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THE GOVERNMENT OF MALAYSIA

AN INVESTIGATION

OF THE

GUNONG SUMALAYANG LIMESTONE

SEPTEMBER 1970

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SOUTH EAST JOHOR PROJECT TANJONG PENGGERANG AND JOHOR TENGAH REGIONAL MASTER PLAN STUDY

FOR
GOVERNMENT OF MALAYSIA AND
STATE GOVERNMENT OF JOHOR

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26th October, 1970.

Chief Secretary to
the Government of Malaysia,
Economic Planning Unit,
Prime Minister's Dept.,
Jalan Dato Onn,
KUALA LUMPUR.

Sir,

LIMESTONE EXPLORATION : GUNONG SUMALAYANG

Following the instructions contained in your letter No.(8) dlm. JPM. (Sulit) 1900/31/13 dated 27th July 1970, we have pleasure in submitting our Report on the nature and extent of the limestone reserves at Gunong Sumalayang.

The results of the exploration indicate estimated reserves of 30 million tons of limestone. Core samples from two bores are currently under analysis by the Department of Geological Survey, Ipoh, and on completion will be submitted as a complementary appendix to the Report.

We wish to record that the utmost assistance and co-operation was received from Federal and State Departments and individual officers in the conduct of the investigation.

I have the honour to be, Sir,

Your obedient servant,

W. SWINSON
Project Manager
SOUTH EAST JOHORE PROJECT

HAR/EW

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1. INTRODUCTION

The work was carried out in the period July 18th to August 22nd, 1970. The aim of the project was to investigate a known limestone occurrence on Gunong Sumalayang, situated some 17 miles north-west of Kota Tinggi (Fig. 1), to establish whether a commercially exploitable deposit occurred in the area.

The limestone was discovered by officers of the West Malaysian Geological Survey in the course of their routine regional mapping programme. Its economic viability as a cement raw material, has probably been tested by Pan Malaysian Cement, who have investigated the area in the last two years.

The importance of a cheap source of carbonate for increasing the pH of certain soils, particularly those under study in the South East Johore Project area and the implications for crop diversification, have been the subject of previous papers and discussions with representatives of the various government departments concerned.

Purely from the point of view of reducing the soil acidity the type of carbonate used is immaterial. However, the cheapest source of carbonate is ground limestone (essentially calcium carbonate). The relative merit of using dolomite (calcium/magnesium carbonate), which in addition provides the nutrient element magnesium, has been the source of some controversy. Strictly speaking, dolomite contains a 1:1 ratio of calcium to magnesium. Treatment with this material is likely to provide more magnesium than is required by plants as a nutrient, and could result in a build up of the element in the soil with undesirable results. In most areas of the world the acceptable ratio of Ca/Mg is 8 or 10:1.

The Sumalayang Limestone is not a dolomite, but work done by

the West Malaysian Geological Survey has shown that the rock contains small amounts of magnesium. Thin sections show small crystals of dolomite and chemical analysis of two samples has shown MgO contents of 0.24 per cent and 0.53 per cent respectively. Analysis of samples taken during the present study will give a better picture of the overall magnesium content of the deposit. If the rock is quarried for agricultural lime, quality control analysis will determine the amount of magnesium which is being added to soils and make it possible to calculate how much is required from other sources, to maintain the optimum nutrient level of this element.

A preliminary study of the area was made by the consultants' geologist assisted by Geological Survey Staff on the 4th and 5th of June, 1970. A report on this study was made to the S. E. J. P. Steering Committee (No. 5 July 1970) and the present investigation results from the follow up recommendations made in that report.

We would like to thank the Director of the Geological Survey for providing staff to help with all stages of this investigation. In particular for providing the services of Enche Hew Kiang Tho, Geological Assistant, whose work in all aspects of the study was excellent. We would also like to thank the drillers, Drilling and Minerals Sdn. Bhd. and the labour force from Sedili Kechil, who remained cheerful in some difficult terrain and weather conditions.

2. LABOUR FORCE

The investigation was led by the consultants' geologist, with the Geological Survey assistant as second in command. The survey party consisted of a surveyor with two assistants. The drilling crew was made up of 1 clerk, 1 foreman driller, 1 fitter, 3 drillers and 6 drilling assistants. The drilling companies' supervisors paid periodic

visits to the site. The general camp labour force consisted of 10 to 14 men made up of 1 cook, 1 man responsible for drill site and route preparation and 8 to 10 labourers. The latter were concerned with movement of supplies, test pitting, rentis cutting etc. A contract team of 7 men was used in the early stages to renovate old timber roads, build bridges and to cut part of the main pattern of rentis lines, prior to the commencement of drilling. An extra crew of 12 labourers was used in the first few days, to carry supplies, erect camp and cut rentis.

3. METHOD OF INVESTIGATION

The immediate aim of the investigation was to prepare a detailed geological map and profiles of the limestone area at a scale of 1" = 200', with a view to estimating the amount of limestone in the area, its structure and the amount of overburden present.

To produce a detailed topographic map of the area at this scale would be an extremely lengthy and costly operation. Therefore survey work was restricted to compass traversing of streams and old timber tracks tied to a pattern of accurately surveyed and levelled rentis lines. The profile lines along the rentises are accurate but we must emphasize that the form lines between them are generalised, and must not be regarded as contour lines, (see Fig. 2). An Assumed Ordnance Datum of 1000' was used in the survey and is approximately equal to 500' O. D.

The geologist and the geological assistant traversed and recorded the positions of all streams and roads. All solid rock outcrops were noted and described (see Section 4. 2) and the more critical outcrops were plotted and levelled (see Fig. 2). The geological staff was responsible for all plotting of results.

The survey party levelled and surveyed the main and subsidiary rentis lines, noting their intersection with streams and roads.

The surface geological information was supplemented by 4 boreholes, 6 pits and 2 trenches.

The collected data were used to prepare the map and profiles (Figs. 2 to 15). Estimates of limestone tonnages and volume of overburden were made from these figures (see Section 5. 2).

At an early stage in the investigation it was decided to concentrate the drilling effort in the west of the limestone area, where surface indications of limestone showed the likely occurrence of a workable deposit. The geological map (Fig. 2), indicates other areas which are thought to be underlain by limestone but where no drilling has been done.

4. GEOLOGY

4. 1 General

The Sumalayang Limestone was first discovered in 1966, by officers of the Geological Survey carrying out the regional mapping programme of the 1 inch to 1 mile sheet No. 125, (Gunong Blumut). In his memoir to this map sheet, Rajah (1969 unpublished), gives a description of the limestone which is substantiated by the present investigation. The regional geology was described in our earlier report and only the details of the limestone and the enclosing metasediments will be given in this report.

4. 2 Geological Observations

Observation numbers refer to localities shown in Figs. 2-15.

1. Argillaceous metasediments in stream bed, brown weathered, bedding strike and dip indeterminate.

2. Cliff of argillaceous metasediments, shaley mudstone B/S 280° dip 46° N. N. E. Top 909', base 888' A. O. D.

3. Dark grey argillaceous metasediments B/S 260° dip 44°N.

4. Brownish argillaceous metasediments B/S 350° dip 25°W.

5. Brownish weathered argillaceous metasediments right bank of stream next to large tufa deposit top 972' A. O. D. B/S 350° dip 35°W.

6. Very dark grey argillaceous metasediments with black limestone ribs, 4' exposed at small waterfall B/S 010° 45°W. 984' A. O. D.

7. Brown weathered shaley mudstones in stream bed B/S 280° dip 70°N.

8. Limestone cliff 12' high in dry stream bed right bank of main stream. Dark grey limestone fine grained with some argillaceous partings B/S 240° dip 28°NW. Top 1057' base 1045' A. O. D.

9. Fine dark limestone with chert bands and nodules. This outcrop forms small waterfall and may be faulted (220°) B/S 260° dip 28°N. Top 1095' A. O. D.

10. Small outcrop in stream bed above (9), dark fine grained limestone with Fusilinids B/S 260° dip 34°N. 1108' A. O. D.

11. Dark grey argillaceous metasediments with black limestone liases B/S 360° dip 55°W.

12. 13. & 14. Dark grey to black indurated shales and mudstones with black limestone bands and lenses. Forms series of waterfalls in main stream.

15. Dark grey limestone B/S 260° dip 24° NW. overlying argillaceous metasediments. Contact here may be faulted.

16. Small outcrops of pale grey limestone in stream bed. Appears to be massive upper limestone. B/S indeterminate.

17. Cliff of massive medium grey limestone. B/S 260° dip 30° NW. Top 1172' base 1118' A. O. D.

18. Cliff of massive grey limestone B/S 240° 33°NW. Top 1119' base 1076' A. O. D.

19. Cliff of massive grey limestone B/S 240° 24°NW. Top 1086' base 1041' A. O. D.

20. Numerous outcrops of mainly massive grey limestone, lower outcrops with shale partings. B/S 220° dip 28°W; 220° 36°W; 230° 30°NW.

21. Dark grey shaley mudstone with limestone ribs at small waterfall. B/S 220° dip 36°NW. Limestone boulders in stream nearby.

22. Dark grey shaley mudstone B/S 210° dip 35°NW.

23. Massive grey limestone forms cliff, 16' visible thickness, overlain by bedded limestone and shales 5'. B/S 200° dip 26°NW; 350° dip 35°E. Evidence from pitting and trenching shows this outcrop is faulted (fault bearing 010°?).

24. Chocolate brown shaley mudstone, weathered, forms waterfall B/S 240° - 245° dip 38°NW.

25. As (24) B/S 330° dip 35°NE.

26. Black indurated shaley mudstones with limestone lenses B/S 250° dip 32°NW.

27. As (26) B/S 240° 54°NW.

28. Dark grey mudstone in stream bed. B/S indeterminate.

29. Tuff in stream bed.

30. Large outcrop of medium to pale grey massive limestone B/S 010° dip 30°W? Top 1179' Base 1123' A. O. D.

31. Small outcrops of massive grey limestone. Top 1173' A. O. D.

32. Brown and grey mudstone forming waterfall B/S 260° dip 35°NW.

33. Brown mudstone B/S 350° dip 60°W.

34. Outcrops of massive grey limestone B/S indeterminate Top 1191' base 1166' A. O. D.

35. Large outcrop of massive grey limestone, with chert modules. B/S 360° dip 20°W. Top 1201', base 1168' A. O. D.

36. Numerous outcrops of grey massive limestone B/S indeterminate Top 1138' base 1069' A. O. D.

37. As (36) Top of highest outcrop 1092', base of lowest outcrop 1075' A. O. D.

38. Numerous outcrops of grey massive limestone B/S difficult to determine. Figures of 200° dip 26°NW and 190° dip 26°W were recorded. Highest outcrop 881', lowest outcrop 859'.

39. Argillaceous metasediments, brown weathered in stream bed. B/S 200° 36°W.

40. Same as (39) B/S indeterminate.

41. Grey fine grained limestone B/S indeterminate.

42. Dark grey to black shaley mudstone B/S 010° dip 50°W.

4.3 Lithology and Stratigraphy

The rock succession is illustrated in the Key to Illustrations following page 20.

Rajah has described the Dohol Formation of which the Sumalaya Limestone Member is a component part. The formation is made up of a wide variety of rock types in addition to limestone. However, in general and certainly in the area under discussion, it consists essentially of argillaceous (clay) sediments. The entire rock succession shows varying degrees of low grade regional metamorphism (a process under which rock

are subjected to heat and/or pressure). Exposures of the Dohol argillites at a considerable depth below the limestone are not common. It is considered, that locality 24 (see Fig. 2) is probably the lowest horizon exposed. Here the sediments show small scale block jointing and consist of deeply weathered chocolate coloured shaley mudstones; the unweathered rock is probably dark grey. Higher in the succession these rocks become progressively harder, tougher, darker and more calcareous. The rocks in the bed of the Sungei Sedili (localities 26, 27 and 42), near the base camp are of this type, as are those forming the series of waterfalls further north, at localities 12, 13 and 14. They consist of grey to black indurated shaley mudstones, which are often quite calcareous and may contain small bands and lenses of black limestone. The latter are particularly in evidence in localities 12, 13 and 14.

Higher in the succession still, in rocks only adequately seen in the boreholes, the amount of argillaceous matter continues to decrease. The general colour of the rocks becomes lighter, limestone beds are thicker and the argillaceous component is largely confined to streaks and partings.

Within the limestone succession itself the change continues. The colour gradually decreases to light grey and almost white in places. The higher limestones are massive, recrystallized and uniform in hand specimen. There are no shale partings and conclusive dip and strike measurements are difficult to record, either from surface exposures or from boreholes.

In general all the limestones are fine grained with rare beds of medium grain size. The colour varies between black and almost white.

Unlike the gradual transition seen at the base of the limestone, the upper boundary with the higher horizons of the Dohol Formation is

quite distinct. The rocks immediately overlying the limestone are different in character to those seen below it. In general they are usually pale grey to golden brown streaked, highly weathered sandy mudstones. In one locality the overlying rock is probably a sandstone, though no actual contact is visible. In another tuff is thought to overlie the limestone. All the overlying sediments seen are highly weathered and quite soft. In the vicinity of area A (see Fig. 2) the top of the limestone can be defined from stream exposures to within 15 or 20 feet. The occurrence of solid rock overburden, as opposed to unconsolidated material, coincides with the development of a pronounced steep slope feature which trends north near area A then swings north-east near the large limestone outcrop at locality 30. From here the feature is traceable running north-east till it dies out in the flatter high ground to the north of area B. The latter is known to be underlain by limestone (outcrops at locality 16). It is considered that the slope feature mentioned above, defines the top of the limestone with reasonable precision, in an area where there are no rock outcrops whatever.

Most of the area underlain by limestone is covered by colluvial overburden. This material consists of large boulders of the Panti Sandstone Formation with more rarely boulders of the Sedili Volcanic Formation which overlie the Dohol Formation. The soils in the area are dominantly yellow brown sandy clays derived from these boulders. Typical dark red limestone soils were found only in the flatter high ground north of area B (see Fig. 2). In this area and also in the high ground near area A, limestone vegetation, typically of one storey, is thought to occur.

The limestone area as a whole has slightly lower vegetation than the surrounding country. This is readily visible on the air photographs and may be due to the drier soil conditions created by limestone, even when it occurs at some depth beneath the overburden.

4.4 Structure

Apart from one major element, a fault shown in figure 2 trending north north-west, the structure is essentially that which was described in our preliminary report. In general the main area of limestone indicated in figure 2 forms an asymmetrical pitching anticline, with its axis bearing approximately west north-west. The rocks forming the eastern limb of the anticline dip at approximately 30^{o}N. W. (strike 230^{o}), while those in the west show a gentler dip, 20^{o}W (strike 010^{o}). Detailed individual observations have been given in Section 4. 2 of this report.

The major fault mentioned above affects the eastern limb of the anticline, with the limestone further west showing a lateral displacement towards the north. The fault has only been observed in pits (6 and 7 locality 23), where it is trending northwards with hade and downthrow to the west. At locality 23, the argillites which are in lateral juxtaposition with the limestones, are quite different in character to those which normally underlie the limestone/localities 6, 7 and B. H. 2. They are chocolate coloured (probably due to weathering) shaley mudstones with small scale block jointing (locality 24). They closely resemble the rocks seen in localities 2, 3 and 5, to the north, which are thought to be some 80 ft. below the limestone. The black argillite and limestone banded sequence seen in localities 21 and 22 is more typical of the succession below the limestone and it is possible that a further small fault occurs between here and locality 24.

The alignment of the fault shown in figure 2 is inferred, and is partly based on the occurrence of a steep ground slope feature running north north-east on profile IIC (Fig. 12). Because of its possible effect on the quantity of limestone available, we have made no estimates north-east of rentis IIB, (see Section 5. 2).

Small faults have been observed at localities 9 and 15; it is not considered that these will affect the economics of the deposit in this area.

The differential movement of the softer argillites, which show a greater degree of folding (steeper dips etc.) relative to the harder limestone, was mentioned in our earlier report. Evidence of interbed movement within the limestone sequence is common. All argillite partings are slickensided, with graphitic partings (presumably due to the high carbon content of the original argillites) being fairly common.

That most of the accommodation movement resulting from folding was taken up along the more argillaceous horizons, is shown by the greater amount of fracturing found at these levels. Limestone fragments "wrapped" in argillaceous material are common, and suggest that this is due to movement of the limestone beds lubricated by the argillaceous partings, fragments of limestone being ground off and mixed with the "lubricant". The greater degree of fracturing and recementation of limestones near argillaceous partings is very striking in B. H. 2. The higher more massive limestones show less evidence of small scale fracturing and recementation, possibly due to the absence of shale partings.

4.5 A Note on Conditions of Sedimentation

Rajah mentioned the possibility that the Sumalayang Limestone Member was a "reef knoll". This cannot be confirmed however, as throughout the succession, the study revealed no trace of any reef building organisms. While the mode of formation of the limestone is largely irrelevant to this investigation, it does affect the type and quality of limestone which occurs in the area, and it is therefore interesting to speculate about the condition of sedimentation. The rocks could provide material for a very interesting academic study

of conditions of sedimentation if more exposures become available as a result of quarrying.

The rock sequence reflects gradually changing conditions of sedimentation, from fairly deep water in the case of the argillaceous sediments to shallower water, particularly for the upper limestones. The original basin of deposition was probably landlocked (back reef or lagoonal facies), against a low lying hinterland with sluggish rivers providing mainly clay sediment. The dark colour of the shales is almost certainly due, at least in part, to finely divided carbonaceous matter, probably land plant derived. Aggregations of iron pyrites show a foetid sea bottom with high reducing conditions and although the macroscopic pyrite, seen in some of the darker limestones, has probably been "sweated" out during metamorphism, micro (framboidal) pyrite almost certainly occurs in the darker argillites and limestones. Sporadic brachiopod and gasteropod shells show no original broken shells, this would suggest little or no current action at the time of deposition. These conditions are quite unacceptable to any reef building organisms.

The gradual filling of the basin of deposition, with an increase of oxygenated water conditions, decrease in mud and pyrite, is quite striking from the change in the type of limestone as one ascends the succession. The upper limestones may have been chemically precipitated in fairly shallow water. This could account for their pale colour and seemingly high purity. The coarser silty and sandy horizons in the Dohol Metasediments above the limestone, appear to continue the trend towards shallow water conditions.

The commonest fossils in the limestone are fusilinids. They are sporadically distributed through the darker limestones, but are more numerous in the blacker more argillaceous bands. It is not known whether these bands, which would appear to reflect bottom conditions at their least favourable, represent a favourable period for

this type of animal, or whether they were killed off in greater numbers due to the bad conditions. The latter seems the more likely.

5. ECONOMIC GEOLOGY

5.1 General

Rajah in the memoir to sheet No. 125 suggests that the Sumalayang limestone had important economic possibilities. He mentions a cement or ornamental stone industry. It is understood, that comparatively recently the deposit was investigated by a team of geologists from Pan Malaysian Cement. The results of their findings are not known, but no evidence of pitting or trenching was found anywhere in the area during the present study. It is concluded that they worked only on surface exposures, and that this evidence suggested an absence of limestone in sufficient quantities to support a large cement industry.

There is evidence around most outcrops of the various investigations which have been carried out in recent years. Lack of such evidence around most of outcrops in area A and the small outcrops in area B (locality 16) suggests that they have not been examined prior to this investigation.

The report on economic geology of the South East Johore Project area does not support the view that the limestone has any particular merits as a dimensional (ornamental) stone. Certain of the lower horizons show quite attractive black limestones with contrasting white fossils and calcite veins. The upper limestones on the other hand are rather unstriking, being more uniform in colour. Obviously if a quarry is started for industrial lime, then those limestone horizons which have a beautiful appearance, should be considered as the raw material for an ornamental stone, particularly in an area of the world which is experiencing something of a building boom. However, it would not be feasible to consider opening the deposit purely as a source of dimensional stone.

5.2 Estimation of Limestone Reserves and Overburden Volume

The profiles shown in figures 3 to 15 are along cut rentis lines, which have been accurately levelled and pegged at 100 feet intervals. Apart from subsidiary rentis line IIE (Fig. 14), which was sited to traverse a limestone outcrop, the other lines were set at approximately 400 feet intervals, and are without intentional bias. It was not possible within the time available to prepare a detailed contour plan, which would have been the most ideal basis for the survey. However, even within the limitations of the observations made, it is considered possible to make a realistic estimate of the tonnage of limestone available in part of the area. We have restricted our calculations to that area which has been studied in some detail by drilling. It would be idle to do other than speculate about other areas at this stage. Boreholes were not drilled near every profile, but from the very constant dip angles recorded in boreholes and the strike and dip directions recorded in outcrops, it is reasonable to infer the limestone structure in areas of no exposure.

The largest imponderable factor in the calculations, and an important one from an economic standpoint, is the volume of unconsolidated overburden present in the area. It was hoped that the thickness of overburden could be assessed by pitting. Experience in the Penggarang area of the South East Johore Project, has shown overburden to 5 feet on tops of hills or ridges, 3 to 4 feet on shoulders, with greater amounts on lower slopes and in valleys. In general the amount of overburden can be correlated with the gradient of the topography. In the Sumalayang area, however, these criteria do not apply. It is obvious that the significant factor, is not the gradient of slope in small individual areas but the position of the limestone on the mountain side as a whole. Being near the base of the mountain, large amounts of colluvium occur in certain areas. Borehole 4 shows 173 feet of overburden. This is

probably exceptional and maybe due to the fact that the hole is sited at the foot of a prominent steeply sloping feature. Elsewhere boreholes have shown thicknesses of 40, 50 and 60 feet of overburden. It is probably fair to assume an average overburden thickness of 80 feet over the whole area. This can only be determined accurately at the development drilling phase of the investigation. Our calculations are based on a thickness of 80 feet, except in areas where there is definite evidence to the contrary.

Based on knowledge of the structure of the limestone, which has been derived from outcrop and borehole information, a series of profiles along the surveyed rentis lines have been prepared (see Figs. 3 to 15).

The limestone has been divided, on its appearance in the field, into an upper and lower series. The paler more massive upper limestones probably have a higher calcium carbonate content and have been observed in area A, the higher outcrops in area B and the boreholes 3 and 4, (see Fig. 2). The lower, dark, bedded limestone sequence probably contains less calcium carbonate but should be quite acceptable for agricultural purposes. The base of the Sumalayang limestone is shown at an inferred position in Figure 2 and was set at 850 feet A. O. D in Borehole 2. As has been mentioned previously, the change from argillaceous Dohol metasediments to limestone above is gradational and therefore the mapped base of the limestone is rather arbitrary.

Our calculations of limestone tonnage are restricted to the area southwest of profile IIA, Figure 10. A more tentative estimate is given for the ground between profiles IIA and IIB. The calculations do not include the lower bedded limestones, and because the top of the limestone is inferred in most of the area the calculations have been made based on an upper outcrop limit set some 100 feet inside that shown in Figure 2.

The shaded area shown in individual profiles (with cross sectional tonnage indicated) is that which has been used in calculations.

The tonnage of limestone assumes an average unit weight of limestone (normally accepted as 146 lbs per cubic foot), which is equal to 15.3 cubic feet per ton. For the purposes of the present calculations we have used a figure of 16 cubic feet per ton.

Each square inch on a profile (scale 1" = 200'), represents 40,000 square feet, which equals 40,000 cubic feet when multiplied by unity and at 16 cubic feet per ton equals 2,500 tons. The cross sectional tonnage is shown on profiles Figures 3 to 15.

5.3 Calculations

(a) Limestone

The reserves of limestone available are given by the formula:-

$$W = t \times \frac{d}{2}$$

where W is the tonnage, t is the cross sectional tonnage and d is the average distance between adjacent profiles.

(i) Estimated tonnage east of Rentis Profile IA

$$W = 20,625 \times \frac{570}{2}$$

$$= 5,877,525 \text{ tons.}$$

(ii) Estimated tonnage east of Rentis Profile IB.

$$W = 13,125 \times \frac{400}{2}$$

$$= 2,625,000 \text{ tons.}$$

(iii) Estimated tonnage west of Rentis Profile IC.

$$W = 20,975 \times \frac{480}{2}$$

$$= 5,022,000 \text{ tons.}$$

(iv) Estimated tonnage east of Rentis Profile IC

$$W = 20,925 \times \frac{400}{2}$$

$$= 4,185,000 \text{ tons.}$$

(v) Estimated tonnage west of Rentis ID

$$W = 9,575 \times \frac{400}{2}$$

$$= 1,915,000 \text{ tons.}$$

(vi) Estimated tonnage east of Rentis Profile ID

$$W = 9,575 \times \frac{400}{2}$$

$$= 1,915,000 \text{ tons.}$$

(vii) Estimated tonnage west of Rentis Profile IE.

$$W = 9,060 \times \frac{400}{2}$$

$$= 1,812,000 \text{ tons.}$$

(viii) Estimated tonnage east of Rentis IE west of Rentis IIA

$$W = 1,710,750 \text{ tons.}$$

Total estimated tonnage between Rentis Profiles IA and IIA = 25,000,000 tons

Between Rentis lines IIA and IIB a further tonnage of limestone can be calculated. No holes were drilled in this area, however, based on outcrop evidence, cross sectional tonnages have been indicated on Profiles IIA and IIB. From these figures the following calculation can be made for this area:

$$W = \frac{13,750 + 17,500}{2} \times 350$$

$$= 5,468,750 \text{ tons}$$

(b) Unconsolidated overburden

As has been mentioned above, a detailed estimate of the overburden is not possible from our investigations. Methods of determining the amount of overburden are discussed in Section 6 of this report. It is fair to assume an average overburden thickness of 80 feet except in those areas where there is direct evidence to the contrary. Overburden will be thickest at the base of steep slopes and thinner on shoulders of hills and ridges. The overburden shown on the profiles (Figs. 3 to 15) probably represents a fairly accurate picture of the amount of overburden present.

We estimate from these profiles, that the tonnage of limestone calculated above, will be covered by approximately 3,000,000 cubic yards of unconsolidated overburden.

6. CONCLUSIONS AND RECOMMENDATIONS

The investigation has revealed the presence of an estimated 25,000,000 tons of massive pure limestone in one part of the area investigated with a further 5,500,000 tons occurring further east. Extraction of this limestone will require the removal of 3,000,000 cubic yards of overburden. It is important to remember that this material will have to be moved over the lifetime of the deposit and not before operations begin. The tonnage of limestone under solid rock overburden of Dohol sediments has not been estimated but indications are that the limestone continues at depth below this material. The latter increases rapidly in thickness in some areas, due to the combined effect of steeply dipping limestone and a rapid increase in ground slope. However, the material is quite soft and should be easily rippable if the limestone is required.

It is not feasible to estimate the tonnage of limestone east of the major fault shown in Figure 2, however, the vegetation and geological structure suggests that the high ground here is underlain by limestone. Time and financial restrictions did not permit the drilling of boreholes which would have been able to establish whether the limestone occurs at a workable thickness in this area. Present indications suggest that the outcrops in the vicinity of area D (Fig. 2) are of the lower bedded lime stones and that the massive upper limestones will occur on the high ground further to the north-west. The streams traversing this area were investigated but no solid rock outcrops were visible. However, the vegetation in this area is similar to that seen in areas known to be underlain by limestone.

We recommend further investigation of the ground between areas A and B (Fig. 2), to establish methods of working, face alignment, depth of overburden etc. Traditionally further investigation would involve development drilling. Holes could be drilled at 100 feet centres over the entire area to determine overburden volume accurately. This approach would necessitate the removal of the vegetation from the area. A detailed topographic survey could be carried out at this time. An alternative method of determining overburden would be to use seismic reflection geophysical techniques. The seismic velocities of limestone and overburden should show a good contrast and make it possible to determine the depth to solid rock rapidly and cheaply without removing the vegetation. It is desirable to leave existing vegetation and drainage intact as long as possible if the area is to remain stable, with minimum erosion and possibility of landslip over the lifetime of the deposit. The geophysical results would have to be checked by drilling and we suggest the use of a crawler tractor mounted, air flush drill. We consider that the advice of an experienced quarry engineer should be sought prior to the working of the deposit. We make the following observations concerning this aspect of the work. It should be possible to establish a

strike face in area A (Fig. 2). In most of the area strike faces should be avoided if possible. The deposit is traversed by a series of parallel streams which should be left undisturbed as long as possible and therefore dip faces aligned roughly north-west may be better. It will be necessary to clear a strip on the uphill slope above any working faces, this will prevent landslip into the quarry and contamination of the limestone. Stability of the slopes will be aided by the prevailing dip of the limestone which in most areas is contrary to the hill slope.

It is possible that detailed investigations to the north-east will reveal further extensions of the deposit. To the south of area A the limestone is probably bounded by a fault which is followed by the line of the Sungei Sedili. An investigation of this fault could reveal limestone further south. Rajah has recorded a small limestone outcrop on the southern side of the fault near the drainage divide between this river system and that of the Sungei Dohol. Unfortunately, time did not permit us to investigate this occurrence in detail.

Borehole 2 - Surface Level: - 1,043 feet A. O. D.
Base of Overburden: - 983 feet A. O. D.
Base of Limestone: - 868 feet A. O. D.
Borehole ends at: - 838 feet A. O. D.

Depth	Core Recovery	Description	Remarks
0-2'	0%		
-4'	40%	Brown clay with sandstones, gritstone pebbles.	
-6'	0%		0-60' - Superficial deposits.
-7'	100%	Yellow/ red clay.	
-9'	0%		
-13'	100%	Yellow/ red clay.	
-17'	0%		
-21'	93%	Yellow/ red clay.	
-24'	0%		
-28'	100%	Yellow/ red clay 2'. Stiff brown clay 2'.	
-30'	0%		
-33'	100%	Stiff brown clay.	
-34'	50%	Broken pebbles of quartzite and vein quartz.	
-35'6"	60%	Stiff brown clay.	
-40'	0%		
-45'	80%	Stiff brown clay. Broken vein quartz.	
-50'	0%		
-52'6"	40%	Stiff brown clay and gravel.	
-57'	0%		
-60'	83%	Stiff brown clay.	
-64'	98%	Medium grey fine grained limestone becoming finer darker to 62'. Calcite joints. Some broken core of fine dark grey limestone.	Rare fusulinids and crinoid ossicles 62'10"-63'2" fusulinids
-65'3"	97%	Fine fine dark grey to black limestone. Numerous calcite filled joints.	Core broken Fusulinids common.

Borehole 2 cont'd.

Depth	Core Recovery	Description	Remarks
0-70'3"	98%	Medium to dark grey limestone Rare argillaceous partings (Dip 32°).	Limonitic and calcite joints common.
-72'6"	90%	Broken core large calcite filled joints (70°).	Numerous fusulinids.
-77'6"	100%	Fine dark limestone. Calcite veins to 78'2" contorted black mudstone at 73'6". Numerous argillaceous streaks and partings (Dip 34°). Thin calcite veins show small scale faulting.	
-80'10"	98%	Medium grey fine grained limestone. 4" broken mudstones at 80'3". Numerous calcite veins and joints.	Dip 33°
-85'10"	100%	Mainly very dark grey fine grained limestone.	Large calcite veins & joints. 2" fusulinid band 85'.
-95'10"	98%	Medium grey fine grained limestone with argillaceous partings, becoming finer dark limestone with argillaceous streaks and partings common.	Fusulinid bands at 89' Dips on argillaceous 30°-32°.
-100'10"	100%	Dark grey fine grained limestone black argillaceous bands (often slickensided) common. 97'4" limestone fragments in argillaceous matrix.	Dip 30° Scattered Brachiopod shells. Gasteropod at 99'4". Fusulinids scattered.
-109'10"	98%	Very dark grey to black limestone. Contorted argillaceous partings often slickensided. Calcite veins and joints.	Fusulinids common to 105'4". Dip 33° at 104'10".
-118'4"	95%	As above. Fusilinds mainly in black limestone and argillaceous bands.	110'5" - Fusulinid band 112'10" - Fusulinid band 111'7" - Slickenside 117'10" - Slickenside Dip 34°.
-120'	90%	Dark fine grey limestone. Calcite veins.	Numerous slickensides Dip 32° Fusulinids rare

Borehole 2 cont'd.

Depth	Core Recovery	Description	Remarks
0-127'6"	98%	Limestone similar, broken and recemented. Broken shale partings, calcite joints and veins.	
-137'	100%	Limestone similar argillaceous streaks and partings (almost vertical).	Dip 36° ? Fault Scattered Fusulinids.
-146'9"	100%	Medium grey fine limestone fine argillaceous streaks. 143'6"-12" Pale greenish grey silisceous mudstone.	
-149'6"	100%	Limestone similar.	
-159'	100%	Limestone similar becoming fine dark with argillaceous bands and Fusulinids.	Fusulinid bands 153'6", 154'7", 155'8". Dips 28°.
-167'	95%	Similar.	162'2" Small faults.
-177'	100%	Similar to 175' with argillaceous bands becoming dominant. Calcite joints.	173'8" Gasteropod Brachiopods. Dip 32°.
-187'	100%)	Mainly grey, green and black mudstones and shales, often mottled, contorted or showing slump structures.	Dips 34°
-196'	100%)		
-205'	100%)		

Borehole 3 - Surface Level: - 1,065 feet A. O. D.
Base of Overburden: - 1,023 feet A. O. D.
Base of Massive Limestone: - 846 feet A O. D.
Borehole ends at: - 779 feet A. O. D.

Depth	Core Recovery	Description	Remarks
0-10'	50%	Stiff Yellow Brown Clay.	
-12'	90%	Grey to Buff coarse grained sandstone.	
-18'	0%		
-42'6"	10%	Clay and Sandstone.	
-53'	100%	Very Pale Grey Fine grained re-crystallized limestone.	
-61'6"	100%	" " " " " "	
-71'6"	100%	" " " " " "	
-76'3"	100%	" " " " " "	Occasional calcite.
-86'7"	100%	" " " " " "	veinings, stybolites.
-91'8"	100%	" " " " " "	
-96'10"	100%	" " " " " "	
-102'	100%	" " " " " "	102' limestone becoming darker
-107'1"	100%	108'-112' limestone darker	
-112'2"	100%	with fusulinids.	
-117'2"	100%	Limestone becomes lighter to 113'7". Then pale grey limestone.	Fusulinids rare.
-122'2"	100%	Pale grey limestone	Dark Calcite vein.
-126'	98%	Grey limestone.	
-131'	100%	Grey limestone.	
-137'	100%	Grey limestone.	Large calcite veins.
-143'	100%	Grey limestone.	
-148'	100%	Grey limestone.	
-153'	97%	Grey limestone.	Fusulinids 152'-153'4".
-157'	100%	Grey limestone.	Scattered fusulinids.
-162'8"	86%	Similar limestone broken.	Scattered fusulinids.

Borehole 3 cont'd.

Depth	Core Recovery	Description	Remarks
0-167'10"	98%	Grey limestone.	
-173'	100%	Grey limestone.	
-178'	100%	Grey limestone	175'6" Darker limestone with fusulinids.
-183'3"	100%	Grey limestone becoming pale grey.	Fusulinids 181'3".
-193'7"	100%	Very pale grey limestone.	
-198'10"	100%	" " " "	
-204'	100%	" " " "	
-208'2"	100%	" " " "	
-213'2"	100%	" " " "	
-218'2"	100%	" " " "	
-223'2"	95%	" " " " 219' dark grey to black limestone shale partings and calcite joints and veins.	? Plant remains in shales. Pyrite common Slickensides common. Graphitic partings. Dip 28°
-228'2"	100%	Similar.	
-233'8"	100%	Similar more argillaceous	Brachiopod - 233'6".
-239'	100%	Similar calcite vein.	238'6" Argillaceous parting dip 27°.
-244'2"	100%	Similar.	
-249'4"	100%	"	
-254'6"	100%	"	
-259'6"	100%	"	
-264'6"	100%	"	
-270'	100%	"	269' - ? Dip 38°.
-275'6"	95%	"	
-281'	95%	"	
-286'	100%	"	

Borehole 4 - Surface level: - 1,152 feet A. O. D.
Base of Overburden: - 980 feet A. O. D.
End of borehole: - 762 feet A. O. D

Depth	Core Recovery	Description	Remarks
0-172'6"	20%	Overburden, Clay and boulders of Sandstone. 15'-18' Coarse angular conglomerate boulder.	Poor core recovery.
-173'10"	95%	Pale grey massive recrystallised limestone	
-175'10"	80%	" " " "	Reduced to BX core.
-181'6"	100%	" " " "	
-195'9"	100%	" " " "	Calcite vein 4'.
-198'9"	95%	" " " "	
-200'	95%	" " " "	
-201'6"	98%	" " " "	
-207'	0%		Core bored away.
-214'	86%	Fine grey limestone calcite joints and veins.	
-219'	90%	Fine grey limestone.	
-222'	96%	" " "	
-232'	100%	" " "	Massive calcite veins.
-237'	100%	" " "	" " "
-246'3"	100%	" " "	237-242' slightly darker with fusulinids.
-256'3"	100%	" " "	Fusulinids 248'3", 252'.
-390'		Individual "draws" not seen by geologist. Core reported by geological assistant as similar, massive grey limestones. Occasional darker bands, no shale partings. Limestone becoming darker to 390'.	

NMLC Reamer Shells.

NXF Core bits and Reamer Shells - core size 2. 1/8".

BMLC Core bits and Reamer Shells - core size 1. 25/64".

NW, BW Reducer/Adaptors.

NX, BX Casing Caps.

Rod Bells and Taps.

Water and Lifting Swivels.

Sheave Block.

1700 ft. Plastic water supply hose.

2000 p. s. i. pressure hose.

Mud Tank.

Mud Mixer.

'Macobar' Bentonite drilling mud.

Jarring hammers.

Ground casing clamps.

Miscellaneous small hand tools.

Core boxes.

APPENDIX II

DRILLING AND EQUIPMENT USED

1. General

The drilling crew from Drilling and Minerals Sdn. Bhd., Kuala Lumpur, arrived at the access timber road, approximately $3\frac{1}{4}$ miles from the first drill site at midday of July 22nd.

After arriving at the first site all work was smoothly and efficiently carried out. The projected figure of 90 feet per three shift drilling day was achieved on most days. Core recovery in the limestone was excellent and fully up to expectations.

The drilling team working in three shifts, consisted of 1 clerk, 1 foreman driller, 1 fitter, 3 drillers and 6 drilling assistants.

All holes were drilled vertically, total of 940 feet being drilled.

2. Drilling Equipment

1 Boyles Brothers BBS10 drilling machine - fitted with hydraulic swivel head and driven by a Perkins P3 diesel engine.

1 Mono Water Supply Pump driven by a Lister diesel engine.

1 Bean Royal Control Pump with Deutz diesel engine.

20 ft. of H casing for collaring.

100 ft. of NX (i. d. 3. 1/16") casing for hole lining.

250 ft. of BX (i. d. 2. 15/32") casing for hole lining.

400 ft. of BW (o. d. 2. 1/8") drill rods.

1 NWF 10 ft. Double tube core barrel with swivel head.

1 NMLC 5 ft. Triple tube core barrel.

1 BMLC 5 ft. Triple tube core barrel.

NX casing bits and shoes.

BX casing bits and shoes.

NMLC core bits (Step and Flat face) - core size 2. 3/64".

KEY TO ILLUSTRATIONS

OVERBURDEN sandstone boulders, soil, clay, etc...

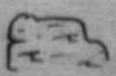
DOHOL METASEDIMENTS OVERLYING LIMESTONE siltstones, sandy mudstones etc...

UPPER SUMALAYANG LIMESTONE medium grey, pale grey to almost white, massive limestones.

LOWER SUMALAYANG LIMESTONE black to medium grey, bedded limestones with argillaceous partings.

DOHOL METASEDIMENTS BELOW LIMESTONE dark grey to black indurated shales and mudstones often with calcareous bands and lenses.

Calculated tonnage of limestone shown on profiles.



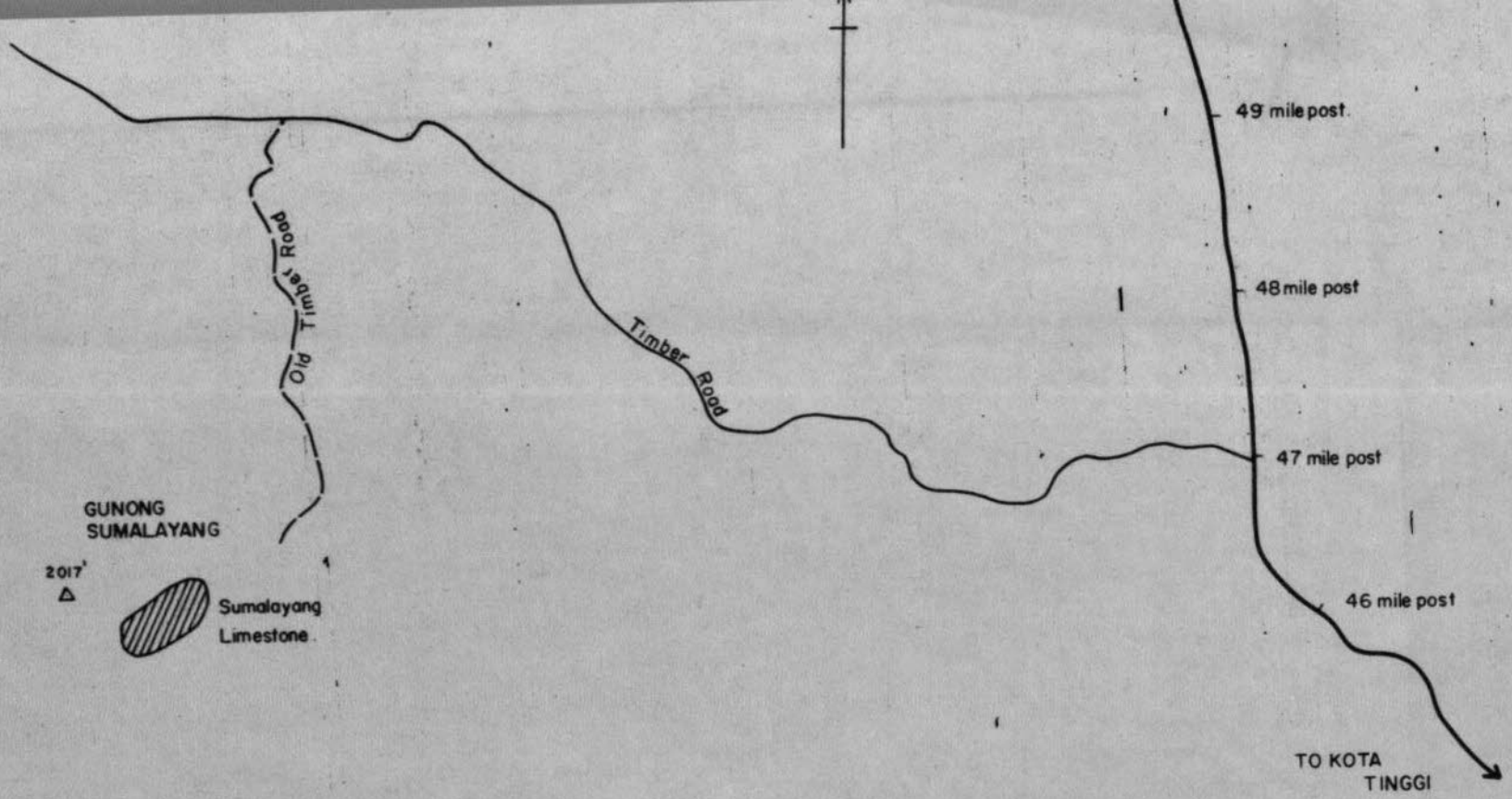
Rock outcrop, shown on profiles.

Borehole.

Stream.

Timber road.

Loc.(18) Refers to geological observation (see text section 4.2.).



LOCATION MAP – SUMALAYANG LIMESTONE

Scale 1" = 1 Mile.

Geological Map of the Sumalayang Limestone

LEGEND

- +(2) Geological Observations (see Text)
- ▪ 3 Pits and Trenches
- ⊙ Borehole (with surface level A.O.D.)
- Rock Outcrop
- 30° Sediments - Dip and Strike Direction
- •T Tufa Deposit
- Fault
- Outcrop Limits of Upper Massive Limestone
- Outcrop of Base of Lower Limestone with shale partings
- -500- Strike Lines on Base of Upper Massive Limestone
- (C) Areas of Main Outcrops (see Text)
- Rentis Line
- ⊗ Rentis Line Zero Point
- Stream
- Timber Track (showing Gradient)
- Drill Track
- -1000- Form Lines

Broken lines show inferred data

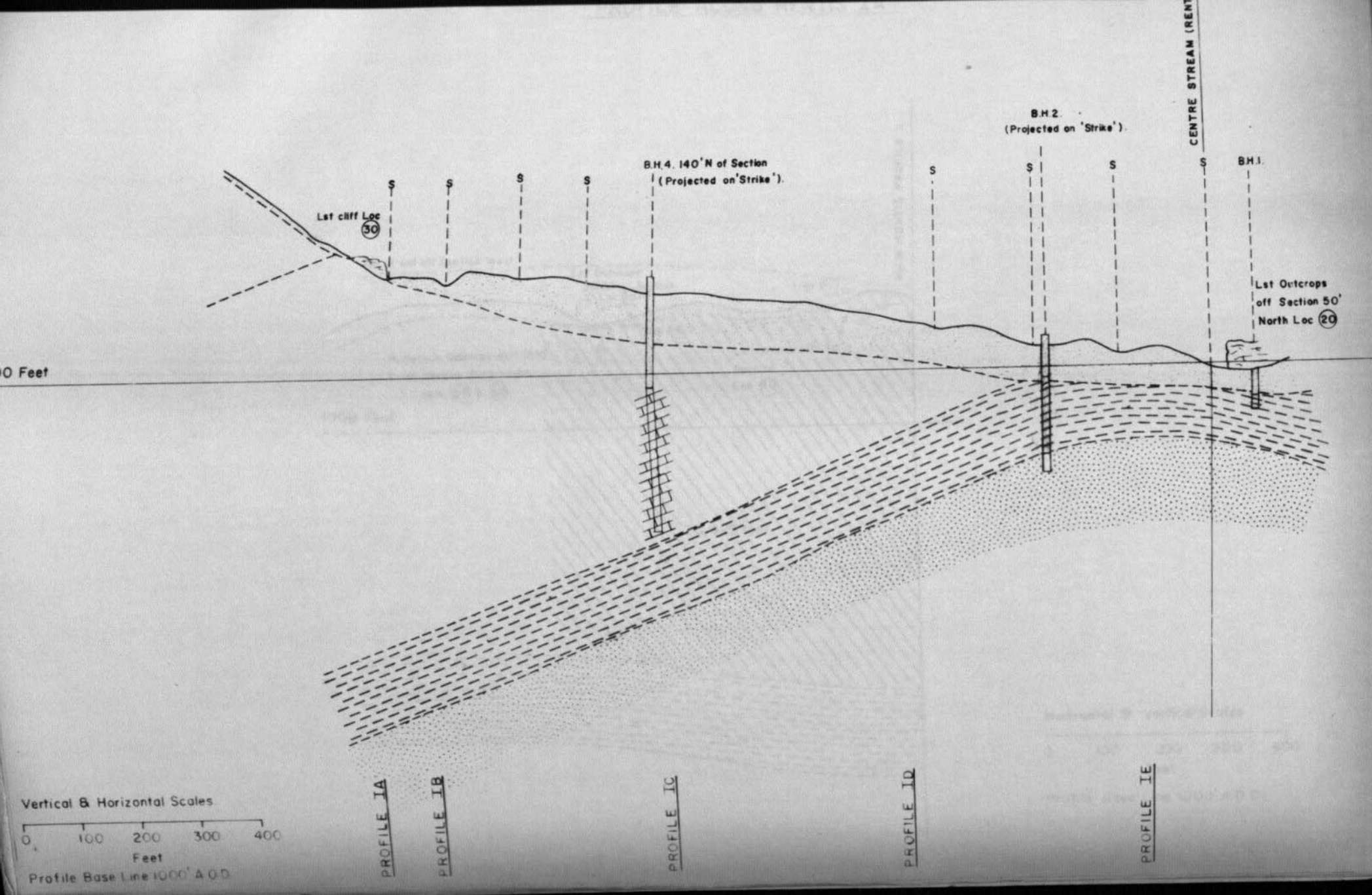
RENTIS IIE
RENTIS IID
RENTIS IIC
MAIN RENTIS II
RENTIS IIB
RENTIS IIA
RENTIS IB
MAIN RENTIS I
RENTIS IC
RENTIS ID
RENTIS IA
RENTIS IE

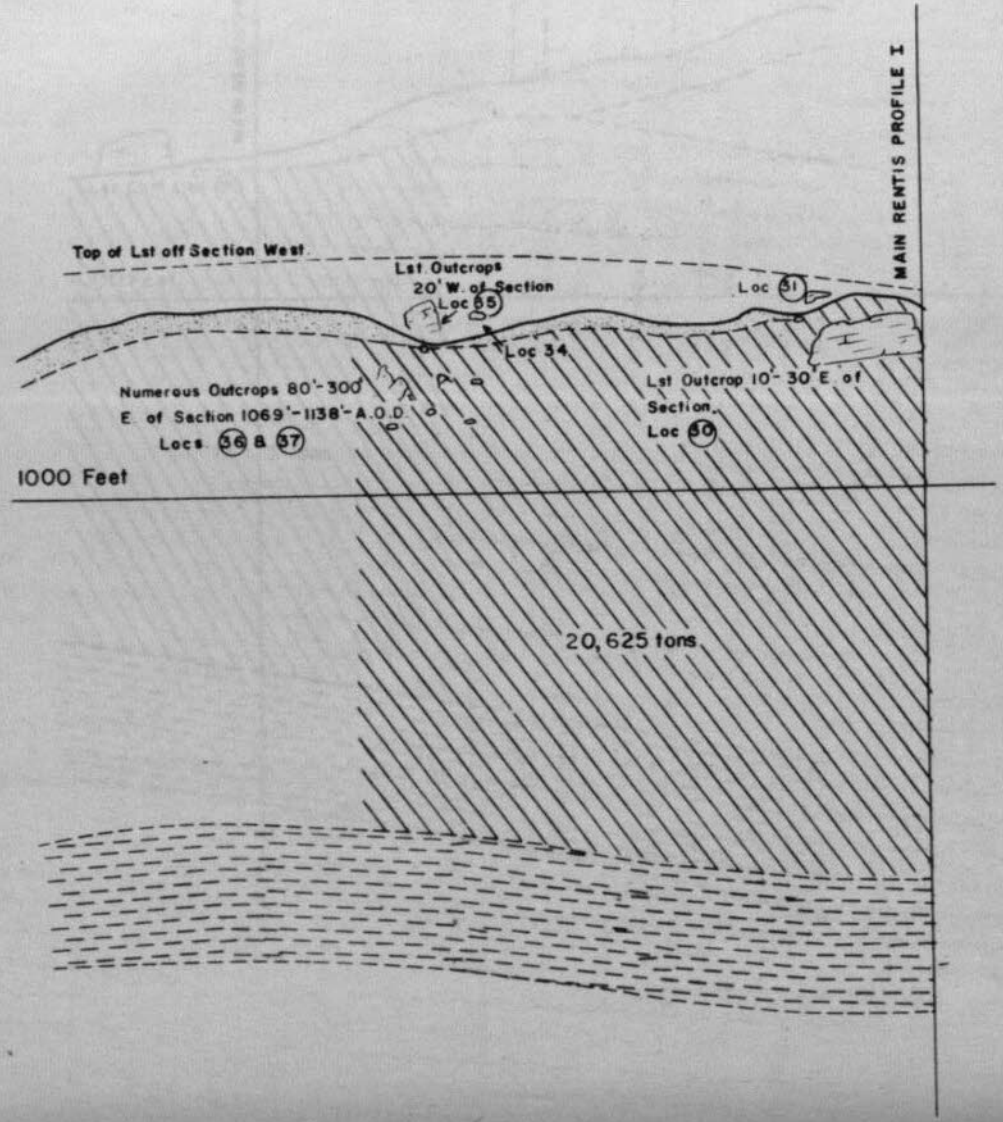
BH1 986 A.O.D.
BH2 1043 A.O.D.
BH3 1065 A.O.D.
BH4 1152 A.O.D.

Track to S. Sedili
BASE CAMP
S. Sedili

SCALE 200 FEET TO 1 INCH

0 100 200 300 400 FEET


B.H.2.
(Projected on 'Strike').
CENTRE STREAM (REN
B.H.1.
B.H.4. 140' N of Section
(Projected on 'Strike').
Lst cliff Loc
30
Lst Outcrops
off Section 50'
North Loc 20
0 Feet
Vertical & Horizontal Scales
0 100 200 300 400
Feet
Profile Base Line 1000' A.O.D.
PROFILE IA
PROFILE IB
PROFILE IC
PROFILE ID
PROFILE IE

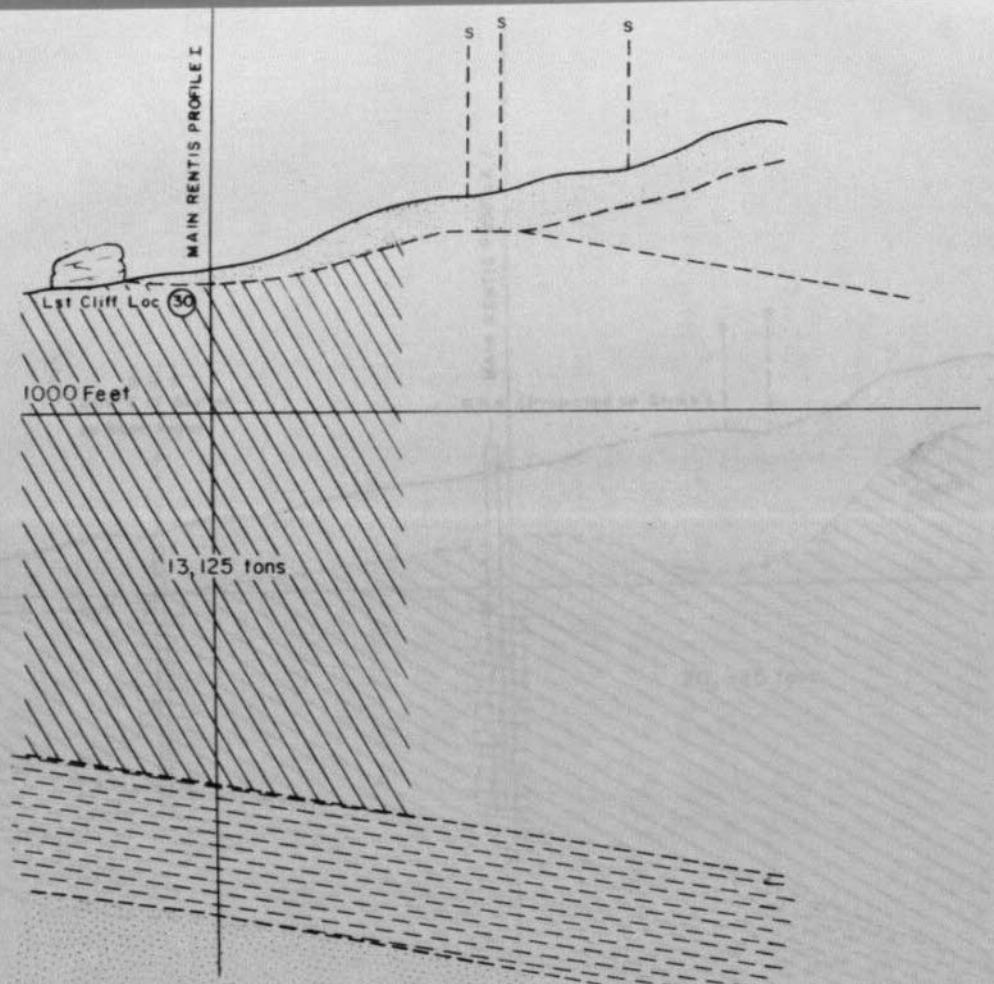


Horizontal & Vertical Scales

0 100 200 300 400

Feet

Profile Base Line 1000' A.O.D.

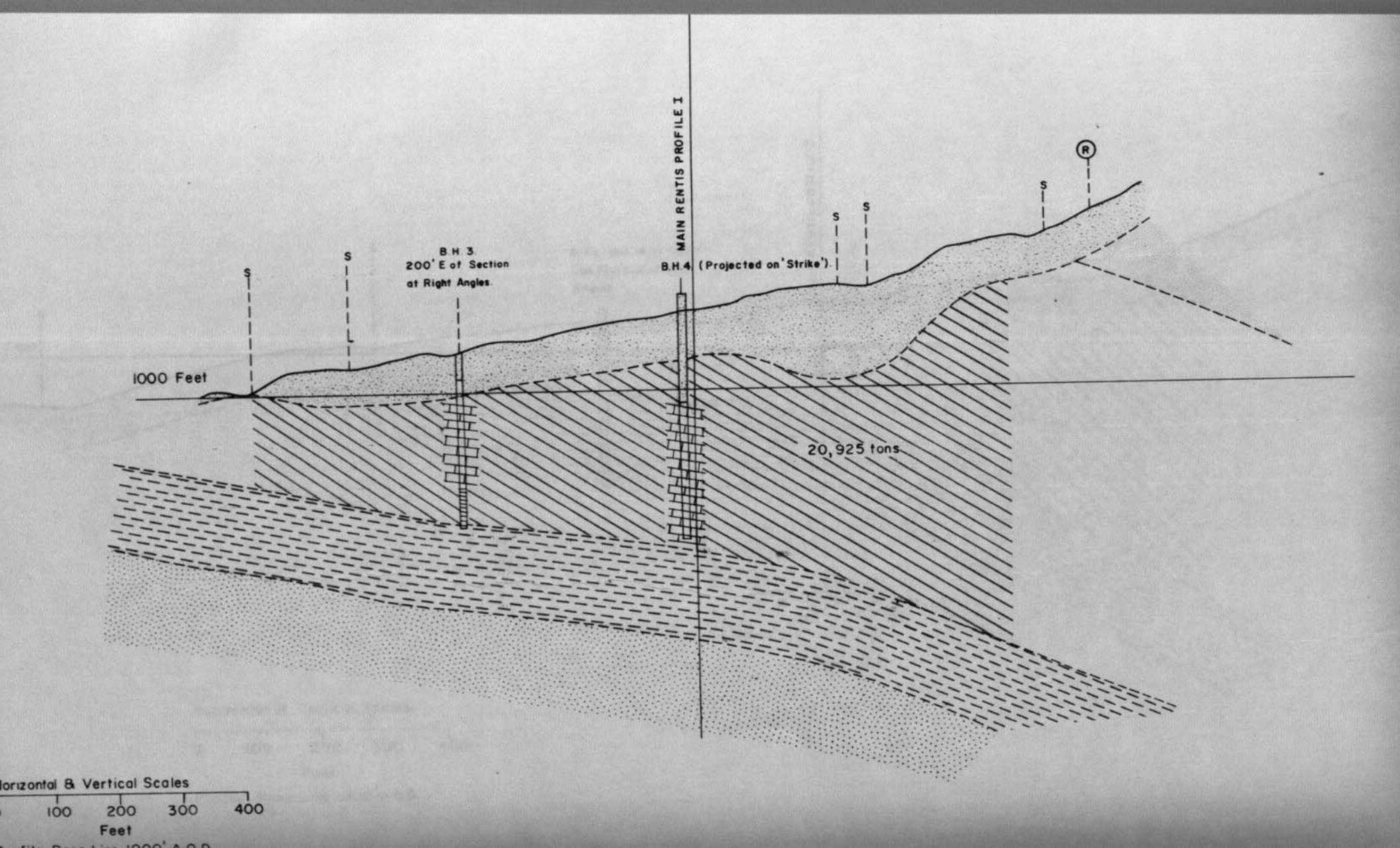


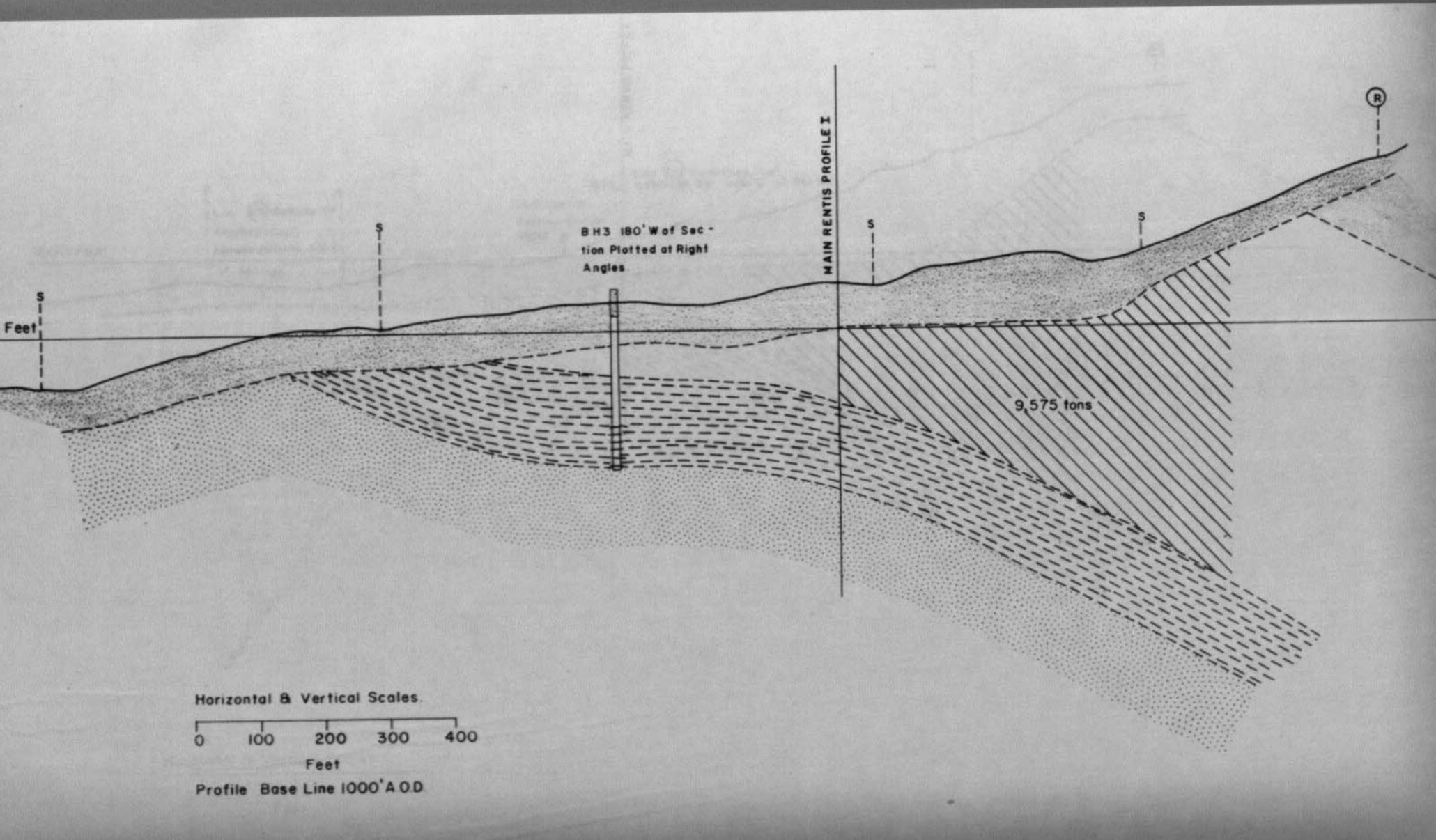
Horizontal & Vertical Scales.

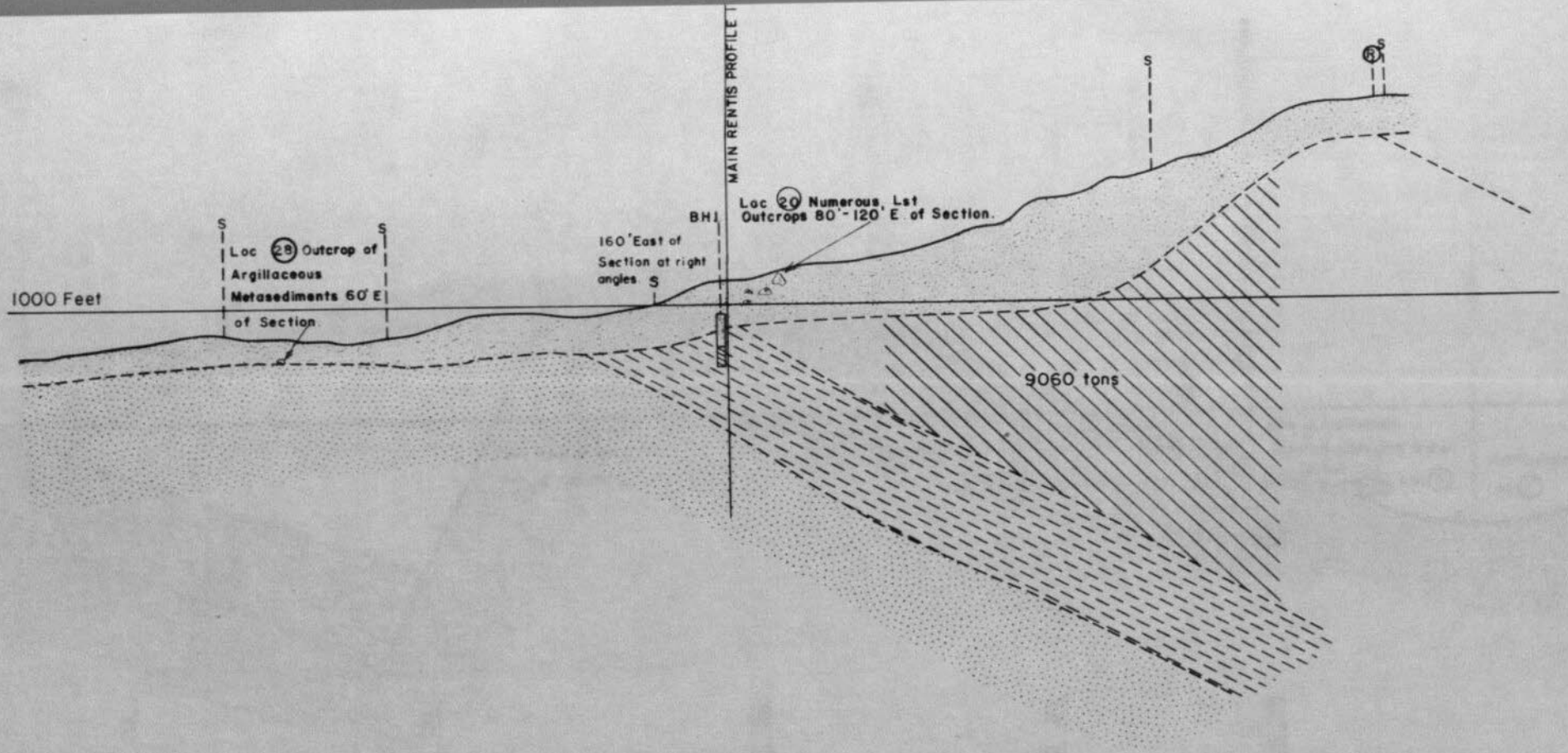
0 100 200 300 400

Feet

Profile Base Line 1000' A.O.D.


MAIN RENTIS PROFILE I
B.H. 3.
200' E of Section
at Right Angles.
B.H. 4. (Projected on 'Strike').
S
S
S
S
S
R
1000 Feet
20,925 tons
Horizontal & Vertical Scales
100
200
300
400
Feet


MAIN RENTIS PROFILE I
BH3 180' W of Sec - tion Plotted at Right Angles
S
S
S
S
R
Feet
9,575 tons
Horizontal & Vertical Scales.
0 100 200 300 400
Feet
Profile Base Line 1000' A.O.D.

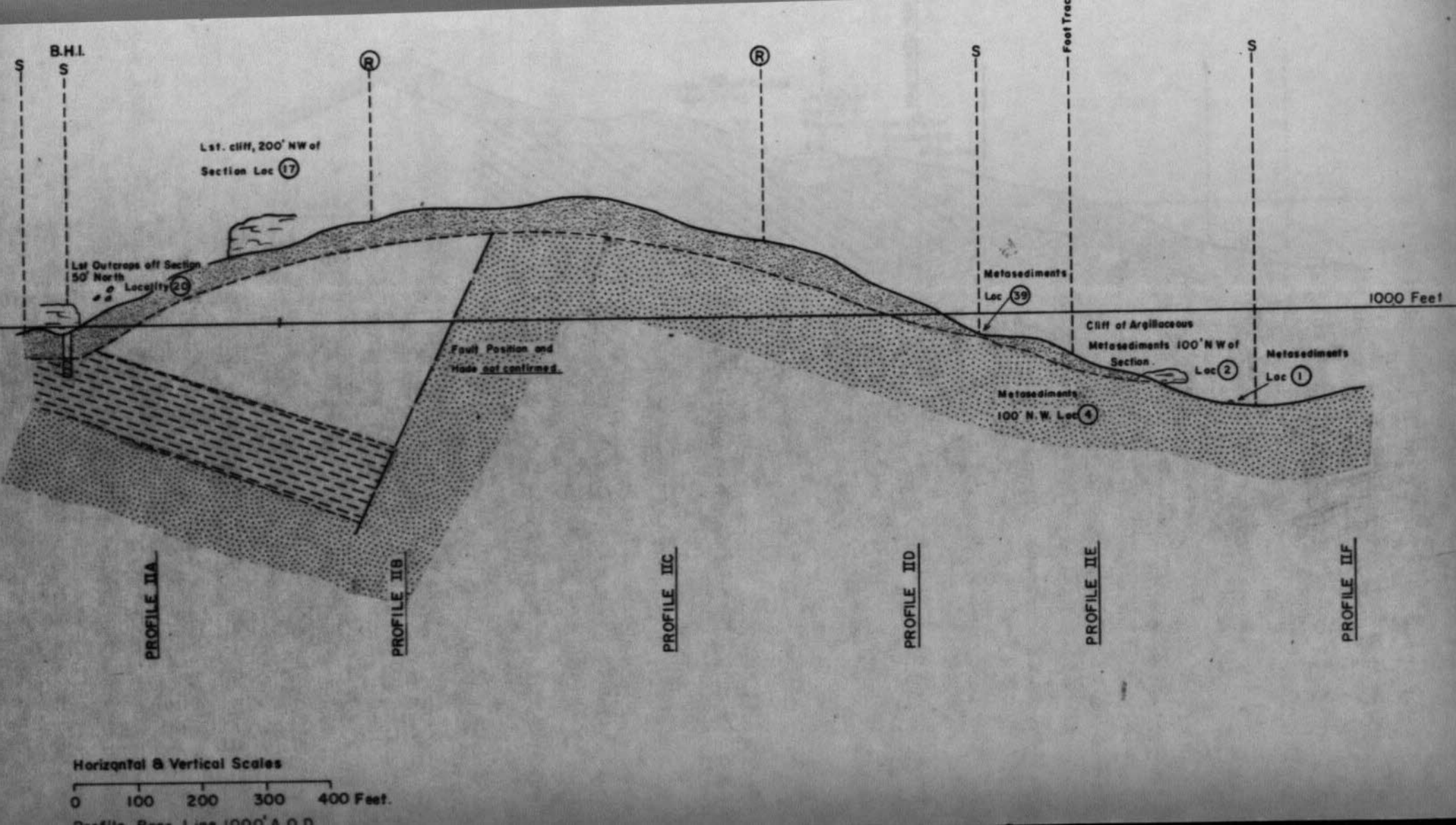


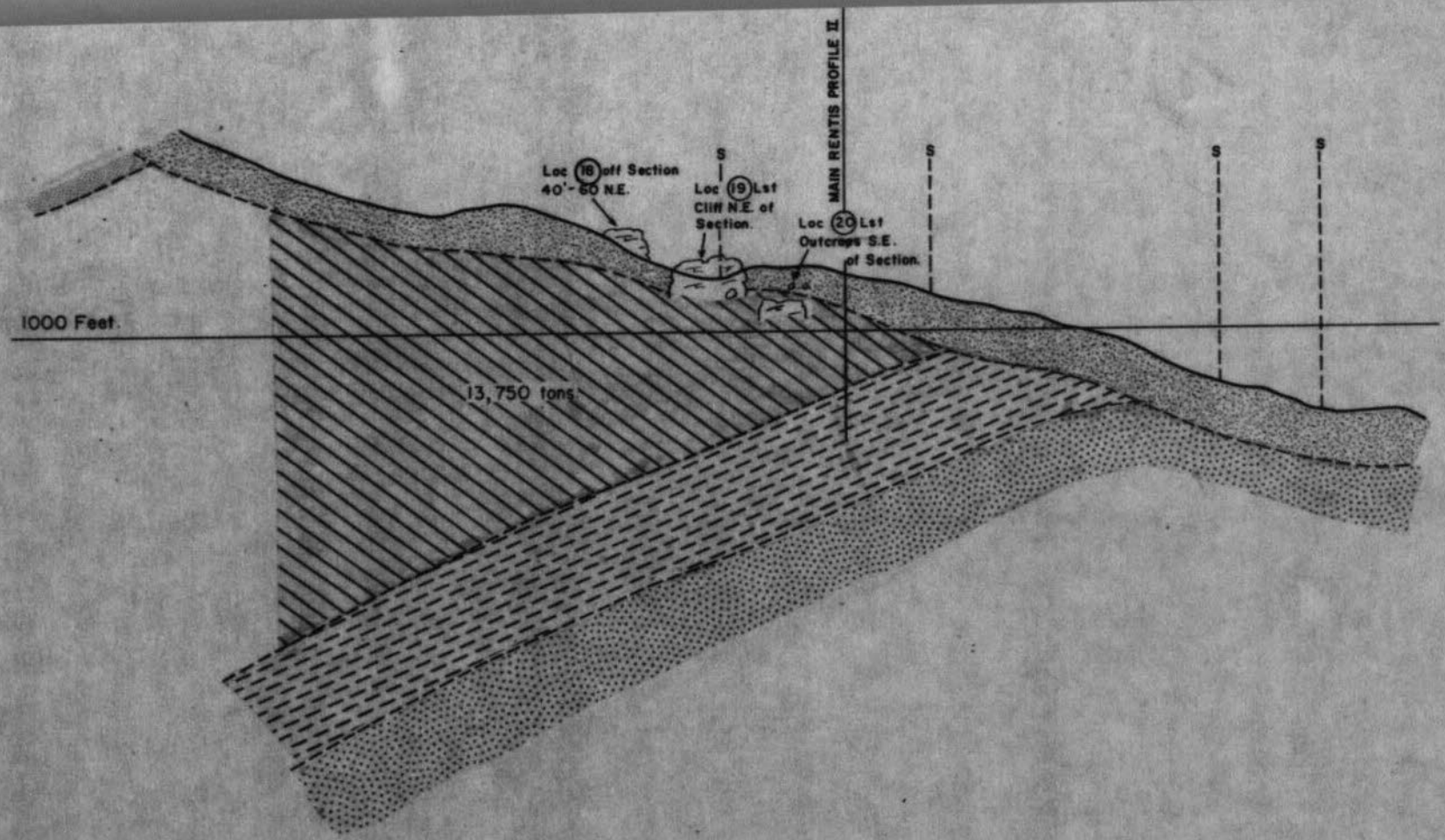
Horizontal & Vertical Scales

0 100 200 300 400

Feet

Profile Base Line 1000' A O D


B.H.I.
S
S
R
R
S
Foot Trac
S
Lst. cliff, 200' NW of
Section Loc (17)
Lst Outcrops off Section
50' North
Locality (20)
Metasediments
Loc (39)
1000 Feet
Cliff of Argillaceous
Metasediments 100' N W of
Section.
Loc (2)
Metasediments
Loc (1)
Fault Position and
Made not confirmed.
Metasediments
100' N.W. Loc (4)
PROFILE IIA
PROFILE IIB
PROFILE IIC
PROFILE IID
PROFILE IIE
PROFILE IIF
Horizontal & Vertical Scales
0 100 200 300 400 Feet.

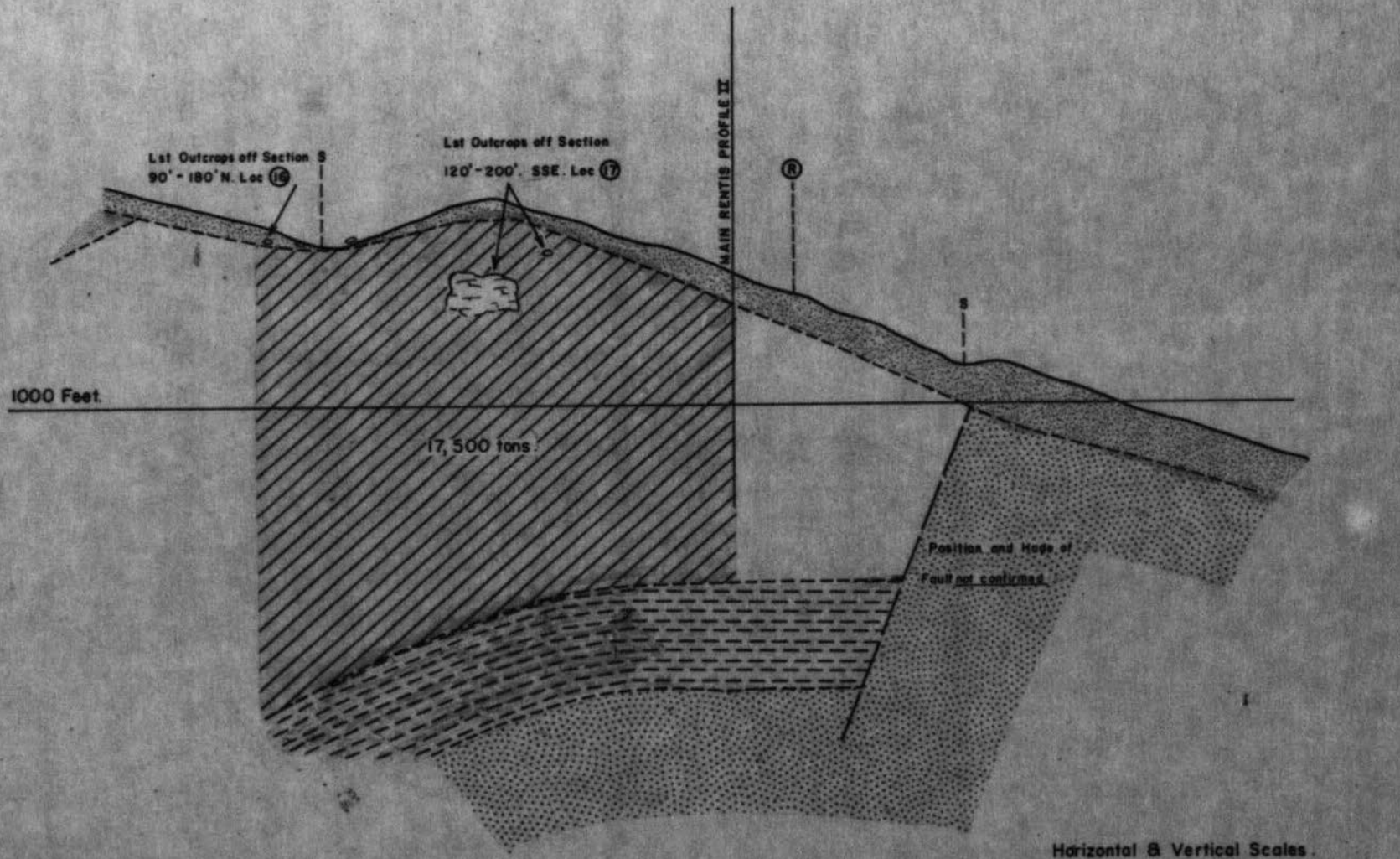


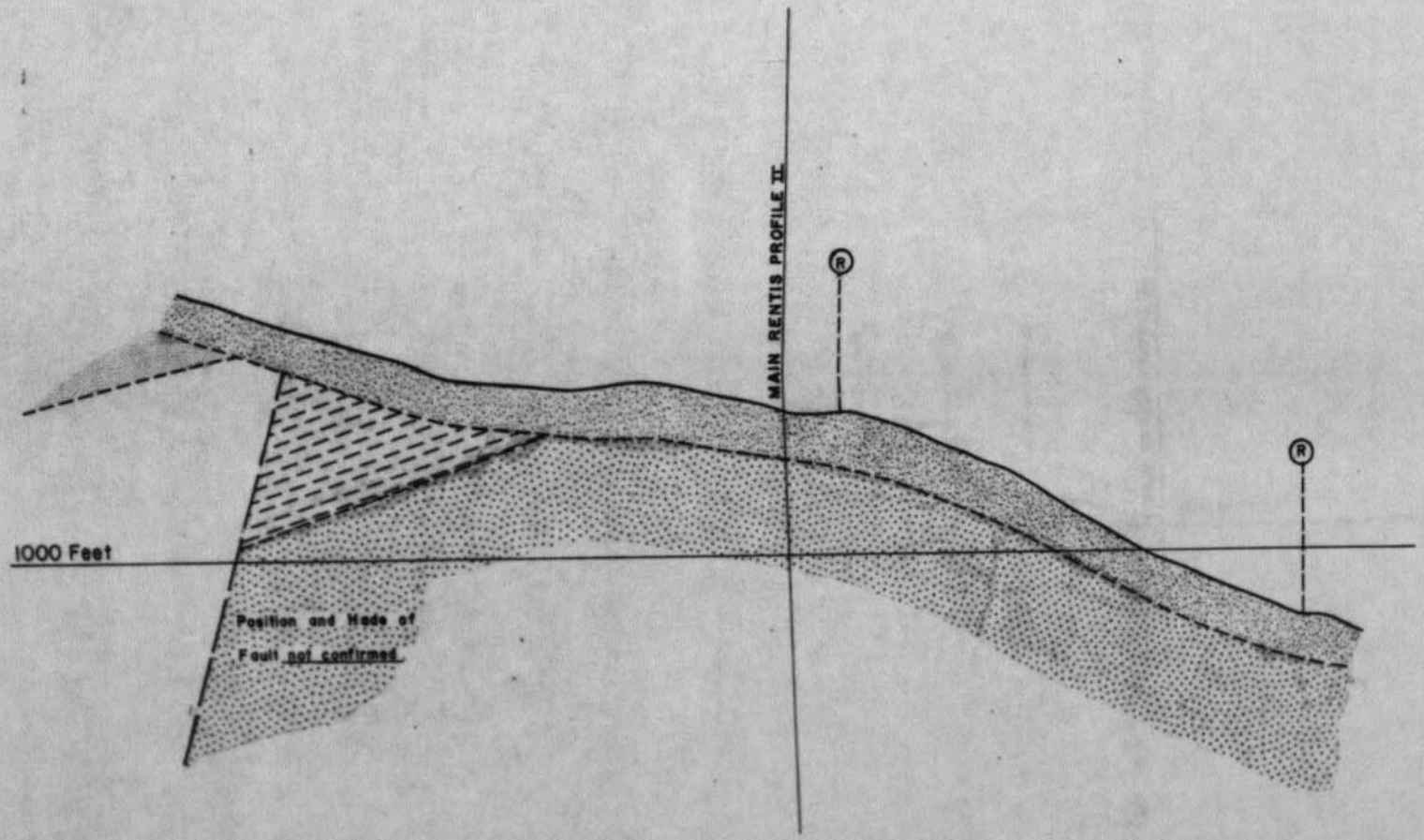
Horizon & Vertical Scales.

0 100 200 300 400

Feet.

Profile Base Line 1000' A.O.D.

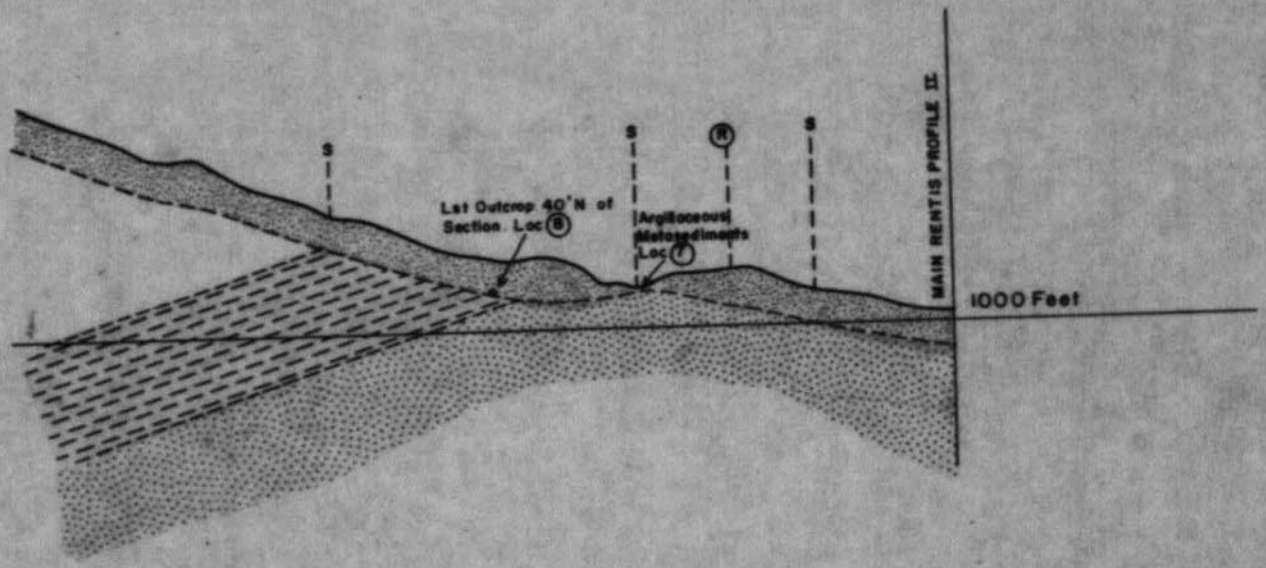

Lst Outcrops off Section S
90' - 180' N. Loc (16)
Lst Outcrops off Section
120' - 200', SSE. Loc (17)
MAIN RENTIS PROFILE II
R
S
1000 Feet.
17,500 tons.
Position and Hade of
Fault not confirmed.
Horizontal & Vertical Scales.
0
100
200
300
400
Feet.
Profile Base Line 1000' A.O.D.



Horizontal & Vertical Scales.

0 100 200 300 400 Feet

Profile Base Line 1000' A.O.D.

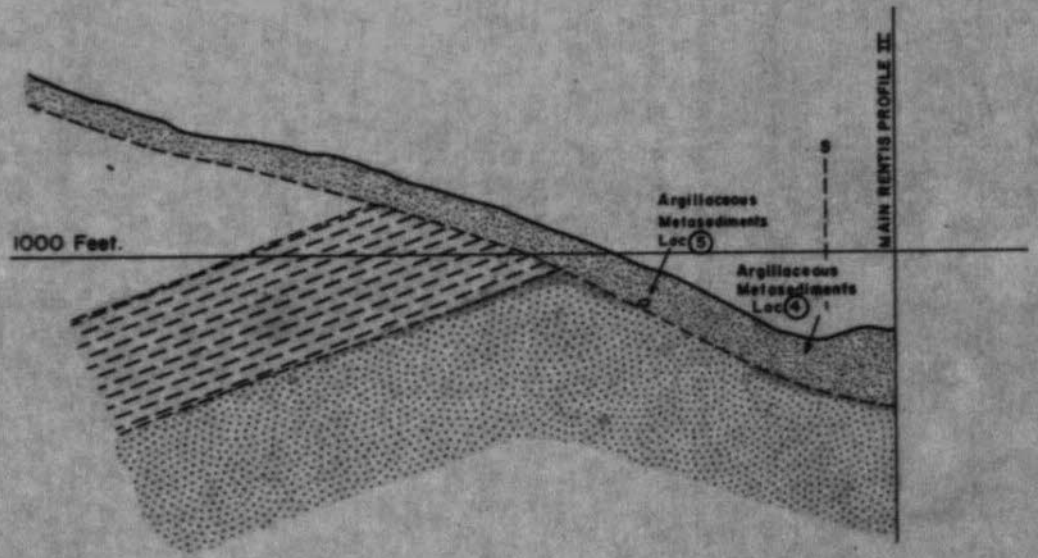


Horizontal & Vertical Scales.

0 100 200 300 400

Feet

Profile Base Line 1000' A.O.D.

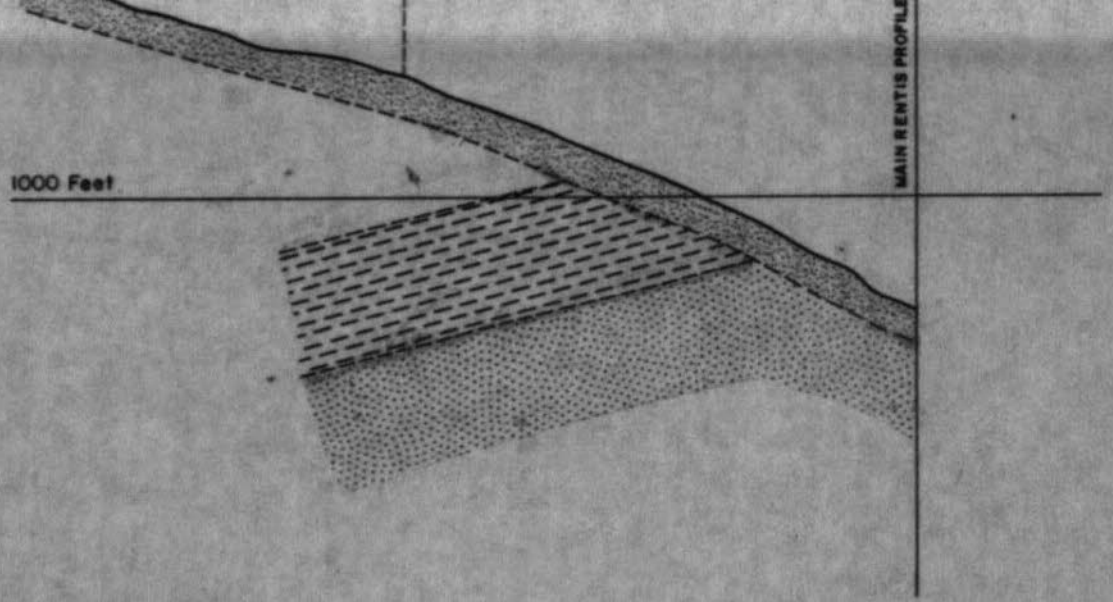


Horizontal & Vertical Scales.

0 100 200 300 400

Feet

Profile Base Line 1000' A.O.D.



Horizontal & Vertical Scales.

0 100 200 300 400

Feet

Profile Base Line 1000' A.O.D.