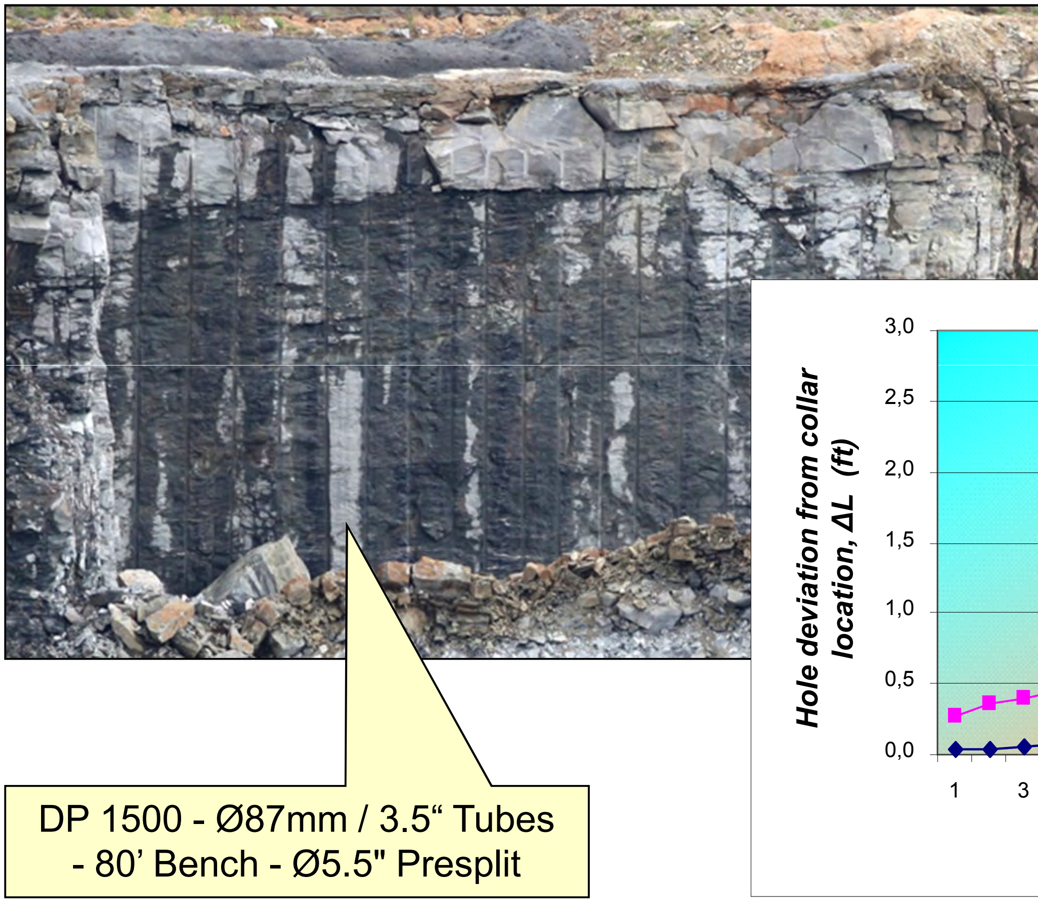
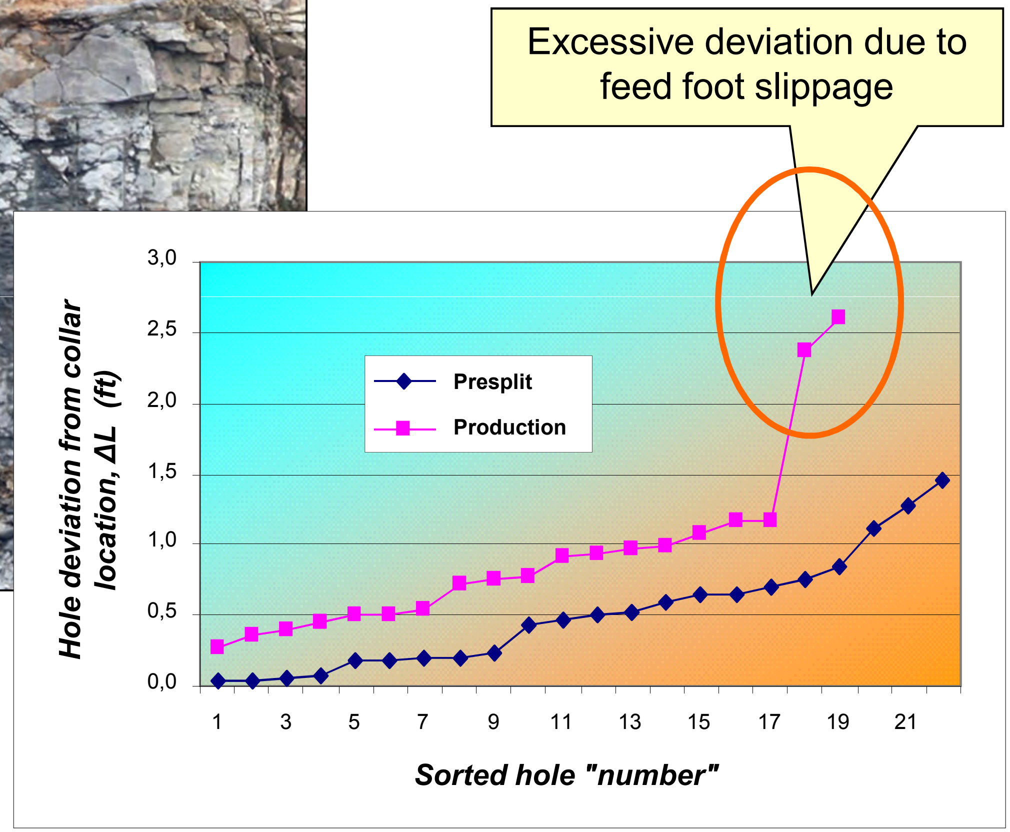
Drilling Management – Wall Control

Wall control drilling – Macon Quarry, GA

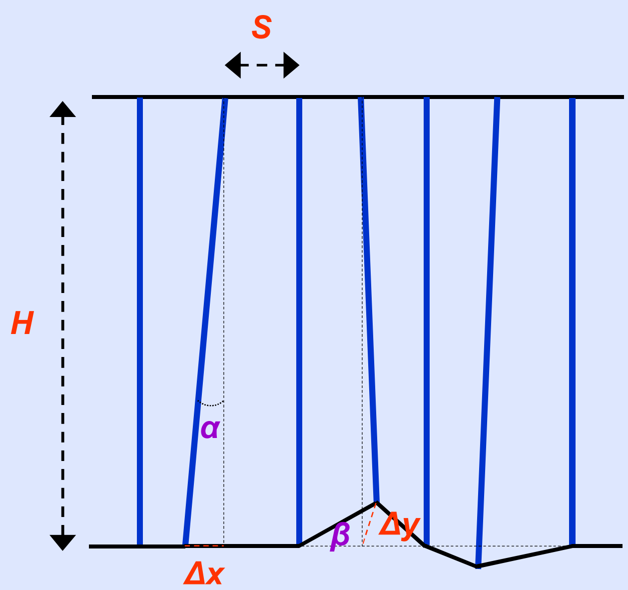




Drilling Management – Wall Control

Wall control drilling - Macon Quarry, GA

	ΔL	%	Δx = Δy	α	β
Max error	*1.48 ft*	*1.8*	*1.05 ft (≈ 2d)*	*0.75°*	*12.0°*
Median error	*0.49 ft*	*0.6*	*0.36 ft (≈ d)*	*0.25°*	*4.2°*



$\Delta L = (\Delta x^2 + \Delta y^2)^{1/2}$

Δy = error perpendicular to wall of greater importance to extent of blast damage in backwalls

β = atan Δy / S

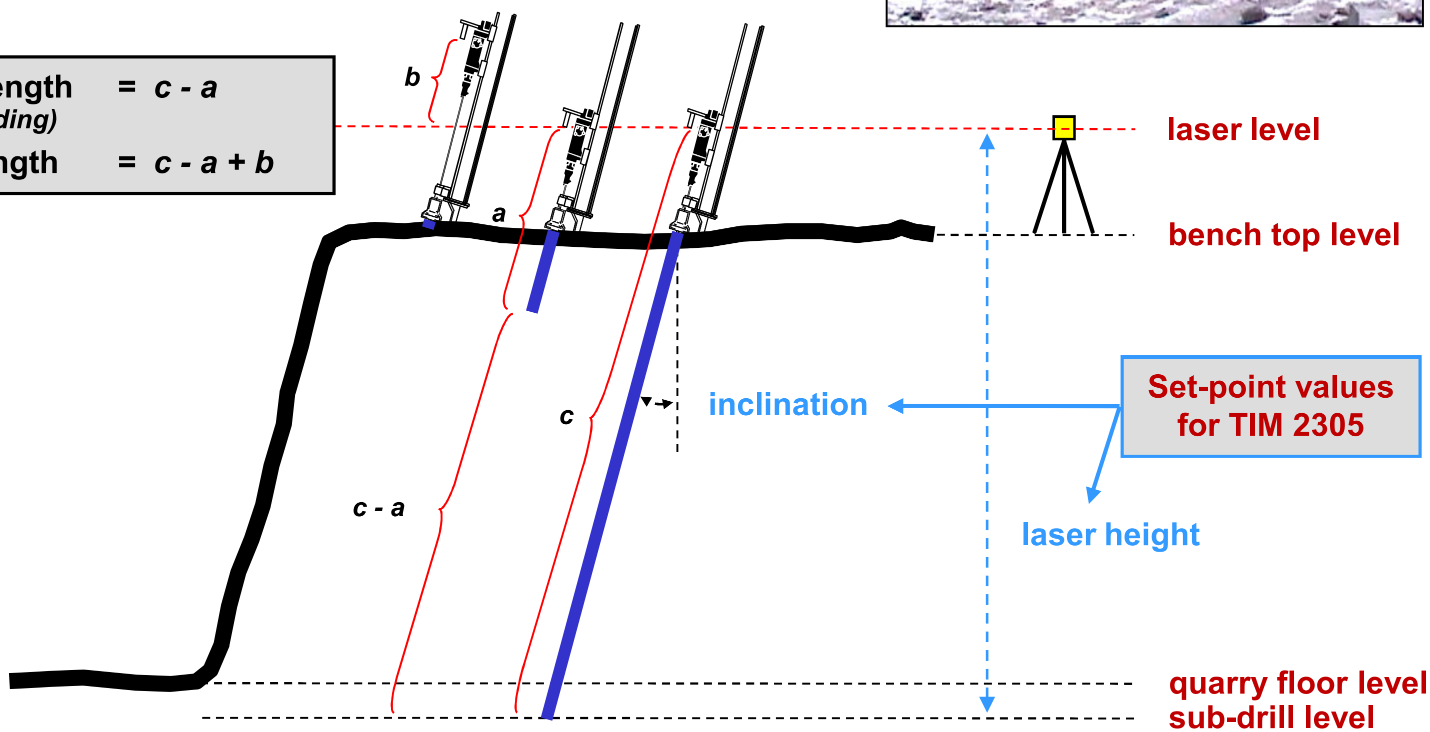
Δx = error parallel to wall of lesser importance

α = atan Δx / H

Drilling Management

Hole depth error control

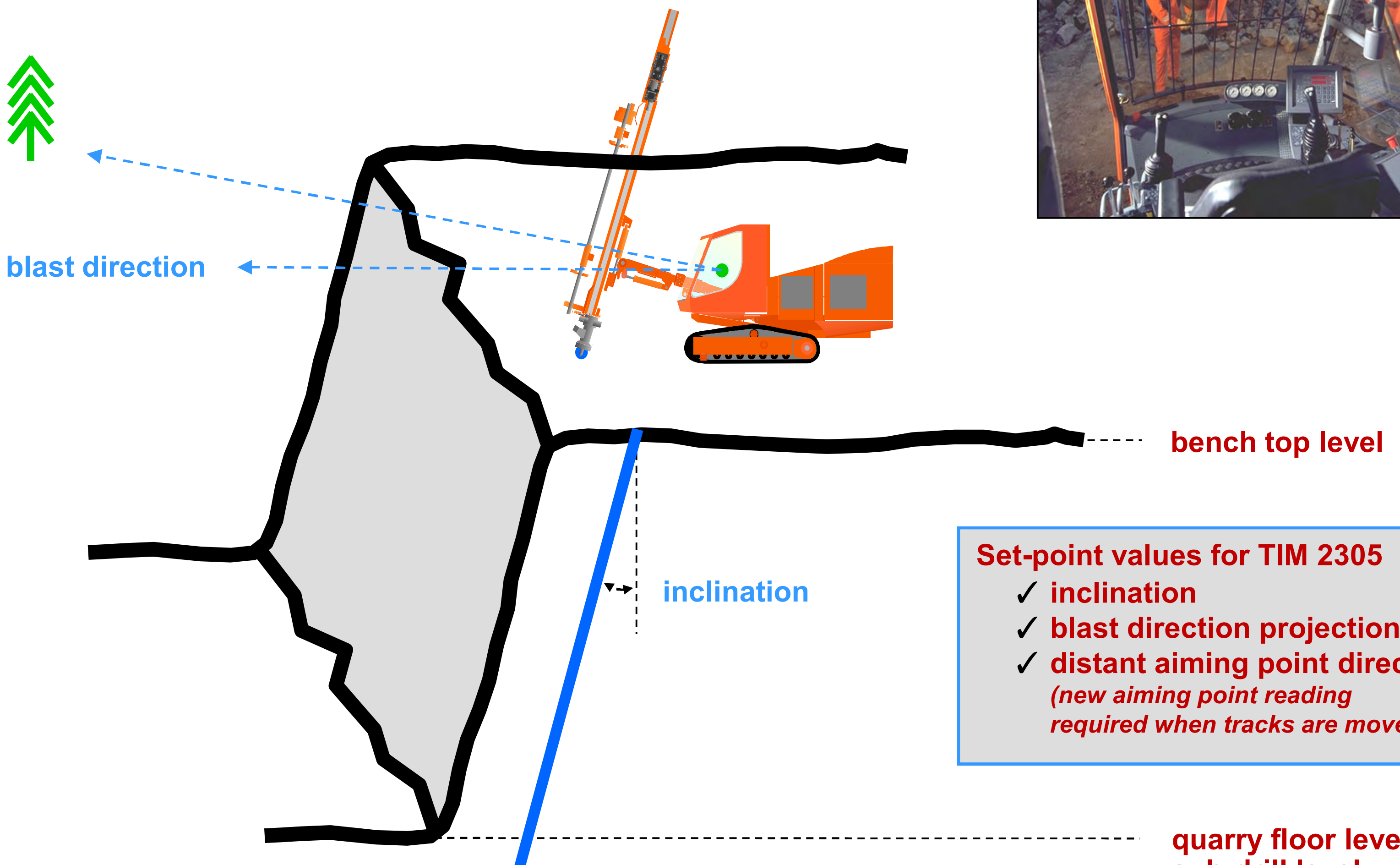
Remaining drill length *(at 1st laser level reading)*	= *c - a*
Total drill hole length	= *c - a + b*



QUARRY
ACADEMY

Drilling Management

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)

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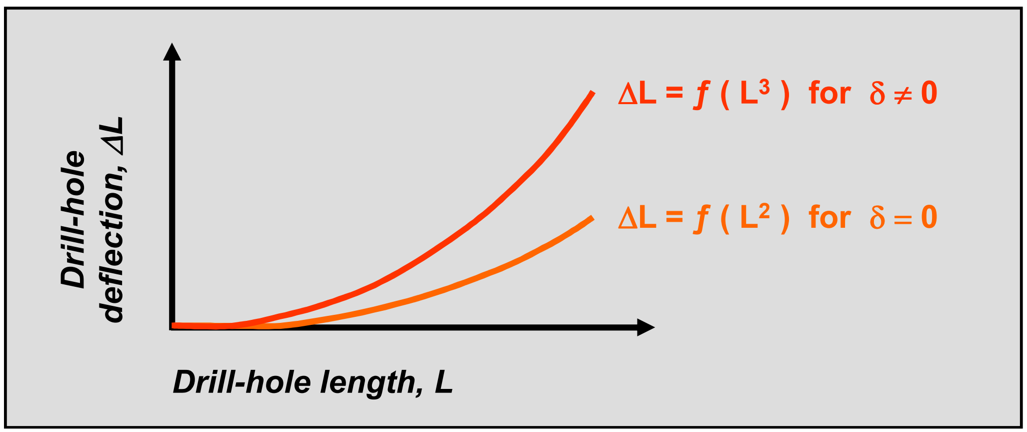
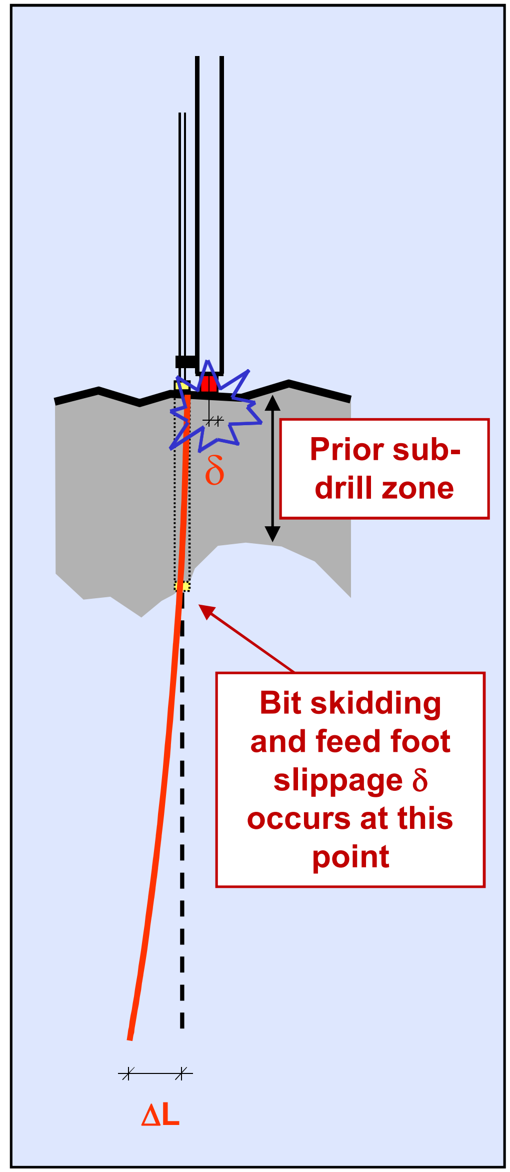
Drilling Management

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*
- *avoid gravitational effects which lead to drill string sagging when drilling inclined shot-holes (> 15°)*
- *avoid inpit operations with excessive bench heights*

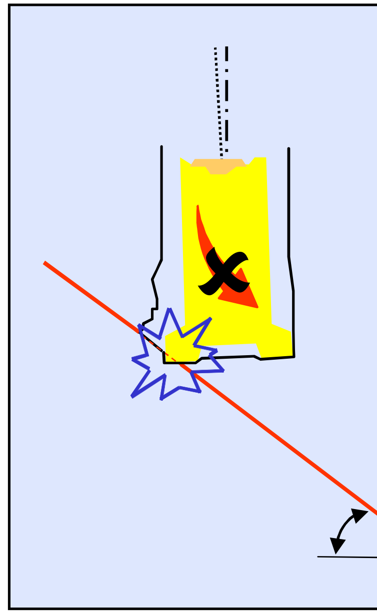




QUARRY ACADEMY

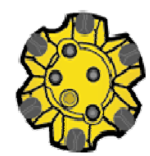
Drilling Management

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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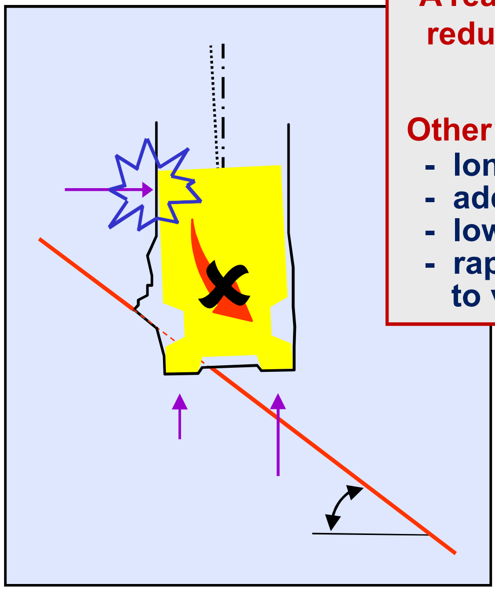
Drilling Management

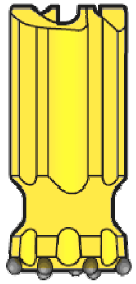
How bit skirt designs enhance drill-hole straightness



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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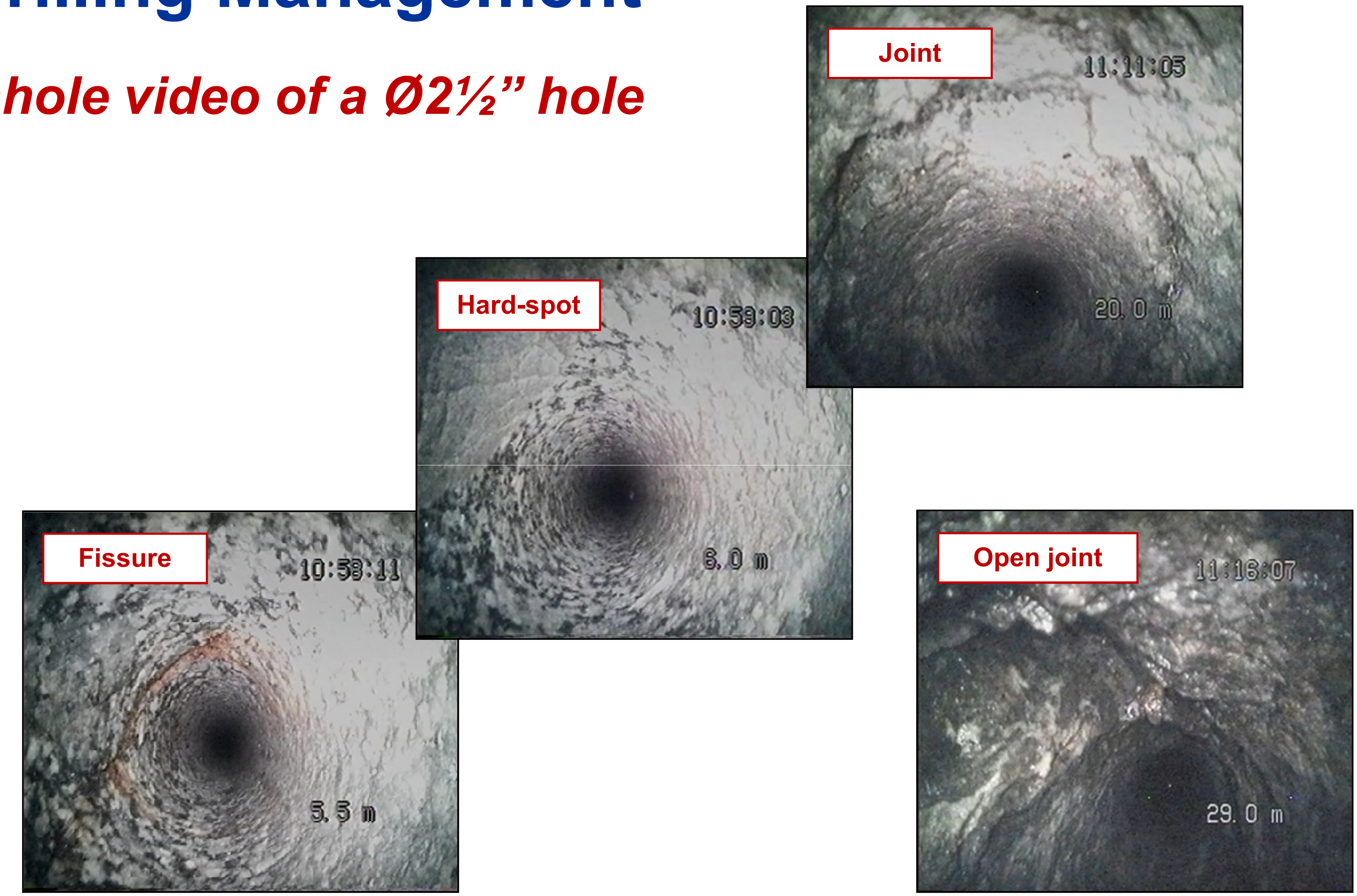
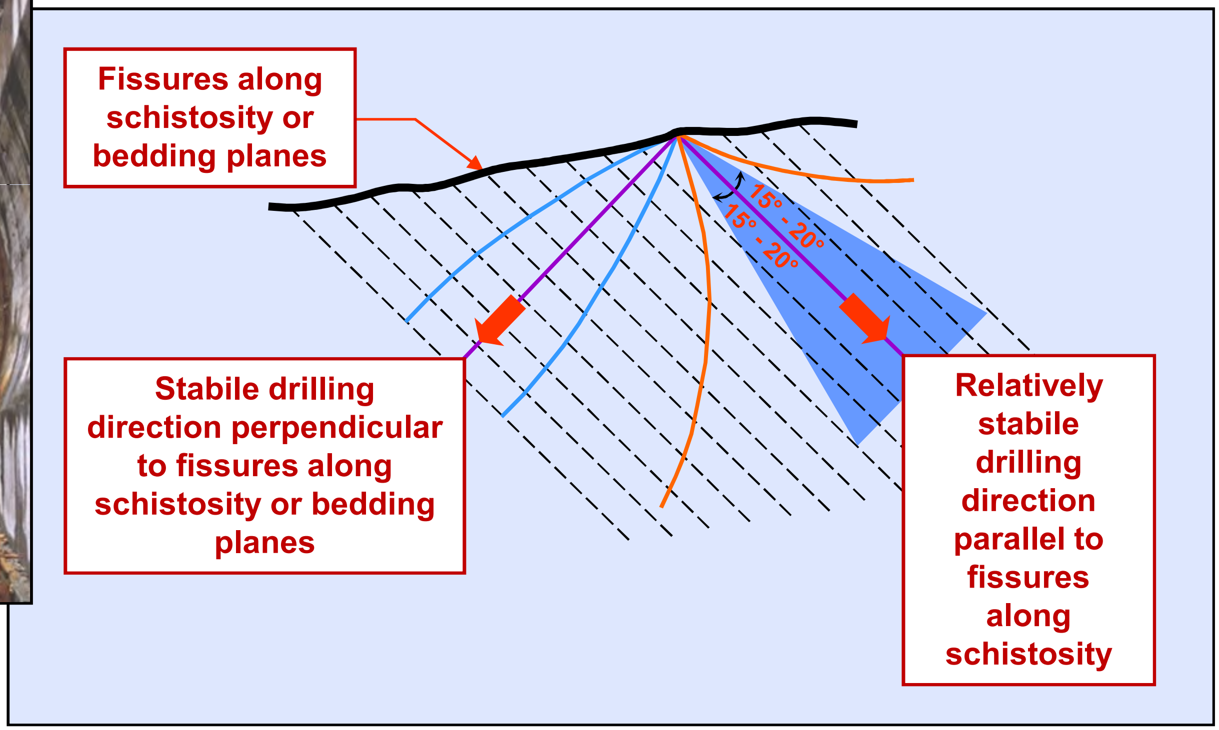
Drilling Management

Inhole video of a Ø2½" hole



Drilling Management

Drill-hole deflection trendlines in schistose rock

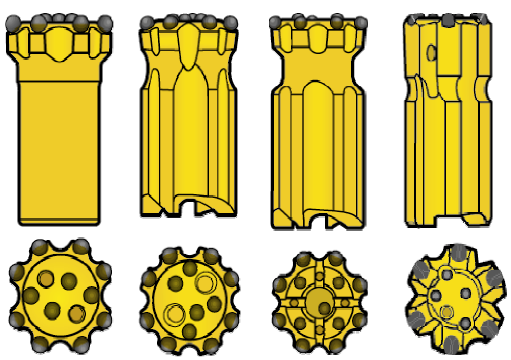


QUARRY ACADEMY

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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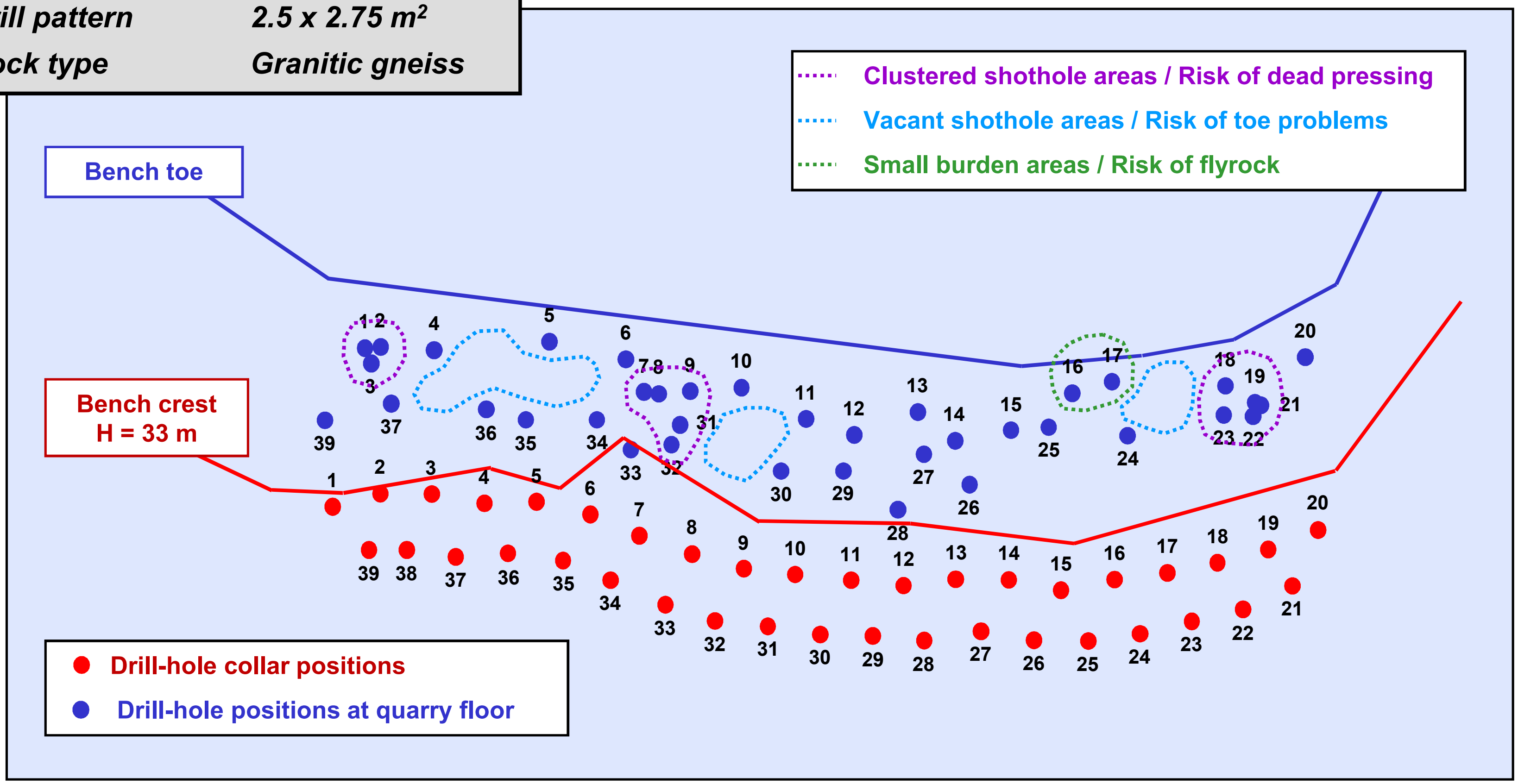
Drilling Management

Bench height	*33 m*
Hole inclination	*14°*
Drill steel	*Ø3" retrac / T45*
Drill pattern	*2.5 x 2.75 m^2*
Rock type	*Granitic gneiss*

Drill pattern at quarry floor



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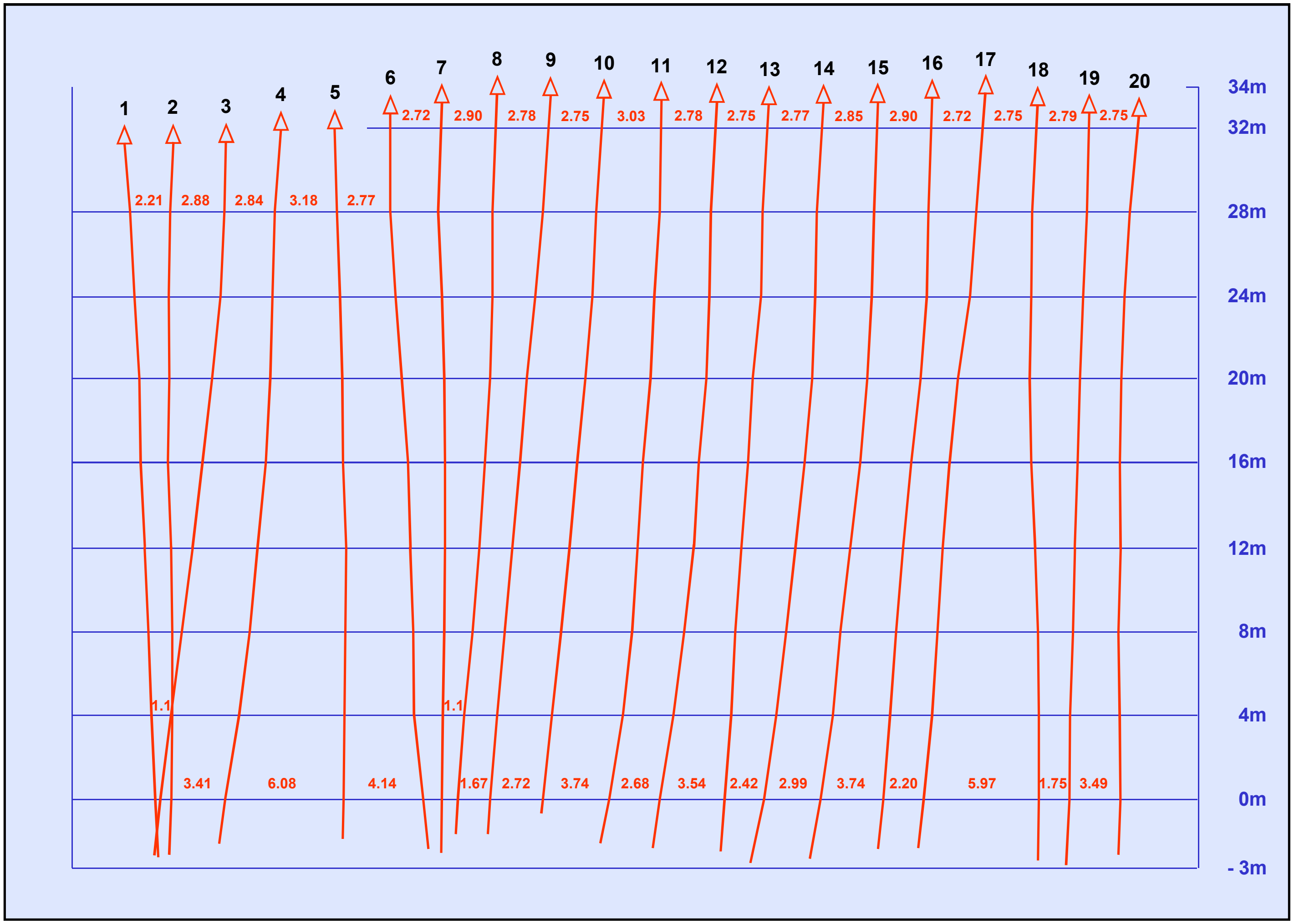
Drilling Management

Vertical projection of Row 1



QUARRY ACADEMY

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

QUARRY ACADEMY

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

QUARRY ACADEMY

Drilling Management

Factors affecting drill-hole deviation

- ***button shape, bit face and bit body design***
- ***applied impact energy and strike frequency***
- ***feed foot slippage***
- ***removal or controlled drilling through prior sub-drill zone***
- ***drilling control systems, i.e.***
  - ***applied feed, torque and percussion dynamics***
- ***drill string stiffness and "tube" steering capabilities***
- ***drill string startup alignment***

QUARRY ACADEMY

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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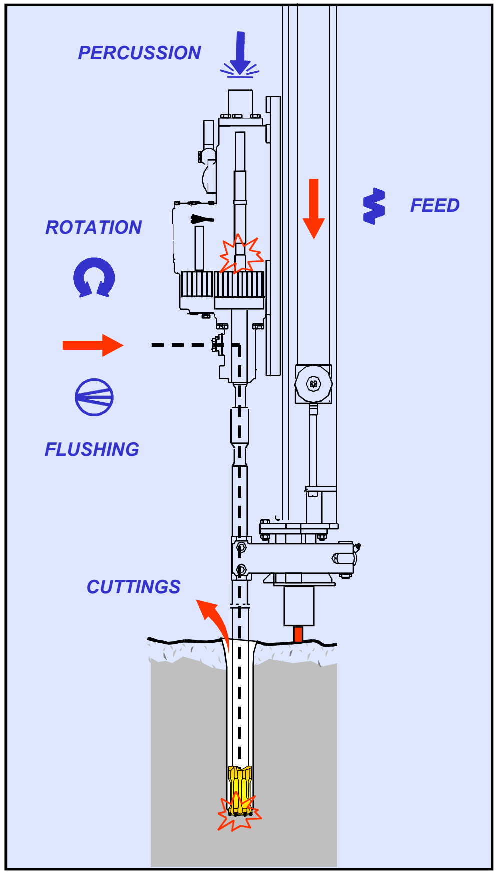
Drilling Management

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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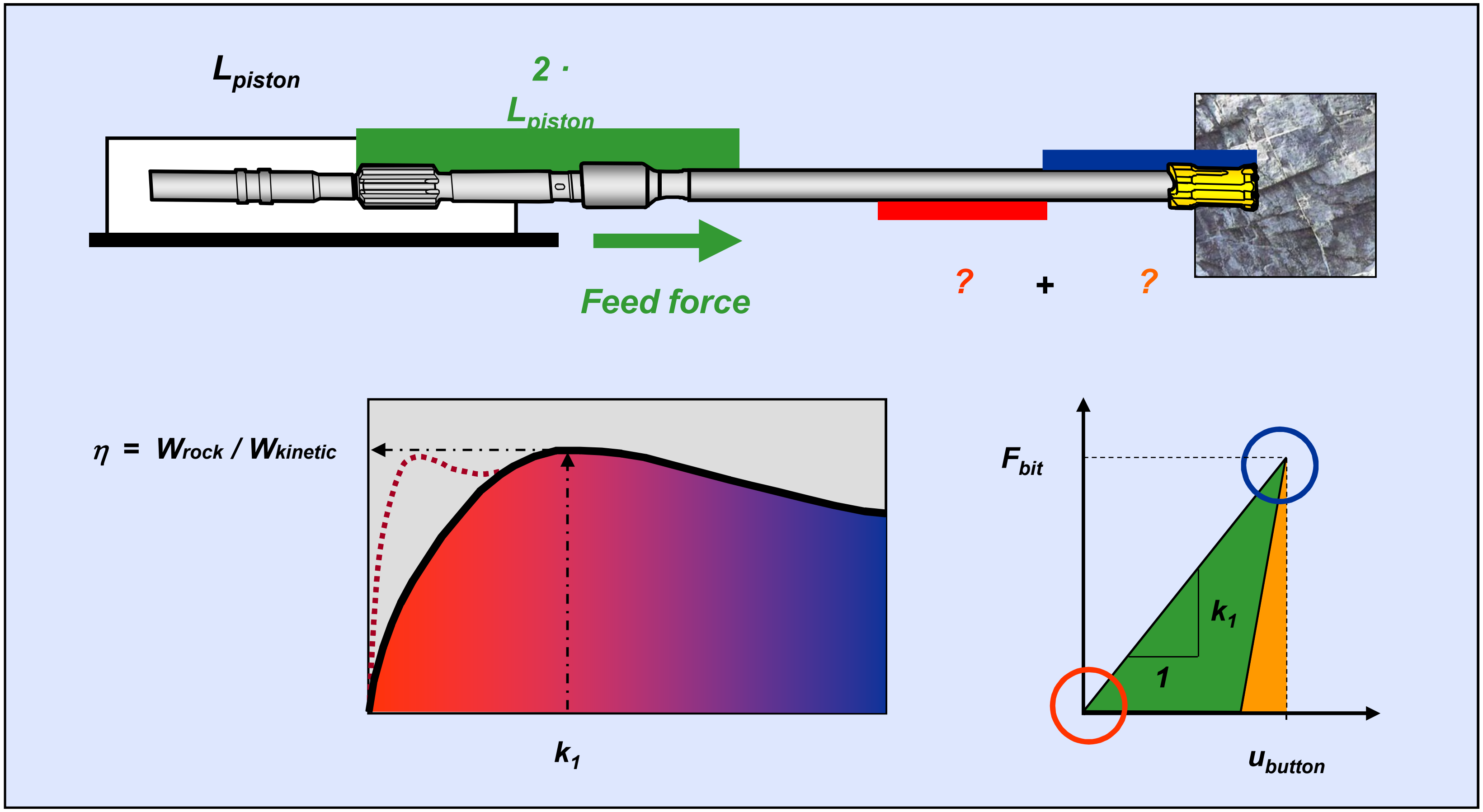
Drilling Management

Energy transfer efficiency in TH drilling



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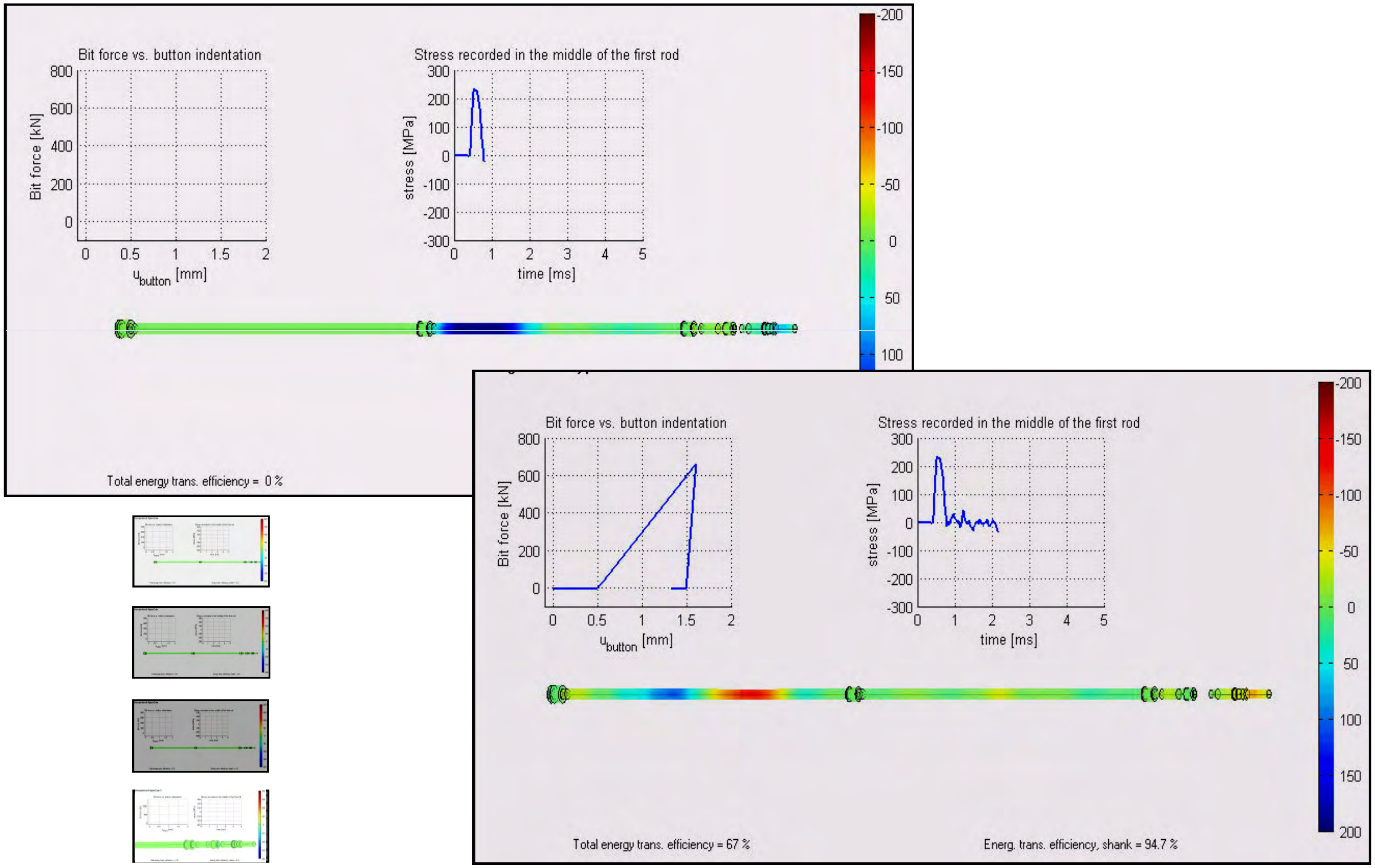
Drilling Management

The energy transfer chain in TH drilling



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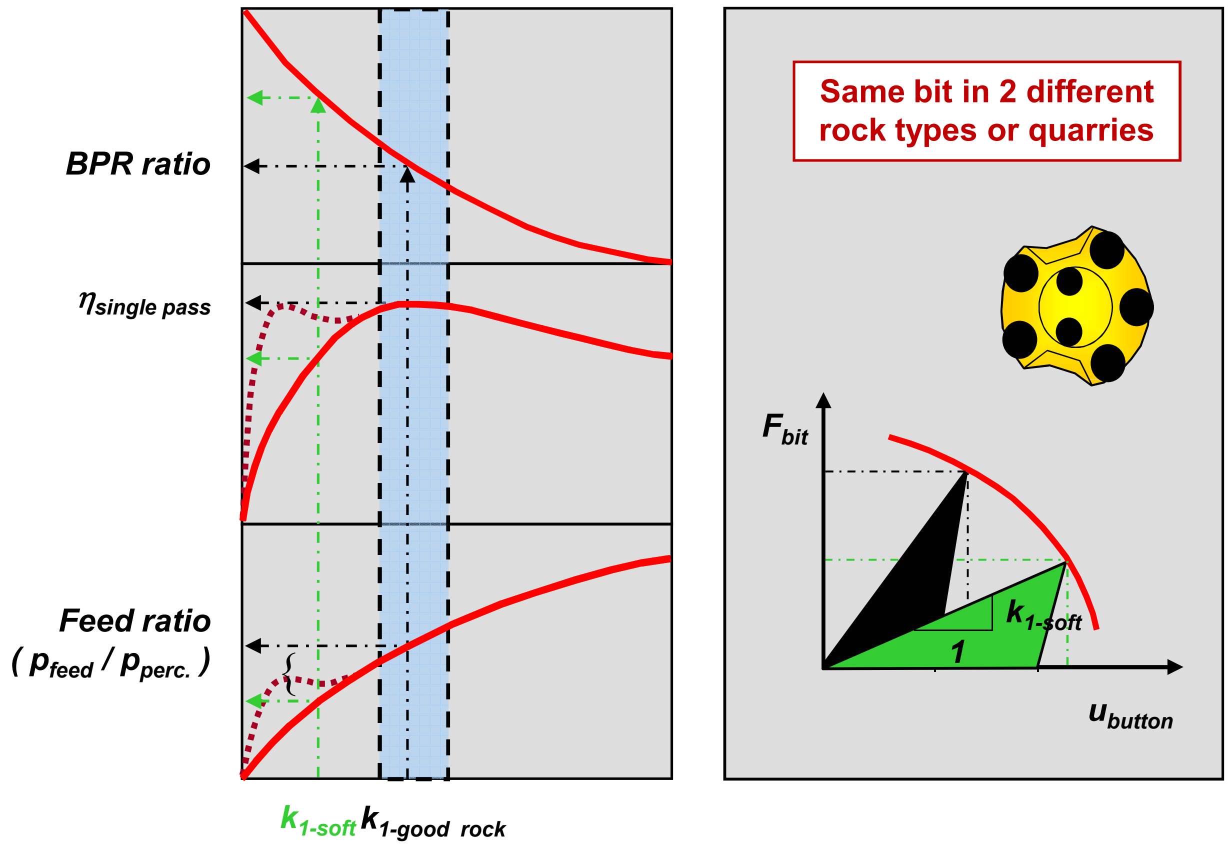
Drilling Management

Matching site drilling to transfer efficiency curve - TH

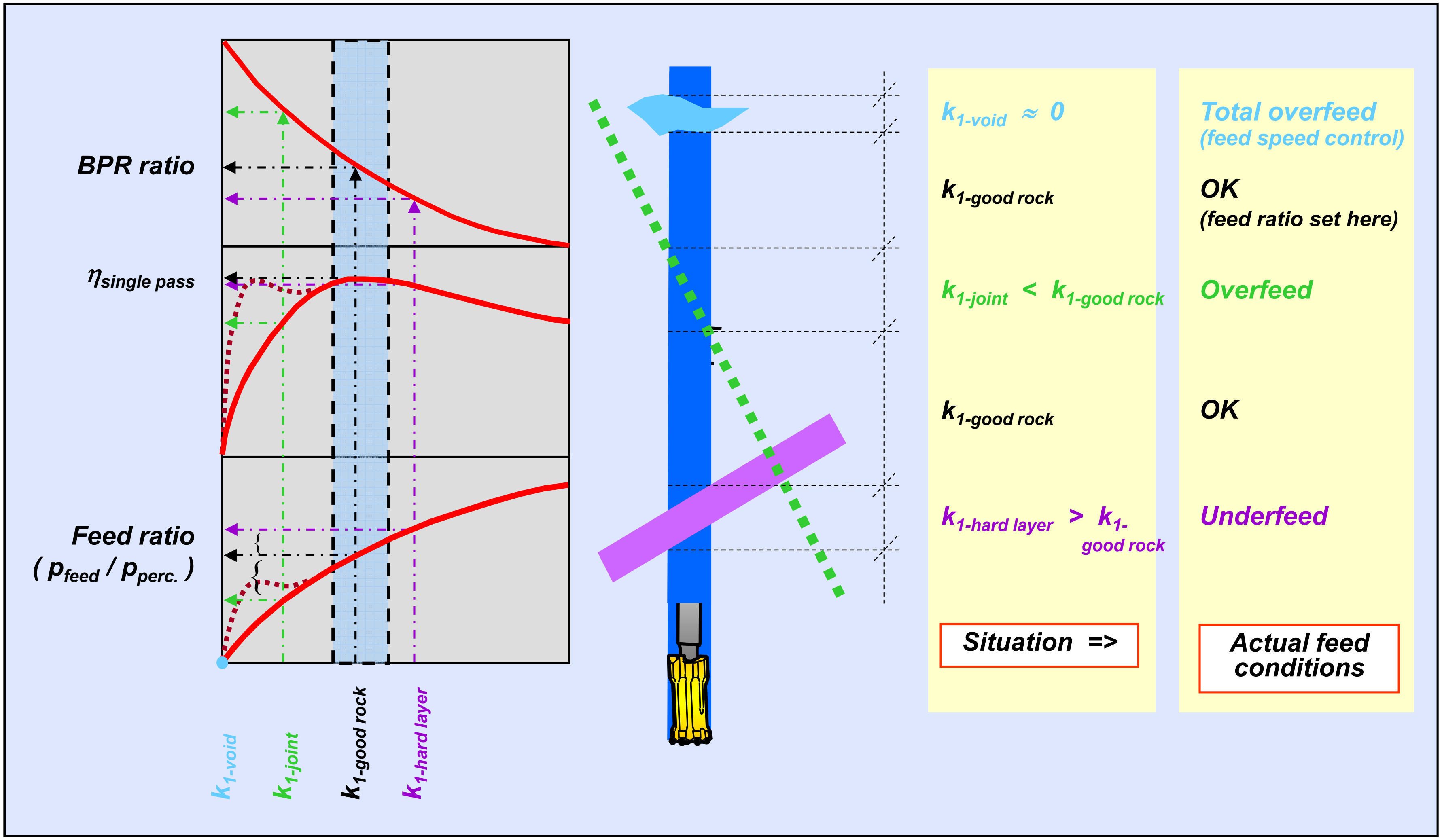


Rock hardness → ← *Chipping frequency*

Button count and size →

(and bit size)

Drilling Management *Drilling in variable rock mass*



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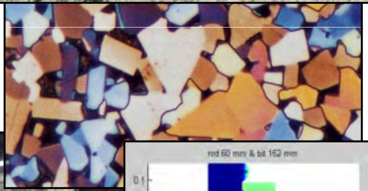
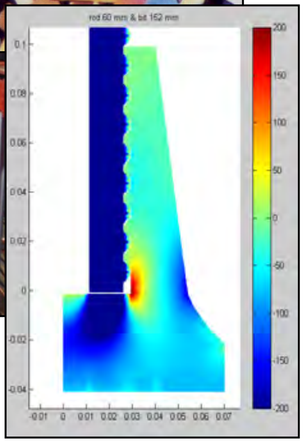
Drilling Management

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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