Gavin Mudd
PhD Student - Part Time Lecturer
Environmental Hydrogeology and Geomechanics
School of the Built Environment
Victoria University of Technology (Footscray)
P.O. Box 14228, Melbourne City MC, VIC 8001

Submitted - Monday, July 6, 1998

SUBMISSION TO THE JABILUKA MILL ALTERNATIVE P.E.R.

As an emerging expert in the field of the interaction of tailings and groundwater and their subsequent environmental management at mine sites, I will concentrate my submission on these aspects.

The thrust of my submission will argue that there are many complex hydrogeological and geochemical processes that will act on the Jabiluka Mill Alternative Proposal and the long term safety of the project can ***NEVER*** be given technical or social guarantees.

It is therefore proposed that all plans and operations at the project site be stopped immediately without hesitation and that the Jabiluka Lease be incorporated into Kakadu National Park.

1 Due Environmental Assessment Process

The spirit of the Environment Protection (Impact of Proposals) Act 1974 is that any environmental assessment conducted should be independent analysis of a proposal's environmental effects. Such a spirit of good faith assessment has never been followed with the Jabiluka proposal, and this is evidenced by the fact that the PER itself is co-authored by the proponent themselves, as was the 1996 Draft EIS (DEIS) and 1997 Supplement.

Given that construction of the mine facilities is currently being attempted before the completion of the overall project concept is finalised and approved by government, it is absolutely evident that the proponent, despite propaganda and manipulation of media to suit their interests, have scant regard for due environmental assessment processes.

The gravity of any mining or industrial facility within the confines of Kakadu National Park, despite being unwanted by most Australians, must meet the most stringent environmental assessment processes, and clearly these are being bypassed by an ideologically driven government and a proponent prepared to sacrifice anything and anyone perceived to be in it's way of starting the Jabiluka mine.

The use of a Public Environment Report (PER) is also inappropriate to assess the Jabiluka Mill Alternative (JMA) adequately. Given the claims of the consultants (whose independence must be held in serious doubt) and the proponent about the benign impact of the JMA proposal, the allotted time of four weeks for public consultation, is simply inadequate and not enough time to undertake a significant scientific and technical assessment of the proposal. Given that the PER was actually being printed while public comments on the Draft Guidelines for the PER were supposedly being finalised[1], the commitment of both the proponent and the government to take serious note of public comment in the proposal is highly questionable.

Such actions are clearly outside of the spirit of the EPIoP Act and relevant regulations and procedures, and both the Australian and International communities will not tolerate such a frivolous attitude.

2 Mill Project Concept

Section 4 of the PER

Although the proponent has tried to promote it's new tailings disposal concept as being underground[2], the facts presented in the PER clearly show that only approximately 50% of the tailings will be disposed of underground, and the remaining 50% will be disposed in surface pits for the first ten years of the proposal.

It is noted in Figure 4.5 does not include the use of any geotextile membrane or clay layer in the above ground disposal pits. Either high density polyethylene (HDPE) plastic must be used, or clay or some form of geotextile as a liner material. Without such a system, there is no way to minimise the potential for seepage, especially after closure of the facilities. Although, as long as there is a higher water content in the disposal pits, there will always be some degree of seepage escaping from such a facility.

There does not appear to be any liner system proposed for the Waste Stockpile. Such a system should be incorporated.

The particle sizes of the tailings that are to be disposed of above and below ground are not explicitly discussed. it is mentioned briefly that the majority of the tailings are expected to be of a fine nature, with 35% likely less than silt size or 20 μm.

This has important implications. At the Olympic Dam (Roxby Downs) copper-uranium mine in South Australia, only the coarse sand fraction is used for underground mine backfill. The fine fraction, laden with the remaining radionuclides and heavy metals, is slurried out to their leaky tailings dam.

[1] - *Questions asked over Jabiluka mill guidelines*, Tuesday 9 June, 1998 (11:03pm AEST);
[2] for example - *No tailings dam for Jabiluka mine*, Tuesday 9 June, 1998 (4:30pm AEST);
ABC NT News Website (http://www.abc.net.au/news/state/nt/default.htm).

The PER should address this issue in detail, as it would be reasonable to assume that only the coarse fraction of the tailings would be suitable for underground disposal, as this is likely to have the requisite strength to maintain mine stability. The fine fraction is therefore likely to remain at the surface and be a potential source for the mobilisation of radionuclides and heavy metals for longevity, especially when the proponents walk away from their responsibility for the site after the cessation of mining and monitoring.

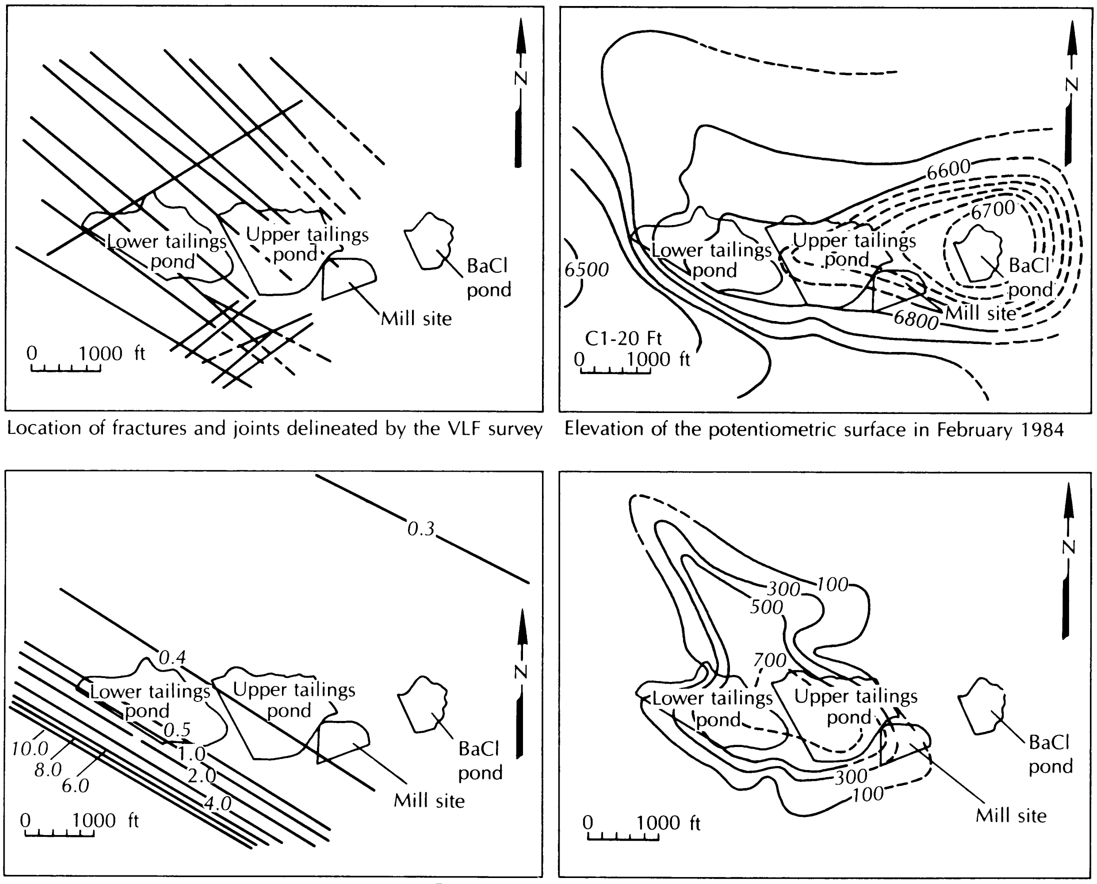
Although it is agreed that paste-cement tailings disposal is an environmental improvement in some respects, the author is not aware of successful demonstration of such a system with radioactive tailings, which has certainly never been used before in Australia at Narbalek, Rum Jungle Mary Kathleen or other old uranium mines. However, there remain many intractable technical issues with the use of paste-cement fill. These are discussed below.

Potential for Seepage

While the potential for seepage is reduced with the use of paste-cement tailings, there still remains certain contexts when seepage is of significant concern :

- although it is argued that the cement will cure rapidly, there is no apparent requirement for this to be achieved - thus the paste-fill could remain "chemically stabilised" but not physically solidified, meaning that the potential for seepage and further mixing of paste-fill pore water and infiltration will remain;
- after mining, infiltration of rainfall can lead to seepage emanating from the base of the disposal pit;
- any seismic event can induce tension cracks within the disposal pit - such cracks would make the overall low permeability of the paste-fill irrelevant as the waste would develop secondary porosity and subsequently the hydraulic conductivity could be dramatically increased by up to several orders of magnitude;
- the consolidation of the cement and possible cracking or fracturing due to increased overburden stresses over time (ie - an increase in effective stress) are ignored;
- the allowance of possibly acidic wet season water on top of the above ground disposal pits could lead to significant saturation and destabilisation of the paste-fill, and there could be potential for seepage - all wet season water entering the disposal pits must be pumped out to an external pond for evaporation. The proposed method of waiting until acidic water is detected could be too late to prevent damage from occurring;
- the overall permeability, including that due to secondary porosity created from tension cracks and fractures, should be effectively lower than 10^{-10} m/s or more than 100 times lower than the surrounding liner and sediments and rocks it is built within in order to minimise seepage;
- the fractures of the surrounding sandstone that the pits are excavated into are ignored as potential contaminant migration paths.

The presence of fractures within a rock layer can also lead to unpredictable hydrogeologic behaviour. A famous case in point is a uranium mine and mill in Utah, USA. The tailings facility of the mine was located on highly fractured sandstone, and the direction of groundwater flow was to the southwest. The primary direction of fractures was northwest. Despite the direction of groundwater flow, seepage led to the migration of radionuclides away from the tailings facility along fracture lines, and not with the flow of groundwater (White & Gainer, 1985; Fetter, 1994).



Location of fractures and joints delineated by the VLF survey

Elevation of the potentiometric surface in February 1984

Baseline natural uranium activity (μCi/mL × 10^7)

Elevated activity of natural uranium in the summer of 1983 (μCi/mL × 10^7)

Geochemical Issues

The long term geochemistry of radioactive tailings can never be proven without the passage of time - engineering is based on experience, and there can never be a time frame established to prove the long term chemical integrity of any tailings disposal system, let alone paste fill.

There are a number of critical geochemical processes that could lead to such a loss of integrity of the paste cement fill method, and it is not simply “much less likelihood of (a) migration of a plume of porewater from the tailings mass” (page 4-39).

Immobilisation of Heavy Metals and Radionuclides

Although most heavy metals are, as a general rule, less soluble under highly alkaline conditions, the PER only includes one technical reference to support it's claim. This is absurd and simply poor science. The referencing of one technical paper neither proves nor disproves the argument put forward - if the proponent were to attempt to publish such a weak technical review in a credible and refereed scientific journal, they would be required to use a substantial weight of technical literature to justify their hypotheses.

It is curious to note that no technical conference or jounral papers are presented for the immobilisation of radionuclides, such as uranium. Only hypotheses are presented.

The cement paste will not be able to immobilise radon, which is an inert gas.

Radium is also more soluble under highly alkaline conditions, a property well established from the operation of In Situ Leach uranium mines in the USA that use alkaline leaching chemistry (Mudd, 1998). *The potential for migration of radium from the cement paste fill would be uncertain, and is ignored in the PER.*

Even if one assumes that heavy metals are immobilised in relatively insoluble mineral forms, the process of diffusion through residual pore water would still occur, and could lead to eventual discharge to surrounding groundwater, although the rates would potentially be slow, there is not enough information presented in the PER to allow an assessment of such rates compard to natural groundwater processes.

As presented in the PER there is simply no way to justify the immobilisation of heavy metals, and especially radionuclides.

Acidic Potential

It has been noted in the DEIS, subsequent further metallurgical work and the PER, that there is potential for net acid production from Jabiluka ore. Although it is argued that this potential is more than likely to be removed from the use of sulphuric acid and hydrogen peroxide (caro's acid) during the uranium extraction process, it ignores a fundamental issue in the chemistry of acid rock drainage - that of kinetic rates of sulphide oxidation.

The analysis of potential acid problems in the cement paste fill is based on very select assumptions using acid-base accounting methods. This does not take into account the kinetic rates widely known to control the formation of acidic mine waters. The groundwater in the area is at quite shallow depths, but no data is presented to give oxygen content of this groundwater, nor if this groundwater is likely to infiltrate the disposal pits after the cessation of operations at the project site.

The cap proposed for the pits does not talk about design features to prevent infiltration of oxygen into the pits after long term closure. The strength of the paste fill is essentially irrelevant - if the caps do not maintain greater than 85% saturation they will allow the ingress of gaseous oxygen into the pits and thereby create the potential for acid drainage to be produced from the disposal pits over the long term, on the scales of tens of thousands of years needed to ensure ecological integrity from the radioactive nature of the tailings.

Ouellet *et al.*, 1998[3] (refer to Appendix One), demonstrated that the structural stability of cement paste fill was compromised by chemical alteration at a mine in Canada within six months of fill placement. This behaviour was unpredicted based on earlier laboratory test results and pilot trials. Perhaps the greatest concern was the presence of a fine system of fractures, which allowed the ingress of water and thus begin the oxidation process by delivery of oxygen and water. The presence and oxidation of sulphides within the tailings paste caused a dissolution of the calcic phases of the cement hydrates and promoted the formation of swelling mineral phases which in turn induced desctruction of the structure of the cement paste fill.

The possibility of a “minimum of several metres of water in the pit at the end of the wet season” (page 4-40) is entirely unacceptable. This will inhibit curing of the cement mix, despite the proposed subaqueous deposition of the cement paste, and significantly enhance the potential for seepage, especially through fractures established within the fill in the pits.

It would appear the a “trial-and-error” approach is being adopted for tailings management, both above ground and also underground, and that due to complex interactions of physical and geochemical processes, ***the long term physical and chemical integrity of the tailings can never be guaranteed***.

3 JMA Project Alternatives

Section 5 of the PER

This section is utterly pitiful. The alternatives presented are instantly dismissed as not viable, and the PER is so arrogant as to appear to assume that the necessary approvals for the JMA will be given without hesitation.

Again, the motives of the proponent are exposed to be less than that required for due environmental assessment.

[3] - a paper from the same conference series as Cincilla *et al.*, 1997 - Tailings and Mine Waste, Colorado, USA.

The possibility of mining the gold contained within the overall ore reserves has been completely ignored. It appears that the proponent intends to avoid public scrutiny and access to this proposal by undertaking such studies if necessary the approvals are given. This is fundamentally unacceptable - there has been noted problems with gold mining for over a century, especially with the modern use of cyanide reagents in the extraction process.

The proponent must not be allowed to extract the contained gold without a new EIS specifically addressing this issue.

4 Existing Environment

Section 6 of the PER

Hydrogeology of the Tailings Area

It is stated that two aquifers are known to exist in the tailings disposal area - a shallow unconfined, alluvial aquifer, and a deeper fractured rock aquifer in the Kombolgie Sandstone. Evidence of secondary porosity and extensive fractures is also presented.

Although it is argued that these aquifers are effectively isolated from each other, the impact of pit excavation on groundwater flow paths is ignored, especially on the shallow aquifer. Potential exists for downward percolation, suggesting that if there was seepage from the tailings pits, they could flow to the east where the groundwater is thought to discharge in local and regional creeks.

The quality of the groundwater is, based on Table 6-2 (page 6-10), is quite good.

Given the observed seasonal variation of up to 4 m in the shallow aquifer due to wet season recharge, there is significant potential for seepage problems with the tailings areas that could negatively impact the quality of groundwater that discharges to local surface water features..

The potential for acidic groundwater to infiltrate disposal pits after closure and the groundwater attempts to re-establish normal flow paths is ignored. This would be a critical issue - if acidic groundwater were to enter the tailings cement fill, any physical and chemical integrity would be severely impacted. There would be significant potential for the mobilisation of heavy metals and many radionuclides, especially uranium and thorium.

Why this issue is ignored is unclear - ***it must be addressed***.

Boyweg Spring Impacts

The review of the hydrogeology controlling the Boyweg Spring is largely irrelevant, including Appendix E - no mention or hydrogeologic connection of the spring to the geology and hydrogeology that is discussed is presented. It appears merely an attempt to address a significant issue without actually asnwering the question of substantial impacts on the flow at Boyweg Spring.

Given the complex nature of the controls on groundwater flow in the area, it would be reasonable to assume that Boyweg Spring will be adversely affected by groundwater extraction in the Mine Valley for potable water supplies and mine dewatering purposes.

5 Environmental Impacts and Mitigation

Section 8 of the PER

Acid Rock Drainage (ARD)

The approach taken by the proponent is to merely wait for ARD to develop before measures will be implemented to mitigate and control the production or treatment of ARD (pages 8-6 to 8-7). This goes against the sound advice of many ARD specialists. Once ARD has begun to form, it is increasingly difficult to bring under control. Simply attempting to treat the problem after it arises is therefore environmentally indefensible and meaningless.

6 Conclusions

The PER, as presented fails to adequately address many of the complex environmental problems that may arise from the proposal. The main impacts highlighted are :

- long term physical and chemical stability of the tailings is highly unlikely, both underground and at the surface, giving rise to the potential for mobilisation of heavy metals and radionuclides into groundwater and surface water systems of the Jabiluka region and thence to Kakadu;
- environmental management proposals appear to be a “trial-and-error” approach, rather than prevention; &
- potential for groundwater contamination from seepage via fractured cement pits.

It is anticipated that the proponent will simply argue that the above scientific views are not widely shared and be openly dismissive of such a technical critique. However, many of my colleagues agree with the above perspective and thus this submission appears to have more scientific peer review than the PER itself !!!

The protection of Kakadu for the Mirrar people and future generations of Australian and fellow global citizens who visit the majesty of Kakadu demands detailed scientific assessment of these potential problems, BEFORE any mine or mill construction begins.

The Jabiluka Proposal should thus be abandoned altogether, as many of the above issues will remain technically unresolved until after the environmental problems have been created.

References

Fetter, C W, 1994, *Applied Hydrogeology,* 3RD Ed., Macmillan Publishing Company, USA, 691 pages.

Kinhill - ERA Environmental Services, 1998, Jabiluka Mill Alternative Public Environment Report and Appendices.

Mudd, G M, 1998, *Environmental Management in In Situ Leach Uranium Mining - The International Experience*, Literature Review submitted to the Australian Minerals and Energy Environment Foundation (AMEEF) for the Review Award prize, 1998, 153 pages.

Ouellet, J, M Benzaazoua & S Servant, 1998, *Mechanical, Mineralogical and Chemical Characterisation of a Paste Backfill*, Tailings and Mine Waste '98, Balkema, Rotterdam, 1998, ISBN 90 5410 922 X.

White, R B & R B Gainer, 1985, *Ground-water Contamination by Uranium Beneath Active Uranium Mill Tailings Ponds*, Ground Water Monitoring Review 5, No. 2, 1985, pages 75-82.

Appendix One

J Ouellet, M Benzaazoua & S Servant

Mechanical, Mineralogical and Chemical Characterisation of a Paste Backfill

Paper presented at Tailings and Mine Waste '98

Balkema, Rotterdam, 1998
ISBN 90 5410 922 X

(best quality copy available at short notice)

Tailings and Mine Waste '98 © 1998 Balkema, Rotterdam, ISBN 90 5410 922 X

Mechanical, mineralogical and chemical characterization of a paste backfill

J.Ouellet, M.Benzaazoua & S.Servant
Université du Québec en Abitibi Témiscamingue, Unité de Recherche et de Service en Technologie Minérale, Rouyn-Noranda, Qué., Canada

ABSTRACT :

Mining backfill is now current practice in many mines. Along the years different pratices have evolved in the industry. Hydraulic fills, rockfills and hign density fills have been in used for quite some time now. But more recently, paste backfill, is spreadind in Canadian mines. It has been used by some Quebec mines for the last four years. This type of backfill is prepared from unclassified tailings and put in place as a high density slurry with cement content varying from 3 to 6% by weigth. This technology seems to have significant advantages compared to conventional cemented hydraulic fills. Since the water content of the paste is reduced no dewatering systems is deemed necessary in the backfilled stopes. For a given cement ratio, the achievable strength is better, due in part to a lower water/cement ratio than hydraulic fills. The tailings need not to be classified, so more tailings are returned under ground, minimising the amount of waste to manage on the surface. In the example treated here, the pilot plant trials tests predicted very good strength for this operation with a bonding agents mix of 60% Portland cement and 40% fly ash. Nevertheless, achievable strength at the production stage had to be revised and when the first pillars were mined out exposing the backfill faces the performance was much less satisfactory than expected. Excessive dilution and instability of the backfill were observed. A drilling program was then implemented to collect in situ samples for laboratory testing. The results of triaxial compression tests on samples prepared from the drilling cores showed very little cohesion which contradicted with test results from initial control samples. Mechanical, chemical and microscopic testing of the core samples demonstrate the presence of a chemical alteration in the backfill.

INTRODUCTION

Paste backfill is a very attractive alternative to hydraulic backfill because it shows significant advantages. It is considered that paste fill requires much lighter barricades to contain the material and no water is entrained in the system, except the amount required to hydrate the cement. Consequently, since no free water is present in the paste fill system there should be no requirements for a drainage system and no need to delay the fill pours. Which results in a faster stope cycle time. Moreover, for comparable amount of bonding agents the strength achievable is greater, due in part to a lower water/cement ratio of the mix (Udd and Annor, 1993).

The limiting factor in the achievable paste density (percent solid by weigth) is its flow properties required for the underground distribution system used. Effectively, strength increases with higher paste density for a given binder content (Lidkea and Landriault, 1993). But the flow characteristics requirements will limit the practical density that can be used. At the pilot plants trials a testing program is implemented to optimize the properties of the backfill. The main goal being to maximize the strength while keeping adequate flow properties of the paste for the distribution system of the mine. The strength parameter used is generally the uniaxial compressive strength measured on cylindrical samples. The feasability studies are generally limited to these aspects, no long term chemical/mechanical stability of the cemented fill is considered. Once the full scale operation is implemented, a quality control program is put in place to insure that operating parameters of the paste fill plant are adequate and predicted strength from trials tests is achieved.

In this paper the authors will present results from a mining operation where the chemical aspects played a significant role in the general performance of the backfill.

1 PHYSICAL AND MECHANICAL CHARACTERIZATION

The mine site discussed here extract a polymetallic ore rich in sulfuric minerals. The waste produced at the concentrator plant is in part recycled to produce a paste backfill with the addition of binders. The mix of binders is 60% Portland cement and 40% fly ash. A quality control program was put in place to assess backfill plant performance. Backfill samples were collected at each pour and tested in laboratory at various curing time (7, 14 and 28 days) to determine shear strength. To this end triaxial compression tests and simple compression tests were performed. The backfill samples wre cylinders of 20 cm high with a diameter of 10 cm. The cylindres were placed in a controlled atmosphere chamber to cure for a 28 days period. Then the void index and water content were measured for each of this cylinders prior to the compression tests. More detailed results can be found in Ouellet (1995) and Ouellet et al. (1995).

Table 1 : Mean physical characteristics of 50 samples.

Void index	1,0
Relative saturation (%)	90
% Solid by weigth	78%
paste slump	7,5

1.1 Control tests during operations

The samples cement content was ranging from 3% to 7% by weigth. The following figure illustrates some of the results from the triaxial tests conducted on the control samples. The strength increased with cement content as expected. The cohesion on the « q-p » diagram is close to 300 kPa at 7% cement and reduces rapidly to less than 100 kPa at 3% cement. The unconfined compression strength varied from 500 kPa at 3 % cement and 1 200 kPa at 7% cement. In this diagram the parameters « q » and « p » are defined as :

$$q = (\sigma_1 - \sigma_2)/2 \qquad p = (\sigma_1 + \sigma_2)/2 \qquad (1.1)$$

The parameter « p » express the mean stress and the « q » parameter the deviatoric stress acting on the sample during the triaxial compression test.

1.2 Comparison of trials predictions and control tests

The strength values measured on control samples are well below predicted strength from the pilot trials. Effectively, the external firm conducting the trials tests for the feasability study had predicted unconfined compression strength of up to 4 MPa at 7% cement. The testing protocol used to performed the trial tests was examined.

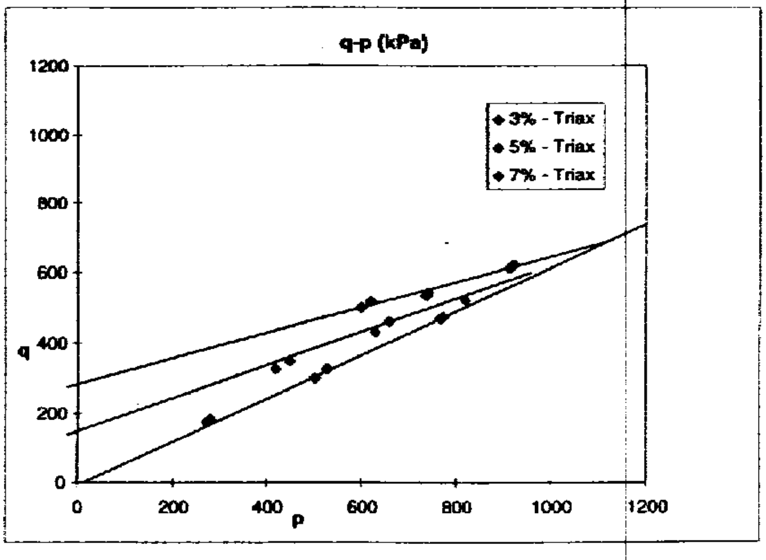


Figure 1 : « q-p » Diagram of triaxial compression tests on control samples.

In order to assess the strength vs cement content relation, samples were mixed with various cement content. A batch of paste was prepared at a certain solid ratio in order to have the proper slump of 7,5. This slump was determined as being the optimal consistency after the looping test used to assess pumpability of this paste. Cement was then added to the paste and some cylinders prepared. Successively the cement content was increased by addind the proper quantity of cement to the paste and cylinders prepared by filling cylinders at each step. Although a quick and simple procedure, this method had the effect of increasing the solid ratio of the paste each time cement was added to the mix. Moreover, the slump from one cement ratio to the other was modified decreasing progressively from 7,5 to 6,0. Consequently trials tests predicted unrealistic results, much higher than the strength achievable at the backfill production stage. The trials tests should have been performed at constant slump, which would have required adding a certain amount of water each time the cement content was increased. Such an experimental procedure would have insured samples representative of real production parameters.

2 BACKFILL PERFORMANCE

Backfill performance when secondary pillar recovery began was not judged satisfactory. Effectively, dilution up to 30% was observed. Based on control tests, this poor performance was unexpected. In order to study this problem, a drilling program was implemented to obtain backfill cores from stopes 6 months old. In order to obtain cores with minimum disturbance drilling was done with triple core barrels and the drilling fluid used was Polymud. From this cores, samples were cut and tested in simple and triaxial compressions tests in the laboratory.

2.1 In situ sampling and laboratory tests results

The cores from the in situ sampling program were tested to determine their saturation level and void index. Then simple compression tests and triaxial compression tests were conducted on a few cylindres cut from these backfill cores.

Table 2 : Mean physical characteristics.

Void index	0,95
Relative saturation	93 %

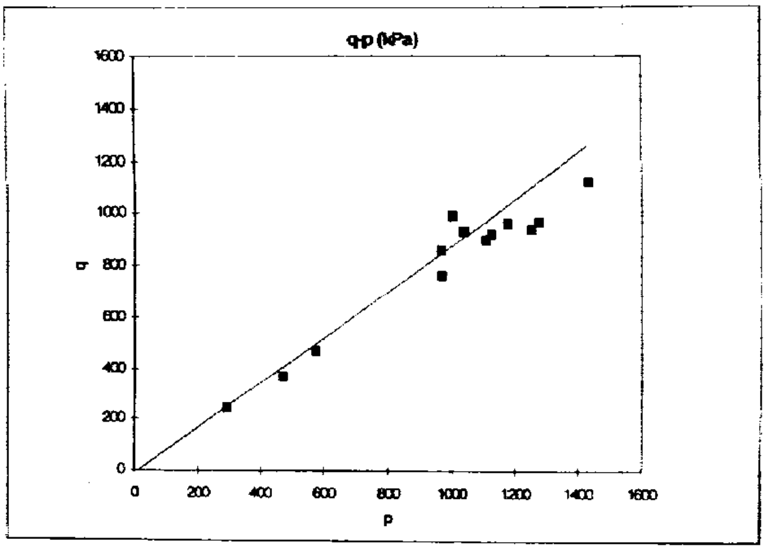


Figure 2 : « q-p » diagram of triaxial and simple compression tests on in situ samples.

The backfill placed in the sampled stopes had been prepared with a cement content of 4,5% by weigth. Test results on the in situ samples showed a very low cohesion as illustrated on the « q-p » diagram of figure 2. This was unexpected since control samples for these stopes, on this same material, had showed a cohesion of 200 kPa after 28 days of curing. The strength of the backfill after 6 months was now much lower than the 28 days strength.

3 MINERALOGICAL AND CHEMICAL CHARACTERIZATION

Detailed observations and analysis of the core samples were conducted to investiguate the cause of this poor in situ strength. A complete and detailed presentation of the chemical analysis performed on the backfill samples can be found in Benzaazoua et al. (1997). In this discussion a summary of main results only will be presented.

3.1 Macroscopic observations

On the picture showed at figure 3 a transverse cut on a backfill core is illustrated. A fine net of fractures is observed and characterized by oxydation traces. This indicates that fluid circulated in these fractures and produced an oxydation of the sufurs present in the backfill.

3.2 Microscopic observations

In order to investigate further this phenomenon observations were made with an elctronic microscope HITACHI S-3200-N equiped with a OXFORD-ISIS-300 analyser. Some of the

detailed view obtained with this equipment are illustrated in figures 4 to 6. These observations were completed with chemical analysis of intersticial water and backfill. The detailed results and analysis description can be found in Benzaazoua et al. (1997).

Some interesting observations on the structure and chemistry of the backfill can be made on the miscroscopic study. The Figure 4 shows the general aspect of the backfill. The high porosity is evident, and the sulfuric grains are well dispersed in the material. The detailed view (figure 5) indicates that the grains are well coated by the cement. But the texture remains loose because of the structure adopted by the cement during the hydratation. A more detailed view of the hydratation minerals (figure 6) show that the hydrates formed are gypsum and not portlandite minerals. No portlandite minerals could be evidenced in the chemical analysis performed which indicates that it is in an amorphe state, Benzaazoua et al. (1997).

The effect of sulfuric minerals on the durability of mortars is well documented in the litterature, we can name a few as Deloy F.X. (1989), Regourd M. et al. (1980) and (1984), Dron R. et al. (1989), Mielenz R.C. Ping X. and Beaudoin J.J. (1992), et Piasta W.G. (1992). The sulfates present in the intersticial water and those produced by the oxydation of pyrite FeS_2 in a basic medium will react with the free calcium ions produced by the dissolution of the

unstable portlandite hydrates $Ca(OH)_2$ resulting in the precipitation of swelling secondary gypsum $CaSO_4.2H_2O$ and very expansive ettringite $3CaSO_4.3CaO.Al_2O_3.32H_2O$. These reactions can be represented by the following equation.

$$3\,FeS_2 + 9\,O_2 + 12\,Ca(OH)_2 + 3\,Al_2O_3 + 56.5\,H_2O = 3\,Fe(OH)_3 + 2(3CaSO_4.3CaO.Al_2O_3.32H_2O)$$

These expansive minerals can generate very high crystallisation pressures (70 to 200 MPa), Divet (1996). This phenomenon can affect drastically the durability of mortars. It provokes the fissuration of the concrete mass and consequently the loss of it's structural strength.

The presence of sulphur minerals in mortar is long since recognized to have very negative effects in civil engineering structures. In mining backfill, the same effect can be anticipated because of the high sulfur contents of some waste materials. This in a much more high degree because of the low cement content and the very high concentration of sulfurs.

Udd, J. E. and Annor, A. « Backfill research in Canada » Minefill 93, Johannesburg, pp. 361-368.

Viles R.F. and David R.T.H. « New material technology applied in mining with backfill » Innovation in Mining Backfill Technology, Hassani et al. Ed., Balkema Rotterdam, 1989, pp 95 - 101.

"Le remblai en pâte, une technologie innovatrice ....." Canadian Mining Journal, Avril 1995, p19.

CONCLUSIONS

This short historycal review of a paste backfill implementation experience illustrates the importance of a detailed study at the feasability stage. Both mechanical and chemical aspects must be investigated. If any parameters is neglected, costly modifications can be required during the operations later on. The long term characteristics of the backfill must be considered. In order to have mechanical stability in the long term, chemical stability of the material must be insured. Chemical alterations of the cement phases can have a negative impact on the strength of the backfill.

Analysis of cores samples in this case showed the presence of a fine system of fractures in the samples accompanied by oxydation traces typical of a chemical alteration. Chemical and mineralogical analysis showed that the presence of sulfides in the tailings caused a dissolution of the calcic phases of the cement hydrates and promoted the formation of swelling phases which in turn induced a destructuration of the cemented backfill.

AKNOWLEDGEMENTS

The authors would like to thank the Institut de Recherche en Santé et Sécurité au Travail (IRSST) and the Fundation of University of Quebec in Abitibi-Témiscamingue (FUQAT) for the funding of this research.

REFERENCES

Annor, A. « In situ determination of dewatered tailings fill properties in Ontario Mines » Canmet report MNG 44866, 286p.
Benzaazoua M. « Caractérisation physico-chimique et minéralogique de produits miniers sulfurés en vue de la réduction de leur toxicité et de leur valorisation » Thèse de Doctorat de l'Institut National Polytechnique de Lorraine. Jan. 1996, LEM-ENSG Nancy, France.
Benzaazoua, M., Ouellet, J., Servant, S. « Cemented Backfill with slfurs : A case study with a mechanical and chemical characterisation » in preparation.
Deloy F.X. "Action conjuguée du soufre et des alcalins dans les réactions liant - granulats au sein du béton" Bull. Liaison Labo. Ponts et Chaussées, 161, 1989, Ref. 3393, pp 4149
Divet L. « Consécutive à l'oxydation des pyrites contenues dans les granulats : Synthèse bibliographique» Bull. de Liaison du Labo. Central des Ponts et Chaussées, 1996.
Dome Mines Ltd. « In situ determination of dewatered tailings fill properties in Ontario mines » Canmet Report MRL 85-147 (COMDA), 120p.
Ducic V. and Miletic S. « Sulphate corrosion resistance of blended cement mortars » Durability of Building Material, 4, 1987, pp 343 - 356.
Lamos A.W. and Clark I.H. « The influence of material composition and the sample geometry on the strenght of cemented backfill » Innovation in Mining Backfill Technology, Hassani et al. Ed., Balkema Rotterdam, 1989, pp 89 - 94.
Lidkea, W., Landriault, D. « Test on paste fill at INCO » Minefill 93, Johannesburg, pp. 337-347.
Ouellet, J. « Comportement contrainte-déformation du remblai hydraulique cimenté pour le remblayage minier » 48e Conférence Canadienne de géotechnique. Tendances en géotechnique, Vol. 1, Septembre 1995, pp. 25-32.
Ouellet J., Bussière B. et Gagnon G. « Simulation numérique du remblayage d'un chantier de mine avec du remblai hydraulique cimenté :élaboration du modèle » 3rd Canadian Conference on Computer Applications in the Mineral Industry, Montréal, Canada, Octobre 1995.
Provencher S. "Comptes rendus de la visite de sites miniers de l'Abitibi" Ministère des Ressources Naturelles du Québec, Septembre1996.
Regourd M. "Corrosion chimique des matériaux de construction minéraux" Chantiers / Suisse, Vol. 15, 2 / 1984, pp 115 - 120
Ross-Watt D.A.J. « Backfilling on the base metal mines of the gold fields group» Innovation in Mining Backfill Technology. Hassani et al. Ed., Balkema Rotterdam, 1989, pp 351 - 360.