OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

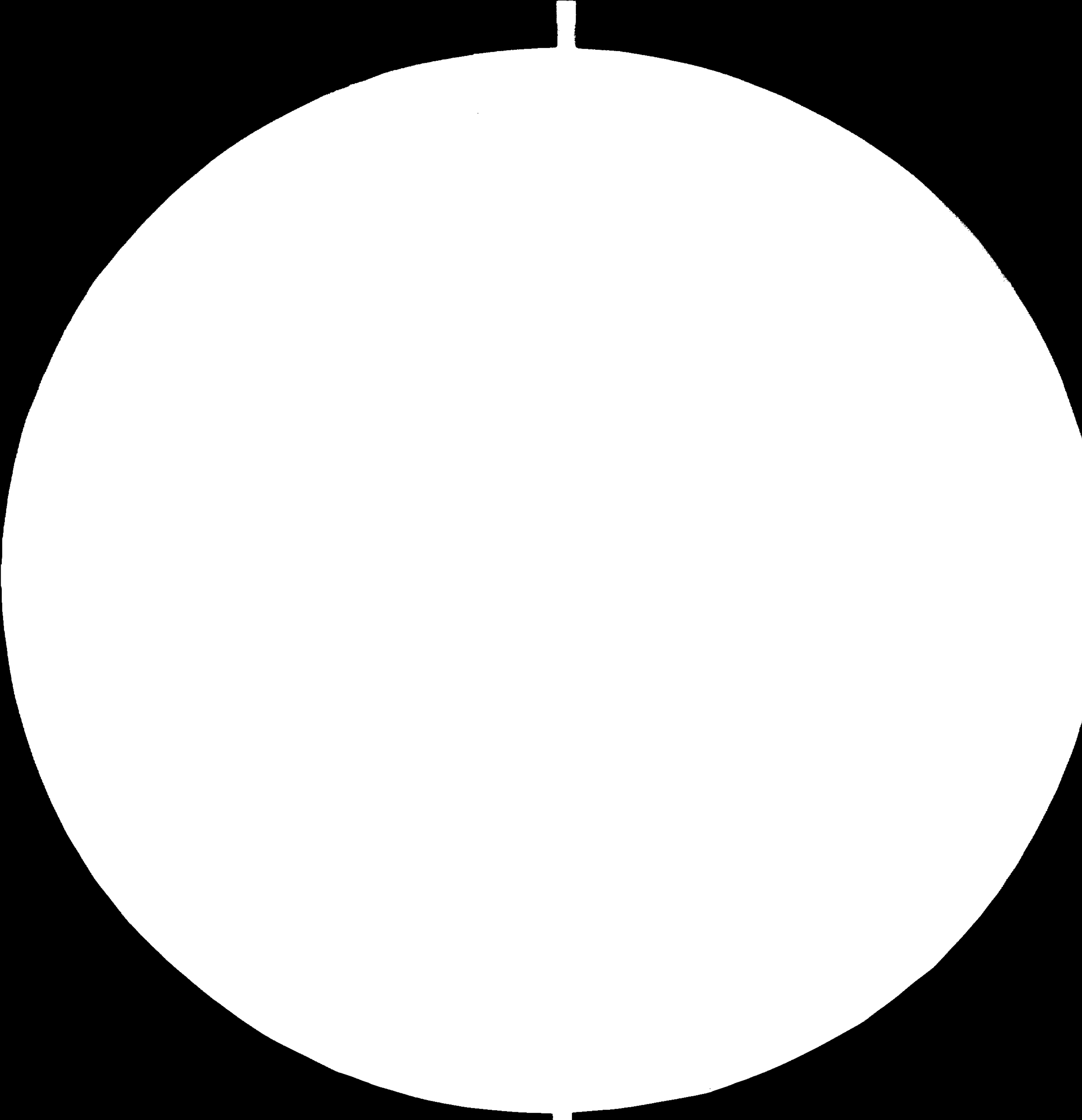
FAIR USE POLICY

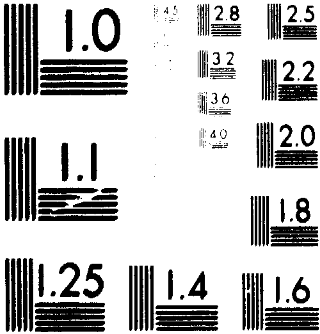
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org





MICROCOPY RESOLUTION TEST CHART

06 [illegible]

UNIDO-CONTRACT NO. 77/54
PROJECT IS/PAR/74/817

10601

DRAFT FINAL REPORT

Analysis of the possibilities of establishing energy-intensive industries in PARAGUAY.

First issue 31.1.78

INDUSTRIKONSULENT A.S

Address: Aslakveien 14, Oslo 7, Norway
Cable address: «industrikonsult»
Telephone: 02 - 24 56 90
Bankgiro: 7032-05-06601

IKO Consulting Group

IN COLLABORATION WITH

KVAERNER ENGINEERING A.S

ADDRESS: Postb.475 - 1301 Sandvika, Norway
TELEPHONE: 02/13 10 60
TELEX : 17727 Kveng n, Oslo.

Table of contents

Introduction

The United Nations Industrial Development Organization (UNIDO), under it's Special Industries Services Programme and as a complement to the Industrial Survey of Paraguay, that was completed in 1976, has undertaken to assist the Government of the Republic of Paraguay in the preparation of an analysis of the possibilities of developing energy-intensive industries in this country and the potential for using domestic raw materials as inputs for them.

Industrikonsulent A.S. on August 19, 1977, with the signature of UNIDO contract No. 77/54 has agreed to do the abovementioned analysis in cooperation with Kvaerner Engineering A.S.

The present report is based on the findings of a project team, consisting of economist Gunnar Åberg (team leader), geologist Bernt Rösholt and electrical engineer Jon Midtsund, who visited Paraguay during a six weeks period in September - October 1977 and the following evaluation with backstopping specialists from Norwegian supporting industries active in the electro-intensive industries fields through Kvaerner Engineering A.S.

Methodology

The terms of reference called for "an analysis of the development of energy-intensive industries and the potential for using domestic raw materials as inputs for them". The analysis was to consist of "an assesment of the country's present industrial raw materials, of it's capacity for industrial development in the area of energy-intensive industries and in the identification of industries to be established".

The basic idea for our approach consists in the matching of a list of processes that are highly dependent on the availability of energy with one of the raw material resources that are or can be made available in Paraguay, and to rank them in order of feasibility and impact on the economy. **For the industries that through this evaluation can be sorted out as of interest for further study more detailed comments have been made.**

During the preparation phase, apart from updating on the general economic and industrial situation of Paraguay and going through available information on existing sources of raw materials as well as the plans for the construction of future hydroelectric power plants, **a preliminary list of possible industries (annex 1) was drawn up.** To complete our geological information Mr. Røsholt, on his trip to the field, visited the U.S. Geological Survey and the department of Geology of the university of Sao Paulo.

During field work our major aims were to investigate at **what prices the new hydroelectric plants would be able to provide power to industry and to check, on the spot, any mineral occurences,** or indications of such, that could be pointed out as a possible source of raw materials. Also **the infrastructural, organizational, financial and market conditions were studied,** mainly through interviews with persons in the administration and in the private sector.

Summary and Conclusions

The Paraguayan economy is based on it's rich soils. Farming, cattle breeding and forestry hitherto have contributed to the major part of GNP and provided the basis for industrial growth. The country still has vast virgin areas unexploited. It is therefore to be foreseen that also in the future these agricultural sectors will be major engines of growth and able to provide growing agroindustry with the necessary raw materials. It is also to be foreseen that, when planning for the future development and industrialization of the country emphasis will have to be put on providing these traditional sectors with the infrastructure they need.

In the mid-eighties, when the Itaipú and Yacyretá hydroelectric power plants come into operation, Paraguay will own an important new asset, the right to vast amounts of relatively low cost power. Although by treaty this asset can give some monetary revenue through the sale of electricity to Brazil and Argentina, it has been questioned whether Paraguay should not be able to benefit more by using these resources herself, for example in electrointensive industries.

At present it is not known whether Paraguay will have at its disposal any mineral raw materials on which EI-industries can be based, although from a geological point of view **there are indications** that some sources **may very well be found.** The government has taken an important step towards securing better knowledge of the contents of the subsoils of the country by conceding exploration rights to three different companies, two drilling for oil and one prospecting for minerals. It is however, recommended that a geological survey should be organized that could administrate these concessions and, above all set up a long range investigation program that in due course would lead to a thorough and detailed knowledge of the mineral and other geological assets of the country.

An important part of this study is **an endeavour to assemble presently known indications of mineral deposits and suggest future activities in the field of geological research. (Annex 2).**

Although Paraguay will have the right to draw vast amounts of electric power from the Itaipú and Yacyretá dams, the prices that industry will have to pay during the first decades of operation, even if they may well be lower than present industrial tariffs, will probably be too high for most EI-industries to be viable, unless raw materials can be made available at exceptionally low cost. This is specially true as far as the metal smelting and metal alloys industries are concerned. The industries that compete with processes based on hydrocarbons, however, may, if the rising trends in prices of oil and natural gas continue, prove to be competitive by the time the power comes on stream.

It has to be noted, that the evaluations made in this study are based on present process technology. Because of world-wide rising costs of energy it is more than probable that new alternative processes will be conceived, through which EI-industries may well be able to pay higher power prices and still be competitive.

If the explorations in the Chaco for oil and gas lead to positive results, a new factor has to be taken into account when evaluating the viability of the EI processes that can be regarded as competitive.

The fact that EI-industries are capital intensive and require a specific infrastructure may create difficulties for Paraguay when it comes to deciding on how to allocate scarce capital resources.

In the study some EI processes are commented on that are deemed to be of interest for Paraguay. Special emphasis is made on the pulp and paper industry and on the possibilities of producing fertilizers, as it is considered that there are good chances that they can prove to be feasable and that they would contribute in a logical way to the next steps on Paraguay's road towards industrialization.

Background

Agriculture, cattle-breeding and forestry - the basis for industrial growth

The Paraguayan economy is, and for the foreseeable future will remain, based on the country's large agricultural potential. Vast cultivable areas are still virgin and those under cultivation can be expected to produce higher qualities and volumes if agriculture is backed with better infrastructure, capital resources and improved equipment and techniques.

Existing industry - vegetable oils , sugar refineries, meat packing, wood processing, leather goods etc. - is based on good agricultural raw materials, and can be expected to ac-count for growing percentages of GNP as well as of the value of total exports, if provided with growing volumes of raw materials, adequate financing and adequate infrastructure.

It is therefore obvious that the major government efforts will have to be geared to providing the infrastructural services that the agriculture and agroindustries need for their evolution and that these sectors will have to be given priority when it comes to taking decisions on how to dedicate the scarce capital resources available in the country.

It is not within the scope of this study to discuss how better transport infrastructure, education, financing etc. can support the agroindustries' growth, but we would like to stress the fact that these industries consume electricity and at present are hampered by the lack or high cost of power.

Electric power - a new asset

With the construction of the Itaipú and Yacyretá dams, Paraguay will have contractual right to enormous hydroelectric power resources. It is estimated that by 1990 some 45.000 GWh year will be at disposal of the country for own consumption or for export. This figure does not take into account the power that may become available from the proposed Corpus dam.

The Paraguayan government has the possibility of exporting power to Brazil and Argentina and receive royalty payment as specified in the Itaipú and Yacyretá treaties.

However, Paraguay also has the option of using all or part of this power for it's own purposes. It would, in such case, according to the Itaipú and Yacyretá treaties, have to pay a price that would cover the financial cost - repayment of and interest on the debt incurred to finance the construction of the dams - and forego part of the above mentioned royalties.

It is natural that when studying the consequences of these two alternatives, and in view of the large potential involved, the possibility of establishing industries that will consume large amounts of electric energy has to be considered. If the value added in these industries covers a) the cost of power, b) depreciation and interest of necessary investment in the power intensive industries, c) their cost of operation and d) foregone royalties, it would seem that the second alternative would be preferable to the country.

To this should be added that if these industries can be based on domestic raw materials, important additional benefits such as new employment have to be taken into account.

Characteristics of Electrointensive Industries (EI)

The so-called electrointensive industries, apart from their high consumption of electric energy have some other common denominators that are of importance for our evaluation.

a) They are based on electrochemical processes and sophisticated technology.

b) They transform or alloy raw materials.

c) In order to be economically viable they tend to require a high production volume and therefore depend on

d) Large volumes of easily accessible **raw materials** of sufficient purity and

e) Sufficiently **large markets** for the end product, preferably transformation industries not too far from the plant;

f) The EI industries are capital intensive and

g) Require little manpower. The EI industries can thus not be expected to be a source of new employment, unless based on domestic raw materials, the extraction of which could require additional manpower.

With the exception of the metals and metal alloys industries, where electric furnaces or electrolytic processes are a must, most EI processes compete with other production methods which are mainly based on hydrocarbons.

The cost of power, is, of course, a crucial factor that in the first, conceptual, stage of analysis leads to the discarding of a number of EI processes, but attention also has to be paid to the complexity and interdependence of chemical engineering plants.

The approach in the present study, the comparison of prices for the finished products, and costs of power and raw materials, is a well established method for the first stage of investigation. In the case of EI industries, however, also the location of the plant with regard to raw material and power sources, markets and transport facilities etc. is of extreme importance, as an uneconomical location may well wipe out the competitive advantages of the process. The availability of water and waste disposal facilities, sensitivity to air pollution and the availability of supplementary industries that can either provide input material to or use by-products from the process are factors that can be decisive when deciding on where to locate EI industries.

The minimum plant size is also dependent on many factors. In our tables for thermal and electrolytic industries an estimated average minimum plant size has been chosen to establish a figure for minimum capital investment.

This is,however, a rough estimation based on experience - the minimum and economically optimal sizes can only arrive at through detailed project development taking into account all relevant local factors.

In the ferrosilicon area Norwegian plants without the benefit of incorporated power plants are in economic trouble due to increased cost of state power. They have either to close or to increase plant size and computerize their operations. One of them is increasing from 20 MWh to 75 MWh to cut down unit production cost. This is a single plant - not integrated with other processes. In Brazil, however, a 5 MWh ferrosilicon plant is operating with satisfactory results due to optimum location and domestic factors.

Integrated processes have a great influence on economy related to minimum size of plant. A ferrosilicon plant with closed furnace produces CO gas which is normally wasted. In an integrated plant the CO could possibly be combined with hydrogen (H_2) to produce methanol (CH_3OH).

DOW, USA, utilize the chlorine gas from electrolytic production of magnesium to produce PVC - all in the same plant.

In the Soviet Union the alumina plants are integrated with cement plants - cement is produced from the waste of alumina production.

A Norwegian method combines production of alumina, pig iron and cement based on raw materials for alumina production (laterite).

The fact that the economic viability of many electrochemical processes to a high degree depends on the possibilities of integration makes it extremely difficult to arrive at any conclusions before geological research has defined qualities, quantities and location of raw materials, on which data detailed project development efforts can be based.

The fact that EI industries are based on sophisticated technologies should be discussed in some detail. It can be said that technology can be bought, either by the purchase of licenses and necessary know-how services or by giving special conditions to foreign investors in order to entice them to make the necessary investment and thereby bring in their technology.

But sophisticated technology requires a series of services and infrastructural facilities that may be costly to provide. It is therefore preferable to choose technologies which are not too different from the level already existing in the country, especially if they can be regarded as the "next step" in the upgrading of technical know-how. Fertilizers are already being mixed and sold on the Paraguayan market. There is thus already some know-how in the fertilizer trade as to grades and compositions needed for different soils. The next step could very well be the establishment of and industry that would produce substitutes for one or several of the components that today are imported. One possibility might be to produce ammonia, synthesized from nitrogen from the air and hydrogen from the electrolysis of water.

If further prospecting proves that phosphate rock is available locally in sufficient quantities and the right qualities, the country could provide the phosphorous component from own sources.

The fact that EI processes often are economically viable only if built up for a high production volume represents serious difficulties for smaller nations, not only because large amounts of raw materials have to be readily available but also because of the large amounts of capital required. To this has to be added the necessity of having sufficiently large markets within reasonable distance, as many of the products can not support long transports. We would also like to underline that most of EI industries, because they have to produce for the world market, are very risky business.
In good times they can show good rentability, but the present situation on the metal alloys market is a good illustration of how these capital intensive industries can fare when having to meet the price fluctuations that characterize their markets.

The development of power-oriented industries to absorb a substantial part of the electricity that will be available from Itaipú will represent an entirely new dimensions of the industrial development of Paraguay.

Such investment will have to be of a magnitude to be mainly externally oriented, producing for the international market. It would represent a formidable challenge to the Paraguayan Government to establish the institutional framework ~~necessary~~ to handle all sides of planning, promotion and cooperation which in this context becomes necessary, while at the same time providing the infrastructural development required for the normal growth and evolution of already established sectors of the economy.

Why is electricity used?

In some cases, like the silicon and metal alloys industries, the only presently known production methods are based on the use of electricity.

Whether an industry will be economically viable will in these cases depend on the following main factors:

- availability and cost of electric power
- availability and cost of raw materials
- accesibility to consumer markets
- cost and property of substitute materials.

In other cases, for example fertilizers and ammonia, the EI industries compete with other processes, based on natural gas or oil. Apart from the abovementioned factors, in these cases the viability and overall economy of the alternative process will have to be studied before being able to ascertain whether the one based on electricity is to be preferred.

Most of the EI processes were originally first used in countries where electricity was superabundant; for example during the night hours, and could be bought at very cheap rates. In many cases it made good sense for the owner of the power plant to make contracts with EI industries with a steady consumption day and night even at prices lower than 3 mils as they thereby acquired a stable base for the production of the plant.

As the different plants nowadays are connected to national and international grids, the amount of surplus power at these utterly low prices is being drastically reduced. Even in countries where the major number of hydroelectric plants are already depreciated to a nominal value, some EI industries such as e.g. that producing ammonia from electrolytically produced hydrogen have for some time been considered obsolete. However, with increasing oil prices and with the electricity price in Paraguay of the level indicated in this report, **we recommend that a feasability study be made for a fertilizer plant based on electrolytically produced hydrogen. If such a plant is found feasable, the possibilities of producing heavy water, hydrogen peroxide and methanol in an integrated plant at the same location should also be studied.**

With the present slump on the international iron and steel markets, and rising demand for electricity for other purposes, some producers of ferroalloys, who also own their hydroelectric plants, are finding it more remunerative to stop the processing of minerals and sell their power to the grid.

In the case under study, there will be no "surplus" power available to Paraguayan industry at exceptionally cheap rates. Through the Yacyretá and Itaipú treaties Argentina and Brazil are bound to buy, from the corresponding binational entity, every kWh produced that is not taken by Paraguay and pay the full price including a compensation to Paraguay for the number of kWhs used that correspond to Paraguay's share.

Future price of ITAIPÚ power

As the cost per kWh of the power from Yacyretá will be higher than that from Itaipú, Paraguay should first try to make use of it's share of energy from the latter hydropower station. We can therefore in our analysis concentrate on the possible evolution of Itaipú power prices.

The mission has had the opportunity to evaluate, with officials of the ANDE and ITAIPÚ, the values presently known on total investment, terms of financing, interest rates, exploitation costs and other cost items as en-numerated in the ITAIPÚ treaty. On the basis of these data, we calculate that the average cost of producing power will evolve approximately as follows:

Year	Cost at the power station
1983-1990	11 mils/kWh
1991-2000	16 -"-
2000-2010	16 -"-
2010-2020	10 -"-

The relatively low average for the period 1983-1990 is mainly explained by the fact that part of the financing has been secured at terms which foresee grace periods during which, for some of the first years, only interest will be payed. It is, however probable that during the remainder of the construction period, additional short term financing will have to be found to cover expenses that are not yet foreseeable, and that will tend to raise the average cost during the first years of operation. It is also possible that, once the plant is on stream, part of the debt can be refinanced for longer terms, which would lower the cost, especially in the period between 1991 and 2010.

For the sake of our study, and in order to base our ana-lysis on one cost estimate, we draw the conclusion that it is not realistic to foresee that the price per kWh, at the plant, will be lower than 15 mils during the rest of this century.

To this price, the cost of transmission and distribution have to be added. Table 1, which is based on international cost data for transmission equipment shows how these costs vary with distance, voltage and amount of power transmitted.

It takes into consideration depreciation and interest on equipment, energy losses, administration and service of the transmission system but does not make any allowances for costs of expropriation of property, payments for damages, etc. that may be necessary to cover in order to build the transmission network.

The calculations are also based on the assumption that the consumer will have to cover the cost of any necessary sub-stations and the distribution within the plant, i.e. the consumers receive the electrical power with the system voltage at the end of the transmission line in question.

PARAMETERS USED:

Power factor: 0.9 Consumers service factor: 6000 hrs/year

Depreciation time: 20 years. Interest: 10% per year.

All prices are referred to the 1977 level.

For our calculations, we have estimated an average cost of transmission of 3 mils per kWh, which, added to the 15 mils cost of generation, gives a calculated pr for industrial energy of 18 mils.

TABLE 1

Power & Voltage \ Transmission length		50 km	100 km	150 km	200 km	250 km	300 km	400 km
		ELECTRICAL ENERGY TRANSMISSION COST IN MILS OF ONE U.S. DOLLAR PER kWh						
500 MW	400 kV	1.00	1.36	1.80	2.20	2.60	3.00	3.80
	220 kV	0,95	1.27	1.65	2.00	2.36	2.68	3.37
400 MW	400 kV	0.98	1.38	1.78	2.18	2.58	2.93	3.78
	220 kV	1.06	1.48	1.95	2.37	2.78	3.22	4.10
200 MW	400 kV	1.22	1.82	2.42	3.04	3.64	4.20	5.43
	220 kV	1.24	1.87	2.52	3.17	3.82	4.45	5.75
100 MW	220 kV	1.64	2.69	3.71				
	132 kV	1.62	2.60	3.62				
50 MW	132 kV	1.76	2.98					
	66 kV	2.44	4.22					

Power & Voltage \ Transmission length		10 km	30 km	50 km	100 km			
		ELECTRICAL ENERGY TRANSMISSION COST IN MILS OF ONE U.S. DOLLAR PER kWh						
30 MW	66 kV	1.02	1.85	2.69	4.80			
10 MW	66 kV	1.26	2.51	3.76				
	22 kV	1.69	3.88	5.82				
5 MW	66 kV	1.02	2.13	3.22				
	22 kV	1.37	3.24	5.08				

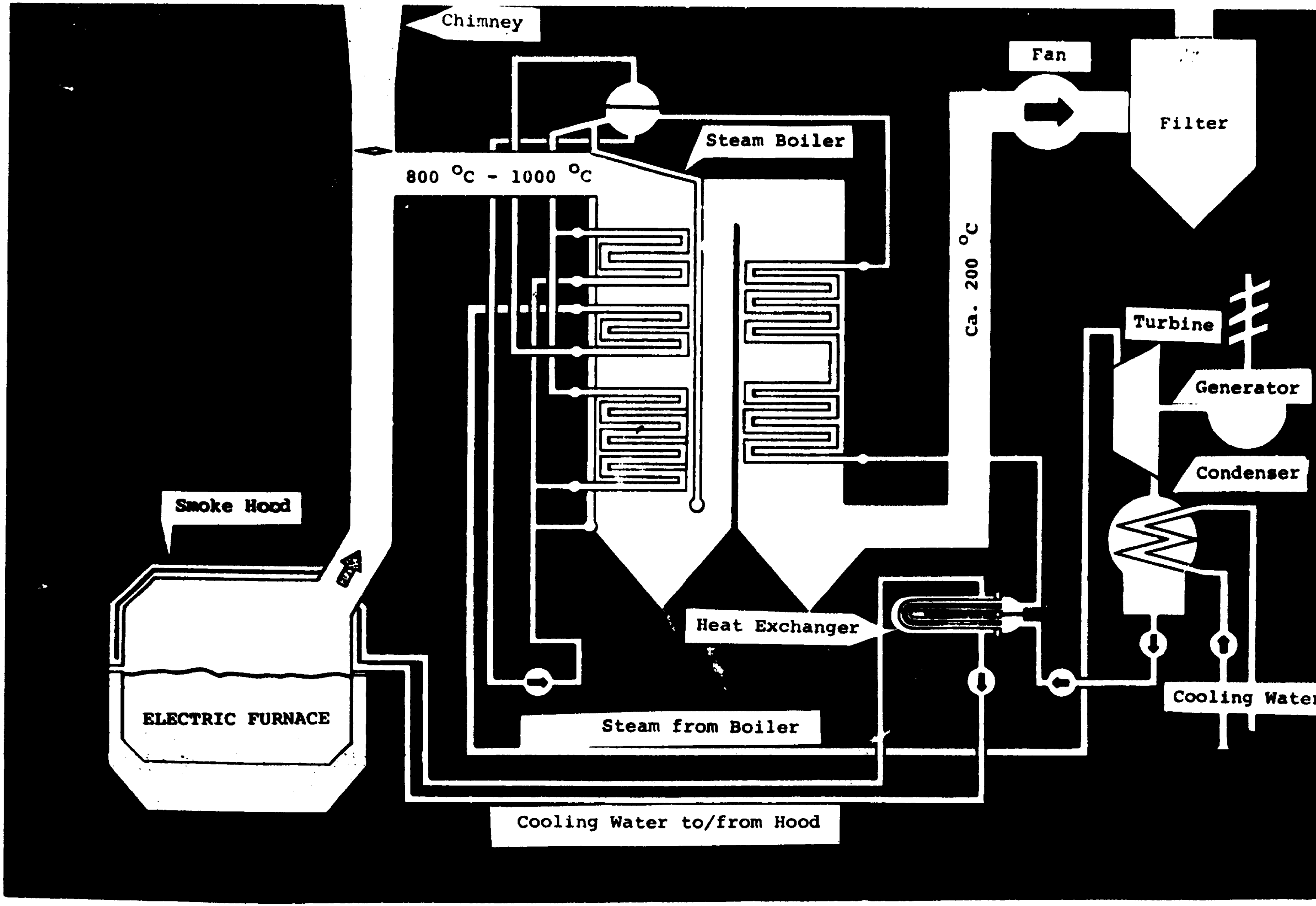
Although this price is lower than present industrial tariffs in Paraguay, it is too high for most of the processes on our list to be economically viable under present standards of technology and world market prices.

As debt is repayed over the years, the cost, as defined in the treaty, will be reduced. It can also be reckoned that during the next forty years, the cost of oil and gas, which are the raw materials for competing processes, will rise. These two price trends, working in opposite directions, indicate the probability that, even if in the short and medium term some EI industries have to be considered as uninteresting for Paraguay, in the long run, and especially if more own capital resources and raw materials will be available, the possibilities of using electricity in these processes can be viewed more favourably. Attention also had to be paid to new possibilities that technological research may provide in the form of new processes that take better advantage of used electric power and therefore may become viable.

A factor with increasing importance and under fast development is energy-recovery in all types of industries. The EI-industries, as well as the paper industry head the list of processes, where great possibilities exists to recover energy due to the quantity of heat produced. At present much effort is dedicated to investigation on methods to produce electric energy from waste heat by means of steam turbines.

In some processes, the exhaust gases may be used directly in gas turbines or gas motors.

In Norway plants are already in operation that recover more than 25% of the electric energy input. Plants which will be able to recover close to 50% of the electric-energy input are presently under planning. Future EI industries will, no doubt, have to take regeneration of energy into consideration.


Chimney
Steam Boiler
800 °C - 1000 °C
Fan
Filter
Ca. 200 °C
Turbine
Generator
Condenser
Smoke Hood
Heat Exchanger
ELECTRIC FURNACE
Cooling Water
Steam from Boiler
Cooling Water to/from Hood

Mineral raw materials

The EI industries, apart from using great amounts of energy at low prices, also depend on the availability of large quantities of raw materials of sufficient quality. During the field work in Paraguay the mission found that **there are no proven mineral deposits of economic value, except the limestone areas** south of **the Brazilian border east of the Paraguay river.** Although these deposits provide an excellent basis for the cement industry and also are well suited for liming the soils in order to regulate their pH-values, they do not provide a basis for any EI industry.

Paraguay is considered to have very few other mineral deposits. Whether this is true or not still remains to be seen. **Up to now very little prospecting has been carried out.** Interest has been focused on the surface of the land, rich in good soils and valuable forests of which many still are virgin.

The fact that the mineral law gives no incentives to prospectors, poor accesibility due to deficient transport infrastructure, the deep weathering and overburden of the rocks that makes prospecting and geological mapping difficult are other factors that can explain the apparent lack of interest in exploring the subsoils of the country.

The geological findings of the mission have been assembled in annex 2, which consists of a map on which are indicated known occurences in Eastern Paraguay of minerals, which can be used in power intensive industries. It is accompanied by a list that describes these minerals with available chemical and geological data. This geological report could well be used as a basis for the future prospecting activities that we recommend be undertaken. It contains several suggestions under the different mineral group headings.

The annex also contains a description of how geological and mineral research is presently administrated as well as some **suggestions as to the planning and structuring of future activities in this field.**

Can necessary raw materials be imported?

If Paraguay can not provide the basic commodities needed to supply EI industries, does this necessarily mean that these industries can not be established on the basis of imported raw materials? **The Bolivian and Brazilian El Mutún and Morro do Urucúm iron and manganese deposits,** for example, have been mentioned as possible supply sources for Paraguay based industries.

First of all an analysis will have to be made on the cost of transporting ore, whether reduced or not, down the Paraná river to some location in Paraguay and add the cost of transporting power to this location. The sum of these costs would have to be compared with the cost of power if delivered to El Mutún or Urucúm. Although we have not exact data that can exemplify these two alternatives, we reckon that it must be more economic to transport the power to the neighbourhood of the mines.

As Paraguay itself will only be able to use a minor part of the production of the iron, manganese and/or ferromanganese that would be produced in the plant, the project would have to be based on a large enough scale to be competitive on the world market. This implies a very substantial capital investment with very little employment or development effects in the country, while at the same time taking substantial risks. Unless very favourable long term contracts can be secured for the raw material supplies, as well as large amounts of capital that can be dedicated not only to investment in the plant itself, but also to better transport facilities on the Paraná river, it would seem that such a venture should not be embarked upon.

With scarce capital resources, Paraguay will have to concentrate on building up it's industry by succesively adding capacity to exploit and transform it's own basic resources and avoid ventures that imply great risks in relation to the relatively modest value added that can be achieved by transforming imported raw materials and selling the produce to third parties.

We therefore have to **conclude, that all the metal smelting and metal alloy processes on our list at present do not appear to be feasible in Paraguay, but that some of them should be analysed if and when mineral deposits of sufficient grade and volume are found that can provide the necessary raw materials.**

The processes based on electrolysis of water at present do not seem to be viable at a cost of power as high as 18 mils., as competitive processes based on hydrocarbons at today's prices of oil and natural gas are more economic. As these latter prices, however, are expected to rise in the coming years, it is not at all impossible that by the time Itaipû comes on stream the comparative situation may have changed.

For an agricultural country like Paraguay the most interesting products that can be produced by these processes are fertilizers, but also the possibility of producing methanol is of great interest for a country that has to rely on imported fuels.

In the following some more detailed comments are made on a number of processes that we consider can be of interest to Paraguay. Of these we recommend that further analysis and **prefeasability studies be made on fertilizers and thermomechanical pulp.**

Fertilizers

It does not seem impossible that in the next decade the price of oil, naphta and natural gas will rise to levels that would make processes whereby fertilizers can be synthisized from nitrogen and electrolytically procuded hydrogen. For an eminently agricultural economy like the Paraguayan it must be considered as very valuable to produce these vital products from own sources. As world demand for fertilizers is foreseen to grow, it should be possible to place any surplus quantities over and above the country's own consumption in the neighbouring countries or on the world market.

It would therefore seem to be indicated to recommend that the evolution of world market prices of these commodities as well as changes in technologies of production be followed closely.

The raw materials used in the production of modern NKP fertilizers are: rock phosphate, nitric acid, ammonia, potassium chloride of sulphate. Smaller quantities of micronutrients are added. The process is well suited for integration with a plant producing ammonia and nitric acid from natural gas/napha or fuel oil.

Ammonia, which is the main building element in fertilizers, can also be synthesized from nitrogen and electrolytically produced hydrogen.

With present international industrial electricity and oil prices it is for the time being not considered economical to produce ammonia from electrolytically produced hydrogen. Given an investment cost of one unit per ton of ammonia to be produced per year from natural gas or naphta, the investment would be 1.25 units if it is based on heavy oil and 1.75 based on electrolysis.

However, the continuous elevation of the cost of oil and gas that is foreseen for the rest of this century has created a genuine interest in new plants based on electrolysis. An example of this is the fertilizer plant that has been in operation since 1973 and which uses electric power from the ASSUAN Dam in Egypt.

The electrolysis capacity of this plant is now being expanded from 20 000 m^3 of hydrogen per hour to 36 000 m^3 per hour corresponding to an annual production of ammonia of some 125 000 tons/year.

The initial price of electric power was 2.2 mils., but today the plant quotes 11 mils. per kWh. In Table 3 we have attempted to put down rough figures for the total investment and for the production costs per ton of ammonia for 100 000 tons/year plants based on electrolysis and on oil.

The electricity price used is 18 mils., and the oil price 143$/ton. The size of the plant chosen is 100 000 tons per year, because it represents the minimum viable plant size based on oil. The normal size of oil/gas based plants today is 1000 tons of ammonia/day. Based on electricity the plant could be made virtually as small as required. The capital cost would decrease correspondingly as there is little to gain by increasing an electrolytic plant in size.

Judging from the figures in the table one would conclude that the electrolysis process can be eliminated as being of potential interest. However, discussions we have had with the main Norwegian chemical company with experience in producing ammonia and fertilizers via both electrolysis and oil/gas processes have led as to believe that a feasibility study should be made on the possibilities of producing fertilizer based on electrolysis in Paraguay.

The stable and relatively low price of ITAIPÚ power in relation to foreseen future cost of oil is the main reason for our belief that a fertilizer industry will be viable in a not too distant future.

If a feasibility study is made, emphasis must also be placed on the question as to what types of fertilizers are needed for the agriculture in Paraguay and the neighbouring countries. It is likely that an NKP fertilizer containing the correct portions of all three basis element is needed.

In some countries, e.g. Denmark, ammonia dissolved in water is spread directly on the fields. Further processing is in these cases not necessary, but this method requires a complicated and advanced distribution system which is also very costly.

The very minimum of conversion needed in Paraguay would be to oxidize a portion of the ammonia to nitrogen oxide.

From this, nitric acid and ammonium nitrate would be made. By dissolving limestone, which is found in Paraguay, in nitric acid, one gets calcium nitrate. Especially ammonium nitrate, but also ammonium nitrate limestone and calcium nitrate are valuable nitrogen-containing fertilizers.

To make a complete NKP product, phosphate rock and a potassium salt will be needed. As indicated in the geological part of the report, there are good indications that phosphate rock will be found in Paraguay. Until these indications have been verified and phosphate rock can be provided from domestic sources, it will have to be imported from e.g. Brazil. The potassium raw material will have to be provided from foreign sources.

Other industries related to electrolysis of water

If in the future production of ammonia by electrolysis of water is economically feasible, the possibility of setting up production facilities for other processes based on electrolysis of water, like methanol, heavy water and hydrogen peroxide should be studied.

TABLE 3

Investment and production cost for a 100 000 tons/year ammonia plant

	Electrolysis	Heavy fuel oil
Investment Million US $	49	35
Electricity prices Mils per kWh	18	
Oil price $/ton		143
Cost of inputs per ton of ammonia, $/t NH_3:		
Energy and raw materials		
Oil		114.4
Electricity	198	21.6
Other inputs	5	10
Total manpower, average $ 12000/year		
Electrolysis 150 man/ year	18	
Oil based 120 man/year		14.4
Less credit for heavy water	7	
Total costs per ton	214	160.4
Servicing of capital, 15% of investment	73.5	52.5
Estimated production costs per ton of ammonia $/ton	287.5	212.9

Thermomechanical pulp

The main reasons for recommending a more detailed analysis of the feasability of establishing a thermomechanical pulp industry can be summarized as follows:

1. - The thermomechanical pulp process consumes energy.

2. - There already are raw materials in sufficient quantities available in the country.

3. - Imports of pulp and paper can be reduced and at least a part of the output of this industry can be placed on the Paraguayan market.

4. - There are markets in the neighbouring countries that could take the volumes that Paraguay itself will not consume.

5. - All forecasts indicate that world demand for pulp will grow in the next two decades.

6. - The reforestation program that presently is being implemented will provide large volumes of long fibre wood that can be used in the process.

7. - It is necessary for the success of the reforestation program that, by the time the plantations are ready for harvesting, a market exists for their produce.

The economic situation for the pulp and paper industry, especially in Europe and Scandinavia, has not been good for the last couple of years, and no signs of improvement are envisaged at the moment. However, on a long term and on world wide basis it is foreseen that the demand for paper will at least be equal to the supply resulting in an economically healthy pulp and paper industry.

In spite of the present situation a survey of major expansion projects shows that in the years 1977-1980 additional production capacity of 18-19 million tons/year of pulp and 14 million tons/year of paper will be installed. Total world production was 121 mill. tons of pulp and 154 million tons of paper in 1976. It is interesting to note that of the total world expansion of pulp production capacity Brazil is the leading country with 3,65 million tons which is more than the total production in South America in 1976.

Taken into consideration that Paraguay has vast forests and has launched a reforestation programme, and considering that the country has a very small paper industry and is importing paper, it would seem natural for Paraguay to develop its pulp and paper industry. There are many different types of pulp and paper industries to consider. These vary not only regarding the process and type of products, but also with respect to size and investment cost. Thus many factors must be taken into account when selecting the industry most favourable to the country.

Pulp for making paper is divided into the two main categories; chemical pulp and mechanical pulp. Of somewhat less importance is semichemical pulp. Mechanical pulp is to be preferred with regard to the yield of pulp per ton of wood raw material and also from the point of view of pollution. The yield of mechanical pulp is 90-95% (thermomechanical: 90%, groundwood 95%), of semichemical pulp about 75%, and of chemical pulp 45-50%.

Of all chemical pulping processes the sulphate process represents by far the biggest share of the world's pulp industry. The sulphate process is expensive with regard to investment, and is technically complicated. The process involves digesting (cooking) of the wood chips, recovery of the chemicals required for the process are sodium sulphate, sodium hydroxide, chlorine and lime. The sulphate pulping process does not require input of external energy because by burning evaporated cooking liquid the necessary energy for the heating needed in the process is generated.

The recently built and planned sulphate mills are very large. It is generally accepted that a sulphate mill must have a minimum production capacity of at least 200 000 tons per year to be economical. The investment for such mills is from 250 million US$ and upwards. The new sulphate mills being built on Brazil are typical examples of this trend. One of these mills, Aracruz Cellulose, which will be finished in 1978, will have a capacity of 400 000 tons/year, and a cost of US$ 455 millions.

Sulphate cellulose is a very versatile pulp for making paper. It is used in printing, writing and packaging papers, and in paper boards. It is too exclusive to be used a a major constituent of cheaper paper qualities like newsprint.

The mechanical pulping processes are not so dependent on size to be economical and they are much simpler as far as equipment, operation and maintenance are concerned. The processes for making mechanical pulp require some electric energy, because mechanical energy is used instead of chemicals to release the fibres from the wood. Thermomechanical pulping represents a development of the refining process for making mechanical pulp. The electric power consumption is in excess of 200 kWh per ton of pulp produced, say 2400 kWh per ton for the pine raw material that will be grown in Paraguay. The pulp has qualitative advantages over groundwood and refiner pulp. It is not as yet used in so-called fine papers, and it is recommended that the pulp is used for newsprint and magazine type of papers and in paper board.

The thermomechanical pulping process is rapidly gaining ground in Scandinavia and North America. To our knowledge none of the planned projects in the neighbourhood of Paraguay is based on this process. For this reason and the other reasons mentioned above it is our recommendation that a further study should be made of the feasability of building a combined thermomechanical pulp mill and a newsprint/ magazine paper mill in Paraguay.

In this report we have made an evaluation of the investment and production costs for three different sizes of thermomechanical mills. The evaluation is made under the assumption that the thermomechanical pulp mill is to be an integrated part of the paper mill. It must be understood that the investment sums of 3.5, 5.2 and 7,6 million US$ for the 50, 100 and 200 tons/day mills would be higher if the mills were independent units for production of dried pulp for sale. A thermomechanical mill itself is quite simple and its share of the costs for office, work shop, laboratory and other facilities is therefore quite small. It is our estimation that a realistic capacity for an integrated thermomechanical mill would be 100 to 200 tons/day.

We recommend that when an evaluation of the cost of the paper mill is made, consideration is given to the possibilities of making use of a second hand paper machine. This represents a cheap, but technically fully acceptable solution. There are many good paper machines to be bought second hand; a feasability study could start by looking for a machine which looks promising.

For newsprint paper it should be realistic, after optimalization of the process, to use thermomechanical pulp as the sole component. As a safety factor we recommend, however, that 5-10% of semibleached sulphate pulp is included in the pulp composition. This pulp could be purchased in the open market, e.g. from Brazil.

The same paper machine could be used for making magazine paper. One would then increase the portion of sulphate pulp and one would have to add white mineral pigment (filler) to the composition (furnish). Also extra machinery would be needed to smoothen the paper surface. Thus a supercalender would have to be installed in addition to the paper machine.

We feel that a detailed market analysis of the demand for different products in the adjacent countries is required before the paper machine and the products are specified.

INVESTMENT AND PRODUCTION COST FOR THERMO-MECHANICAL PULP BASED ON PINE IN AN INTEGRATED NEWSPRINT PAPERMILL

Introduction

The important point of the thermomechanical process is that the chips are heated with steam to a temperature above 100°C and the chips are then run through a normal refiner either single or double-disc. The chips may also be treated with chemicals before heating. If a very fine mechanical pulp is required, it may be necessary to have two refiner stages. With pine as raw material and the product being newsprint, we do not regard this as necessary.

The advantage of the thermomechanical process is that it is less sensitive to the quality of the raw material than the normal refining process. The strength will also be better, in particular the tear strength. This also means that the content of chemical pulp in the furnish may be reduced. In Scandinavia or Canada thermomechanical pulp from spruce is frequently used as the sole component for newsprint. With pine as raw material we believe that 5-10% of semibleached pulp should be added as a safety factor.

It is the experience of the Norwegian Pulp and Paper Research Institute that an adequate quality of pulp may be produced with different species of pine such as Pinus Patula, Pinus Elliotti or Pinus Taeda. The properties of a pulp for newsprint is given in Table 4. Most likely these properties can be improved by putting more work into an optimization of the process, especially in finding the right plate design. The most negative feature of the pulp is the low brightness. This cannot be tolerated with respect to the brightness of the final product, and it is recommended to bleach the pulp with peroxide in the refiner. This does not require much extra as to installations, but the cost of the chemical must be taken into account.

Finally it should be mentioned that the high energy consumption is regarded as the main disadvantage of the thermomechanical process in Scandinavia. In this respect pine will require about 10% more energy than Scandinavian spruce. This has to be taken into account in the estimate of the processing cost.

Necessary investment

The pulp and paper industry is typically an industry which benefits from increasing the scale. The manufacture of mechanical pulp is, however, less affected by scale than chemical pulp manufacturing. In order to show this effect we have, anyhow, used three different alternatives, one plant with a capacity of 50 tons/day, a second with a capacity of 100 tons/day and the third with a capacity of 200 tons/ day. The overall investment for the three alternatives is given in Table 5 . The capital cost is significantly reduced when increasing the capacity of the pulp mill. The effect of scale is, however, relatively small above 200 t/d.

The capital cost will also be dependent upon the amortization time and the interest. If the amortization time is 20 years instead of 15 and the interest 10% instead of 12, the effect on the capital cost for a mill with a capacity of 100 t/d is a reduction from 22.5 to 13 $/ton of pulp.

The variable manufacturing costs are given in Table 6. Apart from the cost of wood, the cost of electricity is the most important item. The disadvantage of the thermomechanical process is as mentioned, the high energy consumption. In this case we believe that 2400 kWh will be required per ton of mechanical pulp. According to our experience from similar countries to Paraguay, 18 $/m^3 may be a reasonable cost of the raw material. This means a total raw material cost of about 49 $/ton of pulp.

In Table 7 we have also tried to indicate the manpower required to operate the mill. Because of lack of relevant data, we have not tried to estimate the labour cost. It should be mentioned, however, that the number of expatriates required will have a very important bearing on the mill economy. If the skilled people required are available from neighbouring countries such as Brazil or Argentina the salaries may be more moderate than if people are hired from Europe or the U.S.

TABLE 4

Properties of thermomechanical pulp
made from pine chips

Canadian Freeness	125	Breaking length, m	3000
Breaking index	30	Tear factor	75
Tear "	7.5	Burst factor	15
Burst "	1.5		
Brightness, unbl.,%	53		

These properties are obtained with Pinus Patula, but the same properties may be expected with Pinus Taeda and Pinus Elliottii.

TABLE 5

Investment in equipment required to make thermomechanical pulp provided that pulp is delivered wet to paper mill

All values in 1000 dollars

Plant capacity	50 t/d	100 t/d	200 t/d
1. Wood handling			
Barking, chipping, screening	138	223	355
2. Chip handling			
Washing, chip, silo, pneumatic feeder	206	330	523
3. System for CTMP *)			
Impregnation unit, refiners preheating units, preparation of bleaching chemicals etc.	810	1300	2090
4. Pulp handling			
Washing unit, press, screening, unit thickening. Pump for conc. pulp.	533	854	1363
5. Technical assistance from supplier	142	142	142
Subtotal **)	1829	2849	4473
6. Transport & erection	533	712	890
7. Building	533	712	890
+ 13%	376	556	814
8. Total investment	3271	4829	7067

*) CTMP means that the unit gives the option of pretreating the chips with chemicals. We regard this as the most favourable solution when using pine.

**) No duty or other import costs are included.

Re 6: We have included the cost to atlantic port, for instance Buenos Aires, but we have not available data to calculate the transport cost up the river. Probably another 10% of equipment cost.

TABLE 5, continued

Plant capacity	50 t/d	100 t/d	200 t/d
1. Total investment	3271	4829	7067
2. Pollution abatement (6% of 1)	196	290	434
3. Share of workshop, labs, office space etc.	54	57	68
4. Total	3511	5176	7569
5. Capital cost/t pulp year	235	174	127
6. Capital cost/t pulp	31.5	22.5	16.5

Re 2: We have assumed the same standard for the pollution as adopted in Western Europe/Scandinavia. If accepted by the government, this cost item can be reduced although we regard it as a question of time when developing countries will have to adopt rigid enviromental codes.

Re 3: The thermomechanical plant is supposed to be a part of an integrated paper mill.

Re 6: Depreciation time assumed = 15 years, interest 12% This means an annual cost of about 13% of the investment.

TABLE 6

Production costs for making 1 ton (metric) 90% thermomechanical pulp of news quality

All figures given in dollars

Capacity	50 t/d	100 t/d	200 t/d
1. Capital cost	31.5	22.5	16.5
2. Insurance + share of cost in intergr.mill	3.8	2.9	2.3
3. Electricity, 2400 kWh Price:18 mils of a US$	43.2	43.2	43.2
4. Spare parts	5.4	5.0	4.7
5. Bleaching chemicals	17.9	17.9	17.9
Subtotal	101.8	91.5	84.6
7. Labour + social cost			
8. Wood cost			

TABLE 7

Personnel demand in a plant making 200 t/d of thermomechanical pulp

300 days/year - 40 hours/week

	Number shifts	Total	
1. Pulp mill			
a) Wood and chip handling			
2 qualified workers	2	4	
3 unqualified	2	6	
b) Pulp manufacture			
1 shift supervisor	4	4	
2 qualified workers	4	8	
1 unqualified	1	1	23
2. Share of maintenance dept.ment			
1 sup.eng. (university ed.)	1	1	
1 qualified eng.	1	1	
1 supervisor	1	1	
8 qualified workers	1	8	11
3. Administration - Sales dep.ment			
3 sup.eng. or corresp.quality	1	3	
5 qualified employees	1	5	
5 unqualified employees	1	5	
5 unqualified workers	1	5	18

Summary

	50-100 ton/d	200 t/d
Sup.eng. or similar	4	4
Qual. engineer	1	1
Supervisors	5	5
Qualified workers	18	20
Unqualified	10	12
Qualified employees	4	5
Unqualified employees	4	5
Total	46	52

CALCIUM CARBIDE

Calcium carbide was one of the first products for which the electric smelting process was adopted. Carbide is made in electric furnaces from burnt lime with a minimum of impurities and coal. The fact that Paraguay has ample deposits of good quality limestone is an indication that this process could be worth studying. The coal constituent would in such case come from charcoal.

Calcium carbide is used for production of cyanamide, an important constituent of fertilizer products, and acetylene, which is used for welding and for production of polyvinylchloride. Calcium carbide is also used in the desulphurization of steel. However, for this use it is being replaced by magnesium.

In some cases carbide furnaces are still competitive with the petrochemical industry for small scale operation and special purposes, but it is the qualified opinion of a formerly large Norwegian producer of carbide that the process is outdated. This company produced PVC from acetylene carbide until some 4 years ago. This was a very complicated process which could not compete with PVC produced by modern petrochemical processes.

The foreseen increase in oil prices may, however, lead to a situation where a calcium carbide process is again considered interesting.

Ferro silicon and silicon metal.

Ferro silicon alloys are used in the production of steel and steel alloys and they are marketed in some standard qualities with varying contents of silicon. The following relations are found between the silicon contents of the marketed product and the quantity of electricity needed for their production:

Ferro silicon quantities	45%	75%	90%
kWh per ton commodity	4800-5100	8500-9500	11000-13000

The demand for metallurgical grade (MG) silicon is particularly high for allying purposes in the aluminium industries, where several hundred thousand tons are used. For the production of aluminium MG silicon of 98% purity is used.

Depending on the composition of the raw material 12000-14000 kWh is needed to produce one ton of silicon. Additional demand for silicon is found in the silicon industry which generally requires an even purer grade of silicon (98-99% silicon). Silicon is used to produce intermediate products such as silanes from which several hundred silicon resins, lubricants, plastomers, anti-foaming agents and water- repellent components are formulated.

Silicon metal of high purity and silicon crystals are used extensively in the electronics industry, more specifically in computers, calculators and communications equipment to control and amplify electrical signals. However, the quantity of silicon used in the electronics industry is relatively small and difficult to calculate. Thus the total world's semiconductor's polysilicon demand comsumes but a fraction of the output from one commercially sized furnace.

Further, the production methods of semiconductor grade silicon and silicon crystals vary widely and the producers keep their methods of refining secret in this highly competitive business. The producers of high-purity silicon and single silicon crystals face numerous problems of a technical and economical nature.

Technology brings such rapid and frequent changes to the field that the producer's process or products are often quickly outdated. While profitability is largely dependent on a certain volume each new technical development tends towards miniaturization and reduced material volume. We therefore doubt that Paraguay should be recommended to enter this very special field.

This leaves the ferro-silicon and silicon metal industries left to be discussed. The smelting processes for silicon metal and ferro silicon are the same except that shredded iron, steel scrap and iron oxide is added to the charge when producing ferro silicon. The most important factors in the production are a steady supply of cheap electricity and good quatzite. The quartzite should be thermally stable and of the highest possible purity, at least 98,5% silocon oxid. In the geological part of the report it is indicated that there are possibilities of suitable qualities to be found in Paraguay. Of the impurities the Al_2O_3 contents should be below one per cent, preferably below 0.5 per cent. Also for other elements, particularly titanium and phosphorus, the accepted limits are strict.

To produce one ton of 75 per cent silicon 1800-200 kg of quartzite is needed. The reduction materials, coke, coal and charcoal must also comply with quality specifications. They should have a low ash content and, particularly, a low phosphorous content. For the production of one ton of 75 per cent ferro silicon about 800 kg of coke and 530 of coal is needed together with 230 kg of iron. The iron for the charge can consist of scrap, mill scale, iron ore or pellets. The comsumption of electrode paste is about 60 kg per ton.

The question of getting hold of enough iron would present a problem in Paraguay. Unless larger steel mills are built, one would have to rely on imports

It should be interesting to study the possibilities of using charcoal as a substitute for imports of coke or coal for the production of ferrosilicon or silicon in Paraguay. The cost of charcoal should not exceed about $60 per ton at the plant. Supplies of sufficient quantities of charcoal would have to come from industrial processing of wood into charcoal.

The only other inputs that would have to be imported are electrode paste and possibly refractory materials for furnace repairs.

A most noteworthy trend in the ferrosilicon industry in recent years is movement towards plant specialization. Instead of using four to eight furnaces for a great variety of products, plants are converting to a two furnace operation producing for example only ferrisilicon and ferromanganese. Much larger furnaces with a lower unit cost are being developed. Transformer capacities are increasing from the 18000 KVA to the 100000 KVA range for most new installations.

The industry is faced with a pollution problem. Several furnaces less than 10 years old have been abandoned because the cost of devices for cleaning polluted exhaust gases could not be justified by the limited productivity of the small furnace. In new plants the cost of pollution control facilities will be 20 to 25% of the total installation cost. The operating cost of a modern pollution control system can be reckoned at 10% of the total operational budget.

To get an idea of the order of size of a plant which could represent a first step in building a silicon industry, reference is made to a proposition made to an African country a couple of years ago. It was suggested that a furnace with a maximum load of 30 MV be considered.

Production capacity:

Maximum furnace load	30 000 kW
Specific electricity consumption	9 500 kWh
Production $\frac{30\ 000}{9\ 500} = 3.15$ ton/h	75 tons/day
Load factor	0.9
Yearly production	25 000 tons

Raw material consumption in the plant:

Quartzite	1,95 ton/ton product		50 000 tons/year
Coke	0,8	" "	20 000 "
Coal	0,53	" "	13 250 "
Electrode paste			1 500 "

We reckon that one fully contained furnace would cost	$20-25 mill
+ baghouse pollution abatement equipment	$ 4- 5 "
	$24-30 mill

These costs include all necessary equipment installed inclusive of workshops, laboratory, offices, welfare installations,internal water supplies and sewerage, transport vehicles and spare parts as well as planning and administration during the period of development.

In addition infrastructural investments, e.g. e quay or jetty with cranes and equipment at the riverside have to be taken into account. The cost of these can be estimated to be about $ 5 mill.

This brings the total cost of a plant with one furnace up to about $ 32 millions. The addition of another furnace would mean additional investments of $ 16 millions.

Based on the manning of corresponding plants in Europe, there would be a need for 100 men in all for one furnace and 140 with two furnaces in operation. In addition one would need about 15 persons for management, supervision and administration.

The growth of the future silicon industry is dependent on the evolution of the iron, steel and aluminium industries. Since most silicon producers make long term electric power contracts to obtain more favourable power costs, they are unable to adjust cost rapidly in order to adapt to changing market conditions. Historically, ferro silicon has been the most common form in which silicon was produced and used, accounting for approximately 75% of the consumption in metallurgical, chemical and other uses. However, the use of silicon in the production of aluminium cast alloys has increased in the past few years, for which reason the aluminium industry may very well be responsible for a major part of silicon metal demand by the year 2000.

Although Paraguay will be able to fulfill one of the basic requirements for the establishment of a silicon industry, namely an abundant and steady supply of electricity, it would be premature to suggest that a feasibility study be made before the quartzite deposits have been explored quantitatively and qualitatively. Also market and transport cost evaluations have to give positive indications before too much time and effort is spent on detailed investigation.

MAGNESIUM

Although no economic quantities of dolomite yet have been evaluated or mapped in Paraguay, there seem to be fair chances of finding sufficiently large deposits of this mineral to permit industrial exploitation. Dolomite is one of the minerals on which the production of magnesium can be based on this fact vindicates a brief description of magnesium.

The production of magnesium is very complicated and the technology has developed rapidly during the last few years. Commercial production began in 1866 through electrolysis.

Magnesium has only played a modest part in the world economy. It's light weight combined with high strength and other vital properties, however, make magnesium an attractive metal for many applications. Main consumers are the transport sector, the iron and steel industry, the aluminium and chemical industries. Demand is growing and was 230.000 tons in 1976 in the western world. Known projects which will be completed before 1980, particularly in the USA, will increase the production capacity to some 300.000 tons. The demand in 1980 is assumed to be 330.000 tons as magnesium at that time will probably have become a major substitute for calcium carbide in the pig iron industry. The automobile industry could kick off a dramatic development in the use of magnesium and thus increase the demand far above the production capacity. The price of one ton of magnesium today is 2.100 US$ f.o.b. and may well increase over the next years.

Magnesium is today manufactured by means of two main methods, the thermal process and the electrolytic process in both of which dolomite may be used as main raw material.

In the electrolytic process dolomite is calcined and mixed with seawater and brine and processed to magnesium oxide. The magnesium oxide is transferred to magnesium metal by electrolysis.

The minimum size of such a plant and the necessity of seawater or suitable brine makes the modern electrolytic process less attractive for Paraguay.

The thermal process "Magnétherm" is more suitable with a minimum plant size of approximately 10.000 tons a year. This is a very promising French development and employs an electric furnace with liquid slag. The Magnétherm Process is in operation in France and Italy in plants producing 7-8.000 tons of magnesium a year. In the USA ALCOA has just put a 25.000 tons a year plant into operation based on the Magnétherm method.

If Paraguay should look into producing magnesium based upon positive results from geological research in the dolomite field, we would recommend a feasibility study to be made with the scope of using a thermal process for production of magnesium.The Magnétherm process is based on dolomite as main raw material and the method does not pass the stage magnesium oxide (MgO), but produces magnesium metal directly from an electric furnace. Dolomite is reduced by ferrosilicon in the presence of alumina, the alumina only serving to reduce the melting point (2100°C) of the Ca_2SiO_4 reaction product so as to provide a calcium aluminium silicate slag which is liquid at the operating temperatur of about 1500°C. Figure No. 8 shows the general layout of the equipment. The preferred unit size of furnace is up to 2 tons per day and the operation is discontinous.
The raw materials are preheated and introduced either in granular or powder form. The magnesium may be kept liquid and removed from the furnace by vacuum. At the end of the cycle, the furnace is restored to atmospheric pressure and the slag and residual ferrosilicon are removed. The process reduction may be written:

$$2(CaO.MgO+Si(Fe)+nAl_2O_3=2CaO.SiO_2.nAl_2O_3+2Mg$$

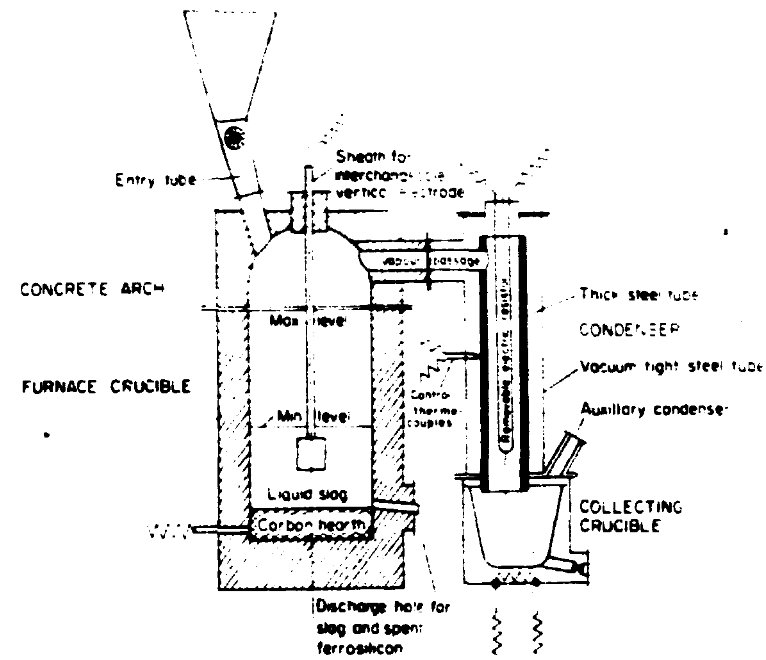
The purity of the magnesium obtained by this process is indicated in some data in figure No. 9.

The furnace is heated by either single or 3-phase current, but the Hopton Plant in the U.K. uses crude oil for heating the retorts.

The magnesium industry has indeed had it's ups and downs. World War II saw the construction at Government cost of thirteen magnesium extraction plants of both types in USA alone with annual rated capacity exceeding 250.000 tons. During the same period additional electrolytic plants and two types of thermal plant (carbothermic and calcium carbide) were installed in the U.K. War-time conditions thus provided an opportunity for the various types of processes to be tried out in comparison with each other on a full production scale (though perhaps not always at the most suitable sites) and in circumstances where quantity rather than price was of first importance. The results are hence of considerable technological interest. With the return of peacetime conditions, many plants have been shut down, and electrolytic and ferrosilicon processes alone have survived.

MAGNESIUM

Fiqure 8



Magnétherm process for reducing calcined dolomite with ferro-silicon using a liquid slag.

Figure 9

IMPURITY CONTENT OF REMELTED PURE MAGNESIUM MADE BY THE MAGNÉTHERM PROCESS

Element	%
Si	0·005–0·05
Al	0·002–0·01
Mn	0·010–0·20
Fe	0·002–0·01

ANNEX I

PARAGUAY
Industrial Survey
Project 1S/PAR/74/017
UNIDO

ENERGY INTENSIVE INDUSTRIES

Checklist for evaluation and selection of possible industries in Paraguay.

Product (Chemistry)	Power consumption kWh/t	Raw Materials	Tonne consumption pr. tonne of product	By-Products [2]	Minimum size of plant [3]
High Carbon Ferro Chrome (FeCr) max 8%C	5.000 (4.000)	Cr-ore Reductants	2,6 0,65		1) 7.500
Low Carbon Ferro Chrome (FeCr) max 1% C	11.000	Limestone,dolomite El.paste	0,3 0,05		11.000 t/year
Silicon Carbide (SiC)	8.000	Quartz Coke			
Calcium Carbide ($Ca\ C_2$)	3.300 (3.000)	Lime(95%CaO) Reductants El.paste	0,95 0,6 0.02		1) 4.800 10.000 t/year
Silicon Manganese (Si Mn)	4.500 - 5.000	Manganese ore Reductants	2.4 0,5		1) 9.000 12.000 t/year
Ferro Manganese (Fe Mn)	2.500 2.800	Manganese ore Reductants	2,1 0,5	30% MnO slag Si Mn	1) 9.000 20.000 t/year

Product Chemistry)	Power consumption kWh/t	Raw Materials	Tonne consumption pr. tonne of product	By-Products[2)]	Minimum size of plant [3)]
Ferro Nickel (Fe Ni)	600	Nickel-ore Reductants El. paste Fuel oil	1,0 0,06 0,004 0,07		1) 7.500 10.000 t/year
Silicon (Si)	20.000	Quartz			
Magnesium (Mg)	20.000	Dolomite, Sea Water	6 800		
Ferro-Silicon (FeSi) (75%)	9.000	Quartz and Iron ore. El. paste	2,0 0,25 0,07		1) 7.500 6.000 t/year
Alumina (Al_2O_3) Pederseus process	4.120	Laterite Limestone Metallurgical coke Coke fines Calsined soda Oil	3,2 1,99 0,33 0,55 0,05 0,1	Pig iron 1,ot Grey mud 1,ot	200.000 t/year

Product (Chemistry)	Power consumption kWh/t	Raw Materials	Tonne consumption pr. tonne of product	By-Products 2)	Minimum size of plant 3)
Aluminium (Al)	14.000 (18.000)	Alumina Petroleum coke Fluoride Cryolite Soda	1,95 0,55 0,05 0,05 0,05		75.000 t/year
Ferro Silicon Chrome (FeSiCr)	8.000	Cr-ore Quartz Reductants Lime stone,dolomite El. paste	1,2 1,1 0,85 0,3 0,06		
Electro Pig iron (Fe)	2.300 2.500	Iron ore Lime stone	1,75		1) 7.500 23.000 t/year
Electro steel (Fe)					

Product (Chemistry)	Power consumption kWh/t	Raw Materials	Tonne consumption pr. tonne of product	By-Products [2]	Minimum size of plant [3]
Electrolytical Copper (Ca)	2.200	Copper			
Copper matte	700	Cu-concentrate Limestone, dolomite, silica El. paste	1,0 0,3 0,004	SO_2 tc Sulphuric acid	1) 4.000 60.000 t/year
Fertilizer (NPK)	65	Phosphate rock (or phosphoric acid)		Ammonium nitrate Nitric acid	
Heavy water (D_2O) 4)		Water			
Hydrogen Peroxide 4) (H_2O_2)		Water Sulphuric acid			
Methanol (CH_3OH) 4)					
Silicon crystals 4) (Si)					
Caustic Soda (NaOH) and Chlorine (Cl_2)	3000 (Cl_2)	NaCl	1.7t pr.t Cl_2	H_2 (28kg/tCl_2)	

Product (Chemistry)	Power consumption kWh/t	Raw Materials	Tonne consumption pr. tonne of product	By-Products [2)]	Minimum size of plant [3)]
PVC 4)		Ethylene Propylene			
Sulphate pulp 5)	NIL Power balance	Pulpwood	2,0		
Paper (newsprint)	1700	Pulp Mechanical and Chemical	1,0		
Fine paper	1000	Pulp	1,0		

REMARKS: 1) Transformer capacity (KVA)

2) By-product column is left open when slags are of no imprtance i.e. "normal conditions".

3) The minimum size of plant is independent of local conditions.

4) Process protected by patent and information protected caused by patent rights - hence little or no information.

5) Power producing from by-product lye. Bleached p. has power balance. Unbleached has surplus power.

A N N E X 2

PARAGUAY
Industrial Survey
Project 1S/PAR/74/017
UNIDO

MINERAL RAW MATERIALS ON
WHICH ELECTRO INTENSIVE
INDUSTRIES CAN BE BASED

MINERAL RAW MATERIALS ON WHICH ELECTRO
INTENSIVE INDUSTRIES CAN BE BASED

Contents: Page:

Annex 2

MINERAL RAW MATERIALS IN PARAGUAY ON WHICH ELECTRO INTENSIVE INDUSTRIES CAN BE BASED

INTRODUCTION

This annex constitutes an integral part of the report "Conceptual Analysis of the possibilities of establishing energy-intensive industries in Paraguay" prepared for the Government of the Republic of Paraguay by Industrikonsulent A.S in collaboration with Kvaerner Engineering A.S at the request of the United Nations Industrial Development Organization.

The annex is a report on the geological findings gathered when preparing for and during the field work in Paraguay in the autumn of 1977 and summarizes the information available at that date on occurrences of minerals on which energy-intensive industries can be based.

The main part of the geological report consists of a map that indicates the localities of mineral occurrences in eastern Paraguay, which could be used in power intensive industries. This map is accompanied by a list that describes the minerals with available chemical and geological data. The geological report should be a good base for future prospecting activities in Paraguay, and it contains several suggestions which are listed under the mineral groups.

The reasons for only presenting a map over the eastern part of the country is the geological fact that the western part of the country or "the Gran Chaco" mainly consists of young sedimentary flat lying rocks of Tertiary and Quaternary age. These rocks will probably not contain any economic mineral deposits although there are possibilities that hydrocarbons and salt layers exist. Very few young intrusive rocks have hitherto been reported in Gran Chaco. If more of the intrusive rocks are found the chances for finding other economic mineral deposits will have to be evaluated.

Geological activities in Paraguay

We have earlier observed that very little has yet been done to investigate the geology of Paraguay and that mineral resources are being dedicated to geological research and exploration for minerals.

The responsibility for these activities is presently shared by the two following institutions:

The <u>Departemento de Geologia</u> of the <u>Direccion de Recursos Minerales</u>
of the Ministry of Communications and Public Works formally is in charge of geological mapping and of the prospecting for industrial minerals. This deparment, however, has an active staff with university training of only one person with a chemical background. Although this person has worked in the Deparment for a long time and has a relatively good knowledge of the geology and mineral occurrences of the country, **he lacks personnel, transport** and other resources **necessary for an efficient pursuit** of even a minimum investigation **program.**

The <u>Departemento de Geologia</u> of the <u>Direccion de Industrias Militares</u>
is concerned with the prospecting for and exploration of metallic minerals and presently concentrating on the search for and investigation of iron deposits. At the time of the mission's visit two of the geologists were away on lease for a longer period, engaged in the preparations for the construction of the Itaipú hydropower plant, for which reason the only active staff with a university background is a chemist assisted by a number of students. The department is equipped with a chemical laboratory, a diamond drilling machine and four cars.

It is thus obvious that the two government geological institutions are underfinanced and understaffed in relation to the tasks they are expected to undertake. The mission recommends that the future activities in this field be taken up for consideration as to goals and resources. We would also recommend that the two **institutions be united and amalgamated to become the Geological Survey of Paraguay.** In this context, as the mineral resources will mainly be used as raw materials for possible future industries, it would seem logical that the Geological Survey be administered by the Ministry of Industries and Commerce.

If the Paraguay Government decides to dedicate more resources to geological research and exploration of mineral resources, expertise will have to be found that is capable of handling the job. Apart from the existing staff and the training of young geologists that is already under way, we would like to mention the possibility of interesting Paraguayan experts presently living abroad, such as dr. Antonio Segovia, at present a professor teaching geology at the University of Maryland, who seems to be highly qualified and well skilled **to build up and head a Geological Survey.**

Although the Governments own efforts on the minerals search field still are very small, the award to "Anschutz Minerals", which is a branch of the Anschutz Corporation, **of a seven year contract for the prospecting and eventual exploitation of minerals in eastern Paraguay** constitutes a significant step towards better knowledge of the assets of the subsoil of the country.

The Concession covers 168.000 square kilometers and allows for the exclusive exploitation of metallic and non-metallic minerals, including radioactive and precious metals.

The Anschutz Corporation is a major US corporation, based in Denver, Colorado, working in the fields of prospecting, drilling for and production of oil and gas, gas transmission, oil tanker operations and mining. They plan to employ, during their working time in Paraguay, a basic staff of twenty people, of which about ten geologists, and intend to spend 0.5 to 1 million US$ per year during the first two to three years. They will be equiped with several field vehicles and an aeroplane, fit to land on primitive landing strips in the working areas, and plan to do some 100.000 kms aerial magnetic survey.

The basic staff will be supplemented by specialized consultants to be brought in as the need for their services arise.

Although we do not know the details of the agreement with Anschutz we would like to underline the **convenience of a close cooperation between the proposed Geological Survey and this contractor in** order to avoid overlapping and to ensure that the geological information gathered is conveniently recorded in Paraguay.

MINERALS IN EASTERN PARAGUAY

List of presently known findings and recommendations for future prospecting activities

Already during the preparatory phase of this study it was obvious that it would be necessary to list all known indications of minerals that may be available in the country and which can provide the raw material base for power intensive industries. Since, except for limestone and kaolin, no mineral deposits of economic value are presently known, we would have to recommend that a prospecting program be planned, through which the mineral assets of Paraguay can be evaluated. We hope that this list and the accompanying map will be a good base for future prospecting activitities.

The list contains 11 mineral groups. For each group a geological description is given with recommendations for possible follow up prospecting. The mineral localities are given the closest possible geographical description. For some of the findings chemical analyses are also given.

At the end of the report there is a chapter where possible imported raw materials, are mentioned with a short description of localities, quantities and qualities of some sources in Bolivia and Brazil.

Limestone, marble, calcite and dolomite

This mineral group is divided into:

a. Limestone deposits in the Vallemi area,(nos. 1,2, 3,4,5,8,9,10,22 and 23).

b. Limestone deposits in the Villarica area (nos.7, 12, 13 and 14).

c. Carbonatite deposits in north-eastern Paraguay (no.6).

d. Marble and calcite deposits (nos.15,16,17,18,19, 20 and 21).

e. Dolomite deposits (nos.1 and 6).

a. Limestone deposits in the Vallemi area

The most important industrial mineral of which there are prooven economic quantities is limestone in the Vallemi area.
On the map nos. 1,2,3,4,5,8,9,10,11 and 23 are limestone deposits. Extensive limestone deposits are found in the Cambrian Itapucumi series in the north-eastern corner of Eastern Paraguay as shown on the map. Close to the main area, limestones of the same series are found both to the east and to the west.

The Itapucumi series mainly consist of limestone and dolomite, but are interbedded with sandstones, siltstones, marls, arcoses and conglomerates. The limestone itself is fine grained with colour from light to dark gray in well defined relatively thin beds. Locally the beds are thick and massive, alternating with shaly limestone and marly shale.

Most of the Itapucumi series are covered with Quaternary deposits. The deposits are up to 30m thick and consist of sinter, breccias and calcite conglomerates as well as sand and gravel.

The Itapucumi series are gently folded with numerous fault zones. In the limestone beds dolomite is often interbedded in thickness of 2-5 meters.

Very little research has been done in the Itapucumi series to outline areas that would be suitable for mining of limestone and dolomite for different industrial purposes.

The typical chemical composition of the limestone is shown in the table below. (Altamirano 1973).

Sample no.1 — Limestone in the "Cordillera de las 15 Puntas 10 kms WNW from Estancia Centurión

Sample no.2 — Oolitic limestone 45 kms NNW from Puerto Max by the Rio Paraguay

Sample no.3 — Limestone from Cerro Paiva 10 kms SW of San Carlos

Sample no	1	2	3
Insoluble	3.34	3.90	1.12
CaO	50.90	52.69	52.85
MgO	0.93	-	-
$(Fe,Al)_2O_3$	2.97	1.97	3.03
H_2O	1.75	-	0.36
CO_2	40.98	41.30	42.40
Organic matter	-	0.69	-
	100.95	100.55	99.66

In the paper "Proyecto Aquidaban" by OAS (Organization of American States) from 1975, there are analyses of 18 limestone samples from the Itapucumi series. In general it can be said that huge quantities of good limestone for all industrial and agricultural purposes can be found in the Itapucumi series. Very little investigation has however been done to outline the most favourable sites for limestone quarries. The best known area is on the banks of Rio Paraguay from San Lazaro in the north to Puerto Itapucumi in the south.

The Vallemi cement plant with it's corresponding limestone quarry lies on the eastern bank of Rio Paraguay, 7 kms south of San Lazaro. The quarry gives excellent limestone for cement production. One analysis from the paper "Proyecto Aquidaban" 1975 gave the following compositions:

SiO_2	$Al_2O_3+Fe_2O_3$	CaO	MgO	Ignition loss
1.87%	0.60%	53.68%	0.36%	42.58%

$CaCO_3$	$MgCO_3$
96.08%	0.76%

There are several continuous beds of pink to white dolomitic limestone in the quarry with thicknesses up to 3m. The dolomite has to be removed by hand or avoided by selective quarrying.

At the eastern bank of Rio Paraguay 12 kms. south of Vallemi at Puerto Risso a few diamond drill holes are said to have been drilled to approximately 60 meters depth. There are no known results from this work recorded. Further south, at Itapucumi, 56 kms from Vallemi about 10 diamond drill holes have been drilled by Industrias Militares. The limestone dips 4-6^o to the east and one of the sections has the following analytical results over 45 m:

SiO_2	CaO	MgO	$Fe_2O_3+Al_2O_3$
3.78%	53.35%	0.04%	0.27%

In the paper "Proyecto Aquidaban" 1975 (pp 166) good and extensive limestone deposits in the vicinity of Garay-cũe 55 kms to the east of Itapucumi are mentioned.

a. Limestone deposits in the Villarica area

West of Caaguazũ at a distance of 30 kms east of Cnel Oviedo there is a small quarry (Calera Cachimbo) where limestone is produced for soil conditioning (no.7.). The limestone is of Permian age (Morinigo 1971). The localities nos. 12, 13 and 14 may be of the same type. In Calera Cachimbo 30-40 tons of soil conditioner is produced per day with the following composition: (average of 7 samples):

SiO_2	$Al_2O_3+Fe_2O_3$	CaO	MgO	Ignition loss
10.51%	1.25%	47.79%	1.16%	38.90%

The limestone which is oolitic is flatlying. In the quarry there are two beds with thicknesses of 1.0 and 1.3 m. Between the two beds there is a 0.3 m thick sandstone layer.

No information was available from a few 30 m deep diamond drill holes in the area. It is believed, though, that the thickness of the limestone beds do not exceed 5 meters. Sr. Casañas, Villarrica, owns the quarry and he also owns the limestone area (Pañetey No.13) NE of Villarrica.

A small sample from Calera Cachimbo analyzed in Norway gave the following composition:

SiO_2	CaO	$Fe_2O_3+Al_2O_3$	MgO	Ignition loss
29.21%	33.40%	3.61%	0.62%	28.2%

The other two localities nos. 12 and 14 are small, 1-2 m thick.

It would be of special interest if the limestone in this area could be used as raw material for a new cement plant, conveniently located near the Itapú, Yacyreta and Corpus hydropower constructions. Although quality and quantity of these deposits on presently known data do not look too promising for cement production, a prospecting program will have to be carried out to clarify whether these limestone sources are suitable for a cement plant.

c. Carbonatite deposits in North-Eastern Paraguay

Carbonatite is mined in several quarries at Cumbre 12 kms east of Cerro Corá (no.6). The carbonatite is used as soil conditioner in acid-rich soils in nearby Brazilian farmland.

A chemical analysis of a sample from the Carbonatite has the following composition (Proyecto Aquidaban 1975):

SiO_2	$Al_2O_3+Fe_2O_3$	CaO	MgO	Ignition loss
4.24%	3.93%	48.43%	2.48%	40.60%

$CaCO_3$	$MgCO_3$
86.68%	5.20

It is believed that there are possibilities to find similar types of carbonatite occurrences further to the south and south-west. If carbonatites are found further to the south, they could be a source of raw materials for a cement plant in the central parts of the country.

d. Marble and calcite deposits

The marble and calcite deposits are of minor importance for the power intensive industries, but they could be actual sources of lime if there are no good limestone alternatives in the vicinity. Nos. 16-21 are marble deposits and no.15 is a calcite deposit.

e. Dolomite deposits (no. 1 and 6)

Dolomite is a very important mineral in the production of magnesium. White dolomite is also used as a filler in the paper, plastic and paint industries. In the Itapucumi series there are several dolomitic horizons. The dclomites are often pink and white. No quantities of dolomite have been evaluated or mapped in the series of Itapucumi, but geologists who have worked in the area believe that there are good chances of finding sufficient deposits of dolomite for industrial purposes. In the Vallemi quarry there appear to be dolomitic beds with thicknesses up to 3m.

Analyses of the "Panceta" - horizon show the following composition:

SiO_2	$Al_2O_3+Fe_2O_3$	CaO	MgO	CO_2
12.4%	4.44%	28.33%	15.23%	38.55%

One smaple of white dolomite has the following composition:

SiO_2	$Al_2O_3+Fe_2O_3$	CaO	MgO	CO_2
1.6%	3.7%	33.7%	15.1%	49.5%

Dolomite is also abundant in the carbonatites at Cerro Corá There should be possibilities for enriched dolomite areas within the carbonatite bodies.

List over Limestone, Marble, Calcite and Dolomite deposits

No.	County	Locality
1	Concepcion	The series of Itapucumi which cover an area of about 2000 km^2 are shaded on the map with NE-SW-striking lines. In the Itapucumi series limestone, marble, calcite, dolomite, sandstones, siltstones, marls, arcoses and conglomerates are found.
2	"	Cerro Paiva (limestone)
3	"	Santa Maria (limestone)
4	"	Taga tiyâ (limestone)
5	"	Machuca cue (limestone)
6	Amambay	Chirigüelo, Cumbre = Cerro Corâ (carbonatite)
7	Caaguazu	Cachimbo (limestone)
8	Alto Paraguay	Cerro Galvan (limestone)
9	"	Cerro Colorado (= Pto Casado) (limestone)
10	Hayes	Pto Pinasco (limestone)
11	Alto Paraguay	Puerto Sastre (limestone)
12	San Pedro	San Estanislao (limestone 1,5-2 in thickness)
13	Guaira	Indepencia, Pañetey (limestone)
14	Caaguazu	Dr. Cecilio Baez, Yhovy (limestone)
15	Concepcion	Puerto Max, Est. Postillon (calcite)
16	"	Col. San Lázaro (marble)
17	"	Cerro Santa Elena (marble)
18	"	Puerto Francia (marble)
19	"	Vallemi (marble and limestone quarry of Vallemi cement plant)
20	Misiones	Villa Florida (marble, small veins)
21	Concepcion	Itapuguacû (marble)
22	"	Itacuâ (limestone)
23	"	Garay-cuê (limestone)
24(1)	"	The series of Itampucumi (also dolomite)
(6)	Amambay	Chirigüelo, Cumbre = Cerro Corâ Carbonatite which also contains some dolomite.

Quartz and Quartite

Quartz occurs in several places in the country both as hydrothermal in veins and pegmatites and as metamorphosed sandstone in quartzites. The vein and pegmatite type of quartz is usually very pure and could possible be a source in the industries of silica glass, silicon metal and silicon carbide. Quartzite usually contains impurities like iron and alumina. If the content of iron and alumina is not too high, it is possible to use quartzite in the silicon-alloys industries.
Very little of the quartz and quartzite localities have been mapped, sampled and analyzed, so here a lot of work remains to be done.

a. Localities of quartz occurrences:

The numbers 1,2,3 and 4 are Precambrian vein quartz and pegmatite quartz. No.1 is the area north and north-west of San Miquel. It is a highly fractured metaquartz and it does not seem to be very pure, because of the presence of some chlorite, but there should be good possibilities of finding veins with crystal quartz of high purity. Analysis of one sample gives the following values:

SiO_2	Fe_2O_3	Al_2O_3
99.05%	0.23%	Not analyzed

In the precambrian rocks in Concepcion there are several localities with pegmatite quartz (nos.2.3.4 and 14).

b. Localities of quartzites

There are several localities with sandstone and quartzites. In most cases they are too impure for industrial use, but within the quartzite layers there should be good chances of finding zones of rather pure quality. Nos.5,6,7 and 8 are localities of a Silurian sandstone and quartzite.
Anal is from three of the localities have given the following results:

Locality No	SiO_2	Fe_2O_3	Al_2O_3
5	96.68%	0.224%	5.11%
7	98.10%	0.24%	Not analyzed
8	97.88%	0.08%	2.47%

The analythical results of these samples show a poor quality quartz with an alumina-content that is far too high and a silica-content that is too low. If the zone, which is 80 km long, if throughly investigated one should have possibilities of finding quartzite deposits with a quality good enough to be used in the silicon-alloys industries.

Nos.9,10,11,12 and 13 are quartzite quarries mentioned in the paper "Plan Triangulo" (1966). The quartzite which belongs to the Misiones series of Triassic age is quarried and used as road material. It is in most cases a red iron-rich quartzite that is believed to be contactmetamorphosed. No mapping or analysis has been carried out on this type of quartzite. Even if it is rich in iron it can very well be used in the ferrosilicon industry, provided the content of other impurities is low.
We would recommend that these deposits be investigated as soon as possible, as they provide a raw material that may be used in a ferrosilicon industry. If so, it should not be used as road building material.

There are also other possibilities for quartz sources in Paraguay.

On the river banks there are huge quantities of sand which may be of good quality suitable for industrial purposes. In the outer rim of the carbonatites quartz is often built. Quartz can also probably be found in pegmatites in the Precambrian formations south of Ascuncion.

A locality of quartz is reported near Villa Florida.

<u>List over Quartz and Quartzite localities</u>

No.	County	Locality
1	Misiones	San Miguel, Itayuru (metaquartzite and vein quartz)
2	Concepcion	Est. Santa Sofia (Pegmatite quartz)
3	"	Potrero Quien Sabe (Pegmatite quartz)
4	"	Zanja Moroti (Pegmatite quartz)
5	Cordillera	Emboscada Noeva (Quartzite and sandstone)
6	"	Colombia (Quartzite and sandstone)
7	"	Piriebuy Pirarétá (Quartzite and standstone)
8	Paraguari	Caballero (Quartzite and sandstone)
9	Central	Ypané (Quartzite)
10	"	San Antonio, Guarambaré (Quartzite)
11	Misiones	San Juan Baptista (Quartzite)
12	"	San Ignacio (Quartzite)
13	Itapua	San Cosme y Damián (Quartzite)
14	Concepcion	Est. J.E. Lopez, Puerto Sino (pegmatite quartz)

Kaolin and Clay

Due to the climatic conditions in Paraguay koalin and clay as weathered products are found all over the country in the favourable rock units. Kaolin and other clays are found mixed in several places and are used as a raw material in the production of tile, brick, pottery, sanitary porcelain and sewage pipes.

There are three different types of kaolin and clay deposits:

a. One type occurs as weathered sediments in rather thin flatlying beds between layers of sandstone. (Nos. 1,2,3,4,5,6,7,10 and 11).

It is said to be of a good quality with very little iron salts.

b. Nos. 8 and 9 are kaolin fillings in subvertical fault zones. Also this type is of good quality, but the quantities seem to be small.

c. The Vargas Peña type (Nos.12,13,14,15,16 and 17) is weathered products of the Vargas Peña shale in the Itacurubi series of Silurian age.

There are several pits of the Vargas Peña type and the thickness of the clays are up to 20 m. The quality is not as good as the two types mentioned, but the zone of the Vargas Peña shale can be followed over several tens of kilometers, so there should be fairly good chances of finding more of these clays.

In general kaolin and clay are not minerals used in the power intensive industries. They are mentioned in this list for two reasons:

1. In the future kaolin and other clays rich in alumina may be used as a raw material for aluminium.

2. In a possible future paper mill, kaolin could be used as a filler.

According to Putzer and Eckel a few analyses have been made of the Paraguayen kaolins. The results of these do not indicate that they are very suitable as fillers in the paper industry, but the geological, mineralogical and chemical studies that still have to be made may give more positive indications.

List ‹ver Kaolin and Clay deposits

No.	County	Locality
1	Cordillera	Piribebuy, Pirareta (type a, weathered sediments in rather thin flatlying beds between layers of sandstone)
2	Paraguari	Piribebuy, Itamoroti (type a)
3,4	Cordillera	Piribebuy, Paso Jhû and Itabyrá (type a)
5	Paraguari	Capilla Cue (type a)
6	"	Chololó, Guazû (type a)
7	Cordillera	Valenzuela, Tobatinguá (type a)
8	Paraguari	Escobar, Mbopicuá and Ybyra tŷ (type b, kaolin fillings in subvertical fault zones)
9	"	Sapucai: Cerro Roquë and Loma Guazû (type b)
10	"	Caballero, Horqueta and Guauirá (type a)
11	Caaguazu	San Antonio, Yhû (type a)
12	Central	Aregua, Caacupemi and Estanzuela (type c, Vargas-Peña type)
13	"	Itauguá, Ybyraty (Type c)
14	"	Ipacarái Cerro Gufy and Mbcayaty (type c)
15	Cordillera	Tobatî, Cerro Aparypy (type c, locality uncertain)
16	Cordillera	Isla Pucû, Cerro Pero (type c, locality uncertain)
17	Guairá	Iturbe, Rojas Potrero (type c, locality uncertain)

Iron Ore

Several small magnetite and hematite deposits are know in Paraguay (Nos.1,2,3,4,5 and 6). They were mined in the 18th century, especially during the War of the Triple Alliance 1865-70. The magnetite and hematite deposits mostly occurs in the Precambrian rocks between Quiindy in Paraguari and San Juan Bautista in Misiones.

In Itapua large areas exist with low grade iron ore of lateritic material (no.7). This type occurs in "Zona de Encarnacion" from Encarnacion in the south of Hehenau in the north. The deposits of Arroyo Pora, Barrero, Chaipé, Santillán, Itá anguá, Col. Urú Sapucai and San Juan belong to this zone. Each deposit covers an area from 1200-71500 m^2 with thicknesses 0.3 - 4 m. and contains:

Fe	20-40%
TiO_2	2-4%
Al_2O_3	10-20%
SiO_2	30-40%
P	0%
S	0%

According to Industrias Militares about 5 million tons of this type of ore has been proven and there are indications of 30-50 million tons of probable ore. The Encarnacion area will be flooded by the Yacyreta power plant project. The laterites of this area have been investigated and found to be of no economic value.

Industrias Militares is presently investigating a number of other ore occurrences. No promising results have yet been obtained.

When the Anschutz Minerals has completed their planned aeromagnetic survey, one will have a much better base for judging the possibilities of large iron ore deposits to be found.

Even a non-magnetic hematite deposit with a size of economic interest should show up on an aeromagnetic survey due to the fact that there nearly always will be some magnetite mixed with the hematite.

The known magnetite and hematite deposits are well described by Eckel and Putzer.

List over Iron ore localities

No.	County	Locality
1	Paraguari	Caapucú, Paso Pindó(=Villa Florida)(hematite)
2	"	Caapuca, Apichapá (hematite and magnetite)
3	"	Caapucú, Aguirre cúe(= Yaguary) (horizontal layers with hematite)
4	"	Caapucú, Est.Del Puerto (hematite and magnetite)
5	Misiones	San Miguel, Itacuá (Magnetite
6	Caazapá	Yutý, Yaratiti (magnetite and limonite
7	Itapúa	"Zona de Encarnacion" with the deposits Arroyo Porá, Barrero, Chaipé,Santillan, Itá angua, Col.Uru Sapucai and San Juan (limonite)

Manganese minerals

Manganese deposits are known in several places in the eastern part of the country. The occurrences are impregnations and fracture fillings with manganese oxides (mainly psilomelan) in sandstones of Silurian and Triassic age. It is in general built by supergene water solutions from weathered rocks. This type of deposits are in general small and uneconomic. The occurrences of manganese are well described by Putzer.

If there are any hidden larger manganese deposits in Paraguay like Morro do Urucum in Brazil, chances are good to detect them with the aeromagnetic survey planned, as the Morro do Urucum type pf ores also contains small amounts of magnetite together with the hematite and manganese oxides.

List over Manganese occurrences

No.	County	Locality
1	Cordillera	"Zona de Emboscada" with the localities Ybera, Cerro Cabará, Cordillera gúy and Dominguez (vein deposits in silurian sandstone)
2	Paraguari	Ita, Valle Yo-á
3	"	Ybycui, Cordillerita
4	"	Caacupe, Azcurra

Other small deposits with Manganese mineralization are also mentioned by Putzer and Eckel.

Salt

Common salt or sodium-chloride is a very important industrial mineral. No economic salt deposits are known in Paraguay. Salt in sediments and ground water is reported from several places of the country, but the only interesting indication of possible salt deposits is the brine well at Lambaré a few kms south of Asuncion.

The salt brine at Lambaré is said to contain about 10% NaCl and to produce about 50 m^3 per hour.

A company called CEISA (Construcciones e Inmuebles S.A.) in Asuncion owns the brine at Lambaré, and they have carried out a study on the brine.
Some salt has been produced by solar evaporation from the salt water at Lambaré. This production was not successful, because of the humid climatic conditions.

Lambaré is the most promising salt locality in Paraguay, and attention should be paid to it. Efforts should be made to determine whether the brine comes from dissolved salt layers or only from sediments containing brines. This can only be determined by diamond drilling.

The composition of salt from Lambaré is:

NaCl	91.40%
$MgCl_2$	2.95%
Mg SO_4	0.90%
$CaSO_4$	4.23%
Difference	0.52%

In the western part of the country, in Gran Chaco, more than 100 water wells have been drilled over an area of 2 million hectares during the last years.

The wells are in average 200-220 m deep and the rocks are Quaternary and Tertiary sandstones. Very pure water is found in the western and northern part of Gran Chaco, while some water containing salt is found in the central part and east. Most of the salts in the wells are sulphates derived from gypsum pockets in the sandstones. The logs from the drillings for water in Gran Chaco are kept in the archives in Filadelfia.

There are several rivers and lakes in the Chaco that contain saline water but it is probably only salty surface ground water, accumulated under the semi-desert conditions of Gran Chaco.

Similar salty water and salt-containing soils are also reported by Eckel at some localities in the eastern part of the country. In the study "Plan Triangulo 1966" a salt indication (no.2) is reported from Pasroteo in the province of Caaguazu. The sediments contain salt, which is evidenced by the saline content of the ground water and the fact that the soils are treeless.

From a geological point of view there could very well be salt layers in the deep layers of Gran Chaco. Eckel: "Nearly all the Gran Chaco consists of hundreds of meters of sediments deposited under continental and desert conditions. It seems reasonable to suppose, therefore, that somewhere within this sequence of beds there may be beds or lenses that represent the evaporation of desert lakes that were high in sodium chloride".

Deep drilling for oil and gas in Gran Chaco started in 1949. Until 1972 - 29 holes had been drilled and today there are about 40 holes on record. With the exception of some gypsum pockets no findings of salt layers have yet been reported.

SALT LOCALITIES

No.	County	Locality
1	Central	Lambaré, Yuguytý (brine)
2	Caaquazu	Pastoreo (salt in sediments and salty ground water)

Salty water is reported by Eckel in Fuerte Olimpio, Concepcion, Rio Piribebuy, Rio Salado and Rio Negro.

GYPSUM

Gypsum is not a very important mineral in the power intensive industries, but known deposits are incorporated in the map since it is used in the cement industry.

LIST OF GYPSUM LOCALITIES

No.	County	Locality
1	Concepcion	Puerto Vallemi (pockets with evaporite gypsum)
2	"	Saladero Risso (pockets with evaporite gypsum)
3	Neembucu	Villa Franca
4	San Pedro	Rosari, Puerta Loma (very small)

Phosphate rocks

Phosphate rock is a very important raw material that provide the phosphorous component for the production of fertilizers.

No phosphate rock deposits are known in Paraguay, but there are some indications that these minerals could be found. Robertson (1975) reports that in a north to north-west trending zone between Sao Paulo and Golania in Brazil, at least seven alkali areas, some with carbonatites, have been investigated.
Two of these, Araxa and Tipara have large tonnages of niobium and phosphate that has been concentrated by weathering.

At Tapira, the carbonatite is hidden by a thick cover of limonitic canga, a fact which has to be taken into account when exploring these types of deposits.

Locality no.1 and 2 Cerro Cora and Cerro Sarambi are alkaline intrusive rocks, Corro Cora with a rime of carbonatite. These localities are described in the paper"Proyecto Aquidaban(1975)". No analysis has been done on these alkaline rocks, but the soils in the area contain 3.3% P_2O_5 and the carbonatite rocks 0.1-0.3% P_2O_5.

The phosphate mineral is a chlorine apatite.

It it believed that similar alkaline intrusions could well be found south of Cerro Cora and Cerro Sarambi, which however is an area that is very difficult to prospect due to thick overburden and dense tropical forests.

In the southern part of Paraguay between Ascuncion and Villarrica there are several alkaline intrusive rocks. The geological map in the paper "Plan Triangulo (1966)" was drafted from data of aerial photographs and shows the outlines of more than 30 alkaline intrusive rock bodies.

Eckel (1959) and Putzer (1962) give a very good description of the magmatic rocks of Post-Triassic age.

The Sapucai area (No.3) is especially mentioned for it's abundance of phosphatic soils.

As a whole there is good information on carbonatites and alkaline rocks in Paraguay that provides a good base for the prospecting for phosphate rocks.

LIST OVER ALKALI ROCKS AND POSSIBLE LOCALITIES FOR PHOSPHATE ROCKS

No.	County	Locality
1	Amambay	Chiriquelo (=Cerro Cora) (carbonatite and alkali rock in ring structure)
2	"	Cerro Sarambi (Alkali rock in ring structure)
3	Paraguari	Sapucai and Ybytym (alkali rock)
4	"	Acahay (alkali rock)
5	"	Paraguari (alkali rock)
6	Guaira	Mbocayata (alkali rock)
7	Concepcion	10 kms.SE of Est.Centurion (alkali rock)

Bauxite and rocks that could be a source for bauxite

No bauxite occurrences have been found in Paraguay except for one location recently reported near the Villarica in Guaira. (Not shown on the map). Putzer (1962 and Eckel (1959) point at the possibilities of finding bauxite as alteration products of alkali rocks like nepheline-bearing syenite, shonkinite and basalt.
Alteration of alkali rocks gives bauxite when weathered under tropical conditions.

Under the previous chapter reference is made to several alkali rocks in Paraguay as these also can be a source for phosphate rocks.

Bauxite deposits in the Pocos de Caldas area in Brazil has been altered from alkaline rocks of a similar type and age as the alkali rocks in Paraguay. (Patterson 1967). Bauxite deposits are often indicated by barren areas. Such areas should be picked out from studies of the air photos and checked on the spot.

The best chances of finding bauxite are possibily in the alkali areas in the eastern part of eastern Paraguay, where at present rainfall is heavier than in the western parts.

COAL, GAS AND OIL

Coas, gas and oil are by no means minerals on which power intensive industries are based, but are mentioned here because of their importance as input materials in several industries.

In Gran Chaco a deep drilling at Pirizal has perforated coal-like material at depths from 1668 to 1671 and from 1676 to 1687 m. reported by Eckel (1962).

One piece of coal is reported by Putzer (1967) from the upper parts of Rio Pirapo, a small tributary to Rio Alto Parana. Putzer means that this piece of coal comes from a small lense of coal in the Caiva-sandstone which lies above the basalt layers of the Sao-Bento-series which possibly is of Cretaceous age.

The western part of the Parana basin with the Gondwana series reaches into eastern Paraguay. In the same basin 1000 km's to the east there are several coal deposits in the Gondwana series. Coal findings are also reported in Brazil near the Paraguayan border in the area of Capitan Bado. The possibilities for coal findings in the north and mid-eastern part of the country should therefore be rather good.

Putzer (1962) has reported traces of oil and gas in the Gran Chaco from three deep drill holes.

In the drill hole at Picuiba traces of both oil and gas were found in several layers, and in the holes in Santa Rosa and Mendoza traces of gas was found.

The Oil and Gas Journel of April 12th 1976 pp.44 reports on three gas strikes in Bolivia 40-300 km's from the border of Paraguay.

Possible import of raw materials

The neighbouring contries of Paraguay are relatively rich in minerals. Due to the lack of communication facilities and the vast distances only a few deposits can be considered as sources of raw material for power intensive industries in Paraguay. The most interesting deposits will be mentioned under this heading.

Iron and manganese

The Mutun iron or deposit is situated on the border between Bolivia and Brazil with 7 parts on the Bolivian side and one part on the Brazilian side. It lies 350 km's north of San Lazaro and only 35 km's from Rio Parguay.

N.H.Fisher (1955) describes it as a hematite deposit with 54% Fe, 20.7% SiO_2, 0.30% Mn, 0.5% S and 0.13% P.

The total tonnage of iron ore is estimated to be more than 50.000.000.000 tons.

Less than 30 km's to the east of Mutun is the Morro do Urucum iron and maganese deposit in Brazil. This deposit has been described by John V.D.Dorr, 2nd(1944) and Volker Eisenlohr (1964) and is very similar to Mutun. It contains about 4.500.000.000 tons of hematite ore and 4.420.000 tons of measured manganese ore. The hematite ore contains about 50%Fe and 25% SiO_2. No sulphur or phosphorus analysis are available, but it is believed that the contents are similar to those of the Mutun deposit. The manganese ore contained 45.6% Mn and 11.1% Fe.

Phosphate rock

In Brazil several phosphate rock deposits are known. Some of these deposits like Jazida de Cataloa in Goias, Patos de Minas, Mino do Barreiro and Jazida de Tapiro in Minas Gerais, Jazida de Ipanema, Serrote and Jacupirauga in Sao Paulo are located 800-1000 kms from the border of Paraguay (andery 1977).

In Eastern Bolivia near the Brazilian border 450 kms north of San Lazaro reserves of 20 million tons of phosphate rock is reported in Laguna Mandiore. "Industrial Minerals Nov. 1976".

REFERENCES

Altamirano 1973 — La materia prima para fabricacion del cemento Portland en el Paraguay. Unpublished report.

Andery,P.A. 1977 — Brazil's busy phosphate industry. World Mining February 1977

Blade V.et al. 1971 — Raw materials for fertilizers and soil conditioners in eastern Paraguay. U.S. Geological Survey.

Dorr, J.V.N. 1945 — Manganese and Iron Deposits of Morro do Urucum, Mato Grosso, Brazil. U.S. Geological Survey Bulletin 946-A

Eckel, E.B. 1959 — Geology and Mineral Resources of Paraguay - A Reconnaissance. U.S. Geological Survey Professional paper No. 327.

Eisenlohr, V. 1964 — Die Schwemmfächer der Eisenerze vom Morro do Urucum bei Curumbá/Brazilien als Beispiel terrestrischer Trümmer-eisenerz-Lagerstätten. Bergakademic Chlausthal/Technische Hochschule.

Fernandez Lima y De La Inglesa 1963 — Informe Sobre el mineral de Hierro de la Provincia de Misiones Informe Technico No.16. Direccion National de Geologia y Mineria. Republica Argentina.

Fisher, N.H. 1955 — Geological report on the Mutun Iron Deposit. UNDP library, Asuncion.

Harrington, H.J.1955 — Handbook of South American Geology.

Industrial Minerals 1976 — World Phosphate producers Industrial Minerals Nov. 1976

Ministerio de Obras Publicas y Comunicaciones- Dpt, de Geologia 1966 — Plan de Prospeccion Geologica y Mineral. Quadricula 40 "Ita"

" " 1966 — Plan de Prospeccion Geologia y Mineral. Quadriicula 41 "Coronel Oviedo"

" " 1975 — Lista de Manifestaciones Minerales conocidas del Paraguay. Direccion de Recursos Minerales.

Morinigo,V. 1971 Calizas Fosiliferas del Permico en "Cachimbo", oeste de Caaguazu. Rev. Soc. Cientifica-Vol.12 No.1, Universidad Nacional de Asuncion, Paraguay.

Morinigo,V 1969 Informe sobre la Techtonica de la Republica del Paraguay, Ministerio de obras Publicas y Comunicasiones.

Patterson 1967 Bauxite reserves and Potential Aluminum Resources of the World. U.S. Geological Survey, Bull. 1228

Plan Triangulo 1966 Estudio Agricola y Vival. Zona: Asuncion-Encarnacion- Purto Pres. Stroessner. Consultores: Aero Service Corporation y Gannet Flamming Corddry and Carpenter Inc. UNDP-library, Asuncion.

Proyecto Aquidaban 1975 Cuenca del Plata. Estudio para su planificacion y desarollo. Republica del Paraguay - Proyecto Aquidaban. Desarollo de la Region Nor-oriental. Secretaria General de la Organización de los Estados Americanos. Washington, D.C. 1975.

Putzer, H. 1962 Geologie von Paraguay. Gebrüder Borntraeger, Berlin-Nikolassee.

Robertson 1975 Note on Mineral development, Paraguay. UNDP - library, Asuncion.

Vivar, V.D. y Morinigo, G.V. 1968 Geologia del Paraguay, Sintesis Descriptiva. Ministerio de Obras Publicas y Comunicaciones.

81.12.02