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A REVIEW OF CHROME MINING IN ZIMBABWE

By

P. Musarandega (Zimasco)

PRESENTATION LAYOUT

- Introduction
- Mines support infrastructure
- Critical geo-technical parameters
- Categories of mining
- Labour requirement guideline
- Challenges in chrome mining
- Productivity improvements; way forward
- How Zimasco is managing challenges

INTRODUCTION

- Presentation aims to:
  - Provide seasoned chrome miners with alternative approaches/models for benchmarking purposes (comparing notes)
  - Enlighten novices who are contemplating joining the sector or have just joined the sector (ceded claims)
  - Draw researchers/academics to joint the battle to tackle mine design and planning challenges encountered in chrome mining
  - Keep alive the dialogue concerning productivity challenges within the chrome mining sector, lest we forget
  - Tap ideas from fellow professionals, to improve productivity and viability in view of market volatility

MINES SUPPORT INFRASTRUCTURE

Include the following:

- Administrative offices
- Residential houses
- Workshops
- Explosives magazines
- Loading bays & sidings
- Timber plantations (for underground rock support)
- Schools
- Clubs & guest houses
- Power supply (ZESA, generators)

CRITICAL GEO-TECHNICAL PARAMETERS

Key geo-technical parameters that drive selection of mining method are as follows:

Seam mining

- Seam width /thickness
- Seam dip
- Seam continuity
- Friability of seam
- Strike length

Pod mining

- Pod size (length, width, height)
- Depth from surface
- Dip
- Rock strength

CATEGORIES OF MINING

- **Underground Mining:** on & off the dyke; Semi-Mechanised
- **Open Pit Mining:** Mechanised & Semi-Mechanised; podiform deposits
- **Strip mining:** *Mechanised & Semi-Mechanised; stratiform & elluvial deposits*
- **Small Scale Mining**
  - Adits and winzes
  - Surface (manual)
  - Dump reclamation

LABOUR REQUIREMENT GUIDELINES: COMPLEMENT VS MINE CAPACITY

Operation	Mine Capacity (t)/month	Average Labour Complement
Dyke Semi-mech underground mine (SD & MD)	≈500 - 1,500	≈60 - 200
Dyke Semi-Mech Underground (ND)	≈250 - 800	≈75 - 235
Podiform Semi-mech underground mine	≈2,800	≈180
Dyke mechanized surface	≈3,500	≈95
Small Scale (North Dyke)	≈150	≈25
Small Scale (Middle & South Dyke)	≈150	≈15

SMALL SCALE MINING

- Mainly pick and shovel operations
- Adits & winzes used in hilly areas in Mutorashanga; surface mining in rest of the areas on and off the dyke.
- Equipment used includes coal drills, generators, wheelbarrows, picks, hammers, & shovels; Windlasses are used in winzes for hoisting purposes.
- Mining depths of 0m to 5m in surface mining
- Winzing with mechanical hoisting is done to limited depths of 40m on dip where there are favourable geo-technical parameters
- Adits (small tunnels) within 150 meters on strike into the hill/mountain due to limitations of wheelbarrow tramming.
- Mining methods are applied in areas with limited strike.
- Aditing and winzing require timber support; need for establishment of timber plantations to constantly supply the required timber.
- Minimum skills required include but not limited to MBL holders, winch operators, drill operators and semi skilled artisans for maintenance of the equipment like drills and winch hoists.

SMALL SCALE MINING, CONT.

Adits

Winzes

SMALL SCALE MINING, CONT.

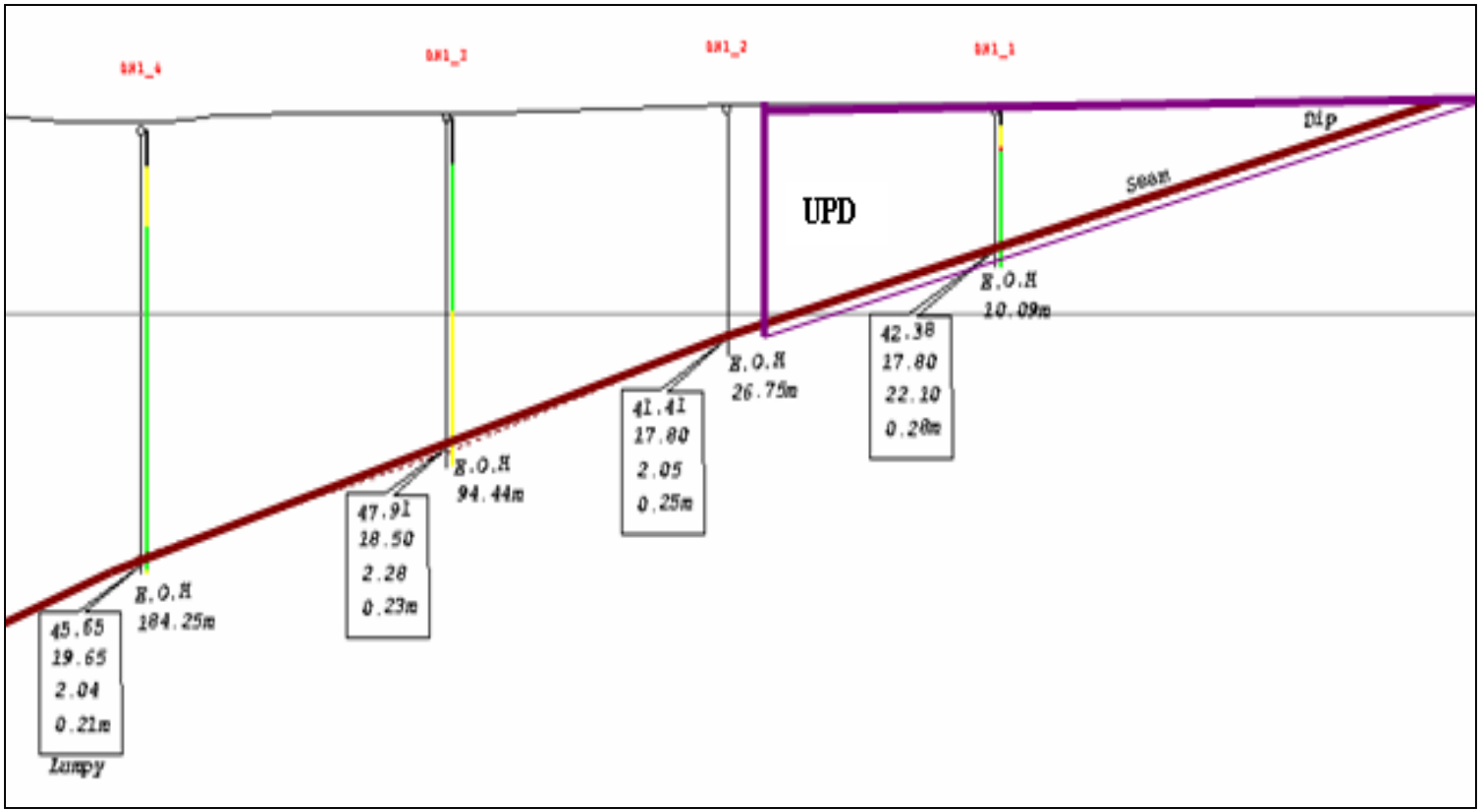
Dump Reclamation

MECHANISED SURFACE MINING

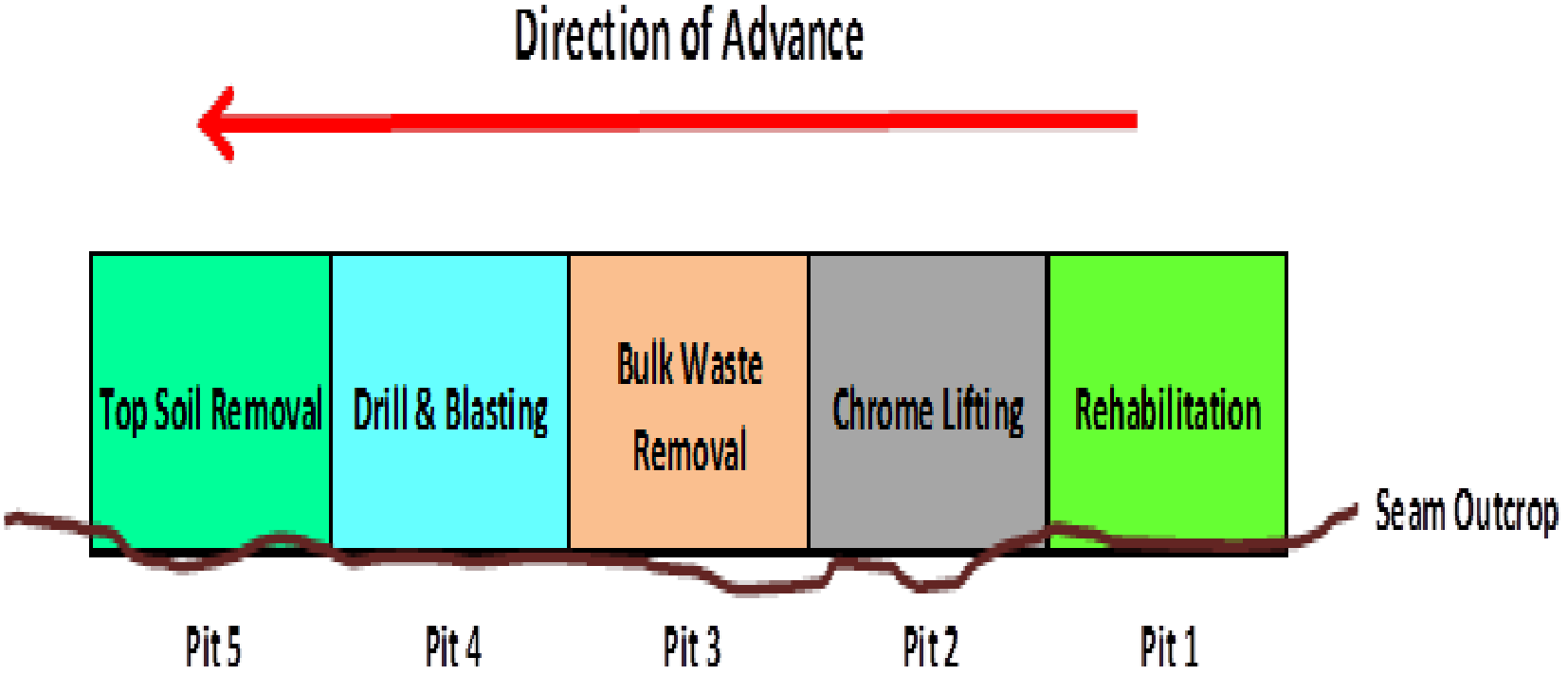
- Includes strip mining (on dyke) & open pit mining (off-dyke)
- Requires full set of mobile equipment
- Mining depth (UPD) up to 23 meters on the dyke and up to 90m off the dyke; can be deeper if the stripping ratio is favourable.
- Typical equipment for one operation includes at least 2 excavators (45t), 5 ADTs (30t), 1 Drill Rig, 1 Dozer (minimum D6), 1 Front End Loader, 1 Grader, Dewatering Pumps (depends on depth of water table), Lighting Equipment and utility vehicles.
- Production capacity of more than 1,500tpm; can go to 5,000tpm
- Critical skills include a Mine Manager, Pit Supervisors, SHE Practitioner, Artisans Class 1 (ratio 6:1), Earth Moving Equipment operators
- For strip mining, 5 Pit Mining Method is applied to enable continuous rehabilitation as mining progresses.
- For Open pit mining (pods) the inverted cone method is employed with proper benches and haul roads being maintained.
- These methods are illustrated in the following slides

MECHANISED SURFACE: STRIP MINING

- Typical cross-section of seam from outcrop



STRIP MINING – FIVE PIT MINING SYSTEM



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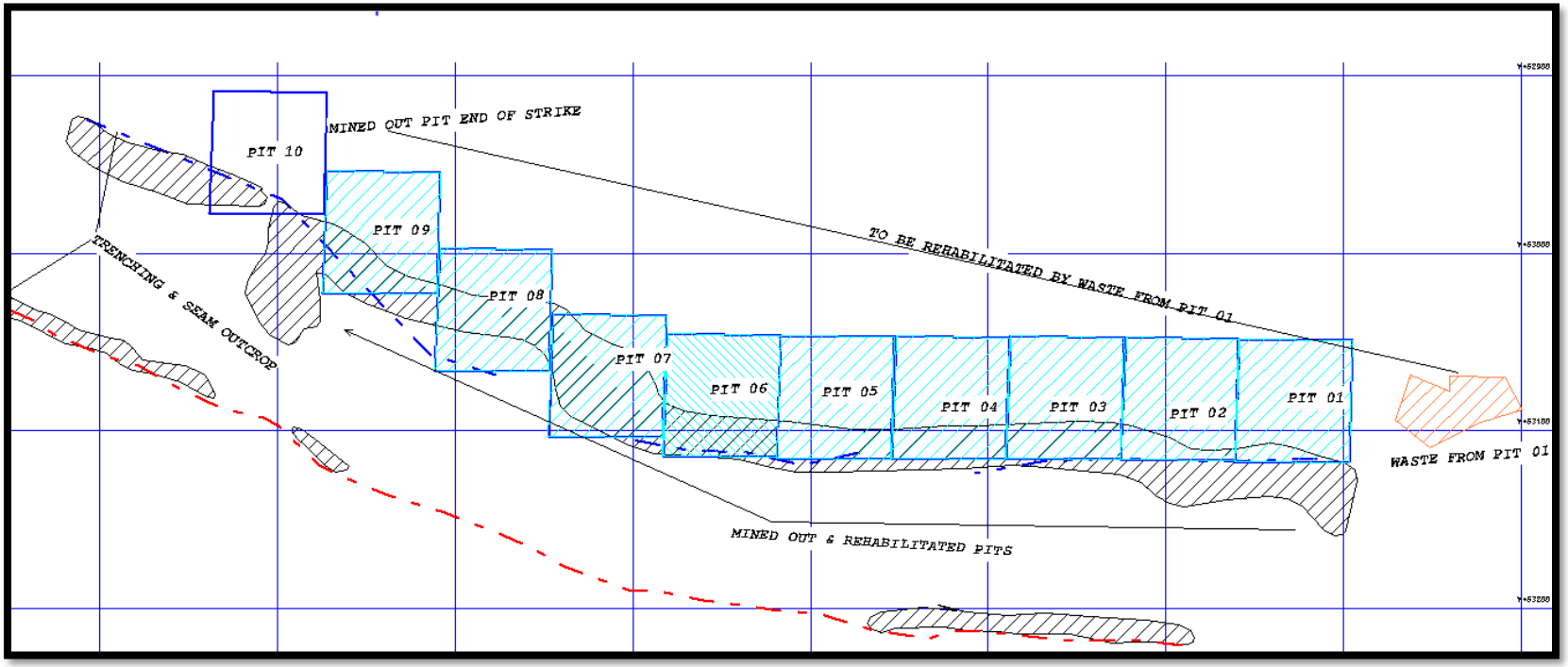
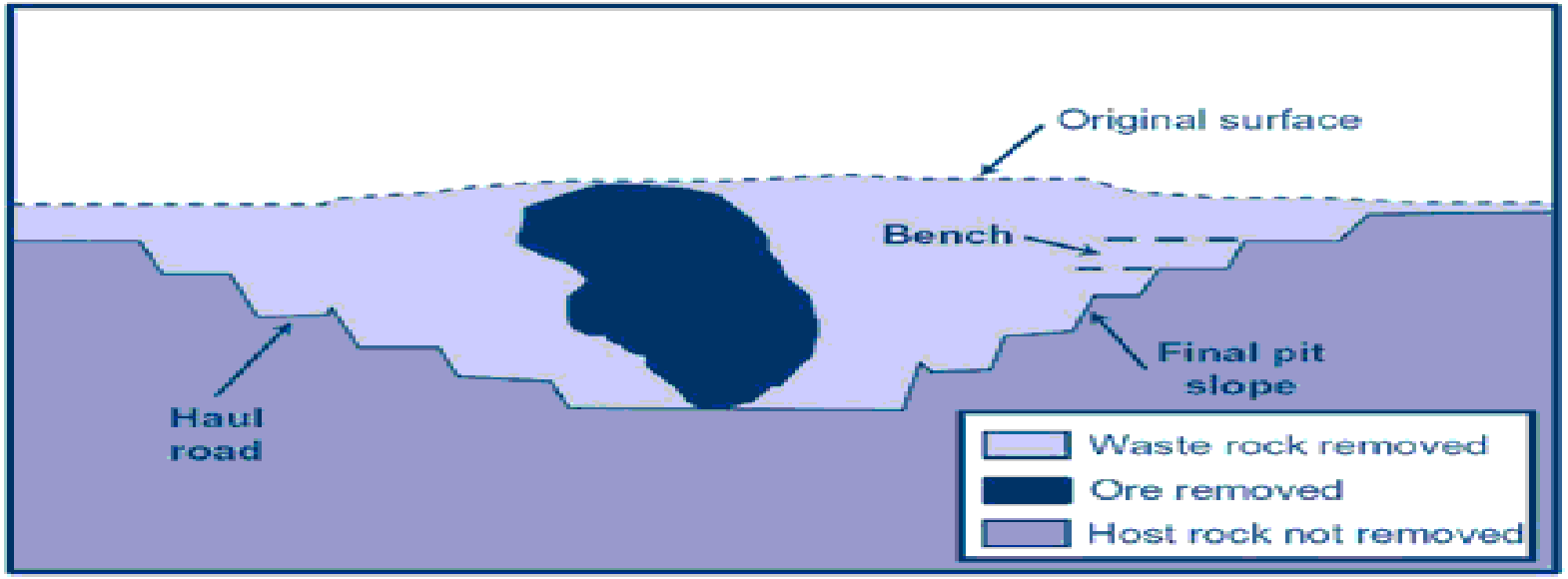


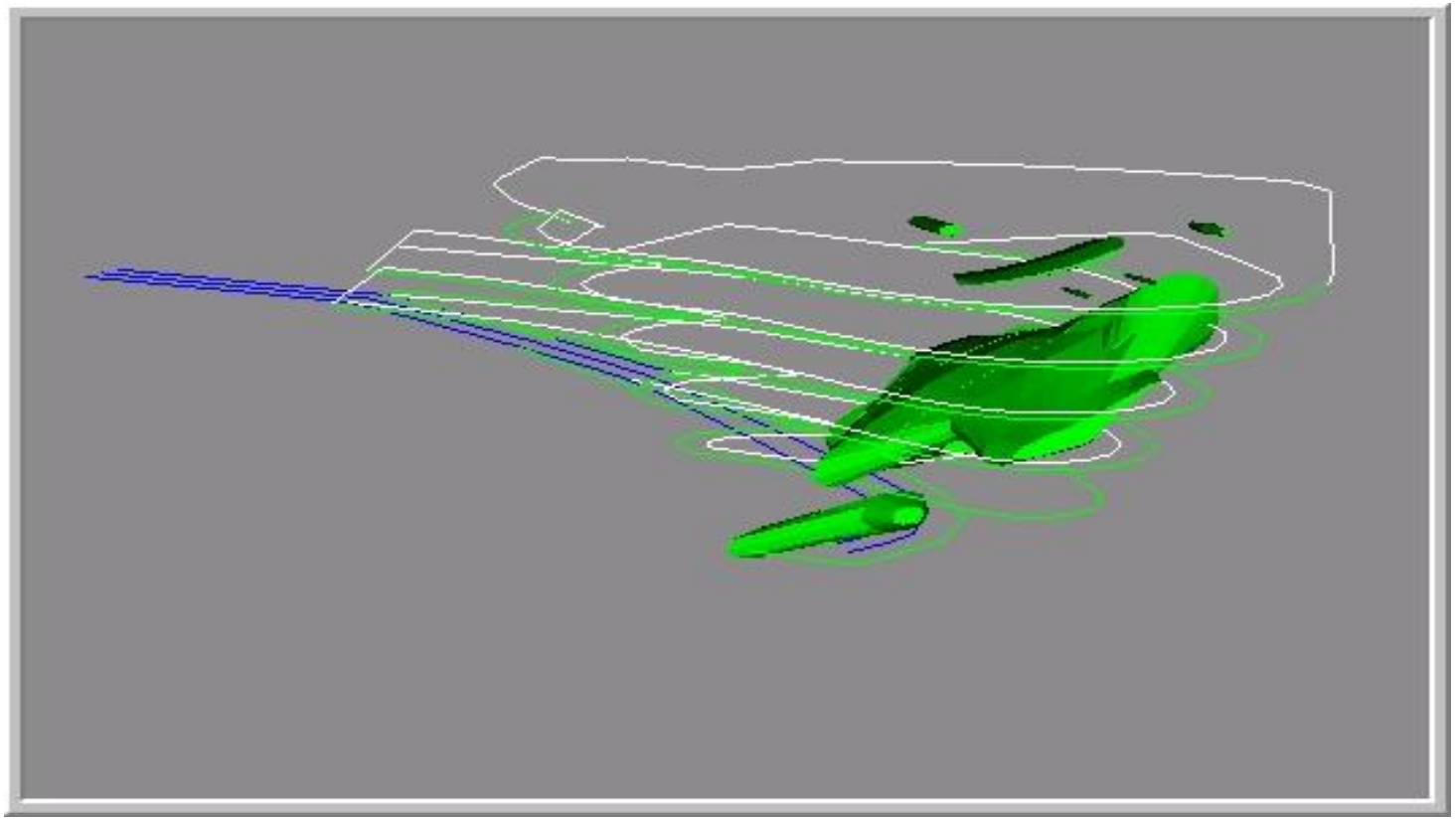
SURFACE MINING: OPEN PIT

- Used on podiform deposits
- Mined out waste is hauled out of the pit and dumped at a waste dump; no backfilling during the life of the mine.
- Benches are developed and maintained at intervals
- Proper haul roads and developed and maintained to facilitate earthmoving.



SURFACE MINING: OPEN PIT, CONT.

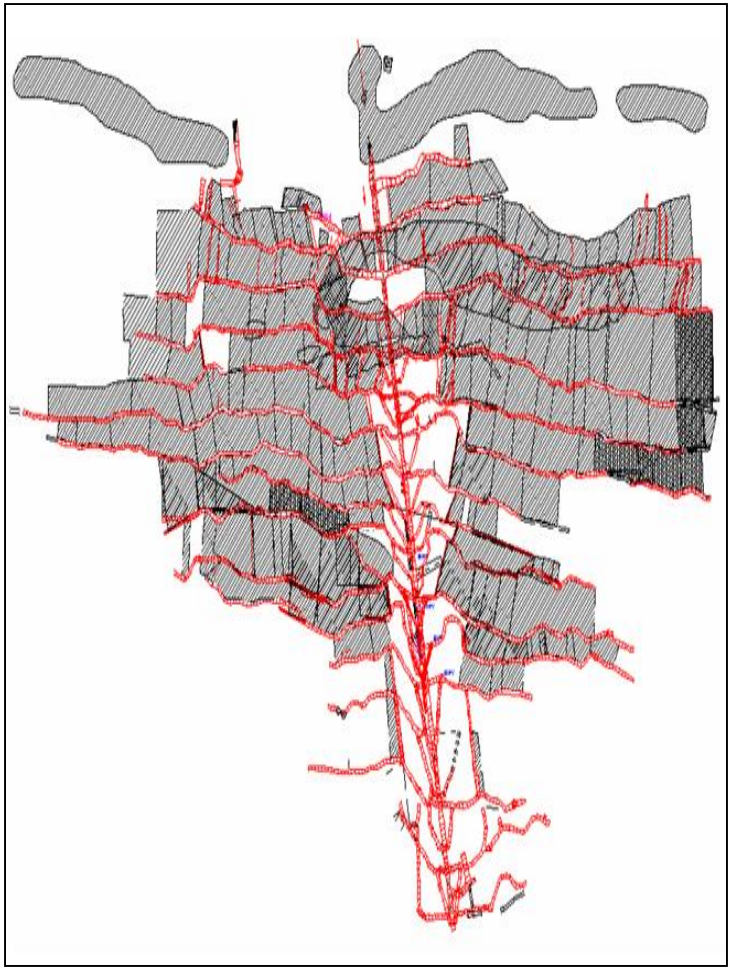
- Typical model: RBEII Mine, Zimasco



SEMI-MECH UNDERGROUND MINING

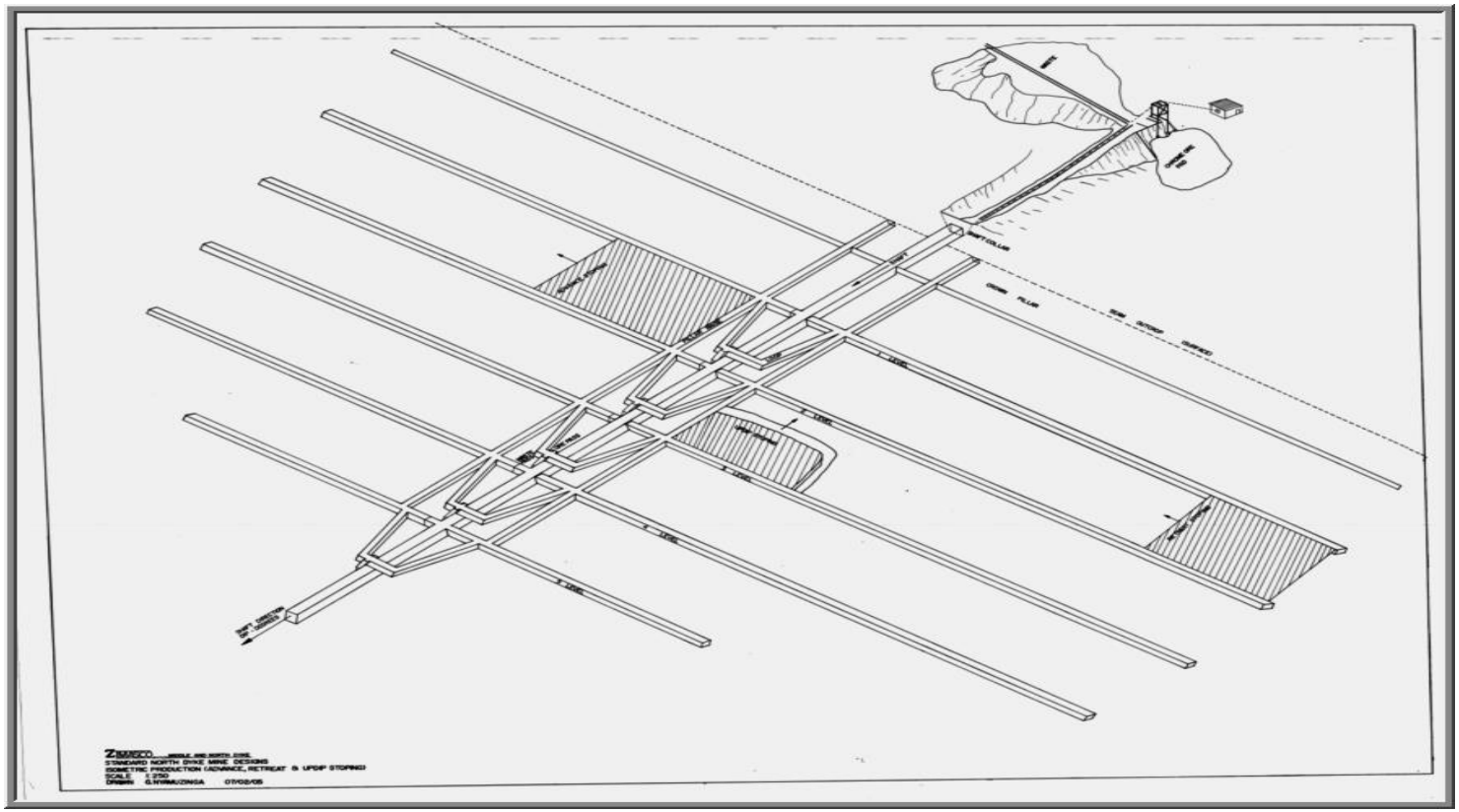
- Access to ore body is by way of shafts and tunnels and ore is extracted from stopes
- Installed infrastructure almost the same; main difference is on capacities of the equipment used.
- Monthly production: on the Dyke - up to 2,000tpm; off the dyke - can be more than 8,000tpm.
- Equipment used includes compressors, hoists, standby generators, dewatering pumps, jackhammers, cocopans , rails, pipes, headgears etc.
- Dyke mining:
  - mines are on dip and follow seam with smaller excavations (Resue mining - Breast mining method is applied)
  - the void created by ore extraction from stopes is backfilled by waste rock from continuous development
  - depths more than 100 meters (4 levels) on dip and can go beyond 500 meters dependent on claims boundary, geological parameters of seam and rock mechanics of ground.
- Podiform:
  - stopes remain as an open void.
  - Access through vertical shafts with mining depths of more than 800m.
  - sub-level open stoping method mostly used; also shrinkage and underhand. Excavations bigger

SEMI-MECH DYKE UNDERGROUND MINING



SEMI-MECH DYKE UNDERGROUND MINING

- Shaft on seam – Pilot Winze



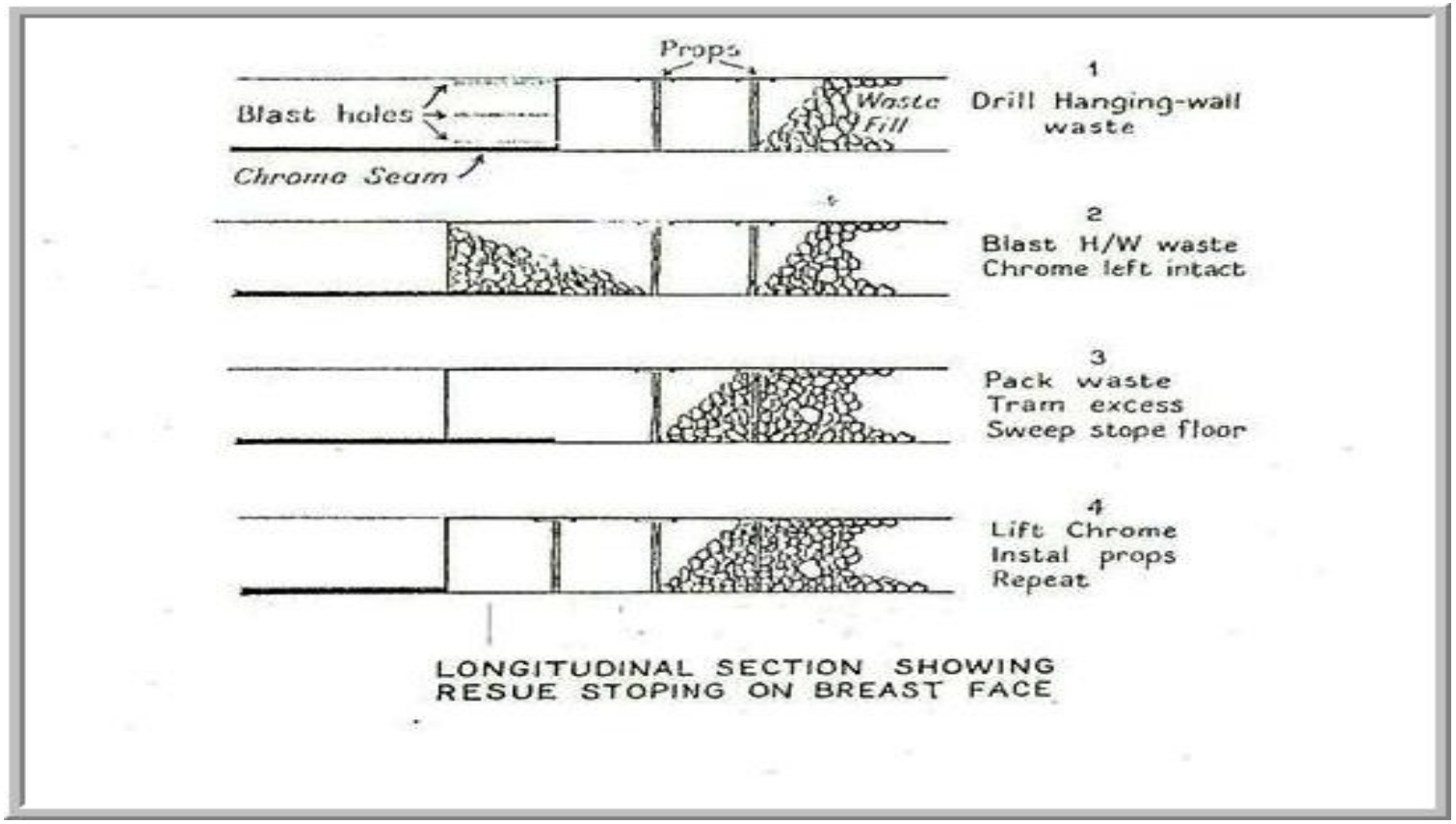
SEMI-MECH DYKE UNDERGROUND MINING

- Incline shafts sited on outcrop at intervals of 500m and sunk on dip carrying seam +/-1m from footwall
- Seam drives developed at 20m intervals and a tramming loop in the hanging wall provides short passes for storage of ore and waste
- Shafts generally produce 800tpm (North Dyke) to 1,800tpm (Middle Dyke) and 1,250tpm (Lalapanzi & South of Shurugwi) from 6 stopes and carry 2 stopes as spare
- Shafts equipped with 70HP hoists and mining progresses on dip to maximum depth of 500m before shaft is re-sited or re-deepened
- Tramming in the drives is by hand, using 1.0-1.5t cocopans.
- The simple layout of an on-seam shaft is most common on the Dyke because:
  - Class 2 artisans can maintain the shaft.
  - The development off-seam is minimal, thus reducing negative exposure to blanks.
  - There is minimal mine planning and survey as day to day face direction is determined by seam behaviour.

SEMI-MECH DYKE UNDERGROUND MINING

- **Stoping Practice:**
  - The essential considerations in extraction of chrome seams is the removal of the seam with minimum fragmentation of the ore and with minimum contamination by waste
  - The method of exploitation almost universally employed is that of Resue Stoping on breast faces (for dips ≤30°) and up-dip faces (for dips >30°).
  - Drill and blast hanging wall waste down full length of stope face
  - Pack waste between timber props to fill stope from h/wall to f/wall
  - Excessive waste (swell) +/-30% lashed into seam drive for tramming to waste pass and subsequent hoisting to surface for dumping
  - Stope floor is swept clean before breaking chrome seam
  - Chrome seam exposed is broken to induce separation and lifted carefully to minimise fragmentation
  - Support consists of timber props on chevron pattern close to the face, with waste backfilling behind
  - Resue Stoping on breast faces is in most cases practised on Advance Stoping with Retreat Mining only employed in areas where the ground is considered blocky and unstable
  - Up-dip stoping is seldom applied where dips are less than 30°. In such cases, local faulting/jointing will be the determining factor

SEMI-MECH DYKE UNDERGROUND MINING



SEMI-MECH DYKE UNDERGROUND MINING

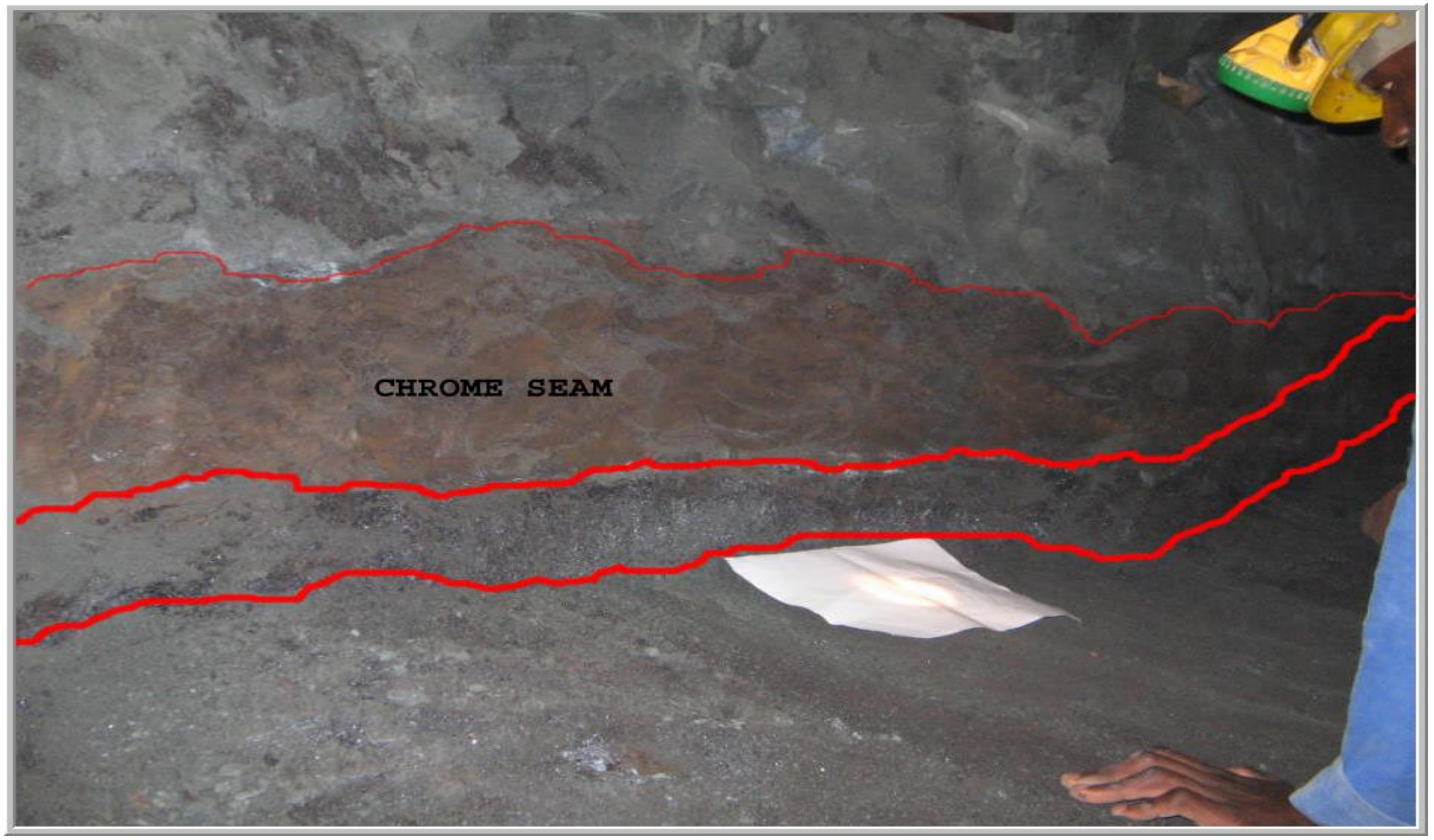
- Drill ; charge and blast in a stope

SEMI-MECH DYKE UNDERGROUND MINING

- Waste packing & timber support in a stope

SEMI-MECH DYKE UNDERGROUND MINING

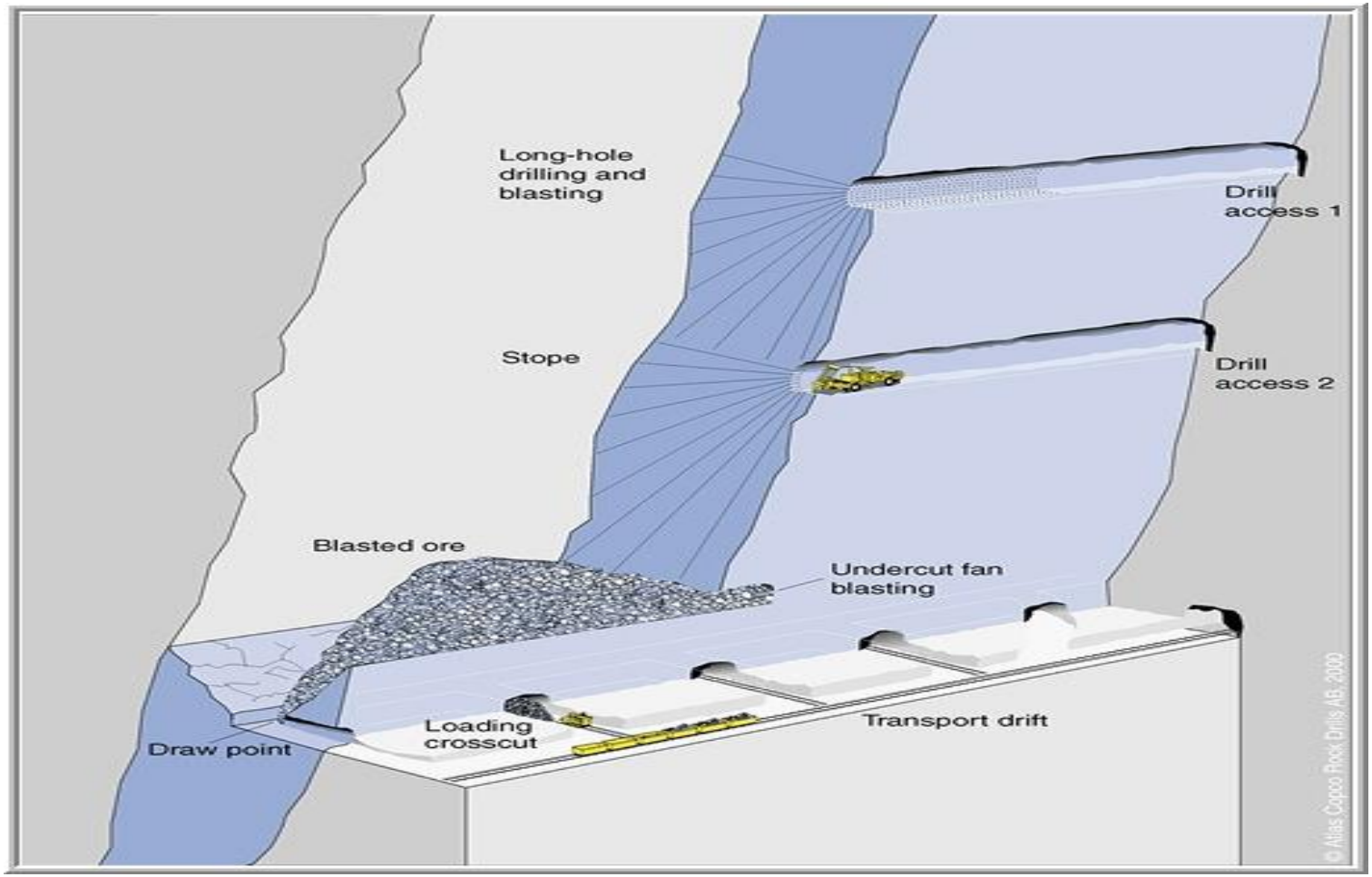
- Chrome seam lifting in a stope



SEMI-MECH PODIFORM UNDERGROUND MINING

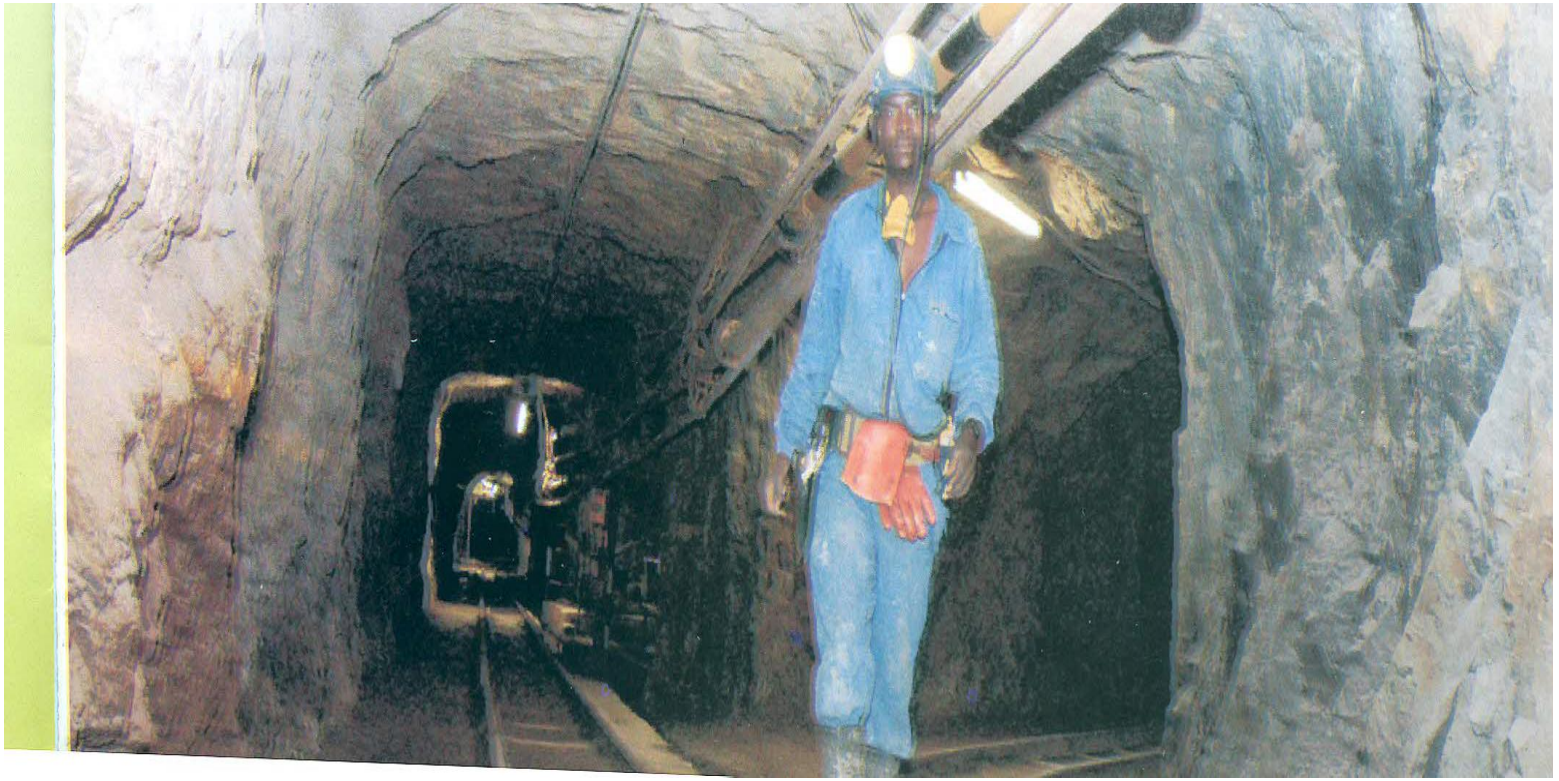
- The common Mining Methods applied are **Sub-Level Open Stoping** and **Shrinkage Stoping**.
- Access through vertical shafts/adits, drives, raises
- Processes include:
  - Drilling and blasting,
  - Tramming and hoisting then
  - Processing (mineral dressing - HMS)
  - Equipment & infrastructure maintenance

SEMI-MECH PODIFORM UNDERGROUND MINING



SEMI-MECH PODIFORM UNDERGROUND MINING

- Typical haulage



CHALLENGES IN CHROME MINING

- Bulk of chrome ore from strip mining; cheaper (opex and capex)
- Unsustainable; remaining resource economically mineable this way (a)limited in quantity, & (b) friable & of poor quality
- Over the years low prices forced companies to focus on mining lower cost-high quality deposits; also starved companies of capital to develop viable dyke u/g mines which are the future of chrome ore mining in Zimbabwe (for others it was deliberate – lack of u/g mining skills)
- Available sinter technology costly to acquire; also requires optimisation to suit local ores
- Other alternative: furnaces that can take friable ore. Significant capital required.
- Harsh reality: in the near future, more should come from u/g on the dyke. Challenging cross-over as current mining method has low productivity and capacity.
- Sector seriously threatened in the future

CHALLENGES IN CHROME MINING, CONT.

- **Geo-technical challenges:**
  - Podiform deposits (off-Great Dyke): Cheaper to mine but running out
  - Stratiform deposits: on the Great Dyke; bulk of the resource. Costly to mechanise with current technology
- **Resource limitations:**
  - Globally mining companies tackling viability challenges with innovation and advanced technology.
  - Zimbabwean companies , Zimasco included, lack resources and facilities for effective mine engineering research and development.
  - Continued reliance on old, labour intensive and inefficient mining methods and technology which compromises competitiveness.

PRODUCTIVITY IMPROVEMENTS: WAY FORWARD

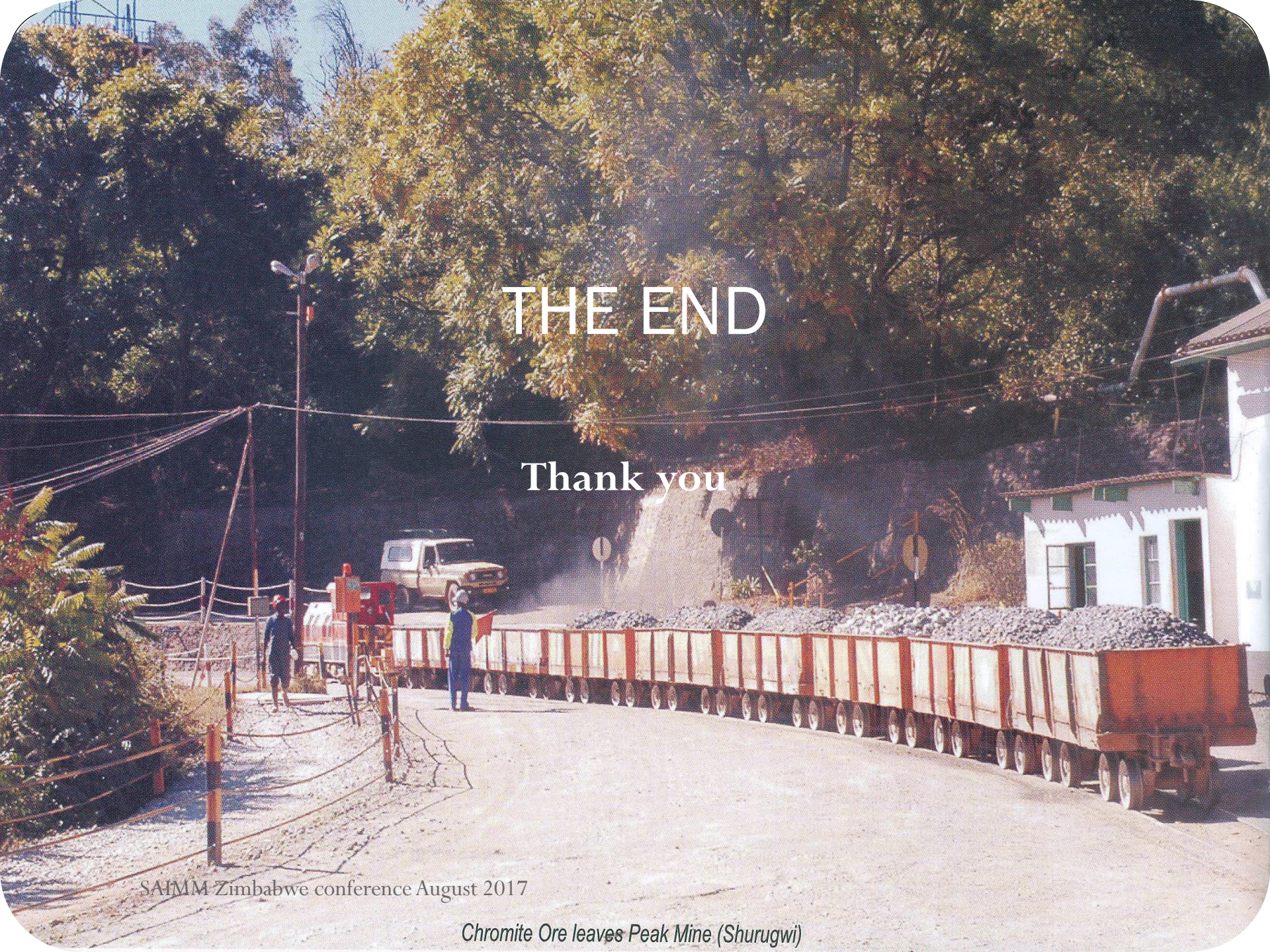
- **Collaboration between companies, universities & equipment manufactures:** to share costs and expertise
- **Extensive trials:** required to ensure suitability of new equipment & proposed mining methods
- **Modeling & simulation:** determine realistic productive & value parameters given impracticality of piloting all possible options
- **R&D focused institutions @ national level**
- **In-house innovation departments**

WAY FORWARD, CONT.

- Our mining will become unsustainable from a cost point of view (with depletion of podiform deposits and shallow lumpy ore deposits on the Great Dyke) if solution not found urgently
- Need to quickly develop innovative, mechanised dyke u/g chrome mining methods which are productive, efficient and viable economically
- Dedicated resources required to fund an internal research program
- Collaborative effort required with all stakeholders locally, in the region and across the world

WHAT ZIMASCO IS DOING TO MANAGE CHALLENGES

Challenge	Mitigation measure
Low productivity	R&D/consultations/trials
Dwindling open pitable resource	U/G mines – capex (≥5 year plans)
Friability	Sintering (owner outsourced)
Quality variations	Use of blends
Steep dips	U/g mining methods
Poor seam continuity	Probing; selective mining
Rehabilitation	Backfilling (5 pit mining system)


THE END
Thank you
SAIMM Zimbabwe conference August 2017
Chromite Ore leaves Peak Mine (Shurugwi)