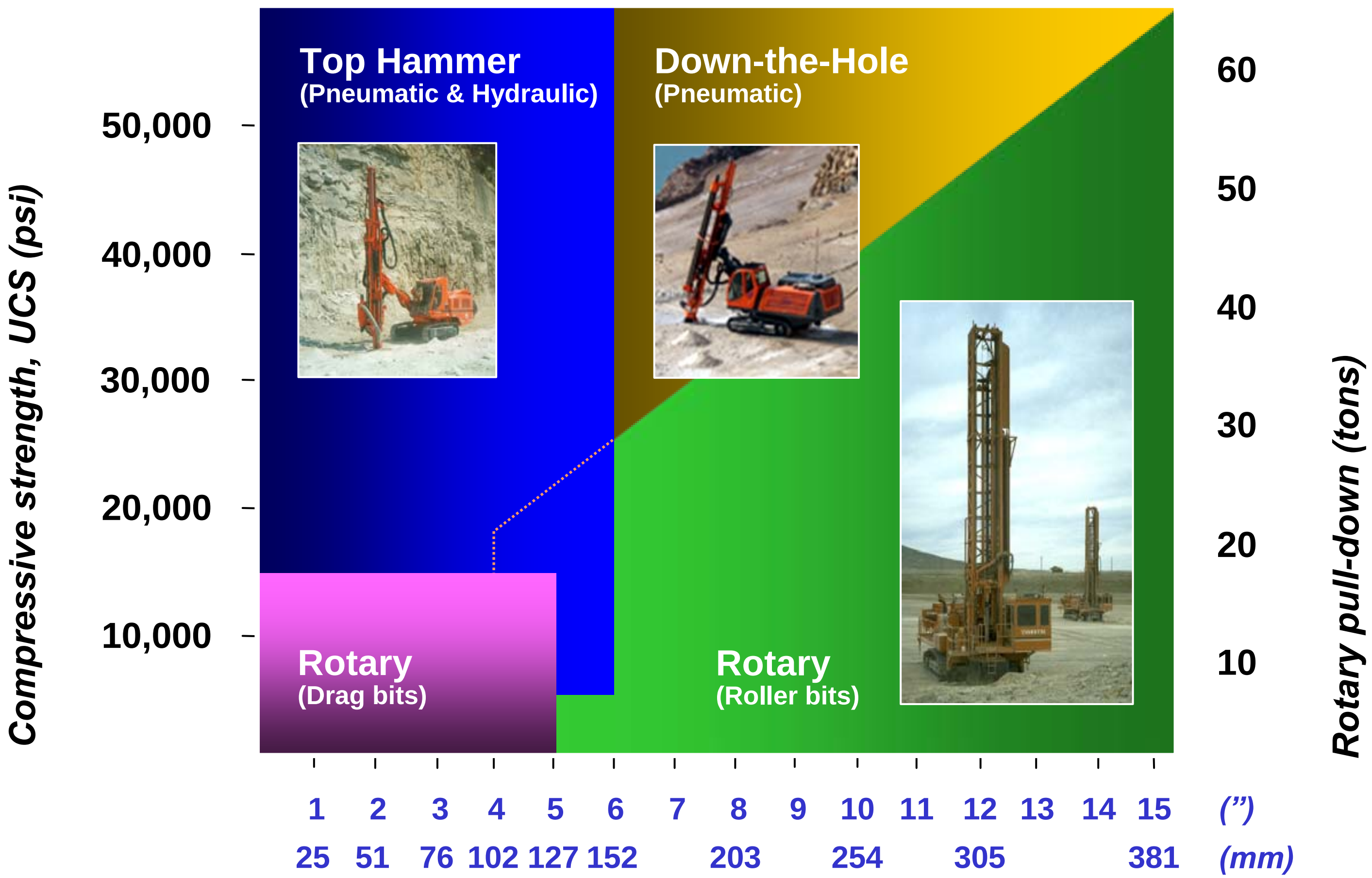
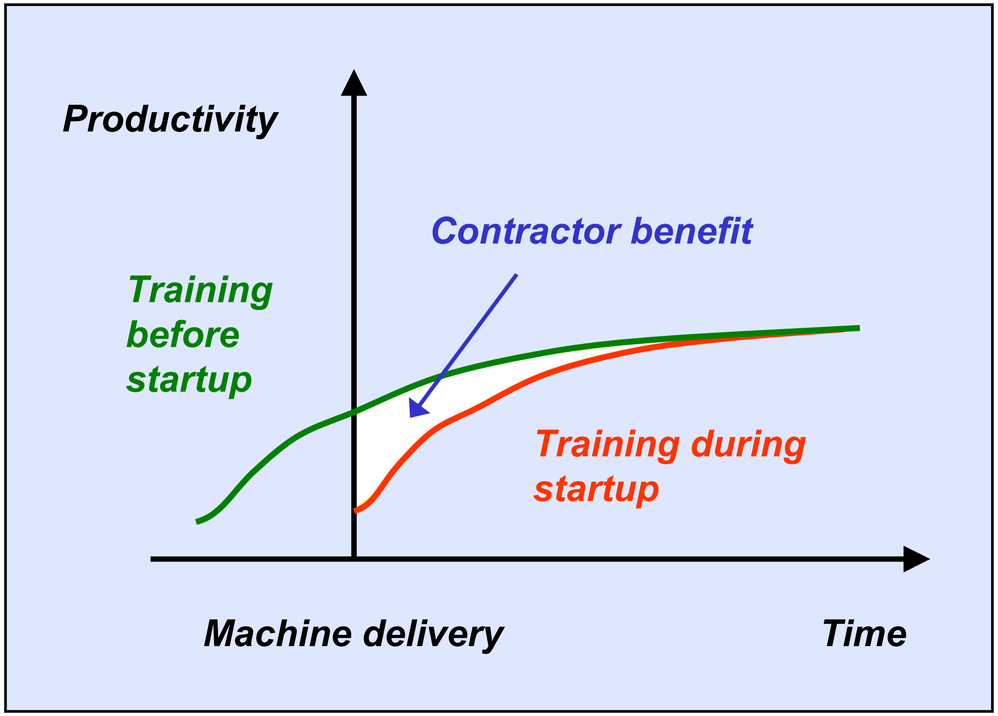
Drilling Management

The most common drilling methods in use



Drilling Management

Simulation tools – Operator training for DPi



Drilling Management

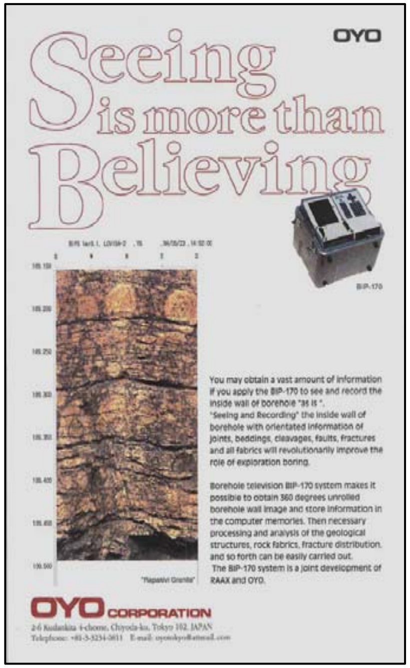
Drilling consists of a working system of:

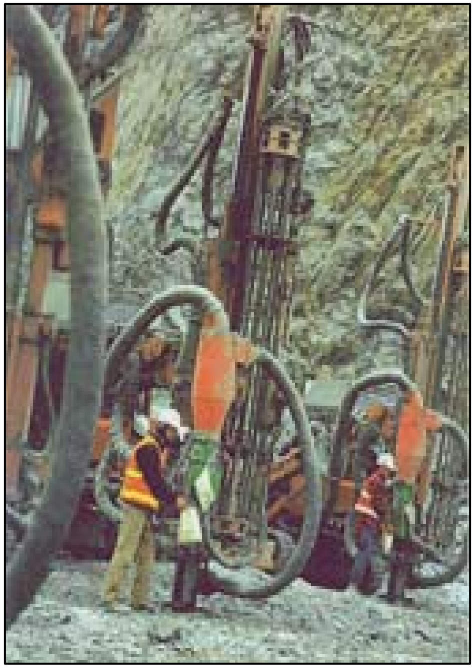
- *bit*
- *drill string*
- *boom or mast mounted feed*
- *TH or DTH - hammer*
  Rotary - thrust
- *drill string rotation and stabilising systems*
- *drilling control system(s)*
- *powerpack*
- *automation and data acquisition packages*
- *collaring position and feed alignment systems*
- *flushing (air, water or foam)*
- *dust suppression equipment*
- *sampling device(s)*

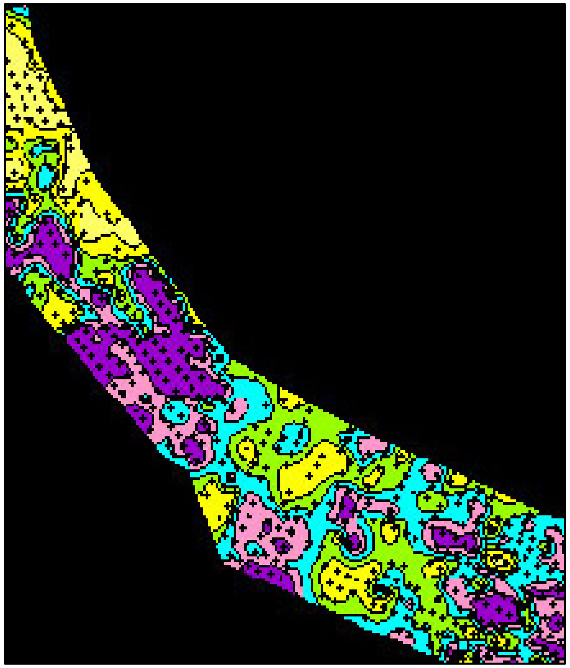
Drilling Management

In situ testing of rock mass properties

- *inhole video surveys of shotholes*
- *sampling of cuttings for chemical analysis*
- *measurement-while-drilling or MWD based digital pit mapping*







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Drilling Management

Occupational health and safety

- ***work related accidents for:***
  - ✓ ***mobile equipment***
  - ✓ ***hazardeous work areas***
- ***emissions control***
- ***noise control***
- ***dust control***
- ***fly rock / charging / straight-hole drilling***
- ***falling rocks / wall control***

=> safety is as much equipment as it is attitude

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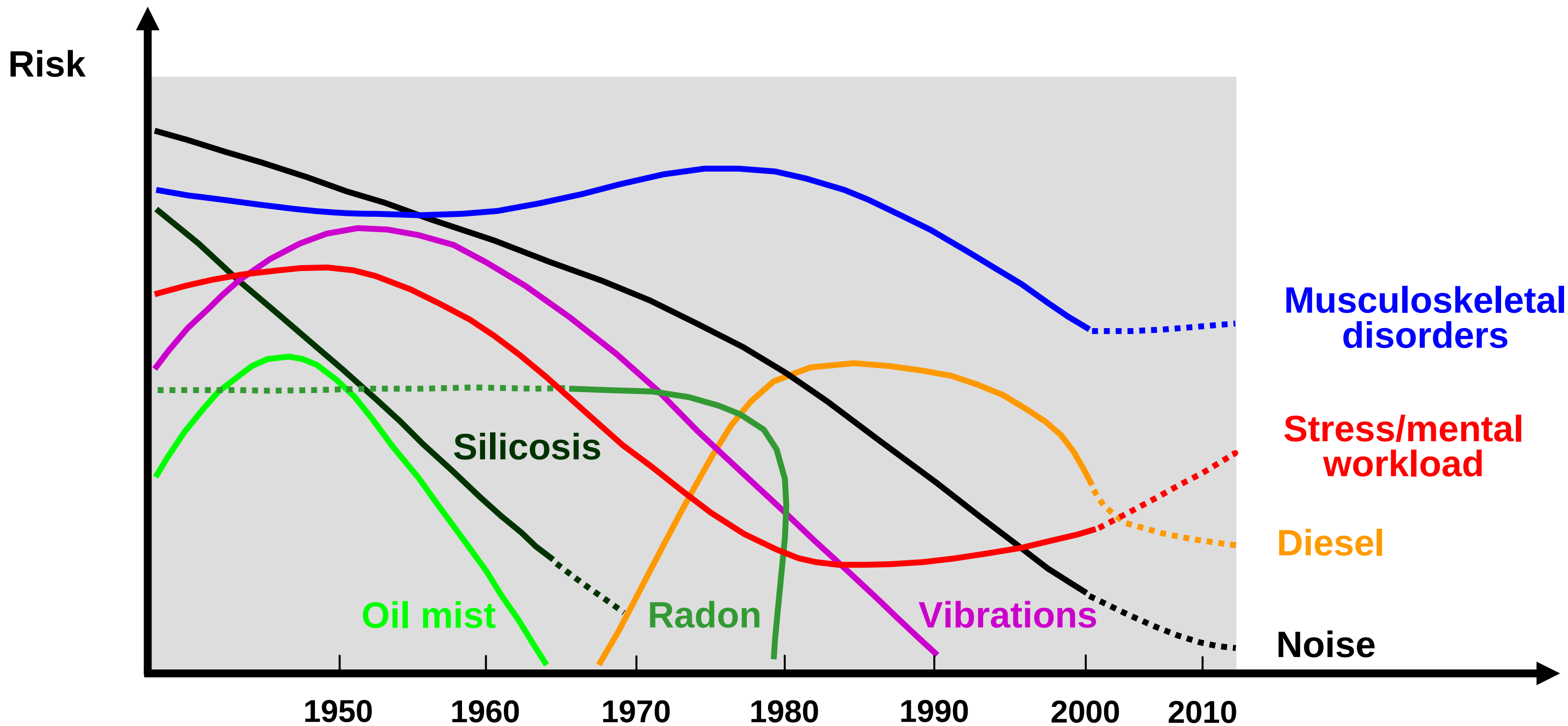
Drilling Management

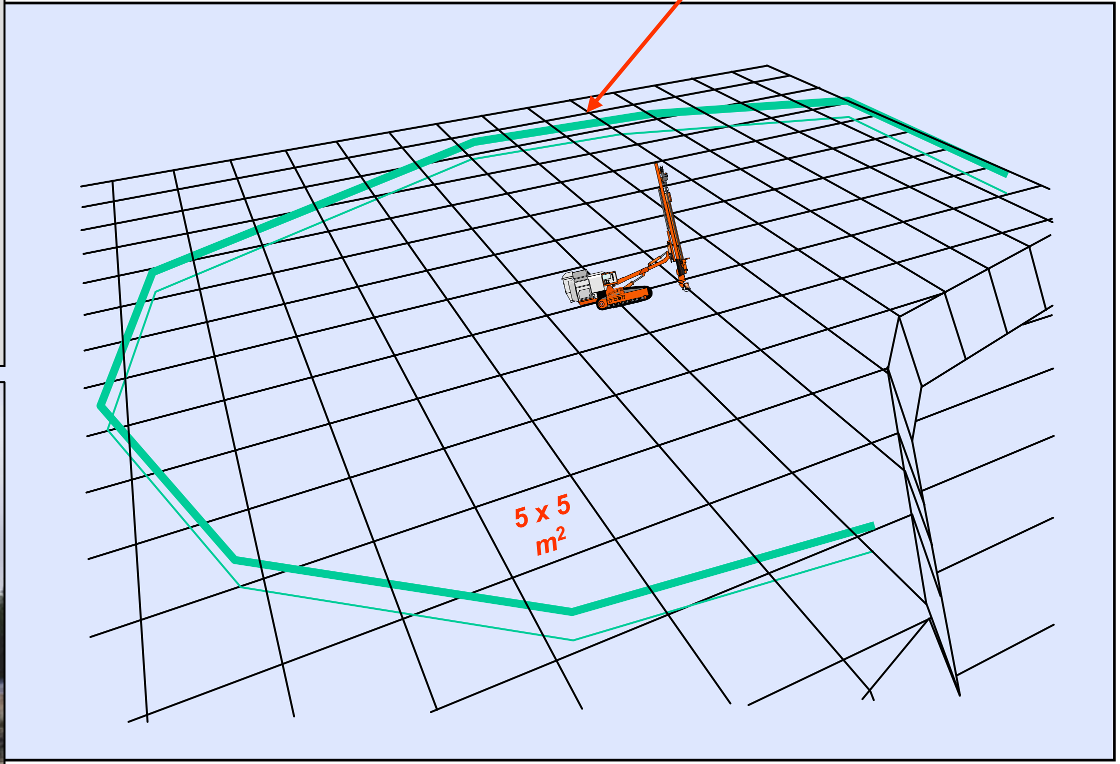
General assessment of some health risks by Swedish authorities (UG + SF)



Drilling Management

Drilling noise levels - TH

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. 10 dB(A)

Drilling Management

Safety issues of inpit operations

- *pit planning and operations supervision*
- *safety consciousness of workforce*
- *operator hazard training*

=> minimum occurrence of accidents

Rollover from terrain bench - 35m drop

Premature ignition of electric detonators and blast due to lightning

Pit wall failure burying 3 drill rigs in rubble

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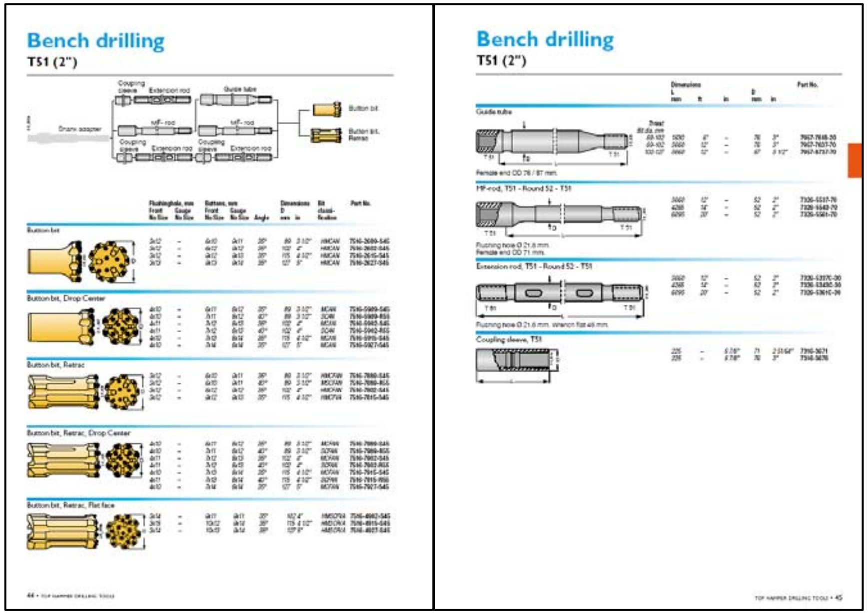
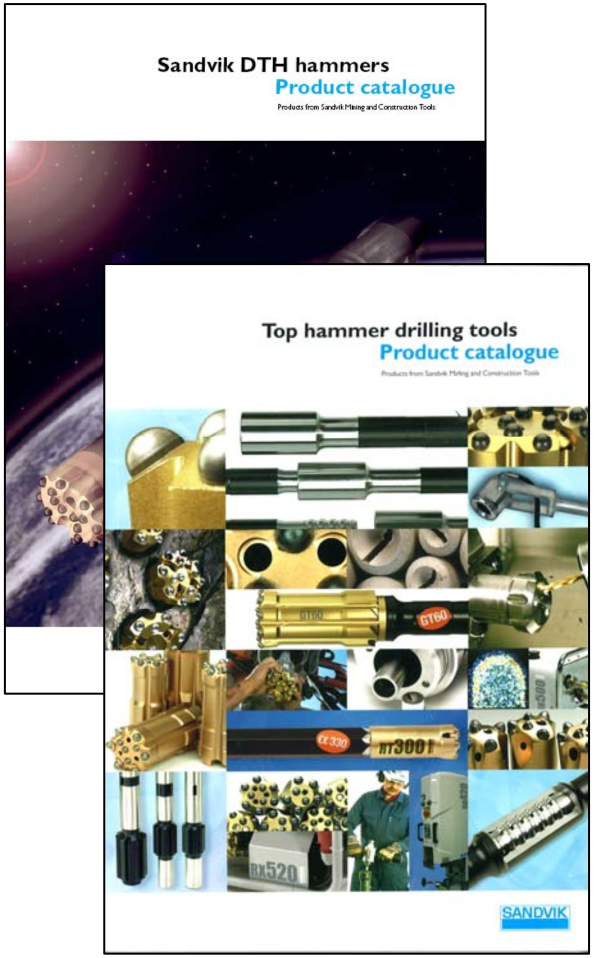
Drilling Management

Selecting drilling tools - TH

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





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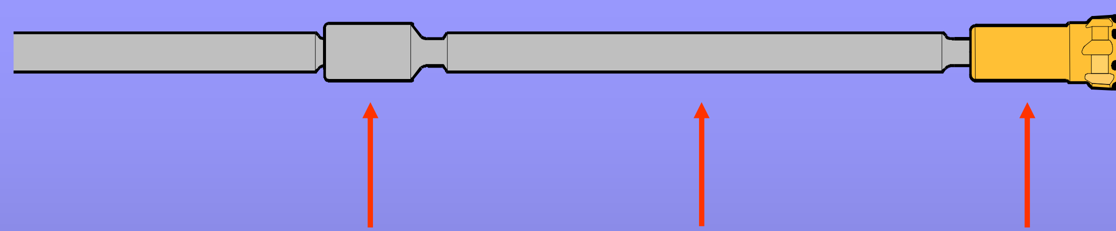
Drilling Management

Optimum bit / rod diameter relationship - TH



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	∅60/64	∅102

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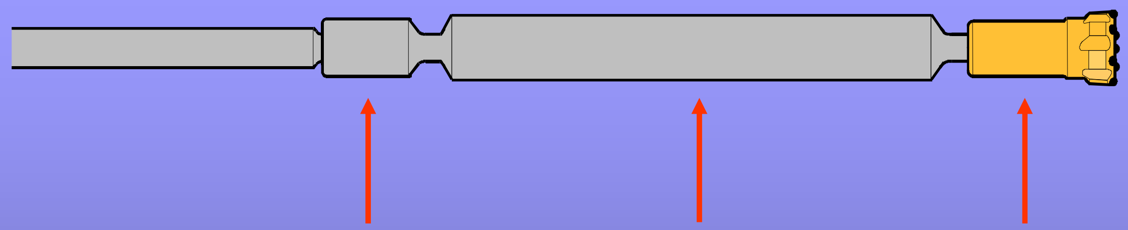
Drilling Management

Optimum bit / guide or pilot (lead) tube relationship - TH



Thread	Cross section coupling	Cross section	Optimum bit size
T38	∅55	∅56	∅64
T45	∅63	∅65	∅76
T51	∅71	∅76	∅89
GT60	∅85	∅87	∅102
GT60	∅85	∅102	∅115

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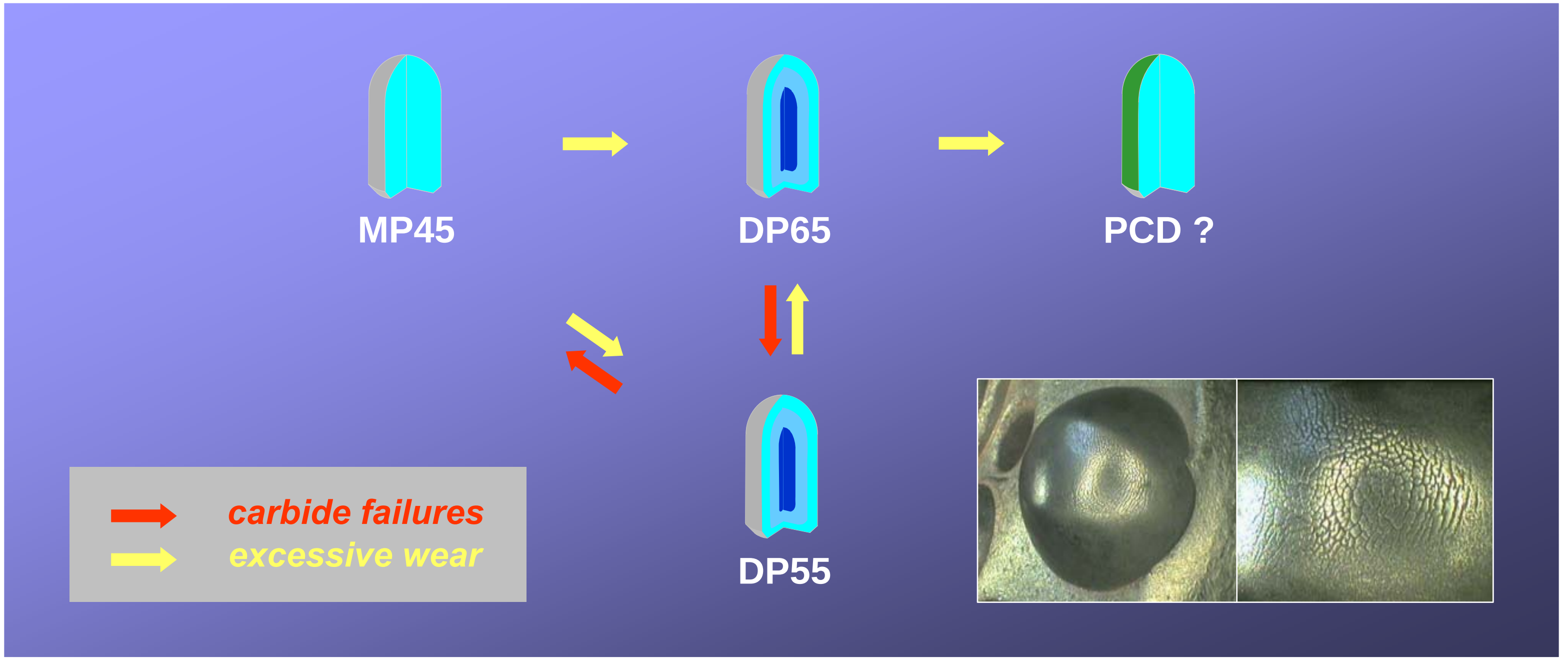
Drilling Management

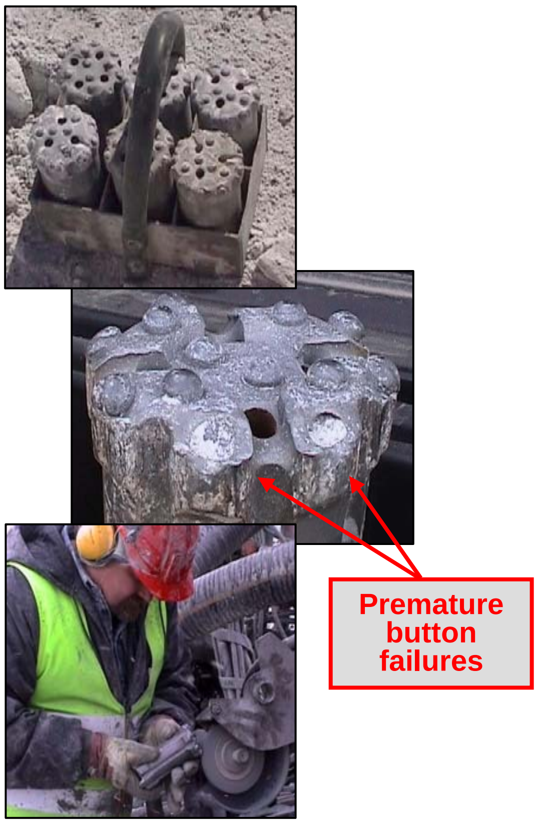
Guidelines for selecting cemented carbide grades

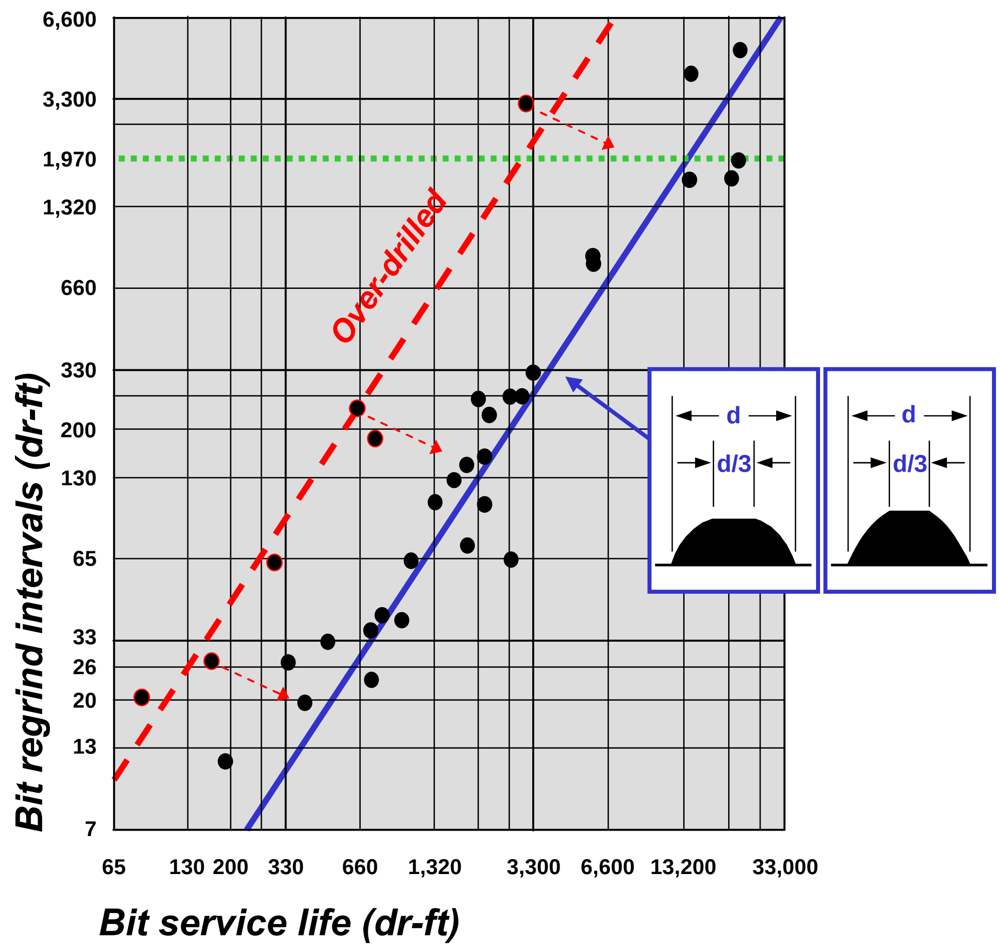
- *avoid excessive button wear (rapid wearflat development)*
  => select a more wear resistant carbide grade
- *avoid button failures (due to snakeskin development or too aggressive button shapes)*
  => select a less wear resistant or tougher carbide grade or spherical buttons



Drilling Management

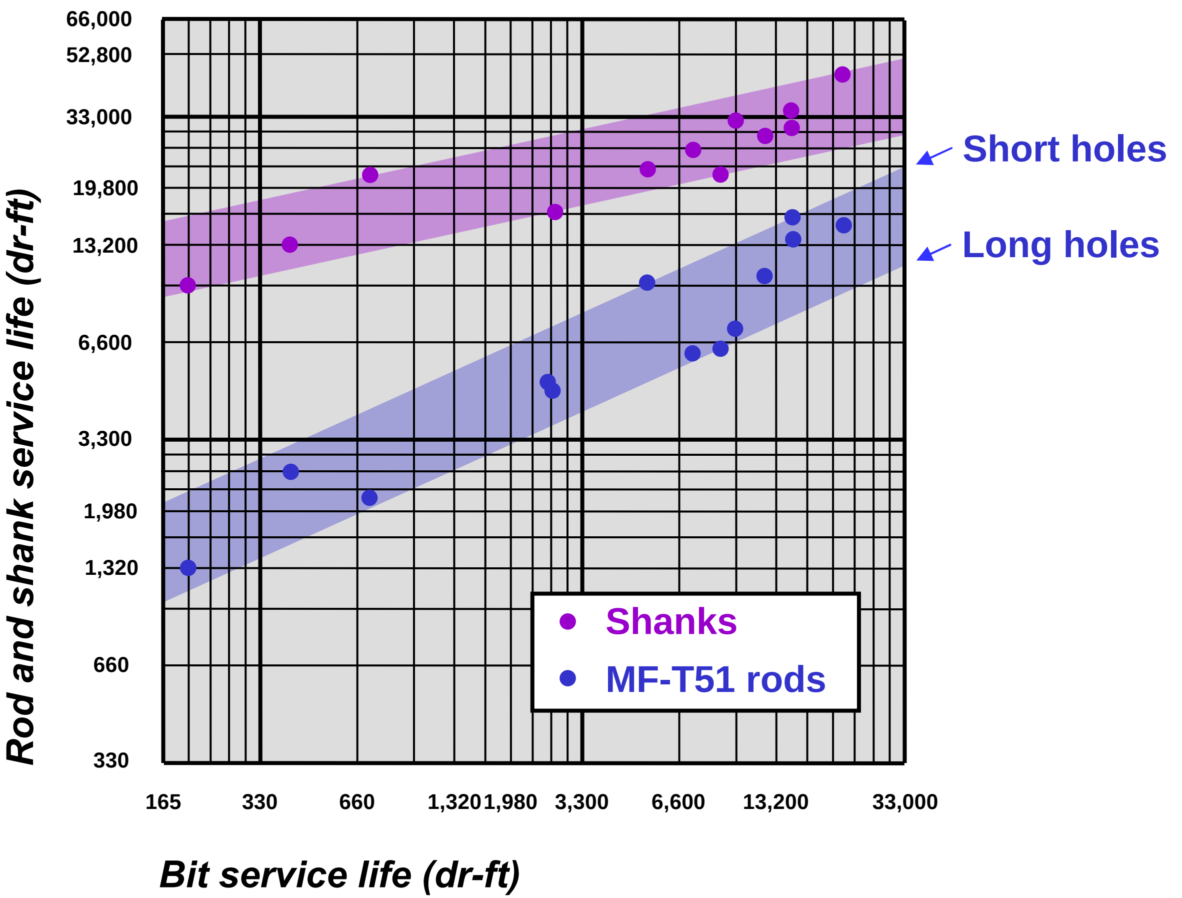
Bit regrind intervals, bit service life and over-drilling





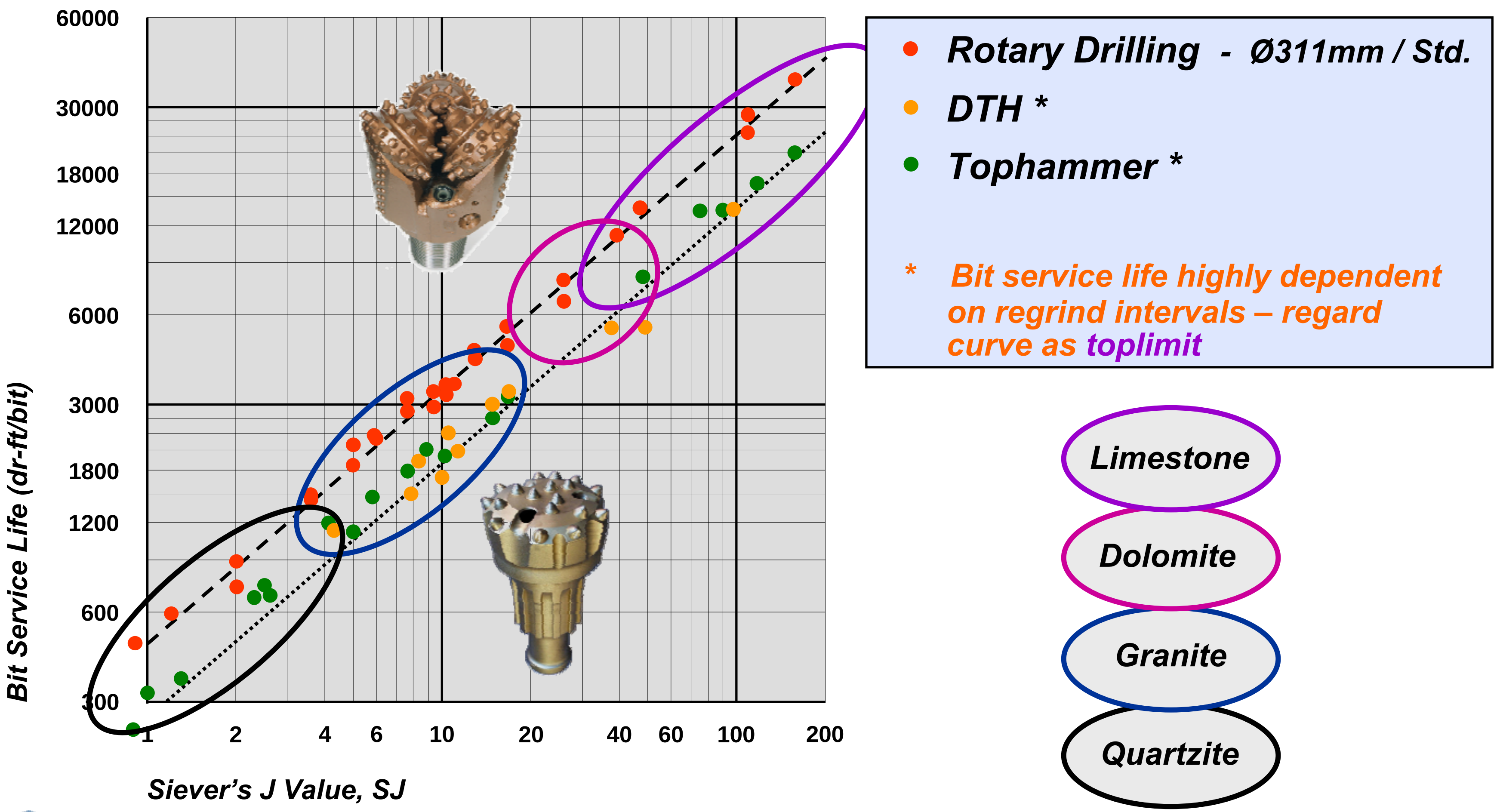
Drilling Management

Example of drill steel followup for MF-T51



Drilling Management

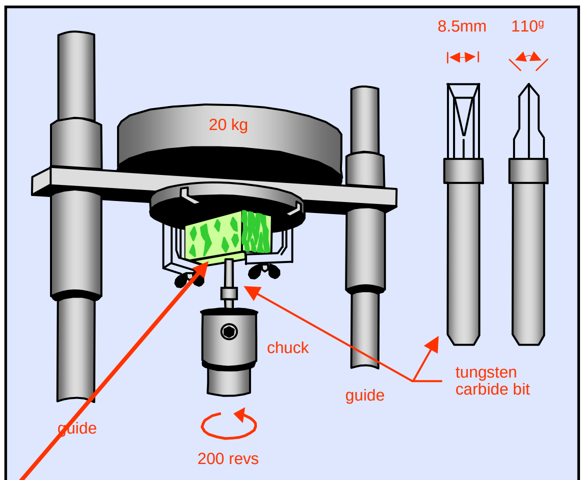
Trendlines for bit service life

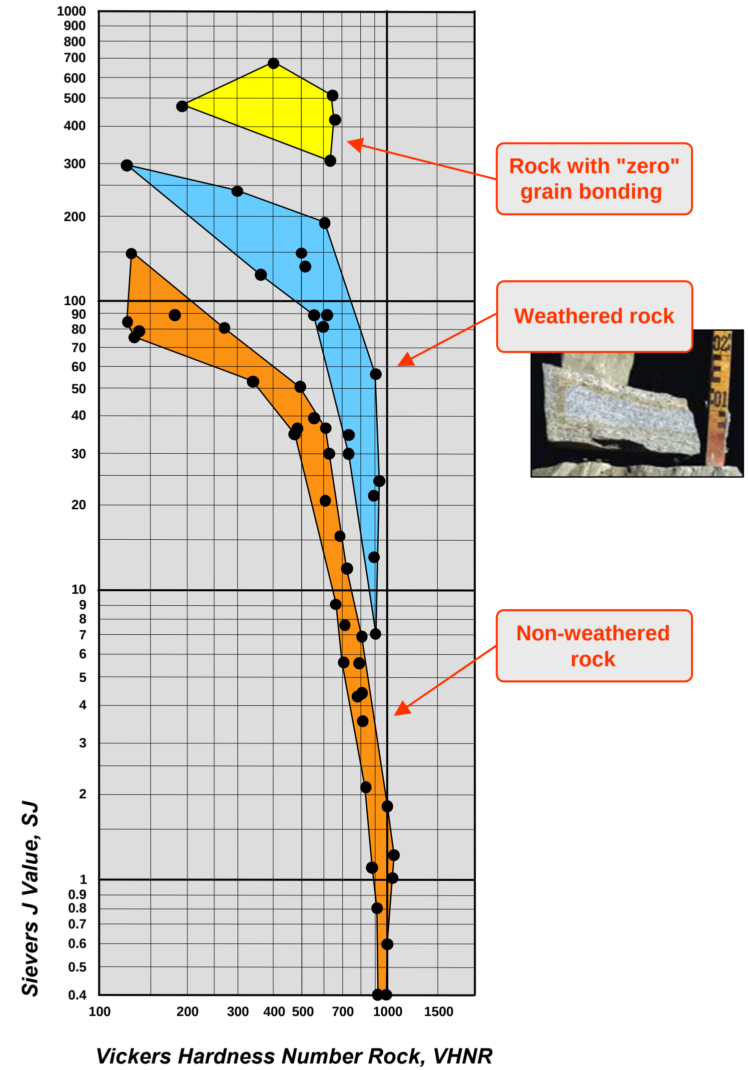


Drilling Management

Relationship SJ and VHNR

- ***rock surface hardness, VHNR***
- ***rock surface hardness, SJ***



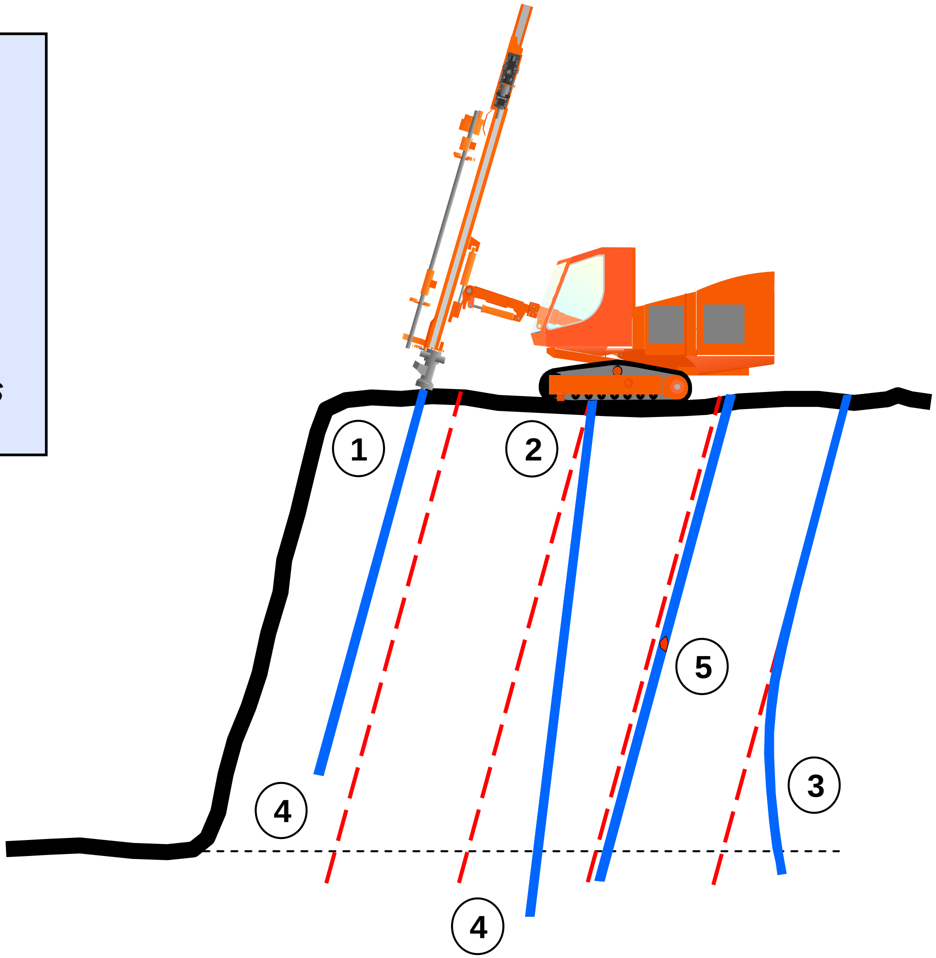


Drilling Management

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

Deflection with and without pilot tube for Ø3½” DC retrac bit / T51 in micaschist

Directional error Ø3½” retrac bit / T45 in granite

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

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 with PS feeds*
Bench height	*7.6 m with 40° inclined walls*
Drill steel	*Ø3” retrac / T45*
Target accuracy at hole bottom	*152 mm at 10.0 m or 15.2 mm/m*
Rock type	*biotite-granite gneiss*

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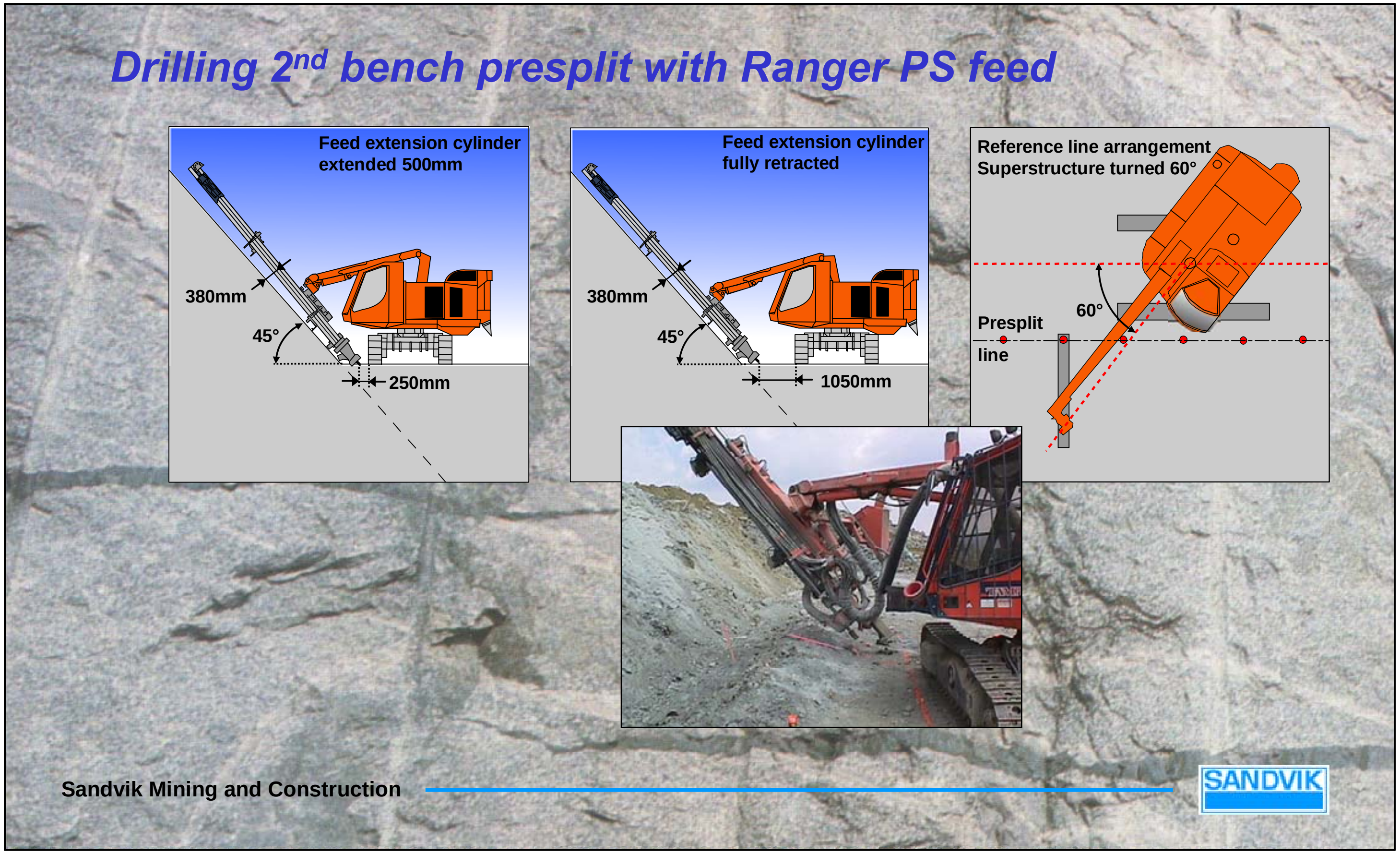
Drilling Management

I-26 Mars Hill Highway Project, North Carolina



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Drilling Management

Lafarge Bath Operations, Ontario

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

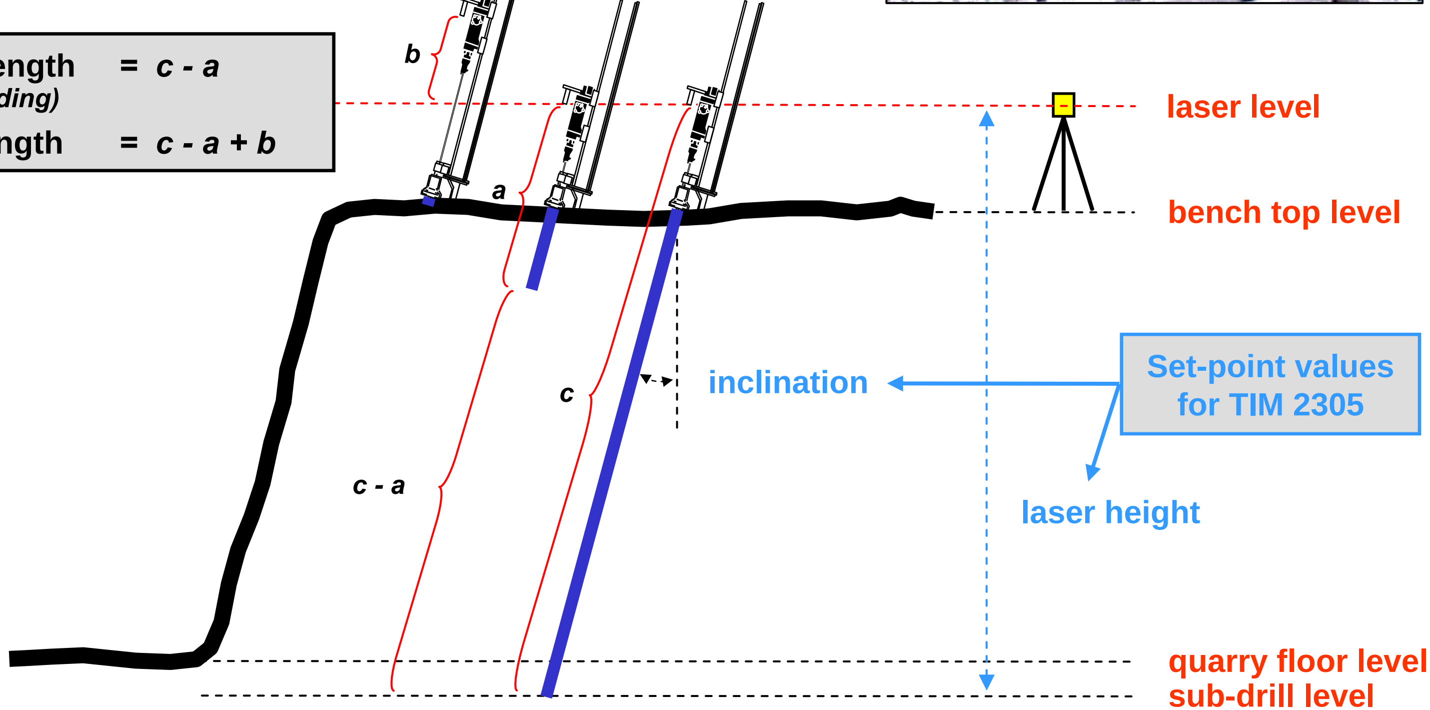
Current program - Pantera 1500

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

Hole depth error control

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



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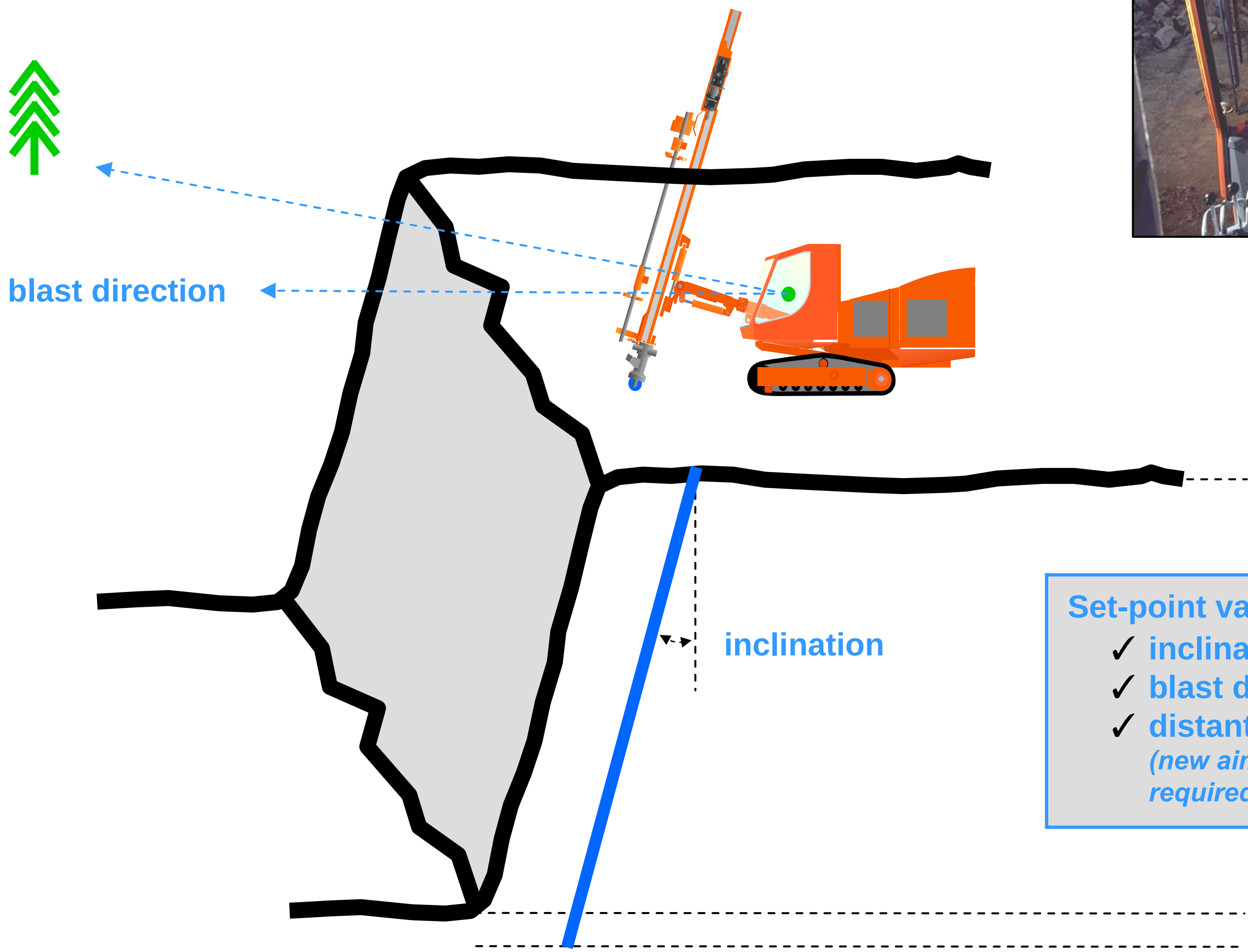
Inclination and directional error control

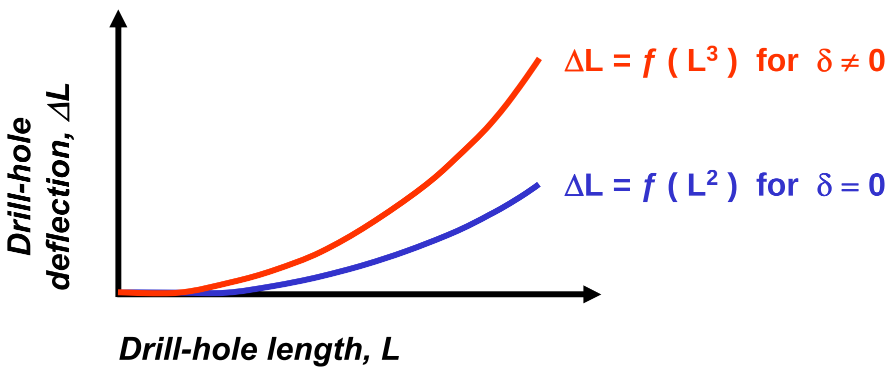


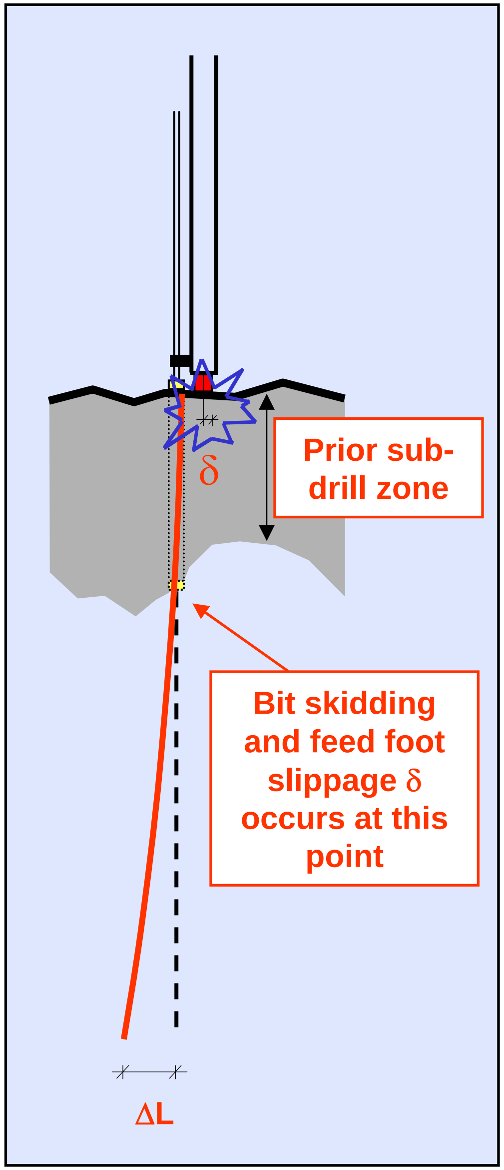
Set-point values for TIM 2305
- ✓ inclination
- ✓ blast direction projection
- ✓ distant aiming point direction
  (new aiming point reading required when tracks are moved)

Drilling Management

Drill-hole deflection error control

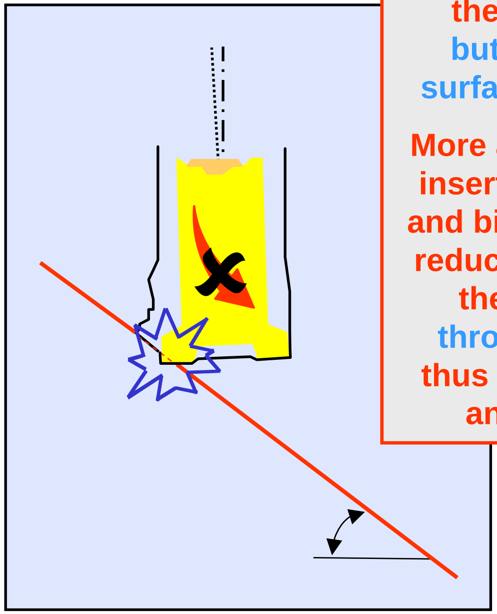
- *select bits less influenced by rock mass discontinuities*
- *reduce drill string deflection by using guide tubes, etc.*
- *reduce drill string bending by using less feed force*
- *reduce feed foot slippage while drilling - since this will cause a misalignment of the feed and lead to excessive drill 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*





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.

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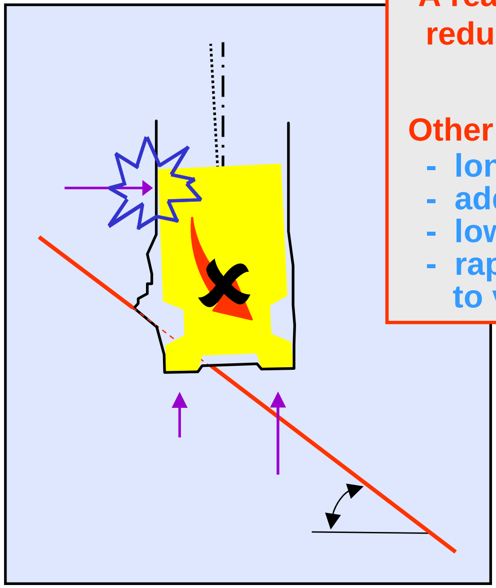
Drilling Management

How bit skirt designs enhance drill-hole straightness

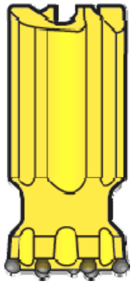


As the bit cuts through the joint surface - an uneven bit face loading condition arises; resulting in bit and drill string axial rotation - which is proportional to bit impact force imbalance.

A rear bit skirt support (retrac type bits) reduces bit and string axial rotation by "centralizing" the bit.

Other counter measures:

- longer bit body
- add a pilot tube
- lower impact energy
- rapid drilling control system reacting to varying torque and feed conditions



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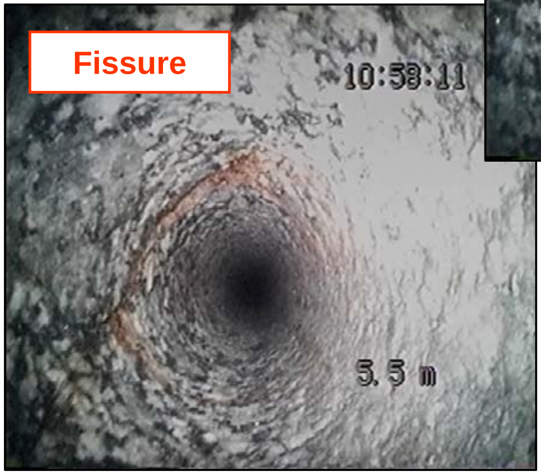
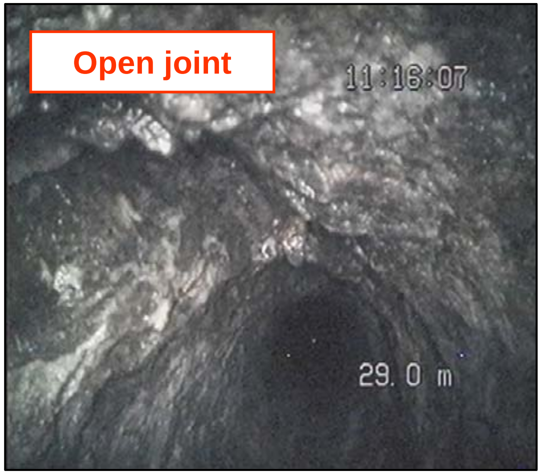
Drilling Management

Inhole video of a Ø64mm hole





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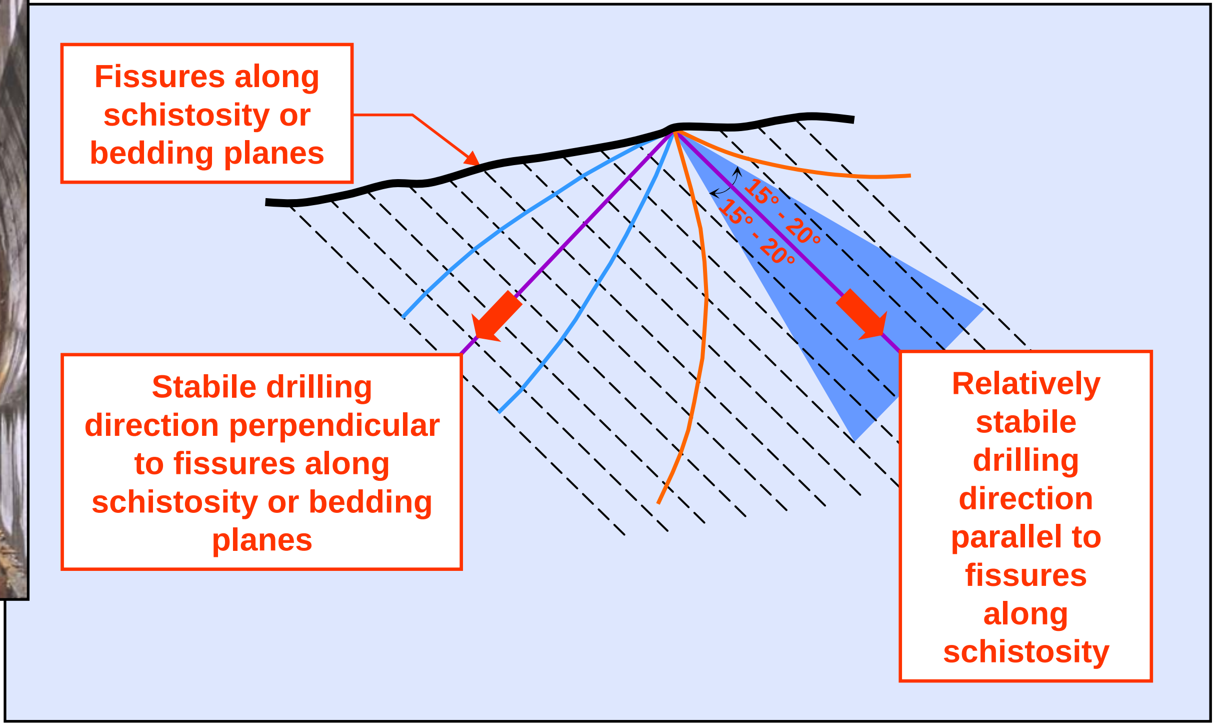
Drilling Management

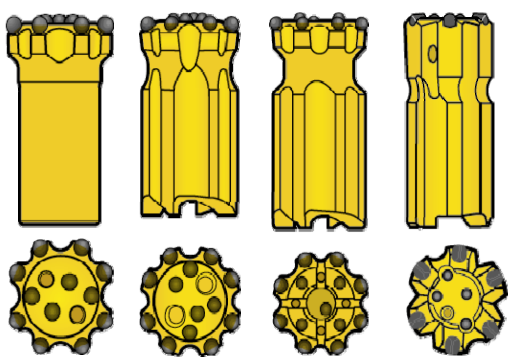
Drill-hole deflection trendlines in schistose rock



Drilling Management

Selecting straight-hole drilling tools - TH

- ***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*



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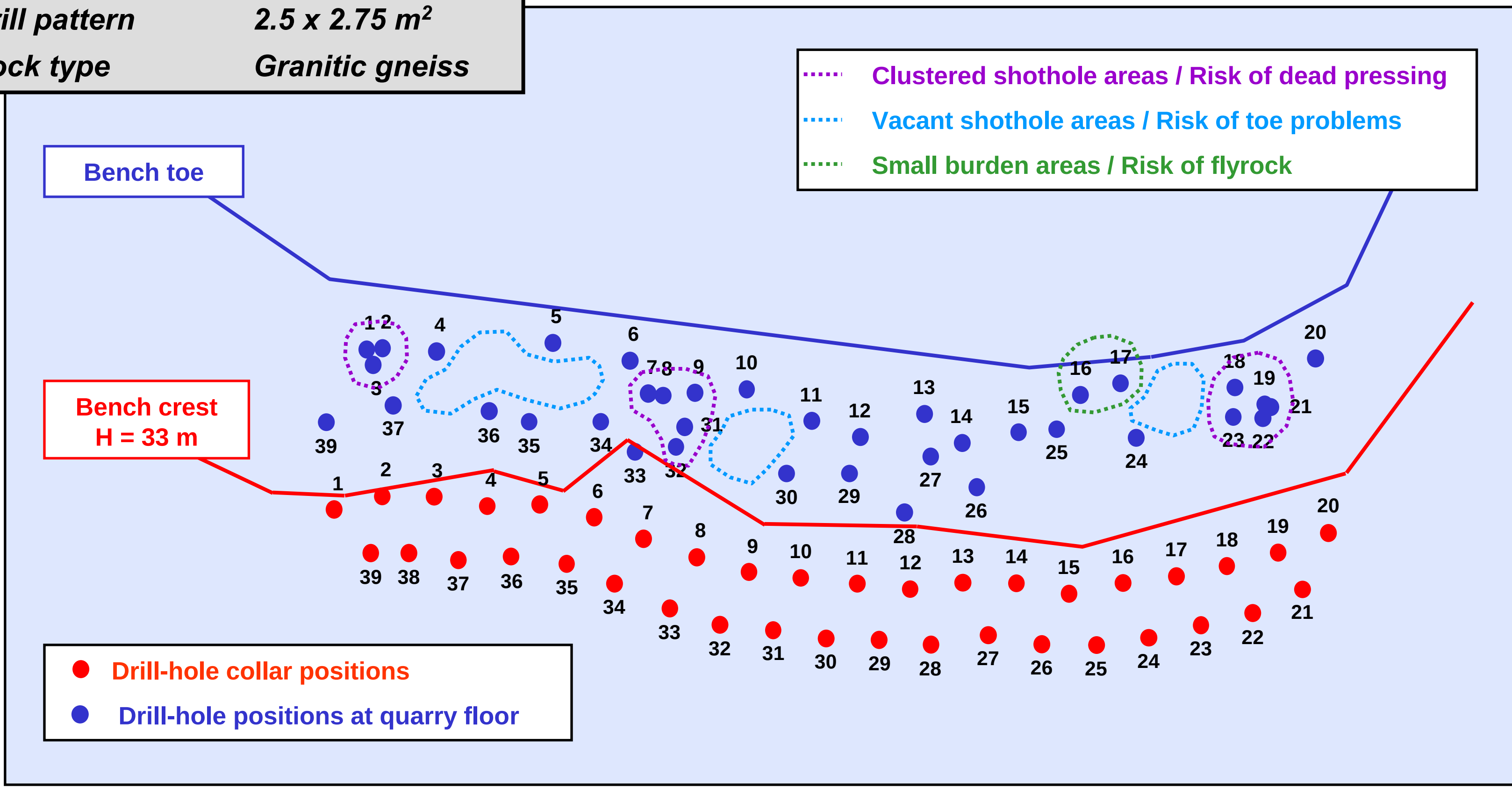
Drilling Management

Drill pattern at quarry floor

Bench height	*33 m*
Hole inclination	*14°*
Drill steel	*Ø3” retrac / T45*
Drill pattern	*2.5 x 2.75 m²*
Rock type	*Granitic gneiss*



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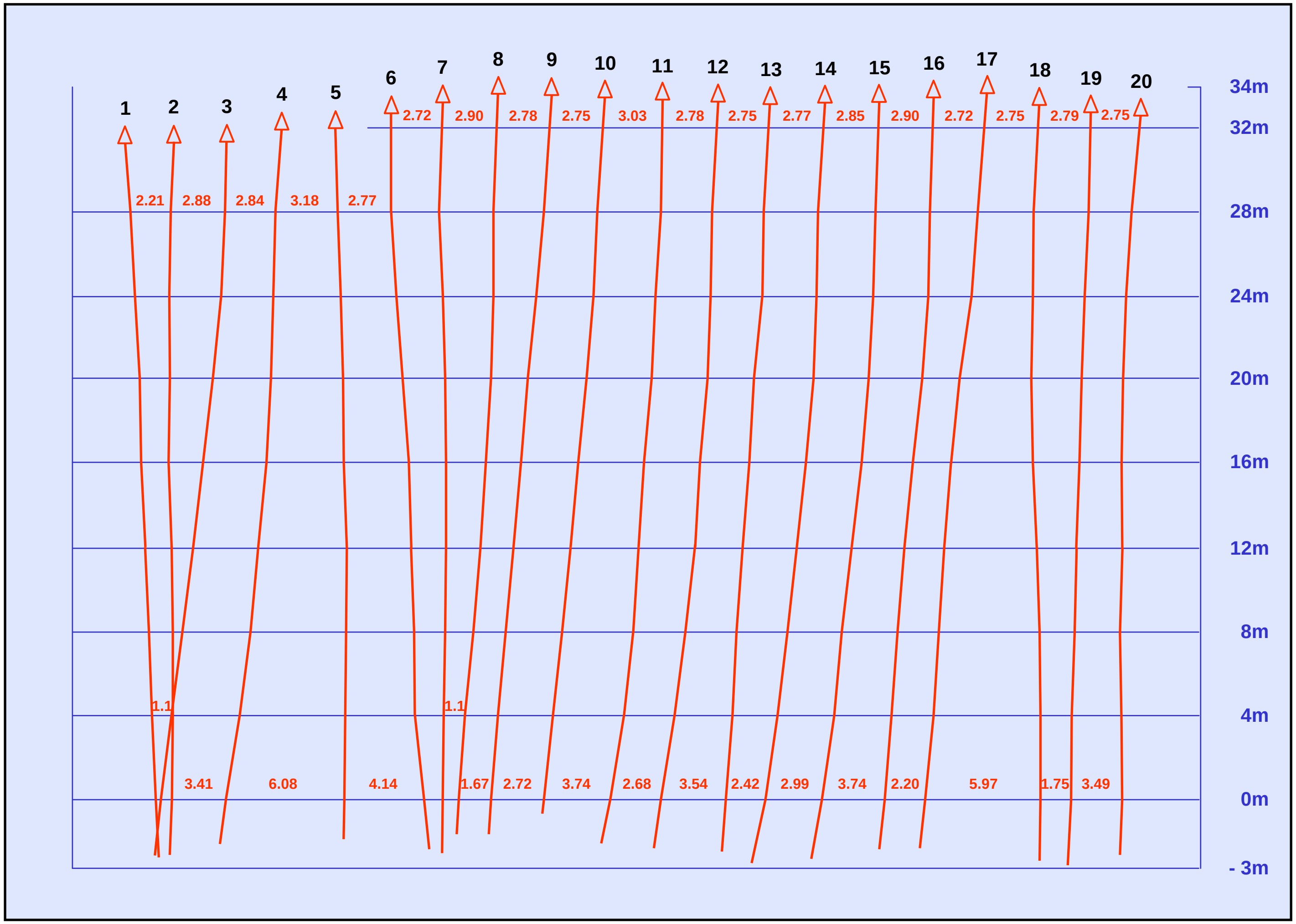
Drilling Management

Vertical projection of Row 1



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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

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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 %***

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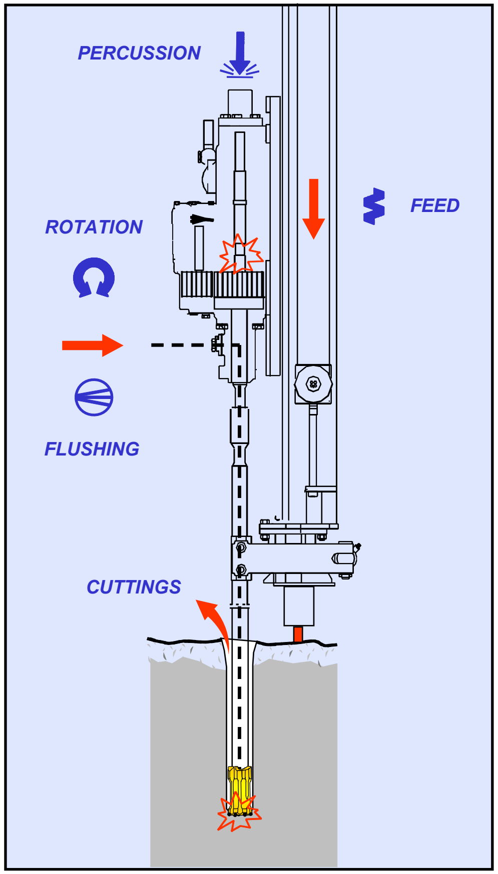
Drilling Management

Mechanics of percussive drilling



Percussive drilling

✓ Down-the-hole, DTH
Stress waves transmitted directly through bit into rock

✓ Tophammer
Stress wave energy transmitted through shank, rods, bit and then into rock

Basic functions

✓ percussion - reciprocating piston used to produce stress waves to power rock indentation

✓ feed - provide bit-rock contact during impacts

✓ rotation - provide bit indexing

✓ flushing - cuttings removal from hole bottom

✓ foam flushing - drill-hole wall stabilisation

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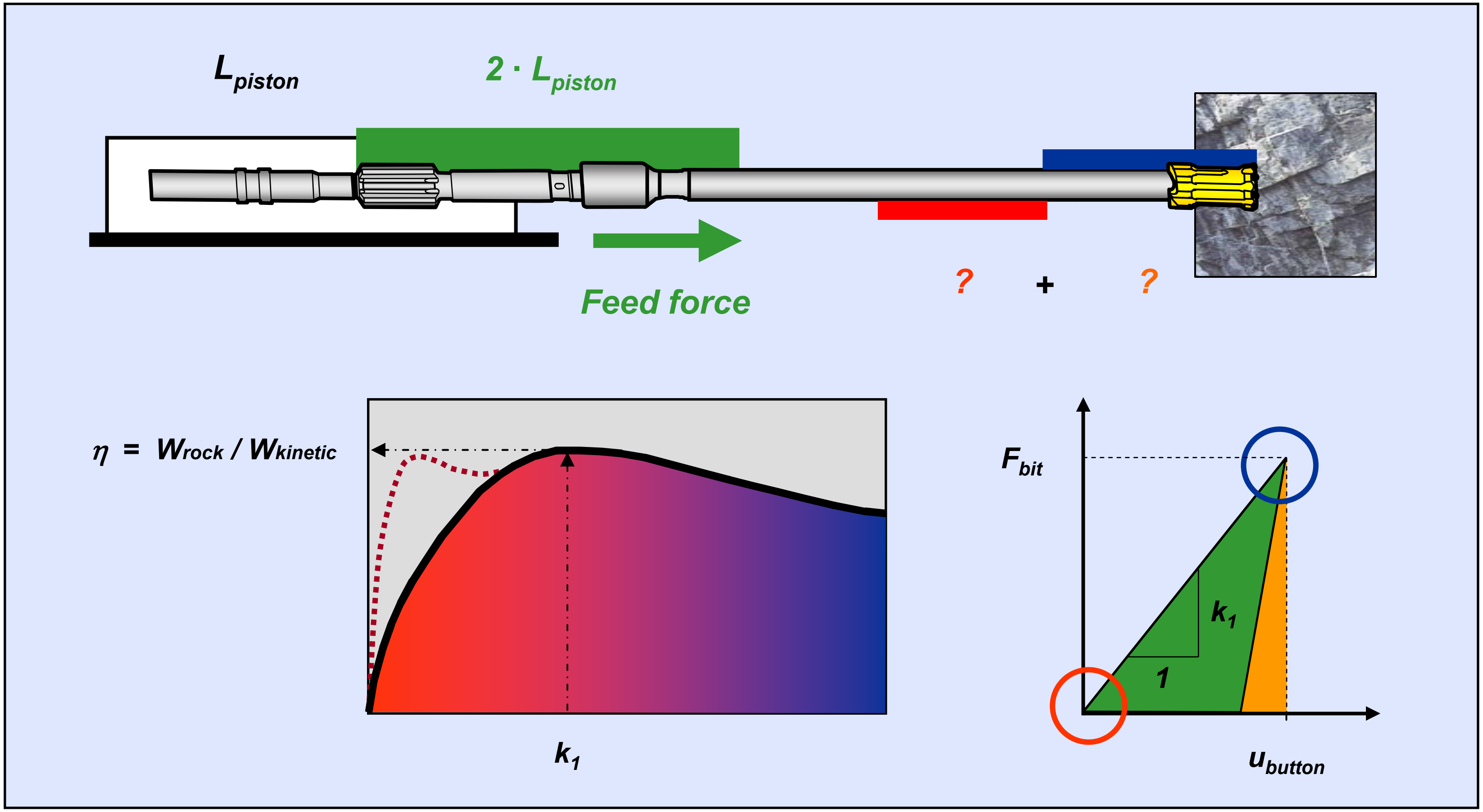
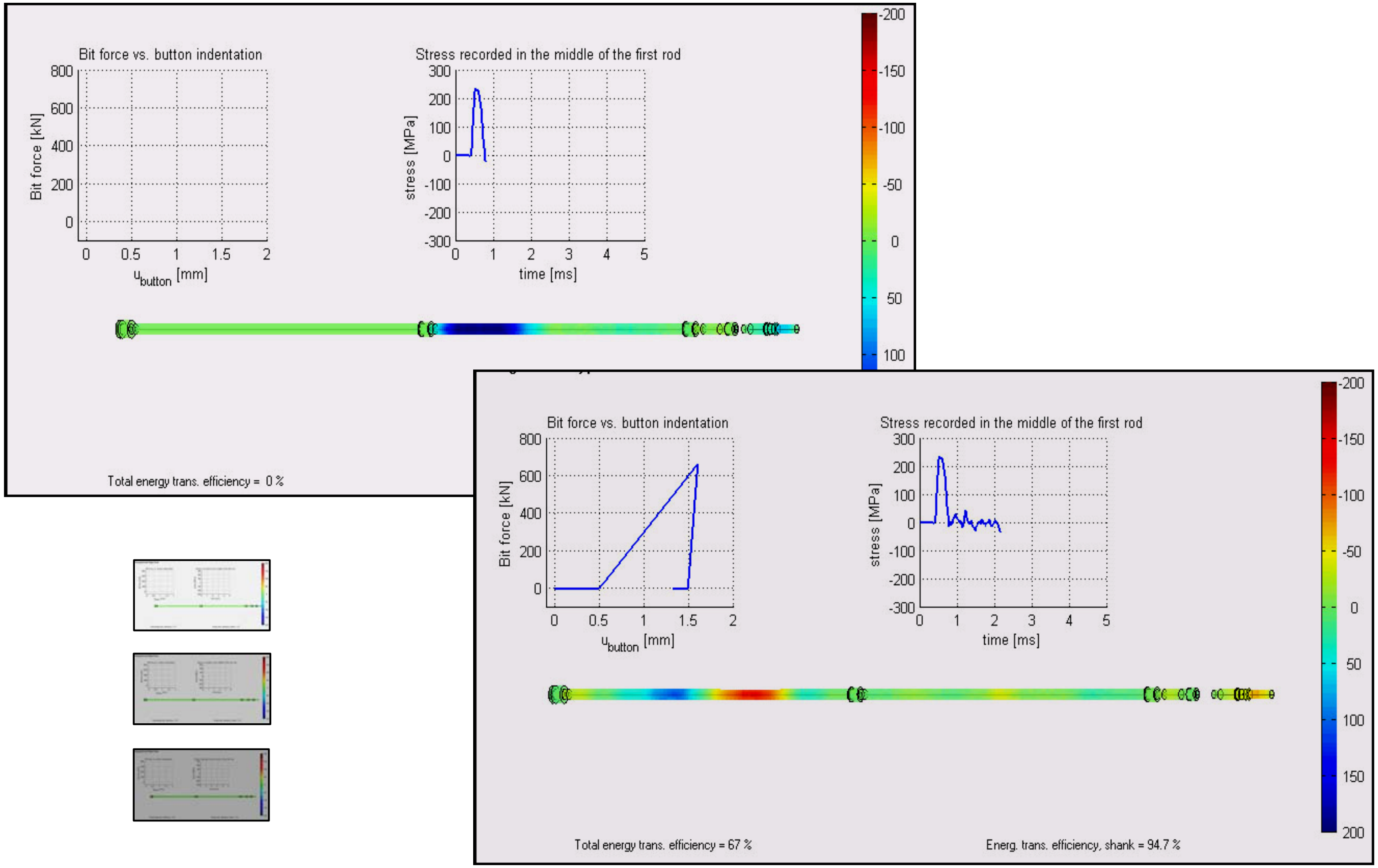
Drilling Management

Energy transfer efficiency in TH drilling



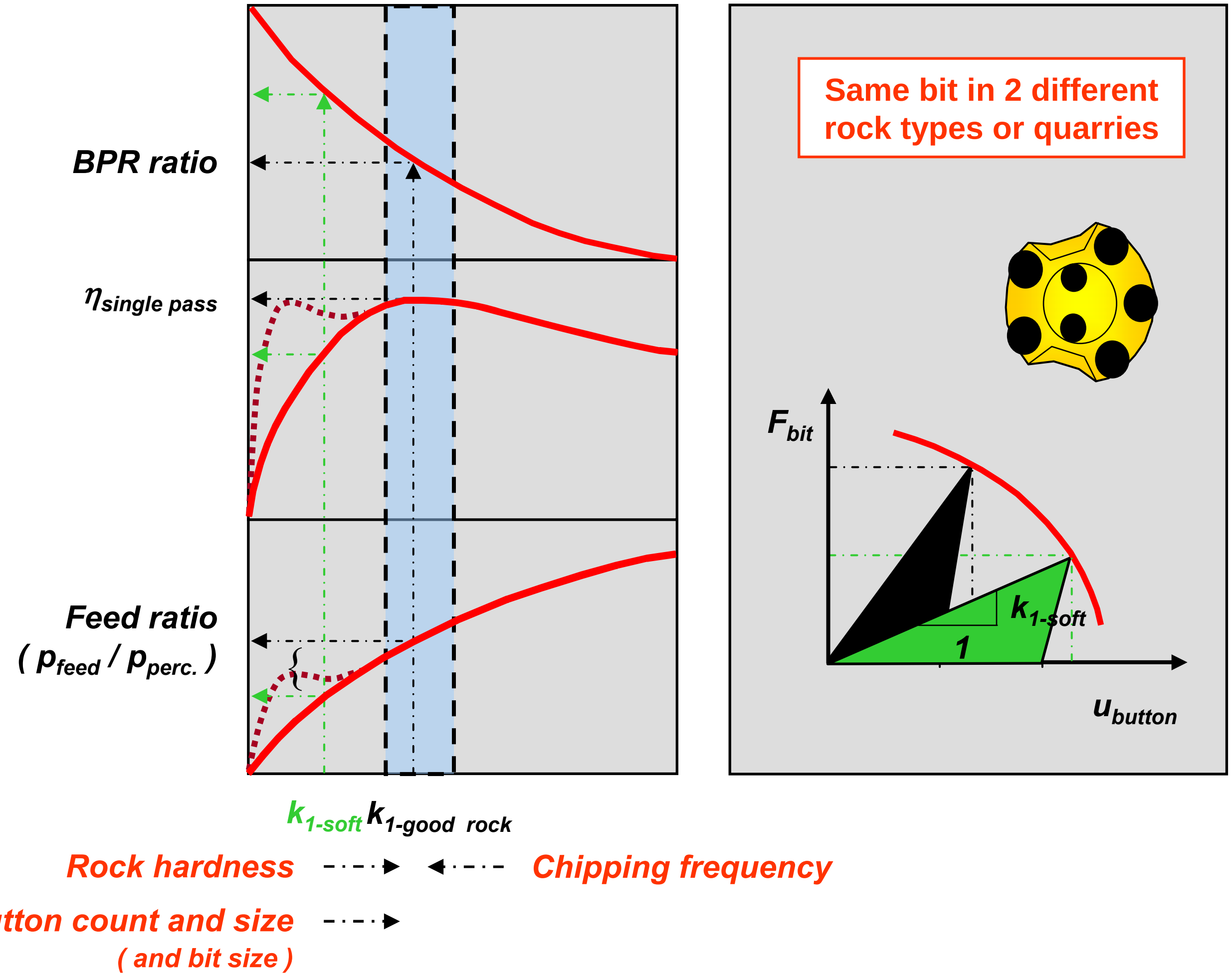
Drilling Management

The energy transfer chain in TH drilling



Drilling Management

Matching site drilling to transfer efficiency curve - TH



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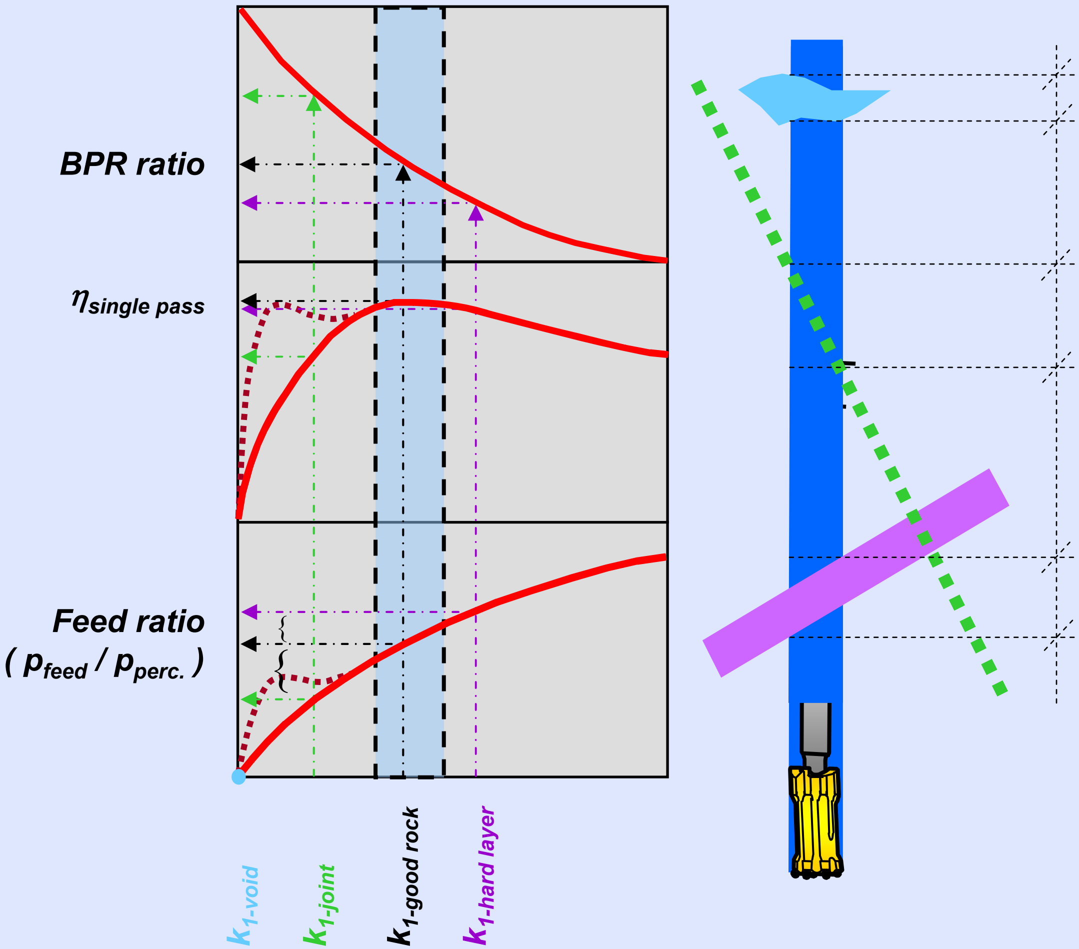
Drilling Management

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

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Drilling Management

Summary of some topics in percussive drilling

Drill bits

- ✓ induce rock chipping
- ✓ sets conditions for impact energy transfer efficiency in TH drilling
- ✓ clean hole bottoms - flushing
- ✓ self stabilising bit bodies - enhance straight hole drilling

Bit regrinding – extended bit life

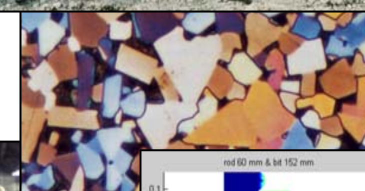
- ✓ remove snakeskin - avoid premature button breakage
- ✓ reshape topworn buttons - reduce bit forces and button breakage
- ✓ avoid flat buttons, low protrusion and bit bottoming

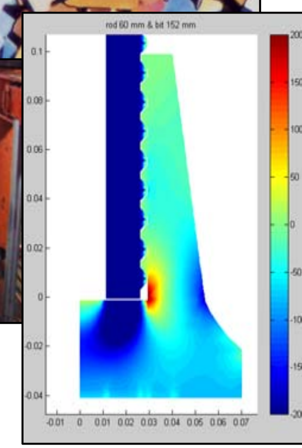
Drill steel

- ✓ impact energy transfer efficiency in TH drilling
- ✓ flushing - return air velocity
- ✓ tubes or pilot tube/rods - straight hole drilling

Drilling control systems

- ✓ bit feed speed control
- ✓ flushing flow control
- ✓ drill string anti-jamming
- ✓ feed force and impact power control
- ✓ feed alignment, hole length and rig positioning systems
- ✓ input source for condition monitoring and MWD





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