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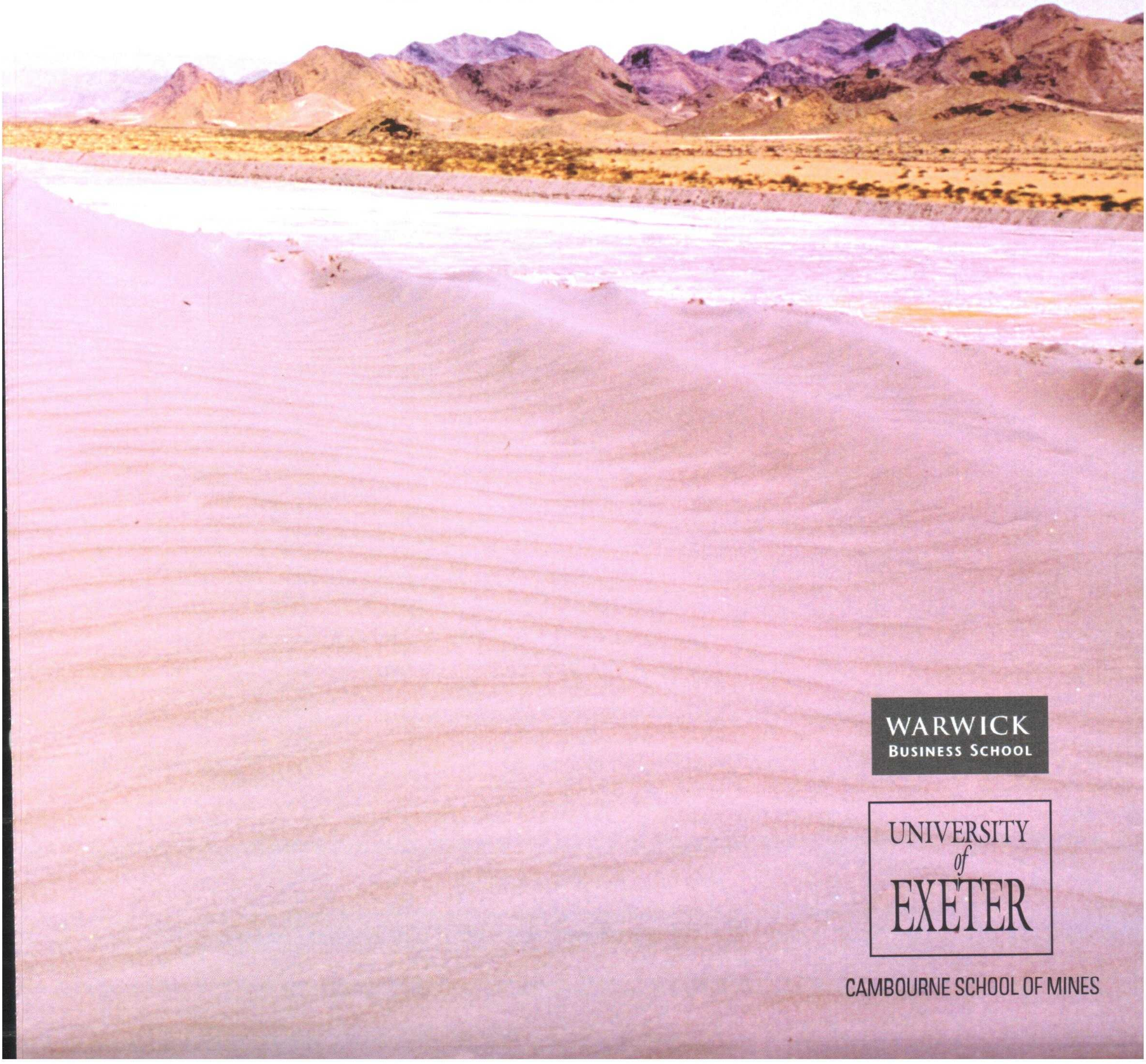
Utilisation of mineral waste: Case studies

Economic Minerals and Geochemical Baseline Programme

Commissioned Research Report CR/02/227N



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BRITISH GEOLOGICAL SURVEY

COMMISSIONED REPORT CR/02/227N

Utilisation of mineral waste: Case studies

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Dunes formed from fine tailings on top of waste heap at Rosh Pinah mine, Namibia as a result of reworking by wind.

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Contents

Summary

Mines and quarries generate considerable volumes of mineral waste, most of which is stockpiled on site or stored in tailings ponds. Fine grained residues from processing especially create problems in their containment and disposal. They usually remain at the mine site after extraction has long since ceased.

Mines and quarries are major income generators in rural areas of developing countries. A working mine is attractive to an indigenous population, who often congregate around the mine site. When the mine closes, the local community of miners and their dependants are left to fend for themselves and may sink into poverty. The production of a saleable mineral product from the mine waste can provide further employment and sustain the community, at least for as long as the waste resource is available and there is a market for the mineral product. Reclamation of mine waste allows these communities to become more sustainable, whether or not the mine with which they are associated is active or closed. By reducing the environmental impact of the mine, the community can come closer to restoring their land to its pre-mining status and increasing its bio-diversity.

The 'Minerals from Waste' project aims to improve the sustainability of current and former mining and quarrying communities by investigating the utilisation of mineral waste as a source of construction and industrial minerals. The work was carried out under the Department for International Development Knowledge and Research programme, as part of the British Government's programme of aid to developing countries. The project was undertaken in collaboration with key organisations in Costa Rica and Namibia, who provided field guidance and local support.

A Scoping Study Report (Harrison and others, 2001) provided an overview of the types of waste found in extractive operations and the general economic, environmental and social issues involved in mine waste utilisation. This initial phase of research showed that opportunities exist for the production of saleable mineral products from mine waste.

This report presents the results of three case studies of mineral wastes from mines and quarries in Costa Rica and Namibia. Each case study includes:

- Investigations of the technical properties of the waste
- Mineral product evaluations
- Market and economic appraisals
- Social impact assessments of local communities

The objective of the research has been to develop a waste utilisation methodology which is generic and applicable to developing countries world-wide.

The case study in Costa Rica focused on waste from a silica sand quarry and processing plant near Cartago in the Central Valley. The fine grained waste from processing the silica sand is stored in two tailings lagoons which are nearing capacity. Laboratory investigations showed that the waste consists of a mixture of fine grained sand and clay. The clay product fires to a reddish colour and hence is unsuitable for whiteware manufacture. However, it is technically suitable for brick manufacture or for the production of pipes, tiles and artisanal pottery. Costa Rica has a relatively small brick industry and the projects financial appraisal has been based on the assumption that a larger market can be developed. The financial model indicates that it is likely that such a venture would not be profitable, although indirect cost benefits would arise to the quarrying company by reducing the need for additional waste storage capacity. The social impact assessment of the proposed waste utilisation scheme shows that it will have low positive and negative impact, but recommends several mitigation and enhancement measures.

Two case studies were chosen in Namibia. The first, at Uis in north/central Namibia, features the large waste tips and fines lagoons from tin mining which ceased in 1990. Most of the former mining community remains at the site with little or no employment. The tailings from both tips and lagoons contain a mixture of minerals and laboratory work has shown that two industrial grade products, mica and silspar (a feldspar concentrate containing some quartz) could be produced from the waste. The markets for such products are likely to be in South Africa or maybe international with shipment in bulk via Walvis Bay. The financial appraisal suggests that a large scale, high technology, capital intensive venture to recover both feldspar and mica products would be profitable. A much smaller scale, artisanal venture is likely to be less profitable and would remain financially marginal, despite enormous waste resources. The attitude of the local population at Uis to a waste utilisation project is extremely positive, as it would provide significant employment opportunities and be of major benefit to the local economy. The processing of the waste would, however, create additional airborne siliceous dust enhancing the current high levels of respiratory disease. Steps would need to be taken to reduce exposure of Uis residents to dusts from both processing and transportation of the waste.

The second case study from Namibia considers the wastes generated from a large, working lead/zinc mine at Rosh Pinah in a remote part of southern Namibia. Here, very fine grained mineral waste from processing of the ore is stored in a very large tailings lagoon. The waste was investigated to determine its barite content and to assess its potential for producing a saleable barite by-product from the waste. If barite could be reclaimed then potential markets exist in offshore oil and gas drilling in Namibia and also in adjacent areas of South Africa. Unfortunately, the barite content of the waste proved to be low, and the high costs of processing make the recovery from the waste pile uneconomic. The mine currently supports a large indigenous population through direct and indirect employment. A mine waste reclamation scheme (which may also recover lead and zinc from the waste) would undoubtedly benefit this community, provided that such a scheme is efficiently and sensitively managed by the project operators.

The case studies are based on, and illustrate the project's waste utilisation methodology covering technical,

market, financial, environmental and social issues. The principles, strategies and procedures of this methodology are applicable to mine and quarry waste utilisation schemes in other regions and countries. Overall, the results presented in this report are aimed to be of benefit not only to mine and quarry engineers and geologists, but also to planners, social scientists, environmentalists, financiers and all involved in the management of mine waste.

Introduction and Acknowledgements

Mine and quarry waste from the extraction and processing of minerals, ores and rocks commonly occurs in substantial volumes which remain in waste piles or tailings heaps. Fine grained waste especially creates problems in its containment and disposal, and usually remains at the site after mining has long since ceased. There is an obvious environmental benefit achieved by the reduction or removal of waste and there can also be a socio-economic advantage, as the production of a saleable mineral product from the waste can provide employment and help sustain the local community.

The 'Minerals from Waste' project aims to improve the sustainability of current and former mining and quarrying activity by investigating the utilisation of mineral waste as a source of construction and industrial minerals. This project (Project R7416) has been funded by the UK's Department for International Development (DFID) as part of their Knowledge and Research (KAR) programme. This programme constitutes a key element in the UK's provision of aid and assistance to less developed nations.

The first part of the project was a scoping study phase to review the potential of mine and quarry wastes, as well as the economic, environmental and social issues involved in their extraction. The scoping study report (Harrison and others, 2001) uses a fact sheet approach to present a mini-profile of each major type of mineral waste, together with its main downstream products and derivatives. Mineral Waste Factsheets are included for:

- Building stone quarry waste
- Coal mine waste
- Crushed rock aggregate waste
- Kaolin waste
- Limestone and dolomite waste
- Waste from mineral sand mining
- Waste from mining of pegmatites
- Sand and gravel quarry waste
- Silica sand waste
- Slate waste
- Waste from talc mining
- Waste from phosphate mining
- Waste from metal mining

Separate chapters in the scoping study report describe the economic factors involved in mine waste utilisation, including the economic viability of small-scale mining. The report also gives a summary of the diverse social and environmental impacts of mineral development and the best practice methodologies for assessing these impacts.

The scoping study report was intended to offer guidance on the potential use of mineral waste and gives background information for informed decision making. This initial research phase found that opportunities exist for the production of mineral products from mine waste.

In order to investigate further the potential for the successful and sustainable use of mine waste, a series of case studies were undertaken at several former and current mining sites in Costa Rica and Namibia. This report presents the results of this second phase — the implementation phase — of the project. It describes evaluation of waste materials from a silica sand quarrying operation near Cartago in Costa Rica, waste resulting from the extraction of pegmatite-hosted tin from the former mine at Uis, Namibia, as well as waste from the active lead/zinc mine at Rosh Pinah, also in Namibia. The goal of these implementation studies has been to develop and test a methodology for investigating the technical properties of the waste materials, to identify suitable applications for any products, to appraise markets and economic potential, and to assess the environmental and social impacts of mine waste utilisation. This goal has been achieved by:

- The design and testing of exploration methods to identify prospective waste materials
- Market studies for the identified mineral products
- The design of economic criteria for evaluating a mineral waste product
- Development of best practice methodologies for socio-economic impact assessment
- Capacity building through joint field studies with counterpart staff
- The provision of advice and technical information to public bodies and the private sector
- The publication of the Scoping Study Report and this report on the implementation studies in Costa Rica and Namibia.
- The dissemination of the project findings through regional workshops and seminars

The 'Minerals from Waste' project, which terminates in late 2002, has been led by a team at the British Geological Survey comprising David Harrison, Andrew Bloodworth, Clive Mitchell and Ellie Steadman. The other UK-based collaborators were Professor Peter Scott and John Eyre from the Camborne School of Mines (University of Exeter) and Dr Magnus Macfarlane and Professor Alyson Warhurst from the Corporate Citizenship Unit at the University of Warwick. The other key participants have been Fernando Alvarado (Instituto Costariccense de Electricidad, Costa Rica) and Ramon Tiongco (Ministry of Mining and Energy, Namibia).

The authors would like to thank the many organisations in Costa Rica, Namibia and South Africa who have contributed to the project. In addition to the collection of data, many individuals have freely given their time and advice and provided the local knowledge so important to the field investigations. Of the many people who have contributed to the project, we would particularly like to thank the following:

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Willem van der Merwe, Kumba Resources, South Africa

Wim Diedericks, Rosh Pinah Zinc Corporation, Namibia

Johan Horn, Council for Geoscience, South Africa

More information about the 'Minerals from Waste' project can be obtained from contacting the Project Manager David Harrison at the British Geological Survey, Keyworth , Nottingham, UK, email: djha@bgs.ac.uk

Structure of the report

Each case study is described separately in the body of the report. These studies can be viewed as stand-alone documents and are set out in an identical format which reflects the methodology employed during the investigations. Each study begins with an overview of the location and general characteristics of the trial site, as well as the source of the mineral waste, its general composition and the development problem posed by the mine and its associated waste.

The introductory statement is followed by a detailed technical assessment of the waste. This provides a summary of the sampling and laboratory methodology and sets out the results of the technical investigation. This includes results of use-related testing in any relevant industrial mineral applications.

Following on from the technical investigation, an economic assessment sets out likely markets for potential industrial mineral products which (on the basis of the technical study) might be derived from the waste. The economic assessment also includes a detailed financial appraisal of the likely methods to be used in extraction, processing and transport of any products. The technical and economic evaluations are complemented by a site-specific assessment of the socio-economic impact of mine waste reprocessing. Each case study is concluded with a series of site-specific recommendations.

The Appendices contain detailed technical data and results. Appendix 1 contains detailed information relating to the silica sand waste site in Costa Rica. Appendix 2 contains project data on the Uis mine in Namibia and Appendix 3 contains the research information on Rosh Pinah mine in Namibia. Laboratory methodological data are given in Appendix 4 and methodologies and information sources for the economic assessment of mine waste are given in Appendix 5. Appendix 6 contains the principles, procedures and methods for social impact assessment.

Case Study A — Sicorsa silica sand, Cartago, Costa Rica

DESCRIPTION OF THE SITE

A1. The mineral site is near the village of Bermejo (1.5 km), district of Quebradilla, canton of Huarco, but closest to the village of Coris (0.5 km). The project area is 41 hectares in size and can be located in 'La Hoja Topográfica ISTARU (1:50 000) del Instituto Geografico Nacional (IGN)' between the co-ordinates 205.7–206 N and 537.2–75 E (Figure A1).

A2. Silica sand for glassmaking is produced at the site. The glassmaking plant (VICESA) is at Cartago about 8 km from the production site. Current extraction at the quarry is around 200 000 tonnes per annum of which some 50 000 tonnes is waste which accumulates in two tailings ponds. The quarry and plant, which are owned by Sicorsa (Silica de Costa Rica), has been producing silica sand since 1995 and there are considerable future resources. The silica sand occurs in the Coris Formation of Miocene age. The sand is variably stained with iron oxides, sometimes very intensely stained. The sand is processed in a complex plant involving screening, washing, hydrosizing, two stages of attrition scrubbing and magnetic separation. This significantly reduces the iron and clay content of the sand. Two products are made; low iron (<0.06% Fe_2O_3) sand for colourless container glass and sand (0.10–0.14% Fe_2O_3) for coloured container glass.

A3. The fine grained waste from sand processing goes directly into the tailings ponds, although the magnetic separator fraction is sold for grit blasting. The tailings ponds are currently almost full of the waste which is thought to be mostly composed of fine grained sand, clay and iron oxide-rich fine grained material. The waste in the ponds is likely to be heterogeneous laterally and vertically and will probably require further processing to make it into a saleable sand or clay product.

A4. The areas directly influenced by the sand quarrying and processing have been delimited to within 200 metres of the site, and the areas indirectly influenced by the waste utilisation project to within 300 metres of the site area. With regard to those areas directly influenced by the project, these are the considerations concerning the increase of noise in the area and the modification of natural drainage. With regard to areas indirectly influenced by the project, consideration was given to the effects on public access routes of the Bermejo road, employment, drainage (either modified or hindered because of the topography of the terrain), the natural conditions of the area, and the community of Coris.

A5. The site is located within the Tree Protection Zone, and its southern extreme is the edge of this Protection Zone. The quarry and processing site is a privately owned property, entered in the land registry, with an uneven topography (30–50%). More than 50% of the ground cover is scrub; there are some bushes and trees. Part of its northern edge is the left part of the Barahona Gorge. The project affects less than 1% of the total area of the Tree Protection Zone.

TECHNICAL ASSESSMENT

A6. The main aim of this investigation is to assess the potential of the bulk samples for use as whiteware and/or structural ceramics (bricks or tiles). Initially the **mineralogy**, **particle-size distribution** and **chemistry** of the waste samples were determined. These data were used to select potential samples for whiteware and/or structural ceramics evaluation. This involved evaluation of the **forming** and **firing** properties of the samples. Details of the laboratory methodology are given in Appendix 4.

Waste sampling

A7. Silica sand is quarried at the Sicorsa quarry, Cartago, Costa Rica and as a result large quantities of mineral residues (waste) are generated mainly as fine grained material (less than 2 mm in size).

A8. Staff from the Sicorsa silica sand plant in Cartago collected two batches of samples (seven in total) of quarry waste from the two tailings lagoons and these were despatched to BGS laboratories. An additional sample of clay currently used to make bricks at a small factory in Cartago near to the Sicorsa silica sand plant was also collected. Table 1A lists the samples. The laboratory codes shown in Table 1A are used as sample identifiers throughout the report.

Waste Evaluation

Mineralogy

A9. The mineralogy data are shown in Table 2A. All the waste samples, from both lagoons, are dominated by quartz with the exception of F800, which is dominated by kaolinite. The other lagoon samples contain either minor or trace amounts of kaolin. Three of the samples (F798, F799, F800) contain traces of hematite. Determinations of clay mineralogy confirm kaolinite as the dominant clay mineral in the Sicorsa samples. The relatively high kaolinite content of sample F800 indicates that it may be suitable as a potential source for whiteware and/or structural ceramics. Other sources from the Sicorsa plant were too quartz rich.

A10. The brick clay (G466) sample is dominated by quartz with trace quantities of mica, kaolinite and hematite.

Particle-size distribution

A11. The particle-size distributions for the samples are shown in Figure A2. All the samples are finer than 1mm except for F798, which has over 50 per cent greater than 1 mm. This sample is significantly coarser than any of the other Sicorsa samples.

A12. F799, F801, G462, G463 and G464 all give very similar distributions with less than 10 per cent clay-sized particles (<2 mm). F800 had a similar distribution to G466 (the commercial brick clay). Both these samples have a

Sicorsa plant from quarry (tailings lagoon in front of plant).

Tailings lagoon (foreground) and quarry (background).

Fine tailings discharging into lagoon.

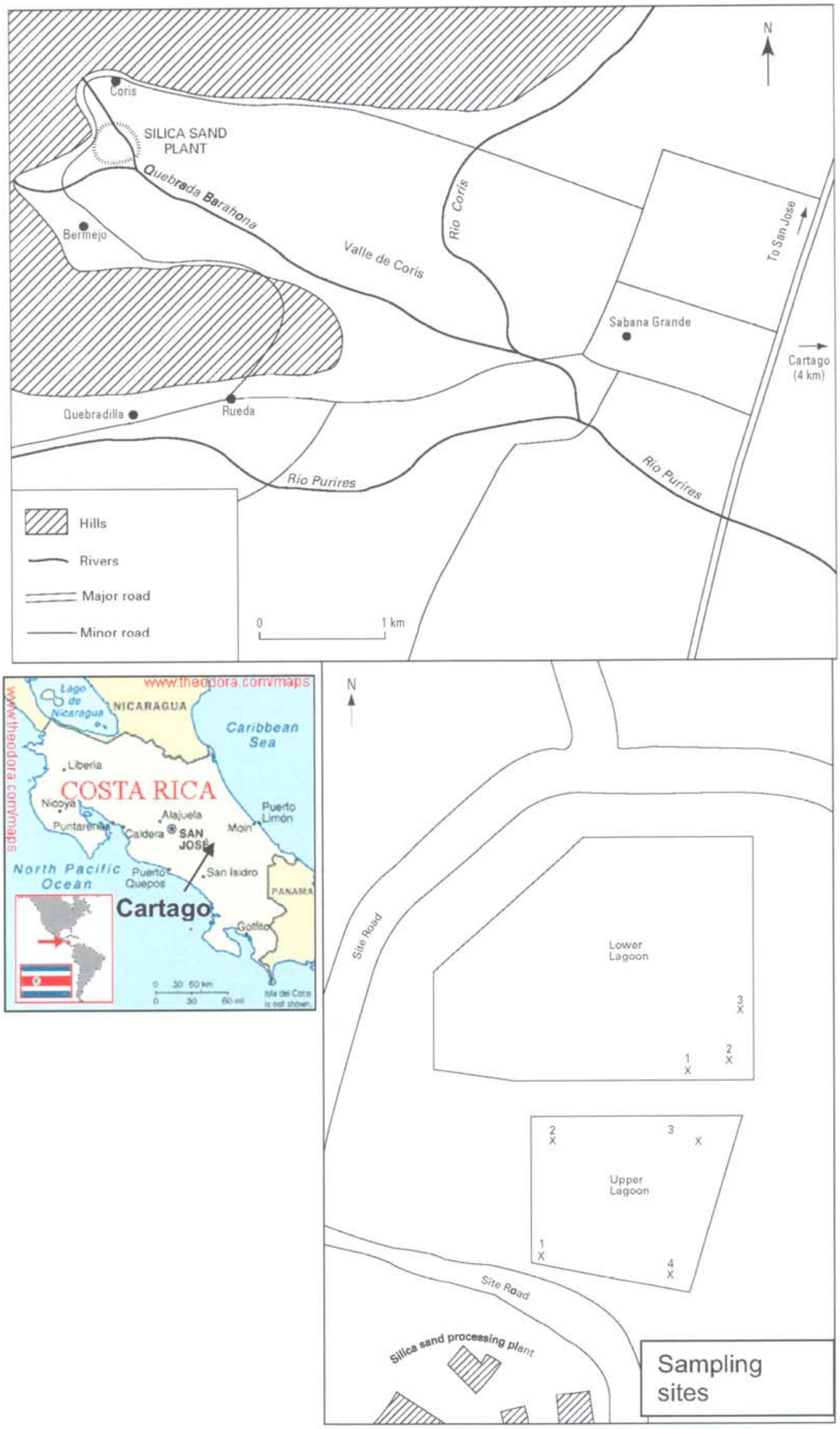


Figure A1 Maps showing location of the Sicorsa silica sand plant, Costa Rica.

Table 1A
Sample list, locality and description.

Bulk Sample	Location	Description	Laboratory Code
Sample 1 (SW corner, upper lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**F798**
Sample 2 (NW corner, upper lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**F799**
Sample 3 (NE corner, upper lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**F800**
Sample 4 (SE corner, upper lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**F801**
Sample 1 (lower lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**G462**
Sample 2 (lower lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**G463**
Sample 3 (lower lagoon)	Sicorsa silica sand plant, Cartago, Costa Rica	Tailings from silt pond	**G464**
Viviana brick clay	Ladrillera, Viviana, Cartago, Costa Rica	Brick clay	**G466**

high content of clay-sized particles, although the Sicorsa sample (F800) is significantly finer than the brick clay (G466).

A13. On the basis of the particle-size data, only F800 was considered for further use-related testing. The remaining samples do not have enough clay-sized material to justify use-related testing for whiteware and/or structural ceramics.

A14. As the samples are not truly representative of the entire contents of the tailings lagoons, further representative sampling from all areas and depths within the lagoon will be necessary for accurate assessment of the waste materials.

Chemistry

A15. The samples are generally similar in chemical composition (Table 3A). With the exception of F800 and G466 all the samples have high SiO2 contents ranging from 91 to 97%. The higher clay content of samples F800 and G466 is reflected in higher quantities of Al_2O_3 (27% and 16% respectively) compared to the other samples.

Use Related Testing

A16. Evaluation of chemical, mineralogical and particle-size data from the Sicorsa waste material suggested that only sample F800 is suitable for use-related testing. A simple fired-colour evaluation (heating to 1000°C for one hour followed by visual inspection) pointed to likely applications in brickmaking as F800 fired to a red colour. This would preclude its use in whiteware ceramics.

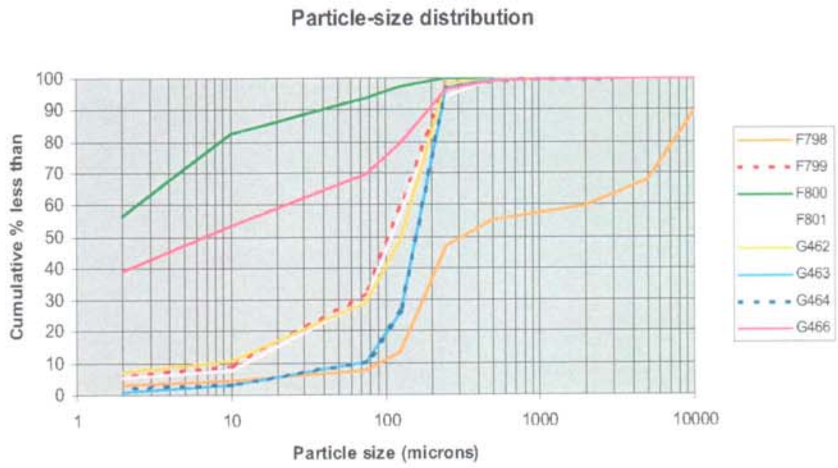
Forming behaviour

A17. The likely forming properties of a potential brick clay can be determined using the Plasticity Index (PI). The PI acts as a guide to the workability of a clay when mixed

Table 2A
Mineralogy.

Sample		Sicorsa 1 SW corner	Sicorsa 2 NW corner	Sicorsa 3 NE corner	Sicorsa 4 SE corner	Sicorsa Lower Lagoon 1	Sicorsa Lower Lagoon 2	Sicorsa Lower Lagoon 3	Viviana brick clay factory
Laboratory Code		**F798**	**F799**	**F800**	**F801**	**G462**	**G463**	**G464**	**G466**
Bulk Mineralogy	Dominant	Quartz	Quartz	Kaolinite	Quartz	Quartz	Quartz	Quartz	Quartz
	Major			Quartz					
	Minor	Kaolinite	Kaolinite		Kaolinite				
	Trace	Hematite?	Hematite	Hematite		Kaolinite	Kaolinite Boehmite?	Kaolinite	Mica (muscovite?) Kaolinite? Hematite?
Clay mineralogy	Dominant	Kaolinite	Kaolinite	Kaolinite	Kaolinite	Kaolinite	Kaolinite	Kaolinite	
	Major								Kaolinite
	Minor	Illite	Illite	Illite	Illite				Smectite Chlorite?
	Trace	Illite-smectite Smectite	Illite-smectite Smectite	Illite-smectite Smectite	Illite-smectite Smectite	Illite-smectite Smectite Chlorite?	Illite-smectite Smectite Chlorite?	Illite-smectite Smectite Chlorite?	

Figure A2 Particle-size distribution.



with water and gives an indication of likely shrinkage on drying. Plasticity tests were carried out and the values are shown in Table 4A. These are represented graphically on a 'clay workability' chart in Figure A3.

A18. The plasticity data, however, proved inconclusive as both samples were outside the 'acceptable' forming properties box on the 'clay workability' chart in Figure A3. The value of such charts is, however, debatable as no workability problems were experienced in practice during forming and drying the extracted clay test pieces from both clays (F800 and G466) during the firing trials (see below). Also, other clays successfully used in brickmaking also fall outside the "box".

A19. Slop moulding was carried out as an alternative method for evaluating forming properties. Slop moulding, (a brick manufacturing method which uses higher moisture contents) proved problematic for G466, which cracked badly on drying (Figure A4). Slop moulded briquettes were also formed from sample F800 (Figure A5). Although these did not crack on drying, they have relatively high linear shrinkage values (up to 17%). Incremental additions of sand were made to this clay in an attempt to reduce linear shrinkage on drying (a process commonly used in the brick industry). Additions of sand up to 30% by weight had little noticeable effect on the linear shrinkage values (see Table 5A). Further testing is needed to establish the optimum level of sand addition to reduce shrinkage in this clay.

Firing behaviour

A20. Vitrification curves (Figures A6 and A7) were produced from the tests carried out with the extruded clay test pieces. G466 shows a very gentle change in porosity and shrinkage over the temperature range whereas F800 is initially refractory, then shows a rapid change in shrinkage and porosity after 1050°C. The steepness of the curves is important because this controls the percentage of shrinkage or porosity over a given temperature range (see Figure A8). Bricks made from clay that show relatively rapid changes in shrinkage may show unacceptable variations in size when fired in a kiln which (as is common) heats to a range of temperatures rather than to a single point. Bricks made with F800 are likely to be quite porous if they are fired below 1050°C. High porosity is a problem in temperate climates due to freeze thaw action, although this is not a significant concern in the tropics.

A21. The laboratory results show that satisfactory bricks can be made from the fine grained clay waste material produced at the Sicorsa plant. Further research on an industrial scale is necessary to assess fully the brick products. The waste in the tailings ponds is also very mixed in lithology and particle size and its consistency of quality and requirements for further processing need investigation.

ECONOMIC ASSESSMENT

A22. The current rate of production of the fine grained waste is 50 000 tonnes per annum, mostly held in two tailings lagoons. There is around 0.5 million tonnes of accumulated residue. A literature search was carried out to compare its properties with those of other clay products (kaolin), and to relate these to potential markets, which include whitewares. For these markets the clay has to fire to a white colour, be rich in kaolinite and low in other clay minerals. The laboratory work has shown that the waste is low in kaolinite and fires to a buff, pale orange or pink colour depending on the temperature. It is therefore unlikely to be suitable for use in whitewares. Thus, a more suitable market for the waste is as a raw material used alone, or as an additive, in brick-making or for roofing tiles. Relevant market information therefore includes the volume of the construction industry in Costa Rica, and the relationship between the consumption of bricks and concrete blocks. A very minor use for the waste could be in artisanal ceramics. No export market is worth considering.

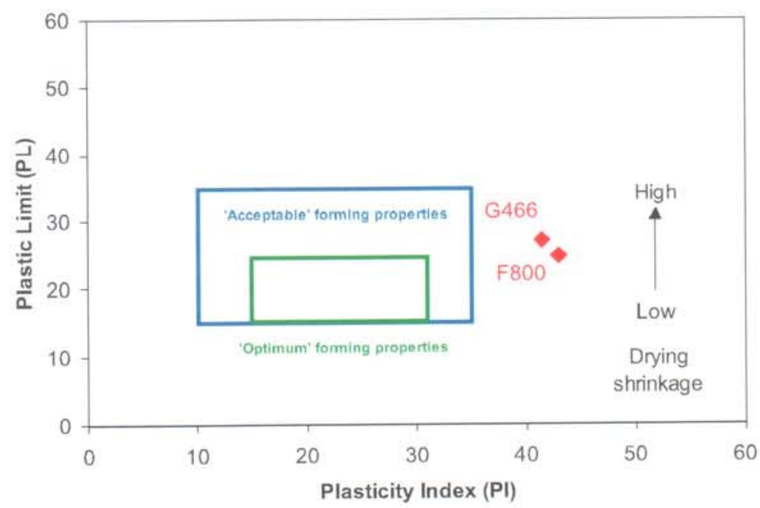


Figure A3 'Clay workability' chart (based on Bain and Highley, 1979).

Table 3A Chemistry of waste samples from Sicorsa silica sand quarry, Costa Rica.

	%	F798	F799	F800	F801	G462	G463	G464	G466
Major elements	SiO_2	92.3	92.3	58.5	91.5	94.7	96.0	96.6	67.3
	TiO_2	0.2	0.3	0.7	0.4	0.3	0.2	0.2	0.8
	Al_2O_3	4.0	4.4	26.6	4.7	2.7	1.9	1.6	16.3
	Fe_2O_3t	2.3	1.0	2.9	0.8	0.6	0.5	0.4	6.4
	Mn_3O_4	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.1
	MgO	< 0.05	0.1	0.2	0.1	< 0.05	< 0.05	< 0.05	0.6
	CaO	0.1	0.0	0.1	0.0	< 0.01	< 0.01	< 0.01	0.1
	Na_2O	< 0.05	0.1	0.1	0.1	< 0.05	< 0.05	< 0.05	0.1
	K_2O	0.2	0.4	1.1	0.4	0.2	0.2	0.2	1.7
	P_2O_5	0.0	0.0	0.1	0.0	< 0.01	< 0.01	< 0.01	0.1
	SO_3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	Cr_2O_3	< 0.01	< 0.01	0.0	<0.01	< 0.01	< 0.01	< 0.01	0.0
	SrO	< 0.01	< 0.01	0.0	0.0	< 0.01	< 0.01	< 0.01	< 0.01
	ZrO_2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.0
Trace elements	BaO	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.1
	NiO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	CuO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	ZnO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	PbO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	LOI	1.8	1.6	9.3	1.7	1.1	0.8	0.7	5.8
	Total	100.8	100.1	99.4	99.7	99.6	99.6	99.7	99.4

Table 4A Plasticity values.

Sample	Liquid Limit % (LL)	Plastic Limit % (PL)	Plasticity Index (PI)
F800	67.6	24.7	42.9
G466	68.5	27.1	41.4

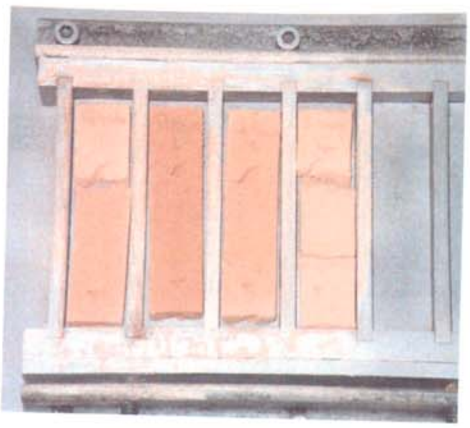


Figure A4 Briquettes made from sample G466 after drying overnight, note the cracking.

Figure A5 Fired briquettes made from sample F800. Firing temperature from left to right are 1230, 1170, 1020, 850°C

A23. Details of the methodology for an economic assessment and general information sources from which market and financial data can be obtained are given in Appendix 5. Specific sources of information on markets for mineral products, costs for production, processing and transport, and details of the mining legislation for Costa Rica were obtained from government agencies, trade associations, a public utility and a large aggregate company.

Market study

Waste as a raw material for brick, tile and pipe manufacture

A24. Bricks, tiles and pipes are important building materials worldwide, although their use varies considerably in different countries depending on the availability of clay, building style and tradition. They are made by shaping a plastic clay and calcining it at high temperatures. The clay is used either in its natural 'as dug' state or by blending clays and other non-plastic or poorly plastic materials from more than one source. The blending of raw materials helps to achieve a greater control on the quality of the product, as well as increasing the variety of colours and properties of the brick, tile or pipe. A small amount of water is added to the clay to develop its plasticity. The plastic clay waste from the Sicorsa silica sand quarry may be considered a suitable raw material either for blending with a plastic clay, or if suitably processed, as a raw material itself for brick and tile manufacture.

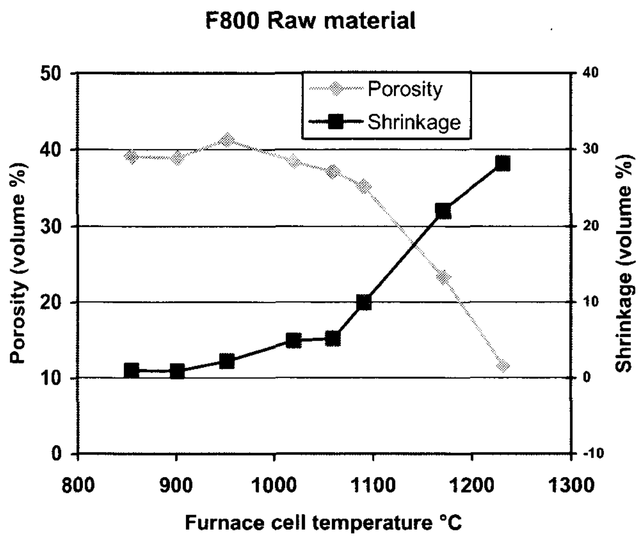


Figure A6 Vitrification curve for F800.

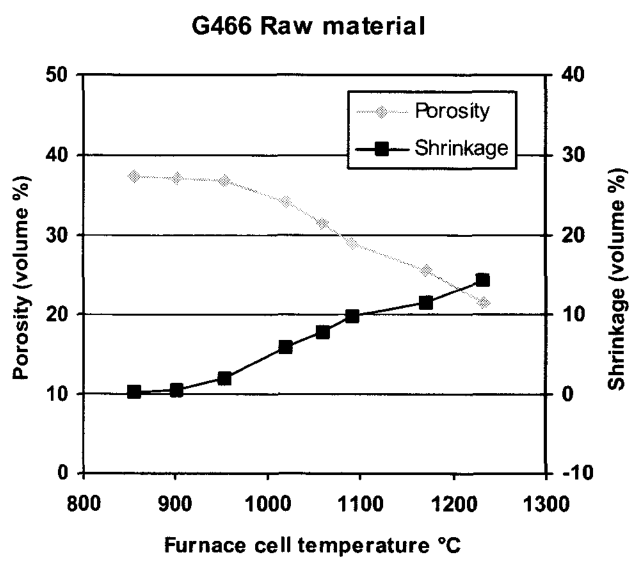


Figure A7 Vitrification curve for G466.

A25. In Costa Rica, bricks, tiles and pipes are used for building, but the construction industry is dominated by the use of mass concrete and concrete blocks. Construction practice is partly dictated by the need to use steel reinforcements within structures so that they can withstand earthquakes, and also by the ready availability of aggregates and cement for concrete. Bricks are used mainly for architectural and decorative purposes. Thus, in Costa Rica the market for clay for bricks, tiles and pipes is small compared with the overall size of the construction industry, and it is specialised. Although a floor tile industry used to exist, products are now imported. Roofing tiles are almost entirely imported. A small scale artisanal pottery industry exists using local clays.

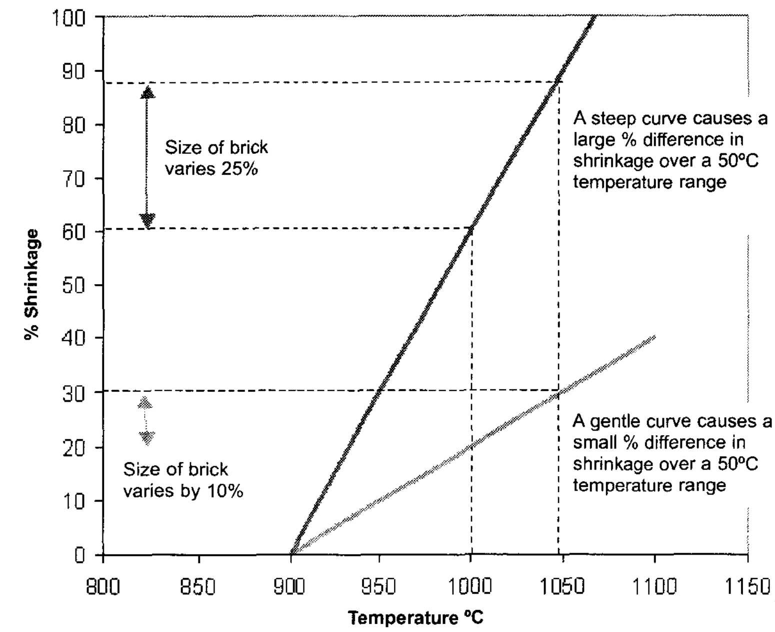
A26. Indicative statistics of mineral production for the construction industry are given in Appendix 1, Table 1. Although a considerable amount of common clay is consumed annually, the major use is as the secondary raw material in cement manufacture, estimated at 330 000 tonnes. This is confirmed by earlier estimates of 300 000 tonnes per annum of clay used for the cement industry (Berrangé et al., 1990).

A27. Brick and tile manufacture in Costa Rica is a small scale industry using local clays. The clay is shaped by extrusion and wire cutting, or pressing in molds, drying in air and firing in batches in small clamp kilns. Up to date specific statistics of clay production for brick, tile and pipe manufacture is not available, but Appendix 1, Table 2 shows the extent of the use of clays for brick production in 1990 (Berrangé et al., 1990). Most of the brick production is centred around the central belt of San José. This is near to the waste from the Sicorsa silica sand quarry, and thus transport costs would not be too high.

A28. From the above data, the total amount of clays currently used for bricks is somewhere between 10 000 and 70 000 tonnes, and probably nearer the lower value, as it is known that at least one of the brick-making operations listed in Appendix 1, Table 2 has closed down. The scope for using the major part of the clay waste from the Sicorsa silica sand in blending with existing brick clays is low. If say 10% of the brick, tile and pipe manufacturers all used 10% of the Sicorsa waste in their operation, it would consume a maximum of around 5 000 tonnes per annum, significantly less than the 50 000 tonnes per annum produced.

A29. The use of secondary raw materials, such as that from the Sicorsa silica sand quarry, is often considered in modern brick-manufacturing plants (cf. Smith, 2002). As well as aiding waste minimisation, its incorporation into the clay body enables a wider variety of brick products to be made. A preliminary evaluation of the suitability of the secondary material is made, before it is accepted (Smith, 2002). This involves establishing its physical and chemical

Figure A8 Comparative effects of different vitrification characteristics on dimensions of a fired brick.



properties. If found to be potentially suitable and compatible with the primary clay, this is followed by making a batch of bricks or tiles in the factory, using the blended materials. A factory scale test product is needed to ensure full compatibility of the secondary material, and to assess the properties of the product and full production costs. The blending of waste with a primary clay increases production costs as the two raw materials require thorough mixing, and initial separate handling. Depending on the composition of the waste, the brick may require a longer or higher temperature firing schedule, again increasing costs. Even assuming the Sicorsa clay waste is supplied at zero price, the increased production cost would need to be offset by either an improvement in the product quality which could command a higher price or larger market share, or a saving in the cost of the primary raw material.

Economic assessment of waste processing

A30. This quarry has been in operation since 1995. Currently, the waste material is contained within two tailings ponds, which are reaching their design capacity. The traditional solutions to this problem are to construct an additional tailings pond or to raise the height of the existing impoundment dam walls. The former option involves a large capital cost of construction and the acquisition of additional land in an already confined working area, adjacent to a Protection Zone. The second option is a technically difficult and expensive procedure. A third option could be considered where the tailings material is excavated, processed and removed, possibly for storage or sale as a raw material for brick, tile and pipe manufacture. In this case the revenue, capital and operating costs have to be set against the construction costs of a new facility. However, the market study has indicated that there is, in reality, very little likelihood of finding a local market for such a product at such a rate that would be needed to generate the required space for future tailings disposal. In view of this conflict it is likely that the existing tailings material would be merely excavated for use as backfill in a worked-out part of the quarry. The financial model has, nevertheless been based on the assumption that a larger market can be developed.

A31. The removal of tailings material could be achieved by use of a mechanical excavator from the tailings pond. By passing this material through a coarse screening and hydrosizing process, a suitable brick clay may be obtained. This would require additional drying to reduce the moisture content before it could be turned into a product suitable for sale. This could be achieved by storing the material on a concrete floor incorporating suitable drainage. In addition, recovery of silica sand from the waste may also be achieved in this process, which would aid the viability of the scheme.

A32. A variety of technical and financial factors can be assessed against a financial model to produce optimum conditions. To illustrate this, the results of a spreadsheet calculation has been presented in Table 5A. All costings are in US dollars. In this instance it has been assumed that one tailings pond (Pila Jales I) is to be worked at a rate of 500 t/day. The capacity of the pond is 200 000 t which is entered as the 'size of deposit'. It has been assumed that 40% of that material is recoverable for market use and is expressed as: '% usable mineral'. With regard to the details of the proposed mining method, it is anticipated that the maximum extraction possible will be achieved and 100% extraction is expected. A dilution of this value is unavoidable. However, with minimum supervision, this can easily be reduced to less than 2%. Losses in the processing system will also be anticipated but a 95% recovery can be achieved with the simple processing technique of hydrocyclone separation and air drying. A conservative operating period of 150 days/year has been taken to represent the fact that wet conditions will preclude efficient extraction during the rainy season.

A33. A selling price of $5/t has been taken to represent a low value for the product in order to maximise volume sales with an internalised freight charge of 10 cents/m^3/km. Cost of capital has been assumed as 28%, based on finance of 70% capital loan repayments to a bank and 30% stock/private funds. Corporation tax rates in Costa Rica are fixed at 30% of the previous years taxable profitable. Royalty payments are not thought to be chargeable since such payments will have already have been paid on the recovery of the primary mineral (silica sand).

A34. A production rate of between 400–500 t/day has been assumed to reflect the optimum extraction rate, whilst still permitting sales to be achieved at a level that will not entail undue stocking levels and simultaneously generating tailings capacity.

A35. Capital costs have been estimated to include site development and preparation by construction of an engineered, concrete base for drying pans and stocking sheds. The purchase of hydrocylones (10 micron size) is expected to cost $30 000. Tailings disposal from the new facility would involve the purchase and construction of a new pipeline to the tailings ponds at a cost of $1 000. An additional electricity supply, access road and ancillary buildings will need to be provided at an assumed cost of $7 000. In addition a contingent administration cost of $1 000 has been allowed to fund the facility. The total capital cost of $41 000 will therefore be required prior to commencement of operations.

A36. Operating costs are based upon the premise that extraction will be undertaken on a single shift/day, by a contractor at a rate of $0.75/t, for the 5 month/year operating cycle. Processing or milling is expected to be operated by 4 plant employees at a rate of $500/month/person. General operating costs include supervision by a plant manager at a salary of $1 500/month. Additional operating costs (maintenance, consumables etc) have been included in the variable cost of $0.20/t.

A37. It can be seen from Table 5A that a negative net present value (NPV) of $27 000 results from the assumed parameters. The cost-benefit of this operation can be realised by calculating and offsetting the construction cost of a new replacement facility (say $250 000) against the advantages achieved by supplying usable raw material from an otherwise waste product. This would represent a modest return on investment and demonstrates that if a local market can be found for this level of production the extra tipping capacity can be achieved at a rate of 70 000 tonnes/year.

SOCIAL IMPACT ASSESSMENT (SIA)

A38. The main objective of the SIA is to identify the potential social impacts of utilising the waste from the Sicorsa silica sand plant. A second objective is to make recommendations to mitigate any negative, and to enhance any positive, socio-economic impacts of utilising the waste.

A39. The detailed methodology for conducting this research is given in Appendix 6. It involved primary field research and extensive studies of secondary sources of literature. During field visits to the quarry site and surrounding area, local secondary sources were contacted, interviews conducted, and observations made to analyse existing socio-economic conditions, to identify, predict and recommend mitigation and enhancement of potential socio-economic impacts.

Landscape

A40. Despite being close to the original site of Cartago City, dating from more than 400 years ago, Cartago is now located further away, leaving the quarry and the rural settlements of Coris and Bermejo at some distance from Cartago's main commercial centres and transportation routes. There are two different topographies in the area. The first are the hills and foothills of the Cordillera de Talamanca and the Atlantic slopes of Carpinterra where cattle rearing is predominant. The other type consists of valley plains where Coris, San Juan Bosco and the estate of La Rueda are located, through which the rivers of Coris and Quebrada Barahona pass, both subsidiaries of the Rio Purires. These river valleys are used to cultivate ornamental plants and for coffee plantations.

A41. The quarry is located at the head of the valley plains, with the vast majority of human settlements located around the borders of the plains. In addition to widespread coffee and flower plantations, there are a number of other small land holdings, surrounded by wind breaks of cypress and hedges to provide shade and protection. The countryside between

Table 5A Financial model.

SICORSA

Best N.P.V.	**-27,123.00**	**$**
Best Prod.rate	**500**	**t/day**

Details of Waste Resource			
Size of deposit	s of d	200,000	tonnes
% useable mineral	ag	40	%

Details of Proposed Mining Method			
Mining extraction	M ex	100	%
Dilution	Di	2	%
Mill recovery	M r	95	%
Operating days/year	op	150	days

Financial details			
Selling Price	price	5	$/tonne
Cost of capital	c of c	28	%
Taxation rate	Tr	30	%
Royalties	Ry	0	%

Limits		
Max. tonnage milled	500	t/day
Min.tonnage milled	400	t/day
No.of runs	9604	

Tonnes milled (Tm)	500	t per/day
Total tonnage mined	204,000	tonnes
Full years milled tonnes	204,000	tonnes
Head grade	39.22	%
Annual o/c	236,300	$/year
Revenue	138,324	$/year
Mine life	2.75	years

CAPITAL COSTS ($)	
Extraction site devt.	1,000
Site preparation	1,000
Crushing	0
Processing	30,000
Water supply	0
Tailings disposal	1,000
Electricity supply	2,000
Ancil. Buildings	4,000
Access road etc	1,000
Engineering	0
Admin. Costs	1,000
TOTAL CAP COST	**41,000**

OPERATING COSTS ($)		
Operation	Fixed ($/year)	Variable ($/t)
Mining	500	0.75
Milling	24,000	0.1
General	18,000	0.1
TOTAL	**42,500**	**0.95**

Coris and Bermejo is very pleasant, consisting of a variety of colourful vegetation as well as a number of different human features such as buildings for religious, sports and educational purposes and activities such as small-scale mining, farming and cattle ranching. Overall, despite not having any outstanding natural or human features, the landscape surrounding the project area is pastoral, pleasant and attractive.

Land use

A42. The land adjacent to the silica sand operation is principally used for agricultural, cattle-raising, residential, quarrying and industrial purposes. There are various extensive properties given over to the cultivation of ornamental plants, coffee growing and pig farming. In the properties to the north, east and west of the quarry, the dominant agricultural activity is extensive cattle rearing in somewhat neglected pastures, with isolated or clustered trees by the streams. A number of windbreaks and hedges increase the tree component, mainly with the use of exotic species such as cypresses and eucalyptus.

A43. In addition to the silica sand quarry, there are several small quarries in the locality extracting limestone for aggregate and agricultural lime. To the south of the Sicorsa plant and on the flat valley plains, which in some places suffer from drainage deficiencies, agriculture is more labour-intensive and involves, for example, extensive covered areas used as nurseries for the cultivation of ornamental plants. In some places salix trees can be found. Some parts of the region are dedicated to the protection of water catchment areas, among the most notable, given its proximity, is the River Reventazón. The silica sand operation is situated near to the edge of the La Carpintera Protection Zone, on the southeastern side of that mountainous area.

Social profile

A44. The village closest to, and most directly impacted by, the quarry and processing plant is Coris. Despite its proximity to the city of Cartago (8 km) the Coris community is made up of people from rural backgrounds and remains semi-rural due to its relative distance and detachment from major connecting roads or industrial centres. The fact that there remain just three surnames among the residents of both Coris and Bermejo, which were established following the intermarriage of the Coris and Bermejo families, is indicative of the rooted culture and demographics of the villages.

A45. Coris is comprised of an estimated 260 people, sixty-five houses, a school, a church and two shops. Families number between 4 and 8 people, and in most cases the household head is male. The people from these communities represent a range of clearly defined social classes from lower to upper middle. However, as in the rest of the country, most people belong to the lower and lower middle classes. Although communal infrastructure in Coris is limited because of its size, there is strong cohesion among its inhabitants, uniting them in the face of common needs.

Housing, education health and crime

A46. In the national context, the quality of housing can be described as ranging from satisfactory to good, reflecting the prevalent socio-economic conditions in the region. Most people are homeowners, but there are also houses on large estates offered to the workers as part of their contract. The level of education among Coris's inhabitants is low to average, most of them having received primary and secondary education and only a few having obtained the bachillerato (secondary education qualifications, similar to A-levels) and even fewer having studied at university. Most of the population has had a primary education, a fact reflected in the age of the workers in the local businesses, which ranges from twelve upward.

A47. Until the production of the census at the beginning of 2002, there is a lack of timely or detailed health data for the area. The most recent data comes from 1990 and refers to the number of births and deaths in the district of Quebradilla. For the villages of Coris and Bermejo there were one hundred and sixteen births and nine deaths. Using this data, the birth rate and mortality rate can be calculated in the following way: Birth rate = the total number of births/population of the first six months × 1000 = 116/2999 × 1000 = 38.68. Mortality rate = 9/2999 × 1000 = 3. According to the District's Chief of Police, the area has recorded no homicides, only two violent crimes, four soft drug related offences and the theft of four cattle. Rather surprisingly, given the relatively high national rate, no domestic violence has been recorded in the district.

Employment

A48. Practically all of the commercial activity and much of the employment in the area is directly dependent on Cartago, this being the main city in the area because of its size and socio-economic importance. However, from a market and employment perspective, there are many, largely agricultural, businesses independent of Cartago developing in association with the rapid development undergone by the industrial zone of Cardallo, just five kilometres from the town of Coris. These agricultural activities are labour intensive and dominated by the production of ornamental plants for export purposes, and dairy and pig products. This situation has resulted in very low level unemployment in the area and a wide variety of job prospects including as agriculturists, herdsmen, administrative positions, drivers, factory workers, etc.

A49. The Sicorsa silica sand plant and quarry presently employs 32 people. Fourteen of these workers are from Cartago or San Jose, with the others coming from Coris or Bermejo. The quarry is due to employ a further twenty people following the completion of their planned expansion in 2002. According to Sicorsa's personnel manager, where possible, the new workers will be drawn from the local communities in Bermejo and Coris. On average, people who work at the plant earn twice as much as those in other local firms. In Coris, the average household income is c.80 000 (approximately 250 US dollars). The able heads of all of the households in Coris are employed, and the eldest children (18–27) also tend to work while the younger children (8–12) go to school.

Facilities and services

A50. Coris's basic services include a rural police station, a public telephone, a church, Saturday buses, a school and two small village shops. Nearly all the villagers have piped drinking water and electricity. The village also has a football field made by Sicorsa for the village youth. They also provide sanitary services, two class rooms and photocopying facilities to the local school, maintain the roads and pathways, supply electricity installations, assist with the upkeep of the Coris and Bermejo churches and the central squares and have built a water tank for Coris. There are no emergency services available in Coris or Bermejo. The Red Cross, fire service and hospitals are located in the city of Cartago, a journey that can take between ten and fifteen minutes by car. In general terms, the basic private services are to be found in the nearby villages, while public services and institutional infrastructure are limited to schools, rural police stations, church and a sports field.

A51. In Sabana Grande, a small village close to the intersection of the road to Coris and the Inter-American Highway, there are coffee bars, public telephones, a garage, street lighting, a wholesaler, a school and public buses. In Quebradilla, close to Bermejo, there is a dental practice, coffee bars, a public telephone, a garage, a police station, a park, small village shops, buses and a wholesaler. In Tobosi, a larger village 5 kms from Coris, there are cafes, restaurants, shops, buses, small village shops, a butchers, public telephones, a bar, a police station, a church, a school and a football ground. Other public services, such as banks, government offices, colleges, universities, health centres, hospitals, as well as other private services such as pharmacies, clinics, supermarkets, ironmonger's shops, are located in the city of Cartago and its suburbs such as San Nicolás and Tejar.

Transportation

A52. The typical means of transport in the area are country lanes interconnecting farmsteads. The Sicorsa project involved the construction of an internal road from the quarry to the plant to avert potentially dangerous trucks using existing public highways. The distance from the quarry to the plant, where the traffic flow increases during the summer when most of the material is transported to the storehouses, is about 1 km. In this section of the road, measures are taken in conjunction with public bodies or the community to increase road and public safety, such as sign posting and improvement of the road surface, as well as landscaping to reduce visual, noise and environmental pollution. Among these measures it has been recommended that a dense hedge be planted along the road and in its green spaces. Given the bad state of the rubble road between Coris and Sabana Grande, little traffic, including the buses (except for two journeys on Saturdays) use it. Therefore, most residents tend to walk along the road to Bermejo and from there to Quebradilla where there are buses using an asphalt road to access (5km) the Carretera Inter-Americana Sur (Inter-American Highway South).

Sites of archaeological, historical or cultural interest

A53. The National Museum indicates that no archaeological sites have been found in the site area or in adjoining areas being quarried. As regards sites of historical or cultural interest, none have been declared, nor are there records of any within the quarries area of direct or indirect influence. Some members of the community claim that a section of a threshing floor that runs through the middle of the property is part of a public threshing floor that they once used. However, there are no records and what exists now is a threshing floor, part of which has disappeared, covered with scrub. All that can be seen now is a few stones in the highest part, outside the area of the project. In the region, historical sites exist in Cartago, such as the original site of this city (1563), more than 4 kms from the quarry area, and the monument to Juan Vásquez de Coronado, more than 6 kms away.

Local perceptions of the quarry site

A54. Senior managers at Sicorsa have expressed their desire and commitment to co-operate with the community, which has benefited from various contributions by the company. Dialogue with the community has always been a part of the company's integral work and development policy. It regularly consults the residents' association, as part of a 'Good Friends' policy, and has carried out many improvements for the village, which were noted earlier. As a result, and because of its small size, the local perception of the quarry, as well as the relationship of the community with the Sicorsa employees, are generally good and, at worst, can be considered indifferent.

A55. The recorded minutes of the residents' association committee reflect this sentiment, as do the accounts of interviews made directly with the community. According to the Chief of Police 'the community is positive about the quarry because it creates jobs and support services without causing too much noise or pollution'. Speaking to other members of the community, comments ranged from 'they've helped us on the whole' and 'they made the sports field and the Patarrá road for us, they're all right' to 'sometimes the lorries are noisy when they go past, but that's all' and 'we haven't got anything against them to complain about'.

Key potential socio-economic impacts of waste utilisation (see Table 6A)

Impact 1: Improved safety

A56. At present the ponds storing the waste residue pose a hazard to safety since they have the characteristics and consistency of 'quick sand'. Indeed, one of Sicorsa's mine managers estimated that if someone were to fall into the ponds, and could not be recovered, they would be consumed and drowned in less than ninety seconds. By utilising this waste material the number of ponds and their depth will be reduced and they could, in theory, be rendered redundant. Although they will still pose a safety threat during any waste utilisation operation, the waste utilisation project will incrementally reduce any potential safety threat posed by the ponds to local residents and company employees.

Impact 2: Employment opportunities

A57. The excavation of the ponds, the drying of the waste material and the transportation of the dried waste material to a local brick-making plant will all demand the input of labour. Preparation of the site for utilisation of the waste will also demand higher levels of short-term labour. Given the limited scale of the potential waste utilisation project, it is anticipated that no more than five relatively low skilled people will need to be employed during the operation itself. Nevertheless, in the economic context of Costa Rica, a direct: indirect employment ratio in excess of 1:1 can be assumed, bringing the potential aggregate level of job creation during operation to at least ten.

Impact 3: Increased noise and dust

A58. It is envisaged that the transportation of the waste material will entail between one and five journeys along the road connecting the site and the brick factory in Cartago. Given the proximity of this road to a number of isolated habitations, the fact that this road is non-tarred and relatively infrequently used at present and the fact that an open-top truck may be used in transporting the waste, an increased noise and dust nuisance will be created. However, it is not considered that this will have any significant detrimental effect on the physical or mental health of those effected. Moreover, any additional noise and dust nuisance caused by these transport needs must be counterbalanced

Table 6A Impact matrix for waste utilisation project at Sicorsa silica sand quarry, Costa Rica

Impact	1	2	3	4	5	6	7	8
Directionality	+	+	-	+	+	+	+	-
Certainty	M	H	M	L	H	L	H	M
Frequency	NA	NA	L	L	NA	NA	NA	NA
Significance	L	L	L	L	M	L	H	M
Chronicity	O,P	C,O	C,O	C,O	O	O,P	C,O,P	C,O,P
Locality	Local	Local	Local	Local	Local	Local	Local	Local
Mitigability	NA	NA	H	NA	NA	NA	NA	NA
Cumulativity	N	M	L	L	L	N	NA	L

Key

+	Positive	N	Negligible
-	Negative	NA	Not Applicable
H	High	C	Construction
M	Medium	O	Operation
L	Low	P	Post Operation

against an indirect reduction in noise, dust and atmospheric impact through reduced reliance by the brick factory on material transported from further afield.

Impact 4: Transport opportunity

A59. The increase in frequency of use of the road by quarry trucks presents an alternative potential transport opportunity for local residents who do not posses their own vehicles and are otherwise reliant on lifts from users of the road into Cartago in the absence of a regular bus service. Since the waste has been processed and is inert is anticipated that the effects of exposure of the waste to road users, employees or residents obtaining lifts will be innocuous.

Impact 5: Local economy

A60. The sourcing of labour and equipment and the supply of the material locally increases the level of reinvestment and therefore growth in the local economy. Because of the proximity of the supplier to the customer there are also potential cost and service advantages stemming from reduced transportation demands and face to face quality, supply and price management and control that can be passed on to end users and customers locally, regionally and nationally.

Impact 6: Aesthetic enhancement

A61. Given that the ponds are located within the grounds of Sicorsa's site, there are unlikely to be any long-term recreational advantages of the reclamation of the pond areas. However, if after a number of years, the complete excavation of waste material from the ponds results in the ponds being landscaped and returned to pastures, the aesthetics of the site will be slightly enhanced.

Impact 7: Averted expansion

A62. The utilisation of the existing waste will avert the need for the construction of supplementary waste ponds that are already at full capacity. This strategy, in turn, allows mine management to utilise their resources more effectively and efficiently and negates the additional safety and aesthetic impact that would result from the development of additional land for waste disposal.

Impact 8: Road risk and degradation

A63. Although the road is already used by mine vehicles and maintained by Sicorsa for this purpose, local residents also use it, and even an incremental increase in the use of the road by a heavy truck will further degrade its already fragile condition. The increase in the frequency of use will also marginally increase the risk to other road users and pedestrians. However, as with the noise and dust impact, any additional degradation and safety risk caused by these transport needs must be counterbalanced against an indirect reduction in road degradation and risk through reduced reliance by the brick factory on material from further afield.

CONCLUSIONS AND RECOMMENDATIONS

Technical evaluation

A64. The waste material from the silica sand plant near Cartago, Costa Rica consists of a mixture of fine grained sand and clay. Most of the samples recovered from the two lagoons were dominated by quartz sand and only one sample was clay rich. The physical properties of this material suggest that it might be suitable for utilisation in the brick industry. It fires to a pale red colour and hence is unsuitable for whiteware ceramics. The laboratory tests can only give an indication of what might happen on an industrial scale and it is recommended that factory scale tests are made to assess fully the suitability of the brick clay. The fired colour is important and market research would have to be carried out in order to ascertain a market demand for bricks with this particular fired colour. The material might also be considered for other uses such as garden pots, and/or floor and roof tiles.

A65. The investigations have shown that the waste in the tailings lagoons is very heterogeneous and the proportion of clay: sand is not known. A systematic sampling programme of the lagoon tailings is required to assess reliably the waste resources of fine silica sand and clay. Recovery of silica sand from the waste would be advantageous to the Sicorsa company and the production of a brick clay by-product would aid the viability of the project.

Economic assessment

A66. Costa Rica has a small brick industry consuming between 10 000–70 000 tonnes of clay annually. A realistic current market for the clay is likely to be small and it is estimated that only up to 5 000 tonnes of the waste clay could be used each year by the present brick manufacturing industry. Blending of the waste clay with existing local clays will add costs to the brick manufacturers and thus there could be resistance to its use.

A67. As there is a considerable amount of accumulated waste, the financial appraisal has been based on an assumption that a significantly larger market for bricks, and hence a brick making clay, within Costa Rica can be developed. The financial model, which is based on the estimation of many financial and technical parameters, results in a negative net present value (NPV) of $27 000 for the clay waste (i.e. a loss). However, an indirect cost benefit could arise, as removal of the waste enables additional tipping capacity for the ongoing production of waste to be achieved, offsetting the construction cost of an additional tailings lagoon.

Social impact assessment

A68. Overall, the positive and negative socio-economic impacts of the proposed waste utilisation project are relatively low because of the limited scale of the project and geographical area that it will effect. Nevertheless, there are a few mitigation and enhancement measures that could, where applicable, be considered.

A69. First, the potential employment utility of the project would be enhanced if a policy to source employees on the project from the local labour pool were formally adopted. Given the relatively low skill nature of the employment opportunities and Sicorsa's managerial record for favouring local workers where possible, this is not envisaged to be a problem.

A70. Second, as well as enhancing vehicular movement generally, the specific potential transportation problems of increased road degradation and dust could be largely averted through the tarring of the road connecting the site to the brick factory and through the use of a dust covers on trucks.

A71. Third, it is suggested that where possible, and without the endangerment of other road users, the drivers of the trucks transporting the waste material are encouraged to provide lifts to local residents between the site and brick factory.

A72. Finally, given that the undertaking of the proposed project will avert a number of clean up and development costs for the Sicorsa company, it is suggested that any project profits be used to finance mitigation and enhancement measures.

Case Study B — Uis Mine, Erongo Province, Namibia

DESCRIPTION OF SITE

B1. The former mine at Uis (Figure B1) worked tin ore which occurs within a series of relatively small, coarse-grained igneous bodies known as pegmatites. They are composed predominantly of quartz, feldspar and mica, but also include the tin-bearing mineral cassiterite, along with some tantalum-bearing minerals. The pegmatites are generally steeply dipping and range from 0.5–40 m wide and 10 m–1 km in length. They form a NNE-SSW trending 'swarm' which is hosted by metamorphic rocks (biotite schists) of the Swakop Group.

B2. Following the discovery of tin deposits in the area by an employee of the Deutsche Kolonialgesellschaft in 1911, tin mining in Uis began in small pits and galleries. Over the following decades ownership of the claims changed hands several times, but it was not until 1951 that large-scale industrial mining operations were initiated by Uis Tin Mining Company Ltd. The South African owned Industrial Minerals Mining Corporation Ltd. (IMCOR) subsequently operated the mine.

B3. In 1989, the mine produced about 140 tonnes of tin concentrate (67.5 per cent metallic tin) per month from 85 000 tonnes of ore. Ore was extracted from a series of pits in the Uis area, before being moved by dump truck to the central processing plant where a combination of crushing and gravity separation were used to produce a tin concentrate. Coarse (grit) size tailings (waste) were discharged in a very large heap adjacent to the mine site by bucket conveyor. Fine-grained waste was pumped to a series of tailings lagoons immediately south of the coarse tailings heap. The mine was, at one time, the largest 'hard-rock' tin mine in the world, although the grade of the ore was relatively low compared to operations elsewhere. The mine ceased production in September 1990 following the collapse in the price of tin on the world market.

B4. Little or no post-closure restoration has been carried out at Uis on the open pits, processing plant site or the tailings dams and heaps. In particular, the large heap of coarse white feldspathic tailings creates a major visual impact which is visible from a considerable distance. Artisanal working of tin and associated tantalum minerals in the pits continued following the mine closure. This activity has been supported by the Namibian Ministry of Mines. In 1996, a small processing plant to concentrate tin and tantalum worked by the artisanal miners was established close to the derelict mine site.

TECHNICAL ASSESSMENT

B5. The technical assessment of the tailings from Uis focused on their potential as a source of industrial-grade feldspar, quartz and mica. These minerals have many industrial uses (see Table 1B). Evaluation of the tantalite concentrate was aimed at determining its quality and making recommendations as to how to improve it.

B6. Tantalite is a source of the metal tantalum. This is used principally to make electronic components particularly those used in portable devices such as mobile phones and lap top computers. Tantalite has been in high demand recently, mostly due to the rapid increase in mobile communications technology Prices peaked at U.S. $200–380 per pound in 2001. Lower than expected sales of mobile phones in the developed world have led to a decrease in portable devices more recently. Other uses include alloys in the manufacture of turbine blades and as a non-corrosive material in medical implants

B7. The waste was characterised by determining the bulk mineralogy, chemistry and particle-size distribution of several samples. Also, a more detailed examination was made (where appropriate) involving determination of

Table 1B
Industrial applications of quartz, feldspar and mica.

Note: Information has been derived from the following sources: Harben, PW (1999) and Carr, DD (1994). Prices taken from the February 2002 Industrial Minerals journal and represent CIF prices (cost + insurance + freight) to main European port.

Feldspar	Quartz	Mica
Raw material in ceramics and glass Mineral filler in paint, plastic, rubber, sealants and adhesives Scouring powder	Raw material in ceramics and glass Foundry sand and refractory bricks Mineral filler in paint, plastic, rubber, sealants and adhesives Silicate chemicals	Plaster/ cement additive Mineral filler in paint, plastic and rubber Foundry sand additive Absorbents and lubricants Surface coatings and anti-friction powder
Typical prices (per tonne)		
Glass grade – US$40 – 90 Ceramic grade – US$22 – 254	US$21 - 23	Block – US$9 – 80 Dry ground – US$240 – 355 Wet ground – US$400 – 1000

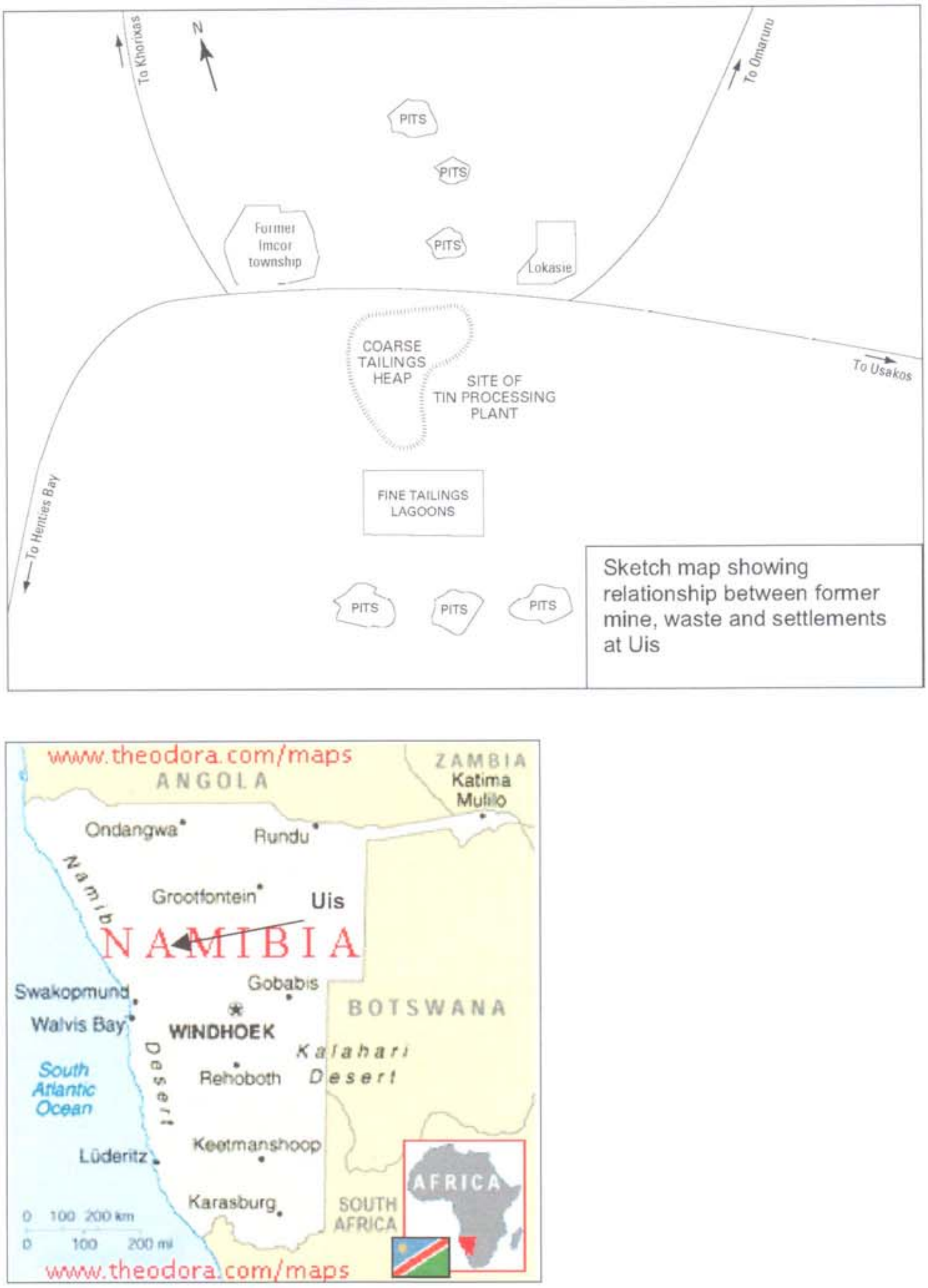


Figure B1 Location of the Uis case study site.

petrographic properties such as the size distribution of mineral components and modal mineralogy. Some laboratory scale mineral processing test work was also carried out in an attempt to produce mineral products which could be assessed against the properties of currently used industrial grades.

Waste Sampling

B8. Two spot samples were collected from different parts of the fine-grained tailings lagoon (BN1 northern extreme; BN2 southern extreme). The lagoons are dry, with large (and often relatively deep) shrinkage cracks and a surface-weathered 'crust' of fine-grained material. Each bulk sample (10 kg) was taken after removal of the top 25 cm of 'crust'. A further two spot samples were collected from the large tip of coarser-grained tailings adjacent to the tailings lagoon. The first sample (BN3) was taken from a roadway cutting that transects the base of the tip and the second sample (BN4) was taken from the top of the tip. The tip consists of loose, sand-grade material which on the surface has been 'winnowed' by wind action (i.e. removal of fine and flaky particles such as mica). The bulk samples (10 kg) were taken by removing the 'winnowed' surface and digging out more representative material.

B9. A batch of samples from the small-scale tin-tantalum separation plant at Uis were also obtained. Sample BN8 (6.5 kg) represented the coarser-grained tailings produced from a mineral jig and sample BN9 (9.5 kg) was of the finer-grained tailings from a shaking table. A sample (BN10; 1 kg) of the tantalite concentrate was also collected. A full sample list is given in Appendix 2 (Table 1).

Coarse tailings heap at Uis.

Tin-tantalum ore concentrated by artisanal miners at Uis.

Derelict former processing plant.

Dried-out fine tailings lagoon.

Tin-bearing pegmatite body.

Artisanal miner concentrating tin-tantalum ore at Uis.

Waste Evaluation

Characterisation

B10. The samples from the tailings lagoon (BN1 and 2) consist mainly of quartz and alkali (Na- and K) feldspar; the latter partially kaolinised (which accounts for the relatively high kaolinite content, 30%). The remainder consist of muscovite and biotite mica, apatite, chlorite, calcite and iron oxide (hematite?). There are also very small amounts of cassiterite, zircon, tantalite, monazite and a manganese-rich mineral (pyrolusite?). The coarser grained samples from the waste tip (BN3 and 4) and also those from the tin-tantalum operation (BN8 and 9) are of similar mineralogy, but with less kaolinite (5–15%).

B11. The chemical analyses confirm the mineralogy of the samples (see Appendix 2: Tables 2 to 5). The similarity of the mineralogy and chemistry of the sample material from the former tin mine and that of samples from the small-scale tin-tantalum operation, separated by over ten years production, gives an indication of the relative uniformity of the ore-bearing pegmatite.

Workers feeding jaw crusher at the small tin-tantalum concentrator at Uis.

Small tin tantalum concentrator at Uis.

B12. Detailed examination of the main mineral components show the following:

Quartz Present as clean, discrete (i.e. not attached to other minerals) grains with a lack of inclusions, fractures, staining or grain coatings (Figures B2 and B3). The particles are generally angular to sub-angular in shape. They are mostly less than 250 µm in diameter in the lagoon fines and less than 1 mm in diameter in the tailings tip. The coarsest grains are up to 3 mm in diameter. Inclusions of apatite, feldspar and mica often occur in the coarser grains of quartz.

Feldspar The feldspar grains are equant and sometimes tabular, reflecting breakage along cleavage planes. Separate Na- and K-feldspar grains and perthitic intergrowths occur. Some have a 'cloudy' appearance in thin section that indicates they have been partially 'sericiticised' (i.e. altered to mica and kaolinite). The feldspar has a similar size range to the quartz. Feldspar (along with kaolinite) forms a large part of the fine-grained material. The chemical composition of the feldspar is summarised in Table 2B (and given in full in Appendix 2: Table 7).

Mica Mica is present as thin flakes (Figure B5). In the tailings tip sample only half of the mica occurs as discrete grains. The chemical composition of the muscovite and biotite mica are given in Appendix 2 (Table 7).

Opaques and accessory minerals Occur as rare prismatic grains typically up to 50 µm in diameter in the tailings lagoon sample (Figure B6) and up to 500 µm in diameter in the tailings tip sample. Tantalite grains occur in the size range 10 to 300 µm, iron oxide 30 to 150 µm, cassiterite 5 to 60 µm, apatite 50 µm, Mn-rich minerals and monazite 10 µm.

Rock fragments These were only found in the coarser-grained tailings tip sample and they consist of quartz, feldspar, mica and opaques (see Figure B7).

Particle-size The tailings lagoon samples are fine-grained with approximately 70% of the material finer than 75 µm and little coarser than 500 µm (less than 3%). The tailings tip samples are coarser with less than 10% of the material finer than 75 µm and with most (85%) in the size range 2 mm to 125 µm. The tailings (BN8) from the jig at the tin-tantalum plant has the coarsest particle-size distribution of all the samples, with 80% in the size range 5 to 1 mm and only 5% finer than 500 µm. The tailings (BN9) from the shaking table at the tin-tantalum plant has a particle-size distribution similar to that from the tailings tip with most in the size range 2 mm to 125 µm.

Mineral liberation The mica, quartz and feldspar grains appear to be well liberated (i.e. discrete) in the lagoon samples. However, in the tip samples there are roughly equal proportions of liberated and unliberated grains. The liberation size (i.e. the size at which mineral processing would effectively separate the mineral components) of the mica, quartz and feldspar is in the size range 500 to 250 µm.

Mineral processing testwork

Dry screening

B13. The particle size distribution of the mica, feldspar and quartz is given in Figures B8 to B10. The full mineralogy of the size fractions is given in Appendix 2: Table 9.

B14. Generally, the mineralogy of the waste is fairly uniform across the size range.

B15. There is however a noticeable decrease in the feldspar content with decreasing particle size. The feldspar content is as high as 80% in the +2 mm material and this decreases to a low of 45% in the -125 µm material. This is

Table 2B Summary of feldspar composition, tailings, Uis Mine, Namibia.

Feldspar	SiO_2 Wt %	Al_2O_3 Wt %	Fe_2O_3 Wt %	Na_2O Wt %	K_2O Wt %
K-feldspar	62.9	18.2	0.05	0.6	15.0
Na-feldspar	66.6	19.2	0.02	11.6	0.06

Note that K-feldspar composition based on average of 6 electron probe microanalyses; Na-feldspar 8.

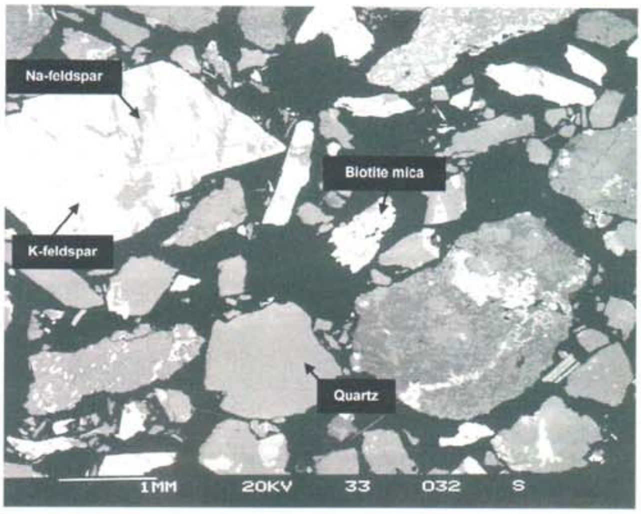


Figure B2 SEM (scanning electron microscope) photomicrograph of fine-grained tailings sample (BN1), Uis, Namibia. The larger grains (>20 µm) are quartz and alkali feldspar. The remainder is fine grained alkali feldspar, mica and quartz, with occasional grains of apatite.

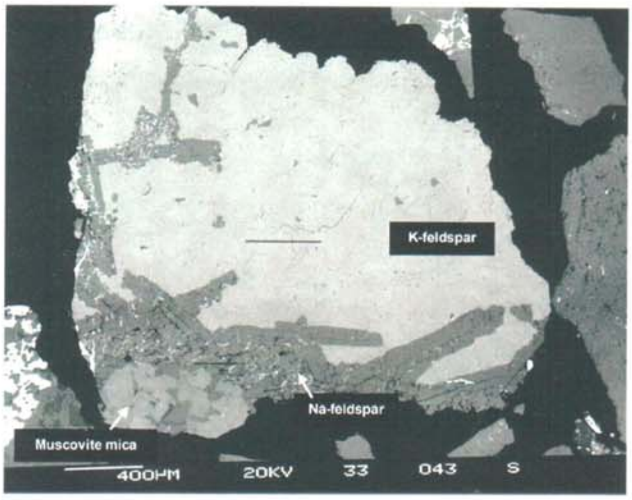


Figure B4 SEM (scanning electron microscope) photomicrograph of coarse-grained tailings sample (BN3), Uis, Namibia. The large grain (light grey) is K-feldspar, with laths (dark grey) of Na-feldspar inclusions and smaller inclusions (intermediate grey) of mica in the lower left-hand corner.

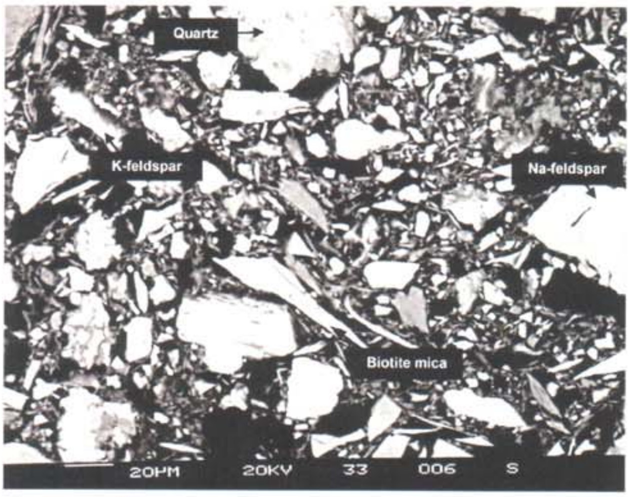


Figure B3 SEM (scanning electron microscope) photomicrograph of coarse-grained tailings sample (BN3), Uis, Namibia. The larger grains (>1 mm) are quartz and alkali feldspar. NB The large grain in the upper left corner is perthitic feldspar (Na-feldspar intergrowths in K-feldspar). The remainder is finer grained alkali feldspar, mica and quartz.

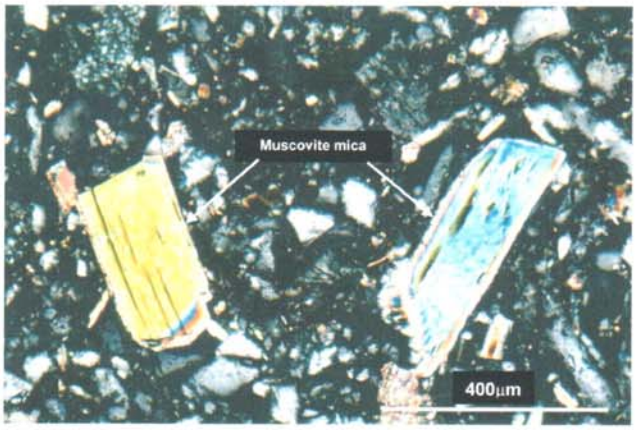


Figure B5 Optical (binocular microscope) photomicrograph of muscovite mica, fine-grained tailings sample (BN1), Uis, Namibia. The muscovite mica is 300–400 µm long. The remainder is fine grained alkali feldspar, mica and quartz.

accompanied by an increase in quartz content, from 10% in the +2 mm material to 50% in the -125 µm material.

B16. In the tailings tip samples, most (90%) of the feldspar and mica is found within the size range 2 mm to 125 µm. In the coarse tin-tantalum plant tailings most of the feldspar and mica is found within the size fractions coarser than 1 mm. The fine tin-tantalum plant tailings sample has a similar size distribution to the tip tailings.

Air classification

B17. The mass balance figures for the mica concentrates and the silspar (quartz and feldspar mixture) produced by air classification are summarised in Figures B11 to B13 and are given in full in Appendix 2 (Table 10). The bar charts show the average mineral content of each size fraction. Each bar represents the amount of mica available (as a proportion of the total mica content of the tailings samples) and the darker coloured part of the bar represents the amount recovered by air classification.

B18. The *mica concentrates* produced by air classification represent the first pass through the separator at the lowest airflow rate for each of the size fractions processed. Figure B11 shows that a substantial proportion of the mica present in the tailings samples is found in the 500 to 1000 µm size range (between 20 to 25% of the total amount of mica in the sample). The darker part of each bar shows that only a small proportion of the mica has been recovered by air classification.

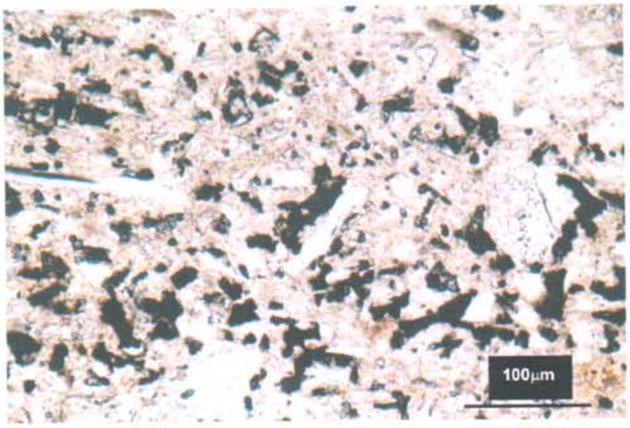


Figure B6 Optical (binocular microscope) photomicrograph of opaque minerals, fine-grained tailings sample (BN1), Uis, Namibia. The opaque minerals (the black grains) are approx. 50 µm in diameter. They are mainly cassiterite, tantalite, pyrite and iron oxides. The remainder is fine grained alkali feldspar, mica and quartz.

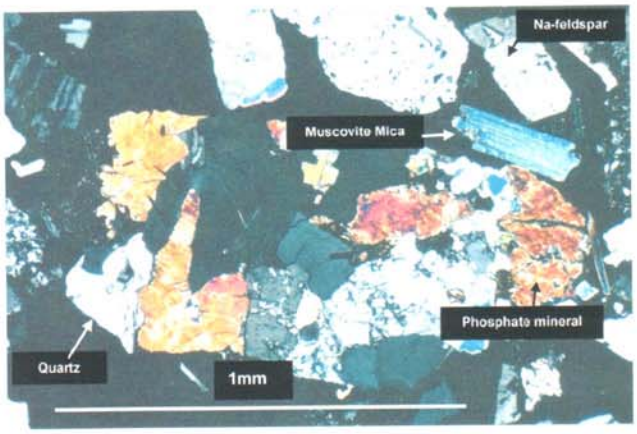


Figure B7 Optical (binocular microscope) photomicrograph of coarse-grained tailings sample (BN3), Uis, Namibia. The rock fragment (1.25 mm long) which forms the major part of the photograph contains quartz, alkali feldspar, apatite and small grains of tantalite. The blue grain in the upper right-hand side is muscovite mica (700 µm long).

B19. As the mica content of the tailings is low (3 to 7%) so too are the yields (*weight proportion of the product*) of the concentrate products, which are between <1 and 5% with an average of 1%. The grades (*mineral content of the products*) of the concentrates are 100% mica (mainly muscovite) with recoveries (*proportion of mineral present in the feed that is recovered to the product*) of 27% on average; the remainder of the mica occurs in the middling air classification products. Mica recovery is highest in the size range 1 to 4 mm (typically 50 to 60%), with recoveries around the average in the +4 mm material and dropping dramatically in the -1 mm material (typically less than 15%).

B20. A *quartz-feldspar (silspar) concentrate* produced by air classification represents the remainder of the material after it has been passed through the separator three to six times. The aim was to remove as much of the mica as possible, which has largely been achieved; the average mica content of the silspar concentrates is only 0.5%.

B21. Figure B12 shows that a substantial proportion of the feldspar present in the tailings samples is found in the 1000 to 2000 µm size range (between 20 to 25% of the total amount of feldspar in the sample). The darker blue of each bar shows that a substantial amount of the feldspar has been recovered to the silspar concentrate by air classification. Figure B13 shows that the quartz has a similar distribution and recovery pattern to that of the feldspar.

B22. The yield of the silspar products is 77% on average. The average grade of the silspar concentrates is 64% feldspar and 28% quartz. The average recoveries are 79% for the feldspar and 83% for the quartz; the remainder of the feldspar and quartz occurs in the middling air classification products. Higher feldspar grades (up to 89%) are found in some of the middling air classification products, especially the last overflow removed to produce the silspar. This is due to the thin, lath-like particles produced during crushing of feldspar, which mimic the flakey shape of mica and are preferentially removed in the overflow.

Froth flotation

B23. The mass balance figures for the feldspar and quartz concentrates produced by froth flotation are summarised in Table 3B, but are given in full in Appendix 2 (Table 11). The feed for the froth flotation testwork was the air classification products (silspar products).

B24. The grades of the *feldspar concentrates* (silspar feed) are 70% feldspar (K- and Na-feldspar); the remainder being quartz. The recoveries are 37% on average. The

Figure B8 Cumulative frequency distribution of mica in the tailings samples, Uis, Namibia.

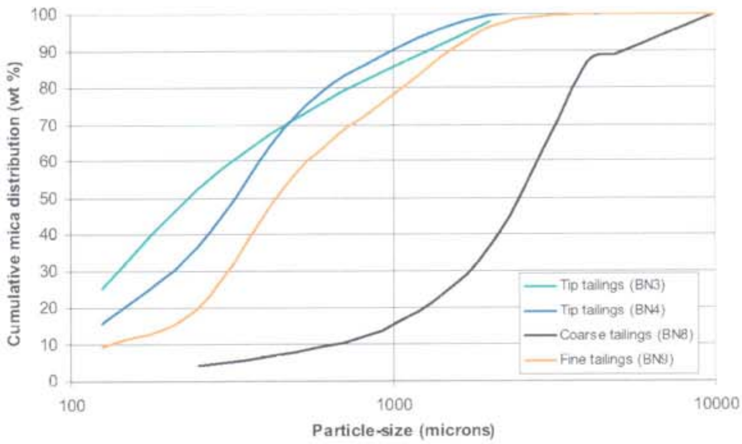


Figure B9 Cumulative frequency distribution of feldspar in the tailings samples, Uis, Namibia.

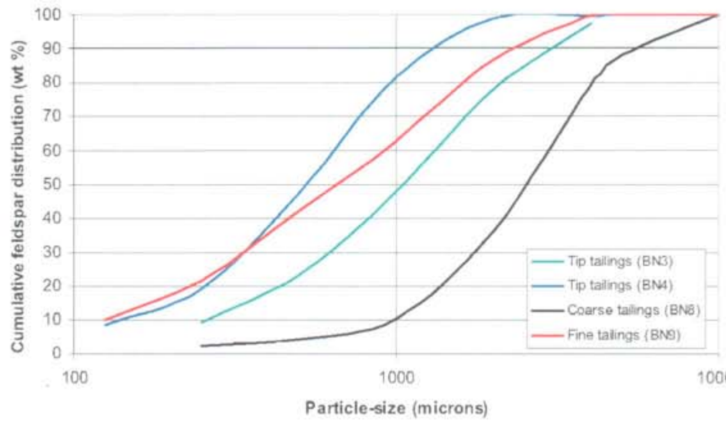
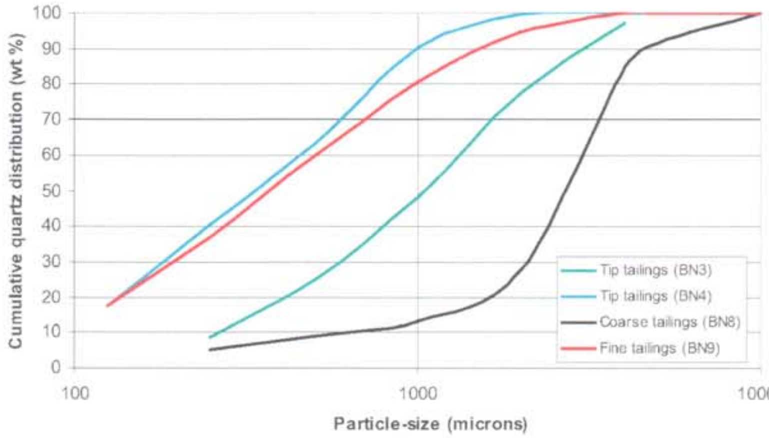


Figure B10 Cumulative frequency distribution of quartz in the tailings samples, Uis, Namibia.



remaining feldspar occurs in the flotation middling and sink products. The quartz 'concentrates' produced by froth flotation represent the sink products. The grades of the 'concentrates' are 50% quartz; the remainder being feldspar. The recoveries are 25% on average. The remaining quartz occurs in the flotation middlings and feldspar concentrates (which accounts for the remaining yield).

Overall mass balance

B25. The mass balance figures given in the preceding tables relate to the mineral processing carried out at each stage. They do not relate to the overall recovery from the samples as taken out of the waste tips, for example the proportion of feldspar recovered from the original sample. The mass balance of the concentrates produced at each stage, in relation to the original samples, are summarised in Table 4B and given in full in Appendix 2 (Table 12).

B26. The overall mass balance figures indicate that the recovery of mica from the tailings has been relatively poor although the grade of the concentrates is very high. The silspar (quartz-feldspar) concentrates recover from two-thirds to three-quarters of the quartz and feldspar present in the tailings. The froth flotation has yielded poor recoveries and the grades of the concentrates are little better than those of the silspar concentrates.

B27. Further mineral processing trials would be needed to optimise the mineral grades and recoveries, however the testwork undertaken gives a broad indication of the likely yield from reprocessing of the tailings at Uis. The production of mica and silspar concentrates from the tailings is the most promising route to follow.

Product evaluation

B28. The chemistry of the concentrates was compared with that of commercially used industrial minerals in order to assess their quality. The chemistry of the mica, silspar, feldspar and quartz concentrates is summarised in Figures B14 to B16, along with that of commercially used industrial minerals, and given in full in Appendix 2 (Table 13). Figure B14 shows the silica, alumina and potash content of the mica concentrates (the size fractions of each sample combined to give five concentrates), with dotted lines representing the upper and lower limits of these oxides present in commercial mica. This indicates that the mica concentrates largely conform to the commercial requirement (in terms of chemical composition).

B29. Figure B15 shows the alumina, soda and potash content of the silspar concentrates (BN3, 4 and 8) similar to Figure B14. This indicates that, in terms of chemical composition, the silspar concentrates from Uis conform to commercial requirements.

B30. Figure B16 shows the alumina, soda and potash content of the feldspar concentrates using a bar chart. This indicates that the feldspar concentrates conform to the commercial requirement for glass-grade feldspar (in terms of chemical composition).

B31. Figure B14 showed that the chemistry of the mica concentrates compares favourably with that of commercial mica. There is a noticeable change in the composition of the mica concentrates with particle-size. There is an increase in TiO_2, Fe_2O_3, CaO and Na_2O and a decrease in Al_2O_3 and

Figure B11 The amount of mica recovered by air classification as a proportion of the mica present in the tailings samples, Uis, Namibia.

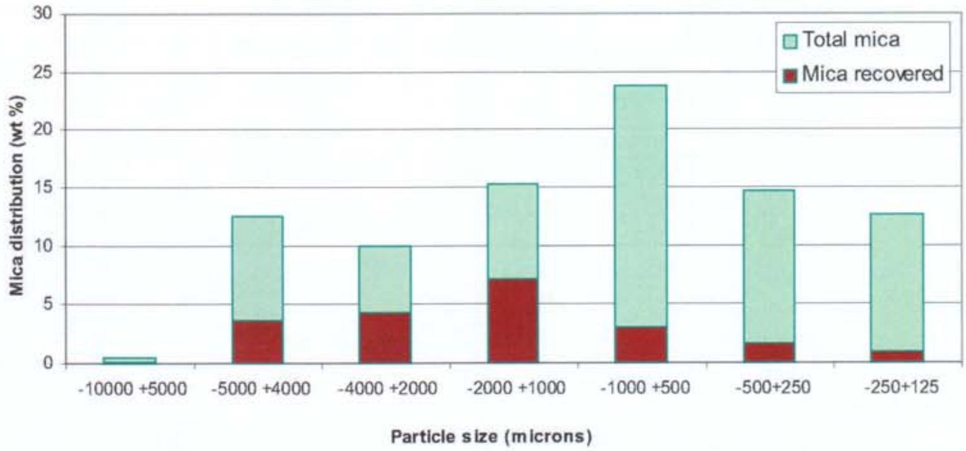


Figure B12 The amount of feldspar recovered by air classification as a proportion of the feldspar present in the tailings samples, Uis, Namibia.

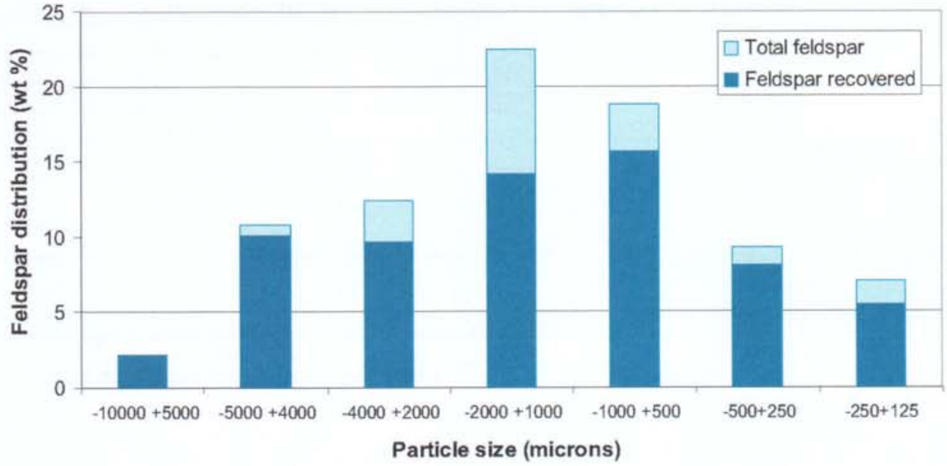
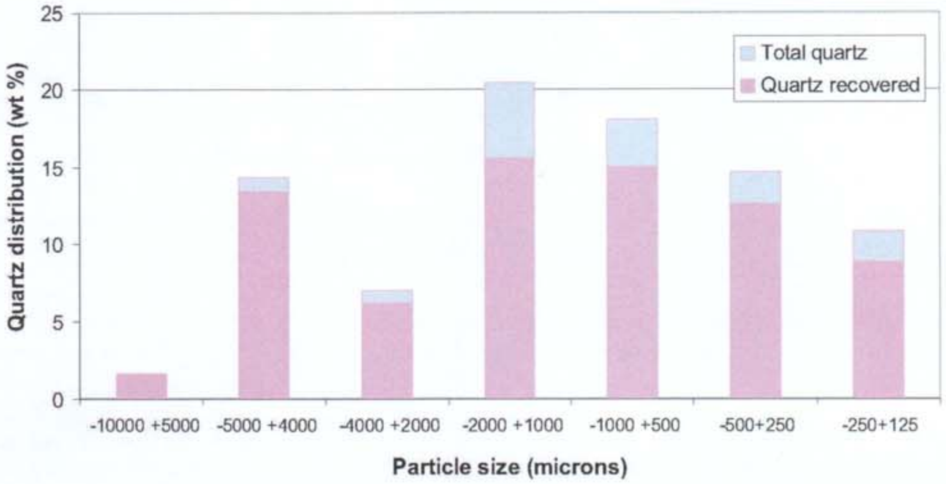


Figure B13 The amount of quartz recovered by air classification as a proportion of the quartz present in the tailings samples, Uis, Namibia.



K_2O with decreasing particle size. The modal mineralogy (summarised in Figure B17), based on the XRF data, shows that the muscovite mica content decreases from 91 to 48% and the biotite mica content increases from 0 to 12% with decreasing size. As commercial mica is predominantly muscovite mica, it suggests that the coarser mica (+500 µm) produced from the tailings at Uis would be the most suitable for commercial use.

B32. Figure B15 showed that the chemistry of the silspar concentrates compares favourably with that of commercial silspar. A low iron content is important as the main application for silspar is as a ceramic raw material. The iron content of the silspar produced from the Uis tailings (0.05 to 0.25% Fe_2O_3) is lower than that quoted for commercial silspar (0.07–0.6% Fe_2O_3) and this is very advantageous.

B33. Commercial silspar typically contains 60 to 80% feldspar (usually mixed alkali, Na- and K-feldspar) and 20 to 40% quartz. Modal mineralogy (Figure B18), based on the XRF data, of the silspar concentrates produced from the tailings at Uis shows that they contain 53 to 58% feldspar, 27 to 32% quartz plus small amounts of kaolinite, apatite

Table 3B Mass balance of feldspar and quartz concentrates produced by froth flotation, tailings, Uis, Namibia.

		Feldspar	
Sample	Yield wt %	Grade wt %	Recovery wt %
Feldspar concentrate	28.8	70	37.2
Quartz concentrate	27.8	50	25.3
Middling products	43.4	nd	37.5
Total	100.0	nd	100.0

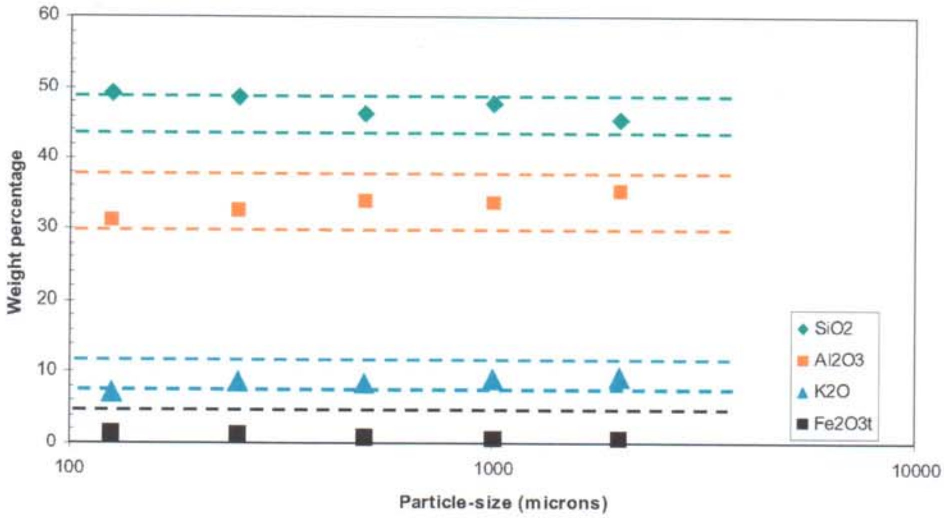
(nd = not determined)

Table 4B Overall mass balance of concentrates, tailings, Uis, Namibia.

Sample	Yield wt %	Grade wt %	Recovery wt %
Mica concentrate	0.9	100.0	24.1
Silspar concentrate	49.9	-	-
- Feldspar	-	57.9	72.8
- Quartz	-	26.3	66.9
- Kaolinite, apatite & mica	-	15.8	nd
Feldspar concentrate	2.3	70	2.5
Middling products	46.9	nd	nd
Total	100.0	nd	nd

(nd = not determined)

Figure B14 Chemistry of the combined mica concentrates compared to the compositional range of commercial mica (bounded by dotted lines; green SiO_2; red Al_2O_3; blue K_2O)



and mica. The silspar concentrates produced from the tailings at Uis are therefore likely to be suitable for commercial use.

B34. Figure B16 shows that the chemistry of the *feldspar concentrates* compares favourably with that of commercial glass-grade feldspar, but comparisons with commercial ceramic-grade feldspar are not as promising. A low iron content is important for feldspar used as a ceramic raw material and the iron content of the feldspar produced (0.03 to 0.08% Fe_2O_3) from the Uis tailings meets those requirements. Glass-grade feldspar usually contains a high proportion of Na-feldspar and ceramic-grade feldspar a high proportion of K-feldspar. Modal mineralogy (Figure B19), based on the XRF data, of the feldspar concentrates produced from the tailings at Uis shows that they contain 47 to 82% Na-feldspar, but only 11 to 27% K-feldspar. The feldspar concentrates produced, therefore, appear to be suitable only for commercial use in glass manufacture.

B35. The chemistry of the quartz concentrates does not compare favourably with that of commercial quartz, which usually consists solely of quartz. Modal mineralogy (Figure B20), based on the XRF data, of the quartz concentrates produced from the tailings at Uis shows that they only contain 59 to 68% quartz and contain a significant amount of feldspar, kaolinite and apatite. The quartz concentrates are therefore considered to be unsuitable for commercial use.

Tantalite concentrate evaluation

Characterisation

B36. The sample of tantalite concentrate from the tin-tantalum separation plant at Uis was found to contain 16% Ta_2O_5 (+3% Nb_2O_5). It consists mainly of columbite-tantalite (30%), cassiterite (19%), quartz (15%), Na-feldspar (13%) and almandine garnet (9%) with trace amounts of muscovite mica, calcite, K-feldspar, apatite, ilmenite, chlorite, magnetite, zircon and kaolinite (Appendix 2: Table 5).

Figure B15 Chemistry of silspar concentrates (BN3, 4 and 8) compared to the compositional range of commercial silspar (bounded by dotted lines; red Al_2O_3; blue $Na_2O + K_2O$.

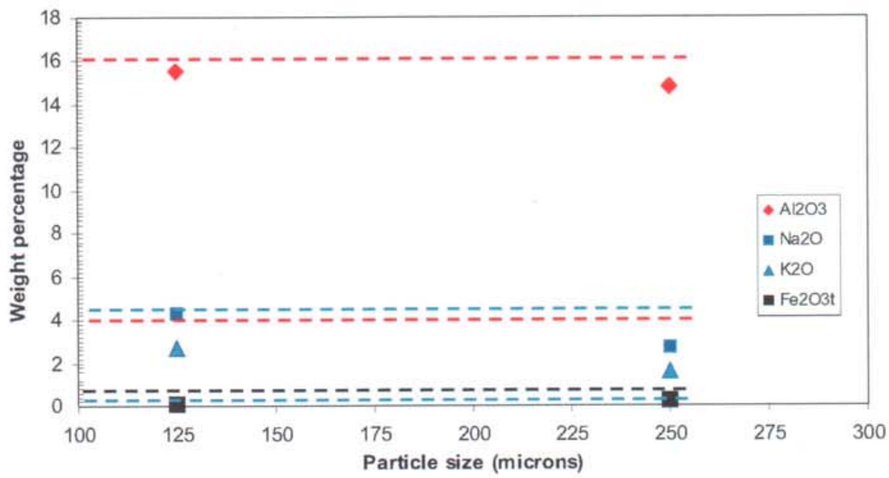


Figure B16 Chemistry of feldspar concentrates (average) compared to the compositional range of commercial feldspar (bounded by dotted lines; Green = glass-grade feldspar; Red = ceramic grade feldspar).

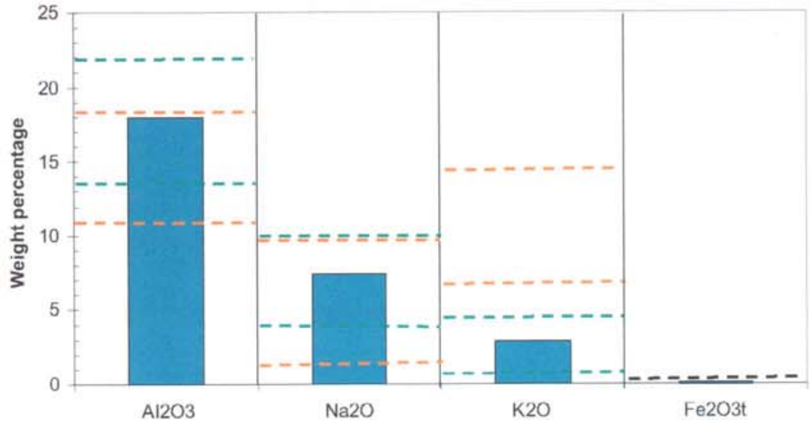
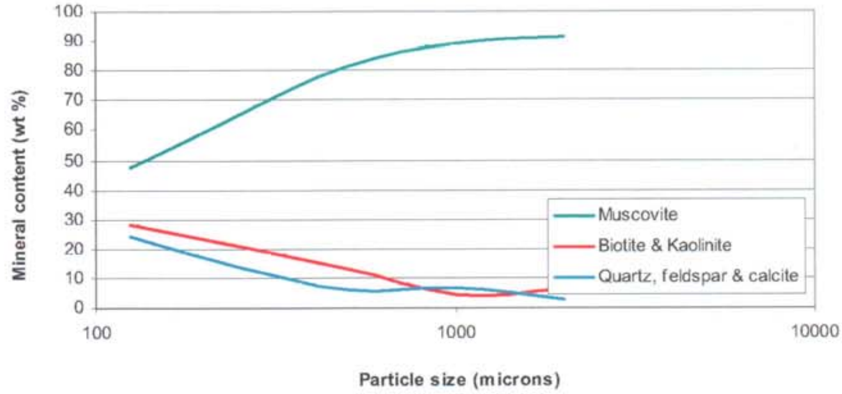


Figure B17 Particle-size distribution of mineral components in mica concentrates.



B37. The tantalite occurs as black to brownish-black grains with a metallic to matt surface appearance, generally irregular in shape with the occasional well-formed tabular crystal and a rough ('hackly') fracture surface. The tantalite is well liberated, with a small proportion (5-10%) occurring in middling grains. It consists of two distinct varieties:

— average 58.3% Ta_2O_5 and 6.1% Nb_2O_5 (23.5%). Low Nb-Ta ratio.

— average 41.9% Ta_2O_5 and 23.8% Nb_2O_5 (6.5%). High Nb-Ta ratio.

The full chemical composition of these minerals is given in Appendix 2: Table 8.

B38. Most of the mineral grains in the concentrate occur in the size range 500 to 63 µm (summarised in Figure B21 and given in full in Appendix 2: Table 14). The dark-coloured opaque minerals (tantalite, cassiterite, garnet, ilmenite and magnetite) also occur mainly in this size range. Figure B21 shows that the size range 250 to 500 µm has the highest proportion (90%) of the dark-coloured minerals.

Gravity separation

B39. The mass balance figures for the heavy mineral concentrate and other products produced by gravity separation are summarised in Figure B22 and are given in full in Appendix 2 (Table 15). The size of the pie charts in Figure B22 represent the weight proportion of the products and the blue areas represent the amount of tantalite recovered from the unprocessed tantalite concentrate to the products.

Figure B18 Mineralogy of silspar products, Uis, Namibia.

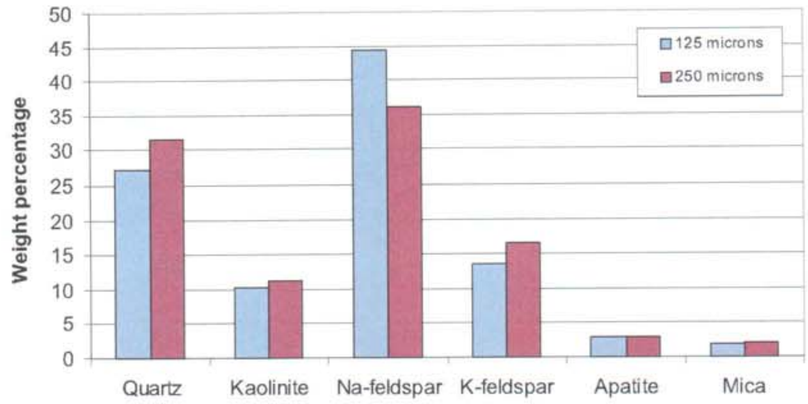


Figure B19 Mineralogy of feldspar concentrates, Uis, Namibia.

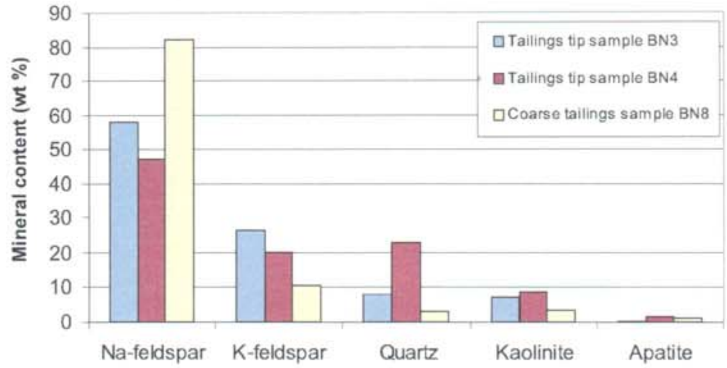


Figure B20 Mineralogy of quartz concentrates, Uis, Namibia.

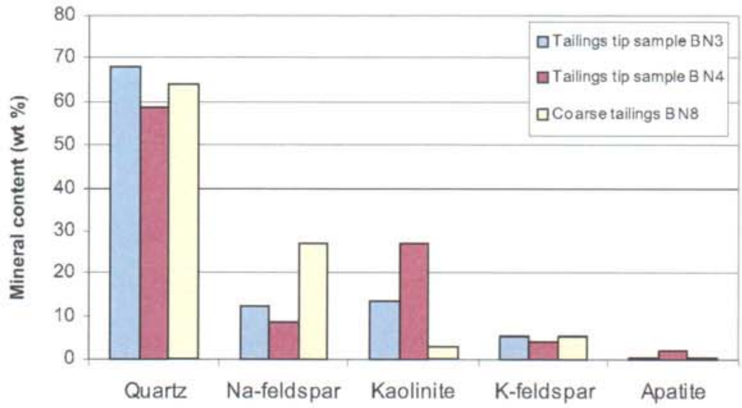
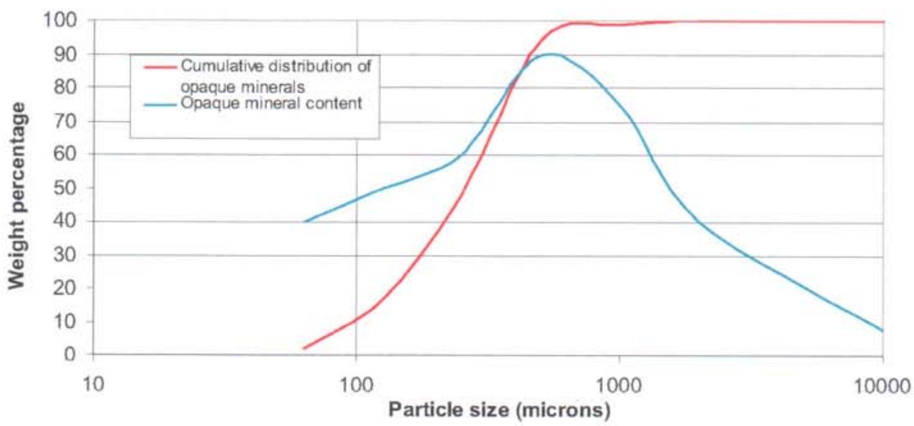


Figure B21 Distribution of opaque minerals in tantalite concentrate, Uis, Namibia.



B40. The gravity concentrate contains most (97%) of the tantalite present in the sample and has a grade of 90%. Size fractionation of the gravity concentrate show that most (89%) of the tantalite occurs in the size range 500 to 125 µm (see Appendix 2: Table 16). The impurities (mainly garnet plus a small amount of rutile, apatite, zircon, quartz, mica and feldspar) occur mainly in the material finer than 125 µm. The material coarser than 125 µm has a combined tantalite grade of 92% at a recovery of 93%. The middling product contains approximately 3% of the tantalite at a grade of 20% and the tailings contain the remaining tantalite at a grade of 2%.

Recommendations for improvement of tantalite concentrate

B41. Currently, the tin-tantalum operation in Uis produces a fairly poor quality tantalite concentrate. It has a low tantalite content and it is contaminated with garnet, cassiterite and other minerals. The following is a suggestion to improve the quality of the tantalite:

— Screening of the concentrate at 1 mm and 250 µm

— Gravity separation of the separate size fractions

— Magnetic separation of the concentrates from the separate size fractions

B42. This should improve the quality of the tantalite produced and concentrates containing 90 to 95% tantalite should easily be achieved.

ECONOMIC ASSESSMENT

B43. It is estimated that there is approximately 75 million tonnes of pegmatite mine tailings at Uis, made of feldspar, mica and quartz. This is a significant resource of these minerals. The waste also contains minor amounts of rare metal minerals, such as tantalite, beryl, petalite and amblygonite. A literature search was carried out to assess the world markets for feldspar and mica, both of which are internationally traded commodities, with extraction taking place in many countries (e.g. Kauffman and Van Dyk, 1994; Scott and Power, 2001; Tanner, 1994). Namibia has almost no manufacturing industry. Thus, the market for feldspar and mica products is likely to be extremely small or non-existent, and has not been investigated.

B44. Details of the methodology for an economic assessment and general information sources from which market and financial data can be obtained are given in Tables 1 and 2 of Appendix 5. Specific sources of information for an economic assessment of the Uis feldspars and micas were obtained from government ministries in Namibia, including the Ministry of Mines and Energy. A separate assessment of potential markets for feldspar and mica in South Africa was made, with specific sources of information being provided by government agencies, research organisations and private companies. A significant factor in assessing the potential for extracting feldspar or mica products from the waste at Uis is the cost of transport, which will be to Walvis Bay by truck, followed by sea freight to international markets, or by truck to South Africa.

Market study

Feldspar

B45. The recent world production of feldspar is around nine million tonnes annually (U.S. Geological Survey, 2002). The major uses are in glass manufacture (approximately 60%) and ceramics (35%) (Kauffman and van Dyk, 1994; Bolger, 1995; Harben and Kusvart, 1996; Scott and Power, 2001). In glass, feldspar provides alumina (Al_2O_3) which is needed to improve the stability and chemical durability of the glass. The soda (Na_2O) and potash (K_2O) in the feldspar act as a flux in aiding the melting of the glass, and simultaneously reduces the requirement for the more expensive soda-ash. Feldspars are an essential requirement in most clay-based ceramics, where the alkali oxides again act as fluxing materials. The feldspars melt at a low temperature during the firing of the body. The melt then coats the other components. It holds the body together whilst the clay and any other components decompose and enables secondary crystallisation to occur. Sodium feldspars are favoured for glass. Potash feldspars are often prefered for ceramics, although feldspar products with both sodium and potassium feldspars are also used. The ceramic uses include vitreous and other china, porcelain and tiles, as well as glazes. Small amounts of feldspar are used as fillers in paint, plastics, rubber, sealants and adhesives (Bolger, 1995). Low grade feldspar products find some use as abrasives (e.g. in household scouring products).

B46. Feldspar comes from a variety of geological sources (see Harben and Kusvart, 1996, p.170, and Scott and Power, 2001). Important ones include pegmatites and feldspathic sands. Pegmatites are often mined selectively or hand sorted from pegmatites, whereas flotation is used to separate feldspars from quartz in feldspathic sands. Other sources of feldspar are alaskite (a leucocratic granite), from which feldspar is separated by crushing, grinding and flotation, and feldspar-rich rocks such as rhyolites and aplites, which are used after crushing and grinding, without further processing. In the UK, china stone is used as a source of

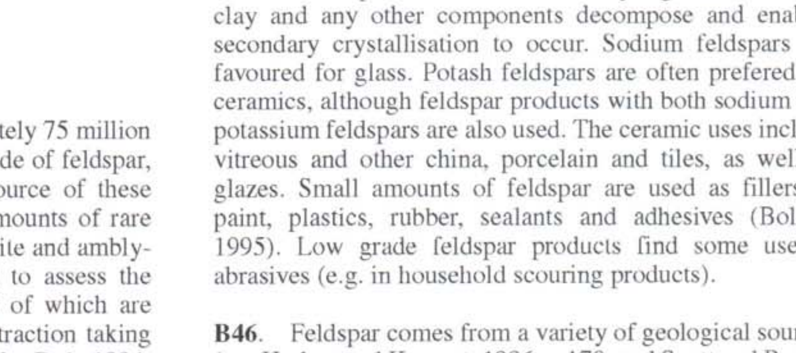


Figure B22 Distribution of tantalite (red) in gravity separation products, Uis, Namibia.

feldspar in porcelain and bone china. This is a partly kaolinised leucogranite, and is hand sorted before crushing and fine grinding. Nepheline syenite is a substitute for feldspar both in glass and ceramics. It contains more alkalis than feldspar, and is processed from the rock by crushing, grinding and magnetic separation. The latter removes any ferromagnesian and iron-titanium oxide minerals. There is no record of feldspar being produced as a mineral product from mining waste; but, feldspars from pegmatites and feldspathic sands are often co-products along with quartz, and occasionally other minerals, including mica.

B47. Feldspars are exploited in numerous countries for internal consumption. Countries without indigenous supplies import feldspar, and there is a significant international trade. For example, the UK imports all of its feldspar requirements (25 707 tonnes of feldspar and 48 000 tonnes of nepheline syenite in 1999) (UK Mineral Statistics 2000) apart from a very minor amount of china stone production. The world statistics on recent feldspar production are given in Appendix 2, Table 21. The world's major producers are Italy, Turkey, United States, France, Germany, and Thailand. The BGS World Mineral Statistics (BGS 2001) show China (2 million tonnes in 2000) and Japan (1 million tonnes in 2000) also as major producers. Numerous countries import feldspar. World trade in nepheline syenite is dominated by production from two localities, one in Norway and the other in Ontario, Canada. A total of 930 000 tonnes was produced in 1998 (U.S. Geological Survey, 2002).

B48. The quality of feldspar products varies enormously (see Scott and Power, 2001; Kauffman and van Dyk, 1994). Some are almost pure potash or soda feldspars, although many contain variable amounts of both components (Scott and Power, 2001), either as distinctly separate phases or as an intimate intergrowth (perthite). Variable amounts of quartz are present in most feldspar products. In some, quartz is a major constituent. Table 22 in Appendix 2 shows representative chemical analyses and mineralogy of some typical feldspar products, indicating their geological origin. Similar data are presented in Harben (1995), in which several more feldspars are mixed Na_2O/K_2O products. An important requirement in the quality of feldspar is for the iron oxide content to be as low as possible. Amounts in commercial products vary, ranging from 0.04% Fe_2O_3 to more than 1% Fe_2O_3 in the data of Kauffman and van Dyk (1994) and Scott and Power (2001), although the majority of products have Fe_2O_3 <0.1%. It is unlikely that a feldspar product with greater than 0.1% Fe_2O_3 would find a significant market for use in glass and ceramics.

B49. The Uis mine tailings contain quartz, feldspar and mica as the main constituents, along with minor amounts of chlorite, calcite and kaolinite. Proportions of the major minerals vary in different parts of the waste. There are trace amounts of tin and tantalum. The alkali oxide content ($Na_2O + K_2O$) of the tailings ranges from 5–7%. Processing using air classification produces a concentrate containing between 67–93% feldspar, with 1.7–4.0% K_2O, 5.6–9.7% Na_2O and 0.03–0.08% Fe_2O_3. These products are mixed Na/K feldspars. More extended processing might be capable of further improving the grade of feldspar products. It is not known whether separation of Na and K-feldspars is possible. An improvement in grade to produce a single Na or K feldspar product would be needed to compete favourably with many internationally traded feldspar products.

B50. The nearest significant market for feldspar from Uis would be in South Africa, where the products would compete with supplies from indigenous resources. Details of feldspar production from South Africa are given in Appendix 2, Table 23, properties of individual products in Appendix 2, Table 24, and a list of operating mines in 1999 in Appendix 2, Table 25. The markets are in glass and ceramics mainly. The feldspars are sourced mostly from pegmatite belts in the Northern Province and in the Northern Cape Province. Mica and quartz are often co-products.

B51. In 1998, production of feldspar in South Africa appears to have been significantly higher than sales (Appendix 2, Table 23) indicating a stockpiling of feldspar products. As there is apparently no import of feldspar, it would appear that South Africa relies entirely on its indigenous supplies, which satisfies its home market. There is also some export of feldspar from South Africa. Separate Na_2O and K_2O rich feldspars and mixed feldspars are produced. The transport of a feldspar product from Uis to South Africa would be by road. As the movement of goods between the two countries is mostly to Namibia, there may be an opportunity for back haulage, gaining favourable rates for delivery to South Africa.

B52. There is a well established international market for feldspar and nepheline syenite products, into which a product from Uis could compete. Approximately 30% of the world's production is involved in export trade. The major consumers most likely would be in Europe and south-east Asia, as these regions appear to be net importers of feldspar. Production and consumption in North America and elsewhere appear to be balanced, although there is a minor excess of consumption in Africa relative to supply (Harben, 1995). An international demand based on the quality of product available from Uis would need to be established before any export market could be developed. Transport would need to be by road to Walvis Bay, followed by shipment in bulk.

B53. Details of international prices for feldspar and nepheline syenite products, with which Uis material would compete are given in Appendix 2, Table 26 (Anon, 2002). The prices vary considerably depending on the grade and particle size of the product. Pulverised grades command the highest prices due to the extended processing required. Differences comparing ex-works and delivered (ex-store) prices indicate a substantial transport and storage cost of up to £100 per tonne for the more expensive grades. Assuming that only a relatively low grade mixed Na/K feldspar could be produced from Uis, the FOB price would need to be substantially lower than that from existing South African deposits (i.e. much less than $150 per tonne) to compete.

Mica

B54. Mica is a name for a group of minerals. It includes muscovite and phlogopite, which are the two main commercial sources of mica. Muscovite occurs in granites, pegmatites and some metamorphic rocks. It is a hydrated potassium aluminosilicate, $K_2A_{14}(Si_6Al_2O_20)(OH, F)_4$. It is extracted mainly from pegmatites as a by-product or co-product with feldspar or spodumene. It is also produced as a co-product from the processing of kaolin from altered granites. Phlogopite occurs in metamorphosed limestones, ultrabasic rocks, especially kimberlites, and carbonatites. It is a potassium iron/magnesium aluminosilicate,

$K_2(Mg, Fe)_6(Si_6Al_2O_20)(OH, F)_4$. The bulk of the world's production is of muscovite. Phlogopite is very restricted in its occurrence, workable deposits are rare, the only significant one being in Canada. Muscovite is extremely common and the mineral is exploited in many countries.

B55. Mica produced commercially is known as sheet, flake or scrap. These terms refer to the mica being found as large sheet-like masses several centimetres at least in size, much smaller flakey mica crystals separated from their host rock, or that recovered from the waste created during the extraction of sheet mica, respectively. Sheet mica is used mainly because of its electrical and thermal insulation properties, stability at high temperature and transparency. Its main applications include optical filters, furnace windows, high pressure gauge glass, transformers, rheostats and other electrical products (Anon, 2001; Harben, 1995). The mica can be used as large sheets, cut and machined to size or as composites, cemented together piece by piece. Sheets are extracted by hand usually and sold on the basis of colour, visual quality, and size and thickness of the sheet. The production of sheet mica is dominated by India, where labour costs are low and the mica can be hand selected; but, there is some production from South Africa and Argentina (Harben, 1995), and Russia (U.S. Geological Survey, 2002a). Sheet mica production worldwide is approximately 5 000 tonnes per annum. As mica recovered from the waste at Uis would be in the form of flakes, the product would not compete with sheet mica. Thus, sheet mica is not discussed further in this section.

B56. Flake and scrap form the major part of mica production, which amounts to approximately 280,000 tonnes per annum worldwide (Appendix 2, Table 27) (U.S. Geological Survey, 2002b), an increase from around 250 000 tonnes per annum in the 1980s (Tanner, 1994). The production is dominated by the United States and Russia.

B57. Mica originating as flake or scrap is sold in a powdered form, either dry ground to give particles between 150 μm and 1.2 mm, wet ground for finer grain sizes from 45–90μm, or micronised to give a very fine powder (<53μm) (Harben and Kusvart, 1996). The type of grinding has a considerable effect on the nature of the mica product. Dry grinding gives a rough-edged particle, with little lustre, and a high aspect ratio (i.e. very thin platelets relative to their size). Wet grinding gives thin, flat platelets with a high lustre and good slip. Examples of mica uses with details of the particle size and the type of grinding used are given in Appendix 2, Table 28. The uses are wide ranging and utilise the physical properties of the mineral, especially its platey form, general inertness to chemicals, moisture, the atmosphere and light (including UV), and its insulating capability. In plastics, rubber and paints, mica acts as a functional filler, modifying the properties of the product to give desired effects such as added strength and flexuring ability. As an example of the relative amounts used, the major markets for powdered mica products in the United States are as joint cements for plasterboard, paint, roofing felt, oilwell drilling additives and rubber products. High quality flake and scrap mica is sometimes made to simulate sheet mica by building up layers of overlapping platelets by bonding them with a cementing agent. The product is called micanite. Also, some high quality scrap mica, passed through a paper-making machine with an adhesive, is used to make mica paper. Mica paper or micanite can be used instead of sheet mica in electrical appliances (Sims, 1997). Some micronised mica is used only after calcination. Fine mica can be coated with silanes for compatibility with polymer systems, and coating of titanium or iron oxides give colour or pearl lustre effects (Sims, 1997).

B58. The chemical composition of mica is not critical for its uses in a powdered form, but the presence of impurity minerals, such as quartz and feldspar are likely to reduce the quality of a mica product. Talc can substitute for mica in some of its markets. Other minerals can also replace mica, but the specific properties which mica imparts in many of its applications generally cannot be replicated with other minerals.

B59. The main consumers of mica are the world's industrialised nations, notably U.S.A., European countries, Russia, Canada and Japan (Harben, 1995; Sims, 1997). For example, Japan imported 43 907 tonnes in 1995 (Sims, 1997) and the UK imported 12 956 tonnes in 1999 (United Kingdom Mineral Statistics, 2000). There is also significant consumption (greater than 1 000 tonnes annually) in Mexico, Australia, Iran, South Korea, South Africa and Singapore (Harben, 1995).

B60. Many producers of mica process the mineral into a powdered form by wet or dry grinding at the mine site for direct use by the consumer. However, a significant amount of the world production, especially that from developing countries such as India and China export flake or scrap mica in a form which requires further grinding to create a specific particle size. The further grinding produces a customised product with high added value. Several countries, including UK, Germany, Netherlands, Austria and Japan import mica, process it by grinding and then re-export the products (Sims, 1997). Thus, published export figures do not always relate to the primary producers (e.g. World Mineral Statistics, 2001).

B61. The prices of various mica products are given in Appendix 2, Table 29 (Anon, 2002). There is considerable variation which reflects the different grades and type of grinding (dry, wet or micronised). The prices ex. Works UK, are for mica which has been imported as flake or scrap, and then custom ground.

B62. Laboratory work on the waste from Uis has shown that mica is liberated and that a pure concentrate can be made using air classification. The nearest significant market for a mica product from Uis would be in South Africa, where a product would compete with supplies from indigenous resources. South Africa produces mica from two locations (Sims, 1997), both in the Phalabora area, Northern Province. Details of production, exports and imports are given in Appendix 2, Table 30. Around one third of production is exported. South Africa also imports mica.

B63. The two producing mines in South Africa beneficiate the mica before sale. One does this at the mine site, whilst the other transports the mica to Johannesburg for processing (Sims, 1997). Export appears to be from Durban (see Appendix 2, Table 29). Thus, overland transport costs will be considerable, and would be comparable with those for the export of a mica concentrate from Uis, via Walvis Bay, or for transport to Durban overland. Air classification to produce mica from Uis could be achieved without the use of water as could dry grinding. As the amount of mica in the tailings is relatively low, yields are also low (1% on average), but grades and recovery are shown to be good from the laboratory work.

Economic assessment of waste processing

B64. The waste dumps from the former Uis Mine contain approximately 75 000 000 tonnes of material which is very rich in feldspar with lesser amounts of mica and quartz and a wide range of accessory minerals.

B65. The options at this site provide for either a highly technical and sophisticated approach to recovery of the maximum percentage of the available mineral/s or a low technology and simple processing technique for a much smaller but easier liberated, lower value product. In the first case, it is assumed that a large commercial operation would seek to achieve the maximum financial return in the shortest period. The second option assumes that a co-operative of artisanal workers could be formed with financial and technical backing to produce a viable operation over a much longer timeframe with much lower costs. These options can be further sub-divided by considering either a single product (feldspar) operation or a dual product (feldspar + mica) recovery process.

Option 1A High technology approach — Feldspar recovery only

B66. In this case a single, saleable product of feldspar is assumed to be made. A crude financial simulation has been conducted and the results of a typical large-scale operation are presented in Table 5B. The chosen values are explained below:

Details of waste resource

B67. The size of the deposit is taken as 75 Mt, which is the total volume of the waste material on site. The percentage of useable material is taken as 45% based on the laboratory results during the project evaluation.

Details of proposed mining method

B68. Mining extraction is assumed to include all of the available material. Of this volume, it is thought that a dilution of 5% could be expected, to allow for the processing of poor grade material. An efficient processing operation has been assumed and a mill recovery of 90% has been used in the calculation of recovery. Operations are expected to work throughout the year with minimal stoppages and an annual operating period of 300 days/year has been entered.

Financial details

B69. The selling price is the critical factor in this model. There is no current demand for the product within the country and the assumption is that the mineral would be exported. In this regard, considerable transport costs would be incurred in delivering the product to market. Current estimates of freight rates within Namibia are $7.5/t delivered to Walvis Bay port facility. Sea freight charges would also be applied in the case of ocean transport. International selling prices are quoted between a range of $36–$80/t which are largely dependent upon quality of the product. An ex-works selling price of $25/t has therefore been used in the example to allow transport costs to be absorbed into the delivered price to a customer on the world market.

B70. Potential investors would be seeking a reasonable rate of return and a figure of 20% has been taken to represent the cost of capital required in this case. Corporation tax in Namibia is currently set at 30% and this value has been assumed throughout the calculation period. Since the recovery of feldspar is achieved by reworking a waste deposit it is thought that no royalty payments will be necessary.

Capital cost estimation

B71. Processing plant equipment has been selected to provide a circuit of vibrating screens, dry air classifiers, electromagnetic separators and froth floatation to separate the feldspar product from the quartz and mica. A plant capacity of 2 500 t/day has been assumed. Estimated total fixed plant costs are $520 000. Installation costs of the order of $750 000 will be required. Process piping and instrumentation (say 50% of installation costs) will require approximately $370 000 to purchase and install. These factors constitute the $1.64 M physical plant costs included in the processing heading.

B72. The extraction site development costs have been estimated at $220 000 to provide internal haulroads and onsite construction costs. Site preparation for the processing plant and service facilities has been included at a nominal sum of $20 000. Supplying water for processing is not an inconsiderable problem and a figure of $300 000 has been included for calculation purposes. An electricity supply will need to be connected and protected and a contingency figure of 5% of installed equipment costs at a sum of $30 000 is included. Ancillary buildings and facilities have been costed at $150 000. Engineering and construction costs have been estimated at 35% of the total physical plant costs at $545 000. Other costs and contingencies are also based on comparative figures for similar mineral projects world-wide.

Operating costs

B73. Direct operating cost elements for mining, processing, tailings, assaying, supervision, maintenance, electric power, surface services, administration and consumables have been included in the three categories detailed in that section. Those costs are further sub-divided between fixed costs (e.g. salaries and wages) and variable costs (e.g. consumables and power).

Financial results

B74. When the spreadsheet is run using the above data (Table 5B), the best net present value (NPV) is $2.4 M at a production rate of 2430 t/day. In these circumstances it would appear that the proposed operation is potentially very profitable. However, it has already been stated that the project is highly sensitive to rates of production and transport costs. A large volume production facility such as that proposed in this option must secure a stable long term export market if it is to realise these profits. The 70 000 t annual rate of production is equal to the total demand in the nearest potential major consumer (South Africa). In these circumstances, it is inconceivable that the project would be able to displace all the existing feldspar suppliers with their geographically and resource advantage. As a result the quality of the Uis product must be capable of being traded on a larger, world market.

Option 1B High technology approach — Feldspar and Mica recovery

B75. Trials have shown that there is a small but significant amount of mica within the waste dump. Whilst this material constitutes less than 1% of the total volume, dry ground mica commands a relatively high international market price. Recovery of mica could be achieved at the air classification stage of processing for feldspar, at little extra

Table 5B Feldspar production by high technological processing at Uis:

UIS (Feldspar) HIGH-TECH OPERATION

Best N.P.V.	**2,390,216.00**	**$**
Best Prod.rate	**2430**	**t/day**

Details of Waste Resource			
Size of deposit	s of d	75,000,000	tonnes
% useable mineral	ag	45	%

Details of Proposed Mining Method			
Mining extraction	M ex	100	%
Dilution	Di	5	%
Mill recovery	M r	90	%
Operating days/year	op	300	days

Financial details			
Selling Price	price	25	$/tonne
Cost of capital	c of c	20	%
Taxation rate	Tr	30	%
Royalties	Ry	0	%

Limits		
Max. tonnage milled	2500	t/day
Min.tonnage milled	2000	t/day
No.of runs	9604	

Tonnes milled (Tm)	2430	t per/day
Total tonnage mined	78,750,000	tonnes
Full years milled tonnes	78,750,000	tonnes
Head grade	43	%
Annual o/c	5,293,714	$/year
Revenue	7,037,206	$/year
Mine life	108	years

CAPITAL COSTS ($)	
Extraction site devt.	220,000
Site preparation	20,000
Crushing	0
Processing	1,640,000
Water supply	300,000
Tailings disposal	100,000
Electricity supply	30,000
Ancil. Buildings	150,000
Access road etc	20,000
Engineering	545,000
Admin. Costs	20,000
TOTAL CAP COST	**3,045,000**

OPERATING COSTS ($)		
Operation	Fixed ($/year)	Variable ($/t)
Mining	500,000	0.1
Milling	2,145,000	1.0
General	1,700,000	0.2
TOTAL	**4,345,000**	**1.3**

Table 6B Mica and feldspar production by high technological processing at Uis.

UIS (MICA + FELDSPAR) HIGH-TECH OPERATION

Best N.P.V.	**5,757,900.00**	**$**
Best Prod.rate	**2450**	**t/day**

Details of Waste Resource			
Size of deposit	s of d	75,000,000	tonnes
% useable mineral	ag	46	%

Details of Proposed Mining Method			
Mining extraction	M ex	100	%
Dilution	Di	5	%
Mill recovery	M r	90	%
Operating days/year	op	300	days

Financial details			
Selling Price	price	28	$/tonne
Cost of capital	c of c	20	%
Taxation rate	Tr	30	%
Royalties	Ry	0	%

Limits		
Max. tonnage milled	2500	t/day
Min.tonnage milled	2000	t/day
No.of runs	9604	

Tonnes milled (Tm)	2450	t per/day
Total tonnage mined	78,750,000	tonnes
Full years milled tonnes	78,750,000	tonnes
Head grade	44	%
Annual o/c	5,405,500	$/year
Revenue	8,112,636	$/year
Mine life	107	years

CAPITAL COSTS ($)	
Extraction site devt.	220,000
Site preparation	20,000
Crushing	0
Processing	1,850,000
Water supply	300,000
Tailings disposal	100,000
Electricity supply	30,000
Ancil. Buildings	150,000
Access road etc	20,000
Engineering	545,000
Admin. Costs	20,000
TOTAL CAP COST	**3,255,000**

OPERATING COSTS ($)		
Operation	Fixed ($/year)	Variable ($/t)
Mining	500,000	0.1
Milling	2,250,000	1.0
General	1,700,000	0.2
TOTAL	**4,450,000**	**1.3**

cost. The financial simulation has been carried out and the results of a typical large-scale operation are presented in Table 6B. The chosen values are explained below:

Details of waste resource

B76. The size of the deposit is again taken as 75 Mt. The percentage of useable material is taken as 46%, which represents 45% feldspar and 1% mica content.

Details of proposed mining method

B77. Mining extraction is the same as that adopted for the single product.

Financial details

B78. The traded price of mica products varies considerably according to quality and type. In this case the lowest grade of dry-ground mica has been assumed . An ex-works selling price has been assumed at $180/t which represents a mid-range price for dry-ground material. The assumption has again been made that there is no current demand for the product within the country and that the mineral would be exported. The same transport and shipping costs for feldspar have been included in determining the optimum selling price for Uis mica. By combining the selling prices of both feldspar and mica an equivalent price of $28/t has been adopted to represent the weighted average of the two products.

Cost of capital, taxation rate and royalties are taken to be the same as that used in the feldspar calculation.

Capital cost estimation

B79. An additional cost of processing has been included in the dual product approach to represent the extra cost of separating mica at the air classification stage. In all other respects the capital costs are the same as those used in recovering feldspar only.

Operating costs

B80. Similarly, the fixed, milling, operating costs have been increased to cater for the additional works involved in removing the mica.

Financial results

B81. Using the above data (Table 6B) the best NPV is $5.8 M at a production rate of 2450 t/day. The dual extraction and marketing of feldspar and mica is potentially more profitable than that of feldspar alone. It is sensitive to rates of production and transport costs and long term export markets for both feldspar and mica would need to be established.

Option 2 Artisanal or small co-operative venture.

B82. By contrast to Option 1 a small, low/appropriate technology approach may be suitable for an artisanal co-operative venture.

Option 2A Silspar recovery

B83. In this case a single, saleable product of silspar (feldspar, quartz) is assumed to be produced. The results of a financial simulation of a small-scale operation are presented in Table 7B. The chosen values, typical of such an operation, are explained below:

Details of waste resource

B84. As in the previous case, the size of the deposit is taken as 75 Mt, which represents the total volume of the waste material at Uis. The percentage of useable material is also taken as 45%, since this accords with the results of the technical assessment of the tested samples.

Details of proposed mining method.

B85. Mining extraction is assumed to include all of the available material. Of this volume, it is thought that a dilution of 2% could be expected, given that the manual working of material of target material will be selective and will concentrate on the visibly high grade feldspar. By contrast to the previous option it is assumed that the processing system will not generate the same efficiency and a value of 40% recovery can be considered as typical for semi-skilled operation of the type of plant envisaged. Operations are expected to work throughout the year with minimal stoppages, due to the simplicity of plant employed, an annual operating period of 360 days/year has been used.

Financial details

B86. Market forces and transport costs will determine the selling price which can be achieved for the product of this type of material. There is no domestic market for feldspar or silspar, but if the product can be delivered to a customer overseas at the right price, be of a consistent standard and present in sufficient quantities it may be sold. Details of transport charges have been given and for the purposes of this calculation an ex-works selling price of $12/t has been used in the example.

B87. A Mineral Development Fund is available within Namibia and if it can be shown that a viable mining scheme can be demonstrated loans can be advanced at advantageous rates of interest. Interest rates of 5–8% can be expected. The example uses the lower figure in this range, since it is assumed that there would be a socio-economic benefit in providing employment to the already resident workforce.

B88. Average corporation tax in Namibia is 30% and has been incorporated into the calculation. It is thought that royalty payments would not be relevant, since such monies would have been paid on the working of the primary deposit.

Capital cost estimation

B89. Appropriate technology for simple processing plant equipment is available and a system of vibrating screens and dry air classifiers incorporating an electromagnetic separator is envisaged. A low volume, plant capacity of 100 t/day has been assumed. Estimated total fixed plant processing costs are $20 000 derived from second-hand prices. Site development and preparation costs of $1 500 are minimal as a result of the low volume of production. The supply of electricity is anticipated to cost $10 000 and an allowance for engineering and building has been included at $10 000 maximum. A nominal figure of $1 000 has been allocated to administration and supervision of the installation of plant. A minimum, total capital cost of $42 500 is therefore envisaged.

Operating costs.

B90. The elements of direct operating costs have been outlined in Option 1 above and a scaled down estimate of this has been made. It has been assumed that the miners will be paid on an amount per tonne basis and a variable cost of $0.8/t has been entered. Milling costs are likely to incur high power charges as consumable items, which is reflected in the fixed and variable costs. Additional variable costs are expended on wages, which have also been factored into this element. An allowance for general supervision and maintenance has also been included at a relatively high rate of $0.10/t to provide for anticipated repairs.

Financial results

B91. The result of the spreadsheet calculation shows a small negative NPV -$40 000 at a production rate of 105 t/day. This value can be misleading in that, if a range of production figures is evaluated from 90–140 t/day the NPV varies from -$70 000 to +$25 000 and the probability is that the venture will be sub-marginal throughout its operating life. The operation would take 2000 years to complete, with the result that the overall volume of the waste dumps would be reduced by less than 20% of the original size.

Option 2B Silspar and Mica recovery.

B92. In this case the recovery of both silspar and co-product mica has been considered. The results of a financial

Table 7B Feldspar production by low technological/ appropriate processing at Uis.

UIS SMALL-SCALE OPERATION

Best N.P.V.	**-40,040.00**	**$**
Best Prod.rate	**105**	**t/day**

Details of Waste Resource			
Size of deposit	s of d	75,000,000	tonnes
% useable mineral	ag	45	%

Details of Proposed Mining Method			
Mining extraction	M ex	100	%
Dilution	Di	2	%
Mill recovery	M r	40	%
Operating days/year	op	360	days

Financial details			
Selling Price	price	12	$/tonne
Cost of capital	c of c	5	%
Taxation rate	Tr	30	%
Royalties	Ry	0	%

Limits		
Max. tonnage milled	110	t/day
Min.tonnage milled	100	t/day
No.of runs	9604	

Tonnes milled (Tm)	105	t per/day
Total tonnage mined	76,500,000	tonnes
Full years milled tonnes	76,500,000	tonnes
Head grade	44	%
Annual o/c	77,700	$/year
Revenue	80,047	$/year
Mine life	2023	years

CAPITAL COSTS ($)	
Extraction site devt.	500
Site preparation	1,000
Crushing	0
Processing	20,000
Water supply	0
Tailings disposal	0
Electricity supply	10,000
Ancil. Buildings	5,000
Access road etc	0
Engineering	5,000
Admin. Costs	1,000
TOTAL CAP COST	**42,500**

OPERATING COSTS ($)		
Operation	Fixed ($/year)	Variable ($/t)
Mining	1,000	0.8
Milling	10,000	0.6
General	10,000	0.1
TOTAL	**21,000**	**1.5**

simulation of a small-scale operation are presented in Table 8B. The chosen values, typical of this type of operation are explained below:

Details of waste resource

B93. As in the previous cases, the size of the deposit is taken as 75 Mt. The percentage of useable material for both products is taken as 46%, in accordance with the results of the technical assessment of the tested samples.

Details of proposed mining method

B94. The mining method is the same as that adopted in the case of the single product Option 2A.

Financial details

B95. A selling price of the combined product range has been calculated at an equivalent figure of $14/t. All other financial details are the same as those assumed in the silspar example.

Capital cost estimation

B96. Additional processing charges have been estimated to reflect the extra costs incurred in separating, recovering and storing the mica.

Operating costs

B97. The fixed costs of milling have also been increased on a pro-rata basis to reflect the extra work involved in extracting the mica. All other operating costs are assumed to be the same as those incurred in the recovery of silspar in Option 2A above.

Financial results

B98. The result of the spreadsheet calculation shows a positive NPV $64 000 at a production rate of 105 t/day of both products. As with the previous case, the probability is that the venture will be on the margins of profitability throughout its operating life. A long term and stable market for feldspar and mica would need to exist.

SOCIAL IMPACT ASSESSMENT (SIA)

B99. In order to identify and predict the potential social impacts of utilising the large amounts of feldspathic waste at Uis two field visits for primary research were made to the Uis site Additional information was gathered from extensive scoping of secondary literature sources. The research work followed the methodology given in Appendix 6. The SIA is based on field interviews and surveys and an analysis of existing socio-economic conditions. Local secondary sources of information were also used. The research aims to identify, predict and recommend mitigation and enhancement of potential socio-economic impacts of mine waste utilisation.

National context

B100. Namibia is one of Africa's largest countries, yet its population is just 1.7 million. The economy is narrowly based on primary resource activities such as mining, fishing and agriculture, manufacturing and tourism, with limited secondary processing. Mining remains the most significant of these activities. Nevertheless, unemployment levels are high, and formal sector employment opportunities are limited. Namibia has become one of the most unequal and inequitable countries anywhere in the world with a highly skewed wealth distribution reflecting a rich minority and very poor majority.

B101. Urban incomes are nearly three times as high as incomes in the rural areas of Namibia with potential earnings at the mines even higher. Traditionally, rural households in Namibia have relied on multiple income sourcing

Table 8B Mica + Silspar production by small-scale processing at Uis.

UIS (MICA & SILSPAR) SMALL-SCALE OPERATION

Best N.P.V.	64,650.00	$
Best Prod.rate	105	t/day

Details of Waste Resource			
Size of deposit	s of d	75,000,000	tonnes
% useable mineral	ag	45	%

Details of Proposed Mining Method			
Mining extraction	M ex	100	%
Dilution	Di	2	%
Mill recovery	M r	40	%
Operating days/year	op	360	days

Financial details			
Selling Price	price	14	$/tonne
Cost of capital	c of c	5	%
Taxation rate	Tr	30	%
Royalties	Ry	0	%

Limits		
Max. tonnage milled	110	t/day
Min.tonnage milled	100	t/day
No.of runs	9604	

Tonnes milled (Tm)	104	t per/day
Total tonnage mined	75,000,000	tonnes
Full years milled tonnes	75,000,000	tonnes
Head grade	44	%
Annual o/c	79,000	$/year
Revenue	91,960	$/year
Mine life	2055	years

CAPITAL COSTS ($)	
Extraction site devt.	500
Site preparation	1,000
Crushing	0
Processing	22,000
Water supply	0
Tailings disposal	0
Electricity supply	10,000
Ancil. Buildings	5,000
Access road etc	0
Engineering	5,000
Admin. Costs	1,000
TOTAL CAP COST	**44,500**

OPERATING COSTS ($)		
Operation	Fixed ($/year)	Variable ($/t)
Mining	1,000	0.8
Milling	11,000	0.6
General	10,000	0.1
TOTAL	**22,000**	**1.5**

as a survival strategy, using a combination of pensions, petty trade and wage labour to augment their agricultural income. However, over-population, diminished soil fertility, and traditional farming practices that are no longer suited to large fixed settlements, have all served to undermine the importance of agriculture to household income. This has led to the migration of families from rural areas into urban and peri-urban settlements in central and southern Namibia.

B102. The hope of employment or other income-generation options, or the possibility of being nearer to family members who are generating an income on which they can draw has stimulated the present migration pattern. As there is virtually no chance of improving household income in the remote rural areas of Namibia, urban migration has become an economically rational strategy, notwithstanding the privations of life in an informal settlement. Nevertheless, once people have moved they often have insufficient resources to return home or move elsewhere and as the in-migration of people from areas with high infection rates escalates, the prevalence of HIV infection and AIDS is likely to increase.

Regional context

Regional setting

B103. Uis is situated at the edge of the Namib Desert, approximately 25 km south east of the Brandberg massif. Major gravel roads connect the town with the larger centres of the area: Khorixas (population 7358) to the north (125 km), Omaruru (population 4581) to the east (125 km), Usakos (population 3548) to the south (130 km) and Henties Bay (population 1612) on the Atlantic coast (130 km). The town falls within the Omaruru district of the Brandberg constituency in the Erongo region (CBS, 1999). Until 1992 it belonged to the former administrative district known as 'Damaraland', which was a communal area designated by the Odendaal Report in 1964 and under the authority of the traditional tribal council. The area of the new Brandberg constituency, within which Uis is situated, approximately corresponds to the former 'South Damaraland'.

Population profile

B104. With a population 55 470, the population density of the Erongo region is low (0.9 per Km^2). However, the largest part of the region's population live in the main centres while the coastal desert remains uninhabited. Although named 'Damaraland', 80–90 percent of the 'Damara' population lived outside their designated homeland during the last two decades. There are no current official statistics on the ethnic composition of the region or district. According to the 1981 census, 64 percent of the district's population were Damara while 15.8% were Herero and 7.4% Ovambo. According to the 2001 census, the Erongo population is concentrated in the 0–9 and 25–44 age group. The average annual population growth rate in Damaraland between 1981 and 1991 was 3 per cent compared to a national average over the same period of 3.1 percent (CBS, 1999, 2001).

Economy and infrastructure

B105. The regional economy is based on the primary sector (subsistence livestock husbandry) and on wage labour migration, which is mainly towards the national urban centres. In the town, cash income is mainly provided by employment in the civil service. The rural households, which rely on extensive small stock husbandry, are sparsely distributed over the semi-arid lands. Many of the farms that have been included in the homeland in the 1960s were formerly white owned and have since been used by cohabiting black households. The main centres in the region's southern and eastern constituencies are linked to the national urban centres by tarred roads and an interregional railway line. Major gravel roads and a weekly bus service from Outjo to Walvis Bay service the Brandberg constituency. Minor gravel roads and tracks connect the rural farm areas.

Local context: Uis

Local setting

B106. Prior to the establishment of large-scale mining, the only solid buildings at Uis were located opposite the mining area and included the mine's office buildings, 12 houses and single apartments for the white employees, and one shop. In 1963 IMCOR started construction of a white township 1.5 km west of the mine called 'IMCOR Township' and construction of a black township 2 km east of the mine called 'Lokasie'.

IMCOR Township

B107. IMCOR Township consists of a number of small shops, a petrol station, four guesthouses and approximately one hundred comfortable private houses. Each of these private houses has at least five rooms, a fully equipped kitchen, a bathroom, electricity, hot water and front and back gardens. All streets in the Township are tarred and illuminated at night (see Picture 1).

Lokasie

B108. There are approximately 400 houses in Lokasie, 296 of these are council owned houses and the rest are privately owned. Most houses are 6 x 7 metres in size, and divided into four rooms. All the houses are supplied with a sewage system. About one quarter of the houses in Lokasie are larger and of a higher standard (bathroom and electricity). About half of the households have water taps and outside toilets although potable water is available to all residence since IMCOR constructed a pipeline from Lokasie to a small reservoir. The main road connecting the IMCOR Township with Lokasie is tarred. However, none of the roads in Lokasie are tarred and there is no street lighting (see Picture 2).

The social environment

Demography

B109. Reliable demographic figures for the period prior to the closure of the mine are not available. Nevertheless, it has been estimated that the population of Uis numbered about 3 500 in 1990. In August 1992, a census put the number of inhabitants at 2 300. A corresponding census in October 1994 put the number of inhabitants at 2 026 (Kuper, 1994). In 2000, Uis's population was estimated to be 1 500 (UVC, 2000). The same census showed that the 54.7% of the population of Uis are women and 45.3% are men. Due to the absence of a male workforce of 425 since the closure of the mine, this ratio has changed considerably. The following graph illustrates the age/sex distribution ratio.

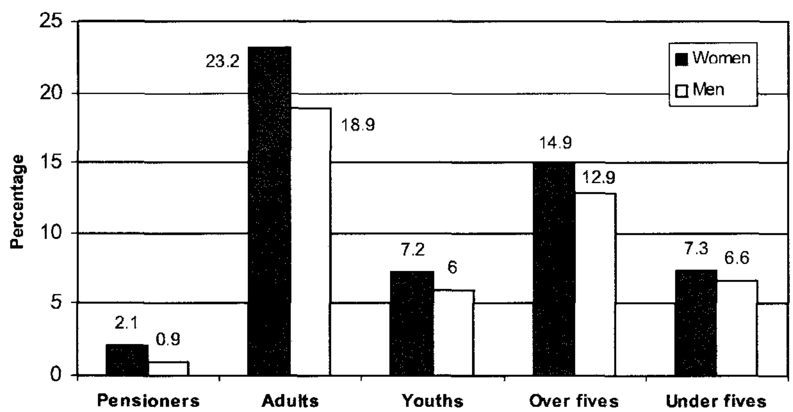
B110. Figure B23 demonstrates a high dependency ratio in respect of the younger age groups to the adults. Indeed, 54.9% of the total population are economic dependants. If the sex ratio is also taken into account, one can see that the situation is particularly exacerbated in Uis because of the outward migration of a large number of economically active male adults into regional urban centres such as Karibib and Swakomund. It was estimated that in the year 2000 the ratio of adult women to men was in excess of 3:2 (UVC, 2000).

B111. Uis is ethnically heterogeneous, Table 9B below shows the proportion of language groups within the population of Uis by sex in October 1994. Although the number of Ovambo and Kavango decreased after mine closure, the ethnic mix shows no other significant alteration when compared to the 1992 census data or to other earlier sources of data (Kuper, 1994). The mine, when operational, did not represent a pull factor for the regional population, but largely benefited them indirectly through the general economic expansion effect it had on Uis. The main local beneficiaries were women seeking wage labour as domestic workers in the white households of IMCOR Township. IMCOR employed migrant workers from all over the country including South Africa. Although many of these workers already had families they established second families with local women. The shutdown of the mine brought particular hardship to many of these women who were subsequently left to support these children without a regular household income.

Household characteristics

B112. Household composition in Uis is highly flexible and dynamic. Visitors often stay for weeks or months at a time, household members migrate in search of wage labour, and, in particular, young people and children shift between

Figure B23 Distribution of age groups by sex.



Source: Kuper (1994)

Township housing at Uis.

Lokasie housing at Uis.

Former school building at Lokasie.

different households within the town. Distinctive household composition patterns can, nevertheless, be observed. Most of the households (n = 479) are headed by females (57.3%) and account for 62.2% of the total population. Male-headed households tend to be smaller with nearly 38.2% of male-headed households being sole occupancy or being restricted to a conjugal partner and their own children (46.2%). In contrast, 76.5 % of the women live without conjugal partners but with a number of children including those of their brothers and sisters.

B113. Although the fluctuation of male partners in female-headed households is high, the number of men who are conjugal partners accepting the social responsibilities and economic responsibilities normally associated with those roles is very low. The most common type of household (26%) is composed of a single woman caring for up to ten children. Households in IMCOR Township tend to be significantly smaller and the larger household sizes in Lokasie constitute the majority of the, predominantly black, underprivileged population. The household size in Uis can be compared with the average size for the Erongo region of 3.8 and the average number nationally of 5.2.

Social organisation

B114. Social organisation in Uis is more highly influenced by urban social network determinants than the sort of determinants normally expected in a traditional African rural setting such as age sets, kin and descent groups. As a result, permanent social structures beyond the household level hardly exist. In addition to the past migrant employment nature of Uis, this is attributable to the physical structure of Lokasie where housing arrangements restrict choice in location and generate random social relations. Though traditional norms, especially in respect of kin, do exist, there is pronounced dynamism and flexibility in the actual behaviour according to these norms and they have little priority over the criteria of sympathy and friendship in constituting social relations.

B115. Instead, the criteria determining social organisation in Uis are manifold and include neighbourhood, friendship, kinship, mother tongue, colleagues and church choir. The greater the number of links two people share, the stronger they are socially networked, and so the closer their relationship. In Uis, an equally high level of social dynamism and flexibility can be observed with regard to ethnicity, which is often changed through extension or shift in emphasis (if they are of mixed origin).

Social facilities and services

B116. Most social facilities in IMCOR Township such as the church, kindergarten and school had closed by 1991. The supermarket reduced its supply intake and the petrol station its opening hours; both clubs thereafter only opened twice a week and the buses that used to connect Lokasie and IMCOR township were stopped. However, the town did retain its supermarket and petrol station, and there is now a butchery, liquor store, bakery, and tourist shop selling gems. There is also a post office that has a public telephone and a digital telephone exchange serving all one hundred private lines in the town. National television programmes can be received although the only regular newspaper locally is the weekly New Era. Tourist and recreation facilities are more numerous in IMCOR Township than Lokasie and there is a café and takeaway as well as four guesthouses.

B117. Lokasie has three general stores and a liquor store. There is also a community hall used for village council meetings, adult education classes, discos etc. More than 77% of Uis's population belong to the Lutheran Church and 22% to the Catholic Church and regular church services are held at Lokasie's Catholic and Lutheran Churches which represent the only regular community gatherings. Here the pastor gives mail to those who do not have P.O. boxes, announces public events and community meetings as well as informing people about important local news and events. Public recreation

Table 9B Language groups by sex in Uis.

.% n=1706	Damara	Ovambo	English	Afrikaans	Herero	Kavango	Nama	Tswana Zulu	Caprivi
Female	45.5	4.0	1.2	1.4	1.2	0.7	0.4	0.2	0.1
Male	34.9	4.0	2.0	1.5	1.5	0.6	0.3	0.3	0.1
Total	80.5	8.0	3.2	2.9	2.6	1.4	0.7	0.5	0.2

Source: Kuper, (1994)

Table 10B Number of medical conditions recorded at Uis clinic (2000).

Ear/nose /throat infections	Muscular conditions	Skin infections	Respiratory infections	STD (sexually transmitted diseases)
592	607	349	778	180

facilities are confined to a soccer field and a drinking place with dancing. There is a bus service every Thursday to Walvis Bay but there is no public transport within Uis, therefore, donkey carts and cars are used between town and surrounding areas and the people of Lokasie generally walk or find lifts in private cars between Lokasie and IMCOR township. There are just a few private telephone lines in Lokasie although a public telephone also serves the township.

Health and education

B118. The nearest hospital is in Omaruru, however, within Lokasie, there is a state-subsidised clinic with three nurses. Once a month the clinic serves out-clinic posts within a radius of 35 km of Uis. Every fortnight a doctor from Omaruru sees patients who could not be treated by the clinic's resident nurses. The cost of treatment at the clinic is 3 R and the cost of follow-up treatment is 1.5 R. Table 10B shows the number of conditions reported at the clinic. The clinic's nurse, Sister Makhule, stated that the incidence of tuberculosis and AIDS are of national concern and have increased significantly over the last ten years. Of local concern, she highlighted the comparably high incidence of general respiratory infections in Uis, attributing it, in part, to airborne dust from the mineral waste dump.

B119. In the context of rural Namibia, the degree of education in Uis is relatively good and most inhabitants of the town benefit from primary schooling. Nevertheless, limited household income restricts the affordability of schooling to between five and ten years. Consequently, the majority of adults in Lokasie are illiterate Afrikaans speakers with few people educated to a standard that enables them to speak or write in English. All of Uis's education facilities are based in Lokasie and include a privately run kindergarten with 2 teachers and 50 children; the Brandberg Primary school with 16 teachers and 432 children and the Petrus Ganeb Secondary school with 23 teachers and 550 students.

B120. The Ganeb secondary school enjoyed an excellent reputation, attracting pupils from all over the country because of its teaching of the Damara language, high pass rate and reasonable fees. However, the school has recently been subjected to two arson attacks, rendering nine classrooms unusable (see Picture 3). The Schools director, Mrs C Araes, suggested that a longer-term factor affecting the educational standard in Uis was the out migration of parents in search of work since mine closure. With nearly two thirds of the students coming from families with absent parents, discipline and drop-out rates among domestic students (who make up 60% of the learners) have been very detrimentally affected.

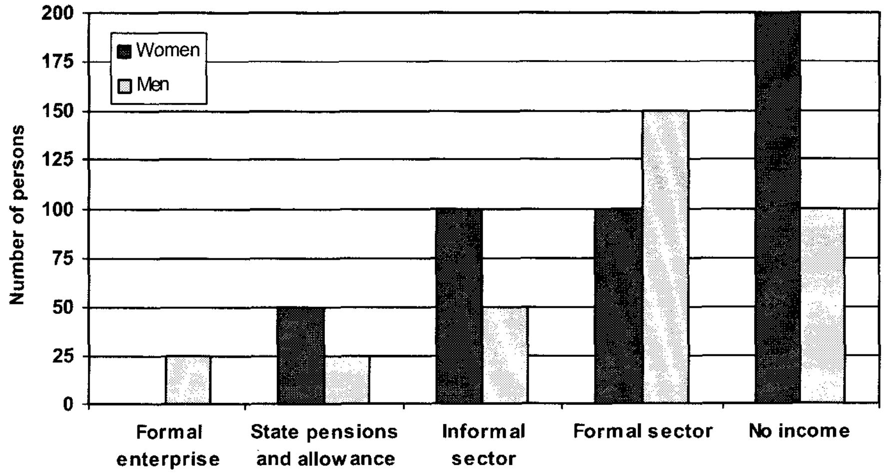
Administration and law

B121. The local authority is represented by an elected village council at an office of the Ministry of Local Government and Housing in Lokasie, as well as by the members of the four village committees in charge of housing, health, school affairs, and garden projects respectively. Additional committees, like the 'White Lady Women's Project' or the 'Tinkapper Kommittee', are self-help initiatives from the community to improve local living conditions. Since the regional elections of 1992 the former Damaraland authorities — the Damara Council and the

Table 11B The incidence of criminal acts in Uis since 1991.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
assault	74	82	83	97	108	119	116	67	67
stock theft	33	49	54	55	64	47	76	74	33
burglary	46	48	24	32	33	26	47	29	24
theft	21	28	47	44	44	59	59	62	26
culpable homicide	2	4	1	1	1	3	5	2	3
rape	3	8	6	1	7	6	9	4	4
robbery	1	3	0	1	2	2	4	5	2
arson	2	3	3	2	0	3	2	3	7
murder	0	0	1	1	2	1	0	3	3
abduct	0	0	0	1	0	0	0	0	0
kidnap	0	0	0	1	0	0	0	0	0
child abuse	0	0	0	0	1	0	0	0	0

Figure B24 Income profile of the total adult population by sex.



headmen of the 12 wards — no longer have an official framework within which to act. Yet, the traditional authority, and particularly the local headman at Uis, is a respected person who still retains the confidence of the majority of the population on most domestic and social matters. As a result, it is important that he is contacted in connection with any decisions concerning the town's development. There is a police station in Lokasie that hosts a court every second month.

Economic environment

Economic setting

B122. The range of economic opportunities in Uis is rather limited. The arid conditions are not suitable for agriculture and the only possibilities for subsistence farming are extensive small stock husbandry with intensive irrigation and fertilisation. However, due to the limited space and grazing in the former homeland, it is not possible for the households keeping stock to exist merely from their herds and most of them depend on income from relatives in employment or receiving state pensions. By far the largest employer is the civil service. In the absence of any manufacturing, tertiary sector economy or other industry, the IMCOR owned mine represented an exceptional income generating opportunity. Prior to closure, the mine employed 400 salaried and 100 contract workers. Based on the mining industry's normal multipliers, over three times this number again would have been indirectly employed by the mine — many as domestic servants.

B123. IMCOR decided to cease production at the Uis mine in September 1990 due to the low price of tin on the international market and has no presence in Uis today. In November the workers were dismissed and received their last salary due; overtime, remaining paid leave and compensation amounting to three months salary. Nearly all those dismissed left Uis to return to their hometowns in search of new jobs. Many were in their forties and fifties and gave up their search for employment relatively quickly. The effect of the closure of the mine was compounded in 1992 when Namibia was blighted by drought.

Income profile

B124. In 1990 IMCOR, as the only local industrial employer, accounted for 40% of the total revenues in Uis. By 1994, 42% of the adult population (n = 766) did not have an income and consequently 27.4% of the Uis households had no source of income (n = 497) while 20% of formal revenues were state pensions or disability allowances. In the same year, the informal sector, which is otherwise poorly developed in the region (Naeraa et al., 1993), accounted for 29.3% of all revenues (n = 444) (see Figure B24). In relation to the income profile of households, 42.3% earn an income either within the formal or informal sector. Most households (56.3%) have the income of only one person at their disposal (n = 497); only 18.9% of households receive the earnings of two people and just 1.9% of households receive the earnings of three household members.

B125. Following the closure of the mine the economy experienced a structural change and the civil service became the major employer and informal sector activities increased. Informal sector activities are numerous (tin mining, beer brewing, selling of firewood and gemstones, car repairs etc) but generally only provide a meagre existence. In contrast, by 1994 the significance of informal domestic service employment had dramatically declined from the 1990 level to include just thirty-three workers. However, it is currently estimated to have increased again to over 120 people following the regeneration of IMCOR Township as a white retirement and tourist location. For example, 'White Lady Guest Camp' alone employs twenty-two people.

B126. After employment in the civil service, tourism is probably the next largest formal and informal employment generator. The village council secretary, Ambros Swartbooi, estimates that over 300 tourists pass through Uis every day. At present most of the package tourists spend one to two hours at the White Lady Rest Camp were they can watch the cutting of semi-precious stones. Generally, tourists are on their way to the coast or attractions in neighbouring southern Kunene region, although the Brandberg, with its mountain range and Namibia's richest repository of rock art (including the famous 'White Lady' frieze in the Tsisab Ravine), contains its own tourist attractions.

B127. The third largest employer in Uis is micro-scale mining, which is an important source of income especially for the economically disadvantaged. These micro-scale miners number about 150 and work individually or co-operatively. Traditionally concentrating on the mining of tin, today such small-scale mining is focused on the extraction of tantalite and semi-precious stones, which are either sold to local business people or to tourists. Thirty four small-scale miners have recently been integrated into a Small Scale Miners

Assistance Co-operative (SMAC) funded by SEDA which has been subject to some internal dispute since its establishment in 1997. Farming is also an important source of income. However, there are no figures more recent than 1992 when about 45% of Uis households owned livestock and 25% owned a small plot of land that they cultivated.

Migration

B128. During the ten years since mine closure Uis has lost in excess of 50% of its mainly young economically productive adult population. Three migratory groups of people can be differentiated. The first are those who are unable to make a living in town and move out to relatives farms in the area. Less commonly there are those who commute between Uis and a working place somewhere else like Omaruru on a weekly or even daily basis. Finally, there are those who leave the town in order to find work at other places where they will then permanently stay. The latter group tend to head for an urban town where they have relatives with whom they can stay while they search for work. Since 1991 the main destinations for out migration has been Henties Bay. Many of these migrants retain families in Uis and provide contributions to their household income. In 1994 12.7% of total household income was generated from employment distant from the town. In the last two years there has been a small net in-migration to Uis as a result of the development of IMCOR Township as a tourist, holiday and retirement location.

Distribution of income

B129. In a setting in which a majority of the population are young dependants, and only a minority of the adult population are economically productive, income distribution is the pivot of the local economy. Since the household is the primary consumption unit, household membership is the crucial criterion for a persons economic well being. Membership is primarily determined by social norms. Households in which there are women and children represent a refuge for men without income since mothers make every effort to ensure food is available for their off spring. Relatives and close friends are generally accepted for up to several months. However, if somebody takes refuge in a household without making efforts to contribute to the budget, problems will arise.

B130. Even when a couple live together, the financial management of the household is in the hands of the woman who is recognised as the owner of the house and as the supporter of the children. Economically, women represent the most vulnerable group but frequently state that men do not accept their share of economic responsibilities and that they have to rely on their own strategies and networks in order to survive. Most pregnancies are unplanned and almost all women, at least once in their lives, have experienced desertion by their partners on becoming pregnant. As a result, brothers and sisters usually have several different fathers who hardly appear and often do not know their own children.

Budgeting

B131. When contrasting the income of Uis households with their daily basic needs, the level of food security is strikingly low. In Namibia, about five different formulae are commonly used theoretically to measure a standard minimum income on which an average family can exist. However, regardless of which minimum poverty level is referred to, the statistical majority of the black population in Uis still survives below this level.

B132. According to a general priority ranking, maize meal, soap and fat are products that are almost always brought. Other foods, hygiene goods, school and clinic fees follow. In 1994, expenses for food, hygiene and cleansing in Uis varied between 100 and 650 R for a Uis household of five people. Prior to the closure of the mine in 1991 housing and services were provided to the town's tenants largely free of charge. These are now charged, and have escalated local housing costs to 54 R per month rent and 154 R per month including bills (water, sanitation, and services) in the year 2000.

B133. Given that the income of many households did not exceed 100 R in 1994, the living expenses outlined above can be seen to challenge the budget of most households and many are forced to reduce their outgoings. As a result, rents, bills and church fees are rarely paid and the Ministry for Local Government and housing have responded by introducing a card metering system for the supply of electricity and water to most houses.

Reciprocity

B134. The majority of household incomes are insufficient to fulfil daily needs and it has been necessary to rely on other, namely social, strategies in order to survive. The main strategy is that of reciprocity which is supported by the evolution of strong social networks. The main forms of reciprocity are the provision of permanent subsistence and regular gifts either in cash or kind. The latter includes the daily exchange of small amounts of goods that are lacking like salt, oil, sugar, coffee or soap in addition to the collective support of network partners when higher expenses such as school fees, marriages and funerals arise. Exchange is especially intensive between Uis households and surrounding farms where all cash, goods, subsistence provision and labour are exchanged. The reciprocity principle is especially strong among the Damara and implies mutual support where a counter gift is not necessarily expected or 'stipulated by time, quantity or quality' (Sahlins, 1988).

B135. Among close network partners, the person who is approached is obliged to give as much as the other has asked for, even though it might strain their own budget. Under normal economic circumstances the system generally provides a sufficient safety net. However, for those who are salaried, it is almost impossible to accumulate wealth or save any money within this framework. Indeed, it is a common derogatory stereotype that the Damara are allegedly incapable of economising, budgeting or saving. Such suggestions are arguably inappropriate given that the effective norm of reciprocity represents an unequalled social security and redistribution system for any future needs in the absence of higher levels of economic independence and security.

Economic potential

B136. Although the majority of households in Uis depend directly or indirectly on income generated from residents working in the civil service, the relatively high standard of infrastructure, facilities and well functioning community represent an exceptionally good environment for potential economic growth. At present this potential is being awakened through tourism and the development of IMCOR Township as a retirement location, manifest in the tripling of house prices there in the last four years. Nevertheless, apart from marginal indirect gains, the beneficiaries of this economic regeneration have largely been the residents of

IMCOR Township, while Lokasie's residents continue to suffer from underemployment and low income.

Key potential socio-economic impacts

B137. A limitation to the provision of a fully comprehensive and robust assessment of the socio-economic impacts of the waste utilisation project is the evolving nature of the proposal itself. There are a number of potential agencies with an interest in developing the scheme and an even greater number of alternative strategies to implement and manage the waste project. As a result, any predictive assessment has to be based on general assumptions about the likely development of mine waste utilisation at Uis.

Impact 1 Inward migration

B138. Given the limited size of a project to exploit the waste at Uis, and the size of the latent indigenous pool of labour, it is unlikely that the project will have a highly significant migratory pull effect within the region and therefore on the demographic or ethnic community profile or social organisation of Uis. However, the level of migration and associated socio-economic impacts is difficult to predict with confidence since it depends on the state of the regional economy at the time, and the proportion of those migrants who can be provided with employment. The level of migration also depends on the degree of accuracy and the scope of project-associated rumours. Dr Ankre Kuper states (Kuper, 1994) that in 1992, exaggerated rumours suggesting the creation of over 350 new jobs at the small tantalite mine started north of the Brandberg, led to the inward migration of up to one thousand people seeking work opportunities there. Nevertheless, on balance, it can be predicted that migration will not happen to the sustained extent that it causes any significant long-term strain to Uis's infrastructure, services and utilities or its cultural and social identity and cohesion.

Impact 2 Employment opportunities

B139. The development of a processing plant at Uis for the mine waste would result in the employment of approximately 80 low/semi-skilled workers, and up to 20 skilled workers. During construction, the employment numbers could exceed 50% of this figure again. In a town suffering debilitating unemployment and underemployment this represents an extremely significant positive social and economic impact. Moreover, within the context of an underdeveloped region such as Erongo, the potential for 'spin-off' employment (e.g. such as domestic service provision etc) is very high. As such, a direct: indirect employment ratio in excess of 1:4 can be assumed, bringing potential aggregate employment at operation to over four hundred.

Impact 3 Local economic security

B140. Similar development projects, including the garden project at Okombahe and, arguably, the current micro-scale-mining project for tin-tantalum at Uis, have failed to fulfil their potential with respect to sustained local economic and social security, and there is a strong need for positive development projects for Omaruru's communities. If a waste utilisation project were able to generate significant profits and these were reinvested into the community, and if the project mainly utilised local human and economic resources, it has the potential to provide significant socio-economic security and sustainability benefits. These benefits would not just enhance the security of those directly engaged with the project but Uis generally as the income and revenue filter down through family and friends and upward to the support and maintenance of public schools, clinics, utilities, infrastructure and services.

Impact 4 Tourism

B141. Although mining has traditionally been the most important industry in Namibia, it has since been superseded by wildlife tourism and it is therefore important that any potential for harming tourism in the area is considered. Given that the boundaries of the Brandberg National Monument Area have recently been extended and are currently under review for status as a World Heritage area protected by UNESCO, this consideration is particularly important. Ironically, the main threat of counterproductive social and economic impacts on tourism posed by mining and processing to reduce the waste relates to the depletion of the waste tip. If not a direct tourist attraction, the mountain of stark white mine waste is the most distinguishing feature of Uis and a talking point for tourists.

B142. Against this, the main reason for tourists to stop in Uis is to break their onward journey, with the guesthouses and bars of IMCOR Township being the main benefactors of these, largely European, transitory tourists whose average stay is just two hours. Moreover, any depletion in the size of the waste tip and the commensurate level of interest shown by tourists could be more than offset by the potential for the waste project itself to attract visitors. A mine waste utilisation project could act as a particularly marketable tool for tourism in Uis if it were presented and promoted among the numerous ecological tourism groups visiting Namibia with an interest in sustainable development. Given the town's proximity to the Brandberg, and the nature of tourism in Namibia there is enormous potential for the residents of Uis to harness and exploit the scheme as a major Eco-tourism attraction.

Impact 5 Visual health

B143. The waste dump at Uis is said to be the primary source of an above average incidence of eye infections in the locality when compared to the rest of the region. This is due to the fine mineral dust from the large tailings tips. Because of its pale colour and reflective nature, the waste dump is also thought to be the cause of a higher than average incidence of a condition known as Labrador Keratitis which is caused by prolonged direct and indirect exposure to the sun's glare. The development of this condition is enhanced by exposure of the eye to fine particulates such as those that constitute the waste tip. The situation is particularly problematic for the residents of Lokasie since they are down stream of the district's predominant westerly wind. If a successful market could be established, it is estimated that around 50% of the waste material could be utilised. In the long term, such depletion of the waste tip is likely to lead to a significant reduction in the incidence of eye infections and the potential for Labrador Keratitis.

Impact 6 Respiratory health

B144. Atmospheric dust caused by mining and related activities has the affect of raising the incidence of respiratory infections such as tuberculosis in neighbouring communities. Much of this dust is composed of silica which has its own brand of pneumoconiosis in the form of silicosis (SGS, 1996). The fine size of the waste particles and the large scale of the tailings tips make, the waste at Uis the primary source of an above average incidence of respiratory infection in the locality when compared to the rest of the region. However, unlike the situation with eye infection levels, the depletion of this waste by up to 50% in the longer-term will not necessarily lead to a reduction in respiratory infection. Indeed, the opposite could prove to be the case. This is because, after processing, the remaining waste would contain a greater proportion of quartz and silica — key elements responsible for silicosis of the lungs. Moreover, the proposed project will entail the processing and transportation of the waste, which increases the propensity for particulates to become airborne and inhaled.

Impact 7 Road mobility and safety

B145. During construction of any mining and processing facilities for the waste there will be a significant rise in vehicular movement around the site and subsequently, during operation, between the site and Walvis Bay, where the waste material will exported. Because Lokasie and Imcor Township reside on trunk roads at least a kilometre either side of the site, this increased traffic movement is not anticipated to directly affect the safety of the vast majority of Uis's population. The people most affected by these heavy vehicles are those residents of Lokasie who lack vehicles and work in, or depend on services in, Imcor Township. Apart from the occasional lift by car or cart and horse they rely on foot to make this journey. Although the journey is relatively safe because of the straightness of the road, there are no designated pedestrian paths and neither are there any road markings or lighting. These factors will mean that an increase in truck movement will marginally increase the risk of accidents. Given the infrequency of the bus service between Uis and Walvis Bay (one a week), the small risk increase is arguably offset by an increase in mobility and access to Walvis Bay if truck drivers are amenable to Uis's customary provision of lifts.

Impact 8 Crime and prostitution

B146. Resource development projects in underdeveloped areas such as a waste utilisation scheme at Uis have the potential to create elements of what is called a 'boomtown' scenario. In particular, this scenario is characterised by increased levels of crime, violence, prostitution and drug and alcohol abuse largely symptomatic of the newly acquired and large disposable incomes of project workers and their financial disparity with those other residents within the locality. In time, as incomes and revenue filter through the entirety of the local economy a more balanced state of affairs is reached. And given that a waste utilisation project is likely to be relatively small there is not anticipated to be a large 'boomtown' effect. Nevertheless, levels of relative, rather than absolute, poverty will be heightened in the short-term and, as a result, Uis can probably expect a small increase in levels of crime and drug and alcohol abuse in the first few years.

B147. The major potential problem, as a result of increased numbers of a relatively affluent and predominantly male workforce, however, will be that of rising levels of formal and informal prostitution. More specifically, the underlying potential problem is of further perpetuating the already rapidly rising levels of sexually transmitted disease, including AIDS, that threaten the Erongo, Namibia and Africa in general. The issue of sexual health will be particularly predominant among any migrant workers, who are more likely to be single or distanced from their wives and families for prolonged periods of time.

CONCLUSIONS AND RECOMMENDATIONS

Technical assessment

B148. The former large-scale tin mine at Uis, worked a series of feldspathic pegmatite ore-bodies and the derelict mine site is now marked by substantial waste tips containing coarse grained tailings and several dry lagoons filled with fine tailings.

B149. The tailings from both tips and lagoons contain a mixture of minerals, three of which were assessed for their potential for use as industrial mineral by-products; alkali feldspar, muscovite mica and quartz.

B150. Testwork has shown that these mineral components are relatively free of impurities and are similar in composition to those used commercially. However, mineral processing has shown that only two industrial-grade products would probably be worthwhile extracting from the tailings. Using a simple dry screening and air classification process, muscovite mica and a mixed quartz-feldspar by-product (known commercially as 'Silspar') could be effectively separated from the waste.

B151. A tantalite concentrate produced by a current small-scale separation plant at Uis is of poor quality; it has a low tantalite content and it is contaminated with garnet, cassiterite and other minerals. Screening of the concentrate, followed by gravity and magnetic separation of the size fractions should improve the quality of the tantalite produced and concentrates containing 90 to 95% tantalite should easily be achieved.

Economic assessment

B152. The laboratory evaluation has shown that a feldspar concentrate containing some quartz (silspar) and a pure mica concentrate can be produced from the waste at Uis. Both minerals are internationally traded commodities.

Table 12B Impact matrix for waste utilisation project at Uis Mine, Namibia.

Impact	1	2	3	4	5	6	7	8
Directionality	-	+	+	+	+	-	-	-
Certainty	H	H	M	M	M	M	H	M
Significance	L/M	H	H	M	M	M	L	H
Chronicity	C,O	C,O	O,P	O	O,P	O	C,O	C,O
Locality	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL
Mitigability	H	NA	NA	NA	NA	NA	H	M
Cumulativity	H	H	H	H	L	L	L	H

Key

+	Positive	N	Negligible
-	Negative	NA	Not Applicable
H	High	C	Construction
M	Medium	O	Operation
L	Low	P	Post Operation

Feldspar (silspar)

B153. The world production of feldspar is around nine million tonnes, and major uses are in glass manufacture and ceramics. As there is no glass or ceramic industry in Namibia, the potential markets for a product from Uis are likely to be in nearby South Africa or elsewhere. The feldspars in South Africa occur mostly in the north of the country, and production from Uis would have to compete with this. An international market for feldspar from Uis, other than to South Africa, would require transporting the product to Walvis Bay, followed by shipment in bulk.

B154. The financial appraisal for the production of a feldspar product from the waste at Uis considered both the option of a large-scale, high technology approach requiring a major capital investment and a much smaller scale artisanal venture. The financial model used to assess the former indicated that such a venture would be profitable. A stable, long term export market would be required, and Uis would become a significant world producer of feldspar. The second appraisal, based on a low volume, lower capital cost plant and producing a lower quality product, indicates that either a small loss or a small profit is likely. The lifetime of such an operation is effectively infinite but financially it would remain sub-marginal throughout.

Mica

B155. The world production of mica in recent years has been around 250 000–280 000 tonnes annually. There is no market for mica in Namibia. South Africa produces around 1 500 tonnes of mica annually. Supplies from Uis to South Africa would compete with that countries indigenous resources, but transport costs would be comparable, as South Africa's resources are in the north of the country.

B155. The technical evaluation showed that mica makes up a small amount of the waste at Uis (1%). The financial models considered, based on a high technology approach and a small-scale artisanal model, showed that the high technology approach for producing both feldspar and mica products is likely to be highly profitable. Thus, there is a significant benefit in recovering mica as a co-product with feldspar, and the cost of additional processing is justified. A small-scale venture for recovering both feldspar and mica is also likely to be profitable, but at a much lower level. Such a venture would remain on the margins of profitability throughout its operating life.

Social and environmental assessment

B156. During field investigations, the attitude of all those consulted in Uis to a waste utilisation project was almost unreservedly positive. To dissuade a large influx of migrants seeking work or unnecessary high levels of speculation that could have damaging effects on Uis, it is essential that expectations of the project be effectively managed.

B157. A policy of local employment prioritisation would also help to allay any risk of large-scale speculative migration and have the important additional benefit of containing and maintaining a critical mass of investment in the local economy. The local economy could further profit from, and at the same time negate any risk of loss in, its tourism potential by actively promoting the project to Namibia's eco-tourists. Once marketed, the project could be capitalised on by *all* in the community through the selling to visitors of locally made clothes and souvenirs, for example. However, in the future, the undesirable effects of current gem selling practice, which 'overwhelms tourists... and happens in an undisciplined and intimidating fashion' (UVC, 2000) will need to be avoided. The village council has moved to rectify the situation by proposing to formalise selling to tourists. A waste utilisation project will reduce the need for laissez fair selling and support any formalisation measures by alleviating levels of poverty and economic urgency.

B158. The processing of the waste material will render the residue proportionally higher in quartz and silica — key elements responsible for silicosis of the lungs, and its transportation will increase the propensity for residue particulates to become airborne and inhaled. Those most vulnerable to exposure will be workers processing and transporting the waste material and it is recommended that they are instructed to wear a dust mask when in proximity to the material. The exposure of Uis residents to airborne particulates from the processed and transported material could be significantly reduced by ensuring all container trucks are covered and access roads to the site and the site itself are watered. In addition to these measures, there is a need to assist and support the local clinic in regularly and carefully monitoring the incidence of respiratory infection.

B159. Finally, in addition to prioritising the hiring and training of local workers for employment on a waste utilisation project, there are a number of other procedural and policy measures that should be adopted by the project agency to help mitigate some negative socio-economic impacts. In relation to transport safety, it is suggested that the speed of vehicles is restricted within a one-kilometre radius of the site. In the interest of local mobility and access needs, it is suggested that truck drivers are encouraged to provide lifts to local residents where it does not jeopardise or hinder the safe or efficient delivery of the waste material. Lastly, in order to minimise the risk of a 'boomtown' scenario, the project agency should provide an education programme in community citizenship, responsible budgeting and AIDS awareness prior to project commencement.

Case Study C Rosh Pinah Mine, Karas Province, Namibia

DESCRIPTION OF THE SITE

C1. The Rosh Pinah mine was established in 1969 and produces some 73 000 tonnes per annum of zinc concentrate and 25 000 tonnes per annum of lead concentrate. The zinc is mostly exported to the Zincor smelter in Gauteng, South Africa. When the mine initiated its operations in 1968, it had an eight-year life span. In July 1997 additional reserves were found and its life span was increased again by 12 years.

C2. The mine is located (Figure C1)about 20 km north of the Orange River (which forms the southern border of Namibia) and about 165 km south of the small town of Aus, which is also the nearest railhead. Rosh Pinah is also about 25 km south of the new zinc mine and refinery currently being developed at Skorpion.

C3. The ore deposit upon which the mine depends is located within the Rosh Pinah Formation. The formation consists of a complex sequence of volcanic and sedimentary rocks. A date of 720 million years has been obtained for the volcanic rocks. The lead-zinc ore is hosted within a variable sequence of sedimentary rocks including quartzites and dolomites. The ore consists of a range of sulphide minerals including sphalerite (zinc sulphide) and galena (lead sulphide). These are often associated with barium-rich minerals such as barytes (barium sulphate) and witherite (barium carbonate).

C4. Primary crushing of the ore is carried out underground prior to transport to the surface for further crushing and milling. Lead and zinc sulphide minerals are then separated from the milled material by a series of froth flotation operations. The concentrates are sun-dried prior to transport by road to the railhead at Aus. The flotation tailings are pumped in slurry form to a large waste heap immediately south of the main mine site.

TECHNICAL ASSESSMENT

Waste sampling

C5. Spot samples were collected from the dry top surface of the tailings in June, 2000 (BN6; 1.3 kg and BN7; 1.4 kg). A further twenty samples were then collected as part of a programme of auger drilling of the tailings heap and represent the waste material at various depths within the heap. A full sample list is given in Table 1, Appendix 3.

Waste evaluation

C6. The laboratory evaluation of the tailings from Rosh Pinah has focused upon their potential as a source of drilling fluid-grade barytes. Both basic and detailed characterisation methodologies were followed (as outlined in the Uis Mine case study and Appendix 4). Laboratory scale mineral processing was carried out in an attempt to concentrate any barytes. Heavy media separation was chosen, as barytes is a dense mineral (4.5 g/cm^3) and can be separated from most of the other minerals in the mine waste (which have a density in the range 2.6 to 2.9 g/cm^3). The products were analysed by XRD. More detailed methodological information is given in Appendix 4.

Characterisation

C7. The samples from the tailings heap consist mainly of dolomite, quartz and K-feldspar, with sulphide minerals (pyrite, sphalerite and galena) and a small amount of barium minerals (barytes, norsethite, celsian and witherite?), apatite, calcite, gypsum and anhydrite. The samples from the drilling programme contain a similar mineral assemblage. The chemical analyses confirm the observed mineralogy of the samples (Appendix 3: Tables 2, 5 and 6), however the samples from the drilling programme have a significantly higher barium content (3.6 to 7.8% BaO) than the surface spot samples (1.1% BaO). This is probably due to the different depths at which the samples were obtained. The spot samples came from the surface of the slimes dam, which represents tailings from the processing of more recently mined material, recognised to be lower in barium-bearing minerals. The samples from the drilling programme came from tailings deeper within the heap and therefore represent older mined material which was thought to have a higher content of barium minerals. Individual minerals occur as follows:

Mineralogy

Dolomite Relatively coarse-grained discrete grains, up to 200 µm in diameter. Also in the fine-grained matrix as silt-grade material, <63 µm in diameter (Figure C2).

Quartz 'Clean' discrete grains with a lack of inclusions, staining or grain coatings (Figure C2). The particles are typically sub-angular to sub-rounded in shape. They are mainly 100 to 200 µm in diameter with the remainder down to silt size (2–63 µm) material.

K-feldspar Appears to occur mainly in the silt grade fraction (associated with dolomite).

Mica Occasional discrete flakes typically 100 µm long.

Sulphate minerals Rare barytes grains, typically 20 to 50 µm in diameter, are found in association with dolomite, K-feldspar, pyrite and quartz. Gypsum typically occurs as discrete lath-like/tabular crystals and also as interstitial/cementing material associated with quartz, pyrite and dolomite (Figure C3). The chemical composition of the barytes is summarised in Table 1C (and is given in full in Appendix 2: Table 5).

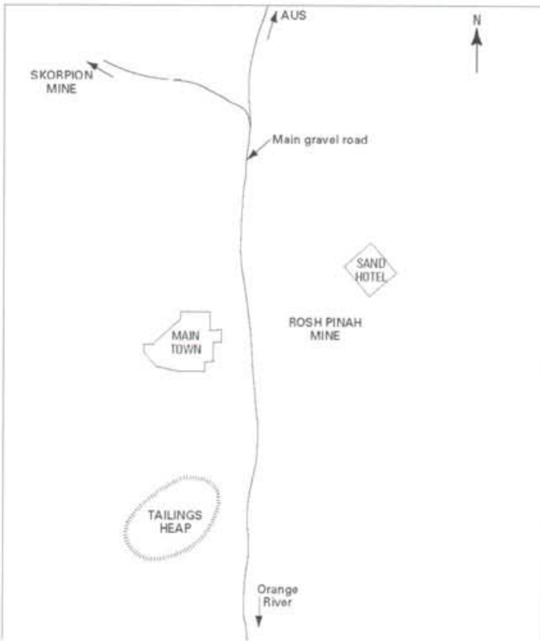
Opaque minerals Pyrite, sphalerite and galena occur as particles ranging in size from 100 to <50 µm in diameter, average size approximately 50 µm.

Particle-size distribution

C8. The spot samples are fine-grained with 60% of the material finer than 75 µm and less than 3% coarser than

Figure C1 Location of the Rosh Pinah case study site.

Sketch map showing relationship between mine, waste and settlements at Rosh Pinah.



250 μm. The auger drill samples are slightly finer as they contain 62 to 74% finer than 75 μm (Appendix 3; Tables 4 and 7).

Heavy media separation

C9. The heavy mineral content of the auger drill samples is 20 to 29%; this breaks down into 14 to 25% in the density range 2.9 to 3.3 g/cm^3 and 5 to 9% denser than 3.3 g/cm^3 (Appendix 3; Table 7). The less-dense fraction (<2.9 g/cm^3) consists mainly of quartz and dolomite (with a small proportion of dark coloured grains occurring as inclusions). The intermediate density fraction (2.9–3.3 g/cm^3) consists mainly of dolomite with a trace amount of sphalerite, pyrite, galena, barytes, norsethite ($BaMg(CO_3)_2$), quartz and K-feldspar. The heaviest fraction (>3.3 g/cm^3) consists mainly of pyrite, sphalerite and norsethite, with minor amounts of galena and barytes and trace amounts of dolomite, quartz, calcite and K-feldspar. Less-dense minerals, such as feldspar, quartz, dolomite and calcite, report to the dense fractions even though their respective specific gravities are lower than the density of the heavy media used. This is due to the presence of dense mineral inclusions which increases the density of the particles and causes them to sink in the heavy media.

Potential of the waste as a source of barytes

C10. The barium (BaO) content of the spot samples is approximately 1%, and the content of the auger drill samples is 4 to 8% (average 5%). The barium content of the

Table 1C Summary of barytes composition, Rosh Pinah Mine, Namibia.

SiO_2 Wt %	Mn_3O_4 Wt %	ZnO Wt %	PbO Wt %	BaO Wt %	SO_3 Wt %
0.36	0.56	0.87	0.39	64.57	32.46

NB Average of 3 electron probe microanalyses

Rosh Pinah mine.

Trench in tailings reveals layers which appear to vary in composition.

Zinc ore is concentrated by froth flotation.

Top of tailings heap with Rosh Pinah mine in background.

Flotation tailings slurry is discharged onto heap via a pipeline.

Dunes formed from fine tailings on top of heap as a result of reworking by wind.

tailings is not solely attributable to barytes as other barium-rich minerals also occur (such as norsethite, celsian and witherite). The densest products (>3.3 g/cm^3) from heavy media separation contain 20 to 50% barytes, the intermediate density products (2.9–3.3 g/cm^3) contain up to 7% and the less-dense products (<2.9 g/cm^3) are assumed to be free of barytes.

C11. It is therefore estimated that the barytes content in the samples ranges from a minimum of 3% to a maximum of 16% (which is equivalent to 2 to 11% BaO). Taking into account the BaO content determined by chemical analysis (8%; equivalent to 12% barytes) and the presence of other barium-rich minerals it is estimated that the barytes content in the tailings samples is approximately 5%.

C12. This is a low concentration and these results (based on a limited number of samples) suggest that the waste at Rosh Pinah is unlikely to be a source of barytes raw material.

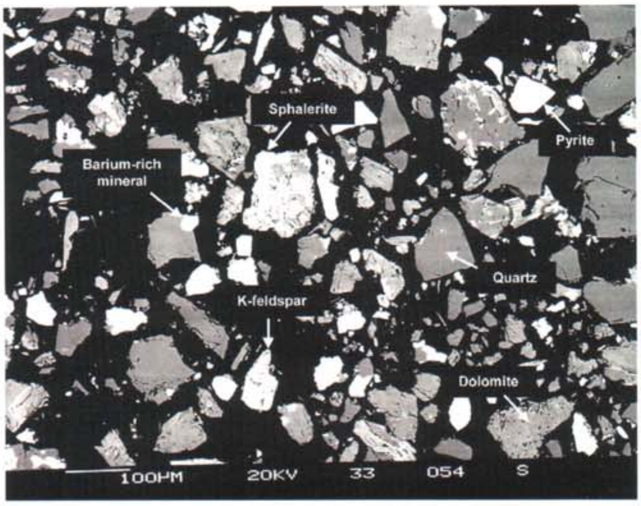


Figure C2 SEM photomicrograph of tailings sample (BN6), Rosh Pinah, Namibia. The larger grains (>100 µm) are quartz (darker grey) and dolomite (mottled dark-paler grey). The remainder is finer grained quartz, dolomite, sulphide minerals (pyrite and sphalerite) and occasional grains of barium-rich minerals.

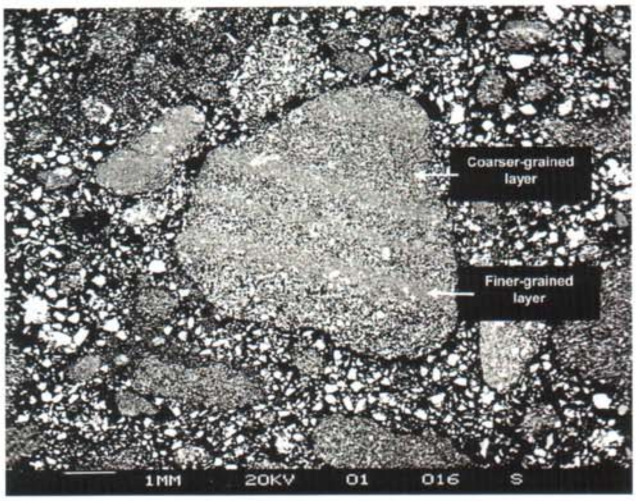


Figure C4 SEM (scanning electron microscope) photomicrograph of tailings sample (BN7), Rosh Pinah, Namibia. The aggregate particle displays layers of finer and coarser grained grains (which probably formed during deposition of the tailings).

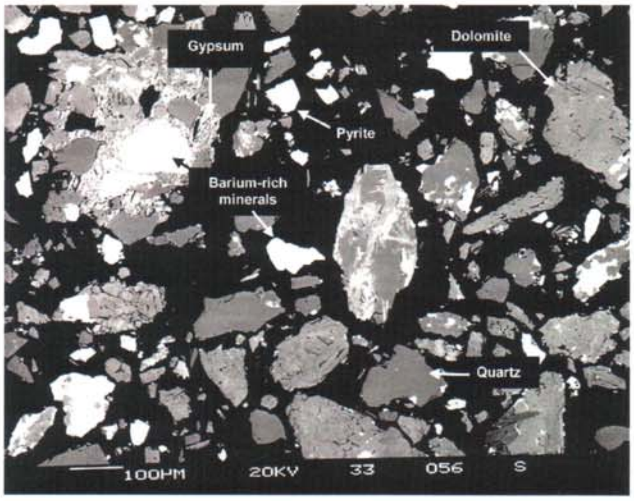


Figure C3 SEM photomicrograph of tailings sample (BN6), Rosh Pinah, Namibia. The larger grains are quartz (darker grey) and dolomite (mottled dark-paler grey). The remainder is finer grained quartz, dolomite, sulphide minerals (pyrite and sphalerite) and occasional grains of barium-rich minerals. Note the barium rich minerals in a gypsum matrix in top left-hand corner.

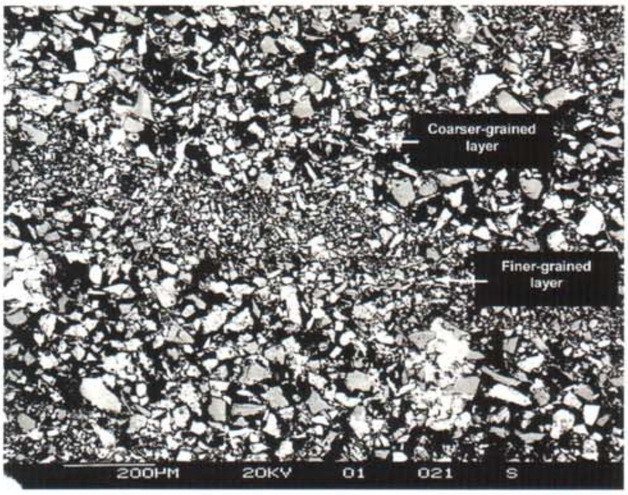


Figure C5 SEM (scanning electron microscope) photomicrograph of tailings sample (BN7), Rosh Pinah, Namibia. This is a close up of the aggregate particle in Figure C4. The coarser layer consists of quartz and dolomite. The finer grained layer also consists of quartz and dolomite with a higher proportion of mica.

ECONOMIC ASSESSMENT

C13. The waste from the lead/zinc mining operation at Rosh Pinah is contained in a very large engineered heap. The heap contains several million tonnes of waste and continues to accumulate. The economic assessment has involved investigating the markets for barytes, and making a financial assessment based on an assumption that significant recoverable barytes is present in the waste. General sources of information are listed in Tables 1 and 2 of Appendix 5, and these, along with specific statistical data obtained from local sources in Namibia and South Africa, have been used in the assessment. The principal market for barytes is as a component of oil-well drilling fluids. Transport costs are a significant factor in making a financial appraisal.

Market study

C14. The recent world production of barytes is around 6.5 million tonnes annually (U.S. Geological Survey 2002). Its major use is in oil and gas well drilling, where it is a constituent of the fluid, known as mud. Around 90% of the world's production is used for this purpose (Harben and Kusvart, 1996; U.S. Geological Survey 2002). The demand and supply of barytes is governed by the extent of oil and gas exploration, which in turn reflects the price of these commodities. Barytes is used as a weighting agent to increase the density of the mud (Brobst, 1994; Harben, 1995). A further use is in a finely ground form as a mineral filler. Its powder is white and addition to paints, rubber and plastics increases their density. A minor use is as a component in some glasses. Lump barytes is used in concrete to provide an increase in density and as a nuclear shield. Barytes is a source for barium chemicals and barium based ceramics.

C15. The specification for barytes as a drilling mud component is dictated by the oil companies and is given in Appendix 3, Table 9. It is crushed so that 95% is <45 µm in size. The minimum density of 4.2 g/cm^3 is critical. There are many different specifications for barytes used as a filler (see Harben, 1995). All require the mineral to be finely pulverised and white or off-white. The barytes content has to be high (>92%) and in high quality grades it is >98% $BaSO_4$ and very white with a brightness >90%. Colouring components such as iron oxides need to be very low in amounts (<0.04% Fe_2O_3).

C16. Barytes occurs in many parts of the world as vein and cavity filling deposits, as bedded deposits and sometimes as residual deposits formed from the weathering of the others. Production is dominated by China (Appendix 3, Table 10) which provides more than 50% of the world's consumption. There is considerable international trade in the mineral with the major consuming countries obviously being those with significant oil and gas production. The United States is a major consumer of barytes and, for example, imported nearly two million tonnes from China in 1999 (U.S. Geological Survey 2002). Barytes for use in drilling muds is a relatively cheap commodity, prices being around $40–60 per tonne FOB in bulk (Appendix 3, Table 11). The much higher prices of ground and micronised grades reflects both an increase in purity of the product and the cost of processing.

C17. The potential sales of any barytes produced from Rosh Pinah in Namibia would be into adjacent South Africa or in off-shore drilling in Namibia. The remote location of Rosh Pinah and the low grade of the raw material would mean that cost of production would be high, which would most likely prevent it from being marketed internationally for drilling muds. Details of South African production and trade in barytes are given in Appendix 3, Table 12. The data show that production is variable, and that South Africa is an importer of the mineral. Thus, a supply nearby would probably find a market.

Economic assessment of waste processing

C18. The lead-zinc mine at Rosh Pinah has a tailings pond ('slimes dam') which contains some 18 Mt of fine-grained dry waste. Preliminary investigations indicate the presence of barytes in small quantities. A financial model has been developed to assess the economic viability of recovering that product. The results of the preliminary evaluation of that model are shown in Table 2C. Factors used in that evaluation are given below:

Details of waste resource

C19. It is assumed that the total volume of the tailings pond will be reworked. As a result the size of the deposit is 18 Mt. The percentage of useable material is 5%. This represents the estimated barytes content of the tailings material.

Details of proposed mining method

C20. Mining extraction is assumed to include all of the available material. Of this volume, it is thought that a dilution of 3% could be expected from a hydraulic mining system. The processing system will not recover 100% of the target mineral and an efficiency of 64% is anticipated. Operations are expected to work throughout the year with minimal stoppages and a maximum operating period of 350 days/year has been used.

Financial details

C21. A selling price of $90/t has been taken to represent the best ex-works price that could be obtained in the locality. Transport charges will be a significant factor in the determination of the delivered price of the barytes product. C22. Mining investments are generally considered as high risk and a 22% repayment rate has been included in the calculations. The capital costs are expected to be high and loan repayments will be required in a short timeframe.

C23. Average corporation tax in Namibia is 30% and has been incorporated into the calculation. Again, it is thought that royalty payments would not be relevant for the reasons given previously.

Capital cost estimation

C24. The separation of barytes from the other heavy medium and barium rich minerals will require sophisticated processing techniques. The cost of providing this facility is considerable and a total capital cost of over $13 M has been allowed. This is based upon costs of similar facilities in Western Europe.

Operating costs

C25. Whilst the costs of mining will be low ($0.50/t), the milling costs will be high ($6.5/t). This reflects the technical difficulty and expertise needed in controlling the process flow through the plant. General maintenance and supervision costs are also included at a nominal rate of $30 000/year and contribute to an additional variable cost of $0.40/t.

Financial results

C26. The results show that the huge capital cost and operating costs involved in recovering such a low percentage (5%) of product do not justify the investment required. The most favourable net present value would indicate a loss of -US$14M and at the optimum rate of 500 t/day this would take 80 years to complete. It may of course be possible to re-utilise some of the existing processing equipment when the underground mining operations cease. In addition there may be other products within the tailings pond which could be recovered. In the first case the initial capital costs may be lowered and in the second case the operating costs may be spread over a larger product range.

SOCIAL IMPACT ASSESSMENT (SIA)

C27. The main objective of the SIA was to identify and predict the potential social impacts of utilising mine waste from Rosh Pinah, and a further objective was to make recommendations to mitigate negative and enhance positive potential socio-economic impacts of any waste utilisation.

Table 2C Rosh Pinah financial model.

ROSH PINAH

Best N.P.V.	-14333496	$
Best Production rate	100.04425	t/day

Details of Waste Resource			
size of deposit	s of d	18000000	tonnes
% useable mineral	ag	5	%

Details of Proposed Mining Method			
Mining extraction	M ex	100	%
Dilution	Di	3	%
Mill recovery	M r	64	%
Operating days/year	op	350	days

Financial details			
Selling Price	price	90	$/tonne
Cost of capital	c of c	22	%
Taxation rate	Tr	30	% of previous years taxable profit
Royalties	Ry	0	%

Limits		
maximum tonnage milled	3000	t/day
minimum tonnage milled	100	t/day
number of runs	9604	

CAPITAL COSTS ($)	
Extraction site development	10000
Site preparation	20000
Crushing	0
Processing	11500000
Water supply	0
Tailings disposal	0
Electricity supply	20000
Ancil. Buildings	1000000
Access road etc	20000
Engineering	400000
Admin. Costs	200000
TOTAL CAP COST	13170000

OPERATING COSTS ($)		
Operation	Fixed (year)	Variable (t)
Mining	35000	0.5
Milling	50000	6.5
General	30000	0.4
TOTAL	115000	7.4

Section 2

Tonnes milled	Tm	2699.724365	t per/day
Total tonnage mined		18540000	tonnes
Full years milled tonnes		944903.5278	tonnes
Head grade		4.854368932	%

Annual o/c	7107286.1	$/year
Revenue	2642060.3	$/year

Mine life	6867.367735	days
	19.62105067	years

C28. The methodology used followed the SIA principles, procedures and methods given in Appendix 6.

C29. Data for the SIA have been acquired from published literature and reports and a visit to Rosh Pinah mine. Interviews were conducted and observations made. This enabled the existing socio-economic conditions to be identified and mitigation to be suggested.

Regional context

C30. The Karas region is the largest regional area in Namibia with a population of 61 000. It comprises the magisterial districts of Luderitz, Keetmanshoop and Karasburg with the regional government based in Keetmanshoop. Mining is the economically most significant activity and the largest employer in the region, accounting for the direct employment of just over one-quarter of Karas's economically active population. This includes diamond mining along the Orange River and up the coast to Luderitz as well as lead and zinc mining at Rosh Pinah and small-scale gem mining throughout the region.

C31. With its relatively affluent mining areas such as Luderitz, Keetmanshoop and Oranjemund, Karas is the second richest region in Namibia. However, this statistic masks the inequitable distribution of wealth in the region, and, in particular, the plight of the Karas region's subsistence farmers and farm labourers who earn as little as N$100 per month. Therefore, despite the economic significance of the mining sector, the Karas region as a whole is poor and underdeveloped with 21% of its economically active population of 28 000 remaining unemployed and a larger proportion underemployed.

C32. The aridity of the region is one the main constraints on economic and, particularly, agricultural development in the region. The karakul market crash in the early 1980s compounded this impediment to agricultural growth as many farmers in the region were bankrupted, with a devastating subsequent impact on farm labour employment. The scale of farm labour retrenchments is an important factor underpinning the number of informal settlements on the outskirts of villages and towns. Remaining farms concentrate on the rearing of stock such as sheep and goats, with an average of 50–70 cattle per farm.

C33. Tourism in the Karas region is focused in and around Luderitz and Kolmanskop, the Huns/Ais-Ais Nature Reserve and Fish River Canyon. Rafting occurs from Noordoewer on the Orange River to the confluence with Fish River. In order to take advantage of the actual and perceived work opportunities there is a small but significant movement of people southwards within the region and nationally. They have been drawn to tourist developments such as a new hotel constructed at Luderitz, recent farming developments at Aussenkeur and the Haib and the proposed Skorpion mine near Rosh Pinah.

C34. Traditionally, the mines of southern Namibia have recruited their waged workers from the north, usually on short-term six-month contracts. As the nature of mining changes and becomes progressively more skilled, there has been a trend towards providing the more highly skilled or senior workers with permanent positions and the supply of family accommodation and benefits. As a result, even though the majority of mine labourers still live in single-sex hostels, a growing number are establishing their homes in the south

Economic environment

C35. Rosh Pinah was built to house employees of the ISCOR owned lead-zinc mine Imcor Tin Ltd. The land on which Rosh Pinah is developed belongs to the government but is managed by Imcor Tin Ltd as part of the company's mining grant.

C36. The mine employs some 410 people, of whom 93.4% are Namibian, and 6.6% are South African. Just over half (54%) of the workforce is recruited from the Northern region, with most of the remainder (34%) from Nama-speakers in the south, while 5% are recruited from the Central region. With the exception of a few professionals like teachers and nurses and a small number of women employed as clerical, administrative or cleaning staff, the vast majority of employees are men in the 31–50 age group. It is estimated that fifty market ('cuca') shops provide informal employment. They sell a range of goods and services, but are largely associated with the provision of alcohol and prostitutes.

C37. The business of Rosh Pinah is mining and financially, if the mine were to close, so too would the settlement itself as all economic activity is focused on the needs of the mine and its employees with their total expenditure on goods and services accounting for around $1 million per annum. The geographical isolation of Rosh Pinah ensures the minimum of economic influence from other towns or economic systems. As such, the nature and extent of Rosh Pinah's economy and of investment in the village reflects the performance of the company and the perceived life span of the mine, at any point in time.

C38. Imcor Tin mine management is pursuing the proclamation of Rosh Pinah as a town and it is expected that the proposed Skorpion mining development nearby will reinforce this intention. The proposed proclamation of the village as a town may have merit given its longer-term prospects, but any attempts to try and separate the economy of the town from the local mine, given its dependence, is considered to be futile while those mines are in operation. Table 3C provides a synopsis of the present infrastructure available at the village.

C39. The land west of Rosh Pinah, called the Sperrgebiet, is principally a diamond mining area that has restricted access and has remained largely undisturbed for the last 80 years except for emergency stock grazing during droughts. Farms near Rosh Pinah are run primarily for hunting, and tourism is restricted to a limited niche market that is attracted to the apparent emptiness of the landscape and its unique geological and botanical features. The potential de-proclamation of the Sperrgebiet may also influence the economic activities at Rosh Pinah as tourism activities in the area could increase.

Social environment

C40. The total population of Rosh Pinah is between 1100 and 1500 people with Afrikaans followed by Ovambo being the language spoken by the majority of residents. Some 640 people live in the formal part of Rosh Pinah where the mine provides for all the housing and services for which residents pay a nominal rate. Housing and services at Rosh Pinah are accorded to employment grade based on the 'Patterson System'. Grade 8 employees and upward are provided spacious houses in the main town. Employees below grade 8 are provided with smaller houses in Bethel 1 and 2 and single sex dorms where most workers, especially the six-month contract staff, live. The mine's domestic staff are either accommodated in a room at their employer's house, or in the informal settlement known as 'Sand Hotel'. Mine guests, visitors and tourists stay at one of the mine's two guesthouses, which have been a combined total of 12 double rooms.

C41. An estimated 500–900 people live in the adjacent informal settlement of 'Sand Hotel'. There is an equal number of men to women in this population and an estimated 50 children. The male population of Sand Hotel is largely there to find contract work at the mine itself and can be observed queuing outside the contractor's office every morning. Sand Hotel has seen an increase in population since independence in 1990 that has probably been related to the retrenchments made by agriculture and to the proposed development of the nearby Skorpion mining project. There are no facilities at the Sand Hotel except for one standpipe for water and two streetlights and residents rely on paraffin or fuel wood purchased from the local shop. Given the positioning of Sand Hotel under the high power electricity line for the site and next to the traffic and rock piles of the mine there is some concern for the residents safety. Despite this, Sand Hotel's residents generally pride themselves on the settlement and it cleanliness and tidiness.

C42. There is no private property or individual freehold title in the formal settlement over which Imcor Tin exercises little control although officially people may only settle in Rosh Pinah with the permission of the mine. The residents of Sand Hotel have their own system of governance while the residents of the formal parts of Rosh Pinah are currently not represented in decision-making over the administration and development of the settlement or its costs which are governed by mine management. For several years, the mine management has considered the option of proclaiming Rosh Pinah a town. Stubenrauch Planning Consultants were recently appointed to investigate the viability and requirements of proclamation. Imcor Tin believes that the settlement is viable as a proclaimed town, regardless of the proposed development of Skorpion project.

C43. Table 3C gives a synopsis of the formal facilities and services currently available at the village of Rosh Pinah. Rosh Pinah's water supply is piped from the Orange River; the reticulation system is being upgraded and from January 1998 residents were charged for any water consumed above the CSIR benchmark of 75 m^3 per house per month. The rate was set at the average municipal tariff for towns in the Karas region. Formal settlements in Rosh Pinah are electrified. Banking services visit Rosh Pinah twice a week and the recent upgrade of the telecommunications network with fibre-optic cables will lead to the instalment of an automatic teller machine (ATM). There is a small post office that is already overburdened and cannot meet local demand for post boxes. A building has been allocated for a police station, and five police members are due to staff the office.

C44. Rosh Pinah residents have local access to a supermarket, take-away/café, home industries outlet, butchery, liquor store, petrol station, and a host of cuca shops. Many of Rosh Pinah's services like the guesthouses, catering and the supermarket are privatised and out-sourced. Groceries and vegetables are sourced almost exclusively from South

Table 3C Rosh Pinah infrastructure

Gravel roads	District roads to Aus or provincial to Noordoewer
Tarred roads	Some in the central village
Landing strip	Tarred
Closest rail head	Aus 165km away
Water supply	From the Orange River
Post office	One overburdened facility
Telecommunications	Upgraded to fibre optic

Table 4C Social infrastructure at Rosh Pinah.

Education	Crèche Mine primary school (grades 1-7) Secondary schools at Keetmanshoop and Springbok
Library	Available to residents of Rosh Pinah
Law and Order	Aus is the closest police station
Health facilities	Mine clinic Closest hospital at Oranjemund or Luderitz
Retail	Supermarket, takeaway, butcher, liquor store, market shops
Petrol stations	Petrol and diesel
Banking	First National once a week
Religion	Two church buildings
Guest accommodation	Twelve double rooms
Recreational facilities	Two social clubs Golf course Swimming pools, tennis and squash courts Soccer, cricket and jukskei

Africa, with just meat supplied locally. Liquor, television and sport are the focus of recreational activities. Apart from the two social clubs, the mine offers a range of sporting facilities including a golf course, swimming pools, tennis courts, squash courts and facilities for soccer, cricket, jukskei, volleyball, gym, snooker, etc.

C45. The mine's school, Hoeksteen Primary School, provides Grade 1 to Grade 7 classes to 100 pupils. The prefabricated building has several empty classrooms. A nearby crèche cares for between 20 and 25 children. Sand Hotel children are accommodated at both facilities. At present pupils from Rosh Pinah attend secondary schools primarily in Keetmanshoop and Springbok. Imcor Tin subsidises their boarding fees, and buses them back to Rosh Pinah once a fortnight.

C46. Rosh Pinah mine recently decided to start a programme, where people of the community could be trained in the basic skills of an occupation or trade. They are presently training ten people in brick making that will be followed by training in bricklaying. They hope to expand the training to other community members in welding, needlework and carpentry in the near future. The aim of the programme is to promote employment opportunities, income generation and the general social up-lifting of the community, in order to reduce unemployment and crime. Apart from the financial support of the initial capital investment by the mine, the programme is designed to be financially self-sustaining and is currently making a small profit that is reinvested in the programme (Rosh Pinah, 2000).

C47. A clinic is open every day, staffed by two nursing sisters, and visited once a week by a doctor from Luderitz. Those requiring hospitalisation are treated in Oranjemund, by means of a special arrangement with Namdeb. In cases where employees require emergency treatment, Rosh Pinah is able to use Namdeb's medical helicopter to airlift them to specialist care. The babies of mine staff, and their spouses, are generally born in Oranjemund where dental patients are also referred. At present, there are no state medical services available in Rosh Pinah. The nearest government clinics are in Aus and Noordoewer, each about 160 km away, and facilities in both are rudimentary. The nearest government hospital is over three hours away, in Luderitz or Keetmanshoop.

C48. Health issues in Rosh Pinah include a large number of dust related respiratory illnesses. The prevailing wind in Rosh Pinah is from the south-east, which means that the main housing settlement, together with the school and crèche, are downwind of the tailings dump, and suffer from high levels of dust on windy days. The tailings dump contains between 15 and 20 million tonnes of fine grained waste material and contributes to 'an above average' level of allergies and respiratory problems in the settlement. Quite apart from the nuisance factor associated with the dust, its composition is of some concern. Based on the findings of comparable zinc and lead mines, it is likely that the dust has a respirable fraction containing high levels of lead and zinc. Imcor Tin's management is investigating ways of managing the tailings dam more effectively. One of the proposed solutions, and the focus of the current investigations, involves the utilisation of at least some of the tailings material and the recovery of the saleable lead and zinc fractions.

C49. The other major health issue in Rosh Pinah generally, but particularly related to Sand Hotel, is that of AIDS. In Sand Hotel the senior nursing sister found over sixty adults to be HIV positive. There is escalation in the number of people known to be HIV positive and it is estimated that about 30% of the children of Sand Hotel are also now infected with AIDS. Some general treatment is available locally, but those who develop full-blown AIDS usually leave Rosh Pinah, to return to families or to places closer to better medical facilities. The medical officer serving Rosh Pinah believes that the proper treatment of AIDS patients could soon become Rosh Pinah's greatest medical challenge.

C50. The isolated nature of Rosh Pinah settlement has resulted in some social problems typical of small mining towns including a higher than average incidence of psychological pathology. In particular, most jobs, amenities, services and benefits in Rosh Pinah are aimed primarily at men with the result that there are a large number of unemployed or under-employed women. Women living in settlements whose needs for intellectual stimulation and social support are not met, who cannot find employment and who feel bored and frustrated, frequently suffer from high levels of stress or depression. Apparently, many of the resident families would benefit from the services of a marriage councillor and alcohol abuse is reputed to be a significant problem throughout the settlement. There is no resident social worker or counsellor in Rosh Pinah.

C51. ***Potential socio-economic impacts***

Impact 1 Inward Migration. Given the relative size of the employment potential at Rosh Pinah and at the planned Skorpion mine relative to a proposed waste utilisation project, it is unlikely that a proposed project will have a distinct migratory pull effect within the region. Nevertheless, migrants seeking work opportunities at Rosh Pinah and Anglo-American's Skorpion mine, adjacent to Rosh Pinah, make up the majority of people living in 'Sand Hotel' and this presents the biggest and most impending socio-economic challenge for the mine authorities. Therefore, any incremental impact on Rosh Pinah's infrastructure, services and utilities and, particularly, the health and sanitation of the makeshift dwellings of Sand Hotel, must be considered significant. Overall, the size and significance of migration and its incremental impact is difficult to confidently predict since it depends extensively on the accuracy and scope of any associated rumours, the state of the regional economy at the time, and the proportion of those migrants who can be provided with employment.

Impact 2 Employment Opportunities. If a viable waste utilisation project can be developed it will require the construction and operation of additional plant. It has been estimated that such an operation would demand the employment of approximately 80 low skilled and semi-skilled workers, and up to 20 skilled workers. During the construction stage, the employment numbers could be in excess of 50% of this figure again. In a site and region that is already suffering from unemployment and underemployment this represents an extremely significant positive social and economic impact. Moreover, within the context of an underdeveloped region such as Karas, the potential for 'spin-off' employment (e.g. such as domestic service provision etc.) is very high. As such, a direct: indirect employment ratio in excess of 1:4 can be confidently assumed. This would bring the potential operational aggregate employment to over four hundred, although only half this number would constitute employment, and therefore associated settlement, at Rosh Pinah itself.

Impact 3 Local Socio-economic Security. A project to utilise the mine waste could provide significant social and financial security and sustainability benefits. These benefits would not just be felt by those directly engaged with the project through gainful employment but for the community in general as the income and revenue filter down through family and friends and upward to the support and maintenance of public schools, clinics, utilities, infrastructure and services. If the proposed project generated significant profits these general benefits would be further enhanced if reinvested, as intended, into Rosh Pinah's community development project, the relocation and reconstruction of Sand Hotel and Rosh Pinah's proclamation as a town.

Impact 4 Sexual Health. Resource development projects in underdeveloped areas have the potential to create elements of what is called a 'boomtown' scenario. In particular, this scenario is characterised by increased levels of crime, violence, prostitution and drug and alcohol abuse, symptomatic of the relatively large disposable incomes of project workers and their financial disparity with indigenous residents possessing relatively little. Given the relatively small size of activities to utilise the waste and the resident population, and the relationship of those residents to a pre-existing mining project, the preconditions for such a scenario at Rosh Pinah are limited. Those most impacted by such a scenario stemming from the proposed mine waste utilisation project are the most socially and economically vulnerable residents of Sand Hotel. Most significantly, this will be in relation to rising levels of formal and informal prostitution and the further perpetuation of rapidly rising levels of sexually transmitted disease, including AIDS, that threaten the Rosh Pinah mine and Namibia in general. The issue of sexual health is particularly pertinent in Rosh Pinah, because of its extreme geographical isolation and therefore the predominance of people distanced from their wives and families for prolonged periods.

Impact 5 Respiratory and Visual Health. The tailings dump contains between 15 and 20 million tonnes of waste material. The prevailing wind in Rosh Pinah is from the south-east, which means that the main housing settlement, together with the school and crèche, are downwind of the tailings tip, and suffer from high levels of dust on windy days. Quite apart from the nuisance factor associated with the dust, it also contributes to above average levels of allergies and respiratory problems in Rosh Pinah. Additionally, based on the findings of comparable zinc and lead mines, it is likely that the dust has a respirable fraction containing high levels of lead and zinc. Given the massive scale of the waste deposit, it is unlikely a mine waste utilisation project will significantly deplete the tailings and will therefore only have a negligible to small positive impact on respiratory health and other possible related conditions in this respect. On balance, in fact, waste utilisation is likely to have a negative impact as it will entail the movement, processing and transportation of the waste, activities that will actually increase the propensity for particulates to become airborne and inhaled, ingested or contacted with the eye.

Impact 6 Mobility and Access. During construction and operation of the waste utilisation facilities there will be a significant increase in the number of trucks operating between Rosh Pinah and the railhead near to the South African border. As most of the present mine vehicles operate between the site and Luderitz to the west, the trucks transporting the processed mine waste could provide a regular alternative mobility and access route to the east for those residents of Rosh Pinah who do not possess their own means of transport. The tailings, and therefore the likely

Table 5C Impact matrix for waste utilisation project at Rosh Pinah mine, Namibia.

Impact	1	2	3	4	5	6
Directionality	-	+	+	-	-	+
Certainty	M	H	M	H	H	M
Significance	M	H	H	H	H	L
Chronicity	C,O	C,O	O,P	C,O	C,O	C,O
Locality	LOCAL	LOCAL +	LOCAL	LOCAL	LOCAL	LOCAL +
Mitigability	H	NA	NA	M	M	NA
Cumulativity	H	H	H	H	L	L

Key

+	Positive	N	Negligible
-	Negative	NA	Not Applicable
H	High	C	Construction
M	Medium	O	Operation
L	Low	P	Post Operation

location of related facilities and connecting roads, are sited over a kilometre from Rosh Pinah. Therefore, the truck movements are not anticipated to have a significant noise or safety impact on residents.

CONCLUSIONS AND RECOMMENDATIONS

Technical assessment

C52. The active lead-zinc mine at Rosh Pinah in a remote area of southern Namibia, produces substantial amounts of very fine grained mineral waste which is stored in a very large tailings lagoon. There is current interest in recovering small, but significant, amounts of lead and zinc from the waste material and other minerals, such as barytes may also be present in commercial quantities.

C53. The laboratory investigations showed that the tailings from Rosh Pinah contain a small amount of barium, which is present in the mineral barytes, as well as other barium-rich minerals. However, characterisation testwork found very little barytes present and this was confirmed by mineral processing testwork.

Economic assessment

C54. The world production of barytes is around 6.5 million tonnes annually. It is an internationally traded commodity with most production being used in oil and gas well drilling fluids. The potential markets for any barytes product from Rosh Pinah would be into adjacent South Africa and in offshore oil and gas drilling in Namibia.

C55. A financial appraisal has been constructed based on several optimistic assumptions for the recovery of the mineral, from the waste at Rosh Pinah. It is assumed that the waste contains 5% barytes, and that the total volume of the existing tailings lagoon could be worked (18 million tonnes). The financial model indicates that the most favourable net present value (NPV) is negative at $14 000 000. It is clear that the low amounts of barytes in the waste and the high costs of processing make the recovery of the mineral from the waste pile uneconomic.

Social impact assessment

C56. In order to dissuade a large influx of migrants seeking work and further straining Rosh Pinah's social infrastructure, and, particularly, conditions at Sand Hotel it is essential that expectations of a project to utilise waste be effectively managed and responsibly communicated by the agency seeking to take this proposal forward. A policy of local employment prioritisation would also minimise additions to the further speculative migration that can be expected on development of the nearby Skorpion project, and would have the important additional benefit of containing and maintaining a critical mass of investment in the local economy.

C57. The processing and transportation of the waste material will increase the potential for waste particulates to be inhaled or brought into contact with eyes and skin. Those most vulnerable to exposure will be workers processing and transporting the waste material and it is recommended that they are instructed to wear a dust mask when working with the material. Ensuring all container trucks are covered and access roads to the site and at the site itself are watered (where practical) could significantly reduce the exposure of residents to airborne particulates. In addition to these measures, there is a need to assist and support Karas' health authorities in regularly monitoring the incidence of respiratory and eye infections.

C58. In the interest of local mobility and access needs, it is suggested that truck drivers are encouraged to provide lifts to local residents, where it does not jeopardise or hinder the safe or efficient delivery of the processed waste material. In order to minimise sexual health risks and any threat to social cohesion posed by migrant or indigenous worker's conduct, the agency responsible for waste utilisation should provide education programmes in community citizenship, responsible budgeting and AIDS awareness prior to project commencement. Finally, the waste utilisation project operators should be fully encouraged to reinvest a major proportion of project profits in community development priorities such as training, education, and public health care as well as best practice mitigation and enhancement of project impacts.

References

ANON. 2001. Mineral Spotlight, Mica. *Industrial Minerals*, **402** (March), 19.

ANON. 2002. Prices. *Industrial Minerals*, **414** (March), 70–71.

BAIN AND HIGHLEY, D E. 1979. Regional Apprasial of Clay Resources — a Challenge to the Clay Mineralogist. Proc Int Clay Conf 1978, Oxford.

BENDER-MOTZ, A. 1983. Historical Documents. In: *Social Impact Assessment Methods*. FINSTERBUSCH, K, LLEWELLYN, L, and WOLF, C (editors). SAGE, London.

BERRANGÉ, J P, MATHERS, S J, MORALES, N, and ALVARADO, F. 1990. The Non-Metallic Industrial Minerals and Rocks of Costa Rica. Proyecto Anglo-Costarricense De Minerales Industriales (PAC-MI)

BRITISH GEOLOGICAL SURVEY. 2001. *World Mineral Statistics 1996–2000: production: exports: imports*. (Keyworth, Nottingham: British Geological Survey).

BOLGER, R. 1995). Feldspar and Nepheline Syenite. *Industrial Minerals* May, 25–45.

BROBST, D A. 1994. Barium Minerals. 125–134 in *Industrial Minerals and Rocks*. Carr, D (editor). Society for Mining, Metallurgy and Exploration, Littleton, Colorado.

CARR, D (editor). 1994. *Industrial Minerals and Rocks*. Society for Mining, Metallurgy and Exploration, Littleton, Colorado.

CBS. 1999. Statistical Abstract No. 6. Central Bureau of Statistics.

CBS. 2000. Statistical Abstract No. 7. Central Bureau of Statistics.

CHAMBERS, R. 1981. *Rapid Rural Appraisal: Rationale and Repertoire. Public Administration and Development 1.*

DEPARTMENT OF MINERALS ENERGY. 2000. *South Africa's Minerals Industry 1998/99*. Department of Minerals and Energy, Mineral Economics Directorate Minerals Bureau, Pretoria, South Africa.

EASTERBY-SMITH, M, THORPE, R, and LOWE, A. 1991). *Management Research: An Introduction*. SAGE, London.

FINSTERBUSCH, K. 1995. In Praise of SIA — a Personal Review of the Field of Social Impact Assessment. *Impact Assessment Bulletin*, 13, 229–252.

GLASSON, J, THERIVEL, R, and CHADWICK, A. 1996. *Introduction to Environmental Impact Assessment*. UCL Press, London.

GRAHAM SMITH, L. 1993. *Impact Assessment and Sustainable Resource Management*. Harlow: Longman, London.

GUEYE, B, and FREUDENBERGER, K. 1991. *Introduction to the Method of Participatory Rural Appraisal*. IIED, London.

HARBEN, P. 1999. A guide to markets, specifications and prices. 296 in *The Industrial Minerals Handybook*. HARBEN, P (editor). Industrial Minerals Information Ltd, London.

HARBEN, P W. 1995. *The Industrial Minerals Handybook 2nd Edition*. Metal Bulletin Ltd, London.

HARBEN, P W, and KUSVART, M. 1996. *Industrial Minerals — a Global Geology*. Industrial Minerals Information Ltd Metal Bulletin Plc, London.

HARRISON, D, BLOODWORTH, A, EYRE, J, SCOTT, P, and MACFARLANE, M. 2001. Utilisation of Minerals for Waste: A Scoping Study. British Geological Survey Technical Report WF/01/03.

HARRISON, D J, and BLOODWORTH, A J. 1994. Industrial Minerals Laboratory Manual: Construction Materials. British Geological Survey Technical Report, WG/94/12.

ICPG. 1995. Guidelines and Principles for Social Impact Assessment. *Environmental Impact Assessment Review*, **15**, 11–43.

INSTITUTO GEOGRAFICO NACIONAL. 1998. *Map of Tobosi Area*, Costa Rica.

KAUFFMAN, R A, and VAN DYK, D. 1994. Feldspars. 473–481 in INDUSTRIAL MINERALS AND ROCKS. CARR, D (editor). Society for Mining, Metallurgy and Exploration, Littleton, Colorado.

KUPER, A. 1994. Socio-Economic Impact Assessment of Uis Micro Scale Tin Mining Project. In: *A Baseline Investigation into the Biotic Environment of the Uis Micro-Mining Concession*. CRAVEN, P (editor).

LEISTRITZ, L, and MURDOCK, S. 1981. *The Socio-Economic Impact of Resource Development: Methods of Assessment*. Westview, Boulder, Colorado.

LUITINGH, J, MUNZHELELE, N, and VERSTER, J. 1998. Producers of Industrial Mineral Commodities in South Africa. Department of Minerals and Energy, Minerals Bureau, Pretoria, South Africa, D11/98.

MITCHELL, C J. 1996. Glass and Ceramic Feldspar from Waste. Southern African Minerals Conference, Durban, 1–3 December 1996.

NAERAA, T. 1993. Coping with Drought in Namibia: Informal Social Security Systems in Caprivi and Erongo. NISER University of Namibia Research Report 12, Windhoek.

ROPER, R. 1983. Ethnography. In: Social Impact Assessment Methods. FINSTERBUSCH, K, LLEWELLYN, L, and WOLF, C (editors). SAGE, London.

ROSH PINAH. 2000. Community Development Programme. Internal Paper.

ROUX, E. 1999. Operating Mines and Quarries and Mineral Processing Plants in the Republic of South Africa. Department of Minerals and Energy, Minerals Bureau Mineralia Centre, D1/99.

SAHLINS, M. 1988. Stone Age Economics. Routledge, London.

SCOTT, P, and POWER, M. 2001. The Influence of Geology on the Quality of Feldspar Products. Proceedings of the 35th Forum on the Geology of Industrial Minerals — the Intermountain West Forum, 1999, Miscellaneous Publication 01-2, Utah Geological Survey.

SEEBOHM, K. 1997. Guiding Principles for the Practice of Social Assessment in the Australian Water Industry. Impact Assessment, **15** (3), 235–44.

SGS. 1996. Environmental Technical Report of East Run-of-Mine Heap Leach Pond Berm Failure. Accra, Ghana. Societe Generale de Surveillance, SA 1/8/96.

SIMS, C. 1997. Mica, Building a Future on Dry Ground. Industrial Minerals, 352 (January), 29–43.

SMITH, A S. 2002. Brick Making: The Ultimate Waste Repository

INDUSTRIAL MINERALS AND EXTRACTIVE INDUSTRY GEOLOGY. In: Industrial Minerals and Extractive Industry Geology. SCOTT, P, and BRISTOW, C (editors). Geological Society, London.

TANNER, J T. 1994. Mica. 693–710 in Industrial Minerals and Rocks. CARR, D (editor). Society for Mining, Metallurgy and Exploration, Littleton, Colorado.

UVC. 2000. Uis Village Council. Minutes of Development Committee Meeting.

Ursula Rehaag Y Asociados S A. 1998. Estudio De Impacto Ambiental. San Pedro.

US Geological, S. 2002. Feldspar, Mineral Commodity Summary, January 2002.

US Geological, S. 2002. Mineral Commodity Summary, Mica (Natural) Scrap and Flake.

US Geological Survey. 2002. Mineral Commodity Summary, Mica (Natural) Sheet.

WHO. 1988. Improving Urban Health: Guidelines for Rapid Appraisal to Assess Community Health Needs. WHO, Geneva.

Glossary

(Including definitions from the online 'Dictionary of Mining, Mineral, and Related Terms' at http://imcg.wr.usgs.gov/dmmrt/index.html)

Activating agent A substance that when added to a mineral pulp promotes flotation in the presence of a collector.

Aggregate Any of several hard, inert materials, such as sand, gravel, slag or crushed stone, mixed with a cement or bituminous material to form concrete, mortar, or plaster, or used alone, as in railroad ballast or graded fill. The term can include rock material used as chemical or metallurgical fluxstone.

Air classification Sorting of finely ground minerals by means of air currents. These are usually controlled through cyclones, which deliver a coarse-grained underflow product and a fine-grained overflow.

Alkali feldspar Those feldspars that are composed of mixtures or crystal solutions of potassium feldspar, $KAlSi_3O_8$, and sodium feldspar, $NaAlSi_3O_8$, with little or no calcium feldspar, $CaAl_2Si_2O_8$.

Alumina An oxide of aluminum, Al_2O_3.

Artisanal mining Often referred to as small-scale mining, micro-scale mining or informal mining. Small-scale mining involves private individuals often working minerals with few resources, little technical knowledge and outside national legal requirements.

Assay To analyze the proportions of metals or minerals in an ore or raw material. This may include determination of its composition, purity, weight, or other properties of commercial interest.

Atterberg limits *See* Plasticity Index.

Barytes The mineral form of barium sulphate, $BaSO_4$. It has a relativity high specific gravity (4.5 g/cm^3). Barytes occurs as masses of crystals with sand and clay (desert rose) and in veins or in residual masses in limestone. It is the principal source of barium (Ba).

Beneficiation *See* mineral processing.

Bentonite *See* smectite.

Birth Rate A measure designed to provide information on the comparative fertility of different populations, most commonly used in demographic analysis. Various calculations may be used. The best known is the 'crude birth rate' which is simply the number of live births in a year per 1 000 population (mid-year figures).

Brick clay An impure clay, containing iron and other ingredients. In industry the term is applied to any clay, loam, or earth suitable for the manufacture of bricks or coarse pottery.

Building stone A general term for any rock suitable for use in construction. Whether igneous, metamorphic, or sedimentary, a building stone is chosen for its properties of durability, attractiveness and economy.

Bulk density The weight of an object or material divided by its volume, including the volume of its pore spaces.

Cassiterite The oxide form of tin, SnO_2. It is reddish brown to black, occurs prismatic crystals or as a massive fibrous structure. It has a high specific gravity (7.03 g/cm^3). It is associated with veins in granite/granite pegmatite, or placers. It is the main source of tin (Sn).

Ceramic(s) Inorganic, non-metallic products that are subjected to a high temperature during manufacture or use.

Certainty Refers to the likelihood or probability of occurrence of impact.

Characterisation The process of determining the mineralogical, chemical and physical properties of a rock, mineral or product.

Chemical composition The weight percent of the elements (expressed as oxides) in a rock or product.

Chlorite Chlorites are associated with and resemble micas (they cleave into small, thin flakes or scales). They are considered as clay minerals when very fine grained. Chlorites are widely distributed, especially in low-grade metamorphic rocks or as alteration products of ferromagnesian minerals.

Chronicity Refers to the time period over which the impact will occur.

Civil Society Refers to public life rather than private or household based activities; it is juxtaposed to the family and the state; and exists within the framework of the rule of law.

Classification The process of separating particles based on their size, density, and shape by settling in a fluid.

Clay A mineral particle less than 2 µm in diameter. An extremely fine-grained natural earthy material composed mainly of clay minerals and small amounts of non-clay materials.

Clay minerals Those minerals that usually occur as clay-size (less than 2 µm in diameter) particles including the minerals kaolinite, illite, chlorite and smectite.

Cohesion Maintenance of a particular or special unit of character, the boundaries of which may be physical or conceptual, through functional and effective ties.

Collector A chemical compound chosen for its ability to adsorb selectively onto mineral surfaces in a froth flotation process and render them relatively hydrophobic (water repelling).

Columbite Generally refers to ferrocolumbite, $FeNb_2O_6$, found in granites and pegmatites. An ore of niobium (Nb).

Concentrate The clean product recovered by mineral processing. It contains the highest proportion of the valuable mineral or metal content.

Construction materials Any type of material used for building including aggregate, building stone, brick clays, ceramics, sand and gravel, etc ...

Cumulativity Refers to the degree to which the impact will lead to other impacts.

Demand The volume consumption of minerals by industry based on market factors such as economic growth and imports/exports.

Demography Human populations and their changing patterns in terms of their growth, distribution and decline, due to factors like migration, fertility and mortality.

Dependency Ratio A simple indicator of the age composition of the population. Current definitions of the dependency ratio refer to the total number of young and old dependants divided by the total number of persons of productive age.

Directionality Refers to whether the impact is positive or negative.

Dolomite The mineral calcium magnesium carbonate, $CaMg(CO_3)_2$. It occurs in large beds as dolomite and dolomitic marble, also in veins and in serpentinite. A source of magnesium (Mg) and dimension stone.

Drilling mud A suspension, water or oil based, used in drilling to seal off porous zones and to counterbalance the pressure of oil and gas. It commonly contains fine-grained bentonite (smectite) and barytes.

Extraction The process of mining and removal of valuable minerals, ore or coal from a mine or quarry.

Extrusion Plastic clay forced through a pug-mill or press to form a rod or tube, which can be cut to any length.

Ex-works The cost of a mineral product collected from the plant by the consumer (i.e. excluding transport and other costs).

Feed Material treated for removal of its valuable mineral or metal content. Also called the mill 'head' ore. In mineral processing this is the grade of ore accepted by the mill for treatment.

Feldspar The aluminosilicate mineral series, plagioclase and alkali feldspar. They are colourless or white and clear to translucent where pure. They form 60% of the Earth's crust. Feldspar occurs in all rock types and decomposes to form much of the clay in soil, including kaolinite.

Ferromagnetic material Iron, nickel, and cobalt are known as ferromagnetic as they are highly magnetic. This term is often used to describe minerals that contain significant amounts of these elements.

Firing properties The properties of a ceramic or brick raw material after firing. These include shrinkage/expansion, colour, density and porosity.

Forming properties The properties of a ceramic or brick raw material before and after forming/ drying. These include the liquid and plastic limits, plasticity index, drying shrinkage and modulus of rupture (MoR).

FOB (Free on board) Price of consignment to a customer when delivered, with all prior charges paid, onto a ship or truck.

Frequency Refers to how often the impact will occur.

Froth flotation The selective separation of minerals in a suspension using air bubbles. Chemical reagents activate (promote) or depress (stop) mineral flotation. The floated minerals are collected in a surface froth.

Frother A substance used in froth flotation to make air bubbles sufficiently permanent, principally by reducing surface tension. Also known as a frothing agent.

Galena The mineral form of lead sulphide, PbS. It forms cubes and octahedra. Galena has a high specific gravity (7.6 g/cm^3). It occurs as coarse- or fine-grained masses with sphalerite in hydrothermal veins and in sedimentary rocks.

Gauss The unit used to define the magnetic intensity required to attract specific minerals during magnetic separation.

Grade The proportion, or weight percentage, of a valuable mineral or metal content in an orebody or product. *See* mass balance, grade and recovery.

Gravity separation Separation of mineral particles, with the aid of water or air, according to the differences in their specific gravities.

Haul road A road built to carry heavily loaded trucks at a good speed. The slope is limited on this type of road and usually kept to less than 17% of climb in direction of load movement.

Heavy media separation A form of gravity separation of mineral or ore particles in a high-density fluid or medium.

Hematite A common mineral form of iron oxide, Fe_2O_3, the most widely mined ore of iron (Fe).

Household A group of persons sharing a home or living space, who aggregate and share their incomes, as evidenced by the fact that they regularly take meals together.

Hydraulic mining Mining using high-pressure water jets to excavate the valuable mineral or ore.

Illite A general term for a group of mica like clays, widely distributed in clay-rich sediments and soils.

Industrial minerals Rocks, minerals, and some naturally occurring and synthetic materials of economic value, excluding fuel and metallic ore minerals. Often referred to as non-metallic minerals.

Jig A form of gravity separation that separates minerals in a pulsating water medium.

Kaolinite A clay mineral, which is soft and white. It is formed by hydrothermal alteration or weathering of aluminosilicates, esp. feldspars and feldspathoids; formerly called kaolin. *See* clay.

Limestone A sedimentary rock consisting of more than 95% calcium carbonate (as calcite) and less than 5% dolomite. Common minor constituents include silica (chalcedony), feldspar, clays, pyrite, and siderite.

Linear shrinkage The degree to which material shrinks after drying or firing, measured against the longest axis of a test piece.

Liquid limit *See* Plasticity Index.

Locality Refers to the area of impact.

Loss on ignition (LOI) The percentage loss in weight that results from heating a sample of material to a high temperature.

Magnetic separation The separation of magnetic materials from non-magnetic materials, using a magnet or electromagnet.

Magnetic susceptibility A measure of the degree to which a substance is attracted to a magnet. *See* Gauss.

Mass balance The material balance of a mineral processing operation. It is often referred to as the metallurgical balance and is a measure of mineral processing efficiency. *See* yield, grade and recovery.

Metallurgical balance *See* mass balance.

Mica A group of phyllosilicate minerals including biotite and muscovite. They are soft, have a perfect basal (micaceous) cleavage and easily split to form tough, elastic flakes and sheets. Mica is a common rock-forming minerals in igneous, metamorphic, and sedimentary rocks.

Micro-scale mining *See* artisanal mining

Middlings A mineral processing product that is a mixture of valuable and non-valuable material. It often contains particles incompletely liberated by crushing and grinding (referred to as 'middling grains'). It is often sent back for crushing and/or further mineral processing to recover the valuable mineral content.

Mill A mineral processing plant.

Mineral dressing *See* mineral processing.

Mineral filler A finely ground inert mineral product. It is used in manufactured products such as paper, rubber and plastics to impart certain useful properties, including whiteness, hardness, smoothness or strength. Common mineral fillers include limestone, kaolin, and talc.

Mineral processing The processes used to produce a saleable product from a mined material. This can include crushing and grinding, hand sorting, dense media separation, screening and classification, gravity treatment with jigs, shaking tables, centrifugal separators, spirals or sluices, magnetic and electrostatic separation, leach treatment and froth flotation. Also known as beneficiation, mineral dressing, milling and ore treatment.

Mineral waste The residues, tailings or other non-valuable material produced after the extraction and processing of material to form mineral products.

Mining The science, technique, and business of mineral discovery and exploitation. Strictly, it refers to underground extraction. Generally, it includes open cast extraction, quarrying, alluvial dredging, and combined operations, including surface and underground extraction and mineral processing.

Mitigability Refers to the potential of the impact to be mitigated.

Mortality Rate Provides a measure of health risks, improvements in the quality of health care, and the comparative overall health of different groups in a population. The most common measure is the 'crude mortality rate' which is the number of deaths in a year per 1000 population in a defined geographical area.

Nepheline syenite An igneous rock composed essentially of alkali feldspar and nepheline.

NPV (Net Present Value) The difference between the gross unit recoverable value and the cost of mining, treating, and marketing ore; in other words, the net operating profit.

NGO Non-government Organisation (NGO) is an organisation, which is neither a business or represents a government. In this way both the International Chamber of Commerce and Greenpeace are NGOs.

Normative mineralogy The theoretical mineral composition of a rock expressed in terms of normative mineral molecules that have been determined by specific chemical analyses for the purpose of classification and comparison.

Ore treatment *See* mineral processing

Overflow The undersize material leaving a classifier.

Oxide A compound of oxygen with another element.

Paramagnetic Paramagnetic minerals, such as olivine, pyroxene or biotite, have a positive magnetic susceptibility (although lower than ferromagnetic minerals) and can be separated using magnetic separation.

Particle size The general dimensions (such as average diameter or volume) of the particles in a sediment or rock. Commonly measured by sieving, by calculating settling velocities, or using microscopic images.

Pegmatite An exceptionally coarse-grained igneous rock with interlocking crystals (1 cm or more in diameter). Their composition is generally that of granite and may include rare minerals rich in such elements as lithium, boron, fluorine, niobium, tantalum, uranium, and rare earths.

Petrography A general term for the science dealing with the description and systematic classification of rocks, based on observations in the field, on hand specimens and on thin sections.

Phosphate Any mineral containing phosphate, $(PO_4)^{3-}$ e.g. apatite, amblygonite, or monazite.

Plant The mechanical installations, machines and their housings used in mining.

Plastic limit *See* Plasticity Index.

Plasticity index In a sediment, the water-content boundaries between the semi-liquid and plastic states (known as the liquid limit) and between the plastic and semi-solid states (known as the plastic limit). The plastic and liquid limits are known as the Atterberg limits. The water-content range of material over which it is plastic is determined as the liquid limit minus the plastic limit and is known as the plasticity index.

Porosity The ratio, expressed as a percentage, of the volume of the pore space in a rock to the total volume of the rock (including the pore space).

Primary Data Data collected by study/research and which was not already available.

Product Material produced by the mineral processing of mined raw material.

Pyrite A mineral form of iron sulphide, FeS_2. It is metallic and pale bronze to brass yellow in colour. It occurs in igneous, metamorphic and sedimentary rocks. It is a source of sulphur (S).

Quarrying The extraction of valuable minerals or ore from the Earth's surface.

Quartz A mineral form of silica, SiO_2.

Reciprocity Refers to when people's relationships to each other are characterised by their mutual support through informal channels of giving and receiving goods, assistance etc. Also referred to as an exchange or gift relationship.

Recovery The proportion of valuable mineral or metal present in the feed that is recovered to a product. This is a measure of the mining or extraction efficiency. *See* mass balance, yield and recovery.

Resource A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Sample A representative fraction of a body of material. Bulk samples are large and used for mineral processing testwork. Channel samples, cores, chips, grab, pannings and stope samples are smaller and used for characterisation testwork.

Sand A rock fragment or mineral particle with a diameter in the range 63 µm to 2 µm. It also refers to loose aggregate, unlithified mineral or rock particles of sand sized grains. The material is most commonly composed of quartz but may be of any mineral composition or mixture of rock or mineral fragments.

Sex Ratio Conventionally defined as the number of males per 1000 females in the population. The sex ratio is regarded as an important social indicator. It affects marriage rates, women's labour market participation rates and sex roles.

Shaking table A gravity separation method that uses a vibrating table and a flowing film of water. See mineral processing.

Significance Relates to the incidence and distribution of impacts and results from estimating the magnitude and severity of the impact and the response that is evoked.

Silica Silicon dioxide, SiO_2. It occurs naturally as five crystalline polymorphs: quartz, tridymite, cristobalite, coesite, and stishovite. Silica also occurs as chalcedony, opal, skeletal material in diatoms and other siliceous accumulations.

Silspar A ceramic raw material that is composed of the minerals quartz and feldspar in roughly equal proportions.

Silt A rock fragment or mineral particle with a diameter in the range 2 µm to 63 µm.

Slate A compact, fine-grained metamorphic rock that can be split into slabs and thin plates.

Slime Extremely fine sediment (finer than 75 µm) produced by the processing of raw material or ore.

Small-scale mining *See* artisanal mining

Smectite A clay mineral with swelling properties and high cation-exchange capacities (CEC). Also known as fuller's earth, bentonite and montmorillonite. *See* clay minerals.

Social Accounting A social account measures the social performance of an organisation during its operation by assessing their social impact and ethical behaviour in relation to its aims and values and those of its stakeholders.

Social Impact The direct, indirect and cumulative social consequences of actions, including change to norms, beliefs, perceptions and values.

Social Impact Assessment The assessment, in advance, of the positive and negative social impacts of a given proposed project or policy development.

Social Indicators Easily identified features of a society or social issue which can be measured, vary over time and reveal some underlying aspect of social reality.

Social Pathology Organic metaphor to suggest that parts of societies, like body parts, could suffer breakdown and disease.

Social Profile A comprehensive and systematic summary of the key characteristics of a community or region. Typically prepared by means of a desk study of the available literature, plus interviews and key informants.

Specific gravity (SG) The specific gravity of a mineral is the ratio between the weight of a unit volume and that of water, expressed as grams per cubic centimetre (g/cm^3) or kilogrammes per cubic metre (kg/m^3).

Sphalerite The mineral form of zinc sulphide, ZnS. It occurs with galena in veins and irregular replacement in limestone. It is a source of zinc (Zn).

Stakeholder Groups or individuals either directly or indirectly affected by the project or who have a significant interest in operational decisions.

Stakeholder Map The analysis, categorisation and understanding of stakeholders in terms of their relative social, political and economic relationship to the organisation.

Survey The systematic collection of facts, usually by means of a questionnaire, about a defined social group.

Tailings The waste material resulting from the extraction and mineral processing of ground ore.

Talc An aluminosilicate mineral. It is very soft, has a greasy or soapy feel and can easily be cut with a knife Talc occurs as an alteration of igneous rocks or metamorphism of siliceous dolomites. It is used as an insulator, a ceramic raw material and lubricant.

Tantalite Generally refers to the mineral, ferrotantalite, $FeTa_2O_6$. It is black and occurs in pegmatites. It is the main source of tantalum (Ta).

Tantalum A brittle, lustrous, hard, heavy, gray metallic element (Ta). Occurs principally in the mineral columbite-tantalite, $(Fe, Mn)(Nb, Ta)_2O_6$.

Tin A rare, soft, malleable, bluish white metallic element (Sn).

Trace element An element that is not essential in a mineral, but that is found in small quantities in its structure or adsorbed on its surfaces. Conventionally assumed to constitute less than 1.0% of the mineral.

Underflow The oversize material leaving a classifier.

Use-related testing Testwork carried out to determine the suitability of a raw material or mineral product for use as an industrial mineral. This includes the determination of mineralogical, chemical and physical properties that can then be compared with mineral products used commercially.

Vitrification The process whereby a ceramic or brick raw material is partially turned to glass during its firing.

X-ray diffraction (XRD) An analytical method used to determine the mineralogy of a rock or mineral sample using X-rays.

X-ray fluorescence (XRF) An analytical method used to determine the chemistry of a rock or mineral sample using X-rays.

Yield The amount of a product obtained from any operation expressed as a weight percentage of the feed material. *See* mass balance, yield and grade.

Appendix 1
Case Study A: Sicorsa Silica Sand detailed information

Table 1 Statistics for mineral production for the construction industry in Costa Rica.

Cement	1,100,000
Clays, common	400,000
Aggregates (includes crushed rock, limestone, sand and gravel and sandstone)	7,650,000

Production in metric tonnes in 1999. Source, U.S. Geological Survey, Minerals Yearbook (http://minerals.usgs.gov/minerals/pubs/myb.html)

Table 2 Summary of clay used for brick, tile and pipe production in Costa Rica in 1990.

Company and location	tonnage (tonnes per annum)
Ladrillera Industriel (Aguacaliente) S.A., Lourdes, Cartago	5,000
Ladrillera San Antonio, Patarrá	1,500
Ladrillera La Sabana, western San José	3,000
Ladrillera Inca, Desamparados	1,000
Productos Caribe S.A. Esparta	not stated
Productos Ceramicos, La Uruca S.A., Ciudad Colon	not stated
Ceramica Industriel SA (CEINSA) Bermejo	not stated
Total	9,500+

Taken from Berrangé et al. (1990). Not all brick works are in current production

Appendix 2
Case Study B: Uis Mine detailed information

Table 1 Sample details.

Sample No.	Sample mass (g)	Sample locality & description
BN1	5628.6	Northern extreme of fine-grained tailings lagoon; spot sample.
BN2	5098.7	Southern extreme of fine-grained tailings lagoon; spot sample.
BN3	5662.1	Base of coarser-grained tailings tip; spot sample.
BN4	7237.5	Top of coarser-grained tailings tip; spot sample.
BN8	6650.0	Coarser-grained tailings from tin-tantalite plant; spot sample from jig tailings.
BN9	9385.0	Finer-grained tailings from tin-tantalite plant; spot sample from shaking table tailings.
BN10	937.1	Tantalite concentrate from tin-tantalite plant; spot sample.

Table 2 Chemical composition of the tailings, Uis Mine, Namibia.

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	Mn_3O_4	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	Cr_2O_3	SrO	ZrO_2	BaO	NiO	CuO	ZnO	PbO	LOI	Total
	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %
<u>Tailings lagoon</u> (finer grained material)																					
BN1	64.05	0.06	19.10	0.84	0.05	0.35	2.07	2.78	2.32	1.83	<0.1	<0.01	0.08	<0.02	<0.02	<0.01	<0.01	0.02	<0.01	4.51	98.06
BN2	62.62	0.13	18.81	1.50	0.07	0.77	2.57	2.95	2.53	1.72	<0.1	<0.01	0.07	<0.02	0.02	<0.01	<0.01	0.01	<0.01	4.85	98.62
<u>Tailings tip</u> (coarser grained material)																					
BN3	69.89	0.08	15.52	0.79	0.06	0.40	1.54	3.11	2.84	1.65	<0.1	<0.01	0.06	<0.02	<0.02	<0.01	<0.01	0.01	<0.01	2.64	98.59

Sample No.	Zn ppm	Rb ppm	Y ppm	Nb ppm	Sn ppm	La ppm	Ce ppm	Nd ppm	Sm ppm	Ta ppm	W ppm	Pb ppm	Th ppm	U ppm
<u>Tailings lagoon</u> (finer grained material)														
BN1	162	1331	5	77	547	29	56	26	6	51	2	9	7	21
BN2	137	1201	8	68	520	38	69	28	4	42	4	12	8	17
<u>Tailings tip</u> (coarser grained material)														
BN3	83	1481	7	49	348	86	170	71	11	33	3	14	9	12
BN4	95	1520	3	52	284	9	23	13	<2	30	2	8	9	13

Table 3 Chemical composition of the tailings, small-scale tin-tantalite operation, Uis, Namibia.

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	Mn_3O_4	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	Cr_2O_3	SrO	ZrO_2	BaO	NiO	CuO	ZnO	PbO	LOI	Total
	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %
BN8	67.34	0.07	13.98	0.63	0.04	0.51	4.35	3.45	3.32	1.15	0.5	<0.01	0.05	<0.02	0.03	<0.01	<0.01	<0.01	<0.01	4.41	99.83
BN9	71.03	<0.01	15.34	0.11	0.02	0.09	1.32	5.14	3.18	1.38	<0.1	<0.01	0.05	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	1.51	99.17

Table 4 Chemical composition of tantalite concentrate, tin-tantalite operation, Uis, Namibia.

Ta_2O_5	Nb_2O_5	TiO_2	SnO_2	ThO_2	U_3O_8	Sb	WO_3	Fe_2O_3	SiO_2	Al_2O_3	MgO	Mn_3O_4	CaO	Na_2O
Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %
16.09	2.97	1.31	21.32	(-)	0.03	(-)	0.11	8.02	30.60	7.88	0.51	3.13	2.40	1.59
K_2O	**P_2O_5**	**SO_3**	**Cr_2O_3**	**SrO**	**ZrO_2**	**BaO**	**NiO**	**CuO**	**ZnO**	**PbO**	**Y_2O_3**	**Rb_2O**	**LOI**	**Total**
Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %
0.78	0.97	0.10	0.05	0.02	0.28	(-)	0.01	(-)	0.04	0.05	0.01	0.01	1.67	97.77

Table 5 Modal mineralogy, tailings and tantalite concentrate, Uis, Namibia.

	Quartz wt %	Kaolinite wt %	Muscovite wt %	K-feldspar wt %	Hematite wt %	Calcite wt %	Apatite wt %	Na-feldspar wt %	Anatase wt %	Pyrolusite wt %	Chlorite wt %	Biotite wt %	Total wt %
BN1	26.0	29.5	1.7	13.0	0.6	0.4	3.5	23.0	<0.1	<0.1	1.8	0.5	100.0
BN3	33.7	16.5	2.6	16.0	0.6	<0.1	3.5	25.7	<0.1	<0.1	<0.1	1.4	100.0
BN8	30.5	5.0	7.0	16.5	<0.1	5.5	2.5	28.0	<0.1	<0.1	<0.1	5.0	100.0
BN9	25.5	8.0	<0.1	20.0	<0.1	<0.1	3.0	42.5	<0.1	<0.1	<0.1	1.0	100.0

Tantalite concentrate, tin-tantalite operation, Uis

	Cassiterite wt %	High-ratio tantalite wt %	Low-ratio tantalite wt %	Ilmenite wt %	Magnetite wt %	Garnet wt %	Apatite wt %	Zircon wt %	Quartz wt %	K-feldspar wt %	Na-feldspar wt %	Calcite wt %	Chlorite wt %	Muscovite mica wt %	Total wt %
BN10	19.0	6.5	23.5	1.8	0.5	8.7	1.8	0.4	15.0	2.0	13.0	2.5	1.3	4.0	100.0

Table 6 Particle-size distribution of tailings and tantalite concentrate, Uis, Namibia.

	Fine-grained tailings, Uis		Coarse-grained tailings, Uis		Tailings, Klein Aub	Tailings, Rosh Pinah		Tin-tantalite plant tailings, Uis		Tantalite concentrate
Size fraction	**BN1**	**BN2**	**BN3**	**BN4**	**BN5**	**BN6**	**BN7**	**BN8**	**BN9**	**BN10**
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
-5 +2mm	0.0	0.0	1.7	1.1	0.0	0.0	0.0	11.05	0.01	nd
-2 +1mm	0.3	0.1	16.8	17.5	0.0	0.0	0.0	7.76	0.15	nd
-1mm + 500 µm	1.2	1.2	30.5	30.7	0.0	0.1	0.1	52.62	9.99	0.1
-500 +250 µm	2.6	4.1	20.8	29.0	0.2	2.5	2.6	18.76	20.20	0.2
-250 +125 µm	8.9	7.3	16.4	11.8	7.3	16.1	16.7	4.68	20.58	2.8
-125 +75 µm	15.1	17.4	7.0	5.5	16.2	19.8	21.3	2.27	21.89	45.5
-75 +10 µm	39.4	36.6	4.1	2.3	30.4	44.5	50.0	2.88	14.47	38.8
-10 +2 µm	19.6	19.1	1.2	1.1	32.2	13.0	7.4	nd	12.73	12.3
-2 µm	13.0	14.1	1.3	1.1	13.8	4.0	1.9	nd	nd	0.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.00	100.00	100.0

nd = not determined.

Figure 1 Cumulative frequency particle-size distribution, tailings, Uis, Namibia.

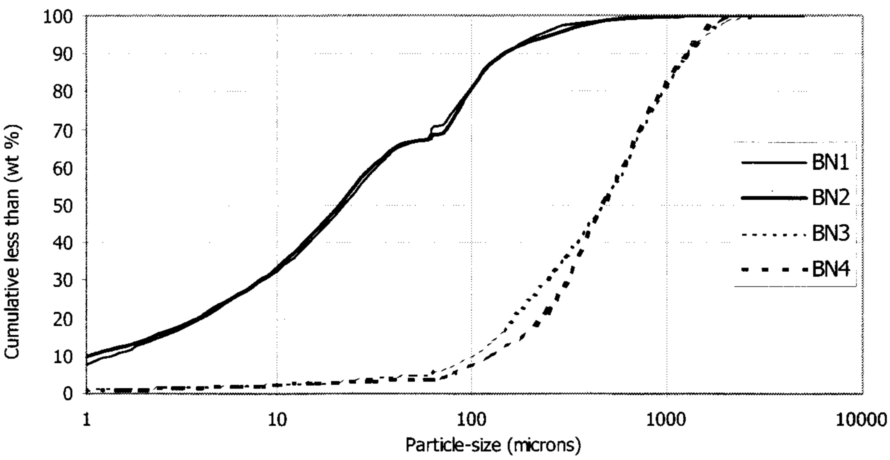


Table 7 Electron probe micro analysis, tailings, Uis, Namibia.

	SiO2 wt %	TiO2 wt %	Al2O3 wt %	Fe3O4 wt %	Mn3O4 wt %	MgO wt %	CaO wt %	Na2O wt %	K2O wt %	Cr2O3 wt %	ZnO wt %	SnO2 wt %	PbO wt %	CuO wt %	BaO wt %	SO3 wt %	Total wt %
K-feldspar	62.89	0.03	18.20	0.05	0.14	0.00	0.00	0.63	14.98	0.00	0.33	0.38	0.05	0.02	0.07	0.12	97.90
Na-feldspar	66.59	0.08	19.16	0.02	0.16	0.00	0.04	11.61	0.06	0.04	0.02	0.08	0.08	0.03	0.06	0.06	98.07
Muscovite	44.68	0.17	35.29	1.07	0.21	0.08	0.00	0.40	10.12	0.00	0.44	0.38	0.00	0.06	0.00	0.00	92.90
Biotite	36.22	2.84	19.68	15.44	1.25	8.95	0.00	0.27	8.91	0.00	0.12	0.25	0.00	0.00	0.00	0.00	93.94

NB K-feldspar average of 6 analyses; Na-feldspar, 8; Muscovite & biotite, both 2; Barite, 3.

Table 8 Electron probe micro analysis, tantalite, Uis, Namibia.

	SiO_2 wt %	TiO_2 wt %	Al_2O_3 wt %	Fe_2O_3 wt %	Mn_3O_4 wt %	MgO wt %	CaO wt %	Na_2O wt %	K_2O wt %	Cr_2O_3 wt %	SnO_2 wt %	Ta_2O_5 wt %	Nb_2O_5 wt %	ZrO_2 wt %	WO_3 wt %	P_2O_5 wt %	SO_3 wt %	Total wt %
High ratio Tantalite*	1.85	0.46	0.02	7.10	21.48	0.09	0.00	0.08	0.03	0.04	0.61	41.91	23.82	0.00	1.67	0.83	0.02	100.00
Low ratio Tantalite**	2.87	1.49	0.09	8.83	10.54	0.12	0.00	0.10	0.01	0.00	8.98	58.33	6.11	0.00	1.80	0.72	0.00	100.00

NB *= High ratio of Nb to Ta; average of 10 analyses; ** = Low ratio of Nb to Ta; average of 9 analyses.

Table 9 Mineralogy and mass balance of size fractions, Uis tailings, Namibia.

BN3

Size fraction	Yield	Mica		Feldspar		Quartz		Non-HM	HM	Total
		Grade	Recovery	Grade	Recovery	Grade	Recovery	Grade	Grade	
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.00	6.2	100.0	58.1	100.0	32.9	100.0	0.1	2.7	100.0
+2mm	2.55	5.0	2.0	58.5	2.6	33.5	2.6	0.0	3.0	100.0
-2+1mm	19.11	4.0	12.3	59.5	19.6	34.0	19.8	0.0	2.5	100.0
-1mm+500 μm	28.63	3.0	13.8	60.5	29.8	33.5	29.2	0.0	3.0	100.0
-500+250 μm	23.82	5.0	19.1	60.0	24.6	32.5	23.6	0.0	2.5	100.0
-250+125 μm	15.62	11.0	27.5	52.5	14.1	34.0	16.2	0.0	2.5	100.0
-125 μm	10.26	15.4	25.3	52.5	9.3	27.8	8.7	0.9	3.3	100.0

NB HM = Heavy Minerals

BN4

Size fraction	Yield	Mica		Feldspar		Quartz		Rock	Opaques	Total
		Grade	Recovery	Grade	Recovery	Grade	Recovery	Grade	Grade	
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.00	4.8	100.0	68.7	100.0	22.2	100.0	4.2	0.0	100.0
+5mm	0.07	0.0	0.0	59.4	0.1	0.0	0.0	40.6	0.0	100.0
-5+4mm	0.08	0.0	0.0	56.4	0.1	2.6	0.0	41	0.0	100.0
-4+2mm	0.98	2.2	0.4	69.5	1.0	10.9	0.5	17.4	0.0	100.0
-2+1mm	15.62	2.8	9.1	76.1	17.3	13.3	9.3	7.8	0.0	100.0
-1mm+500μm	31.95	2.7	17.9	72.9	33.9	19.0	27.3	5.4	0.0	100.0
-500+250 μm	26.79	6.5	36.1	72.3	28.2	18.8	22.6	2.4	0.0	100.0
-250+125 μm	13.90	7.2	20.7	54.7	11.1	36.5	22.8	1.6	0.0	100.0
-125 μm	10.62	7.2	15.8	54.7	8.4	36.5	17.4	1.6	0.0	100.0

BN8

Size fraction	Yield	Mica		Feldspar		Quartz		Rock	Opaques	Total
		Grade	Recovery	Grade	Recovery	Grade	Recovery	Grade	Grade	
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.00	6.7	100.0	47.8	100.0	26.0	100.0	19.4	0.0	100.0
+5mm	11.05	6.5	10.7	52.5	12.1	20.2	8.6	20.8	0.0	100.0
-5+4mm	7.76	2.2	2.5	54.0	8.8	21.8	6.5	22	0.0	100.0
-4+2mm	52.62	6.4	50.0	39.1	43.1	28.4	57.4	26.1	0.0	100.0
-2+1mm	18.76	7.7	21.4	65.1	25.6	19.5	14.1	7.7	0.0	100.0
-1mm+500 μm	4.68	11.1	7.7	60.9	6.0	25.3	4.5	1.9	0.8	100.0
-500+250 μm	2.27	10.0	3.4	42.0	2.0	45.0	3.9	2	1.0	100.0
-250 μm	2.88	10.0	4.3	42.0	2.5	45.0	5.0	2	1.0	100.0

BN9

Size fraction	Yield	Mica		Feldspar		Quartz		Rock	Opaques	Total
		Grade	Recovery	Grade	Recovery	Grade	Recovery	Grade	Grade	
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.00	3.4	100.0	58.8	100.0	36.9	100.0	0.8	0.0	100.0
+5mm	0.01	0.0	0.0	100.0	0.0	0.0	0.0	0	0.0	100.0
-5+4mm	0.15	1.9	0.1	78.9	0.2	12.5	0.0	6.7	0.0	100.0
-4+2mm	9.99	1.2	3.5	77.1	13.1	20.2	5.5	1.5	0.0	100.0
-2+1mm	20.20	3.1	18.2	70.0	24.1	25.8	14.1	1	0.1	100.0
-1mm+500 μm	20.58	3.6	21.5	57.9	20.3	37.5	20.9	1	0.0	100.0
-500+250 μm	21.89	5.8	36.9	55.2	20.6	37.8	22.4	0.8	0.4	100.0
-250+125 μm	14.47	2.5	10.5	47.1	11.6	50.1	19.7	0.2	0.1	100.0
-125 μm	12.73	2.5	9.3	47.1	10.2	50.1	17.3	0.2	0.1	100.0

Table 10 Mineralogy and mass balance of air classification products, tailings, Uis, Namibia.

BN3: -2 +1mm

Air classification product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
16 m^3/H	0.9	100.0	49.4	0.0	0.0	0.0	0.0
20 m^3/H	1.4	50.0	39.1	39.5	0.7	10.0	0.8
24 m^3/H	11.0	1.0	6.4	88.0	12.3	10.0	6.7
26 m^3/H	21.0	0.1	1.2	87.8	23.3	10.0	12.7
26 m^3/H	65.8	0.1	3.8	76.8	63.8	20.0	79.8

BN3: -1mm +500 µm

Air classification product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
6 m^3/H	0.3	100.0	12.6	0.0	0.0	0.0	0.0
10 m^3/H	0.4	99.0	20.1	1.0	0.0	0.0	0.0
14 m^3/H	2.0	60.0	56.0	25.0	0.7	13.5	1.5
18 m^3/H	16.2	1.0	7.5	85.9	18.2	10.0	9.0
18 m^3/H	81.1	0.1	3.8	76.4	81.1	20.0	89.5

BN3: -500 +250 µm

Air classification product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
4 m^3/H	0.5	100.0	11.6	0.0	0.0	0.0	0.0
6 m^3/H	1.0	99.0	24.4	1.0	0.0	0.0	0.0
8 m^3/H	2.2	60.0	32.1	29.3	1.2	10.0	0.6
10 m^3/H	5.9	15.0	21.0	63.4	6.5	20.0	3.3
10 m^3/H	90.4	0.5	10.8	58.0	92.3	38.0	96.1

BN3: -250 +125 µm

Air classification product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
2 m^3/H	0.6	100.0	7.0	0.0	0.0	0.0	0.0
4 m^3/H	4.6	74.5	37.8	20.0	1.6	5.0	0.7
6 m^3/H	31.0	15.0	51.7	54.0	30.1	30.0	27.0
6 m^3/H	63.8	0.5	3.5	59.5	68.3	39.0	72.3

BN4: -2 +1mm

Air classification product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
16 m^3/H	1.5	99.5	52.8	0.5	0.0	0.0	0.0
20 m^3/H	1.7	60.0	35.0	34.4	0.7	5.0	0.6
24 m^3/H	13.0	2.0	9.2	89.0	15.1	5.0	4.9
26 m^3/H	29.0	0.1	1.0	78.9	30.0	15.0	32.6
26 m^3/H	54.9	0.1	1.9	74.9	54.1	15.0	61.9

BN4: -1mm +500 µm

Air classification product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
6 m^3/H	0.4	100.0	15.3	0.0	0.0	0.0	0.0
10 m^3/H	0.5	99.0	20.2	1.0	0.0	0.0	0.0
14 m^3/H	2.6	60.0	57.8	33.5	1.2	5.0	0.7
18 m^3/H	9.1	1.0	3.4	82.5	10.3	15.0	7.2
18 m^3/H	87.3	0.1	3.2	73.9	88.5	20.0	92.1

Table 10 *(continued)*

BN4: -500 +250 µm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
4 m^3/H	1.1	100.0	17.6	0.0	0.0	0.0	0.0
6 m^3/H	1.1	85.0	15.0	15.0	0.2	0.0	0.0
8 m^3/H	4.9	50.0	37.6	33.5	2.3	15.0	3.9
10 m^3/H	10.2	15.0	23.5	67.5	9.5	15.0	8.2
10 m^3/H	82.6	0.5	6.3	77.0	88.0	20.0	87.9

BN4: -250 +125 µm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
2 m^3/H	0.9	100.0	13.0	0.0	0.0	0.0	0.0
4 m^3/H	4.3	85.0	51.6	15.0	1.2	0.0	0.0
6 m^3/H	14.2	15.0	29.7	54.4	14.1	30.0	11.7
6 m^3/H	80.5	0.5	5.6	57.5	84.7	40.0	88.3

BN8: +5mm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
22 m^3/H	1.7	100.0	25.8	0.0	0.0	0.0	0.0
26 m^3/H	0.8	99.0	12.0	1.0	0.0	0.0	0.0
30 m^3/H	1.2	95.0	17.4	5.0	0.1	0.0	0.0
34 m^3/H	1.2	40.0	7.3	40.0	0.9	10.0	0.6
38 m^3/H	4.3	25.0	16.6	25.0	2.1	15.0	3.2
38 m^3/H	90.8	1.5	20.9	56.0	96.9	21.4	96.2

BN8: -5 +4mm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
20 m^3/H	0.6	100.0	28.8	0.0	0.0	0.0	0.0
24 m^3/H	0.2	100.0	10.8	0.0	0.0	0.0	0.0
28 m^3/H	0.3	77.8	12.6	22.2	0.1	0.0	0.0
32 m^3/H	0.8	50.0	18.9	18.1	0.3	18.2	0.7
38 m^3/H	6.7	9.3	28.9	49.5	6.1	17.5	5.4
38 m^3/H	91.3	0.0	0.0	55.3	93.4	22.4	93.9

BN8: -4mm +2mm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
20 m^3/H	2.5	100.0	38.4	0.0	0.0	0.0	0.0
24 m^3/H	1.0	73.1	11.2	13.5	0.3	7.7	0.3
28 m^3/H	2.5	45.0	17.6	25.0	1.6	20.0	1.8
32 m^3/H	7.1	5.0	5.5	50.0	9.0	25.0	6.2
32 m^3/H	87.0	2.0	27.2	40.0	89.0	30.0	91.8

BN8: -2 +1mm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
16 m^3/H	4.7	100.0	60.5	0.0	0.0	0.0	0.0
20 m^3/H	2.1	80.0	21.9	10.0	0.3	7.0	0.8
24 m^3/H	7.8	10.0	10.1	65.0	7.7	15.0	6.0
28 m^3/H	30.0	1.0	3.9	70.0	32.3	21.0	32.3
28 m^3/H	55.4	0.5	3.6	70.0	59.6	21.5	61.0

BN8: -1mm +500 µm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
6 m^3/H	2.9	100.0	50.5	0.0	0.0	0.0	0.0
10 m^3/H	2.4	80.0	33.4	10.0	0.4	7.0	0.8
14 m^3/H	4.1	10.0	7.1	65.0	4.0	15.0	3.0
18 m^3/H	11.9	1.0	2.1	70.0	12.6	21.0	12.4
18 m^3/H	78.7	0.5	6.9	70.0	83.1	21.5	83.8

Table 10 *(continued)*

BN9: -4mm +2mm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
20 m^3/H	0.6	100.0	51.1	0.0	0.0	0.0	0.0
24 m^3/H	0.8	40.0	29.8	50.0	0.5	10.0	0.4
28 m^3/H	3.9	2.0	7.1	87.0	4.3	10.0	1.9
32 m^3/H	26.1	0.5	12.0	89.0	30.1	10.0	12.9
32 m^3/H	68.7	0.0	0.0	73.0	65.0	25.0	84.8

BN9: -2 +1mm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
16 m^3/H	1.1	100.0	35.9	0.0	0.0	0.0	0.0
20 m^3H	2.1	49.9	35.0	45.0	1.4	5.0	0.4
24 m^3/H	16.2	5.0	26.4	84.0	19.4	10.0	6.2
24 m^3/H	80.6	0.1	2.6	68.8	79.2	30.0	93.3

BN9: -1mm +500 μm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
6 m^3/H	0.3	100.0	7.0	0.0	0.0	0.0	0.0
10 m^3/H	0.7	95.0	18.9	4.0	0.0	0.4	0.0
14 m^3/H	3.8	50.0	53.1	25.0	1.7	24.0	2.4
18 m^3/H	25.2	3.0	21.0	48.0	20.9	48.0	32.2
18 m^3/H	70.0	0.0	0.0	64.0	77.4	35.0	65.3

BN9: -500 +250 μm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
2 m^3/H	0.0	100.0	0.8	0.0	0.0	0.0	0.0
3 m^3/H	0.1	99.0	1.9	0.5	0.0	0.5	0.0
4 m^3/H	0.4	10.0	0.8	65.0	0.5	15.0	0.2
6 m^3/H	3.1	50.0	26.8	25.0	1.4	24.7	2.0
8 m^3/H	7.7	25.0	33.9	39.7	5.6	35.0	7.2
10 m^3/H	12.9	10.0	22.6	50.0	11.7	39.7	13.6
10 m^3/H	75.7	1.0	13.2	59.0	80.8	38.5	77.1

BN9: -250 +125 μm

Air classification product	Yield wt %	Mica Grade wt %	Mica Recovery wt %	Feldspar Grade wt %	Feldspar Recovery wt %	Quartz Grade wt %	Quartz Recovery wt %
2 m^3/H	0.1	100.0	3.1	0.0	0.0	0.0	0.0
4 m^3/H	2.8	50.0	57.3	24.7	1.5	25.0	1.4
6 m^3/H	18.0	5.0	36.4	39.7	15.2	55.0	19.8
6 m^3/H	79.1	0.1	3.2	49.6	83.3	50.0	78.8

Table 11 Mineralogy and mass balance of froth flotation products, tailings, Uis, Namibia.

BN3: +125 µm

Froth flotation product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
1	1.7	100	20.3	0	0.0	0	0.0
2	3.0	99	35.2	1	<0.1	0	0.0
3	7.2	50	43.2	30	3.9	20	3.9
4	11.2	1	1.3	70	14.3	29	8.9
5	15.0	0	0	70	19.0	30	12.2
6	16.5	0	0	65	19.5	35	15.8
7	10.0	0	0	60	10.9	40	10.9
Sink	35.4	0	0	50	32.3	50	48.29

BN4: +125 µm

Froth flotation product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
1	20.8	60	98.9	30	11.2	10	6.5
2	14.0	1	1.1	70	17.6	29	12.7
3	14.5	0	0.0	70	18.3	30	13.7
4	7.7	0	0.0	70	9.7	30	7.3
5	3.9	0	0.0	70	4.9	30	3.7
6	8.8	0	0.0	70	11.1	30	8.3
Sink	30.3	0	0.0	50	27.2	50	47.8

BN9: +125 µm

Froth flotation product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
1	4.7	60	100.0	30	2.2	10	1.4
2	41.6	0	0.0	70	46.0	30	37.0
3	30.1	0	0.0	70	33.3	30	26.8
Sink	23.6	0	0.0	50	18.6	50	34.8

Table 12 Overall mass balance of concentrates, tailings, Uis, Namibia.

BN3

Product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.0	3.3	100.0	67.6	100.0	26.1	100.0
Mica concentrates	0.3	100.0	20.7	0.0	0.0	0.0	0.0
Silspar concentrates	37.5	0.3	5.8	59.7	69.0	28.6	72.2
Feldspar concentrate	1.0	0.0	0.0	70	1.3	30	1.3
Quartz concentrate	1.4	0.0	0.0	50	1.2	50	3.2

BN4

Product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.0	4.8	100.0	68.7	100.0	22.2	100.0
Mica concentrates	0.5	100.0	22.9	0.0	0.0	0.0	0.0
Silspar concentrates	39.5	0.3	4.2	64.2	72.9	22.6	71.0
Feldspar concentrate	1.9	0.0	0.0	70	2.2	30	3.4
Quartz concentrate	1.9	0.0	0.0	50	1.6	50	6.0

BN8

Product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.0	6.7	100.0	47.8	100.0	26.0	100.0
Mica concentrates	2.5	100.0	37.6	0.0	0.0	0.0	0.0
Silspar concentrates	77.0	1.3	16.6	49.0	79.4	24.7	75.6

BN9

Product	Yield	Mica		Feldspar		Quartz	
		Grade	Recovery	Grade	Recovery	Grade	Recovery
	wt %	wt %	wt %	wt %	wt %	wt %	wt %
Head	100.0	3.4	100.0	58.8	100.0	36.9	100.0
Mica concentrates	0.1	100.0	15.3	0.0	0.0	0.0	0.0
Silspar concentrates	45.5	0.1	5.4	58.5	69.7	29.3	48.8
Feldspar concentrate	3.9	0.0	0.0	70	4.0	30	1.7
Quartz concentrate	2.4	0.0	0.0	50	4.9	50	5.0

Table 13 Chemistry of the products derived from tailings, Uis, Namibia.

Sample name	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3t %	Mn_3O_4 %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	SO_3 %	Cr_2O_3 %	SrO %	ZrO_2 %	BaO %	NiO %	CuO %	ZnO %	PbO %	LOI %	Total %
Mica																					
+2mm	45.46	0.03	35.31	0.71	0.04	0.11	0.54	0.74	9.41	0.15	<0.1	<0.01	<0.01	<0.02	<0.02	<0.01	<0.01	0.03	<0.01	5.65	98.18
+1mm	47.85	0.04	33.72	0.73	0.04	0.14	0.56	0.82	9.18	0.23	<0.1	<0.01	<0.01	<0.02	<0.02	<0.01	<0.01	0.03	<0.01	5.25	98.59
+500 µm	46.41	0.07	34.11	1.01	0.05	0.25	0.78	0.93	8.49	0.38	<0.1	<0.01	0.02	<0.02	<0.02	<0.01	<0.01	0.03	<0.01	5.71	98.24
+250 µm	49.24	0.10	31.67	1.25	0.06	0.33	1.14	1.12	7.28	0.67	<0.1	<0.01	0.03	<0.02	<0.02	<0.01	<0.01	0.04	<0.01	5.44	98.37
+125 µm	52.09	0.16	28.11	1.67	0.08	0.63	1.52	1.54	6.02	0.87	<0.1	<0.01	0.04	<0.02	<0.02	<0.01	<0.01	0.03	<0.01	5.74	98.50
+250 µm	48.41	0.09	33.33	1.14	0.05	0.17	0.15	0.86	9.04	0.18	<0.1	<0.01	<0.01	<0.02	<0.02	<0.01	<0.01	0.04	<0.01	5.12	98.58
+125 µm	46.55	0.11	34.21	1.31	0.05	0.27	0.20	0.66	8.63	0.27	<0.1	<0.01	0.02	<0.02	<0.02	<0.01	<0.01	0.03	<0.01	5.47	97.78
Commercial mica	44 - 47	0 – 0.9	30 - 38	0.2 – 5.0	na	0.3 – 1.5	0.1	0.1 – 0.8	8.5 – 11.5	na	na	na	na	na	na	na	na	na	na	4 - 5	na
Silspar																					
BN3 + 250 µm	72.42	0.04	14.71	0.25	0.02	0.13	1.38	4.04	2.72	1.41	<0.1	<0.01	0.06	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	1.95	99.13
BN4 + 250 µm	72.08	0.02	14.97	0.21	0.03	0.12	1.48	3.66	2.58	1.75	<0.1	<0.01	0.06	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	2.19	99.15
BN8 + 250 µm	72.36	<0.01	14.62	0.08	0.02	0.10	1.24	5.26	2.97	1.09	<0.1	<0.01	0.04	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	1.58	99.36
BN3 + 125 µm	73.27	0.04	14.32	0.20	0.02	0.12	1.44	4.18	2.35	1.36	<0.1	<0.01	0.06	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	1.91	99.27
BN4 + 125 µm	71.66	0.01	15.29	0.15	0.02	0.10	1.47	3.91	2.54	1.70	<0.1	<0.01	0.06	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	2.21	99.12
BN8 + 125 µm	70.01	<0.01	16.82	0.05	0.01	0.07	0.86	7.80	1.98	0.77	<0.1	<0.01	0.03	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	0.97	99.37
Commercial silspar	74 - 77	na	4 - 16	0.07 – 0.6	na	na	0.1 – 0.8	0.3 – 4.5	2 – 4.5	na	na	na	na	na	na	na	na	na	na	na	na

Table 13 (*continued*)

Sample name	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3t %	Mn_3O_4 %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	SO_3 %	Cr_2O_3 %	SrO %	ZrO_2 %	BaO %	NiO %	CuO %	ZnO %	PbO %	LOI %	Total %
Feldspar																					
BN3	66.71	0.01	18.64	0.07	<0.01	<0.05	0.31	6.99	4.04	1.17	<0.1	<0.01	0.05	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	0.93	98.92
BN4	70.32	<0.01	15.98	0.08	0.01	<0.05	0.70	5.63	2.94	1.91	<0.1	<0.01	0.04	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	1.11	98.72
BN8	66.91	<0.01	19.32	0.03	<0.01	<0.05	0.37	9.68	1.65	0.54	<0.1	<0.01	0.03	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	0.50	99.03
Glass-grade feldspar	64.5- 74.3	na	13.6- 21.8	0.08- 0.4	na	na	0.3- 4.1	4.1- 10	0.8- 4.5	na	na	na	na	na	na	na	na	na	na	na	na
Ceramic-grade feldspar	65 - 79.8	na	11 - 18.5	0.07 - 0.17	na	na	0.1 - 1	1.4 - 10	6.8 - 14.4	na	na	na	na	na	na	na	na	na	na	na	na
Quartz																					
BN3	85.16	0.05	8.61	0.16	<0.01	0.11	0.24	1.49	0.86	0.22	<0.1	<0.01	0.02	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	2.14	99.06
BN4	78.12	0.01	12.68	0.13	<0.01	0.13	0.99	1.06	0.63	1.06	<0.1	<0.01	0.08	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	3.94	98.83
BN8	87.29	<0.01	7.26	0.04	<0.01	<0.05	0.12	3.23	0.86	0.16	<0.1	<0.01	0.01	<0.02	<0.02	<0.01	<0.01	<0.01	<0.01	0.45	99.42
Commercial quartz	92.8 - 99.8	na	0.06 - 3.8	0.01 - 0.13	na	0.01 - 0.06	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Table 14 Particle-size distribution of tantalite concentrate, Uis, Namibia.

Size fraction	Yield wt %	Opaque Minerals Grade wt %	Opaque Minerals Recovery wt %
+2mm	0.26	8	0.03
+1mm	2.00	40	1.18
+500 µm	4.05	75	4.48
+250 µm	35.01	90	46.40
+125 µm	35.45	60	31.32
+63 µm	19.74	50	14.53
-63 µm	3.49	40	2.06
Total	100.00	67.9	100.00

Table 15 Mass balance of columbite-tantalite, gravity separation, tantalite concentrate, Uis, Namibia.

Product	Yield wt %	Columbite-tantalite Grade wt %	Columbite-tantalite Recovery wt %
Concentrate	75.16	90	96.88
Middling	9.36	20	2.68
Tailings	15.48	2	0.44
Total	100.00	70	100.00

Table 16 Particle-size distribution and mass balance of columbite-tantalite of gravity concentrate, tantalite concentrate, Uis, Namibia.

Size fraction	Yield wt %	Columbite-tantalite Grade wt %	Columbite-tantalite Recovery wt %
+2mm	0.12	95	0.13
+1mm	0.23	95	0.25
+500 µm	2.78	99	3.17
+250 µm	45.49	98	51.30
+125 µm	38.77	85	37.93
+63 µm	12.27	50	7.06
-63 µm	0.35	40	0.16
Total	100.00	86.9	100.00

Table 17 Modal mineralogy of mica concentrates, tailings, Uis, Namibia.

	Quartz wt %	Kaolinite wt %	Muscovite wt %	Calcite wt %	Feldspar wt %	Biotite wt %	Total wt %
+2mm	0.0	6.0	91.0	0.0	3.0	0.0	100.0
+1mm	2.5	4.5	89.0	0.0	4.0	0.0	100.0
+500 µm	1.0	10.0	81.0	0.0	5.0	3.0	100.0
+250 µm	7.00	15.0	65.0	1.0	6.0	6.0	100.0
+125 µm	12.0	16.5	47.5	2.5	10.0	11.5	100.0

Table 18 Modal mineralogy of silspar concentrates, tailings, Uis, Namibia.

	Quartz wt %	Kaolinite wt %	Na-feldspar wt %	K-feldspar wt %	Apatite wt %	Mica wt %	Total wt %
+125 µm	27.2	10.3	44.3	13.5	2.8	1.8	100.0
+250 µm	31.5	11.2	36.0	16.5	2.8	2.0	100.0

Table 19 Modal mineralogy of feldspar concentrates, tailings, Uis, Namibia.

	Quartz wt %	Kaolinite wt %	Na-feldspar wt %	K-feldspar wt %	Apatite wt %	Total wt %
BN3	8.0	7.0	58.0	26.5	0.5	100.0
BN4	23.0	8.5	47.0	20.0	1.5	100.0
BN8	3.0	3.5	82.0	10.5	1.0	100.0

Table 20 Modal mineralogy of quartz concentrates, tailings, Uis, Namibia.

	Quartz wt %	Kaolinite wt %	K-feldspar wt %	Apatite wt %	Na-feldspar wt %	Total wt %
BN3	68.0	13.5	5.5	0.5	12.5	100.00
BN4	58.5	27.0	4.0	2.0	8.5	100.00
BN8	64.0	3.0	5.5	0.5	27.0	100.00

Table 21 Statistics of feldspar production: Countries producing >100 000 tonnes of feldspar in 2001 (estimates). (U.S. Geological Survey, 2002).

France	600,000
Germany	460,000
India	110,000
Italy	2,600,000
Korea	330,000
Mexico	400,000
Portugal	120,000
Spain	430,000
Thailand	540,000
Turkey	1,200,000
United States	780,000
Venezuela	150,000
Other countries	1,540,000
World Total	**9,260,000**

Table 22 Summary of feldspar product chemistry and mineralogy (from Scott and Power, 2001). Major and minor refer to the relative abundance of the mineral phases microcline (Mc), orthoclase (Or), albite (Ab), quartz (Qz), mica (Mi), kaolinite (Ka). *Calculated end-member composition assuming perfect stochiometry. % feldspar values were calculated by assigning all K_2O to K feldspar, Na_2O to albite, and CaO to anorthite. Surplus SiO_2 is calculated as free quartz. Total includes 0.25% F.

Source	*K-feldspar	*Albite	Pegmatites					Granite
Major			Ab	Ab	Ab, Mc	Qz, Mc	Mc, Ab	Ab, Mc
Minor			Qz, Mi	Qz	Qz, Mi	Mi, Ka		Qz
SiO_2	64.77	68.74	70.02	68.22	67.43	74.37	66.06	68.66
TiO_2			0.11	0.03	0.25	0.14	0.00	0.02
Al_2O_3	18.31	19.44	17.66	18.46	19.34	14.20	18.61	18.12
Fe_2O_3			0.06	0.13	0.18	0.71	0.05	0.07
MnO			0.00	0.00	0.00	0.03	0.00	0.00
MgO			0.08	0.00	0.01	0.15	0.00	0.00
BaO			0.00	0.01	0.06	0.01	0.04	0.09
CaO			0.49	0.38	1.52	0.00	0.08	1.31
Na_2O		11.82	9.53	11.45	7.76	0.22	2.38	6.62
K_2O	16.92		0.40	0.14	2.73	5.74	13.15	4.67
P_2O_5			0.20	0.03	0.27	0.02	0.00	0.01
S			0.00	0.02	0.00	0.00	0.00	0.00
LOI			0.65	0.65	0.28	4.08	0.42	0.30
Total	100	100	99.20	99.52	99.83	99.67	100.80	99.87
%K-spar	100		2.4	0.8	16.1	33.9	77.7	27.6
%Na-spar		100	80.6	96.9	65.7	1.9	20.1	56.0
Ca			2.4	1.9	7.5	0.0	0.4	6.5
%Quartz			12.0	0.3	8.6	51.1	1.7	9.5

Table 22 *(continued)*

Source	China Stone	Aplite	Rhyolite	Feldspathic Sands				
Major	Qz	Or, Qz	Qz, Or	Mc	Mc, Ab	Or	Qz, Or, Mc	Ab, Mc, Or
Minor	Ab, Mc, Mi, Ka	Ab, Mi	Mi, Ka	Qz, Or, Ka	Or, Mi	Qz	Ka	Qz
SiO_2	71.31	70.43	75.63	66.24	67.39	66.88	85.45	67.56
TiO_2	0.06	0.29	0.07	0.25	0.00	0.07	0.12	0.01
Al_2O_3	16.09	14.73	13.20	17.34	17.64	17.34	8.29	18.81
Fe_2O_3	0.16	0.86	1.07	0.10	0.09	0.26	0.06	0.04
MnO	0.01	0.06	0.03	0.00	0.01	0.01	0.00	0.00
MgO	0.11	0.68	0.00	0.00	0.02	0.00	0.05	0.00
BaO	0.00	0.09	0.05	0.31	0.00	0.34	0.10	0.16
CaO	0.77	1.30	0.03	0.04	0.20	0.04	0.02	1.10
Na_2O	2.15	1.67	0.13	0.46	2.85	0.68	0.18	5.09
K_2O	4.55	7.71	7.41	14.23	10.87	13.14	4.41	7.04
P_2O_5	0.46	0.16	0.01	0.08	0.46	0.03	0.04	0.04
S	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00
LOI	3.07	2.00	2.81	0.54	0.68	1.14	1.40	0.38
Total	98.99†	100.01	100.46	99.60	100.21	99.93	100.13	100.23
%K-spar	26.9	45.6	43.8	84.1	64.2	77.7	26.1	41.6
%Na-spar	18.2	14.2	1.1	3.9	24.1	5.8	1.5	43.1
Ca	3.8	6.4	0.1	0.2	1.0	0.2	0.1	5.5
%Quartz	39.7	28.4	46.5	9.0	8.8	12.5	67.5	8.7

Table 23 Statistics of feldspar production in South Africa (Department of Minerals and Energy, 2000).

Date	1998
Production	56,761 tonnes
Local sales (FOR)	32,010 tonnes
Value	13,051,583 Rand
Export sales (FOB)	1,439 tonnes
Export sales value	1,071,677 Rand
Total sales	33,449 tonnes
Total sales value	14,123,260 Rand
Imports	No data shown, thus assumed to be zero.

Table 24 Properties of feldspar products from South Africa (Luitingh et al. 1998).

Plant	% Al_2O_3	% K_2O	% Na_2O	% Fe_2O_3
Idwala Industrial Minerals,	18 min.	12 min.	-	0.1 max.
Sidi Barani Mine, Kenhardt,				
Swartberg Mine, Springbok				
Consol Ltd., Krugersdorp, Gauteng*	18 min.	K_2O, Na_2O, Li_2O 11 min.		0.06 max.
Consol Ltd., Wynberg, Western Cape*	18 min.	K_2O, Na_2O, Li_2O 11 min.		0.06 max.
Cape Feldspar (Pty) Ltd Blackheath*	-	12	3	0.03
Garieb Minerale – Swartberg Mine	-	approx. 12	approx. 4	-
Namaqualand, Northern Cape				
Freddies Minerals, Phalaborwa	-	11	10	-
Letaba, Northern Province				
Pegmin (Pty) Ltd, Phalaborwa	-	9-11	7.5-10	-
Letaba, Northern Province				
Fine Industrial Minerals CC Elspark*	18	11	2	0.05

* Crushing, screening and milling only

Table 25 Operating mines producing feldspar in South Africa, 1999 (Roux, 1999).

Name of mine and location	Co-products	Type of mine
Cape Feldspar (Pty) Ltd. Western Cape,Stellenbosch,	silica	opencast
Consol Ltd., Wynberg, Western Cape	silica	opencast
Gelletich Mining Industries, Letaba, Northern Province	mica, silica, sulphur, talc	surface
Idwala Industrial Minerals, Benoni, Gauteng	silica, barytes, talc, flintclay, kaolin, limestone	surface
Kamgab Minerals (Pty) Ltd., Namakwaland, Northern Cape	columbite	opencast
Morelag Mine, Phalaborwa, Northern Province	beryl, mica, quartzite, silica, talc	opencast, underground
Pegmin (Pty) Ltd, Phalaborwa, Northern province	beryl, lithium, magnesite, mica, quartzite, silica, sodaspar, talc, tantalite	opencast, underground
Sidi Berani, Kenhardt, Northern Cape	gypsum	opencast

Table 26 Feldspar and nepheline syenite prices in an international market (Anon, 2002). Data are per tonne unless stated.

Feldspar	
Ceramic grade powder, 300 mesh, bagged, ex-store UK	£180-185
Sand, 28 mesh, glass grade, ex-store UK	£99
Ceramic grade, sand, ex-works Italy	$20-25
Ceramic grade, short tonne, ex-works USA, 170-250 mesh, bulk (Na)	$60-75
Ceramic grade, short tonne, ex-works USA, 325 mesh, bagged (Na)	$115-130
Ceramic grade, short tonne, ex-works USA, 200 mesh (K)	$125
Glass grade, bulk, short tonne, ex-works USA, 30 mesh (Na)	$40-52
Glass grade, bulk, short tonne, ex-works USA, 80 mesh (K)	$85-90
South African, free on board Durban, bagged, ceramic grade	$150
South African, free on board Durban, bagged, micronised	$205
Nepheline syenite	
Canadian, short ton, glass, 30 mesh, bulk, low iron	C$32
Canadian, short ton, glass, 30 mesh, bulk, high iron	C$29-30
Canadian, short ton, ceramic, 200 mesh, bagged 1 ton lots	C$85-90
Canadian, short ton, glass, filler / extended, bagged	C$98-195
Norwegian, FOL UK port, glass grade 0.5mm bulk	£99
Norwegian FOL UK port ceramic grade, 45microns, bulk	£116
Norwegian FOL UK port ceramic grade, 45microns, bags	£148

Table 27 World production of flake and scrap mica (U.S. Geological Survey, 2002).

Country	2000	2001(e)
	(thousand tonnes)	
United States	101	95
Brazil	5	5
Canada	17	17
India	2	2
South Korea	30	30
Russia	100	100
Other countries	35	35
Total	290	280

(e) estimated

Table 28 Main uses of flake and scrap mica (mainly from Harben and Kusvart, 1996), but modified using other literature). The size shown is the maximum. For some of the uses listed under the coarser grain sizes, finer size distributions may be specified by a customer.

Grade	Size Mesh no.	Grinding method	Use
Coarse flakes	6 (3.35mm)	Dry	Oil-well drilling, artificial snow
Medium-coarse flakes	10 (2.0mm)	Dry	Christmas ornaments, display material
Fine-coarse flakes	16 (1.18mm)	Dry, wet	Concrete block fillers, refractory bricks, asphalt roofing felts, shingles
Coarse-fine powder	30 (600µm)	Dry, wet	Metal annealing, absorbent in explosives, disinfectants, plastics, including automotive components
Medium-fine powder	60 (250µm)	Dry, wet	Wallboard joint cement, welding electrodes, cables and wires, foundry works, pipeline enamels, mastics, lubricants, adhesives
Fine powder	100 (150µm)	Wet	Texture paints, acoustical plasters, ceiling tiles, wall paper, rubber mould lubrication and dusting
Superfine powder	325 (45µm)	Wet, micronised	Paints, plastics, rubber, paper, cosmetics

Table 29 Prices of mica (Anon, 2002).

	per tonne
Dry ground, ex works, UK	£240-320
Wet ground, ex works, UK	£620-850
Micronised	£310-420
Indian dry ground, FOB India	$230-432
Indian wet ground, CIF Europe	$400-1,000
Indian micronised, CIF Europe	$365-545
Indian mica scrap for mica paper, FOB Madras	$245-365
Dry ground, ex plant NC, USA	$230-400
Wet ground, ex plant, NC, USA	$535-1,300
Micronised, ex plant, NC, USA	$535-930
Flake, ex plant USA	$250-480
Dry ground 20-60 mesh, FOB Durban	$325-355
Block mica, clear, FOB S. African port per kg	£9-80

Table 30 South African production and trade in mica 1998 (Department of Minerals and Energy, 2000).

Production	1,556 tonnes
Local sales	801
Export sales	334
Total sales	1,135
Imports	838

Appendix 3
Case Study C: Rosh Pinah Mine detailed information

Table 1 Sample list.

Sample No.	Sample mass (g)	Sample locality & description
BN6	*1300*	Top of *tailings* tip; spot sample.
BN7	1400	Top of tailings tip; spot sample.
BN11	117.3	Tailings tip; auger drill sample; H6 1-7-12.
BN12	136.1	Tailings tip; auger drill sample; H7 1-10
BN13	124.5	Tailings tip; auger drill sample; J1 1-11
BN14	110.5	Tailings tip; auger drill sample; J3 1-12
BN15	131.2	Tailings tip; auger drill sample; J5 1-9
BN16	150.6	Tailings tip; auger drill sample; J7 1-12
BN17	121.1	*Tailings tip; auger drill sample*; L1 1-15
BN18	139.0	Tailings tip; auger drill sample; L5 1-7
BN19	124.5	Tailings tip; auger drill sample; L7 1-10
BN20	120.4	Tailings tip; auger drill sample; N1 1-11
BN21	109.8	Tailings tip; auger drill sample; N5 1-7
BN22	136.3	Tailings tip; auger drill sample; P1 1-9
BN23	137.1	Tailings tip; auger drill sample; P5 1-12
BN24	118.4	Tailings tip; auger drill sample; R1 1-13
BN25	136.3	*Tailings tip; auger drill sample*; R3 1-11
BN26	112.3	Tailings tip; auger drill sample; R5 1-10
BN27	128.2	Tailings tip; auger drill sample; T1 1-16
BN28	104.1	Tailings tip; auger drill sample; T3 1-8
BN29	118.7	Tailings tip; auger drill sample; T5 1-11
BN30	137.0	Tailings tip; auger drill sample; V3 1-11

Table 2 Chemical composition of the Rosh Pinah tailings.

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	Mn_3O_4	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	Cr_2O_3	SrO	ZrO_2	BaO	NiO	CuO	ZnO	PbO	LOI	Total
	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %
BN6	37.49	0.12	2.49	6.10	1.24	8.47	14.28	0.12	1.32	0.17	3.99	<0.01	0.06	<0.02	0.95	<0.01	0.13	2.92	0.50	16.30	96.63
BN7	38.26	0.12	2.55	5.76	1.25	8.52	14.31	0.10	1.35	0.17	3.99	<0.01	0.06	<0.02	0.94	<0.01	0.12	2.88	0.49	16.50	97.36

Table 3 Modal mineralogy, Rosh Pinah tailings.

	Dolomite	Quartz	Pyrite	K-feldspar	Sphalerite	Gypsum	Barytes	Apatite	Galena	Celsian	Pyrope	Total
	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
BN6	39.8	29.1	12.2	9.6	5.5	1.6	1.3	0.6	<0.1	0.3	<0.1	100. 0
BN7	43.7	33.4	6.7	10.4	3.8	1.7	<0.1	<0.1	<0.1	<0.1	0.3	100.0

Table 4 Particle-size distribution of Rosh Pinah tailings.

Size fraction	BN6	BN7
	wt %	wt %
-5 +2mm	0.0	0.0
-2 +1mm	0.0	0.0
-1mm + 500 μm	0.1	0.1
-500 +250 μm	2.5	2.6
-250 +125 μm	16.1	16.7
-125 +75 μm	19.8	21.3
-75 +10 μm	44.5	50.0
-10 +2 μm	13.0	7.4
-2 μm	4.0	1.9
Total	100.0	100.0

Table 5 Electron Probe Micro Analysis (EPMA), tailings, Namibia.

	SiO2 wt %	TiO2 wt %	Al2O3 wt %	Fe3O4 wt %	Mn3O4 wt %	MgO wt %	CaO wt %	Na2O wt %	K2O wt %	Cr2O3 wt %	ZnO wt %	SnO2 wt %	PbO wt %	CuO wt %	BaO wt %	SO3 wt %	Total wt %
Barytes	0.36	1.00	0.00	0.00	0.56	0.00	0.19	0.40	0.00	0.05	0.87	0.00	0.39	0.13	64.57	32.46	100.98

NB Average of 3 analyses.

Table 6 Chemistry of the auger drill samples, tailings, Rosh Pinah, Namibia.

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	Mn_3O_4	MgO	Na_2O	K_2O	P_2O_5	Sc	V	Cr	Co	BaO
	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	ppm	ppm	ppm	ppm	wt%
BN11	33.60	0.12	2.80	4.83	2.19	7.50	0.60	1.57	0.13	7	32	20	4	5.9
BN12	34.10	0.13	3.20	5.42	2.19	6.90	0.70	1.68	0.12	11	36	29	7	5.8
BN13	36.80	0.14	2.90	4.47	1.78	6.10	0.70	1.64	0.12	3	33	22	5	7.8
BN14	38.40	0.14	3.10	4.22	1.83	6.40	0.70	1.79	0.14	12	34	27	10	6.3
BN15	35.20	0.13	2.90	4.96	2.29	7.60	0.70	1.66	0.13	8	34	29	5	5.5
BN16	38.80	0.14	3.60	4.70	2.32	7.60	0.70	1.91	0.13	10	40	35	8	3.9
BN17	46.00	0.16	3.80	5.03	1.83	6.00	0.90	2.10	0.12	8	38	22	7	3.6
BN18	36.20	0.13	3.10	4.64	2.38	7.40	0.70	1.74	0.14	6	39	13	6	5.4
BN19	38.30	0.13	3.30	4.70	2.32	7.30	0.70	1.78	0.13	7	40	23	8	4.1
BN20	41.00	0.16	3.80	4.72	2.06	6.50	0.70	2.05	0.14	9	45	24	9	4.9
BN21	36.70	0.14	3.40	4.36	2.21	7.00	0.60	1.83	0.13	7	41	22	7	5.9
BN22	35.10	0.13	2.90	4.95	2.02	6.70	0.70	1.60	0.12	8	36	18	8	7.0
BN23	42.40	0.15	3.70	4.30	2.11	6.70	0.60	2.00	0.15	5	41	19	8	4.4
BN24	43.50	0.15	3.60	4.72	1.89	6.40	0.70	1.94	0.12	5	35	23	6	4.7
BN25	39.80	0.15	3.40	4.24	1.93	6.70	0.60	1.90	0.14	9	47	19	7	5.8
BN26	40.30	0.14	3.40	4.94	2.10	6.40	0.70	1.85	0.15	7	39	23	8	4.9
BN27	42.20	0.15	3.50	4.82	1.79	6.20	0.80	1.93	0.12	6	38	20	10	4.8
BN28	41.90	0.16	3.90	4.73	2.24	6.80	0.70	2.10	0.13	8	49	27	4	4.0
BN29	41.80	0.15	3.40	4.93	2.07	6.70	0.70	1.90	0.12	8	38	21	9	4.7
BN30	42.10	0.16	3.70	4.68	1.74	6.40	0.70	2.03	0.12	10	37	21	6	4.8

Table 7 Particle-size distribution and heavy mineral content of selected tailings samples, Rosh Pinah.

Sample	Particle-size distribution				Heavy mineral content			
	+75 µm wt %	-75 +38 µm wt %	-38 µm wt %	Total wt %	<2.9 g/cm³ wt %	2.9 - 3.3 g/cm³ wt %	>3.3 g/cm³ wt %	Total
BN11	26.20	23.17	50.63	100.00	71.31	24.72	3.97	100.00
BN13	34.29	21.90	43.81	100.00	73.85	17.58	8.57	100.00
BN14	31.22	21.49	47.30	100.00	80.36	14.37	5.27	100.00
BN21	27.02	21.11	51.87	100.00	nd	nd	nd	nd
BN22	38.21	20.89	40.89	100.00	nd	nd	nd	nd

nd = not determined

Table 8 Estimated barytes content of selected tailings samples, Rosh Pinah.

Sample	Barytes content:							
	+75 µm >3.3 g/cm³		+75 µm 2.9 – 3.3 g/cm³		+75 µm size fraction		Whole sample	
	Min wt %	Max wt %	Min wt %	Max wt %	Min wt %	Max wt %	Min wt %	Max wt %
BN11	20	50	0	7	<1	4	3	14
BN13	20	50	0	7	2	6	5	16
BN14	20	50	0	7	1	4	3	12

NB Barytes contents based on X-ray diffraction analysis relative intensity data; assuming no barytes is present in the +75µm <2.9 g/cm³ product and that the barytes grade is the same in all the size fractions.

Table 9 Specification for barytes for drilling mud (API Specification 13A. Specifications for drilling fluid materials, 1993, *see* Harben 1995).

Density	min. 4.2 g/cm^3
Water soluble alkali earth metals, as Ca max.	250 mg/kg
Residue >75μm	max 3% by weight
Particles >6μm equivalent spherical diameter	max 30% by weight

Table 10 Statistics of barytes production (U.S. Geological Survey, 2002). Major world producers in 2001 (estimates) in thousands of tonnes.

Bulgaria	120
China	3,800
Germany	120
India	650
Iran	190
Mexico	120
Morocco	320
Turkey	20
United States	400
Other countries	625
Total	6,600

Table 11 Prices of barytes (Anon, 2002).

	Per tonne
Ground white, paint grade 96-98% 350 mesh, 1-5 tonnes delivered UK	£195-220
Micronised, off white min 99% <20μm, delivered UK	£140-150
Unground OCMA/API bulk, SG 4.2 FOB Morocco	$39-41
Ground bagged FOB Morocco SG 4.22	$75-85
Ground OCMA/API big bags (1.5 tonnes) FOB S Turkey	$68-70
Ground OCMA bulk, delivered Aberdeen, UK	£50-55
Ground OCMA bulk, delivered Gt Yarmouth, UK	£58-65
API lump, CIF Gulf Coast:	
Chinese	$42-48
Indian	$48-51
Moroccan	$50-52

Table 12 Statistics of barytes production in South Africa (Department of Minerals and Energy, 2000).

Data for (tonnes)	1997	1998
Production	2,071	610
Local sales	5,531	4,566
Export sales	0	0
Imports	1,980	1,431

Appendix 4 Laboratory methodology

Chemistry (Case Studies A, B and C)

Major element chemistry was determined by X-Ray Fluorescence (XRF) using a Phillips PW 2400 XRF spectrophotometer. Fused glass beads were prepared by fusing 0.9 g of sample with 9 g of dried lithium tetraborate ($Li_2B_4O_7$) flux at approximately 1200°C in a muffle furnace. The melt obtained was poured into a platinum casting dish. Lithium iodide was then added to all samples before fusion to act as a releasing agent. A suite of major elements and some trace elements were analysed and reported as percentages along with the Loss On Ignition (LOI) percentage, which was calculated from the weight loss of 1 g of sample heated at 1050°C for one hour.

Mineralogy

Binocular microscopy (Case Studies B and C) Polished resin-bound loose grain thin sections of the samples were produced. Petrographic analysis was carried out using a Zeiss binocular microscope, with camera attachment. Each sample was examined to determine the:

- the **size** and **shape** of the mineral components
- the presence of **inclusions** (i.e. where a mineral is enclosed within another)
- grain **coating** and **staining** (i.e. a thin layer of clay or iron oxides on their surface)
- the presence of **accessory minerals** (i.e. minerals present in minute quantities)
- the **degree of liberation** of the mineral grains (i.e. the extent to which the individual mineral components present are separated from each other)

X-ray diffraction (Case Studies A, B and C) Whole rock (or bulk) mineralogy was determined for all the samples using X-ray diffraction (XRD) analysis. The samples were prepared by taking a representative 5 g sub-sample from tema milled material. This was micronised for 10 minutes in deionised water and dried at 55°C. The dried powder was disaggregated using an agate pestle and mortar before back loading into a standard aluminium sample holder. The samples were scanned from 3–50°2θ at 0.48°2θ/minute. Diffraction data were analysed using Phillips X'Pert software coupled to an International Centre for Diffraction Data (ICDD) database running on a Gateway personal computer system.

Clay mineralogy (Case Study A) was determined for some of the samples using XRD as above but scanned over an angular range of 1.5–32°2θ. A representative portion of the less than 0.063 mm obtained during sieving (before drying) was taken using a peristaltic pump and the clay fraction was removed by sedimentation. This was dried and 80 mg dispersed in deionised water and deposited onto a porous ceramic disc by vacuum filtration to produce an orientated mount.

Scanning Electron Microscope (SEM) analysis (Case Studies B and C) The samples were examined as back scattered electron (BSE) images using a Cambridge Stereoscan 250 Mk II Scanning Electron Microscope. The semi-quantitative chemical composition of individual mineral components was determined using an integral energy dispersive system.

Electron Probe Microanalysis (EPMA) (Case Study B) The modal mineralogy (i.e. the proportion of minerals present) of selected samples was also determined. Identification of the mineralogy of a minimum of 300 mineral grains per sample was carried out to produce a statistically accurate modal analysis. The mineralogy of each grain was identified by its chemical composition. This was determined by electron probe microanalysis (EPMA) using a Cambridge Instruments Microscan V electron microprobe with a Links Systems energy dispersive system (EDS). The full major oxide chemical composition of selected mineral grains was determined and this confirmed the mineralogy through reference to published mineral composition. Modal analysis of the mineralogy was completed by calculating the volume percentage of each mineral component and ratioing against the specific gravity of the mineral. The mineralogy of the mineral component of the samples is expressed as a weight percentage. EPMA was also carried out on the tantalite sample.

Particle-size distribution (Case Study A)

In characterisation of samples from Costa Rica, particle-size distribution was determined through a combination of wet- and dry-sieving and X-ray sedigraph analysis. Wet-sieving was used to remove any silt- and clay-sized particles from the sample in preparation for X-ray sedigraph analysis. Dry-sieving was used for sand-sized particles.

Each sample was transferred to a leak-proof, screw-top plastic bottle and water added; this was placed on a shaker for a minimum of 4 hours in order to disaggregate the individual particles. Each sample was wet-sieved through a nest of 2 mm and 0.063 mm aperture stainless steel sieves to remove the fine material (silt and clay) for X-ray sedigraph analysis.

The material retained on each sieve was dried and sieved on a nest of brass sieves with the following apertures; 2, 1, 0.5, 0.25, 0.125, 0.075 and 0.063 mm using a mechanical sieve shaker set for 15 minutes. The material retained on each sieve was weighed and the value recorded.

The material passing through the 0.063 mm sieve was collected and dried (at 55°C) until approximately one litre was remaining. A sub-sample of this was taken using a peristaltic pump, whilst the sample was being stirred vigorously to ensure all the particles were kept in suspension; this was dried (at 55°C) then 50 ml of 0.05 % sodium hexametaphosphate (calgon) solution was added in preparation for X-ray sedigraph analysis.

X-Ray sedigraph analysis was carried out using a Micromeritics 5100 D series analyser. A standard reference material was run before the samples to ensure the machine was operating as it should be. Each sample was analysed on the sedigraph from 0.063 mm to 0.001 mm with cumulative percentage less than data collected at intervals.

Particle-size was calculated from these data as a frequency distribution (i.e. mass retained between each sieve or sedigraph size) and as a cumulative distribution (i.e. mass percentage finer than each sieve or sedigraph size).

Particle-size distribution (Case Studies B and C)

The samples of 'fines' were wet screened using the sieve series 2 mm, 1 mm, 500 µm, 250 µm, 125 µm 75 µm and 63 µm. The sieve residues were dried and weighed. The particle-size distribution of the -63 µm material (the filler grade) was determined using an X-ray Sedigraph particle-size analyser. Particle size analysis was also carried out on the tantalite sample (using dry screening).

Ceramic Properties (Case Study A)

Forming Properties

Plasticity The forming properties of a sample were evaluated by determining the Plasticity Index (PI). This is derived from Atterberg Liquid and Plastic Limits, detailed descriptions of these methods are given in Harrison and Bloodworth, 1994. Both methods were carried out on material less than 0.125 mm in size.

Liquid Limit (LL) The Liquid Limit (LL) test was carried out using the cone penetrometer method. Approximately 100 g of material was mixed with water on a glass plate using palette knives to obtain a stiff paste. A portion of the clay was placed in the cone penetrometer cup and any excess clay removed with the straight edge of the palette knife to obtain a smooth level surface. This was placed under the cone on the penetrometer so that it was just touching the surface of the sample, the dial reading was then turned to zero. The cone was released and the penetration depth was recorded. Consecutive readings were taken to ensure consistency, then a small sub-sample was removed to determine moisture content. The process was repeated three times with subsequent water being added so that four penetration depths were recorded along with four moisture contents. These were plotted against each other and the Liquid Limit was determined as the moisture content corresponding to a depth of 20 mm on the flow curve.

Plastic Limit (PL) Plastic Limit (PL) was determined using approximately 25 g of sample. The clay was mixed with water on a glass plate using the hands until it could be moulded into a soft ball. This ball was split into two with one being set aside. The remaining ball was split into four equal parts and each was moulded between the fingers until it was 6 mm in diameter then rolled into a clay thread of approximately 3 mm diameter. This process was continued until the clay cracked longitudinally and transversely. The moisture content of the four clay threads was then determined. The process was repeated for the other clay ball. The Plastic Limit (PL) is the average of the two moisture contents.

Plasticity Index (PI) The Plasticity Index (PI) is calculated by subtracting the plastic limit from the liquid limit.

Slop moulding of briquettes

Forming properties can be further evaluated by slop moulding of briquettes. Slop moulding is an alternative form of brick manufacturing that uses higher moisture contents compared to extrusion methods. Test briquettes were made in metal moulds (Figure 1).

The sample was mixed with enough water to form a stiff paste on a glass plate using palette knives. The mixture was then slopped into the metal mould using the palette knives, any excess was removed with the straight edge of the palette knife. A digital calliper set to 50 mm was indented on each brick so that a measure of linear shrinkage could be determined. The bricks were left in the mould overnight and removed the next day. They were then dried at 110°C overnight and the shrinkage measured using the callipers. The bricks were then fired at four different temperatures in a temperature gradient furnace. The bricks were left to cool in the furnace overnight then the calliper distance measured again and linear shrinkage calculated. Incremental additions (up to 30 % by weight) of sand were made to evaluate the effect on the linear shrinkage on drying (a process commonly used in the brick industry). Slop moulded briquettes with a mixture 50% by weight of one of the Sicorsa samples and the brick clay (G466) were also made.

a

b

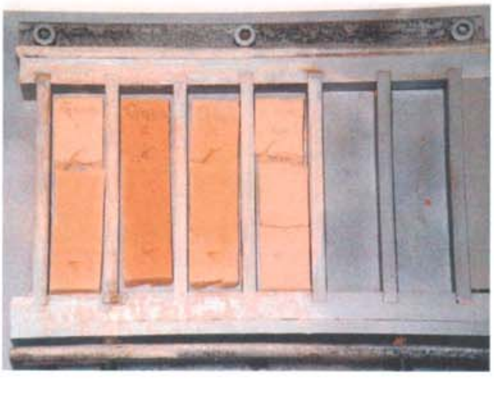


Figure 1 Extruded test pieces (a); Slop-moulded briquettes (b).

Fired Properties

Fired properties of potential brick clays were determined through a series of tests to determine shrinkage, bulk density, specific gravity and porosity. Detailed descriptions of these methods are given in Harrison and Bloodworth, 1994 and Appendix 1 provides some additional images of this method.

Fired properties were determined using extruded test pieces, each measuring 50 mm in length and 6.3 mm in diameter (Figure 1). Eight test pieces were required for each sample. The test pieces were dried at 110°C and their weight in air recorded. The test pieces were weighed in mercury using a mercury displacement apparatus. Each test piece was placed in one of eight cells of a temperature gradient furnace ranging in temperature from 850°C to 1250°C. The furnace heats gradually at 4°C/minute. The samples were cooled overnight in the furnace then weighed in air and mercury as before. Finally the samples were submerged in a dish of deionised water and placed in a dessicator and evacuated for three hours. Each test piece was removed and any excess water dried off and the test piece immediately weighed. Appendix 1 provides a more detailed description of this methodology.

Using a series of calculations derived from the weights obtained, shrinkage, bulk density, specific gravity and porosity were determined. 'Vitrification curves' were then plotted to show any change in porosity and shrinkage over the temperature range commonly used to fire whiteware and structural ceramics (850–1200°C).

Illustrated laboratory methodology for ceramic testing (Case Study A)

The following are a selection of laboratory images with simple annotation intended to supplement the Industrial Minerals Laboratory Manual: Construction Materials (Harrison and Bloodworth, 1994).

Extruded clay test pieces

The clay is mixed with water until a 'breadcrumb' like texture is achieved. It is then transferred to the clay extruder.

The clay is vigorously tamped down with a metal rod until it is fairly compacted.

The test piece is positioned into the holder.

The adjustable hand wheel is turned until the test piece is submerged into the mercury and the weight is recorded.

The clay is extruded, discarding the first 50 mm then a minimum of eight test pieces are extruded.

The test pieces are fired in an eight cell temperature gradient furnace. The temperatures from left to right vary between 1250° and 850°C at 50°C intervals.

Each test piece is approximately 50 mm in length and has a 6.3 mm diameter. Each test piece is dried overnight at 105°C then weighed in air to two decimal places.

Once the test pieces have been fired they are weighed in air and mercury again. Here the test piece on the far left is unfired and the others are from left to right the various firing temperatures (1250°C to 850°C).

The mercury displacement apparatus. The apparatus consists of a balance capable of measuring to two decimal places, mercury in a beaker on the balance, and a stand with an adjustment wheel which houses the test piece holder.

Finally the samples are submerged in a dish of deionised water and placed in a dessicator and evacuated for three hours. Each test piece is removed and any excess water dried off and the test piece immediately weighed.

Briquette making

The following are a selection of laboratory images with simple annotation intended to supplement the Industrial Minerals Laboratory Manual: Construction Materials (Harrison and Bloodworth, 1994).

The clay is mixed with water to form a stiff paste.

The paste is pressed into the brick mould using the pallet knives.

Callipers are set to 50 mm and are indented into each brick.

The bricks are left to dry overnight in the mould. They are then removed and dried at 105°C overnight.

The bricks are fired in a temperature gradient furnace. The temperature gradient ranges from 1250°C in the first cell on the left down to 850°C in the last cell on the right. The temperature difference between each cell is approximately 50°C.

Fired bricks, from left to right firing temperatures are 1232, 1172, 1020 and 855°C.

Table 1 The physical and chemical properties of feldspar, quartz and mica, Uis, Namibia. This list of properties is not exhaustive and is only relevant to mineral processing.

Property	Feldspar	Quartz	Mica
Chemical composition	$KAlSi_3O_8$ - $NaAlSi_3O_8$	SiO_2	$KAl_3Si_3O_{10}$ [F,OH]$_2$
Specific gravity	2.6 g/cm^3	2.65 g/cm^3	2.8 – 3.0 g/cm^3
Hardness (Mohs Scale)	6	7	2 - 3
Magnetic	Non-magnetic	Non-magnetic	Non-magnetic
Electrostatic	Non-conductive	Non-conductive	Non-conductive
Particle-size	3mm to <250 μm	3mm to <250 μm	3mm to <250 μm
Particle-shape	Blocky	Blocky	Platy

Laboratory scale mineral processing methodologies (Case Study B)

The aim of the mineral processing testwork carried out was to assess the feasibility of producing industrial grade products from the tailings at Uis. Mineral processing is a collective term that describes the methods and equipment used for the separation of minerals. The different physical and chemical properties of minerals can be exploited to separate them. The properties of feldspar, quartz and mica which are relevant to mineral processing are summarised in Table 1.

There are no significant differences between the specific gravity, magnetic, electrostatic and particle-size properties of the minerals; this ruled out using gravity, magnetic and electrostatic separation as well as size classification processing methods. The mica has a platy shape, compared to the blocky shape of the feldspar and quartz, which could be utilised using air classification. The feldspar and quartz have sufficiently different chemical composition to enable separation using froth flotation. The mineral processing test work carried out is explained in detail in the following pages and is also summarised in Figure 2, which shows the sequence of methods applied as a flowchart. The tailings samples selected for the mineral processing test work were from the tailings tip (BN3 and 4) and the tailings from the tin-tantalum plant (BN8 and 9).

The samples were screened to produce 'sized feed material' (i.e. material of a certain size range). Sized feed material between 2 mm and 125 μm was processed using an air classifier to remove the mica as a concentrate. The remaining material, which is enriched in quartz and feldspar, was passed over a magnetic separator to remove iron-bearing impurities. Selected size fractions of this quartz-feldspar product, also known as 'Silspar', were further processed by froth flotation in an attempt to separate out pure quartz and feldspar products. The final processing stage was to pass the products over another magnetic separator to remove the last traces of iron-bearing material.

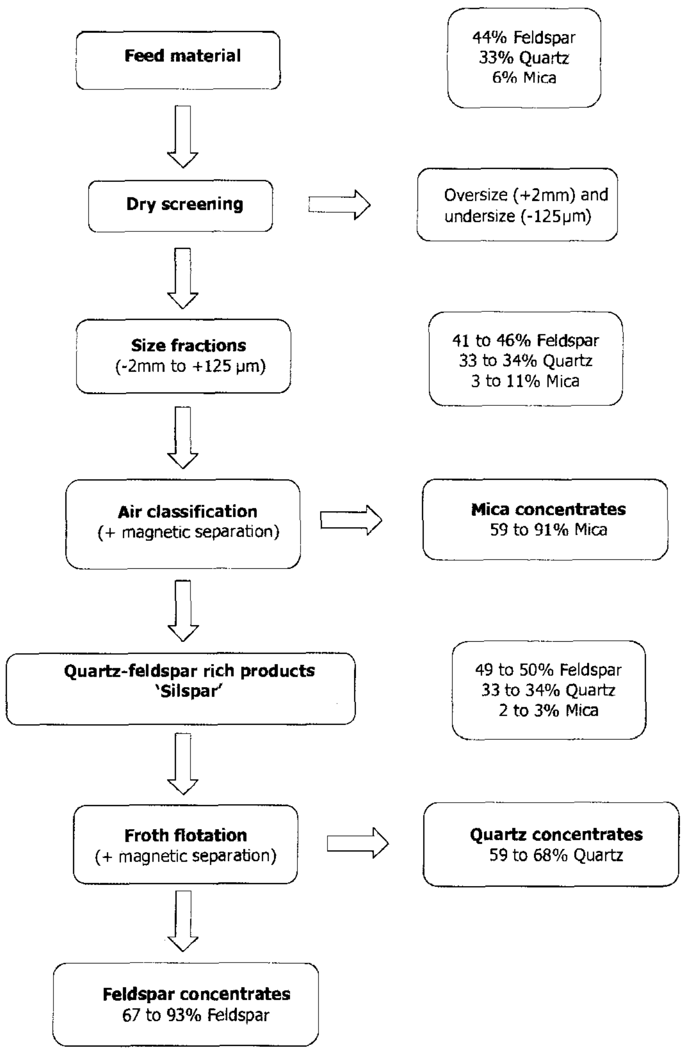


Figure 2 Summary of mineral processing of tailings, Uis, Namibia.

Air classification

Those size fractions that are coarser than 125 μm and contain greater than 200 grams were processed using a Hosokawa Micron zig-zag air classifier to remove the mica. This separator uses a vertical zig-zag shaped column, with an upward moving air current to remove fine-grained, less-dense and flakier material (such as mica) from coarse-grained, heavier and more granular material (such as quartz and feldspar). The cut-point of the separation was controlled by adjusting the velocity of the air flow (expressed in cubic metres per hour, m^3/hr). The products are referred to as underflow (that which drops down out of the flow, in this case the quartz-feldspar, or silspar, concentrate) and overflow (that which is carried up and out of the flow, in this case the mica concentrate). The samples were repeatedly passed through the separator, three to six times to remove as much mica as possible.

Three products were produced from the air classification of each size fraction; a *mica concentrate* (the first overflow product), a *silspar concentrate* (the last underflow product) and a set of products collectively referred to as the *middling* (all of the remaining overflow products). The air flow rate required to produce the concentrates decreases with decreasing particle size. For the mica concentrates this was 22 m^3/hr for +5 mm material, 20 m^3/hr for +2 mm, 16 m^3/hr for +1 mm, 10 m^3/hr for +500 µm, 4 m^3/hr for +250 µm and 2 m^3/hr for +125 µm. For the silspar concentrates this was 32 m^3/hr for the +5 mm material, 38 m^3/hr for +4 mm, 32 m^3/hr for +2 mm, 26 m^3/hr for +1 mm, 18 m^3/hr for +500 mm, 10 m^3/hr for +250 mm and 6 m^3/hr for +125 mm.

The **yield** (weight proportion of the product), **grade** (the mica content of the product) and **recovery** (the proportion of mica present in the feed that was recovered to the product) of the mica concentrates are given in Appendix 2 (Table 2). These are collectively known as the **mass balance** (or metallurgical balance) and are standard terms used to describe mineral processing test work.

Magnetic separation

Carpco induced-roll magnetic separator Those samples that have quartz-feldspar concentrates in the size range 500 to 125 µm (the finer-grained tailings samples; BN3, 4 and 9) were processed using a Carpco induced-roll magnetic separator to remove iron-bearing impurities. The magnetic separator incorporates a large electromagnet, suspended over a laminated drum, which generates a magnetic field gradient that increases in intensity toward the drum surface. A magnetic intensity of 15 700 Gauss was used, which was generated by applying a current of 3.45A to the electromagnet. Minerals with a sufficiently high magnetic susceptibility, such as magnetite (an iron-rich, ferromagnetic mineral) or tantalite (an iron-bearing, paramagnetic mineral) are attracted to the drum surface. They are taken away from the feed stream, deposited into a collection bin and are known as the magnetic product. The minerals in the remaining feed stream are diverted over the drum into a collection bin and are known as the non-magnetic product.

Froth flotation

The non-magnetic products form the feed for further processing by froth flotation, which was carried out to separate the quartz and feldspar.

Froth flotation was carried out using a Denver D12 laboratory flotation machine with a Pyrex cell. Suspensions were made with the sample placed into the cell with de-ionised water and the pH controlled at 2–2.5 through the use of sulphuric acid and caustic soda. Samples were conditioned for 2 minutes at a stirrer speed of 1500 rpm with an organic reagent known as a 'collector'. In this case a proprietary reagent, Armac T (Tallow Alkyl Amine Acetate, supplied by Akzo Nobel) was used. The collector was added at a dosage rate of 400 grams per tonne. An 'activating' reagent (NaF_2), which promotes adherence of the collector onto the feldspar grains, was added at a dosage rate of 1000 grams per tonne. After conditioning a drop of 'frother' (Methyl Isobutyl Carbinol, MIBC) was added; this helps to stabilise any bubbles generated by reducing the surface tension of the water. During the flotation stage of the process the stirrer speed is reduced to 1000 rpm and air is diverted into the cell through the stirrer impellors to generate bubbles within the suspension. Bubbles adhere to those grains whose surfaces have been rendered hyrdophobic (in this case the feldspar) by a layer of collector reagent. The loaded bubbles rise to the surface of the suspension forming a froth, which is periodically removed. The froth is known as the 'float' product and, in this case, is (ideally) enriched in feldspar. The material remaining in suspension is known as the 'sink' and is enriched in quartz.

Magnetic separation

Frantz isodynamic magnetic separator The feldspar-rich and quartz-rich products from froth flotation were processed by magnetic separation to remove the last traces of iron-bearing material. Magnetic separation was carried out using a Frantz isodynamic magnetic separator, which consists of an inclined channel that passes through an electromagnet. Material was fed along the channel, from a vibratory hopper. Minerals with a sufficiently high magnetic susceptibility were attracted to the raised length of the channel and reported to the 'magnetics' bin at the downslope end. The remaining minerals reported to the 'non-magnetics' bin at the downslope end.

Gravity separation

Mozley laboratory separator Several size fractions from the tantalite sample were processed using a Mozley laboratory separator, which is a shaking table type of gravity separator. These are used to separate minerals with different densities, for example tantalite (which has a specific gravity in the range 5.2 to 8.2 g/cm^3) from less-dense minerals such as quartz and feldspar (2.6–2.8 g/cm^3). The shaking table uses a flowing film of water over a flat inclined surface to effect a separation. Water velocity decreases towards the surface of the table. Fine grained and relatively dense particles become entrained in the slow moving lower layer of water adjacent to the table surface. Whereas, larger and less dense particles are caught up in the faster moving water further from the table surface. This causes a relative displacement of the heavy from the less-dense material. The table is also oscillated in the horizontal plane, with an additional 'knock' at the upslope end. The oscillation causes stratification of the minerals. The 'end-knock' encourages the heavy minerals resting on the table surface to migrate upslope, enhancing the displacement between heavy and less-dense minerals. As the separation progresses the less-dense minerals are washed downslope, followed by minerals of intermediate density. The heavy minerals concentrate toward the upslope end of the table. The size fractions processed were separated into three products: a concentrate (the heavy minerals), a middling (minerals of intermediate density) and a tailing (less-dense minerals).

Product evaluation

The mica-, feldspar- and quartz-rich products from the mineral processing test work were evaluated to determine whether or not they meet the technical requirements for industrial-grade industrial minerals. The main evaluation criterion is the chemical composition therefore the chemistry of all the products was determined by XRF analysis.

Heavy Media Separation (HMS) methodology (Case Study C)

Five samples of tailings from the drilling program were chosen on the basis of their relatively high BaO content. Sub-samples were wet screened to remove the -75 µm material. The heavy minerals present in the +75 µm material of three of the samples were concentrated using heavy media separation.

The samples were added to a flask containing the organic liquid bromoform, which has a density of 2.9 g/cm^3. The sub-samples were stirred (to dislodge entrained material) and then allowed to separate. Minerals with a specific gravity lower than the density of the heavy media floated to the surface, whereas minerals with a higher specific gravity sank. The heavy ('sink') products were removed by siphoning off the heavy media through a tap at the base of the flask. The less-dense ('float') products were removed by siphoning into a separate container. The sink products were separated in di-iodomethane (otherwise known as methylene iodide), which has a density of 3.3 g/cm^3, using the same procedure. The products were all washed thoroughly in acetone to remove all traces of heavy media and then weighed. This resulted in three products for each sample:

- a float product (i.e. the float from the bromoform separation that contains minerals with a specific gravity less than 2.9 g/cm^3).
- a middling product (the float from the methylene iodide separation which contains minerals in the range 2.9–3.3 g/cm^3).
- a sink product (the sink from the methylene iodide separation which contains minerals heavier than 3.3 g/cm^3).

A sub-sample from each of the products was analysed by XRD to determine whether or not a significant amount of barite was present.

Appendix 5 Economic Assessment

METHODOLOGY AND INFORMATION SOURCES

An assessment of the economic case for establishing a profitable operation making an industrial mineral product from mining waste can be divided into two parts. Firstly, there is a need for a study of the demand and current supply of the industrial mineral in order to establish if a market for the product exists. Depending on the type of mineral, this may require a knowledge of local, national or international markets. Assuming a viable market is identified, a financial appraisal is then undertaken to establish that an economic return on the money invested can be achieved. This involves establishing the costs of production, processing, handling and transport to the consumer, determining any costs associated with legislative (including mining licences and permits), ownership and environmental issues and agreeing responsibilities with the relevant government or appropriate agencies and owners. There is an advantage in the sale of a waste mineral product, measured in terms of reduced costs and space required for tipping, and there may be an environmental or social gain. These benefits can be set against the cost of production, and in certain situations, it is possible for the mineral product from waste to be supplied at zero cost to a consuming industry.

The activities in undertaking an assessment of potential markets need to involve a search through relevant statistical and other published literature, and includes interviewing key personnel in relevant government departments and public bodies. The interviews are required to validate and augment published data. Details of the current production of primary industrial minerals, the production of potential competing minerals, and a knowledge of the consuming industries, their current and projected future rate of production, are also required. A list of some relevant sources of general literature on the markets for industrial minerals and a generic list of organisations which often hold data on the production, use and consumption of industrial minerals is given in Table 1. A considerable amount of general information on industrial mineral production and consumption is available on the world-wide-web, and most countries publish statistics on their mining and manufacturing industries. Other data are available from industry and quasi-government organisations, and from individual companies if not held in commercial confidence. Further details of the criteria involved in establishing a market for an industrial mineral product made from mining waste are given in the Scoping Study report for this project (Harrison et al., 2001).

Comparisons between industrial minerals made from mining waste and primary industrial minerals have to be made on an equal properties basis. For example, a low quality industrial mineral from mining waste has to be compared with a similar quality product from a primary source in its potential markets. This may restrict a waste mineral's usage. Thus, an apparent demand for a particular industrial mineral may not be satisfied by a mineral product made from waste, unless it meets the required specifications. A further requirement by a consumer would be a consistency of supply at a constant specification. Thus, some method of homogenisation, through mixing material of known composition from different parts of the waste heap, or mineral separation by processing to yield a consistent product, is likely to be required.

A financial appraisal involves establishing the capital cost for plant to recover and process the waste, and calculating the operating costs. The latter include wages, costs of materials, power, fuels, and maintenance, payment of interest on loans, and other indirect costs such as royalties and leases. There may be additional costs associated with environmental compliance and for closure, when the resource is exhausted or extraction ceases. Although transport may not be a direct charge on creating a mineral product from the waste, it can be a significant cost to the consumer. Thus, transport costs needs to be considered when deciding if an viable market for the mineral product exists. In general, a low value, industrial mineral product needs to find uses locally, as transport costs will form a significant proportion of the value of the product to the consuming industry. A higher value industrial mineral product may find a national or international market depending on its quality. Special grants, subsidies or loans from local, national or international sources may off-set some of the operating or capital costs. Further details of the requirements for a financial appraisal are given in the Scoping Study report for this project (Harrison et al., 2001).

The relative costs of mining operations, including extraction of an industrial mineral product from mining waste, vary considerably from country to country. Sources of information where details of costs may be found are listed in Table 2. Inflationary pressures and instability in a developing country may affect costs when expressed in local currency. Thus, it is preferential to specify

Table 1 List of international and country-specific organisations providing data and publications relevant to the assessment of markets for industrial minerals from mining waste.

International:
United Nations, Economic & Social Council, Committee on Natural Resources
United States Geological Survey (www.minerals.usgs.gov/minerals/pubs/country/)
CIA – The World Factbook (www.cia.gov/cia/publications/factbook)
Industrial Minerals Information Ltd. (monthly journal 'Industrial Minerals') (www.indmin.com)
British Geological Survey (publication 'World Mineral Statistics www.mineralsuk.com/)
Roskill Information Services (Roskill Reports on Metals and Minerals) (www.roskill.co.uk)
Mining companies annual reports
Country specific (generic titles, which will differ from country to country):
Ministry / Department of Mines
Ministry / Department of Information
Ministry / Department of Trade and Industry
Ministry / Department of Planning
Geological Survey
Trade associations (e.g. Construction Industry Association, Institute of Quarrying, Institute of Mining)
Government research associations
Export and foreign trade organisations
Chamber of Commerce
Investment boards and banks
Individual companies consuming industrial mineral products
Published accounts of mining companies
Published data from public utilities

Table 2 List of international and country-specific organisations providing data and publications on the costs of mining, processing and transport of industrial minerals made from mining waste.

International:
Australasian IMM (http://www.ausimm.com.au/codes/valmin/valmin.asp)
The World Bank (www.worldbank.org/html/fpd...files/ienim/afmining/afmining.htm)
Minecost (www.minecost.com)
Country specific (generic titles):
Ministry / Department of Mines
Ministry / Department of Trade and Industry
Ministry / Department of Transport
Ministry / Department of the Environment
Trade associations
Investment boards and banks

these in a stable currency (e.g. US$, £sterling, or Euros). It is essential to validate the data on costs obtained from general literature by gaining further information from local sources, as unusual circumstances (e.g. local wage rates and availability of labour, availability of transport and road quality) may influence any financial appraisal.

Appendix 6 Social Impact Assessment

PRINCIPLES, PROCEDURES AND METHODS

The starting point for the development of an approach to the socio-economic impact assessment (SIA) research for Uis, Rosh Pinah and Cartago were the critical guiding principles of SIA. The ICGP (1995) outline a number of these critical guiding principles that should govern the use of SIA. Seebohm (1997) provides a useful précis of these principles, which is outlined below. These principles were used during the planning and conduct of the research to structure and focus the SIAs for Uis, Rosh Pinah and Cartago.

1. Identify the main features of the proposed development project, programme or policy.
2. Identify the types and numbers of people involved.
3. Identify data sources: use published scientific literature, secondary data and primary data from the affected area.
4. Identify and involve the public: including all potentially affected groups and individuals.
5. Focus the assessment: deal with the issues and concerns that really count not those that are easy to handle.
6. Provide feedback on social impacts to project planners and identify problems that can be solved with changes to the proposed action through mitigation or enhancement.
7. Make developments more socially sound.

Given the uncertain feasibility or technical nature of the proposed projects at the time of conducting field studies, the SIA research was steered by an additional principle of 'managing expectations'. The assessor felt it important to not be explicit about the proposal and some of its potential impacts as this might have raised unnecessary pre-emptive resistance or unfounded hopes. As a result, only key informants were presented with a project summation and given the opportunity to respond to the informal proposal. Connected to these overarching principles, used to conceptually steer the research, were a series of procedures and methods used to practically steer and apply the research:

Stage one. Involved desk research to scope issues of mine developments and socio-economic impact at the most general level. The results of this initial scoping study are contained in the Harrison et al (2001) report entitled 'Utilisation of Minerals for Waste'. It is the most important preparatory procedure in the SIA process and helps to clarify the issues relevant to the field including the key social variables to be considered for analyses. The main method used to conduct the general scoping exercise is the review of relevant *general secondary sources* of information.

Stage two. Involved describing the baseline conditions for each site. In addition to providing a base for subsequent socio-economic monitoring, this frames subsequently predicted impacts in a specific context, since all impacts are to some degree relevant to the time and place their effect will be felt. This involved field visits to all three sites in October, November and December 2000 to analyse existing social conditions including social resource profiles, cultural attitudes and population characteristics. The assessor made extensive use of information contained in *local secondary sources*. This information was supplemented and updated through *interviews*, *participant observation* and *surveys* carried out during field visits to Cartago, Uis and Rosh Pinah.

Stage three. Involved the field visits to the sites and desk research to scope and predict issues relevant to the specific site being assessed. Scoping included the identification of impacts at all phases of the development, positive as well as negative, direct, indirect, or cumulative, permanent or temporary. This was facilitated through the use of relevant impact *checklists*, and *semi-structured interviews* with local project stakeholders. The prediction of impacts was key to the research. It involved investigating the probable impacts of the proposal and the likely response of affected stakeholders based on the assessor's own opinion, *expert opinion* and the result of *semi-structured interviews* with project stakeholders.

Stage four. Involved making recommendations for the mitigation of negative impacts and the enhancement of positive impacts at the three sites. This was based on the assessor's own experience as well as some *expert opinion*. It was important to recommend measures that involved, first, avoiding all adverse impacts, second, minimising any adverse impacts that cannot be avoided, and, third, compensating for unavoidable adverse impacts. The aforementioned italicised methods used during the stages of the socio-economic impact assessment research, and their specific relevance to the SIA process, are described below:

Checklists are comprehensive generic listings of potential impacts based on past experience to aid-data gathering and insure that no important factors are overlooked (Graham-Smith 1993). Their task is therefore primarily one of impact identification. Checklists do not usually include direct or indirect cause-effect links to project activities, although there may be some prediction of the character and nature of the impact itself. Glasson et al. (1996) identify two main checklist used in SIA. *Descriptive checklists* give guidance on how to assess impacts. *Questionnaire checklists* formulate a set of questions to be answered regarding impacts e.g. will the project provide job opportunities?

Expert opinion. Experts can contribute to the identification and prediction of impacts possibly neglected by the public or by mandatory considerations. There are several techniques for effectively obtaining expert input, including the Delphi technique (Finsterbusch, 1995). Delphi involves several iterative rounds of individually conducted interviews and questionnaires with the experts, returning to them with the results of earlier rounds for reassessment (Leistritz and Murdock, 1981).

General Secondary Sources provides a major guideline for future expectations can be general and past social experience. To know the probable impacts of a proposed project in location B, one of the best places to start is to assess, through general secondary sources, the impacts of an established project in location A. Finsterbusch (1995) suggests that such case studies and literatures should be summarised in a *Standard Information Module* (SIM). SIMs focus on the dominant impact patterns relevant to the type of project intervention under review. If these patterns are repeatedly documented then the new case, it is held, will approximate the patterns of the previous cases.

Local Secondary Sources are particularly useful in providing baseline information on the social, demographic and cultural context within which project-related social changes occur (Leistritz and Murdock 1981, Bender Motz 1983). This can include sources such as census data, geographical data, administrative reports, and community accounts and newspaper reports. Relevant local literature searches are cheap and simple to conduct, reducing the financial and logistical requirements of the SIA and, used in conjunction with primary sources of data, provide a means of verifying the SIA (ICGP 1995).

Surveys may include structured face to face or telephone interviews, but more commonly refer to questionnaires administered to a sample population group (Easterby-Smith et al. 1991). Typically surveys are used in SIA to determine the attitudes of area residents toward a proposed project or to facilitate the prediction of resident responses to the project. These objectives do not require complex survey designs and can be conducted by relatively inexperienced researchers. Mini surveys are especially popular in SIA and can be conducted cheaply in one or two days. They do not give pinpoint accuracy nor can they sustain a robust multivariate analysis, but SIAs report mainly univariate distributions that require far fewer responses (Finsterbusch, 1995).

Semi-structured Interviews are based on a checklist of general questions which can be revised at any time (Chambers, 1981). This leaves a degree of flexibility, so that if other questions are raised during the interview they can be explored. Interviewees are typically key informants, focus or mixed groups. It is important that those interviewed are made to feel at ease. It has therefore been suggested that interviews start with general questions before moving on to more sensitive areas (WHO, 1988). Gueye and Freudenberger (1991) suggest that interviews should be preceded by an explanation of why it is requested.

Participant observation involves the SIA practitioner living among the people being researched, even learning their language and sharing as many of their experiences, customs and practices as possible. It is carried out in a relatively unstructured, free ranging and exploratory manner. Unlike classical anthropology, in SIA the stress tends to be on the obtaining data over a shorter period, rather than dialogue over a more protracted period. As well as providing a good method of cross-checking alternative methods participant observation allows for a rich contextual understanding of social groups and can inform the SIA from initial profiling through to long term monitoring (Roper, 1983).