# CHAPTER 2.

# PLANS UNDER BENTONITE PROJECT

# CHAPTER 2. PLANS UNDER BENTONITE PROJECT

This chapter will describe basic points of both the project and related production plans.

## 1 Basic Points of Project

This project calls for mining clay bentonite and producing and marketing activated bentonite. Details of its feasibility study are as follows:

(1) To identify properties of bentonite and study its uses
(2) To estimate bentonite ore reserves
(3) To draw up basic plans for bentonite clay mining
(4) To draw up basic plans for bentonite production
(5) To study infrastructure required for development of mine and construction of processing plant
(6) To assess economic feasibility of project

### 1-1 Identification of Properties of Bentonite and Study of Its Uses

In Guatemala, bentonite is mainly used as fillers for soap and detergent. In addition, it is used as fillers for insecticides, paints, rubber, plastics, etc., although these application are limited. Since its use for civil engineering is yet to be developed, Guatemala relies on imports from the U.S. for bentonite employed for drilling muds.

In view of this situation, it is essential that the project be studied with specific applications and demand of bentonite in mind after its properties are fully determined.

As a result of analysis of bentonite that occurs in Los Cimientos, it was found that activated sodium exchange bentonite gives excellent physical properties and is best suited as bond for molding sand, drilling muds, muddy water for civil engineering, carriers for agricultural chemicals and fertilizer, fillers for paints, ink, cosmetics, etc. as well as for other applications.

## 1-2 Estimation of Bentonite Ore Reserves

As a result of this survey, bentonite ore reserves in Los Comientos are estimated at more than 900,000 T.

The basic plan for mining and processing will be made based on this estimated reserves of 900,000 T. Additionally, an exploration plan will be drawn up to improve the accuracy of estimation of the bentonite grade and ore reserves and also to mine more than the above quantity.

## 1-3 Basic Plan for Bentonite Clay Mining

The basic plan will be formulated for the mining area, mining method, transportation, machinery and facilities, and investments and costs required for clay production will be estimated.

## 1-4. Basic Plan for Bentonite Production

The basic plan will be made for production method, machinery and facilities, and investments and costs required for production and transportation will be estimated.

## 1-5 Study of Infrastructure

Infrastructure required for operation of the mine and processing plant will be studied, and investments and costs for this infrastructure will be estimated.

## 1-6 Assessment of Economic Feasibility

Economic feasibility of the project will be assessed by making financial and economic analyses of the entire project from the mine to the processing plant and to marketing.

## 2 Basic Points of Bentonite Production Plan (Tables 2-1 and 2-2)

Basic items of the production plan are as follows:

1) Based on the demand in Guatemala for 1978 to 1980, the first stage production period will be established, followed by the second and third stage production periods for increased production.

2) Based on analytical results on properties of bentonite, new demand will be developed and sales be made to such new applications. To be more specific, the project will be started with a production capacity that will meet the present market demand, and then increased production in the second stage will be planned after sales to new applications have been expanded.

3) Each stage of production period will be established as follows:

The first stage operation period will run from the first year of operation to the sixth. The second stage operation period will be the next period of six years from the 7th year onward. The third stage operation period will cover 11 years from the 13th years of operation to the 23rd year (the last year of the project).

4) Output for each stage of the project will be established as follows:

| | |
|---|---|
| First stage operation period | |
| Clay supply to plant | 55 T/day |
| Bentonite production | 42 t/day |
| Second stage operation period | |
| Clay supply to plant | 110 T/day |
| Bentonite production | 83 t/day |
| Third stage operation period | |
| Clay supply to plant | 180 T/day |
| Bentonite production | 139 t/day |

5) Operating hours

The mine will be operated in one shift from 8:00 to 16:00 for eight hours with six actual working hours. The processing plant will be operated in two shifts from 8:00 to 22:00 or 14 hours with 12 actual working hours. The plant will be automated with a daily continuous operation of 11 hours for the first and second stage operation periods, and 12 hours for the third stage operation period. Shipments from the plant will be made during one shift from 8:00 to 16:00.

Table 2-1 Mine Operating Days and Clay Production

| | | | Operating hours: 8 h/day·shift | | |
|---|---|---|---|---|---|
| | | | Stages of Operation Period | | |
| | | | 1 | 2 | 3 |
| Stripping | Monthly Operating Days | Average | 25 | 25 | 25 |
| | Annual Operating Months | | 4 | 4 | 4 |
| | Annual Operating Days | | 100 | 100 | 100 |
| | Stripping Rate | | (Bentonite) 0.48:1 | 0.48:1 | 0.48:1 |
| Clay Mining | Monthly Operaing Days | Average | 25 | 25 | 25 |
| | Annual Operating Months | | 8 | 8 | 8 |
| | Annual Operating Days | | 200 | 200 | 200 |
| | Clay Production T/day | | 83 | 165 | 270 |
| | Clay Production T/month | | 2,075 | 4,125 | 6,750 |
| | Clay Production T/year | | 16,600 | 33,000 | 54,000 |
| Clay Supply | Monthly Operating Days | Average | 25 | 25 | 25 |
| | Annual Operating Months | | 12 | 12 | 12 |
| | Annual Operating Days | | 300 | 300 | 300 |
| | Clay Supply T/day | | 55 | 110 | 180 |
| | Clay Supply T/month | | 1,375 | 2,750 | 4,500 |
| | Clay Supply T/Year | | 16,500 | 33,000 | 54,000 |

Table 2-2 Plant Operating Days and Bentonite Production

Operating hours: 14 h/day·2 shifts

| | | | Stage of Operation Period | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| Plant | Clay Supply 5 T/h unit | | 1 | 2 | 3 |
| | Daily Operating Hours | | 11 | 11 | 12 |
| | Monthly Operating Days | Average | 25 | 25 | 25 |
| | Annual Operating Months | | 12 | 12 | 12 |
| | Annual Operating Days | | 300 | 300 | 300 |
| | Production t/day | | 42 | 83 | 139 |
| | Production t/month | | 1,050 | 2,075 | 3,475 |
| | Prodiction t/year | | 12,600 | 24,900 | 41,700 |

# CHAPTER 3.

# BENTONITE

# CHAPTER 3 BENTONITE

In this chapter, the feature of the bentonite deposit and the property, use or market etc. of bentonite in Los Cimientos are described.

## 1 Bentonite Deposit

### 1-1 Topography

Los Cimientos is located west of Chiquimula Department and is about 16 km southwest to Chiquimula City.

The San José river flows to northeast forming a deep valley at about 2.5 km northwestward from Los Cimientos. The topographically steep undulation extends repeatedly to north on the left bank, and on the other hand, the topographically steep to moderate undulation extends to about 1 km northwest from Los Cimientos and becomes gentler gradually from there to the village. The inclination changes to reverse direction and becomes gentle on the southeast side of Los Cimientos.

This topographic change reflects geology and geological structure.

### 1-2 Geology (Fig. 3-1, 3-2, 3-3)

The Jocotán fault strikes east-west in the turning point from gentle to steep topography on the right bank of the San José river.

Geology of Chiquimula Department differs on north and south sides of the Jocotán fault respectively. The north side consists of the basement rocks such as schists (Plaeozoic?), limestone (Cretaceous), Chiquimula pluton (Late Cretaceous to Early Tertiary) etc., and on the other hand, the south side consists of the El Rincón Formation, the Los Cimientos Rhyolite and the Encarnación Basalt of Tertiary age (Fig. 3-3). Geology on the south side which is related to the bentonite deposit is explained here.

1) El Rincón Formation

The El Rincón Formation was first named in the Informe Del Estudio Sobre La Exploración Minera En Las Areas De Chiquimula, Metaquescuintla Y Llano Del Coyote De La Republica De Guatemala (1981) (Japan International Cooperation Agency - Metal Mining Agency of Japan: hereinafter called JICA-MMAJ Report 1981).

The Formation is distributed on the south contact side to the Jocotán fault and the thickness is inferred to exceed 350 m though the thickness is not accurately distinct because the lowermost part is cut by the fault.

The Formation has no direct relation to the bentonite deposit of Los Cimientos.

It is composed mainly of conglomerate, lapilli tuff and tuff partly with intercalations of mudstone-siltstone, sandstone, calcareous rock and rhyolitic lava. The conglomerate is composed of gravel of schists and matrix of tuffaceous to sandy material, and is pooly bedded showing massive appearance.

The mudstone-siltstone shows lenticular shape with scarce continuity and is distributed in the 200-300 m range from the Jocotán fault. It strikes generally east-west and dips 10°-70°, generally 20°-40°, to south.

2) Los Cimientos Rhyolite

The Los Cimientos Rhyolite was first named by JICA-MMAJ Report 1981.

The Los Cimientos Rhyolite overlies conformably the El Rincón Formation and underlies the later-mentioned Encarnación Basalt.

The rock is composed mainly of biotite bearing rhyolite with fine-banded flow structure and dark-grey perlite partly with intercalations of rhyolitic tuff - lapilli tuff.

Though the thickness is confirmed to be 65 m in the surveyed area, it is reported that the thickness changes remarkably and reaches up to about 100 m at maximum according to the JICA-MMAJ Report 1981.

The biotite bearing rhyolite is distributed widely in the northeast - northwest part and narrowly in the southwest part. It mostly undergoes white alteration and no fresh rock occurs but a comparatively weakly altered part is distributed on the southeast slope (Fig. 3-4) of the 930 m mountain at the central part of the village.

The altered rhyolite generally loses flow structure and becomes white and massive though fine-grained biotite is still recognized, but some show flow structure on the west side of P9*, P18 and P15.

In the southwest part of the surveyed area, the rock is greenish white and the brecciated structure in lapilli size remains and this structure is confirmed on the boulders near P3 or P5 and in the 13 m range of the BA2** drill cores executed by DGMH.

Note: * P : output, ** B : drilling.

The perlite occurs intercalated in the rhyolite on the road on the southwest side of the already mentioned 930 m mountain and also occurs in the north of P12 with over 10 m thickness.

The perlite bodies, other than the above-mentioned perlite in small scale, occur in the southwest and north parts of the surveyed area, with over 30 m at maximum and over 20 m in thickness respectively. These are distributed mainly in the lower part of the rhyolite showing its lower chilled facies, and are classified to a part with remarkable flow structure and a massive part. The former is intensely altered and distributed in the eastern part of the perlite bodies and the latter is rather fresh and distributed in the western part of these.

The flow structure of the surveyed area strikes northeast, northwest and east-west and dips 30° to 90° to north or south. Both strike and dip are remarkably variable.

The flow structure, though it is difficult to infer a general geological structure by strike and dip of each flow structure, suggests the existence of an anticlinal structure on the northwestern road of P14 - P15 - P11 and a synclinal structure in the part near P11 - P16. This coincides well with the geological structure when the perlite is considered to correspond to lower chilled margin of the rhyolite. From the same consideration a dome structure is inferred to exist in P1 - P4 and its northwestern side. A fault is inferred to exist near P1 - P9 - P15 owing to the existence of intense alteration of perlite and the brecciated structure of rhyolite.

The bentonitization occurs in this fault zone and extends to its east side.

This inferred fault is located in the southwestern extension of the Jocotán fault bending to northeast in the east part from the Department Road No. 1, and the strikes of the both faults coincide with each other, and the arrangement of regional bentonite deposits is parallel to the strike of the Jocotán fault. These facts suggest that this inferred fault is originally related to the Jocotán fault.

3) Encarnación Basalt

The Encarnación Basalt was first named by the JICA-MMAJ Report 1981.

The Encarnación Basalt overlies unconformably the Los Cimientos Rhyolite in the surveyed area and the El Rincón Formation partly out of the surveyed area.

The rock is black, compact, hard and mainly composed of basaltic lava with common platy joints.

It occurs in the southern part from Los Cimientos showing a topography sloping very gently to the southeastern direction, but the platy joint does not always coincide with the topography.

Weathering proceeds along the joint and the basalt becomes light-greenish grey and shows onion structure partly showing conglomeratic appearance.

Several basaltic tuff beds are intercalated and these are strongly argillized in the case of the lowermost part of basalt though weakly argillized in the other cases.

Clay and chalcedony fill fissures in basalt near P13 and chalcedony occurs commonly in the surveyed area.

From the result of the drilling survey by DGMH, the maximum thickness of the Encarnación Basalt exceeds 30.05 m and the unconformity surface between the Encarnación Basalt and the Los Cimientos Rhyolite dips gently to over 20°.

A fault with N20°E strike, 85°E dip and about 40 cm wide fault breccia zone is confirmed on the road between BB3 and BB4 drillings and it is inferred that this fault is formed in relation to the Jocotán fault.

## 1-3 Mineral Deposit

### 1) Genesis (Fig. 3-4)

The bentonite deposit of the Los Cimientos area is characterized by the followings.

(1) The bentonite zone in the surveyed area and its surrounding is intermittently arranged about 5 km long in the east-west direction parallel to the Jocotán fault.

(2) The deposit of Los Cimientos (hereinafter called Los Cimientos Deposit) is located in the middle part of the bentonite zone and has a direction related to the structure of the Jocotán fault on the east side of the Department Road as mentioned already.

(3) The brecciated structure remains in the altered rhyolite.

(4) The fault brecciated zone with the direction mentioned in (2) in the Encarnación Basalt is recognized.

(5) The bentonitization occurs along the unconformity surface between the Los Cimientos Rhyolite and Encarnación Basalt, especially strongly on the Rhyolite side.
From above-mentioned facts, the genesis of the Los Cimientos Deposit is considered as follows.

a) The fault zone was formed near each bentonite zone, affected regionally by the east-west structure of the Jocotán fault.

b) The faults similar to the eastern structure of the Jocotán fault were locally formed near Los Cimientos.

c) Because these faults did not strongly deform the basalt, these were formed after the Los Cimientos Rhyolite activity and before the Encarnación Basalt activity.

d) The faults moved repeatedly but slightly after the Encarnación Basalt activity and the fissures in the Basalt with the same direction were produced in small scale.

e) The Los Cimientos Deposit was formed by hydrothermal alteration related to igneous activity in or after the period of the fault movement.

f) The Encarnación Basalt played an important role as a cap rock.

The Los Cimientos Deposit, formed as mentioned above, is the largest one of the already known bentonite deposits in the surrounding area, reaching to 200 m width and 1,100 m length (Fig. 3-4).

2) Classification of bentonite (Megascopic Observation) (Fig. 3-5)

The Los Cimientos Deposit is classified to the following three on the basis of megascopic observation and touch difference.

(1) White to cream color and cheese like
(2) White color but rough touch
(3) Light-brown to light-yellow color and alteration of basalt

The first is smooth to the touch and shows no friction resistance when it is rubbed on the surface by a needle. Perlite occurs always in the surrounding part of such bentonite and the breccia showing flow structure of perlite is generally recognized in the bentonite.

At P1, the following change is observed from above to downward (Fig. 3-5).

i) Bentonite composed of brecciated perlite over 20 cm in diameter and matrix.
   The matrix consists of brown bentonite considered to be of rather low grade by megascopic observation and rough touch, and on the other hand, the brecciated perlite is classified to four type - fresh with flow structure, white-bentonitized along flow structure, almost-bentonitized remaining slightly perlite structure, and typically cheese-like.

ii) Massive, typical cheese-like bentonite without any flow structure.

The second shows friction resistance when it is rubbed by a needle and sounds slightly high. It is mainly distributed in the western part and such bentonite occurs on the outcrops in the central part of the village. Though the weakly argillized rock is white and massive and shows almost no original structure, the comparatively fresh biotite bearing rhyolite is distributed on the western side of P15, rhyolite with flow structure occurs in P9 and P18, and the perlitic structure is not recognized. The above-mentioned facts suggest that the original rock is considered to be biotite bearing rhyolite.

The third is discriminated from the bentonite of rhyolite group origin by its color difference.

Though the Los Cimientos Rhyolite beneth the lowermost part of the Encarnación Basalt is mainly bentonitized, the alteration reaches partly to the Basalt, and clay and chalcedony occur as fissure-fillings in the Basalt near P13.

The first type of bentonite is considered to be of economic use from the view point of quality and dimensions and therefore a basic plan of mine development for the deposit of this type is laid down.

3) Bentonite deposit for mine development

The bentonite deposit for mine development (hereinafter as called Development Deposit) is situated in the southeastern part of the surveyed area and has an extention of 120 m in NW-SE and of 360 m in SW-NE centering around P1, P2 and P4. The highest point of the bentonite outcrop is 890 m in altitude.

No drilling carried out in the area intersected the bottom of deposit, and therefore the bottom was estimated by the result of outcrop survey and property of bentonite intersected by drillings.

P9, P5 and P3 are considered to correspond to the near-bottom of the bentonite zone on the basis of the above-mentioned estimation and these three are arranged nearly parallel to 870 m elevation contour line.

Though it became clear that the bottom is deeper than 860 m in altitude in the central part of the Development Deposit, the bottom of the Deposit is inferred to dip very gentle generally, be situated at 855-870 m in altitude and become deeper southwestward. Especially from the result of BB1 drill, the bottom near P2 is estimated to be deepest (Fig. 3-6, Fig. 3-7).

Table 3-1 Mining Area by Levels

| Level | Mining Area | | |
|---|---|---|---|
| | Bentonite ($m^2$) | Overburden ($m^2$) | Total ($m^2$) |
| 900 m | - | 2,452 | - |
| 895 | - | 8,948 | - |
| 890 | 656 | 11,956 | 12,612 |
| 885 | 4,252 | 13,748 | 18,000 |
| 880 | 14,452 | 11,628 | 26,080 |
| 875 | 24,652 | 5,336 | 29,988 |
| 870 | 23,988 | 3,360 | 27,348 |
| 865 | 14,348 | 3,572 | 17,920 |
| 860 | 7,640 | 1,932 | 9,572 |
| 855 | 840 | 640 | 1,480 |
| Total | 90,828 | 63,572 | 143,000 |

Table 3-2 Ore Reserves and Overburden Dimensions by Levels

| Level (m) | Ore Reserves and Overburden Dimensions | | | | | |
|---|---|---|---|---|---|---|
| | Bentonite ($m^3$) | Overburden ($m^3$) | Total ($m^3$) | Bentonite ($m^3$) | Overburden ($m^3$) | Tota[illegible] ($m^3$) |
| - 900 | - | 6,130 | 6,130 | - | 15,325 | 15,32[illegible] |
| 900 - 895 | - | 28,500 | 28,500 | - | 71,250 | 71,25[illegible] |
| 895 - 890 | - | 52,260 | 52,260 | - | 130,650 | 130,65[illegible] |
| 890 - 885 | 12,270 | 64,260 | 76,530 | 24,540 | 160,650 | 185,19[illegible] |
| 885 - 880 | 46,760 | 63,440 | 110,200 | 93,520 | 158,600 | 252,12[illegible] |
| 880 - 875 | 97,760 | 42,410 | 140,170 | 195,520 | 106,025 | 301,54[illegible] |
| 875 - 870 | 121,600 | 21,740 | 143,340 | 243,200 | 54,350 | 297,55[illegible] |
| 870 - 865 | 95,840 | 17,330 | 113,170 | 191,680 | 43,325 | 235,00[illegible] |
| 865 - 860 | 54,970 | 13,760 | 68,730 | 109,940 | 34,400 | 144,34[illegible] |
| 860 - 855 | 21,200 | 6,430 | 27,630 | 42,400 | 16,075 | 58,47[illegible] |
| Total | 450,400 | 316,260 | 679,770 | 900,800 | 790,650 | 1,691,45[illegible] |

Shape of plan pit (Fig. 3-8) and area of bentonite and overburden by levels are shown in Fig. 3-9 and Table 3-1, and furthermore ore reserves and overburden by each 5 m level are shown in Table 3-2 calculated on the basis of the equal elevation contour method.

As to the specific gravities of bentonite and basalt, the values of 2.0 and 2.5 are adopted respectively and as the result, ore reserves are 450,400 $m^3$, 900,800 T and the overburden is 316,260 $m^3$, 790,650 T.

## 1-4 Exploration (Figs. 3-4, 3-10, 3-11, 3-12, 3-13, 3-14)

The existence of the Los Cimientos Deposit has been known for a long time by inhabitants because of distribution of many outcrops.

The Los Cimientos Deposit is included in the mineralization zone of the Chiquimula area which is one of the three semi-detailed survey areas in 1980 carried out as a part of "Geological Survey of the Eastern Area of Guatemala" conducted by JICA and MMAJ since 1979 and the outline of the deposit became clear for the first time.

In 1981, the Bentonite Project Survey and the drilling work by DGMH were carried out simultaneously. The total 11 drillings were carried out in grid-like pattern (Fig. 3-4, Fig. 3-10) in the area of 200 m in SW-NE and of 100 m in NW-SE, and on the other hand, topographic survey, geological survey, outcrop survey, sampling etc. were carried out as the Bentonite Project Survey in the area of 1,100 m in SW-NE and of 800 m in NW-SE including Los Cimientos.

Transit for base line measurement and transit compass for other measurements were used.

The outcrop survey aimed at mainly megascopic classification of bentonite (Figs. 3-11, 3-12) and the geological survey aimed at solving the relations between bentonite and original rock and between ore deposit and geological structure. Eighty four samples were collected for analysing the properties of bentonite (Fig. 3-13).

The already mentioned ore reserves are calculated on the basis of the result of geological survey, but because the bottom of the bentonite deposit was inferred as to its altitude and the properties of the bentonite are postulated to be homogeneous throughout the whole ore reserves, the further following exploration is necessary in order to make clear both dimensions of the deposit and mining blocks by grades.

1) It is necessary to make clear the altitude of the bottom of bentonite for confirming a definite extension of bentonite deposit.

For this purpose, it is recommended that 24 grid drillings with 40 m interval are performed in the range of 80 m width in N25°W - S25°E centering the B19C drilling site and 240 m length on the N60°E side away from the B19C drilling site. Furthermore, it is recommended that 12 grid drillings with 40 m interval are performed in the range of 120 m on the N20°E side and 80 m on the S70°E side both away from the Sample No. 1 site (Fig. 3-14). Depth is necessary to be 30-50 m for intersecting the bottom of the bentonite deposit.

2) To make clear the mining block by each grade, it is necessary that samples are collected at each site of 5-10 m horizontal interval in P1, P2 and P4 in way of vertical channel sampling in each 0.5-1.0 m interval.

To make clear the grade of the deeper part, it is necessary that samples are collected by 1-2 drillings respectively at P1, P2 and P4. The drilling sites are selected near Sample Nos. 7, 9 and 10 at P1, near Sample Nos. 3, 4 and 6 at P2, near Sample Nos. 1, 5 at P4 and at the BB2 drilling site.

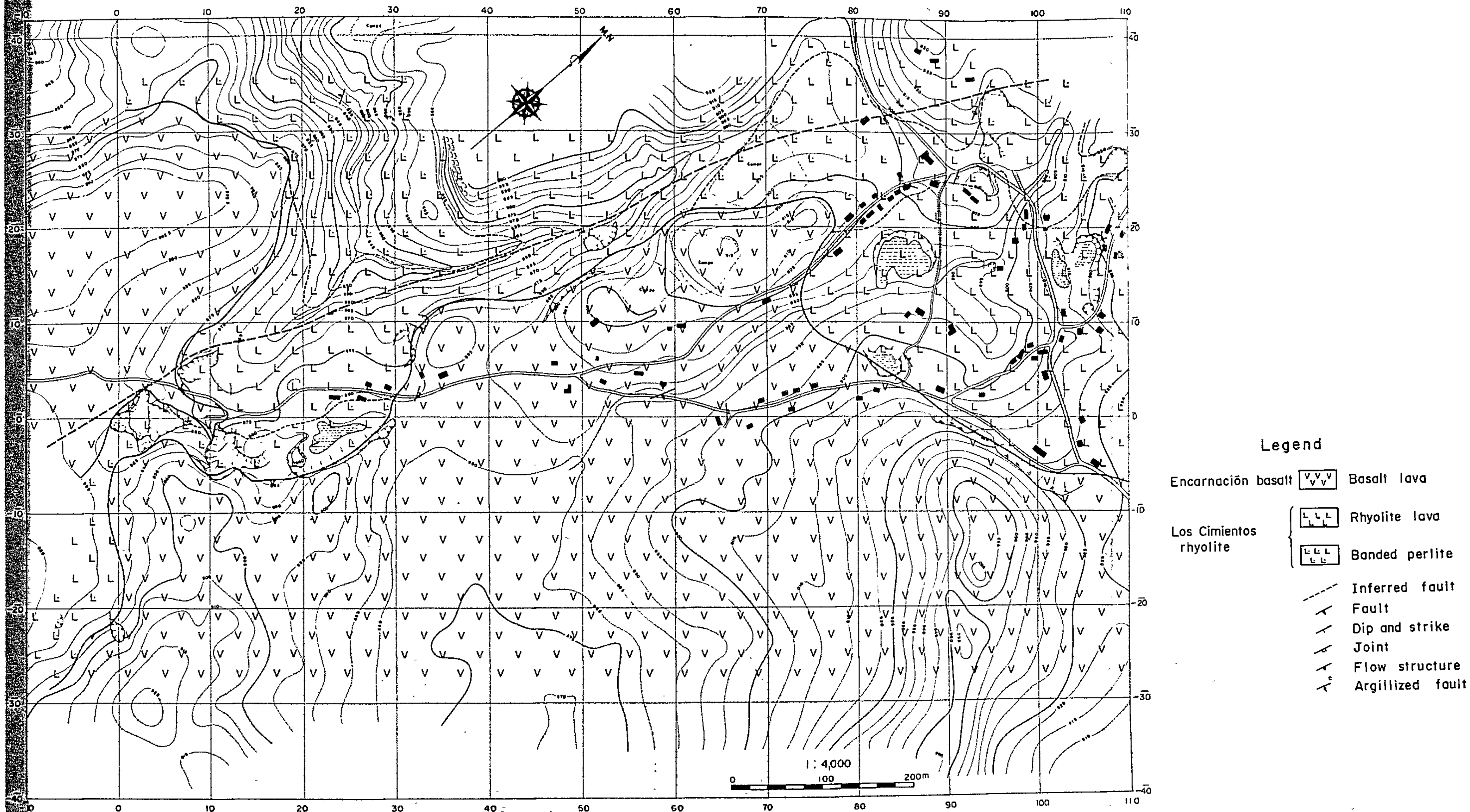
The closely spaced drilling is necessary after the distribution of valuable bentonite is confirmed by the result of above-mentioned sampling and chemical analysis, and this will be carried out in 5-10 m interval in the extension of bentonite of high value added. Though number of necessary drillings has to be determined on the basis of the result of prospecting, 10-20 drillings are considered to be adequate at P1, P2 and P3 respectively.

The quality of bentonite deposit is very difficult to be estimated by megascopic observation.

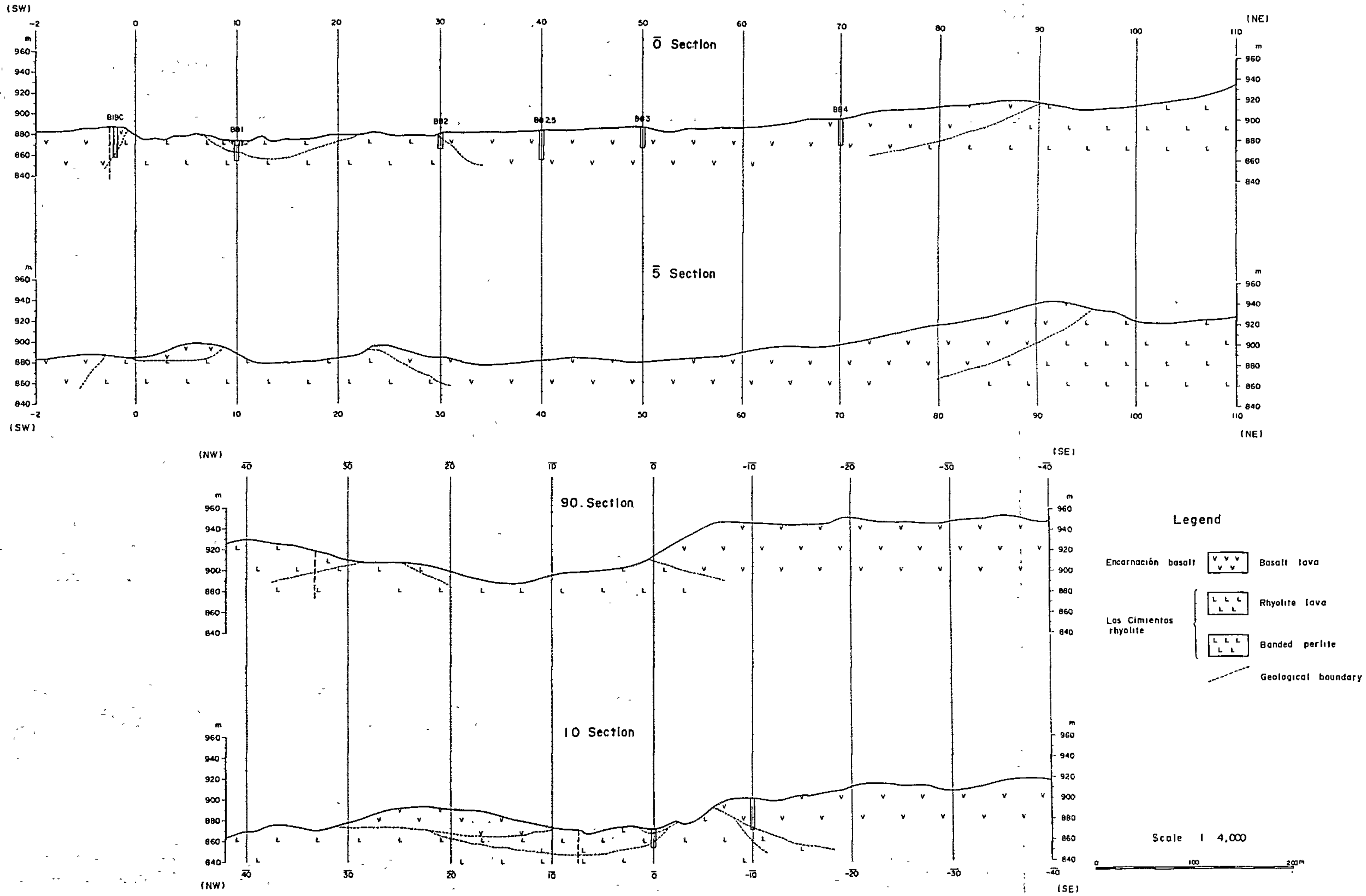
Accordingly, detailed drilling and quality test accurate enough for block mining for the purpose of quality control of crude ore are necessary at the time of mining.

Although the samples of P15 which is situated out of the Development Deposit show very excellent properties as a result of whole test, the outcrop samples in the surrounding area show not so good quality as those of P15, and therefore, further exploration is necessary.

Fig. 3-1 GEOLOGICAL MAP



# Fig. 3-2 GEOLOGICAL CROSS SECTION



# Fig. 3 - 3 COLUMNA GEOLOGICA ESQUEMATICA, AREA DE A-3 (CHIQUIMULA)

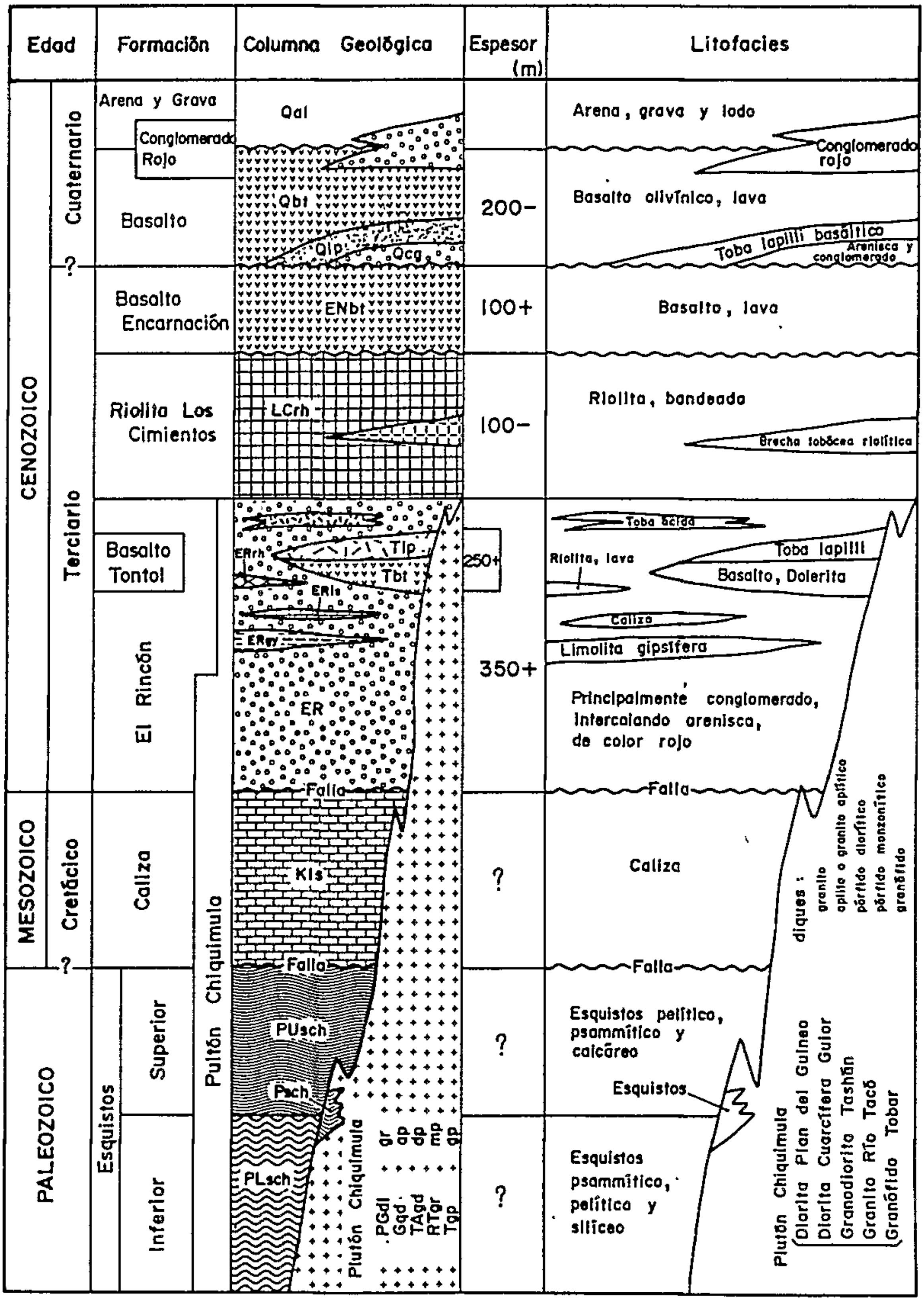


Fig. 3-4 LOCATION MAP OF THE BENTONITE ZONE, OUT CROPS AND BORES

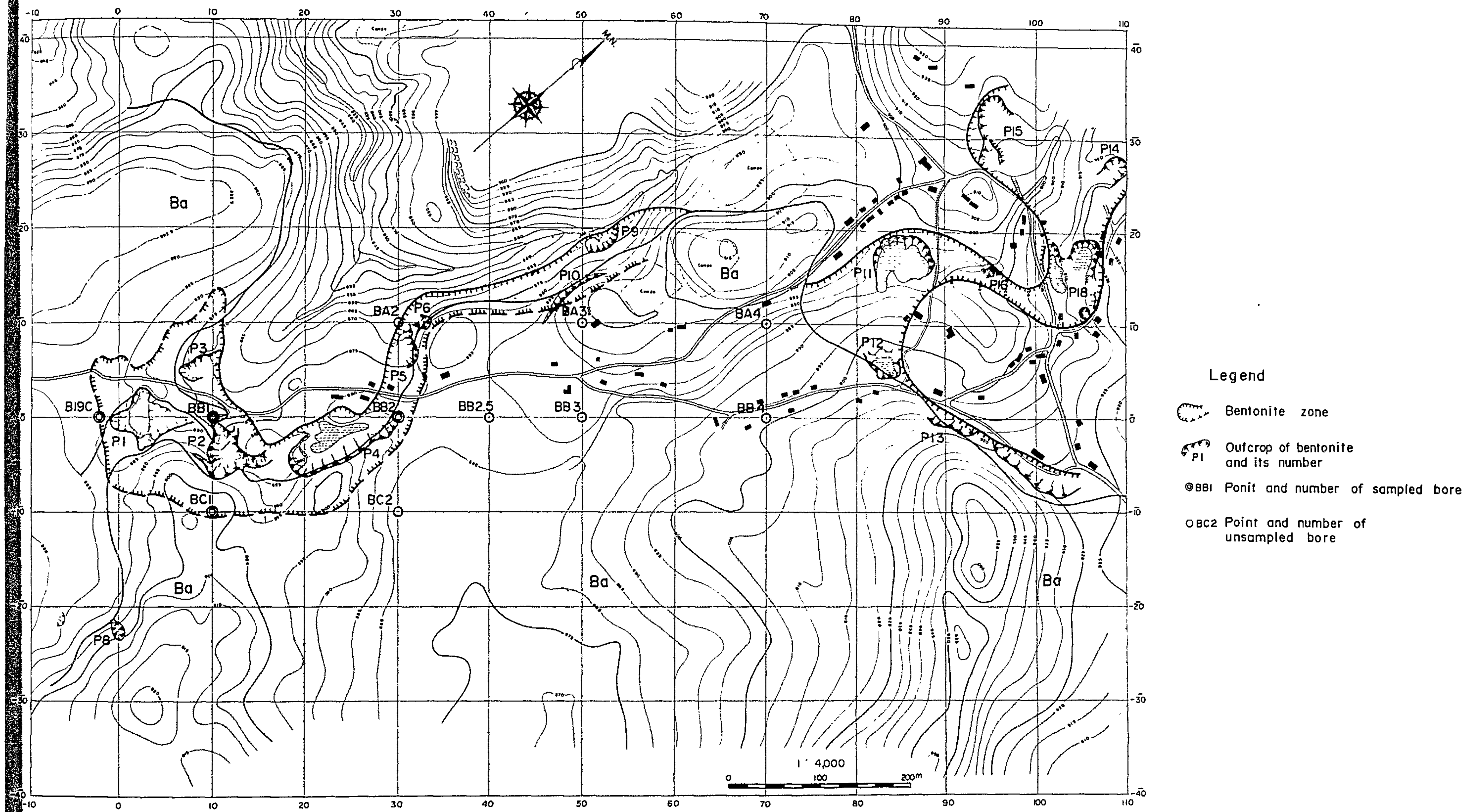
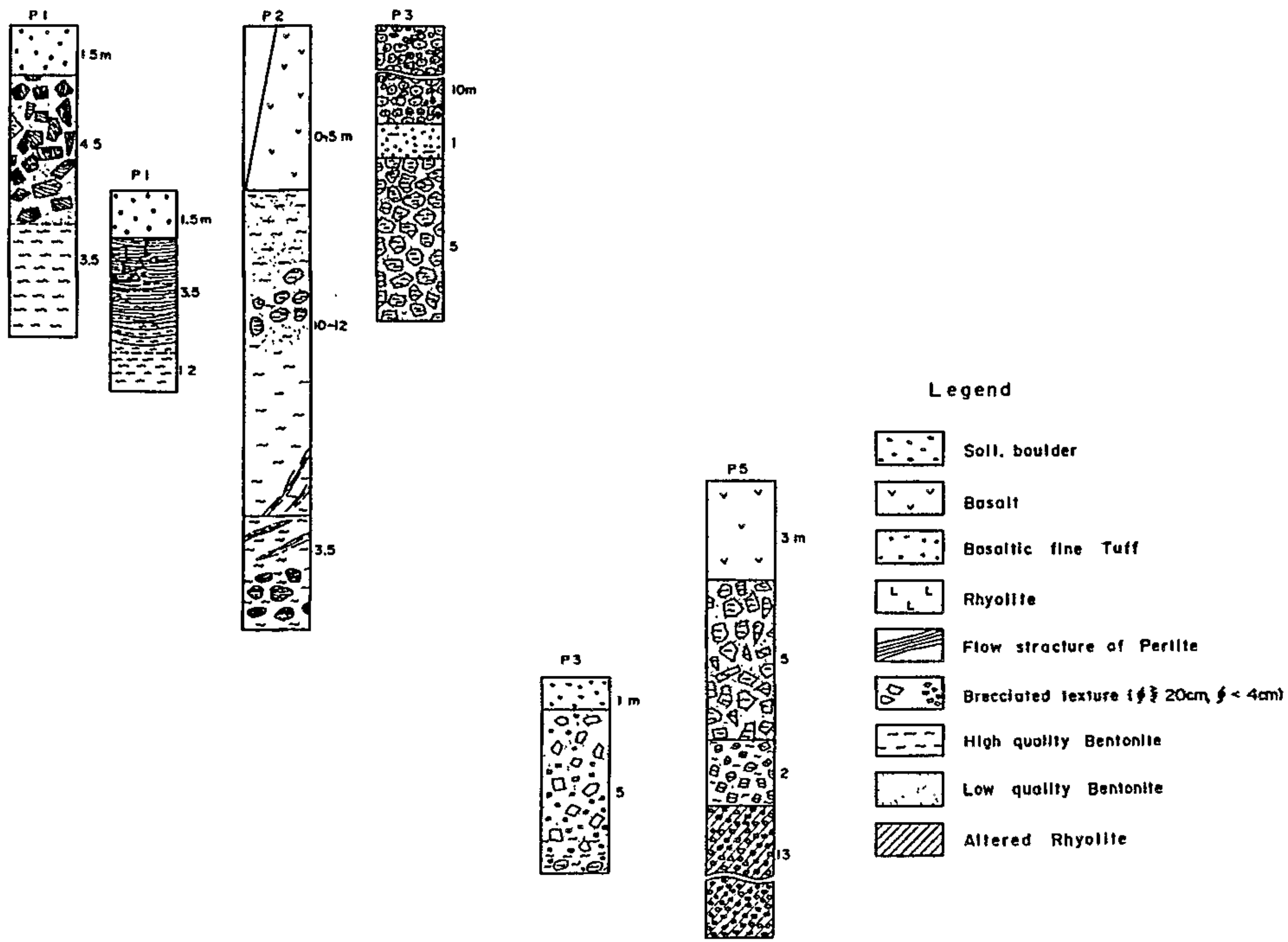


Fig. 3-5 SKETCHES OF THE OUT CROPS OF THE BENTONITE



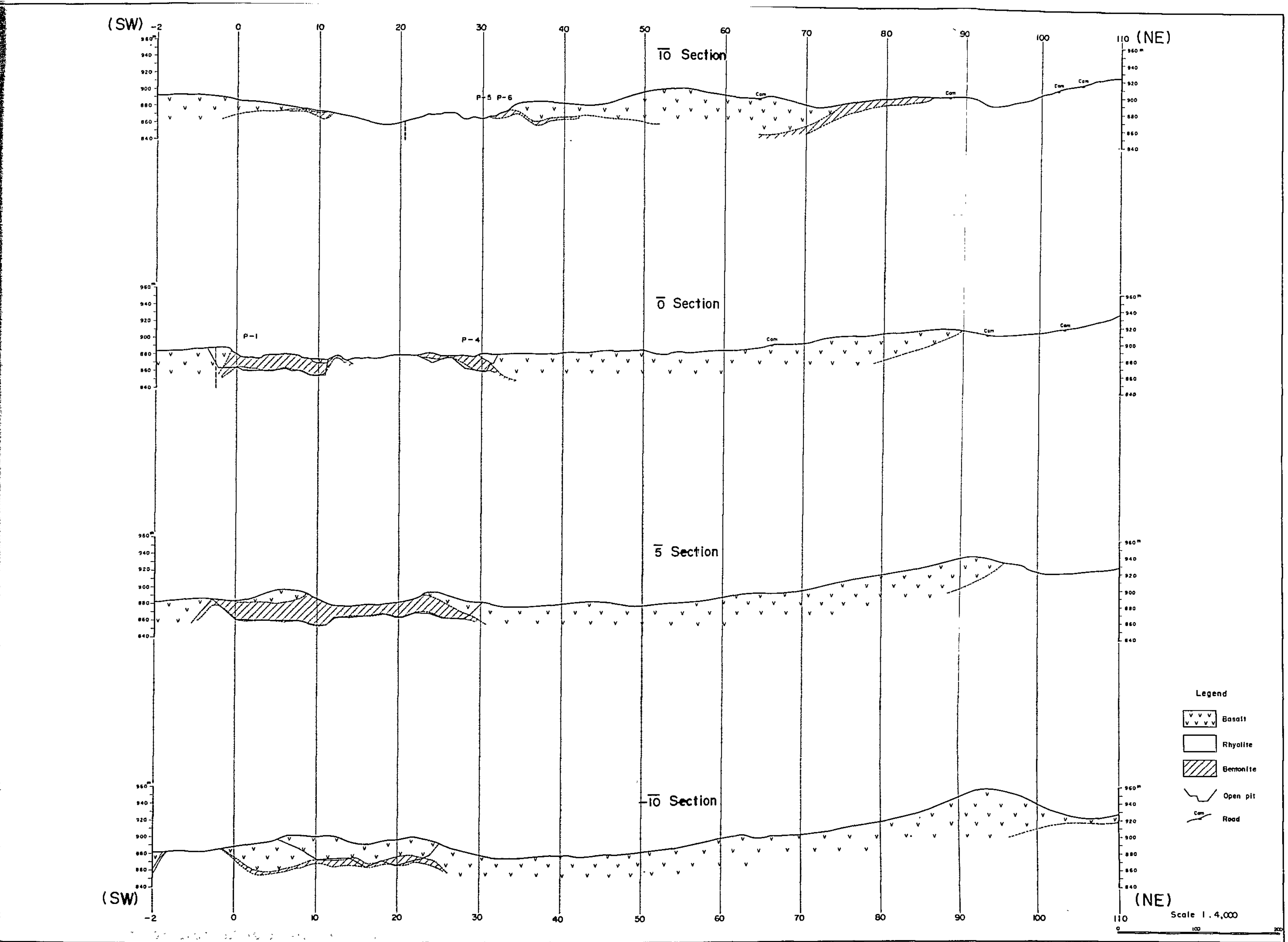
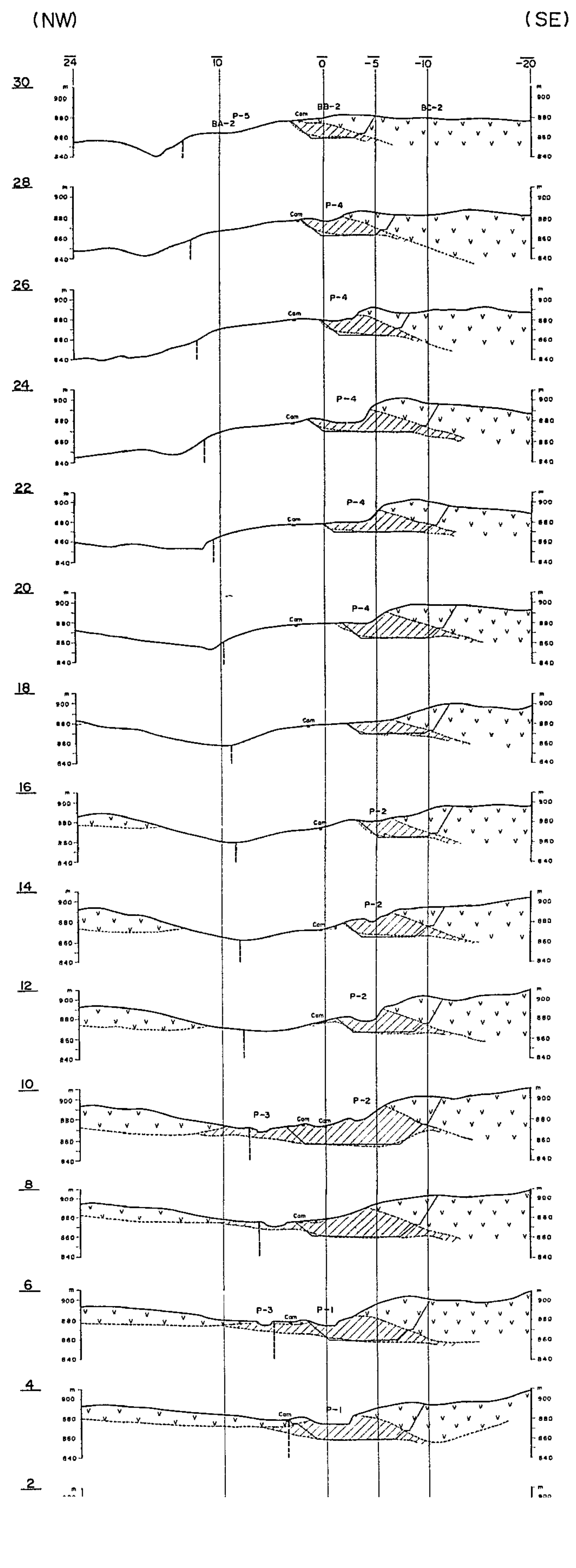

(SW)
(NE)
10 Section
0 Section
5 Section
-10 Section
P-5 P-6
P-1
P-4
Legend
Basalt
Rhyolite
Bentonite
Open pit
Road
Scale 1 : 4,000

Fig. 3-7 CROSS SECTIONS OF THE DEPOSIT (NW-SE)



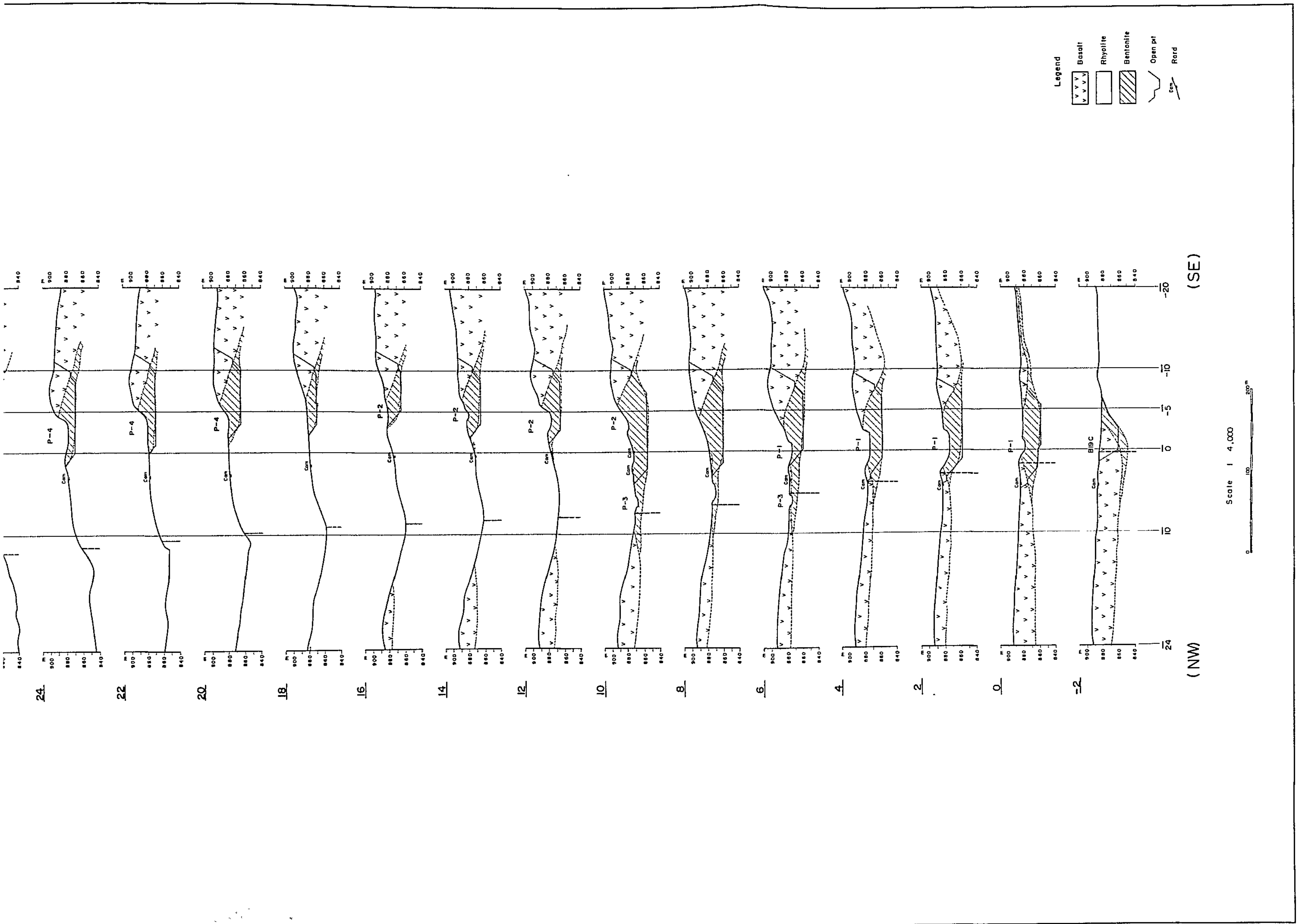

Legend
Basalt
Rhyolite
Bentonite
Open pit
Scale 1 : 4,000
(SE)
(NW)
P-1
P-2
P-3
P-4
B19C
-2
0
2
4
6
8
10
12
14
16
18
20
22
24

Fig. 3-8 FORM OF THE OPEN PIT ( 5 M AT INTERVALS )

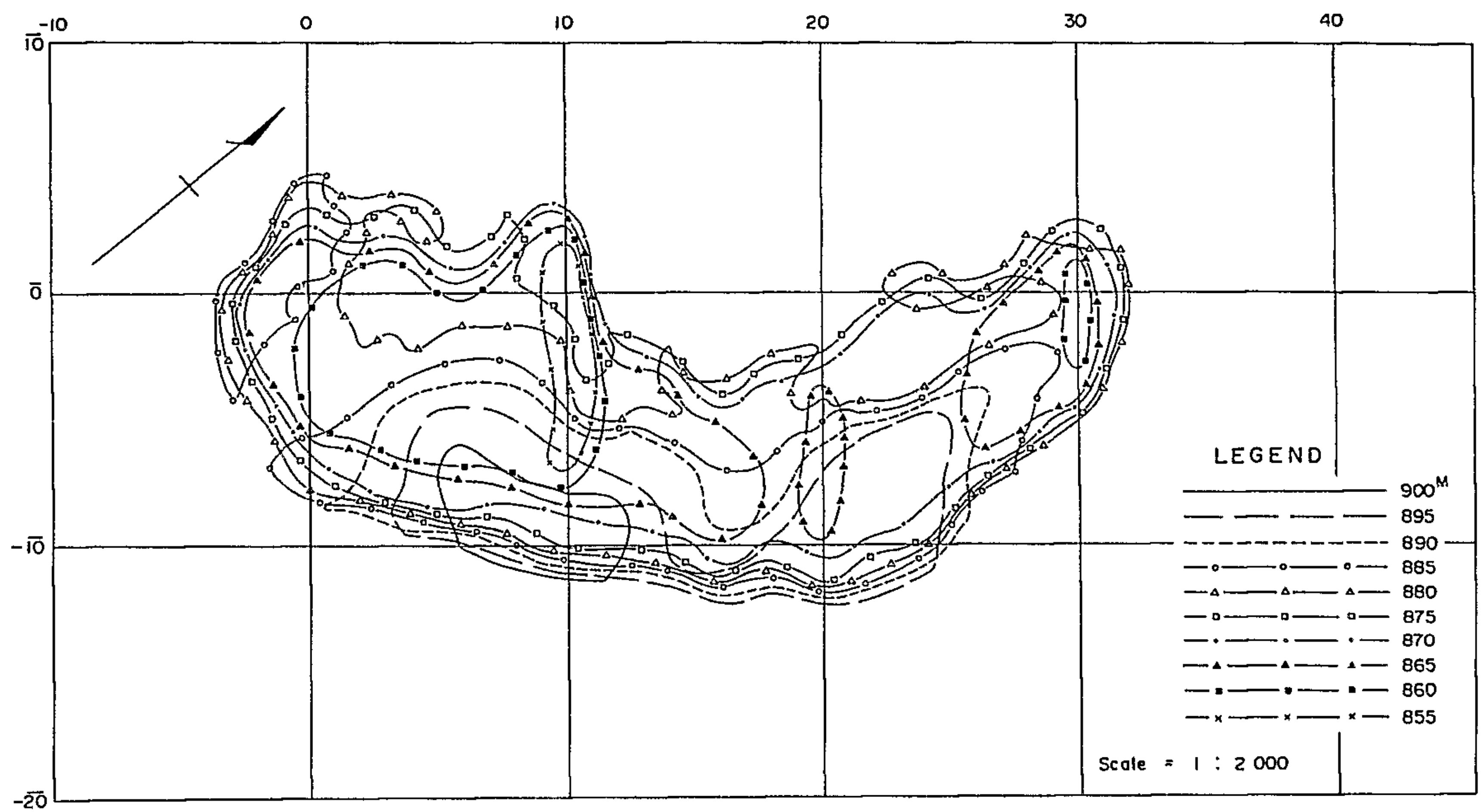
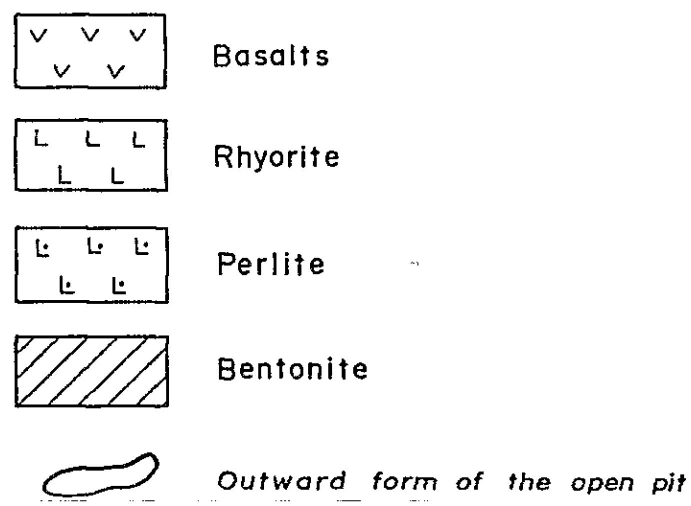
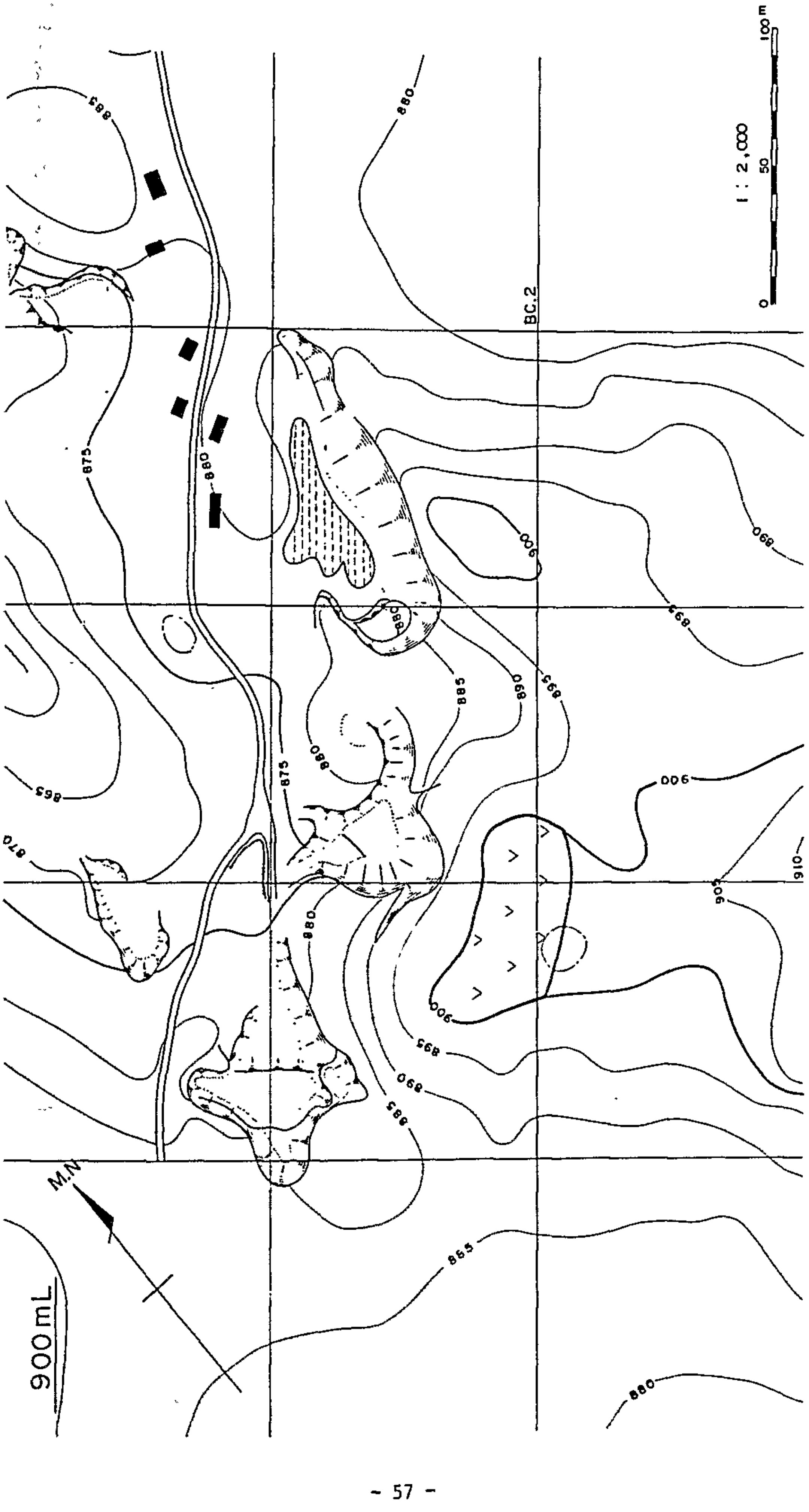
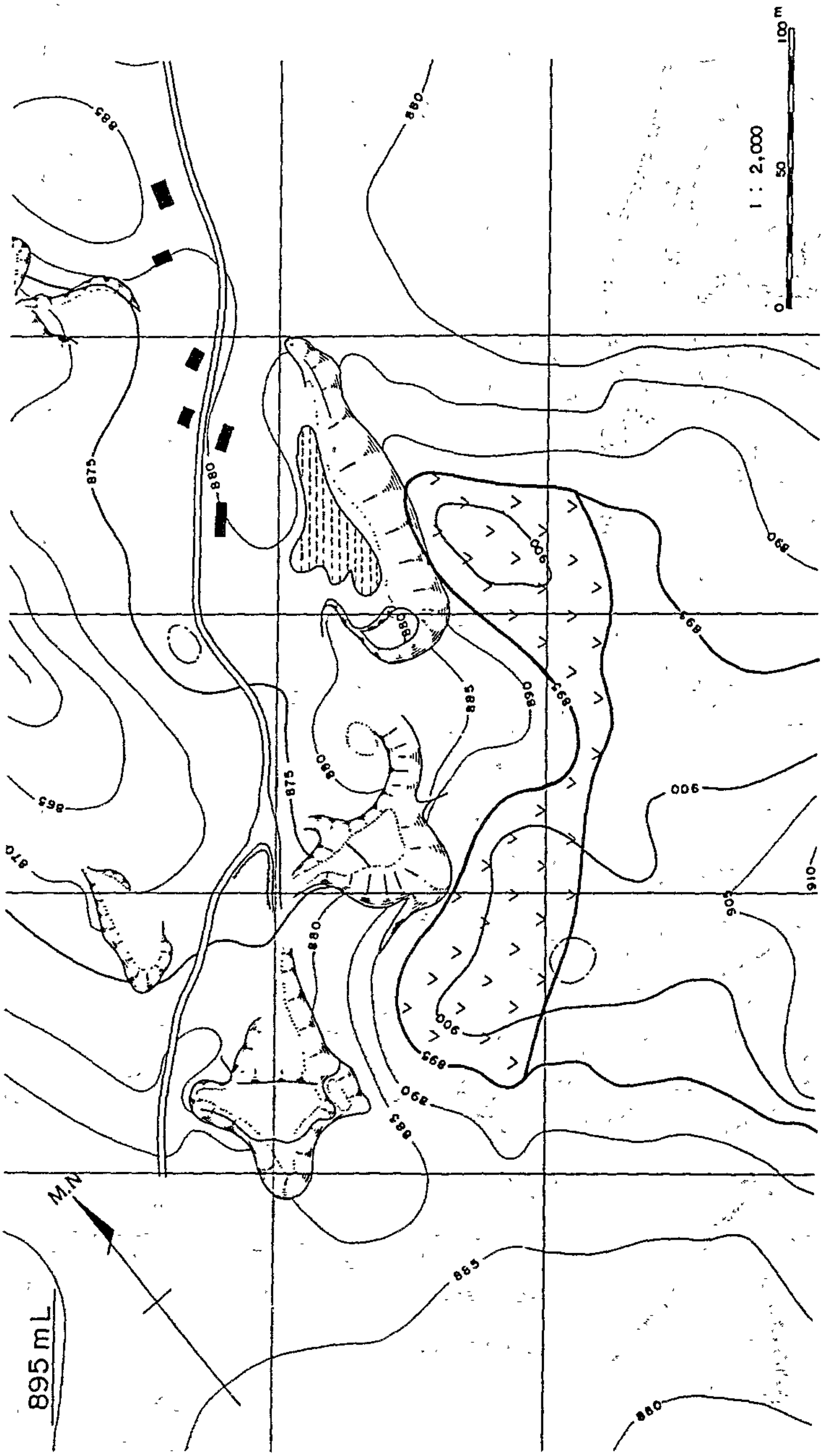


Fig.3-9 MAPS OF THE DISTRIBUTION OF THE BENTONITE BODY ON EACH LEVEL AT 5 METER INTERVALS

( 10 sheets )




900 mL
M.N
1 : 2,000
0
50
100m
BC.2
865
870
875
880
885
890
893
895
900
905
910


895 mL
M.N
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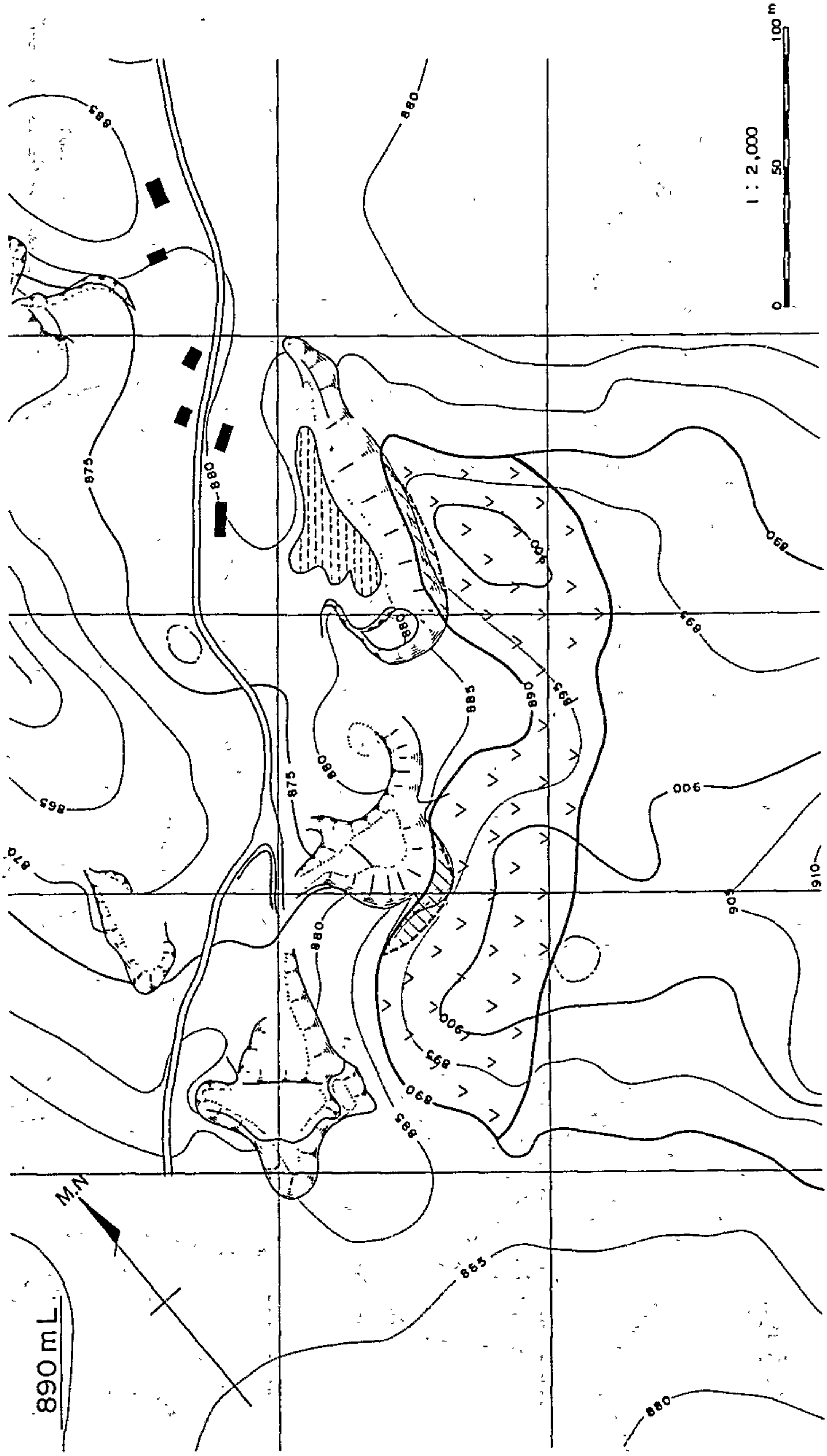
890 mL
M.N
1 : 2,000
0
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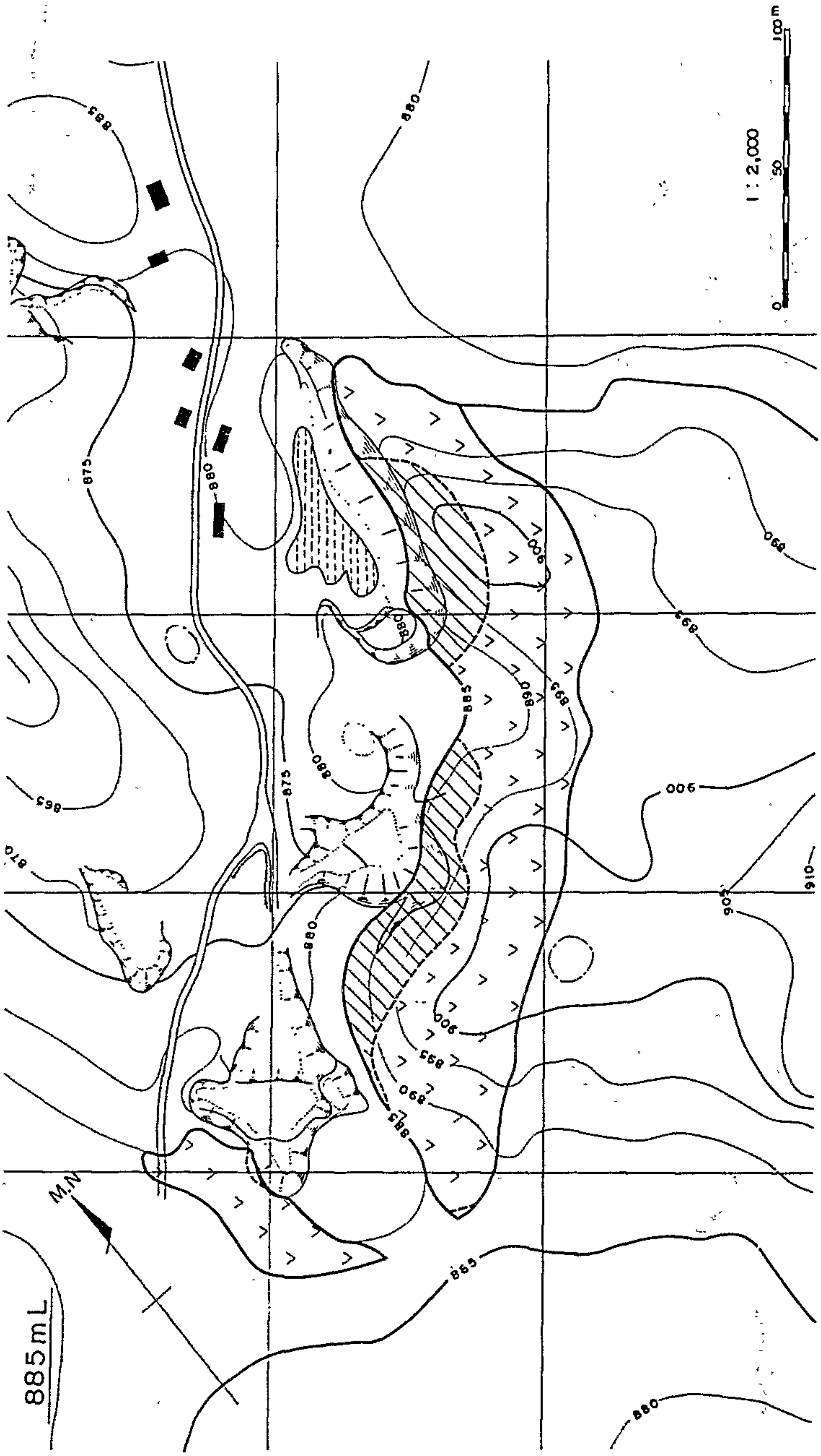
885mL
M.N
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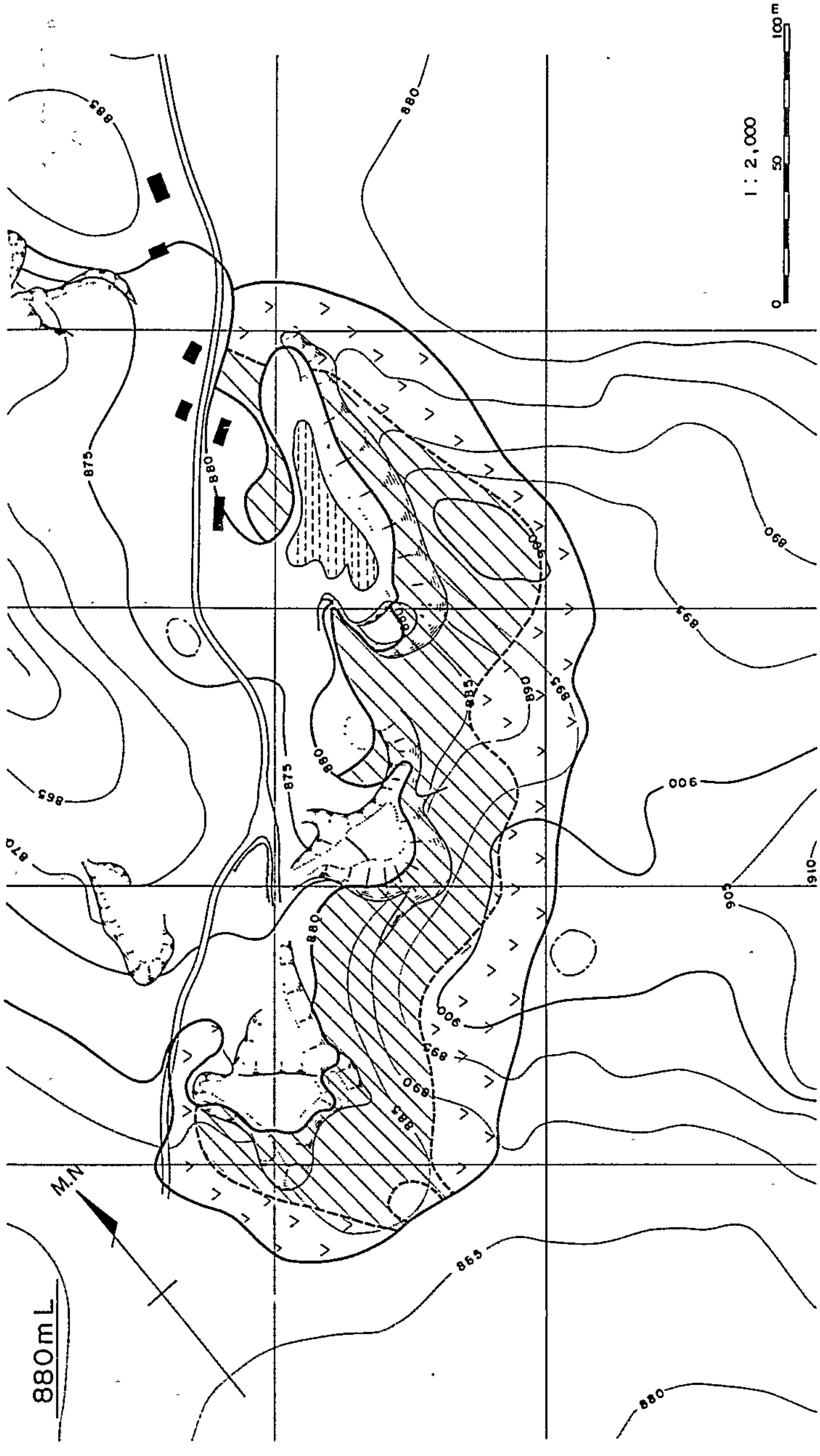
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M.N
1 : 2,000
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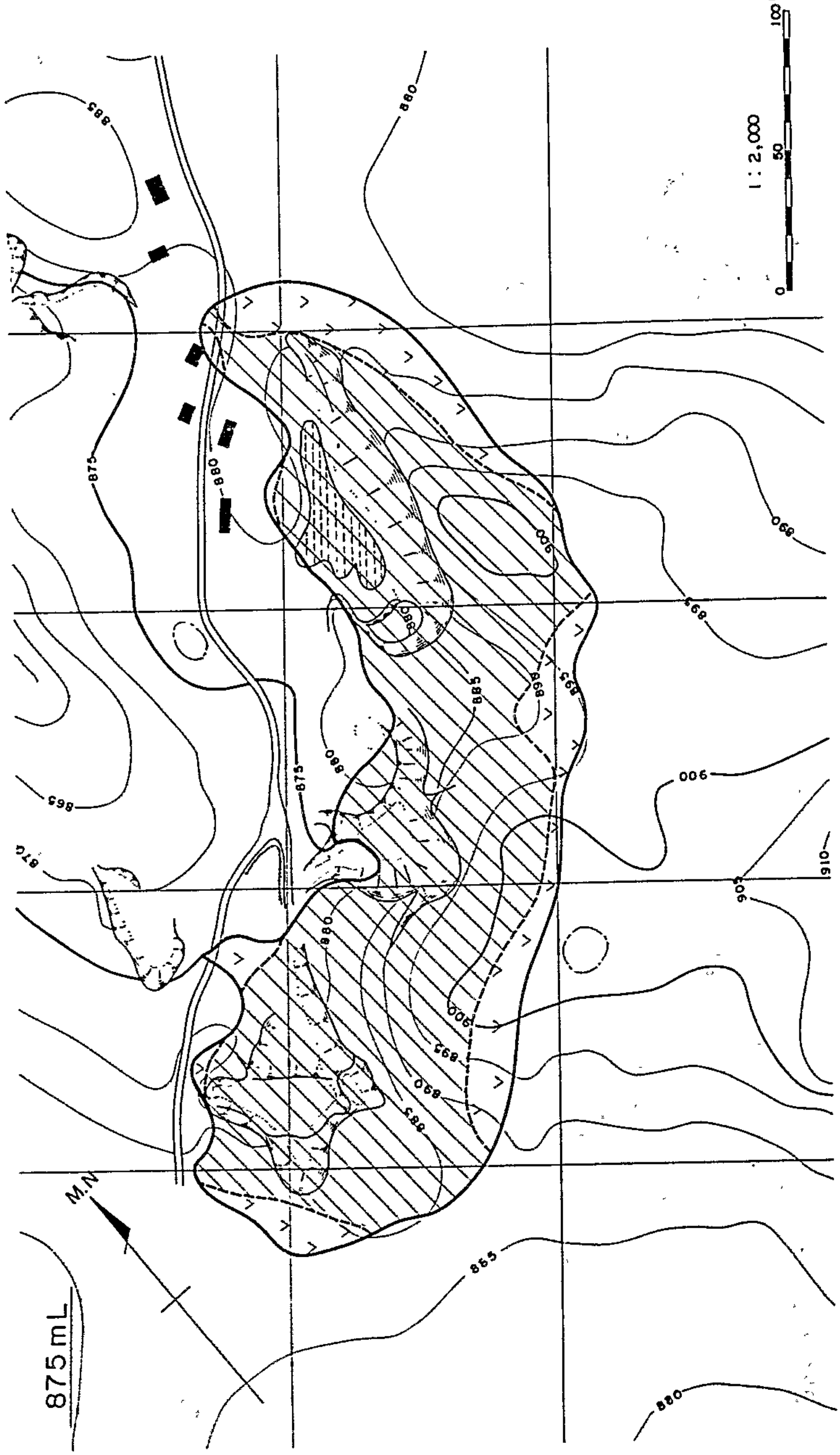
875mL
M.N
1:2,000
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50
100m
875
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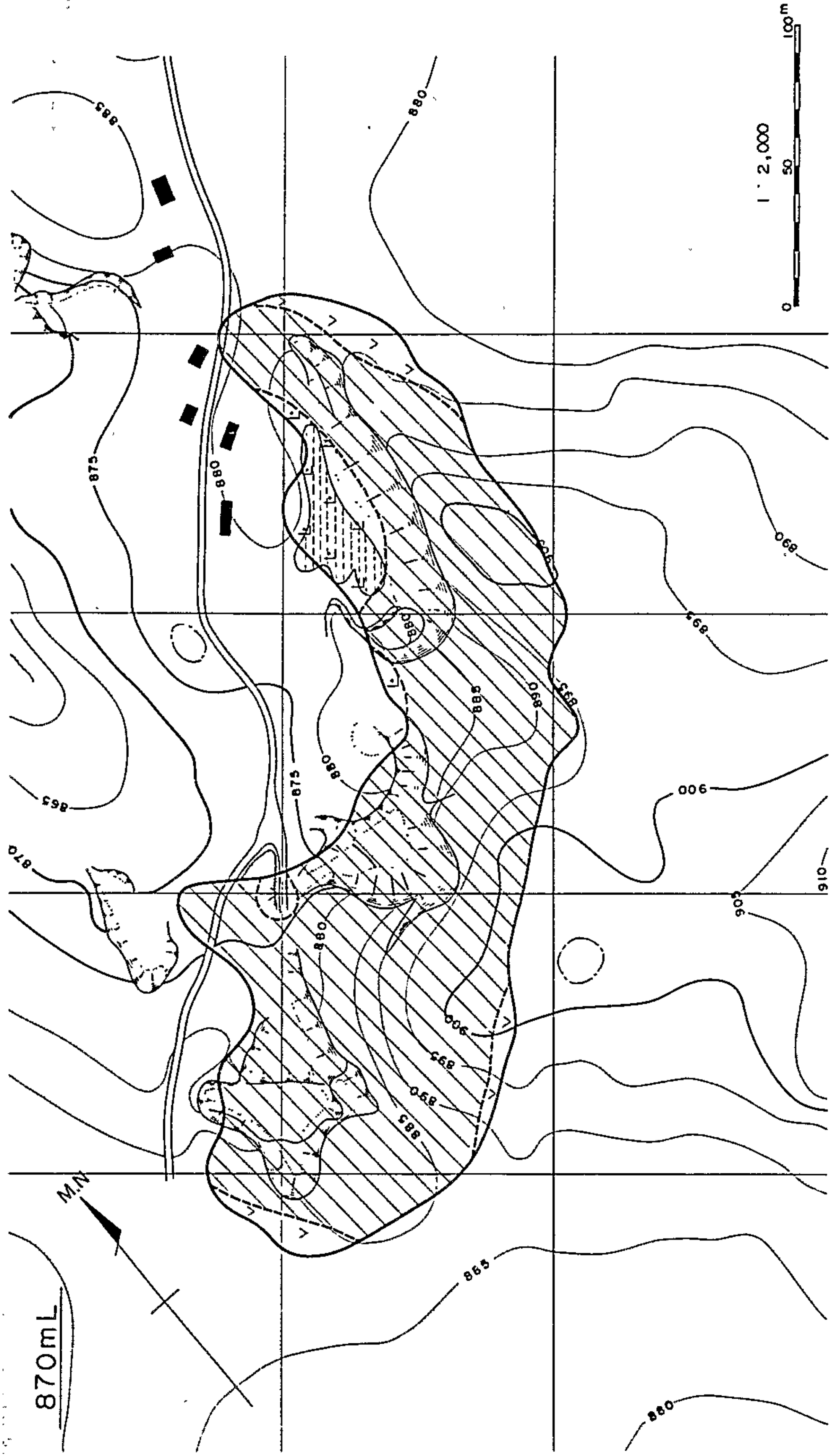
870mL
M.N
1 : 2,000
0
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100m
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893
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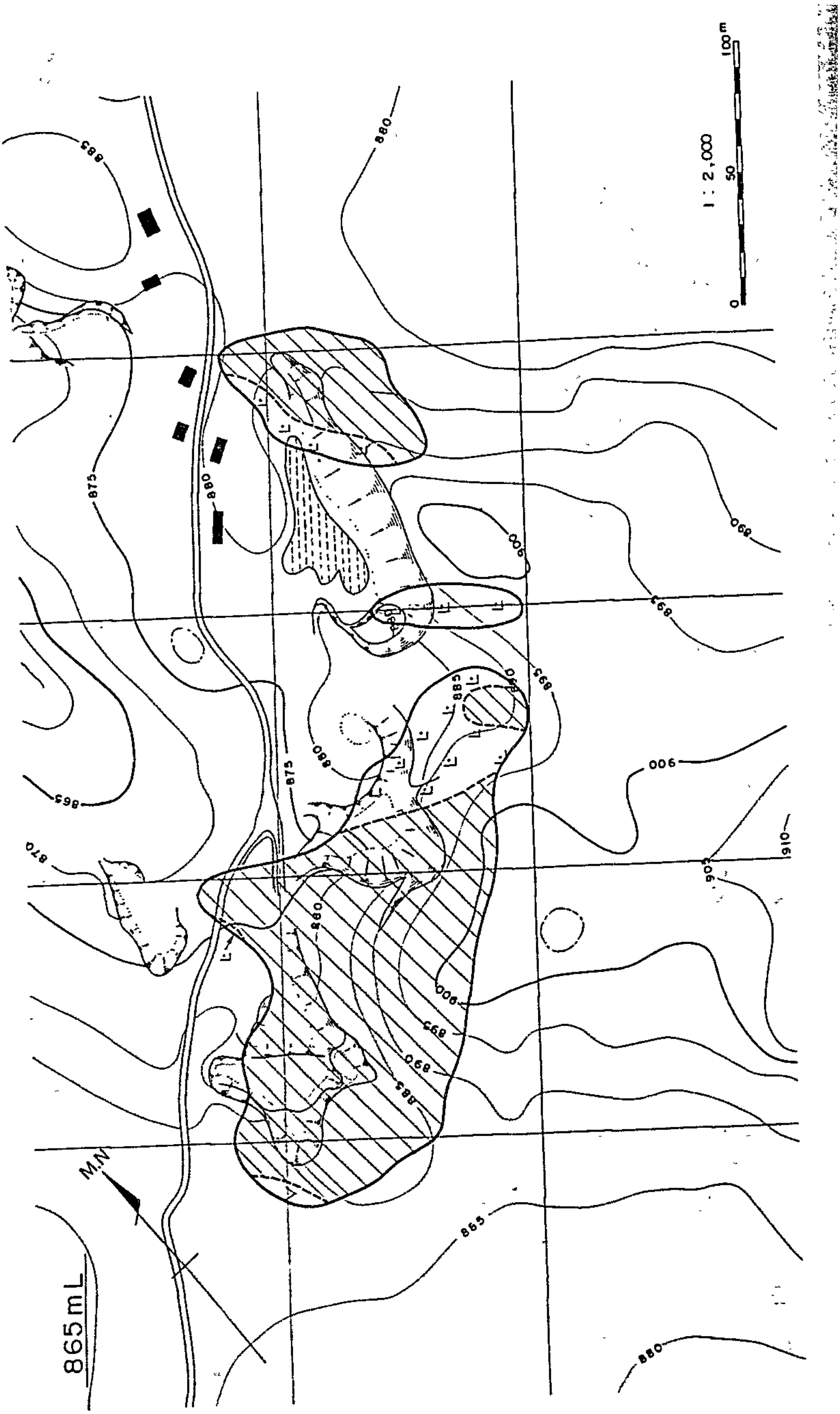
865mL
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903
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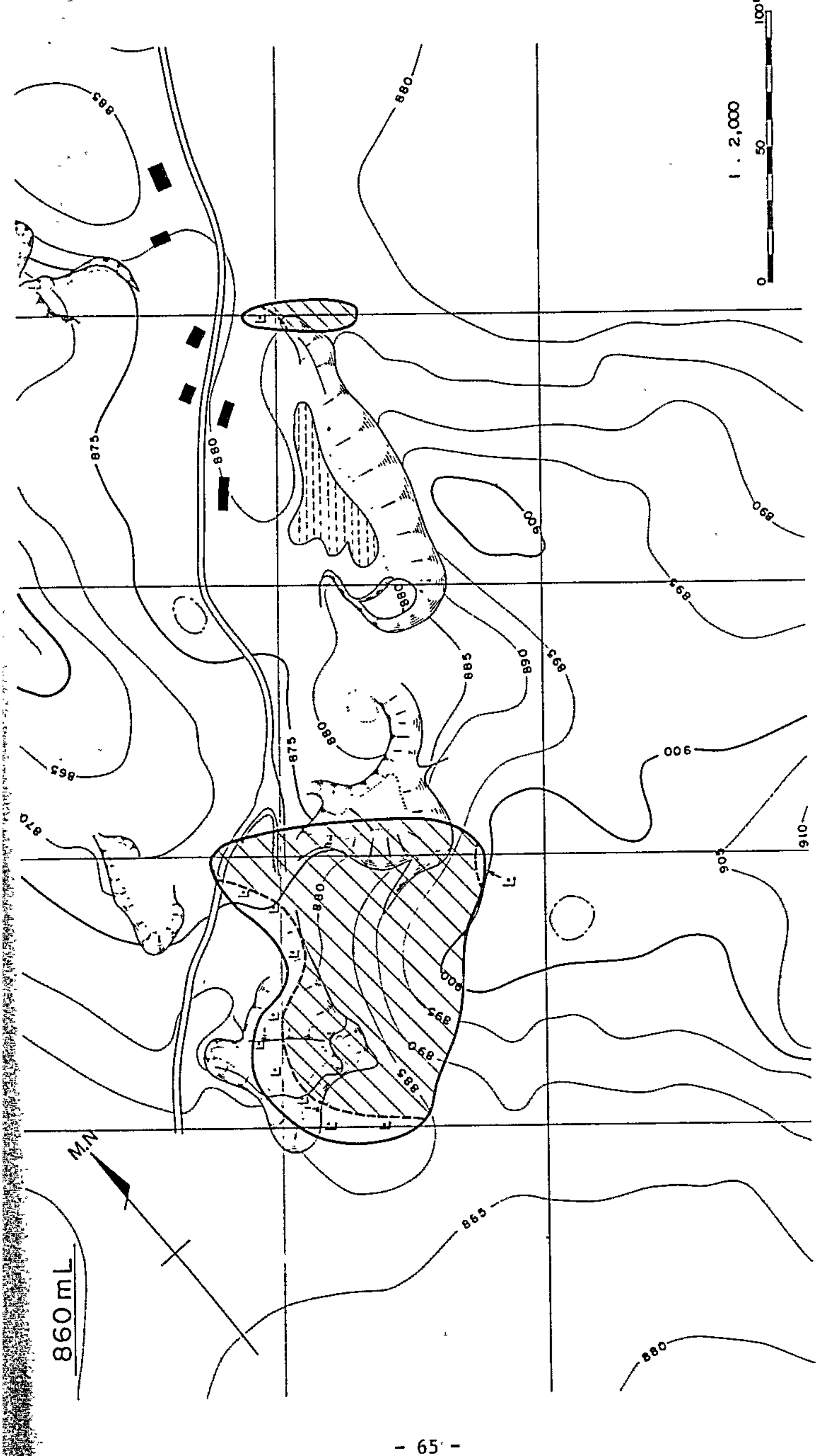
860 mL
M.N
1 : 2,000
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50
100m
865
870
875
880
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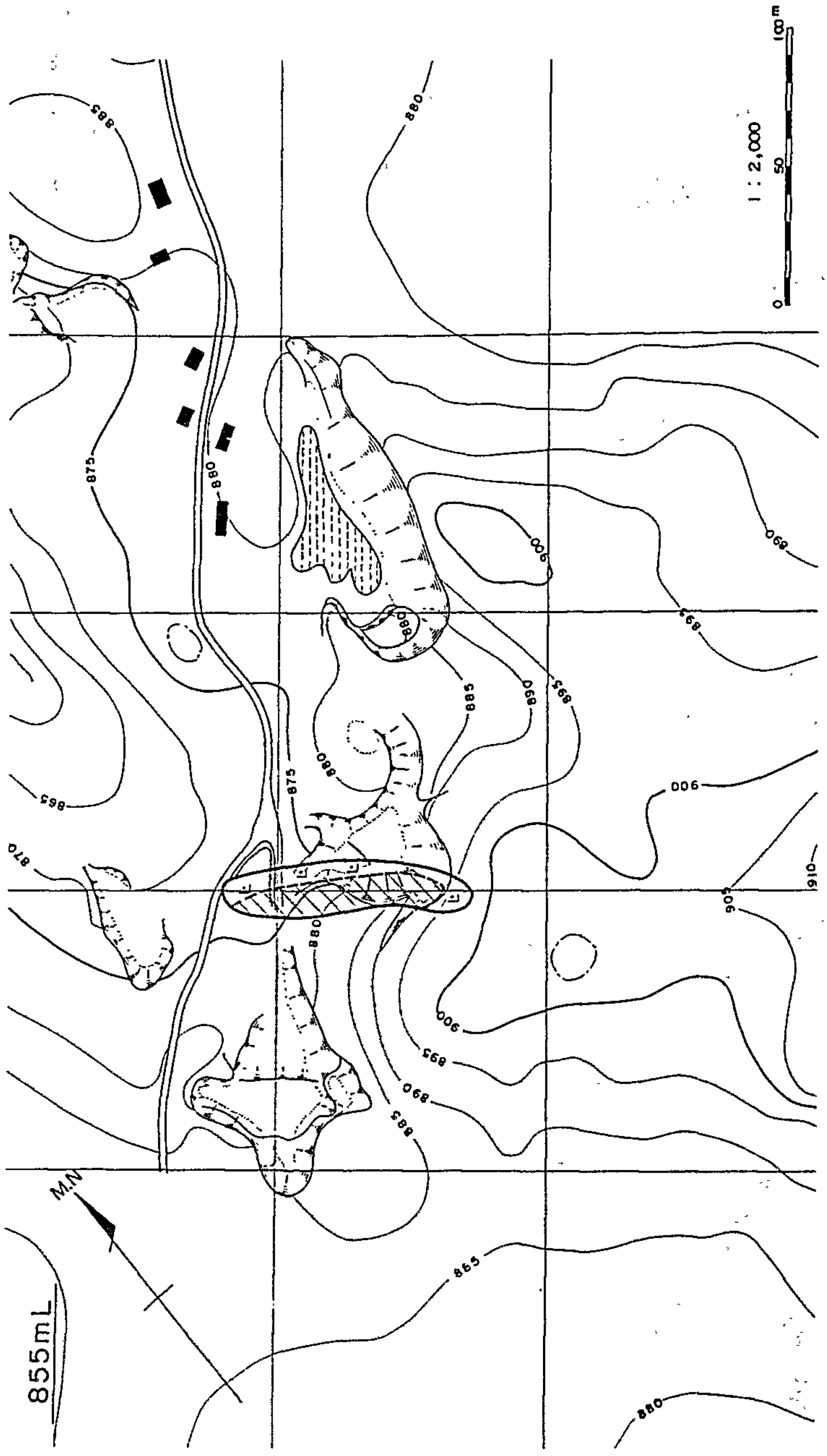
855mL
M.N
1 : 2,000
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895
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Fig 3-10 CORE SKETCHS OF THE BORINGS OF DGMH (11 sheets)

District : Los Cimientos Place : ( -2, 0 )

| Bore number | B19C | Machine | BBS-1 | Diameter | AX m/m |
|---|---|---|---|---|---|
| Altitude | 887.50 m | Final depth | 30.47 m | Final altitude | 857.03 m |

| Altitude | Depth | Width | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|
| 887.50 | 0.00 | 17.82 | Basalt | black | Compact | |
| 870.56 | 16.94 | | | brown | 16.94~17.82 porous | |
| 869.68 | 17.82 | | | | 17.82~18.00 strongly argillaceous | |
| 869.50 | 18.00 | | | brown | Argillaceous Soft | |
| 867.93 | 19.57 | | non core | | | |
| 866.28 | 21.22 | 7.68 | Basalt | brown | cheesy | |
| 862.00 | 25.50 | 2.00 | Basaltic tuff | pale yellowish gray | Argillaceous Soft | 27.00 m B19C-1 |
| 860.65 | 26.85 | | | | 26.85~27.10 palt gray argillaceous tuff | |
| 860.40 | 27.10 | | | | | |
| 860.00 | 27.50 | 2.97 | Clay | white | Cheesy | 27.87 m B19C-2; 28.67 m B19C-3; 29.50 m B19C-4 |
| 857.50 | 30.00 | | Perlite | pale gray | Brecciated fragment: white matrix: dark geen | 30.47 m |
| 857.03 | 30.47 | | | | | |

District : Los Cimientos Place : (10, $\bar{0}$ )

| Bore number | BB I | Machine | win ky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 873.33 m | Final depth | 15.63 m | Final altitude | 857.70 m |

| Altitude | Depth | Width | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|
| 873.33 | 0.00 | 5.15 | Basalt | black | Low recovery | 5.15m |
| 868.16 | 5.15 | 8.04 | Clay | white | Weathered Rough | BBI-1 6.43m, BBI-2 7.10m |
| 865.83 | 7.50 | | | | Rough | BBI-3 8.26m, BBI-4 8.87m, BBI-5 10.09m |
| 863.53 | 9.80 | | | | Flow stracture of rhyolite remains partly | BBI-6 11.36m |
| 860.75 | 12.59 | | | | Rough | |
| 860.14 | 13.19 | 0.61 | Argillaceous lapilli tuff | white | Rough | |
| 859.53 | 13.80 | 1.83 | Perlite | white | Spherulites remain | |
| 859.23 | 14.10 | | | | Brecciated, flow stracture | |
| 858.83 | 14.50 | | | | Hard, glass does not remain | |
| 858.33 | 15.00 | | | pale gray | Altered weakly<br>Flow stracture remains | |
| 857.70 | 15.63 | | | | | |

District : Los Cimientos Place : ( 10, -10̄)

| Bore number | B C 1 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 901.31 m | Final depth | 30.00 m | Final altitude | 871.31 m |

| Altitude | Depth | Width | Geological colum | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|---|
| 901.31 | 0.00 | 18.70 | | Basalt | black, pale yellow | Black basalt is compact. Pale yellow one is altered porous basalt. | |
| 897.31 | 4.00 | | | | grayish white | Altered Fragile Partly stained with limanite | |
| 888.78 | 12.53 | | | | brownish gray | Short cores (platy joint) | |
| 882.61 | 18.70 | | | non core | | | |
| 882.41 | 18.90 | 9.20 | | Basaltic fine tuff | pale green | Weakly argillaceous fine tuff | |
| 879.96 | 21.35 | | | | greenish gray | | 21.49 m |
| 878.63 | 22.68 | | | | | 22.68～22.88 altered into white clay | BC1-1 |
| 878.43 | 22.88 | | | | | | 22.88 m |
| 877.21 | 24.10 | | | | | 24.10～25.32 non core | |
| 875.99 | 25.32 | | | | | | 25.32 m BC1-2 26.34 m BC1-3 28.00 m |
| 873.21 | 28.10 | 1.20 | | Clay | white | Altered rhyolite into white clay | BC1-4 28.83 m |
| 872.01 | 29.30 | 0.70 | | Rhyolite | greenish white | Brecciated structure Fragment: white, matrix: greenish gray | |
| 871.31 | 30.00 | | | | | | |

District : Los Cimientos Place : ( 30, Ō )

| Bore number | BB 2 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 879.17 m | Final depth | 15.57 m | Final altitude | 863.60 m |

| Altitude | Depth | Width | Geological colum | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|---|
| 879.17 | 0.00 | | | | | | |
| | | 4.90 | v v v | Basalt | black | Compact | |
| 874.27 | 4.90 | | | | | | |
| | | 1.15 | . . . | Basaltic coarse tuff ~lapilli tuff | whitish gray | Soft lapilli altered into white clay matrix, whitish gray | |
| 873.12 | 6.05 | | | | | | 6.03 m |
| | | | | | | | BB2-1 |
| | | | | | | | 7.03 m |
| | | | | | | | BB2-2 |
| | | | | | | | 8.31 m |
| | | | | | | | BB2-3 |
| | | | | | | | 9.47 m |
| | | 8.30 | ~ ~ ~ | Clay | white | Cheesy | BB2-4 |
| | | | | | | | 11.30 m |
| | | | | | | | BB2-5 |
| | | | | | | | 13.13 m |
| | | | | | | | BB2-6 |
| 864.82 | 14.35 | | | | | | 14.35 m |
| | | | | | | Falling upper basalt | |
| 863.60 | 15.57 | | | | | | |

District : Los Cimientos Place : ( 30, 1̄0 )

| Bore number | BA 2 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 870.00 m | Final depth | 15.10 m | Final altitude | 854.90 m |

| Altitude | Depth | Width | Geological colum | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|---|
| 870.00 | 0.00 | 15.10 | L L | Rhyolite | white | Compact | |
| 867.90 | 2.10 | | L L | | greenish white | Brecciated fragment. lapilli size white matrix . pole green Compact | |
| 860.10 | 9.90 | | L L | | greenish white | Brecciated fragment . pole green matrix . white Compact | |
| 854.90 | 15.10 | | | | | | |

District : Los Cimientos Place : (30,-10)

| | | | | | |
|---|---|---|---|---|---|
| Bore number | BC 2 | Machine | winky | Diameter | EX m/m |
| Altitude | 879.92 m | Final depth | 30.05 m | Final altitude | 849.87 m |

| | 0.00 – 5.20 | 5.20 – 15.00 | 15.00 – 21.31 | 21.31 – 22.73 | 22.73 – 30.05 |
|---|---|---|---|---|---|
| Sample number | | | | | |
| Description | More or less porous | Compact | Color changes graduary; Compact | 21.31 ~ 22.73 Looks gray by alteration along the network fissures | Argillized Fragile |
| Color | brownish gray | brownish gray | black | gray | greenish gray |
| Lithology | Basalt | Basalt | Basalt | Basalt | Basalt |
| Geological colum | > > > | > > > | > > > | > > > | > > > |
| Width | 22.73 | | | | 7.32 |
| Depth | 0.00 | 5.20 | 15.00 | 21.31 | 22.73 – 30.05 |
| Altitude | 879.92 | 874.72 | 864.92 | 858.61 | 857.19 – 849.87 |

District : Los Cimientos Place : ( 40, Ō )

| Bore number | Machine | Diameter | EX m/m |
|---|---|---|---|
| BB 2.5 | winky | | |
| **Altitude** | **Final depth** | **Final altitude** | |
| 882.78 m | 30.00 m | 852.78 m | |

| Depth (m) | Altitude (m) | Description | Color | Lithology | Width (m) |
|---|---|---|---|---|---|
| 0.00 – 3.36 | 882.78 – 879.42 | Compact | black | Basalt | 3.36 |
| 3.36 – 3.97 | 879.42 – 878.81 | | | non core | 0.61 |
| 3.97 – 7.63 | 878.81 – 875.15 | altered basaltic rock | greenish gray | Clay | 3.66 |
| 7.63 – 8.69 | 875.15 – 874.09 | altered basalt | brownish gray | Basalt | 6.37 |
| 8.69 – 9.47 | 874.09 – 873.31 | argillaceous basalt | white | Basalt | |
| 9.47 – 11.07 | 873.31 – 871.71 | | | non core | |
| 11.07 – 12.07 | 871.71 – 870.71 | altered basalt | brown | Basalt | |
| 12.07 – 14.00 | 870.71 – 868.78 | Soft argillaceous basalt | white | Basalt | |
| 14.00 – 29.62 | 868.78 – 853.16 | Compact | brown | Basalt | 16.00 |
| 29.62 – 30.00 | 853.16 – 852.78 | Compact | black | Basalt | |

Sample number: (none)

District : Los Cimientos Place : ( 50, $\bar{0}$ )

| Bore number | BB 3 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 887.20 m | Final depth | 20.70 m | Final altitude | 866.50 m |

| Altitude | Depth | Width | Geological colum | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|---|
| 887.20 – 88490 | 0 00 – 2.30 | 4 36 | | Basaltic fine tuff | reddish brownish gray | Boulder | |
| 88490 – 882.84 | 2.30 – 4 36 | | | Basalt | black | Boulder Compact | |
| 882.84 – 879 70 | 4 36 – 7 50 | 16.34 | | Basalt | black | Compact Continuous core | |
| 879 70 – 866 50 | 7 50 – 2070 | | | | brownish gray | | |

District : Los Cimientos Place : ( 50, 1̄0 )

| Bore number | BA 3 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 898.08 m | Final depth | 25.00 m | Final altitude | 873.08 m |

| Altitude | Depth | Width | Geological colum | Lithology | Color | Description | Sample number |
|---|---|---|---|---|---|---|---|
| 898.08 | 0.00 | | | Basalt | black | Compact | |
| 895.03 | 3.05 | | | Coarse tuff | pale brownish gray | Fragment . white | |
| 892.58 | 5.50 | | | Basalt | pale purple | | |
| 891.06 | 7.02 | | | | reddish gray | | |
| 885.56 | 12.52 | | | | gray ~ purple | | |
| 884.34 | 13.74 | | | | | chalcedony | |
| 884.08 | 14.00 | | | | | | |
| 881.60 | 16.48 | | | | | chalcedony | |
| 879.83 | 18.25 | | | | brownish gray | Compact | |
| 873.08 | 25.00 | | | | | | |

District : Los Cimientos Place : ( 70, 0̄ )

| Bore number | BB 4 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 896.51 m | Final depth | 25.08 m | Final altitude | 871.43 m |

Sample number:

| Depth | Altitude | Description | Color | Lithology | Width |
|---|---|---|---|---|---|
| 0.00 – 1.50 | 896.51 – 895.01 | Weathered | pale brownish gray | Basalt | 5.80 |
| 1.50 – 5.80 | 895.01 – 890.71 | Weakly weathered | brownish gray | Basalt | 5.80 |
| 5.80 – 7.95 | 890.71 – 888.56 | Fragments are altered into white clay | pale yellowish brown | Basaltic coarse tuff | 2.15 |
| 7.95 – 10.08 | 888.56 – 886.43 | Black basalt remains | white | Basalt | 2.13 |
| 10.08 – 10.69 | 886.43 – 885.82 | Black basalt remains | pale yellow | Coarse tuff | 0.61 |
| 10.69 – 12.00 | 885.82 – 884.51 | Black basalt remains | | Basalt | 1.31 |
| 12.00 – 16.19 | 884.51 – 880.32 | Fragile | pale yellow | Basaltic coarse tuff | 4.19 |
| 16.19 – 18.93 | 880.32 – 877.58 | Compact, Plagioclases are altered into cheey clay | pale brownish gray | Basalt | 8.89 |
| 18.93 – 25.08 | 877.58 – 871.43 | Comparatively compact | pale brownish gray | Basalt | 8.89 |

Geological colum:

District : Los Cimientos Place : ( 70, $\bar{10}$ )

| Bore number | BA 4 | Machine | winky | Diameter | EX m/m |
|---|---|---|---|---|---|
| Altitude | 885.00 m | Final depth | 20.00 m | Final altitude | 865.00 m |

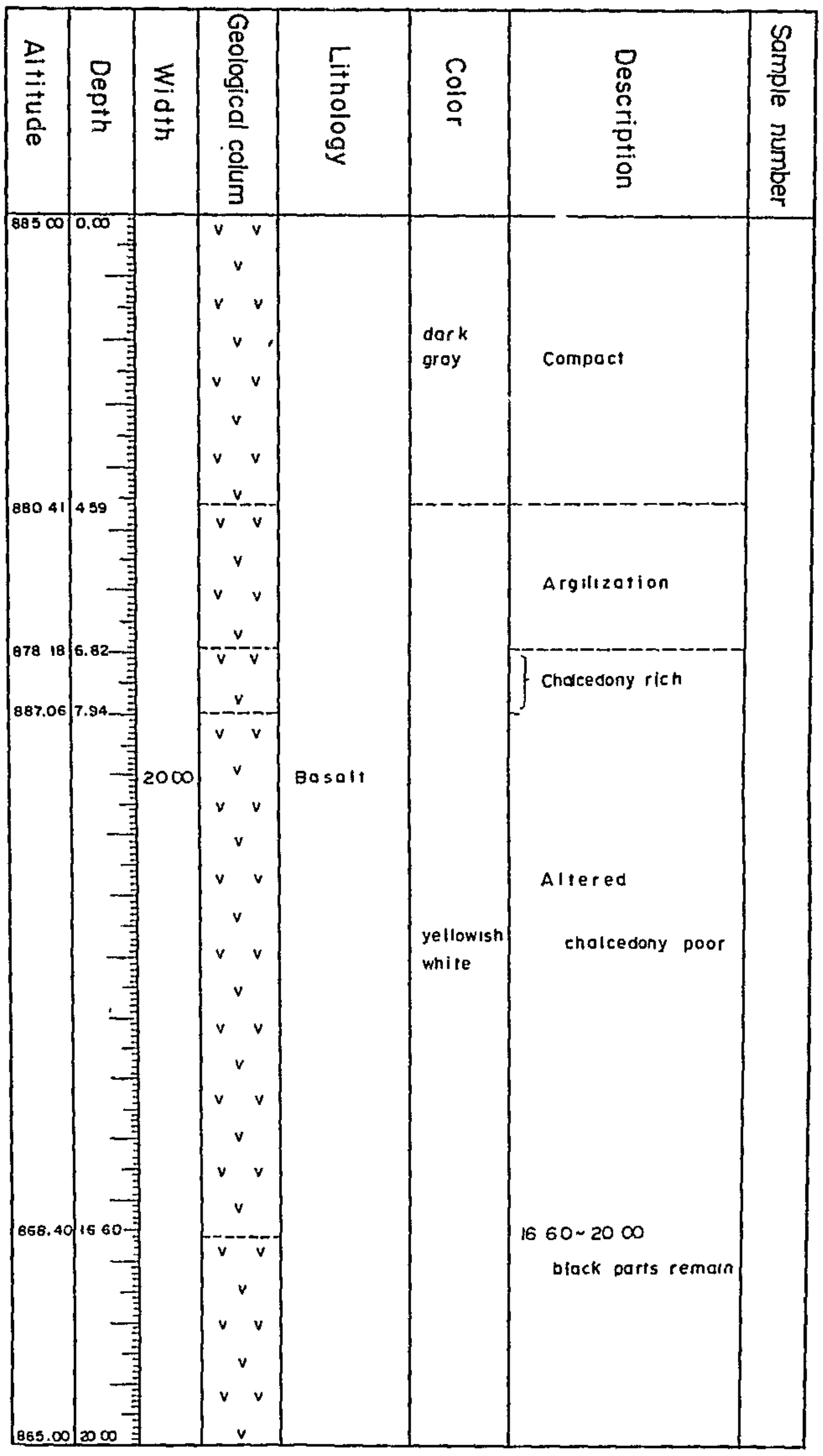


Fig. 3-11 GEOLOGICAL PROFILE THROUGH THE DRILL HOLES (SW-NE)

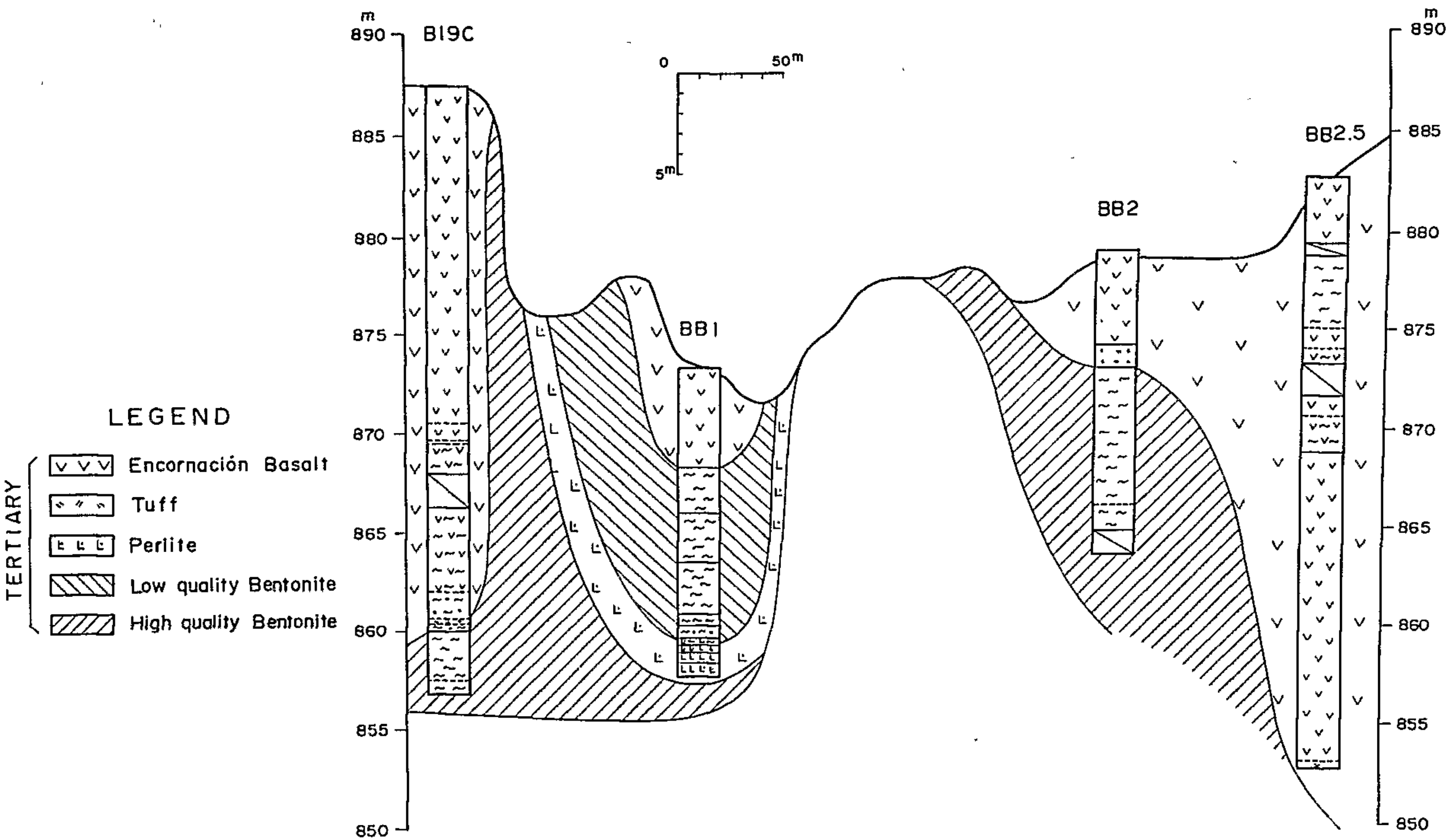
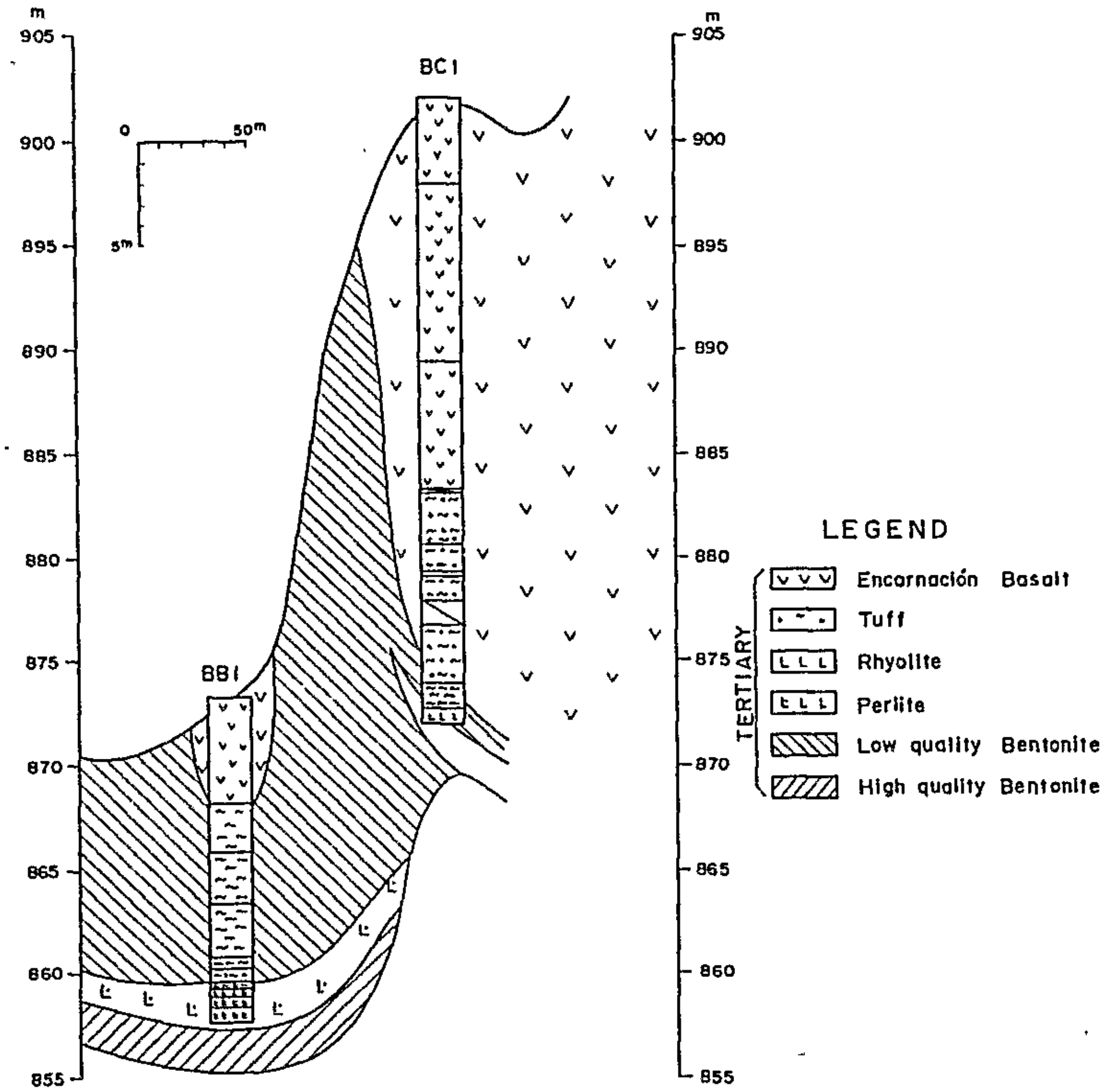
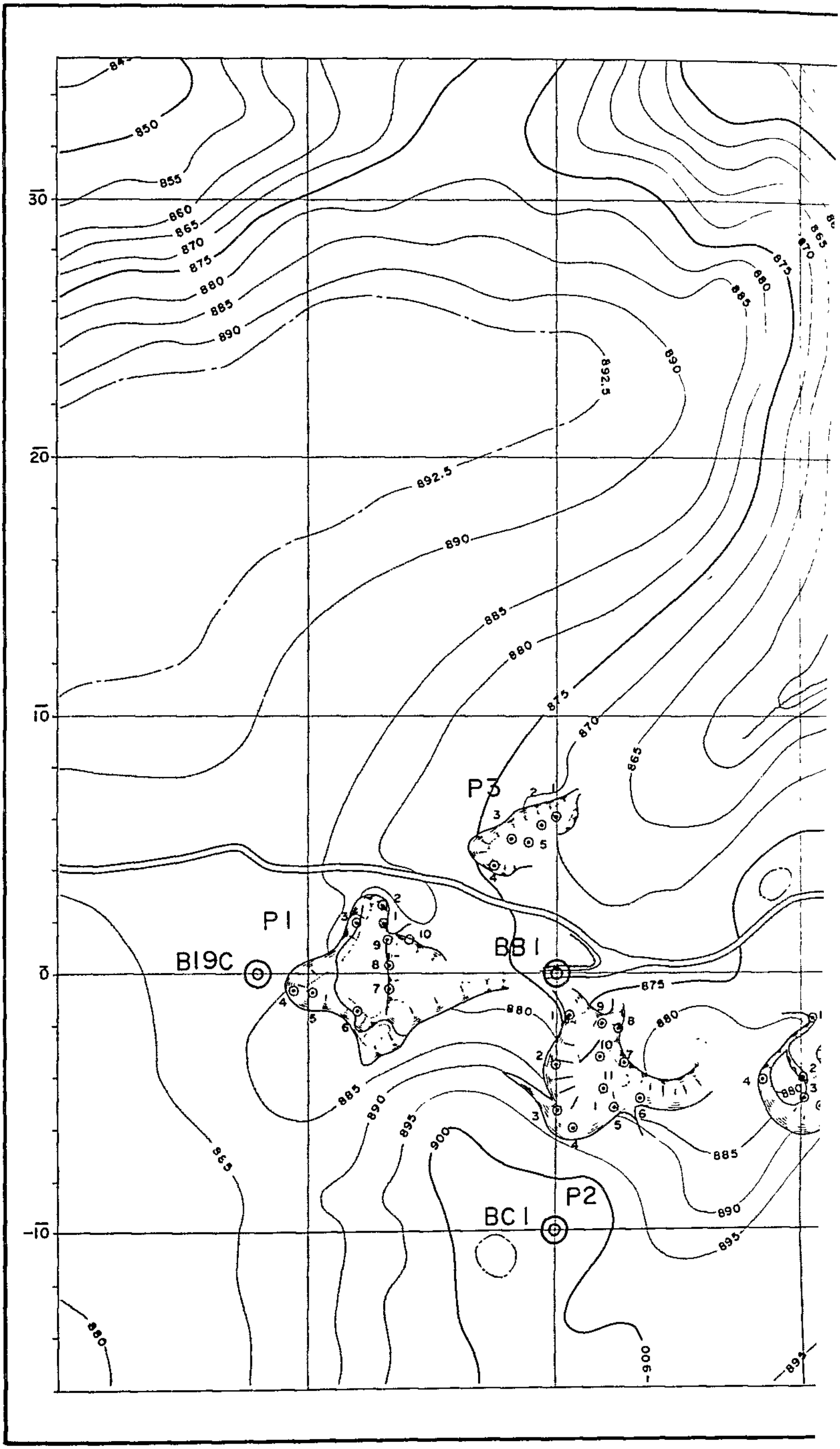


Fig.3-12 GEOLOGICAL PROFILE THROUGH THE DRILL HOLES (SW-NE)





30
20
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0
-10
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855
860
865
870
875
880
885
890
892.5
P3
P1
B19C
BB1
P2
BC1
900
895

Fig.3-13 LOCATION MAP OF THE SAMPLES

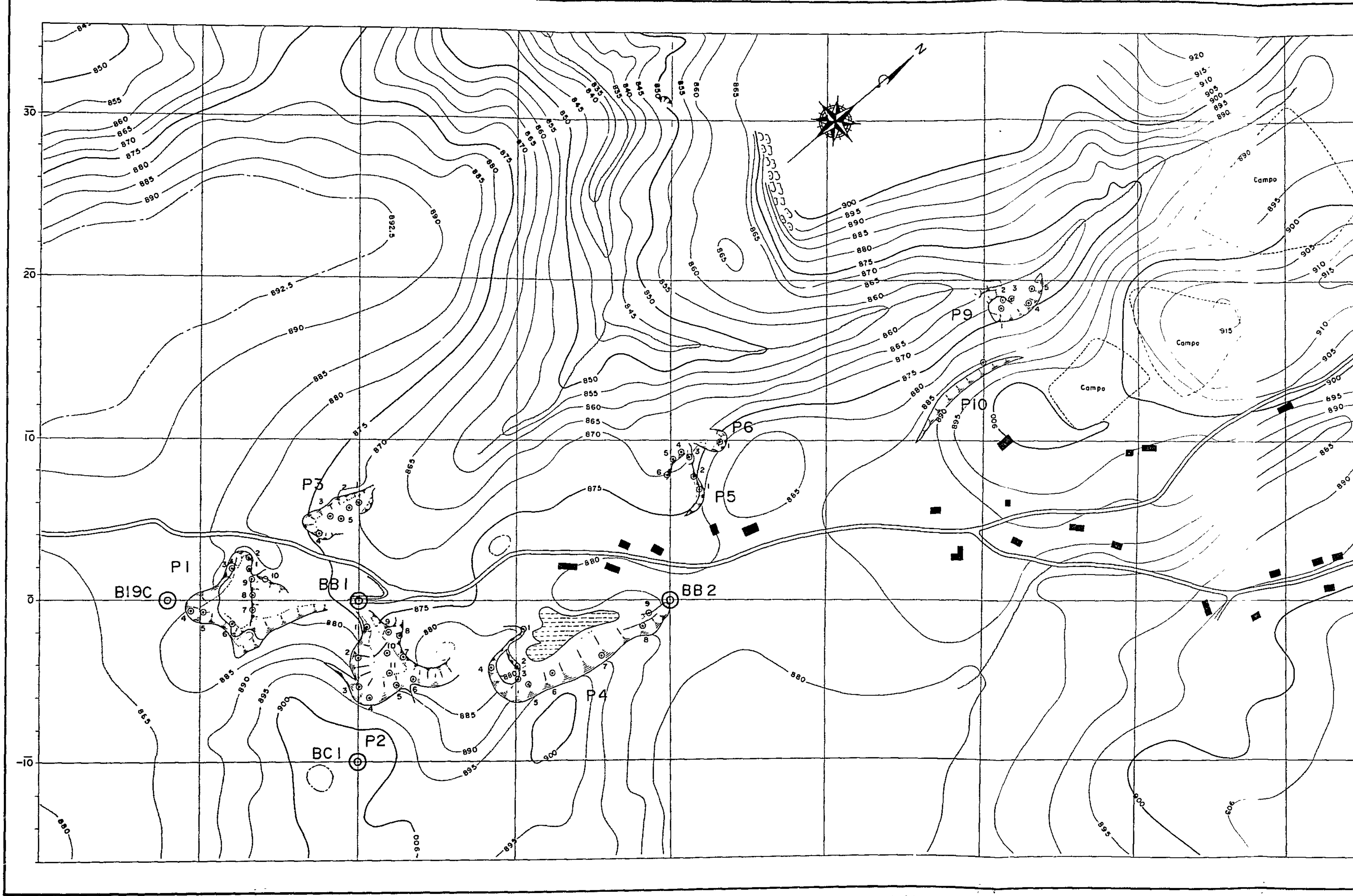


Fig.3-13 LOCATION MAP OF THE SAMPLES

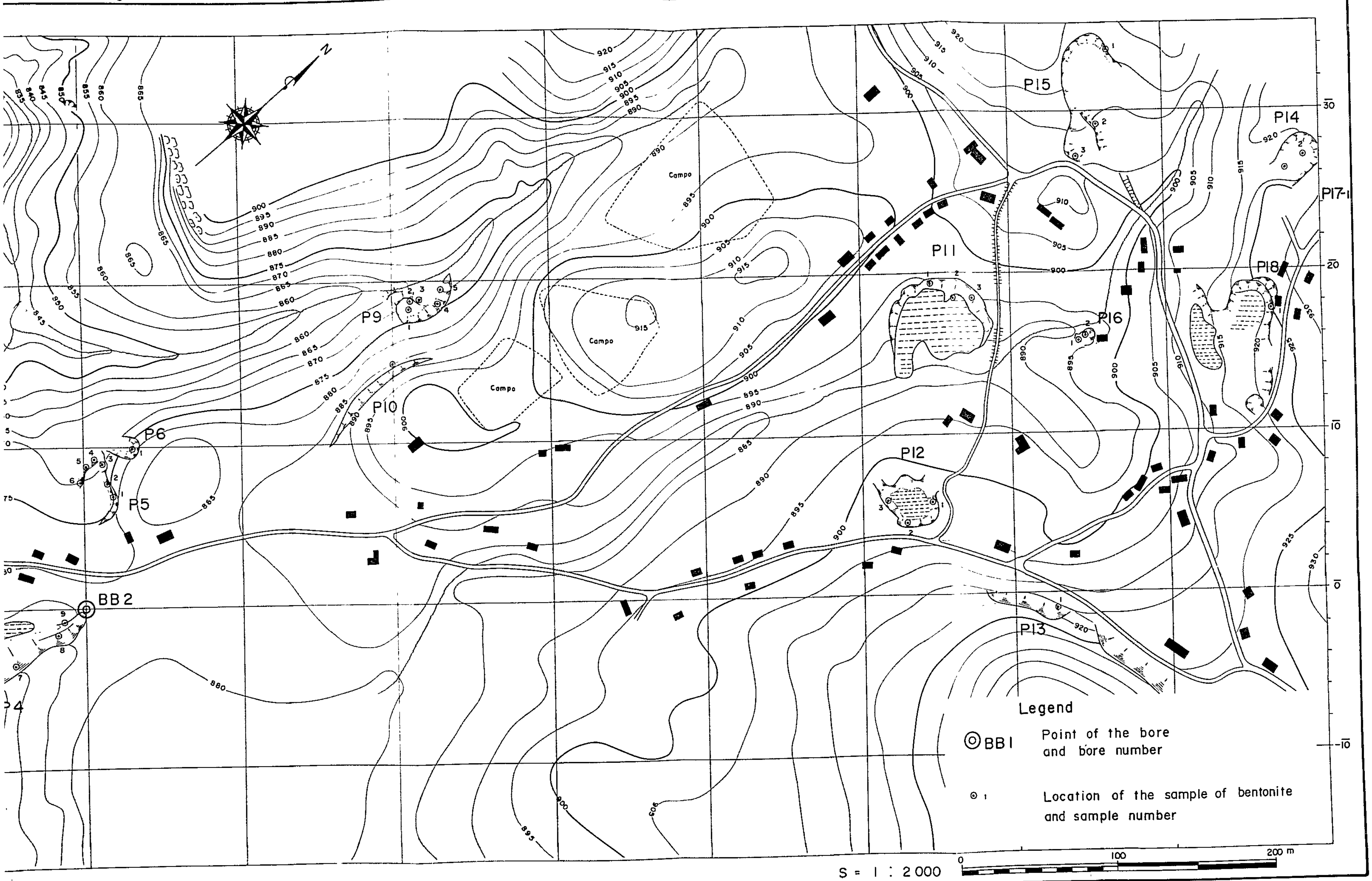
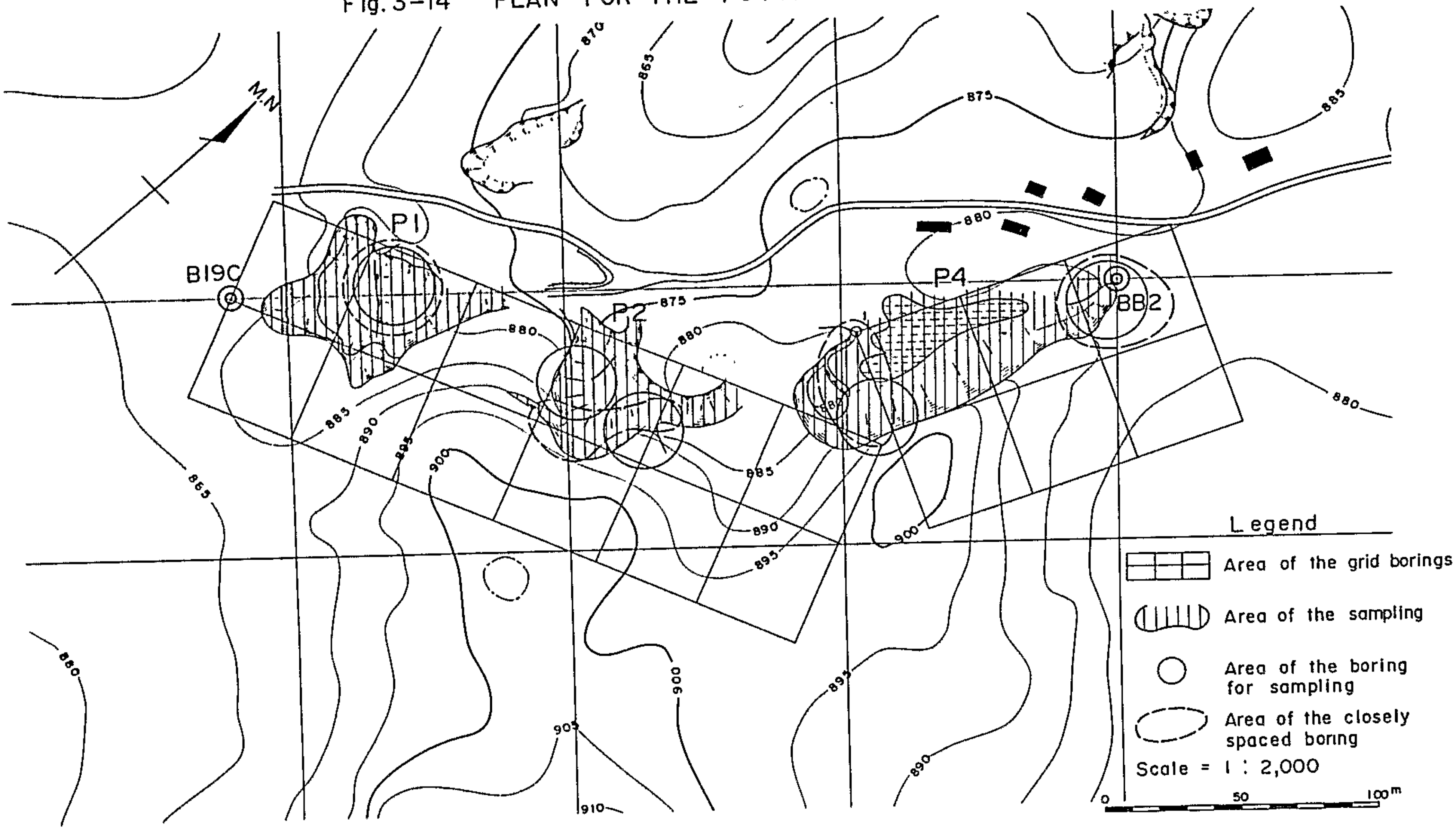


Fig. 3-14 PLAN FOR THE FUTURE PROSPECTING



## 2. Properties of Bentonite

Property analysis was made of 57 samples that were obtained from the outcrops of the bentonite deposits in Los Cimientos as well as from drilling cores of these deposits. As a result, it was confirmed that bentonite in these deposits can be refined to an extremely useful Na-type bentonite by Na activation.

Production of activated bentonite will supply products that have a much higher added value than fillers for soap and detergents, the major applications in Guatemala at present.

### 2-1 Property Analysis (physical and chemical properties)

X-ray diffraction and differential thermal analysis were made on 20 pieces of samples obtained from drilling cores and 64 pieces of samples from the outcrops. From results of these analyses, 20 core samples and 37 outcrop samples were selected for Na activation. Following this activation, these selected samples were further analyzed for swelling property, cation exchange capacity, pH, muddy water quality, and green strength.

Both before and after Na activation pH was determined. Muddy water test was conducted on apparent viscosity, plasticity viscosity, yield value, and filtrate. Furthermore, outcrop samples were subjected to green strength test.

Also, 10 samples representing the surveyed area were analyzed for $SiO_2$, $Al_2O_3$, $Fe_2O$ , MgO, $Na_2O$, $K_2O$ and Ig loss. Results are presented in Table 3-3.

According to the table, $SiO_2$ content of P4, P9 and P15 samples which are thought to be of good quality is 65.0% to 70.8% and it is conjectured that the higher quality shows lower $SiO_2$, but $SiO_2$

content of P2 - 4 and BB2 - 1.2 samples which are as of good quality as the above-mentioned samples is higher than that of these samples. Accordingly, quality of bentonite in Los Cimientos is not able to be estimated only based on $SiO_2$ content.

Either $Al_2O_3$ content or ratio of $Si_2O$ to $Al_2O_3$ showing 4.7 - 6.2 has no correlation to quality.

## 2-2 Analytical Results and Uses

Table 3-3 Results of Chemical Analysis

| Property<br>Sample No. | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | 1,200°C<br>Ig·loss |
|---|---|---|---|---|---|---|---|---|
| P2-4 | 74.8 | 11.9 | 1.41 | 1.99 | 1.32 | 0.08 | 0.15 | 5.30 |
| -6 | 74.0 | 12.2 | 1.12 | 1.94 | 1.24 | 0.10 | 0.23 | 6.12 |
| P4-1 | 70.6 | 14.9 | 1.29 | 2.00 | 1.57 | 0.12 | 0.23 | 7.24 |
| -5 | 70.8 | 13.6 | 1.36 | 2.67 | 1.71 | 0.09 | 0.19 | 7.09 |
| -9 | 70.8 | 12.4 | 3.81 | 2.13 | 1.81 | 0.10 | 0.40 | 7.03 |
| P9-1 | 72.9 | 13.4 | 1.52 | 1.89 | 0.70 | 0.13 | 0.51 | 6.33 |
| P15-1 | 65.0 | 18.0 | 2.18 | 2.18 | 1.30 | 0.17 | 0.80 | 7.70 |
| P18-1 | 74.2 | 13.7 | 1.52 | 1.01 | 0.73 | 0.05 | 1.37 | 5.30 |
| BB1-1·2 | 72.4 | 13.6 | 1.18 | 1.06 | 1.46 | 0.16 | 0.99 | 6.36 |
| BB2-1·2 | 73.6 | 12.4 | 1.29 | 2.36 | 1.52 | 0.07 | 0.36 | 5.94 |

Results of X-ray diffraction analysis are shown in Table 3-4.

High ⟵ Content ⟶ Low

◎ ◯ ◯ ○ ○ ∘ ∘ ∘

Table 3-4 X-ray Diffraction Result (1)

| Mineral / Sample No. | Montmorillonite | Cristobalite | Quartz | Clinoptilolite | Feldspar |
|---|---|---|---|---|---|
| BB1-1 | ◯ | ∘ | | | |
| 2 | ◯ | ∘ | ∘ | ∘ | |
| 3 | ◯ | ∘ | | ∘ | |
| 4 | ○ | ○ | ∘ | ∘ | ∘ |
| 5 | ∘ | ○ | ∘ | ○ | ∘ |
| 6 | ∘ | ∘ | | ○ | ∘ |
| BB2-1 | ◯ | ○ | | | |
| 2 | ◯ | ○ | | | |
| 3 | ◎ | ○ | | | |
| 4 | ◎ | ○ | | | |
| 5 | ◯ | ○ | | | |
| 6 | ◎ | ○ | | | |
| BC1-1 | ◯ | ∘ | ∘ | | |
| 2 | ◯ | ∘ | ∘ | | |
| 3 | ○ | ∘ | ∘ | | |
| 4 | ◯ | ∘ | | | |
| B19C-1 | ◎ | ○ | | | |
| 2 | ◎ | ○ | | | |
| 3 | ◎ | ○ | | | |
| 4 | ◎ | ○ | | | |

Table 3-4 X-ray Diffraction Result (2)

| Mineral / Sample No. | Montmorillonite | Cristobalite | Quartz | Clinoptilolite | Feldspar |
|---|---|---|---|---|---|
| P 1 - 1 | ◯ | ∘ | ∘ | ∘ | ∘ |
| 2 | ◯ | ○ | ∘ | ∘ | ∘ |
| 3 | ◎ | ∘ | | ∘ | ∘ |
| 4 | ◎ | ∘ | | | |
| 5 | ◎ | ○ | | | |
| 6 | ◯ | ∘ | | | |
| 7 | ◎ | ○ | | | |
| 8 | ◎ | ∘ | | | |
| 9 | ◯ | ○ | | | |
| 10 | ◎ | ○ | | | |
| P 2 - 1 | ◯ | ∘ | | | |
| 2 | ◎ | ○ | | | |
| 3 | ◎ | ○ | | | |
| 4 | ◎ | ○ | | | |
| 5 | ◎ | ◯ | | | |
| 6 | ◎ | ○ | | | |
| 7 | ◯ | ◯ | ∘ | | ∘ |
| 8 | ◯ | ∘ | | | ∘ |
| 9 | ◯ | ∘ | | | |
| 10 | ◯ | ∘ | | | |
| 11 | ◎ | ○ | | | ∘ |

Table 3-4 X-ray Diffraction Result (3)

| Mineral / Sample No. | Montmorillonite | Cristobalite | Quartz | Clinoptilolite | Feldspar |
|---|---|---|---|---|---|
| P 3 - 1 | ◎ | ○ | | ∘ | |
| 2 | ◎ | ○ | | ∘ | |
| 3 | ◎ | ◯ | | | |
| 4 | ◯ | ○ | ∘ | ○ | |
| 5 | ◯ | ○ | ∘ | ∘ | |
| P 4 - 1 | ◎ | ○ | | | |
| 2 | ◯ | ○ | | | |
| 3 | ◯ | ○ | | | ∘ |
| 4 | ◎ | ○ | | ∘ | |
| 5 | ◎ | ○ | | | |
| 6 | ◎ | ○ | | | |
| 7 | ◎ | ∘ | | | ∘ |
| 8 | ◎ | ∘ | | | |
| 9 | ◯ | ○ | | | |
| P 5 - 1 | ◎ | ◯ | | | |
| 2 | ◎ | ○ | ∘ | | |
| 3 | ◎ | ◯ | | | |
| 4 | ◎ | ○ | | | |
| 5 | ◯ | ○ | | ∘ | |
| 6 | ◎ | ○ | | | |
| P 6 - 1 | ◎ | ○ | ∘ | | |

Table 3-4 X-ray Diffraction Result (4)

| Mineral / Sample No. | Montmor-illonite | Cristobalite | Quartz | Clinop-tilolite | Feldspar | Gypsum | Kaolinite |
|---|---|---|---|---|---|---|---|
| P 9 - 1 | ◎ | ○ | | | ∘ | | |
| 2 | ◎ | | ∘ | | | ∘ | |
| 3 | ○ | ○ | | | ∘ | | ○ |
| 4 | ◎ | | | | ∘ | | |
| 5 | ◎ | ∘ | ∘ | | | | |
| P 10 - 1 | ◎ | ○ | | | | | |
| P 11 - 1 | ○ | ∘ | | | | | |
| 2 | ∘ | ∘ | | ∘ | | | |
| 3 | ◎ | ○ | | | | | |

Table 3-4 X-ray Diffraction Result (5)

| Mineral / Sample No. | Montmorillonite | Cristobalite | Quartz | Clinoptilolite | Feldspar | Mica | Analcime |
|---|---|---|---|---|---|---|---|
| P 12 - 1 | ◎ | ∘ | | | | ∘ | |
| 2 | ◎ | ∘ | | | | ∘ | |
| 3 | ◎ | ∘ | | | | ∘ | |
| P 13 - 1 | ◎ | ∘ | | | | ∘ | |
| P 14 - 1 | ○ | ○ | | | | | |
| 2 | ○ | ○ | | | | | ∘ |
| P 15 - 1 | ◎ | ∘ | | | ∘ | | ∘ |
| 2 | ◎ | ○ | | ∘ | | | |
| 3 | ◎ | ○ | | | | | |
| P 16 - 1 | ○ | ∘ | | | | | |
| 2 | ○ | ∘ | | | | | |
| P 17 - 1 | ○ | ∘ | | | | ∘ | |
| P 18 - 1 | ○ | ○ | | | | | |

From these results, samples relatively high in montmorillonite purity were picked up and shown in Table 3-5.

Table 3-5 Samples with Relatively High Montmorillonite Purity

| Drilling | Sample No. | Out-crop | Sample No. |
|---|---|---|---|
| BB1 | Nil | P1 | 7, 10 |
| BB2 | 1, 3, 4, 6 | P2 | 4, 6 |
| BC1 | 4 | P3 | 1 |
| B19C | 1, 2, 3, 4 | P4 | 1, 5, 6, 7, 8, 9 |
| | | P5 | 2 |
| | | P9 | 2, 5 |
| | | P12 | 1, 2, 3 |
| | | P13 | 1 |
| | | P15 | 1, 2, 3 |

In addition, results of property analysis are shown in Table 3-6.

These analytical results can be summarized as follows:

X-ray diffraction and differential thermal analyses indicate that bentonite in Los Cimientos contains good H-type montmorillonite as the main constituent mineral, with a small content of cristobalite of relatively low crystalinity.

From results of analysis after Na activation, it was confirmed that bentonite is of the quality that can be refined to an extremely high grade Na-type bentonite.

Generally, Na-type bentonite has the following properties:

1) High swelling property with absorption of water, high cation exchange capacity, and coking property.

Table 3-6 Test Result of properties

| Sample | Depth (m) | Swelling Property (g/g) | Cation Exchange Capacity (meq/100g) | pH (1% susp) | | API Muddy Water Test | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No Activation | Activation | Apparent Viscosity (CP) | Plasticity Viscosity (CP) | Yield Value (ℓb/100ft$^2$) | Filtrate (mℓ) | Cake Thickness (mm) |
| BB1-1 | 5.15- 6.43 | 4.9 | 57 | 8.4 | 10.4 | } 4.1 | } 4.2 | } 0.2 | - | - |
| 2 | 6.43- 7.10 | 5.2 | 59 | 8.1 | 10.4 | | | | - | - |
| 3 | 7.10- 8.26 | 4.9 | 57 | 8.2 | 10.4 | - | - | - | - | - |
| 4 | 8.26- 8.87 | 3.7 | 38 | 8.4 | 10.5 | - | - | - | - | - |
| 5 | 8.87-10.09 | 2.0 | 22 | 8.0 | 10.5 | - | - | - | - | - |
| 6 | 10.09-11.36 | 1.2 | 12 | 8.7 | 10.5 | - | - | - | - | - |
| BB2-1 | 6.05- 7.03 | 7.9 | 76 | 8.8 | 10.4 | } 30.3 | } 22.5 | } 15.5 | } 9.8 | } 1.3 |
| 2 | 7.03- 8.31 | 7.4 | 69 | 8.2 | 10.5 | | | | | |
| 3 | 8.31- 9.47 | 7.6 | 74 | 8.7 | 10.4 | } 34.0 | } 25.0 | } 18.0 | } 9.5 | } 1.4 |
| 4 | 9.47-11.30 | 7.9 | 72 | 9.0 | 10.5 | | | | | |
| 5 | 11.30-13.13 | 6.9 | 67 | 8.9 | 10.5 | } 17.6 | } 15.0 | } 5.2 | } 11.6 | } 1.6 |
| 6 | 13.13-14.35 | 6.5 | 62 | 9.4 | 10.5 | | | | | |
| BC1-1 | 21.49-22.88 | 7.0 | 70 | 9.3 | 10.4 | - | - | - | - | - |
| 2 | 25.32-26.54 | 5.7 | 62 | 9.3 | 10.5 | } 5.4 | } 4.8 | } 1.2 | } - | } - |
| 3 | 26.54-28.00 | 5.0 | 57 | 9.4 | 10.5 | | | | | |
| 4 | 28.00-28.83 | 7.0 | 66 | 9.6 | 10.5 | - | - | - | - | - |
| B19C-1 | 27.00-27.87 | 7.4 | 74 | 8.2 | 10.4 | - | - | - | - | - |
| 2 | 27.87-28.67 | 8.2 | 73 | 8.5 | 10.3 | } 16.1 | } 13.7 | } 4.8 | } 12.2 | } 1.6 |
| 3 | 28.67-29.50 | 7.6 | 75 | 8.5 | 10.3 | | | | | |
| 4 | 29.50-30.47 | 7.6 | 81 | 8.7 | 10.3 | | | | | |

Test Result (continued)

| Sample | $H_2O$* | Swelling Property (g/g) | Cation Exchange Capacity (meq/100g) | pH (1% susp) No Activation | pH (1% susp) Activation | API Muddy Water Test: Apparent Viscosity (CP) | Plasticity Viscosity (CP) | Yield Value (ℓb/100ft$^2$) | Filtrate (mℓ) | Cake Thickness (mm) | Green Strength (kg/cm$^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P1-1 | 3 | 4.8 | 59 | 7.8 | 10.4 | 6.5 | 5.5 | 2.0 | - | - | |
| 2 | 3 | - | - | 8.9 | - | - | - | - | - | - | |
| 3 | 4 | 6.2 | 68 | 9.5 | 10.4 | 11.6 | 9.8 | 3.6 | - | - | ← (3–5) |
| 4 | 3 | - | - | 8.0 | - | - | - | - | - | - | →1.08 |
| 5 | 4 - 5 | 5.9 | 75 | 8.7 | 10.2 | 9.5 | 8.5 | 2.0 | - | - | ← |
| 6 | 2 | - | - | 9.0 | - | - | - | - | - | - | |
| 7 | 4 - 5 | 7.1 | 76 | 8.9 | 10.2 | 14.0 | 12.2 | 3.6 | - | - | ← (7–10) |
| 8 | 4 | 6.2 | 73 | 9.5 | 10.3 | 9.6 | 8.7 | 1.8 | - | - | ← →0.98 |
| 9 | 4 | 6.4 | 69 | 8.9 | 10.4 | 14.1 | 10.7 | 6.8 | - | - | ← |
| 10 | 4 | 7.1 | 77 | 9.2 | 10.4 | 19.6 | 15.0 | 9.2 | 11.8 | 1.4 | ← |
| P2-1 | 2 | 5.2 | 52 | 7.9 | 10.3 | 5.1 | 5.0 | 0.2 | - | - | |
| 2 | 4 | - | - | 8.2 | - | - | - | - | - | - | |
| 3 | 4 | 7.1 | 67 | 7.9 | 10.2 | 14.4 | 12.5 | 3.8 | - | - | ← (3–4) →1.06 |
| 4 | 4 - 5 | 7.9 | 68 | 8.4 | 10.2 | 27.1 | 20.1 | 14.0 | 10.4 | 1.1 | ← |
| 5 | 3 | - | - | 7.8 | - | - | - | - | - | - | ← (5–6) →0.78 |
| 6 | 4 | 6.8 | 68 | 8.2 | 10.3 | 18.1 | 14.9 | 6.3 | 12.4 | 1.6 | ← |
| 7 | 3 | - | - | 7.8 | - | - | - | - | - | - | ← (7–8) →0.63 |
| 8 | 3 | 4.1 | 47 | 8.0 | 10.3 | 3.5 | 3.6 | -0.2 | - | - | ← |
| 9 | 3 | - | - | 7.6 | - | - | - | - | - | - | |
| 10 | 3 - 2 | - | - | 7.5 | - | - | - | - | - | - | ← (10–11) →1.05 |
| 11 | 4 | 6.1 | 61 | 6.9 | 10.1 | 10.8 | 9.5 | 2.5 | - | - | ← |

Note: meg/g : mill. equivalent/gram, CEC : Cation Exchange Capacity, CP : Centi Poise, Susp : suspention,
API : American Petroleum Institute

* $H_2O$

| Rank | Content |
|---|---|
| 5 | > 35% |
| 4 | 30-35 |
| 3 | 25-30 |
| 2 | 29-25 |
| 1 | < 20 |

Test Result (continued)

| Sample | $H_2O$ | Swelling Property (g/g) | Cation Exchange Capacity (meq/100g) | pH (1% susp) No Activation | pH (1% susp) Activation | API Muddy Water Test: Apparent Viscosity (CP) | Plasticity Viscosity (CP) | Yield Value (ℓb/100ft²) | Filtrate (mℓ) | Cake Thickness (mm) | Green Strength (kg/cm²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P3-1 | 3 | 6.4 | 64 | 8.8 | 10.4 | 13.0 | 11.0 | 4.0 | - | - | |
| 2 | 3 | - | - | 8.9 | - | - | - | - | - | - | →0.65 |
| 3 | 4 | 6.4 | 59 | 7.7 | 10.3 | 11.3 | 9.3 | 3.9 | - | - | |
| 4 | 3 | - | - | 8.5 | - | - | - | - | - | - | |
| 5 | 3 | 5.5 | 57 | 8.2 | 10.3 | 7.1 | 6.2 | 1.8 | - | - | |
| P4-1 | 3 | 10.1 | 79 | 8.8 | 10.3 | 41.3 | 29.3 | 23.9 | 10.8 | 2.0 | |
| 2 | 4 | 7.1 | 57 | 8.3 | 10.3 | 8.0 | 7.4 | 1.2 | - | - | →0.63 |
| 3 | 3 - 2 | - | - | 9.2 | - | - | - | - | - | - | |
| 4 | 4 | 6.7 | 59 | 8.5 | 10.3 | 7.8 | 7.5 | 0.5 | - | - | |
| 5 | 4 | 8.1 | 86 | 8.3 | 10.2 | 18.3 | 15.3 | 5.9 | 11.2 | 1.4 | →0.96 |
| 6 | 4 | 7.7 | 73 | 8.3 | 10.1 | 10.8 | 9.3 | 2.9 | - | - | |
| 7 | 3 - 2 | 7.5 | 82 | 8.3 | 10.2 | 10.3 | 8.7 | 3.1 | - | - | |
| 8 | 4 - 3 | 8.4 | 86 | 7.8 | 10.2 | 9.6 | 8.2 | 2.8 | - | - | →0.94 |
| 9 | 4 - 3 | 7.7 | 68 | 9.5 | 10.3 | 19.3 | 16.3 | 5.9 | 12.0 | 1.5 | |
| P5-1 | 4 | - | - | 8.0 | - | - | - | - | - | - | - |
| 2 | 4 - 3 | 8.5 | 74 | 8.4 | 10.3 | 26.0 | 20.0 | 12.0 | 9.9 | 1.3 | - |
| 3 | 4 | - | - | 8.5 | - | - | - | - | - | - | - |
| 4 | 3 | - | - | 8.8 | - | - | - | - | - | - | - |
| 5 | 2 | 4.7 | 50 | 9.0 | 10.3 | 4.6 | 4.2 | 0.8 | - | - | - |
| 6 | 3 | - | - | 8.8 | - | - | - | - | - | - | - |
| P6-1 | 3 | - | - | 8.6 | - | - | - | - | - | - | - |

Test Result (continued)

| Sample | H2O | Swelling Property (g/g) | Cation Exchange Capacity (meq/100g) | pH (1% susp) | | API Muddy Water Test | | | | | Green Strength (kg/cm$^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No Activation | Activation | Apparent Viscosity (CP) | Plasticity Viscosity (CP) | Yield Value (ℓb/100ft$^2$) | Filtrate (mℓ) | Cake Thickness (mm) | |
| P9-1 | 4 | 6.5 | 64 | 8.2 | 10.4 | 15.6 | 12.0 | 7.2 | 13.4 | 1.8 | - |
| 2 | 4 | - | - | 7.7 | - | - | - | - | - | - | - |
| 3 | 2 | - | - | 9.0 | - | - | - | - | - | - | - |
| 4 | 2 | 2.9 | 83 | 8.0 | 10.2 | 2.6 | 2.2 | 0.8 | - | - | - |
| 5 | 4 | - | - | 9.0 | - | - | - | - | - | - | - |
| P10-1 | 4 | - | - | 8.9 | - | - | - | - | - | - | - |
| P11-1 | 2 | - | - | 9.2 | - | - | - | - | - | - | - |
| 2 | 2 | 2.4 | 29 | 9.2 | 10.3 | 2.6 | 2.2 | 0.8 | - | - | - |
| 3 | 2 | - | - | 8.7 | - | - | - | - | - | - | - |
| P12-1 | 3 | - | - | 8.1 | - | - | - | - | - | - | - |
| 2 | 2 | 7.0 | 94 | 7.7 | 10.1 | 13.1 | 11.2 | 3.8 | - | - | - |
| 3 | 3 | - | - | 7.9 | - | - | - | - | - | - | - |
| P13-1 | - | 6.8 | 92 | 7.7 | 10.1 | 12.0 | 10.0 | 4.0 | - | - | - |
| P14-1 | 4 | 6.5 | 64 | 6.4 | 10.2 | 14.0 | 11.7 | 4.6 | - | - | - |
| 2 | 3 | - | - | 8.0 | - | - | - | - | - | - | - |
| P15-1 | 3 | 8.5 | 80 | 7.9 | 10.3 | 46.0 | 33.0 | 26.0 | 9.0 | 1.6 | - |
| 2 | 3 | - | - | 8.7 | - | - | - | - | - | - | - |
| 3 | 3 | 5.8 | 77 | 8.6 | 10.3 | 10.5 | 8.9 | 3.1 | - | - | - |
| P16-1 | 2 | 4.2 | 59 | 8.7 | 10.3 | 5.0 | 4.8 | 0.4 | - | - | - |
| 2 | 2 | - | - | 8.6 | - | - | - | - | - | - | - |
| P17-1 | 2 | 4.5 | 68 | 8.2 | 10.2 | 5.7 | 4.5 | 2.3 | - | - | - |
| P18-1 | 2 | 5.1 | 45 | 7.2 | 10.3 | 6.0 | 5.4 | 1.2 | - | - | - |

2) High viscosity and thixotropy when bentonite is in the form of muddy water.

Applications making use of these properties include bond for molding sand, muddy water for general drilling operations, muddy water for civil foundation work, and carriers for agricultural chemicals and fertilizer.

In Japan, these applications account for 80 to 90% of total utilization.

Bentonite in Los Cimientos is very white in color and highly viscous when used as muddy water. These properties will make it suitable as fillers for paints, ink, cosmetics, etc. Further, if it contains no harmful substances such as heavy metals*, it may also find applications in pharmaceutical preparations.

Some samples showed low consistency and high viscosity when prepared as muddy water. Thus their use as oil-well drilling muds can be also considered.

For an overall assessment, samples in relation to their applications based on results of general physical examination and X-ray diffraction are shown in Table 3-7.

As criteria for these assessments, properties of various products given in Tables 3-8 and 3-9 were used for reference.

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Note: * not included among items for current analysis.

Table 3-7 Relationship of Samples to Uses

| Uses / Sample | Bond for Molding Sand | Muddy Water for Drilling and Civil Foundation Work | Muddy Water for Oil-well Drilling | Chemicals and Fertilizers | Paints and Ink | Cosmetics and Medicines |
|---|---|---|---|---|---|---|
| BB1-1 | o | | | o | | |
| 2 | o | | | o | | |
| 3 | o | | | o | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| BB2-1 | ◎ | | ◎ | | o | o |
| 2 | ◎ | | ◎ | | o | o |
| 3 | ◎ | | ◎ | | | |
| 4 | ◎ | | ◎ | | o | o |
| 5 | o | o | o | | | |
| 6 | o | o | o | | | |
| BC1-1 | ◎ | o | | | | |
| 2 | o | o | | | | |
| 3 | o | | | o | | |
| 4 | ◎ | o | | | o | o |
| B19C-1 | ◎ | o | | | o | o |
| 2 | ◎ | | o | | o | o |
| 3 | ◎ | | o | | o | o |
| 4 | ◎ | | o | | o | o |

◎ : Usable as excellent product. o : Usable as ordinary product.

| Uses / Sample | Bond for Molding Sand | Muddy Water for Drilling and Civil Foundation Work | Muddy Water for Oil-well Drilling | Chemicals and Fertilizers | Paints and Ink | Cosmetics and Medicines |
|---|---|---|---|---|---|---|
| P1-1 | o | o | | o | | |
| 2 | | | | o | | |
| 3 | ◎ | o | | | | |
| 4 | ◎ | o | | | | |
| 5 | ◎ | o | | | | |
| 6 | o | o | | | | |
| 7 | ◎ | ◎ | | | | |
| 8 | ◎ | o | | | | |
| 9 | ◎ | ◎ | | | | |
| 10 | ◎ | | o | | o | o |
| P2-1 | o | | | o | | |
| 2 | o | o | | | | |
| 3 | ◎ | ◎ | | | | |
| 4 | ◎ | | ◎ | | o | o |
| 5 | o | o | | | | |
| 6 | ◎ | ◎ | o | | o | o |
| 7 | o | o | | | | |
| 8 | | | | o | | |
| 9 | | | | o | | |
| 10 | o | o | | o | | |
| 11 | o | o | | | | |
| P3-1 | o | o | | | | |
| 2 | o | o | | | | |
| 3 | o | o | | | | |
| 4 | | | | | | |
| 5 | o | o | | o | | |
| P4-1 | ◎ | | ◎ | | o | o |
| 2 | o | o | | | | |
| 3 | | | | o | | |
| 4 | o | o | | | | |
| 5 | ◎ | ◎ | o | | o | o |
| 6 | ◎ | o | | | | |
| 7 | ◎ | o | | | | |
| 8 | ◎ | o | | | | |
| 9 | ◎ | ◎ | o | | | |

| Uses / Sample | Bond for Molding Sand | Muddy Water for Drilling and Civil Foundation Work | Muddy Water for Oil-well Drilling | Chemicals and Fertilizers | Paints and Ink | Cosmetics and Medicines |
|---|---|---|---|---|---|---|
| P5-1 | o | | | o | | |
| 2 | ◎ | o | ◎ | | o | o |
| 3 | o | o | | o | | |
| 4 | o | o | | o | | |
| 5 | | | | o | | |
| 6 | o | o | | o | | |
| P6-1 | o | o | | | | |
| P9-1 | o | ◎ | o | | | |
| 2 | ◎ | o | | | | |
| 3 | | | | | | |
| 4 | ◎ | | | | | |
| 5 | o | o | | | | |
| P10-1 | o | | | o | | |
| P11-1 | o | | | o | | |
| 2 | | | | | | |
| 3 | o | | | o | | |
| P12-1 | ◎ | o | | | | |
| 2 | ◎ | o | | | | |
| 3 | ◎ | | | | | |
| P13-1 | ◎ | o | | | | |
| P14-1 | o | ◎ | | | | |
| 2 | o | | | o | | |
| P15-1 | ◎ | o | ◎ | | | |
| 2 | o | o | | | | |
| 3 | o | o | | | | |
| P16-1 | o | | | o | | |
| 2 | o | | | o | | |
| P17-1 | o | | | o | | |
| P18-1 | o | o | | | | |

Table 3-8 Evaluation Criteria - 1

(Green strength of bentonite for molding sand)

| Product | Origin | Type | Green Strength |
|---|---|---|---|
| Product A | Japan | Na bentonite | 1.1 $kg/cm^2$ |
| B | " | " " | 1.3 |
| C | " | Activated bentonite | 0.7 |
| D | " | " " | 1.0 |
| E | " | " " | 1.4 |
| Volclay | Wyoming | Na bentonite | 1.2 |

Table 3-9 Evaluation Criteria - 2

| Product | Origin | Apparent Viscosity (CP) | Plasticity Viscosity (C) | Yield Value ($\ell b/100ft^2$) | Filtrate ($m\ell$) | Use |
|---|---|---|---|---|---|---|
| Product A | Japan | 5.0 | 4.5 | 1.0 | 17.5 | Civil work in general |
| B | " | 6.5 | 6.0 | 0.5 | 19.0 | " |
| C | " | 10.5 | 9.0 | 3.0 | 12.0 | " |
| D | " | 36.8 | 27.0 | 19.5 | 9.5 | Oil well grade |
| Wyo-Bon | Wyoming | 20 | 14 | 16 | 13 | " |
| " " | " | 13 | 10 | 5 | 13 | Cementing grade |

## 3 Bentonite Market

### 3-1 Guatemalan Market

Bentonite is used in Guatemala mainly as an extender in detergent manufacture and for drilling. The domestically produced bentonite is almost entirely used for the former, and American bentonite of higher grade is imported for drilling use. Judging from Table 3-10, the bentonite output in Guatemala is likely to be about 3,000 t per year.

The quantity of imported bentonite is not accurately known, but judging from the drilling implementation situation in Guatemala, and from the figures given in Table 3-11, the imports are estimated at about 4,000 t per year.

### 3-2 Markets in Countries Around Guatemala

1) The United States of America

The USA is the greatest bentonite producing country in the world. The production situation is as shown in Table 3-12.

The output in the USA increased at a high average rate of 17.1% a year between 1971 and 1980. American bentonite as a whole is high in grade and is principally used for drilling, civil engineering construction work and pelletizing iron ore. It is highly competitive in the international market. However, as the output in the year 2000 is estimated to total 6,250,000 t, the average production growth rate (1980-2000) is estimated at only the 2.6% a year.

About 15% of bentonite recently produced in the USA is exported. The principal reason for long-range decline in the output is likely to be a ceiling reached in the domestic demand.

## Table 3-10 Bentonite Output in Guatemala

(Unit: t)

| | | | | |
|---|---|---|---|---|
| (1) Bureau of Mines Minerals Yearbook 1978-79 | | | | |
| | 1978 | 2,593 | | |
| | 1979 | 2,700 e | | |
| (2) Mineral Industry Survey, Oct. 1981 | | | | |
| | 1978 | 2,552 | | |
| | 1979 | 2,589 e | | |
| | 1980 | 2,589 e | | |
| (3) Direccion General de Mineria e Hidrocarburos | | | | |
| | | EXPORTS | | DOMESTIC |
| | | El Salv. | Honduras | |
| 1978 | 2,430 | 816 | 455 | 1,159 |
| 1979 | 2,850 | 808 | 796 | 1,246 |

Note: e : estimate

## Table 3-11 Quantity of Imported Bentonite from USA

| | | | |
|---|---|---|---|
| (1) Mineral Industry Surveys, Oct. 1981 | | | |
| 1980 | 3,570 t | 469 thousand US$ | 131.4 $/t |
| (2) US Dpartment of Commerce 1980 | | | |
| 1974 | 4,081 t | 614,713 US$ | 150.6 $/t |
| 1976 | 2,000 | 415,514 | 207.8 |
| 1979 | 1,302 | 181,000 | 139.0 |
| 1980 | 3,439 | 468,530 | 136.2 |
| 1981 (Jan-Aug) | 4,520 | 689,496 | 152.5 |
| (3) The Economics of Bentonite, Fullers Earth and Allied Clays Third Edition, Sept. 1979 | | | |
| 1973 | 630 t | 0.05 mil. US$ | 79 $/t |
| 1974 | 4,110 | 0.61 | 148 |
| 1975 | 2,590 | 0.21 | 81 |
| 1976 | 1,965 | 0.42 | 214 |

Table 3-12 Production Situation of Bentonite in USA

| | Quantity (thous. t) | Value (thous. $) |
|---|---|---|
| 1971 | 2,380 | 27,892 |
| 2 | 2,471 | 29,331 |
| 3 | 2,734 | 348,39 |
| 4 | 2,955 | 43,970 |
| 5 | 2,883 | 50,475 |
| 6 | 3,143 | 58,465 |
| 7 | 3,345 | 66,832 |
| 8 | 3,989 | 88,426 |
| 9 | 3,948 | 106,529 |
| 1980 | 3,737 | 115,235 |

Source: Mineral Industry Surveys, 1981

Table 3-13 Ratios of Bentonite Used for Various Purposes in USA

| | Domestic | | Exports | |
|---|---|---|---|---|
| | 1979 | 1980 | 1979 | 1980 |
| Animal Feed | 5.0 | 4.8 | - | - |
| Drilling Mud | 34.3 | 40.4 | 25.5 | 52.5 |
| Filtering, Clarifying, Decoloring Oils | 3.1 | 3.2 | - | - |
| Foundry Sand | 24.1 | 17.8 | 37.8 | 37.1 |
| Pelletizing | 24.3 | 24.3 | 24.4 | - |
| Waterproofing and Sealing | 2.0 | 2.6 | - | - |
| Others | 7.2 | 6.9 | 12.3 | 10.4 |
| | 100.0 | 100.0 | 100.0 | 100.0 |

Source: Mineral Industry Surveys, 1981

Tabel 3-14 USA Exports of Bentonite, Including Calcined

(Unit: thous. t)

| | 1973* | 1974 | 1975* | 1976 | 1977* | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|
| Argentina | 0.80 | 0.74 | 0.54 | 0.19 | 0.27 | 0.18 | 0.20 | 0.75 |
| Bolivia | - | 0.15 | 0.71 | 1.04 | - | - | - | 0.37 |
| Brazil | 13.31 | 11.78 | 7.59 | 7.71 | 9.29 | 7.01 | 13.05 | 11.89 |
| Chile | 0.45 | 1.35 | 2.59 | 2.66 | 2.50 | 4.71 | 3.06 | 4.47 |
| Colombia | 2.14 | 2.34 | 2.14 | 3.03 | 2.41 | 1.58 | 6.93 | 10.27 |
| Costa Rica | - | - | - | - | - | - | 0.44 | 0.44 |
| Dominica | - | - | - | - | - | - | - | 0.03 |
| Ecuador | 1.34 | 3.33 | - | 0.66 | 0.54 | 0.87 | 1.01 | 0.65 |
| El Salvador | - | 0.36 | - | - | - | - | 1.18 | 0.84 |
| Guatemala | 0.63 | 4.08 | 2.59 | 2.00 | - | - | 1.30 | 3.44 |
| Guyana | - | 1.31 | - | - | - | - | - | 0.07 |
| Honduras | - | - | - | - | - | 1.61 | 0.44 | 0.84 |
| Jamaica | 0.81 | 0.16 | - | - | - | - | - | 0.03 |
| Mexico | 0.80 | 0.86 | - | 1.59 | 4.64 | 5.97 | 14.51 | 9.44 |
| Nicaragua | - | 0.50 | - | 1.11 | - | 0.74 | - | - |
| Panama | 0.27 | 0.17 | - | 0.18 | - | - | - | 0.14 |
| Peru | 1.61 | 2.08 | 47.95 | 1.17 | 1.25 | 0.51 | 1.62 | 0.52 |
| Surinam | - | - | - | - | - | 0.48 | - | 0.04 |
| Tr. Tobago | - | 2.61 | - | 3.86 | - | 2.19 | 2.04 | 2.80 |
| Uruguay | - | - | - | - | - | - | - | 0.02 |
| Venezuela | - | 19.24 | - | 19.43 | - | 28.70 | 29.28 | 31.51 |
| Sub-total | (21.53) | 51.06 | (64.11) | 44.63 | (20.90) | 54.55 | 75.06 | 78.54 |
| Canada | 212.63 | 242.74 | 272.19 | 354.70 | 339.34 | 275.92 | 327.70 | 371.50 |
| Australia | 41.17 | 50.74 | 51.97 | 29.90 | 15.00 | 33.86 | 67.75 | 35.50 |
| Japan | 20.45 | 21.84 | 19.65 | 71.23 | 35.72 | 55.55 | 61.02 | 52.69 |
| Netherland | 21.25 | 34.30 | 27.06 | 21.47 | 27.77 | 34.24 | 63.95 | 70.80 |
| S. Arabia | - | 20.53 | - | 15.97 | - | 33.78 | 35.06 | 25.24 |
| Singapore | - | 23.78 | - | 11.54 | - | 38.02 | 26.71 | 58.07 |
| U.K. | - | 55.92 | - | 42.58 | - | 33.15 | 41.40 | 45.14 |
| W. Germany | 41.97 | 66.52 | 24.65 | 65.48 | 42.33 | 16.68 | 1.34 | 6.57 |
| Others | - | 69.85 | - | 45.31 | - | 70.23 | 46.15 | 57.64 |
| Total | (358.99) | 637.28 | (459.63) | 702.81 | (481.06) | 645.98 | 761.45 | 801.69 |

Source: US Department of Commerce

Note: * The Economics of Bentonite, Fullers Earth and Allied Clays, Third Edition, Sept. 1979.

2) Mexico

The demand for bentonite in Mexico for oil drilling purposes and so forth is postulated to be large, but imports from the USA are insignificant. Mexico is likely to be producing considerable quantities domestically. In fact, Mexico exported 46.4 t of bentonite to the USA in 1980. This quantity is small, but Mexico is one of the biggest export countries from which the USA imports bentonite. As a consequence, no large-scale imports are likely to be necessary under the existing situation.

3) Central American Countries (Honduras, El Salvador, Costa Rica, Nicaragua, Panama)

Bentonite production in the Central American countries is limited and its uses are also limited. In the case of export of Guatemalan bentonite, the Central American market must be the most practical target. But as the transport cost is relatively high if the bentonite is limited to its present use of manufacturing detergent, small-scale truck transportation to Honduras and El Salvador now being undertaken would be about the limit. In addition, the Central American market itself is still small and, since the neighboring country Honduras imposes a 10% import tax, Guatemalan exporters' incentive is low.

Virtually no bentonite is produced in Hoduras and El Salvador, but small quantities are produced in Nicaragua. In any case the market is not likely to expand unless the demand in the mining and industrial sectors increased.

4) South American Countries

In South America, large quantities of bentonite are produced in Argentina for export to Brazil, Chile, Paraguay, Uruguay, Bolivia and Colombia. In addition to Argentina, South American countries also import bentonite from the USA, West Germany, France and Italy. High-grade and special grades of bentonite are assumed to be imported from these countries. The scale of the market is unknown.

## 3-3 Demand Outlook by Use

The market for the bentonite produced in Guatemala is limited both in quantity and in purposes of application. If the situation continues unchanged, no market expansion can be expected.

Guatemalan utilization in fertilizer and agricultural chemicals is first conceivable, but none is used in these areas now, and even if applications should be found, the quantity will be very small as is evident in the statistics by use compiled in the USA. (The quantity is likely to be about 1% of domestic sales, which is about 4,000 t a year in gross weight - 1979 and 1980 statistics.)

According to US figures on exports by use, drilling, civil foundation works and pelletizing account for nearly 90%. Increasing the needs in these areas would be indispensable to future expansion of the demand.

## 3-4 Market Estimation

An example of market estimation, when supply destinations of Guatemalan bentonite are limited to the domestic market and Central American countries, is given in Table 3-15. The bases for the estimation are given below.

Table 3-15 Market Estimation

[Estimated Case A]

(Unit: t)

| | 1980 | 1990 | 2000 |
|---|---|---|---|
| Mining and Industrial Uses (domestic supply) (drilling, pelletizing, civil engineering uses) | 4,000 | 6,516 | 10,613 |
| Mining and Industrial Uses (for Central America, including Mexico) ( " ) | 20,000 | 32,578 | 53,066 |
| Sub-Total | 24,000 | 39,094 | 63,679 |
| For Other Uses (domestic supply) | 3,000 | 4,032 | 5,418 |
| For Other Uses (for Central America, including Mexico) | 1,500 | 2,016 | 2,709 |
| Sub-Total | 4,500 | 6,048 | 8,127 |
| Grand-Total | 28,500 | 45,000 | 72,000 |

Average annual growth rate for mining and industrial uses is estimated at 5%, while that for other uses is estimated at 3%.

[Estimated Case B]

(Unit: t)

| | 1980 | 1990 | 2000 |
|---|---|---|---|
| Mining and Industrial Uses (domestic supply) | 4,000 | 7,689 | 15,479 |
| Mining and Industrial Uses (for Central America, including Mexico) | 20,000 | 39,343 | 77,394 |
| Sub-Total | 24,000 | 47,212 | 92,873 |
| For Other Uses (domestic supply) | 3,000 | 4,887 | 7,960 |
| For Other Uses (for Central America, including Mexico) | 1,500 | 2,443 | 3,980 |
| Sub-Total | 4,500 | 7,330 | 11,940 |
| Grand-Total | 28,500 | 55,000 | 105,000 |

Average annual growth rate for mining and industrial uses is estimated at 7%, while that for other uses is estimated at 5%.

1) Premises for calculations

No drastic change in the uses of the bentonite will take place. In particular, the demand for detergent manufacture will not be replaced by other substances and exports for other uses will be limited to Honduras and El Salvador.

2) The numerical values for the standard year (1980)

It is based on the analysis of present bentonite supply and demand. The value of bentonite for mining and industrial use intended for Central America was estimated on the basis of quantities these countries import from the USA.

3) Basis for setting growth rate

(1) The most recent output in Guatemala is on a slight increase.

(2) The average annual increase in output in the Central and South American countries (Guatemala, Mexico, Argentina, Brazil, Colombia, Peru) was 3.5% (1976-1980).

(3) The average annual output increase in the 30 leading producing countries of the world was 4.6% (1976-1980).

(4) The future output of the USA is estimated to mark an average annual increase of 2.6% between 1980 and 2000.

(5) According to the Guatemalan manufacturer, the demand will not increase significantly under the existing uses.

(6) The average annual growth rates in substantial industrial output in the Central American countries are as given in Table 3-16.

Table 3-16 Average Annual Growth Rates of Actual Industrial Output in the Central American Countries

| | 1960 ∿ 1979 | 1970 ∿ 1979 |
|---|---|---|
| Mexico | 9.1 | 6.4 |
| Guatemala | 7.8 | 8.0 |
| El Salvador | 8.5 | 6.0 |
| Honduras | 5.4 | 5.0 |
| Nicaragua | 11.0 | 3.2 |
| Costa Rice | 9.4 | 8.5 |
| Panama | 10.1 | 0.5 |

Source: World Development Report, 1981, World Bank

(7) In the Central American countries, resource development is likely to become vigorous in the future, and there is a possibility of the needs expanding beyond the average demand, including industrialized countries.

As export destinations, the Central American countries are most practical. Meanwhile, as the quality of the bentonite is good and it is usable for multiple purposes, South America and Europe may also be considered as export destinations. If these markets are included, the market for Guatemalan bentonite is very large in comparison with the production scale.