BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1981/6

Notes to accompany the 1:25 000-scale geological field compilation sheets of the CANBERRA 1:100 000 Sheet area

by

R.S. Abell

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Dyline or transparent copies of the 1:25 000 compilation sheets are available from Copy Service, Government Printer (Production), GPO Box 84, Canberra 2600; telephone (062) 954560.

ABSTRACT

This Record gives a provisional outline of the geology of the CANBERRA* 1:100 000 Sheet area.

The area, in the southeastern part of the Lachlan Fold Belt, includes parts of the Cowra-Yass Synclinorial Zone, the Molong-South Coast Anticlinorial Zone, and the Captains Flat-Goulburn Synclinorial Zone (Scheibner, 1973). Ordovician to early Devonian rocks are overlain by patchy Cainozoic sediments.

The earliest known geological record on the Sheet area probably starts with deep-water marine sedimentation in the mid-Ordovician which reached a maximum development during the Late Ordovician with the deposition of graptolitic black shales. Initial deformation (F_1) occurred at the close of the Ordovician, largely as gravity-type deformation triggered by sediment load instability resulting from uplift along the Molong Volcanic Rise. During the early Silurian a marine proximal flysch sequence was deposited disconformably on the meridionally trending proto Canberra-Yass Shelf. An F_2 deformation in the mid-Silurian refolded the earlier gravity folds to give variably plunging tight upright folds and low-grade regional metamorphism. The end of the F_2 deformation saw the onset of Late Silurian acid volcanism on the Canberra-Yass shelf; this consisted of widespread extrusion of thick pyroclastic flows and was associated with shallow-marine terriginous and carbonate sedimentation. The Captains Flat Trough was initiated at this time by incipient crustal rifting leading to the deposition of thin beds of felsic volcanics, local development of proximal flysch and marginal intrusions of dolerite and gabbro. At the end of the Silurian an episode of mild NE-trending folding (F_3) brought acid extrusion to a close on the Canberra-Yass shelf. Associated with this deformation was a phase of granitoid intrusion with the older 'S' type intrusions emplaced in the west grading into younger 'I' types as the centres of activity spread eastwards. An F_4 deformation in the Carboniferous brought sedimentation to a close in the Captains Flat Trough where rocks were intensely deformed into tight flexural folds and have a strong cleavage-foliation. On the Canberra-Yass shelf, the same deformation was milder, being expressed mainly as complex faulting and associated conjugate kink folds.

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* For identification, the names of 1:100 000 Sheet areas are typed in capitals

After the close of the F_4 deformation the area was subjected to weathering and erosion until epeirogenic uplift occurred towards the end of the Mesozoic. Basalt extrusion is absent from the local area but continental sedimentation and weathering occurred during the Miocene and Pliocene interspersed with minor uplift episodes partly controlled by older meridional fault lines. Unconsolidated Quaternary sediments were deposited in lakes and streams largely in response to climatic changes associated with the Pleistocene Ice Ages.

INTRODUCTION

This Record aims to present geological data as a series of eight field compilation sheets. Although these maps show a provisional interpretation of the geology they are mainly designed as a geologic data base for the interpretation of the geology of the CANBERRA 1:100 000 Sheet area. These sheets will be modified to compile a preliminary 1:100 000 map which in turn will contribute to the production of a third edition of the Canberra 1:250 000 geological sheet.

The Canberra Sheet area is bounded by latitudes 35°00'S and 35°30'S, and longitudes 149°00'E and 149°30'E. It forms the north-central portion of the Canberra 1:250 000 Sheet (SI 55-16). About one-third of the Sheet area lies within the ACT and the remainder in New South Wales (Fig. 1). The total area is about 2500 km^2.

The field compilation sheets were produced in three phases:

(a) Compilation (January - April 1976). Geological maps relating to the Sheet area were collected and plotted at 1:25 000. At the completion of this phase it was found that only about 20 percent of the Sheet area was without some form of geological information (Fig. 2). The main sources of data were BMR and NSW Geological Survey published and unpublished reports, university theses, and company reports. The compilation maps were used as a base for planning field-work.

(b) Fieldwork (May 1976 - June 1978). The compilation phase showed up the scarcity of field data maps. It was not possible to spot check the quality of the field data on which most geological interpretations were based. This lengthened the fieldwork program and made closely spaced vehicle and foot traverses necessary for understanding the geology of the area. Air photographs were used mainly in planning traverses and to locate outcrops.

(c) Assessment (July 1978 - October 1980). This period was largely spent interpreting the field data, and producing the 1:25 000-scale maps and accompanying Record. Considerable time was also spent examining critical areas and attempting to solve specific structural and stratigraphic problems.

PHYSIOGRAPHY

Relief

The Canberra Sheet area forms part of the Southern Tablelands of New South Wales. Relief is moderate with physiographic features ranging from dissected upland and tableland areas with youthful valleys, rapids and occasional waterfalls to mature plains with wide valleys and perched alluvial basins.

Undulating country in the northwest, with isolated hills and ridges at elevations of 500-700 m, rises gradually southwest to higher ground with local rugged terrain reaching over 1000 m; the highest point is 1120 m at Mount Molonglo (grid ref. 108718).

Drainage

The general northwest direction of the main drainage results from the position of the mapped area, immediately west of the Main Divide. The country is drained largely by the Molonglo and Yass drainage basins (Fig. 3), streams and creeks in these bains flowing towards the Murrumbidgee River, which acts as the local base level. Lake George is the centre of a basin of internal drainage. Most of the streams follow or cut sharply across the meridional tectonic trend of the underlying geology. Small earth movements during the Cainozoic initiated local disruptions and rejuvenation of the drainage pattern to form Lake George, cause stream capture along the Lake George escarpment and Molonglo-Yass drainage divide, and incised meanders of the Molonglo River (Jennings, 1972; Ollier, 1978).

Physiographic units

Six physiographic units are recognised: the Canberra Plain, Cullarin Tableland, Mount Kelly Upland, Mount Campbell Upland, Bungendore Plain and Rocky Pic Upland. Boundaries between these units may be gradational or coincide with faults (Fig. 3).

At the end of the Mesozoic the Canberra region was part of a moderately dissected landscape with some upland development to the south. The physiographic units originated by differential uplift of portions of this Mesozoic landscape by movements along fault lines during the Cainozoic. Subsequent rejuvenation of streams and selective erosion of rock types has also contributed to their formation.

The Canberra Plain is the most extensive physiographic unit, taking up most of the western half of the Sheet area. It is a broad plain which extends west onto BRINDABELLA, but narrows southwards onto MICHELAGO. The plain is interrupted by the incised valleys of the Molonglo and Murrumbidgee rivers west of Canberra and monadnock features at Mount Spring, Mount Ainslie-Gooroo ridge and Mount Taylor. Topographic expression of the Deakin, Winslade, and Sullivans Line faults is poor. Perched alluvial basins occur at Tuggeranong, Lanyon, and Jeir Creek. Other landforms and features of the landscape history of the Canberra Plain are discussed in Jennings (1972) and Ollier & Brown (1975).

The Mount Campbell and Mount Kelly Uplands are dissected relics of the original Mesozoic upland. The Mount Kelly Upland is developed most extensively on BRINDABELLA and the Mount Campbell Upland can be traced onto MICHELAGO.

The Cullarin Tableland is an uplifted fault block with a slight westerly tilt. The old planated surface remaining along the Lake George Range has been dissected by streams flowing west towards the Canberra Plain. Erosional remnants standing up to 200 m above the general level of the tableland are Yarrow Peak, Balcombe Ridge, and Turalla Hill.

The narrow Bungendore Plain is a complex unit which is partly gradational with, and partly abutting the Rocky Pic Upland at the eastern margin of the Sheet area. The Bungendore Plain is divisible into two subunits: (a) the Lake George Basin and (b) the Molonglo plain. These subunits are separated by a strong NNW-trending lineament (visible on LANDSAT 1:500 000 black and white imagery) which corresponds in part with the Ballallaba Fault, and can be traced as far south as Tuross River (Cobargo 1:100 000 scale topographic sheet).

The Lake George Basin probably developed from minor tectonism in the Tertiary which was controlled by pre-existing NNW-trending Palaeozoic fault lines. These movements were sufficient to disrupt the drainage pattern of the Upper Yass River catchment to create Lake George and associated fluvio-lacustrine sedimentation. The youthful nature of the western margin of the Lake George Basin is illustrated by steep slopes, a new consequent drainage, truncated spurs following landslip activity, and associated alluvial fans. These features developed in response to fault line rejuvenation and scarp retreat during high levels of Lake George in the Quaternary (Coventry, 1976).

The Molonglo Plain to the south has remained less affected by this activity since portions of the more mature and older south-southwest-trending Lake George escarpment south of the Bungendore-Gundaroo Road, has been maintained, and there has been continuous headward erosion of Millpost Creek and antecedant drainage of the Molonglo River.

DATA AVAILABILITY

Outcrop distribution

Outcrop is generally plentiful over the Sheet area except for alluviated areas around Lake George and the Molonglo Plains west of Hoskinstown. The best exposures are restricted to incised portions of creeks and rivers, e.g. the west Molonglo gorge and Jerrabomberra Creek, road and rail cuttings, and quarries at Canberra and Queanbeyan; outcrop is therefore good enough to allow detailed observations of rock units. Ridge and hill traverses often give good views of the surrounding country along the Lake George Range and the monadnock topography around Canberra, but outcrops are commonly weathered. Soil creep is a potent agency of erosion on valley and hillside scarps e.g. the Lake George and Queanbeyan fault line scarps, and care needs to be exercised when recording geological structure. Heavily timbered areas restrict exposure because of a mat of organic debris.

The imposition of urban development on the Canberra landscape has led to the excavation of many temporary exposures in building foundations, tunnels, underground sewerage systems, and drainage lines. More permanent exposure is provided by road cuttings excavated along State Circle, Tuggeranong Freeway and Hindmarsh Drive, which now provide good representative sections of the Late Silurian sediments and volcanics.

Since the Second World War rapid suburban development and afforestation has tended to obscure outcrop, and has caused topographic maps and aerial photographs to become rapidly dated. These and other environmental changes are documented in photographs held by the Australian Information Service, National Library of Australia (pre-1927 Canberra views series), reports (Cambage, 1918; Opik, 1958; Seddon, 1977); and aerial photographs.

Natural and artificial water cover occupies about 6 percent of the CANBERRA Sheet. In the areas of Lake Burley Griffin and Googong Reservoir an attempt has been made to show geological boundaries after Henderson (1979b) and Goldsmith & Evans (1980). Little is known about the bedrock geology beneath Lake George.

In recent years better access and new exposures have been created by roads feeding new land subdivisions in country areas of New South Wales, along the northern and eastern borders of the ACT. Access is now possible along a well defined fire trail to hilly country and creeks southeast of Queanbeyan, and east of Googong reservoir (keys to open gates may be obtained from the NSW Forestry Commission offices, Queanbeyan).

Although much of the field evidence on which past workers have based their interpretations of the geology of the Canberra area has been partly obliterated, the constant uncovering of the geology will always ensure an opportunity to review geological interpretations.

Aerial Photography

A listing of the aerial photograph coverage for the CANBERRA Sheet is given below:

(a) National Mapping black and white photography entitled 'Canberra 1968'. Nominal scale 1:85 000. Flying altitude 7625 m. Focal length 88.45 mm (RC 9). Negative numbers CAC/CII, CI. Total coverage.
(b) National Mapping colour photography entitled 'Australian Capital Territory 1968'. Nominal scale 1:28 000. Flying altitude 4270 m. Focal length 156.56 mm. Negative numbers CAC/C5, C7, C9, C12, C13, and C14. Part coverage (Fig. 2).
(c) NSW Lands Dept black and white photography entitled 'Canberra 1967'. Nominal scale 1:40 000. Flying altitude 5340 m. Focal length 114.44 mm. Negative numbers NSW 1484, 1485, and 1598. Total coverage.
(d) LANDSAT imagery (black and white, and false colour-CSIRO enhanced) corresponding to flight path 096, row 084. Common scale 1:250 000. Particular benefit was obtained from LANDSAT scene 1034-23192 which emphasised structural features because of low sun elevation (30°). In addition a 1:500 000-scale black and white mosaic of the ACT and SE Australia produced by BMR from Landsat band 7 was useful for regional photographic interpretation.
(e) Australian Survey Office colour photography. Nominal scale 1:10 000. The first set of photographs was flown in 1965 to assist in the planning and development of the ACT. Since 1972 the record has been updated by the issue of new sets of photographs on a 6-monthly basis.
(f) National Mapping infra-red colour photography entitled 'Canberra 1979'. Nominal scale 1:140 000 (RC 9). Flying altitude 12 500 m. Negative numbers CAC/C2612, C2613. Coverage eastwards to Long. 149°20'.

Since the first aerial photographs were flown in the Canberra region by Dept of Interior/Dept of Defence in 1940, there has been a great acceleration in the demand for such photographs, and more recently for remote sensing data, as an aid to scientific work.

Aerial photographic interpretation has been of limited assistance to geological mapping. Recognition of lithologies and mapping of boundaries has been hampered by complex geologic structure, lack of marker horizons, poor lithology-morphology relationships, and a thick weathering profile. Human activities such as urbanisation and alteration of natural vegetation patterns (conifer plantations and land clearing, etc.) obscure natural trend lines that might have been detected on undisturbed ground.

Colour photography has delineated areas of reddish brown soils which correspond with calcareous rocks (limestone and calc-silicate hornfels), iron ore gossans, iron-rich volcanics, and basic rocks. Grey soils have been used to identify and map beds of black siliceous shale. In a few places resistant rock types such as quartz veins along fault-lines, arenite beds in flysch sequences, and small granitoid bodies have been mapped directly from photographs.

The best use of aerial photography at all scales inclusive of LANDSAT imagery has been in the interpretation of large N-S trending folds and lineaments. Maffi & others (1974) made a geological evaluation of ERTS I imagery over the Canberra 1:250 000 Sheet area and concluded that most lineaments correspond with mapped faults, unmapped extensions of faults or major joint and fracture patterns. The present study has emphasised the extent to which the strong meridional trend of tectonic lineaments reflects a structural parallelism brought on by repeated unidirectional folding and faulting along similar active zones during and since the Palaeozoic.

Some land use effects can be demonstrated from aerial photographs. On the 1:28 000 colour photography dark and light green strips (not to be confused with lineaments) crossing paddocks result from aerial spraying and crop dusting for pasture improvement (Run 13, Tuggeranong area and cover photograph on Photogrammetric Engineering and Remote Sensing, Vol. XLI, 1975). Modern aerial-photographs illustrate the extent of removal of natural vegetation followed by cultivation or grazing in rural areas that has led to a rapid deterioration of land quality and the formation of erosion gullying and badlands topography. Conservation is practised and supported by government at local and state levels; the most notable and best documented for the Sheet area is the soil conservation scheme in the catchment of Lake Burley Griffin (Williams, 1977).

Reference data and previous work

An extensive geological and geophysical reference list exists for the CANBERRA Sheet area. Although more than 60 published references cover a wide spectrum of geoscience investigations, the bulk of the literature is in the form of unpublished BMR Records, NSW Geological Survey reports, and student theses. As BMR is the principal authority concerned with the geology of the Canberra region, a need has arisen through numerous requests and enquiries for a comprehensive listing of all published and unpublished work as a bibliography covering the Canberra 1:250 000 Sheet area (Lorenz & Abell, 1980). Compilation of this ongoing bibliography uses the BMR H-P 1000 minicomputer system; items are entered in a data base named CABIB; at present about 160 references have been indexed. Copies of the bibliography can be obtained from the Inter-Library Loans Officer, BMR. In this Record a restricted reference list is provided as general background and to assist those using the accompanying maps; many references are listed with the Summary Description of Rock Units (Table 1).

Geological exploration in the CANBERRA Sheet area began about the mid-19th century, when the Rev. W.B. Clarke, travelling through the Southern Tablelands of New South Wales, collected some of the first Silurian fossils found in Australia from shales (now assigned to the Canberra Formation) exposed in Woolshed Creek. After these early reconnaissance expeditions, geological work became largely economic in emphasis, following a suggestion in 1852 by the Rev. W.B. Clarke that the Gundaroo-Sutton district would be a prospective area for gold (Clarke, 1860). This led to a minor gold rush to the Bywong area in the latter part of the 19th century, reported on by Carne (1896). Hydrology and geomorphology were considered at an early stage, largely through curiosity aroused by Lake George (Russell, 1887) and the prominent meridional scarp on the western side of the lake (Taylor, 1907 and 1911). When Federation was proclaimed in 1901 it led to the establishment of the ACT, and Canberra as the national capital of Australia; these new developments prompted more detailed geological studies in the Canberra district (Taylor, 1910; Pittman, 1911; Mahoney & Taylor, 1913). After their early investigations little was accomplished in the Sheet area for the next 30 years except for the work of Garretty (1936) in the Lake George area. However, post world war II urban growth of Canberra prompted the need for updated geological controls, which led to the work of Opik (1954) and Strusz & Henderson (1971) in the Canberra district and numerous engineering geology investigations by BMR officers, the results of which are held by BMR mostly in its unpublished Records series. Most of this material and the earlier work assisted in the compilation of the First Edition of the Canberra 4-mile geological sheet (Joplin & others, 1953). The Second Edition of this map at a scale of 1:250 000 was compiled by Best & others (1964); the Explanatory Notes accompanying the map (Strusz, 1971) report the first significant attempt to present a stratigraphic synthesis for the local region and an extensive bibliography. Regional geological maps covering the CANBERRA Sheet area produced by the Geological Survey of New South Wales include the Monaro 1:500 000-scale geological sheet (Brunker & others, 1971), a geological map of New South Wales at 1:1 000 000 scale (Pogson, 1972), a tectonic map of New South Wales at the same scale (Scheibner, 1974) with explanatory notes (Scheibner, 1976), and the Canberra 1:250 000-scale metallogenic map accompanied by mine data sheets (Gilligan, 1974 and 1975).

The earliest regional geophysical map covering the Canberra region followed an aeromagnetic survey flown by BMR in 1958. The map, at a scale of 1" : 1 mile, shows contours of residual magnetic intensity; the magnetic 'relief' corresponding well with the known geology. A total-magnetic-intensity map of the Canberra 1:250 000 Sheet area was published by BMR in 1974: intrusive and extrusive rocks of ultrabasic, basic, and intermediate composition and some "I"-type granites are the source of moderate to intense magnetisation, but there is only a weak response from the 'S'-type Murrumbidgee batholith. A Bouguer gravity anomaly map of the Canberra 1:250 000 Sheet area appears to provide only limited correlation with known geology.

Earthquake data held by the Observatories & Regional Section of BMR show 124 events recorded between 1940 and 1977 in an area bounded by latitudes 35°S to 36°S and longitudes 149°E and 150°E; specifically for CANBERRA there are 86 events, mostly at or below 3 on the Richter scale. Although the data have yet to be assessed in terms of the tectonics of the Sheet area, it appears that most epicentres may relate to northwest-trending lineaments.

Prospecting geophysical surveys have been carried out mainly by private companies to determine the location and extent of metalliferous deposits. A variety of techniques (mainly electrical and magnetic) have been used to prospect for base metal mineralisation in the Captains Flat trough and in leases north of the ACT border. The Water Resources Commission, Sydney, has used seismic methods to prospect for groundwater in fluvio-lacustrine sediments at Bungendore; during 1980 BMR carried out a program of geophysical logging (mainly gamma and neutron) in the same area as part of a study of Cainozoic sedimentation.

Drilling

In the ACT portion of the sheet area, over 400 drillholes (mostly less than 100 m deep) have been drilled by BMR and other government and consultancy agencies to obtain bedrock data for tunnel, building foundation, and other engineering geology investigations. Most of the core is stored at the BMR Core & Cuttings Laboratory, Fyshwick. Some of the holes were drilled to obtain information on the succession of rock units within the Silurian (Henderson, 1978a?). The deepest hole (C.145, 300 m deep) is located southeast of the BMR building; (east of Anzac Parade, between Parkes Way and Constitution Avenue); it provides good lithological detail on the uppermost units in the Canberra Formation. Another hole (C.155) is 240 m deep and gives useful data on the lithological succession at the southern extremity of the Yass Formation. In addition more than 50 water bores yield some lithological data.

During 1979 five holes were drilled and geophysically logged by BMR to examine Cainozoic sediments and weathering profiles in the Captains Flat Trough; the data are available from the Geological Branch, BMR. Geophysical logs of these sediments have been obtained in the Bungendore area from water bore drilling by WRC Sydney. Data on Cainozoic sediments in the Montrose-Willeroo basin, an alluvial embayment at the northeastern end of Lake George, were obtained by Jododex (Aust.) Pty Ltd as part of a water supply investigation for Woodlawn Mine (Cifali, 1973; AGC 1976, 1977). As a result of these drilling operations some data are now available on the nature of bedrock beneath the Cainozoic cover in the Captains Flat Trough.

Petrography

An extensive thin-section library covering the CANBERRA Sheet exists in BMR. The main collections are (a) in the BMR museum covering the period 1947-63 (Wilson, 1960), (b) in the Geological Services Section, Geological Branch, BMR (1964-present) which mostly covers the western portion of the Sheet area, and (c) 350 thin sections (76460001-76460350) made for the present study. Thin section and geochemical data are stored on tape at BMR in a Hewlett Packard 9825A desk-top computer.

Apart from the normal identification of rock types, other uses of thin sections have been (a) the determination of volcanic stratigraphy and the division of granitoids, volcanics, and high-level porphyry intrusions into 'S' and 'I' types by reference to index minerals, (b) differentiation of pyroclastic flows and high-level porphyry intrusions using textural patterns, and (c) grouping of basic rocks according to their mineral assemblages and alteration products. A potential value may lie in differentiating between quartzites in Ordovician and Silurian flysch sequences.

Geochemical analyses and isotopic age determinations

To date more than 100 major- and trace-element geochemical analyses are available for CANBERRA. Their use and importance lies in assessing the stratigraphic and petrogenetic relationships of volcanic, granitoid, and basic intrusive rocks. Geochemical analyses will be tabulated as an appendix to a report accompanying the 1:100 000 scale map.

During this study only three age-determinations have been made by AMDEL. Interpretation of these results and other geochronological data has been restricted by poor stratigraphic control, difficulty in obtaining fresh specimens, and the deformed nature of the rocks. The most reliable results have been obtained from the whole rock and biotite Rb-Sr isochrons. In addition some dates on Silurian sediments and volcanics in the Canberra area made prior to this study will be corrected using new decay constants (Steiger & Jager, 1977; Dalrymple, 1979). Results show that the State Circle Shale is Llandoverian, the Mount Painter Volcanics are Wenlockian, and the Mugga Mugga Porphyry Member (a basal member of the Deakin Volcanics) is Ludlovian. These new ages agree with the known stratigraphy and support at time scale for the Silurian proposed by Owen & Wyborn (1979).

Palaeontology

Extensive collections of fossils are available mainly from Late Silurian sediments of the Canberra-Yass shelf. Strusz (1975) discusses diagnostic fossils from Silurian units in the Canberra-Queanbeyan area. The use of these fossils for precise correlation of stratigraphic units is difficult since most are long-ranging or facies-sensitive forms. The Late Silurian-Early Devonian stratigraphy and fauna at Yass (Packham, 1969; Link, 1970; Link & Druce, 1972) still remains the only faunal succession against which Silurian units in the Canberra area can be correlated. Unfortunately fossil occurrences in the Captains Flat trough are sparse, although fossil listings by Felton & Huleatt (1977) and Richardson (1979) have assisted in broadly dating some of the Silurian units. Poor fossil preservation and slow taxonomic progress have retarded the preparation of fossil listings for CANBERRA.

Difficulty still remains in the faunal dating of Late Silurian volcanic sequences. To date some success has been achieved i.e.:

(a) Retrieval of an extensive shelly marine fauna from sedimentary interbeds in the Walker Volcanics below Coppins Crossing suggests a late Wenlockian age, and correlation in part with the Mount Painter Volcanics (D.L. Strusz, pers. comm., 1980).

(b) Faunas collected from the Yarralumla Formation are probably Ludlovian in age (Strusz & Henderson, 1971).

(c) A fauna that may be worthy of further study exists in sedimentary interbeds (Sul_1) of the Laidlaw Volcanics north of Freshford Station (grid refs. 860775 and 843782).

Opinion appears to be divided as to whether the Canberra Formation is Ludlovian or Wenlockain in age. Stratigraphic superposition, faunal correlations, and geochronology seem to favour a late Wenlock age. However, a conodont fauna collected in the central Canberra area (Link, 1970) suggested the Canberra Formation was early Ludlovian, but this has not been confirmed from recent reconnaissance sampling of the limestone outcrops in the Sheet area. Some exposures near the top of the Canberra Formation may give diagnostic conodonts after detailed sampling (R.S. Nicoll pers. comm., 1979).

A fair certainty now exists for the age range of black siliceous shales (Acton Shale, Bullongong Shale, and Picaree Shale Members). Extensive listings of graptolites from these and other similar rock units show an age range from Gisbornian to Bolindian, statistically the largest number being Eastonian. This confirms that at least parts of the distal flysch sequences are Late Ordovician Monograptids recently collected from the State Circle Shale in State Circle cutting beside Camp Hill, Canberra, confirm these rock units as being Llandoverian age (D.L. Strusz, pers. comm., 1980).

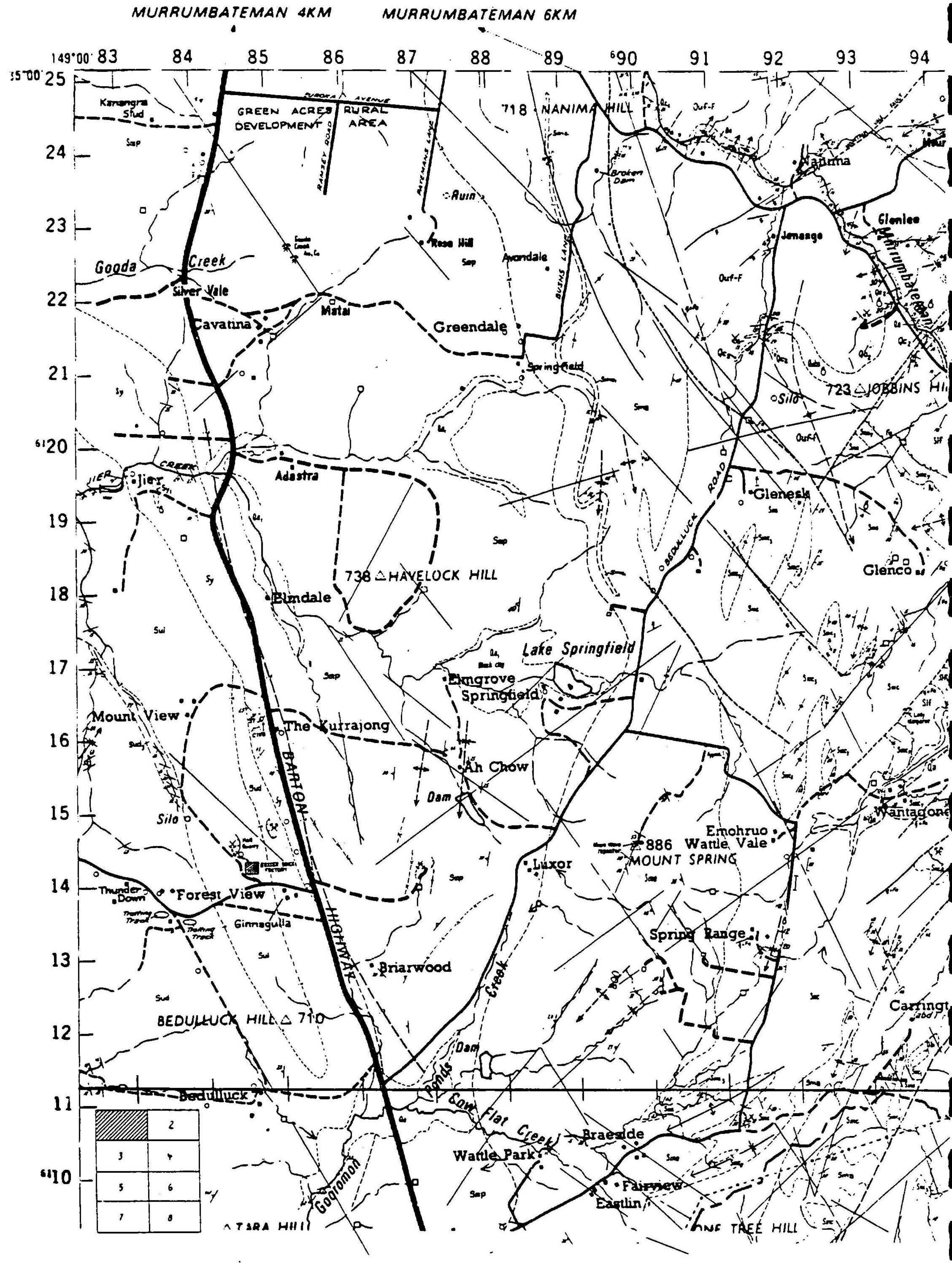
1:25 000-SCALE COMPILATION SHEETS

Eight field compilation sheets have been prepared at a scale of 1:25 000, and are reproduced here at a reduced scale. The sheets are designed to provide detailed mapping data and a provisional interpretation base for the Preliminary and First Editions of the CANBERRA 1:100 000 Sheet. Some geological boundaries and symbols will either be removed or simplified as a result of scale change in the production of the 1:100 000 map. Copies of the sheets at 1:25 000 scale can be obtained from the Copy Service (see Contents for details).

The provisional reference accompanying the field compilation sheets attempts to depict the stratigraphic relationships and geographical distribution of rock units from west to east across the area. Greater (though still summary) detail on lithological and stratigraphic relationships is given in the tabulated Summary of Rock Units (Table 1) which should be used in conjunction with the compilation sheets. Difficulty exists in mapping the thickness variations of rock units on CANBERRA because of poorly known stratigraphy and complex tectonics; hence thickness of rock units unless stated otherwise is tabulated as approximate maximum thickness (Table 1). Stratigraphic names in inverted commas in the 'Remarks & References' column are informal units unlikely to receive formal definition.

Structural data

The compilation sheets show interpretation of the structural data. Most fold axes have been deduced from the strike and dip pattern of bedding and cleavage; they are seldom seen in the field. Some fold axes will be deleted on the 1:100 000-scale map because of overcrowding.



MURRUMBATEMAN 4KM
MURRUMBATEMAN 6KM
149°00' 83
84
85
86
87
88
89
690
91
92
93
94
35°00' 25
24
23
22
21
6120
19
18
17
16
15
14
13
12
11
6110
GREEN ACRES RURAL
DEVELOPMENT AREA
Kanangra Stud
718 NANIMA HILL
Nanima
Ruin
Rose Hill
Avondale
Jenange
Glenlee
Gooda Creek
Silver Vale
Cavatina
Matai
Greendale
Springfield
Murrumbateman
723 JOBBINS HILL
Silo
Jier Creek
Jier
Adastra
Glenesk
738 HAVELOCK HILL
BEDULLUCK ROAD
Glenco
Elmdale
Lake Springfield
Elmgrove
Springfield
Mount View
The Kurrajong
Ah Chow
Dam
Silo
BARTON HIGHWAY
Wantagong
Emohruo
886 Wattle Vale
MOUNT SPRING
Luxor
Thunder Down
Forest View
Ginnagulla
Spring Range
Briarwood
Creek
BEDULLUCK HILL 710
Carringt
Dam
Ponds
Bedulluck
Cow Flat Creek
Braeside
Wattle Park
Fairview
Eastlin
Gooromon
TARA HILL
ONE TREE HILL
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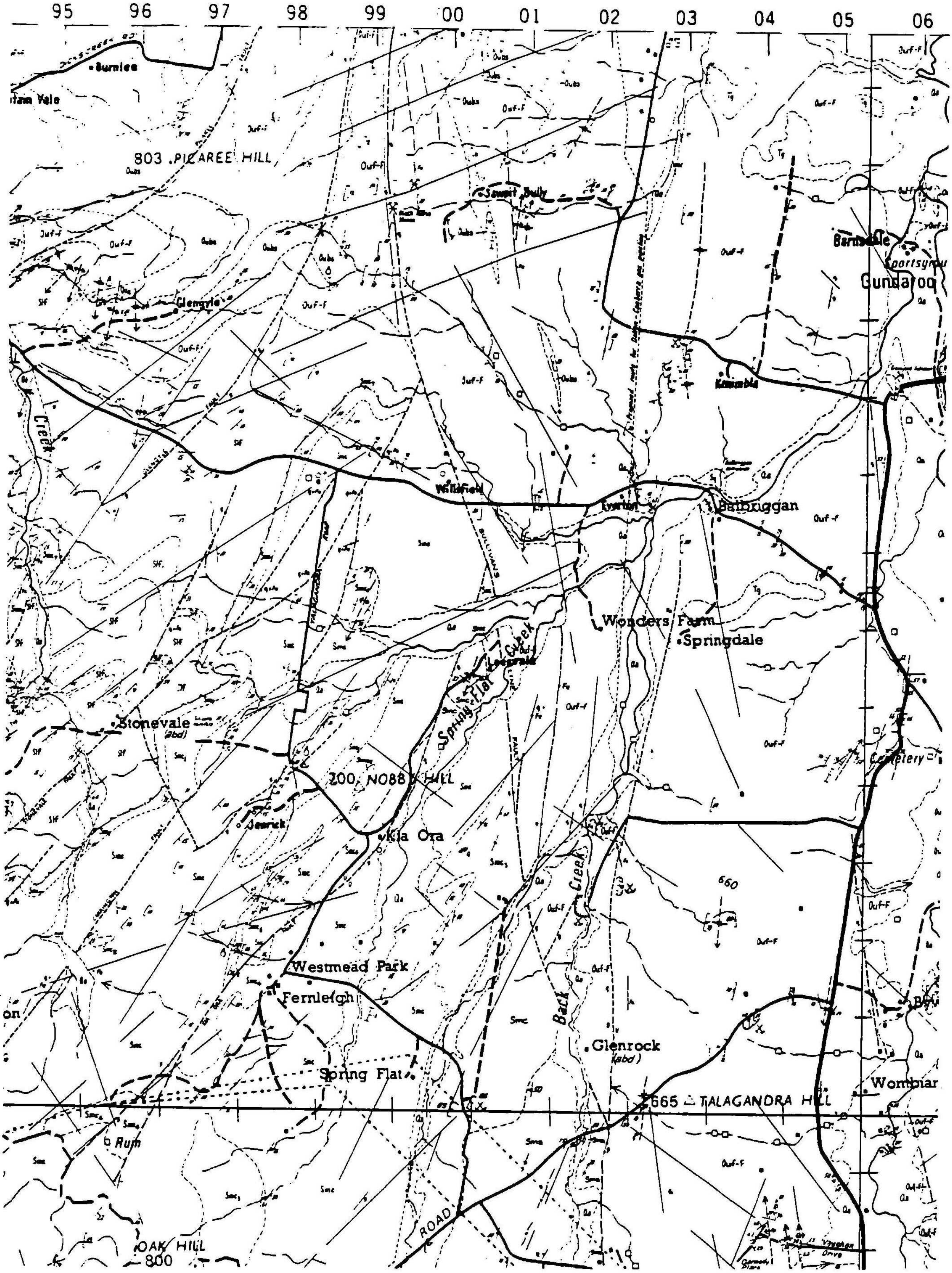
7
8


95
96
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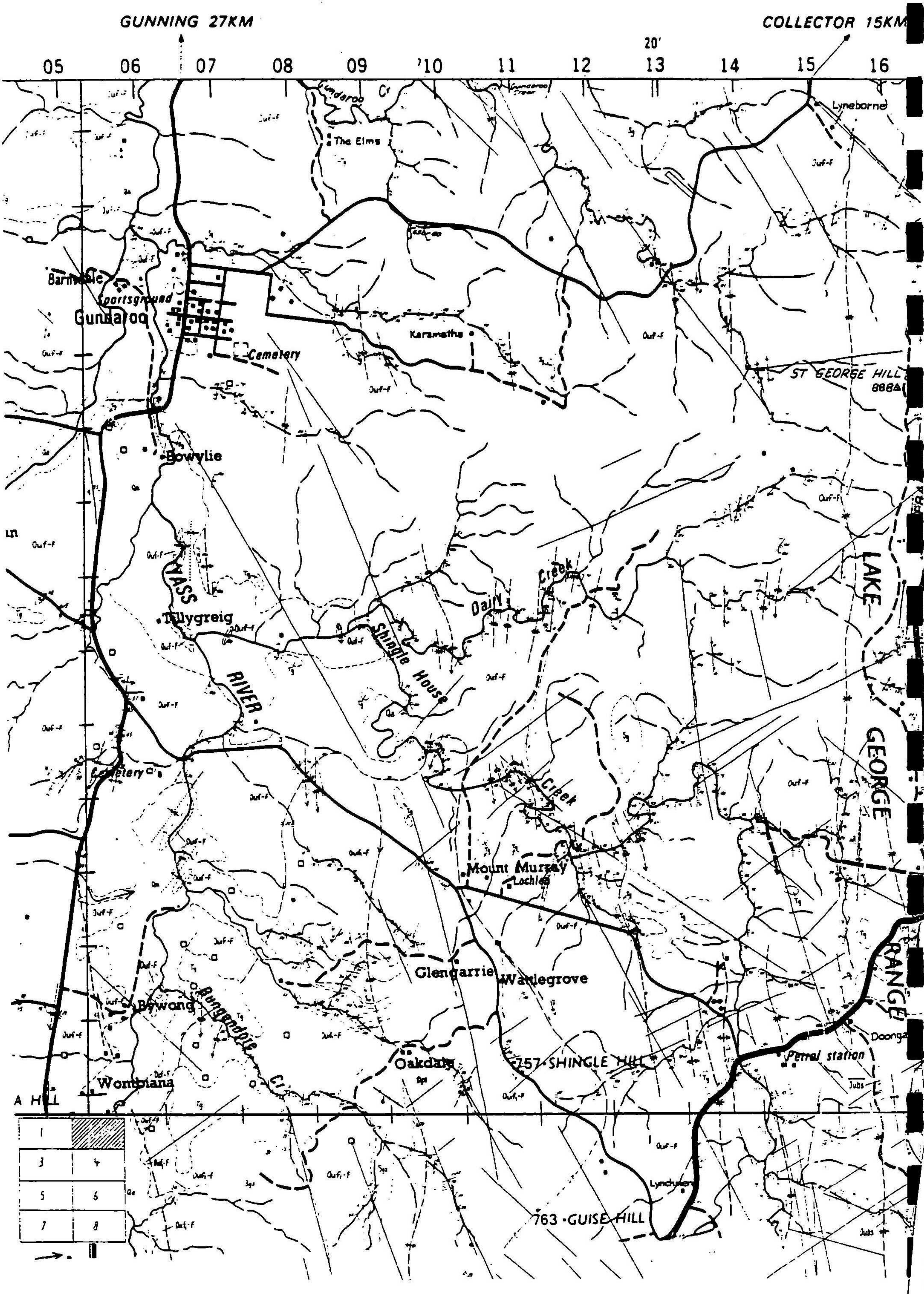
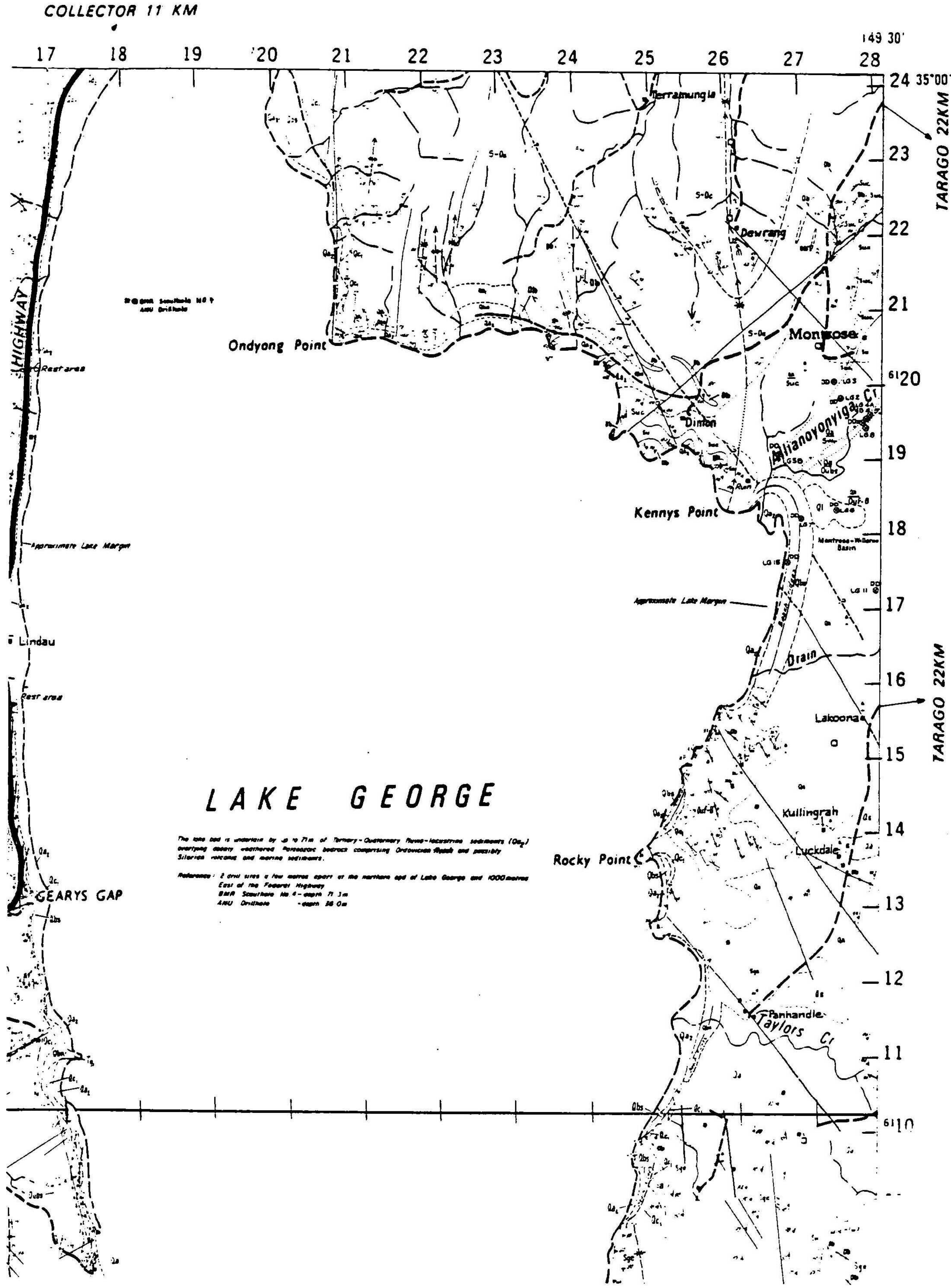
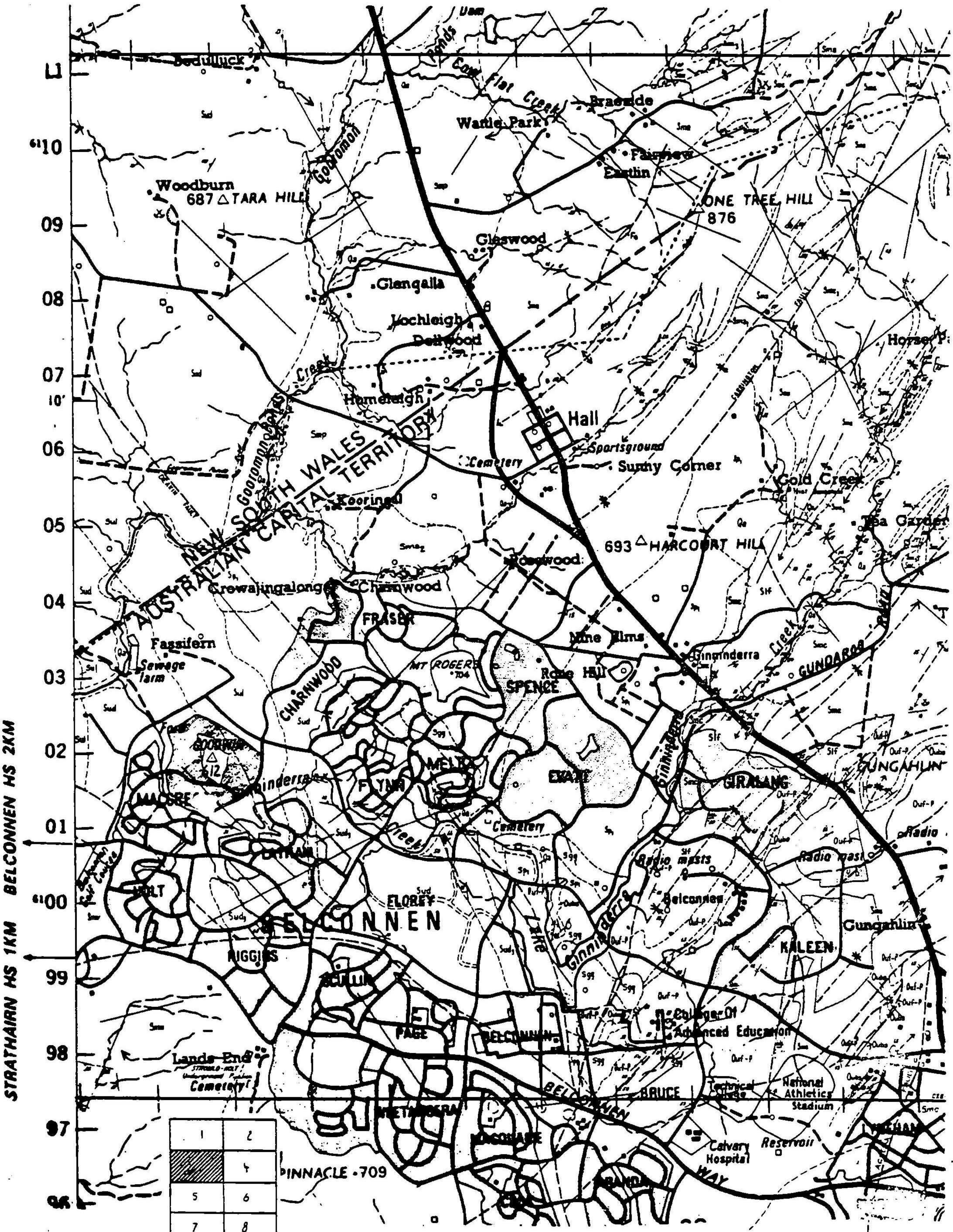
Burnlee
803 PICAREE HILL
Glengyle
Willafield
Balbriggan
Barnsdale
Gundaroo
Wonders Farm
Springdale
Stonevale
(abd)
200 NOBBY HILL
Kia Ora
Spring Flat Creek
Back Creek
Westmead Park
Fernleigh
Spring Flat
Glenrock
(abd)
665 TALAGANDRA HILL
Wombiar
Cemetery
Creek
Rum
OAK HILL
800
ROAD
660


GUNNING 27KM
COLLECTOR 15KM
20'
05
06
07
08
09
10
11
12
13
14
15
16
The Elms
Lyneborne
Barnsdale
Sportsground
Gundaroo
Cemetery
Karamatha
ST GEORGE HILL
888
Bowylie
YASS
Tallygreig
Daily
Creek
Shingle House
RIVER
LAKE
GEORGE
Cemetery
Creek
Mount Murray
Lochlea
Glengarrie
Wattlegrove
Bywong
Bungendore
Cr
Oakdale
757 SHINGLE HILL
Wombiana
A HILL
RANGE
Doonga
Petrol station
Lynchmere
763 GUISE HILL
1
3
4
5
6
7
8


COLLECTOR 11 KM
149 30'
17
18
19
20
21
22
23
24
25
26
27
28
24 35°00'
23
22
21
6120
19
18
17
16
15
14
13
12
11
6110
TARAGO 22KM
TARAGO 22KM
HIGHWAY
Rest area
Rest area
Lindau
GEARYS GAP
Terramungle
Dewrang
Montrose
Ondyong Point
Dinton
Kennys Point
Allianoyonyiga Cr
Drain
Lakoona
Kullingrah
Luckdale
Rocky Point
Panhandle
Taylors Cr
LAKE GEORGE
Approximate Lake Margin
Approximate Lake Margin



Bedulluck
Wattle Park
Braeside
Fairview
Eastlin
Woodburn
687 △ TARA HILL
ONE TREE HILL
876
Gleswood
Glengalla
Lochleigh
Dellwood
Homeleigh
Hall
Sportsground
Cemetery
Sunny Corner
Gold Creek
NEW SOUTH WALES
AUSTRALIAN CAPITAL TERRITORY
Gooromon Ponds
Kooringal
693 △ HARCOURT HILL
Tea Garden
Rosewood
Crowajingalong
Charnwood
FRASER
Fassifern
Sewage farm
Nine Elms
Ginninderra
GUNDAROO
MT ROGERS 704
SPENCE
CHARNWOOD
GIRALANG
GUNGAHLIN
FLYNN
MELBA
EVATT
MACGREGOR
LATHAM
Cemetery
Radio masts
Radio mast
HOLT
FLOREY
BELCONNEN
Belconnen
Gungahlin
KALEEN
HIGGINS
SCULLIN
PAGE
College Of Advanced Education
Lands End
Cemetery
BRUCE
Technical College
National Athletics Stadium
BELCONNEN WAY
Calvary Hospital
Reservoir
MACQUARIE
ARANDA
PINNACLE 709
Horse Park
11
10
09
08
07
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03
02
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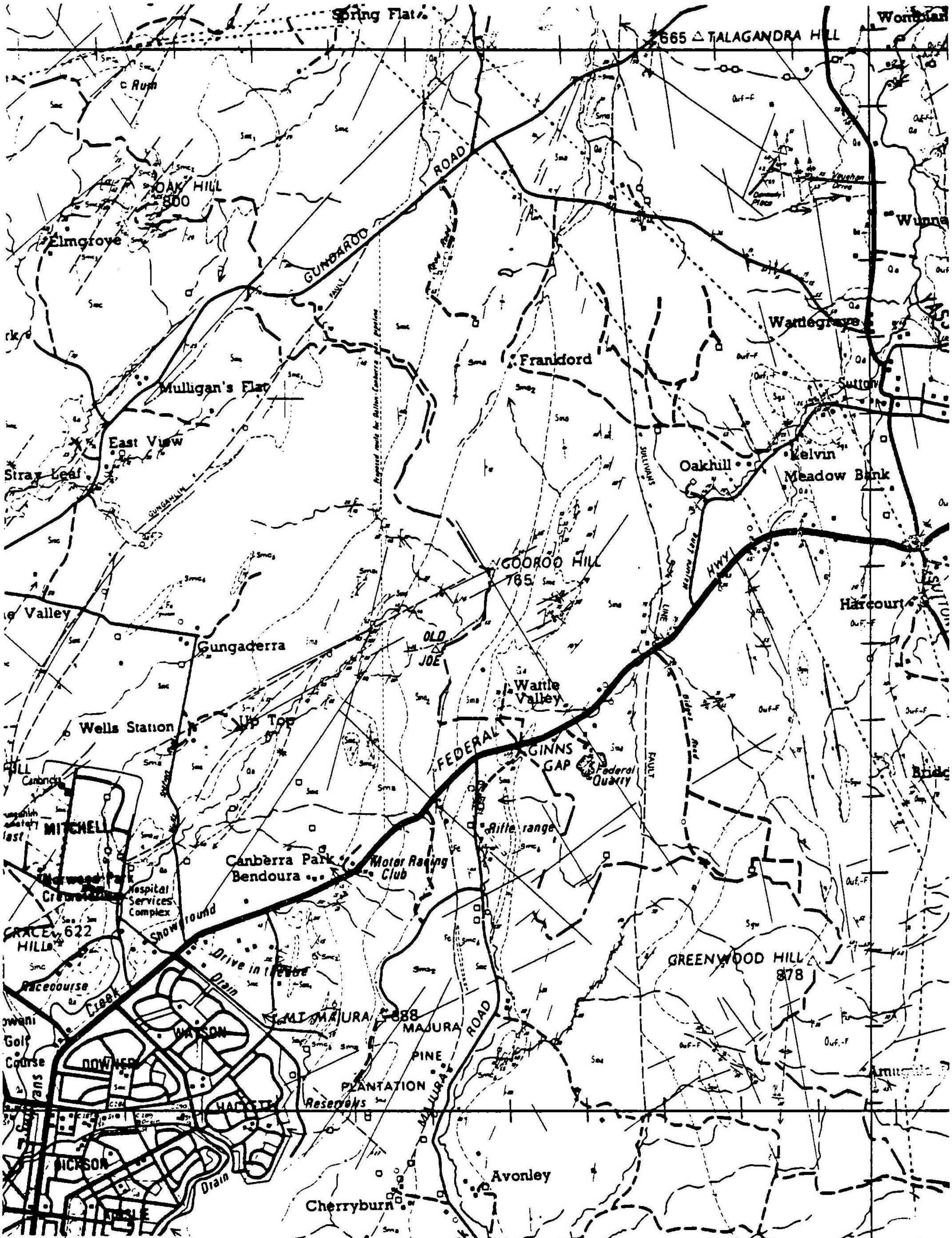
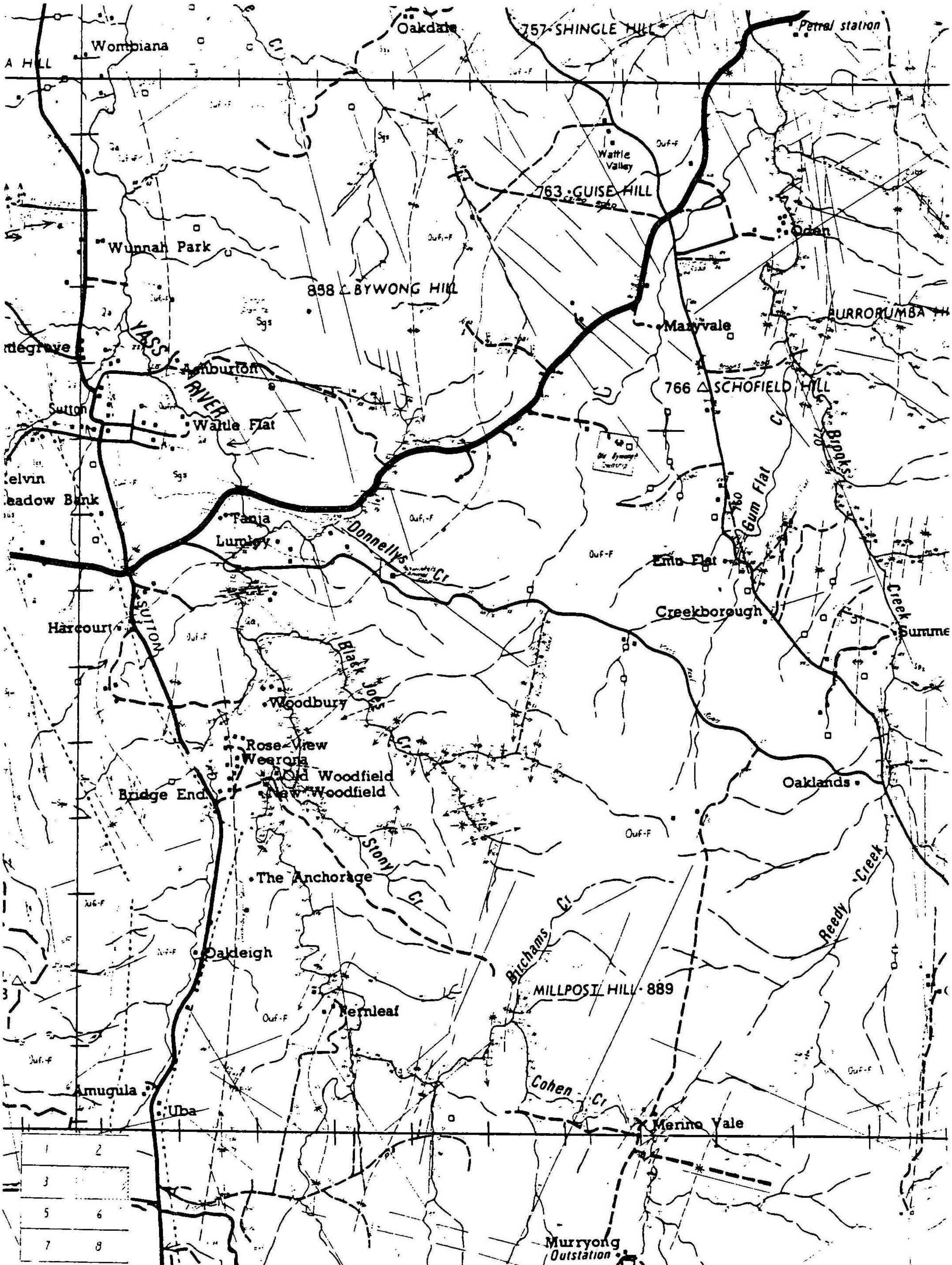
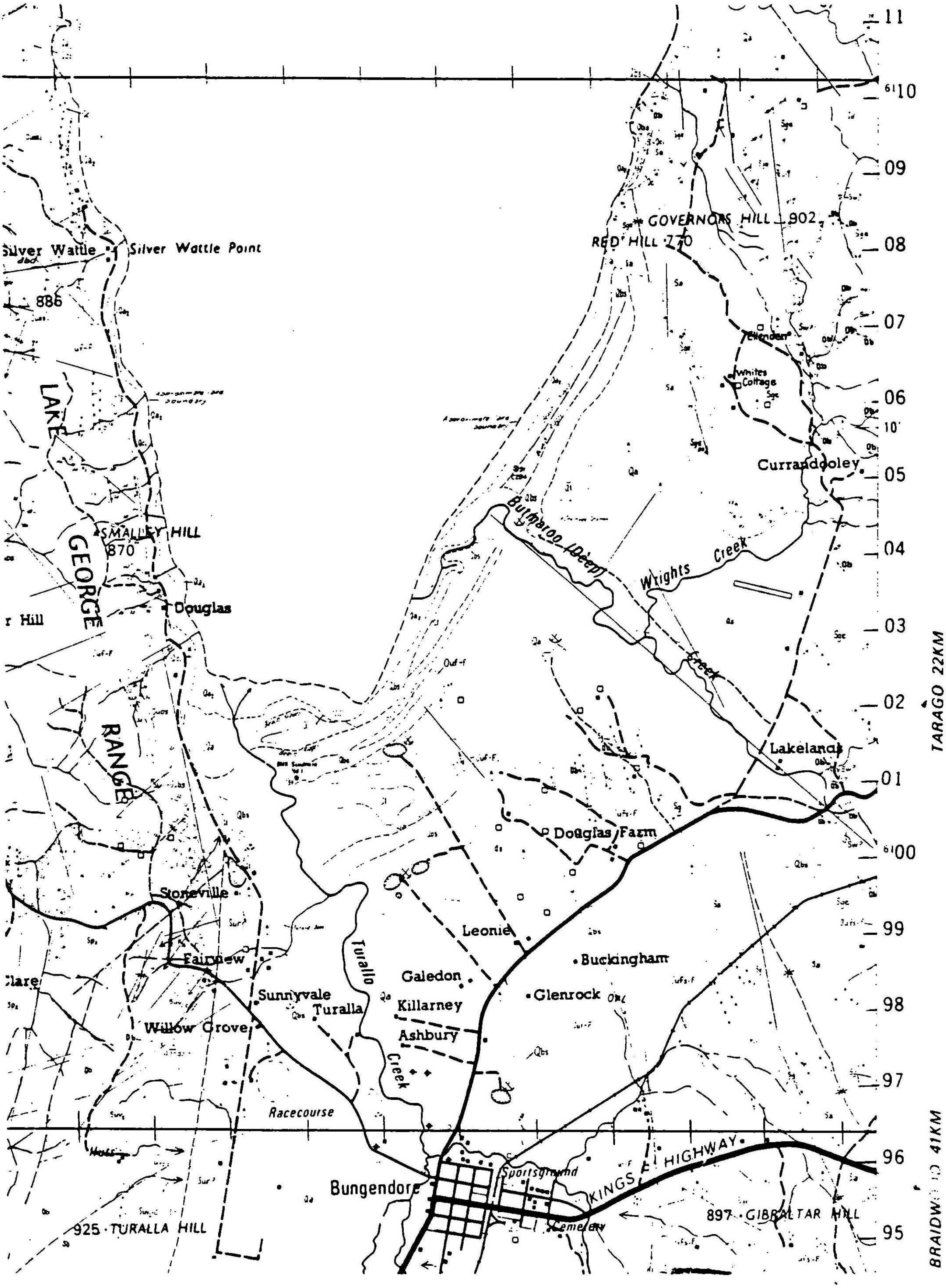
99
98
97
96
STRATHAIRN HS 1KM
BELCONNEN HS 2KM

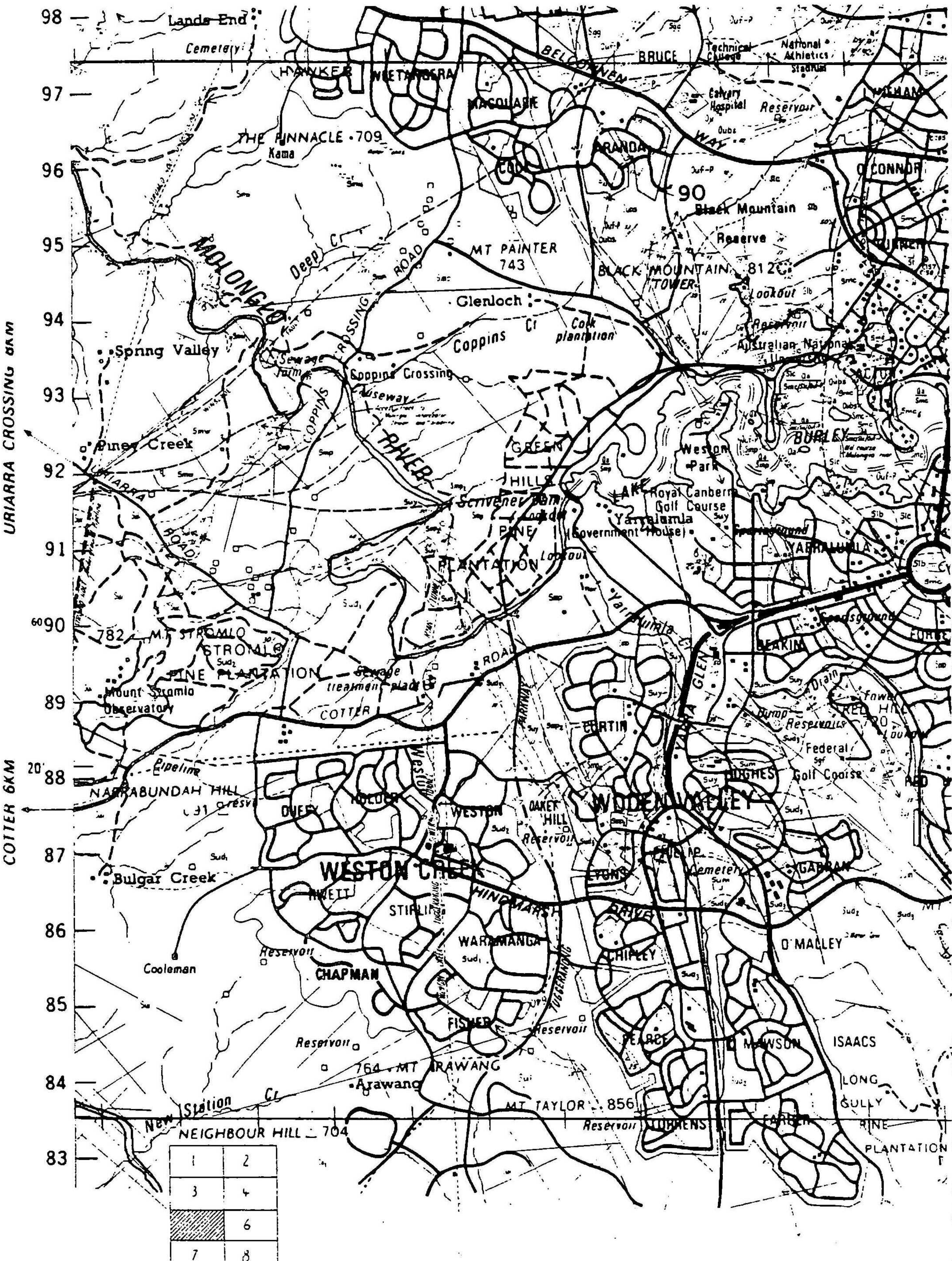

Spring Flat
665 TALAGANDRA HILL
OAK HILL
800
Elmgrove
GUNDAROO ROAD
Mulligan's Flat
East View
Stray Leaf
GUNGAHLIN
Frankford
Wardegrave
Sutton
Oakhill
Kelvin
Meadow Bank
GOOROO HILL
765
Harcourt
Valley
Gungaderra
OLD JOE
Wattle Valley
Wells Station
Up Top
FEDERAL HWY
GINNS GAP
Federal Quarry
MITCHELL
Rifle range
Canberra Park
Bendoura
Motor Racing Club
Hospital Services Complex
Showground
GRACE HILL
622
Racecourse
Creek
Drive in theatre
Drain
GREENWOOD HILL
878
MT MAJURA
888
MAJURA ROAD
PINE PLANTATION
WATSON
DOWNER
HACKETT
Reservoirs
DICKSON
Golf Course
Avonley
Cherryburn
SULLIVANS
FAULT
LINE



Wombiana
A HILL
Oakdale
757 SHINGLE HILL
Petrol station
Wattle Valley
763 GUISE HILL
Oden
Wunnah Park
888 BYWONG HILL
Sgs
Marryvale
BURRORUMBA
YASS RIVER
Ashburton
Sutton
Wattle Flat
766 SCHOFIELD HILL
Gum Flat Cr
Brooks Creek
elvin
eadow Bank
Tania
Lumley
Donnellys Cr
Emu Flat
Harcourt
SUTTON
Creekborough
Summe
Black Joes Cr
Woodbury
Rose View
Weerona
Old Woodfield
New Woodfield
Bridge End
Oaklands
Stony Cr
The Anchorage
Reedy Creek
Buchams Cr
Oakleigh
MILLPOST HILL 889
Fernleaf
Cohen Cr
Amugula
Uba
Merino Vale
Murryong
Outstation
1 2
3
5 6
7 8



Silver Wattle
Silver Wattle Point
886
LAKE
GEORGE
RANGE
SMALLEY HILL
870
Douglas
GOVERNORS HILL 902
RED HILL 770
Ellenden
Whites Cottage
Currandooley
Bumbaroo (Deep) Creek
Wrights Creek
Lakelands
Douglas Farm
Stoneville
Fairview
Sunnyvale
Turalla
Willow Grove
Turallo Creek
Galedon
Killarney
Ashbury
Leonie
Buckingham
Glenrock
Racecourse
Bungendore
Sportsground
Cemetery
KINGS HIGHWAY
925 TURALLA HILL
897 GIBRALTAR HILL
TARAGO 22KM
11
6110
09
08
07
06
05
04
03
02
01
6100
99
98
97
96
95



98
97
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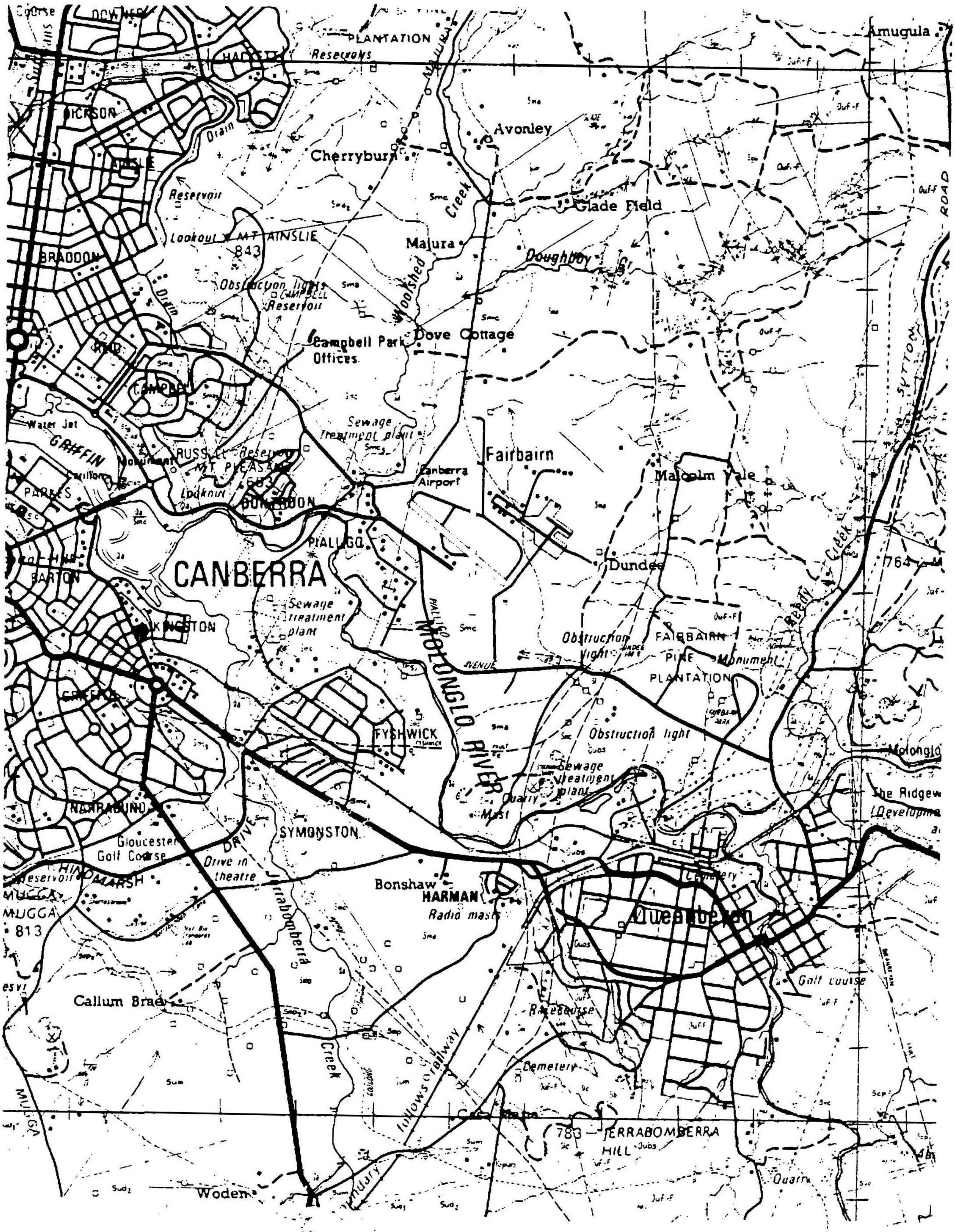
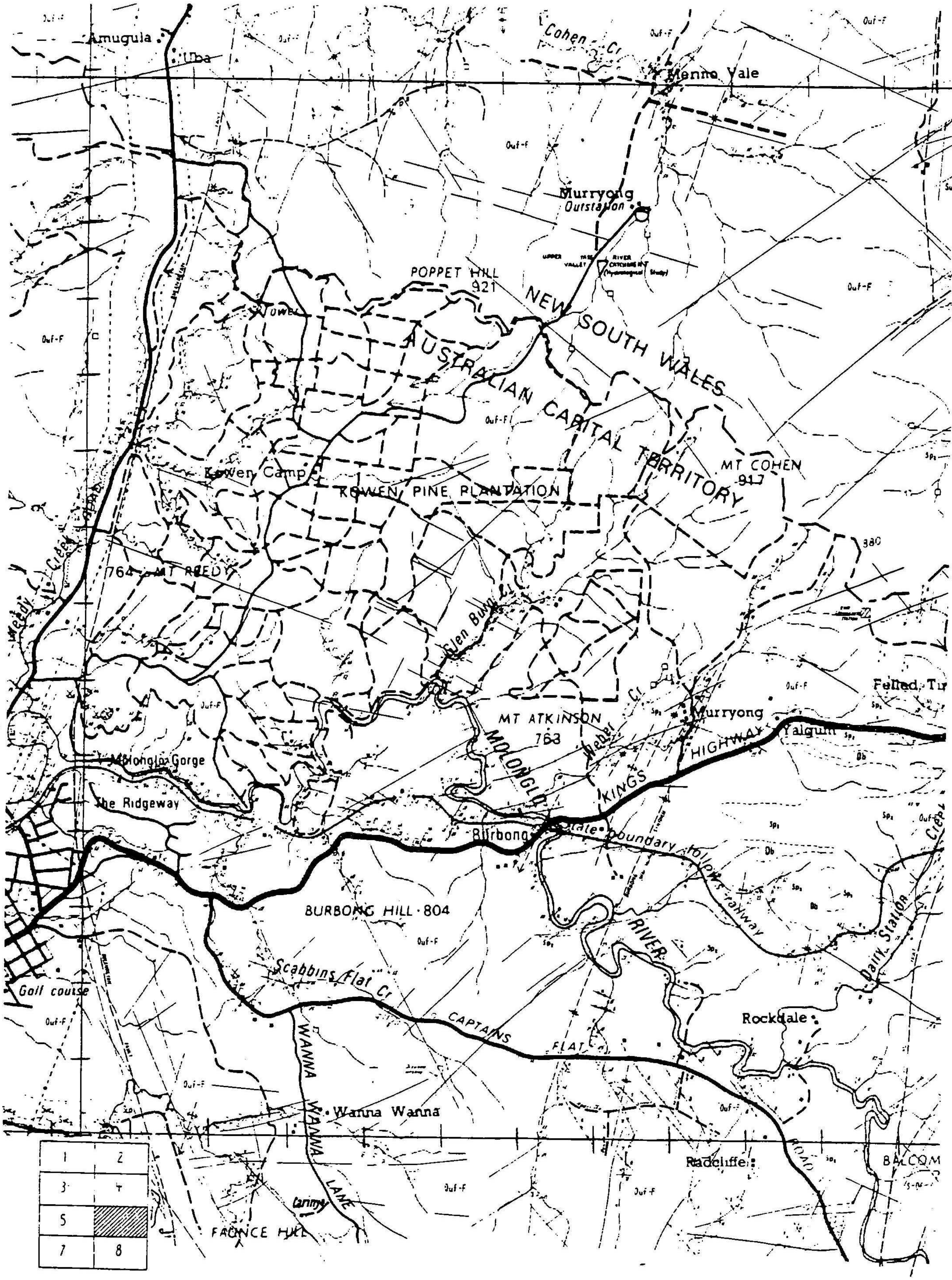
88
87
86
85
84
83
URIARRA CROSSING 8KM
COTTER 6KM
Lands End
Cemetery
HAWKER
WEETANGERA
BELCONNEN WAY
BRUCE
Technical College
National Athletics Stadium
Calvary Hospital
Reservoir
MACQUARIE
ARANDA
COOK
O'CONNOR
THE PINNACLE 709
Kama
90
Black Mountain Reserve
MOLONGLO
Deep Cr
ROAD
MT PAINTER 743
BLACK MOUNTAIN 812
TOWER
Lookout
Glenloch
Cork plantation
Coppins Cr
Spring Valley
Sewage farm
Coppins Crossing
COPPINS CROSSING
Australian National University
ACTON
Causeway
RIVER
GREEN HILLS
Weston Park
BURLEY
LAKE
Royal Canberra Golf Course
Yarralumla
(Government House)
Piney Creek
URIARRA ROAD
Scrivener Dam
Lookout
PINE PLANTATION
YARRALUMLA
Lookout
782 MT STROMLO
STROMLO PINE PLANTATION
Sewage treatment plant
Mount Stromlo Observatory
COTTER
ROAD
Yarralumla Cr
DEAKIN
CURTIN
YARRA GLEN
Dump
Reservoir
RED HILL 720
Lookout
Federal Golf Course
Pipeline
NARRABUNDAH HILL
DUFFY
HOLDER
WESTON
OAKEY HILL
Reservoir
WODEN VALLEY
HUGHES
PHILLIP
Cemetery
Bulgar Creek
WESTON CREEK
RIVETT
STIRLING
HINDMARSH DRIVE
LYONS
GARRAN
WARAMANGA
CHIFLEY
O'MALLEY
Cooleman
Reservoir
CHAPMAN
FISHER
Reservoir
PEARCE
MAWSON
ISAACS
Reservoir
764 MT ARAWANG
Arawang
LONG GULLY
New Station Cr
MT TAYLOR 856
NEIGHBOUR HILL 704
Reservoir
TORRENS
FARRER
PINE PLANTATION
1
2
3
4
6
7
8



PLANTATION
Reservoirs
Amugula
DICKSON
Avonley
Cherryburn
AINSLIE
Reservoir
Glade Field
Lookout
MT AINSLIE
843
Malura
BRADDON
Doughboy Cr
Woolshed Creek
Obstruction lights
CAMPBELL Reservoir
Dove Cottage
Campbell Park Offices
CAMPBELL
Water Jet
GRIFFIN
Sewage treatment plant
RUSSELL
MT PLEASANT
Fairbairn
Canberra Airport
Malcolm Vale
PARKES
Lookout
DUNTROON
PIALLIGO
Dundee
BARTON
CANBERRA
764
KINGSTON
Sewage treatment plant
Obstruction light
FAIRBAIRN
PINE
PLANTATION
Monument
MOLONGLO RIVER
AVENUE
GRIFFITH
FYSHWICK
Obstruction light
Molonglo
Sewage treatment plant
Quarry
Mast
The Ridgeway
NARRABUNDAH
SYMONSTON
Gloucester Golf Course
DRIVE
Drive in theatre
HINDMARSH
MUGGA
813
Bonshaw
HARMAN
Radio mast
Jerrabomberra
Queanbeyan
Cemetery
Golf course
Callum Brae
Racecourse
Creek
Cemetery
783
JERRABOMBERRA HILL
Woden
Quarry
SUTTON ROAD



Amugula
Uba
Cohen Cr
Menno Vale
Murryong
Outstation
POPPET HILL
921
NEW SOUTH WALES
AUSTRALIAN CAPITAL TERRITORY
Kowen Camp
KOWEN PINE PLANTATION
MT COHEN
917
764 MT REEDY
Glen Burn
MT ATKINSON
763
Murryong
Yalgum
KINGS HIGHWAY
MOLONGLO
Molonglo Gorge
The Ridgeway
Burbong
State boundary follows railway
RIVER
BURBONG HILL 804
Scabbins Flat Cr
CAPTAINS FLAT ROAD
Dairy Station
Rockdale
Golf course
WANNA WANNA LANE
Wanna Wanna
Radcliffe
FAUNCE HILL
Felled Tr
1
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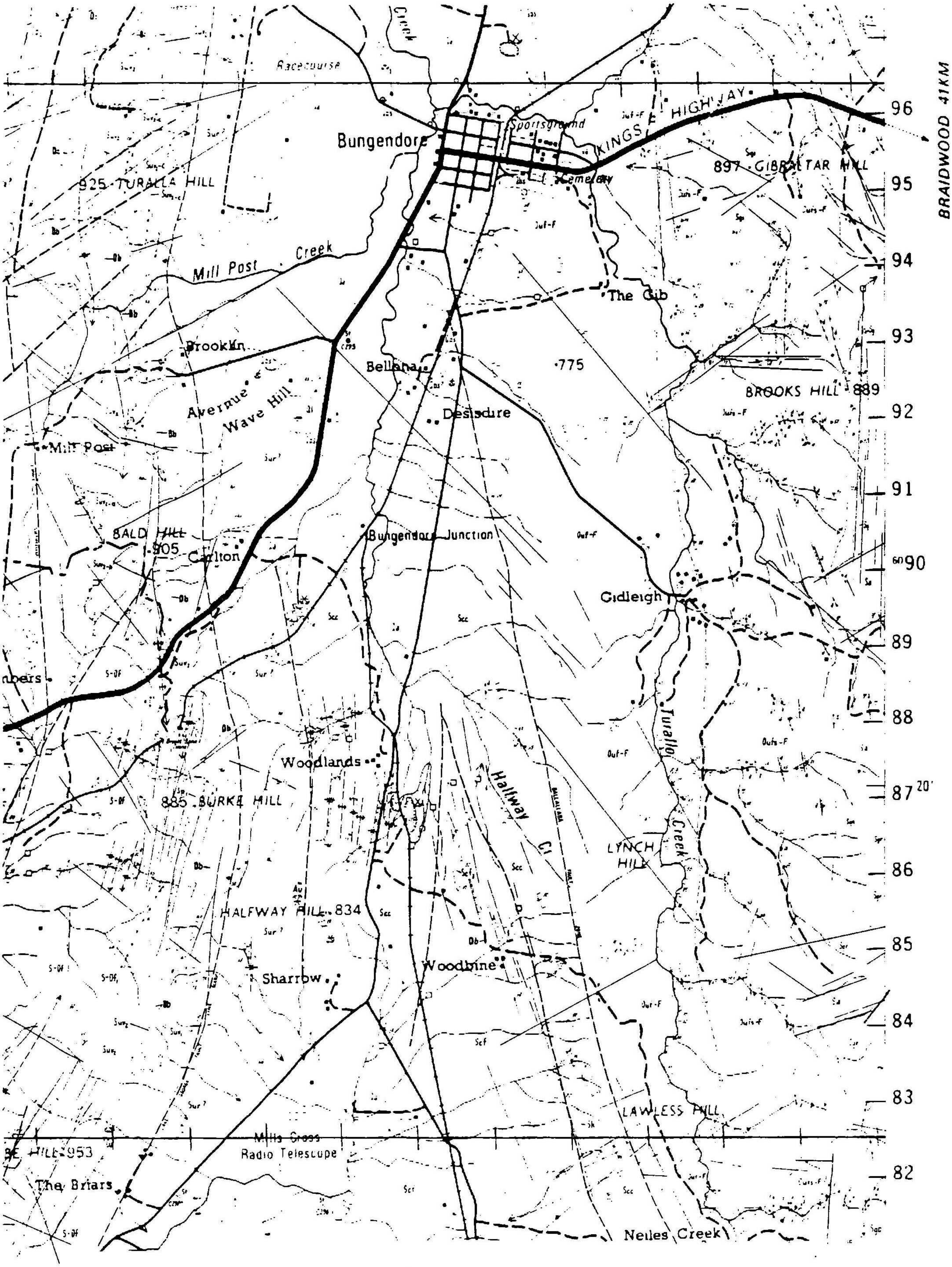

Racecourse
Bungendore
Sportsground
KINGS HIGHWAY
Cemetery
BRAIDWOOD 41KM
897 GIBRALTAR HILL
925 TURALLA HILL
Mill Post Creek
The Gib
Brooklin
Bellona
775
BROOKS HILL 889
Avenue & Wave Hill
Desisdure
Mill Post
Bungendore Junction
BALD HILL 905
Carlton
Gidleigh
Turallo Creek
Woodlands
885 BURKE HILL
Halfway Cl
LYNCH HILL
HALFWAY HILL 834
Woodbine
Sharrow
LAWLESS HILL
Mills Cross Radio Telescope
The Briars
Neiles Creek
96
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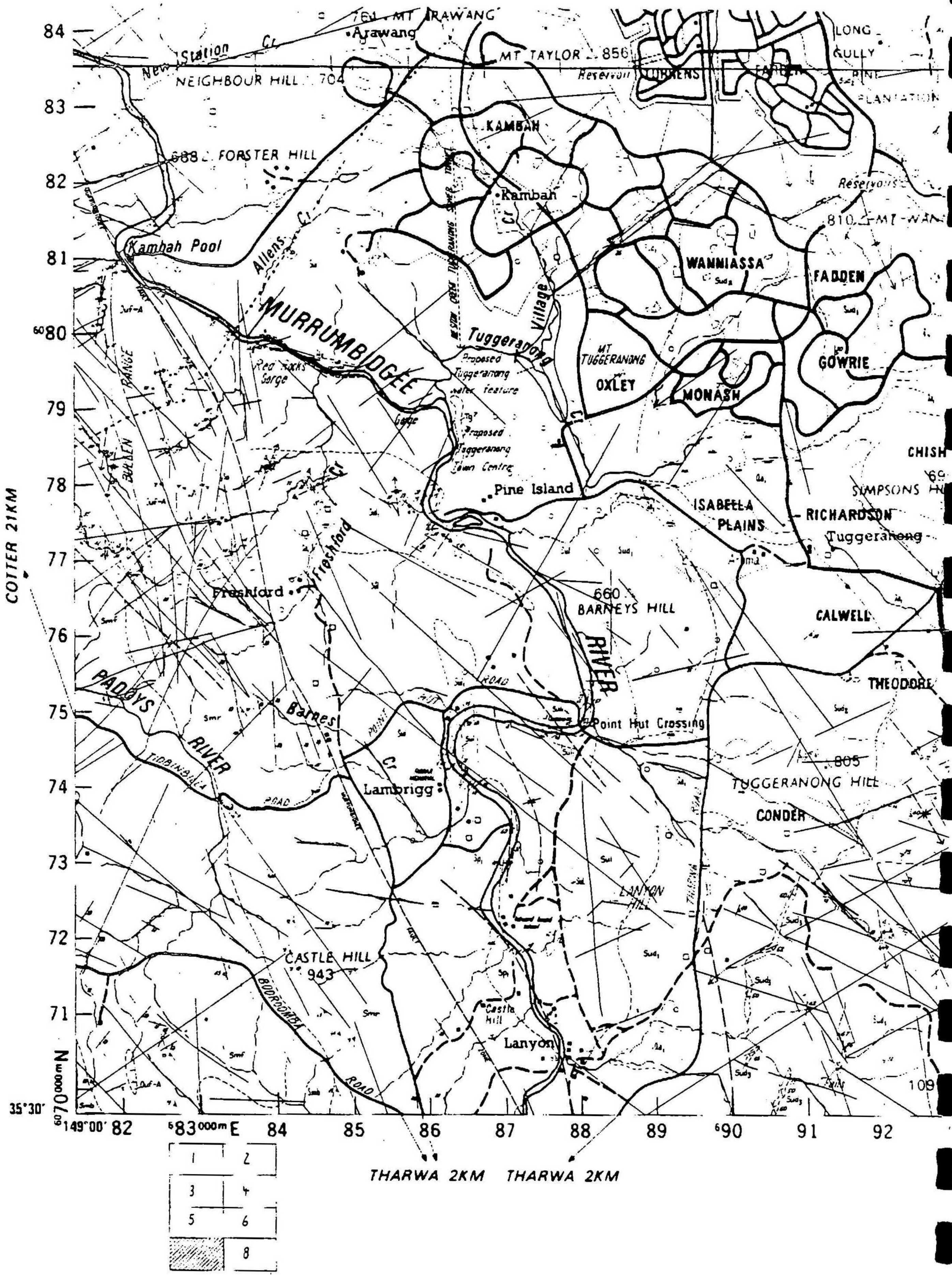
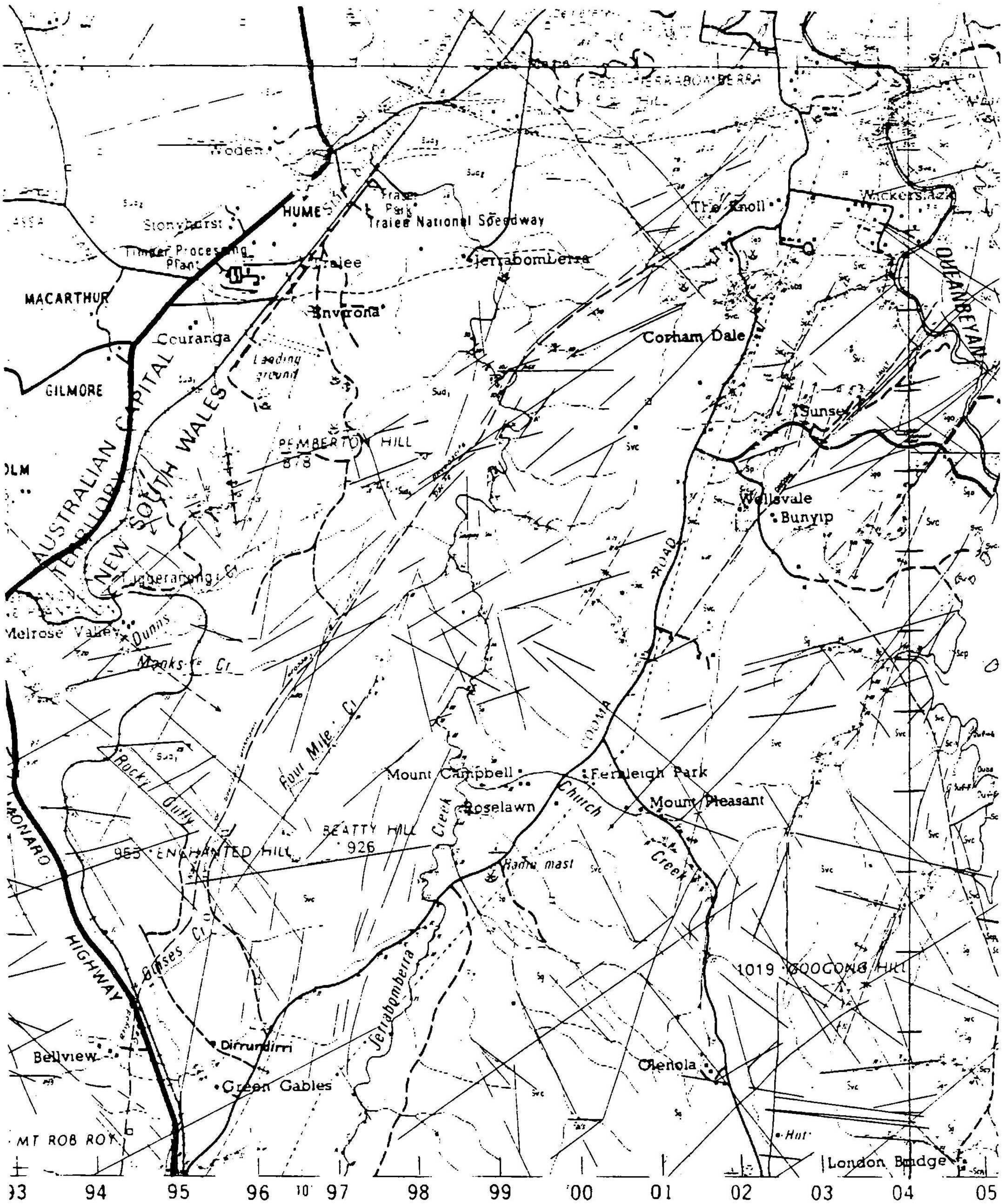
82

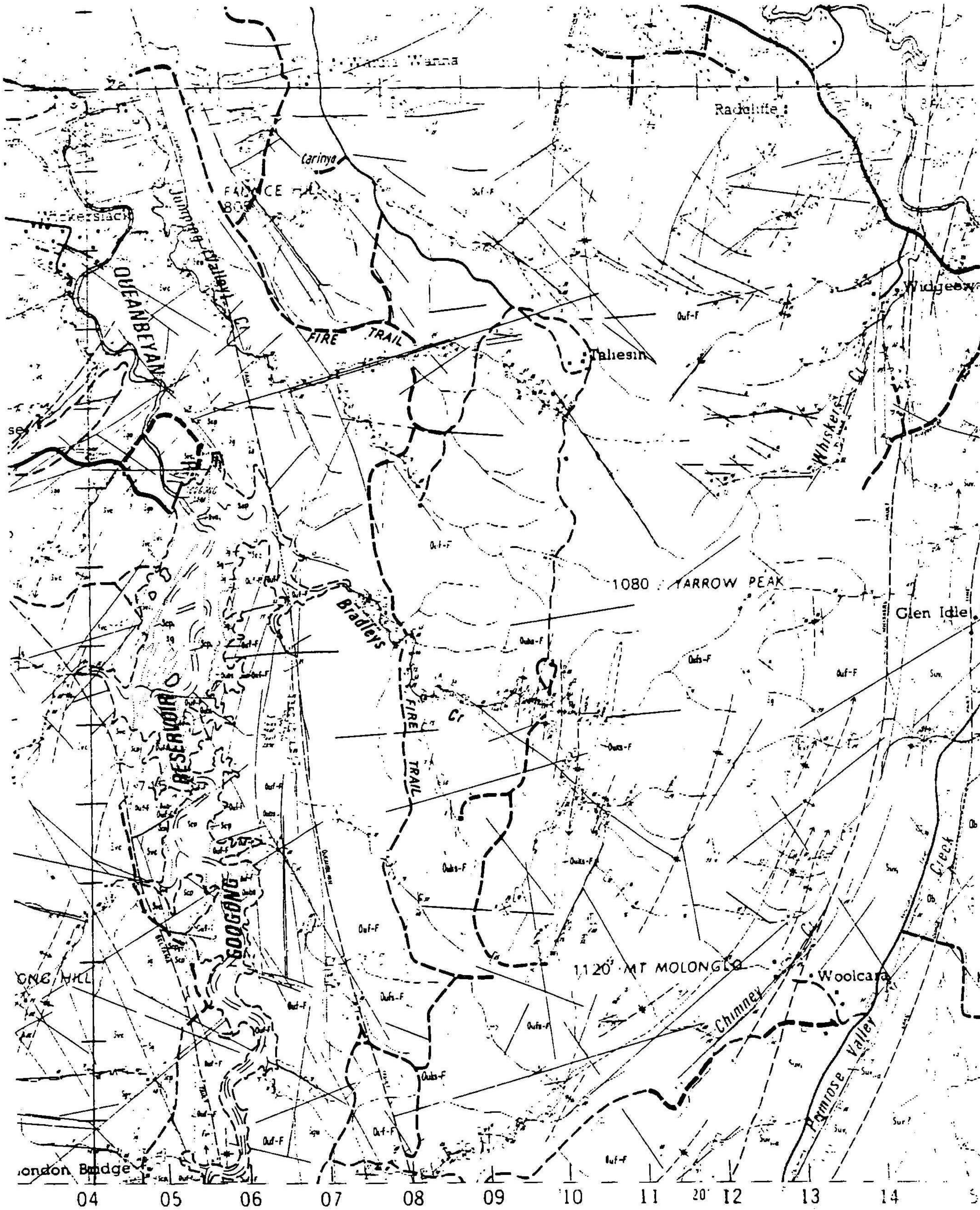


MT ARAWANG
Arawang
New Station Cr
NEIGHBOUR HILL 704
MT TAYLOR 856
Reservoir
TORRENS
FARRER
LONG GULLY
PINE PLANTATION
KAMBAH
Kambah
FORSTER HILL
Reservoirs
MT WANIASSA
Kambah Pool
Allens Cr
WANNIASSA
FADDEN
MURRUMBIDGEE
Tuggeranong
Village
MT TUGGERANONG
OXLEY
MONASH
GOWRIE
Red Rocks Gorge
Proposed Tuggeranong water feature
Proposed Tuggeranong Town Centre
BULLEN RANGE
Pine Island
ISABELLA PLAINS
RICHARDSON
Tuggeranong
SIMPSONS HILL
CHISH
Freshford
660
BARNEYS HILL
CALWELL
RIVER
THEODORE
PADDYS RIVER
Barnes Cr
POINT HUT ROAD
Point Hut Crossing
805
TUGGERANONG HILL
CONDER
TIDBINBILLA ROAD
Lambrigg
LANYON HILL
THARWA ROAD
CASTLE HILL
943
BOBOYAN ROAD
Castle Hill
Lanyon
COTTER 21KM
84
83
82
81
6080
79
78
77
76
75
74
73
72
71
6070000mN
35°30'
149°00'
82
683000mE
84
85
86
87
88
89
690
91
92
109
THARWA 2KM
THARWA 2KM
1
2
3
4
5
6
8



MICHELAGO 25KM

MICHELAGO 25KM



1	2
3	4
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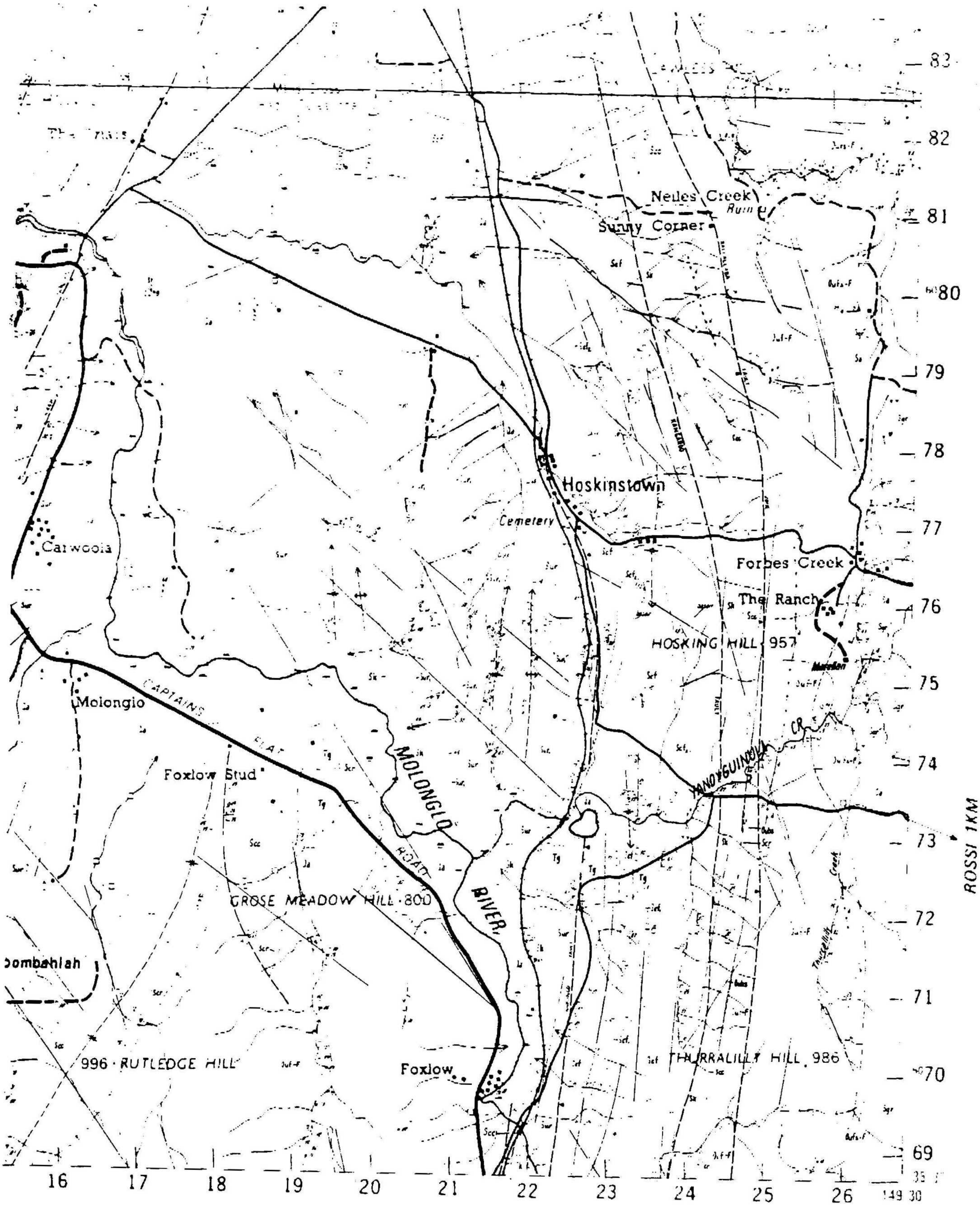
7	

TINDERRY HS 17KM



Neiles Creek
Sunny Corner
Hoskinstown
Cemetery
Carwoola
Forbes Creek
The Ranch
HOSKING HILL 957
Molongio
CAPTAINS FLAT ROAD
MOLONGLO RIVER
Foxlow Stud
GROSE MEADOW HILL 800
Bombahlah
996 RUTLEDGE HILL
Foxlow
THURRALILLY HILL 986
ROSSI 1KM
83
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26
CAPTAINS FLAT 11KM

PROVISIONAL REFERENCE TO ACCOMPANY THE 1:25 000 FIELD DATA COMPILATIONS OF THE CANBERRA 1:100 000 SHEET

Geological boundary, position accurate
Geological boundary, transitional
m Metamorphic boundary, position accurate
Unconformity (U opens towards younger rocks)
Anticline
Syncline
U D Fault (U, D indicate relative movement; up, down)
Reverse fault

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

10 Minor anticline
10 Minor syncline
10 Drag fold
FA Fold axis (FA)

Arrowhead indicates trend of plunge and value indicates plunge value for fold axis

25 Strike and dip of strata
Strike and dip of strata showing direction of facing based on sedimentary structures
25 Strike and dip of strata, facing not known
Vertical strata
Horizontal strata
80 Strike and dip of overturned strata
Lineament (Airphoto interpretation)
60 Strike and dip of cleavage
Vertical cleavage
K 60 Strike and dip of kink fold cleavage
70 Strike and dip of foliation
Vertical foliation
F1 20 Strike and dip of 1st generation foliation
30 Strike and dip of joint
20 Strike and dip of platy flow structure,
Lineation, bedding-cleavage intersection
Lineation, mineral elongation

Some structural element symbols observed at a single locality may be combined on the map

Ar Arenite bed
Tf Tuff bed
Quartz vein

ap Aplite dyke
gr Granite dyke
d Dolerite dyke
Db Dolerite dyke (Devonian or younger)
a Quartz-feldspar porphyry
Fossil locality
Drillhole; St - BMR stratigraphic hole; DD - diamond drillhole
Abandoned mine
Open cut, quarry; major
Open cut, quarry; minor
Open cut, quarry; abandoned

Bore
Bore, abandoned
Interpolated structural trend-line
Prominent ridges
Lake
Intermittent lake
Windpump
Earth dam
Primary road
Secondary road
Railway with tunnel
State boundary
Landing ground
Glen Idle Homestead
Building
Town or built-up area
500 Trigonometrical station
•24 Elevation in metres, approximate

	149°00′	149°30′
35°00′	1	2
	3	4
	5	6
35°30′	7	8

INDEX TO COMPILATION SHEETS

CAINOZOIC	QUATERNARY	PLEISTOCENE - HOLOCENE	Qa	*Gravel, sand, silt and clay : alluvium*
			Qa_1	*Sand, silt and black clay : perched alluvium*
			Qs	*Fine sand : aeolian*
			Ql	*Clay : lagoonal*
			Qbs	*Coarse sand and gravel : strandline*
			Qc_1	*Poorly cemented conglomerate, gravel and sand*
			Qc_2	*Fanglomerate : slopewash*
			Qa_2	*Silt, clay with sand laminae, minor coarse sand and gravel beds with minor calcrete : fluvio-lacustrine*
	TERTIARY	MIOCENE OR YOUNGER	Tg	*Ferruginous gravel : weathered fluvial*
			Tg_1	*Silcrete : weathered fluvial*

COTTER BLOCK / CANBERRA-YASS SHELF / CULLARIN BLOCK

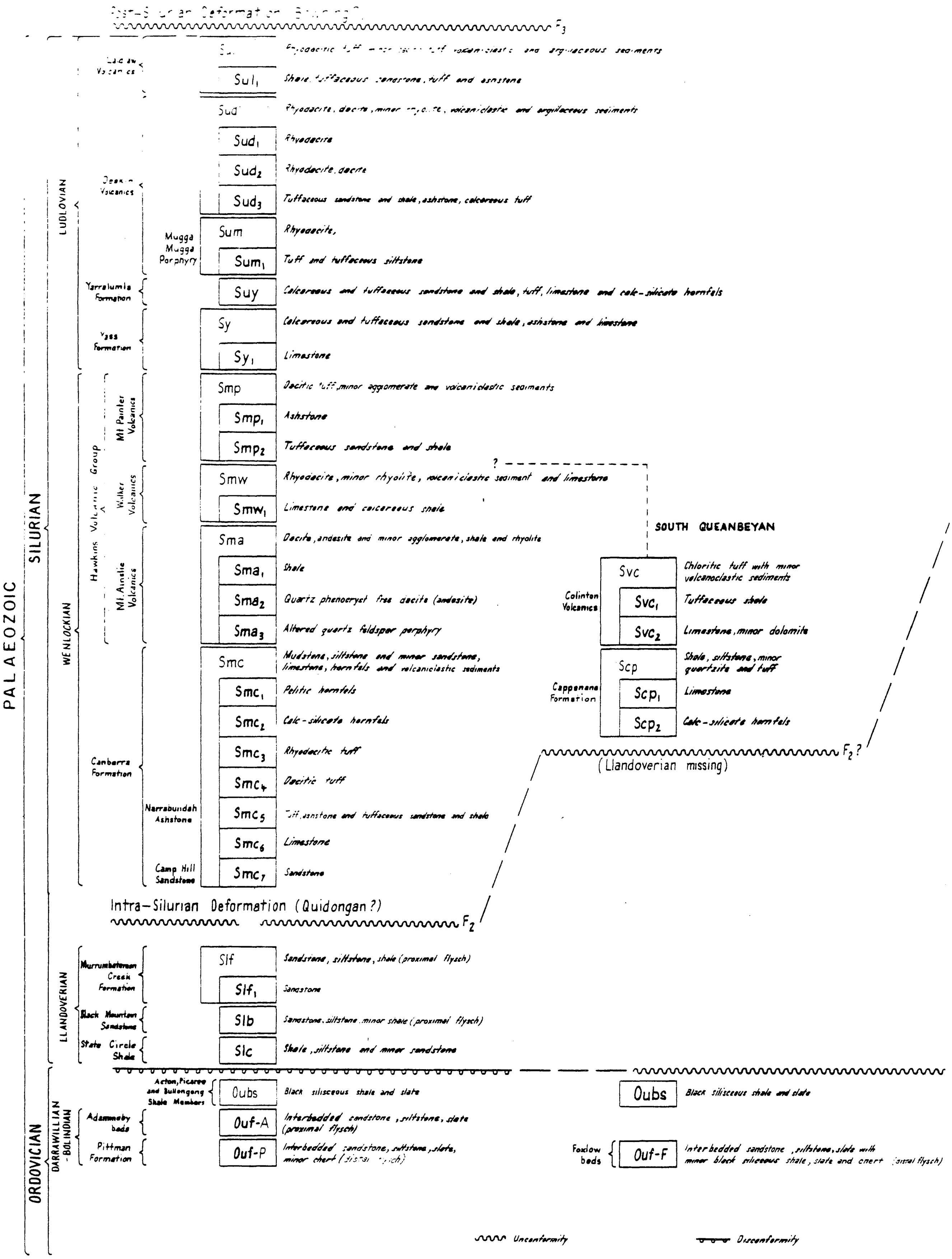
Post-Devonian Deformation (Kanimblan?) F_4

PALAEOZOIC	DEVONIAN AND YOUNGER		Db	*Massive dolerite and gabbro*
	SILURIAN	Greenwood Adamellite	Sgw	*Medium adamellite*
		Sutton Adamellite	Sgs	*Coarse adamellite*
			Sp	*Quartz-feldspar porphyry*
			Sp_1	*Quartz-feldspar porphyry (associated with Silurian volcanics)*
			Sg	*Unnamed granitoid bodies*
		Glebe Farm Adamellite	Sgg	*Porphyritic adamellite*
		Federal Golf Course Tonalite	Sgf	*Tonalite*
		Googong Adamellite	Sgo	*Porphyritic adamellite*
		Barracks Creek Adamellite	Sgb	*Medium adamellite*
		Urialla Granite	Sgu	*Adamellite*
		Booroomba Leucogranite	Smb	*Leucogranite*
		Tharwa Adamellite	Smr	*Foliated coarse adamellite*
		Shannons Flat Adamellite	Smf	*Coarse adamellite*
			Sp_2	*Foliated quartz-feldspar porphyry with mylonite*

CAPTAINS FLAT TROUGH AND ROCKY PIC BLOCK

Post-Devonian Deformation (Kanimblan?) — F_4

	Db	Foliated dolerite and gabbro
Ellenden Granite	Sge	Foliated pink to grey adamellite and leucogranite
Gibraltar Adamellite	Sgi	Foliated adamellite
Rossi Granodiorite	Sgr	Foliated granodiorite
Lockhart Complex	Sa	Amphibolite and gabbro



F3
Sul1
Shale, tuffaceous sandstone, tuff and ashstone
Rhyodacite, dacite, minor rhyolite, volcaniclastic and argillaceous sediments
Sud
Sud1
Rhyodacite
Sud2
Rhyodacite, dacite
Deakin Volcanics
Sud3
Tuffaceous sandstone and shale, ashstone, calcareous tuff
Mugga Mugga Porphyry
Sum
Rhyodacite,
Sum1
Tuff and tuffaceous siltstone
Yarralumla Formation
Suy
Calcareous and tuffaceous sandstone and shale, tuff, limestone and calc-silicate hornfels
Yass Formation
Sy
Calcareous and tuffaceous sandstone and shale, ashstone and limestone
Sy1
Limestone
Hawkins Volcanic Group
Mt Painter Volcanics
Smp
Dacitic tuff, minor agglomerate and volcaniclastic sediments
Smp1
Ashstone
Smp2
Tuffaceous sandstone and shale
Walker Volcanics
Smw
Rhyodacite, minor rhyolite, volcaniclastic sediment and limestone
Smw1
Limestone and calcareous shale
Mt Ainslie Volcanics
Sma
Dacite, andesite and minor agglomerate, shale and rhyolite
Sma1
Shale
Sma2
Quartz phenocryst free dacite (andesite)
Sma3
Altered quartz feldspar porphyry
Canberra Formation
Smc
Mudstone, siltstone and minor sandstone, limestone, hornfels and volcaniclastic sediments
Smc1
Pelitic hornfels
Smc2
Calc-silicate hornfels
Smc3
Rhyodacitic tuff
Smc4
Dacitic tuff
Narrabundah Ashstone
Smc5
Tuff, ashstone and tuffaceous sandstone and shale
Smc6
Limestone
Camp Hill Sandstone
Smc7
Sandstone
SOUTH QUEANBEYAN
Colinton Volcanics
Svc
Chloritic tuff with minor volcanoclastic sediments
Svc1
Tuffaceous shale
Svc2
Limestone, minor dolomite
Cappanana Formation
Scp
Shale, siltstone, minor quartzite and tuff
Scp1
Limestone
Scp2
Calc-silicate hornfels
F2?
(Llandoverian missing)
Intra-Silurian Deformation (Quidongan?)
F2
Murrumbateman Creek Formation
Slf
Sandstone, siltstone, shale (proximal flysch)
Slf1
Sandstone
Black Mountain Sandstone
Slb
Sandstone, siltstone, minor shale (proximal flysch)
State Circle Shale
Slc
Shale, siltstone and minor sandstone
Acton, Pialligo and Bullengong Shale Members
Oubs
Black siliceous shale and slate
Adaminaby beds
Ouf-A
Interbedded sandstone, siltstone, slate (proximal flysch)
Pittman Formation
Ouf-P
Interbedded sandstone, siltstone, slate, minor chert
Oubs
Black siliceous shale and slate
Foxlow beds
Ouf-F
Interbedded sandstone, siltstone, slate with minor black siliceous shale, slate and chert
PALAEOZOIC
SILURIAN
LUDLOVIAN
WENLOCKIAN
LLANDOVERIAN
ORDOVICIAN
DARRAWILLIAN - BOLINDIAN
Unconformity
Disconformity

WOODLAWN–MULWAREE SHELF

DEVONIAN — GEDINNIAN / SILURIAN — LUDLOVIAN-PRIDOLIAN

Covan Creek Formation	S-Dc	*Sandstone, siltstone, shale (proximal flysch)*
Currawang Basalt	Suc	*Basalt, chert and minor argillaceous sediments*
	Suc_1	*Siltstone, shale and minor sandstone*
Woodlawn Volcanics	Sw	*Rhyodacitic tuff, rhyolite, minor shale, agglomerate, ashstone*

CAPTAINS FLAT TROUGH

WESTERN MARGIN

	S-Df	*Sandstone, siltstone and shale (proximal flysch)*
	$S\text{-}Df_1$	*Sandstone*
UNNAMED UNITS	Suv_2	*Argillaceous sediments with minor basalt acid tuff and lavas*
	$Suv_{2\text{-}a}$	*Limestone*
	$Suv_{2\text{-}b}$	*Rhyodacitic tuff*
	$Suv_{2\text{-}c}$	*Rhyolite*
	Suv_1	*Volcaniclastic sediments and minor rhyodacite*
	$Suv_{1\text{-}a}$	*Lithic tuff*
	$Suv_{1\text{-}b}$	*Limestone*

SE CORNER SHEET

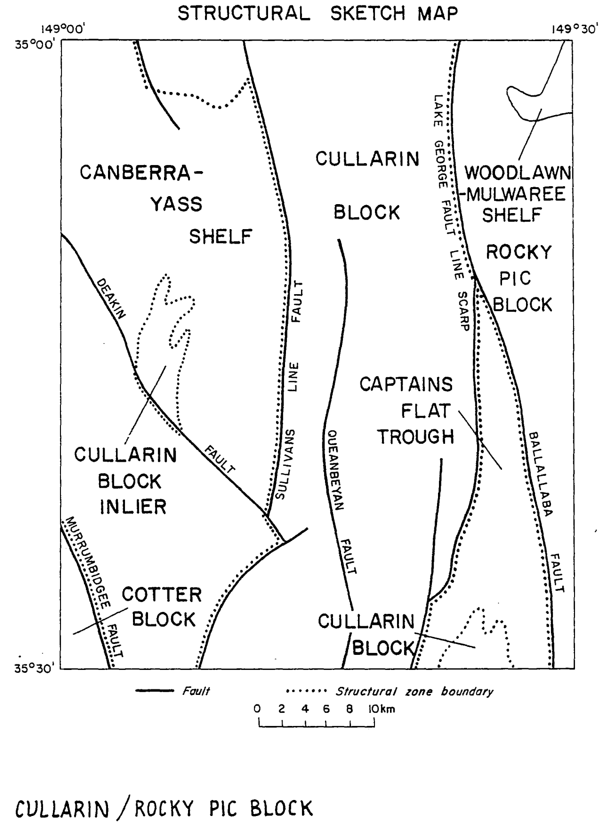
Captains Flat Formation	Scf	*Volcaniclastic dacite sediments, minor basalt, tuff and shale*
Sinclair Conglomerate	Scf_1	*Lithic tuff, conglomerate with minor shale*
	Scf_2	*Rhyodacitic tuff and agglomerate*
	Scf_3	*Basic metavolcanics*
Carwoola Beds	Sur	*Sandstone, siltstone, shale and thin volcaniclastic beds*
	Sur_1	*Sandstone*
Kohinoor Volcanics	Sk	*Rhyodacitic tuff, agglomerate, minor argillaceous sediments*
Copper Creek Shale	Scc	*Dark grey shale, siltstone and lithic tuff*
Rutledge Quartzite	Scr	*Conglomerate and quartzite*

F_2 ?

(Llandoverian and Wenlockian? missing)

F_2 ?

STRUCTURAL SKETCH MAP



CULLARIN / ROCKY PIC BLOCK

Post – Ordovician Deformation (Benambran ?)

F_1 ?

ORDOVICIAN — DARRAWILLIAN-BOLINDIAN

	Oubs	*Black siliceous shale and slate*
Birkenburn beds	Ouf-B	*Interbedded sandstone, siltstone, slate (proximal flysch)*
Foxlow beds	Ouf-F	*Interbedded sandstone, siltstone, slate, minor chert*
	$Ouf_1\text{-}F$	*Hornfelsed greywacke and spotted hornfels*
	Oufs-F	*Psammitic and pelitic schist*
	Ouks-F	*Knotted schist*

Lineaments shown on the field compilation sheets are taken from two sets of aerial photographs: 1:28 000 colour and 1:40 000 black and white (RC 5). The longer and more strongly expressed lineaments that occur on LANDSAT and RC9 photography have been excluded from the compilation sheets but will be shown with the 1:100 000 map.

Base map information

The base map used was the Canberra 1:100 000 Sheet, No. 8727, Edition 1, series R651, published by the Division of National Mapping in 1971. This map was enlarged to 1:25 000 for the compilation of field data, and updated using maps of the Canberra City area (NCDC Annual Reports, 1977 and 1979) and the new 1:100 000 topographic map of the ACT (National Mapping, Edition 1, 1976).

During the course of mapping a large number of changes were made to the base map: changes included the deletion of some rural tracks, re-plotting of creek courses, addition of access roads servicing rural holdings along the NSW-ACT border, and new property names. Changes in the Canberra-Queanbeyan urban area have been made largely from NCDC and Yarrowlumla Shire maps. These changes have been included on the 1:25 000-scale base map and will be retained for the CANBERRA Sheet.

STRATIGRAPHY

Status of stratigraphic units

One purpose of this study was to rationalise as far as possible the stratigraphy of the CANBERRA Sheet. There are over 60 stratigraphic names which either have been or are in current usage. Some of the names are regarded as informal since such units to not appear to have properly recorded definitions, although detailed descriptions have been given of type localities or reference sections where the best exposures occur.

The stratigraphic units that will be adopted for the CANBERRA Sheet area listed in Table 1 under Rock Units and Dates. In a later report to accompany the 1:100 000 map some of these units will be defined in terms of the format used by Owen & Wyborn (1979) and Richardson (1979).

The following stratigraphic units occurring on CANBERRA Sheet have already been defined according to the above format as a result of mapping on adjacent sheets:

Adaminaby beds (Ouf-A), Richardson (1979), Owen & Wyborn (1979)

Booroomba Leucogranite (Smb), Owen & Wyborn (1979)

Cappanana Formation (Scp), Richardson (1979)
Captains Flat Formation (Scf), Richardson (1979)
Carwoola beds (Sur), Richardson (1979)
Colinton Volcanics (Svc), Richardson (1979)
Copper Creek Shale (Scc), Richardson (1979)
Foxlow beds (Ouf-F), Richardson (1979)
Kohinoor Volcanics (Sk), Richardson (1979)
Laidlaw Volcanics (Sul), Owen & Wyborn (1979)
Rutledge Quartzite Member (Scr), Richardson (1979)
Shannons Flat Adamellite (Smf), Richardson (1979)
Sinclair Conglomerate Member (Scf), Richardson (1979)
Tharwa Adamellite (Smr), Richardson (1979)
Walker Volcanics (Smw), Owen & Wyborn (1979)

Some of these units are likely to require redefinition, but most will only need minor amendments in terms of their occurrence on the CANBERRA Sheet.

Three other defined units occurring on the MICHELAGO Sheet, and shown by Richardson (1979) as extending northwards onto CANBERRA, are:

(a) Sedimentary units (Sul_1) cropping out north of Tharwa and near Mount Stromlo that may be either folded sedimentary interbeds in the Laidlaw Volcanics or downfolded outliers of the Bransby beds. Their stratigraphic identity and position on the CANBERRA Sheet may depend on whether the Laidlaw Volcanics can be recognised on MICHELAGO.

(b) Tuggeranong Tuff Member; a unit that may be a member of the Deakin Volcanics but is not differentiated on the CANBERRA Sheet.

(c) Yandyguinula Shale Member; a unit that cannot be recognised with certainty on CANBERRA around the northern keel and eastern limb of the Captains Flat syncline.

Records from the Stratigraphic Index at BMR show that the following units also recognised on the CANBERRA Sheet, have been approved by the NSW Stratigraphic Nomenclature Committee of the Geological Society of Australia:

Birkenburn beds (Ouf-B),	BRAIDWOOD 1:100 000 sheet
Boro Granite,	" " "
Covan Creek Formation (S-Dc)	" " "
Currawang Basalt (Suc),	" " "
Ellenden Granite (Sge)	" " "
Urialla Granite (Sgu),	MICHELAGO 1:100 000 sheet
Williamsdale Volcanics,	" " "
Woodlawn Volcanics (Sw),	BRAIDWOOD 1:100 000 sheet

The Boro Granite (Felton & Huleatt, 1977) is to be renamed and redefined as the Rossi Granodiorite (Sgr), as a result of recently completed mapping on ARALUEN (D. Wyborn, pers. comm., 1980). The Williamsdale Volcanics, stratigraphically equivalent in part to the Colinton Volcanics (Svc) on the MICHELAGO Sheet (Richardson, 1979) are not differentiated as a separate unit within the Colinton Volcanics on the CANBERRA Sheet.

Revisions of the following stratigraphic units have been submitted but have not yet been approved by the ACT Stratigraphic Nomenclature Committee:

Canberra Formation (Smc)

Mount Painter Volcanics (Smp)

Mugga Mugga Porphyry (Sum)

Other stratigraphic units in the Canberra area that have been given some definition or a full description in the published literature (Opik, 1958 LEXIQUE STRATIGRAPHIQUE INTERNATIONAL, 1956-60) are the Acton Shale, Ainslie Volcanics (Sma), Black Mountain Sandstone (Slb), Camp Hill Sandstone (Smc_7), Canberra Group, Deakin Volcanics (Sud), Fairbairn Group, Fyshwick Gravel, Mount Pleasant Porphyry, Pittman Formation (Ouf-P), State Circle Shale (Slc), St Johns Church beds, Turner Shale, and Yarralumla Formation (Suy). Rock units listed without symbols are old stratigraphic names not used on the accompanying maps.

The following is a listing of the stratigraphic names on CANBERRA that are proposed for formal definition.

(a) Sedimentary and volcanic units

Black Mountain Sandstone (Slb)

Canberra Formation (Smc) with Camp Hill Sandstone Member (Smc_7) and Narrabundah Ashstone Members (Smc_5),

Deakin Volcanics (Sud) with Mugga Mugga Porphyry Member (Sum),

Mount Painter Volcanics (Smp),

Mount Ainslie Volcanics (Sma),

Murrumbateman Creek Formation (Slf),

Pittman Formation (Ouf-P) with Acton Shale, Bullongong Shale, and Picaree Shale Members (Oubs). These member units are sufficiently extensive to have the status of named units although similar lithologies are known to occur elsewhere in the Sheet area.

State Circle Shale (Slc),

Yarralumla Formation (Suy).

(b) Intrusive units

Barracks Creek Adamellite (Sgb),

Federal Golf Course Tonalite (Sgf),

Glebe Farm Adamellite (Sgg)
Gibraltar Adamellite (Sgi),
Googong Adamellite (Sgo),
Lockhart Complex (Sa)
Sutton Adamellite (Sgs).

The Yass Subgroup (Sy), which is exposed best on YASS (Cramsie & others, 1978), has now been given formation status by Owen & Wyborn, 1979; its formation status will be retained on CANBERRA.

Among the Ordovician rocks on CANBERRA four named stratigraphic units have already been subdivided by various workers. For the purposes of the 1:100 000 map it is probable that only the Pittman Formtion (Ouf-P) can be satisfactorily defined in terms of a strict stratigraphic format from exposures in the CANBERRA Sheet area. The Foxlow beds (Ouf-F) will be merged with the Pittman Formation, which was the first named Ordovician unit in the Sheet area, and has the same rock types and age control seen in the Ordovician outcrops in the Cullarin and Rocky Pic Blocks. The Adaminaby beds (Ouf-A) may be retained, as, according to Owen & Wyborn (1979), fossils collected from this proximal flysch unit span an age only from late Eastonian to early Bolindian. The Birkenburn beds (Ouf-B) crop out only in a small area on the eastern shore of Lake George; this unit occurs extensively on the BRAIDWOOD sheet to the east. Finding a suitable stratigraphic format for the Ordovician is hampered by (1) lack of palaeontological control; (2) few marker lithologies and difficulty in tracing them over large distances owing to complex tectonics; (3) problems differentiating rocks of Ordovician and lower Silurian age; and (4) nowhere is the base of the Ordovician seen, and only in a few places, notably around Canberra, can relationships with the Silurian be deduced.

Captains Flat Trough

The stratigraphic problems of greatest complexity occur in the Captains Flat Trough. The Late Silurian stratigraphy in the Captains Flat Syncline was originally established by Glasson (1957). This was modified by Oldershaw (1965) and the units traced northwards to the northern keel of the Captains Flat Syncline. However, identification of the units between Hoskinstown and Bungendore, and along the western margin of the Captains Flat Trough, as suggested by Wilson (1964), cannot be adequately demonstrated in the field. An attempt has also been made by Huleatt (1971) to correlate the Late Silurian stratigraphy on the BRAIDWOOD sheet, west of Tarago, with that of the Captains Flat district. Correlation of the volcanic units in the Captains Flat Trough over long distances is hampered by (a) the nature of the volcanic environment, with its rapid thickness and facies variations, complex intertonguing of units and local unconformities, (b) subsequent tectonic activity resulting in isoclinal folding and reverse faulting, causing development of a strong foliation/cleavage which obscures field relationships and has destroyed the mineralogical characteristics of the volcanic rocks, (c) a cover of superficial Cainozoic sediments which obscures the outcrop pattern, and (d) lack of palaeontological control.

As the established successions at Captains Flat mine and Tarago cannot be reliably correlated in detail, consideration is being given to an 'intermediate' stratigraphy for the Late Silurian sedimentary and volcanic rocks along the western margin of the Captains Flat Trough. At this stage the provisional sequence comprises three unnamed units (S-DF, Suv_2, Suv_1) based on lithological divisions mapped by Wilson (1964). These stratigraphic units, which are upward-facing, are best exposed from Glenidle Station northwards to the Kings Highway. Possible correlatives of these units are given in Table 1.

Further elucidation of the stratigraphy of the Captains Flat Trough needs to take account of regional geology. Lithological and structural characteristics of the trough suggest it may be related in time and evolution to the Hill End Trough. Scheibner (1972) suggests the Captains Flat Trough is a 'southern continuation' and an 'en echelon equivalent of the Hill End Trough'. Davis (1975) states that it is a 'southern component of the Hill End Trough'. Talent & others (1975) state that 'the sequences at Captains Flat, Tarago and Taralga which are largely made up of deep water sediment with greywacke prominent are taken to indicate a southward extension of the Hill End Trough to at least 36°S'. However, Cas & Jones (1979), in their proposition that the Harvre Trough and Central Volcanic region of New Zealand are modern analogues of the Palaeozoic Hill End Trough and Canberra magmatic province, represent the Hill End Trough as terminating in the Burraga area, the region to the south being assigned to an emergent shallow-marine Canberra magmatic province. This view may require modification, since mapping by Henry (1978) in the Tarago area suggests that the Covan Creek Formation (S-Dc) is a Late Silurian - Early Devonian proximal flysch sequence which may be correlated with similar sequences near Goulburn. Support for this suggestion is given by the stratigraphic sequences in the Captains Flat Trough, which generally young northwards, owing mainly to the northerly plunge of major fold axes, e.g. the Antill Anticline and large-scale folds northeast of Lake George.

Canberra-Yass Shelf

The stratigraphy of the Canberra-Yass Shelf is now fairly well understood.

Mapping by Henderson (1975b), and the use of thin-section studies and geochemistry, have now made it possible to extend north of the Deakin Fault units of the volcanic stratigraphy recognised to the south of the fault (Sma, Smp, Sud, and various high-level intrusions, Sp).

South of the Deakin Fault a few problems remain, notably the stratigraphic position of the Capanana Formation (Scp) and the Colinton Volcanics (Svc). Three possibilities exist: either (a) these units correlate with part of the Canberra Formation and Hawkins Volcanic Group, or (b) they correlate with the Yarralumla Formation and part of the Deakin Volcanics or (c) they are separate units representing a local volcanic centre which has only broad affinities with surrounding stratigraphic units. At present the stratigraphic, faunal, structural, petrographic, and geochemical evidence is inconclusive, and needs further work. The precise stratigraphic position of the Walker Volcanics (Smw) is uncertain, but they may be older than the Mount Painer Volcanics (Smp) and possibly a lateral equivalent of the Ainslie volcanics (Sma). As elements of the Walker Volcanics do not occur within the Mount Painter Volcanics it is probable that the Mount Painter Volcanics were deposited as one major ignimbrite eruption; remnants of which now occur in synclinal zones within the Walker Volcanics (D. Wyborn, pers. comm., 1981; Henderson, 1979b).

TECTONICS

There appears to be evidence for four main Palaeozoic tectonic events on the CANBERRA Sheet:

F_1 (Benambran) - Late Ordovician/Early Silurian;
F_2 (Quidongan) - Mid-Silurian;
F_3 (Bowning or Tabberabberan) - Early to Middle Devonian;
F_4 (Kanimblan) - Mid-Carboniferous.

In addition there is evidence for uplift and block-faulting during the Cainozoic. Numerous workers in the Lachlan Fold Belt have used orogenic names for these events that have now become entrenched in the literature (Packham, 1969; Crook & others, 1973).

F_1 deformation

The F_1 episode is poorly documented. The most direct evidence comes from a shallow-dipping biotite foliation in the Foxlow Beds (Ouf-F) exposed in Bradleys Creek in the Cullarin Block and Yandyguinula Creek in the Rocky Pic Block. This early F_1 foliation was later isoclinally folded and cut by a steeply inclined axial plane cleavage during the F_2 deformation. Indirect evidence for an early phase of recumbent folding (F_1) has been provided by Stauffer & Rickard (1966) from facings and geometrical variation of second-generation folds in Ordovician rocks of the Cullarin Block east of Queanbeyan. Unconformable relationships in support of this deformation cannot be shown as first hand field evidence in the Sheet area.

F_2 deformation

This deformational event produced northward- and southward-plunging tight, upright, flexural, sometimes isoclinal folds with a strong meridional axial plane cleavage in Ordovician and Early Silurian rocks in the Cullarin Block. Local NE trending folds and cleavage occurs in Ordovician and Early Silurian inliers of the Canberra-Yass Shelf.

The importance of this event is deduced largely from unconformities with variable angular discordance. The most intense unconformity known is exposed on Capital Hill, Canberra (Strusz & Henderson, 1971) where mildly folded marine Wenlockian sediments (Smc) overlie slumped and tightly folded proximal flysch of Llandoverian age (Slc and Slb). Near the junction of Ginninderra Creek and the Barton Highway Crook & others (1973) have described shallow dipping marine Wenlockian sediments resting with high angular discordance on slightly overturned proximal flysch of Llandoverian age (Slf). Northeast of Wantagong station Henderson (1978b) has mapped a basal arenite unit (Smc_7) of the Canberra Formation in apparent unconformity with proximal flysch of Llandoverian age (Slf), and at Acton in central Canberra Henderson (1979a) described the Canberra Formation as unconformably resting on the Pittman Formation (Ouf-P) with high angular discordance (this was a temporary exposure uncovered during the construction of the Molonglo Parkway). The possible extent eastwards of this time break to the Captains Flat Trough is indicated by the Rutledge Quartzite Member (Scr), a basal conglomerate and arenite unit of the Copper Creek Shale (Scc) which rests with apparent unconformity on Ordovician rocks (Ouf-F).

The uplift associated with this fold episode produced a major change in the geological environment. Ordovician-Early Silurian flysch accumulation ceased and shallow-marine sediments were deposited, followed by a thick terrestial sequence of acid pyroclastic flows (Crook & others, 1973). Variably plunging, tight and sometimes isoclinal folds with a strong cleavage which subparallels bedding constitute a distinct deformational style characteristic of Early Silurian rocks; this style also extends into Ordovician rocks without structural discordance. By contrast the overlying Middle-Late Silurian rocks on the Canberra-Yass shelf show a milder deformational style with folds trending northeast (Table 2).

F_3 deformation

The F_3 fold episode is demonstrated on the Canberra-Yass Shelf by northeast-trending open similar-style folds with axial plane cleavage, which grade eastwards into tighter folds with a strong cleavage/foliation at the eastern margin of the shelf. The exposure, as inliers, of Ordovician (Oup-P) and Early Silurian (Slb, Slc, Slf) rocks north of the Deakin Fault suggests northeast and southwest-plunging culminations caused by an interference fold pattern set up by the superimposed effects of F_3 folds on older F_2 structures. The unusual northeast-trending fold pattern in Ordovician rocks near Nanima, and the strike swing of steeply dipping Silurian strata wedged into Ordovician rocks south of Queanbeyan, indicates that the F_3 deformation had some minor effects along the western margin of the Cullarin Block. Accommodation folds which postdate F_2 are displayed by a flattening of dips and a gradual displacement west of meridional F_2 fold axes around the southern margin of the Sutton (Sgs) and Greenwood (Sgw) Adamellites. Other similar examples caused by the intrusion of Early Devonian granitoid bodies have been mapped along the southern margin of the Michelago Complex (Richardson, 1979).

Evidence for an F_3 fold episode is weak in the Captains Flat Trough, but it is possible that this deformation is represented by the Tarago Conglomerate, which lies unconformably on the Covan Creek Formation (S-Dc) near Tarago, and is also reported by Felton & Huleatt (1977) as unconformably overlying Ordovician rocks to the south; folding and foliation associated with this episode have not been recognised and it appears that this tectonism was no more than a mild phase of warping and faulting.

F_4 deformation

In the Captains Flat Trough the F_4 fold phase is represented by meridional, variably plunging isoclinal folds, reverse faults, and conjugate kink or crenulation tectonics. The westward extent of this deformation in the

Captains Flat Trough is probably limited by the Lake George-Whiskers fault zone. A folded and cleaved segregation banding in the Foxlow Beds, exposed in Turallo Creek and Yandyguinula Creek in the Rocky Pic Block, may be attributed to the refolding (F_4) of an earlier fold episode (F_1 or F_2). In the Canberra-Yass shelf the F_4 deformation was milder and denoted by complex conjugate faulting and kink tectonics.

Faulting

The origin and age relationships of the fault pattern across the Sheet area suggest that major meridional faults such as the Murrumbidgee, Sullivans Line, Lake George-Whiskers and Ballallaba Faults were probably deep-seated basement fractures initiated during the F_2 deformation. These faults, which helped to control Late Silurian sedimentation patterns on the Canberra-Yass shelf and in the Captains Flat Trough, were reactivated during the Late Palaeozoic. The mapping of an orthogonal pattern of northwest and northeast faults on the Canberra-Yass Shelf is also confirmed across the Sheet area by the grouping of airphoto lineaments (Fig. 4). An analysis of the three fault trends (meridional, northwest, and northeast) suggests a pattern developed as conjugate stress release through movements along meridional fault lines in response to several pulses of east-west compressions during the Late Palaeozoic. The north-west and northeast conjugate faults appear to postdate the meridional faults, e.g. the northwest-trending Deakin Fault cuts the Sullivans Line Fault, which probably had its antecedence in what is now called the Queanbeyan Fault. Although a relationship between northwest and northeast fault trends is probably arbitrary, mapping has shown that, where these two trends intersect, the northeast trend is the younger, e.g. the Deakin Fault is truncated south of Queanbeyan and is slightly displaced by the Winslade-Gungahlin Fault in east Belconnen. It is also likely that intersections between northwest and northeast faults are sites favourable for the emplacement of small granitoid bodies (Sgg, Sgb, Sgo).

Conjugate kink tectonics in Early Palaeozoic sedimentary and volcanic rocks east of Queanbeyan have been discussed by Stauffer & Rickard (1966) and Stauffer (1967). The present study shows that both small- and large-scale kink folds occur in association with faults. Small-scale kink folds mapped with shallow-westerly-dipping axial planes may reflect a vertical stress field associated with the reversed nature of movement along the Lake George-Whiskers fault zone. Large- and small-scale kink folds with steeply dipping axial planes may relate to a lateral stress field set up by a complex fault system southeast of Queanbeyan, and movements along the Deakin Fault as shown by the outcrop pattern of the Yarralumla Formation (Suy).

Cainozoic Uplift

Faulting in the Cainozoic is demonstrated by youthful scarps caused mainly by renewal of movement along portions of the Murrumbidgee, Queanbeyan, and Lake George fault lines. Lineaments interpreted from LANDSAT 1:250 000-scale imagery suggest that in the vicinity of Lake George the trend of the escarpment coincides partly with strong north-northwesterly lineaments which can be traced across the Bungendore plain to Hoskinstown. These lineaments may define a line of late Tertiary faulting, as, at Gearys Gap, the western block has been uplifted by about 100 m relative to the eastern block since the deposition of Miocene(?) silcrete and ferruginous gravels. About 4 km west of Bungendore the scarp changes direction by 30° and trends south to Primrose Valley. This section of the scarp with its more mature drainage pattern may relate to an earlier period of Tertiary movement and consequent scarp retreat as Young & Bishop (1980) have dated an early Miocene basalt covering the line of the scarp 12 km south of Crookwell.

ECONOMIC RESOURCES

Construction materials

Most of the available construction materials in the CANBERRA Sheet area have been utilised in the development of Canberra and Queanbeyan. Until recently most of these materials could be obtained within the ACT, but with the expansion of Canberra and the nearing depletion of building materials the ACT has become increasingly dependant for these resources on adjacent areas of New South Wales (Wilson, 1979). Table 3 lists current extractive industry operations in the CANBERRA Sheet area.

Limestone in the Canberra Formation has been quarried on a small scale from sites on Gungaderra Station, from several small pits at White Rocks about 4 km south of Queanbeyan, and from a deposit 2 km south of Millpost Station. Mahoney & Taylor (1913) gave the first detailed descriptions of limestone deposits in and around the ACT, listing reserves and quality (partial analyses). From early times it must have been evident that these deposits were too small to have long-term commercial value; the local demand for cement and lime products is now supplied from quarries at Goulburn and Marulan.

Natural and ornamental stone has been used in a large number of

Canberra buildings, mainly for external cladding, paving, and internal feature walls; it is rarely used as the main structural material, although St Johns Church, Reid and St Ninians Church, Lyneham are built of locally quarried Black Mountain Sandstone from the east slope of Black Mountain. Canberra buildings using natural stone are listed by Warren (1966); documentation is sparse for buildings using natural stone in country areas around the ACT. It is evident from these records that most natural stone has been imported from the Sydney area. The Geological Services Section, Geological Branch, BMR, holds a card index system which records the use of natural stone in Canberra buildings, monuments, and engineering structures. The index is available not only for public interest, but more specifically as a data base for use in restoration, where a source or quarry for matching stone is needed for replacement purposes.

Exposures of quartz-feldspar porphyry (Sp_1) worthy of examination as a source of ornamental stone occur in the Murrumbidgee River between the Outward Bound School and Lambrigg station. This unweathered, massive, coarse-grained intrusive porphyry is characterised by large pink potash feldspar phenocrysts up to 2.5 cm long, set in a greyish granular quartz-feldspar groundmass. The extent of this rock away from the Murrumbidgee River needs to be assessed.

Mineralisation

The known mineralisation on the CANBERRA Sheet is typical of much of the Palaeozoic terrain of southeastern Australia. In the past only gold, base metals, and to a lesser extent iron have received interest from prospecting organisations. Two important base-metal deposits, at Captains Flat and Woodlawn, occur just beyond the southern and eastern margins of the Sheet area. A review of mining activity in and around the ACT was carried out by Smith (1963). Further information on individual deposits has been provided in the form of mine data sheets (Gilligan, 1975) to accompany the Canberra 1:250 000 Metallogenic Map (Gilligan, 1974). The relationship of mineralisation and regional geology in New South Wales is discussed by a number of authors in Markham & Basden (Editor, 1974).

Regional gold mineralisation in the Cullarin Block seems to be related to an association of Ordovician flysch and granitoid intrusion (Herzberger, 1974). On CANBERRA gold occurrences are documented largely from the records of output of the Sutton-Gundaroo goldfields. These goldfields occur within an arcuate zone of mineralisation at and beyond a contact metamorphic zone developed in the Pittman Formation at the eastern margin of the Sutton Adamellite. The mineralisation, which is regarded as hydrothermal, seems to be controlled by the emplacement of the strongly magnetic 'I'-type Sutton Adamellite. Particulate gold has been won sporadically from Shingle House Creek, which drains country containing the same primary gold mineralisation.

Base metal mineralisation appears to be confined to Late Silurian trough zones associated wth volcanic rift environments, e.g. Captains Flat Trough (Gilligan & others, 1979). Workable deposits have yet to be found on CANBERRA, but from 1937-62 a stratiform Cu-Pb-Zn-Ag sulphide deposit was mined from the Kohinoor Volcanics (Sk) at Captains Flat (MICHELAGO), the mine closing following the depletion of ore (Davis, 1975). In the early 1970s Jododex (Aust.) Pty Ltd were successful in finding a similar base-metal deposit in the Woodlawn Volcanics (Sw) which is currently being mined from an open pit a few kilometres west of Tarago (BRAIDWOOD). It is generally accepted that base-metal mineralisation at Woodlawn and Captains Flat resembles the Kuroko deposits of Japan, originating as stratabound lenses where volcanic exhalatives are introduced into a submarine felsic volcano-sedimentary environment. The failure of companies to locate base metal mineralisation between Captains Flat and Woodlawn may be explained by the north-northwest-trending Ballallaba fault zone which restricts the northward extension of Late Silurian sediments and volcanics in the vicinity of Bungendore. North of Bungendore, drilling and field studies suggest that most of the bedrock profile beneath Lake George is probably Ordovician flysch and it is only at the northeastern end of the Lake that Late Silurian sediments and volcanics capable of hosting base metals reappear as proved by Jododex (Aust.) Pty Ltd in drilling programs to prove the extent of base metal mineralisation around Woodlawn Mine.

Some company interest in recent years has been shown in the volcano-sedimentary environment of the Canberra Formation (Smc) north of the ACT border as a source of base metals; detailed mapping and drilling in the Nobby Hill area by Amoco Minerals Company has yet to prove economic deposits.

Iron ore mineralisation occurs as primary ironstone and quartz fillings in fault zones. Occurrences are common along Back Creek in association with the Sullivans Line Fault, and in the upper catchment of Murrumbateman Creek along the northeast-trending Glengyle and Carrington Faults. Secondary ironstone gossans, such as occur on Gungaderra Station, are less common; these deposits formed during periods of prolonged weathering, and consist of limonite, haematite-goethite and magnetite.

BMR drilling in the Lake George basin near Bungendore and on the Molonglo plain south of the Mills Cross Radiotelescope during the course of this study has established the existence of a deep weathering profile of Tertiary age

(M. Idnurm, pers. comm., 1979). The profile has been protected from erosion in most places by downfaulting to an area of minor relief and by a subsequent cover of fluvio-lacustrine sediments of Quaternary age. Where the weathering profile crops out on the watershed separating the Lake George and Molonglo drainage basins lateritised and kaolinised clays, developed in Palaeozoic flysch deposits, have been quarried for building materials. The thickness of the profile in the Lake George basin (Table 4) increases from south to north, exceeding 76 m at Lake George (BMR Scout-hole No. 1). On the Molonglo Flats a hole (C.297) drilled to investigate Cainozoic sediments close to the Lake George faultline scarp detected 20% Mn and 1% Co (AAS and emission spectroscopy) at a depth of 29.3 m in weathered phyllite (B. Cruickshank, pers. comm., 1979 and 1981). Manganese has been concentrated as veinlets and stringers along foliation cleavage, and fracture planes more or less continuously through the full thickness (39 m) of the weathered bedrock profile (Table 4). The manganese may have been emplaced during Palaeozoic movements along the Lake George fault zone, as the metal was not seen in core from a hole (C.296) drilled 2 km further east.

Hydrology

Water resources have been developed largely for domestic use, either from surface water or groundwater, in response to growing urban demand in Canberra and Queanbeyan.

Surface water resources have been developed in terrain west of the Murrumbidgee River, where average annual precipitation in excess of 800 mm is evenly distributed throughout the year. This precipitation is sufficient to maintain a series of three reservoirs on the Cotter river (Corin, Bendora and Cotter dams), water being supplied to Canberra by a pipeline which enters the Sheet area south of Mount Stromlo. To augment this supply and provide for future demand, Googong Reservoir was completed in 1978; water from Googong enters the ACT near the Hume Industrial Estate and will also supply Queanbeyan in the future. Large natural bodies of water such as Lake George are used only for limited stock watering. Lake Burley Griffin and Lake Ginninderra provide Canberra with recreational facilities as well as flood control along the lower Molonglo River and Ginninderra Creek. In the rural areas sufficient surface water is normally available for stock from earth dams and perennial streams draining highland catchments.

Groundwater is available in small quantities and at shallow depths in most areas. Generally the demand is for domestic and pastoral use by rural landowners. Strongly fractured and weathered crystalline and sedimentary rocks give successful bores yielding supplies averaging about 0.5 litres/hour from depths up to 30 m; quality is good, ranging from 500-1000 mg/l of total dissolved solids. Open fracturing commonly occurs to depths of 12-30 m, and weathering to depths of 10-25 m. In the Captains Flat Trough unconsolidated fluvio-lacustrine sediments of Cainozoic age yield moderately good supplies, capable of sustaining a semi-rural population based on Bungendore and Hoskinstown. The water supply at Bungendore is derived from two bores and standby well, each capable of yielding 2-3 x 10^4 l/hour.

GEOLOGICAL SYNTHESIS

The pre-Ordovician history of the CANBERRA region is speculative. The oldest rocks are poorly fossiliferous quartz-rich distal flysch deposited in a deep oceanic basin, the Monaro Slope and Basin, that developed to the east of the Molong Volcanic Arc (Scheibner, 1974). This thick marine sequence of essentially Darriwilian age (Opik, 1958; Nicoll, 1980) contains sandstone, siltstone, and argillite (Ouf-A, Ouf-B, Ouf-P, Ouf-F) in which current bedding and other sedimentary structures indicate a detrital source to the south. Towards the top of the latter unit, black siliceous shale beds (Oubs), representing condensed sequences, contain a rich graptolite fauna Gisbornian to Bolindian in age.

Towards the end of the Ordovician this flysch sequence was deformed by a fold episode (F_1) which was probably the waning phase of a more intense gravity tectonic and recumbent fold event to the west. Unconformable relationships associated with this event can only be inferred in the Sheet area from Smith (1964), who describes an outlier of weathered Silurian siltstone float resting on Ordovician siliceous black slate southeast of Glenlee Station. On the MICHELAGO Sheet, Richardson (1979) regards the Gungoandra Siltstone, a basal member of the Lower Silurian Ryrie Formation, as being in unconformable contact with meridionally trending Ordovician rocks east of Colinton Hill. Following this tectonism new flysch accumulatons were deposited from the west as a series of submarine fans (Crook & others, 1973). The occurrence of a fauna including _Monograptus exiguus_ gives a late Llandoverian age to part of this sequence in the Canberra area (Slc), where most of the rocks are proximal flysch (Slb and Slf). The absence of volcanic detritus suggests that these proximal flysch units were probably re-worked sediments derived from the early development of the Canberra-Yass Shelf. How far eastwards deposition continued is unclear but a *M. exiguus* fauna was recorded by Naylor (1935, 1936) from the 'Jerrara Beds', a distal flysch unit about 6 km west of Bungonia. This was confirmed by Creaser (1973) who described a similar exposure of Llandoverian rocks named the 'Highway Beds' in a road cut on the Hume Highway about 10 km east of Goulburn. It is possible that these distal flysch units represent a facies equivalent of the proximal flysch deposits in the Canberra area that were deposited in deeper portions of the Monaro Basin.

Early in the Wenlockian, flysch deposition was terminated by the F_2 deformation represented by unconformities, tight folding, and locally greenschist-facies regional metamorphism. In a regional context this uplift event can be mapped as a time break which gradually increases in duration from west to east across the Canberra 1:250 000 Sheet. On BRINDABELLA Owen & Wyborn (1979) show only minor uplift, tilting, and erosion in support of this fold phase. North and south of CANBERRA, Crook & others (1973) have discussed unconformable relationships in support of this fold episode in the Quidong and Yass districts. Richardson (1979) describes an unconformity at a site on Burra Creek (now covered by the waters of Googong Reservoir) where shallow-marine Wenlockain/Ludlovian? sediments (Scp) overlie with slight angular discordance distal flysch of Ordovician age (Ouf-F), while west of Colinton Hill she shows an unconformable relationship between the Cappanna Formation (Scp) and the Llandoverian Ryrie Formation. On the BRAIDWOOD sheet Felton & Huleatt (1977) report a significant time break where the Late Silurian DeDrack Formation and the Woodlawn Volcanics (Sw) unconformably overlie the Birkenburn Beds (Ouf-B).

During this deformation, anatexis of the crust caused the formation of granitic magma, and the development of a high heat-flow regime. Although compressional forces operated they did not entirely prevent this magma from rising to the upper crust. Numerous small discontinuous foliated quartz-feldspar porphyry bodies (Sp_2) and granitoids (Sg), generated as offshoot intrusions of this granitoid development at depth, are exposed as meridionally trending slightly discordant intrusions in Ordovician flysch along the Lake George Range, and in the Molonglo River catchment where the river cuts across the Cullarin Block. Stauffer & Rickard (1966) regard these acid porphyries as having been intruded prior to F_2, as they are deformed and foliated parallel to the slaty cleavage in the country rocks. In the Rocky Pic Block and the southern part of the Cullarin Block, highly deformed Ordovician psammitic-pelitic flysch in which two fold episodes are recognised, may relate to zones of locally intense deformation and possibly a later high temperature event associated with granitoid emplacement. The age of the F_2 deformation can be no younger than the intrusive date of the Sutton Adamellite (410 m.y.). The emplacement of this adamellite during the Late Silurian produced a contact aureole in surrounding Ordovician flysch, with spotted hornfels and 'reverse graded bedding' (metamorphic inversion) in downward-facing argillite units. The Sutton Adamellite is unfoliated, and detailed mapping has shown that its intrusion was accommodated by a local strike swing to the west of otherwise meridional F_2 folds.

At the end of the F_2 fold episode there was a major change in the geological environment. In the later Wenlockian the Canberra-Yass Shelf became fully established as a N-S trending shallow-marine platform supporting a shelly fauna in typical shelf sediments (shale, sandstone, and local carbonate). At this time a tensional regime must have developed, allowing vast quantities of felsic magma to rise to the surface. The first evidence of this volcanism is discontinuous volcaniclastic units, which pass upwards into a thick subaerial volcanic pile with interfingering marine sediments, typical of a terrestrial shallow-marine environment. 'S'-type volcanics such as the Hawkinns Group (Sma, Smw and Smp) were the first to reach the surface, followed by the intermediate 'I-S' type Deakin volcanics (Sud) and the 'I'-type Laidlaw volcanics (Sul).

Comagmatic with these volcanics are 'S' and 'I'-type quartz-feldspar porphyry (Sp_1). A line of these intrusive stocks (which may relate to volcanic centres) is associated with 'I'-type Laidlaw Volcanics, and can be traced NNW along the western margin of the Canberra-Yass Shelf from the Murrumbidgee River (near Lambrigg) to Ginninderra Creek. Post-dating Silurian volcanism came the emplacement of the Siluro-Devonian 'S'-type Murrumbidgee Batholith followed by the more common 'I'-type granitoids (Sgg, Sgf, Sgo, Sgb, Sgs, Sgw and Sg). Chemical analyses support the mineralogical evidence for distinct sources for 'S'-type and volcanics and intrusive rocks on the one hand and 'I'-type acid volcanic and intrusive rocks on the other (Owen & Wyborn, 1979).

Towards the end of the Wenlock, the tensional regime that caused the appearance of felsic volcanism on the Canberra-Yass Shelf probably initiated the Captains Flat Trough, by a process of subsidence followed by crustal rifting. A detailed time stratigraphy within the trough, and its correlation with the Canberra-Yass Shelf, has yet to be established. Although the fossil evidence is poor, it appears that the earliest sediments and volcanics deposited in the Captains Flat Trough are most likely Ludlovian. The possibility that Late Silurian volcanics from the Canberra-Yass shelf transgressed eastwards across the Cullarin Block has yet to be demonstrated. It is more likely that the acid porphyry dykes (Sp_1) along the Lake George escarpment were feeders for acid volcanism that developed at the rift margin of the Captains Flat Trough; their occurrence decreased markedly westwards, towards the Canberra-Yass Shelf. The eastward-younging stratigraphic and tectonic environment indicated by the Captains Flat Trough is suggested by:

(a) the reduced occurrence of Late Silurian acid volcanicity in the sedimentary succession and the occurrence of Late Silurian proximal flysch units (Sur) which indicate that the dominance of terrestrial volcanism evident on the Canberra-Yass Shelf has decreased eastwards, with the development of deeper water and only local terrestrial conditions;

(b) the occurrence of minor phases of biomodal volcanism at Kennys Point, where banded acid volcanics (Sw) containing large unorientated clasts of basalt rest on an irregular surface of basic volcanics (Suc), indicating a tensional structural environment typical of rifting;

(c) the appearance of basic intrusions at the western margin of the trough, such as north-south trending dolerites, gabbros, amphibolites (Db), and Lockhart Complex (Sa) at the less well demarcated eastern margin, suggesting that basic intrusive activity at the rift margin of the trough was probably stimulated by rejuvenation along deep-seated crustal fractures, such as the Lake George-Whiskens and Ballallaba faults.

Volcanism ceased on the Canberra-Yass shelf about the end of the Ludlow. As Devonian sedimentation cannot be demonstrated in this part of the shelf, it is possible either that the shelf remained land during the early Devonian, or that the shallow sea which persisted into the Pridolian and Lochkovian in the Yass basin extended southwards, but retreated during uplift associated with the F_3 fold episode. The latter is more likely, for although there is no direct evidence for marine Devonian on the CANBERRA Sheet such rocks are known around Burrinjuck reservoir and Wee Jasper on BRINDABELLA, and Lake Bathurst and Tarago on BRAIDWOOD. East of the Cullarin Block, there was rapid deepening of the Captains Flat Trough at the end of the Ludlow, accompanied by transgressive proximal flysch sedimentation (S-Dc and S-Df) which may have continued into the Early Devonian. Beyond the eastern margin of the trough there was Late Silurian-Early Devonian granitoid intrusion (Sge, Sgi, Sgr) which postdated the basic intrusive rocks of the Lockhart Complex. The known ages for this suite of granitoid intrusions (Richardson, 1979) appear to be slightly younger that for the Murrumbidgee Batholith and related intrusions in the western portion of the Sheet area.

The F_3 fold episode followed Late Silurian-Early Devonian volcanism and intrusive activity on the Canberra-Yass Shelf. This mild tectonism formed variably trending similar folds (becoming locally intense eastwards), with a strengthening of the axial plane cleavage and foliation near faults adjacent to the western margin of the Cullarin Block. As there is no clear evidence of a widespread deformation post-dating F_2 in the Ordovician sediments of the Cullarin Block, the block is assumed to have been stable during this tectonism. In the Captains Flat Trough, sedimentation continued into the Early Devonian withough interruption, with the F_3 fold episode represented by the Tarago Conglomerate and a mild phase of warping and faulting. It appears that meridional bounding fault zones (Murrumbidgee, Sullivans Line, Lake George-Whiskers, and Ballallaba), originally initiated as reverse faults during F_2. folding, acted as zones of stress relief, thereby confining F_3 deformation to shelf and trough zones.

Major tectonic activity in the Canberra region ended in the Late Palaeozoic with the F_4 fold episode. Some evidence for the age of this folding is given by the foliated Gourock granodiorite, which has been dated as 373 ± 6 m.y. (D. Wyborn, pers. comm., 1980) on ARALUEN. The deformation was most severe in the Captains Flat Trough, where Late Silurian-Early Devonian sediments and volcanics are strongly folded and faulted and acid and basic intrusives strongly foliated. Elsewhere, as on the Canberra-Yass Shelf, the effects of this deformation were milder, with stress relief resulting in kink tectonics. The nature and type of kinking is dependent on whether the main stress component along faults was vertical or horizontal, and on the development of NW and NE conjugate fault systems.

The F_4 fold episode brough to a close major tectonic activity in the Canberra region. The geological history of the late Palaeozoic and Mesozoic is unknown, as rocks of this age have yet to be found, but it seem unlikely that Permo-Triassic sedimentation extended southwestwards beyond the confines of the Sydney Basin. The region has remained a stable landmass at least since the Late Carboniferous (following the Kanimblan 'orogeny'), leading to the establishment of an ancient landscape throughout SE Australia by the Late Cretaceous.

The uplift history and continental sedimentation pattern of SE Australia during the Cainozoic was complex (Wellman & McDougall, 1974; Ollier, 1978; Wellman, 1979; Young 1980). Late Cretaceous-early Tertiary uplift started through an epeirogenic process of warping and block-faulting, followed at about 60 m.y. by the extrusion locally of large volumes of basaltic lava flows. Basaltic activity is unknown in the CANBERRA Sheet area, but the alkaline affinities of dolerite dykes at Red Rocks gorge, (grid ref. 842/798) and possibly in excavations for Ryans Tunnel (grid ref. 865/905) suggests that these dykes may have been emplaced during the Mesozoic or Tertiary. Epeirogenesis also rejuvenated old meridional fault lines, causing the reappearance of a landscape similar to that which may have existed at the end of the Palaeozoic. This rejuvenation also caused the formation of fault-line scarps at Lake George, east of Queanbeyan, and near the Murrumbidgee River, and changes in drainage patterns such as river capture and downcutting of streams. It exposed old weathering profiles, high-level gravels, and silcrete deposits, while during quiescent periods there was alluvial and lacustine sedimentation in shallow tectonic basins, and the development of younger soil and weathering profiles.

During the Quaternary, climatic changes related to the Pleistocene Ice Ages, caused colluvial deposits to accumulate in a periglacial environment. North of Bungendore, aeolian, strandline, and lagoonal deposits resulted from changes in the level of Lake George. Since the Pleistocene, alluvial deposition has continued along major streams, but in recent times, with the advent of settlement, land clearing, gully erosion, urbanisation and afforestation have greatly altered the landscape.

CONCLUSIONS

1. The study has resulted in a better understanding of the Wenlockian and Ludlovian stratigraphic units on the Canberra-Yass Shelf. The Late Silurian volcanic stratigraphy on BRINDABELLA can be traced eastwards onto CANBERRA and northwards towards YASS.
2. Only a broad interpretation of the stratigraphy in the Captains Flat Trough is possible. The grouping of lithologies into stratigraphic units and correlation with other known stratigraphies in this area remain in doubt. The Captains Flat Trough may be a younger tectonic unit that the Canberra-Yass Shelf and may have stratigraphic and tectonic affinities with the Hill End Trough.
3. There is now widespread recognition of a Quidongan deformation (F_2) in the Canberra-Yass Shelf and across the Cullarin Block; its further extension eastwards still needs evaluation. The F_3 fold episode at the end of the Silurian (Bowning or Tabberabberan) was mild and it is possible that many of the structures hitherto attributed to this deformation may be related to the Quidongan. Evidence for a late Palaeozoic tectonic event (F_4) which is probably Kanimblan is widespread across the Sheet area.
4. Acid intrusive activity is widespread and associated with repeated phases of Palaeozoic deformation. With the exception of the Murrumbidgee

Batholith, the Siluro-Devonian granitoid intrusions and high-level quartz-feldspar porphyries fall into the 'I'-type group, which generally youngs from west to east (Vistelius, 1980).

5. Basic intrusive activity of Palaeozoic age was most widespread in the east of the Sheet area, where there was crustal rifting to form the Captains Flat Trough. Siluro-Devonian dolerites and gabbros with tholeiitic affinities occur as dykes or elongate bodies with a meridional or northwest trend. A few basic intrusions with alkaline affinities which may be Mesozoic or Tertiary, occur in the west of the Sheet area.

6. The geological synthesis does not immediately suggest further directions for base-metal exploration. In the context of a thick Tertiary weathering profile (protected in most places by a thick Quaternary cover) the Captains Flat Trough needs further investigation as a source of building materials, bauxite, and minerals such as manganese and cobalt. The presence of 'I'-type granitoids, particularly those associated with a high magnetic intensity in anticlinorial zones e.g. Cullarin Block, suggests a geological environment favourable for the occurrence of gold, and other hydrothermal minerals.

RECOMMENDATIONS

As a logical outcome of the 1:100 000 mapping project, and to help bring about a more detailed evaluation of the geology of the Canberra region, the following is a recommended list of topics that could form the basis for research projects in BMR and thesis work by students in universities and colleges.

(1) A detailed mapping and petrological study of the sediments and volcanics in the Captains Flat Trough, to establish a standard stratigraphic succession.

(2) Further study of the Goulburn-Taralga-Crookwell area to establish whether the lithology and structures of the Captains Flat Trough can be related in time and evolution to those of the Hill End Trough.

(3) Further studies of the petrogenesis of the basic igneous rocks. Map in detail the Lockhart Complex; sample for isotopic dating and geochemical analysis to determine if petrogenetic relationships exist with the Currawang Basalt, the Micalong Swamp Basic Igneous Complex, and other basic intrusive rocks which could lead to an overall assessment of Phanerozoic basic intrusive activity in the Lachlan Fold Belt of SE Australia.

(4) A geological-geophysical study, in the south Canberra-Queanbeyan area, of a prominent magnetic anomaly at 149°10'E, 35°25'S. The study should combine geophysical modelling with accurate geologic control, leading to a drilling program to assess the nature and cause of the anomaly and investigate the potential for 'I'-type granitoids as a source of mineralisation in surrounding country rocks.

(5) A stratigraphic, environmental, and sedimentological study of the association of Late Silurian limestones with acid volcanic rocks in the Lachlan Fold Belt which could also combine with a geomorphological appraisal of karst features to assist in establishing in more detail a denudation chronology for SE Australia during the Cainozoic.

(6) A sedimentological study of volcaniclastic units in the upper part of the Canberra formation to determine the palaeoenvironment and palaeogeography that preceded the main episode of Late Silurian volcanism.

(7) Research into the hydrogeology of the Quaternary sediments of the Lake George basin and the Molonglo plains, to assess the groundwater potential of these sediments.

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TABLE 1. - PROVISIONAL SUMMARY DESCRIPTIONS OF ROCK UNITS SHOWN ON THE 1:25 000 FIELD COMPILATION SHEETS

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
QUATERNARY	PEISTOCENE TO HOLOCENE	Oldest radiocarbon date available is 31,778 + 1160 Yrs B.P. (Walker & Gillespie, 1978).	Qa	Gravel, sand silt, clay	20	Widespread along major streams; fluvial tracts draining into Lake George; Molonglo river flats NW of Hoskinstown; Lyneham and Fyshwick.	Unconformable on weathered Palaeozoic bedrock. Interfingering relationship with Qbs, Qc, Qa_2.	Alluvial	Local development of black clay in Yarralumla, Dunns and Monks Creeks.
			Qa_1	Sand, silt, black clay.	20	Isabella Plains, Tuggeranong, Lanyon, Jeir Ck, Yass R. and Rocks gorge.	Unconformable on weathered Palaeozoic bedrock.	Perched alluvial basins and river terraces.	Produced by minor uplift events or climatic changes in the Pleistocene.
			Qs	Fine quartz sand.	2	S. margin Lake George shoreline and Wrights Ck.	Overlies Qa, probably derived from Qbs, Qa_2, Qa.	Aeolian	Opik (1958), Galloway (1967), Costin & Polach (1973), Coventry (1976) and Coventry & Walker (1977).
			Ql	Clay	3	S. margin Lake George shoreline and Allianoyonyign Ck.	Closely associated with Qbs (develops behind strandline ridges), may interfinger with Qa_1, Qa_2.	Lagoonal pans with restricted drainage	
			Qbs	Coarse sand and gravel	10	S. margin Lake George shoreline.	Forms low ridges, banks and spits; closely associated with Ql; may interfinger with Qa, Qa_2, Qc_1.	Strandline deposits related to higher levels and greater areal extent of Lake George during the Pleistocene.	
			Qc_1	Poorly cemented conglomerate, gravel, sand.	10	Lake George shoreline and scarp, slopes of Mt. Jerrabomberra; Mt. Taylor; Black Mountain; Ainslie-Majura ridge and the Queanbeyan fault scarp.	Disconformable but derived from underlying Palaeozoic bedrock; moderately worked deposits.	Slopewash; periglacial?	
			Qc_2	Iron cemented fanglomerate	3	Murrumbateman Ck.	Disconformable but derived from Ouf-F and Oubs; poorly worked deposits.	Slopewash; periglacial?	

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
QUATERNARY	MIOCENE AND YOUNGER		Qa_2	Silt and clay with fine sand laminae, minor coarse sand, gravel, calcrete.	75+ (drill holes)	Underlies Lake George and exposed along lake shoreline.	Unconformable on deeply weathered Palaeozoic bedrock.	Fluvio-lacustrine; locally deltaic	Sediments dated to 5.4 m.y. using palaeomagnetic methods at a depth of 36 m from an ANU drillhole N. end Lake George (Singh & others, (1981,); Truswell (1980)
TERTIARY			Tg	Ferruginous gravel.	10	Gearys Gap, Yass R., Molonglo R; Murrumbidgee R.	Unconformable on weathered Palaeozoic bedrock; top not exposed but probably antedates Quaternary deposits.	High-level fluvial; probable Tertiary weathered floodplain deposits. Poorly consolidated fluvial gravels bordering Lake Burley Griffin may be terrace deposits associated with a Quaternary or older Molonglo R. floodplain.	Wilson (1964), Oldershaw (1965), Henderson (1978b) includes "Wall Conglomerate" (Phillips, 1956), "Fyshwick Gravel" (Opik, 1958), "Barnsdale Conglomerate" (Smith, 1964).
			Tg_1	Silcrete	10	W. shore Lake George	Base not exposed may relate to ancestral Yass R. drainage basin; unweathered.		

CANBERRA - YASS SHELF

*Radiometric ages quoted below are subject to amendment using the decay constants of Steiger and Jager (1977) and Dalrymple (1979).

SILURIAN	LUDLOVIAN	LAIDLAW VOLCANICS (420 m.y; M. Owen and others pers comm.)	Sul	Rhyodacitic tuff, minor dacitic tuff, volcaniclastic and argillaceous sediments	400 +	W. of Belconnen extending NW onto BRINDABELLA; Weston Creek S. to Tuggeranong and Murrumbidgee R; may extend S. to MICHELAGO.	Top not exposed in map area. Disconformable(?) on Sy, conformable on Sud. Faulted against Murrumbidgee batholith. Intruded by Sp, and cut by NW trending dolerite dykes.	Subaerial ignimbritic eruptions with marine incursions.	Thins from north to South (1000 m N. of Yass to less than 500 m on CANBERRA).
			Sul_1	Shale, tuffaceous sandstone, tuff, ashstone.	50 +	N. of Mt. Stromlo; N. of Freshford H.S.; Point Hut Crossing.	Interbedded or downfolded into Sul.	Deltaic to shallow-marine.	Fossiliferous exposures N. of Freshford Hstd and W. of Pine Island.

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	LUDLOVIAN	DEAKIN VOLCANICS	Sud	Rhyodacite, dacite, minor rhyolite, volcaniclastic and argillaceous sediments.	700 +	Belconnen and N. of Hall (W. of Barton Highway).	Conformable on Sy and below Sul. Disconformable? on Smp. In fault contact with Sma and Smp. Intruded by Sp_1.	Subaerial ignimbritic eruptions with minor marine incursions.	Undivided Fm in NW of Sheet area. Thickens from north to south.
			Sud_1	Rhyodacite	400	Pemberton Hill NW. to Mt. Wanniassa and S. to Rocky Gully and Mt. Rob Roy; narrow belt S. from Mt. Stromlo to Barneys Hill.	Conformable on Sud_2 and below Sul. In fault contact with Svc and Smw.	Subaerial ignimbritic eruptions.	Banding shows rock unit is folded into SSE plunging syncline and anticline.
			Sud_2	Rhyodacite, dacite	400	Hume Industrial Estate W. to Woden and S to Tuggeranong Hill.	Conformable below Sud_1; trangresses Sum and Sud_3 in Woden Valley area. In fault contact with Svc and Smw.	Subaerial ignimbritic eruptions.	Poorly banded.
			Sud_3	Tuffaceous sandstone, shale, ashstone, calcareous tuff.	100	S. of Tuggeranong Hill; Woden; Hume Industrial Estate; Belconnen; NW of Hall Quarry.	Interbedded volcaniclastic and argillaceous units at different levels within Deakin Volcanics.	Shallow-marine; deltaic; minor volcaniclastic deposition.	Fossiliferous; includes basal beds of Deakin Volcanics.
		MUGGA MUGGA PORPHYRY MEMBER (423 m.y*; Bofinger and others, 1970)	Sum	Rhyodacite	400	Red Hill ridge SE to Jerrabomberra Ck.	Disconformably? overlies Suy and transgresses onto Smp; conformable below higher units of Deakin Volcanics.	Subaerial ignimbritic eruptions.	Occasional banding; well exposed in Mugga Lane quarries; Opik (1958), Henderson (1975a).
			Sum_1	Tuff, tuffaceous siltstone.	10	A small lens known, NE of Tralee Speedway.	Interbedded within Sum.	Volcaniclastic deposition; shallow-marine.	Fossiliferous.
		YARRALUMLA FORMATION	Suy	Calcareous and tuffaceous sandstone and shale, limestone, calc-silicate hornfels	300	Woden Valley, Yarralumla, Red Hill ridge.	Conformable on Smp but transgressed by Deakin Volcanics; intruded by NW-trending dolerite dykes.	Shallow-marine minor volcaniclastic deposition.	Fossiliferous; correlated with Yass Fm; Opik (1958); Strusz & Henderson (1971).

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	LUDLOVIAN	YASS FORMATION	Sy	Calcareous and tuffaceous sandstone and shale, ashstone, limestone.	240	W. of Barton Highway; extends NW. onto BRINDABELLA	Conformable on Smp and below Sud; disconformable(?) below Sul.	Shallow-marine minor volcaniclastic deposition.	Fossiliferous; correlated with Yarralumla Fm; thickens NW from Hall towards Yass.
			Sy_1	Limestone	10	Jeir Station	Interbedded in Sy	Shallow-marine.	Fossiliferous.
	WENLOCKIAN — HAWKINS VOLCANIC GROUP	MOUNT PAINTER VOLCANICS (438 m.y*; Bofinger & others, 1970; 430 m.y*; Williams & others, 1975)	Smp	Dacitic tuff, minor agglomerate, volcaniclastic sediments.	1000+	Coppins Crossing SE. to Narrabundah; Gooromon Ponds Ck N. to Yass.	Disconformable(?) below Sud; conformable on Sma below Suy. In fault contact with Ouf-P, Sib, Sic, Smc.	Subaerial ignibritic eruptions.	Characterised by garnet, jasper and lithic clasts, may also occur as downfold remnants in Walker Volcanics.
			Smp_1	Tuffaceous sandstone and shale.	10	W. of Glenloch H.S.	Interbedded in Smp	Deltaic to shallow-marine	
			Smp_2	Ashstone	30	Mugga Mugga ridge SE. to Callum Brae H.S.; Woden-Weston Ck area.	Possibly the youngest rock unit in the Painter Volcanics.	Volcaniclastic deposition.	
		WALKER VOLCANICS	Smw	Rhyodacite, minor rhyolite, volcaniclastic sediments, limestone.	1500+	S. of Belconnen and extends W to BRINDABELLA	Strat. relations unknown in Sheet area; in fault contact with Sud and Smp.	Subaerial ignimbritic eruptions.	Top exposed on BRINDABELLA where unit at least 2000m thick. Probably older than Mt. Painter Volcanics; may be lateral equivalent of Mt. Ainslie Volcanics.
			Smw_1	Limestone, calcareous shale	30	NW. of Coppins Crossing; the Pinnacle.	Interbedded in Smw.	Shallow-marine	Fossiliferous, Late Wenlockian fauna NW. of Coppins Crossing (D.L. Strusz pers. comm).
		MOUNT AINSLIE VOLCANICS	Sma	Dacite, andesite, minor agglomerate, shale, rhyolite.	700+	Mt. Ainslie-Gooroo ridge; Hall N. to Nanima Hill; S of Canberra airport.	Conformable below Smp and on Smc; in fault contact with Ouf-F; intruded by NW-trending dolerite dykes.	Subaerial ignimbritic eruptions with minor shallow marine incursions and volcaniclastic deposition.	Fm. becomes progressively foliated towards Sullivans Line Fault, includes "Gladefield Volcanics" (Moore, 1957).

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	WENLOCKIAN	HAWKINS VOLCANIC GROUP – MOUNT AINSLIE VOLCANICS	Sma_1	Shale	30	Nanima Hill S. to Lake Springfield; Hall Ck.	Interbedded in Sma	Shallow-marine	
			Sma_2	Andesite	600	Mt. Ainslie-Gooroo ridge.	Conformably overlies Sma; in fault contact with Smc.	Subaerial ignimbritic eruptions.	
			Sma_3	Altered quartz-feldspar porphyry	Unknown	N. of Mt. Pleasant.	Unknown may be interbedded or intruded in Sma_2.		Unit may be a metasomatised volcanic rock unit; includes "Mount Pleasant Porphyry" (Opik 1958).
		CANBERRA FORMATION	Smc	Mudstone, silt-stone volcaniclastic sediments, minor sandstone, limestone and hornfels.	1000+	Belt N. from central Canberra to Glenco H.S. and Nobby Hill; Fyshwick N. to Wool-shed Ck and Federal Highway.	Unconformable on Slf, Slc, Slb, Ouf-P, Ouf-F(?); conformable below Sma; in fault contact with Ouf-F; intruded by Sp and Db.	Shallow-marine with volcaniclastic deposition increasing toward the top.	Fossiliferous (Strusz, 1975); includes "Fairbairn Group" (Opik, 1958); "Westmoad Park Formation" (Smith, 1964); "Bouchon Beds/Brun Shale" (Phillips, 1956). which correlates with parts of the Canberra Formation.
			SmC_1	Pelitic hornfels.	Unknown	S. of Carrington H.S.			Contact metamorphism of mudstone by small basic intrusion (Db); albite-epidote hornfels facies.
			SmC_2	Calc-silicate hornfels	100	Narrow belt N. from Oak Hill to Nobby Hill			Informillent out-crops normally associated with limestone; contact metamorphism of impure limestone by Small 'buried' acid intrusions; albite-epidote hornfels facies.

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SILURIAN	WENLOCKIAN	CANBERRA FORMATION	SmC_3	Rhyodacitic tuff	100	Belt N. from Gold Creek H.S. to Nobby Hill; S. of Glenesk H.S.	Interbedded towards the top of SmC	Volcaniclastic deposition with some airfall pyroclastic units.	Correlates in part with the "Glenesk Volcanics" (Smith, 1964).
		CANBERRA FORMATION	SmC_4	Dacitic tuff	100	Belt N. from Oak Hill to Nobby Hill	Interbedded in SmC	Volcaniclastic deposition with some airfall pyroclastic units.	
		CANBERRA FORMATION: NARRABUNDAH ASHSTONE MEMBER	SmC_5	Tuff, ashstone, tuffaceous sandstone and shale.	30+ (drill holes)	Fyshwick and W. of Nobby Hill(?)	Interbedded towards the top of SmC	Volcanogenic turbidite deposition	Graded rock units exposed at Woolshed Ck road cutting.
		CANBERRA FORMATION	SmC_6	Limestone	100	Central Canberra; S. of Nobby Hill; Woolshed Creek.	Lenticular units within SmC	Shallow-marine	Fossiliferous
		CANBERRA FORMATION: CAMP HILL SANDSTONE MEMBER	SmC_7	Sandstone	100	Central Canberra; N. of Wantagong H.S.	Basal unit of SmC; unconformable on Slf, Slc, Ouf-P, Ouf-F.	Shallow-marine	Fossiliferous; discontinuous; basal unit of Canberra Formation (Opik, 1958).
			Unconformable relationships Smc with Slf; Slc; Slb, Ouf-P and Ouf-F.						
			WOODLAWN - MULWAREE SHELF						
DEVONIAN	GERDINNIAN	COVAN CREEK FORMATION	S-Dc	Sandstone, siltstone, shale.	1000+	Hill N. of Lake George; extends E. onto BRAIDWOOD.	Top not exposed in Sheet area; conformable on SuC; transgresses E. over Sw on BRAIDWOOD; intruded by dolerite (Db)	Deep-marine; turbidite deposition; proximal flysch	Few poorly preserved fossils; reaches thickness of 1500 m in Covan Creek; possible correlate of S-Df and Sur (Henry, 1978).
SILURIAN	LUDLOVIAN TO PRIDOLIAN	CURRAWANG BASALT	SuC	Basalt, minor chert and argillaceous sediments	700	N. of Montrose H.S. and Dinton H.S.	Conformable below S-Dc and on Sw; intruded by dolerite (Db)	Marine	Pillow lavas; short period of bimodal volcanism with Sw and locally interbedded relationship; 1000 m thick on BRAIDWOOD.

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SILURIAN	LUDLOVIAN TO PRIDOLIAN	CURRAWANG BASALT	Suc_1	Siltstone, shale, minor sandstone.	10	N. of Montrose H.S.	Interbedded in Suc	Marine	
		WOODLAWN VOLCANICS (413 m.y.* and 400 m.y.* Gulson, 1976).	Sw	Rhyodacitic tuff, rhyolite, minor shale, agglomerate, ashstone.	100	E. of Governors Hill; NE. shore of Lake George; S. of Lakelands H.S.	Conformable below SuC; unconformable (?) on Ouf-B from drill holes at Allianoyonyiga Ck, otherwise base not exposed in Sheet area; roof pendant in Sge; cut by dolerite intrusions.	Airfall pyroclastic deposition on a shallow-marine shelf; occasional subaerial ignimbritic eruptions.	Unit is 600 m(+) thick on BRAIDWOOD; main host sequence to base-metal mineralisation at Woodlawn mine; Felton & others (1977) and Gilligan & others (1979).

The Woodlawn - Mulwaree Shelf is separated from the Captains Flat Trough by Ordovician rocks. Stratigraphic units of the Woodlawn - Mulwaree shelf may broadly correlate with the Captains Flat Trough

CAPTAINS FLAT TROUGH (Western margin)

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
DEVONIAN	GERDINNIAN	UNNAMED UNITS	S-Df	Sandstone, siltstone, shale	500+	E. Molonglo gorge area and belt N. to Kings Highway	Top not exposed in Sheet area; disconformable(?) on Suv_2; in fault contact with Ouf-F	Deep-marine turbidite deposition; proximal flysch	Unit locally developed and possibly derived from Ouf-F; possible correlate with S-Dc and Sur.
SILURIAN	LUDLOVIAN TO PRIDOLIAN		$S\text{-}Df_1$	Sandstone	50	Balcombe ridge N. to Burke Hill	Basal unit of S-Df disconformable(?) on Suv_2.	Marine	
			Suv_2	Argillaceous sediments, minor basalt, acid tuff and lava	350+	Balcombe ridge N. to Bungendore - Gundaroo road.	Disconformable(?) below S-Df; conformable on and may interfinger with Suv_1; faulted against Ouf-F and Sur(?)	Shallow-marine with minor subaerial volcanism.	Basalts reported by Wilson (1964); unit thins to the S and thickens to the N.; possible correlation with Scf.
			Suv_{2-a}	Limestone	50	1 km SE of Millpost H.S.	Interbedded in Suv_2.	Shallow-marine	Unfossiliferous.
			Suv_{2-b}	Rhyodacitic tuff	50	W. of Bald Hill	Interbedded in Suv_2.	Subaerial ignimbritic eruptions.	
			Suv_{2-c}	Rhyolite	125	Turalla Hill N. to Bungendore-Gundaroo road	Interbedded in Suv_2.	Subaerial lava flow.	

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	LUDLOVIAN TO PRIDOLIAN	UNNAMED UNITS	Suv_1	Volcaniclastic sediments, minor rhyolite	400+	Narrow belt S. from Glenidle H.S. to Woolcara H.S.; may extend S to MICHELAGO.	Conformable below and may interfinger with Suv_2; in fault contact with Sur(?) at base of Lake George fault line scarp; top in fault contact with Ouf-F; base is unknown.	Airfall pyroclastic deposition and minor subaerial ignimbritic eruptions with shallow-marine incursions.	Acid volcanic unit which thins to the N and thickens S towards MICHELAGO possible correlation with Scf.
			Suv_{1-a}	Lithic tuff	150	Primrose Valley Ck; S. Woolcara H.S.	Interbedded in Suv_1.	Volcaniclastic deposition	
			Suv_{1-b}	Limestone	Unknown	2 km Sw. Woolcara H.S.	Interbedded in Suv_1	Shallow-marine	Only float exposed.

CAPTAINS FLAT TROUGH (SE Corner of Sheet area)

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	LUDLOVIAN TO PRIDOLIAN	CAPTAINS FLAT FORMATION	Scf	Volcaniclastic sediments, dacite, minor basalt, tuff, shale.	500+	A belt S. from Woodbine H.S. to Hoskinstown and onto MICHELAGO	Conformable(?) on Sur N. of Hoskinstown; disconformable(?) on Sk in Captains Flat Syncline; top largely obscured by alluvium.	Marine with sporadic development of subaerial ignimbritic eruptions and airfall pyroclastic deposition.	Thickens S. to MICHELAGO where it exceeds 1000 m in core of Captains Flat Syncline (Oldershaw, 1965) poorly fossiliferous; Scf may grade upwards into Sur and may correlate with Suv_1 and Suv_2.
		CAPTAINS FLAT FORMATION: SINCLAIR CONGLOMERATE MEMBER	Scf_1	Lithic tuff, conglomerate, minor shale.	100	S-trending outcrop; E. of Rossi-Captains Flat road.	Interbedded in Scf	Volcaniclastic deposition	Scf_1, and Scf_2 are marker beds plunging S. which define the N. keel of the Captains Flat Syncline (Oldershaw 1965).
			Scf_2	Rhyodacitic tuff, agglomerate	100	S-trending outcrop; E. of Rossi-Hoskinstown road.	Interbedded in Scf	Subaerial ignimbritic eruptions	
			Scf_3	Basic metavolcanics	50	0.5 km N. Woodbine H.S.	Interbedded in Scf		

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	LUDLOVIAN TO PRIDOLIAN	CARWOOLA BEDS	Sur	Sandstone, siltstone, shale and thin volcaniclastic sediments.	1,200	Centrally distributed between Carwoola H.S. and Hoskinstown; a belt from Sharrow H.S. N. to Bungendore-Hoskinstown road; poorly exposed in Primrose Valley Ck area.	Conformable(?) on Sk; disconformable(?) on Scc in the western limb of the Captains Flat Trough; top largely obscured by alluvium; faulted against Suv_1 and Suv_2.	Deep-marine; turbidite deposition; proximal flysch	Thins S. in western limb of Captains Flat Trough and may be missing from Captains Flat Syncline where Scf is disconformable(?) on Sk; unfossiliferous; Carwoola Beds may be younger than Scf and correlates of S-Df and S-Dc.
			Sur_1	Sandstone	100	Hills W. of Hoskinstown	Interbedded in Sur	Marine	Marker beds which assist in defining the north plunging Anthill Anticline.
		KOHINOOR VOLCANICS	Sk	Rhyodacitic tuff, agglomerate minor argillaceous sediments.	200	N. of Foxlow H.S.; belt S. from Sunny Corner H.S. to MICHELAGO	Conformable on Scc and below(?) Sur; disconformable(?) below Scf in Captains Flat Syncline; in fault contact with Ouf-F and Scf at E. margin of Captains Flat Syncline.	Subaerial ignimbritic eruptions	Thickens S. to reach 760 m in vicinity of Captains Flat; wedges out to the W. across Anthill Anticline; host sequence to base-metal mineralisation at Captains Flat mine (Davis, 1975).
		COPPER CREEK SHALE	Scc	Dark grey shale, siltstone, lithic tuff.	700	Belt S. from Bungendore and Foxlow Stud extending to MICHELAGO	Conformable on Scr but in faulted or sheared contact with Ouf-F where Scr missing; conformable below Sk; disconformable(?) below Sur; faulted against Scf.	Marine, with minor airfall pyroclastic deposition.	Poorly exposed in the Sheet area; appears to thicken N. towards Bungendore and possibly S. along Primrose Ck to MICHELAGO; poorly fossiliferous.
		COPPER CREEK SHALE — RUTLEDGE QUARTZITE MEMBER	Scr	Conglomerate, quartzite	100	Rutledge Hill NE to Grose Meadow Hill; may extend S. onto MICHELAGO	Unconformable on Ouf-F	Marine	Crops out sporadically on E. and W. limbs of the Captains Flat Trough; possibly discontinuous at base of Scc (Oldershaw, 1965).

Unconformable relationships Scc/Scr with Ouf-F

SOUTH OF QUEANBEYAN

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	WENLOCKIAN (?)	COLINTON VOLCANICS	Svc	Dark green chloritic tuff, minor volcaniclastic sediments.	2000+	SW trending belt from Queanbeyan to MICHELAGO; E. limit Queanbeyan River, W. limit Four Mile Ck and Monaro Highway.	Top not exposed in Sheet area; conformable on Scp; faulted against Sud_1. and Ouf-F	Subaerial ignimbritic eruptions and volcaniclastic deposition with shallow-marine(?) incursions.	May correlate with either part of the Hawkins Volcanic Group (Richardson, 1979) or part of the Deakin Volcanics; strongly foliated and folded into SSW plunging synclinorium.
			Svc_1	Tuffaceous Shale	300	Narrow SW-trending belt from Wickerslack to Fernleigh Park H.S.	Interbedded in Svc or Scp preserved in cores of tight local anticlinal folds in Svc.	Volcaniclastic deposition	
			Svc_2	Limestone, minor dolomite.	100	Intermittent outcrops in Queanbeyan River near White rocks; Creek W. of Sunset H.S. (abd)	Interbedded in Svc or Scp preserved in cores of tight, local anticlinal folds in Svc	Shallow-marine	Possible bioherms at White Rocks gorge; includes "Morley Fm" (Phillips, 1956)
		CAPPANANA FORMATION	Scp	Shale, siltstone, minor quartzite, tuff.	800	Queanbeyan R. valley S. from Googong Dam to London Bridge H.S. and onto MICHELAGO; also Jumping (Valley) Ck.	Conformable below Svc; unconformable on and faulted against Ouf-F	Shallow-marine with intervening volcaniclastic deposition.	Within Sheet area now largely covered by Googong reservoir; unconformable contact with Ouf-F in Burra Ck on MICHELAGO; includes "London Bridge Fm" (Veevers, 1953), "Morley Fm" (Phillips, 1956); correlates either with part of Smc or with Suy; Richardson (1979) Goldsmith & Evans (1980).
			Scp_1	Limestone	100	Jumping (Valley) Ck; London Bridge H.S.	Interbedded in Scp	Shallow-marine	Fossiliferous (Veevers, 1953)

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	WENLOCKIAN (?)	CAPPANANA FORMATION	Scp_2	Calc-silicate hornfels	100	W. shore Googong reservoir			Contact metamorphism of impure limestone by Sg; albite-epidote hornfels facies.

Unconformable relationship Scp with Ouf-F

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
SILURIAN	LLANDOVERIAN	MURRUMBATEMAN FORMATION	Slf	Sandstone, siltstone, shale	1000	Sw-trending belt from Gundaroo-Murrumbateman road to Wantagong H.S.; Ginninderra area.	Unconformable below Smc; base not exposed but probably disconformable with Ouf-P; faulted against Ouf-F, Ouf-P and Smc.	Marine; turbidite deposition; proximal flysch	May be correlative of Slc/Slb sequence and possibly also Mundoonen Sandstone near Yass (Smith, 1964 and Crook and others 1973).
			Slf_1	Sandstone	100	N. of Stonevale H.S. (abd)	Interbedded in Slf, but more common near the top.	Marine.	
		BLACK MOUNTAIN SANDSTONE	Slb	Sandstone, siltstone, minor shale	450+	Black Mountain; Jerrabomberra Hill; Dundee Trig(?)	Conformable on Slc; unconformable below Smc on Capital Hill; topmost beds not usually preserved in Sheet area; faulted against Smc and Ouf-P	Marine; turbidite deposition; proximal flysch.	Unfossiliferous; (Opik, 1958).
		STATE CIRCLE SHALE (445 m.y*; Bofinger & others, 1970)	Slc	Shale, siltstone, minor sandstone	200	Capital Hill; N and S. flanks of Black Mountain; E. flank Jerrabomberra Hill.	Conformable below Slb; disconformable with Ouf-F, Ouf-P; faulted against Ouf-P, Smc.	Marine	Fossiliferous with overlapping ranges of 2 or 3 species of graptolite fauna which indicates this unit equivalent to zone 22 of British sequence.

Disconformable relationship Slc with Ouf-P/Ouf-F

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
ORDOVICIAN	DARRIWILIAN TO BOLINDIAN	ACTON, PICAREE AND BULLONGONG SHALE MEMBERS IN Ouf-P and Ouf-F	Oubs	Black siliceous shale and slate	100	Picaree Hill; Queanbeyan; E. Belconnen; Lake George Range; S. of Hosking Hill.	Interbedded and conformable units within Ouf-P and Ouf-F; Limited lateral extent (up to 5 km)	Marine; local euxinic environment	Late Ordovician 'marker' lithology; fossiliferous with a graptolite fauna which gives an age range Gisbornian to Bolindian; condensed sequences; Opik (1958); Smith (1964) and Oldershaw (1965).
		ADAMINABY BEDS	Ouf-A	Interbedded sandstone, siltstone, slate	1000+	Bullen Range; NW-trending belt extending onto BRINDABELLA	Base unknown; top not exposed in Sheet area; faulted against and intruded by Smr; faulted against Sul.	Marine; turbidite deposition; proximal flysch	Eastonian-Bolindian age (Owen & Wyborn, 1979); regionally metamorphosed to greenschist facies; probable correlate of Ouf-P.
		BIRKENBURN BEDS	Ouf-B	Interbedded sandstone, siltstone, slate.	300+	E. shore Lake George; W. of Kullingrah H.S. and Lakoona H.S.; extends onto BRAIDWOOD	Base unknown; top not exposed in Sheet area; N. boundary obscured by alluvium; intruded by Sge and NW-trending dolerite dykes	Marine; turbidite deposition; distal flysch	Felton and Huleatt (1977); regionally metamorphosed to greenschist facies.
		PITTMAN FORMATION	Ouf-P	Interbedded sandstone, siltstone, slate, minor chert.	800+	E. Belconnen and possibly Black Mountain peninsula.	Base unknown; overlain disconformably(?) by and faulted against Llandoverian proximal flysch sequences (Slf, Slb, Slc); faulted against Smc, Smw, Smp; intruded by Sgg.	Marine; turbidite deposition; distal flysch.	Opik (1958); regionally metamorphosed to greenschist facies.
		FOXLOW BEDS	Ouf-F	Interbedded sandstone, siltstone, slate, minor chert.	2000+	Extensive, wide meridional belt from Nanima-Gundarro area S. to Bradleys Ck catchment; similar belt from Bungendore S. to Hoskinstown and onto MICHELAGO	Base unknown; overlain disconformably(?) and faulted against Llandoverian proximal flysch sequences; faulted against Wenlockian-Ludlovian acid volcanics and sediments; cut by NW and N-trending dolerite intrusions (Db); intruded by acid porphyry (Sp_2) and granitoid stock (Sg).	Marine; turbidite deposition; distal flysch.	Includes "Murrlarra Fm"(Phillips, 1956); regionally metamorphosed to greenschist facies.

PERIOD	AGE	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	APPROX. MAX THICKNESS (m)	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	REMARKS AND REFERENCES
ORDOVICIAN	DARRIWILIAN	FOXLOW BEDS	Ouf_1-F	Hornfelsed greywacke and spotted hornfels	500+	W. and S. of Sutton village	Local metamorphism of Ouf-F by Sgs and Sgw.		Contact metamorphosed to albite-epidote hornfels facies; cordierite porphyroblasts; metamorphic inversion; metamorphism post dates F_2 fold phase.
			Oufs-F	Psammitic and pelitic schist	500+	Bradleys creek catchment; meridional belt S. from Lake George to MICHELAGO	Intruded by Sgr Sgl, Sg, Sa, dolerite and acid porphyry intrusions; marginally gradational to Ouf-F.		Shallow dipping foliation (F_1) which is folded and cleaved (F_2) suggests 2 deformations (Bradleys, Turallo and Yandyguinula Cks); regionally metamorphosed to upper greenschist facies.
			Ouks-F	Knotted schist	300+	Bradleys Creek catchment extending S. to MICHELAGO	Associated and interbedded with Oufs-F		Andalusite porphyroblasts (Veevers, 1951); regionally metamorphosed to upper greenschist facies.

INTRUSIVE ROCKS

PERIOD	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS AND REFERENCES
DEVONIAN AND YOUNGER		Db	Dolerite and gabbro	Widespread; concentrated in E. of the Sheet area, decreasing Westwards; common along L. George Range, hills N. of L. George and S. to Bungendore and Hoskinstown; S. Carrington H.S.; Point Hut crossing and Red Rocks Gorge.	Dykes and other tabular bodies intruding Ordovician flysch and Silurian sediments and volcanics; at E. margin of Sheet dykes may relate to Sa and Suc; considerable age range: late Palaeozoic to Tertiary(?)	Foliated N. and E. of Lake George and S. towards Bungendore; apparently massive along and W of Lake George Range; trends vary from N. to W. and relate to lineament patterns.
LATE SILURIAN	ELLENDEN GRANITE	Sge	Adamellite, leucogranite	Meridional belt; E. shore of Lake George S. to Lakelands H.S.; extends E. onto BRAIDWOOD	Intrudes Sa and Ouf-B; post dates Sw; cut by foliated NW-trending dolerite and acid porphyry dykes.	Foliated; I type; antedates F_4; N. extension of Bega batholith; comagmatic with Sgr and Sgl; Garretty (1936), Felton & Huleatt (1977).
	GIBRALTAR ADAMELLITE	Sgl	Adamellite	Gibraltar Hill, E. of Bungendore.	Intrudes Oufs-F; marginal to Sgr.	Foliated; I type; antedates F_4.
	ROSSI GRANODIORITE	Sgr	Granodiorite	E. margin of Sheet area; narrow meridional belt from Lake George S. to MICHELAGO and ARALUEN.	Intrudes and may contribute to metamorphism of Ouf-F (Oufs-F); post dates Sa.	Foliated; I type; antedates F_4; N. extension of Bega batholith.
	LOCKHART COMPLEX	Sa	Amphibolite gabbro	E. margin of Sheet area; narrow meridional belt from Lake George S. to Hoskinstown-Rossi road; extends E. to BRAIDWOOD	Intrudes Ouf-F and Oufs-F; antedates Sgr; maybe comagmatic with Suc.	Foliated; antedates F_4; supports aeromagnetic anomaly; Garretty (1936), Read (1961), Rigden (1976).
	(407 m.y.*)	Sp	Quartz-feldspar porphyry	Lake George Range; Oak Hill; W. of Kanimbla H.S.; Jerrabomberra landfill site; Bullen Range	Dykes and small stocks which intrude Ouf-F, Ouf-A, and late Silurian sediments.	Massive high-level intrusions; possibly comagmatic with Late Silurian-Early Devonian granitoids.
		Sp_1	Quartz-feldspar porphyry	Church Ck (Queanbeyan-Cooma Rd); Murrumbidgee R, S. from Lambrigg H.S. to Lanyon H.S.; Forster and Neighbour Hills; SW-trending belt from Gold Creek H.S. to L. Ginninderra; Gooromon Ponds Ck (nr. ACT/NEW border).	Small stocks which intrude Sul, Sud, Sma and Svc.	High-level intrusions associated with Wenlockian-Ludlovian volcanic rocks; may represent in part volcanic centres; massive; S and I types.

PERIOD	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS AND REFERENCES
LATE SILURIAN	SUTTON ADAMELLITE (410 m.y.*)	Sgs	Adamellite	W. of Sutton Village to Bywong Hill; extends S. to Macs Reef road and Donnellys Ck.	Intrudes and contact metamorphoses Ouf-F; cut by NW-trending dolerite dykes.	Massive; I type; post dates F_2; associated meridional aeromagnetic anomaly; hydrothermal gold mineralisation; Moore (1957).
	GREENWOOD ADAMELLITE	Sgw	Adamellite	Meridional belt of exposures centered on Greenwood Hill.	Intrudes and contact metamorphoses Ouf-F	Massive; I type; post dates F_2; associated meridional aeromagnetic anomaly; Moore (1957).
	GLEBE FARM ADAMELLITE	Sgg	Porphyritic adamellite	Lake Ginninderra, Belconnen.	Intrudes Ouf-P and Sma; appears to post date Sp_1.	Massive; I type; post-dates F_3.
	FEDERAL GOLF COURSE TONALITE (417 m.y.*)	Sgf	Tonalite	Federal Golf Course, W. of Red Hill	Intrudes Sum, Sud_3, Suy; local contract metamorphism of Suy.	Massive; I type; coincides broadly with N. end of meridional aeromagnetic anomaly extending from Canberra to Michelago Igneous Complex/Connelly, (1979); postdates F_3.
	GOOGONG ADAMELLITE	SgO	Porphyritic adamellite	Queanbeyan river downstream of Googong Dam; N. and S. of Googong reservoir access road.	Intrudes Svc; minor contact metamorphism of Svc.	Massive; I type; post-dates F_3 as intrusion cuts across F_3 folds in Svc; comagmatic with Sgb and probably Sgg and Sgf.
	BARRACKS CREEK ADAMELLITE	Sgb	Adamellite	3 km S. of Queanbeyan; Barracks Ck; Queanbeyan R.	Intrudes Ouf-F, Svc and Svc_1; cut by NW-trending dolerite dykes.	Massive; I type; post-dates F_3; Phillips (1956), Stauffer (1964, 1967).
	URIALLA GRANITE	Sgn	Adamellite	SE of Googong reservoir; extends S. onto MICHELAGO.	Only N. tip exposed in Sheet area; intrudes Ouf-F.	Marginally foliated; S type(?); maybe comagmatic with Sgs and Sgw; may postdate F_2; (Richard-son, 1979).
		Sg	Unamed granitoid bodies	Widespread; especially in Cullarin and Rocky Pic blocks and N. of London Bridge H.S.	Mostly intrude Ouf-F and Svc.	Usually massive; mostly I type.

PERIOD	ROCK UNITS AND DATES	SYMBOL	LITHOLOGY	GEOGRAPHICAL DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS AND REFERENCES
LATE SILURIAN	BOOROOMBA LEUCOGRANITE (415 m.y.# Roddick & Compston, 1976)	Smb	Leucogranite	Extensive SW corner of Sheet area; extends onto MICHELAGO, BRINDABELLA and TANTANGARA.	Intrudes Smf; possibly Smr and Ouf-A; maybe correlative of Smf.	Units of the Murrumbidgee Batholith; strongly foliated at E. margin near Murrumbidgee Fault; S type; probably post dates F_3; emplacement of Murrumbidgee batholith started at 424 m.y. and ended about 414 m.y. (Roddick & Compston, 1976); Snelling (1960), Joyce (1973).
	THARWA ADAMELLITE (396 m.y.# Evernden and Richards, 1962)	Smr	Adamellite	Trends SE from Bullen range to Castle Hill and Tharwa	Intrudes and in fault contact with Sul and Ouf-A; intruded by Smb.	
	SHANNONS FLAT ADAMELLITE (414 m.y.# Roddick & Compston, 1976)	Smf	Adamellite	Upper catchment of Paddys river; extends W. onto BRINDABELLA	Oldest(?) unit of Murrumbidgee Batholith in sheet area; intruded by Smb.	
		Sp_2	Quartz-feldspar porphyry; mylonite	Meridional belt W. of Lake George scarp decreasing W. towards Queanbeyan scarp; meridional belt E. of Turallo Ck.	Elongate bodies and dykes intruding Ouf-F, Oufs-F; cut by dolerite dykes; not known to intrude Silurian sediments and volcanics.	Strongly foliated and mylonitised; may either antedate F_2 or intruded during F_2; contain xenoliths; dyke trends vary from N to W; Wilson (1964), Stauffor (1964).

TABLE 2. COMPARISON OF F_2 AND F_3 TECTONICS

	F_2	F_3 (Canberra-Yass shelf)	Comment
Fold type	Asymmetrical, tight, flexural folds - slightly overturned limbs.	Symmetrical, open, similar folds with local zones of isoclinal folding	
Fold trend	Meridional (Cullarin Block) Locally NE (Canberra-Yass shelf)	NE in Late Silurian sediments and volcanics north of the Deakin Fault.	Variably trending F_3 folds and plunges south of the Deakin Fault due to competency of volcanic rocks and superimposition of F_4. faults and conjugate king folds on earlier F_3 structures
Fold plunge	Steep. N and S (Cullarin Block) NE and SW (Canberra-Yass shelf)	Shallow. NE and SW due to fold interference pattern of F_3 folds on older F_2 structures.	
Fold facing	Upward and downward, suggestive of earlier F_1 tectonics	Upward	
Cleavage	Strong. Axial planar to folds and sub-parallel to bedding. Meridional (Cullarin Block). NE (Canberra-Yass shelf)	Moderate. Axial planar to folds. NE trend. Intensifies adjacent to W. margin of Cullarin Block	
Metamorphism	Regional low-grade greenschist facies	Some retrograde metamorphism expected in Ordovician and Lower Silurian rocks subjected to F_3 and F_4 tectonics.	
Age	Mid-Silurian (Quidongan)	Late Silurian/Early Devonian (Bowning or Tabberabberan)	
Intrusive rocks	Foliated acid porphyry (Sp_2) and granitoid (Sg) stocks and dykes in the Cullarin and Rocky Pic Blocks.	Murrumbidgee Batholith (Smf, Smr, Smb) and other marginally foliated granitoid stocks Sgu, Sgb, Sgo, Sgf, Sgg) Local contact metamorphism of Ouf-F caused by Sgw and Sgs.	Basic intrusive activity appears to post date F_2 and F_3 deformations. Acid intrusions near the east margin of the sheet area are foliated and relate to F_4. tectonics.

TABLE 3. CURRENT EXTRACTIVE INDUSTRY OPERATIONS IN THE CANBERRA 1:100 000 SHEET AREA

Extractive Material	Lithology	Stratigraphic Unit	Use	Location (quarry and operator)
Rock aggregate	Rhyodacite and dacite " " Foliated dacite Rhyodacite	Mount Ainslie Volcanics Deakin Volcanics " Colinton Volcanics Laidlaw Volcanics	Road base, concrete aggregate and precast concrete masonery	Federal Highway (Ready Mix) Mugga Lane (Dept. Hsing & Cons.) " " (Blue Metal & Gravel Pty Ltd) Cooma Rd. 5 km S. of Queanbeyan (Ready Mix) Ginna Gulla (Hall quarry) Barton Highway (Boral Resources Ltd)
Road gravel	Weathered volcanic, granitic, and meta-sedimentary rocks.	Most major stratigraphic units in the Sheet area.	Surfacing for rural and forestry roads.	Numerous small roadside pits operated by Shire Councils on privately owned land.
Brickshale	Weathered mudstone and siltstone. " "	Canberra Formation Carwoola Beds Foxlow Beds	Bricks " " "	2 km NW of Crace (Canbricks) 8 km S. of Bungendore Back Creek, Tallagandra
Rough stone	Sandstone	Canberra Formation	Retaining walls on cuttings and embankments, drain-linings and spillways.	Stockmans quarry, Pialligo
	Rhyodacite	Mugga Mugga Porphyry Member	"	Mugga Lane quarries
Sand and gravel	River bed sand, lake-beach deposits, reworked alluvial sands and fine grained wind blown sands winnowed from river flats and lake-beach deposits	Recent to Quaternary (Qa, Qs and Qbs)	Bedding aggregate, concrete aggregate, brick laying and plastering.	Molonglo River, Fyshwick; Yass River, Gundaroo; S. Lake George; Bungendore (Vanden Broek, 1979)

TABLE 4. DEPTH AND THICKNESS DATA FOR TERTIARY WEATHERED PROFILES IN THE LAKE GEORGE BASIN

Drill hole No.	Depth to top of weathered profile (m)	Depth to top of weathered bedrock (m)	Depth to top of fresh bedrock (m)	Drill hole depth (m)	Thickness of weathered profile (m)
Scout hole No. 1 (BMR)	44.0	68.0	-	120.0	76.0(+)
Scout hole No. 4 (BMR)	51.0	-	-	71.3	20.3(+)
C294 (BMR)	26.5	37.2	73.2	84.5	47.6
C295 (BMR)	13.5	13.8	39.4	47.8	25.9
31363 (WRC)	-	44.0	76.0?	110.0	32.0?
30705 (WRC)	-	16.0	-	23.0	7.0(+)
30706 (WRC)	-	21.0	-	24.5	3.5(+)
30707 (WRC)	-	17.0	-	22.0	5.0(+)
30708 (WRC)	-	20.0	-	24.0	4.0(+)
25270 (WRC)	14.0?	33.0	-	42.7	28.7(+)?
25271 (WRC)	-	21.0	-	38.1	17.1(+)
25272 (WRC)	19.2?	48.0	-	51.9	32.6(+)?
30829 (WRC)	36.0	44.0	-	62.5	26.5(+)
30835 (WRC)	-	26.0	-	58.0	32.0(+)
30839 (WRC)	22.0	25.0	-	50.5	27.5(+)
C296 (BMR)*	-	15.9	53.2	61.1	37.3
C297 (BMR)*	-	26.5	64.7	65.3	38.8

* These holes were drilled on the Molonglo Flats immediately south of the Mills Cross Radiotelescope

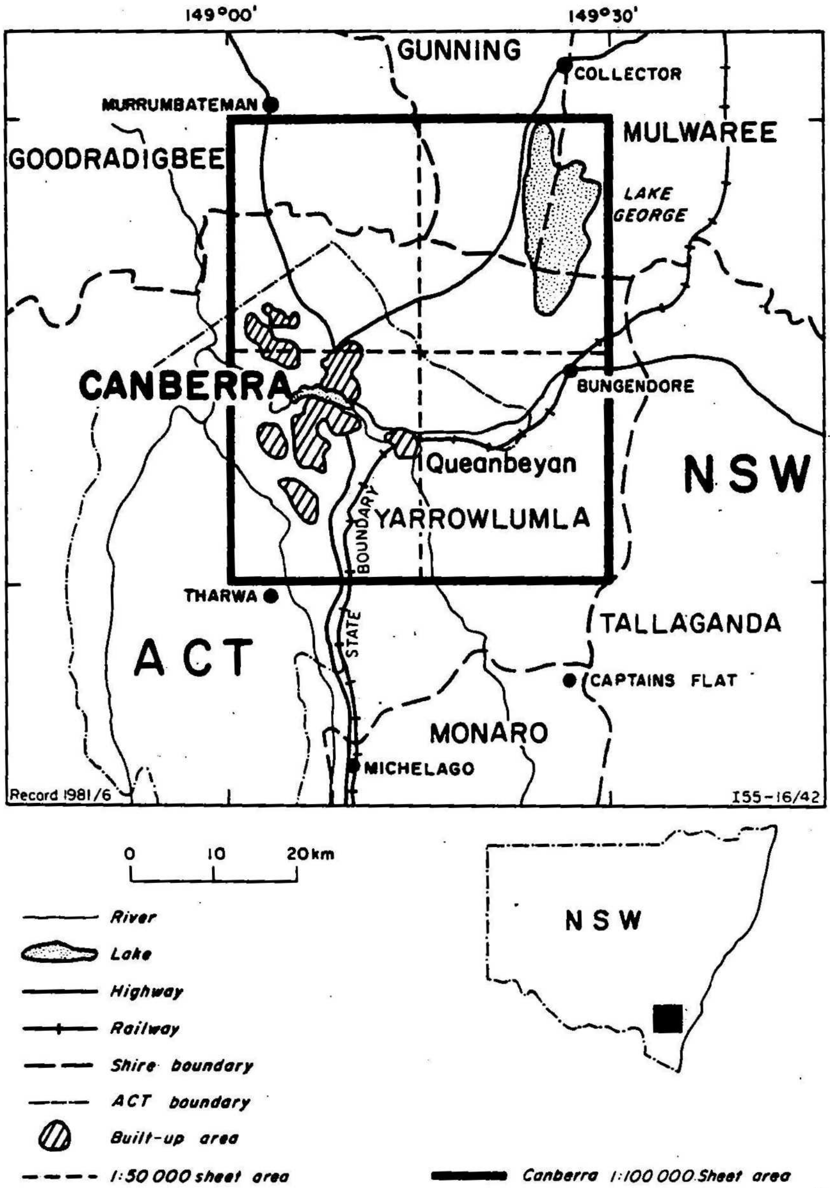

Fig.1 LOCALITY MAP

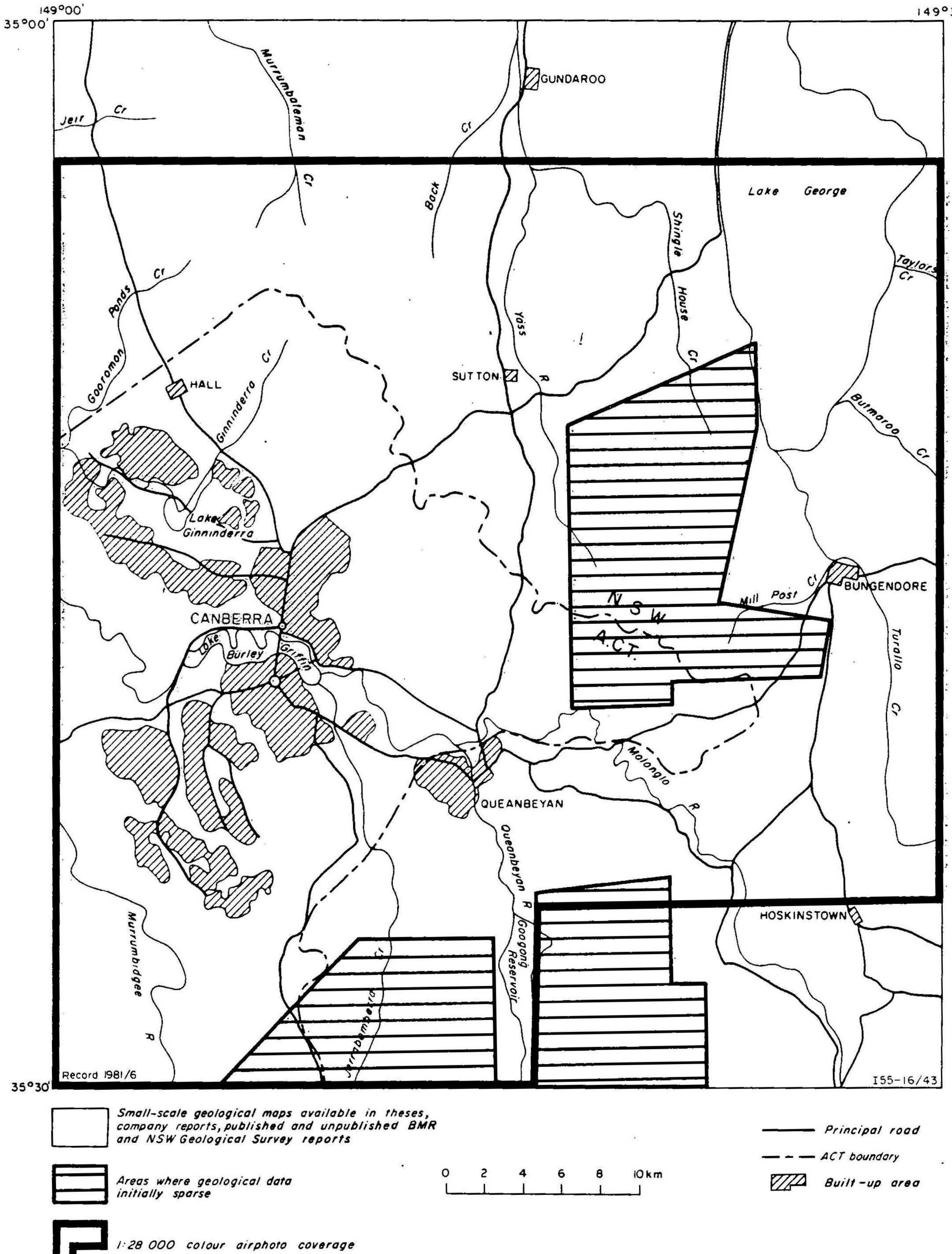

Fig. 2 COVERAGE OF 1:28 000 SCALE COLOUR PHOTOGRAPHY AND GEOLOGICAL DATA PRIOR TO FIELD WORK

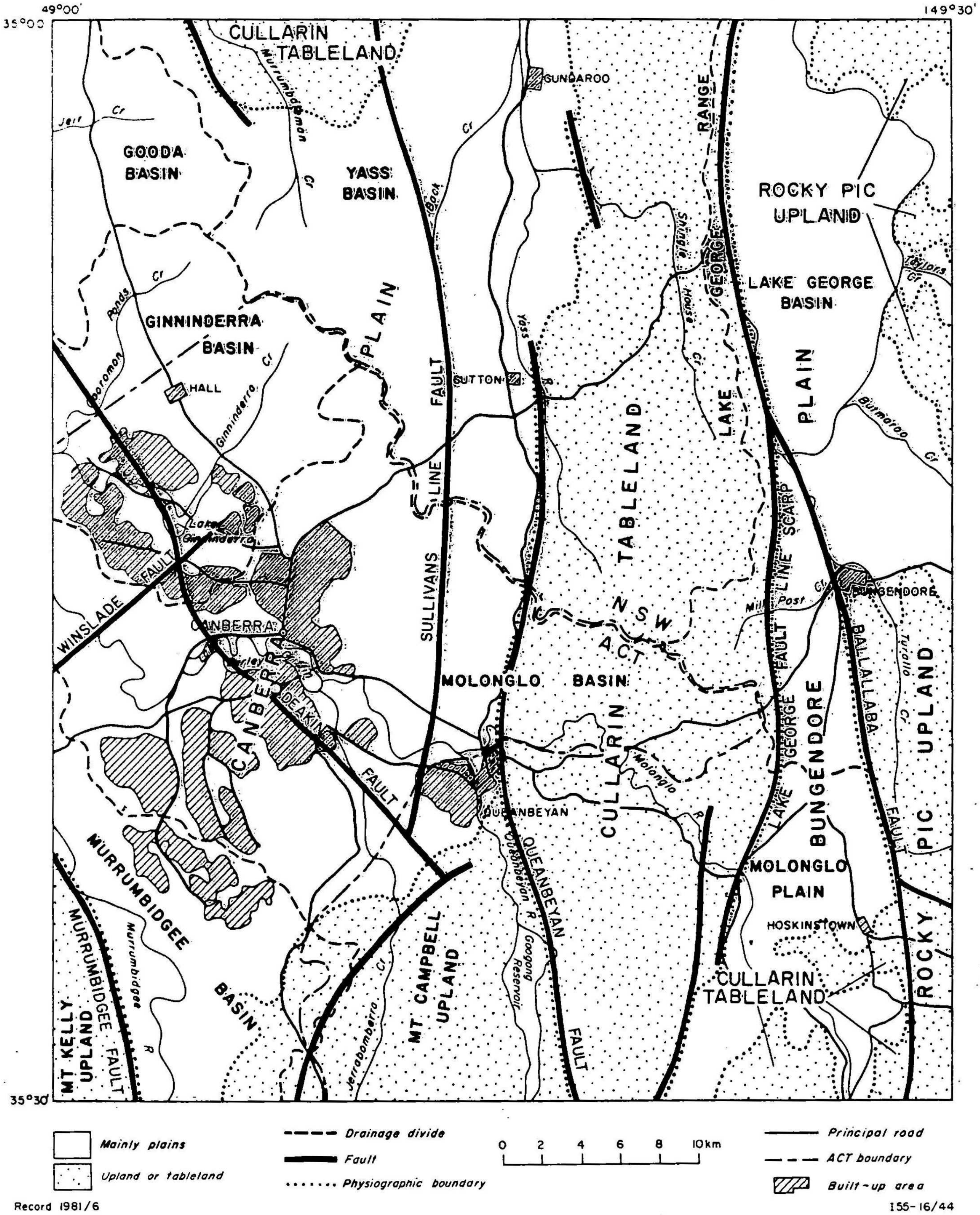

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Fig. 3 PHYSIOGRAPHIC UNITS

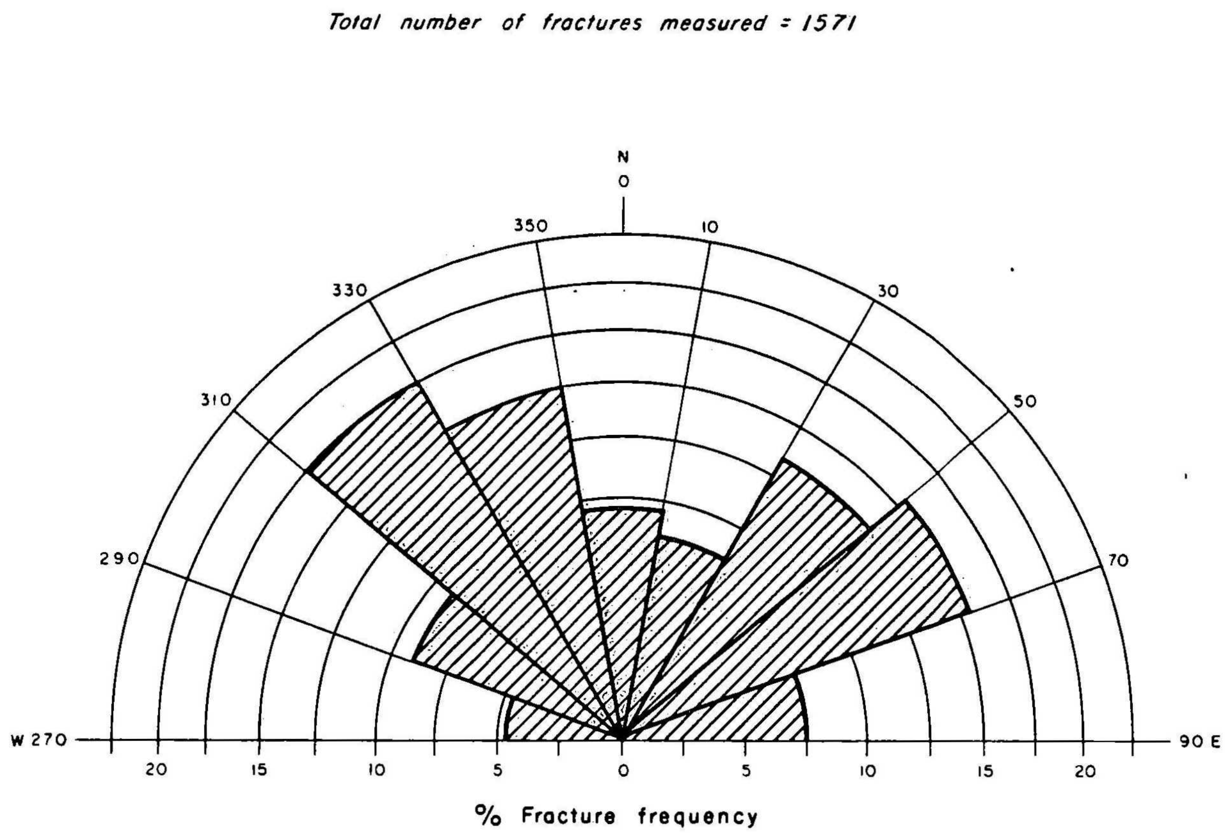

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Fig.4 POLAR GRAPH SHOWING PERCENTAGE DIRECTIONAL FREQUENCY OF AIRPHOTO LINEAMENTS.