Bureau of Mineral Resources, Geology & Geophysics

RECORD

Record 1990/35

LATE SILURIAN GEOLOGY IN THE MICHELAGO-COOMA AREA, A.C.T. AND N.S.W., 1983-1985

by

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Late Silurian geology of the Michelago-Cooma area - preliminary edition.

ABSTRACT

Geological mapping indicates a new, threefold division of the Silurian succession in the Michelago-Cooma area, south of Canberra. The basal, marine sedimentary Cappanana Formation, which is unconformable on older rocks, is overlain by the Colinton Volcanics, which are thickest in the north but lens out to the south of Bredbo. The Colinton Volcanics consist of biotite-bearing dacite and rhyolite. The mainly subaerial Colinton Volcanics are overlain by the Rothlyn Formation, which consists of sedimentary rocks and interbedded volcanics ranging in composition from rhyolite and biotite dacite to hornblende-biotite dacite; minor basalt is also present. The Rothlyn Formation is thickest and most extensive in the Cooma area, but also extends north from Bredbo along the Murrumbidgee River. The previously mapped Bransby Beds belong partly to the Colinton Volcanics and partly to the Rothlyn Formation, and do not therefore warrant retention as a formation name. The Colinton Volcanics correlate petrographically and chemically with the Deakin and Laidlaw Volcanics east of Tharwa. Isotopic age determinations suggest that the Colinton Volcanics are younger slightly than the Laidlaw Volcanics; however the results could have been affected by post-depositional events. The stratigraphic succession is displayed within a faulted synclinorium in the north and south which in the central section dies out or is faulted out with prevailing dip to the west. A faulted boundary between the Colinton and Deakin Volcanics and other faults form major discontinuities within the Colinton Volcanics. Extensive zones of intense shearing are also a feature of the structure. The main deformation period is regarded as middle Devonian from recent studies in the Captains Flat area. The area contains a number of small mineral deposits related to the Silurian volcanism, including gold, base-metal sulphides and barite.

INTRODUCTION

A narrow belt of mainly felsic volcanics, with interbedded sedimentary rocks, of late Silurian age extends south from Canberra through Michelago and Bredbo to southeast of Cooma. The Silurian sequence follows the valley of the Murrumbidgee River to south of Bredbo between the uplands of the Murrumbidgee Batholith to the west and the Tinderry Range to the east. The Silurian belt widens to the south into undulating country between Cooma and the upper reaches of the Numeralla River. The long, straight valley of the Murrumbidgee River provided access in the early days to the Monaro Tablelands and today is the main communications corridor south from Canberra for both road and rail. Mineral prospecting in the last century saw the discovery of a number of small deposits of gold, iron and base metals within the Silurian sequence, particularly near Michelago and east of Cooma, but mining and exploration since then has been sporadic. No mines are being worked at the time of writing.

Geological constraints on the areal extent of the late Silurian sequence are both structural and stratigraphic. In the north the Silurian sequence is down-faulted against the Murrumbidgee Batholith along the Murrumbidgee Fault to the west, and to the east is partly unconformable on and partly faulted against Ordovician and early Silurian rocks. In the south the full limits of the belt are obscured by a Tertiary basalt cover.

Previous mapping on the Michelago 1:100,000 Sheet (Richardson, 1979) shows a mainly west-dipping sequence consisting of the sedimentary Cappanana Formation at the base overlain to the west by the Colinton Volcanics, in turn overlain by the Bransby Beds adjacent to the Murrumbidgee Fault. The Colinton Volcanics and Bransby Beds are shown extending north into the Tharwa area where the rocks were earlier mapped as undifferentiated Silurian volcanics (Best & others, 1964) and later as Deakin Volcanics and Laidlaw Volcanics (Henderson, 1980).

Silurian volcanic formations are not differentiated in the Cooma area of the Bega 1:250,000 Sheet (Hall & others, 1967) where a twofold division into Silurian sediments and Devonian porphyry is shown. On the metallogenic sheet (Barnes & Herzberger, 1975) interbedded sedimentary and volcanic rocks are indicated as probably including equivalents of the Colinton Volcanics, and the porphyry is shown as Silurian.

The general aim of this project was to provide input for a 3rd edition of the Canberra 1:250,000 geological Sheet and for any possible future revision of the Bega 1:250,000 Sheet. The mapping was also carried out as a contribution to a study of the regional geological setting of the Woodlawn and Captains Flat massive sulphide deposits (Bain & others, 1987).

Specific objectives of the project were:

1. to define the boundary between the Deakin and Colinton Volcanics,

2. to define the southern limits of the Deakin and Laidlaw Volcanics,

3. to investigate the stratigraphic status of the Bransby Beds, and

4. to clarify the general structure of the late Silurian belt from Tharwa and Burra to southeast of Cooma.

The volcanic rocks in this report have been classified chemically according to the system proposed by the IUGS Subcommission on the Systematics of Igneous Rocks (Le Maitre, 1984). Thus felsic volcanics are classified as either rhyolite or dacite, and the term rhyodacite is not used. Where more than one analysis of the same unit straddles the dividing line between rhyolite and dacite the mean composition is taken. In borderline cases where the mean composition is doubtful the rock is termed rhyolite to dacite.

METHODS

Field work was carried out at various times between April, 1983 and September, 1985, either on day trips from Canberra or on week-long trips working out of Bredbo or Cooma. The approximate total area mapped was 800 km^2. Much of the area was mapped in considerable detail in order to define, where possible, the extent and sequence of individual sedimentary and volcanic units. 138 samples from the volcanic units were examined petrographically , and 45 were chemically analysed, to try and establish correlations between units in possibly equivalent formations. Isotopic age determinations were carried out on samples from north of Michelago and east of Cooma to compare with previous determinations from the Laidlaw Volcanics (Owen & Wyborn, 1979; Wyborn & others, 1982). No further palaeontological work was done apart from collecting a few limestone samples for examination for the presence of conodonts. The results of the conodont studies proved negative for correlation purposes (R. Nicoll, pers. comm.).

STRATIGRAPHY

GENERAL

The late Silurian succession in the Michelago-Cooma area forms structurally the southernmost part of the Cowra-Yass Synclinorial Zone (Scheibner, 1973) that extends south through Yass and Canberra. However much of the succession is stratigraphically more akin to that in the Captains Flat area (Bain & others, 1987). Three main formations are represented. They include a basal sedimentary unit - the Cappanana Formation; a middle unit of mainly volcanic rocks - the Colinton Volcanics; and an upper formation of interbedded sedimentary and volcanic rocks - the Rothlyn Formation. Two other volcanic formations, the Deakin Volcanics and overlying Laidlaw Volcanics, crop out in the Tharwa area in the northwest corner of the Sheet. Several coarse porphyry, granite, leucogranite and rhyolite bodies intrude the sedimentary and volcanic rocks. The two largest porphyry bodies are the Livingstone Porphyry west of Michelago and the Bullanamang Porphyry between Bredbo and Cooma both defined by Richardson (1979). The other smaller intrusive units are unnamed.

Each of the five sedimentary and volcanic formations has been divided into a number of subunits consisting either of a single rock type, or associations of rock types at a particular level in the succession. Most of these divisions are easily recognisable in the field although the layer-cake system of subdivision adopted means that similar units at different levels in the succession are in some cases mapped as separate units. The lithology, distribution and distinguishing characteristics of each unit are summarised in Tables 1-4 and 6-8.

Cover rocks and deposits include Tertiary basalt in the Cooma area, and Tertiary gravel, silcrete and lake sediments including diatomite near Bunyan. Tertiary to Quaternary alluvium and colluvium is widely developed in open valleys, and alluvium is extensive along major watercourses in the south.

CAPPANANA FORMATION
(defined by Richardson, 1979)

The Cappanana Formation is a marine unit which crops out discontinuously along the eastern edge of the area mapped, from London Bridge in the north to southeast of Cooma. The type section is between GR 992188 and GR 982188 east of Bredbo where the greatest thickness (700 m) of the formation is developed; it is detailed by Richardson (1979) in part of her figure 4. The formation comprises shale and calcareous shale with numerous limestone lenses, minor sandstone and tuff (Table 1). The Cappanana Formation is unconformable on the underlying early Silurian and Ordovician sandstones and (non-calcareous) shales to the east, although the exact position of the boundary is commonly obscured and difficult to identify in some places. A basal sandstone (Sa_1) is mappable in the north, near London Bridge, and also east of Michelago, but is not developed in all places. The basal sandstone, where observed, tends to be more thinly bedded than the older sandstones; it also contains shelly fossils in a few places which are absent in the Ordovician and early Silurian rocks. No good exposures of the unconformity were found during the recent mapping, and the best evidence of the unconformity remains the outcrop in the bed of Burra Creek, 1 km north of London Bridge (GR 053689) (Richardson, 1979, photo). There calcareous shale of the Cappanana Formation is unconformable on Ordovician sandstone but the outcrop is now concealed beneath the waters of Googong Dam.

Table 1. Data on rock units - Cappanana Formation

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sa_2	Discontinuous along eastern side of Colinton Volcanics from northeast of Burra to southeast of Cooma	Shale and siltstone, in part calcareous; quartz sandstone; massive and bedded limestone lenses; minor tuff	Unconformable on Ordovician or Lower Silurian sandstones and shales; upper limit is first major flow of Colinton Volcanics	Basal sedimentary unit of late Silurian succession preceeding volcanism
Sa?	Along western side of volcanic belt from near Cooma to 20km north of Cooma	Slaty shale and calc-silicate hornfels	Underlies Sb_1; base not exposed owing to Murrumbidgee Fault	Correlation with Cappanana Formation speculative based on lithology and stratigraphic position at base of sequence in Bransby Shear Zone
Sa_1	Near London Bridge; southeast of Michelago	Well-bedded, medium and coarse, quartz sandstone	Lenses at base of Sa_2	Represents basal sandstone of Cappanana Formation; difficult in places to distinguish from older Ordovician sandstones

Richardson notes a gradational boundary of the Cappanana Formation with the overlying Colinton Volcanics, with interfingerings of sediments and tuffs. Thus the precise position of the boundary is open to interpretation in some places, depending on what is regarded as the first major volcanic unit, and whether sediments near the base of the volcanics are regarded as lenses within the volcanics or interfingerings of Cappanana Formation. In one area east of Bredbo, north of the Bredbo-Jerangle road, a bed of shale with limestone lenses, mapped by Richardson (1979) as Cappanana Formation, is now shown as unit Sc_b within the Colinton Volcanics; otherwise the recent mapping has resulted in little change from that shown previously. The position of the top of the Cappanana Formation east of Cooma is uncertain where the Colinton Volcanics are missing, and where the formation apparently passes up disconformably into the sedimentary rocks of the Rothlyn Formation (see below).

The Cappanana Formation, until now, has been recognised only to the north and south of the type section area east of Bredbo. Another possible exposure of the formation is adjacent to the Murrumbidgee Fault from 15 km south of Bredbo almost to Cooma where it is shown as on the on the map as S_a?. Sedimentary rocks in this zone consist of shale and calc-silicate hornfels underlying sheared volcanics now regarded as Colinton Volcanics (see below). However the base of the sedimentary rocks is not exposed, and these rocks could be part of a thick sedimentary unit within the Colinton Volcanics.

COLINTON VOLCANICS
(definition modified from Richardson, 1979)

The Colinton Volcanics are a partly marine and partly terrestrial unit which conformably overlie the Cappanana Formation. Richardson (1979) defined the unit formally, and noted previous work in the area and references to the 'Colinton tuffs' before the term Colinton Volcanics was first published by Best & others (1964). A major part of the area mapped is occupied by this unit which extends from Burra to south of Bredbo. Modifications to Richardson's description to accommodate the recent mapping are incorporated below.

The Colinton Volcanics consist of felsic volcanics ranging in composition from rhyolite to dacite with minor interbedded sedimentary lenses in some places. A few thin flows around Bredbo lack quartz phenocrysts and are indicated in the map reference as andesite, but are probably more correctly a variety of dacite. The recent mapping has confirmed Richardson's conclusion that volcanics of dacitic composition make up the lower part of the sequence, and that rhyolites occur only in the upper part. It has been found possible to increase the 9 subunits of the volcanics described by Richardson (1979) to 16 (Table 2); they are designated Sc_a to Sc_p as far as practicable in alphabetical order of succession. A thick, massive dacitic ash-

Table 2. Data on rock units - Colinton Volcanics

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sc_p (Ingalara Ashstone Member)	Belt east of Murrumbidgee River extending south from Ingalara Creek; belt west of Monaro Highway between Colinton and Bredbo	Pale buff to white, siliceous, fine-grained tuff or ashstone; forms blocky outcrops	Overlies leached rhyolite (Sc_o); overlain by shale and tuffaceous shale at base of Rothlyn Formation	Useful marker unit; well exposed along Ingalara Creek and in railway cuttings between Colinton and Bredbo
Sc_o	Extends from Murrumbidgee River north of Ingalara Creek south in almost continuous outcrop to Cosgrove Hill south of Bredbo	Rhyolite and rhyolitic agglomerate, commonly leached white, otherwise pale green; possible leached dacite	Base in north is eastern limit of foliated rhyolite and in south uppermost shale horizon in Sc_l; overlain by Sc_p or Sn_a	Leaching may disguise a more variable lithology within this unit than immediately apparent; rocks foliated north of Ingalara Creek
Sc_n	Small area southeast of Bredbo	Dark grey, slightly purplish andesite with white feldspar phenocrysts	Forms core of syncline; underlain by shale and tuff in Sc_l; overlying unit not preserved	Flow-banded in places
Sc_m ('Cosgrove Porphyry')	Hill immediately south of Bredbo, north of Cosgrove Hill	Dark, slightly greenish, grey dacite with prominent phenocrysts of quartz and pale greenish to pinkish feldspar	Underlies Sc_o; base not exposed	Previously mapped as intrusive but evidence not substantiated; could be core of anticlinal dome
Sc_l	Extends from north of Bredbo near Monaro Highway to southeast of Bredbo south of Bredbo River; possible outcrop east of Cooma near Numeralla Road	Green-grey dacite with some rhyolite and andesite; lenses of shale and reworked tuff; minor purplish and leached dacite	Overlies massive dacitic crystal tuff Sc_g; overlain by rhyolite (Sc_o) lacking shale lenses	Heterogeneous unit that could be further subdivided; dacite east of Cooma could correlate with Sc_a rather than Sc_l
Sc_k	Along belt from northwest of Michelago to northwest of Colinton	Rhyolitic crystal tuff; rhyolite; tuff; minor shale lenses; volcanics generally pale with pink feldspar	Base in most places intruded by Livingstone Porphyry (Spl); overlain by Sc_l	Lower part along eastern side of belt could include some of unit Sc_j
Sc_j	Between Williamsdale and Michelago	Pale to mid-grey rhyolitic to dacitic crystal tuff; minor pink feldspar in some outcrops	Overlies rhyolite with lenses of coarse sandstone (Sc_i); top intruded by Livingstone Porphyry (Spl)	Chemical and petrographic similarity to unit Sl_l in Laidlaw Volcanics suggests possible correlation
Sc_i	Along belt from Williamsdale to south of Michelago	Dark greenish-grey to purple and white, leached rhyolite with a few lenses of of coarse sandstone in the north	Base not generally exposed owing to faulting; overlain by Sc_j or Sc_k, or top intruded by Livingstone Porphyry (Spl); overlies Sc_g north of Ingalara Creek	Mostly pale purple and white; blocky outcrops south and west of Michelago; most varied lithology south of Williamsdale

Table 2 (continued)

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sc_h	Northeast and southeast of Williamsdale	Grey rhyolitic crystal tuff; phenocrysts include pale pink feldspars	Overlies dacitic crystal tuff without pink feldspars; top removed by faulting	Chemical and petrographic similarity to Sd_e in Deakin Volcanics; lacks coarse inclusions typical of underlying dacitic crystal tuff (Sc_f)
Sc_g	Belt extending from north of Colinton to east of Bredbo	Grey, massive or slightly foliated dacitic crystal tuff; very minor hornblende in a few outcrops	Lower limit to east is topmost sedimentary bed in Sc_a, Sc_b Sc_b or Sc_c; upper limit to west is rhyolite Sc_o or Sc_1	Appears to occupy same stratigraphic position as Sc_e, Sc_f and Sc_h to north but lacks coarse inclusions of Sc_e and Sc_f, and pink feldspar of Sc_h
Sc_f (Williamsdale Dacite Mbr-upper part)	North-south belt between Williamsdale and Burra	Dark grey dacitic crystal tuff, with large inclusions of coarser-grained rock (recrystallised pumice); forms very large rounded boulders	Overlain to west by rhyolitic crystal tuff with pink feldspar (Sc_h); base gradational down into paler grey rock with fresh biotite (Sc_e)	Slight indications of bedding in places from orientation of inclusions and indistinct primary foliation
Sc_e (Williamsdale Dacite Mbr-lower part)	North-south belt between Williamsdale and Burra extending south to Michelago	Pale grey dacitic crystal tuff with large inclusions of coarse-grained rock (recrystallised pumice); contains fresh biotite; forms large boulders	Overlies sheared dacite (Sc_d) around Burra or shale (Sc_b) north of Michelago; overlain to west by Sc_f with gradational boundary	As for Sc_f; petrography and chemistry indicate a more rhyolitic composition towards base
Sc_d	Belt extending from north of Burra to to northeast of Michelago; belt immediately east of Monaro Highway between Royalla and Williamsdale	Weakly to intensely sheared, grey dacitic crystal tuff	Lower limit in east is sedimentary rocks in Sc_a and Sc_b; upper limit to west is dacitic crystal tuff with fresh biotite (Sc_e)	Belt east of Royalla may contain some rhyolitic crystal tuff of other units but outcrop too weathered to differentiate
Sc_c	Extends from southeast of Colinton to southeast of Bredbo	Dacite and tuff; minor shale and tuffaceous sandstone lenses	Overlies persistent shale unit Sc_b; upper limit to west is uppermost sedimentary or tuff bed at base of massive dacitic crystal tuff Sc_g	Similar range of lithologies to that in Sc_1 southeast of Bredbo where intervening unit Sc_g lenses out; volcanics may contain minor hornblende in places
Sc_b	Northeast of Michelago and from northeast of Colinton to east of Bredbo	Mainly shale; minor calcareous shale and limestone lenses	Major persistent unit between Sc_ae and Sc_c	Includes some outcrop east of Bredbo previously mapped as Cappanana Formation
Sc_a	East and northeast of Burra; belt from northeast to south of Michelago; belt from northeast of Colinton to southeast of Bredbo	Dacite and tuff, commonly sheared; dacitic crystal tuff (east of Bredbo); shale lenses	Lower limit is first first major volcanic unit above Cappanana Formation; upper limit is base of major and persistent shale unit Sc_b	Chemistry of dacitic crystal tuff east of Bredbo (Anal. 1, Table 9) indicates possible affinity with Wenlock volcanics near Canberra

flow tuff unit in the north was named the Williamsdale Volcanics by Richardson. However, since the unit interfingers with the Colinton Volcanics and is part of the sequence, it has been reduced to member status (Sc_e and Sc_f on map) and its definition revised accordingly (see below). Another particularly distinctive unit and useful marker, an ashstone, which is now regarded as defining the top of the Colinton Volcanics west of Colinton, is named the Ingalara Ashstone Member (Sc_p).

A type section has not previously been described for the Colinton Volcanics, only a type area 'in the vicinity of Colinton Railway Station' (Richardson, 1979). Outcrop is insufficient to define a detailed type section. However, a suitable reference section is along an east-west line 4 km south of Colinton between a point on Colyers Creek (GR 968255) and a point on Gungoandra Creek (GR 934242). Six of the 16 subunits are exposed along this line. The rock types from the base on Colyers Creek going west are:-

0-140 m	:	tuff
140-270 m	:	cleaved siltstone
270-600 m	:	dacite and tuff
600-1780 m	:	dacitic crystal tuff
1780-2180 m	:	rhyolite, dacite and 'andesite'
2180-3300 m	:	rhyolite
2180-3300 m	:	ashstone (Ingalara Ashstone Member)
3500-3600 m	:	tuff

The basal tuff overlies shale of the Cappanana Formation and the topmost tuff is succeeded by shale of the Rothlyn Formation.

The volcanics along the reference section are about 3000 m thick not allowing for possible folding. The thickness increases to the north, and in the Burra-Williamsdale area it could be as much as 8000 m, although it is difficult to estimate owing to lack of bedding or attitudes of contacts between rock units in much of the massive and foliated volcanics. What bedding there is in sedimentary interbeds suggests that dips are steep, except immediately west of the Monaro Highway north of Michelago, where dips of around 40° have been recorded. An unknown thickness of volcanics has been faulted out along the northern extension of the Collingwood Fault.

The Colinton Volcanics become progressively thinner to the southeast of Bredbo. The massive dacitic unit Sc_g lenses out and interbedded shale lenses become more common, indicating an apparent southerly transition from mainly terrestrial to marine deposition. The volcanics lens out altogether east of Cooma. A coarse dacite mapped as Sc_1? that straddles the Cooma-Numeralla road is probably the southernmost volcanic flow judging by its position low in the overall sequence in this area.

The volcanic units in the Colinton Volcanics are mainly dacitic or rhyolitic crystal tuffs containing very numerous phenocrysts of quartz, plagioclase and biotite (generally altered), ± K-feldspar, in a quartzo-feldspathic groundmass. Accessory minerals may include apatite, zircon, occasionally allanite, and rarely hornblende; the hornblende has been noted only east of Bredbo. The lower part (Sc_e) of the Williamsdale Dacite Member is the only unit that contains unaltered biotite. This unit also contains altered hypersthene with an occasional fresh grain. The altered biotite in the other units appears as chlorite with numerous inclusions of opaque minerals and with the original cleavage of the biotite preserved. In both the fresh and altered biotite the crystals are commonly bent, perhaps by flowage during ignimbritic eruption. Most of the volcanics, as well as containing altered biotite, also contain other chlorite pseudomorphs without opaques which could have originally been hypersthene, because occasional square grains with beveled corners typical of pyroxenes have been observed in some thin sections. The composition of the plagioclase ranges from labradorite in the dacites to andesine or oligoclase in the more rhyolitic units. Zoned crystals are also present in some rocks. Commonly the quartz and plagioclase crystals are sharply angular, indicating shattering in the course of eruption and deposition.

Massive and flow-banded volcanics with sparser phenocrysts relative to the ash-flow tuffs are also present in the Colinton Volcanics, especially in the south. They range in composition from rhyolite to dacite. The dacites include those without quartz phenocrysts referred to above that were mapped as andesite. These rocks form units Sc_n and part of Sc_1. A typical flow-banded dacite crops out near Deep Creek south of the Bredbo River at GR 972124.

All the rocks along the western side of the volcanic belt in the Michelago Sheet area were mapped as Bransby Beds by Richardson (1979), largely in accord with Best and others (1964), and discounting the possibility raised by Baczynski (1970) that the Bransby Beds in the Bredbo area were equivalent to the Colinton Volcanics. The recent mapping supports Baczynski's proposition that part of the Bransby Beds do correlate with the Colinton Volcanics. The fault diverging south-southeast from the Murrumbidgee Fault west of Colinton (Bumbalong Fault) separates the sheared volcanics mapped as Bransby Beds by Joplin (1943) from the less deformed sedimentary and volcanic rocks to the east. These sheared volcanics include dacite and rhyolite which are similar in composition to the Colinton Volcanics, and dissimilar to the volcanics in the Rothlyn Formation (described below) that is now regarded as conformably overlying the Colinton Volcanics. Therefore the sheared volcanics, together with minor interbedded sediments, are now regarded as a upfaulted block of Colinton Volcanics. They are shown as on the map as subunits Sb_1 to Sb_6 (see also Table 3). A thick rhyolite unit (Sb_4) southwest of Colinton occurs towards the top of the sequence, and probably correlates with the rhyolitic upper part of the Colinton Volcanics to the east, possibly unit Sc_o. A unit apparently at or near the top of the sequence west of Colinton, a thick limestone bed (Sb_6), is the only unit within the shear zone regarded as possi-

Table 3. Data on rock units - Colinton Volcanics in Bransby Shear Zone

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sb_6	West of Murrumbidgee River northwest of Colinton	Massive and bedded grey limestone	Within volcanic unit Sb_5	Probably correlates with limestone lenses Sn_b in Rothlyn Formation farther to north; plunges north and overturned to east
Sb_5	Belt from northwest to southwest of Colinton	Sheared, coarse and medium-grained dacite and tuff; minor slaty shale lenses	Overlies rhyolite Sb_4; top not preserved	Outcrops commonly weathered; part below Sb_6 possibly correlates with Sc_o, part above Sb_6 with Sn_a
Sb_4	Northwest of Bredbo	Slightly to intensely sheared, pinkish buff rhyolite with prominent pink feldspar	Overlies Sb_1 and overlain by Sb_5	More intensely sheared close to Murrumbidgee Fault; forms a north-plunging syncline; possibly correlates with Sc_k
Sb_3	Small outcrops north-northwest of Bredbo close to Bumbalong Fault	Bedded, pale grey limestone, in places with microfolds	Lenses apparently between Sb_1 and Sb_4 but could be younger	Position close to Bumbalong Fault suggests it could be in a fault slice and hence correlate with Sb_6
Sb_2	Extends south from near Angle Crossing to northwest of Michelago	White marble; slaty shale; black carbonaceous shale; tuff; tuffaceous shale	Bed within Sb_1	No marble north of point 2.5km south of Angle Crossing; possibly correlates with Sc_b
Sb_1	From north of Angle Crossing to northwest of Michelago; from northwest of Bredbo to east of Cooma	Intensely sheared dacite, ? rhyolite and tuff; minor slaty shale and sandstone lenses towards base north of Cooma	Overlies sedimentary rocks north of Cooma; overlain by Sb_4 northwest of Bredbo; base not exposed and top not preserved near Angle Crossing	Outcrops generally more weathered than those in massive volcanics to east; probably correlates with dacite and tuff in lower part of Colinton Volcanics

bly younger than the Colinton Volcanics. The limestone is similar in composition and thickness to other limestone beds mapped as Sn_b west of Michelago farther to the north. These other limestones occur near the base of the Rothlyn Formation which overlies the Colinton Volcanics, but, unlike Sb_6, occur within a shale sequence.

Another zone of sheared and probably upfaulted Colinton Volcanics on the western edge of the volcanic belt, that Richardson (1979) mapped as Bransby Beds, lies to the west of Angle Crossing south of Tharwa. The volcanics in this shear zone are dacite and tuff mapped as (Sb_1) enclosing a thin sedimentary unit of marble and shale (Sb_2). The lack of rhyolite indicates that the volcanics occupy a different part of the sequence to the rhyolite-bearing formations to the south which include the topmost part of the Colinton Volcanics and the lowermost part of the Rothlyn Formation. The petrography and chemistry of the dacite suggests a correlation with the dacitic lower part of the Colinton Volcanics. The pure, white marble unit enclosed by the dacite and tuff differs from the grey, impure limestone (Sn_b) to the south at the base of the Rothlyn Formation.

<u>Williamsdale Dacite Member</u>
(definition modified from Richardson, 1979)

The Williamsdale Dacite Member (subunits Sc_e and Sc_f) takes its name from the village of Williamsdale (GR 933613) and is essentially the Williamsdale Volcanics of Richardson (1979). It extends from about 12 km south of Queanbeyan on the Canberra 1:100 000 Sheet to south of Michelago. A reference section is nominated along the Burra-Williamsdale road from GR 007628 (base) to GR 958605 (top) excluding coarse porphyry intrusives at GR 993620 and GR 975603.

The Williamsdale Dacite Member consists of generally massive dacitic crystal tuff, pale grey with fresh biotite in the lower part (Sc_e) and dark grey in the upper part (Sc_f). A conspicuous feature is inclusions of coarse-grained, recrystallised pumice fragments up to 130 mm long containing feldspar aggregates. Indistinct primary foliation is indicated by alignment of the pumice fragments in some places. The total thickness of the unit is at least 2000 m and possibly as much as 4000 m along the reference section, depending on the dip. The underlying dacitic crystal tuff to the east is dark grey and sheared. The overlying rhyolitic crystal tuff to the west is mainly massive and the phenocrysts include small pink feldspars.

The Williamsdale Dacite Member cannot be recognised with certainty south of the Collingwood Fault where the main, massive part of the sequence at approximately the same stratigraphic level is a dacite mapped as Sc_g. This dacite, although similar in composition to the Williamsdale Dacite Member, lacks distinctive features such as fresh biotite and coarse-grained inclusions.

Ingalara Ashstone Member
(new name)

The Ingalara Ashstone Member (Sc_p) is named after Ingalara Creek and conforms in part with a unit Richardson mapped as 'fine-grained ash tuff' (Sva). It extends discontinuously along a narrow belt from 1 km north of Ingalara Creek near its confluence with the Murrumbidgee River south to a point near the Monaro Highway about 4 km north of Bredbo. The type section is along Ingalara Creek from GR 931350, where it overlies white rhyolite, to GR 928353, where it is overlain by cleaved shale at the base of the Rothlyn Formation. The unit consists of white to very pale grey, fine-grained, massive to faintly banded rhyolitic tuff or ashstone. It ranges in thickness to about 250 m.

ROTHLYN FORMATION
(new name)

The Rothlyn Formation conformably overlies the Colinton Volcanics southeast of Bredbo and is a new name for the formation formerly occupying the stratigraphic position of the Bransby Beds. It includes some rocks formerly mapped as Bransby Beds as well as previously undifferentiated late Silurian rocks. The name Bransby Beds has been dropped because the type area of this formation, and the area mapped as Bransby Beds by Joplin (1943), is now regarded as part of the Colinton Volcanics (see above).

The Rothlyn Formation consists of interbedded sedimentary and volcanic rocks. The main part of the formation crops out between Bredbo and Cooma and was previously unnamed, although a correlation with the Colinton Volcanics to the north was suggested by Barnes and Herzberger (1975). The remainder of the formation comprises the limestones and associated shale and volcanics that conformably overlie the Colinton Volcanics along the Murrumbidgee River west of Michelago. These rocks were formerly included in the Bransby Beds by Sharp (1949) and subsequently by others including Richardson (1979).

The Rothlyn Formation, which has been divided into 18 subunits (Table 4), differs from the Colinton Volcanics in the composition of the volcanic rocks and the much greater proportion of sedimentary rocks. Overall, sedimentary rocks make up about 50% of the formation. The sediments are mainly shale, but also include thick limestone units and, in places, interbedded sandstone and shale. The volcanics are generally more basic than those in the Colinton Volcanics, and consist of dacite, dacitic tuff and minor basalt, with only very minor rocks of rhyolitic composition. Many of the dacitic rocks contain hornblende which is rare or absent in the Colinton Volcanics.

The base of the Rothlyn Formation is regarded as the first thick shale or limestone unit above the Colinton Volcanics, or a horizon at this level. Some difficulty exists in mapping the base of the formation east of Cooma, where the Colinton Vol-

Table 4. Data on rock units - Rothlyn Formation

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sn_r	Near 'Rothlyn' homestead south of Bredbo; east of Cooma	Mainly fine feldspathic sandstone with shale interbeds; also quartz sandstone, banded silty sandstone and coarse feldspathic sandstone	Topmost preserved unit in Rothlyn Formation; overlies shale (Sn_k and Sn_n)	Possibly lowermost part of a post-volcanic sandstone formation; quartz sandstone similar to sandstone in Sn_a
Sn_q	Southeast of Cooma	Mid-grey, amygdaloidal basalt (fresh outcrop) and weathered feldspathic volcanic of uncertain composition	Overlies shale Sn_n; overlying beds either not preserved or relationship uncertain	Fresh rock exposed beside Rock Flat Creek in folded contact with shale
Sn_p	North of Bunyan	Hornblende dacite and tuff	Lenses within Sn_n at higher level than Sn_o	Inferred stratigraphic position assumes that nearby limestone correlates with Sn_o to south of Numeralla Road
Sn_o (Cloyne Limestone Mbr)	Mainly northeast of Cooma; north of Bunyan	Pale, buff-grey, banded limestone and coarsely crystalline marble	Lens at base of Sn_n	Forms extensive outcrop in main area northeast of Cooma
Sn_n	From south of Bredbo to east and southeast of Cooma	Slaty, green to greenish-grey shale	Includes all shale overlying Sn_m up to base of Sn_r	Similar to Sn_k
Sn_m	From south of Bredbo to east of Cooma	Dacite; coarse dacite (east of Rock Flat Creek); dacitic agglomerate; tuff	Topmost dacitic unit in sequence apart from Sn_p	Unit is missing in some places, for example east of Bunyan and north of 'Rothlyn' homestead
Sn_l	From south of Bredbo to east of Cooma	Andesite; andesitic agglomerate; augite dacite, some with hornblende; feldspathic tuff; minor ashstone (north of Square Hill)	Includes all andesitic volcanics within Sn_k and some dacites at same stratigraphic level	Difference between Sn_l and Sn_m not always clear cut
Sn_k	Mainly from south of of Bredbo to east of Cooma; also along Gungoandra Creek north of Bredbo	Slaty shale; siltstone; minor tuff	Includes all shale overlying Sn_j up to base of Sn_m	Similar to Sn_n; contact with Sn_n arbitrary north of 'Rothlyn' homestead where Sn_m missing
Sn_j (Montagu Dacite Member)	East and southeast of Cooma, east of Umeralla Fault	Bouldery outcrops of coarse, grey dacite with large hornblende phenocrysts	Overlies shale (Sn_a?); overlain by andesite (Sn_l)	Bouldery outcrops of overlying andesite in some places not distinct from Sn_j in field

Table 4 (continued)

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sn_i (Billilingra Dacite Mbr)	Extends south from Billilingra Siding, southeast of Bredbo; north and south of Bredbo; ? east of Umeralla Fault near Carlaminda Road	Crystal-rich, greenish-grey, hornblende-biotite dacitic crystal tuff	Lowermost hornblende-rich unit in Rothlyn Formation	Useful marker unit linking sequence north of Bredbo with sequence southeast of Bredbo
Sn_h	Small area north of Carlaminda Road, east of Cooma	Flow-banded, mid-grey basalt	Lens at base of Montagu Dacite Mbr (Sn_j)	Distinguished in field from Tertiary basalt by paler colour and larger size of boulders
Sn_g	Small areas southeast of Angle Crossing	Pinkish-buff rhyolithic crystal tuff; minor tuffaceous sedimentary rocks	Occupies cores of synclines in Sn_f; top not preserved	Uppermost preserved unit in Rothlyn Formation north of Michelago
Sn_f	Belt from southeast of Angle Crossing to west of Michelago	Rhyolitic, banded tuff at base passing up into sheared dacite and tuff, in some places agglomeratic	Overlies limestone-bearing sedimentary rocks (Sn_a and Sn_b) west and northwest of Michelago	Relationships to other to other units near Angle Crossing obscured by shearing and probable faulting
Sn_e	Small area immediately south of Bredbo	Volcanic breccia and tuff	Lens between rhyolite Sc_o and Billilingra Dacite Mbr (Sn_i)	Well exposed in cutting along Monaro Highway
Sn_d	Southeast of Bredbo near Billilingra Siding	Buff-grey rhyolitic crystal tuff; coarse, white feldspathic sandstone; tuff	Lens between Sn_a and Sn_i	Rhyolite near siding; sandstone near Deep Creek
Sn_c	Immediately south-southeast of Bredbo	Green-grey, medium-grained, foliated tuff	Overlies Sc_1 and Sc_o; overlain by Sn_i	
Sn_b	Numerous discontinuous exposures along Murrumbidgee River from northwest to southwest of Michelago	Massive to bedded, grey, fossiliferous limestone	Lenses within Sn_a	Well exposed in steep bluffs along Murrumbidgee River
Sn_a	Extends from northwest of Michelago south to Bredbo, and from southeast of Bredbo to east of Cooma	Slaty shale; calcareous shale; quartz sandstone; tuff	Overlies rhyolite (Sc_o) and ashstone (Sc_p) in north, and other volcanics (Sc_1) in south; overlain by Sn_f in north and Sn_i in south	Lenses out to north, northwest of Michelago; possibly correlates with Sl_2 north of Tharwa; sandstone similar to some of that in Sn_r

canics lens out and shale of the Rothlyn Formation rests disconformably on similar shale of the Cappanana Formation.

The proposed reference section of the Rothlyn Formation is 11 km southeast of Bredbo and northeast of 'Rothlyn' homestead between GR 983085 and GR 963085. The section, going west from the base, contains 6 of the 18 subunits and is as follows:-

0-550 m	: shale
550-900 m	: hornblende dacitic crystal tuff (Billilingra Dacite Member)
900-1350 m	: shale
1350-1500 m	: basalt
1500-1800 m	: siltstone and shale
1800-1950 m	: sandstone

The thickness of the formation along this section is about 700 m, which is a minimum thickness, as the sandstone at the top of the formation forms the core of a syncline and any beds higher in the formation have not been preserved. The basal shale overlies dacite at the top of the Colinton Volcanics. In most other places thickness estimates are difficult to determine owing to folding and faulting, although the thickness probably increases considerably to the south in the Cooma area.

The volcanic rocks in the Rothlyn Formation range in composition from rhyolite to basalt, but dacitic compositions are the most common; all are porphyritic. The dacitic rocks commonly contain hornblende visible in hand specimen. In thin section they are seen to consist of phenocrysts of quartz and plagioclase, together with hornblende and/or chloritised biotite. Some rocks also contain a chloritised mafic mineral that was possibly originally hypersthene. They range from crystal-rich ashflow tuffs, such as the Billilingra Dacite Member to relatively crystal-poor rocks with sparse large phenocrysts, such as the Montagu Dacite Member. The plagioclase in the dacite is generally andesine around An_{30} to An_{35}. Rocks shown as andesites on the map, but which are probably a more basic variety of dacite, contain phenocrysts of plagioclase, generally altered, and clinopyroxene and chloritised ?hypersthene. One rock of this affinity contains plagioclase, clinopyroxene, hornblende and minor quartz. The basalts consist of altered plagioclase, clinopyroxene, and possibly altered hypersthene, in a groundmass of plagioclase needles with much secondary calcite. Amygdaloidal basalt (Sn_q) is well exposed beside Rock Flat Creek at GR 991827.

Rocks of rhyolitic composition are found only in one place south of Bredbo, but are more common at the northern extremity of the formation northwest of Michelago. The rhyolitic rock south of Bredbo (Sn_d) is a crystal-rich ashflow tuff immediately beneath the Billilingra Dacite Member near Billilingra railway siding (GR 960125). It consists of phenocrysts of quartz, plagioclase (An_{32}), K-feldspar and a very minor indeterminable altered mafic mineral. Bedded rhyolitic tuff overlies the limestone and shale northwest of Michelago, and a rhyolitic crystal tuff unit (Sn_g), similar to (Sn_d) described above, forms the topmost preserved part of the succession at the northern extremity of the formation south of Angle Crossing.

Sedimentary rocks in the Rothlyn Formation consist of shale with minor amounts of limestone and sandstone. The shale crops out extensively in the south where it appears to have been indurated and made resistant to weathering and decomposition. It also occurs along the Murrumbidgee River.

Limestone crops out in two areas. One is along the Murrumbidgee River west of Michelago where numerous lenses are exposed associated with shale. Only the largest lenses are shown on the map. Some of these lenses are up to 100 m thick, and in places form steep bluffs beside the river. It is possible that some of the lenses immediately adjacent to the Murrumbidgee Fault, west of the river, belong to the marble/shale unit Sb_2 of the Colinton Volcanics that converges with the limestones south of Angle Crossing. The limestones along the Murrumbidgee River are fossiliferous with several localities listed by Richardson (1979) under her Bransby Beds. The other area of limestone outcrop is northeast of Cooma where it has been named the Cloyne Limestone Member and is described below.

Sandstone is most common towards the top of the Rothlyn Formation. Thick beds of fine to coarse quartzo-feldspathic sandstone with some shale interbeds, mapped as Sn_r, occur in the cores of synclines west of Rock Flat Creek and to the north near 'Rothlyn' homestead. The sandstone appears to be conformable on underlying shale and may indicate a change in the environment of deposition comparable to that which occurs in the upper part of the sequence in the Captains Flat Graben to the northeast (Abell, in press). Minor sandstone beds also occur in the basal unit (Sn_a) of the Rothlyn Formation in several areas. Two resistant hills with fine-grained quartz sandstone outcrop occur east of Rock Flat Creek in the vicinity of GR 013885. The sandstone, at least superficially, resembles some of the Ordovician sandstones farther to the east. However the relationship to the surrounding Silurian sedimentary and volcanic rocks indicates that the sandstone is part of the Silurian sequence. A pale coarse feldspathic sandstone (included in unit Sn_d) crops out immediately beneath the Billilingra Dacite Member east of Billilingra siding. This sandstone is probably a reworked volcanic rock, possibly derived from the nearby rhyolitic crystal tuff at the same stratigraphic level. Fine-grained, bedded, quartz sandstone occurs at the base of the Rothlyn Formation northwest of Colinton immediately above the Ingalara Ashstone Member of the Colinton Volcanics. The sandstone is probably composed at least in part of reworked ashstone.

Some difficulties were experienced in differentiating the volcanics above the Billilingra Dacite Member and below the Cloyne Limestone Member. The twofold division that has been adopted is on a stratigraphic basis with a lower dacite or 'andesite' group commonly lacking quartz phenocrysts (Sn_1) and an upper, generally quartz-bearing dacite group (Sn_m). However, much variety in composition exists within both groups.

The western boundary of the Rothlyn Formation is faulted, north of Bredbo and northeast of Cooma, against the sheared volcanics formerly mapped as Bransby Beds, which are now included in the Colinton Volcanics. South of Chakola the fault is marked by quartz reefs, but between Chakola and Bredbo the position and even the existence of a fault is somewhat in question, as both the Colinton Volcanics and Rothlyn Formation have a prevailing dip to the east, which suggests that the contact could be a simple conformable transition. However, as the interval where the fault is most in doubt is relatively short, compared to the full length of the boundary, the fault is shown on the map as continuous. The position of the boundary is usually marked by a transition from sheared to unsheared rocks.

Billilingra Dacite Member
(new name)

The Billilingra Dacite Member (Sn_i) is a hornblende-rich dacitic crystal tuff in the lower part of the Rothlyn Formation. The name is derived from Billilingra siding, GR 960125, southeast of Bredbo. The unit extends from 1 km northwest of Billilingra siding for about 20 km to the south-southeast; it also crops out from 0.5 km east to 6 km north of Bredbo and in other small areas near Bredbo and east of Cooma. A type section is nominated along the road east of Rothlyn homestead from GR 982074 (base) to GR 975074 (top). Shale both underlies and overlies the unit at the type section. The maximum thickness of about 600 m is attained in this vicinity.

The southern limit of the Billilingra Dacite Member is not well defined. Between the Umeralla River and the Cooma-'Springbank' road the characteristic hornblende-bearing dacitic crystal tuff lenses out and is replaced by a dacitic tuff without hornblende. However, farther to the southeast, and east of the Umeralla Fault, hornblende-rich dacitic crystal tuff appears again in a lens near the Carlaminda Road (GR 055870).

Montagu Dacite Member

The Montagu Dacite Member (Sn_j) is a coarsely porphyritic dacite with phenocrysts that include distinctive large, euhedral, black hornblende. The unit extends from 14 km east to 20 km southeast of Cooma and is named after the parish of Montagu. A type section is nominated 15 km east of Cooma from GR 059830 (base) to GR 048825 (top) where the unit overlies shale and is overlain by clinopyroxene-bearing dacite or 'andesite'. The Montagu Dacite Member ranges to about 800 m in thickness.

Cloyne Limestone Member

The Cloyne Limestone Member (Sn_o) crops out northeast of Cooma and consists of limestone and marble up to 150 m thick. It probably forms the core if a south-plunging syncline overturned to he east immediately west of Rock Flat Creek; the syncline would be a northern extension of the Rock Flat Syncline. The limestone lenses out to the south. A suitable type section is 1 km south of the Numeralla road between GR 993912 (base) and GR 988911 (top). The limestone overlies dacite and is overlain by shale. A variety of fossils have been recorded from the limestone at Rock Flat Creek and from other limestones in the Rothlyn Formation at Dangelong to the southeast. Those shown in Table 5 are from a list compiled by W.B. Clarke (1878), but the grid references where they were collected is not known. These fossils indicate a probable late Silurian age.

Table 5. Fossils recorded by de Koninck from localities at Rock Flat Creek and Dangelong tabled by W.B. Clarke, 1878

FOSSILS		LOCALITY
RUGOSE CORALS		
	Ptychophyllum petelatum	Dangelong
	Rhizophyllum interpunctatum	Rock Flat Creek
TABULATE CORALS		
	Monticulpora (?)Bowerbanki	Rock Flat Creek
BRACHIOPODS		
	Strophomenes rhomboidalis	Rock Flat Creek
	Spirifer crispus	Rock Flat Creek and Dangelong
MOLLUSCS		
	Pterinia	Dangelong
GASTROPODS		
	Euomphalus solaroides	Rock Flat Creek
	Bellerophon Jukesii	
CEPHALOPODS		
	Orthoceras ibex	Rock Flat Creek
TRILOBITES		
	Stavrocephalus Clarkei	Rock Flat Creek
	Lichas nr. 'palmata'	
	Bronteus Partschi	

DEAKIN VOLCANICS

Mapping in the Tuggeranong area (Jacobson & others, 1976; Kellett, 1981) compiled by Henderson (1980) has established that the Deakin Volcanics (Öpik, 1958) extend at least as far south as Tharwa. On the other hand previous compilation by Richardson (1979) showed all the volcanics in the Tharwa area up to the northern limit of the Michelago 1:100,000 Sheet as either

Colinton Volcanics or Bransby Beds. A faulted boundary between sheared Colinton Volcanics and unsheared Deakin Volcanics extending southwest from Queanbeyan towards Royalla was recognised by Henderson (1980) and Abell (in press), but no such fault was recognised on the Michelago Sheet by Richardson (1979). Mapping carried out during this project confirms the continuation of the fault from Royalla through Williamsdale to the Angle Crossing Fault. This fault, named the Royalla Fault on the map, thus conveniently separates the Deakin from the Colinton Volcanics, and allows for the continued use of both stratigraphic names. However, as discussed below, and indicated on the topmost rock relationship diagram on the map sheet, the two formations are of similar composition and probably the same age.

The Deakin Volcanics in the map sheet area, like the Colinton Volcanics, are of rhyolitic to dacitic composition. Minor sedimentary interbeds are found between some of the volcanic units. The 11 volcanic and sedimentary subunits (Table 6), most previously mapped northeast of Tharwa by Kellett (1981), form a generally well-defined sequence dipping to the east, starting from a basal unit against the Angle Crossing Fault southeast of Tharwa. The lower part contains both rhyolitic and dacitic units, whereas the upper part is exclusively rhyolitic. Richardson (1979) separated out the upper part of her Colinton Volcanics as the 'Tuggeranong Tuff Member' on the Michelago Sheet, but this division has proved difficult to apply usefully on the adjacent Canberra 1:100 000 Sheet area where several rhyolite units with markedly different characteristics are exposed within the confines of her Tuggeranong Tuff Member. Consequently the name has been dropped both from the Canberra Sheet (Abell, in press) and from the map accompanying this report.

The Deakin Volcanics consist partly of crystal-rich, ash-flow tuffs, and partly of flows with relatively less abundant phenocrysts. In both types the phenocrysts are generally quartz, plagioclase, and altered biotite, with or without K-feldspar and chloritised hypersthene. The biotite is identifiable in thin section by the relict cleavage and the hypersthene by the shape of occasional euhedral pseudomorphs. Accessory minerals include apatite and zircon. Some of the flows, but not the crystal tuffs, are in part strongly oxidised, giving a purple colour to these rocks. Some of the flows in places exhibit flow banding indicating the dip, but mostly they are massive. The crystal tuffs contain very abundant, sharply angular phenocrysts and bent relict cleavage in the altered biotite.

The sedimentary units include fine and coarse sandstone, shale and bedded, reworked tuff. The most persistent sedimentary unit, mapped as Sd_q, consists of prominent outcrops of coarse, white, quartzo-feldspathic sandstone interbedded with dark, closely fractured, shale that breaks down into small, splinter-shaped fragments. The shale is notable for containing fossil spines of acanthodian fish, at one time regarded as indicating a Devonian age for these rocks (Strusz, 1971). The fossils led Richardson (1979) to place the shale and some of the nearby

Table 6. Data on rock units - Deakin Volcanics

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sd_k	Two small areas near Guises Creek between Royalla and Williamsdale	Purple dacite (or ?rhyolite) similar to Sd_f	?Lenses between Sd_j and Sl_1	Could be haemetised topmost part of Sd_j
Sd_j	Extends from Williamsdale to north of Royalla, west of Monaro Highway; possible outcrop west of Tharwa Road	Pale green-grey, massive, rhyolitic crystal tuff; phenocrysts include a few pink feldspars; grades to north into white, leached rhyolite; some flow-banded rhyolite northwest of Royalla	Lacks the shale lenses of Sd_g which it overlaps; separated from Sd_g northwest of Royalla by Sd_h and Sd_i; upper limit is overlying dacitic crystal tuff (Sl_1)	Possible Sd_j west of Tharwa Road is based on position high in sequence where it immediately underlies Laidlaw Volcanics (Sl_1)
Sd_i	Small area north of Mount Rob Roy; possible outcrop immediately west of Tharwa Road	Dark grey, crystal-rich, rhyolitic crystal tuff without obvious ,pink K-feldspar	Forms lenses between paler, greenish to purplish, more rhyolitic volcanics (Sd_g, Sd_h and Sd_j)	Resembles dacitic crystal tuff (Sl_1) in Laidlaw Volcanics but chemistry indicates rock more rhyolitic
Sd_h	Small area north of Mount Rob Roy	Purple rhyolite with large phenocrysts of quartz, plagioclase and small pink feldspars	Within the more rhyolitic upper part of Deakin Volcanics	Outcrop in mapped area is southernmost tongue of a much thicker and more extensive unit in Tuggeranong area
Sd_g	Mainly on Mount Rob Roy; smaller areas west and northwest of Williamsdale	Various rhyolitic rocks, generally rich in pink feldspar and commonly pale purple or leached white; minor shale and reworked tuff lenses	Overlies purple rhyolite to dacite (Sd_f); overlain by other rhyolites	Flow banding evident in some places
Sd_f	On western slopes of Mount Rob Roy, near near Tharwa Road and west of Williamsdale	Rhyolite to dacite, commonly purple but also greenish-grey in some places; less crystal-rich than Sd_e	Overlies Sd_e with gradational contact in some places; overlain by rhyolites Sd_g and Sd_j	Ashstone lens in middle of widest part of outcrop west of Mount Rob Roy dips 60°
Sd_e	In two parallel belts east of Tharwa	Green-grey, crystal-rich, rhyolitic crystal tuff; phenocrysts a few pink or white K-feldspars	Overlies a persistent thin sedimentary unit (Sd_d);overlain by purple rhyolite to dacite (Sd_f)	Resembles Sl_1 in Laidlaw Volcanics but chemistry indicates richer in K_2O; also resembles Sd_b
Sd_d	In two parallel belts east of Tharwa	Thick beds of coarse to very coarse, quartzo-feldspathic sandstone with very rounded grains; also splintery shale beds	Overlies rhyolite/dacite unit (Sd_c); overlain by rhyolitic crystal tuff (Sd_e)	Shale contains Acanthodian (fish) spines formerly regarded as indicating an early Devonian age for this unit
Sd_c	In two parallel belts east of Tharwa	Coarse, greenish to dark grey or purple rhyolite with large quartz and white feldspar phenocrysts and small pink feldspars	Sandwiched between sedimentary and tuffaceous units; overlies Sd_a and overlain by Sd_d	Regarded at one time as intrusive but petrography does not support this
Sd_b	Areas east and southeast of Tharwa	Green-grey, crystal-rich rhyolitic to dacitic crystal tuff	Lowermost exposed unit in Deakin Volcanics in Tharwa area	Resembles Sl_1 in Laidlaw Volcanics; also resembles Sd_e
Sd_a	Southeast of Tharwa and immediately east of Tharwa Road north of Tharwa	Tuff; reworked tuff; fine to coarse sandstone; shale; ashstone	Includes all exposed volcanics beneath Sd_c other than Sd_b	Well-exposed contact with Sd_c in Murrumbidgee River southeast of Tharwa

volcanics in her late Silurian to early Devonian Bransby Beds at the top of the sequence. However, as the shale is within the Deakin Volcanics, and the Deakin Volcanics are overlain by the Laidlaw Volcanics whose early Ludlovian age is precisely known (Wyborn & others, 1982), an uppermost Silurian or Devonian age is clearly untenable. Other occurrences of Silurian vertebrates have been reported from New South Wales (Turner & Pickett, 1982), so an older age for the shale is not inconsistent with regional considerations.

The general similarity in composition between the Deakin and Colinton Volcanics suggests either a correlation or, at least, that the two formations are coeval. However the similarity does not go as far as making it possible to match similar sequences of units within each formation. Units which are particularly similar are the rhyolitic crystal tuffs Sd_e in the Deakin Volcanics and Sc_h in the Colinton Volcanics. However the most distinctive unit in the Colinton Volcanics, the Williamsdale Dacite Member, could not be identified in the Deakin Volcanics. Purple coloured, hematised rhyolite and dacite are rare in the Colinton Volcanics and common in the Deakin Volcanics, but this may only be a reflection of the environment of deposition.

LAIDLAW VOLCANICS

The Laidlaw Volcanics (Owen & Wyborn, 1979) conformably overlie the Deakin Volcanics and have previously been mapped north of 'Lanyon' Homestead on the southern edge of Canberra 1:100,000 Sheet (Henderson,1980; Abell,in press). Further mapping in this area suggests a division into three successive subunits, two volcanic and one sedimentary, as indicated in Table 7. Farther to the north, in the Weston Creek area, the Laidlaw Volcanics are distinctly different in appearance from the Deakin Volcanics. The Laidlaw Volcanics there are a grey, crystal-rich dacitic ash-flow tuff with fresh biotite in some parts, whereas the Deakin Volcanics are dominantly purple and greenish dacite flows. The Laidlaw Volcanics in the 'Lanyon' area do not contain fresh biotite and are identified as such from superposition on the Deakin Volcanics. The Deakin Volcanics in the Tharwa-Williamsdale area contain some ash-flow tuff units similar to those in the Laidlaw Volcanics. One of the ash-flow tuff units at the top of the Deakin Volcanics near Royalla and Williamsdale is very similar in composition to the lowermost unit of the Laidlaw Volcanics (Sl_1), and has therefore been mapped as queried Laidlaw Volcanics.

The three units in the Laidlaw Volcanics north of 'Lanyon' homestead include the basal dacitic crystal tuff (Sl_1), which is the southern continuation of the dacitic crystal tuff at Weston Creek, and two overlying units. They are a sedimentary unit of mainly shale (Sl_2) and, at the top, a dark grey rhyolite (Sl_3). The rhyolite forms the core of a syncline and is the topmost preserved unit of the Laidlaw Volcanics in the area.

Table 7. <u>Data on rock units - Laidlaw Volcanics</u>

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Sl_3	Near Murrumbidgee River north of Tharwa	Dark grey rhyolite	Overlies Sl_2; topmost preserved unit in Laidlaw Volcanics	Occupies core of a syncline; less crystal-rich than Sl_1
Sl_2	Near Murrumbidgee River north of Tharwa	Shale and minor volcanigenic sedimentary rocks	Overlies Sl_1 and underlies Sl_3	Poorly exposed; mapping based partly on drillhole data
Sl_1	North of Tharwa; probably along Guises Creek north of Williamsdale (Sl_1?)	Dark grey and greenish-grey dacitic crystal tuff	Overlies rhyolites at top of Deakin Volcanics	Outcrop along Guises Creek based partly on petrography and chemistry and partly on apparent superposition

Table 8. <u>Data on rock units - intrusives</u>

MAPPING UNIT	DISTRIBUTION IN MAP AREA	LITHOLOGY	STRATIGRAPHIC LIMITS	REMARKS
Spl (Livingstone Porphyry)	West of Michelago between Monaro Highway and Murrumbidgee River	Mainly very coarse, massive, grey rhyolitic porphyry; phenocrysts include a few, small, pink K-feldspars; local fine-grained very K-feldspar-rich bodies	Intrudes Colinton Volcanics units Sc_i,Sc_j, Sc_k, Sn_a and Sn_f	Intrusive origin indicated by coarse texture and holocrystalline groundmass; west-dipping contact with Sc_i at GR949439 suggests sill-like form
Spb (Bullanamang Porphyry)	Northwest of Bredbo; narrow belt from Bredbo to south of Bunyan	Very coarse, massive to sheared, grey rhyolitic porphyry similar to Spl; local pink feldspar megacrysts	Intrudes Colinton Volcanics units Sb_1, Sb_3 and Sb_4 in Bransby Shear Zone	Intrusive origin indicated by coarse texture and holocrystalline groundmass, and by discordance northwest of Bredbo
Sp_1	Along Murrumbidgee River north of Tharwa	Very coarse, dark grey porphyry with pink feldspar megacrysts	Intrudes Laidlaw Volcanics	Probable Sill-like form
Sp_2	West of Murrumbidgee River Northwest of Michelago	Very coarse, sheared rhyolitic porphyry	Intrudes Laidlaw Volcanics	Probably related to Spl
Sp_3	Near Williamsdale-Burra road	Very coarse, pale grey rhyolitic porphyry with numerous pale pink K-feldspar phenocrysts	Intrudes Colinton Volcanics units Sc_e and Sc_f	Narrow, elongated outcrop crosses strike; therefore probably a dyke
Sp_4	Numerous small bodies between Williamsdale and Burra	Very coarse, grey Rhyolitic porphyry	Intrudes Colinton Volcanics units Sc_d, Sc_e, Sc_f and Sc_h	Bodies commonly elongated parallel to strike and hence probably sill-like
Sg	Small area northwest of London Bridge	Pale, quartz-feldspar-biotite granite forming large boulders	Intrudes Colinton Volcanics unit Sc_d .	Several other similar bodies off map to north
Sgl	Several bodies adjacent to Murrumbidgee Fault between Tharwa and Bredbo	Pale quartz-feldspar granite forming blocky outcrops	Intrude Deakin Volanics unit Sd_b and Colinton Volcanics units Sb_1, Sb_2, Sb_4 and Sb_5	Probably late-stage intrusions related to leucogranite intrusions in Murrumbidgee Batholith
Sr	Mainly east of Tharwa; one body 3km north of Bredbo	White, pale green or reddish, coarse, blocky rhyolite	Intrude Deakin Volcanics units Sd_c, Sd_d, Sd_e and Sd_f, and Rothlyn Formation unit Sn_i	West-northwest trend of bodies east of Tharwa across strike indicates they are dykes

The Laidlaw Volcanics are similar in composition to the Deakin and Colinton Volcanics. The two volcanic subunits (Sl_1 and Sl_3) both contain phenocrysts of quartz, plagioclase, altered biotite, minor K-feldspar and altered ?hypersthene. However Sl_1 is a crystal-rich ash-flow tuff whereas Sl_3 is relatively crystal-poor.

Two mineralogical features of the Laidlaw Volcanics indicate possible correlations with, on the one hand, a subunit near the top of the Colinton Volcanics and, on the other, volcanic units in the Rothlyn Formation. The first is the presence of allanite in subunit Sl_1, which also occurs in subunit Sc_j of the Colinton Volcanics south of Williamsdale. Apart from the allanite, Sl_1 and Sc_j are also particularly similar in major mineral composition, chemical composition and texture. The other feature is the presence of minor amounts of hornblende in subunit Sl_3. Although the hornblende, as seen in thin section, has strong reaction rims and may be xenocrysts, it suggests a correlation with the Rothlyn Formation. These two possible correlations are not necessarily inconsistent as the shale subunit Sl_2 between Sl_1 and Sl_3 could have been deposited during the time interval between late Colinton Volcanics and early Rothlyn Formation time.

INTRUSIVES

Coarse porphyries of rhyolitic to dacitic composition, and rhyolitic dykes (Table 8), intrude the volcanic succession in a number of places. The largest porphyry bodies are the Livingstone Porphyry (Spl) west of Michelago and the Bullanamang Porphyry (Spb) between Bredbo and Cooma (Richardson, 1979). Richardson's description of the Bullanamang Porphyry refers only to the part northwest of Bredbo; however, as the porphyry extending from south of Bredbo to Cooma appears to be identical in composition it is now included with this unit. Richardson concludes that the Livingstone Porphyry is a sill-like body, suggested by the roughly concordant boundaries with the surrounding volcanics. An exposure seen during this survey at GR 949439, where the eastern contact of the porphyry with rhyolite (Sc_i) dips to the west in the same direction as the rhyolite, supports this view. A sill-like nature for the Bullanamang Porphyry is also suggested from the map, particularly where the southern part is taken into consideration.

A rock unit mapped as Sc_m, which Richardson named the Cosgrove Porphyry, crops out on top of a hill south of Bredbo (GR 935165). Richardson apparently accepted evidence of intrusive contacts from Pillans (1974) and classified the rock as intrusive. However the evidence could not be substantiated in the field, and a thin section from the centre of the outcrop area indicates a dacite with typical volcanic texture containing phenocrysts of quartz, plagioclase and altered biotite in a cryptocrystalline groundmass.

Numerous small dacitic porphyry bodies, some previously unmapped, intrude the Williamsdale Dacite Member and underlying units to the east; they are shown as Sp_4 on the map. Most are elongated in the direction of strike of the dacite, and are possibly sill-like bodies similar to the Livingstone Porphyry. They appear to be associated in the field with small granite bodies (Sg), the largest of which forms a prominent hill immediately north of the northern edge of the map. Several very small granite bodies intrude units Sc_a and Sc_d between Burra and London Bridge. A porphyry (Sp_1) similar to the Livingstone Porphyry also intrudes the Laidlaw Volcanics north of Tharwa.

Rhyolitic porphyry bodies (Sr) form two dyke-like bodies in the Deakin Volcanics 4 km northeast of Tharwa. The northwest strike of these bodies probably has regional structural significance relating to the stress regime at the time of intrusion, because another rhyolitic intrusive (Sp_3) in the Williamsdale Dacite Member strikes in the same direction. Pale crystalline rocks mapped as leucogranite (Sgl) crop out in several places adjacent or close to the Murrumbidgee Fault.

The exact age of the intrusives is not known, but they are assumed, from their similarity in composition to the volcanics, to have been intruded during or shortly after deposition of the volcanics. One thin section of the Livingstone Porphyry contains minor hornblende, which indicates an affinity with the Rothlyn Formation rather than the Colinton Volcanics. As the porphyry intrudes the base of the Rothlyn Formation at its northern end it must be in any case younger than the Colinton Volcanics; it is possibly younger than the Rothlyn Formation as well.

CAINOZOIC

The Silurian rocks in many places are covered by Cainozoic deposits consisting mainly of alluvium and colluvium, but also including extensive basalt in the south. The basalt is of Eocene age (Wellman & McDougall, 1974) and extends from the south along the crests of ridges and along terraces from where older rocks are completely covered. The basalt crops out as very numerous, small rounded boulders easily distinguishable from the larger basalt outcrops in the Silurian sequence.

Tertiary sediments northeast of Cooma consist of high-level gravels directly overlying bedrock, and probably antedating the basalt, and post-basalt sediments in lower-lying areas along watercourses associated with the development of an extensive lake in Miocene times (Taylor & Walker, 1986). These sediments include gravel, clay, lignite and diatomite. Minor amounts of silcrete occur on the pre-basalt erosion surface, the most extensive overlying the Cloyne Limestone Member around GR 975948 as shown on the map. Other silcrete occurrences in the general area are referred to by Browne (1972).

Tertiary to Quaternary deposits of alluvium and colluvium flank the main watercourses and cover the lower slopes of the major hills and ridges. They includes gravel, sand, silt and clay. Sand along the Murrumbidgee River has been exploited for building construction purposes. Fine-grained sand of aeolian origin forms dunes east of the Murrumbidgee River south of Bredbo.

CHEMISTRY OF THE VOLCANIC ROCKS

Forty-one volcanic rock samples from within the area mapped, and a few from extensions of units to the north of the area, were analysed by AMDEL for major elements and selected trace elements. The results of the analyses enabled chemical separation of the rocks into dacites and rhyolites according to the system proposed by the IUGS Subcommission on the Systematics of Igneous Rocks (Le Maitre, 1984) as shown in Figure 1.

The aim was to use the analyses to:

(a) help confirm or disprove correlations between individual subunits in the Colinton Volcanics with subunits in the Deakin and Laidlaw Volcanics suggested by field observation and petrography,

(b) correlate similar units within parts of formations now separated by folding and faulting, and

(c) identify any progressive trends in chemical composition from the oldest volcanic subunits to the youngest.

The full results of the analyses, giving BMR registered number, rock type, rock unit and grid references of sample locations, are shown in Appendix 1. Abbreviated results showing major elements only, with analyses grouped according to formations and listed in approximate order of succession within each formation are shown in Tables 9 to 12.

Alteration of all the rocks is, to some degree, a limiting factor that has to be taken into account when comparing compositions. The mafic minerals are chloritised or oxidised in most of the rocks analysed, and in many the plagioclase is albitised or sericitised. The analyses were used to classify the rocks into rhyolites and dacites (Fig. 1).

The chemistry proved useful in indicating differences between subunits in the TiO_2, Mgo and total Feo contents which vary between otherwise petrographically similar dacitic crystal tuffs, and suggest correlations between subunits of different formations. For instance the Williamsdale Dacite Member is a dacitic crystal tuff with similar mineralogy and texture to the lowermost unit of the Laidlaw Volcanics (Sl_1), but whilst it contains comparable proportions of silica to unit Sl_1 the TiO_2, MgO and total FeO from 5 analyses (8-12, Table 9) show appreciably higher values than any that were obtained for Sl_1. The analyses of unit Sl_1 that have been used in this comparison are

Table 9. Major element analyses of Colinton Volcanics (lower part)

	Lowermost Colinton Volcanics							Williamsdale Dacite Member				
	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	63.00	66.80	68.00	67.00	66.60	68.70	68.00	70.40	69.20	68.20	68.60	68.90
TiO_2	0.61	0.50	0.53	0.66	0.58	0.60	0.57	0.54	0.59	0.60	0.62	0.55
Al_2O_3	14.60	13.90	12.80	14.00	14.10	13.70	13.60	13.40	14.10	13.60	13.60	13.90
Fe_2O_3	1.05	2.47	1.41	1.21	2.24	1.60	1.71	1.18	1.73	1.59	1.86	1.59
FeO	4.70	1.99	3.82	3.50	2.40	2.70	2.65	2.50	2.42	2.78	2.63	2.26
MnO	0.06	0.11	0.11	0.11	0.07	0.07	0.07	0.06	0.08	0.08	0.09	0.07
MgO	3.45	2.39	2.35	1.95	1.91	2.06	1.80	1.49	1.65	2.10	2.16	1.78
CaO	3.15	1.93	1.02	3.64	4.80	3.36	4.42	3.38	3.16	2.96	2.80	2.96
Na_2O	2.28	3.72	0.26	2.22	21.4	2.22	2.18	2.40	2.52	2.24	2.30	2.48
K_2O	2.70	2.63	5.85	2.78	2.98	3.14	2.92	3.26	3.32	3.42	3.16	3.40
P_2O_5	0.13	0.19	0.21	0.13	0.10	0.12	0.11	0.11	0.09	0.13	0.14	0.12
H_2O+	2.35	1.82	2.14	)2.28	1.42	)1.41	)1.71	)1.00	0.78	1.57	1.63	1.35
H_2O-	0.46	0.33	0.47	)	0.16	)	)	)	0.24	0.22	0.18	0.17
CO_2	1.16	0.71	0.51	0.50	0.65	0.16	0.50	0.07	0.06	0.34	0.42	0.32
TOTAL	99.70	99.49	99.48	99.98	99.85	99.84	100.24	99.79	99.94	98.83	100.19	99.85
TOTAL Fe AS FeO	5.65	4.21	5.09	4.59	4.42	4.14	4.19	3.56	3.98	4.21	4.30	3.69

Notes:

1. BMR registered numbers of samples:- 1 (85360005), 2 (83360057), 3 (83360060), 4 (84360016), 5 (84360012), 6 (84360013), 7 (84360018), 8 (84360020), 9 (84360011), 10 (84360008), 11 (84360007), 12 (84360006).

2. All samples except 3 are dacitic crystal tuffs; 3 is a reworked tuff.

3. Sample locations:- 1 - base of volcanics east of Bredbo; 2-4 - fault-bounded wedge south of Tharwa; 5-7 - east of Williamsdale Dacite Member near Burra.

Table 10. Major element analyses of Colinton Volcanics (upper part) and Rothlyn Formation

	Upper Colinton Volcanics								Rothlyn Formation			
	13	14	15	16	17	18	19	20	21	22	23	24
SiO_2	64.20	71.30	71.50	69.70	69.80	70.40	69.30	67.90	65.00	65.30	63.50	67.40
TiO_2	0.52	0.37	0.49	0.45	0.48	0.42	0.47	0.48	0.55	0.54	0.61	0.42
Al_2O_3	14.10	13.50	13.00	13.90	14.20	14.00	14.70	15.20	14.80	14.60	15.00	14.90
Fe_2O_3	1.78	1.33	1.79	2.40	2.30	1.58	1.88	1.28	1.46	1.38	1.86	1.33
FeO	2.70	1.45	1.65	1.34	1.28	1.33	1.39	2.28	2.05	3.30	3.50	2.60
MnO	0.05	0.06	0.06	0.10	0.08	0.07	0.06	0.07	0.05	0.08	0.05	0.04
MgO	1.64	1.22	1.38	0.88	1.25	1.02	1.15	1.43	1.18	2.82	2.94	1.73
CaO	3.96	1.86	2.60	2.58	3.10	3.18	3.58	3.80	4.08	3.66	4.40	4.06
Na_2O	2.68	2.30	2.42	3.79	3.15	2.54	2.74	2.54	2.76	3.14	2.84	2.74
K_2O	3.12	4.78	3.30	2.85	3.02	3.60	3.24	3.10	3.24	2.90	2.66	2.82
P_2O_5	0.11	0.09	0.10	0.18	0.11	0.08	0.11	0.13	0.12	0.13	0.12	0.11
H_2O+	1.69	1.08	)1.50	1.12	1.19	1.03	1.09	1.55	)3.84	1.67	1.75	1.59
H_2O-	0.38	0.20	)	0.23	0.19	0.21	0.22	0.13	)	0.27	0.35	0.16
CO_2	2.57	0.35	0.20	0.41	0.09	0.35	0.14	0.39	1.99	0.23	0.16	0.13
TOTAL	99.50	99.89	99.99	99.93	100.24	99.81	100.07	100.28	101.08	100.02	99.74	100.03
TOTAL Fe AS FeO	4.30	2.65	3.26	3.50	3.35	2.75	3.08	3.43	3.33	4.54	5.17	3.60

Notes:

1. BMR registered numbers of samples:- 13 (85360003), 14 (84360005), 15 (84360014), 16 (83360056), 17 (84360003), 18 (84360004), 19 (84360009) 20 (83360072) 21 (84360017), 22 (85360002), 23 (85360004), 24 (85360001).

2. Sample lithologies:- 13 - dacitic crystal tuff; 14,15 - rhyolitic crystal tuff; 16 - rhyolite; 17-20 - rhyolitic to dacitic crystal tuff; 21 - dacite; 22,23 - hornblende dacitic crystal tuff (Billilingra Dacite Mbr); 24 - hornblende dacite

3. Sample locations:- 13,23 - Bredbo area; 14-21 - Williamsdale area; 22,24 - east of Cooma

Table 11. Major element analyses of Deakin Volcanics in the Tharwa-Williamsdale area

	25	26	27	28	29	30	31	32	33	34	35	36
SiO_2	69.00	68.20	69.30	72.40	69.70	69.80	67.70	72.00	70.80	71.10	73.70	74.30
TiO_2	0.38	0.45	0.51	0.35	0.45	0.45	0.44	0.54	0.33	0.41	0.20	0.19
Al_2O_3	14.40	14.30	13.60	13.10	14.20	14.10	14.20	13.00	14.00	14.10	13.50	13.30
Fe_2O_3	1.09	1.49	1.23	1.15	0.97	1.40	2.34	3.09	1.22	1.20	1.15	0.81
FeO	1.85	2.52	2.36	1.79	2.44	2.00	1.87	0.28	1.43	1.53	0.82	0.96
MnO	0.04	0.05	0.09	0.07	0.10	0.11	0.10	0.05	0.05	0.04	0.05	0.09
MgO	1.75	2.19	1.35	0.78	1.24	1.45	1.75	0.71	0.97	1.22	0.45	0.65
CaO	1.86	2.66	1.63	1.67	1.73	1.27	3.35	1.32	2.66	2.80	2.15	1.48
Na_2O	3.60	2.46	2.11	2.27	2.86	3.75	3.08	2.73	2.82	2.52	2.51	3.35
K_2O	3.98	3.30	5.15	4.75	4.42	3.60	2.19	3.93	4.07	3.76	4.53	3.53
P_2O_5	0.06	0.18	0.23	0.19	0.22	0.23	0.23	0.23	0.11	0.08	0.09	0.07
H_2+	)1.84	1.36	1.64	1.22	1.28	1.44	1.79	1.23	0.93	0.99	0.66	0.85
H_2O-	)	0.41	0.27	0.21	0.18	0.27	0.26	0.35	0.13	0.22	0.11	0.20
CO_2	0.42	0.42	0.32	0.12	0.20	0.17	0.15	0.69	0.54	0.07	0.16	0.52
TOTAL	100.27	99.99	99.79	100.07	99.99	100.04	99.55	100.05	100.16	100.04	100.08	100.30
TOTAL Fe AS FeO	2.83	3.86	3.47	2.83	3.31	3.26	3.98	3.06	2.53	2.61	1.86	1.69

Notes:

1. BMR registered numbers of samples:- 25 (84360019), 26 (83360061), 27 (83360062) 28 (83360063), 29 (83360064), 30 (83360065), 31 (83360058), 32 (83360059), 33 (83360070), 34 (84360010), 35 (83360069), 36 (83360075).

2. Sample lithologies:- 25,26 - rhyolitic to dacitic crystal tuff; 27,35 - rhyolite; 28,29,32-34,36 - rhyolitic crystal tuff; 30,31 - dacite.

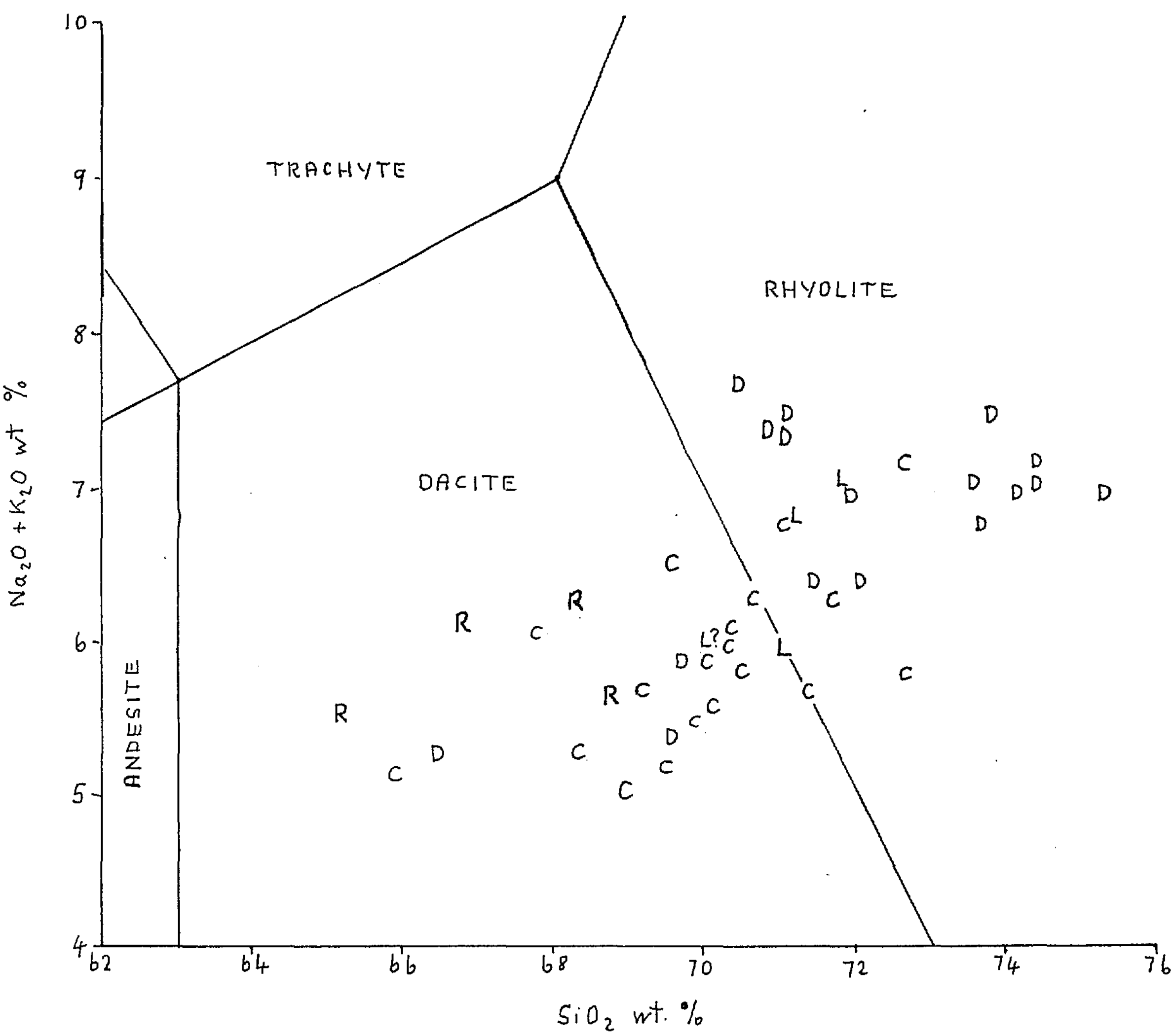
Table 12. Major element analyses of Laidlaw Volcanics in Tharwa-Williamsdale area (37-40) and representative middle and late Silurian volcanics from Canberra area

	Laidlaw Volcanics				Ainslie V.		Mt Painter V.		Deakin V.		Laidlaw V.	
	37	38	39	40	41	42	43	44	45	46	47	48
SiO_2	69.80	69.50	68.90	70.50	66.80	66.16	66.40	66.52	64.80	69.13	68.60	69.62
TiO_2	0.43	0.48	0.43	0.40	0.59	0.57	0.57	0.57	0.71	0.45	0.51	0.48
Al_2O_3	14.10	14.00	14.90	13.70	14.28	14.50	13.80	14.06	14.60	14.23	14.42	13.44
Fe_2O_3	0.90	1.12	1.04	0.89	0.79	0.13	0.81	0.40	1.85	1.59	0.77	0.56
FeO	2.42	2.42	2.24	2.12	3.42	4.17	4.47	4.20	3.60	2.00	2.70	2.75
MnO	0.08	0.04	0.07	0.07	0.04	0.05	0.08	0.07	0.08	0.06	0.05	0.05
MgO	1.46	1.39	1.29	1.19	2.15	2.29	2.92	2.80	2.30	1.40	1.53	1.52
CaO	2.18	3.01	3.55	2.23	2.61	1.57	2.09	1.52	4.34	2.51	3.11	3.43
Na_2O	3.42	2.50	2.65	2.60	2.05	3.95	1.73	1.92	2.38	2.98	2.29	2.40
K_2O	3.26	3.34	3.16	4.38	2.80	3.06	3.38	4.27	2.82	3.32	2.86	2.78
P_2O_5	0.11	0.11	0.12	0.09	0.11	0.07	0.11	0.07	0.17	0.11	0.14	0.10
H_2O+	1.37	1.39	1.11	1.07	1.94	2.04	2.41	2.44	)1.91	1.53	1.68	1.11
H_2O-	0.19	0.14	0.22	0.17	0.06	0.08	0.11	0.08	)	0.09	0.12	0.09
CO_2	0.41	0.23	0.44	0.15	0.55	0.90	0.05	0.40	0.31	0.15	0.35	0.30
TOTAL	100.13	99.67	100.12	99.66	99.19	99.54	98.93	99.32	99.87	99.55	99.63	98.63
TOTAL Fe AS FeO	3.23	3.43	3.18	2.92	4.13	4.29	5.20	4.56	5.27	3.43	3.39	3.25

Notes:

1. BMR registered numbers of samples:- 37 (83360068), 38 (83360067), 39 (83360074) 40 (83360066), 41 (74840012), 42 (74840079), 43 (74840003), 44 (74840086) 45 (84360015), 46 (75360007), 47 (75840001), 48 (75840002).

2. Sample lithologies:- 37-39,47,48 - rhyolitic to dacitic crystal tuff; 40 - rhyolite 41,42,46 - dacite; 43-45 - dacitic crystal tuff.



L Laidlaw Volcanics
D Deakin Volcanics
R Rothlyn Formation
C Colinton Volcanics

Note: Percentages are after recalculation of analyses to 100% minus H_2O and CO_2.

Fig. 1 Rhyolites and dacites between Tharwa and Cooma plotted on part of total alkali silica diagram recommended for the chemical classification of igneous rocks by the IUGS Subcommission on the Systematics of Igneous Rocks (Le Maitre, 1984) three samples from the map sheet area (37-39, Table 12) and two representative previous analyses from the Tuggeranong-Weston Creek area (47 & 48, Table 12). On the other hand the analyses of another similar unit Sc_j (17-20, Table 10) higher in the Colinton Volcanics show an almost identical range of values of these and other elements to those in the Laidlaw Volcanics. This comparison shows up more clearly in graphical form (Fig. 2). A correlation of unit Sl_1 with unit Sc_j rather than the Williamsdale Dacite Member is also consistent with the accessory allanite in each unit (see Laidlaw Volcanics, above).

The inferred correlation between subunits Sl_1 and Sc_j suggests that The Williamsdale Dacite Member, which is lower in the Colinton Volcanics than Sl_j, may correlate with one of the subunits in the Deakin Volcanics. The closest correlation from mineral composition is with unit Sd_b at the base of the Deakin Volcanics; however the lower TiO_2 and total FeO values in unit Sd_b (Fig. 2) make this correlation doubtful and the conclusion is that the Williamsdale Dacite Member is not represented in the Deakin Volcanics.

Chemical and petrographic studies of Silurian Volcanics in the Brindabella 100,000 Sheet area (Owen & Wyborn, 1979), extended later to the Canberra area, have identified a trend with time from volcanics regarded as 'S-type' towards volcanics closer to 'I-type' composition. The two 'types' are analogous with S and I type granites (Chappell & White, 1974), and reflect melting of either a metasedimentary (S-type) or igneous (I-type) source material to form the magma later intruded as granite or extruded as volcanics. In terms of mineral content S-types, such as the Mount Painter Volcanics in the Canberra area, contain accessory cordierite or garnet whilst I-types contain hornblende or clinopyroxene as well as biotite as mafic constituents. The two types can also be identified chemically in several ways. One is by the molecular ratios of Al_2O_3 to $CaO+Na_2O+K_2O$, known as the S-I index; S-types have a relatively high value (generally >1.1) and I-types a low value (generally <1.1).

Most of the volcanics in the Michelago-Cooma area are borderline S and I types in mineralogy. They do not contain cordierite or garnet, which would make them definitely S-type, but neither do most of them contain the hornblende or clinopyroxene characteristic of I-types. Only the dacites with hornblende and/or clinopyroxene in the Rothlyn Formation are definitely I-types from mineralogy. S-I indices were calculated for each of the chemical analyses and plotted in order of succession within each stratigraphic column (Fig. 3). Both the Colinton Volcanics / Rothlyn Formation and Deakin Volcanics / Laidlaw Volcanics columns show overall trends from S-types towards I-types with time.

The wide variations in indices due to mobility of Ca, Na and K during low-grade burial metamorphism within single rock units points to the limited value of these figures. In some cases more than one flow unit could be present, but in others the field evidence suggests that this is not the case. While not

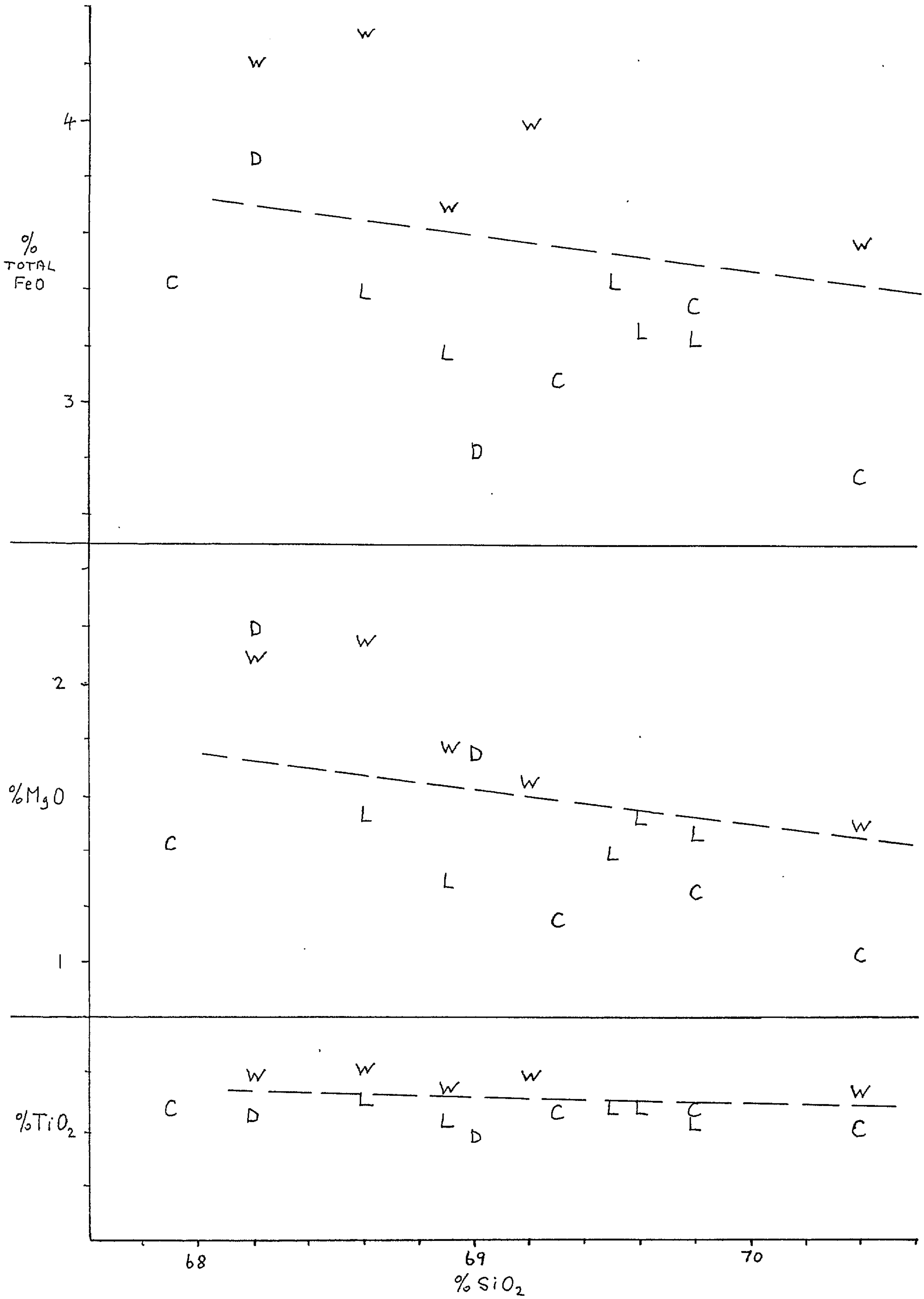


Fig 2 Comparison of total FeO, MgO and TiO_2 figures in dacitic crystal tuffs - Williamsdale Dacite Member (W), Colinton Volcanics unit Sc_j (C), Laidlaw Volcanics (L) and Deakin Volcanics unit Sd_b.

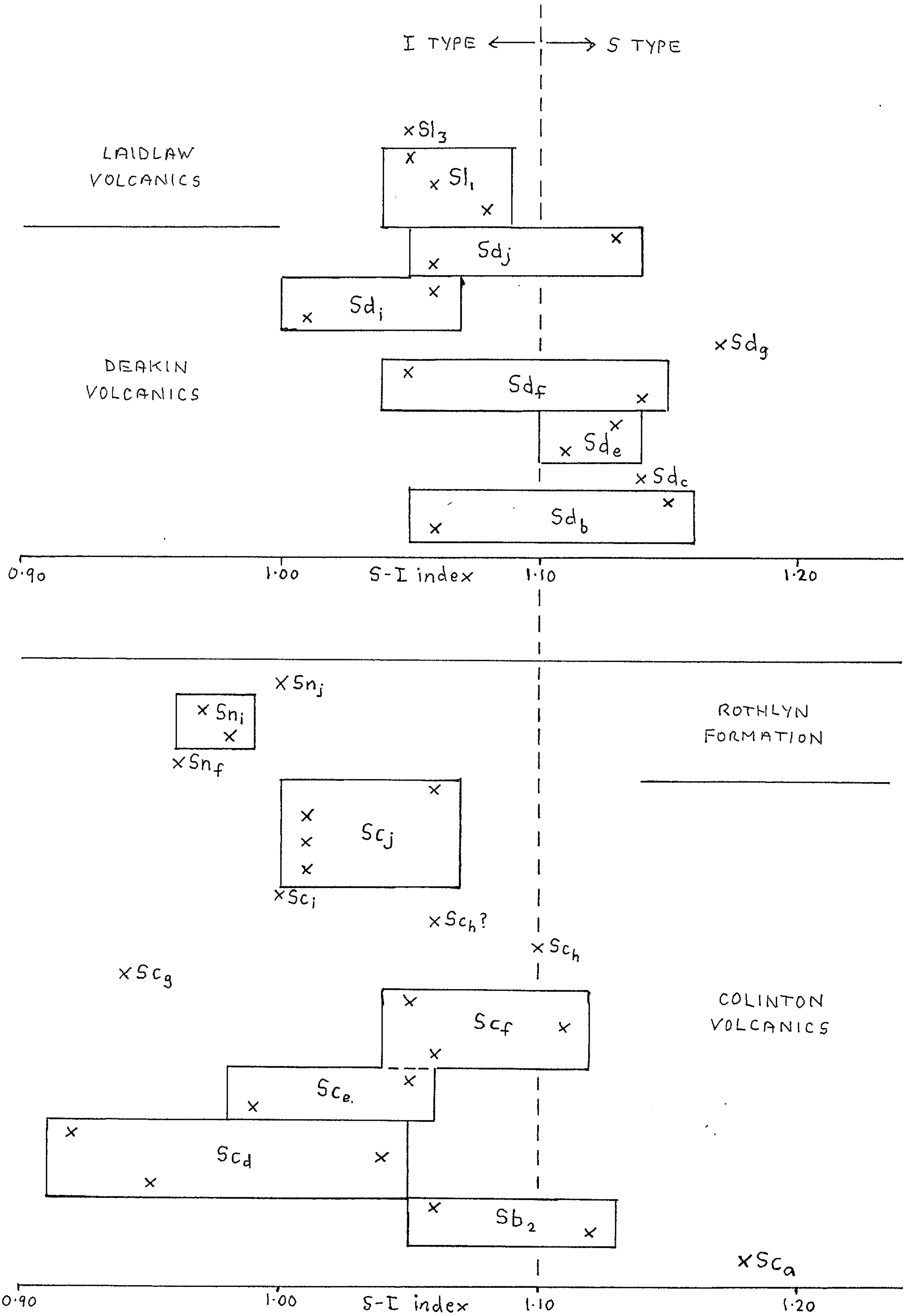


Fig.3 Plot of S-I indices against time for Deakin and Laidlav Volcanics (top), and Colinton Volcanics and Rothlyn Formation.

giving too much weight to single chemical analyses, one sample from unit Sc_a (analysis 1, Table 9) at the base of the Colinton Volcanics east of Bredbo is possibly worth mentioning. This sample has a high S-I index and shows a tendency to resemble the composition of the S-type Mount Painter Volcanics which underlie the Deakin Volcanics in the Canberra City area (representative analyses 43 & 44, Table 12). Both the sample from east of Bredbo and the Mount Painter Volcanics have a high MgO value coupled with a relatively low CaO value, which is unusual in nearly all the Colinton and Deakin Volcanics analyses except where the plagioclase is albitised. No petrographic evidence exists, however, for linking any of the Colinton Volcanics east of Bredbo, or anywhere else, with the Mount Painter Volcanics.

Other samples from subunits near the base of the Colinton Volcanics such as in the Burra area include dacites (in unit Sc_d) with very low S-I indices. No counterparts occur in the Deakin Volcanics, at least in the Tharwa area. However a dacitic crystal tuff forming a relatively small flow within the Deakin Volcanics in the Hume Industrial area was known from previous mapping (Henderson, 1980) to be less rhyolitic than other flows in the Deakin Volcanics. When it was analysed (sample 45, Table 12) its chemical composition was found to be similar to the dacites in unit Sc_d, with low SiO_2 and high CaO relative to MgO. No positive evidence for a direct correlation on petrographic grounds exists, however.

The 17 trace elements analysed in each sample (Appendix 3) show little value for correlation purposes compared with the major elements. The results for some elements are too variable and erratic, and in some cases appear to vary consistently between the different batches of samples sent for analysis, raising doubts about the accuracy of the analyses. In others, the range of results for dacites known to be different units overlap to a large extent, for example in the Williamsdale Dacite Member and unit Sc_j in the Colinton Volcanics. In no instances do the results appear to preclude correlations suggested by the major elements and by petrography.

ISOTOPIC AGE DETERMINATIONS

Three samples, two from the Colinton Volcanics (Williamsdale Dacite Member) and one from the Rothlyn Formation (Billilingra Dacite Member) near Cooma, were submitted to AMDEL for isotopic age determination (AMDEL Report G6406/86, Appendix 2). The samples were selected for the fresh biotite in the former and the fresh hornblende in the latter. The Williamsdale Dacite Member was dated by both the K/Ar and Rb/Sr methods and the Billilingra Dacite Member by the K/Ar method only. A summary of the age determinations is given in Table 13 below.

Table 13. <u>Results of isotopic age determinations</u>

ROCK UNIT	COLINTON VOLCANICS (Williamsdale Dacite Member)		ROTHLYN FORMATION (Billilingra Dacite Member)
SAMPLE NO.	85360051	85360054	85360055
LOCATION (CO-ORDS)	976516	007638	977836
K/Ar AGE (m.y.)	418±3	413±3	407±3
Rb/Sr AGE (m.y.)	411±5	403±4	

The determinations for the Williamsdale Dacite Member compare with a date of 400±6 m.y. obtained by Abell (in press) for the Colinton Volcanics south of Queanbeyan.

Before drawing any conclusions from the results in Table 13 two features relating to the Williamsdale Dacite Member need explanation. One is the variation in results for the two samples and the other is the discrepancy between the results from each age determination method. The variation between the two samples is at least in part due to the amount of slight chloritisation of the biotite, which is greater in sample 85360054 than in sample 85360051. Thus the ages determined for sample 85360051 are probably closer to the true age than those for sample 85360054 and the true age may be older than any of the ages determined. Another factor that could have affected the result is the age of post-Silurian regional deformation known to be mid Devonian (Bain & others, 1987)

An age of 421 m.y. for the Laidlaw Volcanics pooled from a number of Rb/Sr and K/Ar determinations has been arrived at by Wyborn and others (1982). If the chemical and petrographic correlation of the Laidlaw Volcanics with unit Sc_j in the Colinton Volcanics above the Williamsdale Dacite Member is correct, then even the oldest of the four age determinations for the Williamsdale Dacite Member (418±3 m.y.) tends to be too young, although the oldest possible age, 418+3 m.y. or 421 m.y., is exactly the same as that for the Laidlaw Volcanics. As the Laidlaw, Deakin and Colinton Volcanics appear to represent parts of the same volcanic episode the difference in age between the oldest and youngest flow may be very small, and smaller than the experimental error of the age determinations. Further age determinations of the Williamsdale Dacite Member using even fresher samples than those used here could possibly establish with certainty that it is younger than the Laidlaw Volcanics, but at the moment the chemical and petrographic correlations must carry greater weight.

The other result of the age determinations, the younger age for the Billilingra Dacite Member compared with the Williamsdale Dacite Member, corresponds with the conclusions reached from the field work that the Rothlyn Formation is younger than the Colinton Volcanics. The figure of 407 m.y. suggests an earliest Devonian age assuming the Silurian / Devonian boundary falls at 410 m.y.; this is younger than the interpreted Silurian age of fossils in nearby contemporaneous sedimentary rocks. However as for the Colinton Volcanics, the result may have been affected by the later regional deformation.

STRUCTURE

GENERAL

The Michelago-Cooma volcanic belt is bounded to the west by the Murrumbidgee Fault, and, to the east, partly by faults and partly by the unconformity with older rocks. The prevailing westerly dip of the formations in the central part of the belt gives way to synclinoria to the north and south. Shear zones occur along the western boundary and in the north. As already evident from the stratigraphic notes major faults within the belt define six fault blocks, each with a related stratigraphic sequence. The bounding faults of these blocks strike in directions between north-northwest and north-northeast, making the blocks long and narrow in the same meridional direction as that of the belt as a whole. The six blocks recognised, and listed below, are evident in the structural sketch on the map sheet. They are:

1. A main central block of Colinton Volcanics and Rothlyn Formation southwest of the Collingwood Fault extending from Williamsdale to Cooma.

2. The Bransby Shear Zone (southern part) between Colinton and Cooma.

3. The Bransby Shear Zone (northern part) in the Angle Crossing area.

4. A northeastern block of Colinton Volcanics in the Burra-Michelago area.

5. A northwestern block of Deakin and Laidlaw Volcanics.

6. A southeastern block of mainly Rothlyn Formation east of Cooma.

FOLDING

Large-scale folds with wave lengths at map scale are evident south of Bredbo where the prevailing westerly dip in the Michelago-Colinton area changes to a synclinorium. The central syncline of the synclinorium east of Cooma, named the Rock Flat Syncline on the map, is clearly evident in outcrop where resistant shale is extensively exposed south of the Carlaminda Road.

The prevailing plunge of the synclinorium, and the folds within it, is to the south, but locally the plunge is to the north. The synclinorium appears to die out to the north in several ill-defined folds south and east of Bredbo. North of Bredbo nearly all the dips measured are to the west, and even where dips are near-vertical or steep to the east, for example in the shale adjacent to the Billilingra Dacite Member along Gungoandra Creek, bedding is westward facing from observation of sedimentary structures and bedding/cleavage relationships.

Large scale folds are also present in the north. Folding is clearly evident in the Deakin and Laidlaw Volcanics from the dips and outcrop pattern of the sedimentary units, particularly east and north of Tharwa, and west of Williamsdale. A sedimentary unit (Sb_2) reveals a syncline in the northern part of the Bransby Shear Zone west of Angle Crossing. Some folding is probably present in the northern part of the Colinton Volcanics and in the Williamsdale Dacite Member; however, the generally massive nature of the volcanics and the lack of sedimentary units make it difficult to identify. The reappearance of unit Sc_d west of the Williamsdale Dacite Member, west of Burra indicates either a syncline or repetition by faulting, or possible partly both, as shown on cross section ABCD on the map sheet.

Smaller-scale folds exposed in outcrop are commonly tight, with steeply dipping limbs. Overturning of bedding on the limbs is evident in one or two places and suspected in a few others. Small-scale folds typical of those in the Colinton Volcanics are exposed along the Bredbo-Jerangle Road near Connollys Gap (GR 977185), and an anticline in the inferred Cappanana Formation north of Cooma is exposed along the Monaro Highway (GR 927013). In both places the folds are nearly isoclinal.

Although the axial planes of most folds, especially the major ones, are probably near vertical there are some places where overturned bedding, the moderate dip of slaty cleavage in the sediments, or foliation in the volcanics suggest otherwise. One place where an anticline is clearly overturned to the east is northwest of Colinton (GR 915320) where a north-plunging anticline with an overturned eastern limb is well exposed in limestone adjacent to the Murrumbidgee Fault. A clear example of a moderate-dipping cleavage is present in an extensive railway cutting exposure 12 km south of Bredbo (GR 960065).

Finally, small kink folds are commonly developed in the most intensely sheared volcanics. In some places, at least, these folds have horizontal axes, suggesting that they were associated with tension following the compression that produced the foliation (M. Rickard, pers. comm., 1983).

FAULTING

Major faults with large displacements form the boundaries of the main fault blocks. The faults are the Murrumbidgee

Fault, the Collingwood Fault, the Jerrabomberra (Royalla) Fault, the Bumbalong-Middle Flat Fault, the Umeralla Fault and the Angle Crossing Fault. The faults are generally regarded as post dating the initial folding but folds could have been steepened during compressive movements associated with reverse faulting along, for example, the Murrumbidgee Fault.

The Murrumbidgee Fault extends from north of Tharwa nearly to Cooma where its southern extremity is obscured by a cover of Tertiary basalt. The Silurian volcanics to the east of the fault are downthrown against the Murrumbidgee Batholith to the west. Sharp (1949) and Noakes (1957) regarded the fault as a high-angle reverse fault, and observations at GR 923508 near Smiths Road south of Angle Crossing support this view. There a section across the fault is exposed in which the fault is not clean cut but consists of a mylonitic zone several metres wide with a foliation dipping about 65° to the west. Limestone and calcareous shale immediately east of the fault dip west at about 50° into the fault zone. Foliation close to the fault dips to the west in most places, but at GR 893610 west of Angle Crossing a dip of 75° to the east was recorded. The Murrumbidgee Fault was reactivated along some sections during the Tertiary with the formation of a scarp along the central section west of Michelago and Colinton. The scarp dies out to the north in the Tharwa-Angle Crossing area and to the south of Bredbo.

The Collingwood Fault is a northwest-striking fault, marked by quartz reefs, that displaces the Cappanana Formation and Colinton Volcanics between Michelago and Colinton. Both sinistral strike-slip and vertical displacement are involved (Richardson, 1979), the northeast block having moved both up and to the northwest. The lateral displacement near Collingwood is estimated to be about 6 km from the northwest displacement of the Michelago Igneous Complex as shown on the Michelago 1:100 000 geological sheet. A downward displacement of about 2000 m on the southwestern side allows for the greater apparent displacement of the Ryrie Formation. Richardson infers that the fault continues to the northwest from the Monaro Highway through the Livingstone Porphyry to join with the Murrumbidgee Fault. This is unlikely, in view of the large displacement southeast of the highway and lack of displacement of the porphyry. More likely the fault veers to the north parallel to the strike of bedding and continues parallel to the highway for about 20 km towards Williamsdale. A prominent quartz-filled fault striking northwest between 2 and 5 km southeast of Williamsdale may represent the northern end of the Collingwood Fault.

The Jerrabomberra Fault is the name given by Abell (in press) on the Canberra 1:100,000 Sheet to the fault shown as the Royalla Fault on the map. This fault separates the Colinton and Deakin Volcanics between Royalla and Williamsdale. The fault is marked by quartz reefs coinciding with a strain discontinuity between sheared Colinton Volcanics to the east and massive Deakin and Laidlaw Volcanics to the west. The fault continues to the southwest beyond Williamsdale to join with the Angle Crossing

Fault. The eastern block is upthrown in the north, but south of the junction with the Collingwood fault the displacement is uncertain and probably small.

The Bumbalong Fault north of Bredbo and the Middle Flat Fault northeast of Cooma are shown on the map as one continuous fault, but this has not been established with certainty. The Bumbalong Fault in the north, which branches from the Murrumbidgee Fault northwest of Colinton, is inferred from a discordance of strongly foliated rock units in the Bransby Shear Zone to the west from those in the Rothlyn Formation to the east. A steep scarp west of Colinton is possibly related to Tertiary reactivation of the fault, but could also be due to differential erosion between more resistant volcanics to the west of the fault and less resistant sedimentary rocks to the east. The fault is not clearly evident between Bredbo and Bunyan. Platts (1988) gives several reasons for no fault at the eastern edge of this section of the Bransby Shear Zone including:

'1. a coherent depositional sequence,

2. no abrupt change in metamorphic grade (grade decreases from west to east),

3. similar rocks occurring on opposite sides of inferred fault, and

4. strain taken up in sedimentary rocks as the reason for the foliation dying out to the east.'

Farther to the south The Middle Flat Fault is marked by quartz reefs, again with intensely foliated volcanics west of the fault and less deformed sedimentary and volcanic rocks east of it.

The Umeralla Fault defines the eastern side of the volcanic belt between the Bredbo River and the Cooma-Numeralla road. It continues farther to the south where it cuts the Rothlyn Formation, and is finally covered by Tertiary basalt. The fault is poorly exposed in a road cutting near the Numeralla River (GR 998975), and is marked by quartz reefs and silicification of sedimentary rocks near the Cooma-Numeralla road. The displacement on the Umeralla Fault is either west side down or strike-slip with the east side displaced to the south. The latter seems unlikely as it would be in the opposite sense to the strike-slip movement on the Collingwood Fault.

The Angle Crossing Fault is a subsidiary fault of the Murrumbidgee Fault. In the north the fault is marked by a west to east transition from foliated volcanics to massive volcanics and in places by quartz reefs. South of the junction with the Royalla Fault volcanics both sides of the fault are foliated and only a few quartz reefs are exposed.

Three other named faults of lesser importance are the

Burra Fault, the Warri Fault and the Lanyon Fault.

The Burra Fault, on the eastern edge of the volcanic belt south of Burra is marked by sheared ironstone reefs. It does not appear to extend as far south as shown by Richardson (1979). The ironstone gossans southeast of Michelago, exposed in old mine workings, appear to be entirely within the shale of the Cappanana Formation rather than representing fault fillings. The only faults in this area appear to be northwest-striking faults displacing the Cappanana Formation in a similar way to the Collingwood Fault farther to the south.

The Warri Fault forms the eastern boundary of the Williamsdale Dacite Member in the Burra area. The fault is a strain discontinuity marked by the contact of intense foliation on the western edge of unit Sc_d to the east and massive Sc_e to the west. Freshwater springs near the road to Queanbeyan 5 km north of Burra occur along the fault.

The Lanyon Fault is a north-striking fault east of Tharwa that causes a repetition of the east-dipping sequence in the Deakin Volcanics. A downward displacement on the western side of about 700 m is estimated southeast of Tharwa based on the thickness of the sequence displaced.

Numerous other small faults shown on the map, most striking either northwest or northeast, are evident from offsets of sedimentary units.

SHEAR ZONES AND FOLIATION

The most extensive shear zone is the Bransby Shear Zone, which affects the volcanics in belts adjacent to the Murrumbidgee Fault and also the granite immediately west of the fault. Other shear zones are the Williamsdale Shear Zone through Royalla and Williamsdale, and the Burra Shear Zone through Burra and Michelago.

The intensity of deformation of the volcanics and porphyries within the shear zones is controlled by proximity to the major faults. Dacitic volcanics and tuffs in the shear zones tend to be more intensely deformed than rhyolites and coarse porphyritic intrusives. Sedimentary rocks, mainly shale, have well-developed cleavage parallel to foliation, but limestones which lack platy minerals appear almost massive, except for closer jointing parallel to the strike of the shear zone.

Foliation within the shear zones strikes subparallel to the strike of major faults, and generally curves around in sympathy with bends in these structures, such as where major faults diverge. Thus the Williamsdale Shear Zone bifurcates south of Williamsdale; one branch follows the Royalla Fault south-southwest to converge with the Bransby Shear Zone, and the other bends around to the south-southeast along the Collingwood

Fault. The Burra Shear Zone, however, is truncated by the Collingwood Fault south of Michelago. Foliation in some units (Sc_a and Sc_c) east of Colinton and Bredbo could be a southern continuation of this zone offset by strike-slip movement along the Collingwood Fault. The foliation dies out south of the Bredbo-Jerangle road.

Not all foliation is confined to the major shear zones. Narrow zones of intense shearing striking north-northeast are found in a few places, and some of the Colinton Volcanics in the Colinton-Bredbo area besides Sc_a and Sc_c are foliated in places.

STRUCTURAL SYNTHESIS

The folds, faults and shear zones that were produced during deformation are essentially the result of east-west compression. Platts (1988) interprets a single, long-lasting metamorphic event during which two deformational events occurred. The first produced the major regioal synclinorium and the second weak crenulation cleavage. The swings away from meridional strike of folding in some areas is probably due in part to the buttressing effects of the Murrumbidgee Batholith to the west, and possibly also other intrusives to the east. The thickening of the volcanics to the northwest in the north could explain the swing of structural trends to the northeast in this area. The shear zones, such as the Bransby Shear Zone, would have developed against these buttresses. The large strike-slip movement of 6 km on the Collingwood Fault south of Michelago appears to have been taken up in intense deformation in the Burra and Williamsdale Shear Zones. The fault itself is the largest of several in a system of northwest-trending strke-slip faults which developed east of Michelago. Conjugate northeast-striking faults, probably also strike-slip, developed southeast of Bredbo, but are not as prominent as the northwest system.

GEOLOGICAL HISTORY

The late Silurian sedimentary and volcanic rocks in the Michelago-Cooma area were originally deposited over a wide area but are now preserved in a downfaulted rift. Thus an account of the geological history of the Michelago-Cooma area from the beginning of the late Silurian must take into account other nearby preserved remnants of late Silurian and younger rocks of the Canberra-Yass Shelf and Captains Flat Graben.

The regional picture is pieced together and interpreted from the preserved remnants as shown on the relevant 1:100,000 geological sheets (Richardson, 1979; Owen & Wyborn, 1979; Abell, in press). It starts with the formation, in late middle Silurian time, of a submarine sedimentary shelf, the Canberra-Yass Shelf on previously folded uplifted and eroded Ordovician and early Silurian rocks. Sediments of the Canberra Formation were deposited initially. Progressive subsidence caused the shelf deposition to spread laterally to the east, at the same time as volcanic deposits began encroaching on the shelf from the west.

The volcanic activity was not continuous, but was punctuated by quiescent periods during which the submarine eastern extremities of the volcanic deposits were covered with further sediment, and the subaerial volcanic deposits to the west eroded. As each succeeding episode of volcanic activity spread volcanic deposits farther to the east, the composition of the volcanics changed from S-type to I-type. A mainly sedimentary basin, the Ngunawal Basin (Bain & others, 1987) then developed with its axis in the Captainrs Flat area and extending south to the Cooma area. This basin continued to receive more sediments until the region was again uplifted in the Middle Devonian during the Tabberabberan Orogeny.

The succession in the Michelago-Cooma area represents a section extending from the eastern edge of the Canberra-Yass Shelf (Deakin and Laidlaw Volcanics) to the western side of the Ngunawal Basin. The Cappanana Formation represents shallow water marine sedimentation with coral reefs and shoals during the initial formation of the Ngunawal Basin. Sedimentation and volcanism during the earlier (S-type) volcanic episode to the west, apparently did not reach the Michelago area.

Following deposition of the Cappanana Formation in the east and the Yarralumla Formation at Canberra renewed outpourings of volcanics ranging from S to I-type are represented by the Colinton, Deakin and Laidlaw Volcanics. At first these volcanics were submarine, but, as they rapidly built up, the shoreline moved to the east, so that in the Michelago area, and to the north, most of the Deakin, Laidlaw and upper part of the Colinton Volcanics were deposited subaerially. The subaerial volcanics are represented by the leached and purple oxidised rhyolites and dacites west of the Monaro Highway.

As volcanism began to diminish, continuing subsidence caused the sea to advance again from the east. The subaerial volcanics forming the land to the west were eroded, reworked and redeposited in the shallow water, alternating with muddy sediments and coral reefs and shoals, now represented by the thick limestone lenses at the base of the Rothlyn Formation along the Murrumbidgee River west of Michelago. In the south the Colinton Volcanics barely reached the southeastern extremity of the area east of Cooma, and marine sedimentation continued during the period of subaerial volcanics to the north.

During and following the final period of deposition of the Colinton Volcanics high-level intrusive porphyries, such as the Livingstone Porphyry, were emplaced as dykes and sill-like bodies. The rhyolitic dykes in the lower parts of the Deakin and Colinton Volcanics could represent feeders for some of the rhyolites in the upper parts of these formations.

As the sea advanced again from the east a new source of exclusively I-type volcanics began erupting in the south, east or northeast of Cooma. Eruptions were spasmodic, with long periods between each flow during which muddy sediments covered each successive flow. These interbedded sediments and volcanics are now represented by the Rothlyn Formation. Finally volcanism ceased, and the sediments became increasingly sandy (subunit Sn_r) as the Ngunawal Basin filled. Sedimentation may have continued into the early Devonian but any such beds have since been removed by erosion following the Tabberabberan Orogeny in the Middle Devonian, which is known to have been the main deformation episode in the Ngunawal Basin (Bain & others, 1987).

The major folding and faulting movements were complete by the late Palaeozoic, and thereafter movements were epeirogenic, with only minor warping and adjustments along faults such as the Murrumbidgee Fault. Uplift beginning in the early Tertiary was accompanied in the south by extensive basaltic volcanism (Wellman & McDougall, 1974). Erosion and downcutting of river valleys commenced, but later a large lake temporarily developed in the south on the northern side of the basalts (Taylor & Walker, 1986). The lake occupied the valleys of the Murrumbidgee and Numeralla Rivers from about 5 km south of Bredbo, and extended up the valley of Middle Flat Creek. Formation of the lake is attributed to movement on the Murrumbidgee Fault causing damning of the Murrumbidgee River near Bredbo. The lake lasted for much of the Miocene period and was progressively filled with sediment until it overflowed and drained again at the northern end. Thereafter erosion and downcutting of the river valley, which had continued in the north, resumed in the south, and removed some of the lake sediments and basalt as well as the surrounding Silurian rocks. At the same time deposits of alluvium and colluvium accumulated along the major rivers and watercourses and below steep slopes. Continued downcutting of the Murrumbidgee River north of Bredbo has left much of the alluvium and presumably underlying Tertiary deposits perched in open valleys 100 m or more above the level of the river.

MINERAL DEPOSITS

The locations and names of small, abandoned mines and prospects are shown on the map, together with element symbols of the minerals exploited or reported. The information is derived from the Canberra and Bega 1:250 000 metallogenic maps (Gilligan, 1974; Barnes & Herzberger, 1975). Many of the sites have been observed and located accurately during the recent fieldwork. Details derived mainly from the mine data sheets accompanying the metallogenic maps (Gilligan, 1975; Herzberger & Barnes, 1978) are included in a summary of the deposits given in Table 14. Platts (1988) discusses mineralisation in the Silurian volcanosedimentary belts of the Canberra region with detailed study of prospects in the Bredbo-Bunyan area, including some recent ones not listed in Table 14 or shown on the map.

Many of the mineral occurrences are interpreted as stratiform deposits related directly to the late Silurian volcanism. These deposits tend to be in tuffaceous sedimentary rocks associated with the volcanics rather than in the volcanics themselves. Platts (1988) identifies a number of deposits along the western half of the Silurian belt between Bredbo and Bunyan as forming a mineralised horizon along the top of a subaerial volcanic sequence (Colinton Volcanics) and in the overlying transgressive sequence (Rothlyn Formation). He records mineralisation there as consisting of disseminations and veins of pyrite, basemetal sulphides and gold-rich sulphidic barite associated with zones of sericitic, K-feldspar, advanced argillitic and propylitic alteration. Platts interprets the mineralisation as having formed in an epithermal system which operated in a mixed subaerial and submarine setting. The Harnett deposit is one of the deposits included in this group. Deposits higher in the transgressive sequence east of Cooma are the Dartmoor and Skidmore deposits.

The relatively few mineral deposits in the thick, more massive, subaerial dacitic and rhyolitic crystal tuffs and flows north of Bredbo are principally mainly gold-bearing vein deposits. Two such deposits are at the Collington gold mine and the Michelago gold prospect. The three deposits in limestone, the Colinton silver and the Burra silver-lead in the Cappanana Formation and the Bredbo copper, silver, lead are interpreted as hydrothermal replacement deposits. The diatomite deposit near Cooma was laid down in the Tertiary lake (Taylor & Walker, 1986).

ACKNOWLEDGEMENTS

This project originally started with a more restricted scope aimed at clarifying stratigraphic relationships in the volcanics in the Tharwa-Williamsdale area. It was later extended to cover the entire belt of late Silurian formations as far south as Cooma, as part of a study of the regional geological setting of the Woodlawn and Captains Flat massive sulphide deposits. Discussions with D. Wyborn, J.H.C. Bain and R.S. Abell as part of this project provided valuable background on the regional picture. Understanding of the geology of much of the section between Bredbo and Cooma was advanced in discussions with W. Platts of the Department of Geology, Australian National University, who made available the results of his own geological mapping between Bredbo and Bunyan, as well as copies of geological maps prepared by mining exploration companies in the Bredbo-Cooma area. The draft typescript was reviewed by R.S. Abell whose helpful suggestions are acknowledged.

Table 14. Data on abandoned mines and prospects

NAME OF MINE	CO-ORDS	WORKINGS	HOST ROCK	MINERALISATION	FORM OF MINERALISATION
Birchams	990120	Shallow pits	Volcanic breccia, shaly tuff (Sc_a)	Galena; secondary limonite pyromorphite, zinc salts (?)	Disseminated in host rock; large cellular gossan at surface.
Bransby silver mine	988146	Shafts, adits	Altered lithic tuff, limestone (Sa_2)	Galena, pyrite	Stockwork
Bredbo (Baalgammon) copper, silver and lead mine (shown in error as Reed & party on map)	970209	Shafts, drives, cross-cuts, shallow pits	Limestone (Sc_b)	Chalcopyrite, galena, pyrite, bornite(?); secondary malachite, azurite, chalcocite, cuprite	Stockwork
Bredbo barite deposit	958243	Shafts, shallow pits, open-cut	Dacitic tuff, jasper (Sc_g)	Barite, galena; secondary limonite, psilomelane, pyrolusite	Barite veins within the manganese oxides
Burra silver-lead mine	026636	Shafts, shallow pits	Limestone (Sa_2)	Galena, pyrite	Disseminated in host rock
Bushy Hill area mines (Star of the north, No. 1 north , etc.)	937880	Shafts, drives, cross cuts, winzes, stoping, open-cut	Rhyolitic ash-flow tuff, dacitic tuff (Sb_1)	Pyrite, gold, galena, sphalerite, chalcopyrite (?)	In veins and disseminated in host rock
Collington gold mine	934323	Shafts, shallow pits, adits	Dacitic crystal tuff (Sc_o)	Gold, galena(?)	In quartz vein
Colinton silver mine	977243	Shafts, winzes, shallow pits, adits	Limestone (Sa_2)	Galena, pyrite, chalcopyrite; secondary limonite, malachite	Stockwork
Colinton silver prospect	096283?	Shafts	Dacitic tuff (Sc_a)	Pyrite, galena, sphalerite	Disseminated in host rock
Dartmoor and Dartmoor East mines	982865	Shafts, cross-cuts, stoping, shallow pits, drives	Tuffaceous shale, crystal tuff, chert (Sn_m, Sn_n)	Pyrite, sphalerite, galena, chalcopyrite; secondary malachite, limonite, chalcocite, azurite	Disseminated in host rock
Harnett prospect (shown in error as 'Hartnett' on map)	947008	None; mineralisation observed in drill core	Dacitic crystal and crystal vitric tuff, both foliated (Sb_1)	Pyrite, magnetite, sphalerite, galena, chalcopyrite, tennantite; secondary limonite	Disseminated in sulphide bands striking parallel to foliation; extensive zone of silicification at surface
London Bridge mine	031651	Shafts, now filled in	Dacitic crystal tuff (Sa_1?)	Galena; secondary limonite	Uncertain
McTiernans umber mine	990497	Open-cut	Sandstone, quartzite (Sa_1)	Gold; secondary limonite, pyrolusite	Residual deposit near contact of Ordovician and Silurian sedimentary rocks

Table 14 (continued)

NAME OF MINE	CO-ORDS	WORKINGS	HOST ROCK	MINERALISATION	FORM OF MINERALISATION
Michelago copper prospect	965433	None; mineralisation observed in drill core	Dacitic crystal tuff, black shale (Sa_2, Sc_a)	Pyrite, chalcopyrite, sphalerite, galena	Disseminated(?)
Michelago iron quarries	966430	Shafts, open-cut	Shale, siltstone (Sa_2)	Magnetite, pyrite, native copper, chalcopyrite; secondary limonite, haematite, martite	Residual
Michelago gold prospect	940470	Shafts, shallow pits	Dacitic crystal tuff (Sc_i)	Gold; secondary malachite	In quartz vein
Middle Flat diatomite deposit	958924	Shafts, drives, open-cut, stoping	Associated with Tertiary lake sediments	Diatomite	Massive
Reed and party copper lode [shown in error as Bredbo (Baalgammon) on map]	972204	Shafts, shallow pits	Dacitic crystal tuff (Sc_a)	Chalcopyrite, bornite; secondary malachite, limonite, cuprite	In quartz vein
Rosebank mine	003923	Shafts	Slate (Sn_a?)	Chalcopyrite; secondary malachite	In quartz vein related to fault
Ryries gold prospect	932381	Shafts, shallow pits	Dacitic tuff (Sc_k)	Pyrite, galena, chalcopyrite, gold; secondary haematite	In quartz veins
Skidmore copper mine	005885	Shafts, drives, cross cuts, now filled in	Crystal lithic tuff (Sn_1)	Pyrite, chalcopyrite, arsenopyrite; secondary limonite	Disseminated in host rock
Spring Valley prospect	005539	None; mineralisation observed in drill core	Tuff, altered shale (Sc_a	Pyrite, chalcopyr- secondary haematite, limonite	Stockwork and dissem-
Woolshed prospect	985172	Shafts	Tuffaceous shale, crystal tuff (Sa_2, Sc_a?)	Limonite	Residual boxwork
Yarradon iron deposit	018606	Shafts, open-cut	Fine-grained sandstone (Sa_2)	Limonite	Residual
Unnamed, 2 km southwest of Colinton	932284	Shafts, adits	Flow-banded rhyolite, crystal tuff (Sc_o)	Pyrite, gold; secondary limonite	In quartz vein
Unnamed, 8 km south of Bredbo	947106	Shallow pits	Intermediate volcanics, slate (Sb_1)	Barite	In quartz veins

REFERENCES

ABELL, R.S., in press - The geology of the Canberra 1:100 000 Sheet area, New South Wales and Australian Capital Territory. Bureau of Mineral Resources, Australia, Bulletin (in press).

BACZYNSKI, N.R.P., 1970 - Geology east of Bredbo, N.S.W. B.Sc. (Hons) Thesis, Australian National University (unpublished).

BAIN, J.H.C., WYBORN, D., HENDERSON, G.A.M., STUART-SMITH, P.G., ABELL, R.S., & SOLOMON, M, 1987 - Regional geological setting of the Woodlawn and Captains Flat massive sulphide deposits, NSW, Australia. Proceedings of the Pacific Rim Congress, Gold Coast, Australia.

BARNES, R.G., & HERZBERGER, G.A., 1975 - Bega 1:250,000 Metallogenic Map. Geological Survey of New South Wales, Sydney.

BEST, J.G., D'ADDARIO, G.W., WALPOLE, B.P., & ROSE, G., 1964 - Canberra, A.C.T. and N.S.W. - 1:250,000 Geological series. Bureau of Mineral Resources, Australia. Sheet SI55-16 [2nd edn).

BROWNE, W.R., 1972 - Grey billy and its associates in Eastern Australia. Proceedings of the Linnaean Society of New South Wales. 97, 98-129.

CHAPPELL, B.W., & WHITE, A.J.R., 1974 - Two contrasting granite types. Pacific Geology, 8, 173-74.

CLARKE, W.B., 1878 - Remarks on the sedimentary formations of New South Wales. Sydney, Government Printer; 4th edn. 1878.

GILLIGAN, L.B., 1974 - Canberra 1:250,000 Metallogenic Map. Geological Survey of New South Wales, Sydney.

GILLIGAN, L.B., 1975 - Mine Data Sheets to accompany Metallogenic Map, Canberra 1:250,000 Sheet. Geological Survey of New South Wales, Sydney.

GOLDSMITH, R.C.M., & EVANS, W.R., 1980 - Notes to accompany a geological map at 1:10,000 scale of the Googong Reservoir, Queanbeyan River, New South Wales. Bureau of Mineral Resources, Australia, Record 1980/21 (unpublished).

HALL, L.R., ROSE, G., & POGSON, D.J., 1967 - Bega, NSW - 1:250,000 Geological series. Geological Survey of New South Wales, Sydney. Sheet SJ55-4.

HENDERSON, G.A.M., 1980 - Geology of Canberra, Queanbeyan and environs - 1:50,000 scale geological map. Bureau of Mineral Resources, Australia.

HERZBERGER, G.A., & BARNES, R.G., 1978 - Mine Data Sheets to accompany Metallogenic Map, Bega 1:250,000 Sheet. Geological Survey of New South Wales, Sydney.

HERZBERGER, G.A., BARNES, R.G. & BOWMAN, H.N., 1978 - A metallogenic study of the Bega 1:250,000 Sheet. Geological Survey of New South Wales, Sydney.

JACOBSON, G., VANDENBROEK, P.H., & KELLETT, J.R., 1976 - Environmental geology for urban development, Tuggeranong, Australian Capital Territory. BMR Journal of Australian Geology and Geophysics, 1, 175-96.

JOPLIN, G.A., 1943 - Petrological studies in the Ordovician of New South Wales II. The northern extension of the Cooma Complex. Proceedings of the Linnaean Society of New South Wales, 68 (5-6), 159-83.

KELLETT, J.R., 1981 - Hydrogeological investigations of two basins at Lanyon, ACT, 1974-1976. Bureau of Mineral Resources, Australia, Record 1981/61 (unpublished).

LE MAITRE, R.W., 1984 - A proposal by the IUGS Subcommission on the Systematics of Igneous Rocks for a chemical classification of igneous rocks based on the total alkali silica (TAS) diagram. Australian Journal of Earth Sciences, 31(2), 243-49.

NOAKES, L.C., 1957 - The significance of high-angle reverse faults in the Canberra region. Bureau of Mineral Resources, Australia, Record 1957/2 (unpublished).

ÖPIK, A.A., 1958 - Geology of the Canberra City district. Bureau of Mineral Resources, Australia, Bulletin 32.

OWEN, M., & WYBORN, D., 1979 - Geology and geochemistry of the Tantangara and Brindabella area. Bureau of Mineral Resources, Australia, Bulletin 204.

PILLANS, B., 1974 - Surficial geology of the Murrumbidgee-Bredbo interfluve with notes on the bedrock geology. B.Sc. (Hons) Thesis, Australian National University (unpublished).

PLATTS, W.D., 1988 - A study of the base-metal, gold and barite mineralisation in the Silurian volcanosedimentary belts of the Canberra region. M.Sc. Thesis, Australian National University (unpublished).

RICHARDSON, S.J., 1979 - Geology of the Michelago 1:100,000 Sheet 8726. Geological Survey of New South Wales, Sydney.

RICHARDSON, S.J., & BARRON, L., 1977 - Michelago, NSW - 1:100,000 Geological Series. Geological Survey of New South Wales, Sydney. Sheet 8726.

SHARP, K.R., 1949 - The general geology of the Michelago district. B.Sc. (Hons) Thesis, University of Sydney (unpublished).

STRUSZ, D.L., 1971 - Canberra, Australian Capital Territory and New South Wales - 1:250,000 Geological series. Bureau of Mineral Resources, Australia, Explanatory Notes SI/55-16.

TAYLOR, G., & WALKER, P.H., 1986 - Tertiary Lake Bunyan, Northern Monaro, NSW, Part 1: geological setting and landscape history. Australian Journal of Earth Sciences 33(2), 219-29.

TURNER, S., & PICKETT, J., 1982 - Silurian vertebrates in Australia. Search 13, 314-5.

WELLMAN, P. & McDOUGALL, I, 1974 - Potassium-argon ages on the Cainozoic volcanic rocks of New South Wales. Journal of the Geological Society of Australia, 21, 247-72.

WYBORN, D., OWEN, M, COMPSTON, W., & McDOUGALL, I, 1982 - The Laidlaw Volcanics: a late Silurian point on the geological time scale. Earth and Planetary Science Letters, 59, 90-100.

APPENDIX 1

CHEMICAL ANALYSES OF VOLCANIC ROCKS

REG. NO	83360056	83360057	83360058	83360059	83360060	83360061	83360062	83360063	83360064
FORMATION OR MEMBER	COLINTON VOLCANICS	COLINTON VOLCANICS	DEAKIN VOLCANICS	DEAKIN VOLCANICS	COLINTON VOLCANICS	DEAKIN VOLCANICS	DEAKIN VOLCANICS	DEAKIN VOLCANICS	DEAKIN VOLCANICS
SUBUNIT SYMBOL	Sc_i	Sb_1	Sd_f?	Sd_g	Sb_i	Sd_b	Sd_c	Sd_e	Sd_e
ROCK TYPE	Rhyolite	Sheared dacitic crystal tuff	Dacite	Rhyolite	Sheared tuff	Dacitic crystal tuff	Rhyolite	Rhyolitic crystal tuff	Rhyolitic crystal tuff
GRID. REF	936578	919580	924601	916628	901618	892664	893670	906672	898688
1:100,000 MAP SHEET	Michelago	Michelago	Michelago	Michelago	Michelago	Michelago	Michelago	Michelago	Michelago
SiO_2	69.70	66.80	67.70	72.00	68.00	68.20	69.30	72.40	69.70
TiO_2	0.45	0.50	0.54	0.44	0.53	0.45	0.51	0.35	0.45
Al_2O_3	13.90	13.90	14.20	13.00	12.80	14.30	13.60	13.10	14.20
Fe_2O_3	2.40	2.47	2.34	3.09	1.41	1.49	1.23	1.15	0.97
FeO	1.35	1.99	1.87	0.28	3.82	2.52	2.36	1.79	2.44
MnO	0.10	0.11	0.10	0.05	0.11	0.05	0.09	0.07	0.10
MgO	0.88	2.39	1.75	0.71	2.35	2.19	1.35	0.78	1.24
CaO	2.58	1.93	3.35	1.32	1.02	2.66	1.63	1.67	1.73
Na_2O	3.79	3.72	3.08	2.73	0.26	2.46	2.11	2.27	2.86
K_2O	2.85	2.63	2.19	3.93	5.85	3.30	5.15	4.75	4.42
P_2O_5	0.18	0.19	0.23	0.23	0.21	0.18	0.23	0.19	0.22
H_2O^+	1.12	1.82	1.79	1.23	2.14	1.36	1.64	1.22	1.28
H_2O^-	0.23	0.33	0.26	0.35	0.47	0.41	0.27	0.21	0.18
CO_2	0.41	0.71	0.15	0.69	0.51	0.42	0.32	0.12	0.20
TOTAL	99.93	99.49	99.55	100.05	99.48	99.99	99.79	100.07	99.99
Ba	520	600	440	510	1100	610	570	640	690
Rb	135	100	105	185	205	105	230	170	180
Sr	230	165	260	70	55	200	90	160	165
Pb	18	14	26	13	70	10	9	16	12
Th	24	24	26	26	24	16	28	30	32
U	4	4	4	<4	<4	4	4	4	4
Zr	180	140	185	180	160	145	190	140	165
Nb	12	10	12	14	12	14	16	12	12
Y	28	24	32	34	20	16	36	32	30
La	50	65	65	50	40	30	60	70	65
Ce	70	70	75	65	70	50	85	80	90
V	80	105	100	56	96	88	80	58	74
Cr	32	26	42	30	68	72	54	36	38
Co	100	58	48	66	54	66	58	82	62
Ni	8	10	14	10	24	20	18	6	12
Cu	16	12	16	10	36	10	16	18	12
Zn	50	72	54	28	115	20	36	34	52

REG. NO	83360065	83360066	83360067	83360068	83360069	83360070	83360071	83360072	83360073
FORMATION OR MEMBER	Deakin Volcanics	Laidlaw Volcanics	Laidlaw Volcanics	Laidlaw Volcanics	Deakin Volcanics	Deakin Volcanics	Deakin Volcanics	Colinton Volcanics	Deakin Volcanics
SUBUNIT SYMBOL	Sd_f	Sl_3	Sl_1	Sl_1	Sd_j?	Sd_1?	Sd_f	Sc_j	Sd_h
ROCK TYPE	Rhyolite	Rhyolite	Rhyolitic crystal tuff	Rhyolitic crystal tuff	Rhyolite	Rhyolitic crystal tuff	Rhyolite	Dacitic crystal tuff	Rhyolite
GRID REF	890693	874731	880728	887722	890724	892919	894707	934560	932805
1:100,000 MAP SHEET	Michelago	Canberra	Canberra	Canberra	Canberra	Canberra	Canberra	Michelago	Canberra
SiO_2	69.80	70.50	69.50	69.80	73.70	70.80	69.50	67.90	72.80
TiO_2	0.45	0.40	0.48	0.43	0.20	0.33	0.43	0.48	0.28
Al_2O_3	14.10	13.70	14.00	14.10	13.50	14.00	14.00	15.20	13.60
Fe_2O_3	1.40	0.89	1.12	0.90	1.15	1.22	0.69	1.28	0.61
FeO	2.00	2.12	2.42	2.42	0.82	1.43	2.49	2.28	1.73
MnO	0.11	0.07	0.04	0.08	0.05	0.05	0.08	0.07	0.09
MgO	1.45	1.19	1.39	1.46	0.45	0.97	3.00?	1.43	0.74
CaO	1.27	2.23	3.01	2.18	2.15	2.66	0.70?	3.80	1.88
Na_2O	3.75	2.60	2.50	3.42	2.51	2.82	3.14	2.54	3.01
K_2O	3.60	4.38	3.34	3.26	4.53	4.07	3.12	3.10	4.07
P_2O_5	0.23	0.09	0.11	0.11	0.09	0.11	0.12	0.13	0.09
H_2O^+	1.07	1.39	1.37	0.66	0.93	0.93	2.16	1.55	0.86
H_2O^-	0.17	0.14	0.19	0.11	0.13	0.13	0.35	0.13	0.24
CO_2	0.15	0.23	0.41	0.16	0.54	0.54	0.36	0.39	0.10
TOTAL	99.66	99.67	100.13	100.08	100.16	100.16	100.14	100.28	100.11
Ba	570	670	690	660	520	630	600	680	530
Rb	180	195	125	120	200	165	135	125	185
Sr	165	170	180	180	140	170	120	220	140
Pb	17	<5	<5	8	<5	<5	14	14	8
Th	28	22	18	14	22	22	20	18	24
U	4	6	4	<4	6	4	<4	<4	6
Zr	170	130	160	145	75	100	120	170	100
Nb	18	12	16	12	10	10	12	14	14
Y	32	30	25	25	40	25	30	25	40
La	60	55	70	65	65	55	55	75	70
Ce	85	80	120	85	90	95	100	85	85
V	74	55	70	70	30	50	70	70	40
Cr	38	30	30	30	25	25	25	30	<20
Co	62	75	80	75	75	70	60	60	55
Ni	12	<5	6	6	<5	<5	6	<5	6
Cu	12	<2	<2	12	<2	<2	<2	8	3
Zn	50	46	45	39	21	33	88	38	37

REG. NO	83360074	83360075	84360001	84360002	84360003	84360004	84360005	84360006	84360007
FORMATION OR MEMBER	Laidlaw Volcanics?	Deakin Volcanics	Deakin Volcanics	Deakin Volcanics	Colinton Volcanics	Colinton Volcanics	Colinton Volcanics	Williamsdale Dacite Mbr	Williamsdale Dacite Mbr
SUBUNIT SYMBOL	Sl_1?	Sd_1	Sd_h	Sd_h	Sc_j	Sc_j	Sc_h	Sc_f	Sc_f
ROCK TYPE	Dacitic crystal tuff	Rhyolitic crystal tuff	Rhyolite	Rhyolite	Rhyolitic crystal tuff	Rhyolitic crystal tuff	Rhyolitic crystal tuff	Dacitic crystal tuff	Dacitic crystal tuff
GRID. REF	926641	920664	890824	886795	934593	941564	963641	969640	970624
1:100,000 MAP SHEET	Michelago	Michelago	Canberra	Canberra	Michelago	Michelago	Michelago	Michelago	Michelago
SiO_2	68.90	74.30	72.60	73.40	69.80	70.40	71.30	68.90	68.60
TiO_2	0.43	0.19	0.26	0.22	0.48	0.42	0.37	0.55	0.62
Al_2O_3	14.90	13.30	13.60	13.70	14.20	14.00	13.50	13.90	13.60
Fe_2O_3	1.04	0.81	1.01	1.18	2.30	1.58	1.33	1.59	1.86
FeO	2.24	0.96	1.14	0.70	1.28	1.33	1.45	2.26	2.63
MnO	0.07	0.09	0.07	0.03	0.08	0.07	0.06	0.07	0.09
MgO	1.29	0.65	0.66	0.64	1.25	1.02	1.22	1.78	2.16
CaO	3.55	1.48	1.73	2.22	3.10	3.18	1.86	2.96	2.80
Na_2O	2.65	3.35	3.26	2.56	3.15	2.54	2.30	2.48	2.30
K_2O	3.16	3.53	4.08	4.40	3.02	3.60	4.78	3.40	3.16
P_2O_5	0.12	0.07	0.07	0.07	0.11	0.08	0.09	0.12	0.14
H_2O^+	1.11	0.85	0.57	0.63	1.19	1.03	1.08	1.35	1.63
H_2O^-	0.22	0.20	0.28	0.25	0.19	0.21	0.20	0.17	0.18
CO_2	0.44	0.52	0.16	0.10	0.09	0.35	0.35	0.32	0.42
TOTAL	100.12	100.30	99.49	100.10	100.24	99.81	99.89	99.85	100.19

Ba	670	460	640*	1000*	340*	450*	150*	340*	1180*
Rb	135	185	185	175	125	155	200	160	135
Sr	190	170	200*	200*	300*	220*	190*	200*	200*
Pb	8	12	7?*	10?*	9?*	9?*	10?*	9?*	9?*
Th	18	18	22	24	14	16	22	18	16
U	<4	4	6	6	4	4	8	4	<4
Zr	160	60	120	110	170	165	145	190	190
Nb	12	12	4	4	6	6	6	6	10
Y	30	35	32	36	28	26	32	26	24
La	60	50	70	80	70	80	85	85	85
Ce	105	65	85	80	80	95	75	75	80
V	60	30	30*	30*	70*	60*	50*	80*	100*
Cr	30	25	20*	<10*	20*	20*	30*	30*	40*
Co	65	65	120*	100*	100*	100*	80*	90*	80*
Ni	<5	<5	7?*	5?*	6?*	5?*	<5?*	5?*	7?*
Cu	5	<2	120?	56?	46?	86?	<2?	<2?	<2?
Zn	37	28	90	100	150	120	100	120	100

REG. NO	84360008	84360009	84360010	84360011	84360012	84360013	84360014	84360015	84360016
FORMATION OR MEMBER	Williamsdale Dacite Mbr	Colinton Volcanics	Deakin Volcanics	Williamsdale Dacite Mbr	Colinton Volcanics	Colinton Volcanics	Colinton Volcanics	Deakin Volcanics	Colinton Volcanics
SUBUNIT SYMBOL	Sc_f	Sc_j	Sd_1	Sc_e	Sc_d	Sc_d	Sc_h?		Sb_1
ROCK TYPES	Dacitic crystal tuff	Dacitic crystal tuff	Rhyolitic crystal tuff	Dacitic crystal tuff	Sheared dacitic crystal tuff	Sheared dacitic crystal tuff	Sheared rhyolitic crystal tuff	Dacitic crystal tuff	Sheared dacite
GRID. REF	973622	949531	931722	976516	989530	005572	950657	976817	899617
1:100,000 MAP SHEET	Michelago	Michelago	Canberra	Michelago	Michelago	Michelago	Michelago	Canberra	Michelago
SiO_2	68.20	69.30	71.10	69.20	66.60	68.70	71.50	64.80	67.00
TiO_2	0.60	0.47	0.41	0.59	0.58	0.60	0.49	0.71	0.66
Al_2O_3	13.60	14.70	14.10	14.10	14.10	13.70	13.00	14.60	14.00
Fe_2O_3	1.59	1.88	1.20	1.73	2.24	1.60	1.79	1.85	1.21
FeO	2.78	1.39	1.53	2.42	2.40	2.70	1.65	3.60	3.50
MnO	0.08	0.06	0.04	0.08	0.07	0.07	0.06	0.08	0.11
MgO	2.10	1.15	1.22	1.65	1.91	2.06	1.38	2.30	1.95
CaO	2.96	3.58	2.80	3.16	4.50	3.36	2.60	4.34	3.64
Na_2O	2.24	2.74	2.52	2.52	2.14	2.22	2.42	2.38	2.22
K_2O	3.42	3.24	3.76	3.32	2.98	3.14	3.30	2.82	2.78
P_2O_5	0.13	0.11	0.08	0.09	0.10	0.12	0.10	0.17	0.13
H_2O^+	1.57	1.09	0.99	0.78	1.42	) 1.41	) 1.50	) 1.91	) 2.28
H_2O^-	0.22	0.22	0.22	0.24	0.16	)	)	)	)
CO_2	0.34	0.14	0.07	0.06	0.65	0.16	0.20	0.31	0.50
TOTAL	98.83	100.07	100.04	99.94	99.85	99.84	99.99	99.87	99.98

	84360008	84360009	84360010	84360011	84360012	84360013	84360014	84360015	84360016
Ba	50?	540*	540*	<20?	<20?	530*	540*	490*	500*
Rb	150	140	165	185	135	135	130	125	82
Sr	210*	270*	200*	230*	260*	190*	190*	240*	180*
Pb	7?	10?	<5?	<5?*	<5?	<5?	<5?*	<5?*	<5?*
Th	20	18	22	16	16	18	24	18	14
U	6	<4	6	4	4	5	8	4	4
Zr	195	200	160	205	155	200*	190*	290*	220*
Nb	8	6	8	6	8	8	10	10	12
Y	24	24	28	26	22	20*	30*	20*	30*
La	80	80	80	60	85	60	42	36	55
Ce	95	85	85	90	80	100	95	82	100
V	90*	60*	30*	70*	90*	90*	70*	120*	100*
Cr	20*	50*	<10*	20*	<10*	80*	70*	100*	100*
Co	80*	80*	60*	70*	60*	110*	100*	70*	70*
Ni	40*	40*	<20*	<20*	<20*	<10*	20*	<10*	30*
Cu	<2?	<2?	<2?	<2?	<2?	14?	11?	9?	7?
Zn	100*	100*	90*	100*	150*	70*	50*	90*	90*

REG. NO	84360017	84360018	84360019	84360020	85360001	84360002	84360003	84360004	84360005
FORMATION OR MEMBER	Rothlyn Formation	Colinton Volcanics	Deakin Volcanics	Williamsdale Dacite Mbr	Montagu Dacite Mbr	Billilingra Dacite Mbr?	Colinton Volcanics	Billilingra Dacite Mbr	Colinton Volcanics
SUBUNIT SYMBOL	Sn_f	Sc_d	Sd_b	Sc_e	Sn_j	Sn_i?	Sc_g	Sn_i	Sc_a
ROCK TYPE	Sheared dacite	Sheared dacitic crystal tuff	Rhyolitic crystal tuff	Dacitic crystal tuff	Hb dacite	Hb dacitic crystal tuff	Dacitic crystal tuff	Hb dacitic crystal tuff	Dacitic crystal tuff
GRID. REF	928560	007608	892657	002637	039865	058872	954228	940212	981206
1:100,000 MAP SHEET	Michelago	Michelago	Michelago	Michelago	Cooma	Cooma	Michelago	Michelago	Michelago
SiO_2	65.00	68.00	69.00	70.40	67.40	65.30	64.20	63.50	63.00
TiO_2	0.55	0.57	0.38	0.54	0.42	0.54	0.52	0.61	0.61
Al_2O_3	14.80	13.60	14.40	13.40	14.90	14.60	14.10	15.00	14.60
Fe_2O_3	1.42	1.71	1.09	1.18	1.33	1.38	1.78	1.86	1.05
FeO	2.05	2.65	1.85	2.50	2.60	3.30	2.70	3.50	4.70
MnO	0.05	0.07	0.04	0.06	0.04	0.08	0.05	0.05	0.06
MgO	1.18	1.80	1.75	1.49	1.73	2.82	1.64	2.94	3.45
CaO	4.08	4.42	1.86	3.38	4.06	3.66	3.96	4.40	3.15
Na_2O	2.76	2.18	3.60	2.40	2.74	3.14	2.68	2.84	2.28
K_2O	3.24	2.92	3.98	3.26	2.82	2.90	3.12	2.66	2.70
P_2O_5	0.12	0.11	0.06	0.11	0.11	0.13	0.11	0.12	0.13
H_2O^+	) 3.84	) 1.71	) 1.84	) 1.00	1.59	1.67	1.69	1.75	2.35
H_2O^-	)	)	)	)	0.16	0.27	0.38	0.35	0.46
CO_2	1.19	0.50	0.42	0.07	0.13	0.23	2.57	0.16	1.16
TOTAL	101.08	100.24	100.27	99.79	100.03	100.02	99.50	99.74	99.70

Ba	630*	440*	520*	510*	473	526	506	435	580
Rb	135	140	150	155	92	126	120	97	96
Sr	200*	230*	150*	180*	260	304	141	237	183
Pb	<5?	<5?	<5?	<5?	20	22	20	20	24
Th	20	8	18	16	12	11	15	16	12
U	<4	<4	<4	<4	<4	6	5	<4	<4
Zr	250*	190*	160*	220*	159	178	163	177	175
Nb	10	10	8	8	9	8	8	9	9
Y	30*	20*	20*	30*	22	29	27	31	25
La	48	45	52	60	40	45	55	40	45
Ce	88	92	92	96	63	81	74	81	58
V	80*	100*	60*	80*	80	90	30	80	100
Cr	60*	60*	70*	70*	18	29	15	26	30
Co	60*	70*	60*	80*	12	17	11	14	18
Ni	20*	20*	<10*	<10*	21	20	14	21	28
Cu	11?	10?	11?	18?	19	25	21	24	27
Zn	70	100	50	60	41	47	53	45	64
8									

APPENDIX 2

ISOTOPIC AGE DETERMINATIONS - AMDEL REPORT

K-Ar AND Rb-Sr GEOCHRONOLOGY OF 3 ROCKS

1. INTRODUCTION

Three rock samples were received from the Bureau of Mineral Resources (Parcel 1472) with a request to carry out K-Ar and Rb-Sr age determinations on specified total rock and mineral samples.

2. PROCEDURE

Thin sections were prepared and examined to determine the suitability of the rocks for geochronology. Two biotite and one hornblende concentrate were prepared and analysed for K and ^{40}Ar. In addition, the two biotites and the total rock samples from which they were derived were analysed for Rb and Sr.

3. PETROGRAPHIC DESCRIPTIONS

Sample 85360051 : TSC45547

This is a volcanic rock, possibly pyroclastic, containing abundant phenocrysts and broken, angular fragments of quartz, biotite, and minor feldspar set in a fine grained, sugary textured, quartzo-feldspathic groundmass.

The quartz phenocrysts range in size from 4 mm down to fragments as small as 0.06 mm. The margins are slightly rounded and embayed.

Biotite occurs as flakes up to 2 mm in length and tends to be somewhat ragged, with common, altered inclusions and frequent kinking of the cleavage planes. As with the quartz, the grain size range is quite wide and the smaller flakes have similar characteristics to the larger ones. It is not clear whether the distortion of the biotite flakes is due to compaction or to some earlier tectonic stress. Although not obvious in thin section, the biotite flakes contain a very high percentage of needle-like rutile aligned in preferred directions (60° angles).

The groundmass is dominantly quartzo-feldspathic and may be recrystallised. It tends to merge and interlock with the smaller quartz and feldspar of the phenocryst phase, although the larger phenocrysts have sharp margins against the groundmass.

The biotite is reasonably fresh, with only minor chloritic alteration. The interpretation of its isotopic age, however, may be complicated the geological events that produced the bending of the biotite flakes and recrystallisation of the groundmass. If the rock is of pyroclastic origin, a further uncertainty is introduced by the possible inclusion of extraneous material and the question whether the biotite and total rock came to isotopic equilibrium at the time of formation of the rock.

Sample 85360054 : TSC45548

This volcanic rock is similar to 85360051 in mineralogical composition and texture. The phenocryst phase is somewhat coarser grained and feldspars (both K-feldspar and plagioclase) are more abundant. An epidote-sericite alteration is common and, in addition, the biotite phenocrysts appear to be more extensively chloritised than in 85360051.

The comments made on the previous sample in relation to suitability for dating apply equally to the present sample.

Sample 85360055 : TSC45549

This is a porphyritic volcanic rock, quite distinct in mineralogy from the preceding samples. Phenocrysts comprise about 50% of the rock and are variable in size. Quartz, although being less abundant, generally is much coarser grained (up to 2 mm) than either the feldspar or amphibole, which are present in approximately equal proportions. Totally altered ?biotite flakes are the least abundant phase. The feldspar phenocrysts are extensively sericitised but the amphibole is fresh and would be suitable for K-Ar dating.

The groundmass is very fine grained, weakly birefringent, and was probably originally glassy. There are pale green chloritic patches that may represent altered phenocrysts.

3. GEOCHRONOLOGY

The K and Ar analyses and calculated K-Ar dates are given in Table 1. Table 2 lists the Rb and Sr isotopic analyses and gives the biotite - total rock ages and initial ratios for each sample.

The results all fall within the late Silurian - early Devonian although the spread is also slightly greater than experimental error. As discussed in Section 3, for Sample 85360051, the biotite - total rock age calculation assumes that there was isotopic equilibrium between biotite and the total rock sample at the time of formation. The alteration of the biotite, especially in Sample 85360054, may also have caused some open system behaviour with respect to Rb and Sr, producing an age younger than the correct age.

It can be seen that the same apparent difference in age between Samples 85360051 and 54 exists in the results determined by both K-Ar and Rb-Sr methods.

TABLE 1 : POTASSIUM-ARGON RESULTS

Sample	%K	$^{40}Ar^*$ ($\times 10^{-10}$ moles/g)	$^{40}Ar^*/^{40}Ar_{Total}$	Age†
85360051 Biotite	6.17 6.17	50.305	0.979	418 ± 3
85360054 Biotite	6.68 6.66	53.629	0.954	413 ± 3
85360055 Hornblende	0.565 0.563	4.4676	0.863	407 ± 3

* Denotes radiogenic ^{40}Ar.

† Age in Ma with error limits given for the analytical uncertainty at one standard deviation.

Constants:

^{40}K = 0.01167 atom %

$\lambda_\beta = 4.962 \times 10^{-10} y^{-1}$

$\lambda_\epsilon = 0.581 \times 10^{-10} y^{-1}$

TABLE 2 : Rb-Sr ANALYSES AND BIOTITE-TOTAL ROCK AGES

Sample	Rb(ppm)	Sr(ppm)	Rb/Sr	$^{87}Rb/^{86}Sr$	# $^{87}Sr/^{86}Sr$
85360051					
Biotite	593.2	31.89	18.599	55.412	1.0324
Total Rock			0.9352	2.7047	0.7237
Biotite-Total Rock Age = 411 ± 5 Ma					
Initial $^{87}Sr/^{86}Sr$ = 0.7079					
85360054					
Biotite	558.6	11.80	47.337	148.06	1.5579
Total Rock			1.0886	3.1492	0.7264
Biotite-Total Rock Age = 403 ± 4 Ma					
Initial $^{87}Sr/^{86}$ = 0.7084					

Measured ratios normalised to $^{88}Sr/^{86}Sr$ = 8.3752

Constants used : $^{85}Rb/^{87}Rb$ = 2.600
$\lambda^{87}Rb = 1.42 \times 10^{-11} y^{-1}$

Error limits are analytical uncertainties at 1 standard deviation.

LATE SILURIAN GEOLOGY OF THE MICHELAGO - COOMA AREA

BY

G.A.M. HENDERSON

SCALE 1:100000

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

TRANSVERSE MERCATOR PROJECTION

Geology 1983-85 by G.A.M. Henderson, BMR
Compiled 1985 by G.A.M. Henderson, BMR
Cartography by N. Jeffery, BMR
Printed by Watson, Ferguson & Co, Brisbane
Base Map supplied by the Divison of National Mapping. Topographic information is correct to 1980

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of Resources and Energy. Issued under the authority of the Minister for Resources and Energy

It is recommended that this map be referred to as: Henderson, G.A.M., 1987 - Late Silurian Geology of the Michelago - Cooma Area (1:100 000 scale map) *Bureau of Mineral Resources, Canberra.*

CAINOZOIC

TERTIARY TO QUATERNARY

- Cza *Alluvium and colluvium*

TERTIARY

- Td *Diatomite*
- Ts *Silcrete*
- Tb *Olivine basalt*
- Tg *Coarse gravel*

PALAEOZOIC

LATE SILURIAN TO ? EARLY DEVONIAN

- Sg *Pale porphyritic granite*
- Sgℓ *Leucogranite*
- Sp_4 *Coarse-grained rhyolitic to dacitic porphyry*
- Sp_3 *Pale grey K-feldspar - rich rhyolitic porphyry*
- Sp_2 *Sheared coarse-grained rhyolitic porphyry*
- Sp_1 *Coarse-grained rhyolitic porphyry*
- Sr *Rhyolite*

Livingstone Porphyry

- Spℓ *Coarse-grained rhyolitic porphyry; pink feldspar megacrysts in some places*

Bullanamang Porphyry

- Spb *Coarse-grained rhyolitic porphyry, slightly sheared; shearing intensity increases towards margins*

LATE SILURIAN

Rothlyn Formation

- Sn_r *Interbedded, mainly fine, feldspathic sandstone and shale*
- Sn_q *Mid grey amygdaloidal basalt*
- Sn_p *Dacite, tuff*
- Sn_o Cloyne Limestone Member *Pale buff-grey banded limestone; white coarsely-crystalline marble*
- Sn_n *Green to greenish-grey slaty shale*
- Sn_m *Dacite, dacitic agglomerate, tuff*
- $Sn_ℓ$ *Andesite, andesitic agglomerate, augite dacite, tuff*
- Sn_k *Grey slaty shale; minor tuff and sandstone lenses*
- Sn_j Montagu Dacite Member *Hornblende dacite*
- Sn_i Billilingra Dacite Member *Hornblende-biotite dacitic crystal tuff*
- Sn_h *Flow-banded basalt*
- Sn_g *Pinkish grey rhyolitic crystal tuff; minor shale*
- Sn_f *Sheared dacite, tuff*
- Sn_e *Volcanic breccia, tuff*
- Sn_d *Rhyolitic crystal tuff, coarse sandstone, tuff*
- Sn_c *Medium-grained foliated tuff*
- Sn_b *Massive to bedded grey limestone*
- Sn_a *Slaty shale, calcareous shale, sandstone, tuff*

Laidlaw Volcanics

- $Sℓ_3$ *Rhyolite*
- $Sℓ_2$ *Shale*
- $Sℓ_1$ *Rhyolitic to dacitic crystal tuff*

Colinton Volcanics (Bransby Shear Zone)

- Sb_6 *Massive to bedded grey limestone*
- Sb_5 *Sheared dacite and tuff; lenses of slaty shale*
- Sb_4 *Slightly sheared pinkish buff rhyolite*
- Sb_3 *Bedded pale grey limestone*
- Sb_2 *White marble, shale, black carbonaceous shale, tuff*
- Sb_1 *Sheared dacite and tuff, commonly sericitised; lenses of slaty shale*

Colinton Volcanics

- Sc_p Ingalara Ashstone Member *White to buff ashstone*
- Sc_o *Pale green to white rhyolite and rhyolitic breccia*
- Sc_n *Dark purple-grey andesite*
- Sc_m *Dark grey coarse-grained dacite ("Cosgrove Porphyry")*
- $Sc_ℓ$ *Dacite, andesite, rhyolite, tuff; shale lenses*
- Sc_k *Rhyolitic crystal tuff, rhyolite, tuff; minor shale lenses*
- Sc_j *Rhyolitic to dacitic crystal tuff*
- Sc_i *Dark grey, purple and white rhyolite; minor coarse sandstone*
- Sc_h *Rhyolitic crystal tuff*
- Sc_g *Dacitic crystal tuff*
- Williamsdale Dacite Member
  - Sc_f *Dacitic crystal tuff with coarse inclusions, biotite altered*
  - Sc_e *Dacitic crystal tuff with coarse inclusions, biotite fresh*
- Sc_d *Dacitic crystal tuff, mostly sheared*
- Sc_c *Dacite and tuff; minor sandstone and shale lenses*
- Sc_b *Shale; minor limestone lenses*
- Sc_a *Sheared dacite and tuff, shale lenses*

Deakin Volcanics

- Sd_k *Purple dacite*
- Sd_j *Pale green-grey rhyolitic crystal tuff, white and purple rhyolite*
- Sd_i *Dark grey rhyolitic crystal tuff*
- Sd_h *Coarse-grained purple rhyolite*
- Sd_g *White, pale grey and purple rhyolite; minor sandstone, shale and tuff*
- Sd_f *Green-grey to purple rhyolite to dacite*
- Sd_e *Rhyolitic crystal tuff*
- Sd_d *Coarse sandstone, shale*
- Sd_c *Coarse-grained rhyolite*
- Sd_b *Rhyolitic to dacitic crystal tuff*
- Sd_a *Tuff, sandstone, shale*

Cappanana Formation

- Sa? *Slaty shale, calc-silicate hornfels*
- Sa_2 *Shale, calcareous shale, limestone, sandstone*
- Sa_1 *Well-bedded medium and coarse sandstone*

- *Geological boundary*
- *Gradational boundary*
- *Unconformity*
- *Fault, containing quartz*
- *Dacite dyke*
- *Anticline* / *Syncline* — *showing trend of plunge of axis*

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

- 30 *Plunge of fold axis*
- 45 *Strike and dip of strata*
- 80 *Strike and dip of strata, facing not known*
- *Vertical strata*
- 70 *Strike and dip of overturned strata*
- 60 *Strike and dip of foliation*
- *Vertical foliation*
- 80 *Strike and dip of cleavage*
- *Vertical cleavage*
- 80 *Strike and dip of flowing-banding*
- *Macrofossil locality*
- *Abandoned prospect*

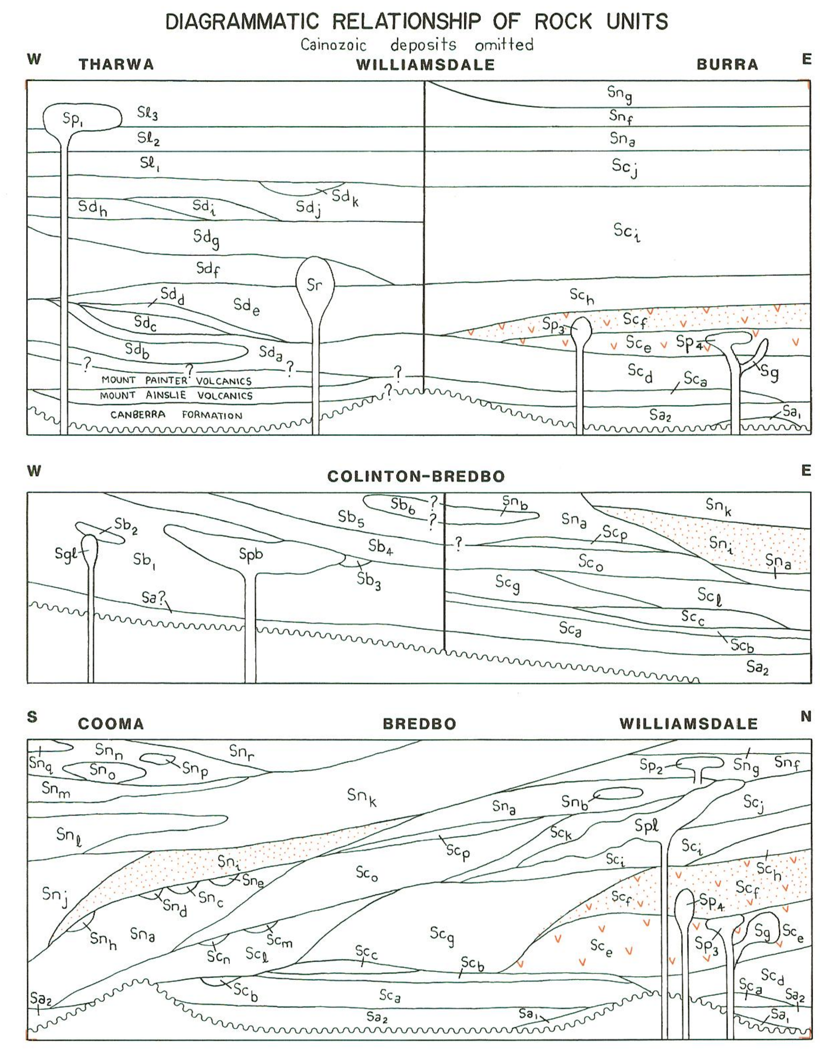
Ag - *Silver*, Au - *Gold*, Ba - *Barite*, Cu - *Copper*, Dt - *Diatomite*, Fe - *Iron*, Mn - *Manganese*, Pb - *Lead*, Zn - *Zinc*

- *Minor gravel quarry*
- *Sample locality for isotopic age determination*

- *Earth tank or dam*
- *Lake*
- *Swamp*
- *Highway*
- *Minor road*
- *Vehicle track*
- *Railway*
- Glenroy • *Homestead*
- *Building*
- Yd *Yard*
- *Trigonometrical station*
- ·1197 *Elevation in metres*

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

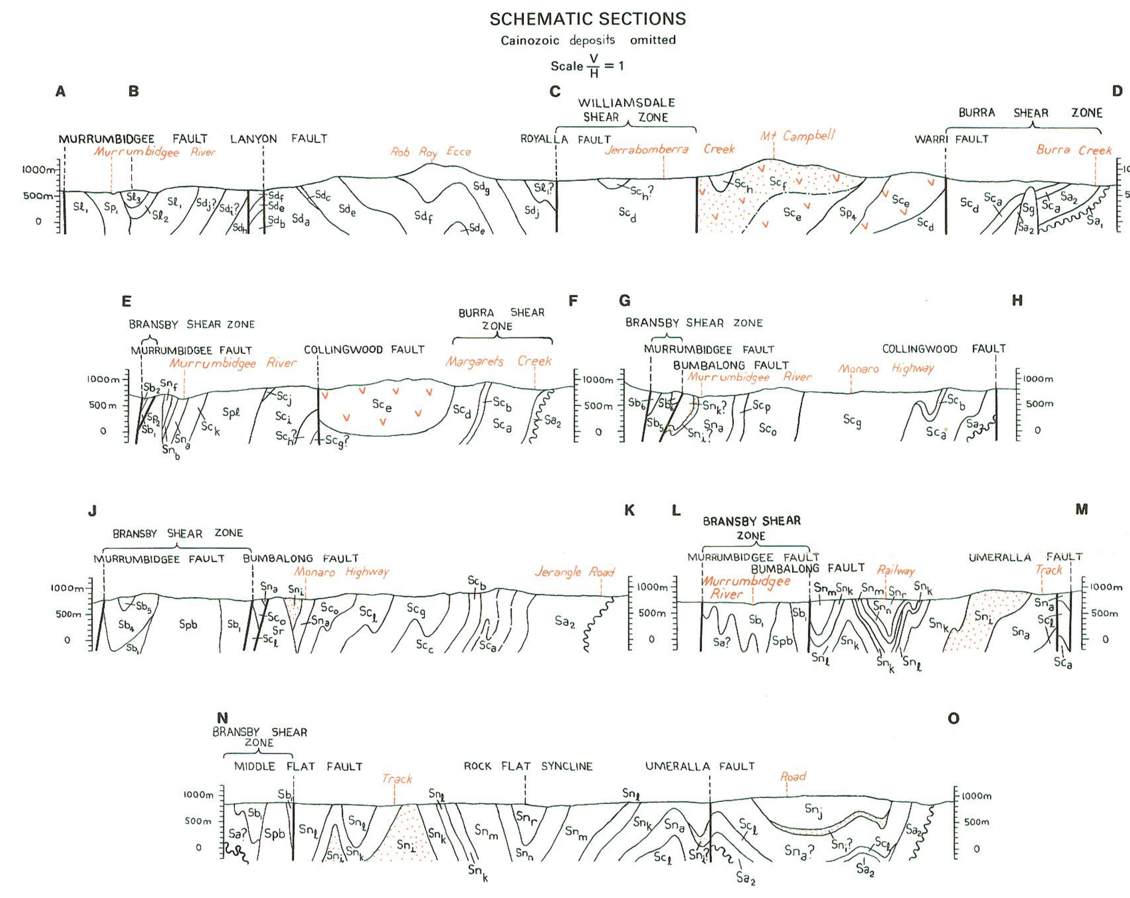
Cainozoic deposits omitted



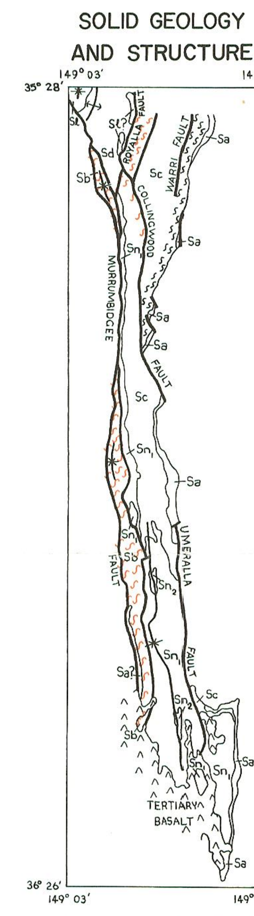
SCHEMATIC SECTIONS

Cainozoic deposits omitted

Scale $\frac{V}{H} = 1$

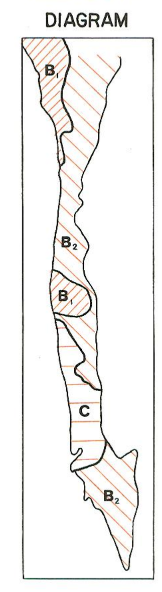


SOLID GEOLOGY AND STRUCTURE



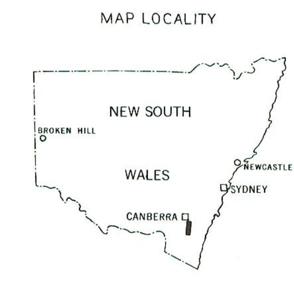
- Sn_2 Rothlyn Formation *Sandstone, Shale*
- Sn_1 *Sedimentary and volcanic rocks*
- Sℓ Laidlaw Volcanics
- Sb Colinton Volcanics (Bransby Shear Zone)
- Sc Colinton Volcanics
- Sd Deakin Volcanics
- Sa Cappanana Formation
- Burra Shear Zone
- Williamsdale Shear Zone

RELIABILITY DIAGRAM



- B_1 Detailed reconnaissance: numerous traverses
- B_2 Detailed reconnaissance and air-photo interpretation
- C General reconnaissance: few traverses, and air-photo interpretation

MAP LOCALITY



UNIVERSAL GRID REFERENCE

GRID ZONE DESIGNATION: 55H

100,000 METRE SQUARE IDENTIFICATION

FA GA FV GV 60 00 700

IGNORE the SMALLER figures of any grid number; these are for finding the full co ordinates. Use ONLY the LARGER figures of the grid number; example: 84

TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 1000 METRES

SAMPLE POINT: △ MYALL HILL

1. Read letters identifying 100 000 metre square in which the point lies: FA
2. Locate first VERTICAL grid line to LEFT of point and read LARGE figure labelling the line either in the top or bottom margin, or on the line itself: 94
3. Estimate tenths from grid line to point: 1
4. Locate first HORIZONTAL grid line BELOW point and read LARGE figure labelling the line in either the left or right margin, or on the line itself: 34
5. Estimate tenths from grid line to point: 9

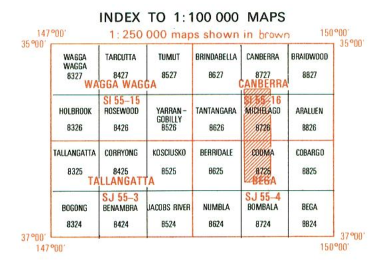
SAMPLE REFERENCE: FA 941349

If reporting beyond 18° in any direction, prefix Grid Zone Designation, as: 55HFA 941349

Brown numbered lines are 1000 metre intervals of the Australian Map Grid, Zone 55. Grid values are shown in full only at the southwest corner of the map

INDEX TO 1:100 000 MAPS

1:250 000 maps shown in brown



PRELIMINARY EDITION
FEBRUARY 1987
SUBJECT TO AMENDMENT

LATE SILURIAN GEOLOGY OF THE MICHELAGO - COOMA AREA