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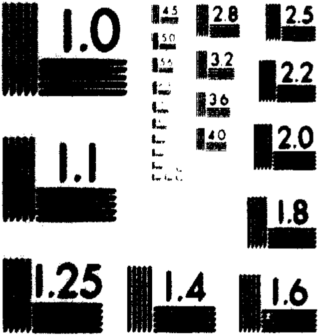

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BONSEGZONA SLATE DEPOSIT, BHUTAN.

A Technical & Economic Feasibility Study

By

Tej Bhan Malhotra

UNIDO Consultant

THIMPHU, BHUTAN

AUGUST, 1981.

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Section - 1

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I wish to pay a sincere tribute to the people who have helped in opening this deposit, and working it during the last few years. Their enterpreanourship and determination is responsible for the establishment of a new mining venture in a remote mountainous part of the country, with little mining traditions, in face of very heavy odds. One of these untiring persons, who deserves a special mention was late Mr. Taula.

I wish to pay a tribute to the geologists of Bhutan unit of Geological Survey of India, who located this deposit about two decades ago, special credit for which goes to Mr. B.S. Jangpangi and Mr. S.P. Nantiyal, who were senior geologist & Director of the Survey at that time. I also wish to thank their present Director Mr.C.P. Vohra and his colleagues for the information that they gave me regarding this deposit.

My family & I have received great kindness & courtesy from the people of Bhutan, from the highest to the humblest, with whom we came into contact during our short stay in this beautiful country of charming people. We carry a very happy memory of our stay here.

(Tej Bhan Malhotra)

Section - 2

INTRODUCTION and SCOPE OF WORK

2.00 Introduction

2.01 Druk Yul, Land of the Thunder Dragon, the country known to the world as Bhutan, occupies an area of approximately 47,000 square km, situated between 26.5 & 29 degrees north latitude and 88.5 & 92 degrees east longitude, on the southern slopes of Himalayas. It is bounded on the north by Tibetan plateau, and on other sides by India. From the Indian plains, the mountains rise rapidly from about 150 metres in the foot-hills in the south to over 7,550 metres perpetual snow-clad peaks in the north. Figure I shows a map of Bhutan.

2.02 Owing to the geographical situation, and its own policy, the country remained in a state of self-imposed isolation until the early 1960's, when it embarked on a process of planned economic development. During these two decades, it has made remarkable progress in all spheres of life.

/condition On the economic front, the two major postulates of the country's national policy are to improve the socio-economic/of the people, and the achievement of overall economic self-reliance.

Bhutan's population is estimated to be 1.2 million, and is concentrated in the valleys of its main rivers and their tributaries, specially in the western & southern regions at comparatively lower altitudes. There are only two major towns including the capital Thimphu, with a population of over 20,000, two towns have population between 10,000 to 20,000, and 13 other towns have a population between 5,000 & 10,000. There are over 4,000 significant human settlements in the country.

2.03 The use of hand-cut wood shingles has been the customary method for roofing houses in Bhutan. Only two or three layers of wood shingles are normally used. As the quantity of wood shingle used is not enough, adequate protection is not obtained from rains. This system of using wood shingles, though it appears to be initially economical, has many disadvantages. It is very wasteful of timber resources, and is really not as economical as it appears to be. Infact, if proper quality roofing is done using a larger number of layers, as is done in some other countries, wood shingle roofing would be quite costly.

2.04 In the last few years, corrugated iron sheets (C.G.I sheets) have replaced wood shingle roofing in many places throughout the country, specially in urban areas. This has happened, because it provides better rain protection and is more permanant than the type of wood shingle roofings being made in the country. But C.G.I roofing in Bhutan is very costly. C.G.I sheets are not produced in the country and are all imported, and thus besides the element of cost, it is not in consonance with the goal of self-reliance, to depend upon them for meeting the growing requirement of roofing material in the country.

2.05 An alternative material for roofing is slate. Used imaginatively, slate is a highly attractive material for roofing & other architectural purposes, and is superior to alternative materials like C.G.I sheets, asbestos sheets etc.

Slate has been known in Bhutan since ancient times, and has been used for engraving the images of Bhagwan Buddha and in other sculptures. But only a very small quantity of slate was needed for such purposes.

2.06 In course of traverse mapping for the Royal Government of Bhutan during 1962-63, the Geological Survey of India located large deposits of slate at Bonsegeoma (Bhel) (27°34'13" : 90°03'30"), about 1 km. south-east of Riakha village, approachable by a 20 km. bridle path from the nearest road-head at Chusum, which is at a distance of 9 km. from Wangdi Phodrang, which is 64 km from Thimphu on the main road to eastern Bhutan.

2.07 Conscious of the fact that with rapid economic development, construction activity in the country will increase at a fast pace, requiring large quantities of roofing material, the Department of Industries & Mines started action for the development of this deposit several years ago. Arrangements were made for training of workmen, and quarries were opened at the outcrop of the slate deposit. These quarries have been in operation on a small-scale for a number of years.

Slate was excavated & dressed manually, and the hand-cut slate slabs were transported by mules, from the quarry at the hill-top to 500 metres below in the valley, and then to Chusum over a 20 km long bridle path. Improvements were made in the operations of the project, when sometime back, a 900 metres long gravity-operated aerial ropeway was installed by the Department to transport finished slate slabs from the quarry to the base camp in the valley below, and an un-metalled road was constructed from Chusum to the base-camp over a distance of 15 km.

Several thousand square metres of slate have been produced from the mine and used for roofing in the country in the last few years. In-fact, most of the exposed out-crop of good slate has been nearly worked out, and it will be now necessary to remove some overburden to provide adequate working room for any length of time, even for the small-scale mining that is being done at present. It speaks volumes for the enterpreanour-ship & determination of the people concerned, that a new mining venture has been established in a remote, mountainous part of the country, with little mining traditions, in face of such heavy adds. This small-scale mine will serve as a pilot-project for a larger mine of optimum size.

2.08 The Department of Industries & Mines has now sought the advice of UNDP & UNIDO as to how this natural resource can make its best contribution to the economy of the country.

2.10 Scope of Work

2.11 The scope of work of the UNIDO consultant is to ascertain the technical & economic feasibility of developing this slate deposit. This may include a study of the current status of the project, an assessment of the quality and reserves of mineable slate in the deposit, its uses & market, methods of mining, mine development programme, estimates of capital & operating costs, financial analysis of the project, and its contribution to the national economy.

2.12 The consultant may also separately prepare a document giving details of assistance that the Government may request from UNIDO for this project.

2.13 The consultant may also prepare a report, setting out the findings of his mission and his recommendations to the Government on further action, which might be taken.

Section - 3

SUMMARY OF REPORT

3.01 A deposit of slate occurs at Bonsegeoma in Wangdiphodrang district of Bhutan, at a distance of about 100 kms from Thimphu, the capital of the country.

3.02 The quality of slate is good, and the reserves in the deposit are large.

3.03 The use of hand-cut wooden shingles has been the traditional method of roofing in Bhutan. It has, however, several dis-advantages, including its impermanance, with replacement required every few years, wastefuluse of timber, and relatively high cost in the long run, when all factors are taken into account. Under the circumstances, there has been a trend towards the use of corrugated galvanised iron (C.G.I) sheets in recent years, particularly in urban areas. But C.G.I sheets in Bhutan are costly. These are not produced in the country and are all imported, and thus besides the element of cost, their use is not in consonance with the goal of self-reliance, which is one of the principal objectives of the country's national economic policy.

3.04 Slate is a highly attractive material for roofing and other architectural purposes, and is valued for its aesthetic quality, dignity & permanancy.

3.05 Conscious of the fact that with rapid economic development, construction activity in the country will increase at a fast pace, requiring large quantities of roofing material, the Department of Industries & Mines opened quarries at the outcrop of the slate deposit a few years ago. These quarries have been in operation on a small-scale, and several thousand square metres of slate has been produced from the mine, and used for roofing in the country during this period.

3.06 Slate is a better roofing material than C.G.I sheets. But because of its indigenous availability, it is much cheaper in Bhutan, C.G.I roofing being about 60% costlier than slate roofing

Use of slate as a roofing material is thus in the best interests of the country and its people.

3.07 On account of its aesthetic qualities, slate is being used by discriminating people in materially advanced countries, even when it is more costly than alternative products that are cheaper to instal. In some of these countries, slate is being used, even when it has to be imported from distant countries, and is far more costly.

3.08 A market study made by the Department of Industry & Mines shows that the likely demand of slate for roofing in the country in the next few years, would be about 12,00,000 square feet per annum. This demand could increase further, if people in rural areas could also be persuaded to use slate for roofing, by providing them, if necessary, some incentives for its use. It should also be possible to find some reasonable export market for Bhutan slate. The total market for slate could thus be greater, but as a measure of abundant caution, the project may be developed initially to produce 12,00,000 square feet of slate per annum.

3.09 Mining until now has been done on the exposed outcrop of the slate deposit. This exposed outcrop is now nearly exhausted, and to continue mining, it is essential to remove overburden and expose the slate bed below it. An attempt was made sometime back to remove overburden manually, but this was not successful, as the overburden is hard. On account of the hard nature of the overburden, and the difficulty of getting sufficient labour for manual work, it is necessary to use machinery for its removal.

3.10 The capital cost of developing Bonsegoома slate project has been estimated at Nu.38 lakhs, including Nu.13 lakhs for construction of a road from the base-camp to the deposit, offices, stores, factory shed, and residential buildings, Nu.21 lakhs for machinery and equipment, Nu.2 lakhs for initial development work, and Nu.2 lakhs for working capital.

3.11 The cost of production, at mine-head, excluding interest charges on capital invested, is estimated at Nu.1.05 per square foot of slate at a production rate of 12,00,000 square feet per annum.

Cost of interest charges and asuitable return on investment will be in addition to the above-mentioned production costs.

3.12 The project can be brought into full production in one year's time, after the equipment has been obtained, the roads have been constructed & improved, and initial facilities provided. The latter activities can be completed within a year, if adequate funds are available.

3.13 The project is highly beneficial from national economic point of view. At current prices, C.G.I roofing is costlier than slate roofing by 64% whereas the import content of C.G.I roofing is nearly 75% of its cost, the import content of slate roofing is only about 0.5%

3.14 At present slate is being sold on a no profit - no loss basis, at Nu.1.20 per sqft. at the mine head, and at Nu.1.63 per sqft. at Thimphu. If its price was increased even by Nu.2.03 per sqft., it would still not cost more than C.G.I roofing. The present price of slate is in fact, too low, and should be increased to place a project of such intrinsic importance on a sound footing.

3.15 The contribution of slate to the national economy may be taken as the cost of imported C.G.I sheets it can replace, that is, on an average at Nu.3.66 per sqft. at present. When the project is developed to its initial capacity of 12,00,000 sqft. per annum, its contribution to national economy will be nearly Nu.44 lakhs per annum.

3.16 Apart from providing gainful & skilled employment to about 65 persons, the project will provide an excellent training ground for Mining & Industrial Project Management. This will be extremely useful for development of other mineral resources of the country, as well as in management of industrial projects.

3.17 It is recommended that the project be considered for implementation on a priority basis.

Section - 4

USES & MARKET OF SLATE

4.00 Uses of slate:

4.01 The most familiar use of slate is as thin but extremely durable roof tiles, and used imaginatively, slate is a highly attractive material for roofing and other architectural purposes.

4.02 Slate for use in architectural styling is quite popular in many rich countries at the moment. This market however, depends a great deal on whims of architectural fashion. Colour of the slate plays an important part in its suitability for some of such uses, and different coloured slates are valued for their aesthetic appeal in flooring, pannelling, wall cladding & paving. Apart from the large variety of colours available, slate slabs of various surface textures can also be produced by different production methods.

4.03 But slate is not used for aesthetic reasons alone. It is hard-wearing, non-porous, generally unaffected by atmospheric pollution, and it will not shrink or warp. Because of this, it is often used for window-sills and surrounds and flooring, as also in damp-proof courses.

4.04 Although in most modern buildings, slate is only a thin veneer cladding the outside, or used in floor slabs and window surrounds, in some places near the production centres, there are houses which are almost wholly built from slate blocks. These may be slabs of irregular dimension skilfully fitted together, or blocks shaped to approximately the size of normal building bricks.

Roughly broken slate is a popular material for crazy paving in certain places like court-yards, garden paths etc.

Slate has been used in the past in Bhutan for engraving the images of Bhagwan Buddha and other dieties. New designs and patterns can be developed and a handicrafts industry established for such engravings. Slate can also be artistically used for creation of murals & sculptures in public buildings, hotels as well as in residential buildings.

Slate can be used in table tops, shelves, benches, draining boards and in various other forms in furniture. Properly designed, they would add beauty and variety to the environment.

Another important use of slate is for making school writing slate. Large slabs of slate can be used for manufacture of better quality black boards. High quality large sized slate slabs may also be used for making billiard tables. There are five sections, 1¼ inch thick, in a full size billiard table (12 feet x 6 feet) and if such good quality slabs are available, these could fetch very high prices for this use.

Slate slabs, as well as waste slate is used for lining of canals and water courses to prevent seepage of water.

4.05 As only a small percentage of the material quarried in a slate mine, usually finishes up as tiles, it is necessary to give consideration to the possible uses of slate waste.

Crushed slate has been used in some countries as a substitute for brick clay in areas, where the latter commodity is scarce. The finer grade slate powders have found application as filler in a number of industries, where chemical inertness is required. Examples of products using such powder include bituminous solutions, bitumen, coal-tar coating materials, roofing and damp course felts, motor car underseal, protective coating for natural gas pipes, terrazo tiles, concrete products, insecticides, adhesives, paints, paper, rubber, plastic and fertilizers. The coarser granulated slate is used for artificial stone manufacture, surfacing, roofing felts and concrete tiles. The size and shape of slate granules used for asphalt roofing felts is important. Flate disc-shaped grains between 8 and 20 mesh are ideal for this purpose.

Crushed material derived from slates is capable of being expanded in rotary kilns. Some of this partly fused material can be used as filter media in sewage treatment works. After perhaps some further crushing, it could also be used in light-weight concrete.

Slate is eminently suitable for the sub-base of road. Tests carried out on frost resistance of slate have proved successful, and there has been considerable growth of this market in certain areas.

Waste slate can be used for making mineral wool, if fused with blast furnace slag. It may also be possible to make mineral wool directly from slate. If this was developed further, and commercial production was viable, a new growing market for slate waste could arise.

Some promising research work has been carried out in some countries on the possibility of producing bricks or blocks by autoclaving mixtures of lime and slate powder in the same way that sand-lime bricks are produced. This may, at some stage, be of interest to Bhutan, where there appears to be shortage of suitable brick clay, and where limestone deposits occur in the vicinity of the slate deposit.

4.06 From above-mentioned large number of possible uses of slate, it should not be concluded that slate and slate waste can be used economically for all these purposes. The location of the deposit, and the availability of slate & slate waste with respect to the industries in which it can be used, is of vital importance. If slate powder, granules or waste has to be transported over long distances, it may not be economical to make use of the same. In many cases, other alternative materials can be as well used as slate powder. For example talc can as well be used as a mineral filler in the paints & plastics industry and can also be used as a dusting agent. Similarly limestone powder can also be used as a filler in some industries. Expanded slate is only one of the many materials that can be used as lightweight aggregates. Other natural materials that can be used for this purpose are untreated pumice, and after heat treatment, such materials as vermiculite, perlite and clay. Artificial products, such as pulverised ash can also be used for this purpose. The object in listing the various possible uses of slate is to keep in view the opportunities that may be available, and make use of the same as on occasion arises.

4.07 While considering the uses of slate, even for roofing which is its most familiar use, attention should also be paid to the alternative materials available as substitutes. Such materials may be corrugated galvanised iron sheets (C.G.I sheets), wood shingles, asbestos-cement sheets, tiles manufactured from brick clays, concrete tiles in various colours & finishes, and several other types of roofing material. For wall-cladding, artificial tiles made from plastic material and ceramic clays can be used. Glazed ceramic tiles are well-known for such uses. For flooring, thermo-plastic tiles can substitute slate blocks.

4.08 The choice of roofing material is based on its availability, economy, and on its other qualities. In materially advanced countries, the prime consideration in choosing slate for roofing is its aesthetic quality, compared with lower cost alternative products. Roofing slates are much more costlier in these countries, but inspite of their high prices, these are still in demand by discriminating buyers. In Bhutan, the position is entirely different. Slate is available indigenously, whereas alternative roofing materials like C.G.I sheets have to be all imported. Slate roofing therefore, works out much cheaper. Slate should thus be the obvious choice for roofing in Bhutan.

4.09 Other uses for which slate may be employed in Bhutan at present or in the near future are

(i) flooring & pannelling, specially in kitchens & bath-rooms
(ii) School slates & black-boards
(iii) Engravings & murals, and for decorative fu[illegible]ure.

4.10 World wide market trends

Slate was used extensively for roofing purposes during last few centuries in many western countries, specially in U.K., Spain, France & Portugal. Enormous quantities of slate were used during the industrial revolution in U.K. At the end of the last century, the production of roofing & architectural slate in U.K., reached a figure of 650,000 tonnes per annum. The industry, however, declined substantially during the present century, as cheaper mass-produced substitute roofing materials came in the market.

4.11 The production of roofing slates is still extremely labour intensive because, in spite of great deal of research, it has not yet been possible to develop a mechanical method of splitting slate. In view of the high cost of labour in some western countries, the cost of roofing & architectural slate there has increased greatly, and its production has come down substantially. The total production of roofing & structural slate in U.K., for instance, has now fallen to less than 10% of the peak production achieved by it at the end of the last century. Of course, in addition to roofing & architectural slate, much larger quantities of slate material in the form of powder, granules and fill is also being produced and used regularly.

4.12 But the industry now again seems to be holding its ground, as the aesthetic qualities of slate are being appreciated more and more.

4.13 In Europe, the principal producers of slate at present are U.K., France, Spain & Italy. The annual production in France is about 170,000 tonnes per annum, comprising about 95,000 tonnes of roofing slate, about 20,000 tonnes of architectural materials, and about 55,000 tonnes of powder & granules. Production in Spain is about 1.5 million tonnes per annum, although a large proportion of the same is used as road fill and in construction. Some very good quality slate is produced, however, and this makes up most of the 90,000 tonnes per annum of exports. U.S. production of slate is also quite large, mainly from Virginia, North Carolina, Pennsylvania, New York, and Vermount. India and South Africa also produce & export fair quantities of slate.

4.20 Trade

4.21 International trade in slate is normally confined to the better quality higher priced materials. There is a fair amount of exchange even between producing countries, on account of preference for particular colour or grade of slate. Roofing and architectural slates are being transported over enormous distances. From India, roofing slates are being transported to Australia, Fiji and to the Far East. Multi-coloured architectural slates are also being exported from India to Europe , specially to Germany, Belgium, Holand & Scandinavian countries, as well as to middle east, and far eastern countries. U.K exports roofing slates to Canada, and U.S.A and even to Australia. Fairly large quantities of slate are being exported to Germany and to Scandinavian countries from Spain, France and U.K.

4.22 There is little international trade in slate powders but there has been some trading in granules. Because of their lower value, such products cannot bear high freight costs over long distances.

4.30 Prices

4.31 Prices of slates vary enormously, depending upon their size, thickness, strength and colour.

4.32 Thin roofing slates are expensive, because of the extra splitting costs. They are also more profitable for the producer, as more slates can be produced from a given material. They are also the most convenient for use as roofing material, as they are more convenient to handle. The aim of producing a good roofing slate is to get the thinnest slate possible, which has sufficient strength to serve its purpose. The optimum thickness for roofing slates is about 5 to 7 mm though it could be as high as 12 mm.

4.33 Large roofing slabs, normally 600 x 300 mm and larger, are more expensive per square metre, but they are more economical for the consumer, since the cost of installation, which is high, is substantially reduced for a given area of coverage.

4.34 Slate tiles for flooring & pannelling are thicker, varying in thickness from 8 to 20 mm, but preferably between 10 to 15 mm.

4.35 Current prices of machine-cut multi-coloured slate slabs from India, suitable for flooring & pannelling, are Nu.75 per square metre f.o.b Indian ports. For hand-cut slabs of same quality, these are Nu.55 per square metre. The prices of hand-cut black coloured roofing slate f.o.b Indian ports at present is Nu.44 per square metre. The multi-coloured flooring & pannelling slabs are commanding premium prices on account of their colour.

4.40 Market situation in Bhutan

4.41 As has been stated earlier, several thousand square metres of slate has been produced from this deposit and used for roofing in the country in the last few years. The other main alternative materials for roofing being used in the country are wood shingles and corrugated galvanised iron sheets (C.G.I sheets).

4.42 The customary method for roofing until recently was the use of hand-cut wood shingles applied to a heavy wood frame, with stones placed on the top to reduce wind uplift. At present in Bhutan, a person is allowed to cut logs from the forests for his house construction at a very nominal price. His co-villagers help him in cutting & transporting wood, and in construction of the house, but receive no cash compensation for their contribution, although they receive some compensation in kind like food & drinks.

4.43 Only two or three layers of wood shingles are normally used in Bhutan, unlike a larger number of layers that are used in some other countries. As the quantity of wood shingle usually used is not enough, adequate protection is not obtained from rain. Outer layers of this wood shingle need to be replaced every few years, as these get rotten due to effect of weather.

This system of using wood shingles, though it appears to be initially economical, has many dis-advantages. A number of trees have sometime to be cut at the base to determine, if the grain is straight and suitable for making shingles. The trees that are not suitable are left to rot. Some forest fires can be attributed to the small wood slush that is left being.

4.44 If the cost of labour that is contributed in kind, and the indirect subsidy that is given by the Slate in giving timber at nominal prices, is taken into account, and the cost of its frequent replacement is added to that, it would be found that wood shingle roofing is really not as economical as it may appear to be. In fact, if proper quality roofing is done using a large number of layers, as is done in some other countries, wood shingle roofing would be costlier.

4.45 In the last few years, corrugated iron sheets have replaced wood shingle roofing in many places throughout the country, specially in urban areas. Although C.G.I roofing is more costly, this has happened, because it provides better rain protection, and is more permanant than the type of wood shingle roofing being made in the country. C.G.I roofing however, requires maintainance by periodic painting, and more so, as it ages. Rusting first occurs at the holes, where it is nailed or bolted. The rate of failure at the points of attachment and the wear of C.G.I sheets becomes more serious as time goes on.

4.46 An alternative material for roofing is slate. Used imaginatively, slate is a highly attractive material for roofing and other architectural purposes. In materially advanced countries, the prime consideration in choosing slate for roofing is its aesthetic quality, dignity and permanancy, compared with lower cost alternative products that are cheaper to instal and are designed for rapid construction. In some of these countries, slate is used for roofing, even when it has to be imported from other distant countries, and is far more costly. In Bhutan, the position is entirely different. Slate is available indigenously, whereas C.G.I roofing materials have to be imported. A detailed cost analysis has proved beyond any shadow of doubt that slate roofing works out to be much cheaper than C.G.I roofing in Bhutan, C.G.I roofing being 60% costlier than slate roofing. (Annexure I). The use of C.G.I roofing in this country is thus not in the interest of the country or its people.

4.50 <u>Marketing Prospects</u>

4.51 The Department of Industries and Mines has made a market study of requirements of roofing material in the country, which shows that the likely demand of slate for roofing in the next few years, would be about 1,200,000 square feet per annum, if proper quality material at reasonable prices is available. This is enclosed as Annexure IV. This demand projection could, in fact, increase appreciably, if people in rural areas could also be persuaded to use slate for roofing their houses in place of wood shingle, by providing them if necessary, loans and other financial assistance for purchase of slate.

4.52 There is at present a reasonably good market for slate for roofing in Australia, as well as in some other countries nearby, and slate is being exported to these countries from some mines in India. At the present price levels of slate in Bhutan, it should also be possible to find some export market for slate in these countries, provided proper quality is maintained. There should also be market for Bhutan slate in neighbouring hill areas of India like Darjeeling, Kalimpong etc., where C.G.I sheets are used for roofing. Though on account of additional cost of transport of slate to these places, slate roofing there may not be as economical as it is in Bhutan, it would still be cheaper than C.G.I roofing. It is considered that it should be quite possible to develop a respectable export market of Bhutan slate to India, Australia and other countries.

4.53 The total market per annum for Bhutan slate could thus be greater than 120,000 square metres per annum. But as a measure of abundant coution, the slate project could be developed initially with a capacity of 120,000 square metres per annum. On the basis of 300 working days, its initial production capacity will thus be 400 square metres (or about 4,000 square feet) of slabs of different sizes per day.

Section – 5

MINING and PROCESSING

5.00 Location & accessibility

5.01 The slate deposit at Bonsegeoma (27°34'13" : 90°03'30") is located near Riphakha village in Bhel area in the upper part of the Pechu valley. A 7 km bridle path connects the deposit outcrop near the top of the hill to the base-camp in the valley below, besides the Pechu stream. The base-camp is connected to Chusum (27°31'15" ; 90°02'45") by a 15 km un-metalled fair-weather road. Chusum village lies on the confluence of Pechu & Tangchu streams at a distance of 9 km from Wangdiphodrang on the main road to eastern Bhutan.

5.02 Wangdiphodrang is connected to Thimphu, the capital of Bhutan by a 68 km all weather asphalt road. Thimphu is approachable from Phuntsholing on the Indian border by a 179 km long national highway. The closest railway station is Hassimara on N.E. Frontier Railway in India, located at a distance of 20 km from Phuntsholing. Thimphu has a helipad. The nearest airport is at Paro, at a distance of 60 km from Thimphu. A regular air-service of Bhutan, Druk Airways, will be operating from Calcutta to Paro via Bagdogra from October 1981. Until now, Bagdogra near Siluguri in India is the nearest regular service airport. Bagdogra is connected to Phuntsholing by a 180 km long highway.

5.10 Climate & Vegetation

5.11 The slate deposit is located in the higher parts of lesser Himalayas on mountain ranges rising from 2100 to 3400 mts. The terrain is rugged with steeps slopes and deep cut valleys. Pechu with its numerous tributaries drains the region.

5.12 The maximum and minimum temparatures in the Bonsegeoma area are 24°C and 0°C. The average rainfall is about 100 cms per annum, mainly between June & September.

The area is covered by thick vegetation consisting of conifers, oaks, and rhododendrons. At some places in lower slopes, there are picturesque terraces of agricultural fields.

5.20 Regional Geology and Stratigraphy

5.21 The slate formations constitute a part of the Tangchu formations of permian age, which lie unconforbaly over the Chekha formations of pre-cambrain age. The geological succession of the region is as follows:

Tongchu Series (Permian)	Limestones with minor partings of slates & phyllite
	Crinoidal limestones
	Fossiliferous shale & slate and dark grey shales & quartzites
	Calcareous slate
	Arenaceous slate with graphitic slate parting.
	DARK BLACK SLATES
	Argillaceous slates
---------- UNCONFORMITY ----------	
Chekha Series (Pre-cambrian)	Slates & phyllites with layers of quartzite and limestone.
	Schistose phyllites, some with porphyroblasts of biotite.
	Schists & quartzites
---------- THRUST ----------	
Thimphu Series (Pre-cambrain)	Granite intrusions in Chegina area
	Schists with quartzites and abundant pegmatite intrusions
	Gneisses, foliated, banded & porphyritic, with schists & quartzites

5.22 In the above general section, the Dark Black Slates of the Tongchu Series, which lie between the argillaceous slates (below) and the arenaceous slates (above) are of main commercial importance.

5.23 The slates are exposed on both sides of the Pochu valley south of Ripakha and their eastern extensions are seen in the Tongchu valley north of Kobja. The slate zone is 650 m. thick, out of which except the top 125 m. thick arenaceous slates and quartzites, the rest is argillaceous. The slates have well developed slaty cleavage. The general trend is N 75°W-S 75°E and it dips at about 20°-30° towards N 20°E. The slates are uniform in composition maintaining the colour and fineness throughout the upper part of the exposed outcrops. They contain at places pyrite crystals around which some oxidation has developed with a certain amount of corrosion around them.

5.24 According to Geological Survey of India, the top 125 m. thick portion of the slates are arenaceous in nature and are exposed between Bonsegeoma and Koche La Chu. In the area further west slate is exposed in the Samlin Hillock about ¼ km south of Ripakha. These slates are hard and compact, with faintly developed cleavage and consequently the quality of this slate is not very good. Below the arenaceous slate, however, there is a 100 m. thick good quality slate in the Bonsegeoma area. In the Samlin Hillock within the arenaceous slate, there is a small patch of graphitic slate (2m. thick) which is dark black in colour, soils the fingers and is loose and friable in nature.

5.25 In Guinasakha area (27°35'30" ; 90°03'05") a 50 m. thick good quality slate underlies the calcareous slates. In all the three occurrences, viz Bonsegeoma, Koche La and Guinasakha, the upper portion of the slate is dark grey to black in colour and the lower part grey and bleached. The grey and bleached slates are shaly in nature with poorly developed slaty cleavage and these are underlain by fossiliferous green coloured slates at Guinsakha.

5.30 <u>Reserves:</u>

5.31 The slate deposit was located by the Bhutan unit of Geological Survey of India in course of traverse mapping during 1962-63. Further prospecting work was also done on the deposit by G.S.I later during two field seasons.

5.32 According, to G.S.I., the reserves of 'good quality slates' in this deposit are 'vast', though no precise figures have been given by them in their reports. But in one brochure issued by them, a figure of 10 million cubic metres of inferred reserves has been mentioned by them for this slate deposit.

5.33 A consulting firm, Messrs Holtech Engineers Private Ltd., whom the Government had appointed in 1975 for advising them regarding this deposit had given a figure of 252, 242 cubic metres of mineable reserves in the deposit for a strike length of 335 metres only, with the width of workings extending to only 20 metres along the dip at the top of the slate bed.

5.34 What are the reserves that would be adequate for an investment decision for opening the mine?

5.35 We may probably develop a mine with a maximum daily capacity of 1,000 square metres of slate slabs of about 6 to 10 mm thickness in different sizes (i.e. nearly 10,000 square feet of slabs). Considering that the recovery of finished slabs may be only about 30% of the mineable slate reserves, the reserves needed for a mine of say 20 years life will then be.

$$1{,}000 \times \frac{10}{1{,}000} \times \frac{100}{30} \times 300 \times 20$$

(sq.metres/day) x (thickness of slab) x (Recovery ratio) x (no.of working days per year) x (life of mine in years)

= 200,000 cubic metres.

5.36 Considering that a mine of this large capacity is not envisaged in the near future, that the reserves calculated by the consulting firm mentioned above were only for a limited strike & dip length of the deposit, and that the inferred reserves given by the G.S.I are extremely large, it is clear that the mineable reserves in the deposit are adequate for an investment decision being taken for developing the mine.

5.40 <u>Recommendations for further exploratory work</u>

5.41 The slates are exposed on both sides of the Pechu valley. According to G.S.I., a 50 metre thick zone of good quality slate underlies the calcareous slates in Guinasakha area. This may be the extension of the 100 metre thick good slate zone in Bonsegoom area. There should be every possibility of good slate occurring immediately next to the right bank of the Pechu stream, as an extension of the good quality slates of Bonsegoom area. It is recommended that trenches should be made in this area to locate this extension, and if located, its quality and quantity should be ascertained. On account of its much easier location, it may be easier and more economical to produce slate from this area.

5.42 The G.S.I report also refers to fossiliferous green coloured slates at Guinsakha area below the grey and bleached shaly slates. It is recommended that these green coloured slates may be explored in greater detail. If the quality of these slates (their cleavability and strength) is reasonably good, they may have a good market, as their colour would provide an additional attraction for their use.

5.50 Quality

5.51 'Slate' may be defined as a rock derived from argillaceous sediments or fine grained volcanic ashes by metamorphism and characterised by parallel cleavage entirely independent of the original bedding, the cleavage permitting the rock to split easily into relatively thin slabs.

5.52 Because of the differences in their origin, the mineral compositions of slates vary significantly. Quartz, platy minerals like mica, illite, chlorite, haematite and rutile are the most prevalent minerals. Pyrite, calcite, graphite and some other minerals are also sometime present. Pyrite & calcite can be harmful, if they are present in large quantities. They can affect the strength of the slate, and specially if the environment is polluted, these minerals may cause the slate to wear out or break up. Pyrite, on the other hand can be useful, if the slate is to be used for forming light-weight aggregate, by expanding it. Small differences in the mineralogical composition of a slate can produce substantial differences in colour. Graphite & pyrite tend to give dark grey or black colour to slates, while haematite gives a red colour, and iron silicates and ferrons iron oxides give the green varieties. Pyrite & chalcopyrite occuring in the overburden or associated rocks, may give a multi-colour effect to the slates.

5.53 But more important than the mineralogical or chemical composition, are the physical properties of slate.

5.54 The property of cleavage as developed in slates is their single most characteristic and important feature. Good slate should have reasonably straight cleavage and the grains on the slate should be longitudinal and not transverse. Slate slabs should be of uniform texture and should be free from cracks, fissures, white patches and deleterious minerals. These should be strong, tough, compact and hard, as well as durable in colour and in resistance to weathering, and should not be so friable as to crack, when nail holes are punched in them.

5.55 Some of the characteristics outlined above are rather subjective, while for others, test procedures have been laid down in standards specifications issued by various countries. Some of these tests are as follows:

(i) Strength

(a) Transverse strength - This property indicates the capacity of resistance to damage in handling & transportation, and to effect of nails & other stresses, which are brought to bear upon slates in its actual use, rather than those of tension & compression. This is measured by the property known as 'modulus of rupture'. This is expressed as

$$R = 1.5 \frac{WL}{bd^2}$$

where
R = modulus of rupture in kg/cm^2
W = breaking load in kg
L = length of span between supporting steel bearing in cm
b = width of specimen in cm, and
d = thickness of specimen in cm.

According to Indian Standard Specifications (155), the value of modulus of supture should not be less than 600 kg/cm^2 for dry slate and not less than 400 kg/cm^2 for wet slate.

(b) Toughness

This is an absolute parametre independent of size of the slab, and indicates the property of absorbing the energy for fracture.

(c) Shear strength

This property indicates the capability of relative displacement of the different laminace of the slate.

(ii) Moisture absorptio

Slates should not absorb much moisture, so that they are not affected by disintegrating action of water, specially when seasonal and day and night temperature variations cause contraction & expansion of absorbed water. This is of importance in Bhutan, where in winter, temperatures fall below the freezing point.

The absorption of moisture after 24 hours immersion in cold water, should not exceed 2 per cent by weight, and variation between individual samples should not exceed 20%

(iii) Specific gravity

This property is related to durability, hardness and compactness of slate, and is therefore important.

(iv) Cleavability

This is depositional & textural quality, which indicates the capability of slate being split in thin slabs of large sizes. This test is performed by a good workman using a chisel about 5 cm wide.

(v) Corrodibility

This test is to determine the resistance of slate to acids and salts in the atmosphere, rain water and domestic & industrial smoke & fumes. It is performed by immersing a weighed piece of slate in a solution consisting of 98 parts water, 1 part sulphuric acid and 1 part hydro-chloric acid. After remaining in solution for 10 hours, the specimen is dried and weighed.

(vi) Sonorousness

This test is performed by suspending a sheet of slate and striking it with a hard object; good slate should give out a clear note.

(vii) Cross fracture

This is to determine the grain. In practice, the workmen become familiar with the degree of development of grain. It is of importance to an artisan to know the strength of the grain, for it materially affects the case, with which blocks of slate can be prepared.

(viii) Character of cleavage surface

The surface of the cleaved slate should be examined with a magnifier, and the smoothness noted. Generally speaking, the smoother the slate, the better it is. The general structure of good slate should be so fine, that the constituent minerals should not be observable except under the microscope.

5.56 A consulting firm, Messrs Holtech Engineers Private Ltd., whom the Government had appointed in 1975, for advising them regarding this deposit, had collected necessary samples of slates from the quarries, and had got them tested for various essential properties in the laboratory of the Indian Institute of Technology, New Delhi in 1975. On the basis of these tests, the consultants said that 'the Bonsegeoma slates have proved to bear all the necessary qualities to establish its suitability for all the varied uses slates are put to anywhere in the world'. The consultants further added that 'qualitative tests conducted over the representative samples of Bonsegeoma slate established that they are one of the bes, slate deposits, so far known, in the world'.

5.57 The test certificate issued by the Indian Institute of Technology, New Delhi is givenas annexureIIand a tabulation of the properties of Bonsegeoma slates as compared to other slates, which was than prepared by these consultants, is given as annexure III.

5.58 The fact that several thousand square metres of slate have been produced from the mine and used for roofing in the country in the last few years is ample proof that the quality of slate is entirely suitable for roofing purposes.

5.59 Thicker slabs & tiles suitable for flooring or pannelling have not been produced from the quarries so far, as use of slates for those purposes was not considered until now. From the tests conducted in July 1981 on a few thicker slate slabs on the edge-cutting and polishing equipment for marble at Paro, it is found that this slate can be cut & polished without difficulty. The colour of slate from the deposit is however only black, and so its slabs may not be able to obtain premium prices that are being obtained for some multi-coloured slates in some architectural uses. It is suggested that an attempt may be made to produce some thicker slabs of slate, suitable for flooring and pannelling and the market tested for their use in the country as alternative to ceramic tiles and mosaic in flooring and pannelling, specially in kitchens and bath rooms.

5.60 Methods of Mining and Mine Development Programme.

5.61 Present Workings

Quarrying of slate is at present being done from three faces on the out-crop, on the steeply sloping south-east flank of the ridge. One of these faces is just to the east of trench no.7, another is near trench no.6, and a larger working face is near trenches nos. 2 to 5. Another face has been opened near trench no.1, but it is not being worked, as slate from it has to be carried up-hill to the loading station, and it is very difficult to do so.

The working faces are by and large along the general strike direction i.e. N75 W - S 75 E.

The work is being done entirely manually, on a piece-rate basis. Each workmen or a group of workmen perform all the operations, i.e.

(i) Removal of overburden, and broken or poor quality slate by picks or by blasting as necessary, and disposal of the same.

(ii) Excavation of slate slabs, or excavation of slate blocks and splitting the same.

(iii) Cutting & dressing of the slabs to various sizes.

Drilling is done manually by crowbars, and blasting is being done by high explosives, which are supplied by the department. The cost of explosives is borne by the workmen.

Drilling by hand-held crowbars is a difficult job. The present cost of explosives is very high, being about Nu.17 per kg. Due to absence of proper free faces, blasting cannot be done efficiently.

Near trench no.1, a concerted effort was made sometime back to remove overburden by manual drilling and blasting, and then removing the debris manually. But due to non-availability of sufficient labour, and reluctance of available workmen to undertake this drudgery, this effort did not succeed.

On account of these difficulties, the removal of overburden is hardly making any headway in the mine. The result is that most of the exposed out-crop of good slate has been nearly worked out, and it has not been possible to form any proper benches either in the overburden or in the slate. Infact, it has not been possible even to maintain proper pathways in the mine.

As the workmen have to carry out all the jobs of drilling, blasting, overburden removal, and mining & splitting of slate, the production from the mine is rather low, being about 1,000 square feet of slabs per day when sufficient labour is at work.

5.62 <u>Mining methods in general</u>

All over the world, slate is mostly worked by open-cast methods, although in some places, it is worked underground also. Large open quarries are generally worked in a series of benches, whose height & width depends upon the equipment employed. Where the overburden becomes large, under-ground mining may be more economic. This method dispenses with the necessity of removing large quantities of unproductive overburden, but has the disadvantage of having to leave large percentage of good quality slate as pillars to support the roof.

Removal of overburden is the first stage in quarrying. The top-soil, poor-quality weathered rock, as well as slate waste dumped during earlier phases of quarrying is first removed. Overburden may be removed manually, by hand drilling, blasting and loading the debris into mine-tubs. But this is a labourious process. The use of modern earth-moving equipment is generally more suitable for this work, unless the quantity of overburden is very small.

For drilling, compressed air percussion drills using tungsten carbide tipped integral steels are normally used. For primary blasting, gunpowder is generally used in good rock to avoid undue fragmentation.

Many attempts have been made to mechanise extraction methods, with a view to increasing productivity, and reducing the amount of fragmentation. One of such methods involves the use of wire saws. A description of a method using wire saws is given below.

Adits are driven into the rock face at right angles to the cleavage for a distance of approximately 15 metres. The heading is then turned at right angles, and driven along the cleavage. A wire cutting technique using a three-strand wire rope about 4.5 mm in diametre is then used to cut horizontally into the face, level with the bench. Vertical wire cutting on both side of the heading is sometimes necessary in addition, so as to retain a vertical face, and thereby avoiding damage to higher bench levels. The steel wire is held against the rock face by ratchet tensioners, and a sand slurry is fed in to the cut to act as abrasive. Sawing rates of about 25 to 50 mm per hour are achieved, and the wire, which is driven via pulleys from a drum house, is discarded every few days, and a new one fitted. Following wire cutting, gun-powder is placed in the heading parallel to cleavage, and the adit is back-filled prior to detonation. Huge blasts have been produced using this method, but in practice, less fragmentation occurs with smaller blasts.

Another method that has been employed recently is the use of a chain saw. This is used to make a horizontal cut about 1.5 metres deep into the rock. Holes are then drilled at right angles to this cut, and a relatively small and unfragmented block of the rock is blasted out.

5.63 <u>Mining method recommended</u>

The mining methods that may be adopted depend upon the circumstances that are prevailing at the deposit.

Until now, mining has been done on a small scale by manual means. The exposed out-crop of slate is now nearly exhausted. On account of the hard nature of the overburden, and the difficulty of getting sufficient labour for manual work, it is necessary to use machinery for removal of this over-burden.

If machinery has to be employed, it should be reasonably sturdy, which would give reliable service in a remote area, where facilities for its maintainance will not be adequate. As machinery is costly, to get best advantage out of it, it should be kept available and employed to its maximum capacity possible. The aim should be to have maximum production that can be marketed. This will reduce the cost of production, and further help in increasing the demand.

<u>Drilling:</u> Most of the drilling will be required for the overburden, though a small amount will be needed for slate also.

The choice for drilling is between hand drilling with crow-bars, use of petrol-operated small jack-hammers, and hand-held rock drills using compressed air.

Uptil now, drilling has been done only manually with crowbars. Bht, it has not been successful. Petrol-operated small jack-hammers were also tried at the deposit sometime back, and even these did not work well.

It is proposed that compressed air operated hand-held rock drills may be employed for drilling. These may be, say like Atlas Capco RH 658 - 4L or RH 571 - 3L air flushed type. Drill rods may be of 22 mm integral drill steel of 0.8, 1.6 and 2.4 metre lengths.

The size of the drill hole in over-burden may be about 1.8 metres. The holes may be drilled at an angle of 70°. The drill hole size for slate benches should be limited to 1.1 metres length. The angle of the hole should be normal to the dip of the cleavage.

<u>Blasting</u>: For soft overburden, gun-powder or balck powder, which is a low class of explosive may be employed. For hard overburden, 60% – 80% special gelatine may be used.

For blasting in slate, the use of only gun-powder or balck powder is recommended, as it will avoid unnecessary fragmentation.

Gunpowder is much cheaper than special gelatine, and its use may be introduced as soon as convenient. It is cheap, stable, comparatively safe to handle, produces heaving effect, and can be easily manufactured. It can be used in form of paper wrapped cartridges of suitable sizes as per requirement.

Gun-powder is ignited by safety fuse, which consists of a core of fine black powder, wrapped with layers of tape or textile yarn and water proof coating to provide protection against mechanical damage and moisture. Standard safety fuses are readily available in the market.

<u>Removal of overburden</u>:

Soft surface material may be dozed off by a dozer. The harder material below the soft surface layer will require drilling & blasting. This may be worked in benches as described later, and the blasted debris removed by the dozer to the dumping places.

From an inspection of the deposit, it appears that to provide adequate working places for a production of 4,000 to 6,000 sqft. of finished slate per day, the ratio of overburden to slate will be 1:1. In addition, there will be need of removing back-log of overburden, as well as for removal of overburden for initial development work, to provide clear working places for un-interrupted work.

Overburden may be dumped at places where the quality of slate is poor, or below the areas, where the thickness of overburden is excessive. The dumping areas may be kept about 80 to 100 metres apart, so that there is not too much lead to these areas.

The overburden & rejects will roll down the slope of the escarpment, as the natural slope here is quite steep.

Mining Benches

Both in the interests of safety and efficiency, it is absolutely essential that a proper system of benches is laid out and followed, both in the overburden as well as in the slate. This will ensure safety, increase efficiency, lower costs, and raise production as well as productivity.

The benches in overburden & slate may have the following dimensions:

Overburden

Height - 2 metres
Width - 5 metres

At the final stage of workings, the width of the benches may be reduced to 1 metre.

Slope - Slope of the benches may be 70° from the horizontal
Floor - Floor of the benches should be horizontal.

Slate

Height - 1.3 metre
Width - 3 to 4 metres. Here also finally, the width may be reduced to 1 metre.
Slope - It should be maintained normal to the cleavage dip angle.
Floor - It should be along the cleavage dip.

5.64 Mine Development Programme

On account of unusually high rains in the project area this year, it has not yet been possible to complete a contour plan of the area, showing the outcrops of the slate bed and the boundaries of soft and hard overburden. This plan is needed for preparing sections at different intervals, for laying out benches, fixing suitable dumping places for over-burden, planning a programme of work, and for calculating the work-load involved. The work to be done & the method of doing it has however been explained to the counterpart, who will be able to complete the same, when the plan is completed and prepare a programme of work to be carried out.

5.70 Processing

5.71 Extraction & splitting:

The most important thing in ensuring proper extraction of slate is to provide adequate free faces. Two free faces are absolutely necessary, and every effort should be made to create a third free face also. This may be done by digging a narrow groove at the end of the bench by picks or by creating a line of crack there by light blasting. It may be necessary to create this third free face along the dip of the bed also, if we are able to develop long continuous benches after sometime.

When free faces have been established, the artisan should choose the right cleavage planes to split the maximum length & width of slab or block of slate from the bench. This splitting operation should be performed with the help of 2, 3 or 4 sharp chisels assisted by ordinary light hammers. The chisels should be slowly inserted from the two main free faces to help in getting the largest size slab or block without breaking. After these slabs or blocks are removed, they are further split to the thickness required. For this further splitting, all the four free faces should be utilized for slowly inserting the miner's chisel.

5.72 Trimming or dressing

The required size of slates are then trimmed from the split slabs. The aim should be to obtain the largest size slabs possible. Trimming or dressing of slate may be done by hand, or by a trimming machine called a guillotine or a stone-shearing machine or in an edge-cutting machine by circular diamond saws.

Hand trimming is done by first marking the slab by chalk with the help of a steel template and then dressing the edges by a sharp chopper.

Trimming of slabs may also be done by a hand operated guillotive or a stone shearing machine.

The cleanest edge-cutting, of course, is done by a circular diamond saw, operated by an edge-cutting machine.

The choice of method of final trimming or edge-cutting depends upon the use to which slabs have to be put, and the cost that these can bear. It may be kept in view that the cost of edge-cutting by a diamond saw will be about Nu.0.15 per running foot. For roofing tiles, it may not be necessary or economical to have edge-cutting done by a diamond saw. Hand cut slabs are quite suitable for this use. But for flooring and pannelling, it is necessary to have clean straight edges, which are better obtained from diamond saws.

5.73 Roofing slates

The aim of producing a good roofing slate is to get the thinnest slate possible, which still has got sufficient strength to serve its purpose. The optimum thickness for roofing slates is about 5 to 7 mm., but it could be as high as 12 mm.

The production of roofing slate is still extremely labour intensive, because in spite of a great deal of research, nobody has managed to develop a mechanical method of splitting slate. Blocks of slate may be cut by machine, but not down to the thickness required for roofing slate.

Bulk of the production from the mine, at least in the beginning, will be of roofing slates as their usefulness and economics has been already fully established.

As has been noted in sub-section 4.30, larger roofing slates are more economical to use. Sizes suitable for roofing are normally not smaller than about 20 cms x 40 cms.

5.74 Tiles for flooring & pannelling

Thicker slabs & tiles suitable for flooring have not been produced from the quarries so far, as use of slates for these purposes was not considered here until now. In July 1981, tests were conducted on a few thicker slate slabs on the edge-cutting and polishing equipment for marble at Paro. It was found that the slate edges can be cut neatly, and it takes good polish.

Slate tiles of different colours are being used in many countries in the world for flooring and pannelling. In fact, multi-coloured slate tiles are fetching very high prices. Black tiles may be less attractive in some applications, but in some other applications they have equal aesthetic value. They are equally attractive for use in stair cases, cladding of pillars and flooring in verandahs. Functionally, they are equally useful in kitchens & bath rooms. Along with stones or tiles of other colours, they could be used in attractive patterns in other places also.

An attempt should be made to produce various designs in different colours on these tiles, in the same manner, as these are being made on some 'MANI' slabs in Bhutan. If this could be done successfully, it will provide a high value market for such tiles for pannelling. Ceramic tiles & marble tiles being used for pannelling cost around Nu.18 per square foot. Slate tiles with sophisticated designs will be no less attractive, and are likely to cost one-third the cost of ceramic & marble tiles. Functionally, they will be equally useful.

The edges of these slate tiles will be cut by circular diamond saws in edge-cutting machine. One side only of these tiles will be polished, or a design made on it, the other side remaining rough for fixing on the wall.

5.75 Use of smaller pieces of slate

If use of tiles for pannelling is developed as detailed above, it will have the additional advantage that even much smaller pieces of slate, which would otherwise go waste, can also be used. The only cost in manufacturing tiles out of these smaller pieces would be the cost of their edge cutting and of polishing or making suitable designs on the same.

Another important use for which smaller pieces of slates could be employed is for the manufacture of school slates. Pieces of slate as small as 15cm x 22.5cm can be used for this purpose. Besides catering to the internal requirement of Bhutan, school slates can have a market in neighbouring areas of India, as these regions do not have any slate industry. Of course, larger slate slabs can also be used for manufacture of school slates.

Another use of smaller pieces of slate, which would otherwise go waste, is in crazy paving of places like court-yards, garden paths etc.

5.76 Schools slates

The use of slate in manufacture of school slates has been noted above. It will be very useful to explore their market as its prospects appear to be good.

Slate slabs from the mines are cut on edges by a guillotine or a special type of scissors. The slates are then ground one over the other by using water and ordinary sand, and finally by a suitable abrasive. Wooden strips of 12mm to 25mm width and 3mm to 6mm thickness are cut by a wood-saw to fit the slates, and are smoothened by a planer. Grooves are then made in these strips by a groover. The slates are then framed by these wooden strips, which may be further nailed at the joints.

5.77 Furniture, decoration pieces engravings, window sills etc.

As has been noted in sub-sections 4.03 and 4.04, slate can be used for furniture, decoration pieces, engravings and window sills. Thicker slate slabs will be normally used for such purposes, and these could be partly or fully processed in the edge-cutting and polishing machines that will be provided.

5.78 Recovery & wastage

On account of the nature of slate rock, and the manner in which it was deposited and formed, the recovery of slate slabs and tiles from a slate deposit is generally very low. This recovery is further reduced as attempts are made to mechanise the mining and processing of slate. As an example, in the largest slate quarries in U.K., the Penhryn quarries of Penhryn Quarries Ltd, where mining is now mechanised, the recovery of tiles suitable for roofing purposes is reported to be only 2% of the total rock mines. A recovery of 25 to 30% as roofing and architectural material may be considered as a very satisfactory recovery in any mined. The existance of large waste heaps at all old slate quarries bears testimony to this fact. This is the main reason, why so much effort is being made to find uses for smaller pieces and waste slate.

From inspection of the slate quarries at Bonsogooma, it appears that the recovery being achieved there at present is quite satisfactory. This may further increase by adoption of better mining methods, as well as by making use of smaller pieces of slate as has been proposed in this Report.

5.80 <u>Transport</u>

5.81 At present, the artisans split, dress and cut slates into different sizes at the quarry face, and then carry these to a point nearly half-way between trench no.1 & 2. Here is the top-end loading station of a gravity-operated aerial rope-way, that transports slate slabs in buckets to the base camp in the valley below. The rope way is 900 metres long. From the base-camp. slate slabs are loaded into trucks, each containing about 2,00 ft. of slate, and sent to consumers or store yards at different places in the country. The capacity of the trucks is restricted as the 15 km. road from chusum to base-camp is at present not an all-weather road, and it is not convenient to carry heavier loads on this road.

5.82 The aerial rope-way that was installed in 1977, is a great improvement on the earlier system of transport of slate slabs on mules from quarries at the hill-top to the base-camp over a 7 km. bridle path. The 15 km. road from Chusum to base-camp, although it is not an all-weather road, and is at present out of commission for heavy traffic for about four months in a year, is a major improvement over the earlier transport system, when slate was carried by mules over a bridle path from the base-camp to Chusum.

5.83 The question of transport of slate may be considered in following three areas:

(a) From quarries to loading station at the top end of the aerial rope way.

(b) From loading station at hill-top to base-camp in the valley below.

(c) From base-camp to consumers or stock-yards in the country over hill-roads.

5.84 <u>From quarries to loading station:</u>

At present, extraction of slate is being done from quarries near 6 & 7 trenches, as well as between no.2 and 3 trenches. The direct distance from no.7 to trench to the loading point is over 500 metres, but the path-way over which artisans have to carry slate is longer, as it is not along the direct line between the two places. Ofcourse, slate is carried down the hill, as the loading station is at a much lower level. The direct distance between quarries near trenches nos. 2 & 3 to loading station is about 150 metres. Another quarry face was opened near no.1 trench sometime back. Although its direct distance from the loading station is about 100 metres only, it has not been possible to work this quarry as this quarry is at a lower level and it is extremely difficult to carry slate up-hill.

In addition to the distances involved, the path-ways from the quarries to the loading station are narrow and not easy to negotiate.

To save artisans from this very difficult & arduous work of carrying slate as much as possible and to improve their efficiency & productivity, it will be extremely useful to provide some suitable haulage arrangement from different quarries to the loading station. This may be in the form of a simple aerial rope-way, or an end-less haulage system or some other method. The details of this system may be worked out, once a proper contour map of the area is prepared.

5.85 <u>From loading station at hill-top to base-camp:</u>

The existing rope-way is rather flimsy. The structures at both the loading and the un-loading station are also weak. The braking arrangements on the drum are poor, resulting in frequent slippages and break downs, and damage to slate.

As this rope-way is a very vital part of the project, it is essential to have a more sturdy properly designed system, which is fully dependable. The circumstances that exist are very favourable for the installation of an economical rope-way system. Only one span of 900 metre length is required, and the quantity of material to be handled is also small. It is recommended that a properly designed rope-way may be installed in place of the existing one.

5.86 <u>From base-camp to consumers or stock yard in the country:</u>

At present, slate slabs are loaded in-to trucks, each containing about 5 tonnes and sent to consumers or stock yards during dry seasons, when the road is open.

It is essential to have an all-weather road between Chusum and the base-camp, so that the mine production can be taken away regularly.

At present, slate slabs are loaded directly into trucks. It is suggested that trials should be made using wooden crates for packing slate, and loading these wooden crates into trucks. This system is likely to reduce breakages. As timber for making crates is available at site, it may be more economical to use crates than loading slate directly into trucks.

When slate is exported, it will in any case be necessary to use wooden crates for packing slate, before it is transported over long distances.

5.90 **Mine and Processing Plant Equipment list**

The main equipment required for the mine and the processing plant, together with its specifications is given below:

(i)	Dozer – medium capacity, say equivalent to BEML D-50 type	one
(ii)	Compressor – portable diesel-operated, capacity 250 cfm (or nearly 7 m^3/ min), normal working presure 100 p.s.i.g. or 7.0 kg/cm^2, say equivalent to Atlas Capco model VT 250	one
(iii)	Hand-held compressed air operated, air flushed Rock drills	3 nos.
	with piston dia. 65mm., piston stroke 60 mm. and weight about 25 kg.	
	Say equivalent to Atlas Capco RH 658 – 4L.	
(iv)	Hose-pipes, nipples, accessories to match items (ii) & (iii) above.	
(v)	7/8" integral drill steels of following lengths:	
	800 mm length 34 mm bit dia	14 nos
	1600 mm length 33 mm bit dia	8 nos.
	2400 mm length 32 mm bit dia	6 nos
	These may be coromant premium integal steel, or equivalent.	
(vi)	Drill steel grinder for grinding drill steel, say Atlas-Capco model 796 – 1401 of 1.3 hp. motor with suitable grinding wheels	one
(vii)	(a) Tractor, medium capacity farm type, say equivalent to Ford 3600 size.	one
	(b) Suitable trailor for above tractor	one
(viii)	Toyota Land Cruiser, Diesel-driven, RHD say model BJ 40 LV – KC or equivalent with front & rear heater and heavy duty tires.	one
(ix)	Edge-cutting & polishing machines for slate.	one each

These may be amongst the following:

(a) (i) Edge-cutting machine, Model T.Z. 3/R/800 complete with electrification, of Messrs Van Voorden b.v, 4870 AA Etten-Leur, Holland P.O Box 15

(ii) Jenny Lind Polisher, M.P of Messrs Van Voorden b.v.

or (b) (i) Edge-cutting machine, model ECM - II, complete with electrification of Messrs Shah Granites (P) Ltd., Karamchand Mansion, Barrack Road, Behind Metro Cinema, Bombay - 400 020, India.

(ii) Polishing machine - Pol - II with electricals of Messrs Shah Granite (P) Ltd.

or (C) (i) Automatic Slate stone edge-cutting machine of Messrs Rajasthan Industries Behind Power House, Jodhpur - 34 2001, Rajasthan, India.

(ii) Polishing machine for slate stone of Messrs Rajasthan Industries, Jodhpur.

(Descriptive literature & quotations for these machines have been left with the Department of Industries and Mines).

(x) Aerial Rope way - for transporting slate slabs from quarry on hill-top to the base-camp in the valley below.

Distance 900 metres

Single spares

Capacity : 30 tonnes of material in one shift of 8 hours.

Slate slabs will be of following sizes

Maximum size 900 x 600 mm x 10 mm each, weighing 15 kg.

Normal size 600mm x 600 mm x 10 mm each weighing 10 kg each.

The rope way may be Gravity operated and or Power operated.

With a spare rope, and essential spare for a year.

(xi) End-less haulage/ropeway from quarry near trench no.7 to quarry near trench no.1, with capacity similar to the aerial rope way.

The details of this rope way may be fixed, when the contour plan of the area is completed. Perhaps the existing small aerial rope way & structure with some alterations may be used for this work.

Auxiliary Facilities

6.01 The following auxiliary facilities will be required for successful operation of the mine on a continuous basis.

(i) Site development
(ii) Mine office - cum - store
(iii) Shed for processing slate
(iv) Workshop & Blacksmiths shop
(v) Explosive magazine
(vi) Water supply & distribution
(vii) Power supply & distribution
(viii) Residential colony

6.02 Site development

A tentative site has been selected for the colony. After proper survey, some land grading may be required for location of buildings there. This can be easily done by the dozer that will be available.

The offices, stores, workshop and sheds for processing slate, may be sited near the present base-camp. Some small site preparation may be required for this purpose.

6.03 Mine office - cum - store

An office has to be provided for the Project Manager, Mine Manager, Trainee Manager, and the staff. The building will also have a store for keeping spare parts and other consumables required for the mine.

The building will be of Ekra walling, timber flooring, and slate roofing.

6.04 Shed for processing slate

A shed has to be provided for installation of equipment for edge-cutting and polishing of slate near the mine offices. This will be required, when power becomes available, and this equipment is shifted here from its earlier temporary location. About 40 square metres of space will be needed for the purpose.

6.05 **Workshop & Blacksmiths shop**

For sharpening tools and implements of the artisans, a blacksmithy shop will be provided at the hill top near the quarries.

For small maintenance work, a room may be provided near the mine offices, which will be later attached to the shed for processing slate. Major maintainance work of the mine equipment will however, be done in workshops at Thimphu.

6.06 **Explosive magazine**

For storing various types of explosives and fuses, it will be necessary to have a proper magazine located at a safe site, sufficiently away from other buildings.

6.07 **Water supply & distribution**

The requirement of water for the project will be about 50 cu.m. per day, including about 40 cu.m per day for the colony.

Water may be collected from Pechu stream flowing nearby by pumping to a central raw water tank near the top end of the colony. An irrigation channel is likely to be constructed above the colony site. When this is constructed, water may be obtained from this channel by gravity to the raw water tank. After settling and filteration, this water will come to a clear water tank, from where it will be distributed by gravity to different places of requirement by G.I. pipes.

6.08 **Power supply & distribution**

At present, there is no power supply at the project site. It will be extremely useful, for the continued progress of the project, to have power supply available there.

A small hydro-power generation scheme for generating about 220 KVA power very near the project site is under active consideration of the Government. This will be of great help to the project, which will be able to sonsume a good part of the available power in the mine, processing plant, and the colony.

6.09 Residential colony

The colony will have houses for the Project Manager, Mine Manager, Trainee Mine Manager, and for staff and artisans.

In addition, there will be a guest house, a community centre (which will also house a school in the day time), a Co-operative store, a dispensary, and a post & telegraph - cum - telephone office.

The aim will be to provide two room accomodation with kitchen and toilet facilities, covering an area of about 400 square feet to the junior most employees. If due to considerations of economy, it is not possible to provide this immediately, this objective will be kept in view, and every effort will be made to provide the same, as profits of the mine increase in course of time.

All buildings will have timber flooring (except in kitchen & bath rooms, where flooring will be of slate tiles), Ekra walling and slate roofing.

Section - 7

Organisation Set-up

7.01 The organisation structure is shown in the attached chart. A Project Manager, who will be reporting to the Department of Industry & Mines, will be the head of the organisation, and will be responsible for direction, supervision, control, production and operation of the mine. He will be assisted by competent and qualified personnel for construction and operation of the project, including a Manager, an assistant Manager, an Accountant, two Supervisers, a Store-keeper, a Compounder, a Mechanic, four operators-cum-drivers and a general clerk.

7.02 The Mine Manager shall have a degree or equivalent diploma in mining engineering or at least a second class mine manager's certificate of competency. He will be responsible for production at the mine with safety and efficiency, as well as for future planning.

7.03 Other personnel shall have 2 to 3 years experience in their fields.

Section – 8

Project Schedule

8.01 All the main activities required to be carried out for implementation of the Project, showing the sequence and duration of each activity, are given below.

8.02 The project schedule has been drawn up on the basis of a realistic time of delivery of equipment, construction and erection, wherever necessary.

8.03 Description of Activity — Starting date & duration

		Description of Activity	From start	Duration
I		Preparatory activities		
	(a)	Approval of Feasibility Report	Starting Point	
	(b)	Signing of Project Document	Starting Point	
	(c)	Inviting quotations for equipment, and evaluation of tenders	Within one month	One month
	(d)	Appointment of Mine Manager	Within 4 months	
	(e)	Appointment of other staff & workmen as necessary	Within 4 months	
	(f)	Preparation of plans for construction of offices, stores, houses and other related preparatory work	Within 4 months	Three months
	(g)	Finalisation of alignment of road from Chusum to base-camp	Within 4 months	Two months
	(h)	Finalisation of alignment of road from Base-camp to the mine near hill-top	Within 4 months	Two months

8.04

		Description of Activity	From start	Duration
II		Main Project Activities		
	(a)	Purchase and delivery of equipment	Within 4 to 8 months	
	(b)	Improvement of 15 km long road from Chusum to Base-camp by PWD	Within 15 months	8 months
	(c)	Construction of 7 km road from base-camp to mine near hill-top	Within 12 months	6 months

(d)	Removal of soft & hard overburden for preparation of working places	Within 15 months. To be continued thereafter	3 months
(e)	Preparation of working places	Within 18 months. To be continued thereafter	3 months
(f)	Construction of offices, stores, sheds, houses, and other facilities	Within 16 months	12 months
(g)	Installation of aerial ropeway from the mine near the hill-top to the base-camp	Within 15 months	6 months
(h)	Installation of an end-less rope-way, from near trench no.7 to trench no.1, for haulage of slate from the quarries to the aerial rope-way loading station	Within 15 months	3 months
(i)	Mining, splitting, and sizing of slate for roofing purposes (at full capacity)	Within 16 months	Will be done continuously thereafter
(j)	Installation/and operation of equipment for edge-cutting & polishing of slate tiles for flooring & pannelling.	Within 16 months	Will be done continuously thereafter
(k)	Transporting & marketing of slate at full capacity	Within 16 months	Will be done continuously thereafter
(l)	Preparation of monthly, quarterly and annual progress reports, Accounts & Balance sheets	Within 3 months	Periodically thereafter

Note : Although full production capacity may be attained only by 16th month, every effort will be made to achieve a production of 12 lakhs square feet of slate in the second year, by utilising the extra capacity of the mine.

Section - 9

FINANCIAL ESTIMATES

9.00 Capital cost estimates & their phasing

9.01 Mining until now has been done on the exposed outcrop of the slate deposit. This exposed outcrop is now nearly exhausted, and to continue mining, it is essential to remove overburden and expose the slate bed below it. An attempt was made sometime back to remove overburden manually, but this was not at all successful, as the overburden is hard. On account of the hard and compact nature of the overburden, and the difficulty of getting sufficient labour for manual work, it appears necessary to use machinery for removal of this overburden.

9.02 The quantity of overburden necessary to excavate for a production of 4,000 square feet of slate per day, is not large. But it will be advisable to employ sturdy equipment of a reasonable capacity, which would give reliable services in a remote area, where facilities for its maintainance will not be adequate. This equipment will infact, be adequate for a production of even 6,000 square feet of slate per day.

9.03 The equipment and facilities needed and their capital cost is estimated as follows:-

			Cost Nu.
I	(i)	Improvement in road between Chusum & base camp (this is expected to be done by PWD on its own account at a cost of Nu.15 lakhs, as this road will serve the general public of the area. Its cost to the project will be nil, though its provision is essential for the project)	Nil

(ii)	Construction of new road from the base camp to the slate deposit. (It is proposed that the equipment obtained for the project may be employed for construction of this road. Thus only the cost of labour, and consumables for dozer, compressor, drills etc., and explosives may be debited to this account) 7 km @ 100,000 per km.		7,00,000
(iii)	Buildings:		
	(a) Office & Store (b) Shed for processing slate slabs (c) Residential, including buildings for common facilities		5,00,000
(iv)	Furniture & fittings		20,000
(v)	Miscellaneous		80,000
			13,00,000

II Equipments

(a)	Dozer	8,00,000
(b)	Compressor	1,70,000
(c)	Drills, accessories	1,00,000
(d)	Tractor & Trailers	1,00,000
(e)	4-wheel drive vehicle (6-seater type)	70,000
(f)	Processing Equipment like edge-cutting & polishing machines, including installation	2,00,000
(g)	Ropeway, including spare rope, pulleys etc. It has not been possible to obtain budget quotations for this work, and so its cost has been roughlyestimated	2,00,000
(h)	Pumps, pipes etc.	20,000
(i)	Survey & drafting instruments	40,000
(j)	Initial spares for equipment	2,00,000
(k)	Electrification	1,00,000
(l)	Miscellaneous	1,00,000
		21,00,000

III	Cost of initial development work (operating cost only for removal of approximately 10,000 tonnes of overburden @ Nu.20/- per tonne. This expenditure may be kept in suspense account for subsequent adjustment in operating cost).	2,00,000
IV	Working Capital to cover approximately three months revenue expenditure	2,00,000
		38,00,000

9.04 After funds are sanctioned, practically the entire amount can be utilised in one year's time, as the delivery period of the equipment required is short, and the work of construction & improvement of roads, and construction of buildings & other facilities can be started simultaneously.

9.10 Production cost estimates

9.11 An estimate of costs for production of slate at three levels of production, i.e. at 4,000, 5,000 and 6,000 square feet per day is given below:-

9.12 The norms of depreciation, interest charges, maintenance costs & consumption have been taken as follows:-

1. Operating time and consumption of fuel & lubricants

Dozer - 7 litres of diesel fuel per hour of operation
Compressor - 6 litres of diesel fuel per hour of operation
Tractor - 2 litres of diesel fuel per hour of operation
Cost of lubricants - 5% of value of fuel used
The equipment will operate for 1,000, 1,250 and 1,500 hours per annum at the three levels of production.

In view of the location of the project in a remote area, away from sources of supply of spare parts and any large maintenance workshop, and till such time as the mechanics & operators become more experienced, it will not be a mean achievement to ensure the availability of equipment for these periods.

2. Depreciation:

Depreciation of equipments has been taken at 12, 14, and 16 percent of value/an average at production levels of 4,000, 5,000 and 6,000 squarefeet of slate per day.

/ on

Depreciation on road and buildings has been taken at 5% of their cost.

3. Cost of maintainance of equipment, including cost of spare parts hase been taken at 10, 12 and 14 percent of the value of equipment at three different levels of production.

Cost of maintainance of road & buildings has been taken at 7½% of their cost.

4. As it is not clear at present, how the project is to be financed, by a grant, or fully through loans, or partly by equity and partly through loans, or in some other manner, no interest charges have been included in the cost estimates. The impact of interest charges on total operating costs under different financing arrangements, has however been analysed, under 'Pricing Policy and Financial Analysis' in this section.

5. The cost estimates include the adjustments of expenditure of Nu.2,00,000 incurred on initial mine development.

I Personnel salary & wages:

			Annual expenditure. Production level sq.ft. per day		
			4,000	5,000	6,000
(A)	(i)	Manager @ 1,800 p.m	21,600	21,600	21,600
	(ii)	Asst.Manager-cum-Trainee Manager @ 650 p.m	7,800	7,800	7,800
	(iii)	Accountant, two supervisers, store keeper, compounder, mechanic, four operators-cum-drivers, one clerk- 11 persons @ 450 p.m on average	59,400	59,400	59,400
	(iv)	Peon & two handy boys- 3 persons @ 250 p.m	9,000	9,000	9,000

	(v) T.A&D.A of above staff @ $\frac{1}{3}$rd of salaries	32,600	32,600	32,600
	(vi) Project allowance of staff @ 50% of salaries	48,900	48,900	48,900
B	Earnings of artisans on piece rate	2,40,000	3,00,000	3,60,000
C	Contigencies	10,700	10,700	10,700
		4,30,000	4,90,000	5,50,000
II	**Stores & material**			
	(A) **Consumables:**			
	(i) Cost of fuel for dozer, tractor, and compressor per annum (7+2+6) litres x Nu.3 per litre x (1000 or 1250 or 1500 hours)	45,000	56,250	67,500
	(ii) Cost of lubricants @ 5% of the cost of fuel	2,250	2,813	3,375
	(iii) P.O.L for six-seater, 4-wheel drive vehicle	9,000	9,000	9,000
	(B) Maintainance supplies & spare parts for equipment	1,90,000	2,28,000	2,66,000
	(C) Maintainance of road & buildings	90,000	90,000	90,000
	(D) Explosives	30,000	37,500	45,000
	(E) Medicines, etc.	10,000	12,500	15,000
		3,76,250	4,36,063	4,95,875
III	**Depreciation:**			
	(A) On equipment	2,28,000	2,66,000	3,04,000
	(B) On road, buildings etc.	65,000	65,000	65,000
		2,93,000	3,31,000	3,69,000
IV	Royalty @ Nu.0.05 per sqft.	60,000	75,000	90,000
V	**Miscelleaneous:**			
	(i) Cost of crating	@ 10% of other costs		
	(ii) Loss on breakages			
	(iii) Transport cost of stores & fuel to site			
	(iv) Overheads, including sales overheads	1,16,200	1,33,100	1,50,000
	(v) Sundries			

Grand total	12,53,450	14,39,163	16,24,637
or say	12,55,000	14,40,000	16,25,000
Cost of production excluding interest charges per sq.ft.			
Nu.	1.05	0.96	0.90

9.20 **Pricing Policy & Financial Analysis**

9.21 Uptil now, slate is being sold at a no-profit, no loss basis, at a price of Nu.1.20 per sqft. at the mine head.

9.22 As this is the only slate producing mine in the country at present, and its usefulness for roofing purposes is not yet fully known to the people in general, the Government will have to decide on its price for some time to come.

9.23 One way to fix its price would be to make it equal to the price of alternative commonly used materials that it replaces. In that case, the price of slate at the mine head could be Nu.3.23 per sqft. (see section 10- National Economic Benefits)

9.24 The cost of production, excluding interest charges on capital employed, has been estimated at Nu.1.05 per sqft. At a sale price of Nu.3.23 per sqft, the project will be a money-spinner, after providing for all interest & other charges.

9.25 A project should stand on its own merits, and should not have to depend upon subidies, and should be able to bear all direct & indirect costs necessary to operate it. In the case of this project, the only cost that has not been taken into account is the cost of improvement of road between Chusum and the base-camp, which is estimated to be Nu.15 lakhs. Although this road is not for the benefit of the slate project alone, and is in fact included for improvement in the general national road programme of PWD, the economics of the project may be ascertained taking this cost also into account, so that there is no element of indirect subsidy to the project. The additional cost on account of interest charges, maintenance & depreciation of this road will amount to about Nu.3,00,000 per annum, or Nu.0.25 per sqft. At a price of Nu.3.23 per sqft. (which is the right price for slate, if the project is not to subsidise other sectors of the economy), the profitability of the project will still be high, as would be seen here:

		Nu.
1.	Production cost of 12,00,000 sqft. of slate	12,55,000
2.	Interest charges on Nu.36 lakhs at 15%, with repayment of principal & interest in 12 equal instalments.	5,70,000
3.	Interest, depreciation & maintainance charges on road from Chusum to base-camp	3,00,000
		21,25,000
4.	Sale price 12,00,000 @ 3.23 per sqft.	38,76,000
5.	Profit per annum	17,51,000

(Actually the profit will be more, as nearly Nu.3,00,000 will be available on depreciation account per annum, which money can be used for repayment of interest & principal).

9.26 But the Government has to take many other factors into consideration. It may consider it advisable to keep prices low, even by subsidising the same, to help people in improving their living accommodation, or to encourage replacement of imports at the earliest possible time.

9.27 This may be done by selling slate at its production cost of Nu.1.05 per square feet. The investment of Nu.36 lakhs may be considered as an investment for a public purpose, as is done for construction of roads, or say for an agricultural development centre, or for other public services.

9.28 Another alternative would be to fix the price at no-profit, no-loss basis, but adding to the production cost, the interest charges incurred on investment. The cost as well as the sale price of slate would in this case be approximately Nu.1.25 per square foot. The depreciation charges would be used for repayment of Capital. It may be noted, that this is also the present cost of production and selling price of slate, the Nu.0.05 apparent differencein price being due to the royalty charges which are not being paid at present.

9.29 Another alternative is to operate the project as a commercial enterprise. The capital requirement of Nu.38 lakhs (including Nu.2 lakhs required on suspense account for a short period) may be raised by an equity capital of Nu.11 lakhs, a 12 year term loan of Nu.22 lakhs at 12% interest, and a short-term bank overdraft of Nu.5 lakhs at 15%. A price of Nu.1.40 per square foot would yield a discounted cash flow (DCF) return of 15% on the equity capital. This will be a very satisfactory return to begin with, specially when it is considered that a royalty of Nu.0.05 per square foot would be payable now, which was not paid before, and the sale price is much less than even half of Nu.3,23, which itself is not an unjustified price. A cash flow table and calculations of Present Values, showing the financial position in this alternative is shown in Table I.

Table I

Cash flow Table and Calculation of Present Value

Values in Nu.Lakhs Years	1	2	3	4	5	6	7	8	9	10	11	12	Total
A. Cash Inflow													
(a) Sales Revenue		16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80	184.80
(b) Depreciation		2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	32.23
		19.73	19.73	19.73	19.73	19.73	19.73	19.73	19.73	19.73	19.73	19.73	217.03
B. Cash Outflow													
1. (a) Equity –	11.00												11.00
(b) Repayment of term loan			2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	22.00
(c) Interest on term loan		5.60	2.64	2.38	2.11	1.85	1.58	1.32	1.06	.79	.53	.26	20.12
(d) Repayment of bank overdraft			1.00	1.00	1.00	1.00	1.00						5.00
(e) Interest on bank overdraft			0.75	0.60	0.45	0.30	0.15						2.25
2. Production costs		12.05	12.05	12.05	12.05	12.55	12.55	12.55	12.55	12.55	12.55	12.55	136.05
		17.65	18.64	18.23	17.81	17.90	17.48	16.07	15.81	15.54	15.28	15.01	196.42
C. Net Cash flow (A–B) –	– 11.00	2.08	1.09	1.50	1.92	1.83	2.25	3.66	3.92	4.19	4.45	4.72	20.61
D. Present Value (at 15% DC.F.) --	$\frac{1}{2}$(11.00 +9.56) = 10.28	1.57	0.72	0.86	0.95	0.79	0.85	1.21	1.11	1.03	0.96	0.88	+0.75
E. Cumulative net cash balance		2.08	3.17	4.67	6.59	8.42	10.67	14.37	18.29	22.48	26.93	31.65	

9.30 It may be noted, that the price of slate as well as the cost of production has been shown constant for a 12-year period in this financial exercise. In practice, this will not be the position. But it is anticipated that inflation will affect both the cost as well as the sale price equally, and will therefore, not affect the general accuracy of this projection. This is a very valid assumption and is generally made for such purposes.

9.31 It may also be noted that no funds have been provided for renewal of equipment during this period. At the production capacity being considered, no major renewal of equipment is anticipated during this period. Any minor requirements can be taken care of from the adequate funds that have been provided for maintainance.

9.32 Although there is no reason to assume that the initial production & sale targets of 12 lakh square feet of slate per annum will not be met, it will be useful to know the financial implications, if these targets are not achieved for any reason, whatsoever.

At 80% achievement of the targets, the production & sale will be 9,60,000 sqft. per annum. The reduction of costs will however, be only as given below:

		Nu.
(i)	Earnings of artisans (12,00,000 - 9,60,000) = 2,40,000 @ 0.20/sqft.	48,000
(ii)	Royalty 2,40,000 @ 0.05/sqft.	12,000
(iii)	Reduction in cost of fuel, lubricants for production equipment, explosives, & maintainance supplies, and cost of crating, loss on breakages, transport cost of stores & fuel to site etc. @ 10% of Nu.3,40,000 (Nu.2,76,000 from item II A and Nu.64,000 from item V of para 9.12)	34,000
		94,000

The cost of production (excluding interest charges) of 9,60,000 sqft. of slate per annum will thus be	12,55,000
	94,000
	11,61,000
∴ Cost of production per sqft.	Nu.1.21

Thus if the production and sale was lower by 20%, there will be an increase in cost of about Nu.0.16 per sqft.

This further highlights the importance of not only achieving, but exceeding the targets of production & sales.

Section - 10

National Economic Benefits

10.01 An analysis of cost of Slate and C.G.I roofing has been given in annexure I. It will be seen from this that the total cost of Slate roofing works out to Nu.6.49 per sqft., whereas C.G.I roofing costs Nu.10.64 per sqft. Thus C.G.I roofing is costlier than slate roofing by $\frac{(10.64 - 6.49)}{6.49}$ per cent or nearly 64%

10.02 Slate roofing is more durable and if properly installed lasts the life of the building, whereas C.G.I roofing requires to be painted, and may also need to be replaced, when its gets rusted. This will add to the cost still further.

10.03 It will be further noted from annexure I, that the import content of material in C.G.I roofing (C.G.I sheets, nails, L hooks, roofing screws, Limpet washers, bitumen washers) works out to be nearly 75% of its costs, whereas the import content of slate roofing (nail & roofing screws is about 0.5% only.

10.04 The cost analysis further shows as follows:-

Cost of roofing 2500 sqft.

		Nu.
(i)	By C.G.I sheets	
	(a) Cost of C.G.I sheets, 1.743 tonnes	18365.99
	(b) Others costs	7237.37
	Total	25603.36
(ii)	By Slate	
	(a) Cost of Slate, 2 314 nos, of size 30 cm x 60 cm (or 2 sqft. each)	7520.50
	(b) Other costs	8710.92
		16231.42

10.05 This means that if the price of slate was higher even by (25603.36 - 16231.41) = Nu.9371.94, the cost of roofing will be the same . That is, the cost of slate could even be higher by $\frac{9371.94}{2314x2}$ per sqft. or by Nu.2.03 per sqft. Thus, even if the cost of slate at Thimphu is (1.63 + 2.03) i.e. Nu.3.66, it will still not cost more than C.G.I roofing.

10.06 Hence the contribution of slate to the national economy, on an average, at present is Nu.3.66 per sqft. When the project is developed to its initial capacity of 4000 sqft. per day, its contribution to national economy will be 12,00,000 x 3.66 or Nu.43,92,000 per annum.

10.07 Apart from providing gainful and skilled employment to about 65 persons, the project will provide an excellent training ground for Mining and Industrial Project Management. This will be extremely useful for development of other mineral resources of the country, as well as in management of industrial project.

The Project fits in beautifully with the national economic policy of attainment of self-reliance.

Section - 11

Conclusions & Recommendations

11.00 **Conclusions:**

11.01 Bonsegoona slate deposit in Wangdi Phodrang district of Bhutan has large reserves of good quality slate, which are adequate to sustain an efficient modern mine & processing unit for a long time.

11.02 The quality of slate is entirely suitable for roofing purposes.

11.03 Thicker slate slabs from the mine can be cut & polished into slate tiles for flooring & pannelling.

11.04 Slate is a better & cheaper roofing material than corrugated galvanised iron sheets(C.G.I sheets), C.G.I roofing being about 64% costlier than slate roofing. Slate is available indigenously, whereas C.G.I sheets have to be all imported. Therefore, apart from meeting the objective of self-reliance, the production & use of slate in Bhutan is in the best interests of the country and its people.

11.05 As most of the exposed outcrop of good quality slate has been nearly worked out in the last few years by small-scale mining, it is necessary to remove overburden to provide working places for future production. On account of the hard nature of the of the overburden, and the difficulty of getting sufficient labour for manual work, it is necessary to use machinery for removal of this overburden.

11.06 To enable this indigenous natural resource to make its best contribution to the economy of the country, it will be necessary to develop it into a proper & efficient mine of optimum size. To start with, the mine may have a capacity of producing 4,000 square feet of slate slabs per day. This will require an investment of Nu.38 lakhs. The mine can be brought into full production within a year's time, after the equipment has been obtained, the roads have been improved & constructed, and initial facilities provided. The latter facilities can be completed within a year, if adequate funds are provided. The cost of production, excluding interest and financing charges is estimated at Rs.1.05 per square foot.

11.07 To ensure safety an. efficiency, it will be necessary to work the mine on a s fic basis, special emphasis being laid on the maintainance orking places with proper width and height.

11.08 In view of the location of the project in a remote area, it will be necessary to lay special emphasis on proper maintenance of equipment, as well as of approach roads to the mine.

11.10 Recommendations:

11.11 As many people are not yet aware of the superiority of slate as a roofing material, a concerted effort should be made to educate them in this regard by suitable publicity.

11.12 Suitable financial incentives, like preference in grant of loans for house-building, may be considered for those using slate for roofing their houses.

11.13 For buildings using public funds, only slate roofing should be installed in future.

11.14 Efforts should be made to promote the use of slate in neighbouring areas of India, as well as in countries like Australia.

11.15 In view of the highly beneficial effect that this project will have on national economy, consideration may be given to its implementation on a priority basis.

ANNEXURE IV

Analysis of rate for C.G.I sheets roofing

Sl. No.	Description of items	Unit	Quantity	Rate	Amount
A.	Meterials.		Details of cost of 2500 sq.feet		
1.	C.G.I sheets	M.T	1.743 M.T	10537.00	18365.99
2.	Timber	Cft	174.08 Cft	17.00	2959.36
3.	Nails	Kg.	58.1 kg	6.65	386.37
4.	L. hooks	kg.	58.1 kg	7.65	444.47
5.	Roofing screw	kg.	29.05 kg	11.00	319.55
6.	Limpet washer	gross	29.05 gross	1.75	50.84
7.	Bitumen washer	gross	29.05 gross	3.35	97.32
B.	Labour				
	Carpenter 1st class	each	17.43 nos.	12.10	210.90
	Carpenter 2nd class	each	32.24 nos.	9.90	230.08
	Male mazdoor	each	34.86	6.05	210.90
					23275.78
	Add 10% for over heads				2327.58
					25603.36

$\therefore$ cost per sq.m $= \frac{25603.36}{2500} \times 10.76$

$= 110.19$

Say Nu.110.20/square metre.

cost per sqft. $= \frac{25603}{2500} =$ Nu.10.64

ANNEXURE IV

Analysis of rate for Slate roofing

Description of items	Unit	Quantity	Rate	Amount
Details of cost for 2500 sqft.				
A. Materials				
Slate	each	2314 nos (30cm x 60cm)	3.25	7520.50
Nails	kg	5.75 kg	6.65	38.24
Roofing screw	kg	4.1 kg	11.00	45.10
B. Labour				
Mason 1st class	each	37.72 nos	11.00	414.92
Carpenter 1st class	each	5.74 nos	12.10	69.45
Male mazdoor	each	28.70 nos	6.05	173.64
C. Timber for trussess	Cft	278.8 cft	17.00	4739.00
D. Labour for preparing trussess.				
Carpenter 1st class	each	28 nos.	12.10	992.20
Carpenter 2nd class	each	36.9 nos	9.90	365.32
Male mazdoor	each	65.6 nos	6.05	396.88
				14755.84
Add 10% for over heads	-	-	-	1475.58
		Rate for 2500 sqft.		16231.42

∴ Rate for sq.meter = $\frac{16.231.42}{2500} \times 10.76$

= 69.86

Say Nu.69.90/sq.metre.

Cost for sqft. = $\frac{16.231.42}{2500 \text{ ft.}}$ = Nu.6.49

Annexure II

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

HAUZ KHAS
NEW DELHI - 110029
DATE: 25th July, 1975
REF.: IITD/CE/PK/75

Dr. P. Kumar
Division of Engg. Geology
Civil Engg. Deptt.

CERTIFICATE

This is to certify that the Slate Samples from Bonsogeona Slate Deposits were tested and the following results were obtained for various tests mentioned below:

1.	TRANSVERSE STRENGTH (ISS-1121)	-	12,010 p.s.i.
2.	SHEAR STRENGTH (ISS-1121)	-	3,094 p.s.i.
3.	SPECIFIC GRAVITY (ISS-1122)		2.765
4.	a/ WATER ABSORPTION (24 Hrs. Immerson) (ISS-1124)	-	.10% by weight
	b/ WATER ABSORPTION (ISS-1124) 5 Hrs. Boiling	-	.12% by weight
5.	TOUCHNESS	-	0.292 p.s.i
6.	DURABILITY (ISS-1126)	-	0.52% $Na_2 SO_4$
7.	CLEAVABILITY	-	FAIR upto 3/16" (Normal)

Sd/-

(P. Kumar)
Officer-in-Charge
Division of Geology

Annexure III

Properties	Bonsegeoma slate of Bhutan.	India			Indian Standarod IS:6250-1971.	United Kingdom South Wales.	America	
		Dharmsala	Kund	Kurnol			Eastern Newyork	Pensilvenia
Specific gravity	2.765	2.706	2.782	2.784	-	2.766	2.783	2.764
Medules of Transverse strength	884.30 kg/cm^2 12010 psi	489.85 kg/cm^2 6968 psi	547 kg/sq. cm	861.72 kg/cm^2 12260	600 kg/cm^2	861.87 kg/cm^2 12059 psi		844.65 kg/cm^2 121015 psi
Shear length	216.10 kg/cm^2 psi	172.44 kg/cm^2 2453 psi	231.63 kg/cm^2 3295 psi	239.58 kg/cm^2 3408 psi	-	210.61 kg/cm^2 2996 psi		223.97 kg/cm^2 3186 psi
Water absorption	0.1%	0.10%	0.09%	0.08%	0.2%	0.07%	0.098%	-
Corrodi-bility	0.52%	0.60%	0.42%	0.40%	-	0.60%	-	0.49%

Annexure III

Properties	Bonsegeoma slate of Bhutan.	India: Dharmsala	India: Kund	India: Kurnol	Indian Standared IS:6250-1971.	United Kingdom South Wales.	America: Eastern Newyork	America: Pensilvenia
Specific gravity	2.765	2.706	2.782	2.784	-	2.766	2.783	2.764
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Shear length	216.10 kg/cm^2 psi	172.44 kg/cm^2 2453 psi	231.63 kg/cm^2 3295 psi	239.58 kg/cm^2 3408 psi	-	210.61 kg/cm^2 2996 psi		223.97 kg/cm^2 3186 psi
Water absorption	0.1%	0.10%	0.09%	0.08%	0.2%	0.07%	0.098%	-
Corrodi-bility	0.52%	0.60%	0.42%	0.40%	-	0.60%	-	0.49%

Annexure IV

Marketing Prospects for Slate in Bhutan

Slate from Bonsegeoma deposit is now getting popular as a roofing material in many parts of the country, and specially in areas, which are comparatively at a lesser distance from the deposit, as the transport cost of slate to these places is rather low. These areas include the districts of Wangdiphodrang, Punakha, Thimphu, Paro, Tongsa, Bumthang and Haa.

According to a statistical report of the Department of Registeration, the number of houses in these districts is as follows:

			No. of Houses
1.	Wangdiphordang		2,486
2.	Punakha		952
3.	Thimphu		2,893
4.	Paro		2,436
5.	Tongsa		1,247
6.	Bumthang		1,093
7.	Haa		817
		Total	12,059

At present most of these houses have wood shingle roofing, though some houses had recently installed slate and C.G.I roofing.

Wood shingle roofing is being slowly replaced, as the advantages of more permanant roofing are being appreciated. As people are now building houses away from the older villages, the cost of transport of subsidised wood from the forest areas is increasing, and sometime even enough co-villagers are not available for carrying out this work.

As the cost of wood shingle roofing will increase, there will be greater prospects of more permanant types of roofing being installed. As C.G.I roofing is definitely more costly, and as the advantages of slate roofing are becoming known, slate roofing is likely to be the choice for permanant roofing in future.

A very conservative estimate shows that at least 2% of the total number of houses will change their roofings to slate roofing every year. As an average houses requires about 3,000 sqft. of slate for roofing, the quantity of slate likely to be required in these districts per annum will be as follows:

Total no. of houses	2% of houses, changing to slate roofing per annum	Average quantity of slate required per house	Total quantity of slate required
12,059	241	3,000 sqft.	241 x 3,000 =7,23,000 sqft.

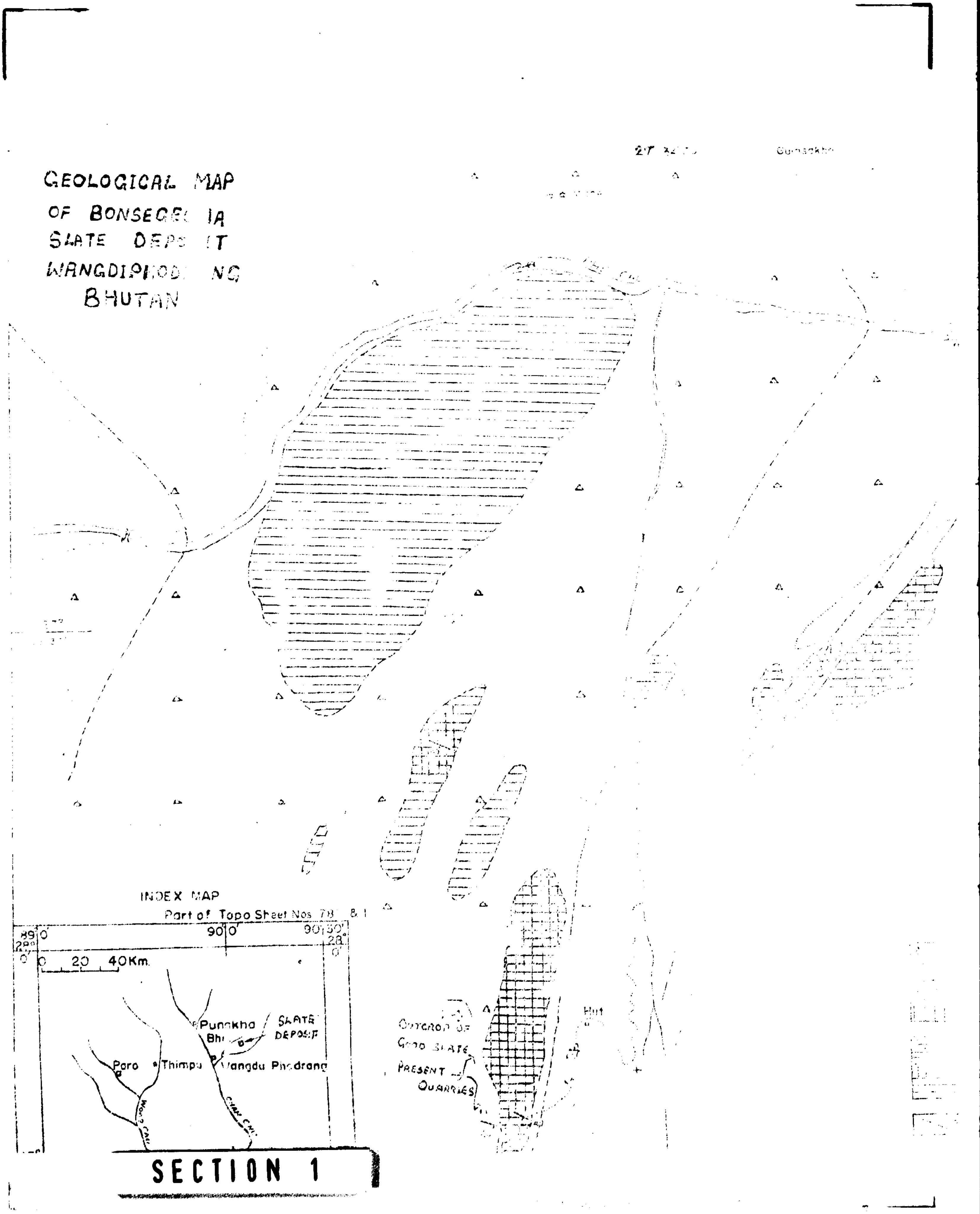
In a quest for having more permanant type of roofing, C.G.I roofing has been coming into use recently. In 1979 - 80, the import of C.G.I sheets in the country was 2,182 bundles, each bundle having 191.52 sqft. of sheets. The total area of sheets imported was thus 2182 x 191.52 = 4,17,896 sqft. or say 4,18,000 sqft. Slate should replace the use of C.G.I sheets in future. As on account of overlapping required in slate roofing, the quantity of slate used is at least 50% greater in area, the quantity of slate needed for this purpose will be 4,18,000 x 1.5 =6,27,000 sqft. (In comparing costs of C.G.I sheets & slate roofing, the need of this 50% extra quantity of slate has been taken into account). As most of these C.G.I sheets were for new construction from public funds, this demand is in addition to that for replacement of roofing in the districts considered above.

The total demand of slate therefore, is likely to be as follows:

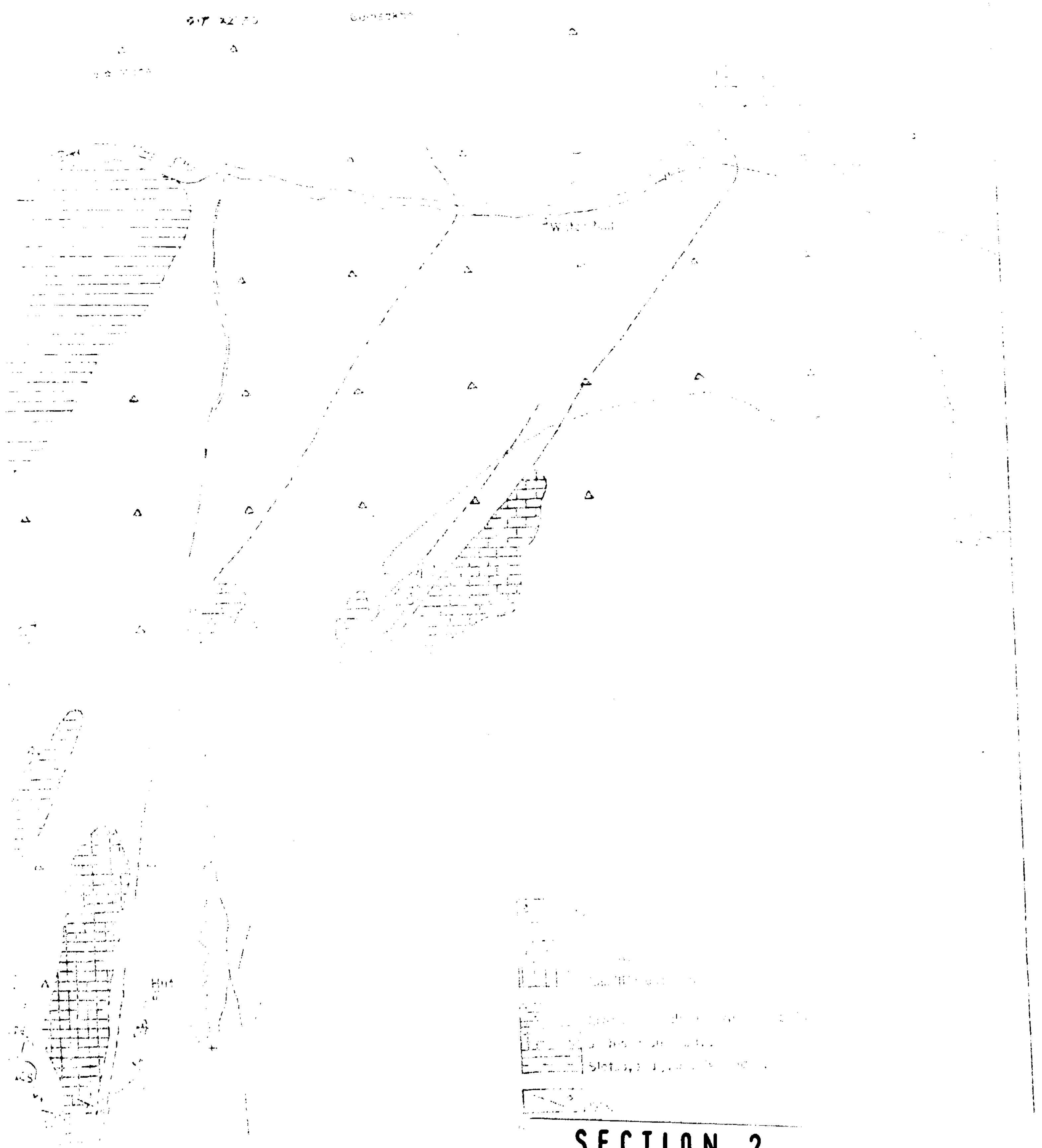
1.	For replacement of roofing in seven districts mentioned above	7,23,000 sqft.
2.	For substitution of C.G.I sheets being imported at present	6,27,000 sqft.
3.	In new construction for developing activities of various departments like schools, hospitals, army, and in private establishments	1,50,000 sqft.
		15,00,000 sqft.

As a matter of abundant caution, the firm demand may be taken at 80% of the above estimate, giving a figure of 12,00,000 square feet per annum.

It is clear that if supplies can be assured, there would be definitely a good market for slate in the country. This demand will increase further, if people in rural areas can be persuaded to use slate for roofing their houses, by providing them if necessary, soft-term loans and other financial assistance for purchase of slate. As the use of slate is of economic benefit to the country, if necessary, the Government could even stop the import of C.G.I sheets, when enough supplies of slate are available in the country.


GEOLOGICAL MAP
OF BONSEGE[illegible] IA
SLATE DEP[illegible] IT
WANGDIPHOD[illegible] NG
BHUTAN
INDEX MAP
Part of Topo Sheet Nos 78
89 0'
90 0'
90 30'
28°
0 20 40 Km.
Punakha
SLATE DEPOSIT
Paro
Thimpu
Wangdu Phodrang
Outcrop of Good Slate
Present Quarries
Hut

SECTION 1



SECTION 2

MAP OF BHUTAN

FIG. 1