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ANVIL PIT

REPORT ON
GEOTECHNICAL REVIEW
OF THE EAST WALL
OF THE ANVIL PIT

by

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PHOTO 1 Northern portion of East Wall. Note "A" Zone and calc-silicate portions of wall. Also note overburden failure on "A" Zone wall.

PHOTO 2 Southern portion of East Wall. Note calc-silicate and JB portions of wall. Also note 120 ft (36m) high slope below 3510 level and failure next to calc-silicate buttress.

FIGURES

FIG. 1 Schematic Plan of Eastern Portion of Pit

1. INTRODUCTION

As per your request, Piteau Associates has completed a review of a number of geotechnical concerns in the Anvil Pit. These concerns, which are related to the stability of the east wall of the pit, are discussed below as: i) short term stability of the east wall in the JB area of the pit; ii) stability of a ramp to be located along the east wall in the "A" Zone; iii) general long term stability of the east wall as it is developed; and iv) methods and procedures for monitoring movements on the east wall. This review follows a brief report prepared in November, 1985 which identified potential slope stability and hydrogeological problems in the east wall and which outlined a proposed program of work to address those problems.

Mr. A.F. Stewart visited the site between August 13 and 16, 1986 to conduct a site inspection of the east wall of the pit. During this site visit, mining plans were reviewed and discussions were held with mine personnel concerning various relevant aspects of the operation. All accessible areas of the east wall were traversed and assessed with respect to stability. As hydrogeological and hydrological conditions of the east wall of the pit are being addressed in a separate, ongoing study being conducted by Mr. A.T. Holmes of Piteau Associates, a detailed assessment of these aspects was not conducted by Mr. Stewart. However, relevant hydrogeological or hydrological aspects which directly impact on the stability of the east wall are discussed herein.

2. BACKGROUND INFORMATION

2.1 PROPOSED MINE PLAN

Overall plans for the pit indicate that mining could be completed in approximately five years, with the general sequence of mining being from north to south. The existing western ramp that accesses the portion of the pit that is presently under water (i.e. Zone 1) will apparently continue to be maintained and extended. In addition, a second main ramp (designated herein as the eastern ramp), that will traverse the east and north walls of the pit will be built. Initially, this ramp will follow along the northern side of the existing calc-silicate buttress (see Fig. 1) before turning northward along the existing east wall at about 9100N at an elevation of about 3720 ft. At about 9700N, the eastern ramp will turn westward and cross the north wall on primarily a fill ramp before joining up with the western ramp at an elevation of about 3610 ft. As mining progresses from north to south, the eastern ramp south of about 9100N will be re-established on the east wall. That is, as the final wall is excavated in a southward direction (in a number of discrete phases), the eastern ramp will be relocated onto the east wall.

Following the completion of mining from north to south over about the next five years, an additional phase of mining may take place. This would involve pushing back the east wall of the pit a distance of up to about 200 ft (60m). Mining would be initiated at the top of the east wall, and would result in the eastern ramp being mined out as mining progresses to pit bottom. It is apparently estimated that up to about two additional years of pit life could be gained by undertaking this final pushback phase of mining.

2.2 EXISTING SLOPE DESIGN

All phases of the final slope on the east wall of the pit have been designed at an overall slope angle of 38.5°, comprising 40 ft (12m) high single benches with

70^{o} bench face angles and 35.5 ft (10.8m) wide berms. This design is identical to one prepared for much of the east wall in a previous report by Piteau Gadsby Macleod Limited (PGML) dated January, 1976. In this previous design report, the slope design assumed that high groundwater conditions existed in the slope and that controlled blasting would be utilized on the final wall. It is noteworthy that PGML's 1976 report recommended an overall slope angle of 35^{o} to 37^{o} if control blasting was not used.

2.3 GEOTECHNICAL DATA BASE

During the site visit, it was observed that no up-to-date geotechnical data base exists at the mine. That is, there is no comprehensive and ordered collection of geologic structural and strength information from which data can be readily retrieved for stability assessment purposes. This is particularly true of structural mapping data, where it appears that relatively little joint and fault mapping of the walls has been conducted since the 1976 study. Information that has been gathered was compiled and stored in a format that makes it very difficult to retrieve and use in a meaningful and efficient manner. At the present time, however, an updated lithologic and major structures map of the pit is being developed by Curragh Resources' geologists.

With regard to core logging data, it is understood that all relevant available drill core has been relogged and entered into a computer data base. Included in information that was logged is foliation dip (where possible) at regular intervals in the core. Apparently this information is easily retreivable and can be readily plotted on cross-sections using in-house computing facilities.

Existing monitoring data, from past attempts at monitoring surface movement of the east wall, is of limited value. The monitoring records are such that few, if any, conclusions can be reached with regard to rate of movement, net movement, vector direction of movement, etc.

3. EXISTING SLOPE CONDITIONS

For purposes of discussion, the existing east wall can be subdivided into three main areas, as follows (see Fig. 1):

i) the "A" Zone area north of the calc-silicate buttress (i.e. north of about 9000N)

ii) the calc-silicate buttress area (i.e. between about 9000N and 8000N)

iii) the JB area (i.e. south of about 8000N)

At the time of the site visit, mining was progressing in the JB and "A" Zone areas. The Zone 1 flooded area of the pit was being developed, with the projected completion date for pumping being November, 1986.

3.1 "A" ZONE

The existing slope in the "A" Zone area (see Photo 1) is up to about 500 ft (150m) high and is excavated primarily in muscovite schist, which has a foliation dip of about 35^{o} to 50^{o} directly out of the slope. Due to breakback and sloughing of most benches which has occurred over the life of the mine, the wall resembles a rubble or scree slope at an overall slope angle of about 33^{o} to 35^{o}. It is apparent from the loose debris and active ravelling that some movement is occurring. However, rates of movement would appear to be very slow.

Near the crest of this portion of the wall there is an active slope failure which occurs largely in overburden. This failure, which is estimated to be about one to two benches high and up to about 800 to 1000 ft (240 to 300m) wide, appears to be situated in an infilled depression in the bedrock surface. The overburden/ bedrock contact has not been well defined but appears to be relatively steep in some areas (i.e. dipping up to 65^{o} west). It is noteworthy that, while only overburden was observed to be moving in the northern portion of this failure, some bedrock has moved with the overburden in the southern portion of the failure.

Based on a comparison of the height of a scarp that was observed during the recent site visit and during a site visit in late October, 1985, it is estimated that the southern end of the failure may have moved about 10 to 15 ft (3 to 4.5m) vertically in approximately the last ten months. It is suspected that much of the movement of this failure occurred during wet and rainy weather or during spring runoff. During the recent site visit, when rainy weather had been experienced, a total of up to about 30 igpm of water was observed to be flowing into the head of the slide from at least three separate surface and subsurface sources. In addition, a number of fresh cracks less than about 1/4 inch wide were observed near the head of the failure.

While there is little doubt that the failure is moving, there appears to be little risk that failing material will endanger men and equipment at the toe of the slope. The material that has failed to date has not progressed downslope further than about the 4030 level. Should any of the individual blocks that comprise the slide mass fail suddenly, the relatively flat (i.e. 33^{o} to 35^{o}) overall angle of the slope should prevent the slide material from reaching the active mining area.

3.2 CALC-SILICATE BUTTRESS AREA

The portion of the east wall that is "buttressed" by the calc-silicate (i.e. between about 8000N and 9000N) is considerably lower than the "A" Zone wall, being only about 300 ft (90m) high (see Photos 1 and 2). In general, the upper portion of the wall is excavated largely in schist, while the lower portion of the wall is in calc-silicate. At least one major dyke traverses obliquely down the wall from north to south. Although the existing overall slope angle appears to be approximately the same as in the "A" Zone, the condition of this portion of the wall is somewhat better than that of the "A" Zone. While numerous bench scale failures have occurred in this area, general degradation and breakback of the benches is not as severe, particularly in the generally stronger calc-silicate rocks.

Instability is most noticeable where the intrusive dyke is exposed and considerable alteration and weathering (particularly near the contacts) has occurred. In the vicinity of 8500N at the south end of the 4150 level, where a block of in-place intrusive dyke material is exposed, a number of near vertical cracks that strike normal to the wall were observed. These cracks, which were also observed on two or three benches immediately below the 4150 level, are up to about 1 ft (0.3m) wide, and appear to have existed for some time. The explanation for the formation of such cracks is uncertain, although they are approximately parallel to one of the joint sets observed in the 1976 geotechnical study.

It is noteworthy that, where the wall will be excavated in calc-silicate, the contact with the underlying schist will be at a relatively shallow depth. As the calc-silicate in the vicinity of the contact has been observed in some areas to be broken and/or altered, and not nearly as competent as the main mass of calc-silicate, the benches in this rock may break back and degrade at a more rapid rate than would otherwise be expected.

3.3 JB AREA

The JB area (see Photo 2), which is south of about 8000N, was being actively mined at the time of the site visit. This portion of the east wall, which is excavated primarly in schist, is up to about 240 ft (73m, or six benches) high with a berm up to 200 ft (60m) wide on the 3910 level. Below the 3910 level, to the present pit bottom at the 3790 level, much of the wall has been excavated with no safety berms. In this area, it would appear that overblasting and overdigging have taken place, with the result that there is considerable cracking and breakback occuring at least 20 ft (6m) behind the crest on the 3910 level. The 120 ft (36m) high slope face was observed to be heavily fractured and was ravelling almost continuously. The overall slope angle varied between about 40^{o} and 50^{o}.

The most active area of instability is in the northern end of the JB area, where what appears to be primarily a structurally controlled failure is occurring (see Photo 2). In this area, it would appear that continuous structures sub-parallel to the Big Indian Fault zone are possibly combining with foliation joints and at least one major structure that strikes approximately normal to the slope to form a plane and/or wedge shaped failure. The broken nature of the in-place rock, combined with the apparent overblasting, has resulted in continuing breakback and ravelling of the slope in this area.

4. DISCUSSION AND RECOMMENDATIONS

Based on observations during our recent site visit and on discussions with mine personnel, the following comments and recommendations are made.

4.1 SHORT TERM STABILITY OF THE EAST WALL OF THE JB AREA

As discussed above, the east wall of the JB area appears to have been overblasted and overdug. The resulting slope below the 3910 level, which is up to 120 ft (36m) high with no safety berms, is heavily fractured. Breakback of the crest of this slope will likely continue (particularly during wet weather and during spring runoff) until a stable overall slope angle is reached. Judging from the orientation of some structural discontinuties in the slope, breakback of the crest at the 3910 level may continue until a slope of about 40^{o} is achieved. However, the highly fractured nature of much of the rock, and the likely presence of a number of faults or shears, may allow the slope to break back to a slightly flatter angle. As rockfalls and ravelling can be expected to continue on this slope, it is important that an adequate catchment berm be left on the 3790 level at the base of the 120 ft (36m) high unbenched slope.

According to Drawing No. 200-05-09; JB Phase-Modification II, a ramp will traverse the east side of the JB area at about elevation 3750, with the pit bottom for this phase of mining being at the 3710 level. While this phase of mining in the JB area should be finished in a relatively short period of time, some measures should be taken to improve the stability of future benches and the ramp. As discussed at the mine, efforts should be made to use control blasting on all final walls to reduce the amount of blast damage to, and hence, breakback and ravelling of the slope. Overdigging of the benches should also be curtailed. In addition, it may be necessary to place a windrow of material about 5 ft (1.5m) high on the inside edge of the ramp to prevent rockfalls and ravelling material from reaching the travelled portion of the ramp.

To evaluate the potential for further breakback and failure of the east wall of the JB area, it is recommended that monitoring of the wall be conducted. While mining is being carried out in this area, regular visual inspections of the slope, particularly on the 3910 level, should be made to assess the amount of movement taking place and the amount of breakback which may occur. The amount of movement can be determined by a number of means, the simplest being the visual inspection of a straight line of survey stakes or the direct measurement (using a tape measure) of the distance between two pins placed on either side of a crack. More sophisticated techniques, such as the use of survey prisms, can also be used.

Based on conditions at the time of the site visit, it is suggested that the simple visual and direct measurement techniques be implemented as required near the slope crest where imminent failure of a few small blocks is anticipated. It is further suggested that two survey prisms be placed further behind the crest on the 3910 level to monitor potential failures of a larger scale (i.e. such as the whole 120 ft (36m) high wall). These prisms should be placed about 15 to 20 ft (4.6m to 6m) behind the crest of the slope and should be monitored initially at least two to three times a week. Visual inspection of the slope should be conducted daily while working under the slope. Further general comments with regard to monitoring of slope movement are included below in Section 4.4.

4.2 "A" ZONE RAMP

In the vicinity of the proposed "A" Zone ramp, the existing east wall (i.e. above the 3470 level), stands at an overall angle of about 35°. This wall appears to be failing as a series of planar bench scale failures along foliation joints which, at the toe of the slope, dip out of the slope at about 35° to 45°. It is suspected that, during or at some time following excavation of the designed benches, planes of weakness parallel to foliation were opened up or otherwise disturbed (likely by blasting). This disturbance probably led to loss of shear strength parallel to foliation and to eventual planar sliding of individual blocks on individual benches. As movement occurred on each bench, the failed material filled and, in some areas, likely spilled over the catchment berm below. While the end result is a slope covered by failed material with little or no remaining catchment on any berms, the overall slope appears to be stable from a deep-seated standpoint. Unless undercut and oversteepened beyond its angle of repose, the relatively "thin skin" of loose material will likely continue to move downslope only as a slow moving, ravelling failure.

Based on the behaviour and overall angle (i.e. about 35^{o}) of the slope to date, it must be anticipated that similar instability problems and similar overall slope angles will exist in the area of and below the proposed ramp. Thus, while construction of the ramp along the east wall of the "A" Zone north of about 9100N appears feasible, a number of possible remedial measures should be considered for stabilizing the ramp and possibly allowing the designed 38.5^{o} overall slope angle to be achieved. As discussed for the JB area, the use of control blasting on all final walls should be implemented to reduce blast damage which leads to failure of the benches. The type of control blasting technique to be used on the final slope will depend on the results of blasting trials. Effects of using such methods as cushion blasting, unstemmed and stemmed holes, buffer blasting, sequential blasting, etc., could be evaluated based on appropriate blasting trials on the wall.

Another potential remedial measure that is sometimes used to help protect critical installations, such as haulroads, is to reinforce the benches immediately below and/or above the haulroad. This can be done in a number of ways; however, the simplest technique is to grout dowels, consisting of old shovel cable, train track, etc. into vertical holes drilled in a line just behind the crest of the bench or the edge of the ramp. To maintain as much strength as possible within the rock mass, the vertical dowels are often installed in advance of blasting and mucking the bench below. While this technique is a relatively economical means of reinforcing a rock mass, it is by no means certain that such a remedial measure will work in the "A" Zone ramp area. The highly broken nature of the rock mass would likely require very close spacing of the dowels, which by themselves may not be sufficient to prevent degradation and breakback of the bench crests or haulroad. However, the use of such a technique could be attempted on a trial basis to assess its technical feasibility and cost effectiveness.

It has been suggested by mine personnel that prevention of breakback of the ramp could be accomplished by drilling and blasting the ramp area to break up the continuous foliation structure along which breakback and failure have occurred in the past, and along which failure is anticipated in the future. Rather than breaking back to a slope angle of about 35^{o}, it is envisaged that the broken rock will stand at an overall slope angle of about 37^{o} or 38^{o}, which is the approximate angle of repose of broken rock. After reviewing this concept, it is our opinion that little or nothing would be gained by blasting the rock immediately beneath the haulroad. In all likelihood, the blasting of the ramp area would likely disturb and weaken foliation planes deeper in the slope and may, in fact, cause a somewhat deeper failure which could undercut the ramp. In any event, such drilling and blasting would be an added expense with little certainty of success. Thus, this method of attempting to stabilize the ramp area is not recommended.

The final method of maintaining a stable ramp would be to assume that the slope below the ramp will break back to an angle similar to that of the existing slope (i.e about 35^{o} overall slope angle) and to allow for such breakback to occur without interfering with the proposed ramp. Such a solution would require stepping out below the ramp, initially creating a ramp that is wider than required.

It is recommended that the easiest and most practical method of building the "A" Zone ramp would be to provide for enough initial extra ramp width to allow breakback to occur without interfering with the travelled portion of the ramp. In addition, it is strongly recommended that the use of control blasting be investigated further in an effort to prevent loss of strength in the rock mass due to overblasting. As discussed above, the use of vertical dowels may not be an effective method of reinforcing the slope. However, should suitable materials be available, an inexpensive trial installation should be attempted to see if this technique warrants further use in the ramp area.

Once the ramp is constructed, it is suggested that a windrow of waste rock about 5 ft (1.5m) high be placed along the eastern edge of the ramp to help prevent any rockfalls from reaching the travelled portion of the ramp. While few rockfalls are expected from the relatively flat (i.e. 35°) slope above the ramp, it is not inconceivable that some loose material could reach the level of the ramp, particularly during wet and rainy weather or during spring breakup. Under extreme climatic and runoff conditions, it may even be necessary to close down the ramp for short periods of time.

With regard to monitoring, it is suggested that the ramp be visually monitored for cracks and settlement on a regular basis. Should such signs of movement be observed, it may be advisable to monitor the movement with prisms or tripod type surface extensometers placed along the edge of the ramp in the area of concern.

4.3 LONG TERM STABILITY OF THE EAST WALL

According to mine documents, numerous failures have occurred on the east wall, with most of the movement occurring in the summer months. Apparently, the wall was initially excavated according to design recommendations contained in PGML's January, 1976 report, assuming a dewatered slope where control blasting had been effectively utilized. However, it is evident that the east wall has probably always been subjected to high groundwater conditions, and any attempts at control blasting have met with little or no success to date. According to internal mine memos prepared by the previous operators, consideration was given to flattening the overall slopes to the "high groundwater" design contained in PGML's 1976 report, but it is uncertain as to whether, and at what time, such flattening was attempted. As discussed above, the present overall slope angle along much of the east wall is about 35°. A number of internal memos at the mine indicate that, while some of the slope failures observed in the past involved a number of benches, these failures were all thought to be relatively shallow and not deep-seated.

Based on our site inspection and discussions with mine personnel, the overall geologic interpretation of the east wall of the pit does not seem to have changed significantly from that discussed in PGML's report of January, 1976. Stability of the east wall appears, for the most part, to be a function of the same parameters. That is, planar failures primarily parallel or subparallel to foliation, or wedge failures involving both foliation and other joints or faults, appear to be the prime modes of failure. High groundwater conditions continue to have a significant influence on wall stabilty. With increased exposure of the east wall it would also now seem that major structures (i.e. with continuity over a number of benches) such as the Big Indian Fault Zone, the Faro Fault and the intrusive dykes and associated contacts may, individually or in discrete combinations, play an important role in the overall stability of this wall. Besides apparently acting as back scarps or slip surfaces for many of the failures that have occurred to date, these faults, dykes and contacts appear to contain a significant amount of water which probably has an adverse effect on the stabilty of the east wall.

At this stage, it would seem that significant steepening of the wall (i.e. beyond the present slope design) in the muscovite/biotite schistose rocks may not be possible. It would also seem that mining at the planned overall slope angle of 38.5° may not be possible unless certain remedial measures are implemented. Such remedial measures could include improved surface water and groundwater control using interception by ditches, wells, etc., and implementation of an effective program of control blasting. Surface and groundwater related control measures are being assessed in a parallel study being conducted by Mr. A.T. Holmes of Piteau Associates, and are not discussed in detail here. Additional safety to personnel and equipment working in the pit could also be achieved if mining adjacent to the final wall could be scheduled for winter months when slope movements have traditionally been at a minimum, or if the mining plan could be altered to include a rock waste buttress along portions of the slope (particularly below the proposed east ramp) once the final wall has been achieved. While it is likely that measures such as these may not be practical or possible, they should be considered. The use of a buttress would not only improve slope stability, but could also reduce waste haulage costs.

4.4 MONITORING

As discussed during the site visit, there are a number of methods available for monitoring slope movements on pit walls. Based on existing site conditions, it is suggested that fairly simple techniques, ranging from regular visual inspections of active mining areas, to direct measurement across cracks, to precise surveying of survey prisms, be employed.

Regular visual inspections of benches in active mining areas is an important and simple means of initially detecting slope movement. Once movement has been detected, the direct measurement of cracks, sighting along a straight line of survey stakes, or the use of prisms, is the next logical step in a monitoring program. As discussed above for the JB area, the use of a straight line of survey stakes, or the direct measurement of the width of cracks, is often used in easily accessible areas and/or in short term situations where it is expected that more sophisticated and expensive equipment either could be lost or is unwarranted. Prisms are usually utilized in areas that are inaccessible and/or where long term monitoring is anticipated. Other more sophisticated slope movement instrumentation techniques can be used in specialized situations as the specific need arises.

Besides those prism locations already discussed for the JB area, it is suggested that two other areas of the east wall should be monitored at this time. In the "A" Zone portion of the wall, prisms could be used to monitor the overburden failure. Specifically, it is suggested that two sets of prisms should be used in this area, one toward each end of the main failure mass. Each set of prisms should be aligned perpendicular to the trend of the slope and should consist of one prism mounted on the main failure mass that is obviously moving (i.e. at about the 4230 level) and one prism mounted on the bedrock bench immediately above and behind the main failure mass. The upper prism will serve to determine if the failure is regressing further into the slope. While it would be of some interest to position prisms downslope of the main sliding mass, it is concluded that, due to the condition of the slope and the amount of loose debris, the monitoring results could be inconclusive and/or misleading.

It is also recommended that at least one set of prisms be mounted in a line down the wall above the calc-silicate buttress. At this time, it is suggested that the area in which cracks trend normal to the wall be monitored. An upper prism could be mounted near the crest of the wall, a middle prism on the intrusive block at about the 4150 level, and a lower prism on about the 4030 level. At a later date, when the calc-silicate buttress is being mined out, an additional prism may be required on about the 3910 level.

During the site visit, a number of large, loose blocks were observed on the north wall immediately below the contact with the Faro Valley alluvium. While the overall slope angle in this area is relatively flat (i.e. about 36^{o}), it is planned to construct a fill ramp across this slope at about the 3650 level. Before this ramp is constructed along the north wall, it is suggested that a careful inspection of the upper slope be carried out. Depending on conditions observed at the time, it may be advisable to carry out a minor amount of slope scaling and/or to mount a limited number of prisms in this area of the wall. As discussed for the "A" Zone ramp area, under extreme climatic or runoff conditions, it may be necessary to close down the ramp for short periods.

All monitoring should be carried out from a stable base station, or from an intermediate station which can be back sighted onto a long term stable base station. Initially, sufficient readings should be taken at a close enough frequency to establish background or initial starting points with which future long term monitoring results can be compared. A suggested, initial monitoring frequency is once or twice a week. After a background data base has been established, the frequency can be adjusted, depending on such factors as climatic conditions, distance from active mining area and blasting, results of previous monitoring, etc. It can be expected that the frequency of monitoring should increase during runoff or following periods of heavy rainfall. As soon it has been recorded, all monitoring data should be reduced, plotted and reviewed by mine personnel familiar with and responsible for slope stability at the mine. As discussed with Mr. T. Cloutier of Curragh Resources, monitoring data from the prisms should be generated in terms of northing, easting and elevation.

Simple data manipulation and plotting programs should be obtained or written to handle all prism monitoring data. For each prism, a continuously updated computer file of all readings should be maintained which tabulates relevant information, as follows:

- date and time of survey
- northing, easting and elevation of the prism
- incremental and net horizontal movement
- incremental and net vector direction of movement
- incremental and net vertical movement
- incremental and net plunge of movement
- incremental and net rate of movement in distance per day
- incremental and net time since monitoring was initiated

Along with the tabulated data, plots that show direction and magnitude of movement should be prepared. In this regard, the following plots are suggested:

- a plot of vector direction of movement and scaled horizontal movement
- a plot of net vertical movement with time
- a plot of net horizontal movement with time

- a plot of net total movement with time
- a plot of inclination of movement with time
- a plot of rate of movement with time

To thoroughly assess movement, the data could be plotted in both the incremental and net total movement formats. To reduce data noise (i.e. minute fluctuations in the data due to survey or instrument error), statistical manipulation of the data such as the moving average technique could be used before the data is plotted. Typical examples of some of the above plots were given to Mr. Cloutier during the site visit and are not included here. Having prepared the appropriate plots, they can then be visually compared. In this way, a better appreciation can be obtained of movement patterns, measuring errors, environmental influences, etc.

5. SUGGESTED ADDITIONAL INVESTIGATIONS

While the overall geological interpretation of the east wall does not seem to have changed appreciably since our previous involvement at the mine approximately ten years ago, the pit has grown considerably since that time, exposing a number of benches, dykes, major structures, etc. at locations and elevations that were not originally available for study. In addition, a number of core holes have been drilled. The mine plan has also changed somewhat and now includes a main ramp on the east wall of the pit.

Based on the above, and considering that a geotechnical review has not been conducted since the original design study was completed, it is suggested that an update study of this wall be undertaken. Such a study should involve geotechnical mapping of all accessible benches to bring the geotechnical data base up-to-date with the most recent geological model. Besides mapping joints, faults, contacts, etc. with a continuity of about 20 ft (6m) or greater, careful mapping of all major structures, such as the Big Indian Fault and its splays, should be undertaken. In this regard, it was learned during the site visit that geologic mapping and mapping of major structures is presently being undertaken by Curragh Resources' personnel. Detailed geotechnical mapping and slope documentation could also be conducted by mine personnel. However, if time or other constraints (such as weather, lack of personnel) do not permit such work to be completed in a relatively short period of time, Piteau Associates could provide assistance with data collection. In any event, it is suggested that we should spend enough time on site to completely familiarize the appropriate mine staff with the geotechnical data collection techniques. It is also suggested that, if possible, all previous geotechnical mapping be incorporated into the updated geotechnical data base. While it is understood that most of the core has recently been relogged for geological purposes (including the recording of foliation dip at regular intervals), it may also be worthwhile to log the mechanical properties of the core from a few representative and relevant drillholes.

All mapping and core logging data should be compiled and processed. A geologic structural analysis of the foliation and the various fault and joint sets should be carried out and the results compared with our previous structural analysis. At the same time as the structural analysis is being conducted, three or four geotechnical sections should be developed for the east wall. These sections, possibly along the same section lines as previously used, should be selected to be typical of the various geologic conditions and wall orientations and to contain as much of the geotechnical data and hydrogeological data (i.e. from the present hydrogeological study that is being undertaken) as possible.

Following the geologic structural analysis and the preparation of sections, stability analyses should be carried out for each section for both the proposed overall slopes and bench scale slopes. It should be adequate to obtain initial strength values from our previous work and from the results of back analyses of failures performed by the previous operators of the mine. Sufficient analyses should be conducted such that an evaluation of the sensitivity of such parameters as strength, groundwater conditions, etc. could be evaluated. In addition, all discrete major structures that have been located on plan during the field mapping should be analyzed individually and in combination to determine if any deep-seated structurally controlled failures are likely to occur on the final wall.

Based on the results of these analyses, the overall slopes could be redesigned, if necessary, and an evaluation of the potential benefits of various remedial measures could be addressed. Where relevant, the results of the parallel surface water and groundwater study presently being undertaken should be included in the analyses and re-evaluation.

Following completion of the analyses, a report describing the work, engineering geology, analytical procedures, results and recommendations should be prepared. The report should also contain a summary of all the pertinent data used in the investigation. Remedial measures for maintaining the slope in a stable condition and monitoring the slopes for instability should be addressed, as necessary.

The cost for a re-evaluation of the stability of the whole of the east wall would depend on the level of involvement by Piteau Associates' personnel. However, assuming that Curragh Resources' personnel collect most of the data with Piteau Associates conducting all of the data processing, structural and stability analyses and report preparation, but only limited supervision of the mapping, mechanical core logging, etc, the study could be undertaken for about $25,000.

The priority and timing of a stability assessment of the east wall depends on the mine's needs and schedule. However, most of the field mapping portion of the study would have to be conducted when there is no snow on the ground. Ongoing mapping of bench faces as they are exposed by mining can be done any time of year. In this regard, it is recommended that all freshly excavated benches be mapped as soon as possible after being exposed before they either suffer sloughing and ravelling (making it difficult to map) and/or before they are covered in snow.

Respectfully submitted,

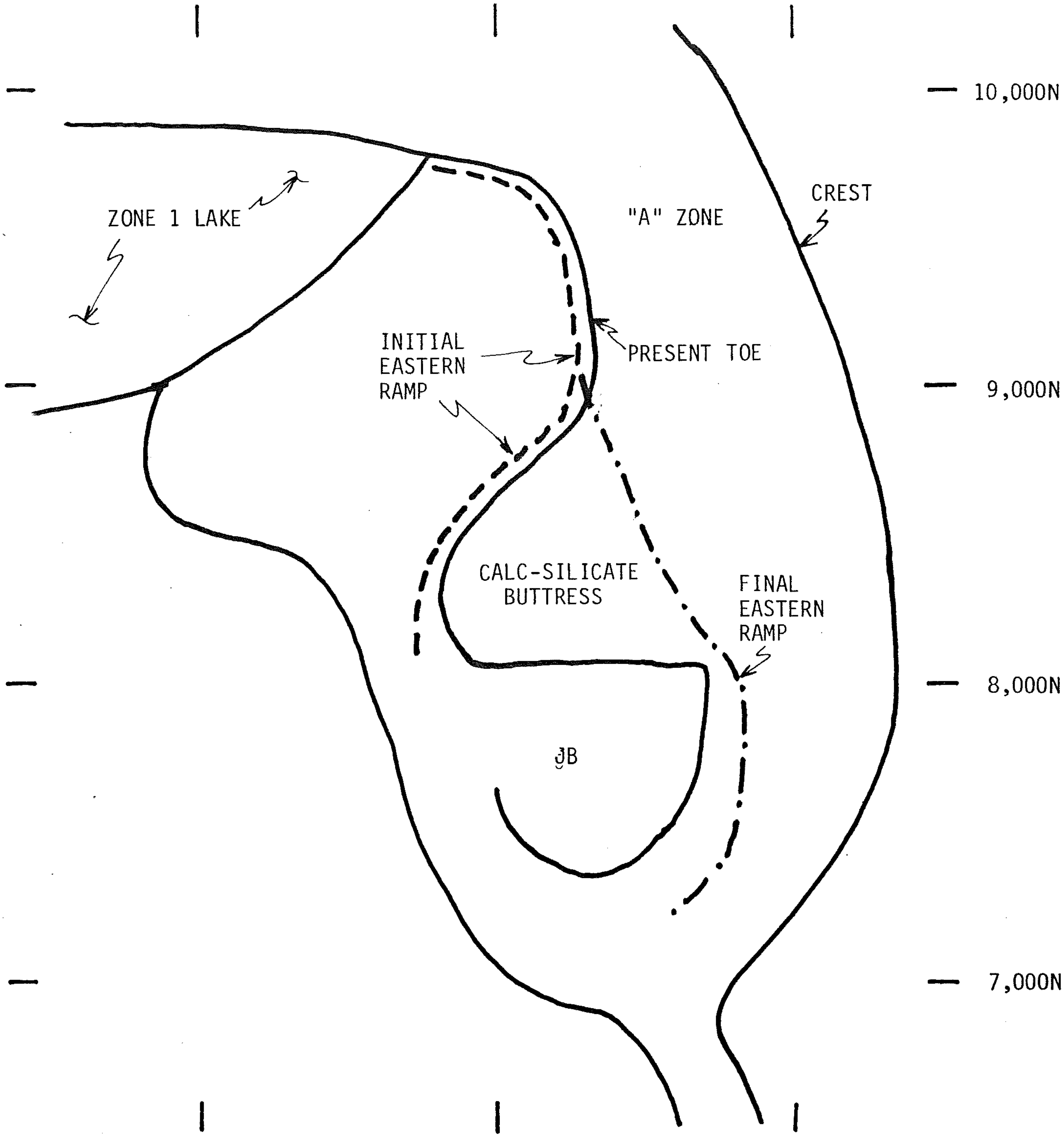
PITEAU ASSOCIATES ENGINEERING LTD.

Alan F. Stewart, P.Eng.

REFERENCES

Piteau Gadsby Macleod Limited. January, 1976. "Slope Stability Analysis and Design of the Open Pit Slopes". Report to Cyprus Anvil Mining Corporation.

Piteau Associates Engineering Ltd. November, 1985. "Report on Phase I Geotechnical and Hydrogeological Assessment of the Northeast Wall of the Anvil Pit". Report to Curragh Resources Corporation.



NOT TO SCALE

FIG. I

CURRAGH RESOURCES CORPORATION ANVIL PIT	**PITEAU & ASSOCIATES** GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY

SCHEMATIC PLAN OF EASTERN PORTION OF PIT	BY: A.S.	DATE: 8/86
	APPROVED: A.T.	DWG: 85-804A-1

PHOTO 1. Northern portion of East Wall. Note "A" Zone and calc-silicate portions of wall. Also note overburden failure on "A" Zone wall.

PHOTO 2. Southern portion of East Wall. Note calc-silicate and JB portions of wall. Also note 120 ft (36m) high slope below 3910 level and failure next to calc-silicate buttress.