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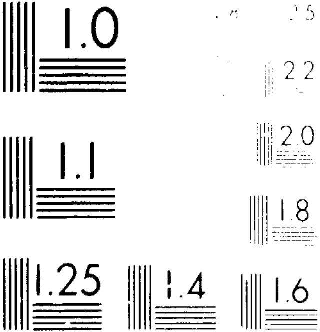
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PILOT STUDY ON NATURAL RESOURCES

RP/URT/81/003

UNITED REPUBLIC OF TANZANIA.

Terminal report

Based on the work of Z. Hokr, A.V. Seifert and J. Žežulka,
geologists of Polytechna

V.82-28805

Explanatory notes

References to tons (t) are to metric tons.

References to dollars ($) are to United States dollars.

The monetary unit in the United Republic of Tanzania is the shilling (TSh). During the period covered by the report, the value of the shilling in relation to the dollar was $1 = TSh 8.25.

The following acronyms are being used in this report:

CCIT	Chinese Coalfield Investigation Team
CDC	Coal Development Committee
GATC	German Agency for Technical Co-operation
STAMICO	State Mineral Corporation
TGI	Tanzania Gemstone Industries Ltd.
TAZARA	Tanzania-Zambia Railway

ABSTRACT

During a programming mission of the United Nations Industrial Development Organization (UNIDO), the Government of the United Republic of Tanzania requested assistance in the establishment of an industrial base to ensure the maximum utilization of local raw materials in order to increase the value added and to generate an income of foreign exchange. Specifically, assistance to the Ministry of Water, Energy and Minerals in the execution of a pilot study reviewing the existing situation regarding commercially exploitable minerals was sought, and on 19 June 1981 UNIDO approved the project "Pilot study on natural resources" (RP/URT/81/003).

The execution of the pilot study was subcontracted to Polytechna, Czechoslovakia, and a team consisting of three geologists, Z. Hokr, A.V. Seifert (team leader) and J. Žežulka, was in the field from 28 January to 19 February 1982.

The immediate objectives of the mission were to:

(a) Review and assess the existing reports, documents, other information and data available with respect to local resources of gold, gemstones, coal, nickel, iron and gypsum;

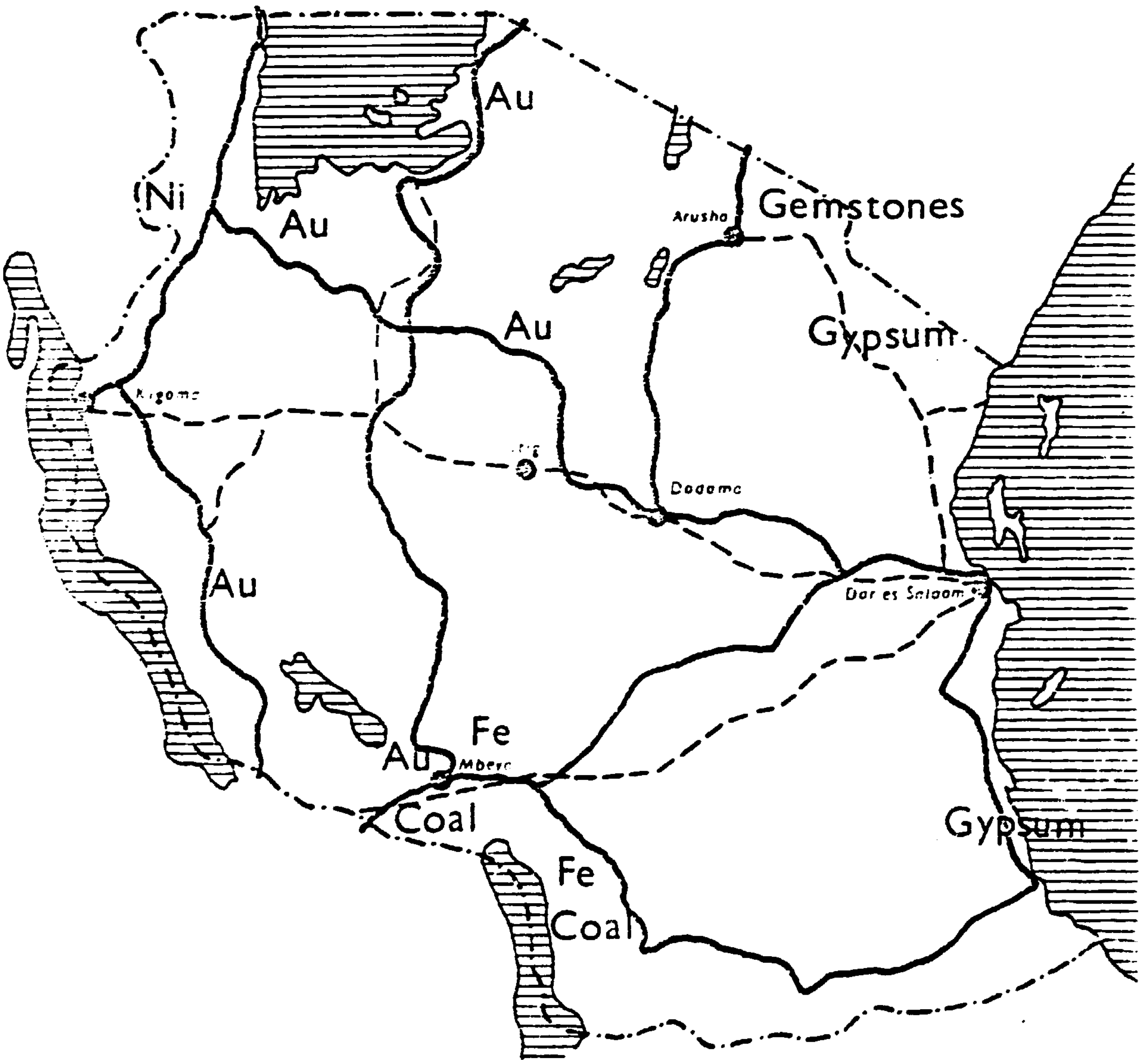
(b) Prepare specific project profiles for each of the above local mineral resources, reflecting their commercially exploitable potential for the consideration of prospective investors;

(c) Prepare a report evaluating the existing situation with respect to the commercially exploitable minerals in the country and recommending relevant projects for viable industrial investment.

The facts, conclusions and recommendations contained in the report are based on a study of the numerous files and unpublished reports kept in the record office of the Wizara ya Madini at Dodoma as well as on valuable information received during discussions and consultations with various officers of the Ministry of Water, Energy and Minerals, the State Mineral Corporation (STAMICO), the Tanzania Saruji Corporation, the Tanzania Gemstone Ltd. (TGI) and specialists from international agencies working in the United Republic of Tanzania.

The experts conclude that, given the adequate development of water supplies, electric power stations and means of transportation, the United Republic of Tanzania has adequate mineral resources to attain a fair degree of industrialization.

The report contains specific recommendations for the extraction and processing of each of the investigated mineral resources.



Au
Ni
Au
Arusha
Gemstones
Au
Gypsum
Kigoma
Dodoma
Dar es Salaam
Au
Fe
Au
Mbeya
Coal
Fe
Coal
Gypsum

CONTENTS

Tables | Page

Figures

INTRODUCTION

During a programming mission of the United Nations Industrial Development Organization (UNIDO), the Government of the United Republic of Tanzania requested assistance in the establishment of an industrial base to ensure the maximum utilization of local raw materials in order to increase the value added and to generate an income of foreign exchange. Specifically, assistance to the Ministry of Water, Energy and Minerals in the execution of a pilot study reviewing the existing situation regarding commercially exploitable minerals was sought, and on 19 June 1981 UNIDO approved the project "Pilot study on natural resources" (RP/URT/81/003).

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(c) Prepare a report evaluating the existing situation with respect to the commercially exploitable minerals in the country and recommending relevant projects for viable industrial investment.

The experts would like to point out that the information obtained is in no way complete. Active search and exploration programmes for specific minerals (e.g. gold, base metals and gemstones) are in progress and the discovery of large economically viable deposits can by no means be ruled out.

The facts, conclusions and recommendations contained in the report have been derived mainly from the numerous files and unpublished reports available in the records office of the Wizara ya Madini at Dodoma. Since many of these works refer to areas on which no recent information is available but only that dating from the time when the investigations to which they refer were carried out, such accounts have been freely drawn upon. Valuable information and assistance has also been received during discussions and consultations with various officers of the Ministry of Water, Energy and Minerals, the State Mineral Corporation (STAMICO), the Tanzania Saruji Corporation, the Tanzania Gemstone Industries Ltd. (TGI) and specialists from international agencies working in the United Republic of Tanzania.

Given the adequate development of water supplies, electric power stations and means of transportation, it is considered that the United Republic of Tanzania has adequate mineral resources to attain a fair degree of industrialization.

SUMMARY OF RECOMMENDATIONS

A. General

1. In view of the steadily increasing oil prices, imported oil and oil products used for the generation of electricity should gradually be replaced, to the maximum extent possible, by coal from Tanzanian deposits and by water power.

2. Simultaneously a country-wide consistent electro-transmission grid should be built successively, connecting in the first stage the principal power stations to the main areas of consumption.

3. For the achievement of an immediate profit for the country, the development of the gold and gemstone industries is the most advantageous and should be furthered. Both industries do not need much capital investment and expenditures and the rapid return of means in hard currency is more or less assured.

B. Coal

4. As final targets it is recommended to aim at substituting the imported oil by Tanzanian coal for the generation of electricity, and to consider the construction of a metallurgical plant based on local coal and iron ore from the Liganga deposits.

5. The exploitation of the coal wealth should be started in the Mchuchuma coalfield by opening one middle underground mine and by building a thermal power plant of 25 MW in its proximity.

6. In the event that the opening of the Liganga iron ore deposit and the construction of the metallurgical complex will not be feasible within the next 30 to 50 years so that coal would be used only for the generation of electricity, the construction of the colliery-power plant complex in the Songwe-Kiwira coalfield, would be more advantageous and should be started.

C. Iron

7. To cover the domestic need in iron and steel it is recommended to utilize the Liganga iron ore deposit in connection with the proposed Mchuchuma colliery and power plant and the surrounding limestone and quartz-sand deposits.

8. Preparatory work and the necessary tests for a design study should be started immediately, and a project for the construction of the integrated complex, including infrastructural variants, should be worked out.

9. Financial assistance for these works should be sought from international organizations.

D. Nickel

10. To attract foreign investment capital the known ore reserves in the Kabanga area should be increased by intensifying the geological investigations.

11. The first target for future exploration should be the areas extending north-east and north-west of Block 2 and in the north-western and south-eastern edges of Block 1 of the Kabanga deposit.

12. For all further exploration in the Kabanga area or north of Kabanga assistance from UNDP should be sought.

E. Gold

13. In selected areas of the main goldfields, such as Geita in the south-west Mwanza Goldfield and Saza in the Lupa Goldfield, research centres should be established. The staff attached to each centre should consist of one economic geologist and one mining engineer.

14. The international staff of the centres should advise small-scale miners on geological conditions of deposits, instruct local staff and miners in the best methods of developing deposits, and co-ordinate and conduct all field mining activities.

15. Simultaneously, a post of a gold consultant should be established within the Ministry of Minerals or STAMICO. The consultant should be responsible for the preparation of investment projects including time-scheduling; site prospecting and probing; mine and plant design; selection of exploration technology and equipment; and negotiating and contracting the legal obligations in respect of the financing of projects.

16. Certain industrial activities should be centralized and production from adjacent mines concentrated at selected sites in an effort to achieve the target of at least 30,000 t/month of ore. This should include a mill as well as cyanisation and amalgamation plants for each of the selected sites.

17. Potential investors involved in joint ventures should be granted the mining rights for an entire area. This would enable the owner of such an integrated concession to co-ordinate and plan exploratory, development and mining activities on a long-term basis.

F. Gemstones

18. In co-operation with foreign experts, a project for the long-term exploitation of the Tanzanian gemstone raw material base should be elaborated. The execution of this project should be entrusted to Wizara ya Madini. UNIDO should be requested to participate in the financing of the project and to provide a geologist and a gemmologist.

19. A state maintenance and consulting service should be established within the State Mining Corporation, which would provide financial assistance, technological and mining consultations, mining equipment and simple processing machinery. The assistance would be reimbursed by a part of the gemstone production.

20. Large nationalized mines should be offered to foreign companies for joint ventures, granting them a share in the production. In such joint ventures the applicable jurisdiction should be observed.

21. The network of purchasing centres should be expanded. It should be ensured that they maintain an operative contact with the miners and that they are provided with sufficient financial and material means for the purchase of gemstones.

22. The existing sales system, especially the retail, should be completely reorganized.

23. Assistance should be extended to the Tanzanian party in the elaboration and execution of the project aimed at the assessment of the gemstone raw material base and in the realization of the TGI bead-making project.

G. Gypsum

24. The present demand for gypsum required for cement production should continue to be satisfied by extraction of the mbuga-type deposits in the north-eastern part of the country (Mkomazi). This raw material is of a low quality and is not suitable for the manufacture of more valuable products, which are being imported.

25. For these reasons the future utilization of the evaporites in the Nondwe-Pindiro region is recommended. The extraction of gypsum would be relatively easy, cheap and could be fairly quickly realized. This would ensure a quick return of the means invested, and there are good possibilities to export the high-quality products.

I. COAL

A. General remarks

The Government of the United Republic of Tanzania being aware of the critical fuel and power situation in the country, authorized the Minister of Water, Energy and Minerals to appoint in March 1978 the Coal Development Committee (CDC) with the task to study and prepare recommendations on problems related to the supply and demand of coal and to the development of the coal industry in the country. The "Report by the Coal Development Committee" provided the most important background data for this chapter. The aim of the present report is similar, i.e. to evaluate on the basis of the available facts and opinions the potential of the Tanzanian coal resources and to recommend how to proceed in their utilization.

At present, the United Republic of Tanzania spends about 60% of its foreign exchange for the import of energy. From the total quantity of electricity, about 65% are produced in thermal power plants operating on crude oil which is obtained from imported oil. Only one third of the power is produced by Tanzanian hydroelectric power plants. And yet there exist completely unutilized coal deposits which could theoretically cover for many years to come the total electric power required in the country, and, in particular, coal could gradually replace all imported oil required for electric power plants. At present, however, there do not exist any coal mines with jointed power plants, there is no consistent national electrical grid, the consumption of electricity is as yet very limited, and finally, the corresponding infrastructure is not prepared. To reconstruct the economic potential of the United Republic of Tanzania will therefore take a long time and require high capital and material investments. Yet unless the Government of the United Republic of Tanzania decides to take this burdensome way in time, whether by itself or with the aid of other countries, its economic situation will inevitably deteriorate, particularly owing to the rising prices of imported oil and other raw materials, while simultaneously its economic and political dependence on other countries will increase.

The experts found that there exist many studies and projects relating to different industrial branches and fields. Usually, however, these are formulated separately and therefore do not consider the effect on other branches and, which is more important, they are not financially secured. Those projects which have already been constructed are mostly insufficiently utilized, causing losses and disproportion. This situation has been borne in mind in considerations on the development of the coal industry which are presented in this report.

B. Coalfields in the United Republic of Tanzania - their reserves and quality

Introductory remarks

The coal deposits in the United Republic of Tanzania were described and evaluated in several reports, amongst which the most important are the work by A.C.M. McKinlay, 1965, the "Report of the Coalfied Investigation Team of the People's Republic of China", 1967, and the above-mentioned "Report by the Coal Development Committee" 1978.

In the Karroo System ten potential coalfields are known, all of which are situated in the southern and south-western part of the country. Of these ten coalfields, only those at Songwe-Kiwira, Ketewaka-Mchuchuma, and of the Ngaka coalfield the section at Mbalawala could become economically significant in the near future. In the other coalfields, either their reserves are small, or they are insufficiently explored, or both.

In addition, several isolated coal and lignite occurrences, today probably without economic value, are known and were also described in various reports. So far neither their age nor other important data have been sufficiently determined, in some cases their mere existence is questionable. Should future investigations prove the economic value of some of them, they could be of great importance for the economy of the respective region and perhaps even for the whole country because of their geographical location (Kasulu near Kigoma, Kipatimu, in the coastal region between Kilwa and Lindi).

As far as reserves are concerned, there exist two appraisals. The older one was published by McKinlay in 1965 on the basis of all drillings and other research data available at that time (G.M. Stockley, Colonial Development Corporation etc.). A later estimate was worked out by the Chinese Coalfield Investigation Team (CCIT) in 1967. This second appraisal was revised by McKinlay (1969) in an internal report. The experts believe that, with the exception of the reserves at Ivogo and perhaps also at Mbalawala, the other reserves reported by the Chinese team represent only theoretical upper limits of the appraisal, very remote from reality even in case that inferred reserves are considered. Since the unstable structure of these seams is known (but the regularities of this feature are not understood), it is unreasonable to presume that the coal seams are in workable thickness and quality over the entire area of the Karroo rocks extension. Moreover, the working of seams of a minimum thickness of 70 cm, which was considered by the Chinese team, would evidently be economically not feasible. And finally, even if the most optimistic appraisals are considered, the exploitation of some deposits is out of question for instance on account of small reserves (Galula) or owing to unfavourable hydro-geological conditions (Liweta).

With regard to data on quality, there are two main problems:

(a) Only a part of the samples was taken from mines or boreholes. Most were collected from outcrops and therefore were more or less affected by weathering;

(b) The analyses were based on different conditions (e.g. on different moisture content) and thus a comparison is difficult.

For these reasons all data and analyses have been converted to dry basis (d) or to dry ash-free basis (daf). The conversion to dry ash-free basis was necessary, especially with volatile matter, in order to enable the correct evaluation of the cokability and classification of the coals according to the International Classification System for coal. The moisture content of raw coal is not known but it is presumed that it approaches the moisture W^a of air-dried samples reported in the documentation.

In the calorific values distinction has to be made between the gross (higher) calorific value Q_s and the net (lower) calorific value Q_i. For the purpose of the coal classification, the gross calorific value of the combustible, i.e. on dry ash-free basis is used; the net calorific value of raw coal indicates the effectivity of coal in the combustion process. As the reports (with the exception of one analysis from Ilima carried out by the Lurgi Company in the Federal Republic of Germany) do not contain any specification as to whether the data relate to the upper or lower calorific values, and sometimes do not even state of the analysed samples, it is presumed on the basis of additional values, in particular of C^{daf} and V^{daf} (carbon and volatile matter on dry ash-free basis) that the number of the calorific values in the studies mentioned denote Q_s^a (upper calorific value of air-dried sample, i.e. with the moisture of the analysed sample). Since the H^d (hydrogen in dry coal) is usually 4.5 to 5.2%, the lower (net) calorific value must therefore be approximately 230 to 270 kcal/kg less then the upper (gross) calorific value.

Table 1. Technical symbols used

	State		
	Air-dried (analytic)	Moisture free (dry)	Dry ash-free
Proximate analysis			
Moisture	W^a	-	-
Fixed carbon	$(NV)^a$	-	-
Volatile matter	V^a	V^d	V^{daf}
Ash	A^a	A^d	-
Calorific value			
Upper (gross)	Q_s^a	Q_s^d	Q_s^{daf}
Lower (net)	Q_i^a	Q_i^d	Q_i^{daf}
Ultimate analysis			
Carbon	-	C^d	C^{daf}
Hydrogen	-	H^d	H^{daf}
Sulphur	S^a	S^d	-
Tar	-	T_{sK}^d	-
Gas	-	G_{sK}^d	-

Equations used for conversions:

$$A^d = \frac{100}{100 - W^a} \cdot A^a$$

$$V^{daf} = \frac{V^a}{V^a + (NV)^a}$$

$$C^{daf} = \frac{C^d}{100-A^d} = \frac{C^a}{100-A^a - W^a}$$

$$H^{daf} = \frac{H^d}{100-A^d} = \frac{H^a}{100 - A^a - W^a}$$

$$Q_s^{daf} = Q_s^d \cdot \frac{100}{100 - A^d}$$

$$Q_i^d = (Q_s^{daf} - 52.3884\, H^{daf}) \frac{100 - A^d}{100}$$

Coal sedimentation and coal deposits

All more significant localities with coal sedimentation in the United Republic of Tanzania orginated as a component of the K 2 and K 4 beds (lower and upper coal measures) of the Karroo System. They correspond to the Ecca Formation in South Africa and to the lower and Middle Permian in the International Classification.

As indicated by the most prospected localities, the coal occurrences and deposits developed in continental conditions, in more or less separated valleys and depressions of the pre-Karroo or post-K 1 relief prevalently formed during the Glacial K 1 (basal sandstone and conglomerate, tillite). The conditions of sedimentation were very variable, depending on time and position. For this reason, the coal seams have a high ash content, variable thickness and quality, they occur only in a certain part of the respective area, and their correlation is usually impossible. All these facts must also be extrapolated to the less investigated localities.

The characteristics of all the deposits were presented in detail in the reports written by McKinlay (1965), CCIT (1967), and the Indian National Coal Development Corporation (1971). A short survey is contained in the report by CDC (1978). Therefore neither the history of exploration, nor the unquestionable details are recapitulated here, and only a summary of the main facts, an evaluation and some arguments are given. The description of the location has been taken over from the report by the CDC.

A common feature of all Tanzanian coalfields is the presence of several coal seams, approximately up to 4 m in thickness, of which usually only one to three are exploitable. The coal seams mostly occur in monoclines or in regions displaying a simply folded or faulted structure with a maximum dip of 20° to 30°. The distance between the neighbouring seams is on the average 10 to 20 m. The seams are located at the surface (outcrops) to as much as several hundred metres depth. On account of all these facts, coal from small and medium pits, i.e. mines with a maximum target production of approximately up to 500,000 t/a, may be extracted industrially only by underground mining methods.

According to the older conceptions (Stockley, McKinlay), workable seams which may be considered as reserves or resources, have a minimum thickness of approximately 110 cm (exceptionally 90 cm), an ash content of 25% or less, and a specific gravity below 1.5 g/cm³. The Chinese experts consider a seam workable at a thickness over 70 cm and with a maximum ash content up to A^d 40%. In our opinion, the Chinese criteria do not correspond to the present Tanzanian economical and technical possibilities and to the situation in the first phases of the development of the coal industry, when the highest rentability, which is not attainable by extracting inferior coal in small thicknesses, is the primary necessity.

Songwe-Kiwira coalfield

Location

This coalfield is located in the Keyla District in the Mbeya region. Close to it is a tarmac road from Mbeya to Itungi Port on Lake Nyasa. Approximately 25 km from Tukuyu deviates an earth road running 5 km westward to the coalfield (Ilima colliery). The distance from Mbeya to the field is roughly 100 km. Uyole, the nearest railhead on the Tanzania-Zambia railway (TAZARA), is about 90 km away.

Geology and reserves

The coalfield fills a tectonic graben of NNW-SSE trend (Nyasa trend) for about 30 km in length; approximately one third of the field lies on the territory of Malawi. On the Tanzanian territory, the field is divided into three sectors: Ilima, Ivogo, and Kabulo (and/or with Matuli).

In the Ilima sector is a small colliery, the only one working in the country. Reserves amounting to 20 million t have been proved (CDC) in this tectonic unit. In the Ivogo sector, the Chinese team determined 35 million t (distinct criteria) above +600 m. By analogy we can presume in the Kabulo sector 30 million t of coal. This amounts to a total of 85 million t of more or less measured and potential coal reserves in two to three extractable seams in the whole coalfield.

Stockley's estimate of 140 million t of coal as potential and measured reserves, based on a total average coal thickness of 425 cm per about 31 km^2, seems more realistic than the estimate of 500 million t of potential reserves inferred from the same thickness per 104 km^2, since this represents the surface of the whole K 2 and of the younger Karroo members in this field, and it does not seem probable that the extractable seams would cover an equal area in full thickness and quality. On the same ground, the Chinese appraisal of 595 million t of inferred coal reserves must also be rejected.

With an extraction rate of 50% and considering the geological conditions, the construction of three collieries with a maximum target production of 500,000 t/a for over 20 years may be anticipated; the real economic production might be less, e.g. 100,000 t/a.

Quality of coal

The Songwe-Kiwira coal is highly volatile bituminous. According to the international classification (based on the Chinese analysis of cleaned coal from 1967), the coal corresponds to codes 622 or 632. For parameters of coal see table 2.

The CDC gives average analyses of the bottom and top seams, the Chinese team presents an analysis of a sample collected underground. This sample lacks any localization, but as follows from the ensuing comparison of V^{daf} and Q_i^d, it was probably taken from the top seam in the Ilima mine.

According to all available analyses, the sulphur content is low, mostly under 1% so that on burning it will not endanger the human environment. Part of the sulphur occurs in small pyrite crystals and infillings of fissures dispersed in the coal.

Table 2. Parameters of coal from the Songwe-Kiwira field

Parameter	CDC		CCIT	
	Bottom seam	Top seam	Raw coal	Cleaned coal
W^a %	3.8	4.2	2.51	2.40
A^d %	21.21	19.00	30.19	8.53
Q_s^{daf} kcal/kg	-	-	7980	8213
Q_i^d kcal/kg	6145	6445	5571	7264
V^{daf} %	29.42	39.95	38.82	38.02
Specific gravity g/cm^3	1.48	1.39	1.56	1.4
Coke residue (bottom)	-	-	weakly coked	-
Swelling index	-	-	-	2 1/2
Gray-King coke type	-	-	-	E
Roga index	-	-	-	55.33
C^{daf} %	-	-	-	83.76
H^{daf} %	-	-	-	5.18

The coal has unfavourable coking properties, i.e. especially a high content of volatile matter (Vdaf about 35 to 40%), very low cokeability, and a low swelling index. It is absolutely unsuitable for the production of metallurgical and foundry coke.

The coal from this region is suitable without further treatment, for the production of electricity and for domestic consumption.

As indicated by the Chinese analyses from the Ivogo sector, on mining in the deeper layers larger outbursts of methane may be expected and there also a great danger of coal-dust explosions.

Ketewaka-Mchuchuma coalfield

Location

This coalfield occurs in the Ludewa District in the Iringa region, approximately 195 km south of Njombe by road, and about 40 km by road north of the Manda port on the Nyasa Lake. It lies about 50 km southwest of the Liganga iron ore deposit.

The TAZARA railway runs northward of the coal deposit and the nearest railhead, Makambako, is by road approximately 255 km from the coalfield. This dry-weather district road leads through a hilly country with great differences in altitudes.

Geology and reserves

In the Ruhuhu river basin, in several great depressions on the buried surface of the pre-Karroo and K 1 originated coal sediments of K 2 and K 4 age. The most important regions of their distribution are in the basins of the lower courses of the Ketewaka and Mchuchuma rivers and in the Ngaka river basin.

Even though the Ketewaka and Mchuchuma region forms a single geologic unit, yet at the time of coal sedimentation two depressions were filled, which were separated by a ridge of Precambrian rocks which today are also buried.

The western area, Mchuchuma, is relatively well explored by CDC boreholes, and its reserves are estimated at 189.6 million t proved and 12 million t indicated and inferred. Simultaneously McKinlay presumes a 1/3 loss on mining, i.e. a total of 126 million t would be extractable. According to the Chinese calculations the reserves amount to 238 million t. Seven coal seams, K 2 in age, have been determined here, four of which are of mineable thickness (on the average 3.9; above 0.8; 3.1 and 2.5 and 5.7 in the thick seam) and quality. The seams dip 5^{o} to 10^{o} north to south; neither faults nor foldings have been determined.

The eastern area, Ketewaka, is only known from geological mapping and a single CDC borehole. It seems that the location of the coal seams will be similar to that in the Mchuchuma area, yet their thickness and quality are not sufficiently documented and for this reason neither McKinlay nor CDC did appraise the reserves here. The Chinese team estimated 257 million t of inferred reserves.

Quality of coal

According to the British classification, the coal in the Mchuchuma sector is medium to high volatile, bituminous. According to the International Classification and grouping based on the Chinese analysis of cleaned coal from samples collected in outcrops in 1967, this coal corresponds to codes 612 (seam in coal-mudstone zone), 400 (middle and lower economic seam or after their union, the thick seam), and 511 (bottom seam). The parameters of coal can be gathered from table 3.

The CDC study (1953) gave the weighted averages of the analyses. The numbers were taken over by McKinlay (1965) and in the report of the CDC (1978). Moreover, McKinlay (1965-Appendix III), on the basis of the CDC data, calculated the reserves and quality of each workable seam separately. The Chinese team analysed the seam in the coal-mudstone zone, the middle and lower economic seams as well as the thick seam and the bottom seam. All these samples were collected from outcrops on the surface and, compared with the data of McKinlay, they are rather weathered. Further, it is not clear whether the data relate to individual samples or are an average. The data presented by NORCONSULT (1972) were taken over from the GATC report (1979) without any further details. In connection with the preparation of the feasibility study on the development of ferrous metallurgy on the base of the Liganga Fe-deposit and Mchuchuma coal deposit, GATC collected in 1977 samples from shafts in the lower and middle seams. The experts drew attention to the fact that the samples might be weathered or partially depreciated by manipulation and transport. In any case, as follows from the data of the analyses, they are less depreciated than, for instance, the Chinese samples.

The coal in the highest-situated seam in the coal-mud-stone zone has a high content of volatile matter and a higher content of carbon and hydrogen

Table 3. Parameters of coal from the Ketewaka-Mchuchuma field

Parameter	CDC (1953) average	McKinlay (1965 - App. III)				CCIT (1967)					NORCONSULT (1972)	GATC (1979)	
		Top seam	Middle seam	Lower seam	Thick seam	Top seam	Middle seam	Lower seam	Thick seam	Bottom seam		Middle seam	Lower seam
W^a %	1.5	1.6	1.7	1.6	1.5	1.90	6.87	11.01	6.19	2.88	-	-	-
A^d %	14.42	19.76	14.24	11.69	14.01	33.03	14.44	18.32	11.03	23.35	15.1	13.9	14.7
Q_s^{daf} kcal/kg	-	8 336	8 448	8 450	8 366	8 105	7 436	6 950	7 451	8 020	-	-	-
Q_i^d kcal/kg	6 918	6 499	7 033	7 243	6 986	5 240	6 186	5 221	6 450	5 960	-	-	-
V^{daf} %	28.47	28.38	28.47	28.08	27.63	37.63	27.61	31.01	29.04	29.19	22.26	32.73	34.68
Specific gravity g/cm^3	-	1.47	1.40	1.39	1.42	1.60	1.56	1.61	1.51	1.54	-	-	-
Coke residue (bottom)	-	-	-	-	-	sticking	powdery	powdery	powdery	powdry	-	-	-
Swelling index	-	-	-	-	-	1	0	0	0	1	-	1	2
Gray-King coke type	-	-	-	-	-	G	A	A	A	B	-	-	-
Roga index	-	-	-	-	-	18.83	0	0	0	12.69	-	15	14
Reactivity	-	-	-	-	-	-	-	-	-	-	0.63	0.84	0.65
S^d%	-	-	-	-	-	0.73	0.39	0.42	0.58	0.58	1.25	0.76	0.64
C^{daf} %	86.42	85.82	86.45	87.23	86.59	84.74	83.08	83.58	80.59	85.39	-	-	-
H^{daf} %	4.68	4.52	4.71	4.74	4.62	5.20	3.93	3.63	3.85	4.67	-	-	-

than the other older seams. A higher swelling index, Gray-King coke type G, a higher Roga index, and coherent coke residue are the result of a higher yield of tar (T^{d}_{sK} 7.34%) and not of more suitable properties for the production of industrial coke. Although the other three seams contain less volatile matter they are not suitable for direct production of coke for metallurgical purposes, which is indicated by an incoherent coke residue and relatively high reactivity. An experiment carried out within the framework of the GATC study showed that the coal may be utilized in the processing of iron ore from the Liganga deposit by non-classical methods without the use of coke. However, the relatively high cost might constitute a problem.

Though the ash content is somewhat higher, the high calorific value and low sulphur content indicate that it is a suitable fuel for thermal power plants with a favourable fusibility of ash according to both the CDC and Chinese data.

At low-temperature carbonization according to Gray-King at 510°C, the middle and lower seams as well as the thick seam have relatively high gas yields (5.58; 9.44, and 6.08% G^{d}_{sK}).

Ngaka coalfield

Location

This coalfield lies approximately 110 km west of Songea. The road connecting Songea and Lituhi on Lake Nyasa passes through the Ruanda village in the southern part of the coalfield. This road is passable only during the dry period. The field lies about 32 km south-east of the Ketewaka-Mchuchuma coalfield.

The Ngaka River, one of the seasonal tributaries of the Ruhuhu River, passes through the coalfield from south to north.

Geology and reserves

The Ngaka coalfield is the second main potential field in the Ruhuhu River basin. Similarly as the Ketewaka-Mchuchuma field, its coal sediments were also laid down in K 2. It is divided into the Ngaka northern field and the Mbalawala (also Ngaka southern) field. The Ngaka northern field is dissected into small, more or less isolated depressions or valleys in an older buried surface. The seams are thin, only partially thicker, inconsistent, and correlation even over short distances is impossible. According to the CDC 1956 estimate, the field contains only 15 million t of indicated and inferred reserves, or 11 million t according to the Chinese estimate, 1967. The Ngaka northern field is therefore of no economic significance.

The succession of the coal-bearing strata in the second field, Mbalawala, is very similar to that in the Ketewaka-Mchuchuma coalfield. It contains four extractable seams of varying thickness (according to Mckinlay - Appendix III: on the average 1.97; 2.77; 0.55 and 1.19 m of coal). The entire field was verified by CDC boreholes which were more densely spaced than in the Ngaka northern field. According to CDC, the field contains 99.5 million t of proved reserves, the Chinese team arrived at 141 million t, at a lower thickness limit and quality limit. The location of the seams is suitable for underground mining, the field is only slightly faulted and the dip of strata does not exceed 15°. However, the coal-bearing complex lies in the basin of the Lutuka River and its tributaries, and therefore hydrogeological problems may be expected.

Quality of coal

According to the British terminology, the coal of the Mbalawala field is bituminous, high volatile. In terms of the International Classification and the Chinese analyses, the shale-coal seam has the code 711, and the upper split seam code 400. The parameters of coal can be taken from table 4.

The CDC study gives weighted averages of the analyses. The numbers were taken over by McKinlay (1965) and CDC (1978). In addition, McKinlay (1965 - Appendix III), on the basis of the CDC data, calculated the reserves and quality of each workable seam separately. The analyses made for the two thickest seams by the Chinese team (1967) are based on samples collected from outcrops; it is not clear whether they relate to a single sample from each seam or to an average of several samples.

The higher located younger seam (shale-coal seam) has a lower degree of coalification than the older, upper-split seam. None of these seams is suitable for the direct production of coke for metallurgical purposes. At low-temperature carbonization according to Gray-King, the two seams in the analyses of the Chinese team give a medium tar yield (4.75 and 4.94% T^{d}_{sK}) and a fairly high gas yield (8.50 and 6.20% G^{d}_{sK}).

The coal from the Mbalawala field is suitable as fuel for thermal power plants and its calorific value, ash and sulphur content and ash fusion characteristics approach the values of the Mchuchuma field.

Other coalfields

The remaining coal-bearing fields, i.e. Njuga, Mhukuru, Mbamba-Bay, Galula, Ufipa, Liweta (South Manda) and Lumecha are very little investigated. In the Ufipa field are only two boreholes and in Mhukuru nine boreholes were drilled by the CDC. The other fields are known only from outcrops and geological mapping. For this reason, the CCIT has estimated only very small inferred reserves in the first tens of million t. McKinlay did not appraise these reserves, and in an internal appraisal he considered the Chinese figures as unfounded.

None of these coalfields is economically significant. For this reason the experts refrain from discussing them any further.

C. Conclusions and recommendations for the utilization of the Tanzanian coal deposits

Conclusions

Suitable for commercial exploitation are only the Songwe-Kiwira (all parts), the Ketewaka-Mchuchuma (part Mchuchuma) and Ngaka (part Mbalawala) coalfields. The reserves in the Songwe-Kiwira coalfield are estimated to be at least 85 million t which could be extracted by three independent underground mines, each with a capacity of 100,000 to 500,000 t/a. From the only Tanzanian colliery at Ilima a few thousand t are extracted annually, and even this low output is not utilized by the existing consumers so that mining is temporarily interrupted, as was the case at the beginning of 1982. With respect to the existing infrastructure and population, the Mchuchuma and Mbalawala fields are less favourably situated than the Songwe-Kiwira fields. Their reserves, however,

Table 4. Parameters of coal from the Ngaka field

Parameters		CDC, 1953	McKinlay (1965-Appendix III)				CCIT, 1967	
			Shale-coal seam	Upper split seam	Lower split seam	Bottom seam	Shale-coal seam	Upper split seam
W^a	%	3.2	3.2	3.4	3.5	2.7	9.45	4.83
A^d	%	16.12	18.70	16.15	12.44	13.77	15.24	13.61
Q_s^{daf}	kcal/kg	7981	8055	7845	8121	8388	7912 a/	7948 a/
Q_i^d	kcal/kg	6479	6346	6366	6886	6992	6480 a/	6673 a/
V^{daf}	%	32.64	31,77	31,11	32,19	36,59	40.73	28.30
Specific gravity	g/cm^3	-	1.47	1.43	1.38	1.37	1.55	1.51
Coke residue		-	-	-	-	-	powdery	powdery
Swelling index		-	-	-	-	-	1	0
Gray-King coke type		-	-	-	-	-	A	A
Roga index		-	-	-	-	-	14,14	0
S^d	%	-	-	-	-	-	0.61	0.64
C^{daf}	%	83.47	83.90	83.33	84.49	83.20	79.09 a/	83.53 a/
H^{daf}	%	4.91	4.76	4.83	4.90	5.33	5.09 a/	4.26 a/

a/ Cleaned coal.

amount to 189.6 and 99.5 million t respectively. Since the two fields are not far apart they can be considered as a single operation, particularly regarding infrastructure, connection to the future power station and to the Liganga Fe deposit.

The coal from none of these coalfields is suitable for the production of metallurgical coke. Since there are no roads which can be used throughout the year, and coal-fired equipment is rare, the only economically feasible solution is to process the coal on site. The products would have to be of a kind that can be stored during the period when the roads are impassable, or such that could be transported irrespective of the state of the terrain. The first alternative means to produce petrol from the coal or other liquid fuel, the second alternative means to produce and distribute electricity or gas. Even without any calculation it is obvious that the production of electricity is the most advantageous solution since it requires only transmission lines which are relatively cheap and can be connected to the existing network.

Concluding it should be emphasized that even though the United Republic of Tanzania has ten known coalfields, only three have economically utilizable reserves amounting to a total of 85 + 189.6 + 99.5, i.e. 374.1 million t. These reserves can, however, be exploited only by underground methods which are always accompanied by 40% to 60% losses on mining according to the method employed. It can therefore be presumed that the consumers will obtain during the lifetime of all these coalfields about 50% of the quantity mentioned, i.e. in total about 180 to 200 million t of coal of a calorific value of about 6,000 kcal/kg. For the generation of 1 MWh approximately 0.5 t of such coal is needed so that about 400 million MWh of electric power can be produced. If future geological exploration will not fundamentally increase the hitherto known reserves (e.g. by discovering new big coalfields), these would suffice for 200 years at a yearly output of 1 million t of coal.

Recommendations

Based on their findings, the experts recommend to proceed as follows:

1. The exploitation of the Tanzanian coalfields should proceed gradually. Simultaneously the necessary infrastructure should be built, and the consumption of coal and products based on coal, especially electricity, secured. The procedure selected, the specific production targets of the mines and the volume of construction should be such as to secure a fast return of the means invested, which could then be employed in further constructions in this branch.

2. The following should be final targets:

(a) In the generation of electricity, the gradual substitution of imported oil by Tanzanian coal and water power. The diesel aggregates which are in working condition should be used as a reserve to cover the peak consumption and in the case of breakdown. The released crude oil derivatives should be exported;

(b) The construction of a national distribution system for electricity;

(c) The construction of a metallurgical plant on the basis of coal and the Liganga Fe-deposit;

(d) The contruction of the necessary infrastructure and communications in the areas of the coal deposits, power plants, and metallugical plant;

(e) The expansion of electricity-consuming industry, throughout the country, with the aim to increase the employment rate and to adequately electrify the agricultural production.

3. The following principles should be observed during the construction of the coal industry, power plants and associated industries:

(a) The exploitation of the coal wealth should begin in the Mchuchuma coalfield by opening of an underground mine with an annual output of 100,000 t and subsequently 200,000 t according to the GATC project of 1979. In the proximity of the colliery the first unit of a thermal power plant of 25 MW should be built. In its design a future expansion by additional units of equal size should be envisaged so that administrative buildings, communications, coal processing plant, switching station etc. may also be utilized after expansion. The design should also take into account future coal supplies from other nearby deposits, especially from Ngaka (mbalawala area) with minimum claims on supplementing investment, especially transportation;

(b) The construction of a transmission line for 132 or 200 kV which would connect the future thermal-power plant in the Ruhuhu region with the hydroelectric-power plant in Kidatu and with the transmission line between Kidatu and Dar es Salaam should be started as soon as possible. This power line is to supply the building site both of the colliery and the power plant until the time when their own production of electricity on the basis of coal will commence;

(c) In the first stages of the development of coal industry one should concentrate on the production of electricity since its transport is the cheapest and does not depend on seasonal weather conditions. Minimum quantities of coal should be transported outside the colliery-power plant complex, and that only in connection with the Liganga metallurgical complex;

(d) The construction of the colliery in the Mchuchuma region will according to the estimate of CDC be approximately 30% more expensive than the construction in the Songwe-Kiwira area. If, however, the costs connected with coal transportation and the construction of communications will decrease or be postponed to a later time, because the coal will be consumed on the spot for the generation of electricity, and if the whole lifetime of the entire complex colliery/power plant, or colliery/power plant/metallurgy is considered, then the Mchuchuma area is unquestionably more advantageous because its coal reserves are larger and because it is more apt to increase production. The Songwe-Kiwira area, though more attractive from a short-term viewpoint, is not favourable with respect to the Liganga Fe-deposit;

(e) The expansion of mining and the construction of the colliery in the Songwe-Kiwira area should be postponed to a later data, i.e. until construction work in the Mchuchuma and Mbalawala areas has been completed and full operation begun. The Songwe-Kiwira area should be utilized for the time being only to supply the local industry (cement factory in Mbeya, processing of tea and tobacco and for small consumption), and the quantity of output adjusted accordingly. Production and transportation costs should be reduced and the working security of miners increased, without big capital investment or costly reconstruction of the colliery;

(f) In case that for the coming 30 to 50 years the opening of the Liganga iron ore deposit and the construction of the associated metallurgical plant is not feasible so that coal would only be used for the generation of electricity, it would be more advantageous to commence the construction of the complex colliery-power plant in the Songwe-Kiwira coalfield, applying the same principles as under paragraphs (a) to (c) above;

(g) Since at the present time the coal deposits are neither adequately explored nor known, any further geological prospecting for coal in the regions of the known coalfields is discouraged. It is recommended to verify only orientationally and within the framework of other works remote localities of possibly different age (e.g. Kasulu, the area between Kilwa and Lindi etc.) and insufficiently explored parts of the Karroo System in the Liwegu and Rufiji River basins. A detailed geological investigation should be conducted only if the contruction of a colliery will directly be associated with it.

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*Number in bracket refers to designation under which the report is deposited in the Mandini archives at Dodoma.

II. IRON ORES

A. Present state

The study is based on a number of reports and official material dealing with possibilities of using the raw material basis of iron ores, especially on comparing several feasibility studies worked out in recent years by organizations in the Federal Republic of Germany, Norway and Switzerland.

At present, the total demand in the United Republic of Tanzania for iron and steel in all saleable form is estimated to be about 100,000 t/a. Its annual growth has in the past years remained invariable within 8-10%. The country's demand is largely covered by imports. Construction of a plant producing 10,000 t annually at Tanga was begun in 1968 and it is now able to cover about one-fifth of the country's demand, especially for rolled material.

In accordance with the United Republic of Tanzania's second five-year plan (1969-1974), consideration was given to the possibility of constructing a metallurgical plant based on domestic raw materials, particularly the iron ore deposit at Liganga, which was studied in detail in the mid-60s by specialists from Canada, Romania, Sweden and United Kingdom of Great Britain and Northern Ireland. Its titanomagnetite ore is difficult to dress, and it was decided to use the most effective method known as direct reduction. The applicability of this method to ore dressing was confirmed theoretically by technological tests performed under auspices of the firms Steel Company of Canada and Lurgi Gesellschaft für Chemie, Federal Republic of Germany. In 1973 Norconsult AS presented a feasibility study to encourage the development of the Tanzanian iron and steel industries based on the demand for both commodities estimated by 1985 to be 112,000 t. It was recommended to exploit Liganga iron ores for magnetic dressing, pelletizing and compaction in an electric kiln. The study failed to satisfy requirements for the full use of domestic raw materials, particularly coal, as it relied upon a considerable import of coke. It was intended to supply energy from hydroelectric power plants in the Stiegler's Gorge and Kitdatu areas. There are also other problems left for further consideration, such as the transport of raw materials, energy, location of dressing plants and even technology. The final negative assessment of the project is based on the reasoning that capital risk surpasses tolerable limits.

A new feasibility study was initiated in 1977 by GATC, entitled "Iron and steel industry based on Liganga iron ore and Mchuchuma coal". The study contains a profound analysis covering markets and transportation and suggests that the raw material be treated by the improved method of direct reduction as developed by the firm Lurgi-Krupp. Despite some problems that await further solution, it gives a reasonable conception of a comprehensive use of the domestic raw material base together with the foundation of a Tanzanian iron and steel industry.

B. Raw materials for the iron industry

Of decisive importance for the use of iron ores is the optimization of suitable raw materials with regard to their quality, quantity and location, followed by an appraisal of other useful materials and a choice of an economic model best fitted to the country's overall economic structure.

Iron ores

On present knowledge, the United Republic of Tanzania has proved resources of iron ores of about 140 to 160 million t. Approximately one half are titanomagnetites containing about 50% Fe and 12-13% TiO_2. The other half consists of banded ferruginous quartzites which contain only 30 - 33% Fe but are easier to treat.

Deposits of titanomagnetite ores form especially several bodies lying between the Ruhuhu River and the Kipengere Mountains in the Liganga area, Njombe District, south-western part of the country. The ore zone is roughly parallel to Lake Nyasa from which it is separated by the Livingstone Mountains. The deposits were studied in 1957 - 1958 by the Geological Survey Division of Tanganyika. The Liganga District was found to contain several thick lenses and irregular bodies extending almost vertically in gabbroic and anorthosite massifs. The ore consists of a finegrained matrix of magnetite with black grains of spinel and minute grains of ilmenite a few millimetre across. In the district 45 million t of ore were essentially proved at two localities, with an average amount of 49% Fe, 13% TiO_2 and 0.7% V_2O_5. These reserves can be exploited by open-cast methods (see figure I). Similar occurences are known from the Uluguru Mountains, east of the Mgeta River (Hundusi) and in the Karema area, Mpanda District (Mbabala), but all are of subordinate economic importance.

Banded ferruginous quartzites of utmost importance are concentrated in the Itewe ore district, south of the town Chunya, Mbeya District, south-western part of the country. The ore bodies are distributed along a NE-ward-trending crest, extending discontinuously for about 3.6 km. Their elevated parts lie at an altitude of up to 100 feet above the surface, with irregularly lenticular and vein-like bodies of ferruginous quartzites extending inward. Wall rocks are quartz-bearing amphibolites and felsic migmatites. The ore in lenses as much as a few tens of metres thick displays a delicate, megascopically faintly visible alternation of laminae of quartz and magnetite, locally accompanied by Mn garnets. The detailed exploration programme conducted in co-operation with the Geological Service of China in the period 1974-1978 confirmed the presence of 47 million t containing some 33% Fe and negligible amounts of limonite- and hematite-bearing weathered ore. The deposit can partially be worked by open-cast methods (see figure II).

In addition to the occurrences just described, there are certainly serveral others which may locally be clearly seen on the airborne geophysical map constructed in co-operation with Geosurvey G.m.b.H. It is therefore highly desirable to make a regional appraisal of the United Republic of Tanzania's potential for iron ores on the basis of a geophysical magnetic survey.

Present-day knowledge indicates that the Liganga deposit is optimal for exploitation because it contains the highest metal amounts, has most favourable mining conditions, and lies near to coal occurrences and resources of electric power, water as well as other raw materials (limestone, flux). The deposit may in the long run satisfy requirements in this field. Export of titanium might also be interesting in this eventuality.

Coal

The 1978 forecast indicates that in the period 1981-1990 some 160,000 to 180,000 t of coal will be needed for an annual iron production, but in the following decade this figure shall double with the increasing rate of

Figure I. Liganga iron ore deposit - map and projection

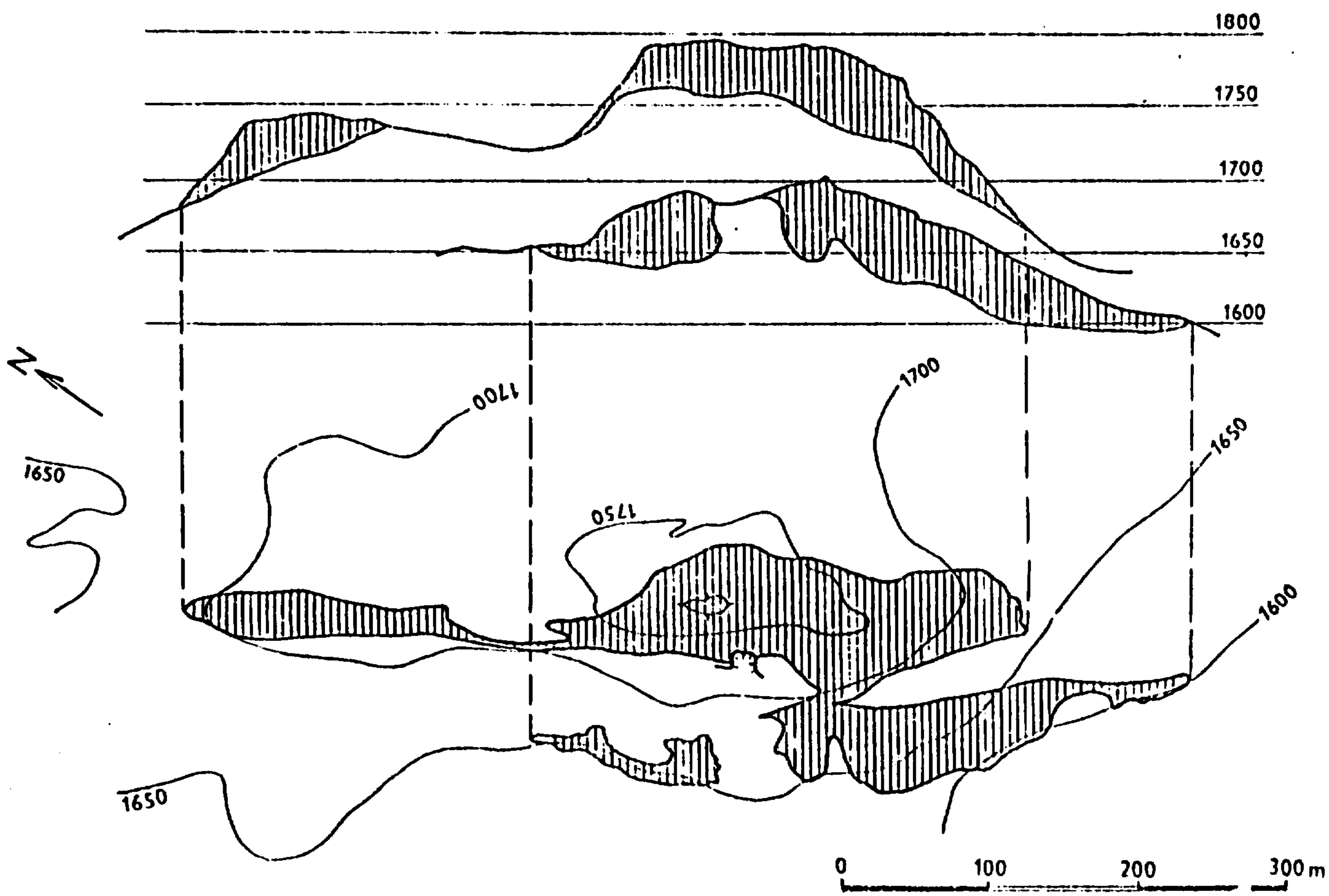


Figure II. Itewe iron ore field - scheme of deposit and faults

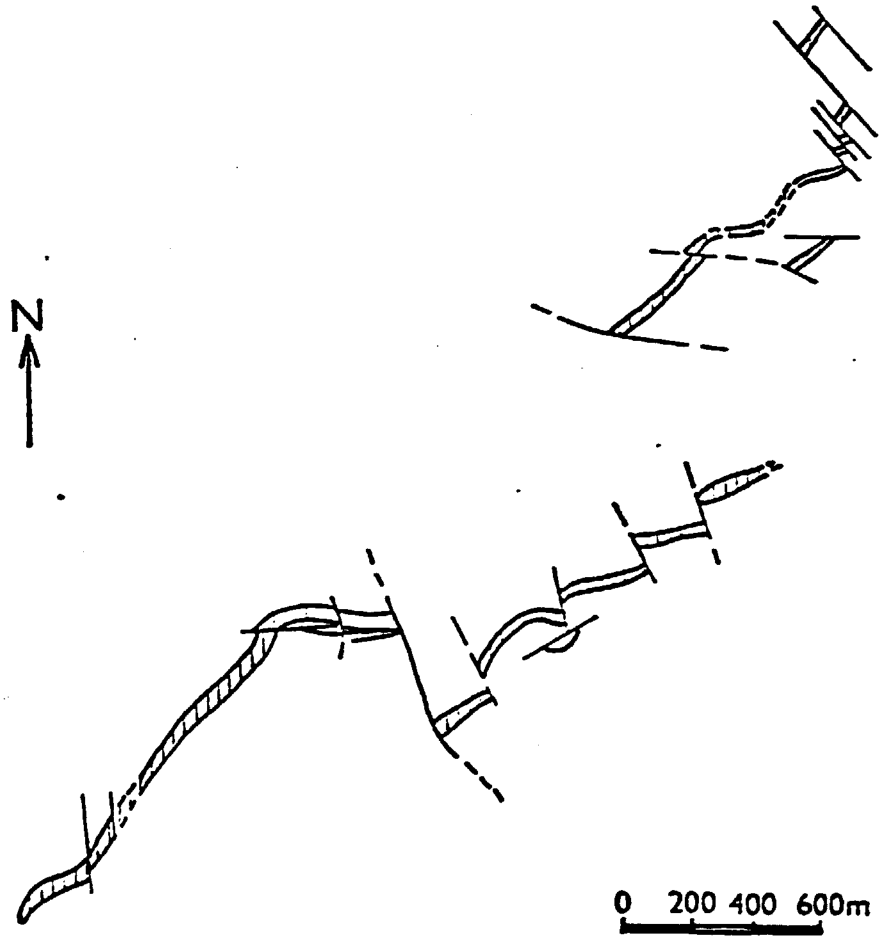
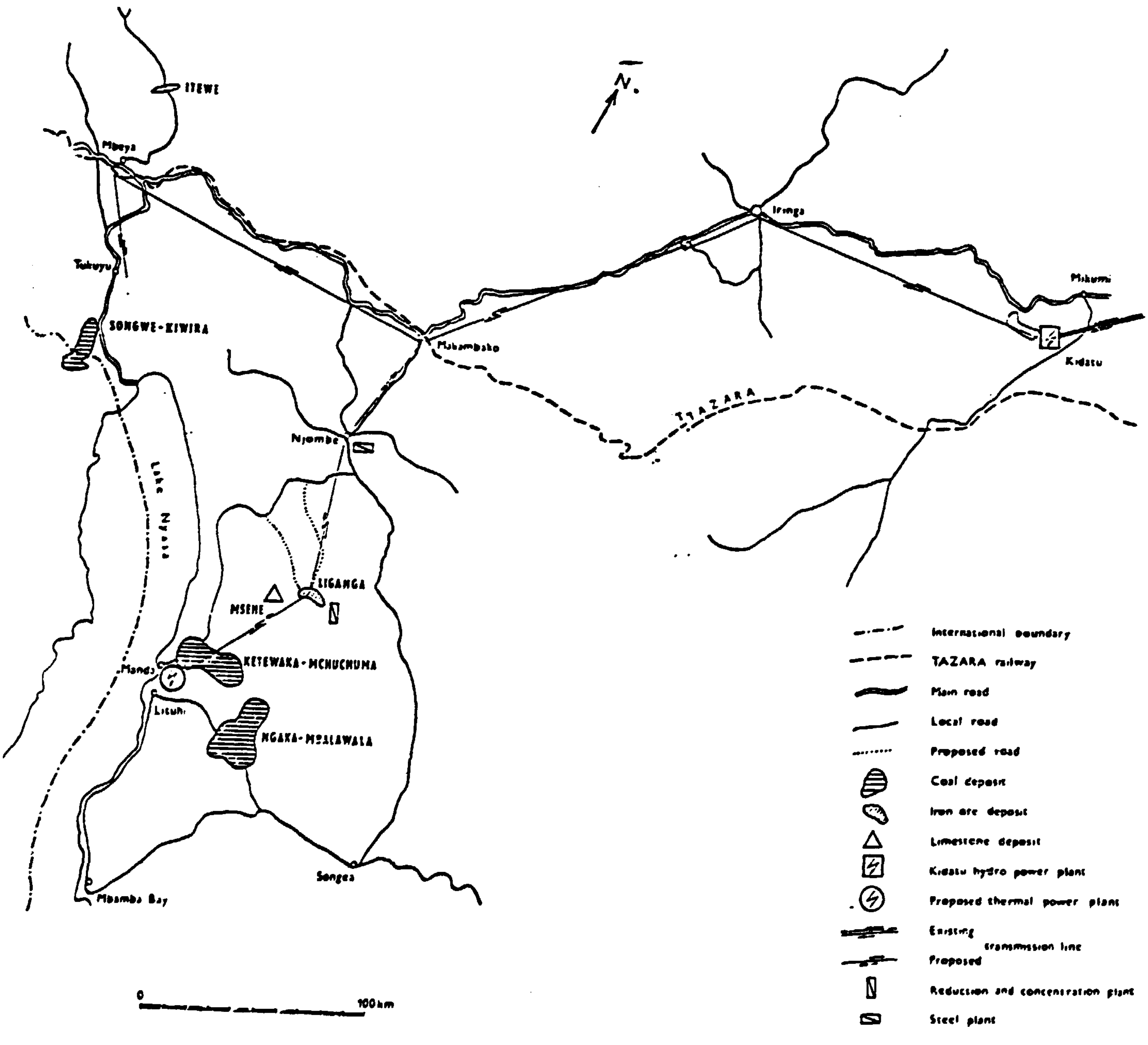


Figure III. Iron ore and coal deposits in the southwest of the United Republic of Tanzania - possibilities of exploitation



production. Additional supplies of coal will be required for the production of electric power plant with an output of 170,000 MWh (1981-1990) and 340,000 MWh (1991-2000). These quantities seem to be secured in the Mchuchuma district (see chapter I).

Limestone, quartz sand and charcoal

Preliminary estimates indicate that iron production will require the use of about 10,000 t of limestone, 1,500 t of quartz sand, 37,000 t of calcined lime, 5,500 t of charcoal and 13,000 t of additives and fluxes a year. It is preliminarily expected that these amounts of raw material can be ensured within a tolerable distance from the projected plants.

Potable and technical water

Daily consumption of water required for the integrated plants is estimated to be 21,000 m^3. Further studies are needed to remove uncertainties as to this kind of raw material.

C. The construction of the iron and steel industry at Liganga-Njombe-Mchuchuma

Liganga complex

A quarry would operate at the iron ore deposit, with an annual production of 440,000 t of raw ore (51.5% Fe, humidity 5%). Capital expenditures would be 18.4 million TSh and product costs 33.6 TSh/t of raw ore.

It is envisaged to construct a magnetic dressing plant and a concentrate pelletizing line. Some 256,000 t of concentrate (64.3% Fe) and 260,800 t of pellets (63.3% Fe) a year would be produced by magnetic separation. Total capital expenditure would amount to 240 million TSh, and product costs would total 113 TSh/t for the concentrate and 213 TSh/t for pellets.

Krupp-Lurgi's direct reduction method would be used to produce 198,000 t of sponge iron pellets (81.7% Fe) a year. Capital expenditure on this plant will be close to 224 million TSh.

The production in the Liganga complex will further require the construction of workshops, laboratories, a carbonizing plant, roads, a water and power supply system etc. Total expenditures on these structures would amount to about 480 million TSh.

Total costs on the Liganga complex will thus reach about 960 million TSh, of which some 580 million TSh in foreign exchange. Liganga employees would total about 300.

Njombe complex

The annual production of the electric steel plant would be 152,000 t of steel billets (92.1% Fe). Costs of production would amount to 2,601 TSh/t of billets, and capital expenditures would total 255 million TSh.

The continuous casting plant would produce 140,000 t of finished steel a year. Capital expenditures would amount to about 70 million TSh.

The operation of the Njombe complex will require additional capital allocation especially to water and power supply, the Itoni-Makambako railway, laboratories etc. Total expenditures on these works would amount to 325 million TSh.

Total costs for the construction of the Njombe complex will rise to about 650 million TSh, of which 380 million TSh in freely convertible foreign exchange. The complex will have 540 employees. If deemed necessary, the first stage of the work involved may not lead the project to its completion, so that for example sponge iron or steel billets could be final products.

Mchuchuma complex

The amount of coal required for the production of iron and steel-making, i.e. 180,000 t at present, from 1990 onwards 360,000 t in general plus 120,000 t and from 1990 onwards 240,000 t respectively for electric power generation, can be supplied from one medium mine at the Mchuchuma deposit, some 40 km away from Liganga.

Comparison and evaluation of constructional alternatives based on three different feasibility studies

Table 5. Comparison and evaluation of alternative proposals for the construction of an iron and steel industry

Parameters	Norconsult AS, 1973 (I)	German Agency, 1979 (II)	Norconsult AS, 1973 (III)
Annual steel-making capacity (t)	130,000	140,000	162,000
Market	Tanzanian	Tanzanian	East African Community
Raw materials	Liganga Fe ore imported coke electric power from Stiegler's Gorge hydro power plant	Liganga Fe ore Mchuchuma coal Mchuchuma power plant	Same as (I)
Treatment	Elkem/SL-RN process electric smelting	Direct reduction system Lurgi-Krupp	Same as (I)
Import required	40,000 t of coke a year	Not indicated	60,000 t of coke a year
Location	Kidatu area	Liganga-Njombe area	Kidatu area
Total capital investment costs	TSh 560 million	TSE 1,610 million	TSh 1,500 million
Employment	750	1,020	1,500

Table 5 (continued)

Parameters	Norconsult AS 1973 (I)	German Agency 1979 (II)	Norconsult AS 1973 (III)
Sensitivity Analysis	Any change in market prices or deviation from planned capacities may have a catastrophical effect on economic indices. Economic characteristics are unfavourable below favourable conditions with regard to the project's economy and capital risk	The economic evaluation did not render a clearly negative or a clearly positive result. Comparison of these projected works has to be effected, followed by additional semi-technical tests for the reduction plant with their technico-economic evaluation known prior to taking a final decision on this project	Same as (I)

D. Overall appraisal and recommendations

The plan to use domestic raw materials for the creation of a Tanzanian iron and steel industry i `ased on reasonable grounds and, despite several problems awaiting final s ..tion, it is recommended to implement it step by step. Its realization will have a favourable impact on the country's infrastructure, thereby providing more working opportunities, improving the energy situation of the area, as well as transportation. Industrialization and restrictions imposed on import to the area will ensure a higher living standard of the population. The main problem is to obtain financial means amounting to TSh 1,600-1,800 million for the project.

Recommendations

To make the project operational, it is recommended that some technical and economic problems be solved as soon as possible, as outlined below:

1. Immediate attention should be given to an assessment of the material base of limestone, quartz sand and fluxes. Furthermore, the problem of securing potable and technical water in the quantities required both for the integrated works and infrastructure should be dealt with. It is also proposed that the magnetic anomalies discovered by geophysical aerial survey in the southern part of the country be studied in great detail. On the basis of data obtained, and with regard to a paleo-geographical analysis of the potentialities for coal also in other areas, it is recommended to make a reappraisal of the optimum use of the raw material base, including the location of treatment centres.

2. Preparatory work should be started immediately for a design study and corresponding projection. This includes the following tasks:

(a) Construct detailed topographical maps of the Liganga-Mchuchuma area including the tracks of planned roads;

(b) Perform a test in the direct reduction of iron ore, using a sample taken from 100 t of the Liganga iron ore deposit and another sample from 80 t of coal at Mchuchuma;

(c) Perform a test of the processing of sponge iron in the steelworks;

(d) Submit the results of both tests for critical examination by at least two independent reviewers from foremost mining and metallurgical companies;

(e) In co-operation with consultant firms, refine the capacities of iron production and steel-making, and optimize the assortment of final products.

3. Under the guidance of a group of experts ensured for the Tanzanian side by an international organization, a project for the construction of the integrated plants should be worked out, including infrastructural variants. The work on the project should be executed by independent consultant firms. It is suggested that the financial means needed for these works be provided by international organizations. It is also proposed that both the project and economic aspects be reviewed by an international group of experts.

4. Mining facilities should be constructed at the Mchuchuma deposit with regard to the prospects for iron ore works but without regard to the work on the project itself. An annual reserve of 170 MWh should be taken into account when building an electric power station to be connected to the country-wide energy system. At the same time, the facilities should be used for the infrastructure of the south-western part of the country.

5. The step-by-step construction of the integrated plants should be ensured and supervised by a consortium of foreign experts in co-operation with the Tanzanian Government. Consideration should be given to the possibility of covering the costs for infrastructure through the World Bank.

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III. NICKEL

A. General remarks

The conclusions and recommendations in this chapter are mainly based on the information contained in reports published by UNDP in 1978 and 1979.

Until 1976 about ten occurrences of nickel mineralization have been reported in the country, all of no economical significance. The representative of the two main types of nickel-ore deposits are known. In past years, some large-scale prospecting campaigns have been carried out (Nippon Mining Co. Ltd., V/O Technoexport and UNDP). Many of the reported occurrences have been re-examined, making use of the most modern geochemical prospecting techniques and drilling programmes, but the outcome has been generally disappointing.

Massive finds of large, economically viable deposits can by no means be ruled out. The nickel, cobalt, copper deposit recently discovered at Kabanga in the north-west of the United Republic of Tanzania is the best example. It should serve as an encouragement to mining companies to investigate more fully the possible existence of large deposits.

B. Review of the deposits

Sulphide-nickel mineralization

Kabanga deposit

During the systematic prospecting programme for base metals which has been undertaken by UNDP in an area of known potential mineralization in the West Lake region, the nickel-bearing ultramafic complex at Kabanga was discovered in 1976 (UNDP 1978).

Magmatic evidence suggests that the ultramafites are found in a belt east of the zone of the gabbroic rocks. The nickel-cobalt-copper sulphide mineralization is found associated with the ultramafic intrusions. The sulphide mineralization, consisting of pyrrhotite with minor pentlandite, chalcopyrite, pyrite and violarite, is found as disseminated, network or massive mineralization within the mafic-ultramafic bodies and in the surrounding metasediments.

More than 20,000 m of drilling were done in 60 boreholes down to a depth of 600 m in the area of 16 sq. km. Taking into account that 100 x 100 m drilling grid was undertaken, the calculation of reserves was performed on the basis of rectangular blocks.

The total drill-indicated and extrapolated reserves in block 2 are given as 5.9 million t of ore averaging 2.51% of nickel, 4.79 million t of ore averaging 1.12% of nickel and 26 million t of ore averaging 0.7% of nickel, with a total of 373,830 t of nickel. The total reserves of cobalt in block 2 are stated as 25,431 t of ore averaging 0.10% of cobalt and 14,510 t of ore averaging 0.14% of cobalt. The total reserves of copper in block 2 are stated as 45,174 t of ore averaging 0.18% of copper and 30,937 t of ore averaging 0.29% of copper (UNDP 1979 c).

The provisional, inferred reserves in block 1 were calculated as 37.8 million t of ore averaging 0.41% of nickel, 0.037% of cobalt and 0.058% of copper, in order to have a general idea of the magnitude of nickel mineralization within the Kabanga ultramafic complex (UNDP 1979 c).

Kapalagulu

The Kapalagulu basic complex is a noritic intrusion situated on the eastern shore of Lake Tanganyika, near Kungwe Bay, about 128 km south of Kigoma.

During 1951-1953, 18 boreholes were drilled totalling 4,844 m, 15 of which encountered a mineralized zone. The average grade was 0.27% of nickel and 0.13% of copper over an average width of 12.6 m in 11 intersections. The total length of the known mineralized zone is about 7.3 km. On the basis of these results, it was considered that a large, low-grade mineralized body of picrite could be proven, but the chances of finding a body of economic ore do not justify further expenditure (Stockley 1952).

In 1961, four boreholes performed by Western Rift Exploration Co. Ltd. failed to disclose any significant nickel values.

A rough estimation of reserves declared by Nippon Mining Co. Ltd., in 1970 in the order of 16 million t of ore averaging 0.7% of nickel and 0.4% of copper is only of the vaguest (Nippon Mining Co. 1970). The estimation is based on many assumptions obtained mainly from surface geochemical indications.

Additional drilling in 1975 disclosed only low nickel values of no economic interest (Saha 1975).

Other occurrences of sulphide-nickel mineralization such as Western Kluguru Mountains, Kimamba near Kilosa, Ntaka in Southern Province in Mpanda area show no economic indications.

Silicate-nickel mineralization

Kabulwanyele

The prospect is situated about 56 km south-west of Mpanda.

Indicated reserves in 1947 were 5 million t averaging 0.72% of nickel to 9 m depth over an area of 0.3 km^2. Re-examination performed in 1952 (Gross 1952) estimated the average value of 0.47% of nickel and in 1958 the overall grade was considered much lower than the earlier estimate (Harris 1961).

The boreholes through serpentine to depths of 103 m and 185 m, did not disclose any significant mineralization.

Twamba, near Sango, Mpanda District

Soil samples over serpentinite body contained up to 0.9% of nickel and nearly 90% of the samples contained more than 0.2% of nickel. Four samples of serpentine averaged only 0.38% of nickel, but the nickel value of the soil samples was considerably higher than at Kabulwanyele (Harris 1961).

Ngasamo area

The elongate serpentine hills, Ngasamo and Wamangolo are situated about 137 km east of Mwanza. Pitting by the Geological Surveying Department in 1957 indicated that the main ore bands averages 1.3% of nickel and 0.75% of Cr_2O_3. However the average grade of serpentinite is less than 0.2% of nickel. The tonnage of the high grade ore is estimated at about 10,000 t per 0.3 m of depth (Windelschmidt 1957).

It is considered that any significant areas of nickel-enrichment occur at Mwahanza Hill, Dodoma District (Fozzard 1939).

C. Conclusions

The following conclusions can be drawn from the information:

The occurence of nickeliferous sulphides in the Kabanga ultramafic intrusions warrants prospection for similar intrusives along the belt of airborne magnetic anomalies. Positive indications for the presence of several ultramafites have already been found north of the Kabanga area.

Since it is necessary to establish additional ore reserves, it follows that, a further drilling programme has to be carried out in an airborne magnetic and geochemical anomalous area 5 to 11 km northeast of the Block 2, and near the border with Uganda, where large geophysic anomaly is covered by recent sediment of Lake Victoria.

To investigate a possible sub-surface continuation of the serpentinite between Ngasamo and Wamangolo Hills, the variation of nickel values with depth, and the extension and width of high-grade nickeliferous bands, diamond-drilling will be necessary.

In a country like the United Republic of Tanzania, where distance is the most powerful of all factors, deposits of base metals of world-wide importance are of great value and would enhance the development of the country's infra-structure.

Unfortunately, the largest deposit at Kabanga is in a remote area which is poorly served by communications. However, this ore field possesses great potential value mainly in relation to development of the steel industry.

D. Recommendations

1. To attract foreign investment capital the known ore reserves in the Kabanga area should be increased by intensifying the geological investigations.

2. As the first target areas for future exploration working may be recommended the areas extending north-east and north-west of Block 2. and in the north-western and south-western edges of Block 1. To test the north-east continuation of mineralization indicated in Block 2, six inclined boreholes at 45° with a probable depth of 500 to 600 m are required and 5 inclined boreholes are proposed to test the ore body in north-west extension. Three boreholes are proposed in Block 1, of which two are inclined holes to test the north-western edge of the ultramafic intrusion, and one a vertical hole on south-western edge. On the assumption of positive drilling the ore reserves at Block 2 may be doubled and at Block 2 half as much. This would make a total of reserves in Block 2 as 40 million t of ore averaging 0.7% of nickel, while in Block 1 the reserves would amount to 56 million t of ore averaging 0.4% of nickel. In the case of such enlargement of tonnage of ore reserves the Kabanga deposit would be economically viable. A rough estimation of the cost of exploration drilling of 14 boreholes to a depth of 600 m gives a figure of $250,000.

3. Further exploration programmes in the Kabanga area, especially north of Kabanga should be undertaken with UNDP aid.

4. Once the geological investigations are completed and reveal positive results, the possible interlinkage with other industries, commercial utilization, export possibilities should be explored and pre-investment studies made.

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IV. GOLD

A. General remarks

The reports "Mineral survey of the Lake Victoria goldfields" by UNDP (1969), "The detailed prospecting at the Mpanda area" and, "The detailed prospecting of the Lupa Goldfield" by V/O Technoexport (1974), as well as "Economic geology" by J.F. Harris (1961) provided the most important background data for this chapter.

From 1930 till 1965 gold was a very valuable export article from the United Republic of Tanzania, reaching its peak during 1939-1941 and 1960-1963 (see table 6). Because of the high cost of mining, the low prices of gold, limited ore reserves and their marginal grade, the mining activities have remarkably decreased from 1963 on, although some small-scale production was still going on.

According to information received from Ministry of Minerals, production amounted to 1.325 kg of gold in 1980, 9.085 kg in 1981 and is expected to attain about 24 kg in 1982.

However, there are good grounds for believing in a high gold potential in the country and more efforts to document this potential should be made.

The continuation of industrial gold mining in the United Republic of Tanzania is important for the economic development of the country.

The recorded gold production is almost entirely confined to several well-defined areas (see figure IV) known as the Lupa Goldfield, The Mpanda Mineral Field, the Iramba-Sekenke Goldfield, the South-west Mwanza Goldfield and the Musoma Goldfield.

The last three are often referred to collectively as the Lake Victoria Goldfield. It has long been recognized that gold mineralization here is common throughout the "Greenstone Belts", defined by the rocks of the Nyanzania System. Although much of the gold has been mined from typical quartz veins or alluvial deposits, the potential for large, low-grade impregnated deposits confined to banded iron-formation has been completely untested.

The occurrences of the gold appear to have been controlled by structural, intrusive and lithological features (UNDP 1969). There are two main types of ore-bodies: aurifeous quartz reefs, stringers and stockworks, and auriferous sulphide impregnations.

B. Review of the deposits

Musoma Goldfield

The Musoma area extend from the shores of Lake Victoria south-west of Musoma for a distance of about 72 km eastwards to Buhemba.

Buhemba mine

Evidence of old prospecting activity, including opencuts, small shafts and some underground development, can be found all over the area. The mine which is situated about 48 km south-east of Musoma was the largest mine during the period 1939 to 1958. There was installed a mill, and a record annual throughput of 47,390 t was achieved in 1941. The amount of gold produced annually has ranged between 226 and 283 kg (Harris 1961).

Table 6. Gold production in the United Republic of Tanzania, 1935-1981

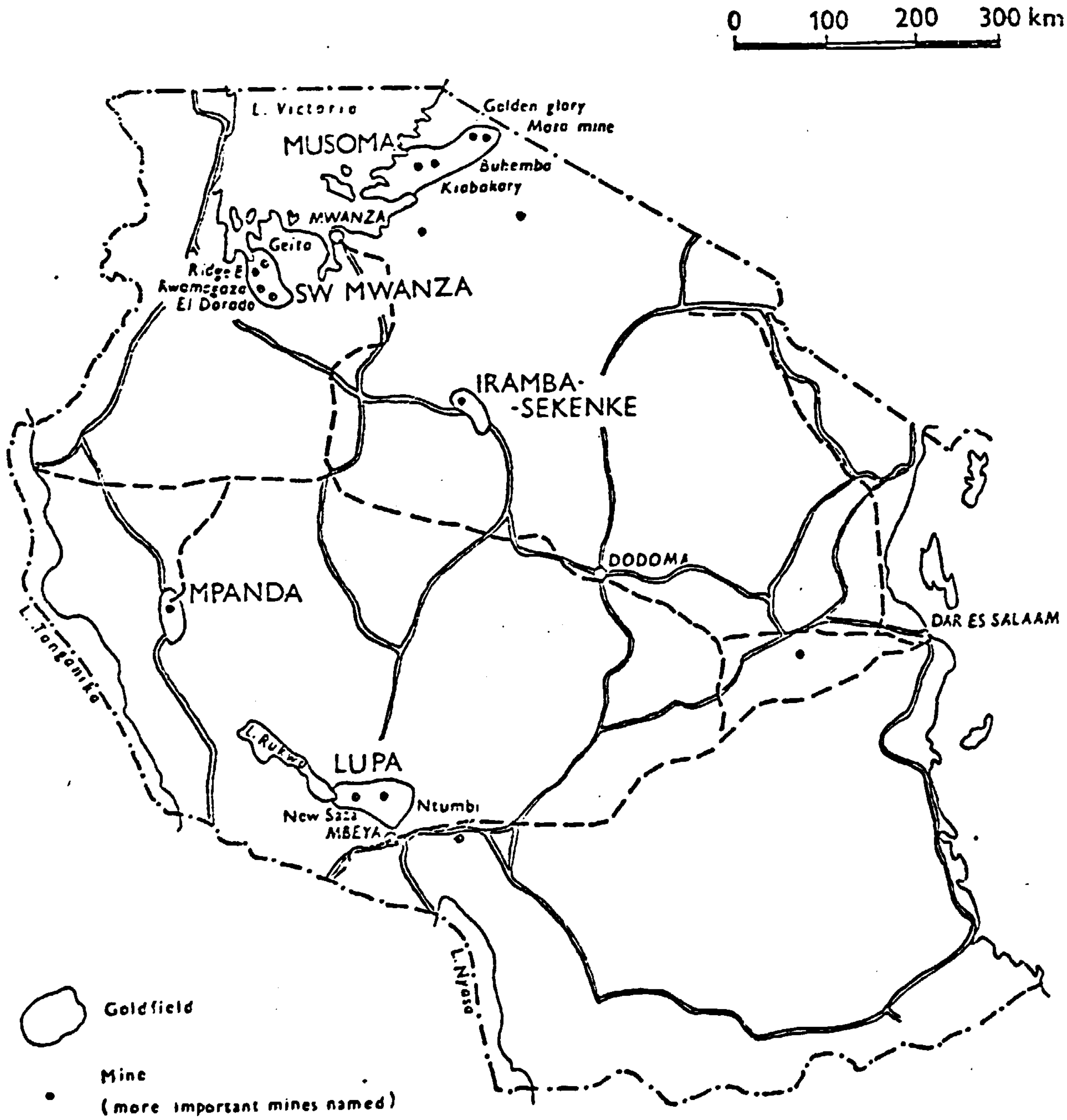
Year	kg	Year	kg
1935	1 467.203	1959	2 421.089
1936	1 968.809	1960	3 328.408
1937	2 124.757	1961	3 188.222
1938	2 310.500	1962	3 171.737
1939	3 658.495	1963	3 201.130
1940	3 974.441	1964	289.392
1941	4 007.018	1965	2 824.834
1942	2 996.773	1966	No data available
1943	1 950.411	1967	No data available
1944	1 606.793	1968	No data available
1945	1 397.152	1969	No data available
1946	1 392.106	1970	No data available
1947	1 303.997	1971	5.185
1948	1 581.307	1972	6.622
1949	1 917.639	1973	4.734
1950	1 859.893	1974	1.577
1951	1 829.446	1975	3.019
1952	1 935.499	1976	9.227
1953	2 099.810	1977	2.519
1954	2 080.909	1978	No data available
1955	2 130.002	1979	8.949
1956	1 975.897	1980	1.325
1957	1 799.736	1981	9.085
1958	1 921.353		

Of the Buhemba, Nyasenero and Kilamongo mines, only Nyasenero was still in operation in 1969 (UNDP 1969).

The ore mined at Nyasenero comes from discontinuous shoots in a quartz reef trending east-south. The reef varies in width from a few cm up to 5.5 m.

Development has been carried out over a strike length of 1.373 m. On the lower levels the grade averages about 15 g of gold per tone. The reef continues to the south but with no values on the lowest levels. In the central section the ore shoot bottomed between 87 and 105 m, but in the northern section stopping has been carried out at 140 m below surface. In the middle levels of the northern section the reef continues strongly (Harris 1961). In 1960,

Figure IV. Location of gold fields and mines



exploratory work was being done to investigate a possible connection with the Kilamongo reef to the north. Unfortunately, no information about it was available.

Prospecting grids were laid out over the old prospects of Lonesome, Blue Ridge, Kejimbura and Njabirundo, as well as Kyarano where a strong electromagnetic anomaly was located by the airborne geophysical survey (UNDP 1969).

At Lonesome, the veins are from 152 to 305 m long, striking east-west and 0.3 to 1.6 m wide. Average gold assay values from 80 outcrop samples ranged between 1.4 and 2.2 g/t, with a few assay up to 8.5 g/t. One sample assayed at 83.9 g of gold/t over 0.4 m of core.

Similar structural features were found at Kejimbura, where quartz veins are 396 to 518 m long and 0.3 to 0.9 m wide. The gold assays from outcrop samples range up to a maximum of 12.3 g/t with an average of about 3 g of gold/t.

From a total of 50 samples taken from exposed parts of the veins at Nyabirundo, only one sample showed a good value of 7.0 g of gold/t across a 0.3 m section.

The gold values obtained from 25 surface samples at the Blue Ridge occurrence ranged from 3.2 to 5.6 g of gold/t, with one high value of 90.1 g of gold/t over an 0.4 m section.

Geological reconnaissance carried out on old gold prospects between the Kurtambe and Muzangumbwe south of Musoma, and in the area of the Mohoji Plains south-east of Mrangi, disclosed only low and highly erratic gold values of no economic interest.

Kiabakari mine

This mine is situated about 32 km south of Musoma, a few km west of the main Mwanza-Musoma road.

After leaving operation in 1940, a new activity started up in 1950, when a programme of trenching, diamond-drilling and exploratory development indicated the existence of a large-tonnage impregnation deposit. The mine came again into production and by the end of 1959 the mill was operating at a capacity of 20,000 t of ore per month with an estimated monthly output of about 113 kg of gold.

The ore body (as developed in 1959) extends over a strike of about 183 m with a width of up to 30 m on vertical or steeply dipping.

The deposit has been developed only to about 200 m below surface but, at that depth, there was no reduction in size or grade of the ore body, and it still can be of considerable extension in depth (Harris 1961).

The grade of proved ore reserves at the end of 1959 was quoted as 7.7 g of gold/t.

The Ikungu area

This area is at the southern end of Itario Bay on Lake Victoria. From 1936 until 1952 about 48 kg of gold were produced.

Forest Reef mine was developed to 60 m below surface with the grade of ore averaging about 12.5 g of gold/t; but exploration on 91 m showed a decrease in values.

Mrangi Mine (or Phönix Reef) about 1.2 km to the north of the Forest Reef, consists of a series of small quartz lenses, from which four carried rich values of between 23.3 and 31.1 g of gold/t and were worked down to 60 m below surface.

The prospecting drilling consisting of seven boreholes (UNDP 1969) into presumably mineralized zone disclosed only poor and irregular gold values. A significant value was only intersected at a depth of 72.6 - 73.5 m, reaching 9.1 g of gold/t.

Seka-Karusenye area

This area lies south-west of Musoma. The old working follows an east-west striking ore zone over a distance of about 4 km. Assays from channel samples revealed poor values with only two samples of significant value, up to 26.2 g of gold/t over a width of 0.6 m.

Mara area

The Mara area is located north of the Mara River, about 32 km north-east of Ngurumi.

Productive mining was developed on the Golden Glory vein and on the main Mara Mine, where the gold-bearing quartz was mined to a depth of 213 m. Other veins were mined to a depth of 30-60 m. The overall grade of the ore can be calculated as 10.2 g of gold/t, and that of the ore shoot at Golden Glory Mine as 25.7 g/t.

The Mill Reef at Mara Mine was developed down to more than 152 m, but two ore shoots proved to be disappointing and work was discontinued (Harris 1961).

Simba Sirori area

It lies east of Musoma, about 16 km south of the Mara River. Three small mills had amalgamation and cyanidation facilities.

The mineralization occurs in several systems of quartz veins and in east-west striking shear zones.

The sampling of quartz veins indicated low gold values ranging from 1.7 to 3.4 g of gold/t, while out of 17 samples taken from shear zone, eight showed values between 6.8 and 10.2 g of gold/t. Four such east-striking mineralized shear zones were located, each of them having about 300 m of inferred extension (UNDP 1969).

Maji Moto area

Maji Moto is situated about 14 km north-east of Simba Sirori. The Maji Moto Mine developed into a small-scale mine operation with several shafts and the ore was treated in the mill at Maji Moto.

The mineralization occurs mainly along a 305 m long north-east trending shear zone. The total length of this shear zone is assumed to be 900 m and its depth at least 150 m (UNDP 1969). The width of the mineralized shear zone ranges from 9 to 10.6 m. Eleven channel samples averaged 8.7 g of gold/t, with the highest assay 25.6 g of gold/t over a 1.1 m section.

On the basis of previous results one can estimate the potential reserves of this shear zone over a depth of 120 m to be as much as 2.6 million t of ore and 22,800 kg of gold.

Kilimafedho area

Kilimafedho area lies on the edge of the Serengeti Plain, about 160 km south-east of Musoma. The principal source of ore was Apex Reef, developed down to 150 m (Walker 1967) over about 122 m of strike. Its average width is only 0.45 m but it carried good values and is reported to have persisted strongly in the deepest workings (UNDP 1969).

Another area around Ikoma, between Musoma and Kilimafedho, contains a number of interesting gold, mainly centred around Negoti.

The South-west Mwanza Goldfield

Geita area

In the Geita area, south-west of Mwanza, several zones of gold mineralization have been exploited in the past. The ore has been worked from five mines - Geita Mine, North-east Extension, Lone Cone, Prospect 30 and Ridge 8, and treated in a central milling plant at Geita.

At the Geita Mine the strike length of the payable ore shoot was about 730 m. The development reached down to a depth of 427 m (9 levels) below surface.

According to results from drillhole G.S. (9/58), the mineralization is unchanged at a depth of 560 m and geophysical results indicate the Nyanzian formation to at least 1.220 m (Carter 1959).

The Geita Mine closed operation in 1966. It may be concluded that there is no obvious reason for the abrupt termination of gold mineralization to at least 700 m at the mine. In particular, the possibility that the rich ore body has a considerable extent to north-east should also be explored.

On the basis of available data (Carter 1959, Harris 1961, McConnel 1947) and an average grade 6.2 g of gold/t, one can estimate the reserves, only within the main shoot to a depth of 800 m, to be as much as 1.5 million t of ore and 9,000 kg of gold.

At North-east Extension Mine an ore shoot was developed over a distance of 457 m. It was mined to a depth of 198 m below surface. Deep drilling has shown that the mineralized zone persists at least to a depth of 400 m (Carter 1959). One borehole (UNDP 1969) drilled into the same ore zone approximately 213 m further to the north-east intersected two mineralized bodies. One of the bodies, 533.7 m below surface, carried 7.2 g of gold/t over 9.1 m of core and the other, 579.4 m below surface, carried 7.7 g of gold/t over 2.1 m of core.

On the basis of previous results (Carter 1959), by analogy and through extrapolation from the new drill hole (UNDP 1969), one can infer the reserves within the main shoot (from -200 m to -500 m) to be 2.8 million t of ore and 20,900 kg of gold, while in the north-east extension of the ore body to a depth of 600 m below surface they would be 3.8 million t and 28,700 kg of gold.

The overall potential reserves at the North-east Extension area are assumed to be 6.6 million t of ore and about 50,000 kg of gold.

Prospect 30 Mine was developed down to a depth of 91 m to exploit a rich ore body which yielded 330,000 t of ore. In 1956 the mine was considered to be worked out and it was closed down.

Ridge 8 Mine was closed down in 1954 reportedly because of the high cost of operation. It has been developed to more than 300 m below surface. At the lower levels, two 275 m long ore bodies are reported to still contain ore reserves, but no further exploration has been done.

Lone Cone Mine has been developed between 183 and 320 m below surface. Considerable ore reserves are believed to have been left in the mine (Harris 1961).

Rwamagana area

The exploration programme carried out in 1966 (UNDP 1969) indicated that gold in small amount is present in practically all quartz veins in the area. Some higher concentrations of gold at the surface were found to range from 3.4 to 8.5 g/t in the central part of the main zone of veins between Thompson Quarry and Blue Reef. One borehole located at Thompson's Quarry intersected a mineralized body showing 20.1 g of gold/t over 3.45 m intersection at 42.5-48.5 m.

On the basis of new information the potential ore reserves in the ore body of 106 m length and to a depth of 50 m are estimated to be 20,000 t and 400 kg of gold.

Blue Reef. Over 610 m of underground development has been done on the 23 m level, 111 m of which was in reef (four separate lenses). The record information state average width of the ore body 1.3 m having average value 26.5 g of gold/t on this level.

Two out of three boreholes located at Blue Reef (Sampson 1961) intersected mineralized body at 57.1-58.9 m averaging 14.8 g of gold/t and at 69.4-72.2 m averaging 63.8 g of gold/t over 1.7 m thickness.

On the basis of these data the potential ore reserves within the rich 111 m long section to a depth of 80 m are estimated to be about 30,000 t and 780 kg of gold.

Blue Reef Extension. The original depth of this working was about 10 m. The ore body was some 4.2 m wide, striking about 106 m due east of the mine and averaging 10.1 g of gold/t.

Glass Reef is situated north-west of Rwamagaza Camps. The reef was worked out at 7.6 m below surface and there is no doubt that the ore body continues at the depth and beneath the laterite.

The borehole UN-RW/3 (UNDP 1969) intersected at 306.3-321.8 m an ore shoot averaging 45.6 g of gold/t over 2.89 m width.

On the basis of these data a rough estimation of potential ore reserves along 150 m extension has been calculated as 150,000 t and 2,300 kg of gold.

Mawe Meru. The most extensive workings are found in the western part of the area around the Main Reef, mined down to 213.5 m below surface. The Main Reef was stopped in 1952 after exploitation over a length of 305 m, having yielded about 85,000 t of ore, averaging about 28 g of gold/t, which was transported to Geita for milling (Harris 1961).

The ore reserves are reported to be exhausted because on the deepest level the reef narrowed to less than mineable width. However, there is no proof of termination of the ore body having good values at the depth.

In the rest of the area only a few pits were sunk as deep as 30 m.

Hyena and Jay auriferous quartz reef prospects are situated about 1.6 km east of Mawe Meru. Two boreholes (Mc Connell 1947) located at Jay Reef intersected at 41.1-43.9 m a mineralized body with an average value of 18.8 g of gold/t over 1.8 m zone.

On the basis of new results we can estimate potential reserves at Jay Reef as about 25,000 t of ore and 470 kg of gold.

The Eldorado Mine. According to old reports some 73,000 t of ore were mined yielding 482 kg of gold. The veins from 152 to 305 m long and 0.1-0.9 m wide, were mined to a depth of 60 m. Sampling of left-pillars revealed (UNDP 1969) that the quartz was rich in gold. No more detailed information is available.

Nyamutondo area

Buck Reef. The mine is located about 32 km south-west of Geita. The old workings include 91 m opencut, trenches, pits and small shafts. One shaft has been sunk to a depth of 23 m, and horizontal tunnels have been driven at the 7.7 m and 23 m levels. Old workings were traced over a distance of 793 m.

During the UNDP project 13 inclined boreholes were drilled indicating an ore shoot whose strike length was 106.7 m, average width 7.9 m and deepest intersection at 115.9 m. A rough estimation of potential reserves was calculated as 330,000 t of ore with an average grade of 16 g of gold/t.

The deposit is recently under development carried out by STAMICO.

Sabura. The area is situated 41.8 km south-west of Geita. According to old reports (Carter 1959) almost 13,000 t of ore were mined during the period 1940-1943, yielding 122.4 kg of gold. The ore was treated in a local mill and cyanidation plant.

Seven inclined boreholes (UNDP 1969) failed to disclose any significant gold values below the outcrop.

Iramba-Sekenke Goldfield

Sekenke

Development on the mine has extended down to 183 m below surface and about 260,000 t of ore have been mined for a recovery of 3,968 kg of gold (Harris 1961). Exploitation was confined mainly to a shoot of about 300 m long.

Diamond-drilling shows (Mustard 1959) that the shoot continues below 200 m although at 335.5 m the reef has again split in two.

According to evidence, considerable tonnages of ore may be proved in the area.

On the basis of scanty data one can give a rough estimation of potential reserves within the main shoot and continuing Dernburg Shear as 500,000 t of ore and 4,500 kg of gold.

Kirondatal

The Main Shear was developed to 39.6 m depth on a narrow but rich quartz vein, averaging 15.5 g of gold/t.

Bulyanhulo

The Bulyanhulo deposit was discovered and mined for a short period by illicit diggers between 1975-1977. A systematic geological prospection and exploration programme was carried out by the Government from 1977-1979 including nine boreholes (Namyaro 1977, 1979). From both, surface and core samples the virgin Bulyanhulo prospect seems to be very promising for medium- or full-scale mining.

The drill-indicated ore reserves from Reef I and II are stated as about 480,000 t, averaging 29.9 g and 11.1 g of gold/t respectively (Namyaro 1979).

Total inferred ore reserves are calculated to be as much as 1.7 million t.

According to data from surface samples (Namyaro 1979), and extrapolation the potential reserves may, in the experts' opinion, amount to about 3 million t.

Such prospect warrants more detailed exploratory development work which is now carried out by STAMICO.

According to the feasibility study which has been recently undertaken (Mohamed 1981) the project is economically viable and deserves an estimated investment of 10.7 million in addition to TSh 103.9 million. The cost of mining and treating one t of ore will be $31 plus TSh 940 whereas the revenue will be $522 indicating a surplus of $391/t of ore treated. This estimate is based on the price of gold in 1981.

Mpanda Mineral Field

The Mpanda Mineral Field was initially a producer of alluvial gold. During later years attention was concentrated on mining various reef gold occurrences. However, with the development of lead and copper, Mukwamba Mine gold was mostly recovered as by-product from Pb/Cu concentrates, averaging 1.5 g/t of ore.

During the period of 1970-1973 the most promising areas have been systematically prospected for reef and alluvial gold by V/O Technoexport. The exploration project included geochemical and ground geophysical surveys, trenches, adits, shallow pits to 25 m and 63 boreholes up to 160 m depth.

Magamba Deposit

During 1971-1973 both reefs (Magamba and Eastern Vein) were explored by trenches, seven deep pits with cross-cuts and 37 boreholes. According to the results, the drill-indicated reserves within the main mineralized body are stated as about 198,000 t of ore (up to the depth of 160 m), averaging 9.7 g gold/t. Inferred ore reserves calculated on the flanks of the reef and among the divided blocks are reported as 964,000 t of ore averaging 4.93 g of gold/t (V/O Technoexport 1974 a).

From surface and borehole samples at the Eastern Vein, about 300 m east of the southern flank of the Magamba Reef, the drill-indicated reserves give figures of about 126,000 t of ore averaging 11.8 g of gold/t. Additional inferred reserves are stated as 158,000 t of ore averaging 7.65 g of gold/t.

The total reserves of the Magamba Deposit have been estimated at as much as 1.446 million t of ore and about 9,366 kg of gold (V/O Technoexport 1974 a).

D-Reef Mine

This mine is situated about 8 km south of Mpanda. The old working include trenches, six shafts, three addits and three boreholes to a depth of 60 m. Ore reserves were estimated (in 1943) at 60,000 t with gold and silver values averaging each 9 g/t.

In 1973 a geophysical survey, trenching and four boreholes to a depth of 140 m and spaced 100 m apart, were carried out by a Russian team.

It was discovered that the reef extends for 300 m with an average width of the ore body of 0.78 m and gold values from traces to 31.9 g/t (averaging 10.8 g/t). On the basis of the results, the inferred reserves are stated as 167,700 t of ore and 1,816 kg of gold.

The Miongwe group of veins, situated south and south-east of the D-Reef contain only poor gold values, no more than 2.7 g/t.

Kapanga group of veins

The area, located south of the Magamba Deposit, consist of about 16 auriferous quartz veins.

Vein No. 17, up to 0.4 m wide, can be traced over a distance of 750 m. Estimated inferred reserves to a depth of 20 m within 80 m long ore shoot give 874 t of ore, with gold values averaging 19.4 g/t.

In vein no. 22 gold mineralization is concentrated in two ore shoots about 60 m long and 0.7 m wide. The ore is said to average 21.3 g of gold/t and the inferred reserves to a depth of 20 m are reported as 6,340 t of ore.

Ibungu group of veins showed a few high but only isolated gold values (Ibindi VII Vein - 14.1 g/t).

Alluvial gold is concentrated at the Kapanda and Magura Rivers. Gold reserves in Kapanda River are estimated to be 160 kg with an average gold value per productive horizon of 1.25 g/m^3, while those of Magura River are 55 kg with an average gold value of 0.55 g/m^3.

Lupa Goldfield

The Lupa Goldfield is a triangular area of about 1,600 km^2 situated north of Mbeya. During its early years, it was essentially an alluvial and elluvial field.

Later on, the gold was worked from numerous quartz veins and shear zones. The length of the reefs varies from tens of metres to 3 km and more, with a width of 0.3 to 10 m, the dimensions of the shears being much larger. Most of the small auriferous veins have been mined to a depth of 25-30 m, some are shoots to 60 m below surface.

Saza Mine

The shear zone at the Saza Mine extends from 60 to 122 m in width, containing 11 quartz veins from 60 to 250 m long. The largest ore shoot was developed to 228 m below surface, where it still carried payable values. The diamond-drilling showed that the structure persists strongly to a depth of at least 300 m (Harris 1961).

The inferred reserves calculated in 1974 (V/O Technoexport 1974 b) figure as 1.458 million t of ore and 11,372 kg of gold. The content of silver in the ore being comparable with the gold values, silver reserves of 10,000 kg can be expected.

Razorback Mine

The reef, situated 1 km north-east of the Saza Mine, consists of several lenses each 250 to 400 m long and 0.3 to 11 m wide. The ore shoot extends over 360 m.

Boreholes intersected ore bodies at a depth of 110-120 m and 125-150 m with an average width of 2.5 m and average value of 5.3 g gold/t. Inferred reserves to a depth of 50 m are stated as 122,000 t of ore and 645 kg of gold (V/O Technoexport 1974 b).

Additional reserves at the south-eastern flank of the enriched part are about 200 m long, giving about 300 kg of gold of drill-indicated category and 497 kg of gold of inferred category (Massawe 1978).

Total gold reserves at Razorback Mine are about 1,440 kg in 272,000 t of ore.

Gap Mine

The mine is situated at the eastern termination of the Saza shear zone about 2 km west of Nkutano. The thickness of the ore body averages 10 m with an average gold value of 10 g/t.

The prospecting activities of the Russian project (V/O Technoexport 1974 b) included ten boreholes and revealed total reserves to be 350,000 t of ore and 4,234 kg of gold. On the assumption that the payable ore grade extends to a depth of 320 m, total reserves amount to 523,213 t of ore and 5,700 kg of gold.

On the basis of revision exploration drilling (ten bore-holes) additional reserves of 1,350 kg of gold of drill-indicated category and 2,500 kg of gold of inferred category have been estimated by STAMICO.

This brings the total reserves in the area covered by STAMICO and the Russian team to 3,855 kg of gold of drill-indicated category and 5,696 kg of gold of inferred category.

Nkutano, Ruth "A", "C" and Maperi deposits are situated in close vicinity of the Gap Mine.

Drill holes intersected ore bodies to a maximum depth of 120 m below surface. The total reserves found so far within these reefs are as follows:

(a) Nkutano: 155,588 t of ore and 1,288 kg of gold (including 512 kg of gold of drill-indicated category);

(b) Ruth Reefs: 45,540 t of ore and 247 kg of gold (including 17,500 t of ore and 97 kg of gold of drill-indicated category to a depth of 80 m);

(c) Maperi: 91,794 t of ore and 1,082 kg of gold (including 63,587 t of ore and 710 kg of gold of drill-indicated category to a depth of 120 m).

The overall reserves at the whole area in the Gap Mine ore field are about 1.2 million t of ore and 12,168 kg of gold of both, drill-indicated and inferred categories.

Numerous auriferous quartz reefs are known in the central part of the Lupa Goldfield, south-east of the Saza shear zone. The occurrences have been developed into small-scale mines to a depth of 10-30 m. The main prospects such as Perseverence, Chapa, Chijoka, Menzis and Kunguta indicate low values with erratic and patchy distribution of gold.

Taking into account the potential reserves of all reefs, the geological reserves in the area as a whole may reach 2,000 kg of gold (V/O Technoexport 1974 b).

Ntumbi area

Over 50 auriferous reefs are known in the area.

Ntumbi Mine

About 140,000 t of ore and 2,400 kg of gold were produced in the past. The Ntumbi C Reef has been mined to more than 120 m below surface. Other reefs have been mined only by opencuts to a depth of 5-15 m (Giraffe, Shenze and Rubble).

About 350 kg of gold remained in Venus, Ntumbi B and C reefs in the sections adjacent to the worked ones. The reserves may be clasified as drill-indicated.

As a rough estimation, the total extent of the payable ore was assumed to be 200 m on strike and 200 m to a depth. With an average mining value of 13.5 g of gold/t and an average width of 0.4 m, the potential reserves at the main reefs in the Ntumbi Mine have been estimated at 450,000 t of ore and 5,830 kg of gold (V/O Technoexport 1974 b).

Including other small reefs, the potential reserves at Ntumbi area add up to 6,350 kg of gold.

Other goldfields

Many small gold occurrences are known in the eastern part of the Lupa Goldfield. The individual reefs are reported to extend from 20 to 1,350 m in length and 0.2 to 1.3 m in width. Scanty geological data are available only to a depth of 10-30 m. The ore above the 30 m level was said to average 2-31 g of gold/t. The area includes Zongwe, Nyahonga, Nigel, Black Jack, Siebert, Twiga, Usanga and other reefs, which are generally limited in reserves and are only convenient for small-scale mining.

From numerous auriferous quartz reefs in the southern part of the Lupa Goldfield, the most promising is Chisu zone extending about 1.5 km in length and 15 m in width. Rough calculations of reserves to a depth of 50 m indicate about 5 million t (V/O Technoexport 1974 b). Even if the average value is low, e.g. 4-5 g of gold/t, it can be mined on a large scale.

Alluvial gold of economic interest is mainly concentrated at the Sira deposit, totalling about 1,547 kg (V/O Technoexport 1974 b).

C. Conclusions

Most of the mining in the country has been to exploit the minerals as cheaply as possible, without proper geological investigations before developing deposits. Most of the gold-bearing reefs had been previously prospected only on the surface by working and drilling in places of high-grade ore, and sometimes no information about it is available. Many deposits and occurrences have been operated on a small-scale basis and without planned development that would be required to exploit the reefs fully.

During the working life of most mines the ore reserves have been poor as there has never been sufficient capital available to enable development to proceed beyond stoping. Therefore, it is almost impossible to determine the gold bearing deposits and hence to forecast ore trends. However, there are indications that most of the known deposits have a greater extension in strike and depth.

The old workings include trenches, pits and opencuts usually worked to a depth of 20-30 m and only some ore shoots have been worked by small shafts sunk to a depth of 50-60 m. Exceptionally, the development of the largest deposits have extended to several hundreds of meters below surface.

Considerable reserves of ore still await development because occurrences in depth were never satisfactorily investigated and there are no obvious geological reasons for the termination of deposits in depth.

It is essential to have sufficient ore reserves of proven or indicated categories to attract the necessary investment for further mining operations. Geological conditions indicate the existence of further ore reserves. It is evident that reserves at major as well as minor deposits have not been exhausted as long as only the outcropping reefs have been worked.

Drilling is considered to be the most effective method of outlining the ore potential below the lowest levels of previous working, in order to plan the future expansion of the mining activity. Many of the reefs undoubtedly deserve further exploration.

An immediate mining of insufficiently surveyed deposits is not advisable since reserves of an indicated category are not enough. Exploration work should continue at first in such areas.

New, promising prospects like Bulyanhulo must definitely receive more exploration, as carried out recently by STAMICO. Joint-venture partners would have been interested in any smaller prospect had there been some conclusive information.

The gold assays from surface samples of the reefs do not necessarily indicate in every case the adequate gold mineralization at the depth.

An evaluation of the potential mineralization in the delta and terrace sediments of Lake Victoria is an integral part of the country-wide survey of gold mineralization.

The North-east Extension Mine at Geita shows every possibility for further development. The estimated reserves based on two drill holes are 6.6 million t of ore and about 50,000 kg of gold. In the first stage it is necessary to outline the ore potential below the lowest levels and in the north-east section of the mine. The cost of drilling five inclined boreholes to a depth of 600 m would be approximately TSh 800,000.

On the basis of previous results, analogy and extrapolation one can assume that the overall potential reserves at the Geita Mine and North-east Extension Mine are 8 million t of ore averaging 6.8 g of ore, on about 59,000 kg of gold. The economical viability of that project is based on the following assumptions:

Capacity: medium-sized plant to treat 1,500 t/d of ore

Raw ore mined: 360,000 t/a

Mine life: about 22 years

Recovery: about 98%

Recoverable gold in the deposits: 57,820 kg

Price of gold: $600/troy ounce

Value of recoverable gold: $1,115.34 million

Annual production of gold: 2,448 kg

Value of gold produced: $47.2 million/a

Gross revenue per t of mined ore: $130

Annual profit: roughly $220,320.

Analyses of samples taken from seven boreholes in the Rwanagaza area between Thompson Quarry and Blue Reef showed that these prospects seem to be very promising small, medium-grade deposits. The same goes for the Hyena and Jay prospects in Mawe Meru area.

Other promising prospects like Sekenke, Kinyele, Papas and Malaia in the Sekenke area should receive more attention.

Revision of the Kapanga Group of veins revealed that veins no. 17 and 22 are convenient for small-scale mining.

According to the information gathered on alluvial gold in the Lupa Goldfield, only the upper parts of the beds, above the water level, have been worked out, whereas the largest quantity of gold is concentrated below the water table, right over the bedrock.

It is also obvious that economically viable gold reserves in the Saza area are not yet exhausted.

The known gold reserves at the Gap Mine might be successfully enlarged by drilling on the eastern and western flanks of the mineralized body, as well as to deeper levels. It is advisable, while working this deposit, to ensure additional drill-indicated gold reserves in the surrounding Nkutano, Ruth "C" and Maperi deposits.

Alluvial gold of economic interest at Sira deposit can support a large-scale dredging operation.

The banded iron formation in the Greenstone Belts has potential for large, low-grade deposits of gold and is completely untested. The iron stone in the Lupa Goldfield seems to be very promising for gold and silver mineralization and has not been given sufficient attention.

D. Recommendations

1. In selected areas of the main goldfields, such as Buhemba in the Musoma Goldfield, Geita in the South-west Mwanza Goldfield, Sekenke in the Iramba-Sekenke Goldfields, Magamba in the Mpanda Mineral Field and Saza in the Lupa Goldfield, research centres should be established.

The staff attached to each centre should consist of one economic geologist and one mining engineer. The Government will still have to rely at least in part on international staff, particularly for posts requiring experience and specialized knowledge. It should request the assistance of one of the agencies of the United Nations family in the recruitment of the international personnel.

The international staff of the centres should advise small-scale miners on geological conditions of deposits, instruct local staff and small miners in the best methods of developing ore deposits, and co-ordinate and conduct all field mining activities.

2. The country's educational institution designed to promote skills in the field of mining engineering should be strengthened. Fellowships should be sought for the training of counterpart personnel and sponsors for postgraduate or technical courses in mining engineering in overseas.

3. A gold consultant post should be established within the Ministry of Minerals or STAMICO. The consultant should be responsible for the preparation of investment projects according to relevancy of the deposits, including time-scheduling; site prospecting and probing; mine and plant design; selection of exploration technology and equipment; and negotiating and contracting the legal obligations in respect of the financing of projects.

4. Certain industrial activities should be centralized and the production of adjacent mines concentrated at selected sites in an effort to achieve the target of at least 30,000 t/month of ore. Each site should have a mill as well as cyanization and amalgamation plants. It is quite possible that, based on centralized plants, the numerous gold occurrences in these areas will lead to profitable mining operations.

5. Potential investors in joint ventures should be granted the mining rights for entire areas, e.g.: Buhemba area including Nyasenero, Kilamongo, Lonesome and Kejimbura; Majo Moto area; Geita area consisting of Geita, Buck Reef, North-east Extension, Ridge 8 and Lone Cone Mines; Rwamagaza area consisting of Thompson's Quarry, Blue Reef, Blue Reef Extension and Glass Reef mines; Mawe Meru area; Sekenke area; Bulyanhulo area; Magamba area consisting of Magamba and Eastern Vein mines; Saza area consisting of Saza, Razorback, Blacktree and Junction mines; Gap Mine area including Nkutano, Ruth A and C and Maperi and Ntumbi area. The owner of such an integrated concession would thus be in a position to co-ordinate and plan his prospecting, exploratory, development and mining activities on a long-term basis.

6. The Government should consider owning the technical equipment required in the selected areas, such as drilling machines or recovery units for alluvial gold, and lending them to small-scale miners.

7. The Government should further protect the medium and large deposits from illicit diggers, while encouraging small-scale miners to work a number of minor auriferous reefs with high gold content.

8. Some areas could be re-opened for small-scale mining by establishing co-operations of neighbouring villagers with a collective ownership of such prospects.

9. Gold dealers should be appointed in the selected areas, who would buy the gold from small-scale miners and sell it to the Government Bank.

10. The Government should seek financing by international organizations of all equipment to be imported from abroad and required to start a new mining policy.

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*Number in bracket refers to designation under which the report is deposited in the Mandini archives at Dodoma.

V. GEMSTONES

A. Present situation

The study is based on a large number of papers published on the raw material basis of the precious stones found in the United Republic of Tanzania, especially on the official conceptions presented in 1974 and 1977 by the Tanzanian Ministry of Water, Energy and Minerals, on the outlook of the Tanzania Gemstone Industries Ltd. (TGI), on unpublished reports of several foreign experts, and, last but not least, on a personal visit to the precious stone deposits and the gem industry.

The Tanzanian territory is abundant in high-quality gemstones. Outstanding among them are some unique minerals occurring solely in this region and highly appreciated world-wide, such as tanzanite, tsavolite, annyolite and others. A number of prospectors and private enterprises have been engaged in the mining and processing of this commodity. Particularly at the end of the 1950s and during the 1960s, their activities were continuously expanding in relation to an ever-growing demand for these stones. The objects of their interest were the Longido annyolite deposit; garnets in the Massai District and Pare Mountains; rubies and sapphires in the Lushoto District; tourmalines occurring in the Tanga-Arusha region; chrysoprase found at Itiso and other claimed occurrences. At the same time, private cutting companies were being established: one at Moshi (1961), another at Dar es Salaam (1968), two at Arusha (1970) and others. However, the boom brought along some negative features as well. No later than at the beginning of the 1960s, the Tanzanian authorities tried to obtain a full picture of the activities of these companies, particularly of their mining production, purchasing, cutting, sales and exports. Efforts were made to protect gemstone deposits against depletion, to thwart their unjustified exploitation, to stop illegal export of gemstones, and to set up an administrative system for a central control in this field. These tendencies resulted in the "Act to Provide for the Protection of the Gemstone Industry and the Establishment of a Gemstone Marketing Department for the Purpose of Encouraging and Promoting the Gemstone Industry in Tanganyika" in 1967. This decree elaborated the general regulations of the Mining Ordinance so that they would extend to gemstones, and set forth the legal background of their prospection, mining, purchase, import and export. An agency controlling the gemstone trade was established (Gemstone Marketing Department led by the Director of Gemstones), as well as a ministerial body whose task was to solve legal and organizational issues of the Tanzanian gemstone industry (Gemstone Industry Advisory Board). At the same time, operating principles of these bodies were set forth.

In 1969, "The Gemstone Industry (Development and Protection) Regulations" were issued which represent executive instructions of the above-mentioned Act.

In 1970, the Director of Gemstones was appointed. He granted mining licences to six companies and to one company having no mining claims but a consulting office at Arusha for providing financial and technical assistance to small-scale miners. Three companies were granted licences for purchasing gemstones, other three for purchasing gemstones only for their own cutting shops. Two firms were charged with the export of gemstones.

However, the Tanzanian Government took over the gemstone industry no later than in 1971.

The Gemstone Marketing Department was established at Dar es Salaam who first elaborated the "Gemstone Policy", a long-term concept for the development of this industry. Firm and regularly revised purchase prices for gemstones were introduced, the purchase of gemstones organized in special centres and a central system for licence and claim granting and administration established. In this period, much work was done to protect gemstone deposits against ruthless depletion and to fight illegal trade and smuggling of gemstones.

TGI, a state company, was established at Moshi, and took over the four largest operating gemstone deposits in the country - Umba, Longido, Manyara and Merelani. The company gradually succeeded in taking over most of the processing capacities as well. Having built its own cutting plant at Moshi in 1975, it processes at present up to 90% of the total gemstones, the remaining part being processed in private cutting shops at Dar es Salaam, Tanga and Arusha. However, the latter generally deal in souvenir production and have to buy the raw material from TGI.

The realization of these undoubtedly correct measures, however, brought a number of problems resulting in a general decrease of the gemstone production, (see table 7) particularly a decrease in purchases, and even in a temporary closing of some nationalized mines.

Table 7. Gemstone production in the United Republic of Tanzania, 1964-1981

Year	kg	Year	kg
1964	9,195	1973	4,965
1965	not available	1974	870
1966	not available	1975	340
1967	7,680	1976	295
1968	15,620	1977	130
1969	1,030	1978	125
1970	920	1979	2,800
1971	1,570	1980	80
1972	1,045	1981	(1203)

In the experts' opinion the reasons for the decrease are serious and can be attributed to different causes:

(a) Insufficient attention is paid to the organized search for new deposits and the elucidation of principal geological features of the existing ones. Most of the deposits have no basic geological documentation. In principal, there is an inadequate generalization of features governing the occurrence of analogous deposits, which could lead to discoveries of new deposits, often near the known ones. There are neither enough specialists nor finances to cover such work. Any interest in a deposit is lost as soon as its reserves are exhausted; thus, perspective occurrences are frequently abandoned prematurely;

(b) In the mining field, the ignorance of geological features brings negative consequences. Frequently, there is no system in mining, this fact leading to the devastation of deposits. As a result, efficient mining methods are difficult to employ at such surficially devastated deposits. Small-scale miners generally do not have adequate technology; such deposits are mined by primitive methods, with huge production losses, without any basic technological processing procedures. At large nationalized deposits, the technical equipment has not been renewed for many years, it is old and often it cannot be used at all due to a lack of spare parts. The low mining efficiency is further decreased by proliferous administrative staff and the lack of skilled workers;

(c) As far as the purchasing of gemstones from miners is concerned, there are numerous problems as well, although these producers have been the most important source of gemstones in recent years. In particular, purchasing agencies do not have enough money to buy all offered gemstones. Therefore, a part of the production disappears and is illegally exported. The selling party, mainly small-scale miners, is interested in getting deficient goods (soap, flour, oil etc.) in exchange for its gemstones;

(d) Sparse is also the network of purchasing centres. There are transport difficulties and it is often disadvantageous for miners to carry gemstones to distant centres, particularly if an illegal purchaser comes to the very deposit, thereby having an opportunity of picking out the best raw material;

(e) Gemstone processing and the manufacture of jewellery, slabs and cabochons meet many problems. The state-owned cutting plant at Moshi does not have a sufficient capacity, its technical equipment is aged and inadequate. The raw material is not processed in a complex way, although terrazzo manufacture has recently been introduced. The jewellery models reflect insufficiently national traditions of art crafts and culture. Therefore, the market lacks unique, typically Tanzanian jewellery and artefacts. It is also a pity that so little attention is paid to local decorative stones such as e.g., annyolites, which are unique even on a world scale. Bad is the situation also in quality control of cut stones which is far below the world's standards. Packing is equally poor. Private cutters therefore compete successfully with TGI, although they are not allowed to buy raw stones; their cut stones are frequently traded illegally. On the whole, it seems that a number of TGI executives suffer from insufficient experience and training in world's top cutting and jewellery manufacturing plants;

(f) The sale of gemstones, whether raw or processed, is very cumbersome. The private offer at the illegal market is far more flexible. Retail organizations are almost non-existent and the network of retail shops is very sparse. These shops do not deal in mineralogical samples which - accounting for the uniqueness of some Tanzanian varieties - would certainly arouse great interest, nor in souvenirs drawing from the local cultural tradition. The price of gemstones is often set at random by shop assistants who do not respect the official price list. This observation has been confirmed in practice. No certificates are issued when gemstones are bought, which would attest to their genuineness and provide data on the locality, cutting shape etc. guaranteed by the TGI. The price does not include customs fees and the export licence must be applied for only after the gemstone has been bought. Generally, the sale system including the hard currency manipulation is very complex and the retail sale is virtually impossible since it takes two days to buy a gemstone.

The whole system would require a thorough analysis. In the recommendations only some basic measures are proposed that should increase the efficiency and, in particular, improve the final effect of the exploitation of Tanzanian gemstones on the national economy.

B. Raw material base of decorative stones and gemstones

There are some hundreds of known occurrences of gemstones in the United Republic of Tanzania. Therefore, it is attempted to provide only a schematic information on principal gemstones, their geological setting and an orientative localization of deposits which might be economically important in future.

Rubies and sapphires

Rubies and sapphires are represented by three principal genetic types:

(a) In intercalations of coarse-grained, dolomitized limestones of variable dimensions and thicknesses. Contaminated parts of these limestones usually contain tiny crystals of rubies, tourmalines and spinels, often opaque and irregularly developed. They are mined only in alluvial fans at feet of limestone reefs. Deposits of this type are found at Handeni, in the Bagamoyo District and at several sites in the Umba Steppe;

(b) In amphibolite massives in the northern part of the United Republic of Tanzania, one finds locally layers of green-coloured rocks composed of chromium zoisite, amphibole, plagioclase and occasional pink ruby which are called annyolite there. The ruby forms flat-shaped crystals parallel to foliation planes, in massive annyolites even several centimetres long; the quality of those isometrically prevalently opaque crystals is variable. They are mined at Longido and there are several similar occurrences of rubies of a poorer quality, mostly in Massailand;

(c) In serpentinite massives of the Usagaran Series in the vicinity of the Umba River, a number of lenticular-shaped bodies of plumasitic pegmatites (sometimes vermiculitic) containing blue, blue-green, sometimes black sapphires and transparent, red-coloured rubies are found. Their quality is excellent. They are mined mostly in alluvial fans, their characteristic features being a zonal colouring and diachroism. The principal deposit is the Umba River.

Tanzanites

Tanzanites are a precious variety of zoisite. Their outstanding feature is a beautiful blue colour and a distinct pleochroism. For these qualities, they are valued higher than diamonds. So far, only a single deposit has been discovered in the country, stratigraphically falling within the upper part of the Usagaran Series represented there by regionally metamorphosed, varicoloured sediments recrystallized into a cyanite-almandine subfacies. The deposit is a part of a gneiss belt surrounded from both sides by crystalline limestone. It is composed of longitudinal reverse fault zones unconformable to foliation directions, in the vicinity of which the rocks underwent an intensive hydrothermal alteration. The mineralization of these fault zones is simple - quartz, graphite, pyrite, zoisite, occassionally tanzanite. The Merelani deposit is mined by surface methods following irregular, gemstone-bearing zones and patches of tanzanite.

Zircones

Zircones come from two principal sources:

(a) Brown-coloured, tetragonal zircone crystals are found in vermiculite lenses with apatites in the Usagaran Series gneisses, or are related to marble intercalating the amphibolitic gneisses of the same series. Genetically, they may be related to carbonatite penetrations occuring near a tectonic line north of the Usambara Mountains;

(b) Small zircone occurrences are related to gravels of kimberlite pipes found in the Singida region. The zircone grains are translucent, golden-yellow to golden-brown, associated with pyropes and picroilmenites. Generally, they can be classified as falling into the jewellery-grade gemstones.

Emerald

Emerald is related to the pegmatites of the metamorphic Usagaran Series occurring near the Manyara Lake. There are two major strike faults: the first one running east-west is found south of the mine, the second one has the same direction and is situated at the northern boundary of the area under study. Some of these pegmatites contain small amounts of chlorite and varieties of beryl and garnet. The raw material has been mined since 1970 by the Manyara Emerald Mine; in 1976, the mine was taken over by STAMICO.

Tourmalines

Tourmalines of various colours have been found and exploited in a number of sites, mostly in alluvial fans. Primary occurrences have been reported at Handeni where green-coloured varieties are found. Beautiful, emerald-green tourmalines are dispersed in graphitic schists of the Umba Steppe at Daluni where they are mined from alluvial deposits. Yellow-coloured tourmalines have been discovered in the Uluguru Mountains.

Topaz

Topaz is known from cyanite-enriched lenses found in the Usambara Mountains granulites.

Garnets

Garnets are reported prevalently from the Usagaran Series metamorphic rocks which are in some places extremely rich in this mineral. Their source are also meta-anorthite massives of the western part of the Uluguru Mountains; sometimes, they have originated from pegmatites or kimberlite pipes, particularly on the Central Plateau. Garnets are found everywhere in the United Republic of Tanzania; in many sites, they are mined from alluvial fans or alluvial deposits; in the latter case, the grains are smaller and more rounded.

Principal garnet deposits are concentrated in the following regions:

(a) In the Massai and Lindi Districts, pyropes are occassionally mined in deluvial deposits. The deposits are represented by slightly weathered gneiss, the local garnet variety is represented by pink-coloured pyrope, rich in almandine. Especially the garnet of the Lindi District deposits is of an extremely high quality;

(b) A number of garnet occurrences have been reported in the Pare Mountains. Their productive substance is represented by gravels and sands of low thicknesses overlying the slightly weathered Usagaran Series gneisses. The areal setting of the deposits is very irregular but their garnet contents are high. A part of the raw material represented by red-coloured garnets of darker shades is usable in the manufacture of jewellery. However, most of it can be used only as abrasives;

(c) In the Central Province, garnets are known to occur in the Mwapwa District, in the Nyarumba Mountains. Their source are eclogite massives. The garnets are of a pyrope-almandine type, falling within lower quality categories;

(d) In the Uluguru Mountains, garnet eluvia are quite frequent which are very rich in jewellery-grade garnets. The garnets are mined in several deposits;

(f) Of an extraordinary interest are the occurrences of chromium-vanadium grossularites of a very striking, emerald-green colouring, for which the term "tsavolites" has been commonly used. These garnets were discovered in 1979 near Kilimandjaro and the zone of their occurrences stretches to neighbouring Kenya.

Turquoises

Turquoises are found in mineable quantities in the mantle of weathered rocks of the copper-bearing, mafic massif at Dodoma. The local "Gerevi turquoise" is of a vivid, blue-green colour and is a favourite among jewellers.

Quartz and siliceous materials

These materials are represented by extra-ordinarily rich concretions of crystalline, varicoloured quartz varieties, quartzites, cryptocrystalline chalcedonies, agates and opals. Rock crystals, smoky quartzes and citrines are found in some quartz veins and in pegmatites, rose quartzes form pegmatite cores in the Uluguru Mountains, ametysts are reported to occur particularly in the Handeni District pegmatites and in several other pegmatite bodies. Avanturine quartz is found at Rabati and in the vicinity of Naberera, crocydolite (blue-coloured, silicified asbestos) is reported from the Itisi Massif and from the western part of Serengeti. Up to several centimetres thick veins of green-coloured chrysoprase of an outstanding quality occur in weathered silicified serpentinites at Itiso, along with common and greenish-coloured opal varieties. Similar opals are found in the Usambara Mountains as well. A belt of agate nodules about 130 miles long has been reported from the Kigoma region. Varicoloured jades are related to altered tectonic zones of the Nyazia Series rocks in the eastern part of the Lake Province. Similar materials are related to the skarnized marbles of the Usagaran Series in the eastern part of the country.

One could give a list of many other occurrences of rhodonite, malachite, scapolite, olivine, amazonite and others whose importance has not been stated in detail so far. These gemstones are occasionally mined and marketed as well.

C. Conclusions

The Tanzanian gemstone raw material base can be considered rich. Provided that proper use is made of it, the base could be an important factor in improving the economy and living standard of the United Republic of Tanzania, maybe not so much on an absolute scale but taking into account the low initial costs inherent to its exploitation, the high return of investment rate and the effectiveness of the realization of the whole concept.

Much work has been done to ensure a sound exploitation of raw materials since the 1970s. The Government has established a raw material policy and related measures were carried out purposefully, in accordance with a long-term concept. Central organizational and legal systems have been established and there exist organizations which are to execute the accepted principles. The system extends as far as the final product. There are regulations concerning the protection of deposits and preventing illegal mining, processing and particularly the sale of gemstones. It is understandable that in solving such a complex problem some slips happened which were pointed out in the first part of this chapter. Their principal cause is a lack of skilled experts in all fields concerned, but mainly on the lowest level of mining, processing and sale. However, the gemstone industry authorities are well aware of these problems and attempt to solve them, as testified to by a number of recent projects aimed at improving the situation. In this respect, the good and purposeful projects of TGI at Moshi should be particularly appreciated.

D. Recommendations

Recommendations to the Tanzanian authorities

Geological survey

1. In co-operation with foreign experts, a project for the long-range exploitation of the Tanzanian gemstone raw material base should be elaborated, which would consist in: collection and dissemination of information on gemstone and decorative stones; prospecting for these raw materials and their technological evaluation up to the final product stage; elaboration of the geological documentation of deposits which either have been mined or are to be mined; assistance to small-scale miners through expert consultations. The execution of this project should be entrusted to Wizara ya Madini.

2. UNIDO should be requested to participate in the financing of the project and to provide two specialists, a geologist and a gemmologist.

Mining

3. One employee of the State Mining Corporation should be responsible for following-up the problems of gemstone mining and processing. This person should supervise the activities of TGI, monitor the observance of mining regulations, particularly by small-scale miners, and have the State Maintenance and Consulting Service at his disposal.

4. A State Maintenance and Consulting Service should be established within the State Mining Corporation which would provide financial assistance, technological and mining consultations, mining equipment and simple processing machinery. The assistance would be reimbursed by a part of the gemstones produced.

5. Large nationalized mines should be offered to foreign companies for joint ventures, granting them a share in the production. In such joint ventures the applicable jurisdiction should be observed.

Purchasing

6. The network of purchasing centres should be expanded and it should be ensured that they maintain an operative contact with the miners. They should be provided with the necessary means to purchase all offered gemstones which would make the sale to state-controlled purchasing centres more attractive. The purchase of gemstones by mobile units directly at the deposits should be considered.

Processing

7. TGI's cutting plant at Moshi should be provided with technological equipment and skilled labour in such a way that it could completely take over the processing of gemstones and decorative stones. The remaining cutting shops should be closed and semi-finished products (cut stones) sold to souvenir and jewellery manufactures.

8. The Jewel Design Department should concentrate on the design of unique, specifically Tanzanian jewels, drawing from national cultural and craft traditions.

9. The qualification of TGI's employees should be improved through courses and practical training at the world's top cutters and jewellery manufacturers. A more favourable rate of productive versus administrative labour should be achieved and the packing design improved.

Sale

10. The existing sales system, particularly the retail should be reorganized in the following way:

(a) The network of shops, especially in the tourist centres. should be extended, and offers improved;

(b) The sale assortment should be increased and include mineralogical samples, typical Tanzanian jewels and hand-made slabs and cabochons;

(c) Each sold gemstone should be accompanied by a TGI certificate containing all data the customer might be interested in. The certificate could at the same time serve as export and customs licence;

(d) Price lists for gemstones should be available in the shops, both in TSh and in convertible currencies. The shop assistants should be able to accept hard currency. The price should include customs fees, when the payment is made in hard currency;

(e) The shops should be equipped by a proper instrumentation for the determination of gemstones and their quality control.

Recommendations to international organizations

11. The following assistance should be extended to the Tanzanian party in the elaboration and execution of the project aimed at the assessment of the gemstone raw material base:

1 geologist for five years

1 gemmologist for five years

$500,000 for the period 1983-1986

12. Further assistance should be given to the Tanzanian party in the realization of mining and processing measures within the framework of the TGI bead-making project:

4 mining engineers for five years

4 gemmologists for five years

1 jewellery designer/modeller for five years

2 cutting instructors for five years

Machinery and equipment valued at $200,000

Training fees for courses abroad $100,000

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VI. GYPSUM

A. General remarks

At present gypsum deposits of inferior quality are exploited in the United Republic of Tanzania, while high-grade gypsum deposits are so far untouched. Products requiring a high-grade raw material must be imported, and the quantity of such imports will even increase in the near future although the country could become an exporter of those goods.

B. Gypsum and anhydrite deposits and their utilization

Two main gypsum and anhydrite deposits exist in the country: the mbuga type and the evaporite type.

Deposits of the mbuga type originated in the soil profile of those parts of the mbuga deposits, where the flow of soil solutions was reduced to minimum and where evaporization gained absolute prevalence, and where at the same time these fluids contained both Ca^{2+} and SO_4^{2-} in adequate quantity. Mbuga designates the undrained parts of the seasonally drying swamps. At small depth, approximately from 0.5 to 1 m below the surface, occurs a horizon about 2 m thick in which gypsum concretions and beds originate, of which about 30 to 50 cm have such a gypsum concentration that they form a deposit. Though of considerable areal extent, the deposits of this type have generally small reserves. The quality of the raw material is low and unstable; at the utmost, the gypsum content is around 70% in sorted concretions which often have a high SiO_2 content. The raw material is therefore only suitable for the production of cement and for agricultural purposes.

The deposits of the mbuga type have two subtypes differing only in the origin of the parent rock in which the gypsum horizons subsequently formed. The first subtype, represented by the worked Mkomazi locality, originated in lacustrine sediments, the second subtype, represented e.g. by the Itigi locality, originated in sediments and residues of different origin.

The deposits of the mbuga type occur in a greater number and they are concentrated in three regions, especially in the north-western and central parts of the country (the Same and Lusotho Districts, the Manyoni District (Itigi), and the Mpwapwa District (Msagali)). For details refer to the works of J.F. Harris (1961), V. Cilek (1970), J.C. Malango (1969), W.Y. Balindile (1979), and others which are given in the bibliography. The richest deposits of the mbuga type are located in the Pangani river basin, between the towns of Same and Mkomazi. Near Mkomazi is also the only to date exploited deposit which is worked only part of the year according to the needs of the cement-making factories at Tanga, Dar es Salaam and Mbeya. The mining method (haphazard mining) is very primitive so that productivity is very low. Likewise the quality is poor which is partly due to the fact that apart from manual collecting of concretions, no additional treatment is applied to the extracted raw material which, however, would be superfluous for cement production. The quality of the raw material is almost not controlled. The mining method leads to a low extraction rate and to great losses on mining and therefore, to a certain extent, to the devastation of the deposit. As a rule, the geodetical documentation of mining is lacking. This also applies to the today abandoned localities like Itigi. An improvement could be achieved by mechanized quarrying with subsequent sorting of the material extracted, preferably by washing. This would considerably increase the rate of production, but, on the other hand, there is at present no equivalent consumption.

The deposits of the evaporite type are concentrated in Jurassic marine sediments in near-shore regions between Kilwa and Lindi. They consist of high-quality gypsum beds, locally of as much as 96% of gypsum, which alternate with shale and limestone. These rocks crop out in a number of places in the cores of two parallel anticlinal structures in the Pindiro and Mandawa regions. Essentially, these structures are diapiric rock salt domes capped by a gypsum and anhydrite arc, at least 150 m in thickness, but perhaps even as much as over 280 m (according to the BP-Shell Co. Ltd. boreholes). Numerous deformations of the beds, irregular folds and faults are also due to diapirism.

The gypsum deposits are genetically connected with the underlying rock salt deposits; one of the BP-Shell boreholes terminated at the depth of over 3,000 m without encountering the rock salt substratum.

The utilizable raw materials from this group of deposits are the following:

(a) Shales, presumably suitable as a component for cement making;

(b) Gypsum for all purposes. The quality of the raw material is suitable for numerous industries (cement factories, building industry, ceramics etc.) and it could also be exported. Cheap surface mining is possible;

(c) Anhydrite. Its quality is not known. It might be worked by the room and pillar method. Its utilization is conditioned by cheap energy;

(d) Rock salt. According to the analyses, its quality is excellent and its reserves are great.

In the available studies the reserves have not been appraised; it is only stated that they are great. The Pindiro deposit is estimated by Harris (1961) at 52,500 t per 1 m of depth. The experts have therefore made a very cautious estimate of the lower limit of the quantity of the resources. According to the published reports and data from boreholes, the thickness of the deposit body is about 40 m, of which 20 m contain gypsum of a grade of 70% gypsum or more. If one considers that the area of each of the three deposits (Pindiro, Mbaru, Mkomore) is only 1 km^2, the specific gravity of gypsum is 2.32 g/cm^3 (rounded to 2), and the total extraction rate of the deposit 0.5, then it is possible to obtain: $3,000,000\ m^2 \times 20\ m \times 70\% \times 2\ g/cm^3 \times 0.5 = 42$ million t of extracted gypsum as a minimum.

To attain an optimal utilization of high-grade layers, selective mining followed by processing (crushing, sorting) preferably on the spot is an essential prerequisite. The question of further treatment of this raw material must be solved not only on the basis of costs, but also, in view of the employment rate of the population, electric power sources etc.

C. Recommendations

1. To satisfy the present demand of the cement-making factories at Tanga, Dar es Salaam and Mbeya for gypsum as a regulator of the setting time of cement, for which the only source today is the deposit of the mbuga type at Mkomazi, it is recommended that the Government continues to make use of that source until the time when the exploitation of evaporites in the Nondwa-Pindiro region will commence. The methods so far applied could be used on the hitherto worked localities and on small deposits of the mbuga type which sofar have not been opened. This hitherto applied method of mining, which depreciates at least 60% of the raw material, should, however, not be allowed for not yet opened deposits, in case their reserves are over 3,000 t, i.e. deposits, where it would be possible to apply effective and economic mining methods with a higher extraction rate.

2. For the long range it is recommended to utilize the evaporites in the Nondwe-Pindiro region, i.e. the Pindiro, Mbaru, and Mkomore deposits, where the geological and technological exploration need to be completed and a study elaborated giving detailed further procedures. At the same time, the separate utilization of gypsum prior to the utilization of rock salt in its substratum may also be considered. In contrast to the costly construction of a chemical industry based on rock salt and the requirements on the infrastructure connected with it, the utilization of gypsum would be relatively unexacting and cheap, and it could be fairly quickly realized. Moreover, the means invested would be quickly returned. It is further recommended that the high-grade types of gypsum (above 85%) be exploited selectively, so as to separate the raw material for the production of the most valuable plaster types for domestic consumption and in the future also for export. In the initial phases a simple mining equipment would suffice, which would work throughout the year, and small-scale, undemanding production facilities (crusher, sorting machine, grinding mill and kiln) which would process the annual output during the dry period. In that case the present-day communications and seasonal transport by motor trucks would suffice. The expansion of production and the perfection of the infrastructure should be accomplished gradually after the running-in of the production and market penetration. The presently extracted low-quality types of the raw material would substitute the gypsum for the cement-making factories at Mbeya and Dar es Salaam, which has so far been imported from deposits in the north of the country (Mkomazi). The future supply to the cement-making factory at Tanga can not be judged, the main factor obviously being the costs of transportation.

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*Number in bracket refers to designation under which the report is deposited in the Mandini archives at Dodoma.