- hangingwall dilution can slow the mill, but does not tend to cause metal loss
- the implication of these is that fill failure may be more costly ton for ton than hangingwall failure
- there is little flexibility in the overall extraction sequence (ie. few primary stopes remain that can be used to augment production when disruptions occur)

A number of potential recovery options were discussed. A final plan was developed at a ensuing meeting the week after the site visit.

5.4 General Pillar Mining Comments

5.4.1 Mass Blasting

A number of mass blasts have been undertaken during pillar recovery operations. Mass blasts are only considered when ground movements in the mining block become a potential safety concern or cause significant blasthole stability problems. Mining blocks of up to 40,000 tonnes have been mass blasted with large quantities of explosives assigned to a limited number of delays. Often, the blasts have had only minor void space.

Mass blasting has both positive and negative results.

Positive

- Efficiency gains through concentrated blasthole loading operations and reduced redrilling potential.
- Good fragmentation potential and therefore efficient mucking operations.

Negative

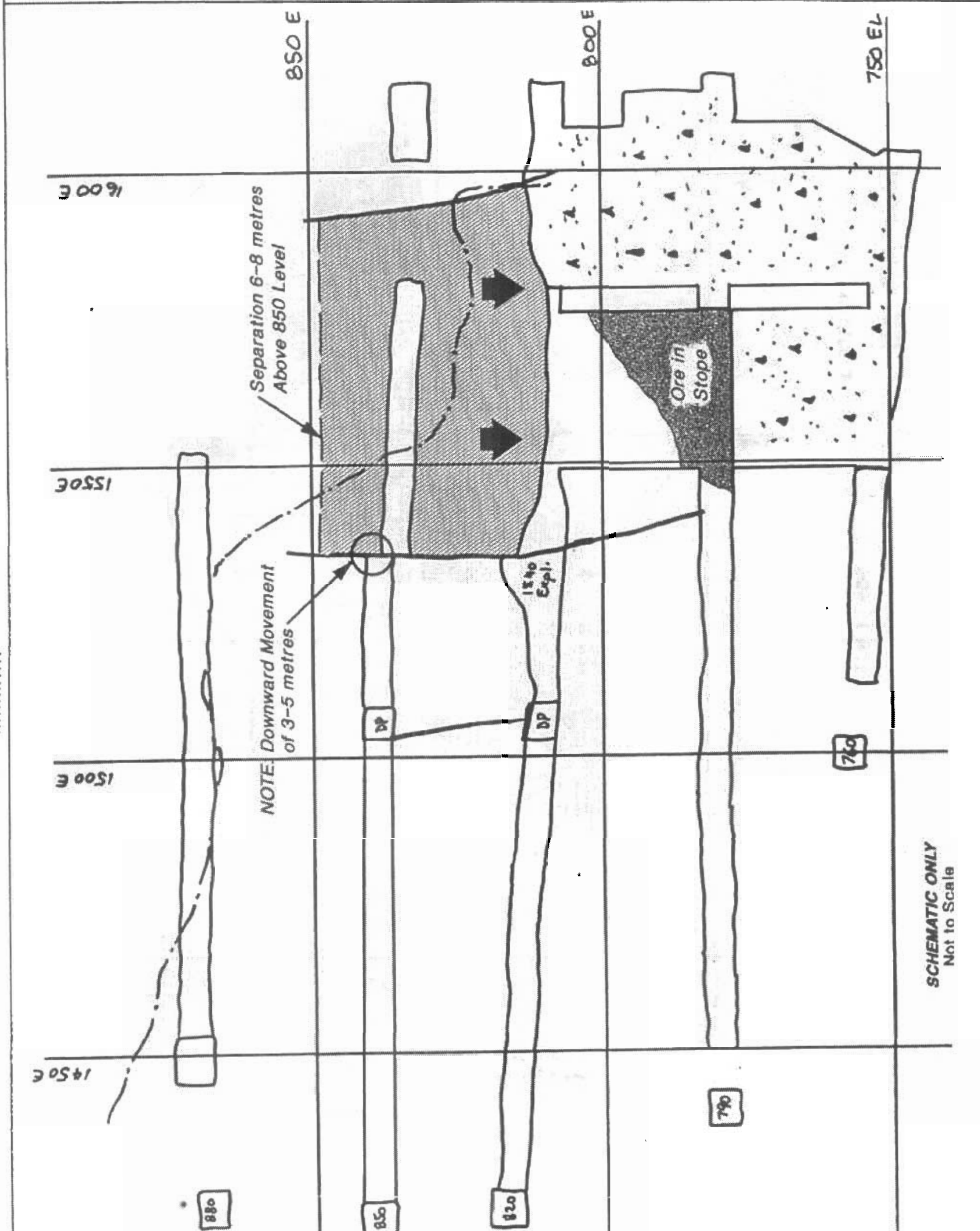
- High explosive quantities detonating over a short time period and small void ratio will result in high vibration and gas levels. This could potentially result in both new fracture creation, extension and opening existing fractures (blast damage).
- Large blast volumes will result in larger local stress redistribution and potentially more severe stress effects.

5.4.2 Size of Mining Blocks

When stability problems have been either identified through geologic mapping or encountered during pillar extraction, the post pillar location has been changed. In most cases the stage size has been increased to include the problem area.

202 PILLAR SECTION

Figure 6



PROJECT NO DRAWN REVIEWED DATE

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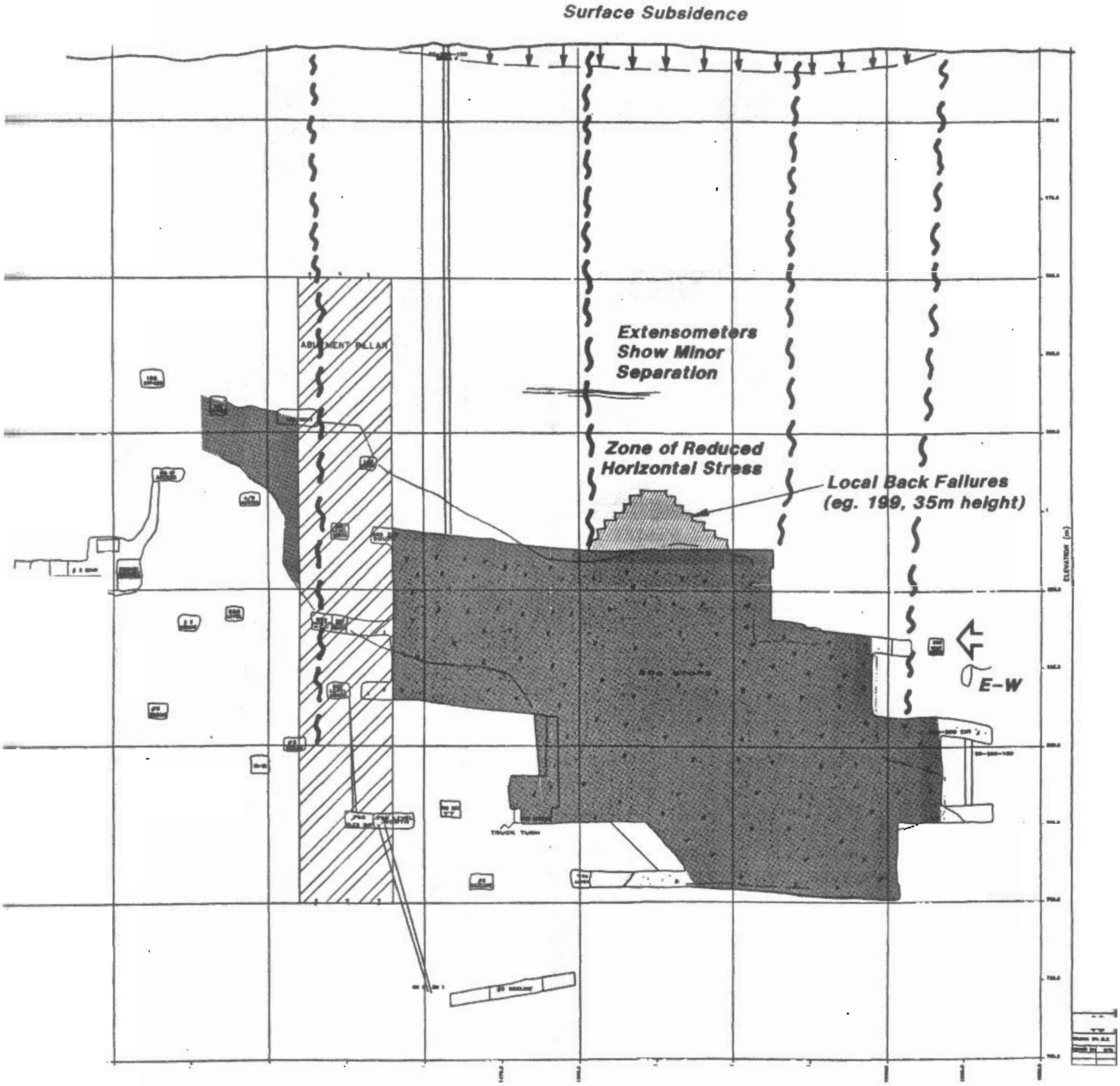
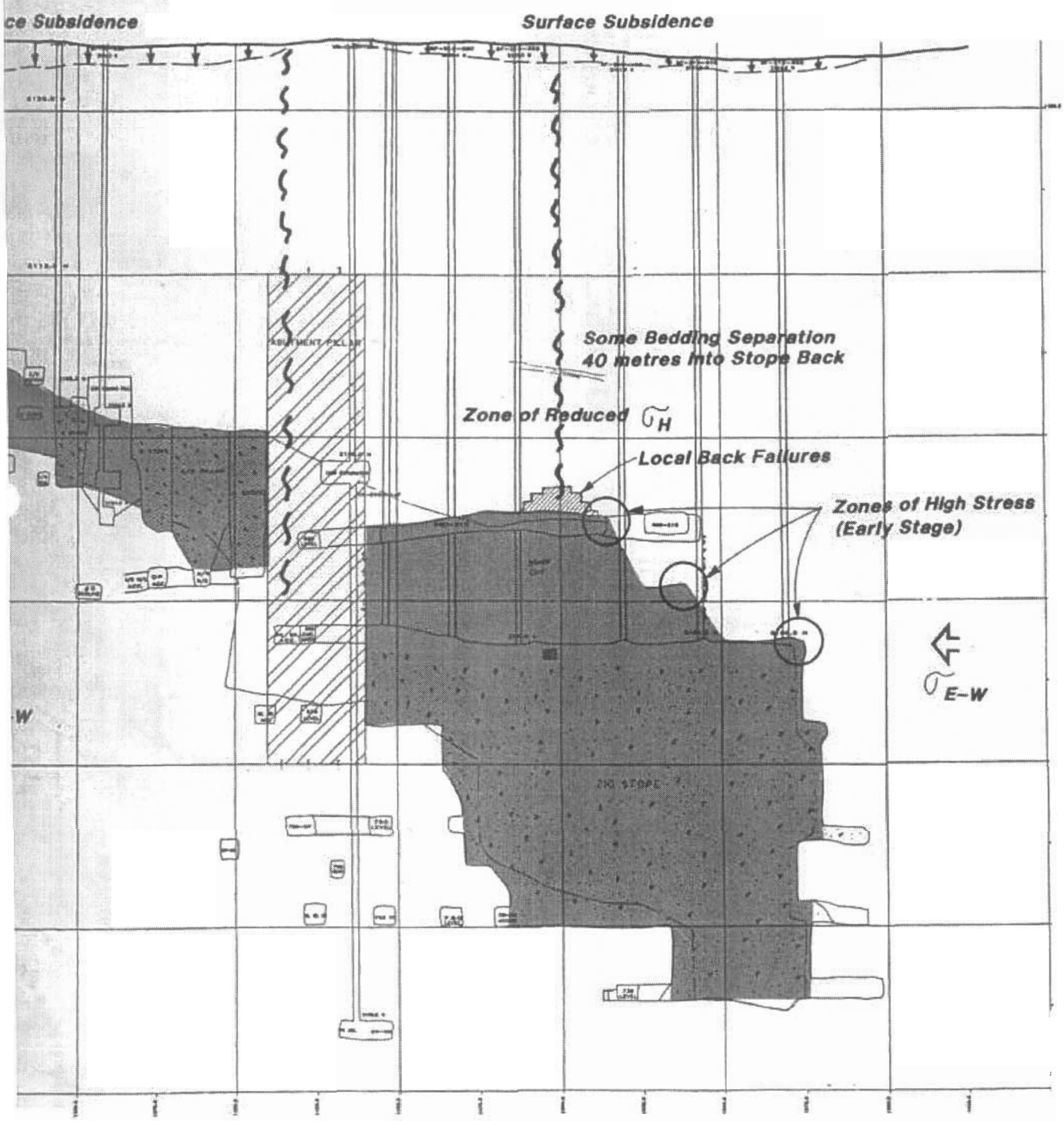
HANGINGWALL MODEL



HANGINGWALL MODE



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REPORT ON

VISIT TO POLARIS MINE
NOVEMBER AND DECEMBER 1995

Submitted to:

Cominco Ltd.
Polaris Operation
Polaris, NWT
X0E 0Y0

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May 31, 1996

952-1472

150 Area (see Photograph 28 and 29)

- **850L:** Stringer ore at fringes of main orebody will provide secondary ore source. Ground conditions rated as "fair". Back supported with Split Sets.

Lower S. Keel (see Photograph 30)

- **790L:** Stringer ore, secondary source. Back conditions rated as "good".

General

- Ground conditions do not appear to have substantially changed between the November and December visits. Overall, observed conditions were better than those during 1994 visit. In part, this is a result of more attention to ground support, both quality and timing of installation;

- Poorest observed ground conditions in abutment development were on the 880 mL;

- Poorest observed pillar conditions were along the 850 mL drill sub in the 208 and 212 pillars.

Support

- More screen is being installed. The quality of installation has improved substantially compared to the 1994 visit. In particular, screen is now being placed tight to the walls and back.

- A remote arm for placement of shotcrete has been built in the mine shops (see Photograph 20). Initial trials have indicated a number of problems with operating the arm and the quality of the placed shotcrete;

Subsidence

- Subsidence induced cracks have appeared on surface (see Photographs 44 to 48).

3.0 GROUND CONTROL

3.1 Current Ground Control Problems

Ground problems continue in the Keel Pillar stopes; for example, loss of access in the 208 pillar and wedging in the 212 pillar. These problems include:

hangingwall failures - Irene Bay;

wall slabbing in P1 ore;

wedging all north-south structure;

movement of ground in all stopes.

The cause of these problems has been discussed in previous visit reports. The important issue is, however, that problems will continue to occur as the highest, widest and weakest of the Keel Pillars are now being mined. The problems encountered in 208 can thus be expected in 212. Access will be lost (850/820), wedging will occur and re-drills will be necessary all leading to slower production and lower recovery.

As discussed in the following section, the majority of ground control problems appear to manifest themselves during Stage III stoping. This is due to a number of factors including thicker ore, weaker ground, etc. Improved support will mitigate against some of the problems. Other approaches include faster mining (with the aid of CRF) or a change in stage size. Observations, made by mine staff, that ground problems increase if a stage remains open for more than about 90 days, underline the benefits of faster mining.

3.2 Stoping Achievements

The mine has maintained a database on a number of key statistics on pillar mining. A review of this database indicates the following:

- Pillar recovery has decreased from approximately 92% of blasthole reserves in 1993 to approximately 82% of blasthole reserves in 1995, Figure 1a;

- Average daily production rates have been very variable (see Figure 1b), ranging from a high of 2,750 tonnes/da to less than 500 tonnes/da. Achievable daily production rates appear to be in the 500 to 750 tonnes/da range (see Figures 1b and 2). Discussions with mine staff indicate that production delays were largely associated with ground control problems;

- Average recoveries by stage were remarkably similar (see Figure 3a). However, the variation in recovery as measured by the co-efficient of variation (standard deviation/mean) clearly demonstrates the substantial risk of not meeting production targets during Stage II and Stage III mining (see Figure 3b);

- A typical section through a Keel pillar is given in Figure 4. This section illustrates that Stage III generally is tallest section and therefore weakest of the overall pillar; closest to the overlying, poor quality, Irene Bay; and contains the highest portion of high grade, weak ore. In addition, loss of access to the 850/820 drill subs leads to production delays due to increased support and poorer fragmentation;

3.3 Subsidence

The following summarises salient events regarding subsidence:

- Subsidence induced cracking has been observed at surface over and adjacent to the Keel mining area. The location of the cracks is shown in Figure 5.

- Surface cracking appears to be closely associated with those areas in the Keel where there has been 100% ore extraction. No cracking has been *observed* over the Panhandle mining area or over partially extracted areas of the Keel. The cracks appear to be located near vertically over the mined out outline on the 850/820 level.

  Surface monitoring shows continuing ground movement (see Figure 6). The maximum *measured* subsidence is approximately 1.25 m and is located over the 189 pillar area.

- Most subsidence monitors are maintaining constant velocity or de-accelerating.

- Analysis by mine staff of the monitoring data suggest an angle of draw of 40°.

- Given the location of the surface cracking, the angle of cave along the east and western sides of the orebody may be about 20° to 30°.

This information will assist in planning the North Keel and Ocean Zones where undue subsidence could lead to water inflow. A number of relationships exist for the prediction of surface subsidence. Unfortunately, these were generally developed for coal mining, where the ratio of depth to mined thickness (coal seam thickness) is high, often 50 or greater. At Polaris, the ore is both shallow and thick, and various coal subsidence formula become difficult to apply.

A recent review by Golder Associates (see Appendix II) found that published information on subsidence over base metal mines was extremely limited and mainly referred to caving. Thus, there is little precedent which can be used to assess future subsidence

(North Keel and Ocean Zone) at Polaris. More or less sole reliance will be on the information currently being gathered and mine derived relationships (assisted, for example, by numerical modelling).

3.4 Support

Improvements continue to be made in ground support practices. These include:

- screening and strapping of walls;
- installation of support prior to changes in ground conditions; and
- substantial reduction in backlog of support installation.

Salient comments are as follows:

Screening in the weak P1 ore should be to the sill. Bolts should be installed at the base of the screen. There may be some operational difficulties with this approach. It will enhance the effectiveness of the screen.

- The shotcrete arm should be modified in order to obtain a better application. Continued experimentation with shotcrete is required.
- The use of Split Set bolts instead of resin bar as a means of wall support has been proposed. From a purely ground control perspective, Split Set bolts can provide effective support. However, it is questionable whether the changes can be economically justified. ?

3.5 Cemented Rock Fill

The CRF plant is in the process of being commissioned. A number of start-up problems are being experienced which have been exacerbated by the extreme climate at Polaris.

The requirements and opportunities associated with CRF have been discussed in previous review reports and extensively by Polaris staff. The major impact of CRF with be the greater stoping control that can be realised and the faster stope cycle time that can be achieved. It is believed that this will be a significant factor in the mining of the abutment pillar.

PHOTOGRAPH 43

Surface subsidence cracks.

PHOTOGRAPH 44

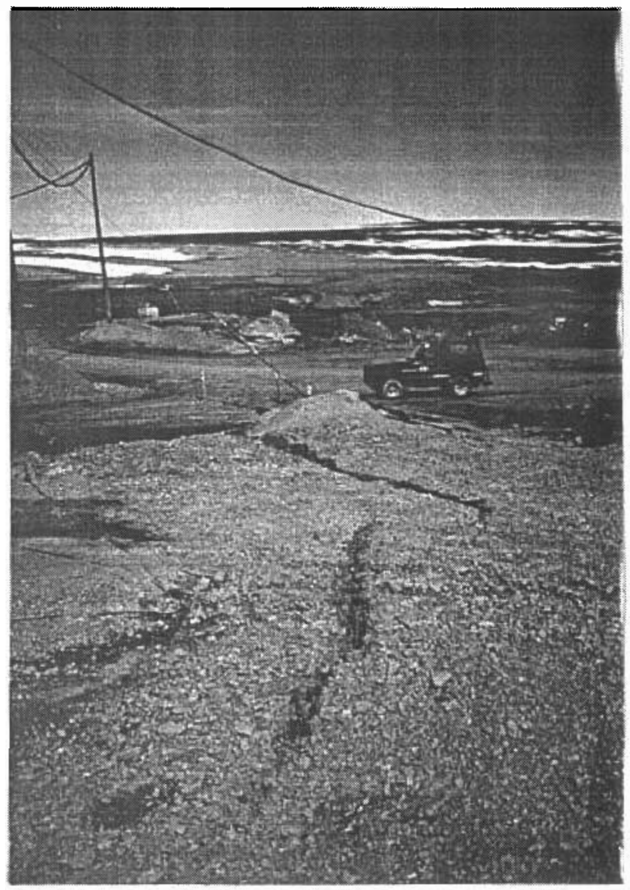
Surface subsidence cracks.

PHOTOGRAPH 46

Surface subsidence cracks.

PHOTOGRAPH 45

Surface subsidence cracks.



PHOTOGRAPH 47

Surface subsidence cracks.

PHOTOGRAPH 48

Surface subsidence cracks.

APPENDIX D

1. **Polaris Operations Internal memorandum – Trevor Feduniak (Senior Mine Engineer) to John Knapp (Manager) Regarding 'Subsidence Analysis', December 4, 2002**

teckcon

Memorandum

To: John Knapp – Mine Manager

From: Trevor Feduniak – Senior Mine Engineer

Date: December 4, 2002

Subject: Subsidence Analysis

A surface subsidence analysis was conducted in the fall of 2002.

Measurement Method:

Subsidence at Polaris has been measured since 1990 by surveying the elevation of monitor posts at strategic locations. New posts have been added over the years to provide more detail, most recently in summer 1999. Some attrition has occurred; posts have fallen over due to large amounts of subsidence, and more commonly, posts have been damaged by surface mining activities.

The survey is done using a leveling instrument, using a benchmark post (located far from mining-influenced ground) as a reference. The posts are measured in sequence, and the loop is closed back at the benchmark. Closure error is distributed evenly among all measurements. In an effort to reduce the closure error, or at least distribute it more accurately, the surveys for the past couple of years were done as a series of sub-loops rather than one large loop of all stations. The results indicate that the new method increases our accuracy.

Typically only two measurements per year are practical, due to the leveling instrument's sensitivity to the cold weather and wind. This year, only one level loop was conducted (July). A measurement in September was not possible due to a decrease in manpower, a direct result of the scheduled completion of mining activities at the end of August.

Analysis:

Subsidence at Polaris is defined as a drop of greater than 50mm from original elevation, along with a downward trend observed over several readings. Closure accuracy, natural ground movement from freeze-thaw cycles, and heavy equipment activity nearby prevent us from defining mining-induced subsidence any more closely. It is important to observe the same post over a long period of time before drawing any conclusions.

The posts have been divided into several areas for convenience of analysis:

Sinkhole:

Located over the centre of the Keel mining zone, the Sinkhole has subsided more than 10 meters (a rough estimate). The Keel Zone was 120m top to bottom, and was mined without leaving posts or pillars. Hangingwall ground support in the stopes was limited to 8' swellex. Large-scale hangingwall caves at 880 level were induced in Pillars from 190 to 212, leaving large voids that were impossible to backfill. Tension cracks appeared on surface (see surface drawing for location).

There is comparatively little subsidence data on the Sinkhole area. Monitor posts were installed in ground that was likely already moving, and were destroyed or fell over quickly.

The attached graph of post movement near the sinkhole is at a different scale compared to the other areas to show the larger movements involved.

SUB-20, started to move in 1998, and has dropped 2.50m. We expect the deceleration phase to begin soon, and when this happens, we would probably be able to predict the final level of subsidence in this area.

SUB-22, continuing north, started moving in 1999. Currently down 0.91m, this post is still in the high velocity part of the expected curve.

SUB-3 is located west of the Sinkhole, over the Panhandle zone. This station has been moving at a fairly constant rate since 1994. Panhandle pillars have been mined during that time. Tension cracks in this area are quite pronounced and extend throughout the cement storage pad area. These cracks may be related to Abutment mining and were probably affected by the undercutting of A Stope late last year.

SUB-12 is right over top of the Abutment Pillar. This post showed some movement before Abutment mining began in 1997, but increased in velocity afterwards. It is down 2.34m. This station should enter the deceleration phase in the near future.

SUB-5 is at the south end of the Sinkhole. There has been very little mining at this end of the ore body in recent years, and the graph shows that this post underwent acceleration, rapid movement, and then deceleration. This station is currently at 1.69m, the same as a year ago. No further subsidence to the south is expected after backfilling 185 Stope during the reclamation phase.

Subsidence Front:

Immediately north of the Sinkhole, the Subsidence Front covers the northern limit of ground movement, and beyond that, posts that have just started to move. These posts are above the North Keel Zone, which has been mined differently than the Central Keel. The North Keel is 30m high, deeper underground, and is filled entirely with CRF. The entire hangingwall has been supported with 26' or 40' grouted cables.

SUB-23 passed the 50mm limit that defines subsidence, having been displaced 0.06m to date. This station is located directly above 232 Stope, our most northern large tonnage North Keel stope. This stope is completely filled with dry fill and is 80m from the shoreline.

SUB-33, 32, 36, 37 and 8 are located north of SUB-23 and none of these stations are defined as subsidence (>50mm). With little to no extraction in this area and no signs of major acceleration, large-scale subsidence similar to the sinkhole is not expected.

North:

These subsidence posts are located over the Ocean Zone and are beginning to trend downward; however, the movement isn't characterized as subsidence. The Ocean Zone has been mined 30m high, with 4m rib pillars running north-south and 5m posts running east-west between pillar stages. The entire hangingwall has been supported with 26' grouted cables. Mining of the Ocean Zone has spanned 4 years with no subsidence. No hanging wall failures have occurred and all stopes were completely dry filled. No major subsidence concerns are anticipated in the Ocean Zone.

Also in the northern end of the orebody is SUB-10. SUB-10 was installed to monitor the northern limit of the Panhandle, which is not part of the Ocean Zone. This station is located over NP-142 stope. This station has entered the high acceleration range due to the recent mining of NP141. This station has been displaced 0.18m and surface tension cracks have appeared on surface. The cracks run parallel to the extraction limits of the Panhandle, not the Ocean Zone. It is expected that the conservative mining method of the Ocean Zone will contain any major subsidence caused from mining in the southern part of the mine.

East:

Delineating the eastern limits of subsidence, this series of posts runs from the end of 215 Pillar (part of the Central Keel) towards the New Quarry.

SUB-18, closest to 215 Pillar, has subsided 1.05m. There was a large hangingwall cave in Stage 1 of 215 Pillar (the easternmost stage). The rest of the pillar was taken in smaller stages and filled with CRF, and no further hangingwall damage was incurred.

The rest of the posts show constant and diminishing movement as they get further from 215 Pillar, as expected. All stations are defined as subsidence with SUB-14 having been displaced 0.063m. Surface tension cracks have not extended further to the east and we predicted that this would also be true for major surface subsidence.

West:

Located over the West Panhandle, these posts have just moved into the classification of subsidence, with measurements ranging from 70mm to 110mm. We can measure these posts most accurately because they are closest to the Benchmark. Like the North Keel, the West Panhandle is filled with CRF and dry fill. The panhandle also has a few 5m posts and the hangingwall has been supported with 26' grouted cables. In 2002, mining in this area experienced high levels of activity with 35% of our total production from this Panhandle zone. Some subsidence was expected due to the high activity levels in this zone this past year.

Conclusions:

The principle reason to monitor subsidence is to predict the possibility of connecting the mine workings directly to the ocean via a large crack. The worst case scenario is a high volume failure flooding the mine before the completion of reclamation backfilling. A lesser problem would be flooding after closure.

From observations of the Sinkhole, tension cracks visible on surface form long before there is a route for large volumes of water to drain underground. It should be noted that we have never had surface water enter the mine workings, even with the existence of surface tension cracks and large seasonal runoff. We will continue to watch for the formation of surface tension cracks during the reclamation project. Underground, we have kept the hangingwall stable through intensive ground support measures and conservative recoveries by leaving large posts behind.

The extent of the subsidence limits is a direct footprint of the orebody with the exception of the Ocean Zone, which has not experienced any subsidence. The stability of the Ocean Zone can be attributed directly to the conservative mining extraction and extensive measures taken in ground support.

The different mining methods for the north end of the ore body will not induce subsidence similar to that experienced over the Central Keel; and there is no significant risk of an inflow of water.

Trevor Feduniak, P.Eng.

Senior Mine Engineer

APPENDIX E

TOPOGRAPHIC SURVEY OF SIBSIDENCE AREA

By FOCUS SURVEYS

Indicates Surveyed Topo Point
DATE of SURVEY = August 29, 2003
CONTOUR INTERVAL = 0.5 m.
DATUM FOR ELEVATIONS IS C.P.#2 = 1065.34 m.

DATE	REVISIONS	DR/CK

TOPOGRAPHIC SURVEY OF SUBSIDENCE AREA POLARIS MINE NUNAVUT

teck

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DRAWN BY : KK	CHK'D BY : MT
DATE : SEPTEMBER 12/03	SCALE: 1:1000
JOB : 322789-00	FILE NO.
DWG : SUBSIDENCE TOPO.DWG	SHEET 1 OF 1