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Industrial Minerals and Artisanal Mining Study (Ethiopia World Bank Energy Access Project): Summary of activities, findings and recommendations of industrial minerals sub-project

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BRITISH GEOLOGICAL SURVEY

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Front cover: Harrar limestone. Stockpile at Modern Building Industry's filler production plant, Awash.

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1 Introduction

This report describes the findings of the industrial minerals sub-project of the Industrial Minerals and Artisanal Mining Study, one of three projects carried out by the British Geological Survey for the Ethiopia Energy Access Project – Mineral Component, under funding from the World Bank.

2 Project implementation methodology

2.1 PHASE 1: DEMAND/SUPPLY SURVEY OF THE ETHIOPIA INDUSTRIAL MINERALS SUB-SECTOR

In the original proposal, this phase was divided into three tasks. Following the project inception visit in November 2005, these were recast into two, namely:

- Undertake a comprehensive survey to identify opportunities for and constraints on Ethiopia's industrial minerals sub-sector
- Based on the above, and a thorough assessment of relevant data held by the GSE and elsewhere, identify further areas for investigation of industrial minerals, principally exploration, laboratory assessment (including beneficiation studies) and pilot-plant testing.

The first of these tasks has been addressed in BGS Report CR/06/180 and its findings are summarised in Section 3 of the present report. The second task has been addressed in Section 4 of the present report (and, to some extent, by Section 3.4).

2.2 PHASE 2: DATA COMPILATION: ETHIOPIA INDUSTRIAL MINERALS INVENTORY

In the original proposal, this phase was divided into the following two tasks:

- Compile and evaluate existing geological data on industrial minerals for promotional work
- Prepare documentation and databases relevant to project activities and findings

Work under Phase 2 was carried out in close collaboration with the parallel project 'Geological Survey and Investment Promotion Study', which is also being undertaken by BGS. Design and construction of a Mineral Occurrence Database is a major deliverable of the latter project and, although in this the emphasis is on metallic minerals, it was agreed at an early stage that there should be a completely integrated approach to defining common fields for 'headline' locational, geological and mineralogical/chemical data on metallic and industrial minerals (including dimension stone) to enable standardised approaches for both data entry and subsequent digital manipulation and display of the output.

2.2.1 Development of the Mineral Occurrence Database

The location and description of mineral occurrences and of previous mineral-related work in Ethiopia is critical to the promotion of commercial investment. In addition to favourable geology and other non-scientific parameters, such as the national mining and tax laws, international companies place a high degree of importance on the availability of information on known mineral occurrences and deposits and the results of previous work carried out on them. A mineral occurrence database designed to provide this information is therefore an important element of this project.

The Mineral Occurrence Database of Ethiopia (MOD) is an inventory system consisting of a stand-alone database accompanied by a database manual/documentation. The MOD is designed for use not only by industry but for other stakeholders, including government departments and organisations, universities and the public, for the following purposes:

- To find information on documented mineralisation anywhere in Ethiopia
- To develop exploration strategies
- For geoscience research
- To evaluate the resource potential of an area
- For land-use planning
- For desktop prospecting such as Mineral Prospectivity Modelling

2.2.1.1 DESIGN

The MOD was built around the tables and fields defined by the NGU under the Ethionor Project (1996-2001). The NGU commenced the development of this database in Oracle 9i and divided it into three separate components: Industrial Minerals, Metallic Minerals and Dimension Stone. However, for financial reasons, they were unable to finish the database.

For reasons of ease of maintenance, ease of use and availability of GSE database expertise, the MOD was developed using Microsoft Access. The Access database is stand-alone and independent of other software applications. Should expertise in Oracle be developed by GSE in the future, the Access database can readily be loaded into Oracle.

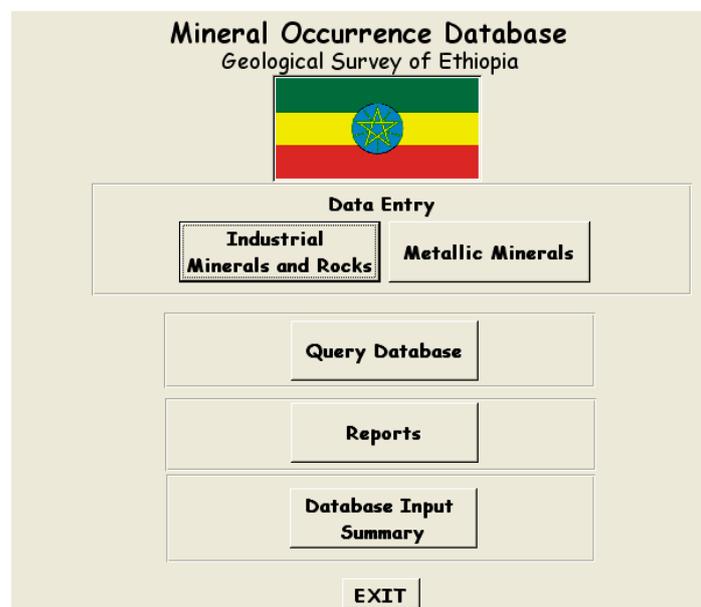


Figure 1 Organisation of Mineral Occurrence Database

The MOD consists of a series of database tables that contain descriptions of metallic, industrial and building stone occurrences in Ethiopia ranging in size from small showings to operating mines. The information contained in the database tables includes:

- mineral commodities
- locational information
- mineral type

7. **Deposit morphology.** Allows the user to search for all mineral occurrences with a particular defined morphology, for example breccia, stockwork or vein. The deposit morphology of interest is selected from a drop-down list.

In addition to retrieving key information relating to mineral occurrences, all data specific to a particular occurrence can be retrieved using the report facility. The user simply selects the occurrence of interest and all information held within the database relating to that occurrence is output in a report format.

By extending the scope of descriptive fields, tables in the MOD were designed to cover both metallic and industrial minerals. However, with respect to the way in which the MOD is likely to be interrogated, there is a distinct difference in the way composition and properties of metallic and industrial minerals need to be recorded. For metallic minerals, if the MOD is to be used as an effective investment promotion vehicle, it requires to be 'outward facing', i.e. headline data on metal grade and style of mineralisation need to be readily available to international mining houses, so that they can target likely exploration areas. For industrial minerals, the MOD will be most useful as an import substitution tool for users within Ethiopia to interrogate in order to identify local material with the desired properties (mineralogical, chemical, or physical, or a combination of these). Thus the 'prime user' needs differ markedly between metallic and industrial minerals modules of the MOD.

A much higher level of detail, in terms of mineralogy, chemistry and physical/technical properties, will eventually be required in the MOD to fully characterise industrial mineral deposits, with the additional complication that such data will also be required on a number of processed products. As noted elsewhere in the present report, the level of 'hard' specification-related information in existing GSE reports is sparse and not well-interpreted, and when this is present it is dominated by full chemical analyses, many of which are of marginal relevance to possible industrial use. To address this situation, a specific table for industrial minerals termed 'use-related properties' has been incorporated into the design of the MOD and this will simply record whether or not such data have been determined, and will identify the source. As the MOD is a relational database, links to the relevant digital source can be made subsequently when the quality and amount of information justifies this. This approach has the merit that the MOD is not overloaded initially by fields and tables of marginal relevance and, just as important, that time of GSE staff is not wasted by the requirement to enter vast amounts of largely superfluous chemical analyses.

2.2.1.2 DATABASE POPULATION

The location and description of mineral occurrences and of previous mineral-related work in Ethiopia is critical to the promotion of commercial investment. An assessment of both analogue and digital mineral occurrence information was undertaken at the beginning of the project. In 2000 and 2002, metallic and industrial mineral occurrence maps, at a scale of 1:2,000,000, were produced by the GSE. These maps displayed 66 industrial mineral and 76 metallic mineral occurrences. These hard-copy maps were produced using MapInfo GIS and contained limited information (locational information, name and commodity of the occurrence).

Between 2003 and 2006, the GSE collaborated with the BRGM project, SIGAfrique, providing mineral occurrence information in spreadsheet format for integration into an Africa-wide database and GIS. To date, the GSE have entered 875 records into this database. The SIG Africa database is designed for a large-scale continental project (1:2,000,000) and thus does not contain the detail required for a national Mineral Occurrence Database. The SIGAfrique data will form the basis of information to be loaded into the MOD but additional information for each occurrence will be required to bring this data up to the preferred level of detail of the MOD.

To date, selected industrial and metallic mineral occurrences have been added to the database to test its integrity and to ensure that the database meets the requirements of the GSE.

2.2.2 Construction of industrial minerals map

An important deliverable of the study has been an industrial minerals map on CD-ROM. Originally it was intended that this should be one of a number of potential GIS products based on the Mineral Information System developed as part of the Geological Survey and Investment Promotion Study. However, as it was not possible during the time-frame of the current study to resolve satisfactorily the shifts and distortions between SIGAfrique contextual and geological datasets and GSE datasets, the industrial minerals map has been based on a platform developed during the GSIPS. This map should act as a digital template for a more flexible GIS product once GSE has achieved resolution of the relevant datum shifts and distortions.

2.2.3 Design of example industrial minerals promotion leaflets

It will be shown later in this report that the serious lack of technical information (mineralogical and chemical composition, use-related test data and processing characteristics) on Ethiopian industrial minerals deposits means that an external investor currently has little on which to base a business decision. The example promotion leaflets have been drafted on the assumption that recommendations relating to changes in remit of the GSE industrial minerals exploration division and increased resources for the GSE Central Geological Laboratory will be implemented.

2.3 PHASE 3: CAPACITY BUILDING AND TRAINING IN INDUSTRIAL MINERALS EVALUATION AND PROMOTION

In the original proposal, this phase contained two tasks, which were slightly modified following the project inception visit:

- Train key national personnel in order to build capacity to pursue stipulated activities effectively
- Familiarise GSE counterpart staff with industrial minerals mining operations external to Ethiopia

Apart from day-to-day interaction and discussion with counterpart staff during the time BGS staff were in Ethiopia, this phase was addressed in three ways by: (i) holding a five-day intensive workshop on industrial minerals evaluation for relevant staff of the GSE, Ministry of Mines and Energy and regional organisations; (ii) arranging a study visit for three GSE counterpart staff to the UK; and (iii) holding a project completion workshop in Addis Ababa at which producers and users of industrial minerals were able to discuss the findings of the current project and agree a way forward with the GSE.

2.3.1 Industrial minerals training workshop

This was held in the Library of the GSE from 22-26 May and was attended by 22 delegates from the GSE, Ministry of Mines & Energy, and regional Agencies and Bureaux. The two BGS tutors were Dr D J Morgan and Mr C J Mitchell. Over 20 formal presentations were given on industrial minerals, ranging from their critical importance to developing economies, through geological and laboratory assessment, to planning and environmental considerations related to their extraction. Attendees were provided with two CD-ROMs, one containing the PowerPoint presentations given at the workshop, and another enclosing reports and other documentation on industrial minerals published by BGS over recent years.

Attendees were encouraged to question the presenters, and reasonable amounts of discussion took place throughout the workshop. It was stressed by the presenters that, to be a successful industrial minerals geologist, it was not sufficient just to be competent in geological and/or laboratory assessment of these materials. Because of the critical need to encourage the use of indigenous minerals by local industry, it is necessary to understand the exact role the mineral

plays in the manufacturing process, so that some skills in ‘materials science’ are required. Having lists of specifications for minerals used in different applications is only the first step in being able to persuade local manufacturers to change from imported to locally-available material. The industrial minerals geologist has to be able to explain exactly why the local material may be suitable or, if necessary, explain why a different mineral with the required functional property may also be suitable for the manufacturing process.

Further discussion on this workshop is given in Section 4.2 of the present report.

2.3.2 Industrial minerals study visit

This took place from 18 October to 3 November 2006, and the three GSE staff that took part were Ato Tibebu Mengistu Teklesilassie, Ato Berhe Gebreselassie Abera and Ato Haileyesus Wale Belette. They visited a range of industrial minerals extraction and processing operations, including those for limestone, silica sand, kaolin, brick clay and aggregates. The emphasis was not on covering all commodities relevant to Ethiopia but on maximising the counterparts’ exposure to modern mineral extraction operations backed-up by routine testing of raw materials and products. The counterparts also had the opportunity to see the way in which BGS approaches digital geological mapping and how this is integrated with other information in GIS to significantly extend and enhance its relevance.

2.3.3 Project completion workshop

This was held in the Library of the GSE on Thursday 22nd November 2007 and was attended by 40 delegates including producers and users of industrial minerals within Ethiopia, GSE, Ministry of Mines & Energy, and regional Agencies and Bureaux.

The workshop was opened by the Minister of Mines & Energy, H.E. Ato Alemayehu Tegenu who stressed the critical role of the GSE in the development of the industrial minerals sector. The morning session was introduced by Ato Hundie Melka, chaired by Ato Tibebu Mengistu Teklesilassie and Ato Berhe Gebreselassie Abera acted as Rapporteur. Three formal presentations were given by BGS (Mr CJ Mitchell) as follows: the importance of industrial minerals to developing economies; the findings of the industrial minerals project; and, the recommendations of the industrial minerals project.

The afternoon session was chaired by Ato Amenti Abraham; this session was devoted to discussion and feedback from the GSE and stakeholders. The feedback from the delegates was positive and demonstrated the success of the project in engaging all stakeholders in the process of improving the capacity of the GSE. Two CDs containing the outputs of the project (both reports, drafts of promotional leaflets and industrial minerals map) and the workshop PowerPoint presentations were left with the GSE.

2.4 PHASE 4: KEY ISSUES AND RECOMMENDATIONS

These are addressed in the current report, specifically Section 5 and Appendix 1.

3 Current status of industrial minerals in Ethiopia

3.1 DOMESTIC CONSUMPTION AND TRENDS

The current status of the industrial minerals sub-sector was assessed through a survey of producers and users within Ethiopia, reference to data on domestic production and imports, and extensive consultation of both conventional publications and information available on the world wide web.

Industrial minerals production is dominated by materials used for construction purposes – raw materials for cement, clays for brickmaking, and igneous, metamorphic and sedimentary rocks used as primary aggregates. **Cement** manufacture has a dominant influence on the industrial minerals sub-sector, not only being by far the major user of limestone and gypsum, but also affecting supply-patterns of other commodities such as lime; considerable amounts of refractory minerals and manufactured products are also imported for construction and repair of kilns at cement plants. Production of Portland cement is currently running at 1.7 million tons per year, but this is insufficient to meet an estimated yearly demand of 2.4 million tons. Shortage of cement has led to delays and general dampening of activity in the construction sector, although plans are currently in place to increase cement production threefold. There is a steadily growing **dimension stone** industry able to meet demands for high-quality material for local use. Although there have been difficulties in the past in penetrating the European export market because of low quality and discontinuities in production, there have been reports recently of marble being exported to China, Turkey and Saudi Arabia. From being almost totally reliant on imports of edible **salt** six years ago, domestic production is now running in excess of 150,000 tons per year against an estimated yearly requirement of 350,000 tons. A number of companies are currently engaged in mining salt in the NE of the country and licences have been granted to others. Production plans will more than satisfy national demand, with the surplus in theory available for export, but to compete effectively on the international market this salt would have to be iodised (and significant investment in iodisation plants is still required). The agricultural sector is a large consumer of industrial minerals and derivatives, being responsible for imports of **fertilizer** of up to 600,000 tons per year, and costing in excess of US\$ 100 million. Nitrogenous fertiliser, mostly in the form of urea, comprises more than half of imported fertiliser, and the rapidly increasing world price of fertilisers may bring forward plans to manufacture urea from coal at Yayu, Oromia. There is currently no domestic production of fertilizers in Ethiopia. Annual **soda ash** production from Lake Abiyata has varied between 3,000 and 8,000 tons, but production ceased in July 2006 for fundamental technical reasons, leaving up to 65 local manufacturing companies needing to import their raw material.

Apart from the construction industry, a small number of enterprises are directly reliant on local industrial minerals for production of bottle glass, aluminium sulphate, sulphuric acid, caustic soda, and ceramic ware. At present, the manufacturing industry as a whole accounts for only 11% of Ethiopia's GDP (and about 10% of employment), covering 130 state-owned and 7,000 private industries. Industries utilising industrial minerals comprise a relatively small proportion of this manufacturing sector, and a large proportion of these use imported materials because the quality of local material is not consistent and/or can not be supplied to a high enough specification. Minerals are often extracted using unsophisticated, labour-intensive methods with little processing. When processing is carried out, either on site (e.g. kaolin at Bombuhwa) or remotely (e.g. carbonates at MBI, Awash), product specifications are pitched near the minimum of the range, and relevant quality control is absent. Many manufacturers (e.g. Addis Ababa Glass Factory, Adami-Tulu Pesticide Processing SC) process their raw materials on site and test in their own laboratories. Because of the relatively small tonnages of imported materials used, and the cost of additional transportation within the country, manufacturers pay well above 'world prices' for their imported materials, and the country overall pays a high premium in foreign exchange. In spite of the high costs of imported materials, a number of the users interviewed complained that locally-produced material was often more expensive.

Although most of the **limestone** extracted is used for cement, significant amounts are also used as a filler by the paint and rubber industries, and for glass manufacture. Consumption of carbonate filler by the paint industry is estimated at no more than 3,000 tons per year, but a planned increase in the number of paint factories should result in a significant increase in demand. Up to 2,000 tons per year of calcium carbonate are imported, probably to meet purity requirements of pharmaceutical and chemical manufacturers. Limestone is also used to produce **lime**, and the major outlet for this is the sugar industry. Nearly 3,500 tons per year are used, but

the increase in number of sugar refining plants planned over the next 7-10 years could result in the annual requirement increasing five-fold. Considerable amounts of lime are also used in water treatment and increase in demand for lime for road construction is likely to increase. Currently, demand for lime is not being met by domestic production (at maximum 4,500 tons per year), partly due to the fact that a large proportion of the lime is produced at the Dire Dawa cement factory and there have been difficulties in securing supply because priority has been given to cement production. Investment in lime production plants is urgently needed, with some of these being located close to or on the sites of sugar refining plants.

Imports of calcined **magnesite** reached 660 tons in 2004, probably for the manufacture of oxychloride and oxysulphate cements used in flooring and wallboards; there is no domestic production of magnesite. Up to 1,000 tons per year of locally-produced **dolomite** are used in glass manufacture, and dolomitic marbles are also used as dimension stone and, after grinding, as a filler (maximum of 2,100 tons in 2005). Up to 2,000 tons of dolomite are also imported, possibly much of this for higher-specification filler uses than can be met by material produced locally. Relatively small tonnages of calcined dolomite (240 tons per year) are also imported for use by the iron and steel industry.

Apart from a lull in 2002, between 45,000-50,000 tons of **gypsum** have been produced yearly from 2000. By far the majority of this has been consumed by the cement industry, although other uses will have been as a soil conditioner and, after calcining, in plasters. The Tabor Ceramics Factory have replaced imported plaster of Paris moulds by ones prepared in their factory, but are experiencing difficulties with the quality of locally-supplied calcined gypsum.

Imported **bentonite** is used mainly in the decolorizing of edible oils, although smaller amounts are used in well-drilling, for wine clarification and, possibly, foundry use. Edible oil processing probably accounts for 90% of bentonite consumption. Currently, there are numerous small-scale edible oil producers who do not bleach their products, but forthcoming government regulations may make this mandatory. This should lead to an increase in demand for bleaching-grade bentonite. There is no domestic production of bentonite.

Domestic production of **kaolin** varied from 1,600 and 4,250 tons per year between 2000 and 2005. Production was entirely from the processing plant in Bombowuha to two main customers, the Tabor Ceramics Factory and Melkasa Aluminium Sulfate and Sulphuric Acid Factory. The aluminium sulphate is used for water purification, but this is under threat from substitution by cheaper, imported polyelectrolyte. The Tabor Ceramics factory is currently favouring kaolin from Hosania, despite lack of consistency in delivered material from this deposit. The quality of product from the Bombowuha plant is low, and the plant has been inactive for the last six months. At least 500 tons per year of kaolin is currently imported, primarily for paper manufacture, with smaller amounts being used as a filler in paints.

Up to 550 tons per year of **feldspar** and **quartz** (undifferentiated) are produced from Kenticha, all of this apparently for the manufacture of ceramics. Only eight tons of feldspar have been imported in the last six years. Silica sand production has remained constant for the last few years at 6,000 tons per year. The bulk of this is used in glass manufacture, with smaller quantities being used by, for instance, the Ethiopian Iron and Steel Factory.

Imports of **mica** from 2000 to 2005 amounted to 123 tons, this being used as a filler for rubber and paint. Over 4,600 tons of **talc** were imported in the same period. The only user identified during the current survey was the Addis Tyre Factory (eight tons per year) and identification of other users should be a priority in a follow-up to the current study.

Just over 11 tons of **graphite** were imported between 2000 and 2005, most probably for refractory use. Thirty-six tons of **kyanite**-group minerals and 144 tons of mullite (the calcined product) were also imported during the same period, probably for furnace repairs in cement and metallurgical plants. Requirements for both minerals will increase with expansion of the cement and metallurgical industries.

Imports of **titanium dioxide** reached 766 tons in 2003 (latest figures available). One paint factory – the Nefas Silk Paints Factory – consumes up to 500 tons per year, and with the anticipated increase in paint factories the demand is likely to increase. There is a steady demand for natural abrasives, imports currently running at over 500 tons per year.

More comprehensive information on domestic production, imports and use of industrial minerals can be found in BGS Report CR/06/180, specifically Sections 3.1 to 3.24 and Appendix 3 (Notes on visits to users and producers of industrial minerals).

3.2 REGIONAL CONSUMPTION AND TRENDS

In general, industrial minerals can only be traded internationally where they can be delivered to the customer at a lower cost than other equivalent materials and to do so is profitable for the producer. In addition to simple price consideration, international buyers may purchase mineral products at premium prices where to do so provides: (i) security of supply, particularly where material is purchased from a number of producers; (ii) blending of feedstock, where a quality commodity can be combined with cheaper materials, the whole being less expensive than alternatives; (iii) unusual or sought-after properties, relevant to the production of specialist or highly-engineered products or for particular applications; (iv) added-value products, where the producer has assumed responsibility for further production stages than is typical. If there is a problem over product quality, consistency and delivered cost within the domestic market – as has been shown to be the case in Ethiopia – then these criteria are even more important with respect to exports. In other words, local suppliers will need first to compete successfully with imported materials on the internal market in terms of price, quality and consistency of supply. Only then can they compete on the export market. Large amounts of industrial minerals imported into Ethiopia are from countries in the immediate region (BGS Report CR/06/180; Tables 2-20), and thus potential competitors in future export markets. The current situation where all exports have to be routed through Djibouti clearly has a major influence on potential competitiveness of Ethiopian industrial mineral in the wider market.

In terms of export potential for Ethiopia's industrial minerals, of the countries in the region, Saudi Arabia and South Africa have the largest import demand, with significant demand in Egypt and Kenya (BGS Report CR/06/180; Appendix 4 (Detailed statistical data on regional consumption of industrial minerals)). Geographically, of the seven countries studied, Kenya and Sudan are the only ones with a common border with Ethiopia. All of the countries have sea ports apart from Uganda, which is relatively close to the SW border of Ethiopia.

The data in Tables 25-33 of BGS Report CR/06/180 show that the richer economies can afford to pay more for their raw material requirements, hence the highest unit prices are mostly in Saudi Arabia and South Africa, and the lowest unit prices are in the less-developed countries. This is mostly a function of the source of origin of these commodities, for example, Saudi Arabia has a high proportion imported from developed countries where the commodities are more highly specified and are more expensive as a result. Egypt has the highest proportion imported from developed countries, but this could be due to its close proximity to Europe. South Africa has a more even spread of imports from developed and less-developed economies; this indicates its close links to Africa but also the advanced state of its economy. The less-developed countries such as Kenya, Tanzania and Sudan have the highest proportion from less-developed countries; this reflects their close proximity to their African neighbours but also indicates that their economy cannot afford to buy the more highly specified commodities.

The preceding analysis indicates that the most promising countries for future industrial mineral exports are Saudi Arabia and South Africa. However, it should be kept in mind that the Saudi economy has a penchant for more highly specified commodities from developed countries and it would require Ethiopian producers to make substantial investments in processing technology. Therefore, the South African market would appear to be the more promising, and receptive, to

imports from Ethiopia, but there will be strong competition from neighbouring African countries who have already established import links with South Africa. Of the other countries studied, Egypt would also appear to hold potential but the same comments as for Saudi Arabia would apply. The other African countries studied would appear to have limited scope for development of export opportunities.

3.3 REVIEW OF CURRENT DOMESTIC PRODUCTION

It is apparent from Section 3.1 of the present report – and much fuller information provided in BGS Report CR/06/180) – that current domestic production of industrial minerals falls short of satisfying national need for these materials. Poor quality and consistency of supply of local minerals and derivatives (and in some instances high cost) mean that many manufacturers have to import their raw materials, despite problems over foreign exchange quotas and possible interruption to production resulting from delays in delivery. Many minerals are imported in spite of the fact that extensive deposits of the same mineral have been identified within Ethiopia. However, the small size of the internal market for the bulk of industrial minerals currently utilised presents a problem to development of such deposits, as tonnages of 1,000-2,000 per year offer little opportunities for local investors/producers, particularly if the corresponding imports are of a high specification. The lack of hard, technical information on most industrial mineral deposits (mineralogical and chemical composition, use-related test data and processing characteristics) also means that an external investor has little on which to base a business decision. This is probably the largest single factor inhibiting development of the industrial minerals sub-sector in Ethiopia.

3.4 REVIEW OF DEPOSITS IDENTIFIED BUT NOT IN PRODUCTION

As part of the industrial minerals demand/supply survey described in detail in BGS Report CR/06/180, a number of mineral deposits and occurrences were identified as candidates for further investigation. Many of these had already been subject to extensive geological exploration, whereas others had only been identified during reconnaissance surveys. However, a common factor was – as noted above – a lack of compositional and use-related test data on, and processing characteristics of, the target minerals. It will be argued below that the only practical way of substantially improving the level of technical information on Ethiopia's industrial minerals is by providing the GSE with increased resources to carry out the task, including the provision of improved laboratory facilities. Appendix 1 contains a list of deposits recommended for further detailed evaluation, together with a suggested investigation methodology.

3.5 DISCUSSION AND RECOMMENDATIONS

The first step in developing the domestic industrial minerals market is to help local producers improve the quality and consistency of supply of their products. In the first instance, whilst their output must meet a minimum technical specification, a 'high quality' is not always required, and many manufacturers would be satisfied by a 'clean' product meeting the minimum standard on condition that each delivery is the same and on time. Once this minimum standard is reached and a steady income stream assured, producers should be encouraged to invest (or seek external investment) in processing facilities to both improve the quality of their products and the overall efficiency of their operations. For the majority of industrial minerals, the technology used need not be particularly sophisticated, and long-established mineral processing techniques are used. Such techniques need to be adapted to particular deposits, but usually require only minor adjustments. The first priority is to determine the specifications required by the consumer, and discuss ways of meeting these specifications. **There is a role here for a better-resourced GSE/CGL to bring solutions to industry problems by developing appropriate technologies and introducing them to the local producers.**

Awareness of markets and marketing is critical to all industrial minerals producers, and certainly to new producers who aspire to compete with existing suppliers. Although an existing supplier may know their own narrow market very well, an assessment of broader markets can often lead to new sales opportunities. All new operations require a thorough study of the markets for the potential producers at an early stage in the development; conversely, lack of awareness of the markets can be a critical flaw in the development of an industrial minerals operation.

On a very local basis, markets are often in balance because of intimate mutual knowledge of the producer and consumer. However, on a wider basis there is often little coordinated assessment of market possibilities. **There is also a role here for the GSE to provide basic and up-to-date statistical information on local and regional trade in industrial minerals, and to provide market intelligence generally.**

There also needs to be awareness that market surveys should be focused on what a specific mineral deposit could potentially supply. For example, a kaolin deposit can sometimes supply several different markets, such as ceramics or paper-filling or -coating. However, not all kaolin grades are suitable for each market. Few are suitable for paper-coating applications and assessment of overall kaolin markets can be misleading if only a ceramic grade can be produced from a specific deposit (as is the case at Bombowuha). However, a market assessment should investigate all the possible products since a diversified range will normally result in the deposit being utilised to its maximum potential and reduce waste production.

Obtaining market know-how can be expensive, and for a small company prohibitively expensive. Since published information and statistics are rarely adequate to get a reasonable assessment of a market, considerable time and effort is required to obtain such knowledge. As the present study has shown, meaningful market studies require considerable time contacting consumers, and visiting as many as possible. There is no substitute for experience (knowing what questions to ask and 'reading between the lines' of the answers), and a lack of personnel experienced in industrial minerals marketing poses problems to fledgling industrial minerals industries in Ethiopia. **Consolidating and building on the current user survey should place the GSE in a strong position to fill this gap and catalyse growth in the sector.**

4 Current status of industrial minerals exploration and assessment capability in GSE

4.1 REVIEW OF EXISTING DOCUMENTATION

Three types of documentation were examined: (i) reports; (ii) external publications; (iii) promotional literature.

4.1.1 Reports of the GSE (previously EIGS)

GSE/EIGS reports on industrial minerals inspected give, in general, clear information on the geological extent of the industrial mineral deposit investigated and demonstrate professionalism in this aspect of the work. However, earlier investigations are nearly always 'headlined' as having identified a *reserve* of x million tonnes of mineral y , which in the absence of any systematic appraisal of the technical properties of the deposit, is of very limited value. There is an over-reliance on chemical analyses in industrial minerals investigation reports as a whole, the default position appearing to have been to submit all industrial minerals exploration samples for analysis at the GSE Central Geological Laboratory (CGL). For investigations of carbonates, diatomite and silica sand, for example, chemical analyses are prime specification-related tests, but for investigations of other industrial minerals chemical analyses are very much secondary to

measurement of physical properties, and the CGL has very limited facilities for this. Because there have been minimal facilities within Ethiopia for industrial minerals processing and testing, most of the (limited) technical data appearing in reports (and publications – see next section) have been obtained by sending samples direct to laboratories in countries providing assistance (e.g. Czechoslovakia) or by GSE staff working on the samples in overseas laboratories, either for a post-graduate degree (e.g. in the UK) or as a training component of bilateral aid agreements (e.g. with Germany, Austria and Norway). By the nature of such arrangements, only a small number of – and possibly the most promising – samples from any deposit can be examined, leading to an incomplete assessment of the resource potential.

The GSE has recently drafted guidelines for exploration and evaluation of industrial minerals and dimension stones. This is a reasonably comprehensive set of guidelines, which draws heavily on previously available information, particularly that published by the BGS (industrial minerals factsheet series and the series of field and laboratory manuals). Attempts have been made to ‘customise’ the approach by incorporating case studies of investigations on Ethiopian industrial minerals. These are not always particularly helpful or informative, partly because of the low level of technical information available (see above), and the use of inappropriate evaluation criteria, for instance comparison of chemical compositions of Ethiopian bentonites with those for commercial products (also see above). The overall approach adopted is sound, however, highlighting essential pre-field mapping activities such as literature surveys and use of aerial photographs, and using the domain approach to target exploration for specific industrial minerals. Choices of exploration techniques for different industrial minerals are illustrated with case studies, and core logging procedures are dealt with in some detail. Laboratory assessment procedures for a range of industrial minerals are covered, even though facilities are very limited within GSE at present, but this is good forward thinking, as it is essential that the industrial minerals geologists are completely familiar with these downstream activities (see section on staff capabilities). A section deals with the distinction between mineral resources and reserves, which is particularly relevant in the light of the consistently wrong use of the term ‘reserves’ in GSE/EIGS reports (see above). A further section on report writing contains two components – an adaptation from an internal GSE publication (1988) on organizing a scientific paper, and an example contents list for an industrial minerals investigation report. The former component sits rather uneasily within the main body of this draft publication and would best remain as a separate publication or, possibly, form an appendix. For the example contents list of an industrial minerals report, although the approach adopted is both logical and comprehensive, there is a danger that the report (and possibly the preceding investigation) is dominated by process rather than what is required from the individual study, i.e. the template is followed ‘to the letter’, with the result that inappropriate or un-necessary field or laboratory procedures are applied. Although there are commonalities to most industrial minerals evaluation programmes, each investigation has to be tailored to a greater or lesser extent to the commodity, and within the text of this draft publication it should be stressed that the contents list for the report should be regarded as indicative rather than comprehensive. The worst-case scenario, if the contents list is regarded as a ‘recipe’, is for the geologist responsible for the investigation to submit his samples for *all* the tests listed in the report sub-headings, and also request un-necessary mineral processing. This is not an uncommon problem in geological surveys in the early stages of upscaling industrial minerals investigations, and there is a precedent in GSE, as in the recent past – as noted above – large numbers of exploration samples were submitted to the CGL for full silicate analysis, regardless of whether the results would be relevant to use-assessment. The draft guidelines finish with a section on environmental considerations, including guidance on how to prepare an environmental impact assessment. This again demonstrates good forward thinking.

The authors of the guidelines should consider incorporating a section on mineral resource mapping. Resource assessment surveys represent a method of obtaining more knowledge about mineral deposits than is offered by geological mapping, but without the cost of the normal reserve evaluation procedures carried out by industry to define sites for extraction. For

limestone, for instance, general variation in resource quality can be represented by superimposing chemical purity (i.e. CaCO₃ content) or 'brightness' on lithological mapping parameters, thus providing a means of potentially 'protecting' high-value material from being used for low-value purposes. Similarly, by superimposing aggregate properties such as strength, porosity and durability on maps of hard rock outcrops, the quality distribution of potential aggregates can be displayed. This approach is particularly valuable in the vicinity of rapidly expanding urban areas, both for identifying different grades of aggregates for use and also for planning purposes to help avoid sterilising high-quality material by building development. Further details of this approach can be found in Harrison (2001).

In summary, these draft guidelines, although containing some very relevant material, should be regarded as 'work in progress'. Many of the sections have been 'imported' with little change from other publications, and work still needs to be done on integrating and linking these. The section on dimension stone also needs to be revised to avoid duplication with other sections.

4.1.2 External publications by GSE staff

External publications – i.e. those published in journals outside Ethiopia – inspected included those on specific industrial mineral deposits, such as kaolin, graphite, kyanite, potash and building stone, as well as more general papers describing the industrial minerals potential of the country. Geological data in these publications derive from EIGS/GSE reports, with technical data primarily determined overseas at laboratories of donor-aid organisations as noted previously, and the publications are often co-authored by scientists from the donor organisations. These publications have been valuable in publicising Ethiopia's industrial minerals resources – thus merging into the strictly promotional literature dealt with in the next section – but in general lack the detail required to attract external investors.

4.1.3 Promotional literature prepared by GSE (and MME) staff

The publication *Industrial minerals and rocks resource potential of Ethiopia* (2003) comprehensively describes exploration activities conducted to date, with the stated intention of stimulating increased activity within the mining sector. For reasons already discussed, this publication is strong on geological information and weak on technical properties but, nevertheless, is an invaluable and professionally-compiled starting point for any further initiatives within the industrial minerals sub-sector. Inevitably, there is much re-cycling of basic information between this publication, papers in the external literature noted in the previous section, and other promotional material such as the *Mining Journal* Special Supplement on Ethiopia (2002), but this only serves to emphasise the need for GSE to adopt a fresh approach to industrial minerals exploration and assessment. This, it will be argued later, should concentrate on detailed geological appraisal of deposits for which there is a current identified requirement by local industry, together with a comprehensive programme of use-related property determination and processing behaviour.

The publication *Building-stones of Ethiopia* (2002), a deliverable of the Ethionor project, is well-compiled and attractively presented. It is an excellent example of a publication that appeals to a general audience – thus contributing to raising public awareness of the GSE – and yet has sufficient technical data to attract a potential investor.

The above investment promotion publications stand in stark contrast to two others covering the same ground and published in 2002 by the Ministry of Mines, namely *Opportunities for investment in Ethiopia's industrial minerals* and *Opportunities for investment in Ethiopia's dimension stone*. A publication seeking to capture the interest of potential investors should be focused, informative and easy to read. These two publications fail in that they contain far too much extraneous information, and the format is such that the reader easily loses track, due to sections on individual minerals being spread out over many pages.

4.2 REVIEW OF STAFF EXPERTISE

The staff complement of the industrial minerals exploration division is currently five senior geologists, although in the past this was as high as 20 staff. All five are highly-skilled field geologists, as evidenced by their authorship of EIGS/GSE reports – and in some cases follow-up publications. They are also competent – or undergoing training – in databasing their field results and subsequent manipulation of the data in GIS. Without exception, all felt that their lack of exposure to modern publications seriously limited their effectiveness.

They are, however, first and foremost field geologists, with limited appreciation of the technology associated with industrial minerals and little evidence of engagement with local users and producers of industrial minerals. This problem has been addressed to some extent during the current project by: (i) a five-day workshop dealing with all aspects of industrial minerals from exploration, through laboratory assessment, to their role in different manufacturing processes; (ii) a two-week study tour of UK industrial mineral extraction and processing operations; (iii) involvement in the market-survey component of the project.

During the industrial minerals workshop it was stressed that to be a successful industrial minerals geologist it is not sufficient just to be competent in geological and/or laboratory assessment of these materials. Because of the critical need to encourage the use of indigenous minerals by local industry, it is necessary to understand the exact role the mineral plays in the manufacturing process, so that some skills in ‘materials science’ are required. Having lists of specifications for minerals used in different applications is only the first step in being able to persuade local manufacturers to change from imported to local material. The industrial minerals geologist has to be able to explain exactly why the local material may be suitable, and if, for instance, an inert white mineral is all that is required in the manufacturing process, why minerals other than that currently used may be suitable for the process. Good knowledge of the properties and economics of industrial minerals is also necessary in order to argue the case for a local producer to invest in processing facilities to raise the quality of his product, so that this can meet specifications of the local manufacturers and ideally replace imported material.

The survey of demand/supply within the Ethiopian industrial minerals sub-sector carried out as part of the project has brought into sharp focus the need for a much closer engagement of GSE industrial minerals staff with local users and producers, and also for a much greater awareness of patterns of use, both of local and imported material. The survey started from an unacceptably low knowledge baseline – most users had to be identified ‘from scratch’, import statistics (Birr values and not tonnages) were only available up to 1999, and there was little evidence of ‘contact history’ with producers. It emerged later in the survey that individual members of the industrial minerals team had previously attempted limited exercises of this type, but there does not appear to have been any central means of recording and retaining such information.

It is strongly recommended that the remit of the industrial minerals exploration division is changed to reflect a much greater involvement with producers and users of industrial minerals within Ethiopia. The provision of market intelligence (building on the approach set out in the demand/supply survey) would be of great value to the development of the industrial minerals industry. Studies to identify markets that offer development opportunities for industrial minerals would benefit the industry as a whole. While a market survey is an essential part of the feasibility study for a new operation to potential investors, the availability of basic market data on a number of consuming industries can provide an incentive to explore for the minerals required *and thus focus exploration strategy*. Compilation and distribution of trade and industry statistics in a timely and accurate manner is also of great benefit to the assessment of markets for industrial minerals, including local markets, import substitution and exports. Improved databasing of existing geological and (limited) technical information on industrial minerals is a deliverable of the current sub-project; the information in this database needs to be complemented by comprehensive information on markets and consuming industries. By holding such

information, the GSE would ensure that it is the 'first port of call' for producers, users and potential investors throughout the private sector.

A further way for the industrial minerals section to increase engagement with producers and users of industrial minerals would be to establish a regular series of meetings with representatives of these ('industrial minerals forum'). These meetings would allow producers and users to share experience and concerns, and provide the industrial minerals exploration division with first-hand information on the state of the sub-sector. The industrial minerals exploration division could provide information on developments within their increased role. The 'Minerals for Development' workshop due to be held at the completion of the current project, at which producers and users of industrial minerals will be present, could be viewed as the inaugural meeting of this series. This arrangement could eventually result in the formation of a formal advisory board to the GSE on industrial minerals exploration and evaluation.

Having a much closer involvement with their 'stakeholders', the industrial minerals exploration division would be in a much better position to focus their exploration and evaluation strategy which, it is strongly recommended, should concentrate on detailed study of specific deposits, identified though assessment of market needs. A number of topics for further study have already been highlighted in the current demand/supply survey and these are consolidated and amplified in Appendix 1.

This increased role for the industrial minerals exploration division will require an increase in staff complement, together with a continuation of re-orientation training for current staff. Because of the age distribution of current staff, it is recommended that some recent graduates are recruited, both to redress the balance and ensure continuity. It is also recommended that two to three members of the enlarged division are given the specific responsibility of 'minerals commodity officers'. Their remit would be to:

- become experts in the geology, mineralogical/chemical and physical properties of a particular group of industrial minerals
- compile data on the use of these minerals by industry generally, including specifications for different uses
- compile data on world trade in these minerals, with particular reference to the immediate region
- liaise with current users of industrial minerals in Ethiopia in order to determine the specific needs of each user, with the ultimate aim of substituting local for imported material
- liaise with producers of industrial minerals, particularly in encouraging them to improve quality and consistency of supply
- deal with enquiries from producers, users and potential investors

Members of the industrial minerals exploration division not designated as mineral commodity officers would still be expected to have a wider role than just geological mapping of specific deposits. They should become more involved in downstream technical assessment of the materials, liaising closely with CGL staff, and playing their part in, for instance, persuading current and future producers of investing in added-value processing facilities.

In order to guide the industrial minerals exploration division through this re-orientation exercise, a two-year attachment by a resident expert is recommended. This expert should have considerable experience in industrial minerals promotion exercises in developing countries, and a sound knowledge of industrial minerals processing technology. The minerals commodity officers would also benefit from a three-month secondment to a geoscience organisation that maintains a commodity/statistics service.

4.3 REVIEW OF LABORATORY FACILITIES

The BGS provided a consultancy to the Central Geological Laboratory in 1995, and made a number of recommendations concerning operational procedures, health and safety protocols, and purchase of new equipment. The leader of the current sub-project, Dr Morgan, was a member of the original consultancy team, and it was gratifying to see the significant improvements that have taken place as a result of these recommendations: a well-equipped sample preparation facility with dust extraction at all work stations; new fume cupboards and extraction system throughout the laboratory complex; investment in X-ray diffraction and X-ray fluorescence equipment (through the ADB phosphate programme); and some use-related testing equipment in the physical testing laboratory.

However, the CGL is still not equipped to provide the level of support necessary to the suggested new remit of the GSE industrial minerals exploration division. Specifically, additional equipment for mineral testing is needed, and a new facility established for *bench-scale* mineral processing. Basic equipment for mineral testing would include a spectrophotometer for measuring mineral brightness (an essential item for assessing suitability for fillers), equipment for automated particle-size analysis, a furnace capable of operating at 1250°C, and a range of minor items to enable, for instance, filtration properties of diatomite and oil-bleaching properties of bentonite to be investigated. The CGL physical testing laboratory already has viscometers for measuring rheological properties of bentonite and kaolin suspensions. The mineral processing laboratory would require equipment for preparing material of controlled particle-size, both in dry and wet states, equipment for size-classification of both dry (air-cyclones) and wet (hydrocyclones) material, magnetic separators and froth flotation cells. It is stressed that all this equipment should be bench- and not pilot-plant scale (although the nature of the equipment would enable indicative flowsheets to be prepared for a possible commercial operation).

A list of recommended equipment is provided in Appendix 2. Location of a possible mineral processing laboratory within the CGL has already been discussed with the Director, Ato Sisay, and the area immediately adjacent to the sample preparation laboratory is both suitable and available.

In order to provide a comprehensive industrial mineral and rock testing service, it is arguable that the CGL should also be equipped with facilities for aggregate testing. This equipment almost certainly exists in other Government laboratories (it was not possible to confirm this during the current study), but the value of incorporating it in the CGL would be to enable fundamental rock properties to be determined and used as parameters for mapping purposes (e.g. to establish 'quality' of potential aggregates around areas of rapid urban expansion – see Section 4.1.1). Accordingly, details of aggregate testing equipment are also incorporated in Appendix 2.

As well as providing improved to GSE industrial minerals exploration and assessment projects, this additional equipment would enable the CGL to bring solutions to industry problems by developing appropriate technologies and introducing them to the local producers. If the capability were consolidated at institutional level, companies could be provided with technical consulting; often there might be a case for shared-cost research, where a specific company benefits, but the investigation also addresses a more generic problem. As an extension to this, the CGL could embark on an exclusive joint venture with a company with the appropriate technical and marketing expertise. Much of this equipment would also be very relevant to investigating mineral processing behaviour of metallic minerals.

Although the CGL has a small core of staff who could probably extend their skills into additional mineral testing and processing, a formal period of training and familiarisation would be required. Ideally, two additional staff with relevant qualifications at MSc level should be appointed. In order to commission the new equipment and carry out on-the-spot training, a two-year attachment by a resident expert is recommended. This expert should have 10 years' experience in

laboratory evaluation and, ideally, some experience in industry. Three-month secondments of relevant staff to external laboratories carrying out similar work are also recommended.

These recommendations are made in the full awareness of laboratory facilities at the Southern and Eastern African Mineral Centre, Dar es Salaam, Tanzania, and the fact that Ethiopia is an active supporting member of this organisation. However, for the types of investigations proposed, which would involve close and frequent liaison between GSE/CGL staff and those from the producing and consuming industries, using remote facilities would not be practical.

5 Overall summary of project activities and recommendations for further work

The current status of the industrial minerals sub-sector in Ethiopia has been assessed through a survey of producers and users, data on domestic production and imports, and reference to conventional publications and information available on the world wide web. In addition, capacity building within the sub-sector has been approached through an intensive five-day workshop on industrial minerals evaluation for Geological Survey of Ethiopia and Ministry of Mines and Energy staff, a two-week study tour of industrial minerals operations in the UK by GSE staff, and a project completion workshop which has brought together, for the first time, producers and users of industrial minerals, together with relevant GSE staff. Input on databasing of industrial minerals information and promotional aspects has also been made to the parallel project 'Geological Survey and Investment Promotion Study', also conducted by the British Geological Survey. A new-format industrial minerals map of Ethiopia has been designed.

Key issues raised by the present study with respect to the industrial minerals sub-sector in Ethiopia are:

- Poor quality and consistency of locally-produced industrial minerals
- Over-reliance by local manufacturers on imported materials
- Lack of technical information on industrial mineral deposits (mineralogical and chemical composition, use-related test data and processing characteristics)
- Lack of central facilities capable of providing the above information
- Small size of the internal market for these minerals, which inhibits investment in existing deposits and new ventures
- Little engagement by the Geological Survey of Ethiopia with producers and users of industrial minerals (the 'stakeholders')

Although current consumption of industrial minerals within Ethiopia is small, increasing industrialisation, and consequent rise in per capita incomes linked to improvements in living standards, will result in a marked rise in demand for these commodities. For the reasons outlined above, the industrial minerals sub-sector is currently ill-equipped to meet this challenge. A better-resourced and focused GSE is seen as essential to improving this situation, and the following recommendations provide a medium-term strategy to help achieve this purpose.

Recommendation 1: The Geological Survey of Ethiopia engages with producers and users of industrial minerals, and acts as a focal point for market intelligence and technical information on these commodities

A methodology for this is described in Section 4.2 and summarised in Appendix 1.

Recommendation 2: The Geological Survey of Ethiopia places greater emphasis on geological mapping of specific deposits and proactive exploration for specific commodities

It is essential that this programme is developed through stakeholder consultation and is thoroughly integrated with laboratory evaluation. A methodology for this, together with outline approaches for specific commodities, are given in Appendix 1.

Recommendation 3: Facilities within the Central Geological Laboratory of the GSE are expanded so that it can provide the technical information on industrial mineral deposits required by producers, users and potential investors

Specific approaches and additional equipment required are described in Section 4.3 and itemised in Appendix 2.

Recommendation 4: The current staff complement of the GSE industrial minerals exploration division is strengthened, ideally by some ‘new-blood’ recruitment at minimum MSc level, to meet the recommended changed remit and increased workload

Resources for this (excluding training requirements) should be met by an increased GSE budgetary allocation.

Recommendation 5: The current staff complement of the GSE Central Geological Laboratory is strengthened, ideally by some ‘new-blood’ recruitment at minimum MSc level, to meet the need to provide enhanced technical information on industrial minerals

Resources for this (excluding training requirements) should be met by an increased GSE budgetary allocation.

Recommendation 6: Donor aid should be sought to provide support and training to the GSE industrial minerals exploration division and the CGL through a transitional period of two years

Recommendation 6.1: A resident expert with 10 years’ experience in industrial minerals promotion exercises in developing countries and a sound knowledge in mineral processing technology should be attached to the industrial minerals exploration division

Recommendation 6.2: A resident expert with 10 years’ experience in laboratory evaluation of industrial minerals and, ideally, some experience in industry, should be attached to the CGL

Recommendation 6.3: The CGL would require a budget of the order of US\$ 350-400K for major items of equipment and up to US\$ 100K for minor items of equipment, reagents and standards, in order to meet its increased commitments for industrial minerals evaluation (details in Appendix 2)

Recommendation 6.4: Staff of the GSE industrial minerals exploration division designated as minerals commodity officers should be seconded for a three-month period to a geoscience organisation that maintains a commodity/statistics service

Recommendation 6.5: Staff of the CGL with specific responsibility for industrial minerals assessment, including testing and processing, should be seconded for a three-month period to external laboratories carrying out similar work

Appendix 1 Recommended priority areas for new GSE work programme on industrial minerals

Activity	Methodology	Additional resources required*	Possible partners
Much greater engagement with producers and users of industrial minerals (the stakeholders)	<p>Hold regular meetings with producers and users through ‘industrial minerals forum’ (which could evolve into a formal advisory board)</p> <p>Following on from the approach used in the current study, establish a comprehensive database of producers and users (with specifications of material produced/used)</p> <p>Maintain up-to-date, and detailed, database of production and imports</p> <p>Compile data on world trade in industrial minerals relevant to Ethiopia</p> <p>Visit producers and users (initially to gain information, but eventually to provide information and advice)</p> <p>Deal with enquiries from producers, users and potential investors</p>	Formation of ‘mineral intelligence unit’ within industrial minerals exploration division. Could be staffed by re-deployment within industrial minerals section, but staff complement in this division needs to increase regardless	All producers and users of industrial minerals
Greater emphasis on geological mapping of specific deposits and proactive exploration for specific commodities	<p>Identify specific commodities/deposits for detailed study on basis of feedback from stakeholders, and data gathering and analysis as detailed above.</p> <p>Ensure field exploration/mapping programme is thoroughly integrated with laboratory evaluation</p> <p>Consider utilising mineral resource mapping approach (see Section 4.1.1)</p> <p>(Suggestions for commodities/deposits requiring detailed study are given below)</p>	Current staff complement of industrial minerals section needs strengthening (by younger recruits to redress age-balance and also ensure continuity)	
Provision of enhanced technical information on industrial minerals deposits (mineralogical and chemical composition, use-related test data, processing characteristics)	<p>Design evaluation programmes to provide information of direct relevance to eventual use</p> <p>Liaise closely with:</p> <ul style="list-style-type: none"> geologists carrying out field evaluation possible users over their exact requirements <p>(Outline approaches for specific commodities/deposits requiring detailed study are given below)</p>	Central Geological Laboratory requires considerable additional equipment (itemised below)	<p>Many</p> <p>Initially, free or shared-cost research to solve generic problems</p> <p>Future opportunities for technical consulting on repayment basis</p>

Activity	Methodology	Additional resources required*	Possible partners
Evaluation of kaolin resources of Hosaina (Belesa)	Geologically map and systematically sample deposit Laboratory examination to concentrate initially on: mineralogy (from X-ray diffraction) ‘whiteness’ measurement Further tests as part of programme below Disseminate results and provide advice as to how best exploit the deposit to local landowners	Spectrophotometer for measuring whiteness	Local landowners
Development of kaolin resources	Systematically sample kaolin resources of Bombohuwa area (to produce 6-10 ‘typical’ composite samples) Laboratory characterisation to concentrate on: mineralogy (from X-ray diffraction) ‘whiteness’ measurement particle-size distribution Laboratory processing to include: disaggregation and screening hydrocyclone separation trials feasibility of colouring matter removal by magnetic or chemical treatment evaluation of products yield/recovery calculations and flowsheet design Disseminate results (Similar approach, either in parallel or subsequently, for Hosaina and Kombelcha kaolins)	Spectrophotometer for measuring whiteness Heavy-duty disaggregator Automated wet-screening equipment Automated particle-size analyser Hydrocyclone test kit High-intensity magnetic separator	EMRDE kaolin processing plant, Bombowuha
Mineral processing behaviour of ilmenite and apatite from Bikilal and Melka Arba	Evaluate existing information on composition and processing behaviour of minerals from these localities Re-sample to provide 6-10 composite samples Petrographic and mineralogical characterisation of composite samples Detailed investigation of processing behaviour using stage-crushing followed by combination of gravity and magnetic separation procedures Yield/recovery calculation and flowsheet design (ideally for co-production of apatite and ilmenite) Disseminate results Evaluation of apatite for fertilizer use (see below)	Roller crusher High-intensity magnetic separator Cross-belt magnetic separator	
Activity	Methodology	Additional resources required*	Possible partners

Development of bentonite resources	<p>Compile and evaluate existing field and laboratory data on bentonite occurrences</p> <p>Selectively re-sample to provide material for laboratory assessment</p> <p>Test samples for:</p> <ul style="list-style-type: none"> use as drilling muds use in foundry moulding sands potential for iron-ore pelletising response to acid activation and oil-bleaching performance of activated products <p>Disseminate results</p>	Colorimeter for measuring oil-bleaching performance	Suitability for use in foundry moulding sands to be assessed by partner in metallurgical industry Addis-Modjo Edible Oil Complex willing to cooperate in evaluating oil-bleaching performance
Development of diatomite resources	<p>Compile and evaluate existing field and laboratory data on diatomite occurrences</p> <p>Selectively re-sample to provide material for laboratory assessment</p> <p>Test samples for:</p> <ul style="list-style-type: none"> disaggregation behaviour and resulting particle-size distribution behaviour during air-classification trials flux-calcining behaviour permeability <p>Disseminate results</p>	Automated particle-size analyser Air-classifier for particles in 100-5 micron range Laboratory furnace	BGI Brewery for assessing filter-aid properties of air-classified products Adami-Tulu Pesticide Processing Plant for more general applications
Development of zeolite resources	<p>Reconnaissance field exploration/mapping of zeolite-bearing sediments of Nazaret area</p> <p>Systematic sample collection</p> <p>Laboratory examination, to concentrate initially on:</p> <ul style="list-style-type: none"> mineralogy (from X-ray diffraction) cation-exchange capacity <p>Evaluate resource</p> <p>If resource is promising, identify possible users and design further test programme in collaboration with these</p>	CGL to install procedure for cation-exchange determination	Possible collaborators in areas of: water treatment agriculture horticulture animal husbandry cement industry

Activity	Methodology	Additional resources required*	Possible partners
Development of graphite resources	<p>Systematically sample known graphite resources (particularly Moyale) to give up to 10 'typical' composite samples</p> <p>Laboratory characterisation to concentrate on:</p> <ul style="list-style-type: none"> petrography (including graphite particle size) mineralogy (by X-ray diffraction) graphite content (by modified loss-on-ignition) <p>Laboratory processing to include:</p> <ul style="list-style-type: none"> stage-grinding air-classification froth flotation evaluation of products yield/recovery calculations and flowsheet design (incorporating pre-concentration stage) <p>Disseminate results</p> <p>Possibly target areas for detailed mapping and further laboratory appraisal</p>	<p>Laboratory furnace</p> <p>Roller-crusher</p> <p>Air classifier for mm-size particles</p> <p>Froth flotation cell and ancillary chemicals and equipment</p>	To be identified
Development of kyanite resources	<p>Continue existing exploration for kyanite-group minerals, but with closer integration of laboratory work</p> <p>Initial laboratory assessment to include:</p> <ul style="list-style-type: none"> petrography (with emphasis on processing characteristics such as particle size) mineralogy (by X-ray diffraction) processing behaviour using gravity and froth flotation chemical analysis of kyanite product <p>Collect bulk samples of most promising material and prepare kyanite product</p> <p>Submit this to industry(ies) currently using imported material</p>	<p>Wilfley table (for gravity separation)</p> <p>Mozley table (for gravity separation)</p> <p>Froth flotation cell and ancillary chemicals and equipment</p>	To be identified
Development of garnet resources	<p>Compile and evaluate existing field data on garnet occurrences, particularly in Moyale area</p> <p>Selectively sample to provide representative bulk samples</p> <p>Laboratory assessment to include:</p> <ul style="list-style-type: none"> petrography (with emphasis on processing characteristics such as particle size) mineralogy (by X-ray diffraction) processing behaviour (stage-crushing and gravity separation) <p>Submit garnet concentrates to industry(ies) currently using imported material</p>	<p>Roller crusher</p> <p>Wilfley table</p> <p>Mozley table</p>	To be identified
Activity	Methodology	Additional resources required*	Possible partners

Evaluation of talc resources	Evaluate existing information on talc occurrences Short field programme to obtain representative samples of most promising occurrences Petrographic and mineralogical characterisation of samples Investigation of processing behaviour using froth flotation Submit products to current users of imported material	Froth flotation cell and ancillary chemicals and equipment	To be identified
Evaluation of mica resources	Evaluate existing information on mica occurrences (Kenticha, Sora Dera, Web, Degogo... areas) Short field programme to obtain representative samples of most promising occurrences Petrographic and mineralogical characterisation of samples Investigate processing behaviour using air classification, froth flotation and magnetic separation (possibility of quartz and/or feldspar co-products) Submit products to current users of imported material	Air classifier for mm-size particles Froth flotation cell and ancillary chemicals and equipment High-intensity magnetic separator	Paint manufacturers
Evaluation of magnesite resources	Detailed field mapping of Kenticha area to distinguish between magnesite and dolomitic marbles Petrographic and mineralogical characterisation of samples (short feedback loop to field geologists required) Investigate processing behaviour using froth flotation (for impurity removal) Submit products to current users of imported material	Froth flotation cell and ancillary chemicals and equipment	To be identified

*** Note that these additional resources do not cover training requirements; these are outlined in Sections 3 and 4**

Appendix 2 Recommended list of mineral testing and processing equipment for Central Geological Laboratory

Item (and specification)	Possible model	Possible supplier	Estimated cost (US\$ k)
High-intensity induced roll magnetic separator (dry sample)	MIH (13) 111-5	Outokumpu	26
Cross-belt magnetic separator (dry sample)	MOS (10) 111-15	Outokumpu	10
High-intensity magnetic separator (wet sample)	3x4L	Outokumpu	20
'Zig-zag' air classifier (mm-scale material)	63*200 MZM	Hosakawa Micron Ltd	38
Centrifugal air classifier (micron-scale material)	100MZR	Hosakawa	46
Hydrocyclone test kit	Test Rig C700	Axsia Mozley	5
X-ray Sedigraph (particle-size analysis of particles below 100 microns)	III 5120	Micromeritics	57
Froth flotation cell and ancillary chemicals and preparation equipment	Denver D12	Sepor	12
Wilfley concentrating table	13A	Outokumpu	6
Mozley concentrating table	C800	Axsia Mozley	18
Spectrophotometer for measuring whiteness		Konica Minolta	5
Colorimeter for measuring colour of oil		Various	2
Heavy-duty stirrer/disaggregator		VWR International	1.5
Automated wet-screening equipment and sets of screens		VWR International	3
Roller-crusher	010C-005	Sepor	7
Aggregate impact test apparatus		ELE International	3
Aggregate crushing test apparatus		ELE International	15
Los Angeles abrasion value apparatus		ELE International	9
Laboratory muffle furnace to 1300°C (10-15 litre capacity, with controller)		VWR International	4.5
Large drying oven (capacity >1000 litre, temp 230°C)		Christison Particle Technologies Ltd	9
Small drying oven (capacity 100 litre, temp 150°C)		Gallenkamp	2.5
Large floor-standing balance (60 kg capacity)		Christisons	1
Top-loading balance (6 kg +/- 0.1 g) (x2)		ELE International	1
Analytical balance (400 g +/- 0.001 g)		ELE International	1.5
Total			301

Notes:

- (1) No particular endorsement of suppliers appearing in the above table is implied**
- (2) Prices are ‘target prices’ and have been included to obtain an indicative budget to enable the CGL to undertake the recommended new work programme**
- (3) An additional 30% should be added to the total in the above table to allow for freightage, installation costs and spares**
- (4) The CGL would also need a budget of at least US\$ 60,000 to purchase smaller items of equipment, reagents and standards to enable them to undertake the recommended new programme (details of these items can be found in the series of Industrial Minerals Laboratory Manuals published by the British Geological Survey)**

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