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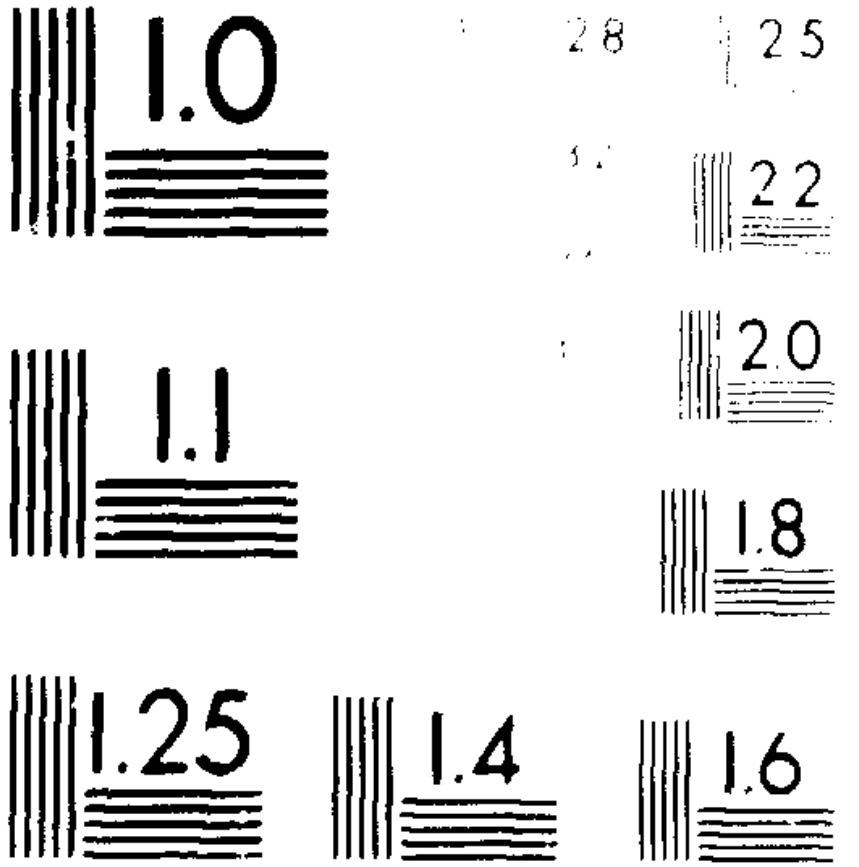
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Bhutan.

DEVELOPMENT OF GYPSUM-BASED INDUSTRIES

RP/BHU/81/002

BHUTAN

Terminal report

Prepared for the Government of Bhutan
by the United Nations Industrial Development Organization

Based on the work of Gerhart Bertolii,
expert in gypsum industries

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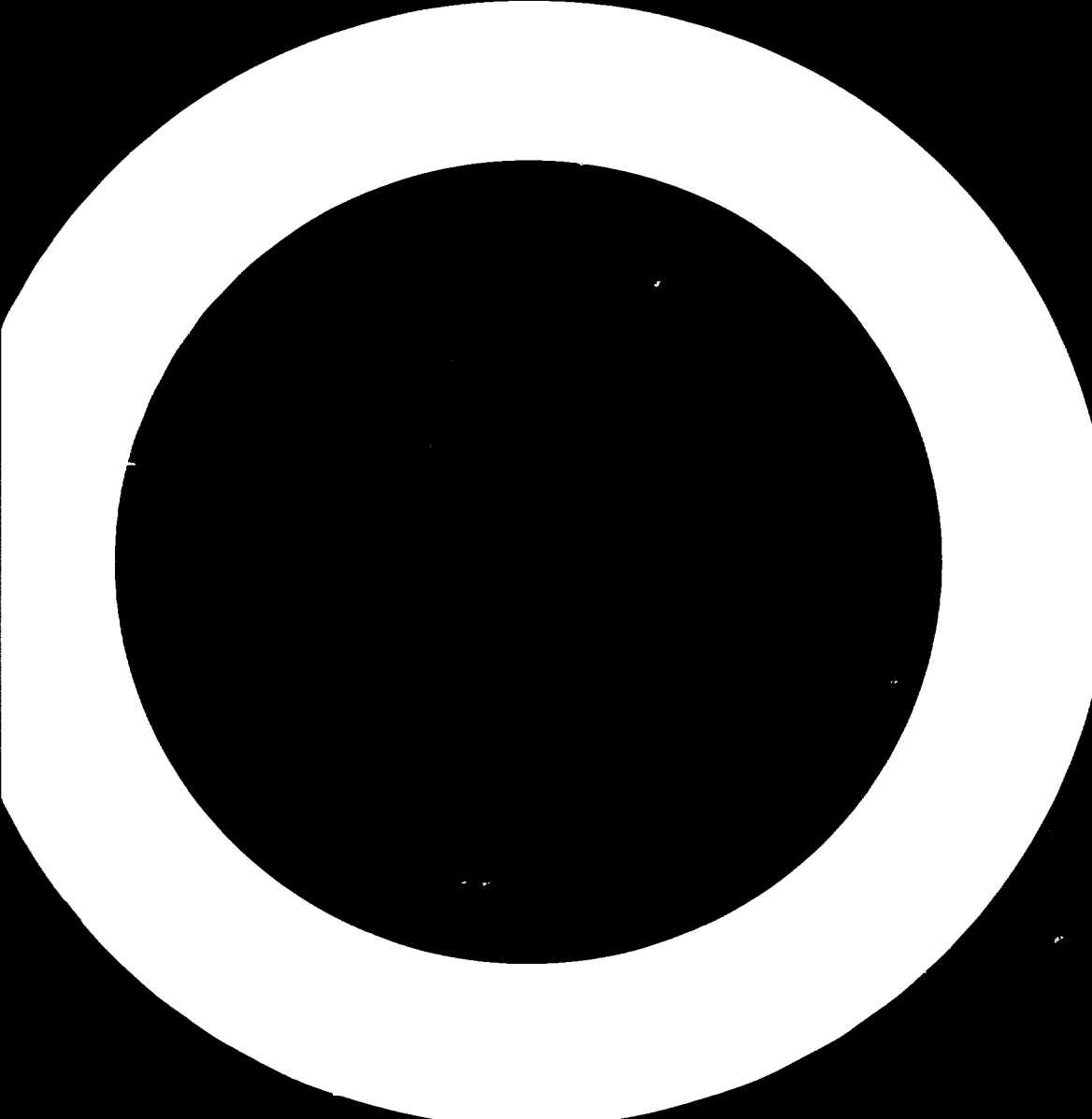

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INTRODUCTION

This paper is based on the following reports on the Khotakpa mine:

(a) Report on gypsum deposits in the Khotakpa area of Bhutan prepared jointly by the Geological Survey of India and the Government of Bhutan, which stated that layers of schist with different contents of calcium sulphates were overburdened with non-sulphatic materials. Also, that between the sulphatic layers there were silicate materials with different mineralogical compositions. There were outcrops at different parts of the deposit. The engineers would start mining at these outcrops;

(b) A study of the Ministry of Trade, Industry and Forestry;

(c) Feasibility study (with two supplements) of the exploration of the Khotakpa gypsum deposit by Shahi Bhawha, New Delhi. This report showed the possibilities of starting gypsum mining for use in cement manufacturing;

(d) Report on small-scale mining in outcrop area of the eastern part of the Khotakpa gypsum deposit, which stated that a road was being built to the eastern outcrop of the deposit. The mining was to be started after the monsoon. Most of the work would be done by hand. The labourers would come from Assam, northern India. The work would be similar to the way stones for street building are prepared, i.e. reduced to smaller pieces by hand. The blasting would be done in small parts.

I. GYPSUM DEPOSIT IN BHUTAN

According to the Geological Survey of India, which gives geological mapping as well as the drillings and the chemical, mineralogical and petrographical analysis, there is no work to be done in the future.

The size of the deposit is sufficiently high to justify industrial exploitation. The following different materials were found in the deposit:

(a) Calcium sulphate dihydrate (dihydrate), $CaSO_4 2H_2O$;

(b) Natural anhydrite, $CaSO_4$;

(c) Phyllite and phyllitic schists consisting of different silicate minerals;

(d) Overburden, consisting also of different minerals;

(e) Mixture of the above materials (mixed during the former geological periods), i.e. mostly low-grade $CaSO_4$.

The Indian engineers of the Ministry are still working on a road to an outcrop of dihydrate, where the mining should start. The first products will be lumps of dihydrate for the cement plant in the northern part of India. Some work will be done by machine but most of it by hand. The workers will be from Assam, northern India. Because of the growing overburden in the future, i.e. the gypsum is falling down under the overburden, it seems absolutely necessary to make a definite work plan for the mine for the next five to ten years. If this is not done, only the profit-making part of the mine will probably be used.

II. LINES OF GYPSUM-BASED INDUSTRIES

The figure below shows the different lines of gypsum-based industries and their products:

(a) Sulphuric acid line:

- (i) Sulphuric acid/cement plant (Müller-Kühne process);
- (ii) Ammonium sulphate;
- (iii) Lime (CaO, $Ca(OH)_2$);

(b) Burned gypsum line:

- (i) Dry burned gypsum (beta plaster, plaster of Paris, stucco);
- (ii) Wet burned gypsum (alpha plaster);

(c) Raw gypsum line:

- (i) Additive for cement manufacturing;
- (ii) Building stones (very soft working);
- (iii) Sculpture stones, if larger blocks are possible;
- (iv) Alabaster handicraft;
- (v) White cheap pigments;
- (vi) Powder gypsum as a fertilizer ($CaSO_4$, solubility of dihydrate 2 g/l).

For all these products different raw materials are needed. Table 1 shows the type of raw material to be used for the end-product.

Table 1. Raw materials to be stored even if only one product line is in operation

Different types of raw material to be stored separately	Used for
Overburden Phyllites Low-grade $CaSO_4$	Cement - sulphuric acid plant
High-grade $CaSO_4$ (Dihydrate + natural anhydrate)	Additive for cement manufacturing Cement - sulphuric acid plant Ammonium sulphate process
High-grade $CaSO_4$ Only dihydrate	β Semihydrate (plaster of Paris) α Semihydrate

A. Sulphuric acid line

For a developing country with a large deposit of raw gypsum this line should be considered because of the by-products, which are rare in many developing countries. One of the by-products is cement. By a special process, called the Müller-Kühne process, cement of good quality and sulphuric acid are obtained from a mixture of gypsum, silicate components and a reducing component such as cheap coal or oil. Cement is in great demand in Bhutan and also in the northern part of India and a small amount of sulphuric acid may be used in Bhutan while the rest is needed for India. Since Bhutan has a big reserve of hydroelectric power, nitrogen compound chemicals could be produced. With the sulphatic compound it is possible to produce ammonium sulphate, which can be used as a fertilizer. There is a demand for fertilizer in Bhutan as well as in India and other bordering countries. Also, sulphuric acid is used as a raw material for a lot of

synthetic processes and products.

This production is, however, not suitable for a small-scale operation or a pilot plant. It can never be the first production in Bhutan or similar countries. But it can be considered for Bhutan after a period of at least five to ten years. For this process a mixture of gypsum and silicate materials is necessary and all the components of the Khotakpa mine can be used. However, in order not to consume an excessive amount of high grade materials, which are the only ones usable for other types of manufacture (see table 2), stockpiling of high-grade $CaSO_4$ (dihydrate and anhydrate) is recommended in spite of the additional investment and operational costs.

The sulphuric acid/cement line can use all materials of the deposit whereas other production lines use only one part. Because the first product cannot be cement and sulphuric acid, one has to start with the other products but different stockpiles should be made for the future.

B. Burned gypsum line

The burned gypsum line is divided into two types. One type is burned dry, which means that the temperature used needs no other physical element, such as pressure or vapour pressure. The raw material is burned in little pieces in a rotary kiln or as powder in big pots. These types of burned gypsum are called beta hemihydrate or beta anhydrite III depending on the burning temperature. The product is a mass product, but in some cases it is possible to make a medium-scale factory, seldom a small-scale factory. Plates, paperboards, plasterboards, bricks and mortar can be made from the beta hemihydrate. It is the basis of building material industry. Since beta gypsum can be made in a little kettle, this process is especially suitable for a pilot plant production.

The so-called wet burned gypsum is always burned under pressure, mostly in autoclave treating blocks with diameters of approximately 10 to 20 cm in steam autoclaves at a temperature of about 180°C. After burning the pieces are milled down to a fine powder and are used for special purposes, for example in medicine or dentistry, modelling in a wide range of industries and for casting and moulding in the ceramic industry. This type is preferable for a small-scale industry. The product can be sold all over the world (see table 2).

Table 2. The scope of the industrial use of gypsum

Product	Relative profit	Estimated raw material needed (tons/day)	Investment	Market (estimated)	Type of raw material needed (DH = dihydrate α = α hemihydrate β = plaster of Paris) DH	α	β	A	W	Manpower (medium automatization)	Energy consumption	Grade of the specific know-how needed
Direct use without chemical processing												
Building stones	Small	1-50	Very small	India	x			x		Medium to high	Very low	Low
Sculptor stones	Small to medium	1-50	Very small	India	x			x		Medium to high	Very low	
Wall plates	Small to medium	1-2	Small	India				x		Medium	Very low	Low
Cement additive	Small	50-200	Medium	India	x			x		Medium	Very low to low	Low
White pigments	Medium	1-10	Medium	India	x			x		Low	Low to medium	Low
Filler	Medium	1-50	Medium	India	x			x		Low	Low to medium	Low
Fertilizer (SO_4)	Small	20-100	Medium	India	x			x		Low	Low to medium	Low
Plaster and derived products												
Hemihydrate (plaster of Paris)	Medium	5-100	Medium	Bhutan and India near border	x					Medium	Medium	Medium
Alpha and beta plaster blocks	Medium to big	5-100	Very small	Bhutan and India near border	x					Medium	Very low	Low
Plaster panels	Medium	50-100	Very small to small	Bhutan and India near border	x					Medium	Low	Medium
Plasterboards	Medium	50-100	Very big	Bhutan and India near border	x					Medium	Low	High
Slipcasting plaster	Medium	5-10	Small	India		x	x			Low	Low	Low to medium
Moulding plaster	Medium to big	10	Small	India		x	x			Low	Low	Low to medium
Medicinal and dental plaster	Big to very big	0.1-10	Very small to medium	World-wide		x	x			Low to medium	Low to medium	Low to medium
Large-scale chemical industry												
Cement and sulphuric acid	Medium	500-800	Very big	India	x			x	x	Medium	High	High
Lime and sulphuric acid	Medium	100	Very big	India	x			x	x	Medium	Very high	High
Ammonium sulphate	Medium	100	Very big	India	x			x		Medium	Very high	High

C. Raw gypsum line

The first use of gypsum in Bhutan will be as a cement additive. Since the cement plant will tend to use only the part of the deposit with the highest sulphuric content, one has to pay attention. If possible, the plant should sell anhydrite of high purity and not dehydrate, which could be used much better for alpha or beta burned gypsum products. In the case of Bhutan natural anhydrite can only be used for cement/sulphuric acid line or for building stones, not for burned gypsum. If anhydrite is used, transportation will be much easier because anhydrite contains about 20 per cent more sulphate, whereas dehydrate contains 2 molecules of water.

Other ways of using natural gypsum and anhydrite have been tried out in Europe and elsewhere. The production of building stones is an example. The workability of the soft material is very good. Also, it is possible to make thin and thick, small and big plates for decoration. And it is especially good for making alabaster objects, which is a big handicraft manufacture. Nearly 8,000 people live from this handicraft in Italy and the products are sold all over the world. Because of the simple nature of the manufacture of alabaster articles they could soon be made in Bhutan, if one or two Bhutanese were sent to Italy, the centre of this handicraft in Europe. Another product of natural gypsum and anhydrite is a white pigment. In the pilot plant of alpha gypsum the white pigment could be produced too, as well as powder for use as fertilizer.

III. THE SCOPE OF THE INDUSTRIAL USE OF GYPSUM

Table 2 shows the different gypsum-based products and related technologies. The alpha gypsum and raw gypsum lines are of special interest for Bhutan. The alpha gypsum line does not require much investigation, is highly profitable, does not require many workers and the tonnage is not high, so there is no transportation problem. Apart from the use as a cement additive the raw gypsum line is of interest as sculpture stone of very good quality, for thin wall plates (similar to the use of marble in Europe, especially in Italy), and in the alabaster handicraft. Alabaster handicraft products from Italy are sold in Europe and the United States of America.

IV. PRIORITIES FOR THE GYPSUM-BASED INDUSTRY IN BHUTAN

The following prioirities should be established:

(a) Cementary additive uses;

(b) Stone wall plates, which are easy to saw by hand, and alabaster handicraft, for which hardly any investment is necessary;

(c) Alpha plaster after one year (investment needed $US 0.4 to 0.6 million);

(i) Beta plaster and plaster of Paris after about three years;

(e) Cement-sulphuric acid line in connection with ammonium sulphate line. For this production the consumption of power is enormous and hydroelectric power plants will need to be established. There is not much likelihood of being able to start this line within the next five years.

V. RECOMMENDATIONS FOR FURTHER TECHNICAL ASSISTANCE

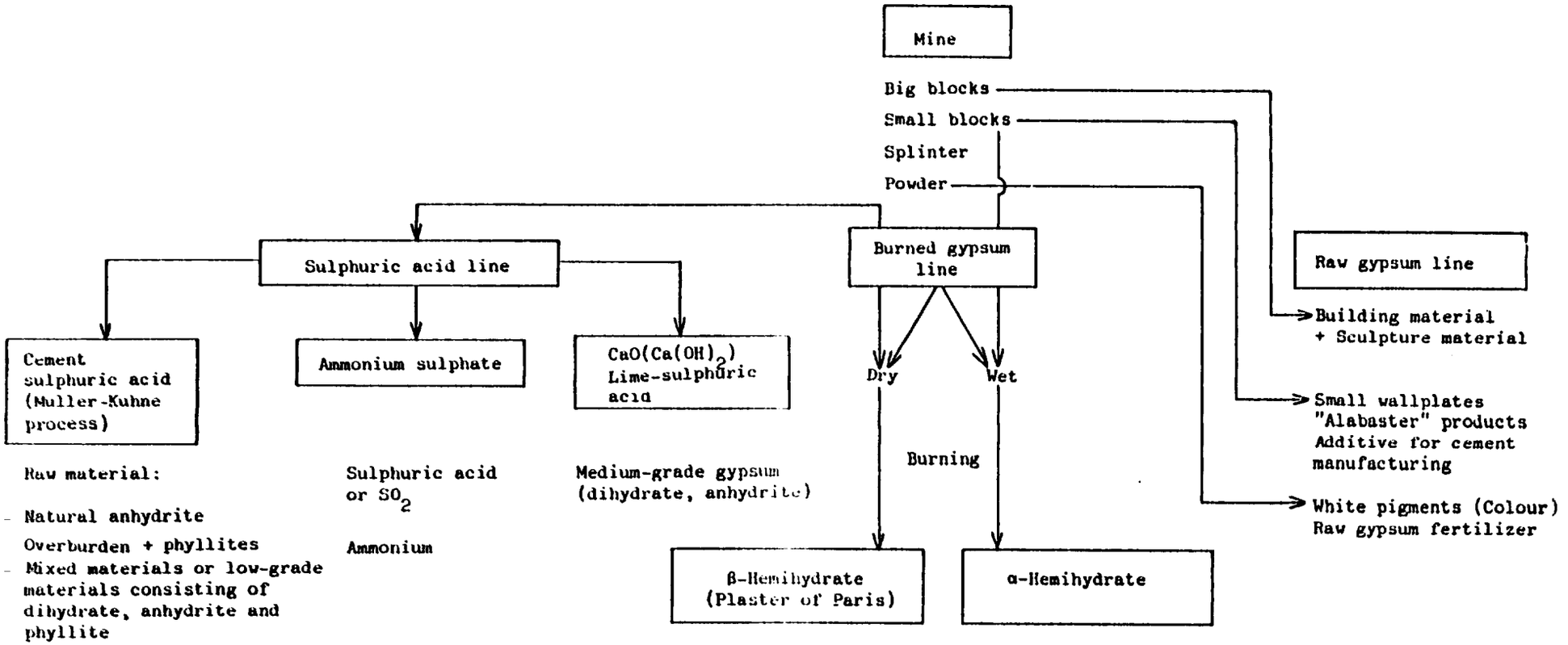
In order to promote a stage-by-stage development of gypsum-based industries in Bhutan the assistance of the following experts is needed:

(a) Marketing expert. The expert would study the market for gypsum, plaster and the products based on these two materials both in Bhutan and in India;

(b) Expert in alabaster handicraft. The expert with experience in the carving of alabaster products - both manually and mechanically - should advise on the establishment of a handicraft industry producing mainly for export;

(c) Expert in plaster and plaster products. The expert should formulate specific recommendations for the establishment of a manufacture of plaster of Paris and of derived products, such as panels, blocks and moulding plaster.

Main possibilities in a gypsum-based industry: products made of raw gypsum



Building uses
Wall blocks
Plaster boards
Plaster mortar

Medical
Dental
Models
Slip-casting material

Dry burned = in kettle, rotary kiln etc.
Wet burned = in an autoclave (under vapour pressure)

Reactions:

$CaSO_4 2H_2O \xrightarrow{180^\circ C} CaSO_4 1/2H_2O + 1\ 1/2H_2O$

Dihydrate → Hemihydrate