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INDUSTRIAL UTILIZATION OF NON-METALLIC MINERALS, BELGRADE*

DP/YUG/73/003

YUGOSLAVIA

Terminal report

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

Based on the work of Michael H. Buckenham,
expert in phosphate enrichment

United Nations Industrial Development Organization
Vienna

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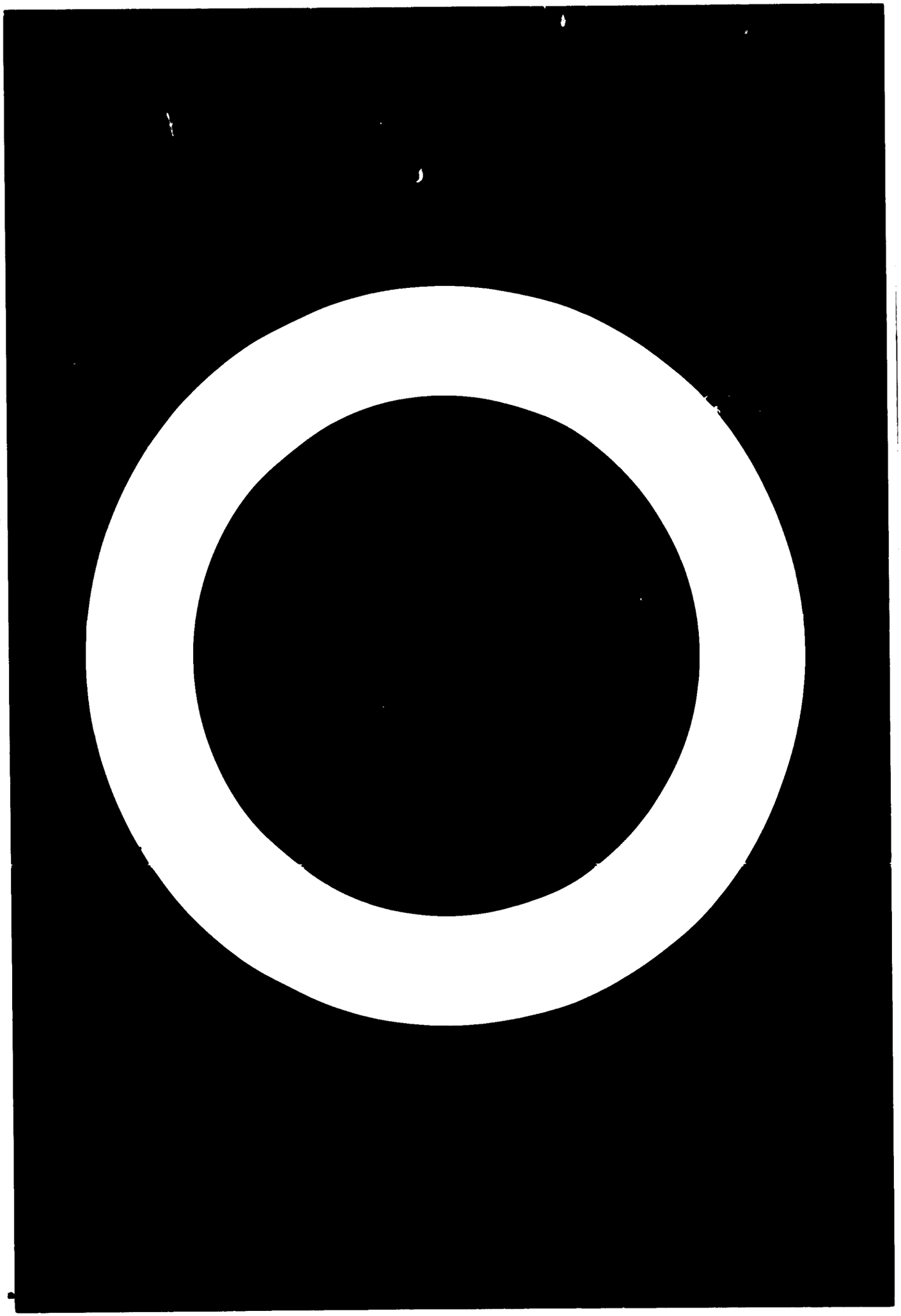
ABSTRACT

Yugoslavia's need for an indigenous source of phosphate rock on which to develop and expand its phosphatic fertilizer industry is obvious. The Lisina Technologiju (ITNDMS) is working and could meet this need at least in part. It is therefore concluded that the Institute should continue with its investigations extending them in particular into product evaluation work and economic assessment.

In this Terminal Report prepared after a brief stay in Yugoslavia, work proposals on the Lisina phosphate project are made together with some more general recommendations relating to the work of the Institute and on how UNDP/UNIDO may most usefully continue their contribution in the future.

Specific details of proposals/submissions are contained in five reports (Refer Appendices 2 - 6) prepared for internal use at ITNDMS during the period of 1 to 27 December 1977 over which the expert was at the Duty Station.



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I. INTRODUCTION

1. Preamble

The specific assignment "Expert in Phosphate Enrichment" formed part of a wider UNDP/UNIDO Project, "Industrial Utilization of Non-Metallic Minerals" under which experts for Clay industries (S. Sen) and general Non-Metallics (K. Engelthaler) have already worked at the Institut za Technologiju Nuklearnih i Drugih Mineralnih Sirovina, (ITNDMS), Franse Deperea 86, Belgrade for extended periods.

The Job Description dated 31 March 1977 (Appendix 1) related specifically to assistance in the assessment of the Lisina-Bosiligrad phosphate prospect in particular with reference to enrichment and overall evaluation.

The expert reported for briefing in Vienna on 5 December at which time the Terms of Reference as detailed in the Job Description were endorsed but it was indicated that a contribution over a wider field would be welcomed. Departure for Belgrade was on 7 December and introductions were completed at UNDP office and at the ITNDMS the following morning.

Following discussions with Mr. Zogovic and Mrs. Pupezin, Directors of the project, it was clear that phosphate work was not currently of high priority at the Institute and assistance in other areas was therefore requested. As it was not possible to visit the phosphate field site (Lisina) or the fertilizer production site (Prahovo) and reports of an economic nature could not be made available to the expert, the phosphate prospect was appraised as fully as possible (in view of its major economic importance to Yugoslavia) and other duties were undertaken in the remaining time available (See Reports - Appendices 4,5 and 6).

This report and the internal reports prepared for ITNDMS indicate the areas of involvement of the expert during his brief stay in Belgrade and present specific and general recommendations together with general observations on the continued development of ITNDMS with the support of UNDP/UNIDO.

The expert departed Belgrade on 27 December after just over two weeks at the Duty Station leaving hand written copies of all reports at ITNDMS and a hand written copy of this report with Mr. Renart (Resident Representative) with whom the expert had the opportunity of discussing his work and the on-going nature of the project "Industrial Utilization of Non-Metallic Minerals".

2. Project Background

The Lisina-Bosiligrad phosphate has been known and investigated for nearly 20 years and a very considerable amount of data are available concerning its assessment and development. Although the logistics in relation to utilization may be unfavourable and the current incentive to develop lacking this deposit at current prices for importing phosphate rock is of major economic importance to Yugoslavia importing about 1.3 million tonnes of rock per year for fertilizer (SSP, TSP, NPK) production.

While ITNDMS has completed detailed laboratory investigations and 1 tonne/hour pilot plant production and some work has been done on the production of fertilizer/acid in France, the project sponsor RTB-Bor requires a higher concentrate grade (reported by 38% P_2O_5). At this stage straight forward technology has achieved a grade of about 35% P_2O_5 at 85% P_2O_5 recovery.

The economics of development have been determined and the higher grade of concentrate demanded apparently arises from freight considerations as the mine site is some 70 kilometers from rail and then a further 400 kilometers from the fertilizer works. This enhanced enrichment is thus the current job requirement of ITNDMS.

3. Project Objectives and Achievements

In brief, the job requirement was to review available reports and technological data on the Lisina-Bosiligrad phosphate project investigated by ITNDMS for RTB-Bor to establish:

(a) the 'ore' quality and extent

(b) the adequacy of the work already undertaken in terms of characterization and beneficiation of the 'ore' in relation to utilization

(c) the economic viability of development and a plan of action for commercialization

In addition as time permitted to contribute to the work of ITNDMS in other areas of technological and economic competence/experience.

As field visits to Lisina and Prahovo were not possible and economic data was not available a comprehensive evaluation was not possible. However, subject to reserves being substantiated and production technology being adequate, it was concluded that this project was of major economic importance to Yugoslavia and the most important in which ITNDMS was involved.

A second phase programme for ITNDMS incorporating fundamental work, economic assessment, product evaluation and plant improvement was recommended. This was proposed as it was not considered that further enrichment of concentrate was the most important current need.

In addition, numerous reports on economic, technical and information subjects were prepared and detailed matters will be followed up at the conclusion of the assignment.

In summary, a good feel for the work and needs of the ITNDMS was obtained, excellent co-operation achieved and positive progress made towards all objectives. It is expected that the Institute will benefit from the visit of the expert and that a more realistic and better overall approach to the phosphate and other projects will be possible as a result of discussions and recommendations.

II. PROJECT DUTIES AND FINDINGS

1. Reserves

The Institute for Geological and Geophysical Research (GEOZAVOD) responsible for the discovery and assessment of the Lisina deposit indicate the presence of approximately 40 million tonnes of 'ore' averaging from 9 - 12% P_2O_5 in a continuous bed from 2 - 10 meters thick. The deposit is apafite in a metamorphic sandstone lying between and grading into granite below and sericitic-chloretic schist above. The presence of marble intercalations within the phosphate horizon, faulting in some locations, variability in grade across the phosphate and changes in carbonate and oxide contents suggest some problems in what otherwise would appear to be a straight-forward underground mining operation.

Within the immediate area between Lisina-Bosiligrad outcrop and gallery sampling and core drilling appear to be sufficient to delineate the 'ore' in this area and to meaningfully assess it in terms of grade and extent. Additional surface exploration in the surrounding areas has indicated a significant extension of the deposit (similar in grade and character?) and therefore sufficient reserves to sustain a long-term large-scale development are indicated.

Insofar as some few thousand tonnes of 'ore' have been extracted for pilot plant beneficiation trials, it may be concluded that the results obtained in this work are applicable to both a practical mining and beneficiation situation.

It was concluded following discussions that the 'ore' definition was not in need of refinement although it did appear from a beneficiation/utilization point of view run of mine grade and carbonate/phosphate ratios would be critical factors.

2. Pilot Plant Investigations

Laboratory and subsequent pilot plant work have yielded concentrates about 32 - 33% P_2O_5 and on occasions, 36% P_2O_5. The contained apatite is expected to contain up to 40% P_2O_5. These results suggest up to

3% of impurity in the concentrates produced. Recovery throughout the work has been high - in the order of 85% of the P_2O_5.

While a practical/economic solution to the removal of silica and carbonate dilutants from concentrate may not be possible, numerous proposals have been made for further work including more detailed mineralogical work, anionic/cationic flotation and calcination (Report DP/YUG/73/003/11-02/MGB/2).

In the opinion of the expert, the beneficiation work is impressive and follows conventional and therefore economically attractive lines. The stated directive from the project sponsors RTB-Bor of obtaining a 34% P_2O_5 concentrate grade appears unrealistic and if obtainable, is only so at a sacrifice in P_2O_5 grade and/or as a consequence of much more complicated processing technology.

The major conclusions from studying the available reports are that more needs to be done in the fertilizer/acid manufacturing area (some encouraging work has been done by Pechiney in France) and that a rigorous economic evaluation of the total project is required.

3. Beneficiation Investigations

The beneficiation work completed includes detailed chemical and mineralogical characterisation of the phosphate and considerable flotation investigation both at laboratory and pilot plant stage. Results in terms of phosphate/carbonate and phosphate/silica selectivity are considered good. In view of the results obtained to date and an indication that with time, the pilot plant separations were improving, it is considered that refinement of beneficiation technology would be most profitably studied as a plant improvement programme.

The most comparable phosphate rock deposits with which to assess the Lisina rock would appear to be those apatitic deposits of Russia (Kola, Kara Jau), South Africa (Palabora) and Brazil, all of which are relatively low grade and utilized following beneficiation by flotation. While available literature would suggest the Russian deposits may be upgraded from 18% to 38% P_2O_5 (only 25% in some cases), the South African from 5 - 10% to 35 - 37% and the Brazilian from about 5% to 36%,

direct comparisons must be made with caution for obvious reasons. Therefore, the P_2O_5 response in the Lisina work can be equated with that of the more important world apatite deposits. However, in view of reported success in phosphate carbonate separation in Brazil, this technology should be sought.

Literature is not on hand to compare beneficiation technology although references are available on complex Russian flotation conditions in order to maximise grade (38% P_2O_5) acceptable for modified (developed) acid/fertilizer technology on a cost/benefit analysis.

4. Economics and Commercialization

While some supplementary lists on beneficiation have been proposed in order to better quantify the potential for upgrading the Lisina 'ore' and to better understand the nature of diluting components, the project, in the opinion of the expert, is in need of a rigorous economic analysis to establish its economic viability. At the same time, the factors to which the total development is most sensitive could be identified and quantified.

Subject to product evaluation and acceptance sufficient information would appear to be available to make this analysis and to compare indigenous production with the cost of imported rock delivered to the fertilizer works at Prahovo. While this has been done by RTB-Bor, it appears that the ITNDMS has a responsibility in this area in order to sell the development on the basis of economic viability. At the same time, it would be within the capability of ITNDMS to undertake product tests in the fertilizer/and production areas.

A simple model on which to base an economic evaluation has been prepared (DP/YUG/73/003/11-02/MHB/1) together with an on-going investigation which the Institute should follow to assist in commercialization. This includes fundamental work, product evaluation work, economic studies and a plant improvement programme leading to the utilization of Lisina concentrate at least in part as a feedstock for the RTB-Bor fertilizer plant at Prahovo.

The Institute has the facilities and expertise to undertake this work in a Project which appears to the expert to be the most important currently being undertaken by ITNDMS.

III. CONCLUSIONS AND RECOMMENDATIONS

1. Specific

(a) Subject to reservations stated earlier, the extent, quality and beneficiation response of the Lisina phosphate have been established sufficiently to suggest that this 'ore' could support an operation producing domestic phosphate in Yugoslavia.

(b) Beneficiation studies both small and pilot scale have been thorough and any significant improvement in product quality above 35% P_2O_5 is only likely to be achieved at a cost disadvantage. However, recommendations for further work have been made to quantify the potential of processing modifications and/or extensions.

(c) For overall evaluation and utilization purposes, the beneficiated concentrate must be assessed for fertilizer/acid manufacture and thus its utilization characteristics and value defined. It is recommended that this work should have priority over attempts to produce a 38% P_2O_5 concentrate which in turn is recommended as a plant improvement programme.

(d) The feasibility of developing and utilizing the Lisina deposit is in need of a rigorous economic appraisal and on-going refinement data on product value, capital requirements, mining costs, concentrate drying and handling, tailings disposal and general logistics etc. are obtained. The Discounted Cash Flow method of evaluation is recommended for this purpose.

(e) The work of ITNDMS particularly in beneficiation is of a high standard but extension of competence in the characterization, utilization, marketing and economic assessment of non-metallic minerals could be further supported/developed. This development would enable a less fragmented and better overall contribution to Yugoslavia's non-metallic resources development.

2. General

(a) The ITNDMS is restricted in the scope of its work as a result of its dependence on sponsored projects for funding. This unfortunately

precludes the initiation of independent projects fundemental research, product research and development and like activities so essential to the proper investigation of non-metallic minerals. It is recommended that UNDP/UNIDO consider sponsoring staff and/or work in these non-profitable areas.

(b) Should (a) be possible ITNDMS could profitably initiate new projects arising from the study of mineral/mineral based imports/exports, country needs and development plans, market surveys and replacement/substitution possibilities. At the same time, the undertaking of feasibility studies and economic evaluations is a logical development.

(c) Some of the sponsored projects being undertaken by ITNDMS appear to be directed at achieving technologically/economically unreasonable solutions. Pre-feasibility studies and Institute-industry discussion might resolve this problem and is consequently recommended. Alternatively, entry into the fundamental research field must be contemplated.

(d) While UNDP/UNIDO has already contributed to the improvement of laboratory and library facilities particularly in the fields in which experts have contributed and in inter-country travel, it is recommended that in future consideration be given to developing a broader and better intergrated approach to mineral projects. Nevertheless specific proposals for phosphate publications have been made.

Finally while these general observations may or may not be in conflict with those presented by other experts following more prolonged experience at ITNDMS, they are offered in the hope that they may contribute to the planning of the proposed extension to the project "Industrial Utilization of Non-Metallic Minerals".

IV. ACKNOWLEDGEMENTS

The expert acknowledges the co-operation and kindness of various staff members at the ITNDMS with whom association was necessary and/or possible, and in particular Mr. B. Zogovic and Mrs. D. Pupezin, Project Directors, and Dr. Vasiljevic ITNDMS, Director.

The UNDP staff is thanked for assistance in dealing with professional and personal matters during the assignment.

Appendix 1

JOB DESCRIPTION

DP/YUG/73/003/11-02/32.1.F

I TITLE	**Expert in phosphate enrichment**
D ATION	**Four weeks**
D REQUIRED	**As soon as possible**
D Y STATION	**Belgrade**
ES	**The expert will advise the Government of Yugoslavia by assisting the investigations in Belgrade on the up-grading of phosphate rock suitable for feedstock in the manufacture of phosphoric acid. Part of this work will also be carried out at the fertilizer factory in Prahovo Specifically the expert will be expected to:**

1. establish the extent of the known or explored phosphate deposits in Lisinia Bosiligrad and their uniformity of P_2O_5 analysis established by analysis available from existing records;

2. review the pilot plant work carried out by the Institute forTechnology for nuclear and other mineral raw materials for beneficiation or up-grading of the mined phosphate feedstock;

3. determine if the pilot plant work information is sufficient to establish a process for the beneficiation of rock and the up-scaling to a commercial process is feasible without further work and modifications;

4. evaluate if other known processes using flotation [illegible], etc. were tried or should be tried before establishing the most economic process for processing the phosphate rock. This appears to be specially

important because of the large percentage of silica present in the deposits;

5. determine if similar phosphate rock deposits were exploited elsewhere and what process or mineral dressing plant was used in the beneficiation process adopted for their exploitation;

6. recommend a plan of action to be followed before commercialization of this process can be realized.

QUALIFICATIONS — University degree in ore dressing, or technology or chemistry engineer with extensive experience in the enrichment of low grade phosphate ores and the technology for the production of phosphoric acid and phosphate fertilizers. Knowledge in technology and economic investigations to determine the most appropriate method of utilising the technical concentrate which contains 30 - 33% P_2O_5 for the production of phosphoric acid and phosphate fertilizers.

LANGUAGE — English

DESCRIPTION OF DUTIES — There are of several tens of millions of tons of phosphates at Lisina in Serbia, with an average P_2O_5 content of about 12%. Preliminary laboratory and small pilot scale trials have shown the technical feasibility of beneficiation of the 12% ore up to one containing 30 - 35% P_2O_5. Further technical and economic studies are needed to determine the most appropriate method of obtaining higher quality concentrates and utilising this material for the production of phosphoric acid and phosphate fertilizers in Yugoslavia.

Appendix 5

ASSIGNMENT REPORT DP/YUG/73/003/11-02/MBH/1 DATED 15 DECEMBER 1977

The Evaluation of Mining Projects using the Discounted Cash Flow (DCF) Method

The use of systematic evaluation techniques to assess mineral projects is necessary because of the inherent uncertainty in various aspects of mining operations. While numerous techniques are available for the economic and financial assessment of a mineral project the discounted cash flow (DCF) method has gained widespread acceptance in particular as it enables a true rate of return on capital, bearing in mind the time value of money, to be obtained and it enables the effects of variations in costs, revenue and other factors to be assessed quantitatively.

While many factors other than the direct financial return on capital invested influence decision making the significance of these factors can be conveniently incorporated into the DCF method of analysis to assist in the decision making process.

The method tends itself to the use of computer techniques for the rapid determination of return on investment, the quantifying of the influence of various project input variables (sensitivity analysis) and the incorporation of statistical data enabling levels of confidence to be associated with calculated returns (risk analysis).

Although formalised proceedures must be followed in some specific situations (Government directives) in assessing projects it is <u>recommended</u> that the DCF method be studied and applied within ITNDMS for evaluation of such projects as the Lisina phosphate one. Such an analysis can be carried out from the earliest feasibility stage and refined as more and more accurate input data becomes available.

No doubt much of the basic information required for such an analysis on Lisina phosphate is available and/or could be compiled a-long the lines detailed by Mr. Engelthaler UNIDO Expert in Annex No.2 of his Project Report on 21 February 1977.

As a model the following example is presented with the following conclutions prevailing:

<u>Scale:</u> Production 240.000 tons of ore per year yielding 125.000 tons of concentrate

Project file: based on 2 million tons of proven ore therefore 8 years

Capital investment: 249.700 million dinars

Mining cost: 179.06 dinars per ton of ore

Processing cost: 52.64 dinars per ton of concentrate

Capital investment over three years prior to production

Value of phosphate concentrate: 867 dinars per ton

The DCF analysis of this data shown in Table 1 establishes a Rate of Return of approximately 12% for the project as costed disregarding depreciation taxes, royalties and other inputs which must be included in a full DCF analysis. Alternatively this means that the project could service capital charges of 12% without yielding a profit.

Such analysis can be made incorporating various phosphate concentrate prices, increased concentrate recovery in beneficiation, modified mining and processing costs and different capital requirements and timing.

The effect of a number of these input changes has been calculated (approximately) by slide rule with the following conclusions:

1. At a lower phosphate price of 640 dinars per ton there is no return on the capital involved (i.e. DCF Rate of Return = 0%)

2. At the above mentioned price and an increase in the weight recovery of concentrate to 60% the DCF Rate of Return = 3.0%

3. Increasing mining costs by 25% to 223.83 dinars/ton and by 50% to 268.59% dinars/ton reduces the DCF Rate of Return from 12% to approximately 8.8% and 3% respectively.

4. The combined effect of phosphate weight recovery and price movements is shown in Figure 1.

Such an analysis shows the factors to which the project is most(sensitivity analysis) the most significant in this case being the value assigned to the phosphate concentrate. The analysis could of course equally well establish the cost of concentrate production using a return on investment (capital) as an input.

It is evident that the above type of analysis tends itself well to computer processing which not only allows computation of rate of return on in-

vestment but sensitivity and risk analysis effects particularly when statistical data is incorporated. Such analysis enables levels of confidence to be associated with expected returns and rapid re-evaluation of projects as additional or refined data becomes available during the course of project development.

Naturally the value of such an analysis depends on the validity of the data much of which has to be projected ahead for some years. Nevertheless the DCF method has universal acceptance and much to commend it as a practical method of establishing the economic viability of capital projects. This viability quantitatively measured in terms of expected profitability must of course, be tempered by judgement on such intagibles as the related geographical, sociological and political factors appertaining to the particular project under evaluation. It would be meaningful to apply such an analysis to the Lisina phosphate project.

The references listed below will assist in the development of the above introduction to the DCF method of evaluating mineral projects.

1. Miskelly and Willsteed (1969). The Evaluation of Mining, Projects Aus/MM Annual Conference, Sydney.

2. O'Brian (1969). Financial Analysis Applications in Mineral Exploration and Development. Trans AIME Vol 244 December.

3. Mackenzee (1970/1). Examining the Economics of Mine Development. Can. Min. Jul. Dec 1970 and Mar. 1971.

4. Harvard(1970). Mineral Project Evaluation. Mining Magazine Vol. 123 No.4.

Table 1. Discounted cash flow example (figures in millions of pounds)

Year	0	1	2	3	4	5	6	7	8	9	10
1. Capital	(112.0)	(100.0)	(37.7)	-	-	-	-	-	-	-	-
2. Mining cost	-	-	-	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
3. Processing cost	-	-	-	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
4. Returns	-	-	-	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
*5. "Profits" 4 - (3+2)	-	-	-	58.8	58.8	58.8	58.8	58.8	58.8	58.8	58.8
6. Cash flow	(112.0)	(100.0)	(37.7)	58.8	58.8	58.8	58.8	58.8	58.8	58.8	58.8
7. Cumulative	(112.0)	(323.0)	(239.7)	(180.9)	(132.1)	(73.3)	(14.5)	44.3	103.1	161.9	220.7
8. Cash flow Discounted @ 11%	(112.0)	(90.1)	(30.6)	43.0	38.6	35.0	31.4	28.3	25.5	23.0	20.7
9. Cumulative	(112.0)	(202.1)	(232.7)	(189.7)	(151.1)	(116.1)	(84.7)	(56.4)	(30.9)	(7.9)	12.8
10. Cash flow Discounted @ 12%	(112.0)	(89.3)	(30.0)	41.8	31.3	33.2	29.7	26.5	23.7	21.2	18.9
11. Cumulative	(112.0)	(201.3)	(231.3)	(189.5)	(152.2)	(119.0)	(89.3)	(62.8)	(39.7)	(18.5)	0.4

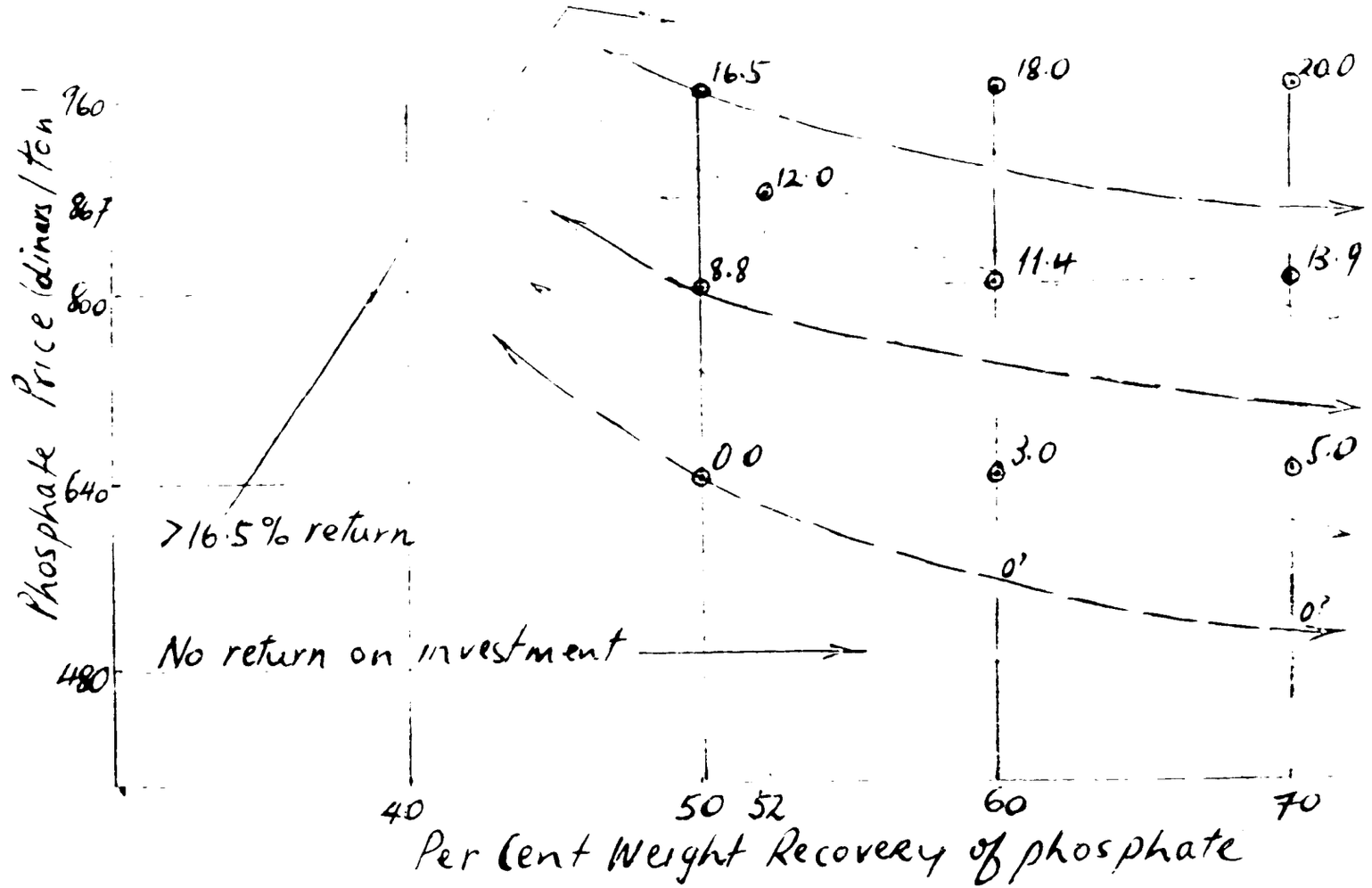
DCF Internal Rate of Return is approximately 12%

* Note: 5. "Profits" should involve a more complex calculation involving depreciation, taxation and other profit determining factors.

Figures in brackets ( ) negative

Discount valves obtained by $FV = PV \times \frac{1}{(1+r)^n}$, where r is discount rate and n is number of years

FIGURE 1 INTERRELATIONSHIP OF PHOSPHATE PRICE AND PHOSPHATE WEIGHT RECOVERY ON RATE OF RETURN ON INVESTMENT (FIGURES IN %)



Appendix 3

ASSIGNMENT REPORT DP/YUG/73/003/11-02/MBH/2 DATED 19 DECEMBER 1977

The Improvement in Grade ($\%P_2O_5$) of Lisina Phosphate Concentrates

Having examined technological reports on both laboratory and pilot plant work on the beneficiation of Lisina phosphate the following comments and recommendations concerning further work are made.

The work done by ITNDMS appears thorough and in view of the continuous pilot plant operations descriptive of what might be expected from commercialization of the established technology. The production of concentrate at from 35 to 36% P_2O_5 at about 85% recovery using a straight forward beneficiation approach supported by favourable fertilizer production tests indicates the need for a critical economic analysis to establish viability of utilizing the Lisina deposit.

However as a higher grade of concentrate (38% P_2O_5) has been requested by the sponsors of the project the following proposals are made on work that could be done by ITNDMS to establish if this is possible and if so at what additional cost.

1. Additional mineralogical work and chemical characterisation as necessary to ascertain the potential (maximum) for physical beneficiation and thermal improvement. Such work can at the same time elucidate other properties of economic significance. The basis for this evaluation is as detailed in the attached paper, "Phosphate Rock Characterisation" by G.H. McClellan and F.J.Klear.

2. Associated mineralogical and physical work on phosphate concentrates as produced, in particular to establish potential for upgrading. Reported analyses would suggest up to 20% of deluting material particularly in the form of carbonate and silica. The form and destribution of these delutants should be established by complete size fractionation followed by chemical and numeralogical analysis. As a consequence grade improvement by size separation could be quantified and investigated as could the practicality of other forms of beneficiation.

3. Direct calculation over say 600-900°C followed by washing before and after NH_4CL treatment to establish resultant loss in wieght and P_2O_5 upgrading. It should be noted that this treatment may adversely affect the subsequent response of the concentrate in utilization. (eq. Ref. Chem. Abs. Vol. 58 No. 4 Ref 3125A).

4. Combined anionic/cationic flotation in particular the removal of silica by cationics from the primary concentrate (c 35% P_2O_5). This however introduces processing complexities such as acid removal of anionic collector prior to further treatment.

5. Reconsideration of both the preparation (grinding) and separation (flotation) circuitry established in laboratory work and used in pilot plant work. It is considered that the circuits used in both these areas favour P_2O_5 rec rather than concentrate grade. Some analytical and numerological work on size fractions from grinding including antogenous may prove rewarding although bask numerological work is not encouraging.

6. The conducting of a release analysis evaluation as proposed initially by Dell (International Mineral Dressing Congress London 1953?) are refined in his subsequent papers. This work should establish a practical and optimum relationship between concentrate grade and P_2O_5 rec

7. In relation to 5 above concerning grinding investigate the significance of desliming on P_2O_5 losses and resultant flotation performance in particular with respect to grade, reagent demand and flotation rate.

8. In relation to 2 above and results from 4 above assess the effect of silica rejection resulting from concentrates size separation eg by hydrocyclone.

9. The investigation of some reagent modifications and changes in flotation procedures. The literature suggests many of these which could include (a) the use of Oilic acid emulsified with kekosene or fuel oil (b) the use of amonia for pH control and (c) the modification of pH prior to sodium silicate addition. (d) AC 700 series and (e) conditioning pulp density etc.

1.. More exhaustive flotation investigations following a literature search relating in particular to the beneficiation of low grade carbonate and silica bearing phosphate ores, particularly Brazilian experience (XII Int. Mineral Processing Congress, Aug. 1977 Sao Paulo Brazil - Phosphate Session).

In view of the character of the Lisina ore and the numeralogical data that is available, the detailed work done to date and the general tenure of concentrates produced it is unlikely that the above proposals will achieve technological/economic advantages. It should however better establish the maximum attamaker grade of concentrate and the relationship between grade and recovery.

It is suggested that it would be more profitable to investigate the suitability of the existing concentrates for acid/fertilizer manufacture and to establish processing technology and parameters for this purpose. At the same time it would appear to be more appropriate to undertake a regorous economic evaluation of the project and to investigate beneficiation improvement as a plant development programme. Reports indicate that to date some improvement in performance has resulted with experience.

On the basis of the work review by the Expert, the Institutes objectives and the capability of the ITNDMS staff there seems no reason why this Institute could not undertake the four (fundamental, product evaluation, economic and plant improvement) programmes recommended. Reference material will be made available in due course to assist in this work.

Appendix 4

ASSIGNMENT REPORT DP/YUG/73/003/11-02/MBH/3 DATED 21 DECEMBER 1977

NOTE ON THE SEPARATION OF QUARTZ AND FELDSPAR

As a result of discussions with Mr. Vukovic on the production of high purity quartz and feldspar products from a sand under sponsored investigation by ITNDMS the following comments are made:

1. The work already done follows conventional benefication practice and has achieved effective separation particularly with respect to the quartz product.

2. The separation of the two major components to meet the stringent specifications demanded by the sponsors is unlikely certainly in economic terms.

3. The effective production of high quality quartz has been achieved and the value of the bi product feldspare should be assessed along the linee proposed by Mr. Engelthalsr in his report on the Rgotina kaolin - quartz - feldspar material.

4. Following definition of the form and distribution of Fe_2O_3 in the sand this should be effectively reduced to requirements by gravity, flotation or combined high tension - high intensily magnetic separation. The choice between processy to be made on techno - economic grounds.

5. For the separation of quartz from feldspar flotation appear to be the only process although electrostatic separation with or without pre conditioning possibly warrants investigation.

6. The process of HF vapour conditioning prior to electrostatic separation is not known to the Expert but would appear to relate to the similar concept of HF conditioning prior to flotation. Halogen pre conditioning for the separation of K feldspar from mixed spars is reported in the literature (eg Ref.: Chem. Abs. Vol 58 No.8 Ref. 7638c)

7. In view of high reagent consumption and costs tne work with which the Expert has been associated whereby mixed anionic - cationic flotation is used might be persued. (Trans AIME 1976 Vol. 260 No.1)

8. As feldspar is the most valuable component of the sand beneficiation might be more profitably directed at making a high purity spar rather than a high purity silica. Details of the Experts work for achieving this on a similar sand will be made available.

9. Should electrostatic separation be persued it would be desirable to use the existing roll type separator without the ionising electrode or a plate type separator relying on contact charging of the quartz - feldspar. Information will be provided.

10. For quantitative assessment of products direct mineralogical identification by microscope (using staining techniques) is useful and is recommended.

11. The literature is full of references to practical and fundamental work on the quartz - feldspar system and a through literature survey would be profitable.

Summarising the discussions revealed that good work has been done at ITNDMS and promising results obtained following an established and practical approach to the problem. Sponsors demands however should be discussed in the light of potential utilization of the products and if necessary at a later date consumer trials be undertaken or firing tests in the laboratories of ITNDMS. At the same time an economic evaluation of various alternatives should be made. Should however a technological solution meeting the product demands of the sponsor still be demanded then a comprehensive literature survey followed by a long term fundamental research programme would appear necessary. In the opinion of the Expert the project does not justify this latter approach.

Appendix 5

ASSIGNMENT REPORT DP/YUG/73/003/11-02/MBH/4 DATED 22 DECEMBER 1977

Notes on the Evaluation of Diatomite for Filter Aid Production

Following discussions with Mr. Djakovic on a sponsored project relating to the characterization, assessment and utilization of diatomite from Macedonia as a filter aid (particularly for the brewing industry) the work sequence below is presented based on the experience of the Expert in a similar project in New Zealand.

While diatomite has many uses of a less sophisticated nature than beer filtration the discussion in this note will relate to this application only. Nevertheless use as a pozzolan and in less demanding filtration applications should not be lost sight of in the course of the evaluation.

Cost and consumption of filter aids in Yugoslavia is not known by the Expert but at perhaps $600 per tonne for 4-5000 tons per year development of an indigenous supply is of some economic importance.

1. Mr. Djakovic has a good understanding of the project and the material and already microscope examination, chemical analyses, grinding and calculation work has been done. He has available a comprehensive reference on testing - USBM Bulletin 460- to guide further work and therefore a generalised scheme for the investigation only will be given.

2. As it is reported that a similar diatomite from a close proximity has until recently been utilized for filter aid production this experience should be used to advantage, if available, in the present investigation.

3. Microscopic identification and quantification of the diatoms with respect to type form and size and the determination of contaminating constituents is essential for early assessment of the potential of diatomites. Careful disintergration of the material for this purpose is desirable.

4. Current demands (imports) for the brewing industry should be established as should the specific grades being utilised. While trade literature presents specifications these materials should be examined for purposes of comparison and particle size distributions in particular should be measured.

5. Size distribution by sedimentation (Sedimentation Balance or Andreasen Pipette methods) is most suitable and while resultant size characterization is not likely to agree with published specifications this forms the basis for comparative purposes. These are expected to show short range products with distinct cut offs at fine (5n) and coarse (40-50n) ends.

6. Material under investigation should then be milled/classified in order to achieve similar size characteristics. For this purpose a high speed hammer (swing) mill has been found suitable (6000 rpm, 20cm diameter). Degree of comminution can be controlled by modifying grate size (or removal) and by feed rate. This is a critical aspect of the investigation. Feed must be dry presenting some problems in view of the high capacity of diatomite for water (200%).

7. Classification can be achieved by air cyclone for removal of fines and additional cyclonels) may be used for top size control and multi-product production. The available Denver cyclone classfier unit may be useful for this purpose but a continuous milling classification system can be developed and the required cyclones fabricated.

8. Resultant products must be assessed by sedimentation sizing in order to evaluate production conditions and to compare them with standards.

9. The most suitable products together with standards should be evaluated for filtration performance preferably using the Filter bomb developed by the industry for this purpose. However alternative filter systems can be constructed.

10. Initially flowrate against time using water should suffice for purposes of comparison and for acceptance/rejection.

11. Further filtration with suspensions can follow or preferably with raw beer as standard equipment is available in the brewing industry for rapidly evaluating the clarity of feed and products.

12. In this work flow rates, filtration efficiency, clogging ratios and other criteria can be assessed.

13. Finally taste trials, acceptance trials and health regulations have to be met as well as market penetration for which pilot production may be necessary.

14. For drying prior to grinding a fluid bed dryer may be useful with feeding difficulties aided by recirculation of some of the dried product.

15. For grinding/classification purposes many mills are available that s multaneously grind/dry (Refer Mr. Engelthaler) and grind/classify (eg Alpine-Microplex Mill and Sturtevent)

16. Alpine and no doubt other companies will investigate, possibly without cost, the capability of their mills/classifiers to meet product requirements and should be contacted for advice, information and service.

* Contact address will be provided at a later date.

Appendix 4

ASSIGNMENT REPORT DP/YUG/73/003/11-02/MBH/5 DATED 23 DECEMBER 1977

EQUIPMENT AND LIBRARY ACQUISITIONS ITNDMS

Various equipment lists/priorities have been prepared in the past under the Non-Metallic Project. Books and journals have also been procured. Needs in both areas have tended to relate to the specific projects under evaluation and/or the specific interests of the Experts.

Equipment suggestions made below would fill general (not specific) deficiencies and if coinciding with Phase 2 recommendations from other sources could perhaps be given priority.

The publication suggestions are made in order to assist in broadening the scope/interests within the Institute and to help in providing a better overview in the field of Non-Metallic minerals. Specific proposals relating to phosphate work are also included. As it has not been possible to consider other library collections in Belgrade the suggestions should be assessed in the light of these.

If the proposed publications cannot be obtained under UNDP/UNIDO support for the ITNDMS collection they could at least be profitably consulted by staff members of the Institute.

Equipment

The equipment in the general fields of beneficiation seems excellent but for better internal capability in characterization, beneficiation and utilization the following are recommended.

1. Optical microscope(s) for transmitted and reflected light with sample preparation equipment and camera attachment. This is essential for materials and particle characterization and evaluation.

2. Fine sizing equipment. Sedimentation Balance eg Shimadzu, Satorius etc. and/or a Coulter Counter together with a suitable elutriator for fracturiation in the equivalent size range. Centrifuge.

3. High Intensity Wet Magnetic Separator eg Gill or Iones etc.

4. High Speed milling/classification equipment eg Alpine or Sturtevent etc.

5. Various cyclone test units of different and flexible dimensions.

6. Atomic Absorption Spectrophotometer with associated instrumentations and XRD equipment.

Library - General books

1. Communs + Given Society of Mining Engineers Handbook. 2 Vols. AIME Seeley Mudd Series.

2. Perry. Chemical Engineers Hand book Latest Edition.

3. USB Mines Mineral Facts and Problems.

4. Zussman Physical Methods of Determinative Mineralogy. Academic Press.

5. Robie. Economics of the Mineral Industries AIME Seeley Mudd Series (Latest Edition).

6. Lefond. Industrial Minerals and Rocks. AIME Seeley mudd Series (4th Edition 1976).

7. Bates. Geology of the Industrial Rocks and Minerals. Teffer and Simons Co.

8. Parks and Baxter. Examination and Valuation of Mineral Property. Addison Webb Publishing Co.

9. Peters. Plant Design and Economics for Chemical Engineers.

Journals etc.

Industrial Minerals - back numbers.

Mineral Processing - Elsevier ?

Particulate Technology - Elsevier ?

Transactions AIME - Quarterly.

Proceedings International Mineral Processing Congresses eg Italy 1974.

Proceedings International Industrial Minerals Congresses eg London 1974, Munich 1976.

USB Mines Reports, Bulletins, Information circulars.

Phosphate Publications

1. The British Sulphur Corporation - Phosphate Rock - A World Survey.

2. Moldovan, Popovici and Chivu. The Technology of Mineral Fertilizers British Sulphur Corporation.

3. Waggaman. Phosphoric Acid, Phosphates and Phosphatic Fertilizers. Reinhold Publishing Co.

4. Special Volume "Benefication of Lean Phosphate Ores with Carbonate Gangoe" 11th International Mineral Processing Congress, Cagliari, 1974.

5. Contact should be made with the following organizations/ institutions, all working in phosphate, many of which offer publications on a free or exchange basis.

The British Sulphur Corporation Ltd.
25 Wilton Road, London SW1V 1NH

The Tennessee Valley Authority and the National Fertilizer Development Centre
Muscle Shoals, Alabama, 35660 U.S.A.

The US Bureau of Mines.

The International Superphosphate Manufactorers Assn.
6 Rue de Leningrad, 75008 Paris, France

The Fertilizer Society.
93 Albert Embankment, London SE1 7TU

CERPHOS.
47 Rue de Liège, 75008 Paris, France

CENTO -Ankara, Turkey.
(Symposium on Mining and Benefication of Fertilizer Minerals. Istanbul, Nov. 1973 and Seminar on Fertilizer Analytical, Sampling and Quality Control. Lahore, March 1974)

The Sulphur Institute. 1725 K Street , N.W.Washington.

The Fertilizer Institute.
1015 Eighteenth Street, N.M. Washington.

The United Nations-Particularly UNIDO.
(Fertilizer Monographs and Technology Meetings - Kiev 1968 and Kiev/ New Delhi 1971)

Industrial Information Section
P.O.Box 707 Vienna 1011, Austria.

The Fertilizer Association of India.
Near Iawa hartal Nehru University, New Delhi, 110057.

The Australian Mineral Development Laboratory, Adelaide, Australia.

The New Zealand Fertilizer Manufactures Research Association
Papatoetoe East, Auckland, New Zealand.

NOTE: As precise details of some publications and required addresses are not available these will be forwarded.

Appendix 7

PROFESSIONAL CONTACTS

Dr. R. Vasiljevic,	Director, ITNDMS, Belgrade
Mr. B. Zogovic	Project Director, UNDP/UNIDO, ITNDMS
Mrs. D. Pupezin	Project Co-Director, UNDP/UNIDO, ITNDMS
Mr. M. Milosevic	Head, Ore Dressing Section, ITNDMS
Mr. Z. Djordjevic	Ore Dressing Section, ITNDMS
Mr. D. Milic	Ore Dressing Section, ITNDMS
Mr. N. Djakovic	Ore Dressing Section, ITNDMS
Mr. R. Vukovic	Ore Dressing Section, ITNDMS
Mr. K. Engelthaler	UNIDO Expert, Project DP/YUG/73/003/11-03
Mr. S. Petrovic	Geologist, GEOZAVOD, Belgrade
Mr. S. Maric	Geologist, GEOZAVOD, Belgrade

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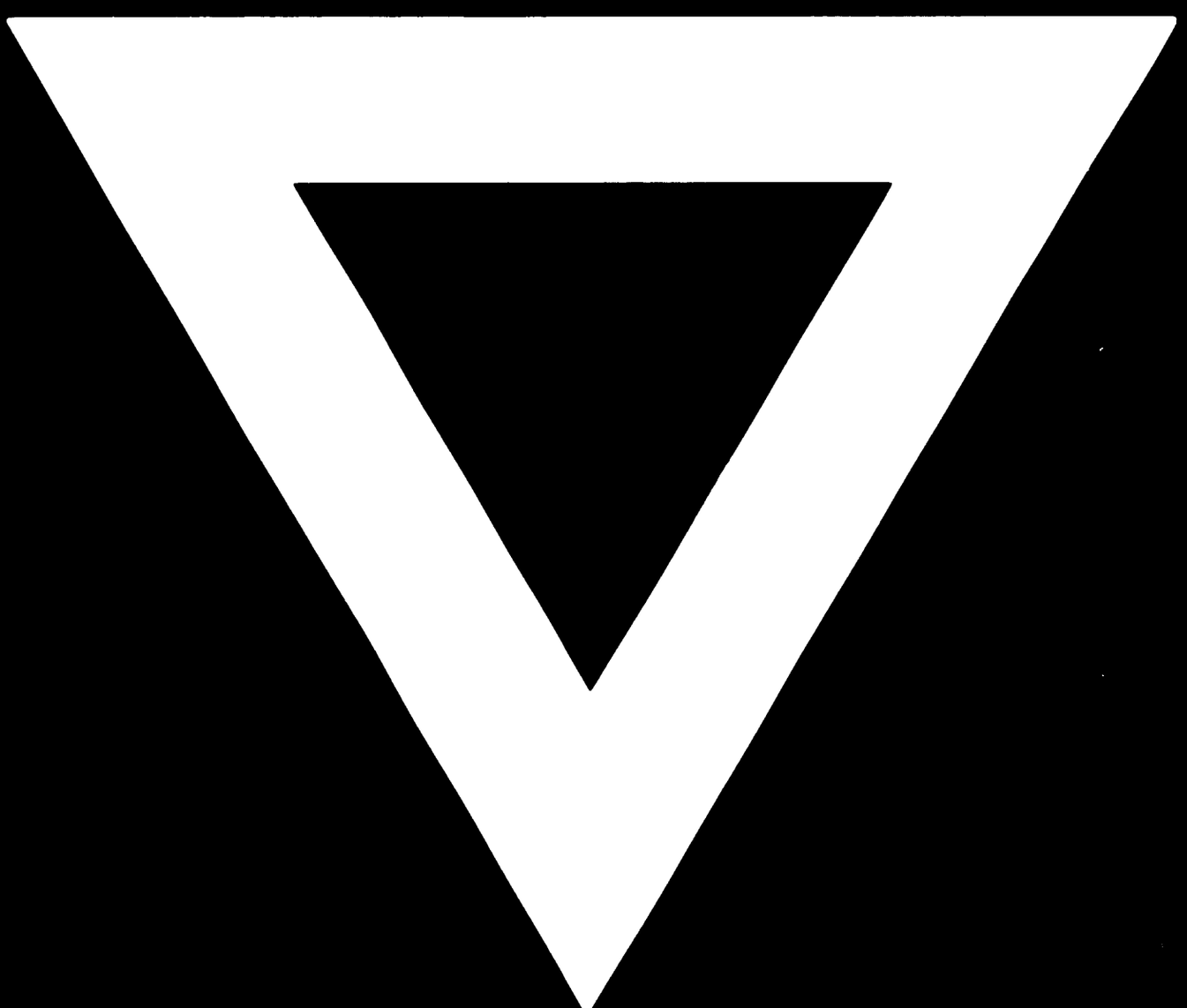

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