DEPARTMENT OF
MINERALS AND ENERGY

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS



Record 1974/23

# LUNAR LASER RANGER SITE FOUNDATION INVESTIGATION, ORRORAL VALLEY, A.C.T., 1973

Introduction & Summary

Part 1 Seismic Refraction Survey

by B.H. Dolan

Part 2 Geological Technical Note

by G.B. Simpson

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## Introduction & Summary

This record contains the results of seismic refraction investigations (Part 1) carried out at chosen sites for a Lunar Laser Ranger installation near the Orroral Tracking Station, A.C.T., and the report (Part 2) of the geological inspection of the most favoured site, referred to as the collimation-tower site.

Part 1, dealing with the refraction results, was written before the geological inspection (Part 2) took place. It is necessary to read both parts to obtain a full appreciation of the site evaluation.

Significant tilting of the granite tor selected for the installation seems likely to occur during the operational life of the Lunar Laser Ranger. Further site investigation and the installation of tiltmeters for long-term monitoring of boulder movement are recommended.

# PART 1 SEISMIC REFRACTION SURVEY

## 1. INTRODUCTION

The Division of National Mapping of the Department of Minerals and Energy proposes to install a Lunar Laser Ranger in the A.C.T.

Three sites near the Orroral Tracking Station have been chosen for further investigation. A necessary prerequisite for the site is that it provide a sound foundation with no local subsidence or other movement. To assist in the assessment of the sites the Bureau of Mineral Resources (BMR) was asked to carry out an engineering seismic refraction survey on the sites; the object of the survey was to find the depth to a solid foundation at these sites.

The work was completed by two parties from the Engineering Geophysics group. The first party in April 1973 consisted of B.H. Dolan (party leader), M.I. McDowell, D.C. Ramsay (geophysicists), and S.J. Hall (field hand). The second party carried out two other traverses in July 1973; it consisted of F.J. Taylor (party leader), F. Michail, M.I. McDowell (geophysicists), and R. Cherry (shooter).

## 2. GEOLOGY

In the areas surveyed, bedrock consists of contaminated granodiorite (Snelling, 1960). The Orroral Valley itself is a mature alluviated valley trending in a south-easterly direction. The favoured site is near a tracking-station collimation tower, well up the south-western face of the valley at the top of a steep slope and separated from the southwestern peaks by a shallow depression trending roughly parallel to the valley.

## 3. METHODS AND EQUIPMENT

The depth to bedrock and nature of the overburden were investigated using a 24-channel SIE refraction seismograph with TIC 20-Hz geophones. A geophone spacing of 2 m was employed on all traverses. Charges were fired in line with the spread at distances of 1 and 40 m from it. A shot was fired at the centre of each spread to give additional information on the overburden.

Results were interpreted by the 'reciprocal method' (Hawkins, 1961), which gives the depth to bedrock at each geophone position and the depth to formations with different seismic velocities underneath the end and centre shot holes. The longitudinal seismic velocity was measured in the laboratory on several samples taken from the site.

## 4. RESULTS

The location of the survey area is shown in Plate 1, and the locations of traverses in Plates 2 and 3. The sites investigated were (1) down in the valley next to the proposed site of the Baker Nunn Camera (Traverse A), (2) on a rocky outcrop near the collimation tower (Traverses B and E), and (3) in a small depression about 60 m southwest of the collimation tower (Traverse C). Traverse D was surveyed in order to obtain further knowledge of the nature of the depression to the west of the tower. Seismic cross-sections are shown in Plates 4 (Traverses A, B, C, and D) and 5 (Traverse E).

Along Traverse A (valley site) the depth to bedrock ranged from 8 to 17 m. The overlying material had average velocities of 550 to 850 m/s and would consist of highly weathered rock and gravel interspersed with some boulders of fresher rock. This material would not form a solid foundation for the proposed installation. The bedrock has a seismic velocity of 3200 m/s to 4400 m/s. The 4400 m/s layer should provide a hard solid foundation.

Along Traverse B and much of Traverse E (collimation-tower site) bedrock velocities of 3000 and 3200 m/s were encountered at a depth of 2 m or less. Apparent depths to bedrock of up to 3 m were recorded even though the geophones were placed directly on large boulders of slightly weathered granodiorite. This indicates that there is weathered material between the boulders on which the geophones were placed and the underlying rock.

Traverse E shows that there is a steady increase in the depth of weathering to the south, increasing to 8 m about 30 m from the collimation tower.

Traverse C (collimation-tower site - southwest) shows that there is a rapid increase in the depth of weathering southwest of the collimation tower. The depth to bedrock increases to over 20 m only 30 metres from the proposed site near the collimation tower. The increase in depth of weathering is also accompanied by a large decrease in bedrock velocity indicating more severely weathered and jointed bedrock.

Traverse D shows that the depth of weathered material decreases on the western side of the depression in the area.

The laboratory measurements of longitudinal seismic velocity gave values of from 5100 m/s to 5700 m/s for the rock pieces collected from the collimation-tower site. The difference between average in-situ bedrock velocity (between 2500 and 4400 m/sec) and laboratory measurements indicates that the rock mass in situ has extensively weathered joints.

## 5. CONCLUSIONS

Of the three sites examined the depth to bedrock is least at the collimation-tower site, which is the favoured site. Over 8 m of highly weathered rock would have to be removed from the other sites to reach bedrock. In order to confirm the existence of significant zones of weathering beneath the boulders on the collimation-tower site it would be necessary to obtain a core from a diamond-drill hole. Because of the nature of the survey results and the topography, a geological investigation of the site is recommended.

## 6. REFERENCES

HAWKINS, L.V., 1961 - Reciprocal method of routine seismic refraction investigations. Geophysics, 26(6), 80619.

SNELLING, N.J., 1960 - The geology and petrology of the Murrumbidgee Batholith. Quart. J. geol. Soc. Lond., 116, 187-217.

PART 2

## GEOLOGICAL TECHNICAL NOTE

On Inspection of Lunar Laser Ranger Site - Orroral Valley, A.C.T., on Friday 16 November 1973

Present - Dr P. Morgan (National Mapping) M.G. Allen, Dr E. J. Polak, B.H. Dolan, G.B. Simpson (BMR)

### Introduction

The proposed Lunar Laser Ranger site (referred to as like collimation-tower site in Part 1) is on a ridge of granodiorite to the west of the Space Tracking and Data Acquisition Network (STADAN) installation. The ridge is part of the upper western slopes of the Orroral Valley and trends parallel to the valley. To the west of the ridge is a saddle feature also parallel to the valley. To the west of the ridge is a saddle feature also parallel to the main valley which is probably fault-defined; it has a prominent (Traverses C and D). The slopes from the ridge to the main valley floor are steep and of similar gradient to the natural slopes throughout most of the valley. The top of the ridge shows tor development and it is on one of the larger tors that the Ranger is to be sited.

Plate 6 shows the approximate position of tors at the site. The Ranger is to be sited on 'tor A'; 'tor C' forms the foundation for the collimation tower.

### Description of structure and settlement limits

The Ranger will be mounted on a pedestal structure and will have a total weight of about 8 tons; it will be housed in a concrete-block building about 10 m in diameter and 13 m high with an aluminium dome forming the roof. The total weight is estimated to be about 30 to 40 tons.

Lateral displacements of the Ranger are not critical as these can be measured and allowed for. Tilting movements to a limit of 0.1 second of arc can be tolerated. In terms of settlement this represents a differential settlement of about 0.3 mm across the proposed foundations. At the time of inspection about 45 cm of rock had been removed from the top of tor A by blasting, to give a flat surface. It is proposed to excavate a triangular trend, about 45 cm deep, for the foundations of the structure.

## Geology

The rock at the site is a coarse-grained granodiorite with plagioclase feldspar phenocrysts up to 6 cm in length. The rock shows a coarse foliation trending 90/360.

Three prominent joint sets were measured at the site; 80N/260, 90/360, and horizontal. These joint sets are continuous and to a large extent define the shape of the tors. Two weathered zones were observed and these are shown in Plate 6. It should be noted that gum trees with trunks up to 0.5 m diameter are growing on the weathered zones.

The excavated surface of tor A shows no continuous joints but does show discontinuous incipient joints trending 80N/260. These joints are weathered and the rocks adjacent to them are limonite-stained for up to 15 cm either side. The horizontal joints have spacing of between 1 m and 6 m, and, where exposed, are weathered and open. The joints at the base of tors B and C are well exposed. About 35 cm of weathered material has been removed from these joints leaving the joints open. These open joints extend to about 5 m under the tors.

## Seismic results

The seismic traverses across the site gave an average longitudinal velocity of 3000 m/s, which is considerably lower than the velocity that would be expected in tightly jointed granite.

The low velocity is attributed to weathered material between the tors. Whilst it cannot be determined by seismic means that low velocity material is also present under the tors, the nature of weathered granite indicates that it is to be expected.

## Stability of foundations

The reduced seismic velocity and the distribution and continuity of weathered joints at the site indicate that tor A is capable of moving independently of the surrounding rocks. Movement may occur as a result of the following processes:

1) Loading of tor A

The weight of the structure will be small compared with the probable total weight of tor A. However, some movement of the tor may occur especially if the tor is in a critical state of equilibrium. The size of the movements will depend on the configuration and weathering of joints beneath the tor, and the siting of the structure.

2) Turning effect of structure

If the base of the tor is formed by weathered or open joints which are not horizontal, a couple may be set up about the point of contact tending to produce a tilting movement of the tor.

Sliding of the tor may also result in this situation when loaded by the structure.

3) Effect of groundwater

The foundations of the Ranger are well above the watertable. Run-off at the site will be channelled between the tors and will enter the weathered material and open joints which are expected to have a high permeability. The movement of water through the weathered zones removes material in solution and in suspension thus weakening the weathered-zone, and in the long term causing settlement.

4) Removal of trees

The trees at the site probable have extensive root systems in the weathered joints. These trees have recently been cut down and voids may be left when the roots die back. This may cause some channelling of groundwater within the weathered rock and could induce settlement of the foundations.

5) Movement of the surrounding tors

Tors B and C may be considered to be in a critical position. They are situated at the top of the steep valley slopes and are underlain by open joints. The critical state of these tors is indicated by the drill-induced crack which formed across tor C when the anchorage for the collimation-tower guy wires was being installed. The crack is up to 4 cm wide and 15 m long. Movement of tors B and C may cause movement of tor A, either directly or by loosening the weathered material.

Conclusions

1. The processes listed above are likely to cause tilting of tor A in excess of that which can be tolerated during the operational life of the Ranger (between 20 and 40 years).

2. Insufficient data on the nature and extent of jointing and weathering beneath tor A are available to assess the magnitude of probable movements or to assess the possibility of stabilizing the foundations.

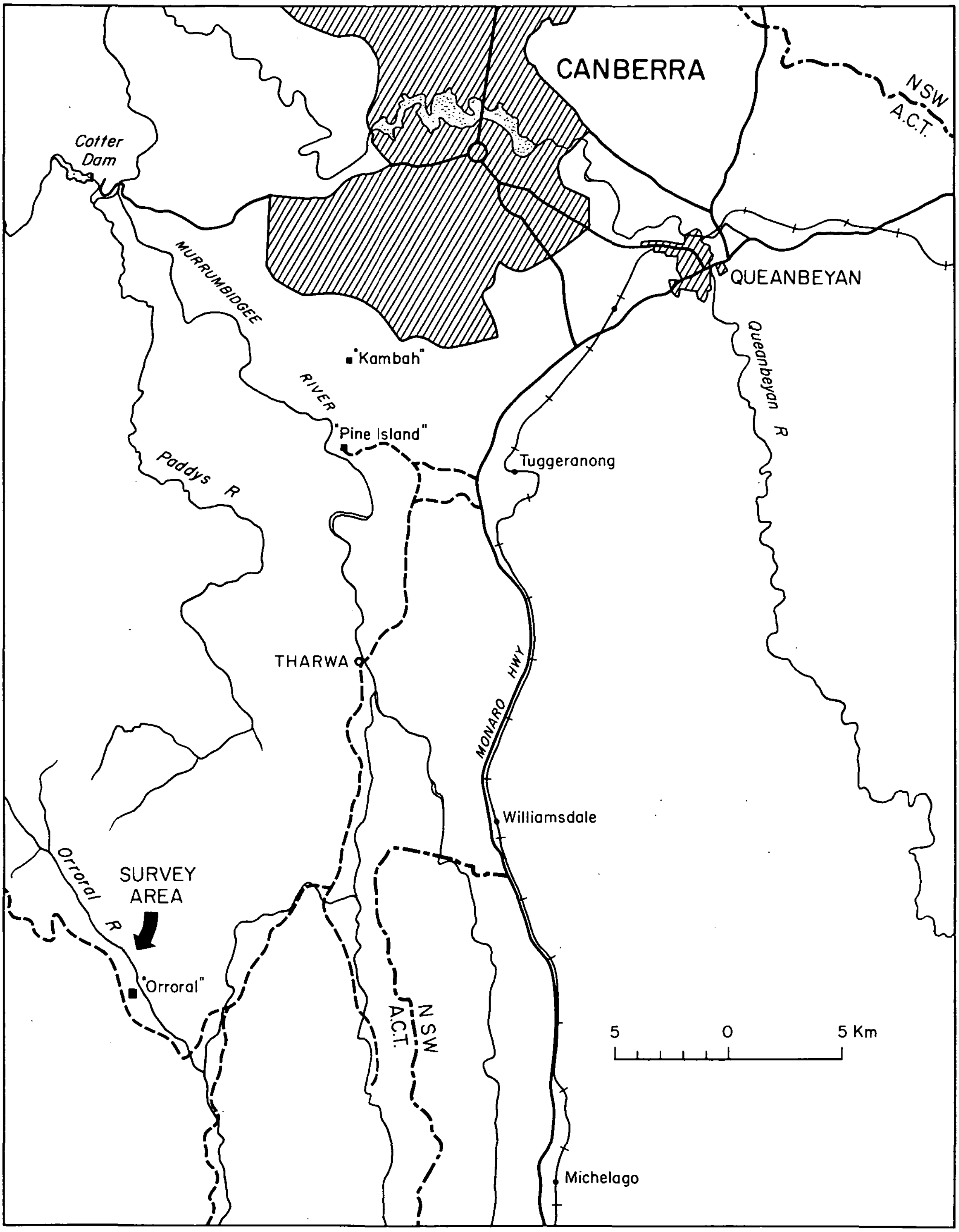
3. In order to fully ascertain the foundation conditions that exist at the site it would be necessary to undertake further geological mapping, diamond drilling, and possibly further geophysical surveys.

Recommendations

1. A Foundation Engineer, Engineering Geologist, and Geophysicist be consulted to plan and assess the results of additional investigations, and recommend possible foundation treatment.

2. Whether or not foundation treatment is undertaken, it would seem essential that tiltmeters be installed at the site to monitor any movements which might occur.

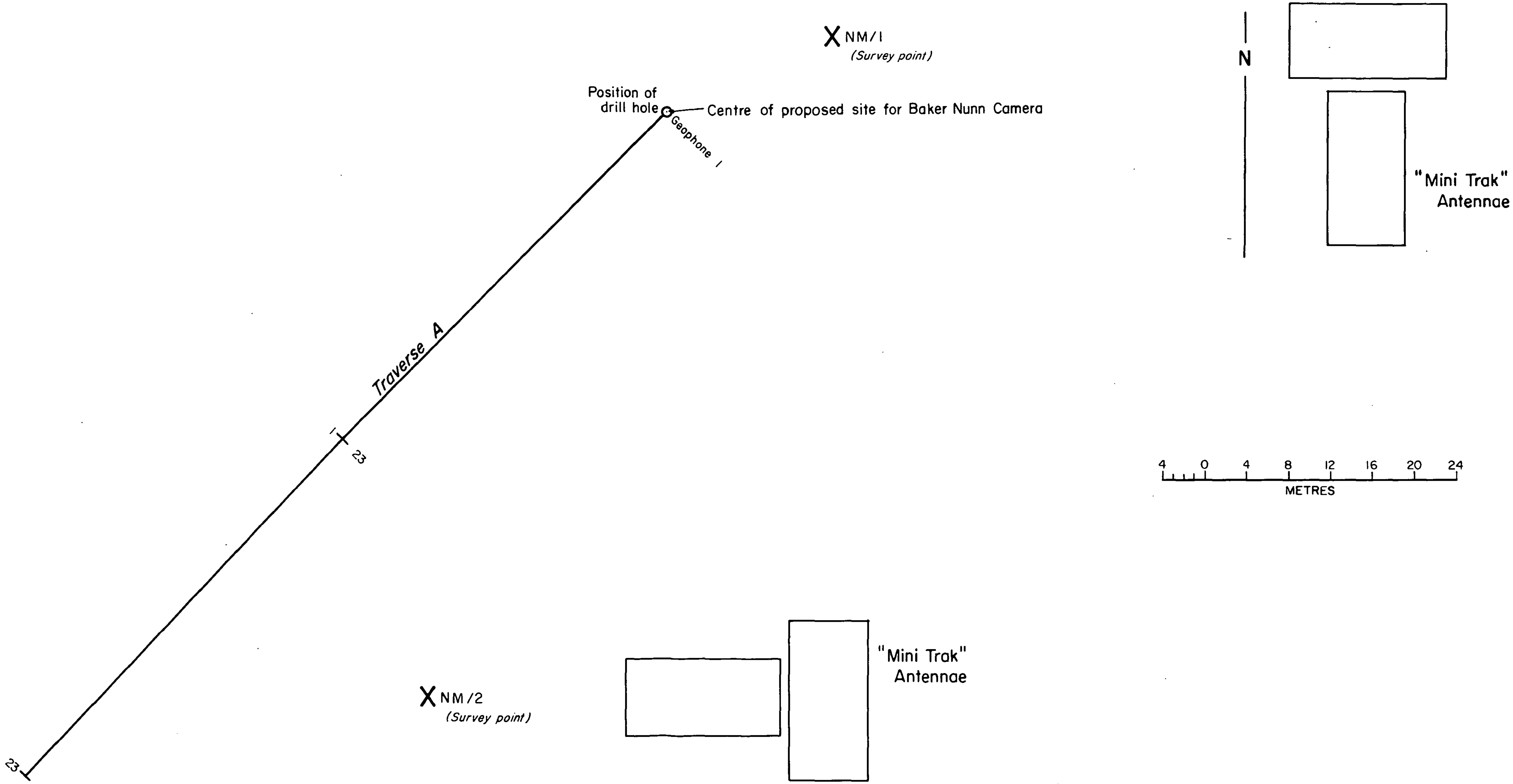
# PLATE 1




## LOCALITY MAP

*To Accompany Record No. 1974/23*

I55/B5-191A

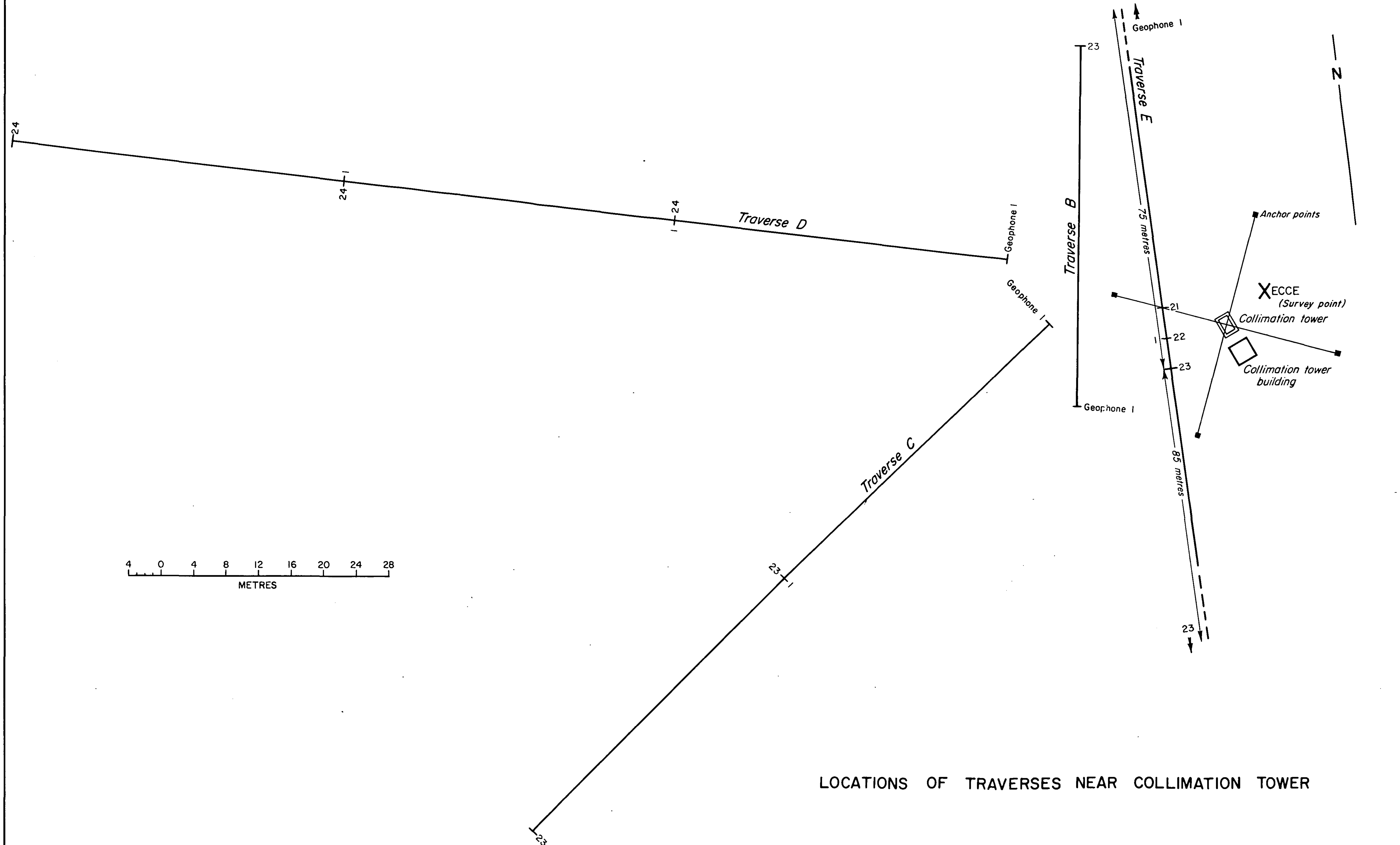



LOCATION OF TRAVERSE ON VALLEY SITE

*To Accompany Record No. 1974/23*

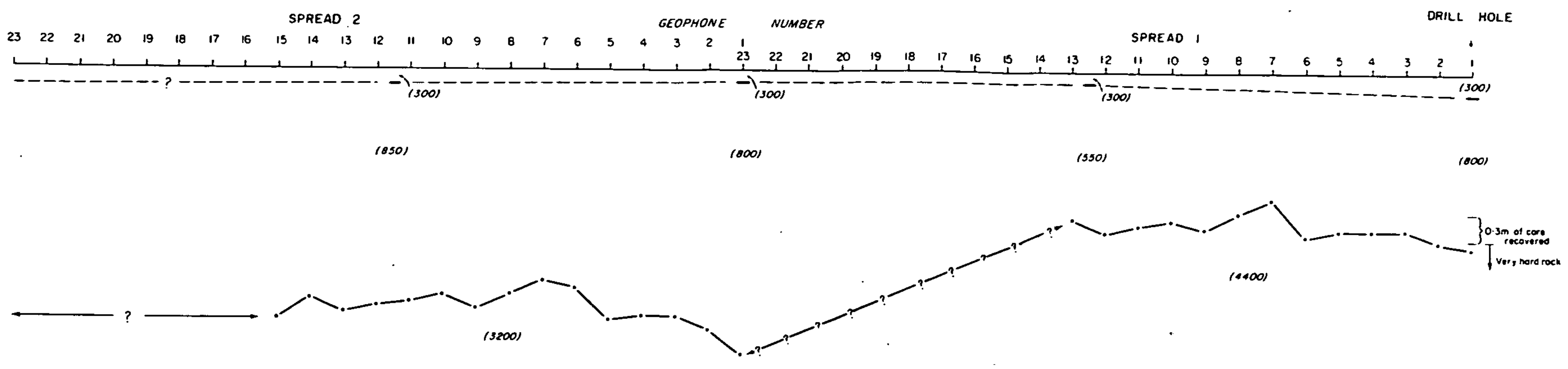
I55/B5-200

PLATE 3

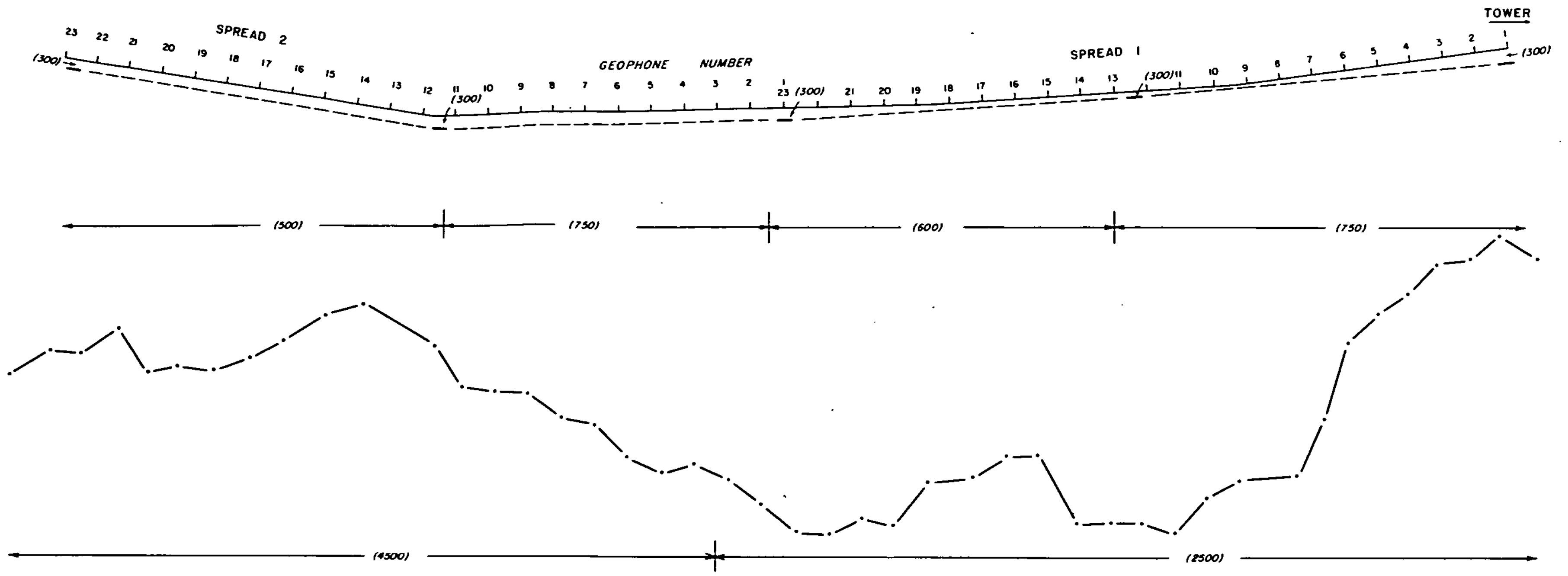



LOCATIONS OF TRAVERSES NEAR COLLIMATION TOWER

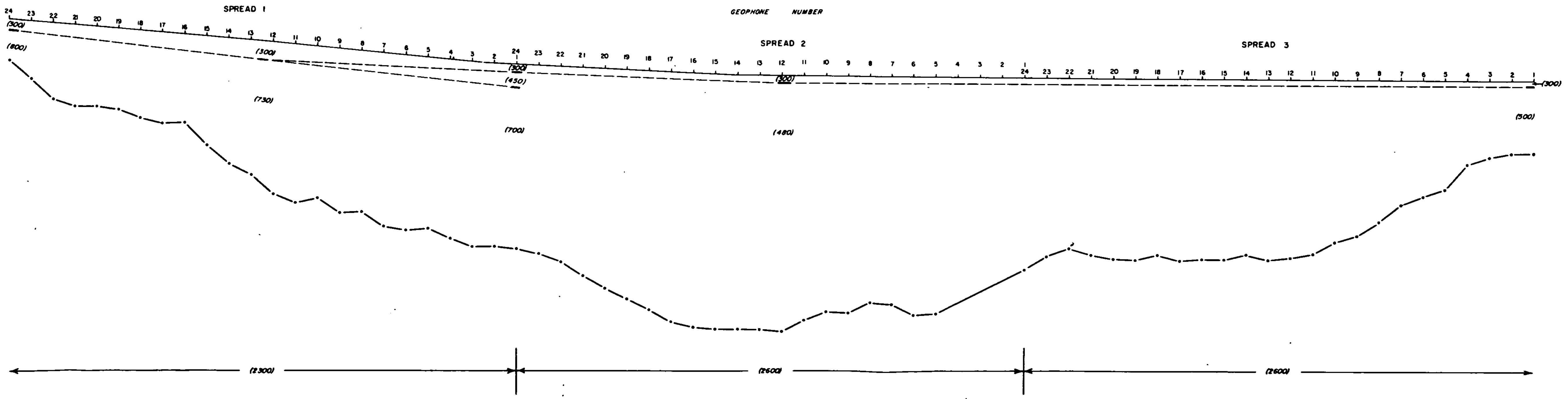
## TRAVERSE A



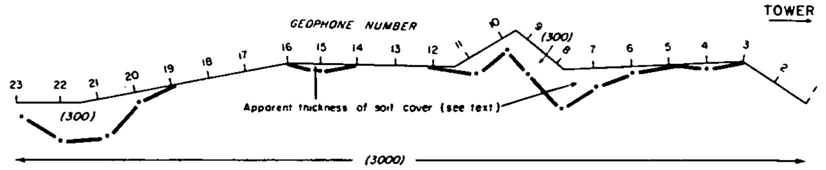

## TRAVERSE C




## TRAVERSE D




## TRAVERSE B




### LEGEND

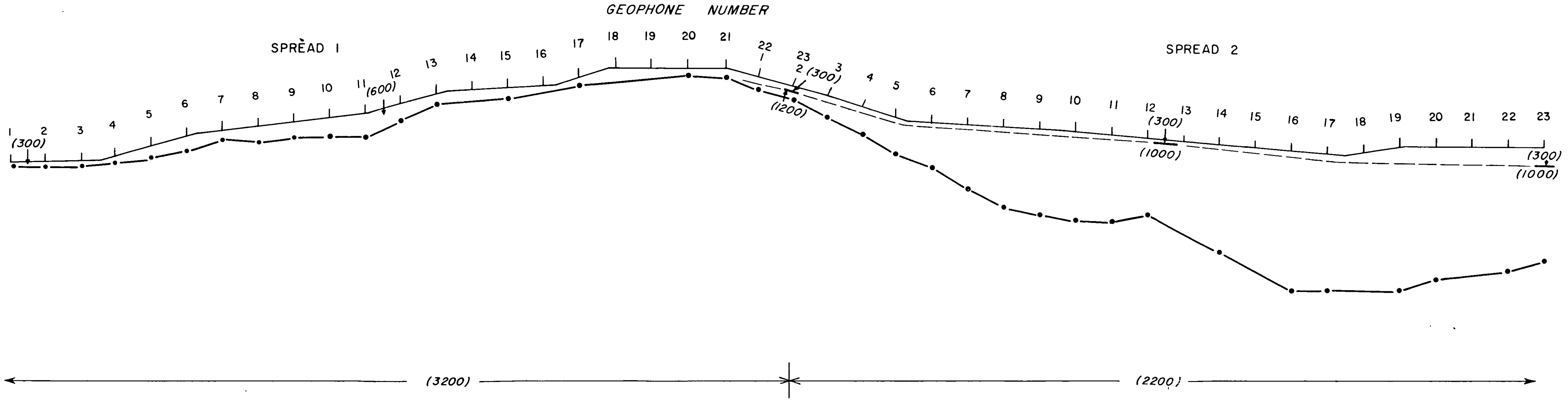
*(300)* — *Longitudinal seismic velocity information (m/s)*

*Bedrock boundary*

*Boundary of formations with different seismic velocities*

4 0 4 8 12 16 20 24 28
METRES

**SEISMIC CROSS-SECTIONS FOR TRAVERSES A,B,C, AND D**




LEGEND

(300) Longitudinal seismic velocity information (m/s)

Bedrock boundary

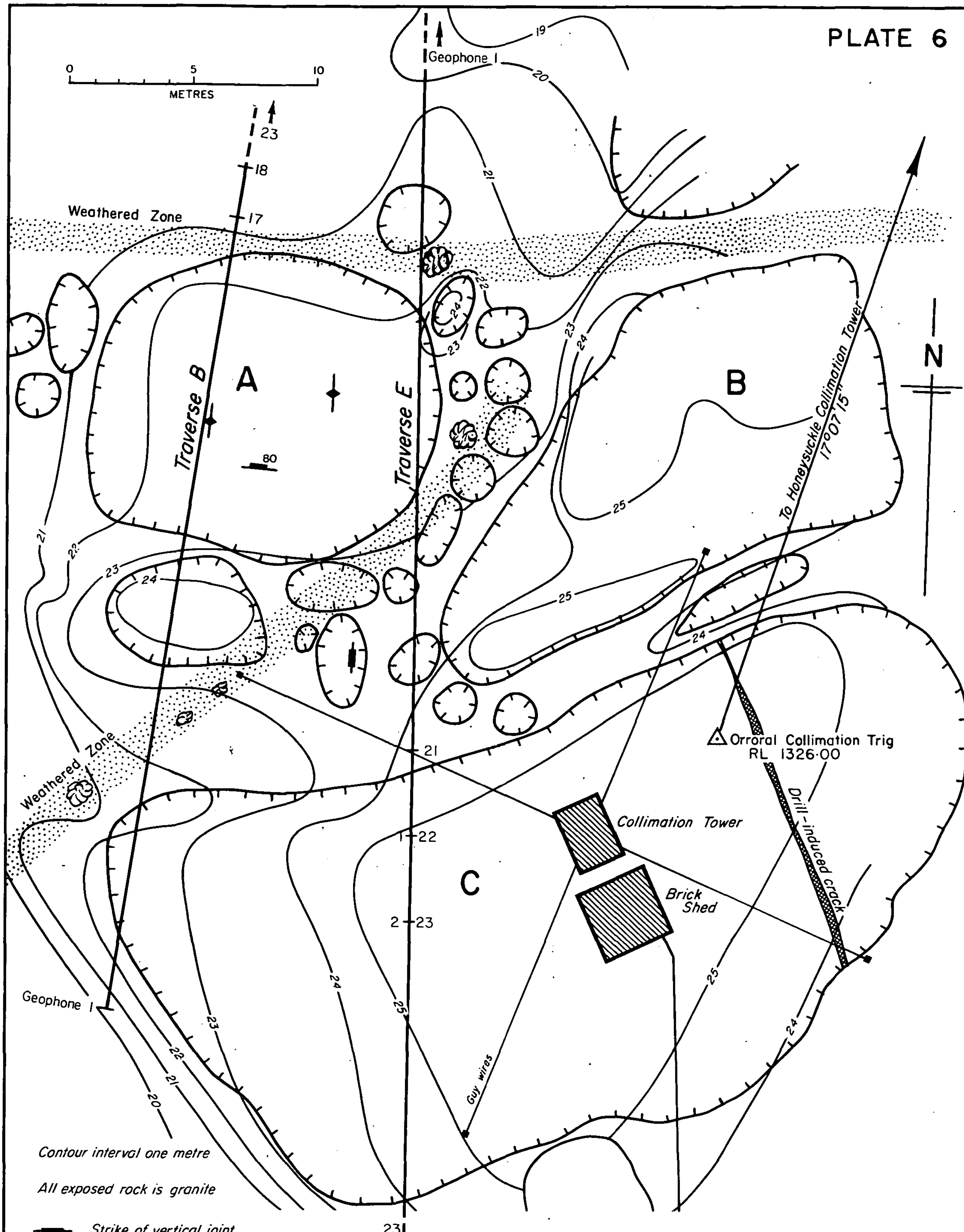
Boundary of formations with different seismic velocities

HORIZONTAL / VERTICAL SCALE

0 4 8 12 16 20 metres

SEISMIC CROSS-SECTION FOR TRAVERSE E

# PLATE 6




Contour interval one metre

All exposed rock is granite

*Strike of vertical joint*

*Strike of vertical foliation*

*Dip and strike of joint*

*Outline of Tor*

*Position of tree*

## SURFACE GEOLOGY

*To Accompany Record No. 1974/23*

I55/B5-2II A