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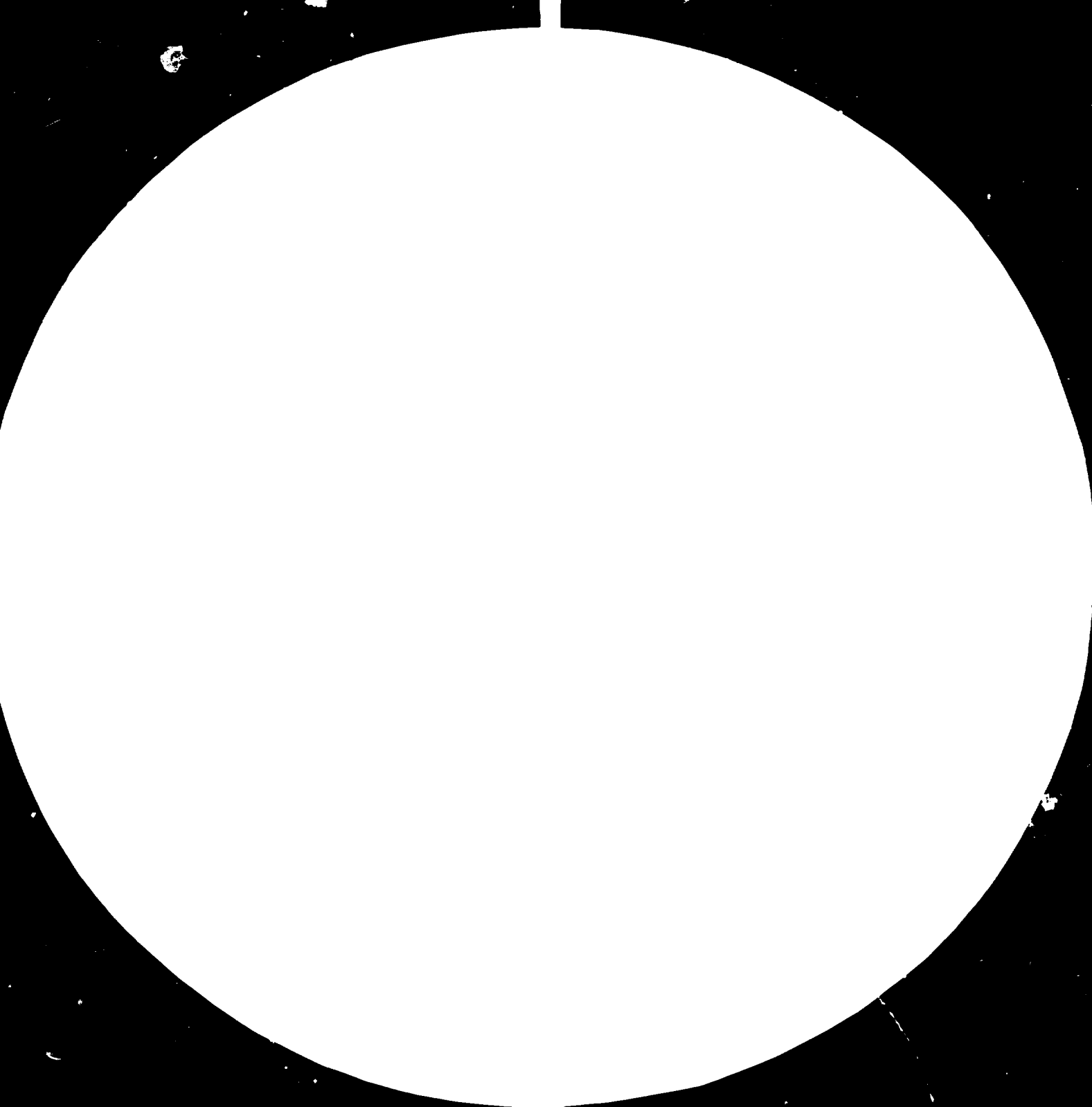
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ANSI/ISO Resolution Test Chart
Resolution Test Chart
Resolution Test Chart

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11 March 1983
English

PROCESSING OF KYANITE
ORES IN ZIMBABWE

SI/ZIM/82/801

ZIMBABWE

Terminal report

Prepared for the Government of Zimbabwe
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Henry E. Cohen
expert in mineral resources engineering

United Nations Industrial Development Organisation
Vienna

ABSTRACT

The project on Processing Kyanite Ores in Zimbabwe (ref. No. SI/ZIM/82/801) was carried out during the period 22.1.1983 to 12.3.1983 inclusive, a total of seven weeks. The objective of the single expert mission was a preliminary resources study of opportunities for industrial developments based on deposits of the alumino-silicate mineral kyanite and on other indigenous mineral resources such as clays, feldspars and lithium silicates. The mineral resources of Zimbabwe were reviewed. A strong possibility was identified for manufacturing ceramics for domestic requirements, especially electrical insulators and sanitary ware. Negotiations for manufacture were initiated between the Industrial Development Corporation (I.D.C.) and private industry. Supportive research and development projects were proposed for the Geological Survey, the Institute of Mining Research and the Department of Metallurgy. It was recommended that the Ministry of Mines, the Industrial Development Corporation and the Minerals Marketing Board should set up a Cooperative Corporation for mining, processing and export marketing of kyanite at rates up to 50 000 tonnes per year. It was proposed that UNIDO should support a major project for the preparation of an Industrial Minerals Inventory of Zimbabwe. A further proposal concerns an industrial research project for electric plasma-fired calcining of kyanite. Other recommendations include the updating of facilities for industrial research, the exploitation of a deposit of diatomite and the modernisation of treatment processes for lithium silicate deposits.

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I. SUMMARY OF FINDINGS AND RECOMMENDATIONS

1. The alumino-silicate mineral kyanite is an excellent industrial raw material with many uses in refractories and in ceramics. Zimbabwe has ample reserves of kyanite and of the other necessary components such as clays, feldspars, silica and lithium silicates.
2. Kyanite occurs in substantial quantities in commercially workable surface and near surface deposits. Total reserves are likely to be in excess of 17 million tonnes. The deposits are amenable to simple processes of concentration so as to meet user specifications for refractories and for ceramics.
3. About 20 main deposits are grouped in two areas, in the north of the country near Karoi and in the north-east beyond Mtoko. Road transport over unsurfaced roads is needed to take the ore some 80 - 100 km to the nearest railheads at Lions Den and at Shamwa, respectively. The alternatives of road transport to railheads or extension of the railway lines to the two mining areas need careful examination. Greater national benefit would accrue from the railway extensions.
4. The immediate utilisation of kyanite should be for diversified ceramic manufacture of sanitary ware, electrical insulators and table ware. This can be based entirely on domestic raw materials and should replace all imports. Production should be scaled initially to meet the domestic markets. One company can cover that market profitably. Negotiations have been initiated between I.D.C. and two ceramic companies.
5. There is a domestic market for electrical insulators worth Z\$ 4 000 000 - 5 000 000 of which 20 - 25% should be targeted initially. At present all insulators are imported. It is estimated that there is a domestic market of several thousand sanitary units per year, currently all imported.
6. Diversification into exports and into other products (ceramic fibres, etc.) is envisaged later, when the necessary quality controls and operational skills have been firmly established.
7. It is recommended that manufacture of refractories should not form a first industrial target (apart from such small-scale manufacture as exists at KweKwe and Bulawayo). The depressed state of the world-wide

metallurgical industries does not permit penetration of a competitive market by an unknown new manufacturer.

8. The kyanite requirements for ceramic manufacture are small (200 - 400 tonnes per year) and can be covered easily by casual mining until a major mining operation is established for kyanite exports.
9. After a ceramics industry has been established it might be possible to initiate trial manufacture of refractories and to offer samples to users, for gradual market penetration.
10. Export markets for raw and calcined kyanite should be actively sought now through a planned marketing campaign. Small samples for marketing can be prepared by the Department of Metallurgy of the Ministry of Mines.
11. It is recommended that full scale mining and processing activities should be planned and initiated immediately so as to be capable of producing 50 000 tonnes per year within the next 5 years. This represents 3% of estimated forecasts of world consumption of kyanite.
12. It is recommended that the Ministry of Mines, the Industrial Development Corporation and the Minerals Marketing Corporation should jointly set up a Kyanite Cooperative Corporation for mining, processing and marketing kyanite.
13. Mining would be carried out by small workers on a cooperative basis during 8 - 9 months of dry season, so as to achieve low costs and a maximum distribution of additional income without disturbing the farming pattern. The ore would be roughly pre-concentrated and then transported to a central concentrator at Harare.
14. From mined ore of about 100 000 tonnes per year, depending on ore grade and concentrator recovery, the concentrator at Harare should produce about 50 000 tonnes of concentrate per year.
15. The concentrates would be partly calcined and partly high grade raw kyanite, destined largely for export, with an FOB Beira value of not less than Z\$ 150 - 180 per tonne. Total production and freight costs (to Beira) are estimated to be not more than Z\$ 100 per tonne, but detailed costings will have to await the production plan.

16. The Geological Survey, the Institute of Mining Research and the Department of Metallurgy are regarded as key organisations in developing and supporting the industrial exploitation of Zimbabwe's mineral resources. The following proposals depend heavily on the utilisation of these three institutions. Additions to their staff and their facilities are recommended to enable them to make the necessary efforts effectively.
17. A major new project proposal for support by UNIDO concerns the creation of a systematic industrial mineral inventory for Zimbabwe. This will provide an information base for industrial developments, giving grade, reserves and applications for all major deposits in the country. The work can be carried out jointly by the Geological Survey, the Institute of Mining Research and the Department of Metallurgy. The basic project will extend over 2 years. Staffing and facilities will call for a total budget of the order of Z\$ 500 000. This proposal also assumes some bilateral aid funding for equipment.
18. The laboratories of the Department of Metallurgy need to be updated. It is proposed that UNIDO should provide an expert on short mission (1 - 3 months) to assist in drawing up a rational programme of refurbishment, additions to equipment and staff improvements. Training assistance by the British Council for Zimbabwe nationals and bilateral aid for equipment need to be explored.
19. A major project of industrially oriented research into the use of plasma firing for calcining kyanite is proposed for the Institute of Mining Research. UNIDO and/or I.D.C. should fund the work over 2 years with a budget of up to Z\$ 50 000 for one expert. Equipment funding of the order of Z\$ 50 000 - 100 000 will need to be sought from EEC, U.K. or U.S.A. sources.
20. A grant from UNIDO of Z\$ 5000 - 10 000 (equivalent) for purchase of foreign books is recommended to update the library of the Institute of Mining Research. It is also desirable to explore the possibility of providing an international data link facility.
21. Exploitation of a diatomite deposit is recommended. This can be undertaken by I.D.C., but UNIDO should support the initial investigation by providing an expert on short mission (1 month).

22. A new look at updating the processing methods at Bikita (lithium silicates) is long overdue. This is in the national interest and I.D.C. could investigate. A specialised expert in mineral processing of silicates could be provided with UNIDO assistance.

INTRODUCTION

A. The Purpose of this Mission

At the request of the Ministries of Mines and Economic Planning and Development in Zimbabwe, UNIDO arranged for the writer to carry out a resource-based opportunity study. This was to examine the possibilities of developing industrial activities based on the country's deposits of the aluminium silicate mineral kyanite and other allied minerals. The establishment of new industrial capabilities, the provision of employment in regions of subsistence farming and an increase in GDP as compared with exporting raw materials are important components of the aims of the project. This preliminary investigation should enable the Government of Zimbabwe and UNIDO to select suitable industrial targets for development and feasibility studies.

The writer was in Zimbabwe during the period 22.1.1983 to 12.3.1983, a total of seven weeks.

Mission Support

The Mission was based at the Ministry of Mines, under the care of Dr.M.Kanyangarara who acted for the Secretary for Mines, Mr.C.M.Ushewokunze. Most valuable support was received from the Geological Survey Department (Director Mr.E.R.Morrison), the Institute for Mining Research (Director Professor K.Viewing) and the Department for Metallurgy (Director Mr.W.Furusa). Useful assistance was also provided by Mr.G.Field who is on ODA secondment to the Department of Mining. All these Departments of the Ministry of Mines represent very substantial support capabilities for the types of systematic work that may be needed as a result of this mission.

The writer also worked with the Industrial Development Corporation of the Ministry for Industry. Details are given in a later section of this report.

The writer was enabled to make visits to the two main areas of kyanite deposits and to other mineral sources of possible relevance to the project. These included the lithium silicate and feldspar deposits at Bikita, the corundum deposits in the Concession - Mazoe area and the Chimutsi diatomite deposit some 30km north-east of Makuti. Together with most detailed information provided especially by Professor Viewing and by Mr. Morrison, these visits generated an adequate overview of the scope for industrial mineral developments in Zimbabwe.

The work was further supplemented by detailed discussions with several owners of mineral claims and examinations of samples from many sources. Test work was carried out by Mr.G.Davies at the laboratories of the Metallurgical Department. Test firing of several ceramic mixes with kyanite produced excellent first results. Discussions on industrial possibilities were held with several companies. Resultant developments are reported in appropriate sections of this report.

The writer gratefully acknowledges the enthusiastic help provided by so many individuals. Without such support the range of work could not have been accomplished in the available time.

Especial thanks are due to Mr.S.Tejno, JPO at the UNDP office in Harare, for constant support in making arrangements, often at very short notice.

II. MINERAL RESOURCES OF ZIMBABWE

1. The Background of Mining in Zimbabwe

The Republic of Zimbabwe has a rich variety of deposits of metalliferous ores and industrial minerals. Many of these deposits have been known for a long time and are well documented through the work of the Geological Survey. However, the mining industry has traditionally concentrated its efforts on metalliferous deposits such as gold, copper and chromite, as well as nickel, tin and tungsten. Coal receives major attention and asbestos is the most important industrial mineral.

The mining industry is essentially oriented towards exports and its fortunes are strongly dependent on external commercial and political factors. During the 14 years of UDI (1966 -1979) about 40 different metals and minerals were produced. The most important ones, in decreasing order of declared values, were asbestos, gold, copper, nickel, coal and chromite, as shown below:

	Z\$	% (totals for 1966 - 1979)	
Asbestos	485 546000	23.1	} 90.4%
Gold	368 390000	17.5	
Copper	360 485000	17.2	
Nickel	282 397000	13.4	
Coal	192 000000	9.2	
Chromite	155 263000	7.4	
Tin	55 552000	2.6	
All others	200 787000	9.6	
Total	2 100 420000	100	

Since independence in 1980 the fortunes of the various mining activities have fluctuated widely, largely for external reasons. In 1980 gold rose in value to about 35% of total metal and mineral production. The world economic recession had adverse effects on copper, nickel and chromite production. Shortages of skilled personnel and increases in wages have contributed further difficulties. Mining now accounts for some 6% of the GDP, as compared with about 18% for agriculture and 26% for manufacturing industry.

2. Industrial Minerals in Zimbabwe

More than 30 different kinds of industrial minerals occur in Zimbabwe, many of them in several separate deposits and geographically widely distributed across the country. A few of these are used for some kind of domestic industrial activity, including obvious examples such as manufacture of cement, phosphatic fertilisers, bricks, refractories and pottery. Important deposits were mined essentially for export of the raw mineral. Examples are the lithium minerals of Bikita for export

to Europe, USA and Japan, magnesite of Gatooma for South Africa, or graphite from the Ungwe District for Germany. 97% of Zimbabwe's asbestos is exported as fibre to more than 50 countries.

Without exception, the value of the raw minerals exported is small compared to the potential value of industrial products. The lack of local industry in Zimbabwe has been explained partly by the small domestic market and by the difficulty of competing with imports, especially from South Africa.

3. Mineral Appraisal of Kyanite

Kyanite is an aluminium silicate mineral closely related to two others, andalusite and sillimanite. The three minerals differ in crystallographic and physical characteristics, but have identical chemical compositions representable as Al_2SiO_5 or $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$. Upon heating to high temperatures, all three minerals dissociate to mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) + silica (SiO_2). The silica may be vitreous or crystalline (cristobalite), depending on the heat treatment. Kyanite dissociates above about 1300°C , the other two minerals dissociate at higher temperatures. An important and unique characteristic of kyanite is that its dissociation results in a volume expansion of about 17%.

Kyanite forms during metamorphic processes in the Earth's crust, in sediments and other rocks of high alumina contents. The resultant metamorphic rocks are quartz - mica schists with kyanite, garnets, staurolite and other accessory minerals. For practical purposes, rocks containing 5 to 40% kyanite may be economically workable. Weathering processes generally lead to loose surface accumulations of kyanite, the other minerals being removed by dissolution and/or transport. The inert, hard and heavy crystals of kyanite thus form easily recoverable natural concentrates. Because of its high resistance to weathering, kyanite can also accumulate in beach sand deposits (e.g. Florida) where it may be recoverable as a by-product with zircon and rutile.

4. Deposits of Kyanite in Zimbabwe

Due to the detailed work carried out by the Geological Survey, the occurrences of workable deposits of kyanite are well documented. A very useful summary of information is presented in the Mineral Resources Bulletin No.18, written by E.R.Morrison (currently Director of the Geological Survey) and published in 1976. Although there are deposits of kyanite in various parts of the country, the most substantial reserves occur in mica-schist belts in the north-east of the country beyond Mtoko and in the north around Karoi. Mtoko lies 133km from Harare along a good surfaced main road. The kyanite deposits are within 60 to 70km of the

main road, along various unsurfaced roads. The nearest rail head is at Shamba, a distance of some 90 to 100km along unsurfaced roads.

Karoi lies 204km from Harare along the good surfaced main road from Harare to Lusaka. The kyanite deposits are within 25 to 35km of Karoi, along various unsurfaced roads. The nearest rail head is at Lions Den, a distance of some 60 to 80km along unsurfaced roads, or 60km from Karoi on the main road.

The two groups of deposits probably represent the largest known reserves of this mineral outside North America. Several million tonnes are available for simple surface mining and the potential reserves at depth are large, although unexplored. The deposits which have been variously known since 1955 have been pegged under large numbers of claims. Some claims (e.g. Kyanite Hill in the Fungwe Communal Lands, north of Mtoko) have been the subject of considerable expenditure on prospecting and pilot plant treatment by major mining companies such as R.S.T.Ltd. and General Mining & Finance Co., but production was not initiated, possibly due to sanctions during UDI. Actual production occurred over some years (1966 to 1978) at the Ky Mine and at Inanga North with total outputs oscillating between 1000 and 9000 tonnes per year, depending on market, transport and military hazards.

The deposits vary in grade from 75% kyanite for some surface accumulations (which may amount to more than 0.5 million tonnes in individual claims) to about 7% kyanite in friable schists which may be mined to depths of 30 metres or more.

There can be no doubt that kyanite concentrates of marketable grade can be produced by simple methods of screening, washing and concentration. Grades of 58 to 62% Al_2O_3 , Fe_2O_3 0.3 - 0.7 and very low alkalies have been produced again and again in widely differing circumstances from different deposits. The main reasons for lack of exploitation so far are remoteness and conditions associated with UDI. However, there is an associated reason in the size of individual claims being marginal for the cost of comprehensive treatment plants. Such plants would be essential to ensure guaranteed high qualities of products which would command premium prices. It should be noted that there have been substantial advances in processing methods during the last two years, especially in high intensity magnetic separation. Another recent development of great relevance are plasma furnaces which could be used to calcine kyanite efficiently and without fuel-derived contaminants.

III. KYANITE INDUSTRY

1. Industrial Uses of Kyanite

The largest tonnage consumption for kyanite lies in the production of high alumina refractories. Kyanite is used as a pre-fired grog to impart high physical strength and high temperature resistance to furnace lining in the metallurgical and glass industries. High alumina content, low iron and low alkalies are the chemical specifications. Various size gradings are specified for different purpose bricks, castables, mouldables and ramming mixes. A certain proportion of raw kyanite is used to offset shrinkage of clays and other components on firing. High grade refractory shapes and kiln furniture are composed mainly of size-graded calcined kyanite and a little clay binder. Non-ferrous metal melting furnaces, particularly for brass, bronze and aluminium, and furnaces for the glass industry are large consumers.

Kyanite is used by ceramic manufacturers of wall tiles and sanitary ware to offset shrinkage and cracking after firing. Another important use is for electrical porcelain. However, in terms of tonnage all ceramic uses amount to only a few percent of the quantities used for refractories.

2. Markets for Kyanite

Before the current world-wide industrial recession, the largest consumers of kyanite were the U.S.A., Europe and Japan, with annual consumptions of the order of 100 000 tonnes, 50 000 tonnes and 25 000 tonnes respectively. The U.S.A. was also the largest producer of kyanite with a domestic production capacity of the order of 70 000 tonnes per year. Reserves are mainly in Virginia, North and South Carolina, Georgia, Florida and Idaho. The U.S.A. both exported (e.g. to Europe) and imported kyanite (e.g. from India), depending mainly on price and transport cost considerations. It should be noted that during World War II supplies for the U.S.A. came mainly from India. Now, exports from India have practically ceased in order to preserve remaining reserves for Indian domestic demands. No doubt, India also appreciates the low returns of exporting raw kyanite.

Due to the recession in the metallurgical industries consumption of refractories was depressed and current statistics are unreliable. However, it is notable that enquiries for calcined and raw kyanite have recently been received in Zimbabwe from the U.S.A. and from Germany.

The forecast level of consumption for the year 2000 is approximately 500 000 tonnes of kyanite per year for the U.S.A., plus 1 000 000 tonnes per year for the rest of the world. This compares with a total world production of about

400 000 tonnes in 1980, and with total identified world resources of about 500 million tonnes.

On balance, the emerging industrialisation of nations in several continents may well produce a changed pattern of demand for refractory raw materials. The long-term reduction in the use of refractories in the U.S.A. and in Europe may well be matched by increasing metallurgical activities elsewhere and by new uses in ceramics, precision components, heat shields for space vehicles, etc. It is thus possible that a total world market for the year 2000 would still lie at around 1 500 000 tonnes of kyanite per year, even if the geographical distribution of consumption is somewhat changed. It would be a modest target for Zimbabwe to seek to secure 3% (45 000 tonnes per year) of that total market, corresponding approximately to Zimbabwe's share of 3% of total world reserves.

IV. A STRATEGY FOR ZIMBABWE KYANITE

1. Market and Product Choice

In view of the depressed world market for refractories it would be impractical to start a major new refractories industry in Zimbabwe. Even if the products were excellent, the initial competitive position vis-a-vis established producers would be poor. The users are traditionally conservative and would be reluctant to abandon known and trusted brands in favour of a newcomer. The diversity of sizes and shapes of furnaces and of liner blocks would necessitate carrying very large stocks, unless manufacture were undertaken only to specific orders. It is suggested, therefore, that refractories do not present an immediate industrial opportunity and should be relegated for later development.

More amenable domestic markets exist in the ceramics field, especially in the production of electrical insulators and in large sanitary ware. Electrical insulators have always been imported into Zimbabwe from established producers in the U.K., in South Africa and even as far afield as China. Imports of all types of electrical insulators for power transmission, railway electrification, municipalities, radio and telecommunications are currently running in the region of Z\$ 4 - 5 million per year.

Similarly, large porcelain sanitary ware such as toilets and wash basins are entirely imported from South Africa and the U.K. It is difficult to define rates of consumption, but considerable building programmes are under way in the cities, including large hotels, conference centres, public buildings and Government offices. The Ministry for Rural Development envisages country-wide construction of new housing units. The plans include modern sanitation. Thus it might be expected reasonably that the market for sanitary ware could move into the region of several thousand units per year.

2. Ceramic Industry in Zimbabwe

The existing ceramics industry in Zimbabwe is small, comprising essentially two potteries producing low quality stoneware and earthenware goods such as table ware, ash trays, etc. Additionally, there are small cottage industry potters, a manufacturer of small steatite electrical components and a discontinued manufacture of wall tiles.

It is proposed, therefore, that a more broadly-based ceramics manufacture should be established to include electrical insulators, sanitary ware and domestic ware. Diversified production would insure better survival of the inevitable market fluctuations in individual lines. More importantly, higher degrees of quality control would be introduced and the labour force would be required to attain higher levels of skills and work discipline. If these aims can be achieved,

under proper guidance, they would lay the foundation for further developments into high quality ceramics that might well compete on export markets. The fundamental facility lies in the ready availability of excellent raw materials. These include first class feldspars, lithium silicates and kyanite. The kyanite would be used to improve workability, increase strength, compensate for firing shrinkage and improve electrical properties. Uncalcined kyanite is an important additive in the manufacture of electrical and chemical porcelain. The local lithium silicates are invaluable in the use as fluxes, to lower firing temperature and to provide good adhesion of glazes. The question of local clays needs to be clarified.

3. Clays in Zimbabwe

Clays are available from several deposits, such as Gway River, Chakari, Wankie and the Nkai district. They are reputed to be of not very good quality and to require the addition of imported ball clays for adequate plasticity. Simple sedimentation tests commissioned by the writer at the Metallurgical laboratories of the Ministry of Mines showed conclusively that the clays are contaminated with coarse siliceous and ferruginous impurities. Removal of the coarser of the impurities (say + 0.075mm) by classification yields greatly improved clay products. The improvements include better plasticity and better fired colour of the body. The normal practice in Zimbabwe is to grind the crude clays and then to screen out some coarse oversize. This should be avoided and be replaced by wet screening or classifying (hydrocyclones) of the unground clays after thorough dispersion in a dilute suspension.

For example a sample of unground clay from the Chakari deposit was found to contain only 38% (by weight) of -0.005mm material. Rejection of the 62% of +0.005mm fraction would yield an excellent clay. For less stringent purposes one could accept some +0.005mm material, say up to a size of 0.020mm. The entire -0.020mm product would represent 62% of the original crude clay. It should be noted that even if only the 38% of -0.005mm material were used, this is still cheaper than importing foreign ball clays.

It is thus entirely feasible to set up manufacture of soft and medium hard porcelain ceramics for sanitary ware and electrical insulators, using entirely local raw materials.

4. Industrial Competence

By using the right combination of purified clays, high quality kyanite, high grade potash feldspar and lithium silicate fluxes it should be possible to produce high quality wares with considerable export potential.

However, the initial aim would be to secure a sufficient proportion of the

domestic market for profitable operation on a modest scale. This first phase would permit the establishment of proper quality control methods for the raw materials. Such control is a vital prerequisite for consistently good products. Under the supervision of an experienced quality control engineer the operators in the raw materials preparation section would have to learn the necessary technology and discipline through on - the - job training. Similar considerations apply to the operators involved in the manufacturing processes. The consistently good production of slip-cast, large sanitary ware is a complex and highly skilled operation. This applies especially to single-fired bodies where many small details such as correct drying, or correct matching of glaze, require considerable operator experience. Equally, the moulding and turning of intricate, large electrical insulators cannot be achieved instantly by operators whose only experience is with earthenware cups and saucers.

In the case of electrical insulators, the aim would be to concentrate initially on a few of the simpler shapes and thus to penetrate perhaps only 20 to 25% of the domestic market. This would still represent an annual turnover of around Z\$ 1 million. With growing competence the range of insulators could be extended to larger and more intricate items. ~~There is no good reason why~~ No further imports of insulators should become the ultimate target. Indeed, the kyanite/petalite bodies should be of high enough quality to compete successfully in export markets (South Africa, Zambia) on grounds of technical quality and price.

5. Development of Ceramic Body Mixes

Good ceramics are produced in many countries and from an extremely wide range of raw materials. Although the main ingredients generally tend to be mixtures of clay, silica and feldspar, the proportions of these vary greatly and many minor additives are used. Hardly any two mineral deposits have identical characteristics. The minerals vary in composition and in crystal structure. Minor impurities play important roles in affecting the physical and the chemical behaviour of body mixes. The size distributions of particles, the particle shapes and densities, or even the surface quality of particles in a mix can have far-reaching effects on plasticity, moisture retention, dimensional stability and firing behaviour of the body.

As a result, transfer of practices from one centre to another is possible only in the broad sense of using similar processes. However, the precise make-up of a mix for some specific purpose, such as sanitary ware or electrical insulators, needs to be developed in relation to the characteristics of locally available minerals. The development of improved mixes is likely to be a long term process based largely on operational experience. This applies especially in a developing country where mining practices may be variable and where quality

control of the various minerals may not be as precise as is desirable. It is considered practical, therefore, to develop some acceptable body mixes as quickly as possible, without seeking perfection. This work can be carried out in collaboration with the laboratory of the Metallurgical Department, using available facilities and the ceramic expertise of Mr. G. Davies. Some preliminary mixes prepared by him from 100% local materials have already proved to be very good. The mixes comprised Chakari, Gway and Wankie clays, with potash feldspar from Bikita and kyanite from the Karoi and Mtoko areas. Further test work is necessary to define preferred proportions and to examine the effects of fluxes, such as lithium silicates from Bikita, on firing temperature, fired density and glaze adhesion.

It should be noted that the successful kyanite bodies were made without the addition of silica. It was assumed that sufficient silica would be present as impurities in the clays as well as with the feldspar and the kyanite.

Any mixture identified as suitable in laboratory tests will have to undergo pilot tests on a larger scale, followed by trial production runs. This is discussed below, under Industrial Manufacture Proposals.

6. The Role of Kyanite in Ceramic Mixes

Kyanite can perform three different functions in ceramic bodies.

For bodies fired at low temperatures, say up to 1200°C, kyanite acts as a stabilising grog. Its high density (S.G. about 3.5) and the needle-shape of its ground fragments result in better physical stability than can be attained with pre-fired grog which is porous, or with silica which melts at a low temperature. In replacing silica with kyanite, the weakening effects of the $\alpha \rightarrow \beta$ quartz transformation are minimised. An additional strengthening factor lies in the growth of mullite on the surfaces of the kyanite needles. There is evidence that incipient mullite formation from clays occurs at relatively low temperatures and this tends to form firm bonds with the kyanite laths.

For bodies fired at higher temperatures, say in the range of 1250 - 1350°C, the addition of small proportions of uncalcined kyanite is beneficial in providing the expansion of kyanite to counteract the shrinkage of the clay. The silica present is sufficiently fluid to accommodate the differential volume changes and the result is a body of high density and high dimensional stability.

Kyanite can also be used as a pre-fired grog and this is beneficial for bodies fired up to very high temperatures (up to 1450°C or higher). This is especially suitable for saggars and kiln furniture which need high physical strength and high temperature resistance. It is usual to use two parts of grog and one part plastic material with a minimum of alkalies. For improved plasticity it is better to add 1 or 2% bentonite than to reduce the proportion of grog.

The best proportions and size gradings of kyanite need be determined experimentally for each type of body, depending on the behaviour of the other components. For example, soft porcelains of the types commonly used for sanitary ware and for electrical insulators contain clays in the range of 35 - 59%, feldspars in the range of 9 - 32% and silica in the range of 9 - 30%. If silica were to be replaced wholly or partly by kyanite, the proportions of the other two components may have to be modified in dependence on size gradings, impurities and fluxes. The use of kyanite should be allied especially to the use of lithium minerals which lower the vitrification temperature and decrease the final porosity of porcelain. Lithium silicates improve frit porcelains and give lower expansion. Thus, combined lithium - aluminium bodies can be closely regulated to give zero, small negative, or small positive expansion. This is important also in controlling the expansion and interaction of glazes for single-fired ware.

V. INDUSTRIAL MANUFACTURE PROPOSALS

1. General Assessment

In the course of investigations and discussions it became apparent that Zimbabwe's needs for ceramics might be well served by setting up an integrated and diversified manufacturing centre. Technically, this would provide the best utilisation of scarce skills and equipment. Diversified manufacture of sanitary ware, electrical insulators and domestic ware would provide greater commercial safety in respect of individual market fluctuations in these commodities. Financially, the investment per unit product would be smaller because equipment and facilities would be shared to a large extent for the different commodities. This means that in spite of the relatively small domestic market it would be possible to install sensibly large production units. The units would be fully utilised because they could be switched to comparatively short productions for each type of product. The alternatives would be either to use economical large units for long runs on single products, thus having excess capacity, or to use small units which have disproportionately high capital and operating costs.

It was considered reasonable that the diversified centre could be created by expansion of an existing operation. Three companies were found to operate in the general field of ceramics. Willsgrove Brick and Potteries Ltd. in Bulawayo, Norbel Potteries Ltd. at Msasa in Harare and Cerama Ltd. at Norton, 40km west of Harare. Willsgrove and Norbel produce domestic and table ware pottery. Cerama have produced wall tiles, but, due to overproduction, are selling from stock. Cerama had been planning for some time to enter into sanitary ware. They have obtained a licence for this purpose, but have not so far produced a suitable ceramic mix. New buildings and plant are under construction and the services of foreign consultants have been arranged. They have committed the necessary capital.

Norbel successfully produce various earthenware and stoneware goods, but are short of space on their existing site. A move to a new and larger site would be essential for producing sanitary ware or electrical insulators. Their existing electric furnaces and other equipment could be transferred, but would need some augmentation. The necessary capital is available.

Problems over travel prevented the writer from visiting Willsgrove in Bulawayo. Their position was not assessed although it was noted that their trade in pottery showed a marked down-turn for the second six-month period of 1982.

Since the new diversified manufacture is designed essentially for the domestic market in Zimbabwe, there may be a small advantage in a location in Harare rather than Bulawayo. There is no strong argument based on power, transport or

labour that would tip the balance in either direction.

The idea of diversified manufacture was discussed with the Industrial Development Corporation of the Ministry for Industry. Mr. B. McCurdy, Administration Manager, and Dr. S.E. Peterson, Investigations' Controller, confirmed I.D.C.'s interest in getting such an industry established. I.D.C. would be willing to participate either as industrial banker, or in a joint venture, as a majority or minority holder of equity. I.D.C. has undertaken to carry out a detailed survey of the domestic markets for electrical insulators and for sanitary ware.

As far as Norbel and Cerama are concerned, various options for joint or separate action are under discussion. After talking to each company, the writer arranged a joint round table meeting of their principals with I.D.C. Further negotiations have been initiated.

2. Alternative Groupings

The writer can envisage various possible groupings:

The reasoning for a Norbel, Cerama and I.D.C. joint venture is that Norbel has strong technical and managerial competence but lacks space for expansion on its present site. Cerama is technically weak but has a large site, very adequate buildings, much new equipment and a licence to manufacture sanitary ware. The various assets of both companies could be used to best advantage by combining the two companies at the Cerama site. One possible disadvantage is the distance of Norton from Harare residential areas and schools. The project would be totally dependant on attracting highly competent managerial and technical staff.

A good raw materials technologist and at least one more ceramist with experience in electrical insulators production would be essential staff additions. I.D.C. would make important contributions in frontend finance, licensing and market penetration.

Either Norbel or Cerama could decide to proceed without the other company.

The following consequences may be envisaged:

Cerama could decide to proceed alone, because they have a licence to manufacture sanitary ware and they have made the necessary capital investment. They would depend heavily on advice from consultants and they have not so far developed a suitable ceramic mix. They appear to underestimate the complex problems inherent in this type of ware. I.D.C. as a foreign-controlled company, except perhaps as a majority share holder, would not be acceptable to Cerama's parent company, Abercom Ltd. (controlled).

Faced with Cerama's decision, Norbel could proceed separately into electrical insulators and secure collaboration with I.D.C. Provided that Norbel is able to maintain its managerial competence it could expect to

maintain profitable operation by combining its present business with electrical insulators. Cerama might have commercial problems in relying solely on sanitary ware, might decide to go out of business and might sell its licence to manufacture.

In view of all the circumstances and considering the size of the domestic market, it is not realistic to envisage the successful operation of two small producers of sanitary ware and electrical insulators in Zimbabwe.

3. Continuing Development of Ceramics

The facilities available for ceramic work at the laboratories of the Department of Metallurgy should be used in coordination with commercial production. The large variety of appropriate minerals in the country opens up enormous possibilities for developing mixes that are better for specific product requirements. High physical strength, high dielectric constant, thermal shock and impact resistance are some of the properties that could be developed under a long-term programme of research. Similarly, development of improved methods of purifying the constituent minerals would deserve systematic investigation. The clays, feldspars, kyanites, lithium minerals, talc, pyrophyllite, etc. could all be purified to different degrees and at different costs by various combinations of processes. Quality and cost optimisation routes should be explored systematically.

This work could be linked to the industrial minerals survey outlined below.

4. Longer Term Developments in Ceramics

Following the establishment of good ceramic production practices and good operator skills, the ceramic industry could diversify into other products. These might include fused mullite and fused alumina bodies for special applications in the glass and metallurgical industries. Special opportunities are open for the production of ceramic fibres. Both alumino-silicate and alumina fibres are likely to find growing markets in replacing conventional thermal insulator bricks. These fibres can stand hot face temperatures up to 1700°C, are of low weight and low in bulk. Their low specific heat capacity is of especial importance during the heating up of furnaces and for intermittent kilns. Together with greatly superior insulating properties, these characteristics lead to valuable savings in energy consumption and in maintenance costs. Savings of the order of 20% of heating time and 11% of fuel consumption are possible. Manufacture of fibres would have to be under licence from patent holders, such as Morganite, Carborandum or I.C.I., who would also provide plant design and process know-how. The products would have immediate

applications in Zimbabwe and in neighbouring countries. Wider export potential would be excellent. Ceramic fibres constitute a very versatile material. They can be woven into boards, blankets, sheets, tapes, ropes or yarn. They can be used in liquid mixtures or with mouldable mastics for spraying, coating or moulding to form complex shapes and prefabricated modules. Their versatility and variety of uses are only just beginning to be realised.

The availability of high quality alumino-silicate minerals, corundum, lithium silicates, etc. in Zimbabwe, together with relatively cheap electric power, make ceramic fibres one of the important future growth points for industry in this country. This by itself would form ample justification for the development of a sound ceramic industry so as to provide a basis of technological capability and skilled labour.

VI. KYANITE PRODUCTION AND PROCESSING

1. The Past

During 1964 - 1968 R.S.T. (Rhodesian Selection Trust Exploration Ltd.) spent several hundred thousand dollars on exploration and pilot plant work at the Madaicheche group of claims in the Fungwe Communal Lands north-east of Mtoko. Possible ore reserves of 17 million tonnes to a depth of 3 metres were established, with a yield of about 2.4 million tonnes of kyanite per metre of depth. Several thousand tonnes of ore obtained from a deep pit were treated in a pilot plant that was erected on the deposit. The flow sheet comprised wet scrubbing, gravity concentration and dry magnetic separation. Concentrate grades were about 60% Al_2O_3 , 37% SiO_2 , 0.6% Fe_2O_3 , 0.5% TiO_2 and very low alkalis. A modern plant, especially with the new types of very high intensity magnetic separators, would almost certainly yield even better grades, due to more complete removal of biotite, staurolite and iron-contaminated kyanite.

In 1965 R.S.T. considered a CIF price, U.S.A. East Coast, of £20 - 22 per long ton. At that time (1965 - 66), a production plant for treating 50 000t/year was estimated at a capital cost not exceeding £150 000 (excluding costs of roads and providing power supply). The cost calculation per tonne of kyanite concentrate was as follows:

	£ Sterling
mining and concentration	4. 06. 0
transport to railhead (Shamwa)	1. 10. 0
loading at Shamwa	0. 01. 0
rail transport Shamwa - Beira	1. 12. 6
port charges at Beira	0. 15. 0
royalty	0. 09. 8
total cost FOB Beira	8. 14. 2
revenue (FOB value at Beira)	16. 00. 0
operating surplus per long ton	7. 05.10

The road transport costs from the mine to Shamwa allow for road maintenance.

The total U.S.A. market for 1964 was given by Arthur D. Little Inc. as 50 000t/year for refractories; 17 000t/year for fired shapes (kiln furniture, saggars and setters); 1000t/year for porcelain, especially electrical insulators; 1000t/year for wall tiles; 4000t/year for other uses (pellets, glass, aeronautics); a U.S.A. total of 73 000t/year. Comparable totals for Europe

and Japan were 50 000t/year and 42 000t/year respectively. Combining the U.S.A., Europe and Japan the total market for kyanite was 165 000t/year. Thus the production envisaged by R.S.T. would have taken 30% of the total market volume. After R.S.T.'s interest had ceased due to UDI, the market position was re-appraised in 1970 when General Mining & Finance Corp. of South Africa took an interest in the same deposit. They were using a price of Rand 38 per ton for raw kyanite and Rand 50 per ton for the calcined product. Intended production was 30 000t/year of raw kyanite and 20 000t/year of calcined kyanite. In 1971 General Mining obtained two firm customer requirements of 20 000t/year each. General Mining considered a mine life of 19 years at a milling rate of 781 000t/year. A considerable amount of test work was carried out in South Africa, but details are not available. The project was abandoned due to circumstances arising from the military situation in the area.

It is evident that during the period 1965 -1970, kyanite from Zimbabwe was considered a serious contender on world markets. The dominant producer of kyanite outside the U.S.A. was India. Since Indian kyanite has now (1983) virtually disappeared from world markets, the potential for exporting kyanite from Zimbabwe must be rated as good.

The projects by R.S.T. and General Mining were the only substantial proposals for kyanite production in Zimbabwe. Actual mining occurred at the Ky Mine, North of Mtoko, where variably a few hundred tons or up to 6000 - 9000t/year were produced over a number of years by Southern African Minerals Co. and Otavi Ltd. There has been no significant production from the Miami area, north-east of Karoi, where some 13 claims are located along a strike of about 18 km of the ore formation.

2. The Future

The proposals outlined in this report for the creation of a ceramics industry would not require any substantial mining of kyanite. If both sanitary ware and electrical insulators were produced to meet the entire domestic markets, the consumption of kyanite would be below about 400 tonnes of concentrate per year. This would require mining and processing between 500 and 5000 tonnes of ore per year. The lower figure of 500 tonnes per year applies if high grade surface material were collected selectively and this is envisaged as quite practicable for an initial period of say 3 to 5 years. The larger figure of 5000 tonnes/year applies if high grade concentrates were taken as a by-product from more general mining of larger tonnages for export. Thus the kyanite needs for a domestic ceramics industry can be regarded as safely assured without dependence on other markets. Any one of several of the many claim areas could produce 500 tonnes in one week by means of nothing more

sophisticated than a front-end loader.

The establishment of a significant mining industry for kyanite would depend essentially on export markets. Entering the world markets for kyanite should be regarded as a major priority for the Minerals Marketing Board. The aim should be for an annual production of about 50 000 tonnes of high grade concentrates for export, partly raw and partly calcined. According to the writer's integration of all available international market forecasts, 50 000 tonnes/year represents approximately 3% of annual world requirements, which remain more or less static at 1,500 000 tonnes/year, for the period 1985 - 2000. A production of 50 000 tonnes/year of high grade concentrates would require an averaged mine output of ~~at least~~ ^{up to} 600 000 tonnes/year of ore, depending on mine grade and concentrator recovery. It is possible that this tonnage could be derived from say two sites which probably have large enough reserves to sustain production for some 10 - 20 years. However, from national considerations, this course would be imprudent for the following reasons:

- (i) The totality of the kyanite deposits should be regarded as a national resource. This resource should be exploited in a balanced fashion so as to yield overall the largest GDP. Selective mining of the largest and best deposits would not meet this requirement.
- (ii) The kyanite deposits occur in two separate regions where they are widely distributed. In each region, the kyanite deposits should be used to provide maximum employment without causing significant displacement of the local population. In these regions there is at present little other prospect of industrial development. The population depends largely on subsistence farming.
- (iii) Climatic hazards and the inevitable lack of industrial discipline amongst a rural population might make it difficult to attain production targets reliably when depending on one or two production centres. It would be safer to derive production from a larger number of centres so as to minimise the effects of individual shortfalls.
- (iv) Combination of the products from all areas would facilitate the maintenance of control over the quality of the export products. Reliable product quality would be an important factor in holding and extending the country's share of world markets.

The above considerations lead to the proposal of establishing a cooperative corporation for the production of kyanite.

3.A Kyanite Cooperative Corporation

Under leadership and organisation from the Ministry of Mines it is proposed to set up relatively simple and small-scale surface mining on perhaps 20 or more separate claims groups in the two districts designated for convenience as Karoi and Mtoko. The mining would be carried out by local farmers on a seasonal basis. They would mine for 8 or 9 months during the dry season and would attend to their crops during the wet season. The Geological Survey and the Department of Mines would define the mining areas, would assist with mining lay-out and would define production targets. The farmers would have to be shown how to strip vegetation for mining purposes and how to set aside soil for subsequent land restoration, where applicable. They would be provided with, and instructed in the use of basic mechanical equipment such as bulldozers and front-end loaders. The equipment would be provided and maintained on a cooperative basis and all members of the scheme would be charged a proportional rent for the equipment. This charge would serve the important secondary purpose of encouraging each operator to meet his production target so as not to be out of pocket.

In each of the two mining districts, each operator would take his product to a central collecting point, using trailers, ox carts or whatever seems appropriate for the distance and the nature of the terrain. Preliminary dry screening and scalping of the ore could occur at the mine or at the collecting point so as to reduce the carriage of waste. From the collecting points the ore would be transported by 20 tonne trucks to the railheads at Lions Den and at Shamwa respectively. At each railhead a stock pile would be established. These buffer stocks would assist in balancing both the tonnage and the grade of production.

From the railheads the ore would be transported to one central processing plant in the Harare area. This plant would perform crushing, grinding, concentration, calcining, size grading, blending, etc., as may be necessary to achieve guaranteed product qualities under which the output would be traded. It is envisaged that the processing plant would be controlled and operated by I.D.C. A nucleus for such an operation exists in I.D.C.'s wholly owned subsidiary G & W Industrial Minerals Ltd. at Willowvale. The Minerals Marketing Corporation would be responsible for marketing and export promotion.

Payment to the participating miners would be in two stages. Upon weighing and inspection (to avoid obvious dilution) at the collecting point, the miner would be paid a first instalment on a tonnage rate fixed on the notional grade of the ore, say half the expected recoverable value. The miner would be paid a further share weekly or monthly, based on the value of the actual

concentrates produced by the plant. Royalties to owners of claims could be paid on a similar basis. Details of the payment scheme need to be worked out so as to generate the maximum incentive for production. The concentrator plant would calculate its charges and profits in analogy with schedules employed by smelters in metal mining.

The Geological Survey and the Department of Mines would have to provide professional supervision and advice. Their function would be to make mining as rational as possible and to ensure adequate advance development of reserves. Since they would have an overview of the grade and rate of production they could direct miners so as to lower or raise cut-off grades. This would ensure the fullest possible extraction of the mineral.

4. A Notional Examination of Transport to the Railhead

At a notional total peak mining rate of 100 000 tonnes per year (high grade ore, say 60% kyanite), averaged over 20 mining claims, each would have to produce 5000 tonnes per year. Over 8 - 9 months working, say 200 - 225 working days, this equals 22 - 25 tonnes per day, or about 3 tonnes per hour (8 hour day) from each claim area.

At a total mining rate of 600 000 tonnes per year (low grade ore, say 10% kyanite), over 20 claims the averaged output would have to be 18 tonnes per hour (8 hour working day) or 9 tonnes per hour (two 8 hour shifts per day). The overall mining rate is likely to lie somewhere between these extremes, possibly at around 10 tonnes per hour for one 8 hour shift, or 5 tonnes per hour for two shifts. These seem entirely manageable quantities. The work force and the mechanical equipment would have to be sized accordingly.

With high grade ore little pre-concentration (or screen scalping) would be needed at the collecting points. With lower grade ore it may be assumed that scalping will reduce the tonnage for transport so as not to exceed 100 000 tonnes per year. This would be equal to 40 truck loads (of 20 tonnes) per day's production, or 20 truck loads per day from each of the two areas (Karoï to Lions Den and Mtoko area to Shamwa). For a 10 hour trucking day this equals 2 trucks per hour in each of the two areas. If it is assumed that each truck has an average speed of 25 km per hour for the round trip of, say 2 x 100 km, each truck requires 8 hours for the return journey. This means that 20 trucks will have to be provided in each of the two areas in running order, with additional 3 trucks in each area to allow for down time and maintenance. If the trucking hours were doubled so as to allow two shifts

(journeys) per truck per day, the number of trucks would drop to 10 per area plus about 2 trucks in each area for down time and maintenance.

In the above examination it was assumed that road haulage by means of 20 tonne trucks would constitute a reasonable system of transfer between the collecting point and the railhead in each area. Since the operation is likely to have a life of at least 20 years it would be prudent to examine the possibility of extending each of the two railway lines so as to eliminate road haulage. The railway extension would be of value not only for the kyanite operations but would be of far wider benefit in the overall development of these two backward regions. This requires detailed comparative evaluation.

INVENTORY OF INDUSTRIAL MINERAL DEPOSITS

The mining industry has been too heavily preoccupied with metalliferous ores. This is a failing shared by many countries. Even in highly developed countries it is not realised that industrial minerals often exceed metalliferous ores in tonnage and that they can represent a substantial portion of the GDP. In order to enable Zimbabwe to utilise its industrial mineral resources to best advantage, it is proposed to set up a comprehensive inventory project over a period of, say, 2 years. The aim is to qualify and quantify all major deposits in terms of mineralogy, grade, reserves and applications. The inventory project would be based on the excellent work and records of the Geological Survey, the applied mineralogy capabilities of the Institute for Mining Research and the processing facilities of the Department of Metallurgy.

Each substantial deposit of industrial minerals should be assessed in terms of mineralogy, grade and reserves. Amenability tests should define the possible qualities of commercially usable minerals. Applications testing should identify possible advantages in industrial processes and products.

The end result should be a nationwide inventory of industrial minerals which would enable potential users to gauge the merits of each raw material. It should never happen again that a tile plant is mistakenly located near a clay deposit fit only for brickmaking, that the value of minerals like kyanite is not appreciated by local industry, or that raw materials like clay or diatomite are imported from abroad when perfectly good supplies lie unused within the country.

The range of minerals to be included in the inventory project should not be restricted. Feldspars, limestones, steatite, clays, phosphate, quartz, mica, are just a few examples from a possible list of more than 30 industrial minerals which are known in this country. It is probable that work on the inventory will bring to light additional resources.

Work of this type is of great importance for the industrial development of Zimbabwe and should receive fullest possible support from UNIDO. Support would be needed especially in the form of provision of some experienced professional personnel to augment existing staff. The following additions are envisaged:

- One economic geologist or mining engineer experienced in the assessment and evaluation of reserves of industrial mineral deposits; for secondment to the Geological Survey.
- One applied mineralogist experienced in microscopy, X-ray and thermogravimetric examination of industrial minerals; for secondment to the Institute for Mining Research.
- One mineral processing engineer experienced in physical and chemical treatment methods for industrial minerals; for secondment to the laboratories of the Department of Metallurgy.
- One ceramical engineer, either experienced in manufacture of electrical insulators, or with a broad background of experience of applied research in ceramic materials; for secondment to the laboratories of the Department of Metallurgy.
- One Project Manager who would have to be adequately conversant with the scientific and the industrial aspect of the work. He could be a separate appointment, or any one of the other four, depending on calibre and personality.

In addition, it would be most desirable to strengthen the permanent staff of the laboratories of the Department of Metallurgy. Two or three suitably trained Zimbabwe nationals could be selected from those already in training overseas. The purpose would be to establish strong local competence and to derive maximum profit from the foreign experts engaged on the mineral inventory.

In order to compile the inventory, the three centres (Geological Survey, Institute for Mining Research and Department of Metallurgy) would fulfil mutually supportive functions. Their outputs would be combined in the inventory so as to form a complete dossier on each deposit.

It is probable that some specialised items of additional equipment may have to be provided in order to generate the necessary data efficiently.

A minimum period of two years should be allowed for completion of a sufficient initial inventory. This period should also be regarded as basic training for local staff. The local staff is expected to continue the work,

subsequent to completion of the initial phase. The practical knowledge of the industrial geology of the country will grow and the demands of industry for raw materials will change with progressive development. It is, therefore, predictable that there will be considerable demand for additions and for updating of the inventory. The initiation of this process is one of the best services that UNIDO can render.

LABORATORY OF THE DEPARTMENT OF METALLURGY, MINISTRY OF MINES

The laboratory should be regarded as one of the key facilities in the development of industrial activities based on the mineral resources of Zimbabwe. It should perform the following functions:

1. For any mineral deposits that come under investigation, the facilities of the laboratory should be capable of producing clean concentrates for all necessary bench-scale testwork and for subsequent larger scale pilot plant tests.
2. The laboratory should be capable of generating the technical and cost data for mineral processing information needed in pre-feasibility and feasibility studies.
3. The laboratory should perform the test work and provide appropriate technical information for meeting user specifications in connection with mineral product promotion and market development projects for the Minerals Marketing Board.
4. A processing advisory service should be provided for mineral producers who encounter difficulties in meeting tonnage and grade targets. The difficulties could be due to process inadequacies or could be caused by changes in the ore.

The laboratory was initially well equipped to perform these functions, especially in respect of metalliferous ores which were the major target of the country's mining industry for many years. Standard facilities include crushing, grinding, screening, gravity concentration, flotation, etc. However, the original equipment is now out of date in many respects. For example, the laboratory lacks modern classification equipment (hydrocyclones), efficient jigs, dense media separation systems for coarse and fine feeds, high intensity magnetic separators (wet and dry), a thermo-gravimetric balance and differential thermal analysis apparatus, a high temperature electric kiln capable of firing up to at least 1750°C and various other items. The additional equipment would also necessitate some additions to staff strength. The laboratory at present is short of mineral processing engineers and needs more staff in the ceramics section.

It is strongly recommended that UNIDO should provide an expert on short mission (1 - 3 months), to assist the staff of the laboratory in drawing

up a rational programme of refurbishment, modifications and additions to equipment, as well as staff improvements. The UNIDO expert would have to work closely with the Ministry of Mines and with other Government departments in establishing an order of priorities of needs in relation to the developing mineral resources programme. Care should be taken to avoid duplication of functions which are available at the Institute of Mining Research. The two centres have distinctly separate capabilities and should be regarded as mutually complementary in the mineral resources programme.

Additional training programmes should also be arranged under bilateral schemes, for example with the British Council. Preliminary discussions were held by the writer with the British Council Representative in Harare, Mr. Colin Perchard. It was noted that several potentially suitable Zimbabwe nationals are currently undergoing training at various British Institutions. Several of these might be suitable for the requirements of the Department of Metallurgy, possibly with some additional specialist instruction. -

Similar discussions at the British High Commission, with Mr. K. Cullen, indicated the possibility of applying for British bilateral aid funds in respect of the equipment costs for modernising the laboratory.

INSTITUTE OF MINING RESEARCH UNIVERSITY OF ZIMBABWE

The Institute has established an excellent record of high quality research in applied mineralogy across the whole range of geological raw materials, from metalliferous ores to industrial minerals and fuels. It has strong capabilities in mineral identification and in the analysis of mineral problems associated with physical, chemical and pyrometallurgical processes. Most of the work is done for industrial or governmental sponsors. Especial expertise was developed in respect of some of the more important mineral resources of Zimbabwe. The physical, chemical and pyrometallurgical treatment of chromite ores is an excellent example of important contributions made by the Institute. Its microscopy, X-ray and analytical equipment is good. The most serious shortages are in the library, in staff and in one or two modern items of equipment.

The Institute should be commissioned to carry out the following important functions in respect of developing industrial uses of kyanite in Zimbabwe:

1. Mineralogical modal analyses should be carried out for the ore from each of the claims or deposits which are considered for the project. It would be especially important to identify any presence of undesirable mineral components, so that proper steps can be taken in the control of feed qualities and in the selection of treatment methods.
2. The kyanite from each of the ores should be examined in respect of mineralogical, physical and chemical characteristics. This should include impurities, calcining behaviour and reaction with other components of ceramic or refractory mixes.
3. The calcining behaviour of the various kyanites should be the subject of a special investigation. The Institute of Mining Research has the right background of experience and most of the necessary laboratory equipment for carrying out the initial phases of this investigation. Arrangements for pilot scale work will have to be considered later.

Kyanite has to be calcined at different temperatures within the range 1350 -- 1750°C in order to be used as grog in different refractories and ceramics. Various applications place different emphasis on high density, high strength, shape stability, dielectric constants and others. These can be modified by the proportion, size grading and calcining temperature of the kyanite. A separate, but related aspect is the fusion of kyanite at temperatures of about 1800 - 1815°C, for use in special bodies.

The conventional methods of using oil- or gas-fired kilns are not applicable in Zimbabwe, Kilns fired with pulverised coal would result in unacceptable contamination of the kyanite by coal ash. Electric firing is the only real alternative and the recent development of plasma burners has opened exciting possibilities for Zimbabwe.

Both calcining and fusion of high purity kyanite by means of electric plasma firing should be investigated as a matter of greatest urgency. It is strongly recommended that an experimental plasma burner unit should be commissioned at the Institute of Mining Research for the basic studies in developing a new process of firing kyanite. Small units, such as the Westinghouse system with a CO₂ plasma, are commercially available and are highly suitable for the purpose. One purpose of the investigation would be to determine whether the plasma flame can be placed directly in the calcining chamber. If there are problems of excessive thermal shock, it may be preferable to use a separate combustion chamber and to control the calcining temperature by means of a variable air flow. These aspects need to be clarified in order to finalise design of a plasma-fired rotary kiln for commercial production.

Such a firing system should place Zimbabwe in a strong position in international markets, because the kyanite fired with a highly controllable high temperature plasma burner should be greatly superior in uniformity and quality. Relatively low power consumption should add a commercial cost advantage.

The second purpose of the plasma firing project at the Institute would be to study the firing characteristics of different kyanites at various temperatures right up to fusion. Because of the inevitable differences in minor impurities in different ores, it is likely that different kyanites show different suitabilities for firing at various temperatures. It would thus be possible, by blending or segregation, to prepare special grogs to meet requirements for different applications. This could yield major commercial advantages, for example in competing for substantial orders for glass tank blocks.

Other developments would also follow. For example, it would become possible to market a blended kyanite product consisting of exact proportions of calcined and raw kyanite, with precise characteristics of stability, expansion and size grading/plasticity. This would be especially suitable

for refractory ramming mixes where it is desirable that expansion should be pre-determined precisely. Other applications would be for special ceramic mixes, for example for very large electrical insulators.

The commercial yields of such work could be very substantial and it is recommended that the Institute of Mining Research should be asked immediately to formulate and cost detailed proposals for this purpose. The work should be funded by IDC or by UNIDO and the equipment might be appropriate for bilateral funding under arrangements with the EEC, U.K. or U.S.A. It would be a major set-back for Zimbabwe's industrial development if this project were delayed and if other countries were given time to pick up this idea.

As a separate proposal, it is suggested that the Institute of Mining Research should be considered for a grant from UNIDO (or some other appropriate agency) to supplement its library facilities. Substantial additional purchases of books are necessary, in the range of foreign exchange costs of Z\$ 5000 - 10 000. In addition it would be most desirable to provide an international data link facility to obtain access to data stores, reference collections, etc. at institutions overseas. This facility would also prove most valuable to other users such as the Geological Survey, the University, etc.

OTHER MINERAL PROJECTS

In the course of investigations carried out by the writer, it was inevitable that other mineral opportunities should be noticed. These may lie outside the terms of reference of the present mission, but are listed below, possibly for separate attention, or when the mineral inventory is commissioned.

1. Diatomite

An extensive deposit of diatomite (Kieselguhr) was discovered in 1965 in the north of Zimbabwe. It lies about 6.5 km off the surfaced main road between Makuti and Chirundu. Some 50 000 to 100 000 tonnes of reserves are present in a flat-lying deposit which varies between 1.5 and 3 metres in thickness under shallow overburden of sandy diatomite and soil. The overburden depth increases from less than one metre in the west to more than 5 metres in the east. The diatomite appears to be of good quality and is said to have been tested successfully in 1972 at a sugar refinery. The deposit is not being worked, but is easily accessible and could provide employment in an underdeveloped area.

Diatomite is used for filtration purposes in sugar refineries, breweries, wine making and other food processing plants. Other uses are in metal refining, fertilizers, light weight building materials, etc. Imports into Zimbabwe probably run at several hundred tonnes per year and the price must run in the region of Z\$ 400 - 500 per tonne. It is recommended that UNIDO should send an expert on a short mission (1 month) to investigate the technical requirements and economic viability.

2. Lithium Minerals at Bikita

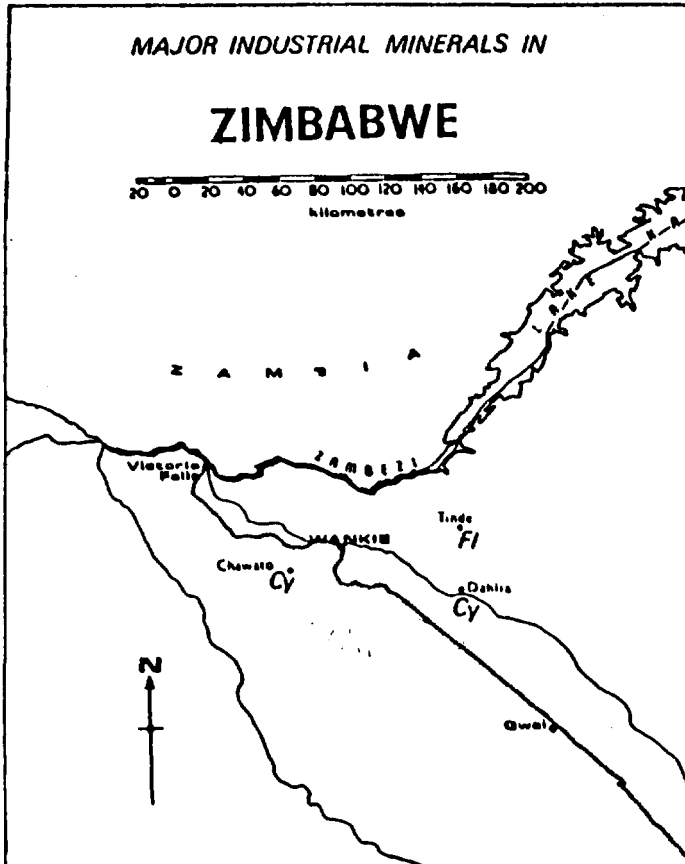
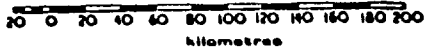
The pegmatite deposits at Bikita were visited because the various lithium silicates and the potash feldspar available from that operation are important for the ceramic developments recommended by the writer.

It was disconcerting to find that production of this unique deposit of mixed lithium minerals is at present largely dependent on manual sorting. Some 30 - 40% of the mined ore is extracted and the remainder is stockpiled for future consideration. It would seem desirable to mount a concentrated

research and development effort in order to double extraction and thus to halve the unit costs. The various minerals from Bikita could be of widespread world use in the production of heat-resisting glasses, as well as in ceramics and glazes, but trade at Bikita is very sluggish after the cut-backs resulting from UDI. Since strong production would be in the national interest, consideration should be given to possible assistance from I.D.C. in funding the necessary research expenditure. Alternatively, UNIDO could be asked to provide an expert for a period of not less than one year to assist the local staff in finding new methods of treatment. Even if hand-picking were to be retained, a new approach to processing the rest of Bikita's minerals must be long overdue.

MAJOR INDUSTRIAL MINERALS IN

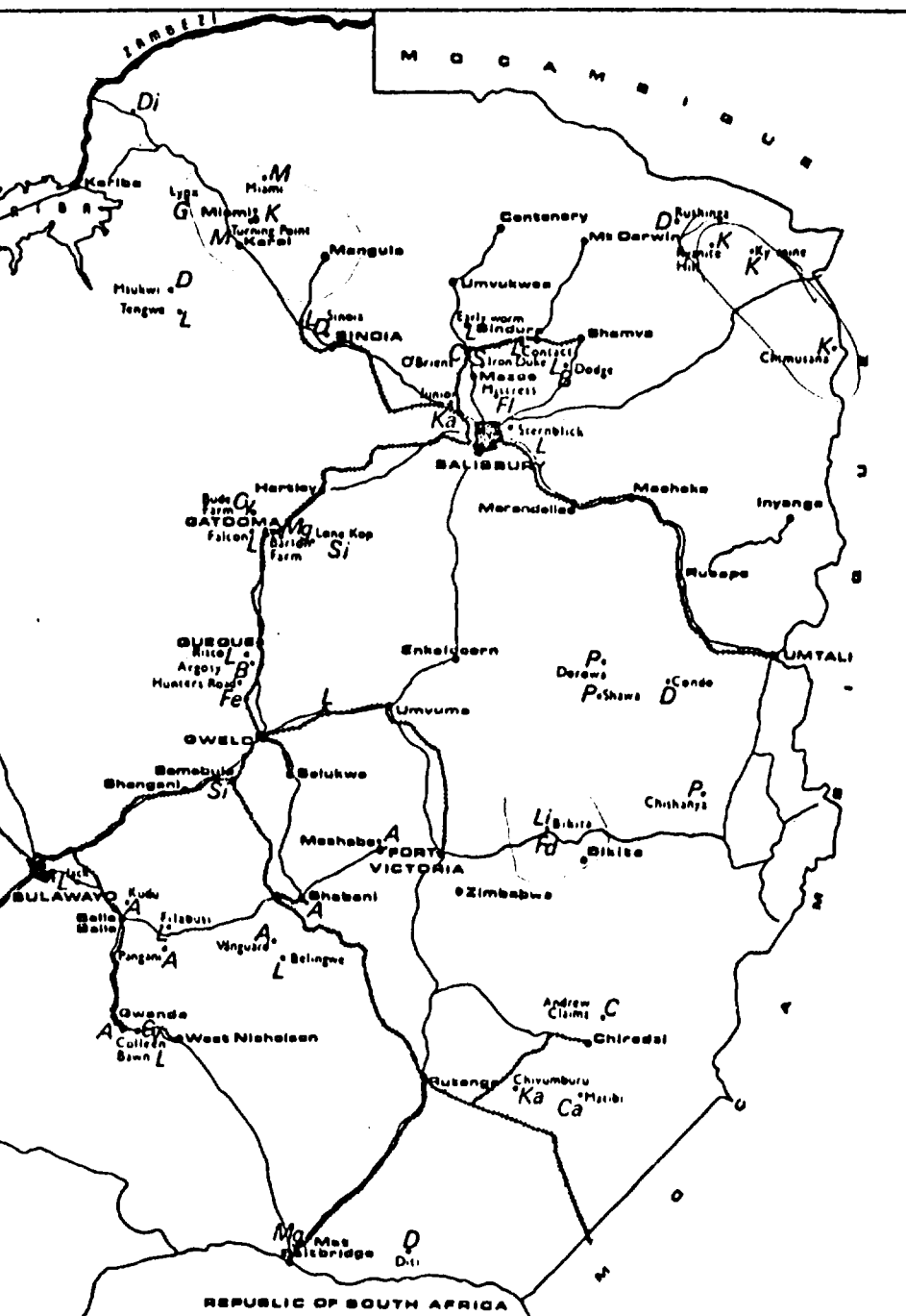
ZIMBABWE



KEY

- A Asbestos
- B Barytes
- C Corundum
- Ca Calcite
- Cy Clay
- D Dolomite
- Di Diatomite
- Fd Feldspar
- Fe Iron oxide
- Fl Fluorspar
- G Graphite
- K Kyanite
- Ka Kaolin
- L Limestone
- Li Lithium
- M Mica
- Mg Magnesite
- S Pyrites
- Si Silica
- main road
- ≡ railway

Adapted from the Zimbabwe Geological Survey



ORGANISATIONS AND PERSONS CONTACTED BY H.E. COHEN

Ministry of Mines

Mr.C.M.Ushewokunze Secretary for Mines and
Chairman Minerals Marketing Corporation
Dr.M.Kanyangarara, Counterpart Officer in charge of the
Project

Geological Survey

Mr.E.R.Morrison, Director
Mr.C.Anderson, Economic Geologist
Mr.T.Broderick, Senior Field Geologist

Department of Metallurgy

Mr.W.Furusa, Director
Mr.G.Davies, Ceramist

Institute of Mining Research

Professor K.Viewing

Department of Mines

Mr.G.Field, Consultant

Industrial Development Corporation

Mr.N.Cambitzis. Director
Mr.B.McCurdy, Administration Manager
Dr.S.E.Peterson, Investigations Controller

Ministry of Construction: Mr. Shepherd

Ministry of Finance and Economic Planning

Mr A.M.Sigobodhla
Mr.W.Fairbairn, UNDP Adviser

Electric Supply Commission

Mr.A.Sprouson, Production and Contracts Engineer

Norbel Potteries, Msasa, Harare

Mr.K.Hulse, General Manager
Mr.K.Morris, Managing Director

Cerama Industries, Norton

M.P.Lockett, General Manager

Mr. Davis, Ceramist

Abercom Central Africa Ltd., (Parent Company of Cerama)

Mr.D.McDevitt, Managing Director

Mr.R.A.Sparkes, Manager Building Products Division

G + W Industrial Minerals Ltd., Willowvale, Harare

Mr.S.Bloor, General Manager

M.T.D.Geochemical Services Ltd., Beverley, Harare

Mr.H.T.Bichard, General Manager (kyanite from Miami area)

Gypsum Industries Ltd., Cleveland, Harare

Mr.J.Marr-Levin, General Manager (kyanite from Madaicheche)

Bikita Minerals Ltd.

Harare: Mr.J.C.Graylin, Managing Director

Mr.D.Cooper, Consultant

Bikita: Mr.C.Ross, General Manager

Mr.A.Marsh, Geologist

Corning Glass Works, Corning, New York

Mr.G.H.Edwards, Chief Geologist (visiting Bikita)

Mr.R.G.Ecklin (to contact at Corning for licensing process)

British High Commission

Mr.R.Ralph, First Secretary

Mr.K.Cullen, Commercial Officer

British Council: Mr.C.Perchard, Director

Mr. Reid

Commonwealth Development Corporation

Mr.T.Davidson

Ruenya Mining Co., Mtoko (kyanite from Ky Mine)

Mr. A. Smit

DIARY OF THE MISSION

Project SI/ZIM/801; 18 January 1983 - 36 March 1983

- Tuesday 18 January: 08.45 Depart Northwood. 10.30 Depart London Heathrow; 13.30 arrive Vienna airport; 14.30 arrive hotel; 15.00 telephone Ms.Mazué to arrange briefing.
- Wednesday 19 January: Briefing: Ms.Mazué, Ms.Mennel, Mr.Dobos
- Thursday 20 January: Briefing: Mr.Surguchov; Medical Centre; Zimbabwe Files; Library Search.
- Friday 21 January: 12.55 Depart Vienna airport via Zurich and Athens.
- Saturday 22 January: 07.00 Arrive Harare. Morning: settle into hotel, find location of UN and Government offices. afternoon free.
- Sunday 23 January: Morning discuss separate requirements and procedures for the two respective projects with Mr. P. Hadzeriga (lithium project). Afternoon free.
- Monday 24 January: 08.30 Report to UNDP office. Meet Mr.Tejno, JPO and Mr.Ambachew, Res.Rep. Discussion of project plan. 14.30 Ministry of Mines, meet Dr.Kanyangarara, counterpart officer; Mr.Morrison, Director Geological Survey and Mr.Anderson, Economic Geologist.
- Tuesday 25 January: Call at UNDP office for further discussions. 10.00 Geological Survey. Discussions with Mr.Morrison and Mr.Anderson. 14.00 Work through records, exclusive prospecting orders, mining claims, etc., in library, Geol. Survey.
- Wednesday 26 January: 08.30 Laboratories of the Department of Metallurgy: Meet Mr.Furusa, Director and Mr.Davies, Ceramist for discussion of project. 14.00 Institute of Mining Research, Professor Viewing, Director. Discussion of project.
- Thursday 27 January: 08.00 UNDP office. 09.00 Ministry of Mines, meet Dr.Kanyangarara and Mr.Ushewokunze, Secretary for Mines and Director of Minerals Marketing Corporation. I propose outline of industrial minerals utilisation programme. 14.00 Continue library work at Geological Survey.
- Friday 28 January: 08.30 MTD Ltd., Beverley, Meet Mr.Bichard, Manager of Exploration Services. Discuss their deposit of kyanite. 14.00 Department of Mines. Mr.Field, consultant seconded by ODA. 15.30 British High Commission, Mr.Ralph, First Secretary. I explain mission.

Saturday 29 January: Morning: notes and study of papers loaned by Mr. Richard. Afternoon: meeting with Prof. Viewing to discuss ceramics aspects of the project.

Sunday 30 January: Morning trip to Mazoe - Concession area to visit deposits of corundum, clays, steatite. Afternoon free.

Monday 31 January: 08.00 UNDP office, arrangement of various meetings and visits. 09.00 British Council, Mr. Perchard, Director and Mr. Reid. Discussion of training arrangements for Zimbabwe personnel. 10.30 Bikita Ltd., Mr. Graylin, Managing Director. Discussion of industrial uses of their lithium silicates, feldspars, etc. 11.30 UNDP office. 12.00 Department of Metallurgy, arrange for tests of kyanite mixes. 14.00 Institute of Mining Research to collect reports on clays, refractories, ceramics. Arrange further meetings. Meet Mr. Cambitzis, Director, Industrial Development Corporation (IDC) to set up cooperation.

Tuesday 1 February: 08.30 G + W Industrial Minerals Ltd., Willowvale. Meet Mr. Bloor, General Manager. Examine the plant for mineral processing; stocks of minerals. Discuss prices, labour and transport costs. Obtain papers and arrange further meetings. 11.30 Department of Metallurgy to assess progress of test work. 14.30 British High Commission, Mr. Cullen, Commercial Officer. Discuss bilateral funding for industrial development projects. 15.30 Ministry of Mines to report progress to Dr. Kanyangara. 16.30 UNDP office to report progress to Mr. Tejno.

Wednesday 2 February: 08.30 Gypsum Industries, Cleveland, Mr. Marr-Levin, General Manager. Discuss their kyanite deposits, previous test work, product qualities. Problems of infrastructure. They will supply kyanite for test work. I obtain reports on deposits. 14.00 UNDP office to work on papers.

Thursday 3 February: 08.30 Geological Survey to report progress to Mr. Morrison. 09.00 UNDP office to note details of Zimbabwe imports. 10.00 Electricity Supply Commission (ESC), Mr. Sprouson, Contracts Engineer. Discuss details of ceramic electrical insulators imported for power supply. 12.30 Meet Mr. Bloor, G + W Minerals to arrange for clay samples; discuss progress with Mr. Furusa; 16.30

collect clay samples from G + W Minerals.

- Friday 4 February: 08.30 Department of Metallurgy; test arrangements. 09.30 Industrial Development Corporation (IDC), Mr. McCurdy, Administration Manager; Dr. Peterson, Developments Controller. I explain project and suggest joint action in setting up ceramic industry. Agreement to follow up. 10.45 Geological Survey to report progress to Mr. Morrison and Mr. Anderson. 11.30 Ministry of Mines to report progress to Dr. Kanyangarara. 14.00 Ministry of Mines Round Table Meeting: UNDP? Ministries of Mines, Finance, Construction, etc. to discuss principles of national development of industrial minerals. 16.45 UNDP office to arrange further contacts.
- Saturday 5 February: Morning: work over papers and notes. Afternoon draft detailed requirements for ceramics manufacture.
- Sunday 6 February: Free.
- Monday 7 February: 08.00 UNDP office to arrange visits. 09.00 Ministry of Mines to arrange travel facilities. 09.30 Geological Survey to check details in library. 10.30 Norbel Potteries, Msasa, Mr. Hulse, General Manager. Inspect their works and discuss possible developments. 14.30 Cerama Ltd., Norton, Mr. Lockett, General Manager. Inspect and discuss existing plant, discontinued tile manufacture. 16.00 UNDP office report progress to Mr. Tejno. 16.45 Ministry of Economic Planning, Mr. Fairbairn, Consultant. Arrange for joint visit to Bikita Mine.
- Tuesday 8 February: 08.00 Ministry of Economic Planning. Confirm arrangements with Mr. Fairbairn. 08.45 UNDP office to check details. 09.30 Department of Mines, Mr. Field, Consultant. Discuss costs of mining, labour, transport. 10.30 Geological Survey to report progress. 11.00 Ministry of Mines to discuss ceramic proposals with Dr. Kanyangarara and discuss IDC participation. 14.30 Abercom Ltd., Graniteside, Mr. McDevitt, Managing Director, Mr. Sparkes, Manager. Parent company of Cerama. Detailed discussion, technical and commercial. Agreement on further joint discussions with IDC and Norbel.
- Wednesday 9 February: 08.30 UNDP office. Correspondence and discussions. Meet Mr. Holland, Engineering + Equipment Ltd. who plans to introduce American plastic insulators.

14 00 Norbel Potteries to explain proposals for joint venture in diversified ceramics. Agreement for round table discussion with Cerama and IDC. 15.30 Department of Metallurgy to report progress to Mr.Furusa. 16.30 G + W Minerals to deal with U.S.A.enquiry for calcined kyanite.

Thursday 10 February: 08.30 UNDP office. 10.00 IDC meeting to discuss further details of joint venture. 12.00 UNDP office to report progress to Mr.Tejno. 12.30 Ministry of Mines to report progress to Dr.Kanyangarara. 14.30 M.T.D.Ltd. to arrange visit to kyanite deposits. 15.30 Department of Metallurgy to assess tests on clays. 16.30 Institute of Mining Research.

Friday 11 February: 08.00 UNDP office for progress briefing and pay arrangements. 11.00 move to new hotel. 14.00 Reports and notes for field visits.

Saturday 12 February: Morning:prepare lecture for Zimbabwe Association for the Advancement of Applied Science and Technology. Afternoon: Prof.Viewing to arrange trip to Mtoko area.

Sunday 13 February: Morning: draft report. Afternoon free.

Monday 14 February: 08.00 UNDP office; correspondence. 08.30 Bikita Minerals Ltd. Discuss ceramics and glass development. 09.30 UNDP office to report progress. 10.15 British Council to discuss funding. 11.30 Geological Survey to report progress. 12.15 Department of Mines to collect information. 14.00 Department of Metallurgy to assess progress with different kyanite samples. 15.30 Meeting with Mr.Furusa. 16.30 UNDP office.

Tuesday 15 February: 08.30 M.T.D.Ltd., Msasa. Collect large sample of kyanite and discuss possible export. 09.30 Gypsum Industries Ltd. Collect large sample of kyanite. 10.30 Geological Survey library to study Bikita papers. 11.30 Department of Metallurgy to deliver kyanite samples and arrange for processing. 12.45 Mr.Graylin (Bikita) and Mr.Edwards, Corning Glass, U.S.A., to discuss local glass industry. 14.15 UNDP office to consult with Mr.Tejno. 15.15 Commonwealth Development

Corporation, Mr. Davidson. Discuss loan funding or equity participation.

- Wednesday 16 February: 08.15 G + W Minerals Ltd., Willowvale. Collect large samples of clays and feldspar for test work. Discuss diatomite deposit. Discuss pilot rotary kiln for calcining kyanite. 09.30 Deliver samples to Department of Metallurgy and assess progress. 11.30 UNDP office. 14.00 Notes and drafts. 17.30 lecture at Harare Polytechnic to ZAAAST.
- Thursday 17 February: 08.15 Ministry of Mines to arrange trips. 09.00 UNDP office. 10.00 Meeting at IDC to discuss short term/long term prospects. 14.00 Norbel Potteries. 15.30 Department of Metallurgy to assess progress. 19.00 Meeting with Mr. Sparkes (Abercom) to discuss project.
- Friday 18 February: 08.00 UNDP office. 08.30 Gypsum Industries. 09.30 Department of Metallurgy. 10.30 Geological Survey. 11.30 Ministry of Mines. 12.30 Ministry of Economic Development. 14.00 UNDP office. 15.30 Institute of Mining Research.
- Saturday 19 February: 06.00 Trip to Mtoko area deposits of kyanite with Prof. Viewing. Return 22.00.
- Sunday 20 February: Morning: notes. Afternoon free.
- Monday 21 February: 08.00 UNDP office. 09.30 Depart for Bikita Mine.
- Tuesday 22 February: 08.00 Bikita quarries, processing plant, all day.
- Wednesday 23 February: 07.00 Depart for Harare. 15.00 UNDP office to report progress.
- Thursday 24 February: 08.00 Department of Metallurgy to review progress and collect samples. 09.00 Round table meeting at IDC with Norbel, Cerama and Abercom. 14.00 Ministry of Mines to report progress. 15.30 UNDP office.
- Friday 25 February: 05.30 Depart for Karoi. 08.00 Meet Mr. Bichard and visit kyanite deposit. All day.
- Saturday 26 February: 06.30 Examine diatomite deposits. Afternoon: notes for report.
- Sunday 27 February: Morning: notes. Afternoon free.
- Monday 28 February: 08.30 Ministry of Mines. 09.30 UNDP office.

Progress reviews. 11.00 Meeting at Abercom. 14.00 Ministry of Mines. 15.00 UNDP office.

Tuesday 1 March: 08.20 Ministry of Mines. 10.30 Geological Survey. Briefings. 11.40 UNDP office. 14.00 Dept. Metallurgy.

Wednesday 2 March: 08.00 UNDP office. 09.30 Department of Metallurgy. Meeting with Abercom/Cerama. 14.00 UNDP office. 15.00 Institute of Mining Research.

Thursday 3 March: Notes and revision of details.

Friday 4 March

Saturday 5 March Project Report

Sunday 6 March

Monday 7 March: 07.30 Department of Metallurgy. 08.30 UNDP Office to prepare copies of Project Report. 14.00 Gypsum Industries Ltd. to collect large kyanite sample. 15.30 Department of Metallurgy to deliver sample for processing. 16.30 Institute for Mining Research.

Tuesday 8 March: 08.10 Geological Survey. 08.30 Ministry of Mines. 09.10 UNDP office. 10.30 IDC office. 11.30 Norbel Ltd. 14.00 Bikita Minerals; Mr. Cooper and Mr. Graylin. 15.30 UNDP office. 16.00 Dept. of Metallurgy.

Wednesday 9 March: 08.00: Notes and diary of mission. 14 00 UNDP office. 14.30 IDC. 15.30 Abercom, Mr. McDevitt.

Thursday 10 March: 08.20 M.T.D. Ltd., Msasa. 09.00 G + W Industries, return diatomite papers to Mr. Bloor. 09.30 Department of Metallurgy, Mr. Furusa. 10.30 IDC. 12.00 UNDP office. 12.40 Norbel Ltd. Mr. Morris and Mr. Hulse. 15.00 Institute of Mining Research.

Friday 11 March: 08.00 UNDP office; completion of follow-up arrangements. 09.30 Dept. of Metallurgy; Mr. Furusa. 10.00 Abercom; joint meeting with Mr. McDevitt and staff + Mr. Furusa and Mr. Davies. 14.00 Ministry of Mines for final debriefing; Mr. Ushewokunze and staff + Mr. Furusa and staff + Mr. Tejno. 19.00 Dinner-reception by Ministry of Mines.

Saturday 12 March: Morning completion of notes and travelling arrangements. Afternoon meeting with Professor Viewing to arrange follow-up work. 23.25 Depart Harare airport.

Sunday 13 March: in transit. Arrive Zurich 10.00; depart Zurich 11.40; arrive Vienna airport 12.45; arrive Vienna hotel 14.15.

