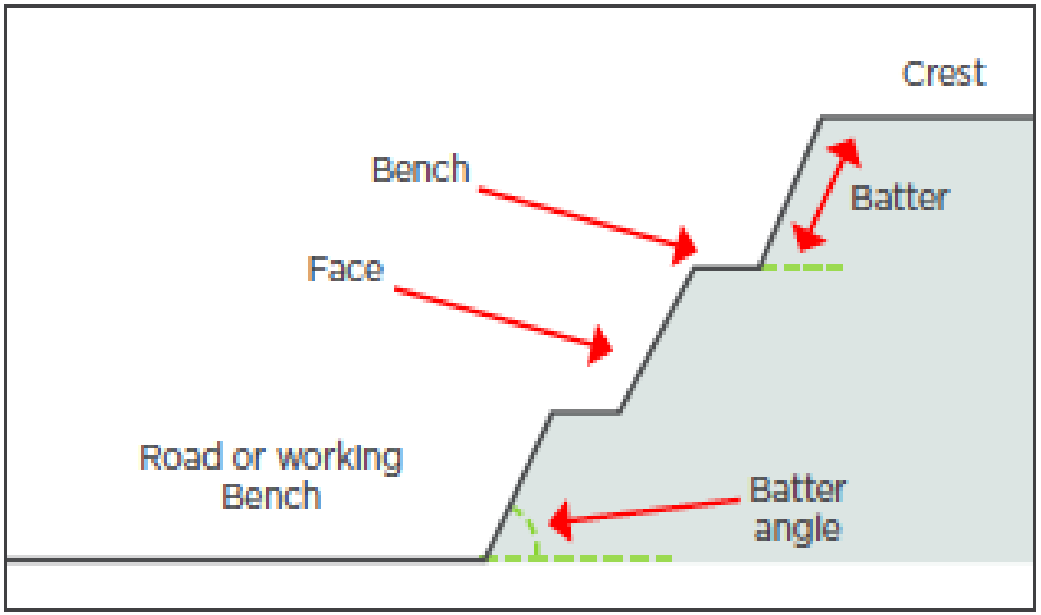
Slope Stability

Purpose of this presentation:

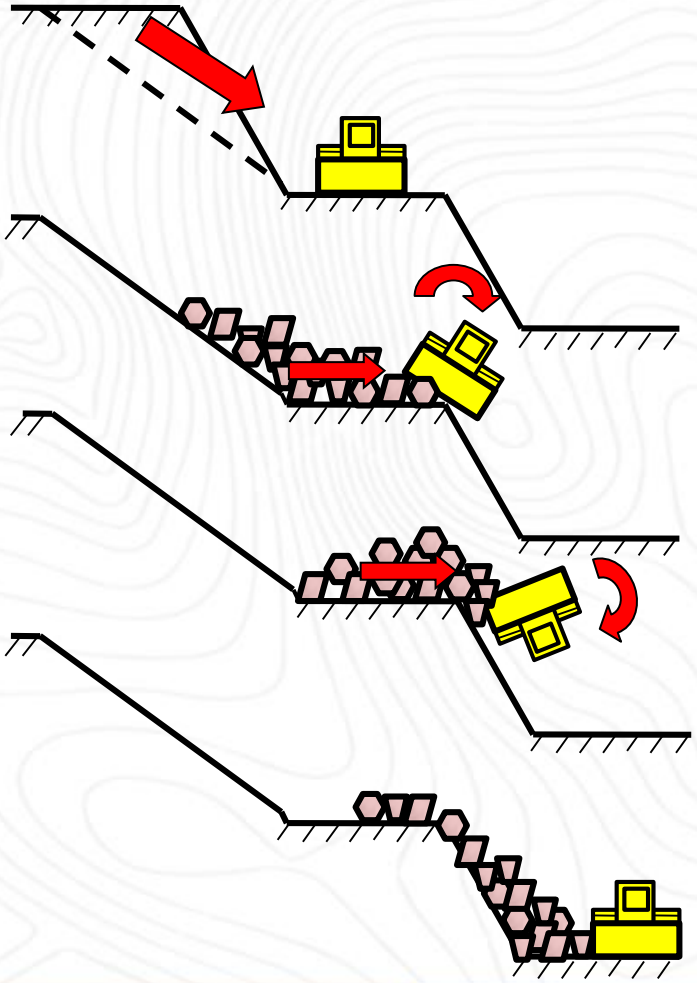
To provide you with:

- an understanding of instability in soils and rocks in quarries,
- an appreciation of the hazards associated with quarry excavations
- an increased awareness of inspections and safe working procedures in relation to excavations, tips and stockpiles

Terminology



Why consider slope stability in your quarry?



- Hardrock quarry in South Australia – Adelaide Hills - 2005;
- No recorded history of significant batter slips;
- Loader clearing access road for contract drill rig first thing in the morning - foggy;
- Rainfall previous several days
- Highwall batter suddenly gave way;
- Damage to Loader when it flipped over the bottom batter onto the next bench;
- Driver sustained minor injuries to jaw – was wearing seatbelt;

New Zealand has had it's share





What are the potential costs?

- Injury and loss of life
- Damage to plant
- Lost production
- Restoration works
- Legal liability

When is a slope not stable?

Slope stability is based on the interplay between two types of forces:

- **Driving forces promote downslope movement of material.**
  (gravity, slope angle, type of material and water)

- **Resisting forces deter movement.**
  (shear strength of the material, ability of particles in the rock to stay together)

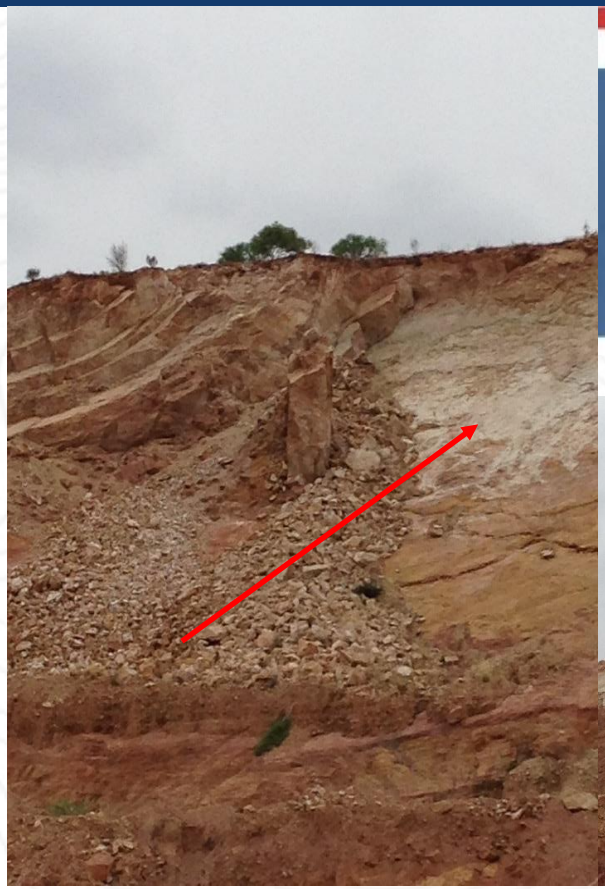
When driving forces overcome resisting forces, the slope is unstable and results in movement.

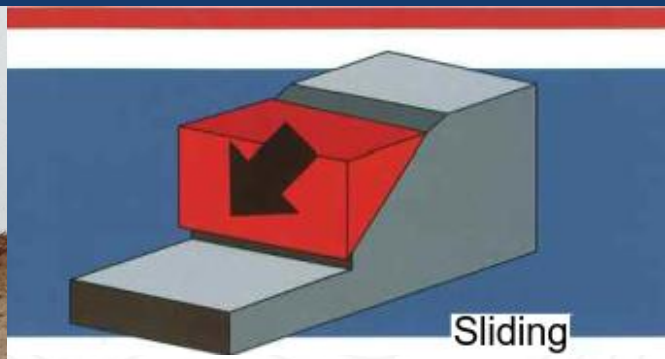
Failure mechanisms- Planar failure

- Also known as sliding failure
- Attributed to a mass of rock moving downwards along a surface
- Prominent along slippery backs

Opportunities to reduce risk:

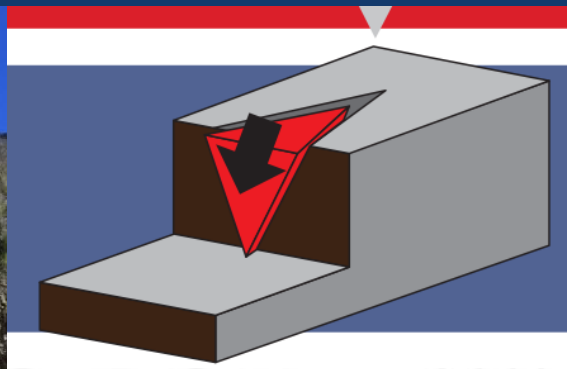
- Understanding of site geology
- Reduce bench heights
- Blast across the plane not with the plane
- Sufficient catchment berms and barriers to remove people from the hazard
- Sufficient berms at crest of bench





Failure mechanisms- Wedge failure

- Wedge formation two intersecting surfaces (bedding, faults, joints) meet and the block moves downwards.



Opportunities to reduce risk:

- Surface water management

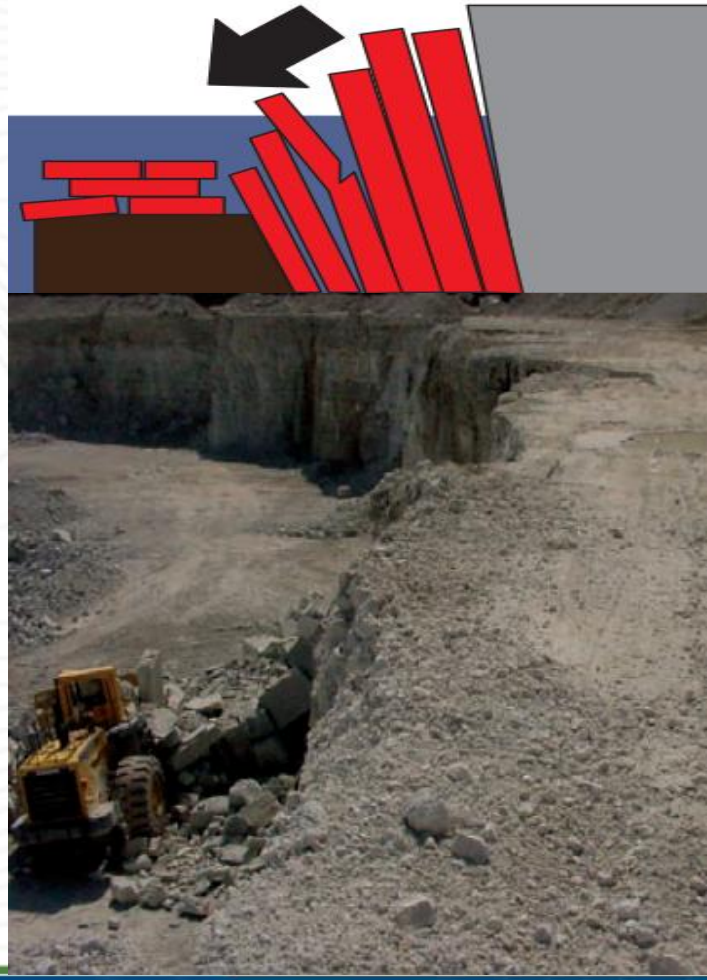
  Divert water away from pit walls
- Implement sufficient catchment berms
- Identify areas of pit of differing geology
- Toe bund areas of concern to limit mass of rock being under stress
- Sufficient catchment berms and barriers to remove people from the hazard

Failure mechanisms- Toppling failure

- Occurs as a result of vertical type structures moving out and down due to lack of confinement

Opportunities to reduce risk:

- Ensure site is geotechnically assessed and recommendations on total slope angle and face angle are clear
- Maintain sufficient catchment berms and barriers to remove people from the hazard
- Walk site often to understand if ground is under stress (tension cracking etc)
- Water Management
- Divert water away from crest lines of pit

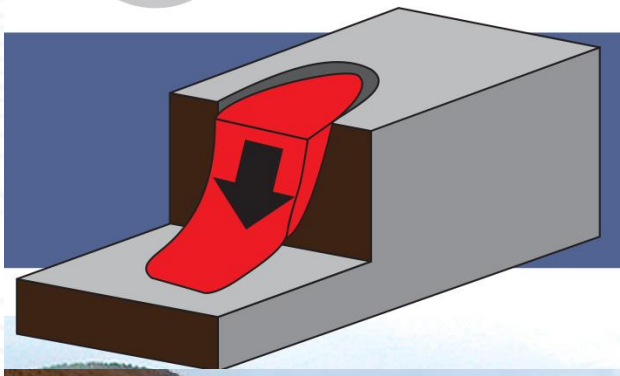


Failure mechanisms- Circular failure

- Also known as rotational failure
- Failure occurs when a mass of material moves in a downward motion leaving a circular shaped scour
- Often attributed to overly steep walls, insufficient toe bunding and water saturation after high rainfall events

Opportunities to reduce risk:

- Maintain sufficient catchment berms and barriers to remove people from the hazard
- Pit planning to ensure stable wall faces are recommended
- Visual assessment of crest lines after high rainfall events
- Toe bunding where possible
- Limit mass of material on benches with reduced face heights



Controls to reduce risk

- Decrease bench heights and overall slope height and angle
- Increase catch bench width and height
- Remove overhangs and other face hazards by blasting, scaling or cleaning faces
- Use appropriate type and size of equipment
- Place an adequate catch bund near the toe
- Create an adequate stand-off distance/exclusion zone near the toe
- Stabilise the toe by placing material against the face (butressing)
- Establish procedures for safe entry to the pit following weather events or blasting

Controls: Understand your geology

- **Geotechnical mapping may help**

INSPECTION CHECKLIST

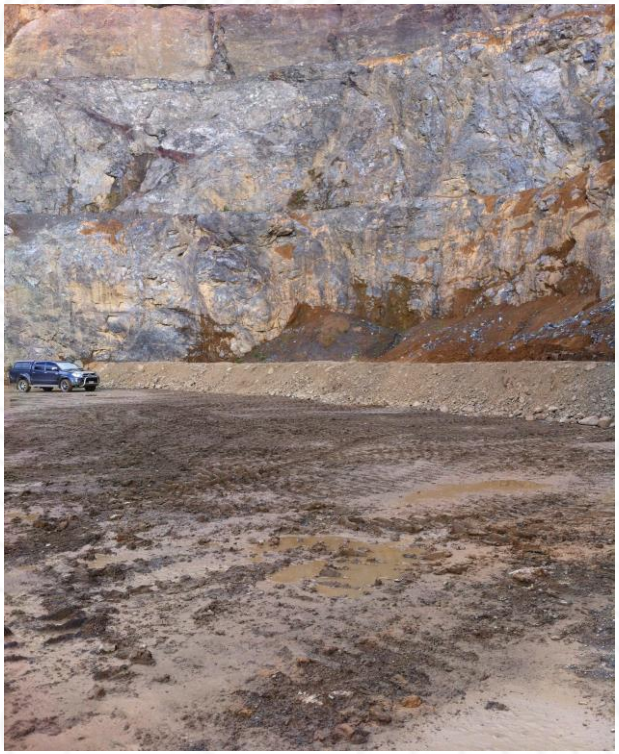
Feature	Location	Ok Y/N	Comment
Batters/Walls			
Constructed to design angle			
Face spalling or fretting			
Cracks/over hangs			
Toes maintained			
Water seepage			
Access ramp away from face			
Ramp bunded			
Blast damage			
Berms/Benches			
Design width achieved			
Crest loss			
Signs of instability			
Drainage adequate			
Pit surrounds			
Drainage away from pit			
Surface water ponding			
Windrows adequate			
Surface settlement or subsidence			
No environmental damage			
Road conditions			
Wide enough for vehicles			
Adequate passing areas			
Drainage adequate			
Roads in good condition			
Signage			
Access to site adequately sign posted			
Open pit hazard identified			
Exclusion zones			
Windrows/Catch bunds			
Catch berms installed			
Adequate height for rockfall			

Person Inspecting _____ Signature _____ Date _____

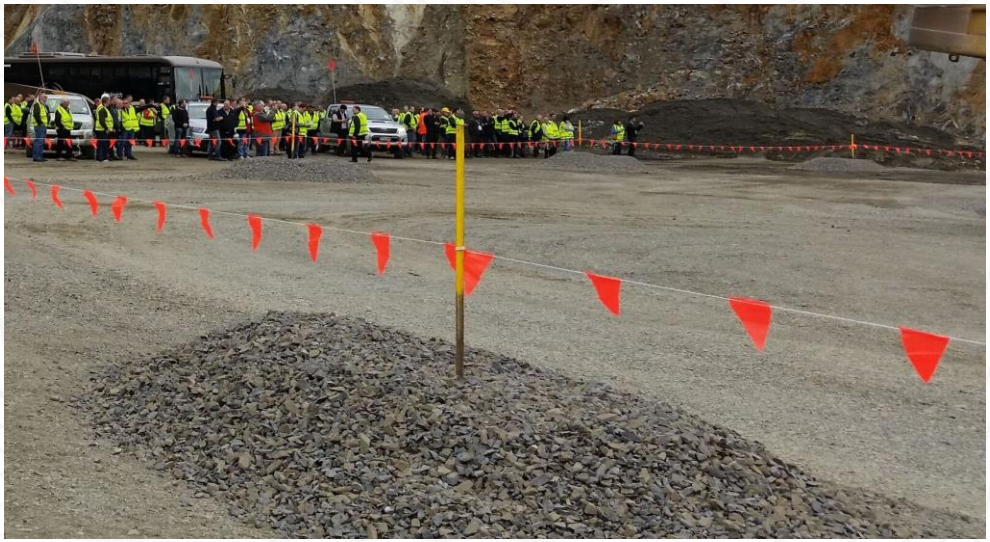
- **Operators know best as to the historical performance of the ground and stability of rock formations**

- **Regular inspections**

Controls: Sufficient catchment berms



- **Sufficient catchment berms and barriers to remove people from rock fall hazards**



Controls: Rehabilitation of final walls

- **Softer materials may require additional stability rehabilitation by way of hydro – mulching etc.**

- **Implement a site water management plan in line with quarry development to ensure that saturation of clays etc do not affect the integrity of the quarry walls**

- **Rehabilitate faces where possible with various plants and grasses to reduce the affect water will have on erosion of soils that could accelerate failure mechanisms occurring.**

Controls: Blasting techniques can help

- Presplit Blasting practices can achieve competent safe walls in highly joint rock masses
- Decrease overhanging rocks on crest therefore reducing additional hazards
- Additional smooth wall blasting techniques can be achieved in jointed rock types
- Reduced spacing on the back row of shot holes with faster initiation timing to “cut off” the back row provides cleaner and safer faces for loading out from and hauling underneath

Monitor for slope instability

- **Regular workplace inspections**
- **Identify rocks on berms or roads, cracks, crest loss and changes in water flow**
- **Measure movement in cracks**


Questions???