SHAFT REHABILITATION AND PILLAR EXTRACTION AT ASHANTI GOLDFIELDS

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Abstract

Ashanti Goldfields have been mining gold at Obuasi, Ghana since 1897. Since the early 1990s a major expansion programme has resulted in greatly increased gold output. This was initially from open pits but, as the open pit production drops, underground production is increasing. The increase in waste and ore hoisting requirements peaks in the year 2000 at which point the current hoisting capacity will be exceeded. The required increase in hoisting capacity will be achieved by a combination of an additional shaft and surface decline and rehabilitation of the old Eaton Turner Shaft (ETS). The ETS lining and service excavations have suffered major damage since the 1960s and the hoisting capacity in 1996 was estimated at only 30000 tpm. In January 1997 the shaft was closed for major shaft rehabilitation, winder replacement and alterations to rock handling facilities to increase the hoisting capacity to 85000 tpm. A small, high grade, shaft pillar between 32 and 36 Levels is also being mined to reduce elevated stresses acting on the shaft barrel and to increase cash flows whilst the shaft is off line.

Introduction

The Eaton Turner Shaft, located at the northern end of the underground workings at Ashanti Goldfields, is a 5.5m (18') diameter, concrete lined shaft with rope guides sunk in the mid 1950's and extending from surface to 43½ Level (1383 mbs).

The stations excavated from the shaft include 8, 26, 32, 35, 38, 40, 41 and 42 Levels, with levels spaced at approximately 30m (100 feet). The skip loading pocket is situated opposite 42 Level station and the spillage handling facilities on 43 Level. The guide rope tensioning weights are situated between 43 and 43½ Levels.

The shaft lining, stations and other excavations in the vicinity have experienced varying degrees of damage since the early 1960's. This damage was mainly due to increases in field stress levels, from stoping in the shaft region, and associated rock mass deformation. Major damage can also be attributed to seismic activity, structural features, the close proximity of service excavations and the poor quality of concrete lining.

The deformation of the rock mass and subsequent failure of the lining has been severe in places and monitoring during 1996 indicated movement was still occurring.

The shaft, below 31 Level, is located in the footwall of the orebody, in the pillar area, with the orebody dipping at approximately 80° to the West. The shaft pillar, between 32 and 36 levels (1033 to 1155 mbs) is 60m on strike, 120m down dip, 10 to 21m from the shaft, with an average orebody width of 3.9m. The pillar contains approximately 92660 tonnes at a grade of 51 g/t, which equates to over 4500kg (152060 ounces) of gold.

The shaft hoisting capacity forms an integral part of the current mine expansion plan and hoisting tonnages of 85000 tpm are programmed from the year 2000. The shaft will be rehabilitated to ensure production is not delayed by failure of the lining, rock handling facilities (bins, conveyor drive, skip loading steelwork etc.) and other services.

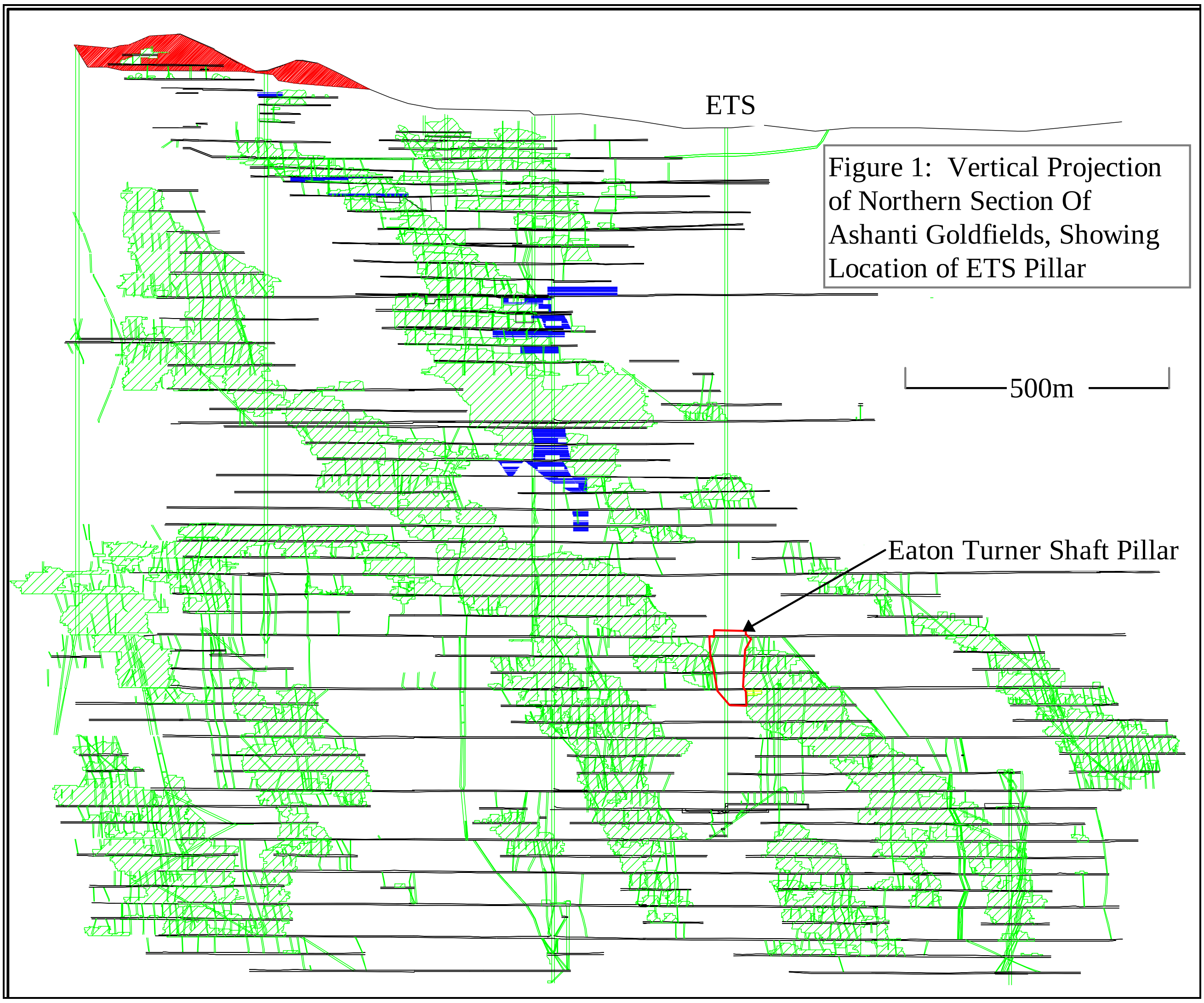


Figure 1: Vertical Projection of Northern Section Of Ashanti Goldfields, Showing Location of ETS Pillar

The risk of future damage to the rehabilitated shaft due to increased stress levels in the pillar area, and the grade of the pillar, resulted in a decision being taken, in July 1996, to mine out the pillar.

The required commissioning of the shaft by January 2000 effectively leaves only 2 years to mine out the pillar. The mining method chosen for the pillar is a scaled down version of sub-level open stoping. This involves ramp access in the hangingwall, sub-levels at 15m vertical spacing, 6m wide stopes and 12m blastholes. The ramp access also gives flexibility in case of problems with the mining as stress levels increase. The on-reef stress levels indicated from simulations are very high (up to 180 MPa).

The pillar mining and shaft rehabilitation project involves;

1. Stripping the old, damaged, shaft lining, adjacent to the shaft pillar, and supporting with a strong, flexible support (split sets, mesh, yielding Swellex)
2. Reinforcing the rock mass between the shaft and the orebody with cable bolts
3. Stoping
4. Re-lining the shaft after stoping has been completed.

Winder repairs, rehabilitation of the shaft outside the shaft pillar area, and alterations to the rock handling facilities will be undertaken concurrently with shaft pillar mining.

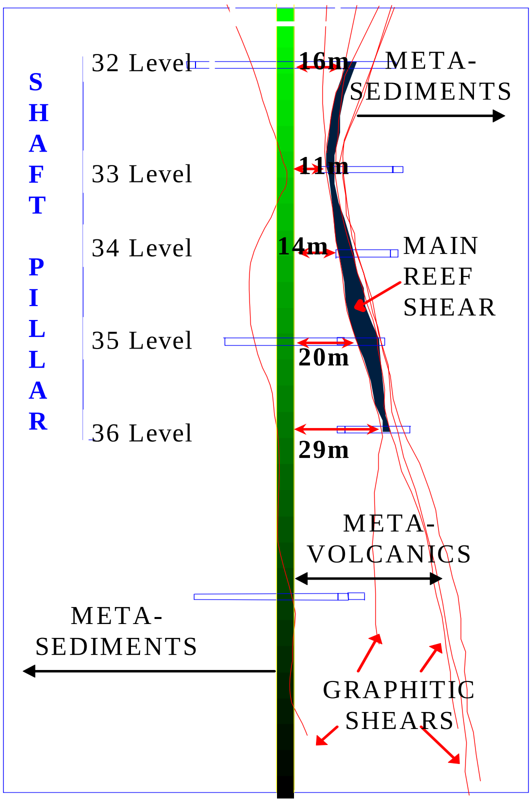
Reef driving commenced in February 1997 and stoping in May 1997.

Geology

The rock types in the area include steeply dipping metasediments (greywacke/phyllite), shear zones (hydrothermal, mainly quartz and graphite) and metavolcanics. The strike of the strata varies from 015° to 040° and the general dip in the lower sections is to the West at 70º to 80º. Steeply dipping shear zones follow and cross the strata, dipping at approximately 80º to the West below 32 Level and 40º to the West from 32 Level to 29 Level. These shear zones generally contain graphite, quartz and schist. The width of the shears varies from a few millimetres up to 6 metres in this section of the mine.

The Eaton Turner Shaft is located in the hangingwall greywacke/phyllites above the Main Reef fissure intersection at 31 Level. The shaft is located in the steeply dipping footwall metavolcanics and phyllites below the intersection.

Figure 2: Section through Shaft Showing Location of Main Reef Shear below 32 Level



Rock Properties

Typical rock strength properties are listed in the table below. In summary, the quartz, schist and greywacke have Uniaxial Compressive Strengths (U.C.S.) of around 150 MPa, the phyllites 180 MPa and the metavolcanics 107 MPa. The graphite contained within shear zones has not been tested due to its weakness.

Table 1: Major Rock Strength Properties

Rock Type	Density (kg/m³)	UCS (MPa)	Young's Modulus (GPa)	Tensile Strength (MPa)
Quartz Ore	2671	145.25	61.467	11.43
Schist Ore	2766	154.30	50.085	10.63
Metavolcanics	2812	107.37	42.140	14.12
Phyllite	2781	181.51	46.409	24.94
Greywacke	2729	151.90	44.913	19.75

The rock mass strengths of these rocks varies greatly between sections and is controlled to a major extent by structural features. The presence of discontinuities, shear zones and local variations in dip and strike all reduce the rock mass strengths, especially due to the addition of joint sets containing low strength graphitic materials.

Stress

The virgin stress regime, assumed for computer analyses of stress related damage, has been extrapolated from the results of a stress measuring programme conducted at the southern end of the mine in June 1996. The maximum principal stress is orientated in an East-West direction, acting approximately perpendicular to the major structural and bedding features, with a magnitude 1.7 times that of the vertical stress. The minimum principal stress is approximately vertical and equal to the gravitational loading of the overlying strata, with a rock density of 2700 kg/m³. The North-South stress, parallel to the shear zone, is 1.3 times the gravitational loading.

Regional Stress Related Damage

The phyllites in this section of the mine are generally fairly massive and competent. Drives, and other excavations developed in phyllite, below 40 Level suffer moderate stress damage and spalling if unsupported and orientated on strike (North-South). Cross-cuts, developed East-West, in undisturbed phyllites and in the absence of mining related stress changes, can generally stand unsupported with only minor damage down to 50 Level. Above 40 Level most types of development suffer only localised damage in competent phyllites, away from the stress changes related to stoping operations or other major excavations. Unsupported raises and shafts in these phyllites similarly suffer from minor spalling below 40 Level.

The rock mass strength of the metavolcanics is noticeably weaker than the U.C.S. values due to the presence of multiple joint sets. With an average U.C.S. of 107 MPa this rock type is the weakest of the rocks in the E.T.S. region, apart from the altered and graphitic shear zones. Excavations below 40 Level, within the metavolcanics and/or containing shear zones, commonly require support even in areas unaffected by mining induced stress changes. Strike orientated drives are far more susceptible to damage and, in old drives, this usually requires steel sets, timber sets or shotcrete to control the unravelling of the rock mass.

The lower North section of the mine is relatively old, with stoping below 32 Level commencing in the late 1950s. The development in the section was generally unsupported, or supported with rockbolts or timber sets which have since corroded or deteriorated to such an extent that the rock is now basically unsupported. In areas of good ground conditions this has not been problematic but where conditions have been moderate to poor, and where stress changes have occurred, the subsequent rock mass movements have only been controllable with major steel set support.

The main areas of observed damage in the shaft pillar area have been concentrated along mining abutments and adjacent to structural features, including graphitic shears and the contact between the metavolcanics and metasediments. Stress concentrations adjacent to major, or multiple, excavations have similarly increased the severity of damage where weak geological structures are present.

Once graphite is exposed in a high stress environment it tends to unravel fairly rapidly with time. In the past this was only supportable with sets and lagging but current practices include shotcrete and/or split sets with mesh. Graphite intersections in old cross-cuts within the shaft pillar have failed and shotcrete is applied as soon as these areas are re-opened.

Shaft Damage and Repairs

The shaft lining has suffered damage from 32 to 36 Levels, and 40 to 43 Levels, dating from around 1961 (Table 1). This damage was mainly due to increases in field stress levels, due to stoping in the shaft region, and subsequent rock mass deformation. Major damage can also be attributed to seismic activity, structural features, the close proximity and orientation of service excavations and the poor quality of concrete lining.

Table 2: History of Major Shaft Damage

Date Of Damage	Location of Damage	Description
1961	41 to 42 Level	First cracks noted
Feb. 1963	Below 32 Level	First cracks noted
Feb. 1963	Below 32 Level	Seismic activity (?)
May 1963	Below 32 Level	Seismic activity (?)
Aug. 1963	15-60m below 32 L	Extension of damage
Sept. 1963	Below 35 Level	First cracks noted
Dec. 1963	Below 35 Level	Additional damage
Dec. 1963	42 Level	Additional damage
May 1964	Below 35 Level	Serious damage
July 1964	Below 32 & 35 L	Additional damage
Mar. 1965	Below 32 Level	Additional damage
Aug. 1966	30-50m below 32 L	Additional damage
Mid 1969	32-35 Levels and 41 to 42 Levels	Extensions and expansions of cracks
Sept. 1972	36 Level	First major damage noted
Apr. 1973	Below 32 Level	Severe damage
Jan. 1974	Below 38 Level	Major damage noted
1996	42 Level station and skip pocket	Continuing closure damaging steelwork
1996	32-36 Levels and 38-42 Levels	Weekly removal of loose concrete and rockbolts from lining

The damage varies in severity, from very minor cracking to major failure measuring 4m wide, 2m deep and extending over 60m down the shaft.

The major mode of failure observed was shear failure of the concrete lining.

Minor repairs, such as the removal of loose pieces of lining, mesh and roofbolts have been conducted during the regular shaft examinations since the major damage commenced in 1963.

Two sections of the shaft have also undergone major repairs; from 32 Level to 45m below 32 Level and from 41 to 42 Levels. The section below 32 Level, repaired in the mid-1960s, was stripped of loose lining and rock, relined with concrete and supported with rockbolts and mesh. This relining failed and was replaced again in late 1966. This repair work subsequently failed again and has not been repaired. The rockbolts installed during this repair work are now severely corroded at the concrete/rock interface and are not functioning. The mesh has also been severely damaged in places by failure of the concrete lining and by falling rocks in the shaft.

The West side of the shaft, from 41 to 42 Levels, was supported in the 1980s with resin bolts, mesh and shotcrete. This area has continued to deteriorate and the rock movement in the re-supported area has pushed the shotcrete/mesh into the shaft. This has required removal of the repair work in places to ensure adequate clearance between the sidewall and the conveyance. The steelwork around the skip loading pockets was also severely damaged due to lateral closure in the shaft. Damage to drives and other excavations has not been as fully documented. The 41 Level drive, 41½ Level conveyor drive, the 42 Level skip pocket and the 42 Level station steelwork have all been damaged, repaired and re-repaired at various times since the mid-1960s. Steel sets have been installed in the 41 Level drive and 41½ Level conveyor drive, together with additional sections of mesh, rockbolts, concrete and rebars.

The mining induced stress increases in the E.T.S. area have been analysed using *BESOL-MS* software. The simulation was aimed at indicating the total mining induced stress increases which caused previous damage. The *BESOL* input data is listed in Table 3.

Table 3: *BESOL* Input Data Summary

PROPERTY	PARAMETER	VALUE
Element Size (on reef)	Minimum Definition	3.0m
Element Size (off reef)	Minimum Definition	2.0m
Rock Mass Property	Young's Modulus	45000 MPa
	Poisson's Ratio	0.2
	Increase in σ_{zz}	0.027 MPa/m
	Increase in σ_{xx}	0.035 MPa/m
	Increase in σ_{yy}	0.046 MPa/m
Seam Material	Young's Modulus	35000 MPa
	Shear Modulus	16000 MPa
	Stoping Width	4.0 m

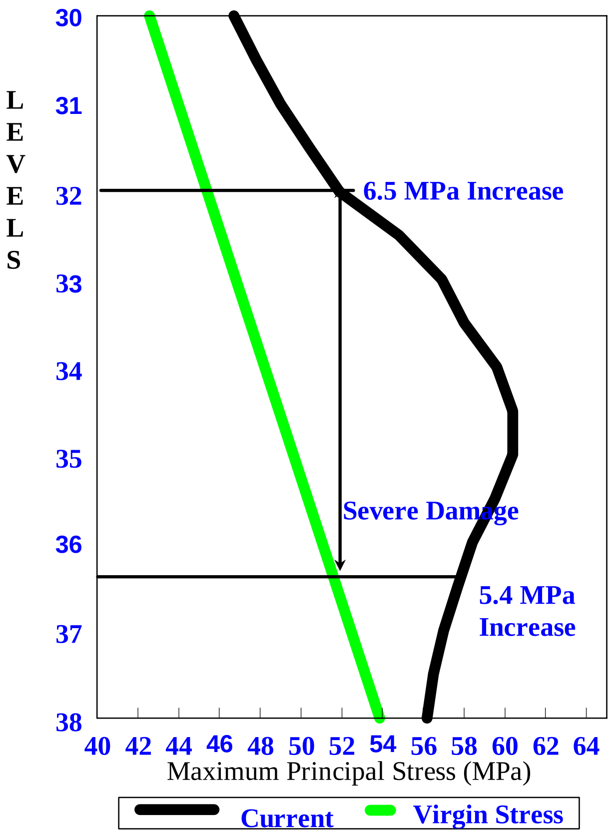
The results, of the effects of mining on the shaft, were obtained from East-West orientated windows positioned down the shaft, from 31 Level to 44 Level. 2 metre elements were utilised for this portion of the simulation to give greater definition of the results.

Rock mass properties have been determined from intact rock values, down-rated for the local rock mass conditions, where practical. The simulation was conducted assuming that the previously stoped areas were not backfilled - the effect of the old fill, as interpreted from previous simulations of the E.T.S. area, is minimal. The square set mining method utilised in the past incorporated large volumes of timber which have generally either deteriorated with time or have been burnt in a major underground fire during the 1970s. Additional simulations have assessed the increase in stress due to the removal of all fill, such as in a major fill reclamation programme. The results indicated maximum stress increases of up to 1 MPa in the shaft pillar area.

The main criterion assessed during the analysis of the results was the maximum principal stress. In a single reef pillar situation, such as this, the orientation of the maximum principal stress is generally perpendicular to the orebody. The results indicate fairly high stress increases in the shaft pillar area between 32 and 37 levels (Figure 3), with reducing increases, down to 4.5 MPa, to the shaft bottom.

It was concluded that the mining induced stress increases were the major factors causing, or initiating, damage to the shaft and associated excavations. The results of the simulation also indicated that these stress increases could not have caused all the damage in the shaft and that the effects of geological structures, weak rock mass and other factors must also have increased the severity of the damage.

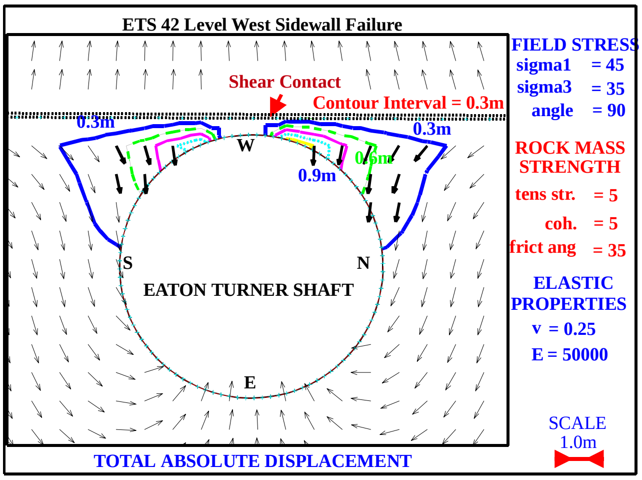
Figure 3: Maximum Principal Stress Increase Due to Previous Mining (MPa)



There are sections of the shaft, where 5 MPa increases are indicated, which are not damaged, however, and this implies that the threshold for damage to the original lining was of the order of 6 MPa.

Back analysis of previous lining failure, using the Lame formula, indicated a damage threshold stress of 4.26 MPa. This also implies that the damage in the lower sections of the shaft, where increases are around 4.5 MPa, has been caused by the effect of additional, structurally concentrated, stress increases. This was confirmed using the *EXAMINE* software, with a shear located adjacent to the shaft (Figure 4).

Figure 4: Plan of Total Displacements around Shaft Due to Effect of Adjacent Discontinuity (*EXAMINE*)



These results confirm the stress concentration effect of weak structures on the shaft and the large associated deformations (up to 0.9m). Taking into account damaged sections of the shaft, where regional stress increases of 4.5 MPa should not have caused severe damage to intact concrete lining, the effect of these additional structural increases would have led to the observed deteriorations. This, and the close proximity of large excavations, would account for the major lining failure from 38½ to 42 levels.

Shaft Rehabilitation

The main purpose of rehabilitating the shaft is to increase the hoisting capacity to 85000 tpm, and to eliminate possible delays due to stress related damage and subsequent shaft repairs. The work required involves the removal of damaged concrete lining, replacing the lining, and upgrading the hoist, skip loading and tipping facilities, spillage arrangements and guide rope tensioning device. The decision to mine the shaft pillar required an alteration to this sequence

- reinforcing the shaft after removal of lining, followed by pillar mining and then replacing the lining.

Following the closure of ETS the most urgent work in the shaft is the stripping of the lining and installation of a strong, but flexible, support to cope with the expected large deformations from 31 to 37½ Levels. This has to take place concurrently with the shaft pillar stoping due to the planned early stoping of the pillar. The magnitude of the large stress changes and deformations can be noted in Figures 8 and 9. This support work will be conducted from the stage and will start from 31 Level, working down to 37½, always below fully supported ground. Without this support the current lining would not prevent, or sufficiently control, large rock mass deformations in the shaft sidewalls. Large scale collapses of the rock mass, between the shaft and the orebody, could subsequently fall into the shaft causing delays to shaft re-commissioning.

The height of lining removed per lift and hence rock exposed, will be kept to a minimum during this operation. 3m high sections will be typical, with reduced exposure in very poor ground areas. Due to the expected poor ground conditions the lower platform of the stage has been fitted with a rockbreaker for breaking up the lining. If blasting is used the charges will be as light as possible to prevent damage and overbreak into the rock.

The support system in the shaft pillar area, from 31 to 37½ Levels, will be installed as the lining is removed and consists of mesh, yielding bolts and cables.

Mesh - Heavy duty chainlink mesh to provide areal support of the rock surface. The chainlink mesh currently used at AGC is galvanised 50 x 50 x 5 mm which is very strong, more deformable than weldmesh and easier to handle from the sinking stage.

Yielding bolts - The rock mass will deform as pillar mining progresses and these deformations will be beyond the capabilities of split sets and other items available on the mine. Yielding, EXL, Swellex is suitable for the requirements. These bolts are quick and easy to install and yield 20 to 30% at a reasonably constant 90kN. 2.7m bolts will be used, the reduced drilling time, compared to 3m holes, outweighing the additional support benefits. Split sets are also available on the mine and will be used as a supplementary support and for pinning the mesh, if required.

The support system is designed around the mesh, with overlapping layers and tight pinning to the walls. Bolts are planned on a 0.7m diamond pattern.

Poor ground conditions are expected in places and drilling holes for support elements could become difficult. Short, 0.9 m, Swellex are kept available for these situations. Plain or Fibre reinforced shotcrete would be utilised if drilling becomes impossible.

This support system is heavy duty and takes into consideration the expected stress changes and associated deformations expected in the shaft. The orebody on 33 Level, for example, is only 10m from the shaft, stripping the lining will remove approximately 1m (including broken rock) and stoping will possibly incur an overbreak of 0.5m. This leaves 8.5m of poor quality rock between the shaft and the stoping - the support has to control movement in this parting and prevent major failure causing a collapse of this material into the shaft.

Cables - Grouted cable bolts are planned for reinforcement of the rock mass between the shaft and the orebody. Owing to drilling and time constraints, however, these will be installed after the mesh and yielding bolts have been completed from 31 to 37½ Levels. Cable bolts are also being installed from the footwall drives and reef drives towards the shaft, initially from 35 Level and thereafter from 34, 33 and 36 Levels and the inter-levels, once access has been established. The cable bolts utilised consist of 15.2mm pre-stressing cable (single or twin) with plates, fully grouted with Ordinary Portland Cement.

Lining Replacement - Once Pillar mining has been completed the shaft lining will be replaced below 31 Level. A minimum thickness of 0.6m using 30 MPa concrete is planned. The support system for the rock mass will include 3.5m mechanical anchored, fully galvanised, 20mm Gewi bars, with full column grout, installed on a 1.0m diamond pattern. 3m holes will be drilled, allowing 0.5m of the bars to extend into the lining for additional lining shear strength. The bars will be tensioned prior to the grout setting. Cement capsules or pumpable grout will be used.

Mechanical anchored cables (6m long, 380 kN, corrosion protected, tensioned and post grouted), will also be installed in the lower section of the shaft, below 41 Level. This section of the shaft has previously suffered major damage due to the proximity of graphitic shears and large service excavations, and the rock mass requires additional reinforcement. The planned pattern for these cables is 8 per ring, 4 in the east and 4 in the north/west quadrant. The anchors are required between 1268 and 1353m below surface.

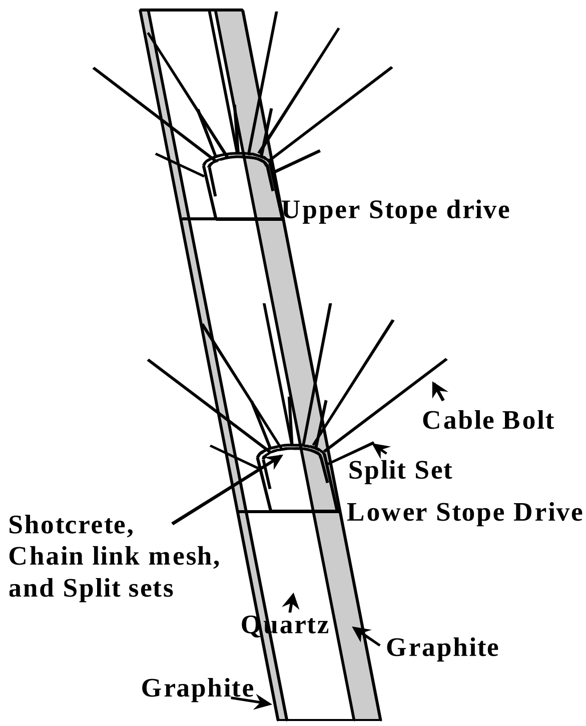
Long life fibreglass extensometers will be installed adjacent to critical excavations in the lower levels - this includes the 42 Level station and the 41½ Conveyor drive.

Pillar Mining

The decision to mine the shaft pillar was taken in July 1996 and the available window for mining is only 21 months, from April 1997 to January 1999. The ideal mining method for a highly stressed, steeply dipping, high grade pillar such as this would be underhand cut and fill. Unfortunately the relatively low production rates attainable using such a method would not have allowed sufficient extraction of the pillar in the available time period. The mining method chosen for the shaft pillar is a short panel, sub-level open stoping method. This method will have the required production capacity and the workforce will be working under fully supported ground at all times.

Sub-level reef drives are being developed ahead of the stoping, to allow support to be installed and to provide early ore tonnage. The reef drives are located in the quartz, with the graphite stripped to the hangingwall contact. The height of these drives has been kept to 2.4m, developed using conventional hand held air-leg machines. Support in the reef drives is intense, with split sets and straps as temporary support and shotcrete over exposed graphite Permanent support consists of 50 x 50 mm x 5mm chain link mesh installed with more split sets (or Swellex), tensioned cable bolts and an additional layer of shotcrete in very poor ground areas (Figure 5).

Figure 5: Orebody Support

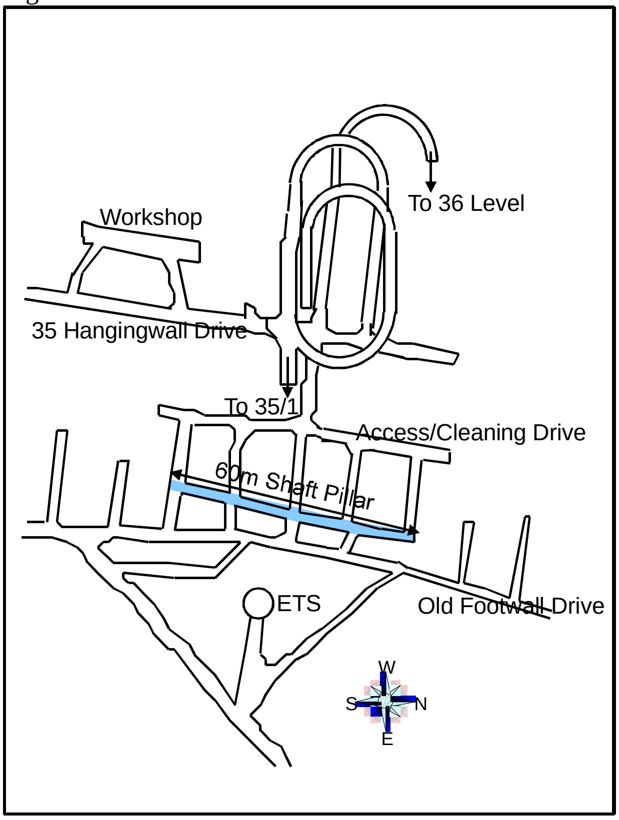


The split sets used are non-galvanised, 1.8m Ingersoll Rand SS39. Shotcrete is obtained from the local cement manufacturer in dry, bagged form and is placed up to 100m thick. A thickness of only 10-20mm is generally sufficient at the face to prevent the graphite running and permit the safe installation of mesh and split sets. Cable bolts are installed once the shorter tendons and areal support have been completed. These cable bolts are comprised of twin, 15.2mm, pre-stressing cable, in 57mm holes, with plates, grouted with Ordinary Portland Cement, and with lengths varying from 5m to 15m. The stopes will utilise conventionally developed slot raises and longhole drop raises.

Cable bolt holes and blastholes are drilled using a pneumatically powered Boart Carrier (BCI-2) with Seco S36 drill. Cable grouting is conducted using a Langford grout pump. Two Wagner LHDs, an ST2D and an ST1A, are used for cleaning the reef drives and the stopes.

The initial access for the pillar is on 35 Level and the initial stoping horizon will be from 35 to the next sub-level, halfway to 34 Level (Figure 6).

Figure 6: Plan of 35 Level



Access development is located in the hangingwall, including a trackless ramp, hangingwall drive, and raisebored waste and ore passes and ventilation raise. The sub-levels are being developed at 15 m intervals, supported with split sets as temporary support followed by grouted 20mm rebars (or Gewi bars), with plates, as permanent support. Mesh, straps and shotcrete are installed in poor ground areas, as required. Access development is being developed using an Atlas Copco H104 Single Boom Jumbo, with cleaning being conducted by Wagner ST2D LHDs.

Stoping has commenced from 35 Level, in the centre of the pillar, and will advance up and down dip, and towards the pillar boundaries, symmetrically from the centre-out, in a diamond pattern. The rationale behind the stope sequencing has been to reduce the leads and lags between stopes on adjacent levels and to mine out first the stopes closest to the shaft. In this way the maximum stresses, and hence worst mining conditions, will occur in the 4 corners of the pillar, away from the shaft. As the pillar size decreases, and stress levels increase, there will be a greater probability of ground related mining problems in these corners. By mining from the centre-out the remnant pillars will be far enough away from the shaft to have a reduced detrimental effect on shaft stability.

The old 35 Level footwall drive is located between the orebody and the shaft, 4m from the orebody and 12m from the shaft, and is expected to suffer severe damage once stoping is underway. Access for the pillar mining was therefore planned and developed in the hangingwall of the orebody, away from old drives and the shaft. Extensometers have been installed between the 35 Level footwall drive and the shaft to indicate whether excessive movement is occurring. Results from *BESOL* simulations indicate that stress levels in the shaft, due to pillar mining, will change considerably (Figure 7).

Figure 7: Maximum Principal Stress at Shaft Due to Pillar Mining (MPa) (*BESOL*)

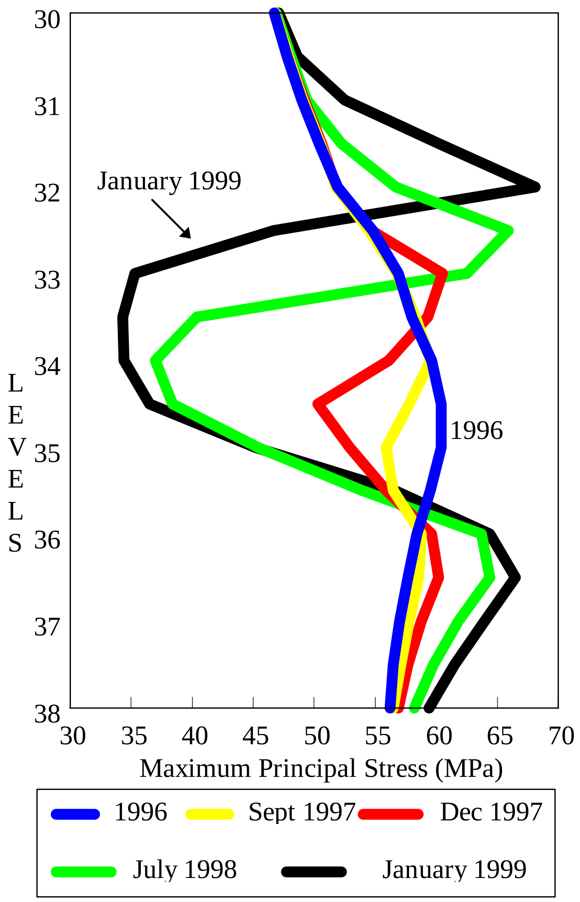
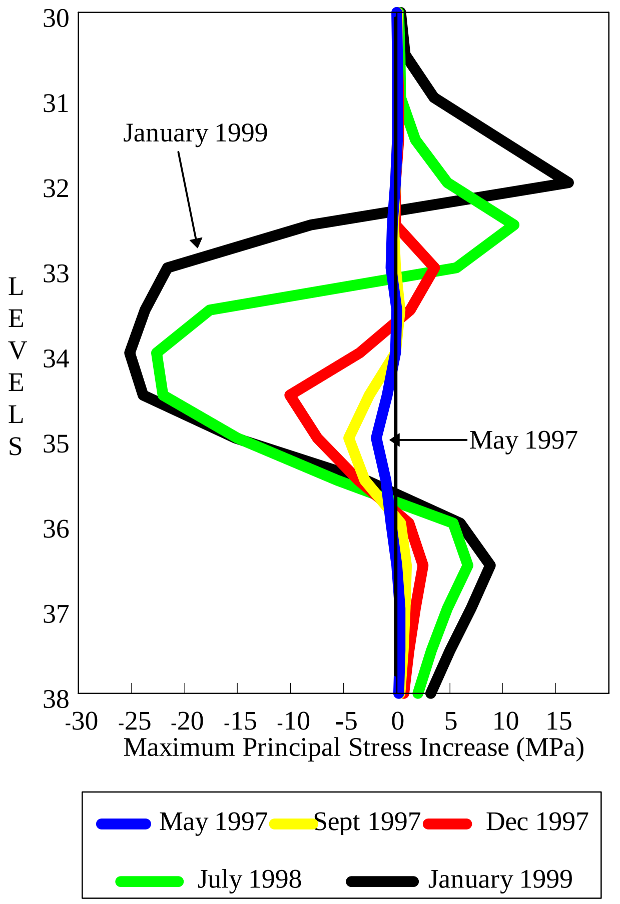


Figure 8: Maximum Principal Stress Increase at Shaft Due to Pillar Mining (MPa) (*BESOL*)

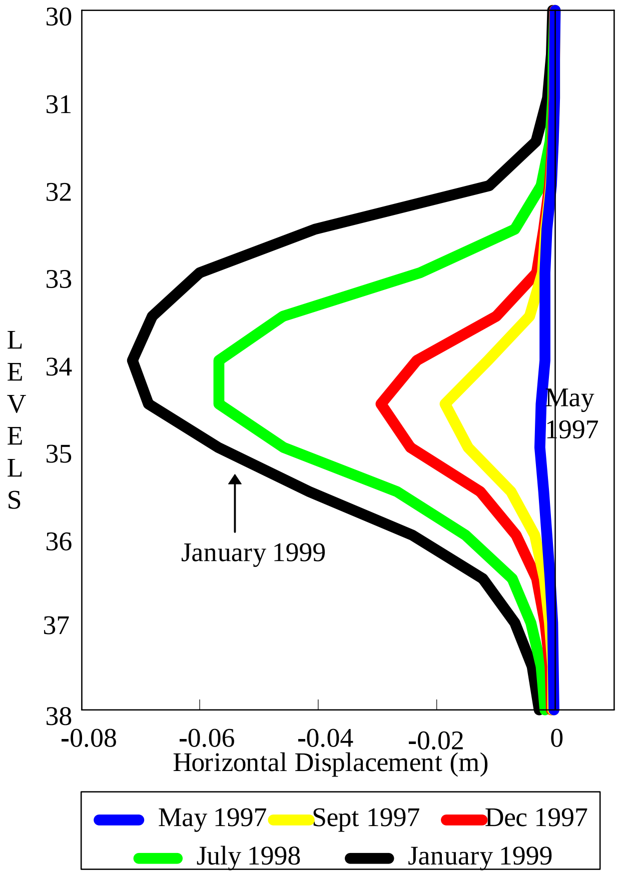


A Maximum stress level of 68 MPa is indicated for 32 Level and a minimum stress level of 34 MPa for 33 Level following complete extraction of the pillar. The maximum increase in the shaft, opposite the upper abutment, is predicted to be 17 MPa and the maximum stress drop is 25 MPa (Figure 8). The shaft around 33 Level will suffer the largest stress change differential - an increase of 6 MPa followed by a drop of 27 MPa.

Results from the simulations also indicate that elastic horizontal movement up to 8cm will occur in the shaft (Figure 9). Taking into account the inelastic component the expected total movement could be 30cm. Vertical strain increases peak at -0.25 mm/m, in tension, and 0.2 mm/m in compression (Figure 10). These values are minor compared to the expected horizontal displacements.

The stopes will be backfilled with cemented waste rock as soon as possible, after the ore has been cleaned, to minimise time dependent hangingwall and footwall movement and collapses. The majority of waste will be sourced from development within the shaft pillar access development, but can be supplemented via a waste pass from 32 Level. Cement will initially be transported underground in bags, with bags being broken on the LHD buckets. Once the sinking stage has been assembled in the shaft 2 cement slurry lines will be installed in the shaft and connected to a cement slurry agitator tank on 32 Level. Initial planning has assumed a 10% cement content with the addition of an accelerator to reduce the curing time. Temporary waste rock barriers will be placed at the lower accesses to the stopes to prevent cement slurry escaping.

Figure 9: Predicted Horizontal Elastic Displacement Due to Shaft Pillar Mining (m) (*BESOL*)



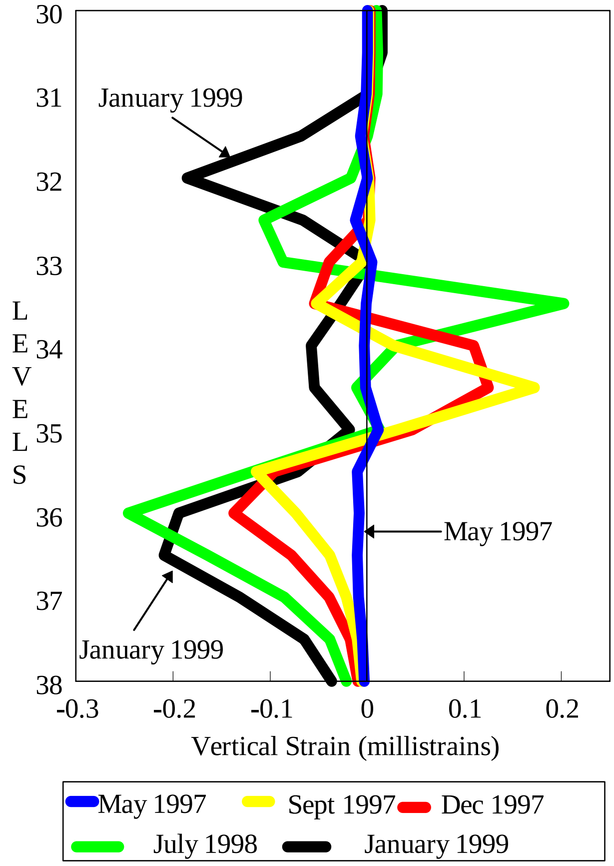
Restricted Mining Area

In order to reduce the probability of future damage in the shaft, due to increases in mining induced stresses, and the possibility of seismic activity, restrictions are required on stoping and development, which could influence the shaft. This includes a shaft pillar and a restricted mining area.

The shaft pillar from surface to 23 Level will be maintained at the current size, i.e. 120m on strike, projected with the shaft in the centre, and 240m perpendicular to strike, also with the shaft in the centre. The shaft pillar from 23 to 44 Levels will be increased in size to a minimum of 240m on strike, and perpendicular to strike, and will extend to the orebody, where the orebody is greater than 120m from the shaft.

A restricted mining area will also be implemented during the final shaft lining replacement period,

Figure 10: Predicted Vertical Strain Due to Shaft Pillar Mining (mm/m) (B*ESOL*)



approximately 400m in width and extending from
31 to 46 Levels. Stoping within the restricted mining area will be prohibited and fill reclamation only conducted if the void is to be re-filled with waste.

Conclusions

Mining of the Eaton Turner shaft pillar is a challenge and would not have been attempted without the current local skills in trackless mining, open stoping, cemented fill, cable bolting, shotcrete, and geotechnical analyses.

The use of trackless equipment gives additional flexibility to the method which will be particularly useful in case of possible ground related mining problems. This flexibility, in combination with the high grades and frequent sub-level access, will allow the mining method to be adjusted to suit conditions.

The shaft rehabilitation has been approached in three phases, including; stripping of services and lining; installing flexible support (for shaft pillar mining); and finally re-installing new permanent lining. This has permitted major modifications to be completed in the shaft, winder, headgear and rock handling facilities concurrently with the shaft pillar mining.

Mining of the pillar in conjunction with the shaft rehabilitation will increase cash flow and improve the long term stability of the Eaton Turner Shaft.

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References
Budavari, S, 1983. Rock Mechanics In Mining Practice, SAIMM.
Hutchinson, D. Jean and Diederichs, M, 1996. Cablebolting in Underground Mines, BiTech Publishers, British Columbia, Canada.