1973/35
Copy 3

DEPARTMENT OF
MINERALS AND ENERGY

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS



Record 1973/35



## GEOLOGY OF THE CAPITAL HILL AREA, CANBERRA, A.C.T.

by

G.A.M. Henderson

006835

Record 1973/35

# GEOLOGY OF THE CAPITAL HILL AREA, CANBERRA, A.C.T.

by

G.A.M. Henderson

CONTENTS

## SUMMARY

Five stratigraphic units are known in the Capital Hill area. They are the Black Mountain Sandstone, State Circle Shale, Camp Hill Sandstone, Deakin Volcanics and Mount Painter Porphyry. Two others, Turner Mudstone and Riverside Formation, may occur but have not positively been identified. After geological mapping of excavations for roadworks in recent years, a partial re-interpretation of the stratigraphy presented by Öpik (1954, 1958) has been made. The Black Mountain Sandstone, formerly considered to be pre-Middle Ordovician, is now believed to be of similar age to the Lower Silurian State Circle Shale. The Camp Hill Sandstone, formerly considered to be Lower Silurian and to underlie the State Circle Shale, is now believed to overlie the State Circle Shale unconformably, and to be Middle or possibly Upper Silurian in age. The Late Silurian age of the Deakin Volcanics and Mount Painter Porphyry remains unchanged. The sequence of Black Mountain Sandstone and State Circle Shale is estimated to be at least 300 m thick in the Capital Hill area, and the Camp Hill Sandstone more than 120 m thick. The thicknesses of the Deakin Volcanics and Mount Painter Porphyry could not be estimated.

The mapping revealed several previously unknown folds and faults, including a large fault on the eastern side of Capital Hill. Numerous minor faults were exposed in the main cuttings in Capital Circle and State Circle. Joints in the Black Mountain Sandstone and State Circle Shale show a definite relationship to the original folding.

The mapping also increased knowledge of excavating and foundation conditions in the area. The Black Mountain Sandstone is hard and strong at shallow depth and difficult to excavate, but it would provide very firm foundations for large structures. The State Circle Shale and Camp Hill Sandstone are soft and weak to considerable depth, and provide easy excavation but relatively poor foundations. Little direct information is available on the properties at depth of the Deakin Volcanics and Mount Painter Porphyry. Zones of weakness along faults may affect foundation conditions locally, especially in the softer rocks. The area is well drained and groundwater is not expected to pose any serious problems.

# INTRODUCTION

Capital Hill in Canberra is a locality of special geological interest (Fig. 1); it was here that Dr A.A. Öpik first described an angular unconformity below Silurian rocks (Öpik, 1954, 1958). Excavations for roadworks between 1969 and 1971 created extensive new exposures of rock, including another exposure of the unconformity, and the geological information recorded has enabled a more complete picture of the geology of the area to be formed. Mapping of the road cuttings was carried out by members of the Engineering Geology Group of the Bureau of Mineral Resources (BMR), assisted by students during University summer vacations. Interpretation of the mapping has brought about a revision of the age of the unconformity, and the stratigraphic and structural relationships between rock units were reviewed. This report describes the geology of the area and discusses its application to engineering in excavation and foundation investigation.

## Previous Investigations

Previous geological investigations include work by Öpik in the early 1950s as part of his mapping of the Canberra city district. In 1958 a sewer tunnel was excavated beneath the south side of Queen Victoria Terrace and was geologically mapped by D.E. Gardner (Gardner, 1969). D.A. Buchhorn mapped the excavation for the South African chancery building in 1967. In 1968 G.A.M. Henderson carried out a geological investigation of the area and assessed the foundation conditions for building on Camp Hill (Henderson, 1969), and five diamond-drill holes were put down; in addition, core from a drill hole put down some years before for the Australian National University (ANU) was logged. Several geophysical investigations, mainly seismic refraction work, have been made in the last few years. The results of these investigations were used in writing this report and in compiling the accompanying map.

# ROCK TYPES

Rock types in the Capital Hill area comprise sedimentary rocks, porphyry, and acid volcanics. General lithological descriptions of the stratigraphic units are set out below, and are referred to by the formation names assigned to them by Öpik (1954, 1958).

## State Circle Shale

The State Circle Shale consists mainly of shale with minor siltstone, mudstone, and beds of hard fine-grained sandstone. The weathered shale is brown, pale grey, cream, or purple, but is grey-green where fresh. In places sedimentary breccia, formed by slumping of the rocks, has been observed. Graptolites, in particular *Monograptus exiguus*, are found at some horizons.

Black Mountain Sandstone

The Black Mountain Sandstone is a fine-grained quartz sandstone with rare and thin interbeds of siltstone and shale, and local thin conglomerates. The colour of the sandstone ranges from brown where weathered to pale grey where fresh. Current bedding, ripple marks, and bands with clay pellets have been observed; slumping is common. The sandstone is generally hard and commonly silicified; the interbedded finer-grained sediments may be strongly weathered and friable. Fossils have not been found in the formation.

Camp Hill Sandstone

The Camp Hill Sandstone comprises soft flaggy originally calcareous quartz sandstone interbedded with soft siltstone and silty mudstone. No exposures of fresh rock have been observed. The sandstone in its weathered form is commonly coloured distinctive reds, yellows, and browns, and the siltstone and silty mudstone are generally cream-coloured. The sandstone is mostly fine-grained but medium and coarse beds have been observed. The formation is fossiliferous, containing corals, trilobites, and brachiopods; the pentamerid brachiopod Rhipidium has been identified.

Turner Mudstone

The Turner Mudstone is a calcareous mudstone with interbeds of siltstone, fine-grained sandstone, and occasional thin tuffaceous bands. Fossils are rare.

Riverside Formation

The Riverside Formation comprises calcareous shale and mudstone, current-bedded fine-grained sandstone, lenses of limestone, tuffaceous sediments, tuff, and rhyolite flows. The formation is highly fossiliferous containing a variety of faunas in which brachiopods, corals, and trilobites are dominant.

Deakin Volcanics

The Deakin Volcanics include porphyritic rhyolitic to dacitic lavas and welded tuffs, with minor ashstone and tuffaceous sedimentary rocks.

Mount Painter Porphyry

The Mount Painter Porphyry is a blue-grey to green-grey porphyritic dacite to rhyodacite, and is believed to be intrusive.

Fig. 1

# LOCALITY MAP

SCALE 1:50,000


To accompany Record 1973/35

Bureau of Mineral Resources, Geology and Geophysics, October 1971 I55/A16/945

# STRATIGRAPHY

## LOWER SILURIAN

### Black Mountain Sandstone and State Circle Shale

It was formerly believed that the Black Mountain Sandstone was pre-Middle Ordovician and the oldest stratigraphic unit in the Canberra area (Öpik, 1954, 1958). It was thought to be overlain unconformably by a Lower Silurian sequence consisting of the Camp Hill Sandstone followed by the State Circle Shale. The unconformable relationship between the Camp Hill Sandstone and the Black Mountain Sandstone was, and still is (1972), visible at the top of Capital Hill. The stratigraphic position of the State Circle Shale was not evident in outcrop, but available evidence, including the known Early Silurian age of the contained graptolites and the suggested similar age of the fauna in the Camp Hill Sandstone, was taken to show that the sandstone was conformable below the shale. Examination of the recent excavations on Capital Hill revealed no evidence to support this interpretation, and it now appears more likely that a conformable sequence of Black Mountain Sandstone and State Circle Shale is unconformably overlain by the Camp Hill Sandstone.

The conformable relation of the Black Mountain Sandstone and State Circle Shale is deduced partly from the close association of the two formations and their similar bedding attitudes (Plate 1), and partly from exposures in the cutting in Capital Circle (Plate 2) now hidden behind a concrete facing. In the cutting the Black Mountain Sandstone and State Circle Shale appeared to form a succession of interbedded sandstone and shale dipping mainly to the north and northwest. State Circle Shale, containing the characteristic graptolite Monograptus exiguus, was exposed near the northwest end of the cutting. Both to the east and west, despite disruption of the sequence by small faults, it could be seen that the shale is conformable on the sandstone.

Shale and sandstone were also exposed together in the excavations for the South African chancery building and for a pedestrian underpass on the western side of Capital Circle. At the site of the chancery building a fault was seen to separate the sandstone and shale. The displacement along the fault could not be determined, but as its attitude is similar to bedding in both the sandstone and shale (Plate 1) a relation can be reasonably inferred in which the sandstone is younger than, and conformable on, the shale despite the fault. The other exposure in the pedestrian underpass showed sandstone conformably overlying shale.

In most places lithological characteristics alone were used to identify the shale exposures as State Circle Shale. Only at the two graptolite localities was definite identification possible. The Black Mountain Sandstone, however, could be identified only on lithological characteristics because of the absence of fossils. Öpik's definitions of the Black Mountain Sandstone as containing shale beds and the State Circle Shale as containing sandstone beds led to some confusion in the mapping. This difficulty was resolved by regarding those exposures consisting mainly of sandstone as Black Mountain Sandstone, and those consisting mainly of shale as State Circle Shale.

The apparent interbedded arrangement of the Black Mountain Sandstone and State Circle Shale on Capital Hill suggests that a revision of their names and definitions is required. However, the succession on Capital Hill does not readily correlate with observations elsewhere. At the southern foot of Black Mountain and in the eastern part of Belconnen the shale appears to be unconformable on the Pittman Formation, and wholly overlain by the sandstone. However, north of the Ginninderra Creek crossing on the Barton Highway interbedded sandstone and shale similar to those at Capital Hill have been recognized. Because of the conflicting evidence it is thought best to hold any stratigraphic re-definitions in abeyance until more information is available.

The age of the State Circle Shale is well established as upper Lower Silurian by the presence of the graptolite Monograptus exiguus and other fossils listed by Öpik. No fossils are known in the Black Mountain Sandstone, but an Early Silurian age would apply if its relation to the shale, as discussed above, is accepted. The evidence does not now favour a pre-Middle Ordovician age as suggested by Öpik.

The thicknesses of the Black Mountain Sandstone and State Circle Shale can be estimated from the cross-section EF (Plate 1). Figure 2 shows the succession of rock units. The exposure sequence starts with at least 120 m of sandstone, which could be thicker as older beds are concealed beneath Camp Hill Sandstone. The sandstone is overlain by about 30 m of shale, about 45 m of sandstone, and then by at least 90 m of shale. Downfaulted against the upper shale is more sandstone of unknown thickness. The figures given above are approximate, because of probable interfingering of sandstone and shale and also the possible effect of undetected folds and faults. The thickness of Lower Silurian beds exposed is about 300 m, but the total thickness is probably greater.

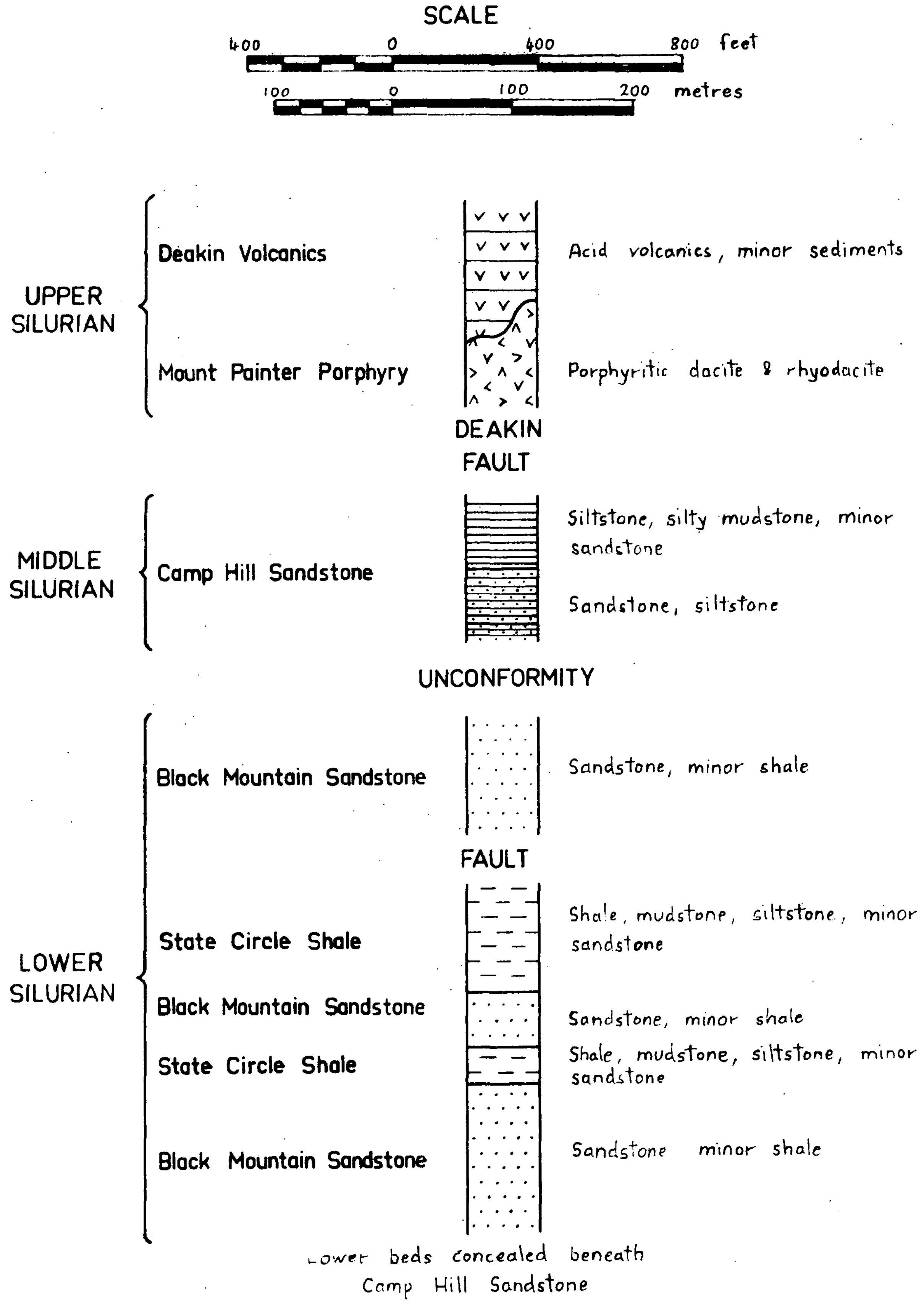
## MIDDLE SILURIAN

### Camp Hill Sandstone

The Camp Hill Sandstone is now exposed at three main localities in the Capital Hill areas:- (1) at the top of Capital Hill where Öpik observed it unconformably overlying Black Mountain Sandstone; (2) in the southeastern part of the main cutting in Capital Circle, and (3) in the cutting in State Circle between Capital Hill and Camp Hill.

# SUCCESSION OF ROCK UNITS IN THE CAPITAL HILL AREA

Fig. 2




To accompany Record 1973/35

Bureau of Mineral Resources, Geology and Geophysics, October, 1971 I55/A16/946

The deepening of the cutting in State Circle increased the exposure of the Camp Hill Sandstone and created a new exposure of the unconformity (Plate 3). Beneath the unconformity is a shale and mudstone formation containing slumped sandstone, which is probably part of the State Circle Shale. This further suggests that the State Circle Shale does not overlie the Camp Hill Sandstone as was concluded by Öpik.

Circular reasoning

In the cutting in State Circle, where the basal part of the Camp Hill Sandstone is exposed, the formation consists of interbedded sandstone and siltstone. In the southeastern part of the Capital Circle cutting, siltstone and silty mudstone with minor sandstone beds, which are shown on the map as a higher part of the Camp Hill Sandstone, may possibly represent passage into the Turner Mudstone which is now believed to overlie the Camp Hill Sandstone (Strusz & Henderson, 1971). However, the Turner Mudstone has not been positively identified in the area. A similar upward progression from interbedded sandstone and siltstone into mudstone was also observed by Gardner in the tunnel beneath Queen Victoria Terrace (Gardner, 1969).

Excavations for extensions to the western side of Parliament House exposed fossiliferous shale and siltstone. The fossils are considered by Dr D.L. Strusz to be generally similar to those in both the Camp Hill Sandstone and the Riverside Formation which overlies the Turner Mudstone (Öpik, 1958). Lithologically the beds appear similar to parts of the Riverside Formation, but as that formation has not been positively identified south of the Acton Fault (believed to lie northeast of Parliament House), the beds are shown on the map as ?Camp Hill Sandstone. Camp Hill Sandstone is known a short distance to the southeast, where it was exposed in the sewer tunnel beneath Queen Victoria Terrace. The nearest known rocks of the Riverside Formation are shale and limestone which were exposed in the foundations of the Secretariat Building north of Parliament House (Best & Henderson, 1968).

The age of the Camp Hill Sandstone requires re-interpretation since the revised stratigraphic position of the State Circle Shale. It was formerly believed to be Lower Silurian (Öpik, 1958), but this age is unlikely if the unit unconformably overlies Lower Silurian Black Mountain Sandstone and State Circle Shale. Öpik based his age partly on the presence of the pentamerid brachiopod Rhipidium; however this genus is now known to be Middle and Late Silurian (Strusz & Henderson, 1971). A Middle Silurian age for the sandstone is considered more likely as it is older than the Riverside Formation, the upper part of which has recently yielded probable Late Silurian conodonts (Strusz & Henderson, op. cit.).

Figure 2 shows the estimated thickness of the Camp Hill Sandstone. About 60 m of sandstone and siltstone is overlain by at least 60 m of siltstone and silty mudstone with minor sandstone beds. The top is not exposed.

## UPPER SILURIAN

### Deakin Volcanics and Mount Painter Porphyry

These rocks occur in the southwestern part of the Capital Hill area, southwest of the Deakin Fault. They are believed to be Upper Silurian and younger than the rocks northeast of the fault (Öpik, 1958). A weathered volcanic rock was exposed beside the Deakin Fault, near the Adelaide Avenue bridge over State Circle; apart from this no new information on the two formations was obtained.

From evidence elsewhere it is considered that the Mount Painter Porphyry intrudes the Deakin Volcanics (Öpik, 1954, 1958). The boundary shown on the map is that shown on Öpik's map. No estimates can be made of the thicknesses of the two formations in the Capital Hill area.

# STRUCTURE

## FOLDING

There are no major folds in the Black Mountain Sandstone and State Circle Shale in the Capital Hill area, but minor folds and warps are common. An anticline and a syncline were exposed in the Capital Circle cutting; bedding dips indicate a gentle plunge to the west-southwest. Tight folds in the shale were seen in places, particularly in the cores of larger folds (Plate 2).

In the Camp Hill Sandstone two folds can be seen in the State Circle cutting. One is an anticline plunging south-southeast and the other a syncline plunging south-southwest; the plunge of both is about 15 to 20°. The anticline is also present in the Capital Circle cutting. Another anticline in the Camp Hill Sandstone can be inferred from the bedding attitudes in the sewer tunnel where it crosses Kings Avenue.

No folding was seen in the Deakin Volcanics and Mount Painter Porphyry.

Drag folds occur against some faults. Drag folding is more common in the finer-grained beds and is also related to the size of the fault. Intense drag folding was visible in the siltstone east of Fault A in Capital Circle, but the sandstone west of the fault was unaffected.

The attitudes of bedding in the formations northeast of the Deakin Fault, and the variable orientations of folds indicate more than one episode of folding. The geometry of the unconformity also indicates that the Black Mountain Sandstone must have been steeply dipping and hence already folded when the Camp Hill Sandstone was deposited.

## FAULTING

Several major faults and numerous minor faults occur in the Capital Hill area. Only faults with considerable displacement are shown on the map.

### Deakin Fault

The Deakin Fault is the largest fault in the area. Öpik estimated the vertical displacement to be not less than 1200 to 1500 m. The fault lies southwest of Capital Hill, and separates Upper Silurian porphyry and volcanic rocks to the southwest from older rocks to the northeast. It is a normal fault dipping at about 70 to 75° to the southwest; the downthrow is on the south-western side. A trench near Adelaide Avenue exposed the fault as a crushed, sheared zone about 9 m wide.

### Fault A

Fault A is on the eastern side of Capital Hill. Its vertical displacement is estimated from the offset of the Camp Hill Sandstone to be about 300 m. The fault is a normal fault dipping 63 to 66° to the east; the downthrow is on the eastern side. The best exposure was in the Capital Circle cutting, where siltstone and silty mudstone of the Camp Hill Sandstone could be seen downfaulted against Black Mountain Sandstone (Plate 2). The siltstone beside the fault was dragged and crumpled, but the sandstone was practically unaffected.

### Fault B

Fault B is on the southern side of Capital Hill and was seen in a cutting as a quartz reef dipping at about 60° to the north-northeast. The poor exposure appeared to show Camp Hill Sandstone on the northern side down-faulted against Black Mountain Sandstone. The fault would thus be normal. The displacement is unknown, but probably considerable.

### Fault C

Fault C was seen in the sewer tunnel beneath Queen Victoria Terrace and is also visible in the main cutting in State Circle (Plate 3). It is a normal fault dipping at about 75° to the northwest; the downthrow is on the north-western side. The displacement is estimated to be about 30 m.

### Fault D

Fault D was observed in the excavations for the South African chancery building. It took the form of a quartz reef dipping at about 75° to the northwest. Black Mountain Sandstone to the northwest is downfaulted against State Circle Shale to the southeast. The fault is normal, and of unknown displacement.

### Fault E

Fault E, along Queen Victoria Terrace, is inferred in order to explain the exposure of possible Camp Hill Sandstone or Riverside Formation in the extensions to Parliament House in relation to the Camp Hill Sandstone and State Circle Shale exposed in the sewer tunnel along Queen Victoria Terrace. The northeast block would be downfaulted.

### Fault F

Fault F was seen in the sewer tunnel as a zone of disturbed bedding. Its attitude is not known and its extension to the southwest is inferred. The apparent presence of the basal part of the Camp Hill Sandstone southeast of the fault suggests that the northwest block is downfaulted.

### Minor Faults

A number of minor faults of small displacement were exposed in Capital Circle and State Circle (Plates 2 and 3), and those not hidden behind the concrete facing are still visible. The commonest direction of strike is north to northeast. Where displacements can be seen they are generally less than 1 m; however, some show displacements of as much as 5 m and possibly more. Most of the faults dip at angles steeper than 50° and are normal, but there are a few reverse faults. There are two low-angle thrust faults in the State Circle cutting, one near fault C and the other towards the eastern end of the cutting. Similar faults were observed in the Black Mountain Sandstone and State Circle Shale in the Capital Circle cutting; they dip to the west or northwest. Most of the minor faults contain little crushed rock, although some show slight drag of the adjacent beds. A large quartz reef in the southeast part of the Capital Circle cutting may represent a fault; no displacement is evident. Slumps?

## JOINTING

Joints are prominent in the Black Mountain Sandstone and State Circle Shale. They are moderately to widely spaced in the sandstone and closely spaced in the shale. A study of joints in the two formations in Capital Circle revealed two prominent directions, one striking at 125° and dipping at about 80° to the northeast and the other striking at 025° and dipping at about 85° to the northwest (Figure 3). The orientation of fold axes in an east-northeast direction indicates that the main joints are diagonal or shear joints, with each set at about 50° to the axial planes of the folds. A number of joints sub-parallel to the axial planes (longitudinal joints) were recorded but no definite maximum appears on the plot. There are no cross joints.

Joints in the Camp Hill Sandstone are not prominent and are generally moderately to widely spaced. The number of joint attitudes measured was insufficient for a statistically meaningful plot.

No measurements of joints were made in the Mount Painter Porphyry and Deakin Volcanics.

# ENGINEERING GEOLOGY

Recent excavations for roadworks in the area have revealed variable thicknesses of overburden (residual and colluvial soil and completely weathered rock), and contrasting excavation and foundation conditions for the various rock types. The following notes describe excavation and foundation conditions in the area.

## EXCAVATING CONDITIONS

Overburden ranges in thickness up to 6 m through the area except locally at rock outcrops. The thickness of overburden is related mainly to the underlying rock type, but local deposits of colluvium may occur. In all places the overburden can easily be excavated by mechanical means.

The Black Mountain Sandstone is generally covered by less than 1 m of overburden, below which the rock is moderately to highly weathered. The moderately weathered rock generally requires explosives for excavation, but is rippable where soft shale beds enable the rock to be broken. The moderately weathered rock contains patches of highly weathered rock and can generally be ripped, though with difficulty. An increase in hardness with depth in the sandstone can be expected as highly weathered rock grades into moderately weathered rock. The depth to uniformly fresh rock is not known; some patches of fresh and slightly weathered rock were found at less than 6 m in the main Capital Circle cutting. Blasting was necessary in the sandstone in the main Capital Circle cutting, but not in the small cutting in the western part of the road nor in the cutting crossed by Fault B.

The State Circle Shale is generally covered by 1 to 3 m of overburden, below which the rock is moderately to highly weathered. It is generally rippable, although beds of sandstone can cause difficulty in places. Blasting is only needed where a thick sandstone bed is intersected. The depth of weathering in the shale was about 30 m in the ANU drill hole on Camp Hill. If this depth is typical, little increase in hardness and strength can be expected to at least that depth in other places.

The Camp Hill Sandstone is covered by 1 to 6 m of overburden, below which is moderately to highly weathered rock. Overburden is shallowest over the basal part of the formation, which contains sandstone and is largely confined to Camp Hill and the top of Capital Hill. There is deeper overburden over the siltstone and silty mudstone. Beneath the overburden on Camp Hill, alternating layers of moderately soft sandstone and soft siltstone can be ripped fairly easily. The soft siltstone south and east of Camp Hill are very easily ripped and only local difficulties, such as an isolated sandstone bed or quartz reef, are likely to be met. No increase in hardness and strength of bedrock in the Camp Hill Sandstone was found to a depth of 25 m in the drill holes on Camp Hill.

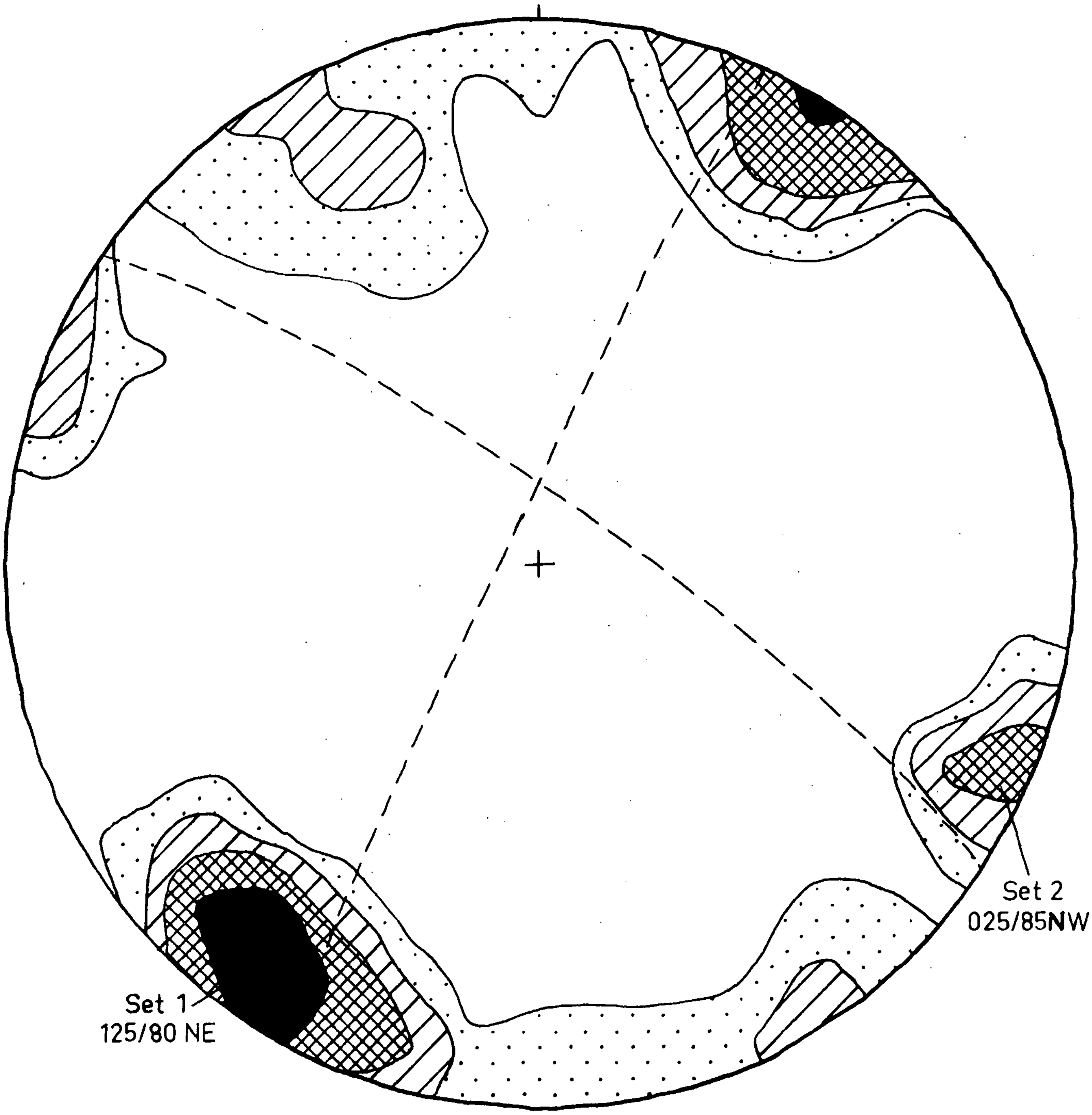
Excavating conditions in the Deakin Volcanics and Mount Painter Porphyry are not as well known as in the other formations. Overburden and highly weathered rock which could easily be excavated were found to a depth of 3 m in a trench near the Adelaide Avenue bridge over State Circle. In the Mount Painter Porphyry the depth of weathering is probably variable, with occasional boulders of hard fresh rock surrounded by moderately or highly weathered rock.

In most formations weathering tends to be deeper along major faults. Weathering in crush zones along the faults is more severe in siltstone, shale, and mudstone than in sandstone. The Deakin Fault is the largest fault and forms a zone of crushed and decomposed rock about 9 m wide. Hard quartz reefs along some faults make excavation difficult. Minor faults generally have little effect on the surrounding rock.

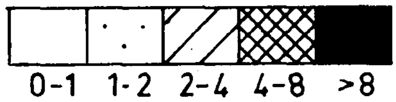
# CAPITAL HILL JOINT STEREOGRAM

Fig. 3

Plot represents 270 joints in Black Mountain Sandstone and State Circle Shale in Capital Circle cutting




Poles to joint planes have been plotted on an equal area lower hemisphere projection and contoured to represent the distribution of joint directions. The orientations of joint sets are shown to the nearest 5 degrees. The curved dashed lines on the plot are the great circles which represent the joint planes.




percentage of points per percentage of area

To accompany Record 1973/35

I55/A16/947

The stability of excavations depends on the nature of the material excavated and also on the orientations of joints where rock is exposed. The strength of the rock material of the Black Mountain Sandstone is more than adequate for stability of steep cuts, but rock defects such as unfavourably oriented joints may affect stability. One instance of instability owing to a joint occurred in the Capital Circle cutting. The joint, which dipped steeply towards the cutting, had a strike parallel to the cutting which created an unstable block threatening to slide into the cutting. The block was supported with lagging before being covered by the concrete wall. In the State Circle Shale and Camp Hill Sandstone instability is to some extent dependent on unfavourably oriented joints, but is also related to weathering and to the soft nature of the rock which is liable to fret away under the action of rain and frost. The present deep cuttings in Capital Circle and State Circle may require some form of treatment to preserve them from erosion. The stability of the overburden depends on moisture content and the geometry of the excavation, and a collapse could occur in deep cuttings. One such collapse occurred near the southeastern end of the Capital Circle cutting where there is thick colluvium; this section of the cutting has since been covered by a wall.

## FOUNDATION CONDITIONS

Foundations for buildings and other structures in the area will need to be appropriately designed to cope with the conditions at the site. Drilling is recommended to determine the conditions, and a variety of conditions is to be expected on the site of any major structure. Some drilling has already been carried out on Camp Hill and seismic traverses across Capital Hill and Camp Hill provide additional information on conditions at depth.

Black Mountain Sandstone should prove to be hard and strong at shallow depth and provide good foundations. On the crest of Capital Hill outcrops are common, and the seismic results indicate rock of sufficient strength for foundations with high unit loading between depths of 1.5 and 8 m.

Camp Hill Sandstone or State Circle Shale are likely to provide poorer foundation conditions than the Black Mountain Sandstone. They may not support footings with high unit loadings at shallow or even moderate depth, and piled foundations may be necessary, particularly in zones close to the major faults. The seismic results in the Camp Hill area indicate hard near-fresh rock at 9 to 30 m, but the drilling results indicate that it is probably deeper. A notable increase in thickness of soft weathered rock occurs in the seismic traverse across Capital Hill to the east of Fault A. About 15 to 30 m of soft weathered rock is indicated in the siltstone to the east of the fault.

No information is available on foundation conditions in the Deakin Volcanics and Mount Painter Porphyry. However, from experience elsewhere it is considered that fresh or slightly weathered rock would be found between depths of 10 to 15 m.

No limestone or other rock which could cause special or unusual foundation conditions is known in the Capital Hill area. The area is well drained, and groundwater is not expected to pose any serious problems. The area of poor drainage near the Forrest Primary School does not extend north to the area mapped.

## REFERENCES

BEST, E.J., & HENDERSON, G.A.M., 1968 - Geology and foundation conditions at the Secretariat Building site, Canberra. Bur. Miner. Resour. Aust. Rec. 1968/111 (unpubl.).

GARDNER, D.E., 1964 - Capital Hill, Canberra, A.C.T.: Seismic investigations of soil and weathered bedrock, August, 1964. Bur. Miner. Resour. Aust. Rec. 1964/194 (unpubl.).

GARDNER, D.E., 1969 - Geology of the central area of Canberra, A.C.T. Ibid., 1969/11 (unpubl.).

HENDERSON, G.A.M., 1969 - Geology of the Camp Hill area, Parkes, A.C.T. Bur. Miner. Resour. Aust. Rec. 1969/41 (unpubl.).

ÖPIK, A.A., 1954 - Geology of the Canberra city district. In CANBERRA, A NATIONS CAPITAL (ed. H.L. White). Aus. Ass. Adv. Sci., Handbk. for Canberra, 131-48, Pl. 33a.

ÖPIK, A.A., 1958 - Geology of the Canberra city district. Bur. Miner. Resour. Aust. Bull. 32.

POLAK, E.J., & WAINWRIGHT, M., 1965 - Capital Hill tunnel, geophysical survey, Canberra, A.C.T. 1964. Bur. Miner. Resour. Aust. Rec. 1965/208 (unpubl.).

STRUSZ, D.D., & HENDERSON, G.A.M., 1971 - Canberra City, A.C.T., 1:50 000 geological map and explanatory notes. Bur. Miner. Resour. Aust. explan. Notes.

WHITELY, R.J., 1968 - Camp Hill, Canberra, A.C.T., seismic survey. Bur. Miner. Resour. Aust. Rec. 1968/128 (unpubl.).

# APPENDIX 1

## DEFINITION OF SEMI-QUANTATIVE DESCRIPTIVE TERMS

### Bedding

| | |
|---|---|
| Laminated | - Less than 10 mm thick |
| Thinly bedded | - 10 mm to 100 mm thick |
| Thickly bedded | - More than 100 mm thick |

### Grain Size

| | |
|---|---|
| Coarse-grained | - 1 mm to 4 mm in diameter |
| Medium-grained | - 1/4 mm to 1 mm in diameter |
| Fine-grained | - Less than 1/4 mm in diameter |

### Hardness of Rock

| | |
|---|---|
| Hard to very hard | - Impossible to scratch with a knife blade |
| Moderately hard | - Shallow scratches with a knife blade |
| Soft | - Deep scratches with a knife blade |

### Joint Spacing

| | |
|---|---|
| Closely spaced | - Joints spaced less than 15 cm apart |
| Moderately spaced | - Joints spaced between 15 cm and 90 cm apart |
| Widely spaced | - Joints spaced more than 90 cm apart |

### Percussive Strength of Rock

| | |
|---|---|
| Strong to very strong | - Cannot be broken by repeated blows with a hammer |
| Moderately strong | - Rock broken by 3 or 4 blows |
| Weak | - Rock broken by 1 blow |

### Weathering of Rock

| | |
|---|---|
| Fresh | - No discolouration or loss in strength |
| Fresh Stained | - Limonitic staining along fractures; rock otherwise fresh and shows no loss of strength |
| Slightly weathered | - Rock is slightly discoloured, but not noticeably lower in strength than the fresh rock |

| | |
|---|---|
| Moderately weathered | - Rock is discoloured and noticeably weakened; N-size drill core generally cannot be broken by hand across the rock fabric. |
| Highly weathered | - Rock is discoloured and weakened; N-size drill core can generally be broken by hand across the rock fabric |
| Completely weathered | - Rock is decomposed to a soil, but the original rock fabric is mostly preserved. |

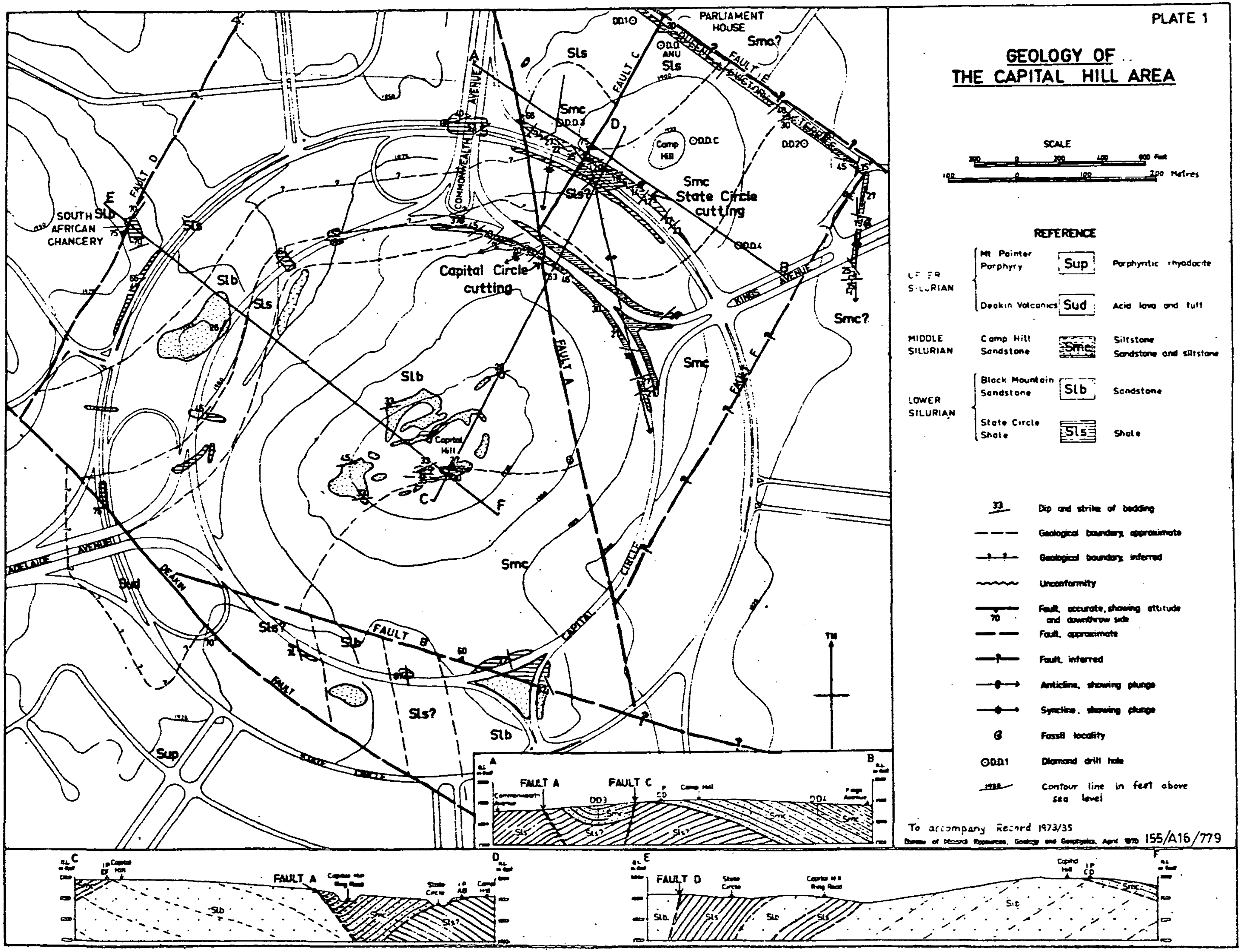
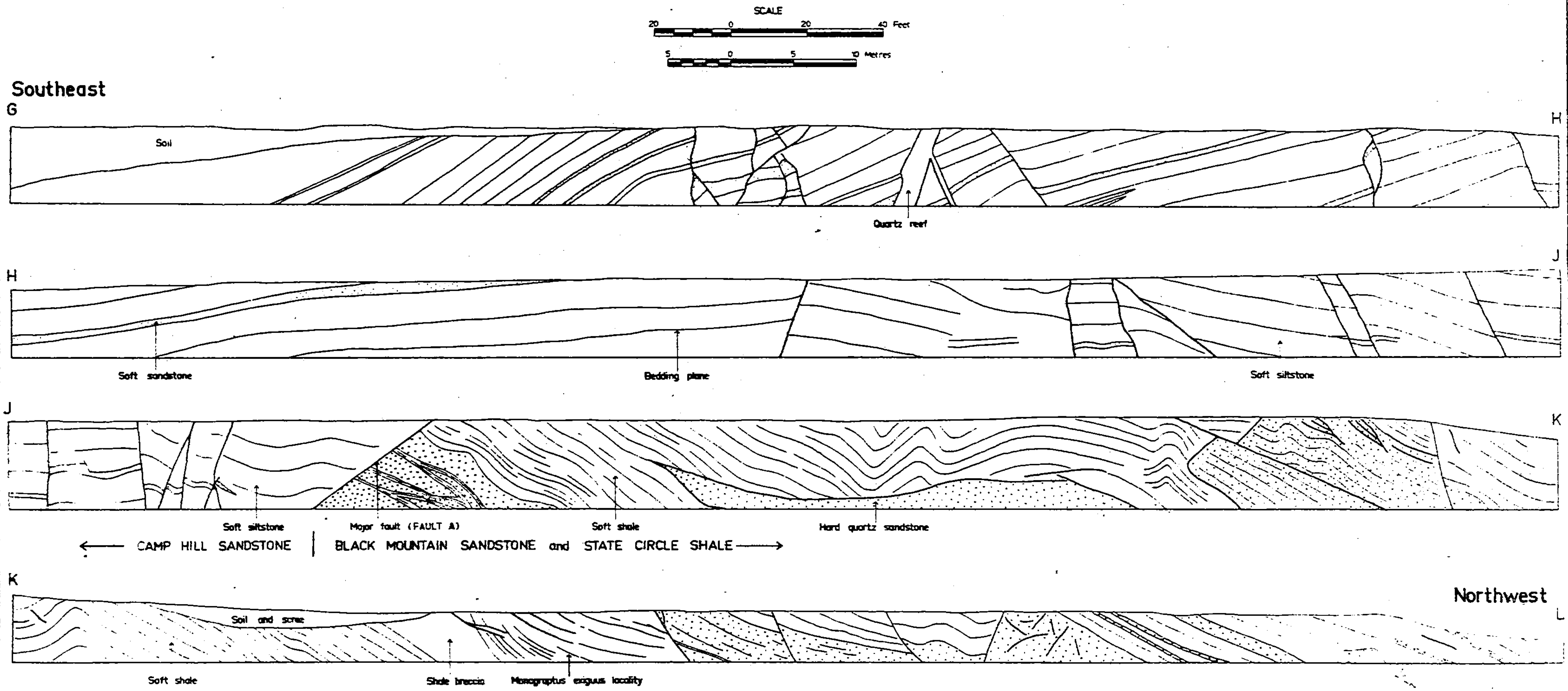


PLATE 1
GEOLOGY OF THE CAPITAL HILL AREA
SCALE
Metres
REFERENCE
Mt Painter Porphyry
Sup
Porphyritic rhyodacite
Deakin Volcanics
Sud
Acid lava and tuff
MIDDLE SILURIAN
Camp Hill Sandstone
Smc
Siltstone
Sandstone and siltstone
Black Mountain Sandstone
Slb
Sandstone
LOWER SILURIAN
State Circle Shale
Sls
Shale
Dip and strike of bedding
Geological boundary, approximate
Geological boundary, inferred
Unconformity
Fault, accurate, showing attitude and downthrow side
Fault, approximate
Fault, inferred
Anticline, showing plunge
Syncline, showing plunge
Fossil locality
Diamond drill hole
Contour line in feet above sea level
To accompany Record 1973/35
155/A16/779
PARLIAMENT HOUSE
SOUTH AFRICAN CHANCERY
State Circle cutting
Capital Circle cutting
Capital Hill
Camp Hill
FAULT A
FAULT B
FAULT C
FAULT D
FAULT E
FAULT F
COMMONWEALTH AVENUE
ADELAIDE AVENUE
DEAKIN
KINGS AVENUE
CAPITAL CIRCLE
STATE CIRCLE

PLATE 2

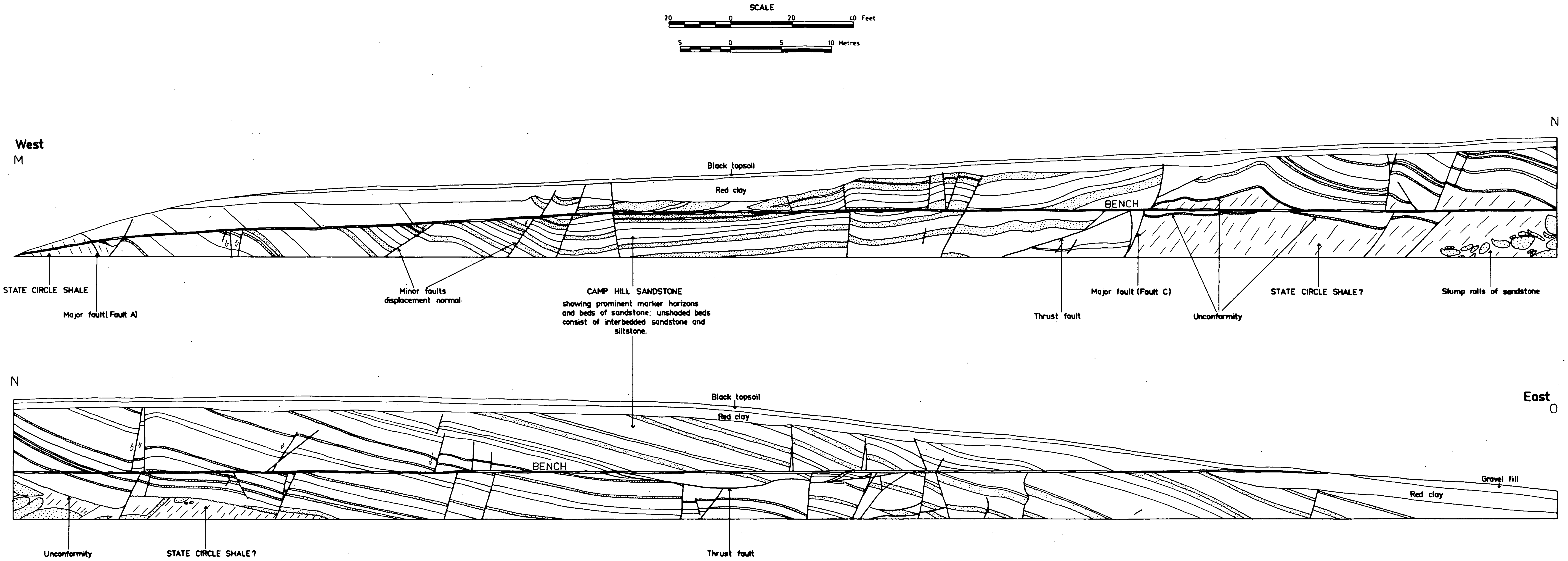
# GEOLOGY OF CUTTING IN CAPITAL CIRCLE




Bureau of Mineral Resources Geology and Geophysics October 1971 To accompany Record 1973/35

PLATE 3

# GEOLOGY OF CUTTING IN STATE CIRCLE




Bureau of Mineral Resources, Geology and Geophysics, October 1971

To accompany Record 1973/35

I55/A16/949