Drill & Blast Controls

Arne Lislerud

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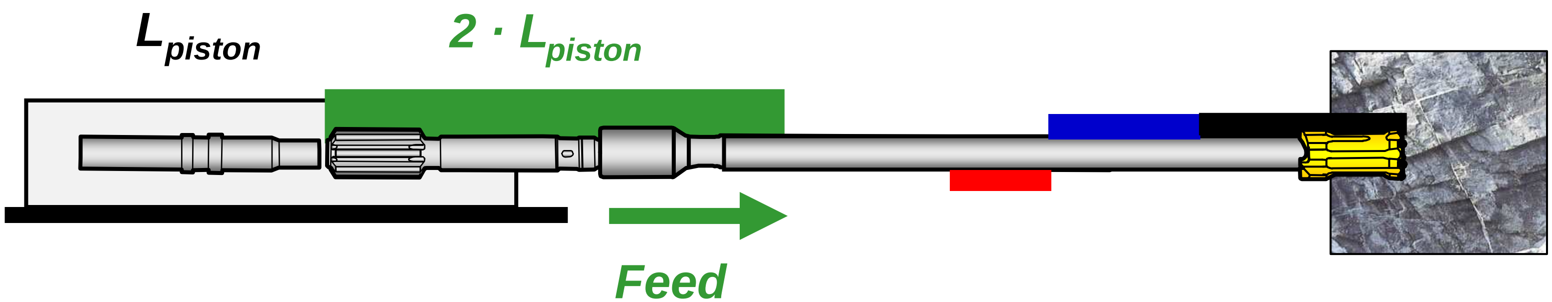
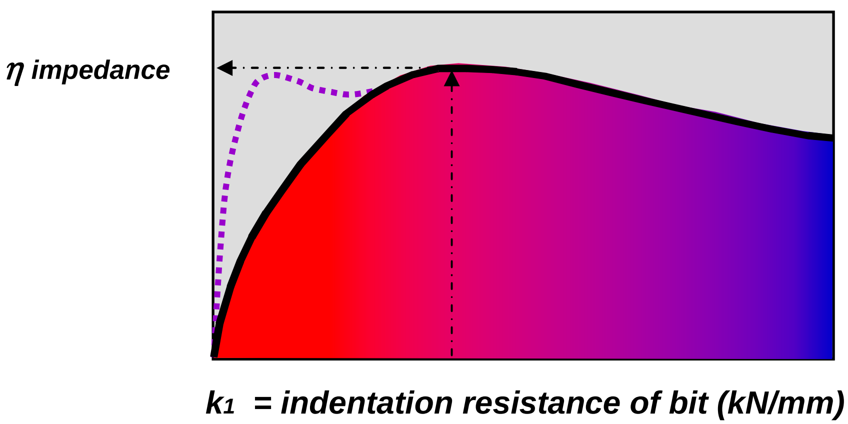
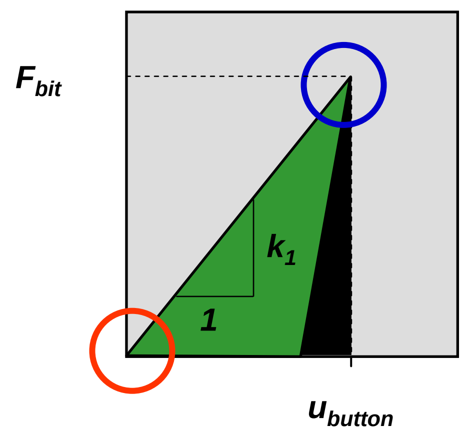
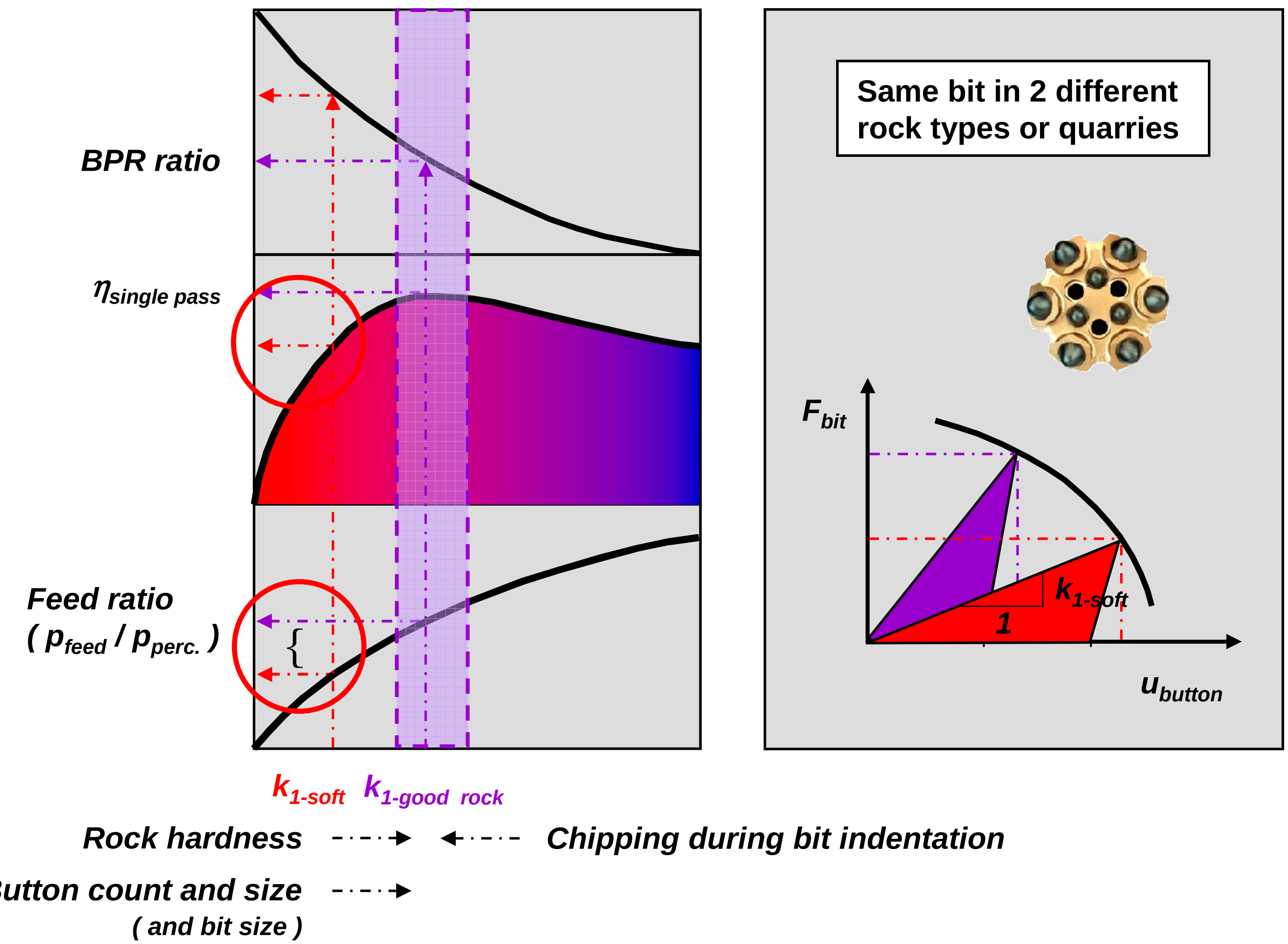
Energy transfer efficiency η related to impedance matching between bit and drill steel forces



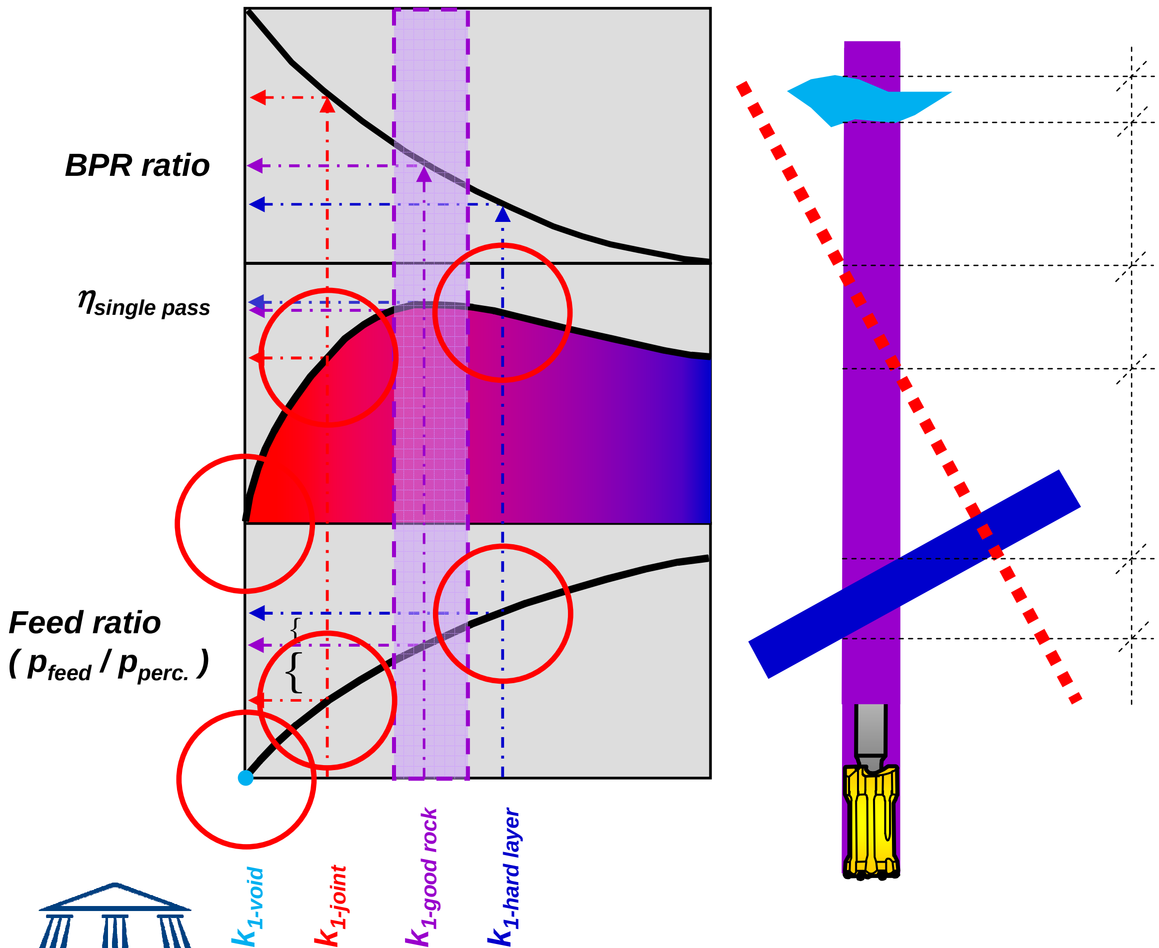




Matching drill settings to site conditions



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 (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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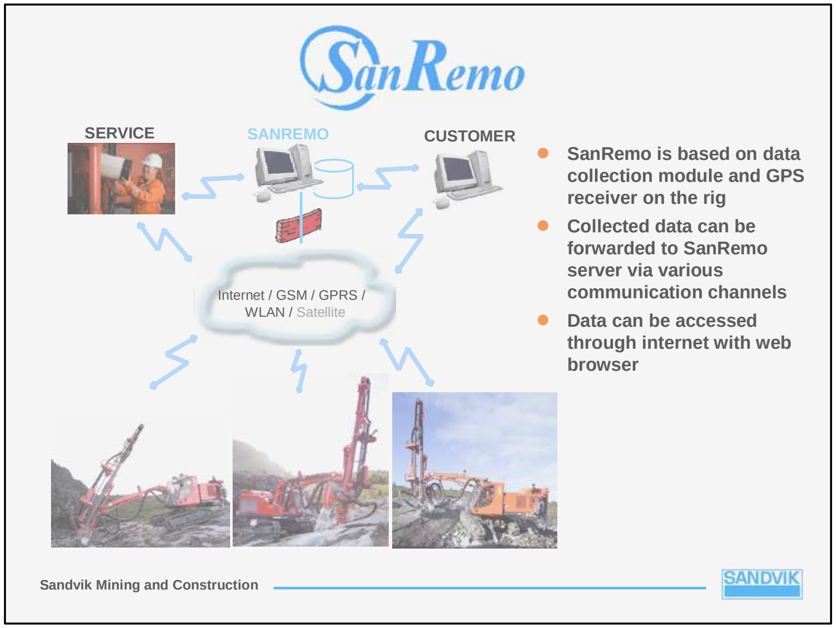
Jobsite KPI's for drilling operations

- ***drilling capacities ft/ph & ft/eh***
- ***drilling capacities in ft/shift***
- ***avg. percussion pressures***
- ***fuel consumption in gal/eh***
- ***drill steel consumption & costs***

- ***drill-hole straightness***
- ***geological conditions***

- ***cost in $ per ft or yd³***



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Improving operator productivity and skills

- ***training facilities***
  - ***traditional inpit***
  - ***simulator for DPi series***
  - ***vocational schools***
- ***objectives***
  - ***improve overall drilling performance***
  - ***increase skills as to drilling in difficult rock mass conditions***

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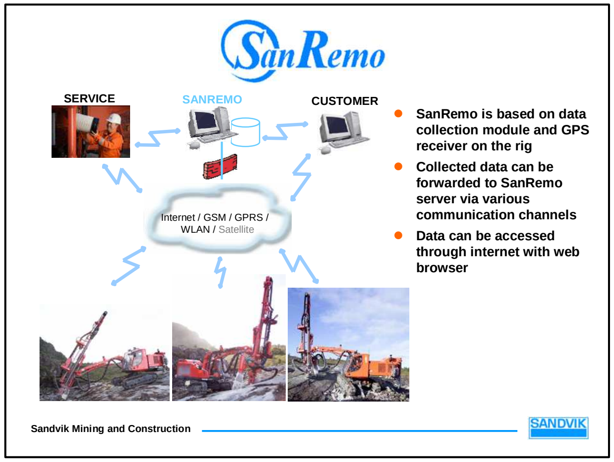
Operator requirements as to drills

Quarries and D&B Contractors

- ***equipment flexibility and reliability***
- ***D&B as to aggregate production requirements***
- ***ability to handle difficult ground conditions***
- ***availability of local / on-call field service***
- ***system for tracking engine hours, production rates, schedule service times, …***



Mines and Mining Contractors

- ***wall control blasting (plus dewatering, depressurisation and bolting holes)***
- ***grade control (sampling, MWD, …)***
- ***system for tracking consumables, engine hours, production rates, …***
- ***inpit remote controlled / automated drills***
- ***availability of service contracts***

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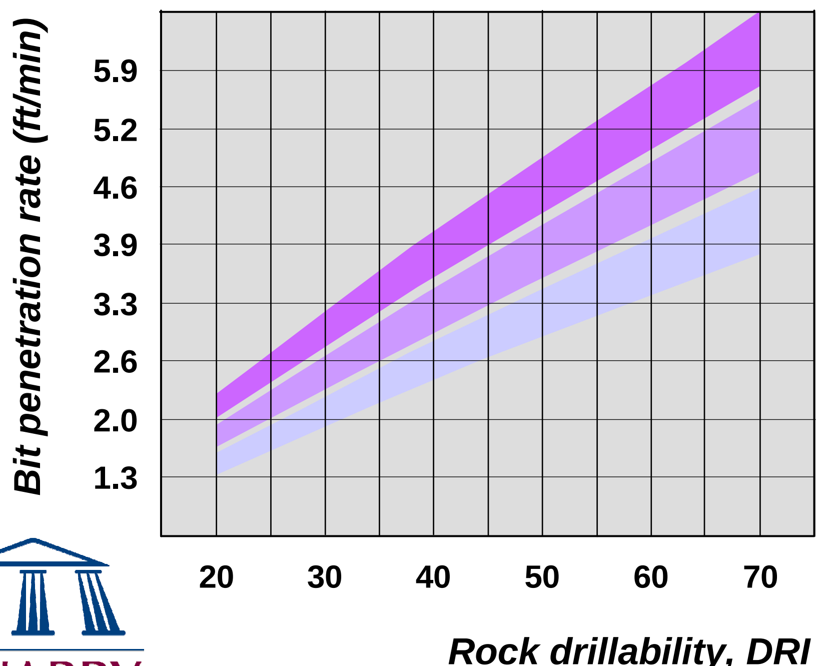
Predicting bit penetration rates - TH

- *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”

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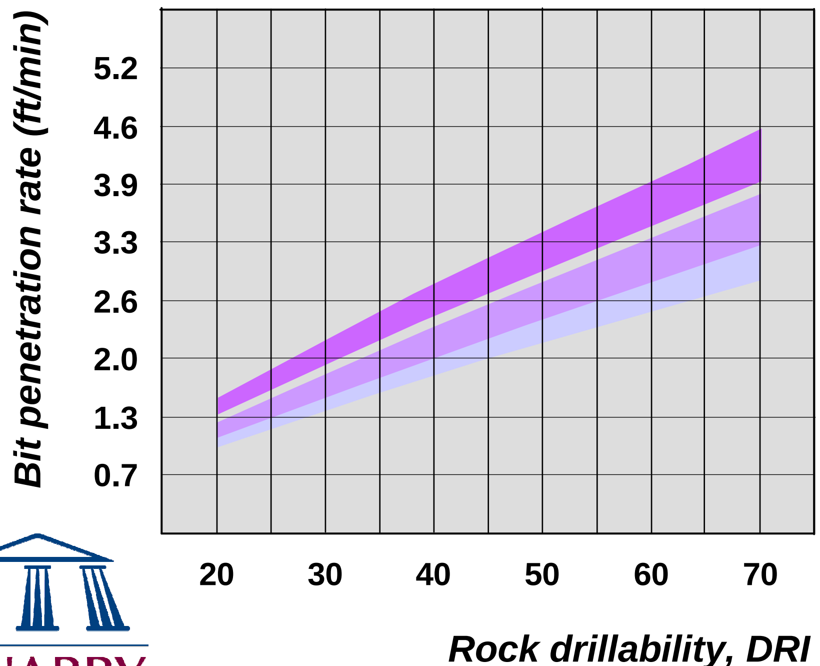
Predicting bit penetration rates - DTH

- *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*



5" RH550 (M50)	140 mm	5.5"
6" RH550 (M60)	165 mm	6.5"
3" RH550 (M30)	89 mm	3.5"
4" RH550 (M40)	115 mm	4.5"
6" RH550 (M60)	203 mm	8"
8" RH550 (M85)	251 mm	9 7/8"

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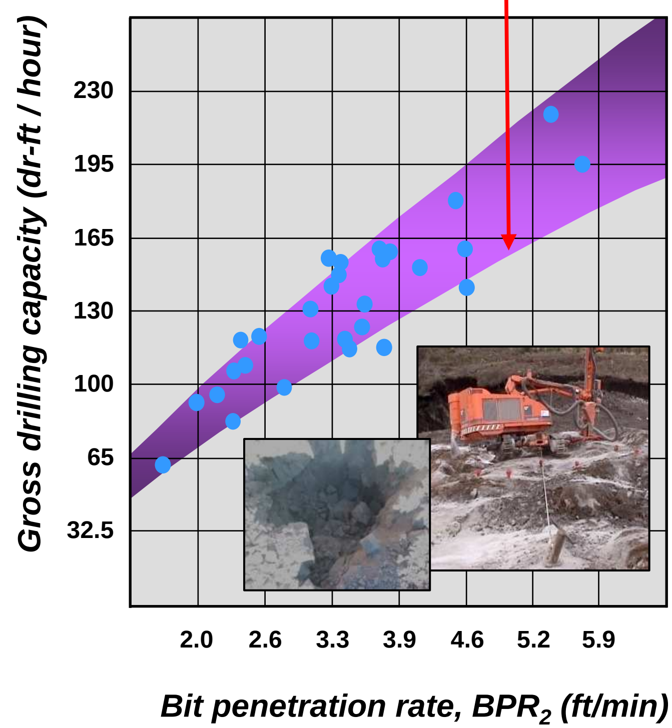
Gross drilling capacities (dr-ft/h)

- ***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)***
- ***bit penetration rate loss 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:***
  - ✓ *bit 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



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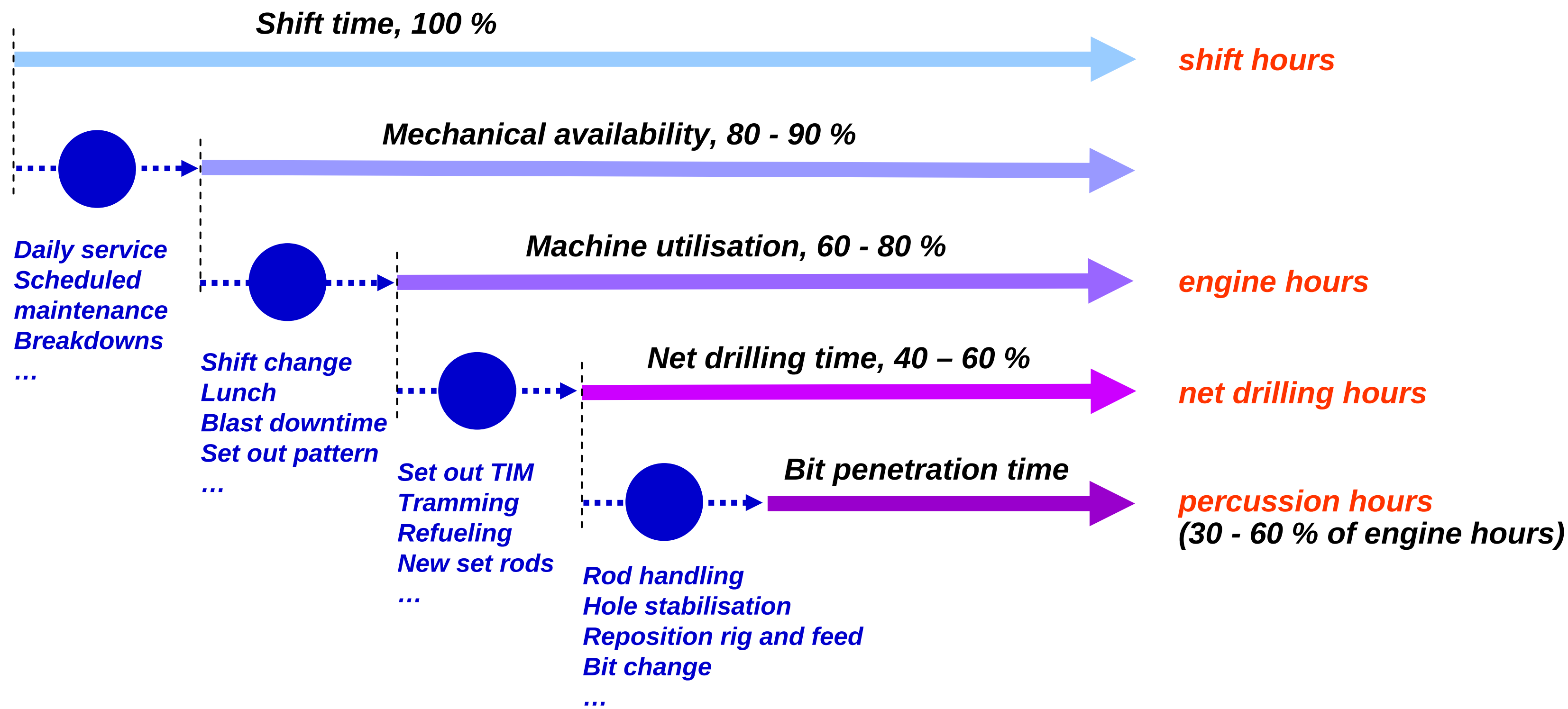
Typical breakdown of longterm rig usage and capacities



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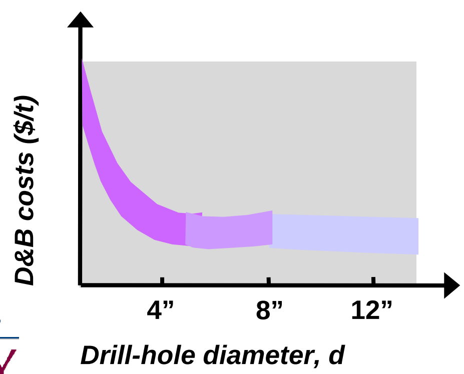
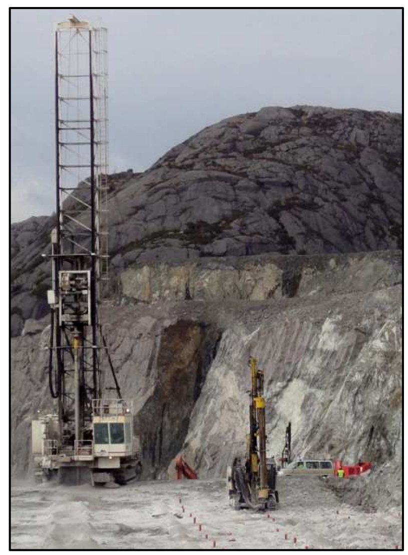
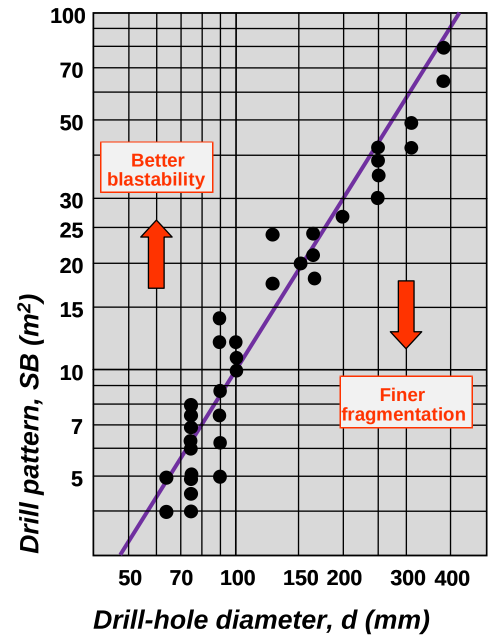
Criteria for selecting drills

- *annual production requirements in bm³ or t* => *number of drills*
- *critical diameter of explosive* => *hole size big enough?*
- *flexibility in usage* => *different types of work?*
- *application costing* => *D&B costs per t*
- *level of automation*
- *operator training and support*
- *operator comfort and safety*
- *ease of transport between pits*







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How drilling and blasting affect down-stream operations

Drilling ↔ **Blasting** ↔ **Loading** ↔ **Crushing**

Drilling
- *sizing drill patterns*
- *drilling accuracy*

Blasting
- *field performance of explosives*
- *shotrock fragmentation*
  - *boulders*
  - *floor humps*
  - *fines and fragment microfractures*
- *muckpile profiles & swell*

Loading
- *loadability and loading capacities*
- *selectivity in mining & industrial mineral operations*

Crushing
- *boulder downtime*
- *crushing capacities*
- *power consumption*
- *production of fines and waste*

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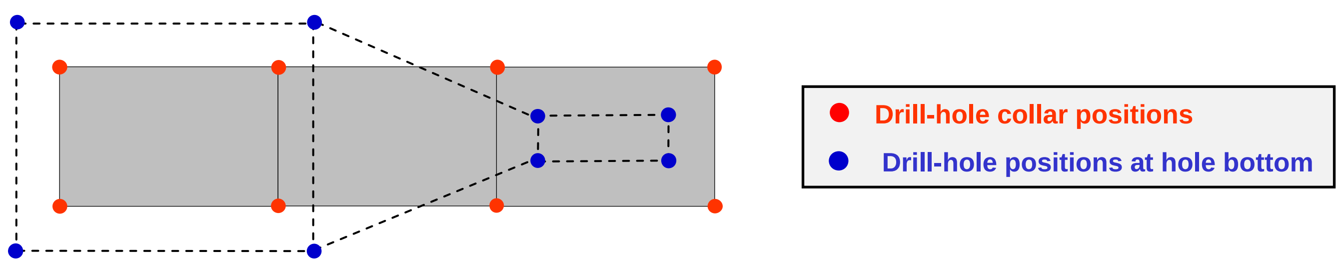
What happens when we shoot holes that look like spaghetti?

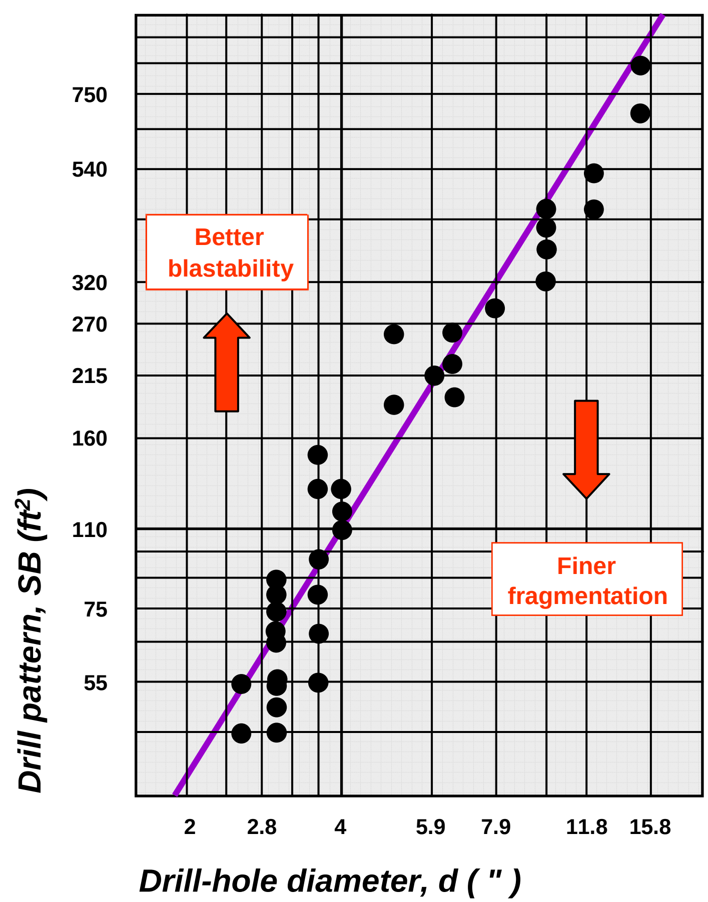
■ *floor humps*	=> *poor loading conditions, uneven floors*
■ *poor walls*	=> *unstabile walls* => *difficult 1st row drilling*
■ *flyrock*	=> *safety*
■ *blowout of stemming*	=> *safety, dust, toes, …*
■ *blast direction*	=> *quality of floors and walls*
■ *shothole deflagration / misfires*	=> *safety* => *locally choked muckpiles (poor diggability)*
■ *good practice*	=> *max. drill-hole deviation up to 2 – 3% for production drilling*



Shothole diameter error control

- ***bits loose diameter due to gauge button wear***
- ***typical diameter loss for worn out bits is ~ 10%***
- ***diameter loss effect on drill patterns***

	Diameter new bit	*Ø102mm – 4”*
	Diameter worn out	*Ø89mm – 3½”*
	Diameter loss	*(4 – 3½) / 4 = 12.8 %*
=>	*Drill pattern too big*	*$(4 / 3½)^{1.6}$ = 24%*



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Collar position error control

- *use tape, optical squares or alignment lasers for measuring in collar positions*
- *use GPS or total stations to measure in collar positions*
- *collar positions should be marked using painted lines – not movable objects such as rocks etc.*
- *completed drillholes should be protected by shothole plugs etc. to prevent holes from caving in (and filling up)*
- *use GPS guided collar positioning devices e.g. TIM-3D*

Difficult 1st row drilling

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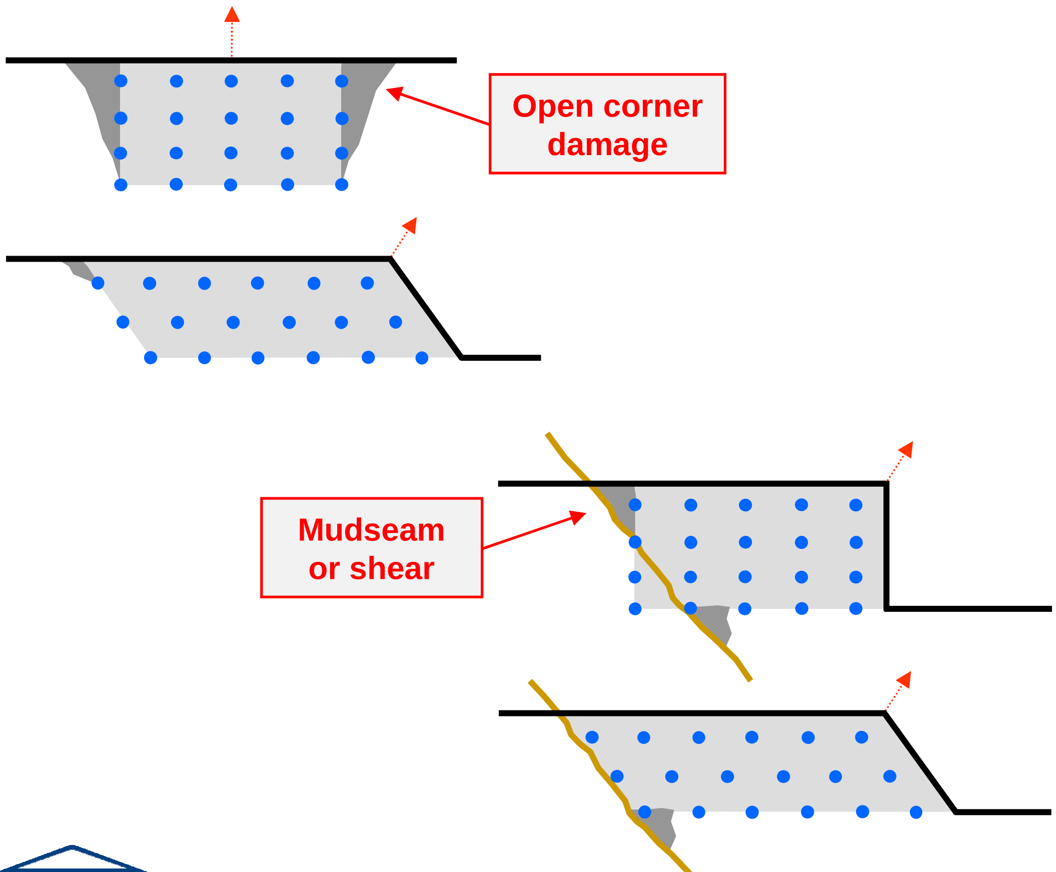
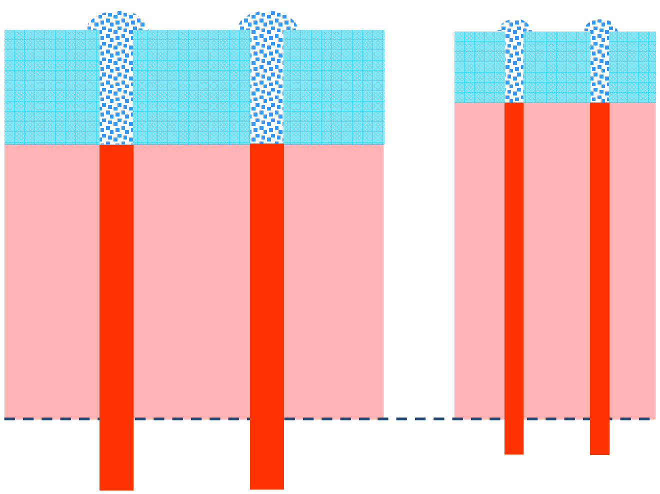
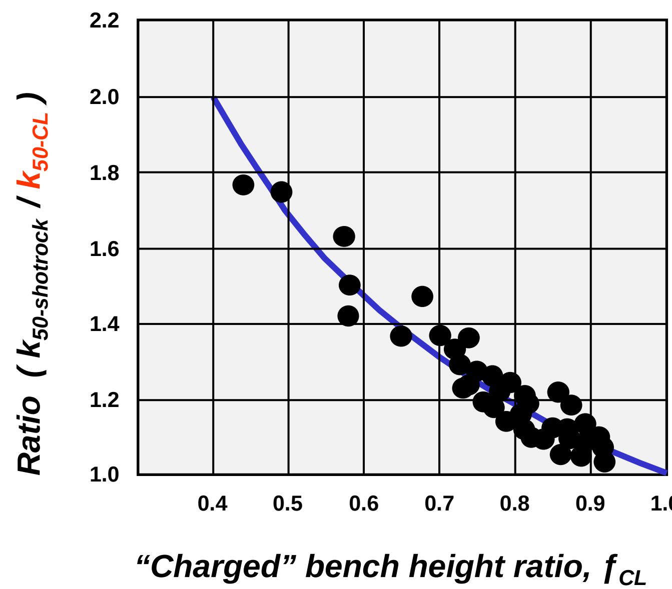
Open corner and mudseam damage



Where do boulders originate?

- ***primarily from the uncharged portion of blasts***
- ***poorly blasted backwalls (now front rows), sidewalls and corners***
- ***seams / dykes within blasts***
- ***poor field performance of explosives***
- ***poorly drilled patterns (drill-hole deviation)***





$$k_{50\text{-}shotrock} = k_{50\text{-}CL} / f_{CL}^{0.76}$$

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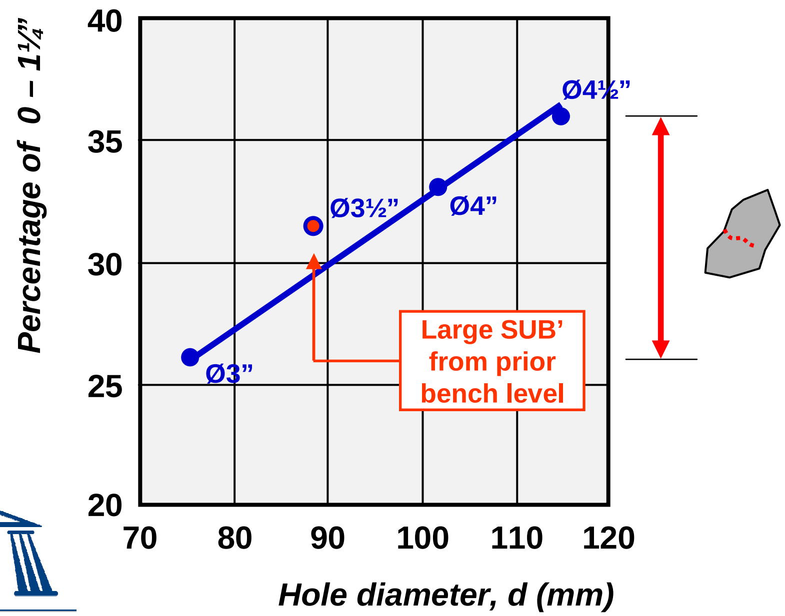
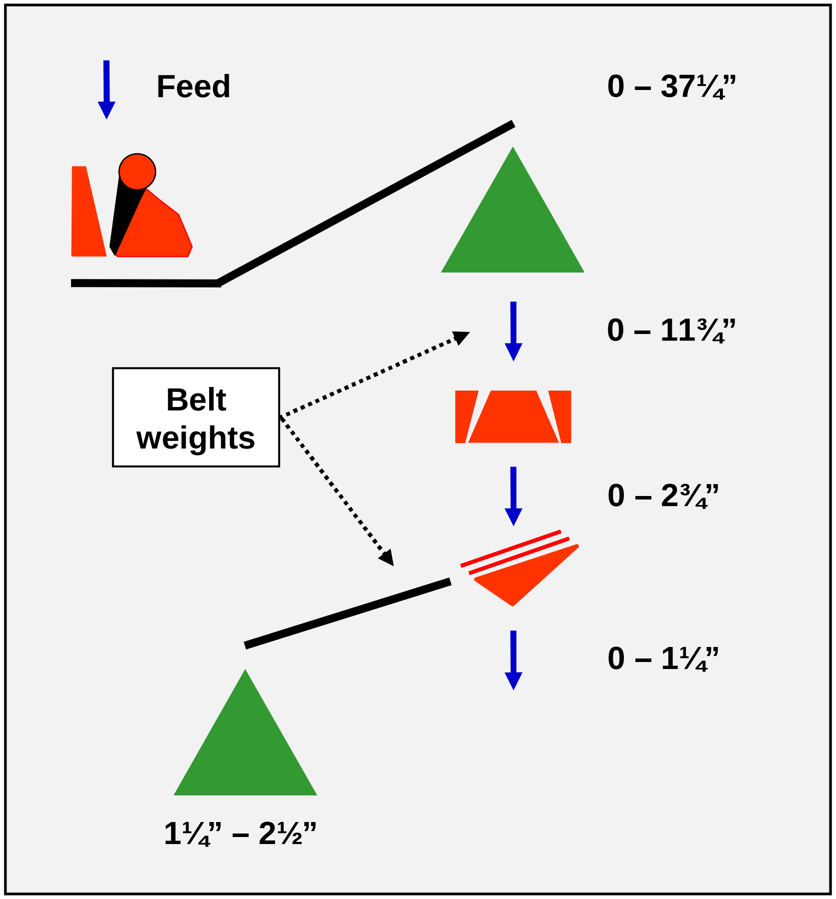
Quality feed – effect of micro-fracturing

Rock type	*Anorthosite*
Explosive	*Slurrit 50-10*
Test blasts	*4 x 50,000 tons*
Bench height	*36'*





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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 linked as much to equipment as it is to attitudes*

⇒ *health, safety and environmental issues are everyone's concern*

⇒ *the ultimate safety target is zero harm – not just a mimimum occurrence of accidents*

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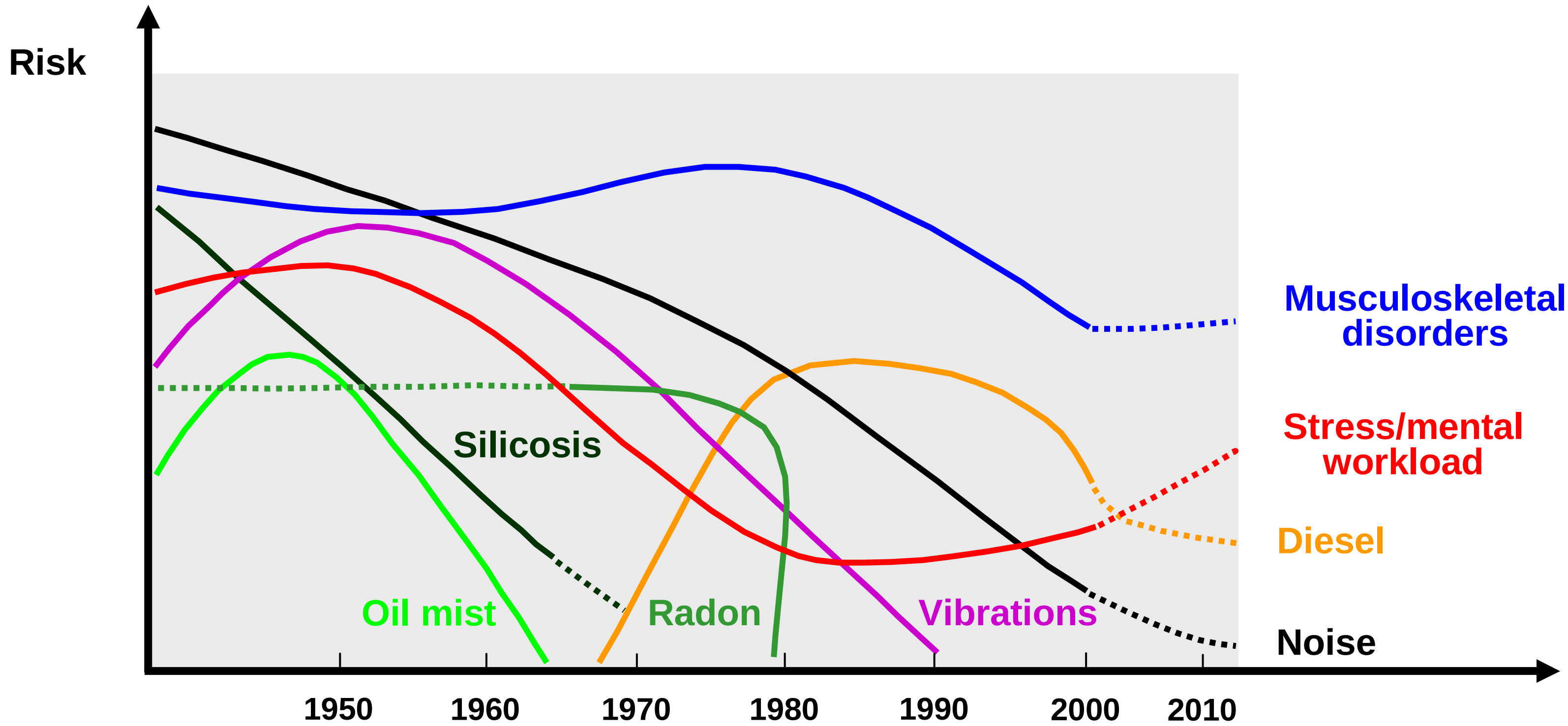
Assessment of some work related health risks



Safety of inpit operations

- ***unwanted incidences do not just happen – they have root causes***
- ***actions can be taken so as to reduce frequency and consequences of unwanted occurrences***
- ***the relationship between complexity and knowledge in the workforce is often unbalanced - e.g. operator hazard training is a must!***

Premature ignition of electric detonators and blast due to lightning

Pit wall failure burying 3 drill rigs in rubble

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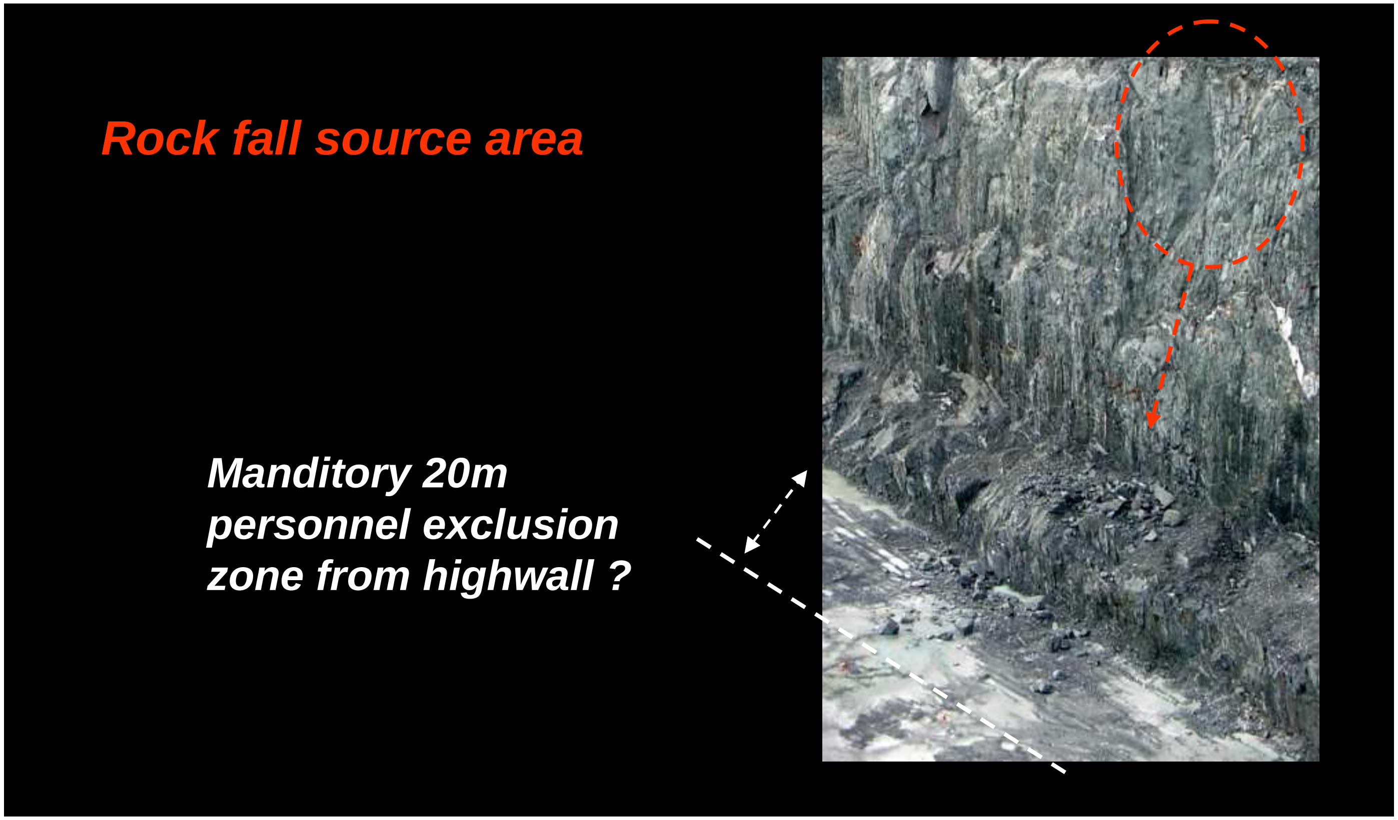
Safety of inpit operations

- ***new equipment requirements for the future?***



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Safety of inpit operations

Tramming

Rollover from terrain bench - 35m drop

Fire in motor

Drilling into dynamite

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Mina Alumbrera -
Double bench presplitting

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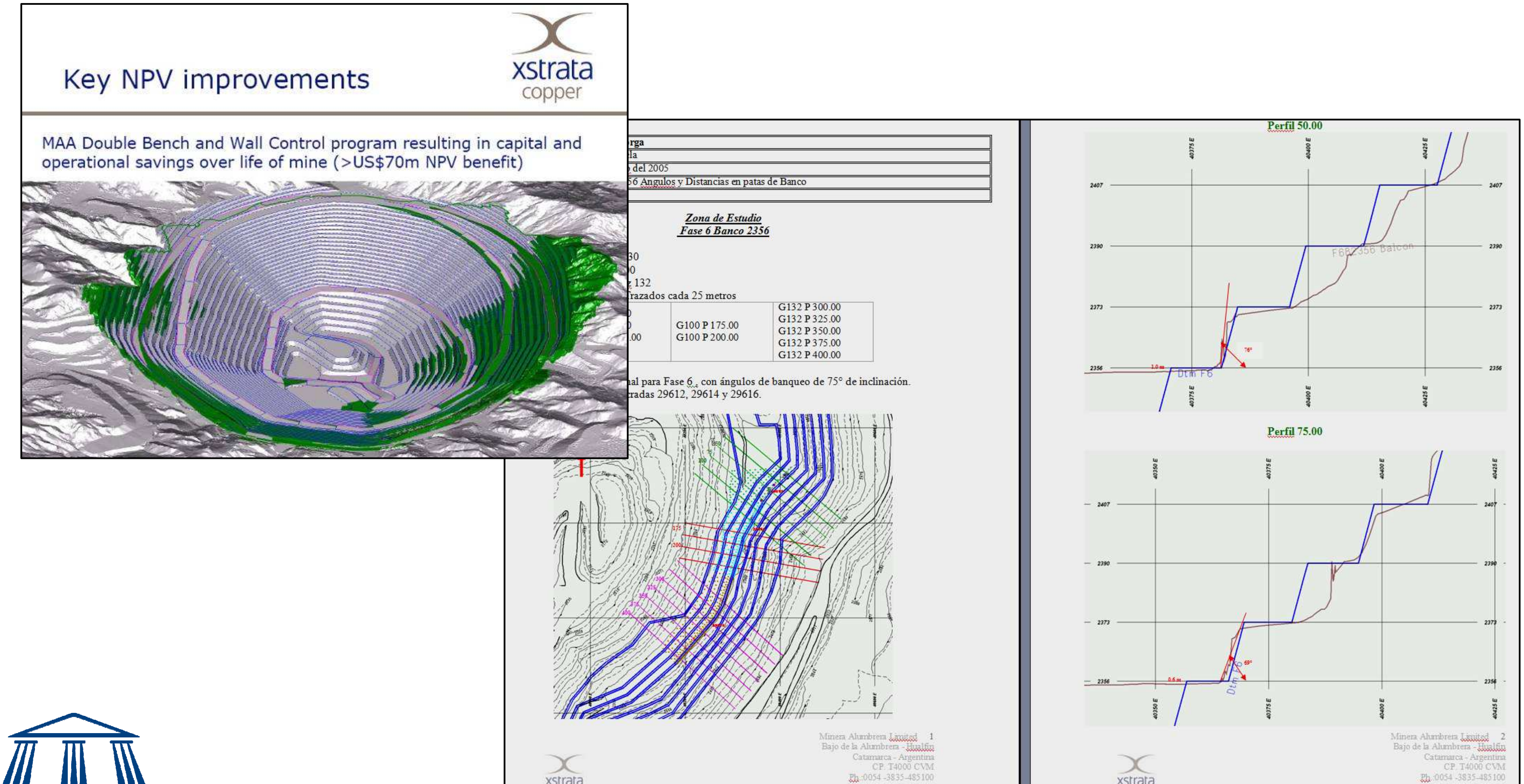
Mina Alumbrera - Pitwall scanlines



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