DEPARTMENT OF NATIONAL RESOURCES

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Record 1978/57

GEOLOGY OF THE GUNDAROO-WESTMEAD PARK - NANIMA AREA, NEW SOUTH WALES

by

G.A.M. Henderson

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SUMMARY

The Gundaroo-Westmead Park-Nanima area contains Ordovician to Silurian and possibly Lower Devonian rocks partly covered by probably Tertiary gravel and Quaternary alluvium. A previously unrecognised unconformity has been mapped between the Lower and middle Silurian rocks, and corresponds with a lithological change from older non-calcareous rocks, mainly sandstone and shale, to predominantly shale containing calcareous horizons and interbedded acid volcanics. The Palaeozoic rock formations are folded and faulted. A few, mostly minor, intrusions of acid and intermediate composition have caused some local contact metamorphism. Mineralisation appears to be concentrated along faults and in calcareous rocks adjacent to faults; mineral exploration has been carried out recently, but no significant mineral deposits have been reported.

Most of the area is suitable for urban development, the main constraints being areas of steep slope, hard unrippable rock at shallow depth, areas of swampy ground, and extensive areas of low relief subject to flooding. Material resources that are being extracted include road gravel and brick shale; aggregate, stone, gravel, sand, and silty loam have potential value. Groundwater is pumped from bores for stock and domestic use in some places; the water quality is variable.

INTRODUCTION

The area described in this report is in New South Wales, and adjoins the northernmost part of the Australian Capital Territory (Fig. 1). This investigation followed earlier work in adjacent areas to the west and south, and will be a contribution to the Canberra 1:100 000 geological map. The gathering of geological information relevant to urban development in the area was also included as part of the investigation.

The earliest recorded geological work in the area was done by Day (1952), who made a general reconnaissance of the whole area, and by Sherrard (1952), who mapped the western margin of the area. Hill (1969) mapped an area to the east of Gundaroo. No further work was done until Smith (1964) mapped in considerable detail most of the area covered by this survey. Smith's work was incorporated in the 2nd edition of the Canberra 1:250 000 geological sheet (Best, D'Addario, Walpole, & Rose, 1964). Strusz (1975) has summarised the Silurian stratigraphy of the surrounding region.

The present mapping was carried out using 1:10 000 and 1:9600 detail map sheets, 1:25 000 colour aerial photographs (available only for the southern half of the area), and 1:50 000 black and white photographs. The mapping party consisted of G.A.M. Henderson (party leader), L. David and W.R. Evans (graduate field hands), and J. Cox, P. Rosengren, and D. Guy - student field hands. The mapping was done between December 1975 and April 1976.

PHYSIOGRAPHY

The area ranges from gently undulating in most of the eastern part to hilly in the west and northwest. The highest summits are Bywong Hill (858 m), in the southeast (Fig. 2) and Picaree Hill (803 m), in the northwest (Fig. 3). Most of the area has been cleared for grazing, but a few thickly wooded areas remain on the higher country in the northwest.

The area is drained by two stream systems. The eastern two-thirds lies in the catchment of the Yass River, and the western third in the catchment of Murrumbateman Creek. Both systems drain to the north.

GEOLOGY

STRATIGRAPHY

General

The stratigraphic nomenclature introduced by Smith (1964) and shown on the 1:250 000 Canberra geological map (Best & others, 1964) is retained, except for the Silurian Glenesk Volcanics, which are now included in the Westmead Park Formation. Further subdivision of some formations has been attempted. The approximate thicknesses of the various formations and their subdivisions is shown in the cross-section, Plate 1.

Ordovician sedimentary rocks

Ordovician rocks were first recorded by Sherrard (1952) who found several localities with late Ordovician graptolites. Later Smith (1964) divided the Ordovician rocks into two formations, the Pittman Formation (after Opik, 1958) and the younger, graptolite-bearing Picaree Formation.

The recent mapping has revealed that only the upper part of Smith's Pittman Formation resembles the rocks typical of the Pittman Formation in the Canberra city area. Consequently, a lower limit of the Pittman Formation in the Gundaroo area has been delineated (Plate 1). The restricted Pittman Formation (Omp) consists of micaceous sandstone, shale, and chert. The underlying rocks (designated as Om) are sandstone and shale, commonly feldspathic and green or purple, and do not include any chert.

At least part of the Pittman Formation can be subdivided into distinct lithologies: in the northwestern part of the area the recent mapping indicates a generalised sequence down from the top of the formation as follows:

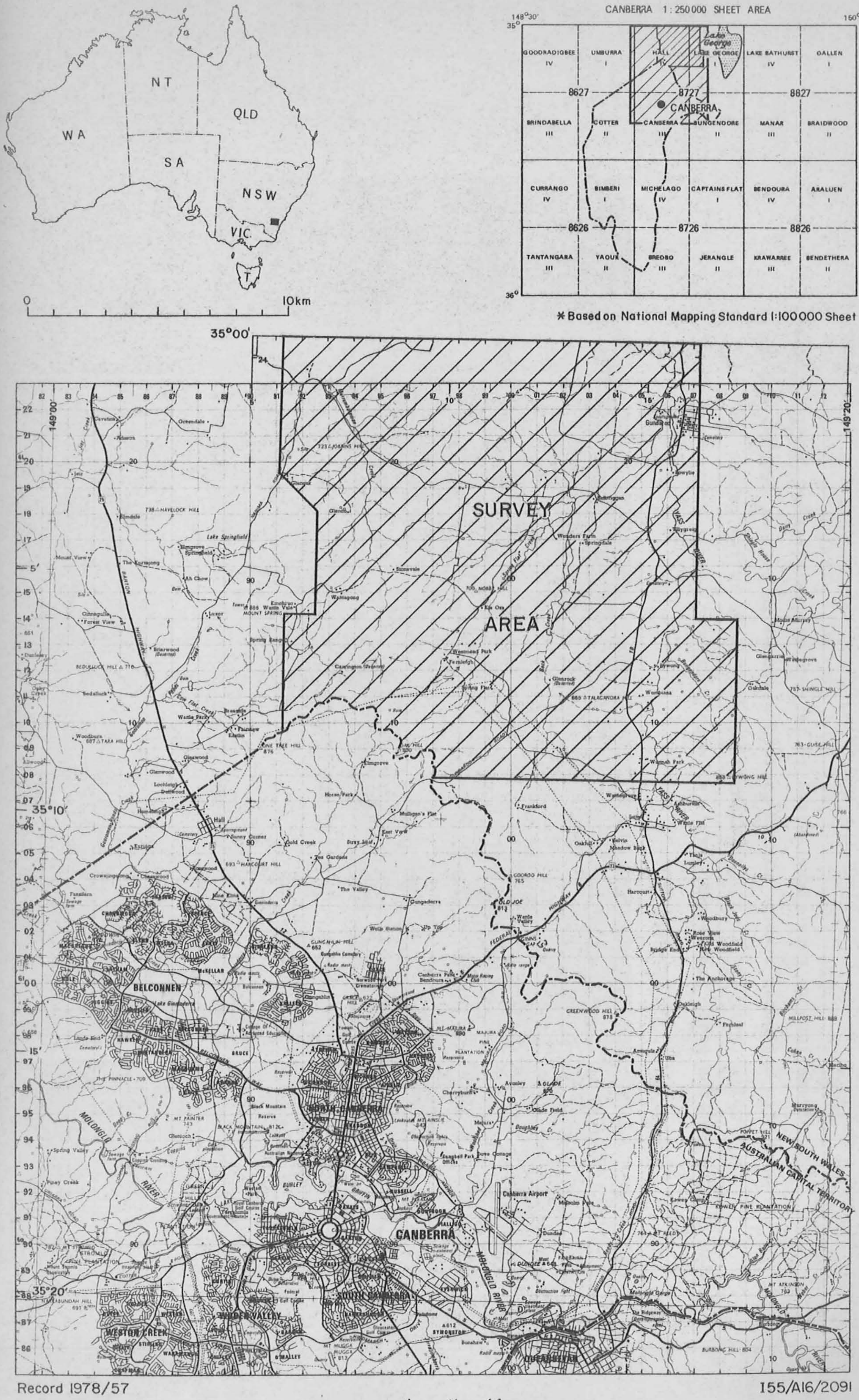

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Fig. 1 Location Map
Gundaroo – Westmead Park – Nanima area

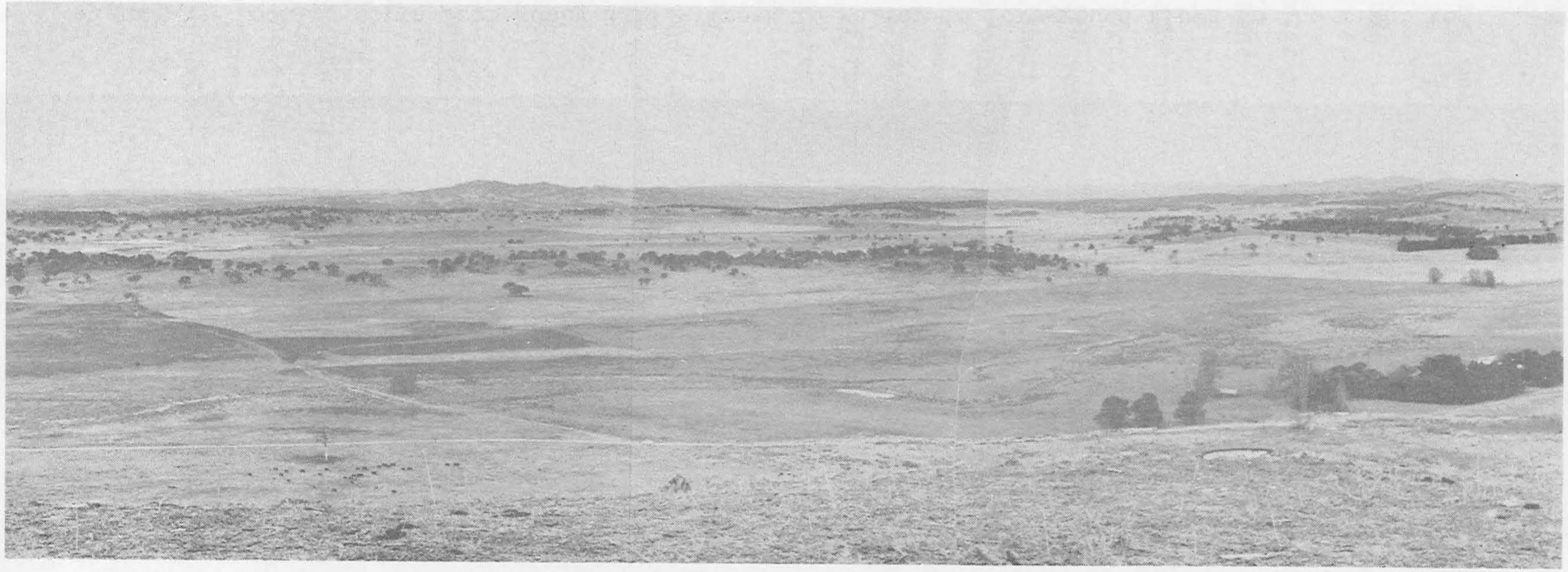


Figure 2 - Looking southeast from Nobby Hill. Kia-Ora homestead, lower right at foot of hill; Spring Flat valley in foreground and Back Creek valley beyond the low rise with scattered trees; Bywong Hill in distance to left of centre; and white clay excavations in Back Creek valley to left in middle distance (M2071, frames 16, 17, 18).

Figure 2

Figure 3 - Looking north from Nobby Hill. Creek in valley in foreground flows to the right to join Spring Flat Creek. Hills in middle distance left trend northwards to Picaree Hill, on skyline to the left (M2071, frames 29, 30, 31).

Figure 3

	Thickness m (approx.)
Yellow-brown mudstone with ironstaining in circular patches	20
Pink and blue-grey massive chert	30
Soft grey mudstone	50
Coarse to medium-grained brown feldspathic, micaceous sandstone	30+

The sandstone at the base of this sequence forms the most common outcrops in the area shown as Pittman Formation east of Sullivans Fault, and, together with some interbedded shale, appears to form the bulk of the formation. Chert exposures are rare east of Sullivans Fault, but some outcrops of pink chert southwest of Tallagandra Hill (022103) are probably at the same stratigraphic level as that in the sequence shown above. A small area of Pittman Formation is indicated by a chert outcrop north-northeast of the Sutton Granite.

The Picaree Formation, which overlies the Pittman Formation, consists of two rock units. The lower of the two (Oup_1) is fossiliferous grey and black carbonaceous, siliceous shale and slate, similar to the Acton Shale (Opik, 1958) in the Canberra city area and containing similar late Ordovician graptolites. The rocks overlying the graptolitic shale consist mainly of a distinctive coarse yellow-brown quartz sandstone (Oup_2); fine sandstone, mudstone, and black carbonaceous shale are present in some places.

Early Silurian? sedimentary rocks

The Murrumbateman Creek Formation, which overlies the Picaree Formation is regarded as Silurian. Smith (1964) found fossils of middle Silurian age in shale west of Glenco homestead, and found evidence for an unconformable relation with the Ordovician sequence. The recent mapping yielded no further evidence to confirm Smith's unconformity, and the fossiliferous shale is regarded as part of the younger Westmead Park For-

Figure 4

Figure 4 - Looking south along outcrop of metamorphosed banded fine-grained tuff, western slope of Nobby Hill (982 152). Dip of tuff is to left. (M2176, frame 33).

Figure 5

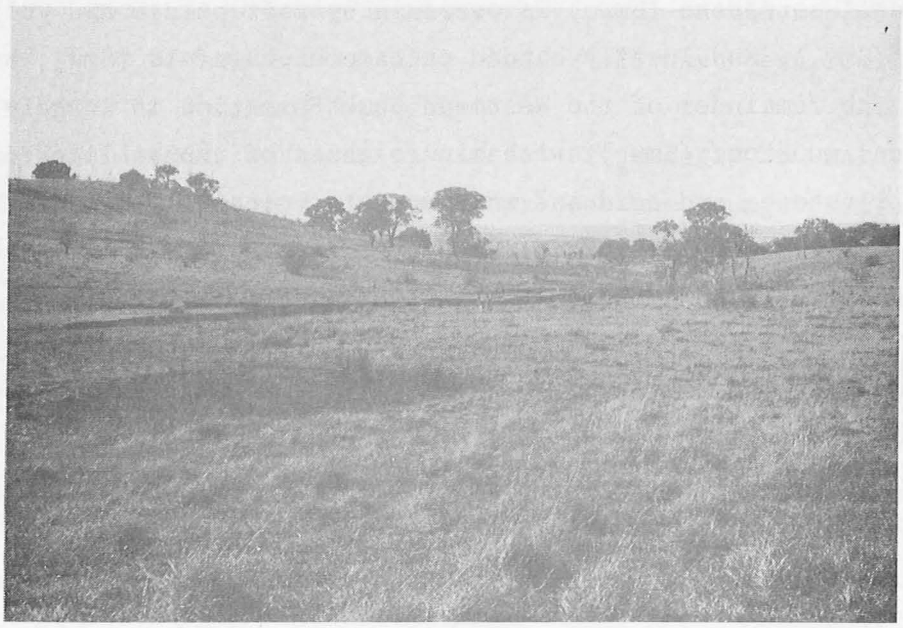


Figure 5 - Looking northeast across a small seepage and erosion gully (967 158) about 2 km west of Nobby Hill. Outcrops of hornfels on top of hill to left. (M2176, frame 31).

mation. Nevertheless an Early Silurian age for the Murrumbateman Creek Formation is likely, because the laminated shale towards the top of the formation is lithologically similar to the Lower Silurian State Circle Shale (Opik, 1958) in the Canberra city area; alternatively it is not impossible that the laminated shale rests with slight unconformity on the lower part of the Murrumbateman Creek Formation.

The recent mapping has enabled the Murrumbateman Creek Formation to be divided into two parts. The lower part (Slm_1), which is possibly unconformable on the Ordovician sediments, consists of massive siltstone and mudstone with minor coarse quartz sandstone. The upper part (Slm_2) consists of micaceous and feldspathic sandstone, similar to some of the Ordovician rocks, and laminated siltstone and shale.

Middle to Late Silurian sedimentary and volcanic rocks

The Westmead Park Formation overlies both the Ordovician Picaree Formation and the Lower Silurian? Murrumbateman Creek Formation, and an unconformity has been inferred at the base of the Westmead Park Formation. The basal rock unit (Smw_1) of the Westmead Park Formation appears to be a white to dark purple quartz sandstone which can be traced around the nose of an anticlinorium plunging south-southwest. This sandstone, which was previously regarded as part of the Murrumbateman Creek Formation, is possibly a correlate of the Camp Hill Sandstone (Opik, 1958) in the Canberra city area.

The basal sandstone (Smw_1) is overlain by soft purple and yellow-brown siltstone (Smw_2), and locally banded calcareous hornfels (Smw_3; see Metamorphism). The remainder of the Westmead Park Formation is largely hard siltstone and mudstone (Smw_4), with minor lenses of impure limestone and calcareous siltstone, and acid and intermediate volcanic flows and tuff (Fig. 4). The largest lens of calcareous siltstone (Smw_8) extends southwest from Nobby Hill and contains fossils of middle to Late Silurian age. A graptolite locality (978153) in hard green-grey mudstone was found during the mapping but the specimen recovered there was too poorly preserved to identify.

The volcanic rocks in the Westmead Park Formation consist of dacite, agglomerate, quartz andesite, and andesite; they include the dacite and agglomerate on the western margin of the area which Smith named the Glenesk Volcanics, and some previously unmapped volcanics southwest of Westmead Park. The recent mapping indicates that all the volcanics, including Smith's Glenesk Volcanics, can be regarded as belonging to the Westmead Park Formation; there is no structural reason for separating the Glenesk Volcanics from the other volcanics, now that the Glenesk Volcanics have been found to overlie part of Westmead Park Formation and not the Murrumbateman Creek Formation. The boundaries of the volcanic rocks appear in some places to be discordant with structures in the surrounding shale and in other places conformable; the explanation is uncertain. Further description of the volcanic rocks is given in Appendix 1.

The Fairbairn Group (Opik, 1958), as mapped in the area, includes all the sedimentary rocks which occupy a graben between the Sawpit Gully Fault and Sullivans Fault. By virtue of the known downward displacement on the eastern side of the Sawpit Gully Fault, from its southern extension as the Gungahlin Fault (Hohnen, 1974), the Fairbairn Group must be younger than the Westmead Park Formation. The rocks, which consist of purple, and pale grey shale with sandstone in the survey area, are assigned to the Fairbairn Group because they are overlain by the middle to Upper Silurian Gladefield Volcanics at Majura Road, farther south in the Canberra area (Moore, 1957), and because the southern part adjacent to the volcanics has previously been shown as Fairbairn Group (Best & others, 1964). Smith showed these rocks as Ordovician where they occur on his map, presumably because of their strong deformation. No fossils have been found in the Fairbairn Group in the area mapped.

The Gladefield Volcanics consist of strongly to weakly foliated dacite and tuff (see Appendix 1) and represent the youngest Silurian rocks in the sequence in the area.

Acid intrusives

Several Siluro-Devonian? intrusions of acid composition occur in the Ordovician rocks east of Sullivans Fault. The largest is the northern half of an adamellite body originally named the Bywong Granite (Day, 1952), but shown on the Canberra 1:250 000 geological map (Best & others, 1964) and referred to by Stauffer, Wilson & Crook (1964) as the Sutton Granite (gbs). The smaller intrusions to the north were mapped by Smith as microadamellite, microgranodiorite, and microtonalite. A good exposure of one of these intrusions and its contact with sedimentary rocks has recently been opened up by roadworks on a new deviation of the Sutton-Gundaroo Road about 2 km southwest of Gundaroo (Fig. 6).

Intermediate intrusives

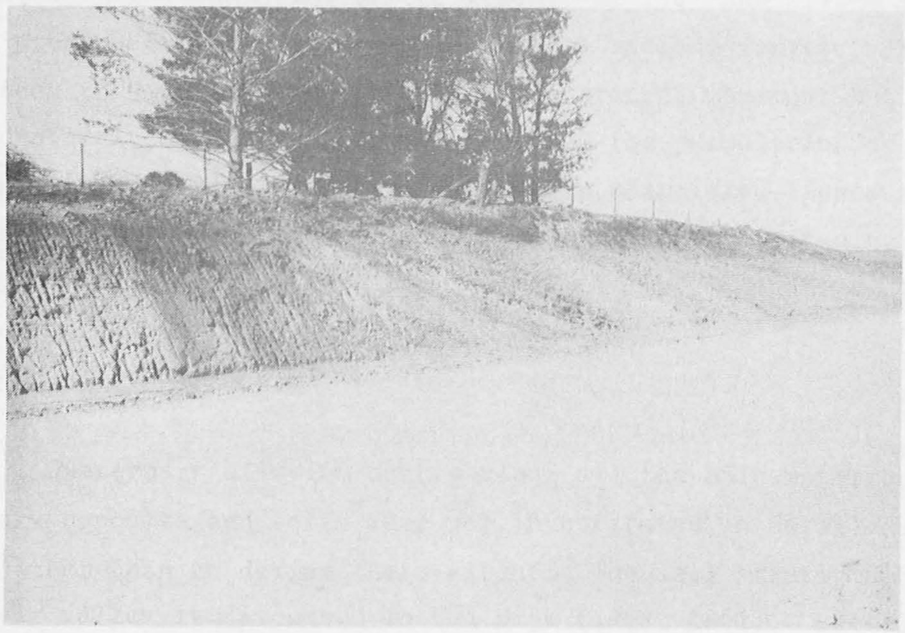
A small previously unmapped diorite intrusion crops out in the southwest corner of the area (935114; see Appendix 1 for description). The intrusion is almost circular in plan and is emplaced in rocks of the Westmead Park Formation.

A weathered intermediate or basic intrusive crops out adjacent to hornfels east of point B on the cross-section line (967 159; Plate 1, Fig. 5). The rock is possibly a sill, as shown in the cross-section. Alternatively, it could be a volcanic flow and dyke.

Both these intrusions are probably of middle Silurian to Early Devonian age.

Tertiary? gravel

High-level quartz pebble gravel, in some places cemented by iron oxide and silica, which Smith named the "Barnsdale Conglomerate", is found on terraces and flat topped hills in several places in the east of the area (Fig. 6). The gravel is subangular to well rounded and ranges in size up to more than 10 cm in places. It was presumably deposited along the ancestral courses of the Yass River and its tributaries. Its thickness does not exceed 10 m. The RL of the base of the gravel ranges from 590 m near the northern edge of the map to 640 m in the south near the Sutton Granite. Erosion since deposition, probably in the Tertiary, has left the gravel at elevations ranging from 15 to 45 m above the present-day watercourses. In two places more than one level of gravel is apparent. One is north of Springdale (028 168) where the highest and lowest base levels of the gravel are at RL 630 and 610 m; the other is east of Bywong (056 120) where the highest and lowest gravels are at RL 640 and 610 m.



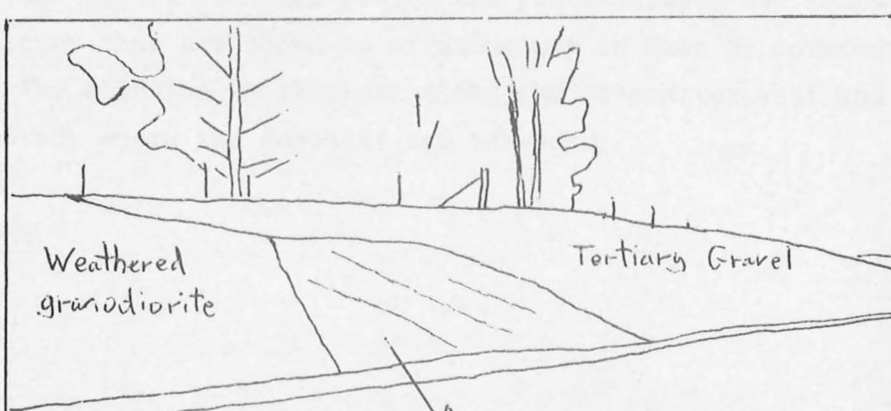


Figure 6 - Contacts between granodiorite, Ordovician sedimentary rocks, and Tertiary gravel exposed in road-cutting (at 057 199) about 2 km southwest of Gundaroo. (M2176, frame 7).

The gravels were probably deposited and reworked over an extended period; later, erosion entrenched the watercourses about 15 m below the lowest gravel level. The cementing of the gravels by iron and silica seems to be most pronounced where the gravel overlies ancient faults. The faults do not seem to have displaced the gravel by recent movement but the iron and silica could have been derived from the percolation of mineral solutions along the fault zones. A strongly silicified linear zone in the gravel nearest to the Sutton Granite may coincide with a fault, as shown in Plate 1.

Quaternary alluvium

Quaternary alluvium occurs along all the main watercourses. The Quaternary deposits and soils were not investigated in detail during this survey, other than to define their extent. The soil stratigraphy of the Yass River valley is discussed in Van Dijk (1959, 1961). The alluvium is probably less than 2 m thick in most places, other than along some sections of the Yass River. In some places the gentle slopes and flats lacking rock outcrop that are shown as alluvium may in fact be covered by residual soils. The alluvium is thickest along the Yass River west and northwest of Gundaroo, where the deposits are terraced.

STRUCTURE

Folding

Two structural zones are present in the area: one in the east, where the rocks are strongly folded, and the other in the west where the rocks are less strongly folded. A gradational boundary between the two zones lies immediately west of, and parallel to, the Sawpit Gully Fault.

Both Ordovician and Silurian rocks in the eastern zone are folded about meridional axes. Dips in the Ordovician rocks are generally steep, and plunges of lineations and minor folds both to north and south indicate more than one episode of folding. Several anticlines and synclines can be delineated, with axes paralleling the strikes of nearby faults. Minor folds on the limbs of major folds are evident; they are well exposed, for example, in cuttings along the Gundaroo-Murrumbateman road east of

Balbriggan. Microfolding occurs in the core of the syncline in the Picaree Formation on the northern edge of the area (007 231) and also in the Pittman Formation in the anticline immediately to the east about 600 m beyond the northern margin of the map. The Silurian sedimentary rocks between the Sawpit Gully Fault and Sullivans Fault are strongly cleaved, and bedding tends to be obscure. The overlying volcanics are dominated by foliation; flow banding that would help to delineate folds was not observed.

In the western structural zone the Ordovician and Lower Silurian? rocks are more complexly folded than the middle to Upper Silurian rocks. Smith's mapping of a recumbent syncline along the ridge between Picaree and Jobbins Hills was partly confirmed, although it appears more likely that there are two recumbent folds, as shown in Plate 1. Folding is gentler in the middle to Upper Silurian Westmead Park Formation than in the older rocks; dips rarely exceed 45^{o}. The formation is folded into a major antiform plunging south-southwest and is apparently unconformable on the Ordovician and Lower Silurian formations. A few smaller folds on the limbs of the antiform are present.

The Tertiary? gravel has not been tectonically folded; however, slump folding is evident in a small pit on top of the hill east of Springdale (035 170).

Faulting

The fault with the largest displacement in the area is Sullivans Fault along which the oldest Ordovician and youngest Silurian rocks have been brought into proximity. The recent mapping indicates that the fault passes farther to the east than previously thought, and does not converge with the Sawpit Gully Fault east of Westmead Park. The Sawpit Gully Fault appears, at least in places, to comprise several parallel faults; the downthrow is on the eastern side, but the amount of movement is unknown. The northern extension of the Queanbeyan Fault forms the western boundary of the Sutton Granite, and the fault can be traced northwards to a point west of Gundaroo; the amount of downward displacement on the western side cannot be determined in the area mapped.

Several faults, most of small measurable displacement in the western part of the area strike north-northeast. Four faults mapped by Smith - the Mountain Vale Fault, the Picaree Fault, the Glengyle Fault, and the Kia Ora Fault - were confirmed, and their southward extensions traced. Smith's Stonevale Fault, which he regarded as partly forming the boundary between the Murrumbateman Creek and Westmead Park Formations, was found to be somewhat indefinite and not to form the formational boundary. The fault shown on the map (Plate 1) immediately west of the Kia Ora Fault was previously unmapped; the downthrow on the western side is indicated by the repetition of the basal sandstone (Smw_1) of the Westmead Park Formation about 3 km north of the ACT-NSW border.

Faults in the area are indicated mainly by quartz reefs and sheared ironstone gossans, combined in some places with lithological discontinuities. The reefs and gossans indicate that all faults are steeply dipping but precise dips are only measureable on one or two minor faults.

METAMORPHISM

Regional metamorphism

Low-grade regional metamorphism affects the rocks in the area east of the Sawpit Gully Fault. Metamorphism is even more pronounced to the east of the Queanbeyan Fault, where transposition of bedding in shale has resulted in the formation of laminations parallel to the cleavage. In the coarser siltstone and fine sandstone mica has recrystallised parallel to the cleavage. A good exposure of bedding transposition occurs at the northern end of the new road-cutting which also exposes the small intrusive 2 km southwest of Gundaroo (057 198).

Contact metamorphism

A low-grade contact aureole surrounds the Sutton Granite and extends at least 3 km north-northeast of its northern margin, indicating that the granite body plunges at a shallow angle in this direction.

Rocks of the Westmead Park Formation show contact metamorphism in several places with the formation of pelitic hornfels and calc-silicate hornfels, in places containing needles of actinolite. Smith inferred a granitic body at depth as the reason for the metamorphism. A weathered rock of intermediate or basic composition which is possibly a sill may have caused the metamorphism near the base of the Westmead Park Formation (965 157), as shown on the cross-section; however, the reason for the more extensive, but lower grade, metamorphism of outcrops near Nobby Hill is not evident in the field.

A small contact aureole surrounds the diorite intrusion near the ACT-NSW border. Other such diorite or granite bodies may underlie the Nobby Hill area as Smith suggested. If so, the metamorphism could have been caused by hot metasomatic solutions penetrating permeable tuffs adjacent to those calcareous rocks most susceptible to metamorphism. The possible sill mentioned above could have been one of these tuffs. This would explain the tendency of the metamorphism to be concentrated at several stratigraphic horizons rather than distributed uniformly.

MINERAL DEPOSITS

Smith (1963) has made notes on past mining activities in the area. The mining, principally for gold, was not sustained by worthwhile ore bodies, and generally petered out after sporadic working before the turn of the century. White clay for brickmaking is the only commodity now being worked, and is being won from pits close to Back Creek about 9 km southwest of Gundaroo.

Several mineral exploration leases have recently been taken out to test the ironstone gossans which occur in several places, but so far no significant mineral deposits have been reported. The recent mapping indicates that the gossans are stratigraphically controlled, as they commonly occur in the more calcareous parts of the Westmead Park Formation, or in adjacent faults. Gilligan (1975) gives results of four diamond-drill-holes put down at the Glenesk gossan, about 200 m east of Nanima Road, showing that the ironstone there occurs at the contact of limestone and weathered acid volcanics. Other gossans are also associated with calcareous rocks in the area.

HYDROGEOLOGY

Groundwater extraction

The locations of water-bores in the area are shown in Plates 1 and 2. All the bores are in the Yass River catchment.

Table 1. Water-bore and well data

	BORES			WELL
BMR NO.	130	143	163	157
Co-ordinates	053 080	983 190	998 190	994 111
Depth (m)	6.8	54.9	29.2	1.8
Depth to WT (m)	5.4	-	4.6	0.9
Yield (1/hr)	-	1500	3400	380
Quality EC (mhos)	1035	595	551	1010
TDS(ppm)	725	358	386	600
pH	8.5	-	-	7.7
Ca	16	38	39	108
Mg	4	22	27	60
Na ANALYSIS	23	45	28	60
K 9ppm)	1	1	1.5	1
HCO_3	73	289	155	475
Cl	12	16	101	119
SO_4	14	25	10	70
NO_3	8	-	-	-
F	-	-	0.15	-
B	-	-	0.25	-
TOTAL HARDNESS AS $CaCO_3$	56	185	209	517

Groundwater is derived from fractured-rock aquifers and permeable layers in alluvium and colluvium. Water quality is variable as indicated by the chemical analyses (Table 1) and from the comments of landholders.

The potentiometric surface is high in the valley 5 km northwest of Gundaroo, and a spring in one place (028 243) in which a well has been sunk yields good potable water. The limited information available indicates that water quality is poorer in aquifers in the sedimentary rocks of the Westmead Park Formation and Fairbairn Group, which are in part calcareous.

DRAINAGE PROBLEMS

Low-lying swampy areas occur in some places along the main watercourses, as shown in Plate 2. Some such as those along Murrumbateman Creek, appear to be the result of a high potentiometric surface in colluvium at the food of adjacent hills, possibly brought by a restriction of lateral groundwater movement by hard-rock barriers at depth.

ENGINEERING GEOLOGY AND URBAN CONSTRAINTS

ENGINEERING FACTORS

The following notes are a preliminary outline of the geological and hydrological factors which should be allowed for in planning any future urban development in the area. Eight mapped units - each characterised by a particular constraint or combinations of constraints to urban development - have been defined in an urban constraints map (Plate 2). The generalised characteristics of each unit (Table 2) do not take into account possible departures from the predicted conditions locally, eg., in fault zones; site investigations should be carried out for all engineered structures.

A factor not mentioned in Table 2 is the possibility of special foundation difficulties with limestone, in which cavities can occur. Although no pure limestone likely to contain cavities was mapped in the area, calcareous rocks occur throughout the Westmead Park Formation and Fairbairn Group (see Plate 1), and limestone with cavities may be present.

Table 2. Urban Constraints

(Note: To be read in conjunction with text and Plate 2)

MAPPING UNIT	FOUNDATION CONDITIONS	METHOD AND EASE OF EXCAVATION	HYDROLOGY	SLOPE AND SLOPE STABILITY
A	Good: rock at shallow depth generally about (0.2 m)	Blasting required for most excavations; numerous rock outcrops	Well drained	Slopes mostly greater than 10^{o} and possibly unstable in places
B	Good: hard rock at shallow depth in most places	Blasting required for excavation in many places; scattered rock outcrops	Well drained	Moderate slopes less than 10^{o}; unstable slopes unlikely in most places
C	Good: hard shale at shallow depth common	Blasting needed for excavation in many places; hard shale at shallow depth	Mostly well drained, but the hard massive shale is of low permeability, and low-lying ground may become saturated	Moderate to gentle stable slopes
D	Hard crust of cemented gravel may be foundation difficulty in places; otherwise good	Cemented gravel in places may qrequire blasting; otherwise easily excavated	Well drained	Gentle slopes (less than 5^{o}); slumping in gravel possible on steeper margins
E	Good at moderate depth (2.5 m) in most places. Possible zones of very deep weathering, e.g. where white clay is present	Mostly rippable to 2 m depth except on and close to sparse outcrops readily excavated	Mostly well drained	Moderate to gently stable slopes

TABLE 2 (Continued)

MAPPING UNIT	FOUNDATION CONDITIONS	METHOD AND EASE OF EXCAVATION	HYDROLOGY	SLOPE AND SLOPE STABILITY
F	Large structures should be founded on rock below surficial deposits. Deep foundations (more than 5 m) in places	Mostly rippable to 2 m depth; easily excavated	Drainage mostly adequate, but possibly poor in a few places; may be subject to flooding	Flat terrain
G	Deep foundations to rock below surficial deposits for large structures	Easily rippable to greater than 2 m throughout	Subject to flooding	Flat terrain
H	Doubtful foundation conditions for all structures; will require site investigation for most structures	Easily rippable but drainage of excavations would be a problem	Subject to frequent and prolonged flooding	Depressions in flat terrain

Excavation conditions would differ for areas underlain by igneous rock (granite and volcanic rocks), and areas underlain by sedimentary rock. In areas underlain by igneous rock, hard fresh or slightly weathered boulders at shallow depth would tend to be found surrounded by rippable, moderately and highly weathered rock. The sedimentary rocks, on the other hand, would generally display a more uniform weathering profile, with a progressive increase in hardness and strength with depth.

Another factor is possible allowance for seismic activity. Although earth tremors occur occasionally, they are of low magnitude. Epicentres of the nine tremors of greatest magnitude over the last 60 years have all been outside the area and the felt intensity around Canberra has not exceeded IV on the Modified Mercalli scale (see Jacobson, Vanden Broek, & Kellett, 1976). Multilevel buildings should be designed according to specifications for Zone A of the Standards Association of Australia Draft Code No. DR76100 'Draft Australian Standard Rules for the Design of Earthquake-Resistant Buildings', 15 September 1976. Buildings founded on unconsolidated material such as alluvium and colluvium would be more susceptible to damage than those founded on rock.

ENVIRONMENTAL FACTORS

Should urban development be planned in the area it is suggested that the steep slopes with numerous rock outcrops be left in their natural state as parks and nature reserves. Difficulties in excavation would, in any case, make them more costly to develop.

Outcrops of special geological interest should also be preserved, if possible. Six outcrops which represent the most interesting geological features in the area are shown in Plates 1 and 2, and their characteristics are listed below.

1. A fossil locality (926 186) in shale about 1 km northwest of Glenco where slabs of fossiliferous shale have been unerthed by a fallen tree.
2. The outcrops of diorite (935 114) and the surrounding contact metamorphic aureole near the ACT-NSW border.

3. The basal sandstone of the Westmead Park Formation and banded calcareous hornfels at the top of a hill about 700 m east of Stonevale (962 158).
4. Actinolite hornfels outcrop about 800 m east of locality 3 (970 159).
5. Gravel cemented by iron oxides at the junction of the Sutton-Gundaroo and Gundaroo-Murrumbateman roads (052 172); the northerly plunge of an anticline is well exposed in the underlying Ordovician sandstone and shale.
6. The contact between porphyritic microgranodiorite and Ordovician sedimentary rocks with bedding transposition in shale in a road-cutting about 2 km southwest of Gundaroo (057 198).

EXTRACTIVE RESOURCES

Topsoil and sand

Deposits of silty loam suitable for use as top-dressing are most likely to be found along the alluvial flats of the Yass River near Gundaroo. Useful sand deposits may also be present in the alluvium.

Road-base materials

Several small quarries in the area have been worked for plastic and non-plastic gravel for surfacing the local roads; their locations are shown in Plate 1. Rocks quarried include: slightly weathered siliceous shale in the Picaree Formation (Oup_1); slightly weathered siltstone and mudstone in the Westmead Park Formation (Smw_4) about 1.5 km northwest of Kia Ora; moderately to highly weathered siltstone in the Pittman Formation (Omp) west of Murrumbateman Creek and north of Jobbins Hill; slightly to moderately weathered shale in the Pittman Formation about 2 km west of Bywong; and moderately to highly weathered shale in the Fairbairn Group about 3 km southeast of Westmead Park. Small pits in the unconsolidated parts of the Tertiary? gravel deposits have provided gravel for surfacing unsealed roads; the gravel is not generally satisfactory as it lacks grains and binding clay.

Brick shale

Highly weathered white leached shale and white clay is being worked at a locality beside Back Creek east of Kia Ora. The shale forms part of the Fairbairn Group. Shale and siltstone potentially suitable for brick-making form the major part of the Westmead Park Formation, Fairbairn Group and the lower part of the Murrumbateman Creek Formation (Slm_1), and many deposits of brick shale will be found in the area.

Stone

Siliceous shale (Oup_1) near Murrumbateman Creek (938215, Fig. 7) has been quarried at times for rough stone. The pale grey Sutton Granite may be suitable for use as facing stone, feature walls and exposed aggregate. The dacites in the area could be suitable for stone, but the outcrop areas are generally small, and more suitable sites in such rocks could be expected to occur to the west of the area towards Gooromon Ponds, where dacite and other rocks of related composition are extensive (Henderson, 1975). The outcrops of porphyritic microgranodiorite are too small to provide a source of building stone.

Rock aggregate

It is unlikely that there are any locations for possible rock aggregate quarries more favourable than could be found in the Gooromon Ponds area to the west. The Sutton Granite could provide a quarry site on the steeper, less deeply weathered slopes of Bywong Hill.

Gravel

Some of the larger unconsolidated Tertiary gravel deposits may be suitable for screening for aggregate and for use as pebbles and cobbles in garden features.

Figure 7 - Looking east towards a stone quarry in the Picaree Formation near the Gundaroo-Murrumbateman road, and swampy alluvial flats bordering Murrumbateman Creek (938 215). (M2176, frames 20 & 21).

Figure 7

CONCLUSIONS

1. The area is underlain by Ordovician and Silurian sedimentary rocks, Silurian acid volcanics, and intrusives of probable Late Silurian or Early Devonian age, and covered in places by Cainozoic gravel and alluvium.

2. A previously unrecognised unconformity separates the Westmead Park Formation (middle Silurian) and rocks of Ordovician to Early Silurian? age.

3. The nature and position of the Ordovician-Silurian boundary in the area is not known.

4. The Westmead Park Formation extends further west than previously mapped, and includes volcanic rocks that were previously mapped as a separate formation, the Glenesk Volcanics.

5. Faulting in the area has been clarified by the mapping of extensions of known faults.

6. The cause of the metamorphism in the Westmead Park Formation is at least partly due to small intermediate or basic intrusions.

7. Mapping and water-bore data indicate a high potentiometric surface in at least some parts of the area. Groundwater quality ranges from good to poor.

8. Most of the area is suitable for urban development. Additional investigations of the alluvial soils and areas of poor drainage would be required for the planning of urban development.

9. Areas with extractive resources should be reserved to ensure that urban development does not preclude their exploitation.

10. Outcrops of special geological interest are located in the area, and their preservation should be considered.

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APPENDIX 1

NOTES ON PETROLOGY OF IGNEOUS ROCKS

Thin sections were cut of rocks covering the range of igneous rock types in the area. The following notes briefly describe their mineralogy and texture.

Volcanic rocks

The volcanic rocks in the Westmead Park Formation range in composition from dacite through quartz andesite to andesite. The dacite is coloured grey in hand specimen, and in thin section is seen to consist of phenocrysts of quartz and altered plagioclase in about equal proportions, and lesser altered mafic minerals, in a microcrystalline quartzofeldspathic groundmass; the phenocrysts range in size to about 5 mm and constitute about half of the rock. The andesite and quartz andesite resemble the dacite in colour and mineral composition but most of the phenocrysts are plagioclase, and rarely quartz in the quartz andesite almost absent; the grainsize of the phenocrysts tend to be less than in the dacite and is rarely more than 3 mm in diameter.

Dacite is the most common rock type in the Gladefield Volcanics, and is of similar composition to that in the Westmead Park Formation. The texture is characterised by a distinct tectonically-induced foliation which in thin section shows a subparallel zones of diverse crystallinity in the groundmass of the rock. Different flows have different grainsizes; in some the phenocrysts may range to 5 mm in diameter; in others they do not exceed 1 mm. Foliation appears to be most pronounced in the finest-grained rocks.

Sutton Granite

The rock is a pale grey adamellite and consists essentially of quartz (40%), plagioclase (30%), orthoclase (15%), and biotite (15%). The plagioclase is strongly zoned with cores of altered labradorite and albite margins. The maximum grainsize is about 6 mm.

Minor acid intrusives

The composition of these rocks ranges from adamellite to tonalite; all are porphyritic. A thin section of the intrusive at Bowylie contains about 50% phenocrysts, to 6 mm diameter, of quartz, plagioclase, biotite, and clots of an altered mafic mineral; the microcrystalline groundmass consists mainly of quartz, orthoclase and scattered flecks of biotite.

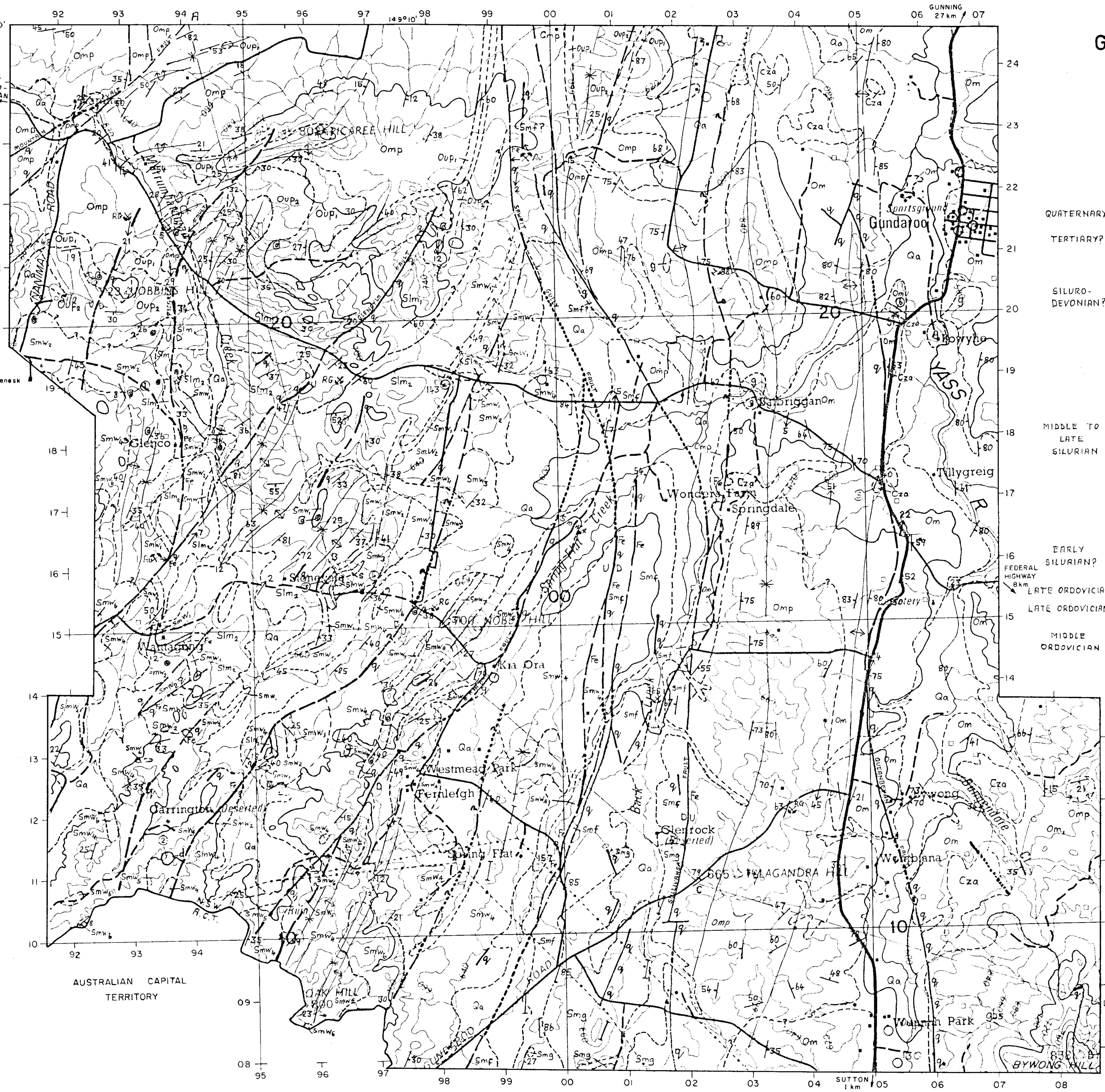
Diorite

The diorite is leucocratic, and consists of plagioclase (labradorite), augite, hornblende, and patches of chlorite. The plagioclase, the domminant mineral, forms elongated laths intergrown with large patches of augite in optical continuity. The hornblende is brown and strongly pleochroic, and partly replaces the augite. The chlorite contains criss-crossing acicular inclusions.

GEOLOGICAL MAP OF THE GUNDAROO-WESTMEAD PARK-NANIMA AREA

SCALE 1:50000

compiled by G.A.M. Henderson



QUATERNARY		Qa	Alluvium
TERTIARY?		Cza	Quartz pebble gravel & conglomerate
SILURO-DEVONIAN?		s	Intermediate or basic sill ?
		d	Diorite
		g	Porphyritic microgranodiorite
	Sutton Granite	gbs	Biotite adamellite
MIDDLE TO LATE SILURIAN	Gladefield Volcanics	Smg	Foliated dacite & tuff
	Fairbairn Group	Smf	Purple & grey cleaved shale, sandstone
	Westmead Park Formation	Smw_8	Green-grey to yellow-brown siltstone & mudstone
		Smw_7	Andesite & quartz andesite
		Smw_6	Dacite, dacitic tuff & agglomerate
		Smw_5	Pale grey, banded fine tuff
		Smw_4	Calcareous siltstone & impure limestone
		Smw_3	Purple & yellow-brown siltstone
		Smw_2	Pelitic & banded calcareous hornfels
		Smw_1	White to dark purple quartz sandstone & quartzite
EARLY SILURIAN?	Murrumbateman Creek Formation	Slm_2	Micaceous & feldspathic sandstone, laminated siltstone
		Slm_1	Massive siltstone & mudstone, minor sandstone
LATE ORDOVICIAN?	Picaree Formation	Oup_2	Quartz sandstone, minor siltstone & shale
LATE ORDOVICIAN		Oup_1	Black to pale grey carbonaceous, siliceous shale
MIDDLE ORDOVICIAN	Pittman Formation	Omp	Micaceous sandstone, chert siltstone, shale, and mudstone
		Om	Purple, green & brown feldspathic sandstone & siltstone
		Om_1	Contact aureole of Sutton Granite

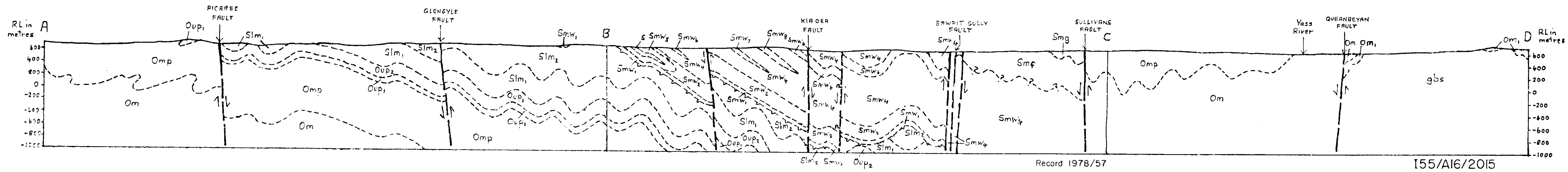
- Geological boundary
- Unconformity
- Fault (q, quartz-filled fault, Fe, iron oxide filled; DU indicates relative movement down, up)
- Anticline
- Syncline
- Anticline, overturned
- Syncline, overturned

Where locations of boundaries, folds, and faults are approximate, line is broken; where inferred, queried; where concealed, boundaries are dotted, faults are shown by short dashes

- Strike and dip of strata
- Strike and dip of cleavage
- Strike of vertical cleavage
- Plunge of fold axis or lineation
- Fossil locality
- Au Abandoned gold mine
- Quarry; RG - road gravel, BS - brick shale, S - stone
- Massive ironstone gossan
- O143 Water bore showing BMR number
- □13 Well showing BMR number
- Spring
- ② Outcrop of special geological interest

CROSS-SECTION A-D

(Alluvium omitted)



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URBAN CONSTRAINTS MAP OF THE GUNDAROO – WESTMEAD PARK – NANIMA AREA

SCALE 1:50000

0 1 2 3 4 km

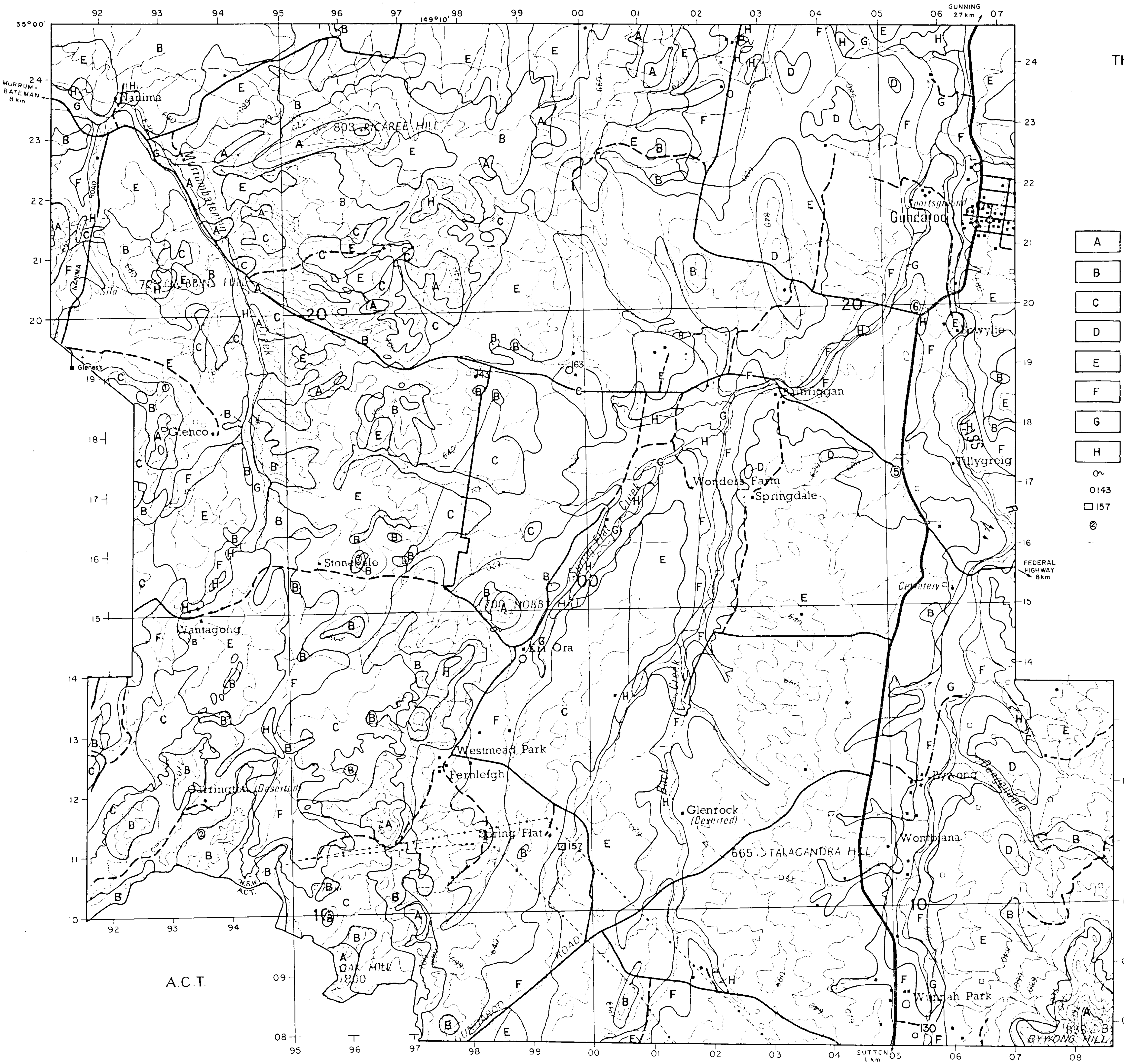
A	*Slopes mostly greater than 10°; shallow soil and numerous rock outcrops*
B	*Moderate slopes <10°; shallow soil and rock outcrops common*
C	*Moderate to gentle slopes <5° with hard shale at shallow depth*
D	*Cemented gravel may lie at or near surface*
E	*Moderate to gentle slopes <5° most favourable for urban development*
F	*Alluvial flats; mostly suitable for urban development provided drainage adequate; flooding possible*
G	*Alluvial areas subject to flooding*
H	*Low-lying swampy areas*

Spring

0143 *Water bore*

□157 *Well*

② *Outcrop of special geological interest*



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