GUIDEBOOK FOR FIELD EXCURSION 4

The Ordovician Graptolite Sequence of Victoria

SIXTH INTERNATIONAL SYMPOSIUM ON THE ORDOVICIAN SYSTEM

BMR GEOLOGY AND GEOPHYSICS AUSTRALIA

GEOLOGICAL SURVEY OF VICTORIA

VI ISOS SYDNEY 1991

RECORD 1991/51

by A.H.M. VandenBerg & I.R. Stewart

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
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INTRODUCTION

Victoria's Ordovician graptolite sequence is one of the richest and most finely zoned in the world. It has long been regarded as the standard for the Pacific Province; the zones and/or stages have been directly used for sequences in NW Canada (Lenz, 1988) and Newfoundland (Kindle & Whittington, 1958), and as the framework for world wide correlation (Cooper & Lindholm, 1990). A review of the succession, including zone and stage definitions and faunal content, zonal ranges of all species, global correlation and a census of all Australasian species, is in press (VandenBerg & Cooper, in press).

After their discovery in the 1850s, taxonomic work on graptolites began in the 1870s with publications by McCoy (1874, 1875, 1876, 1877) and Etheridge (1874). This work was continued in a remarkable series of publications by T.S. Hall (1892, 1895, 1897, 1899a,b, 1900, 1902a,b, 1905, 1906, 1907, 1909, 1912, 1914a,b, 1920), in which much of the early Ordovician fauna was described and many of the stages and zones recognized. This work was continued by Harris, first alone (Harris, 1916, 1924, 1926, 1933, 1935) and later with Keble and especially with Thomas in a long and productive partnership (Keble & Harris, 1925, 1934; Harris & Keble, 1928, 1932, Harris & Thomas, 1935, 1937, 1938a,b,c, 1939, 1940a,b, 1941a,b, 1942, 1949, 1954, 1955). A review of this work was given by Thomas (1960). Taxonomic work has since been continued largely by Cooper (1973, Cooper & McLaurin, 1974; Cooper & Ni, 1986; Cooper & Stewart, 1979).

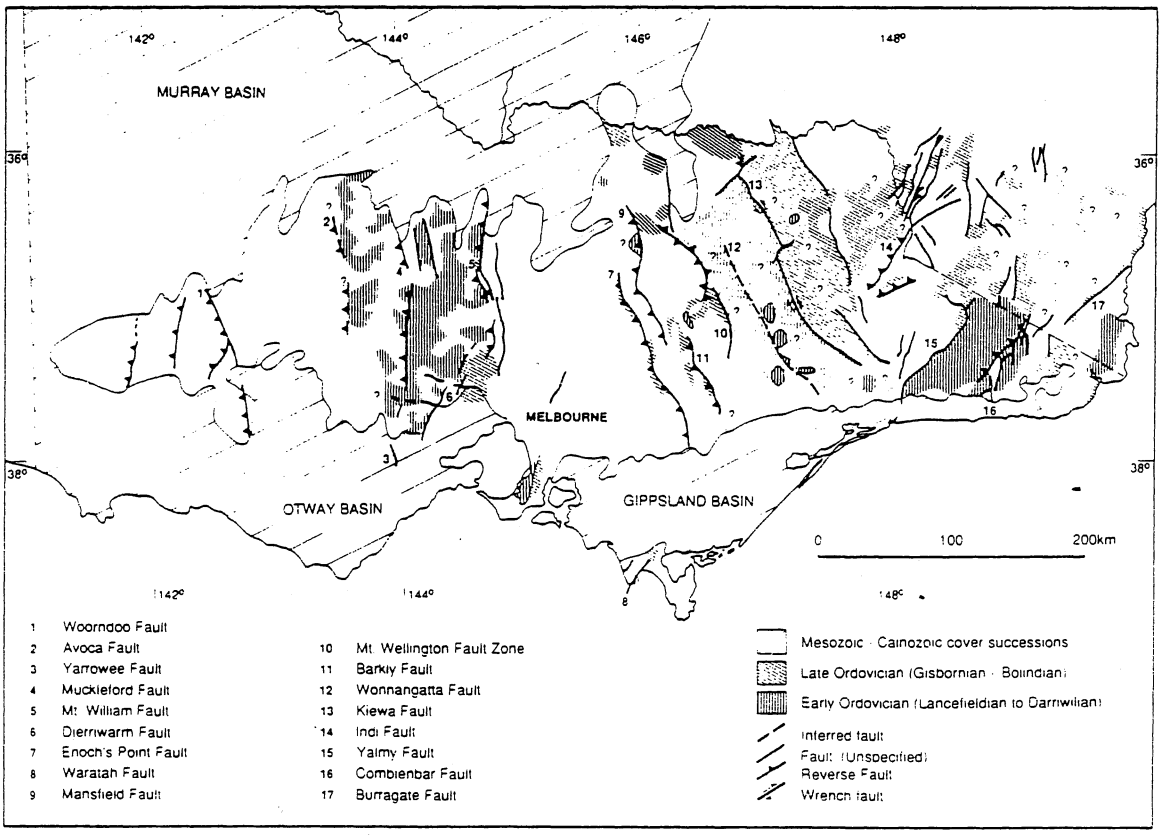

Fig. 1: Distribution of Ordovician rocks in Victoria. From Cas & VandenBerg (1988).

Silur.	Llandovery		*Parakidograptus acuminatus*
Upper Ord.	Bolindian	Bo5	*Normalograptus? persculptus*
		Bo4	*Normalograptus? extraordinarius*
		Bo3	*Paraorthograptus pacificus*
		Bo2	no zone fossil
		Bo1	*"Climacograptus" uncinatus*
	Eastonian	Ea4	*Dicellograptus gravis*
		Ea3	*Dicranograptus kirki*
		Ea2	*Diplacanthograptus spiniferus*
		Ea1	*Diplacanthograptus lanceolatus*
	Gisbornian	Gi2	*Orthograptus calcaratus*
		Gi1	*Nemagraptus gracilis*
Lower Ord.	Darriwilian	Da4	*Archiclimacograptus riddellensis*
		Da3	*Pseudoclimacograptus decoratus*
		Da2	*Undulograptus? intersitus*
		Da1	*Undulograptus austrodentatus*
	Yapeenian	Ya2	*Cardiograptus morsus*
		Ya1	*Oncograptus upsilon*
	Castlemainian	Ca4	*Isograptus victoriae maximodivergens*
		Ca3	*Isograptus victoriae maximus*
		Ca2	*Isograptus victoriae victoriae*
		Ca1	*Isograptus victoriae lunatus*
	Chewtonian	Ch2	*Isograptus primulus*
		Ch1	*Didymograptellus protobifidus*
	Bendigonian	Be4	*Pendeograptus fruticosus* (3-br.)
		Be3	*Pendeograptus fruticosus* (4-br. + 3-br.)
		Be2	*Pendeograptus fruticosus* (4-br.)
		Be1	*Tetragraptus approximatus* + *Pendeograptus fruticosus*
	Lancefieldian	La3	*Tetragraptus approximatus*
		La2	*Adelograptus victoriae*
		La1b	*Psigraptus jacksoni*
		La1a	*Rhabdinopora scitulum* + *Anisograptus*

Fig. 2: Victorian Ordovician stages and graptolite zones.

Most of this impressive body of work concerns early Ordovician graptolites, which are prolific in the goldfields of the Bendigo-Ballarat Structural Zone and were vital in elucidating the complex structure of this zone. Work on late Ordovician graptolites lagged behind, because most of the well-preserved faunas are in rugged mountain terrain in eastern Victoria, which remained inaccessible until relatively recently (Fig. 1). Taxonomic work is still in progress although some has been published (VandenBerg, 1990), but the biostratigraphy is now reasonably well understood (VandenBerg, 1981; Cas & VandenBerg, 1988; VandenBerg & Cooper, in press).

As a result of this work, thirty zones are recognized, two (La1, Da4) each with two subzones. These are grouped into nine stages, six (Lancefieldian, Bendigonian, Chewtonian, Castlemainian, Yapeenian, Darriwilian) in the early Ordovician and three (Gisbornian, Eastonian, Bolindian) in the late Ordovician (VandenBerg & Cooper, in press; Fig. 2). The census given in VandenBerg & Cooper (in press) lists 313 currently recognized species.

DEPOSITIONAL AND TECTONIC SETTING

The Ordovician rocks of Victoria form part of the Lachlan Fold Belt, an Early to Middle Palaeozoic mobile zone which extends across most of Victoria and New South Wales. In most of this fold belt, the Ordovician consists of quartzose turbidites and mudstones which overlie Cambrian volcanics of MORB and boninite affinities. The turbidites where deposited in an enormous deep marine fan on the palaeo-Pacific margin of the Australian Craton (VandenBerg & Stewart, in press), then part of Gondwana. The tectonic setting of the fan is open to debate: most consider it to be a back-arc basin behind the Molong Volcanic Rise (or 'Arc') (Cas etc.), but VandenBerg & Stewart (in press) have pointed out that the Molong Rise is a poor analogue for an arc.

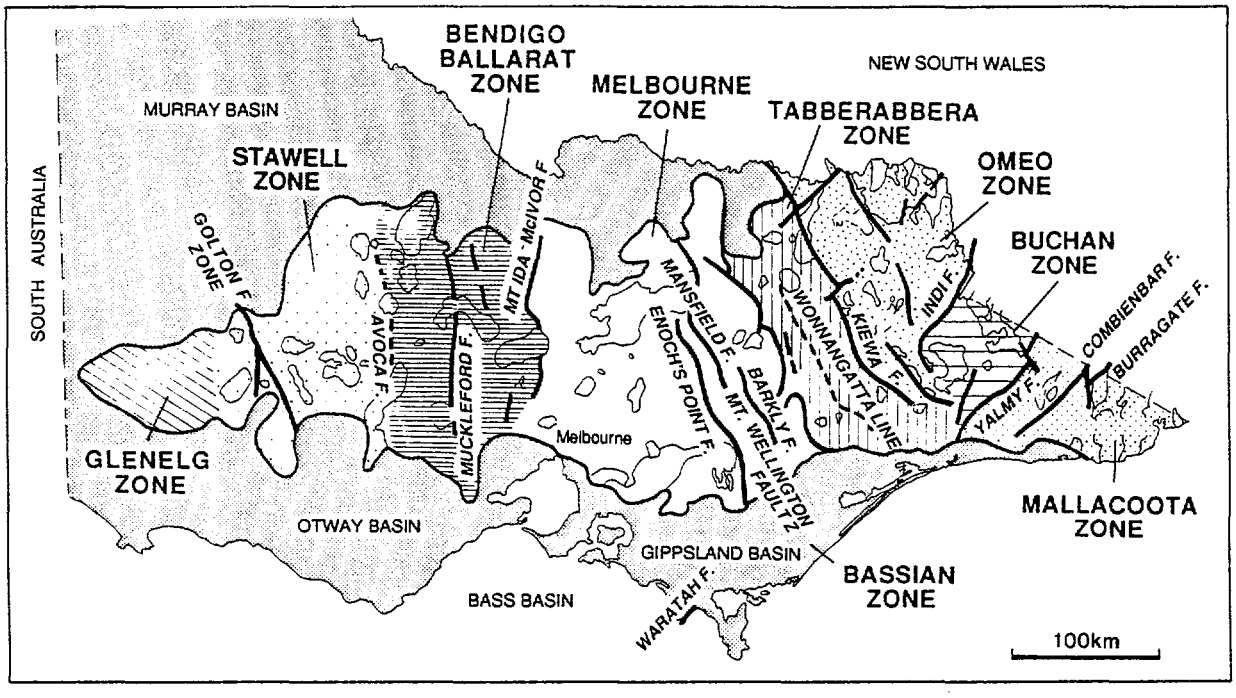

Fig. 3: Map outlining the structural zones of Victoria. From Gray et al. (1988).

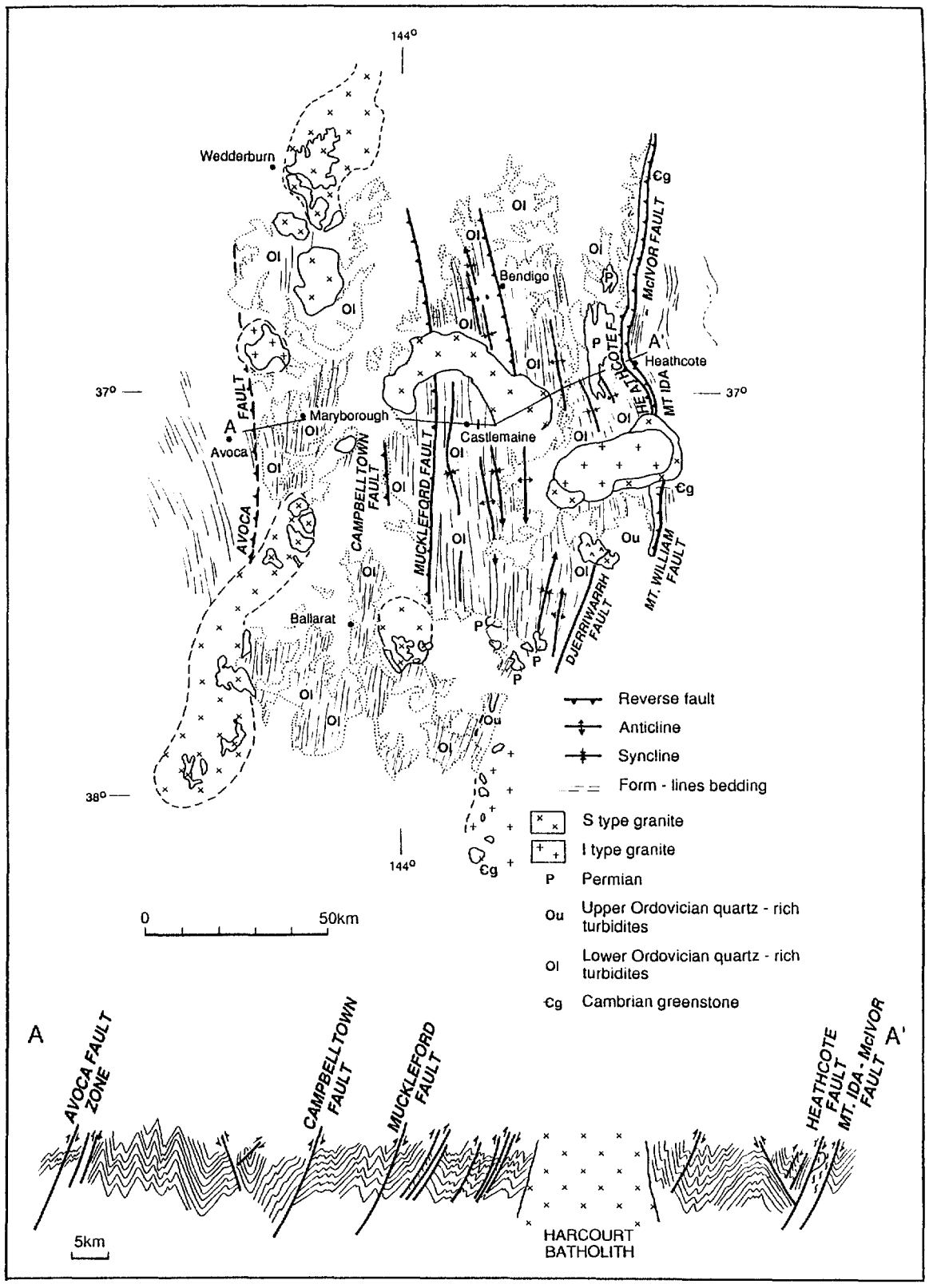

Fig. 4: Structural map and cross-section of Bendigo-Ballarat zone. From Gray et al. (1988).

The Palaeozoic basement of Victoria has been divided into structural zones (Fig. 3), of which only two will be visited: the Bendigo-Ballarat Zone, and the Melbourne Zone. In the Bendigo-Ballarat Zone, the bedrock consists of about 3 to 4 km of lower Ordovician turbidites with interbedded mudstones and black shales, which have been tightly folded into chevron-like symmetrical folds with limbs dipping at 60-70°. The enveloping surface in any place is nearly horizontal, generally gently dipping to the west. This simple pattern is disrupted by a large number of steeply dipping (mostly west-dipping) reverse faults with (in most cases) eastward transport (Fig. 4). The quartzose turbidites are underlain by Middle to Late Cambrian pelagites (shales and cherts) and Early Cambrian marine metabasalts and meta-andesites (Crawford, 1988); these Cambrian rocks are only exposed in the narrow Heathcote Greenstone Belt, which separates the Bendigo-Ballarat Zone from the Melbourne Zone by a series of faults (Fig. 4).

Shales interbedded in the early Ordovician tubidites contain a very diverse graptolite fauna ranging from basal Lancefieldian (La1) to late Darriwilian (Da3). At the southern end of the Heathcote Greenstone Belt, there appears to be a conformable passage into late Ordovician turbidites and black shales (Da3 to mid-Bolindian Bo3), and thence into late Bolindian and Llandovery mudstone; the latter characterizes the Melbourne Zone. Within the Melbourne Zone, early Ordovician turbidites are only exposed in the Mornington Peninsula southeast of Melbourne. Early Ordovician shales occur in tiny outcrops in several fault zones within the Melbourne Zone. Somewhere within the Melbourne Zone is a drastic facies change in the late Ordovician, to black shale with virtually no interbedded sandstone. This black shale facies extends from here to the east coast.

The combination of tight folding, gently dipping enveloping surfaces, high angle reverse faulting and the relatively low thickness of the Ordovician turbidite pile, have the effect that much of the early Ordovician sequence is exposed in any particular area. At Lancefield, for instance, there is a complete succession from Lancefieldian to upper Darriwil (Da3); at Bendigo, the sequence is almost as complete (La3 to Da3), and the same is the case at Castlemaine. Whilst it should therefore be possible to visit most zones in one particular area, the vagaries of accessibility and preservation militate against this. In order to visit localities with easily collectable, large assemblages with reasonable preservation, we have been forced to traverse a large portion of the Bendigo-Ballarat zone. It will also not be possible to visit localities in any stratigraphic order, although we will begin in the Lancefieldian and end in the Darriwilian.

STOPS 1-2, LANCEFIELDIAN, LANCEFIELD AREA (Fig. 5).

Stop 1: La1, *Rhabdinopora scitulum* Zone, PL101*, Stauro Gully near Romsey (Fig. 5).

* PL indicates Museum of Victoria fossil locality.

The locality is in a small tributary of Deep Creek and is accessible from Buckley's Lane, Romsey. Permission must be obtained from the owners.

This is the classic La1 locality from which Harris & Keble (1928) described the first La1 graptolites. The fauna comes from a 20-35 m thick black siliceous shale unit, the Stauro Gully Shale (Fig. 6), and the same bed outcrops in Bryo Gully, 800 m to the NNW (VandenBerg,

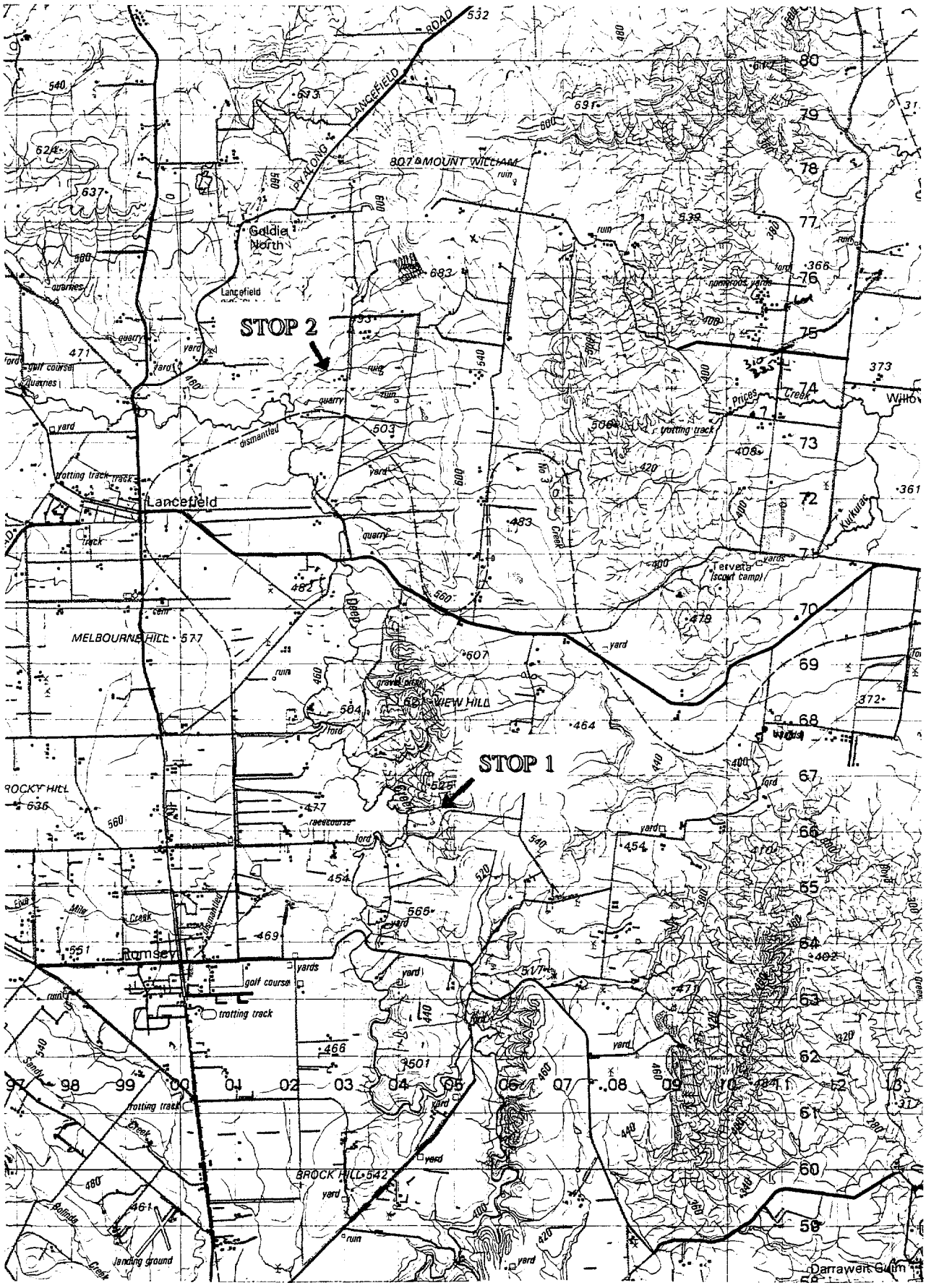

Fig. 5: Locality map, Lancefield-Romsey region. Scale = 1:100,000.

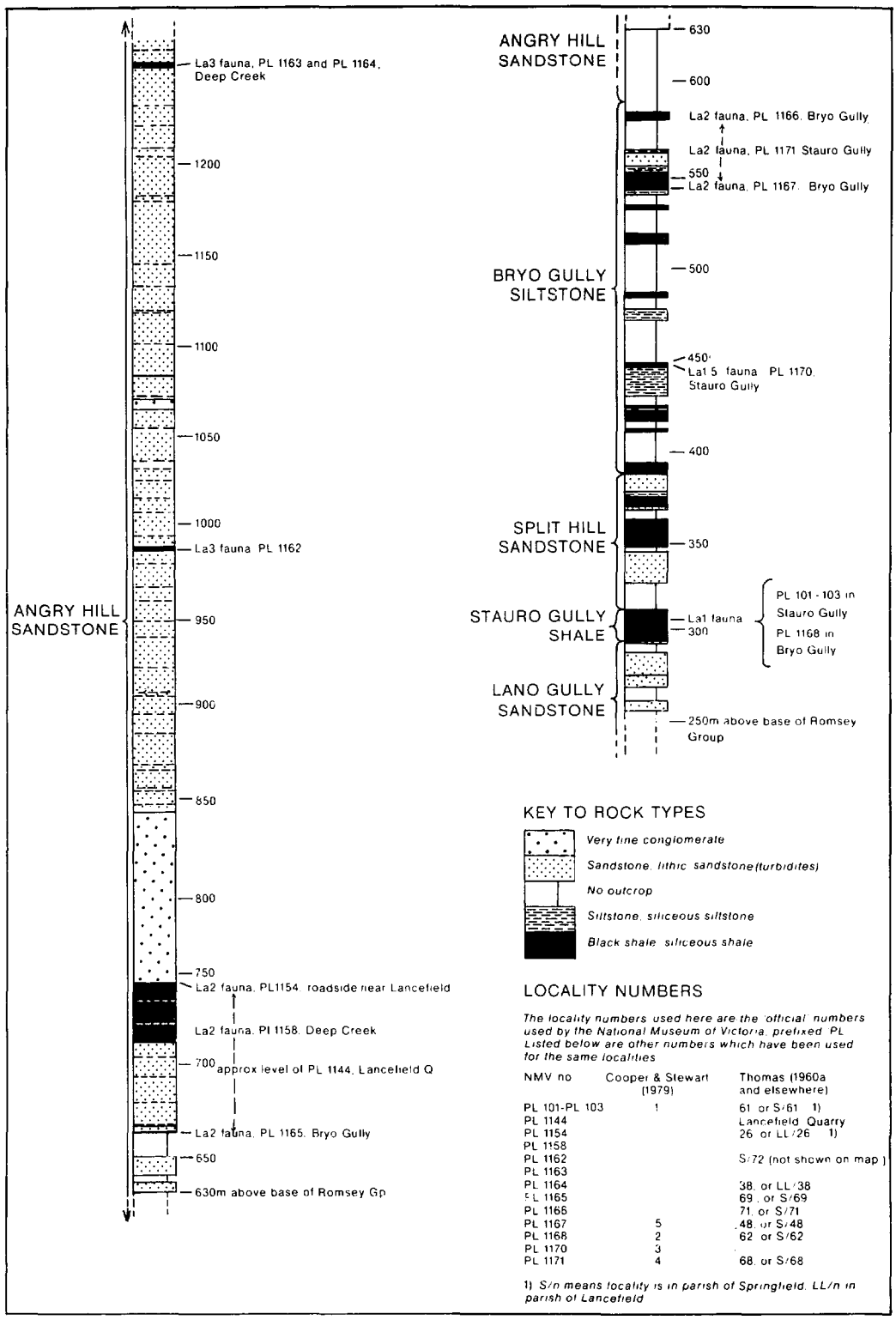

Fig. 6: Stratigraphic section of lower Lancefieldian Romsey Group, Romsey. From Erdtmann & VandenBerg (1984).

in press). The sequence in Stauro and Bryo gullies and continuing into Deep Creek to the west is the only complete Lancefieldian in Victoria (Erdtmann & VandenBerg, 1985), and this is also the only place where a continuous sequence down into Cambrian volcanics occurs (VandenBerg, in press). The Stauro Gully Shale is underlain by the 'proximal' turbiditic, and very rapidly deposited, Lano Gully Sandstone, below which lies the Goldie Chert, containing *Cordylodus* sp. The second Lancefieldian zone, La2a (La1.5 of Cooper & Stewart, 1979) occurs farther downstream in Stauro Gully but is not easily accessible. Outcrops of basal Zone La2 in both Stauro and Bryo gullies have recently been made inaccessible by human activity.

The La1 fauna was revised by Cooper & Stewart (1979) and contains only anisograptids. It consists of *Rhabdinopora scitulum* (Harris & Keble) (formerly *Dictyonema campanulatum* Harris & Keble and *D. scitulum*), *R. enigma* (Cooper & Stewart), *Anisograptus compactus* Cooper & Stewart and *A. delicatulus* Cooper & Stewart (both formerly included in *Staurograptus diffissus* Harris & Keble). The fossiliferous band also contains a great many phyllocarid crustaceans, belonging to *Caryocaris stewarti* Jell, and rare specimens of the enigmatic crustacean *Corcorania bispinosa* (Jell, 1980). All the fossils are preserved as white markings on a near-black uncleaved siliceous shale.

Stop 2: La2, *Adelograptus victoriae* Zone at PL 1144, Lancefield Quarry (Fig. 5).

Lancefield Quarry is a small excavation about 4 km northeast of Lancefield. It is on private property on Goldie North road, and permission must be obtained from the owner, Mr Harold Smith, for access.

This is the site from which the first Lancefieldian graptolites were described, by Pritchard (1892, 1895) and Hall (1892, 1897, 1899a), and from which the Lancefieldian takes its name. Hall's 1899a paper gives the most recent comprehensive description of the assemblage, although some species have been revised more recently (Berry, 1966; Cooper & Stewart, 1979; Erdtmann & VandenBerg, 1985; Erdtmann et al., 1987). The entire assemblage from PL1144 has been redescribed by Morris (1988), who made some important taxonomic changes. However, these are still unpublished, so that this report uses the most recent published taxonomy.

This zone marks the appearance of a very diverse anisograptid assemblage, and most of the species display a particularly broad range of morphologic variations. The fauna consists of *Adelograptus victoriae* (T.S. Hall) (particularly abundant), *Paradelograptus antiquus* (T.S. Hall), *P. pritchardi* (T.S. Hall), *Clonograptus flexilis* (J. Hall), *C. rigidus* (J. Hall), *C. tenellus* (Linnarsson), *Araneograptus macgillivrayi* (T.S. Hall), *A. pulchellum* (T.S. Hall), *Temnograptus magnificus* Pritchard, *"Tetragraptus" decipiens* T.S. Hall, and *"Didymograptus" taylori* T.S. Hall. The fossils are preserved as white markings on a near-black, uncleaved shale.

The interval encompassed by La2 is the thickest of any graptolite zone in Victoria, and contains a considerable thickness of black shale. It seems likely therefore that this zone spans a longer interval of time than any other.

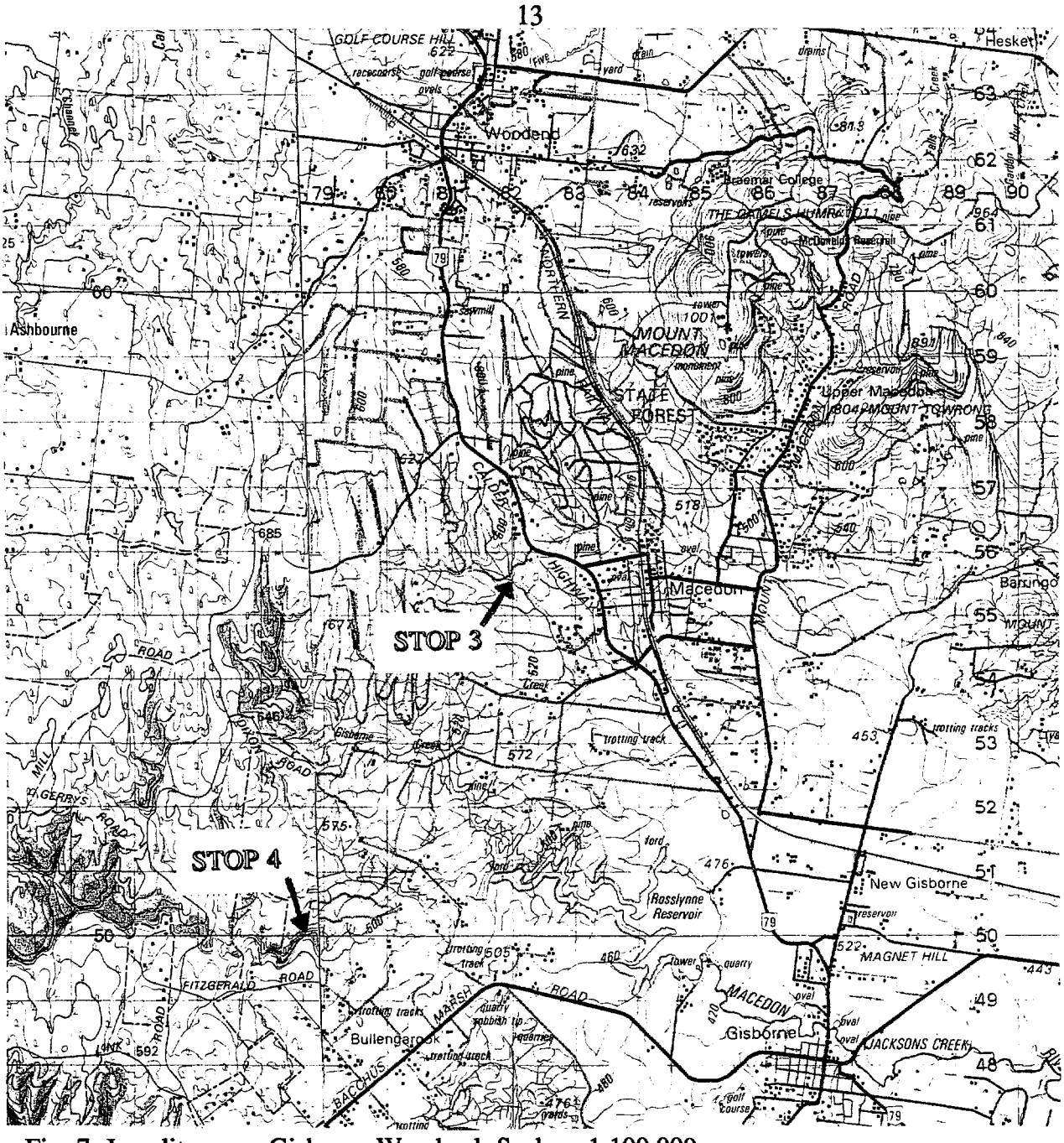

Fig. 7: Locality map, Gisborne-Woodend. Scale = 1:100,000.

STOPS 3 AND 4, CASTLEMAINIAN AND YAPEENIAN, GISBORNE AREA (Fig. 7).

Stop 3: Ca4, *Isograptus victoriae maximodivergens* Zone, Bullengarook Slate Quarry (Fig. 7).

Bullengarook Slate Quarry is a long-disused slate quarry on the north bank of Jackson's Creek at Bullengarook, near Gisborne. In Gisborne, turn west from Calder Highway into Robertson Street at roundabout, continue west to Bullengarook, turn right into Hassed Rd., left into Webb Rd., right into Fitzgerald Rd. Turn right off Fitzgerald into unmarked dirt road at edge of forest, and follow rough bush track for 650 m down to turntable just above Jackson's Creek. The quarry is opposite the turntable. From Fitzgerald Rd., the track may be too rough and slippery for normal vehicles.

The fossils are easily obtained from the large spoil heap below the quarry itself. The assemblage consists of *Tetragraptus serra* (J. Hall), *T. amii* Elles & W., *T. quadribrachiatus* (J. Hall), extensiform *Didymograptus* spp., *Etagraptus tenuissimus* (Harris & Thomas), *Isograptus victoriae maximodivergens* Harris, *I. caduceus imitatus* Harris, *Pseudisograptus dumosus* (Harris) and *P. tau* (Harris). They are preserved as white markings on dark grey slate.

Stop 4: Ya2, *Cardiograptus* Zone, Willey's Quarry near Woodend (Fig. 7).

Willey's Quarry is on private land at the end of Willey's Road, Macedon, a signposted track leaving the western side of Calder Highway 7 km south of Woodend. It is the westernmost of three small, long-disused slate quarries on the north bank of Slaty Creek near Woodend. The fossils are best collected from spoil below the excavations.

This is the type locality for several *Pseudisograptus* spp., including the type species, *P. manubriatus* (T.S. Hall). Harris (1933) listed a large assemblage consisting of *Tetragraptus serra* (J. Hall), *T. quadribrachiatus* (J. Hall), *Dichograptus octobrachiatus* (J. Hall), *D. solidus* Harris & Thomas, *Didymograptus v-deflexus* Harris, *Phyllograptus*? sp., *Goniograptus speciosus* T.S. Hall, *G. sculptus* Harris & Thomas, *Isograptus caduceus australis* Cooper, *I. victoriae divergens* Harris, *Oncograptus upsilon* T.S. Hall, *Cardiograptus morsus* Harris & Keble, *Skiagraptus gnomonicus* (Harris & Keble), *Pseudisograptus manubriatus manubriatus* (T.S. Hall), *P. dumosus* (Harris), *P. tau* (Harris) and *Pseudotrigonograptus ensiformis* (J. Hall) (taxonomy updated). Cooper & Ni (1986) listed and described several more *Pseudisograptus* taxa, including *P. m. manubriatus* (T.S. Hall), *P. m. harrisi* Cooper & Ni, *P. m. koi* Cooper & Ni, *P. m. janus* Cooper & Ni, and figured the *P. dumosus* as *P. dumosus* form B. The fossils are preserved as white, rather micaceous markings on dark grey slate.

STOPS 5 AND 6, BENDIGONIAN, DAYLESFORD REGION (Fig. 8).

Stop 5: Be3, *Pendeograptus fruticosus* 3+4-br. Zone, PL190, Daylesford (Fig. 8).

The locality is a road cutting on Midland Highway 2.4 km west of the Hepburn Springs turnoff in Daylesford. It is the first large cutting on the right hand side from Daylesford.

The assemblage consists of *Clonograptus* sp., *Temnograptus* sp., *Phyllograptus* sp., *Didymograptus (Expansograptus) latus, D. (E.)* spp., *Pendeograptus fruticosus* (J. Hall) 4-br. and 3-br., *Goniograptus macer* T.S. Hall, *G. thureaui* (McCoy), *Etagraptus harti* (T.S. Hall), *Kinnegraptus*? sp., and the conodonts *Oepikodus evae, Bergstroemognathus extensus* and gen. et sp. nov. (platform elements). A large sponge has also been recovered. The graptolites are preserved as whitish markings on grey slate, or occasionally as dark, delicately outlined markings on bleached, near-white bedding planes. The conodonts occur as tiny limonite-stained cavities.

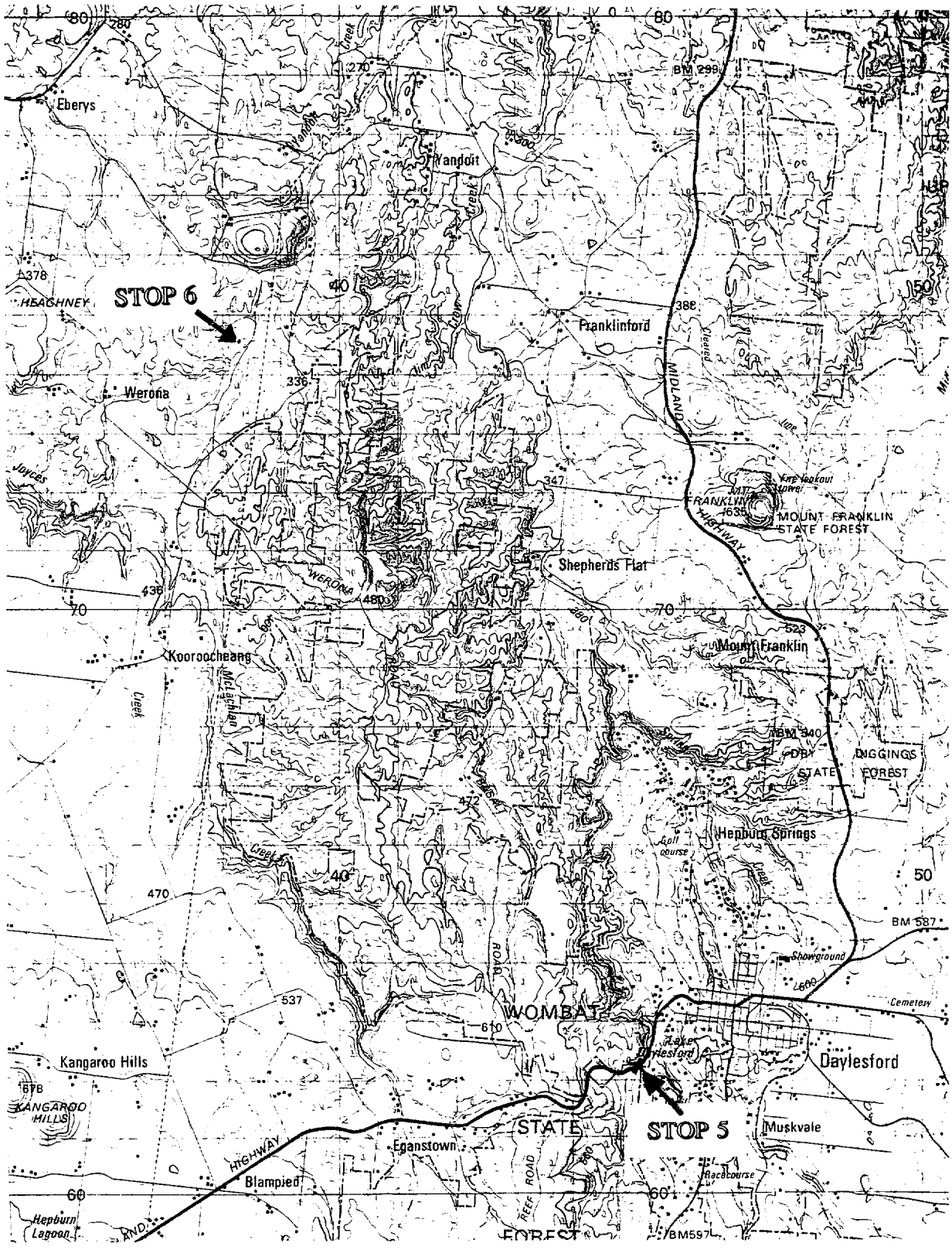

Fig. 8: Locality map, Daylesford and Yandoit. Scale = 1:100,000.

Stop 6: Be1, *Tetragraptus approximatus* + *Pendeograptus fruticosus* Zone, "Good bed", Campbelltown (Fig. 8).

The locality is a small trench on private land at Campbelltown. To gain access, permission must be obtained from the owner, Mr C. Culvenor.

The locality was discovered and excavated by a previous owner, Thomas Smith, a keen graptolite collector who discovered many graptolite localities in the district (see Harris & Thomas, 1948). It contains the largest known Be1 assemblage, comprising *Clonograptus tenellus problematicus* Harris & Thomas, *C. persistens* Harris & Thomas, *C. rarus* Harris & Thomas, *C. timidus* Harris & Thomas, *Tetragraptus approximatus*, *"T." decipiens* (as *T. volitans* Harris & Thomas), *Pendeograptus fruticosus* 4-br., *P. crassus* (Harris & Thomas), *Dichograptus maccoyi* Harris & Thomas, *"D." sedecimus* Harris & Thomas (probably a new genus), *Didymograptus (Expansograptus) abnormis* Hsu, *D. (E.) asperus* Harris & Thomas, *D. (E.) latus latus* T.S. Hall, *D. (E.) latus aequalis* Harris & Thomas, *D. (E.)* cf. *suecicus* Tullberg, *D. (E.) vicinus* Harris & Thomas, *D. (E.)* sp. (listed as *D. similis*), *D.* (sensu lato) *eocaduceus* Harris, *D.* (s.l.) *hemicyclus* Harris, *Temnograptus (Schizograptus) incompositus* Harris & Thomas, *Loganograptus rectus* Harris & Thomas, *Sigmagraptus yandoitensis* Harris & Thomas (?= *S. praecursor* Ruedemann), *Goniograptus thureaui thureaui* (McCoy) (includes as *G. thureaui inaequalis* Harris & Thomas), *G. thureaui clonograptoides* Harris & Thomas, *G. macer* T.S. Hall, and *G. tumidus* Harris & Thomas. The fossils are preserved as dark red micaceous aggregates on a pink slate.

Zone Be1 marks a most spectacular burst of new forms, and especially of dichograptids and sigmagraptines: no fewer than 47 species make their appearance here, of which 15 are confined to the zone (VandenBerg & Cooper, in press).

STOPS 7 AND 8: YAPEENIAN AND CASTLEMAINIAN, CASTLEMAINE REGION (Fig. 9).

Stop 7: Ya2, *Cardiograptus* Zone, Chinaman's Creek, Muckleford (Fig. 9).

The locality is a small bluff on the right (north) bank of Chinaman's Creek, Muckleford. It is on private land and permission must be sought from the owner.

The fossils here are in a very soft shale interbedded in sandstone. Preservation is quite good, as grey "ghosts" on a pale brown slate. Care must be taken to protect the collected fossils from damage by rubbing.

The fauna, listed in Harris & Keble (1932) and McLaurin (1976) is quite large but dominated by isograptids and glossograptids. It includes *"Phyllograptus"* sp., *Didymograptus (Corymbograptus) v-deflexus* Harris, *Isograptus caduceus australis* Cooper, *I. victoriae divergens* Harris, *Oncograptus upsilon* T.S. Hall, *Skiagraptus gnomonicus* (Harris & Keble), *Cardiograptus morsus* (H. & K.) (narrow form), *Pseudisograptus manubriatus* (T.S. Hall), *P. dumosus* (Harris) form B, *Apiograptus crudus* (Harris & Thomas) and *Pseudotrigonograptus ensiformis* (J. Hall).

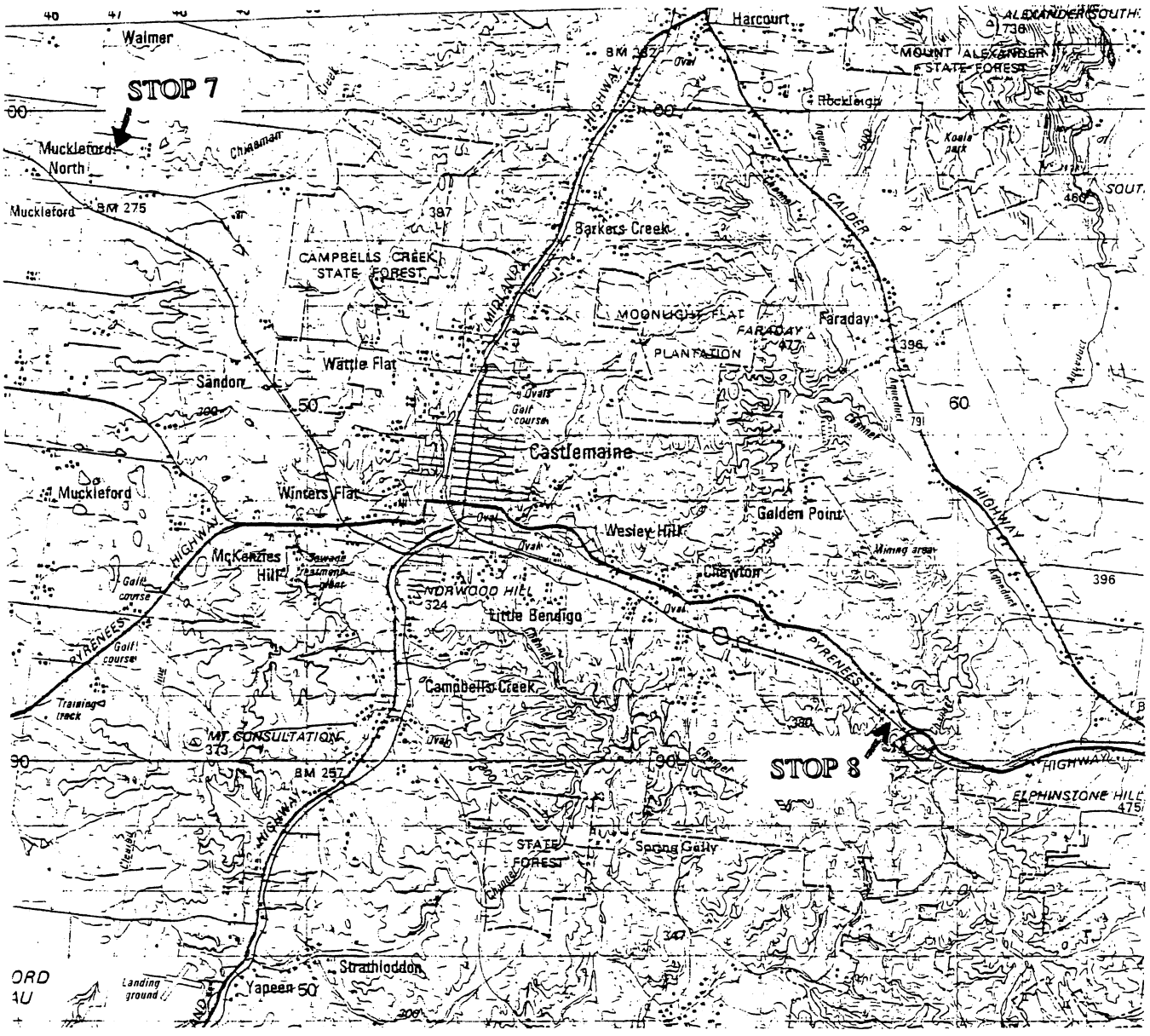

Fig. 9: Locality map, Castlemaine and Muckleford. Scale = 1:100,000.

Stop 8: Depositional and structural style of Castlemaine Supergroup sediments, Castlemaine-Chewton railway cutting (Fig. 9).

The long series of railway cuttings between Castlemaine and Chewton provides the best continuous exposure of Castlemaine Supergroup anywhere in the State. There is a variety of depositional styles, from thick-bedded turbidites with complete Tabce Bouma sequences, to intervals of thin-bedded sandstone and mudstone. Most of the mudstone is massive and quite unfossiliferous, and may have been deposited as mud turbidites, or as silty "tails" of turbidity currents. The sequence exposed in a series of cuttings ranges from Chewtonian to Yapeenian, but in spite of the long exposures, it has not been possible to locate stage boundaries in outcrop--they coincide either with outcrop gaps, or with known faults.

In the cutting to be visited, there are Ca3 graptolites (*I. victoriae maximus*) at one end, and

Ca2 (*I. v. victoriae*) at the other.

STOPS 9 - 11, BENDIGO REGION (Figs 10, 11).

Stop 9: Ch1, *Didymograptus protobifidus* Zone, PL2963, Spring Gully Reservoir, Bendigo (Fig. 10).

The locality is a small pit just outside the reservoir fence. Fossils can be found in the spoil material which is liberally strewn around the pit, and may be freshly excavated from the pit.

The assemblage consists of *Tetragraptus serra, Phyllograptus typus, Didymograptus (E.) extensus, D. (E.) sp., D. (Didymograptellus) protobifidus, Pendeograptus fruticosus* 3-br. and 2-br., *P. pendens, Sigmagraptus praecursor, Goniograptus thureaui, Zygograptus irregularis* (?), *Etagraptus harti* and *Perissograptus pygmaeus*. The fossils are preserved as dark red markings on a pale pink slate, and show a small amount of tectonic distortion.

Stop 10: Da3, *Pseudoclimacograptus decoratus* Zone at Wellsford Rifle Range, east of Bendigo.

The stop is at the rifle butts of Wellsford Rifle Range, east of Bendigo.

Darriwilian rocks outcrop extensively to the east of the Whitelaw Fault, east of Bendigo. This "east Bendigo" region was where the early Darriwilian sequence was first worked out (Harris, 1935; Harris & Thomas, 1935). The Darriwilian is much less sandy than the older Ordovician rocks, hence this is a region of low relief with deep Tertiary weathering. Outcrops are therefore scarce, and many of Harris' outcrops were ephemeral.

The outcrop at Wellsford Rifle Range consists of deeply weathered soft cream-coloured shale, on which graptolites are preserved as brown and grey marks which show reasonably good preservation. Take care, however: the rock is very soft and specimens need to be carefully wrapped, otherwise they will suffer damage in transport.

The locality contains a very diverse assemblage consisting of *Tetragraptus* aff. *serra*, *Pseudophyllograptus nobilis* Harris & Keble, *Didymograptus (Expansograptus) acriculus* Keble & Harris, *Acrograptus cognatus* (Harris & Thomas), *Brachiograptus etaformis* Harris & Keble, *Holmograptus spinosus* Ruedemann, *Atopograptus woodwardi* Harris, *Pseudotrigonograptus ensiformis* (J. Hall), *Isograptus subtilis* Williams, *Pseudisograptus*? n. sp., *Bergstroemograptus crawfordi* (Harris), *Paraglossograptus tentaculatus* (J. Hall), *Cryptograptus schaeferi* Lapworth, *C. circinus* Keble & Harris, *Pseudoclimacograptus decoratus* (Harris & Thomas), *P. modicellus* (Harris & Thomas), and *Climacograptus*? n. sp., together with phyllocarid crustacea and some large conodont elements.

This zone reflects an extraordinary faunal revolution. The full Da3 assemblage includes 33 species, of which 21 make their first appearance, 17 are confined to within the zone, and 27 disappear within the zone. Of the five taxa that survive into the next zone, Da4, only two make it into the Gisbornian, making this end-Darriwilian event the greatest graptolite extinction event next to the end-Ordovician extinction (VandenBerg & Cooper, in press).

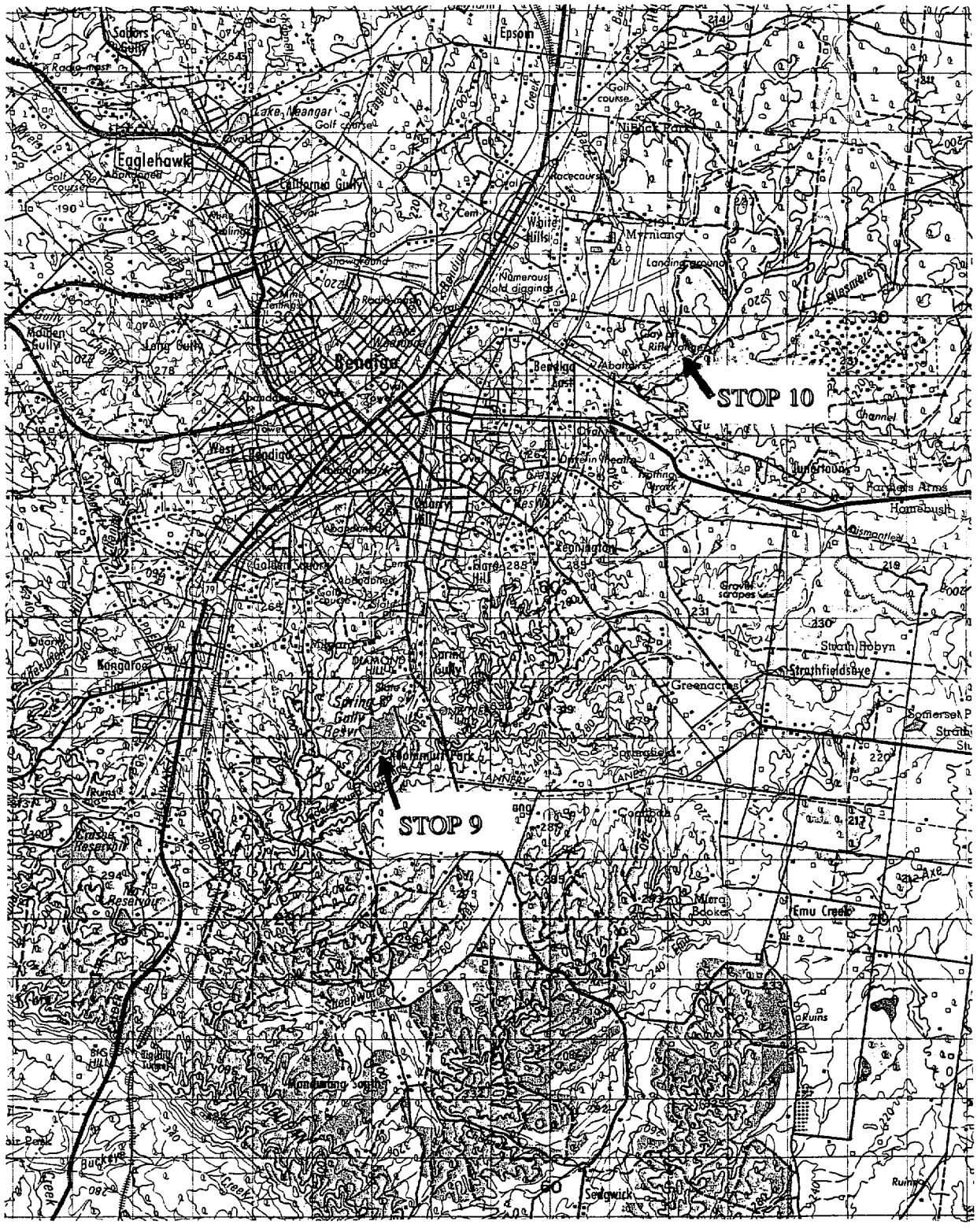

Fig. 10: Locality map, Bendigo region. Scale = 1:100,000.

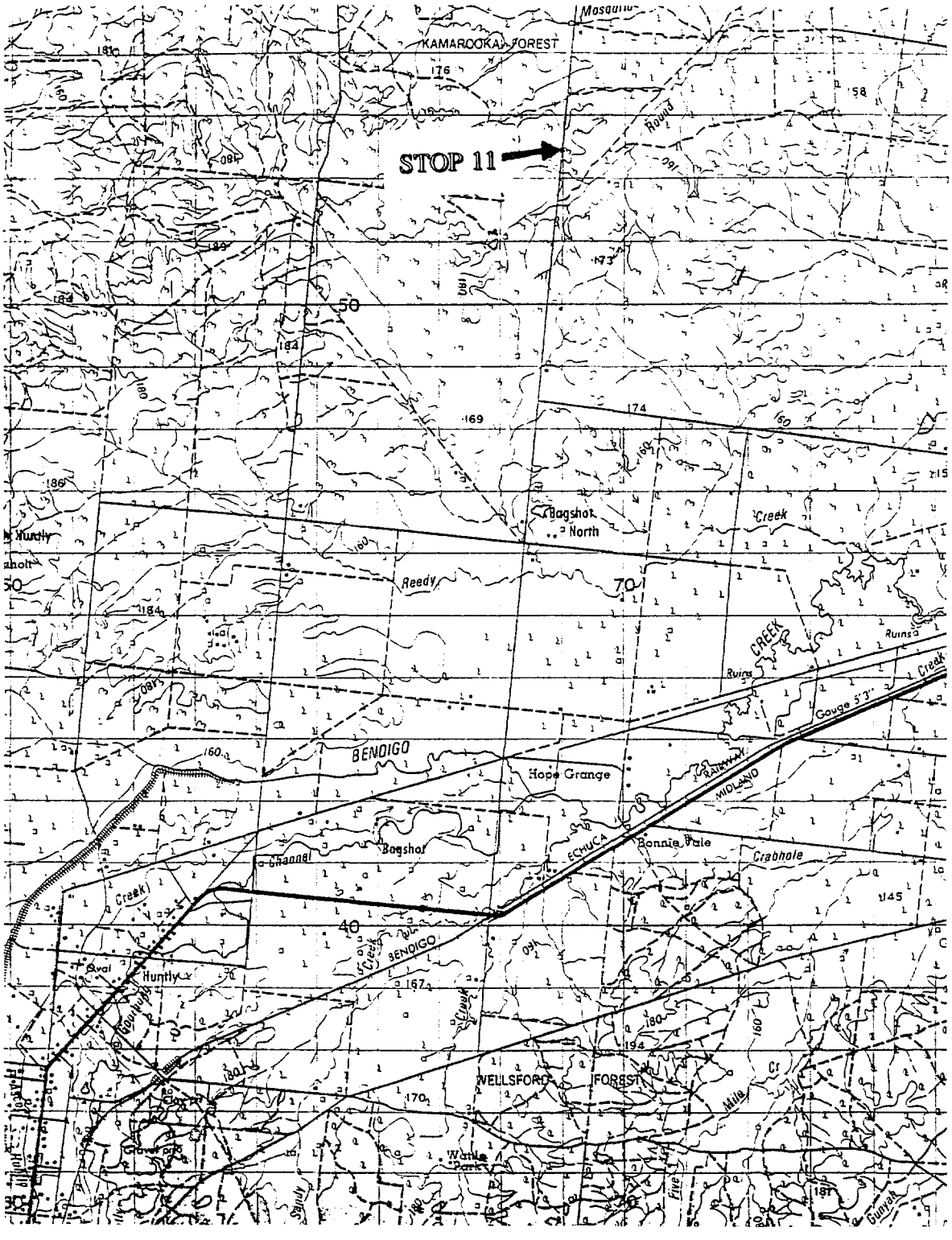

Fig. 11: Locality map, Bagshot North. Scale = 1:100,000.

Stop 11: Ca3, *Isograptus victoriae maximus* Zone, PL2962, Bagshot North.
The locality is in a low road cutting on either side of the Bagshot North road, 6.5 km north of Bagshot North (Fig. 11). It is newly discovered, and our faunal list is therefore quite brief.

The assemblage is dominated by *Isograptus victoriae maximus* which occurs together with *I. caduceus australis* and *Pseudisograptus gracilis*. The graptolites are preserved as reddish brown markings on pink or cream-coloured shale.

In transit: Whitelaw Fault, Bendigo East.

The McIvor Highway crosses the Whitelaw Fault in the eastern outskirts of Bendigo. The Whitelaw Fault is one of a series of major strike faults with east-side-down displacement; they are inferred to be listric high-angle reverse faults rooted in a large, near-horizontal decollement zone at a depth of 5 km or more. There is no surface expression of the fault, which is barely exposed in the road-side gutter. Graptolites show that it is a large fault, with Lancefieldian on the west and Darriwilian on the east.

In transit: Permian tillite, Derrinal.

Permian glacials and periglacials are preserved in many places in southeastern Australia, as thin, flat-lying cover rocks on the folded Ordovician. A large area of Permian is reserved at Derrinal, and is surrounded by a gently undulating exhumed Permian landscape, as shown by the abundance of grooved and polished pavements preserved under the soil (Robbins, 1973; Bowen & Thomas, 1988). Grooved surfaces also occur within the tillite sequence.

STOPS 12 AND 13: CASTLEMAINIAN, HEATHCOTE - MIA MIA AREA

Stop 12: Ca1, *Isograptus victoriae lunatus* Zone, PL159, Mia Mia (Fig. 12).

The locality is in a gutter in a small road diversion on the western side of the Mia Mia-Derrinal road, 2 km north of Mia Mia.

The assemblage here is dominated by *Isograptus victoriae lunatus, Zygograptus* spp., and by phyllograptids (sensu lato). Most remarkable of these is *Phyllograptus* sp., a large, near-spherical species with delicate threads several centimetres long attached to the "mucros" of the proximal 3-5 thecae on each stipe. It is abundant. Several species of *Zygograptus* occur (*Z. irregularis, Z. junori* and others), but identification is difficult because most are preserved in lateral aspect, and are tangled up.

The remainder of the assemblage consists of *Phyllograptus typus, Pseudophyllograptus angustifolius* and n. sp. (extremely slender), *Tetragraptus serra, T. quadribrachiatus, Dichograptus octobrachiatus, D. maccoyi*, and *D. (Expansograptus)* spp. The graptolites are preserved as dark grey-brown aggregates on a cream slate. The slaty cleavage hinders obtaining a bedding plane split, but there is no tectonic distortion other than the normal flattening on bedding. Exceptional specimens are preserved in full relief.

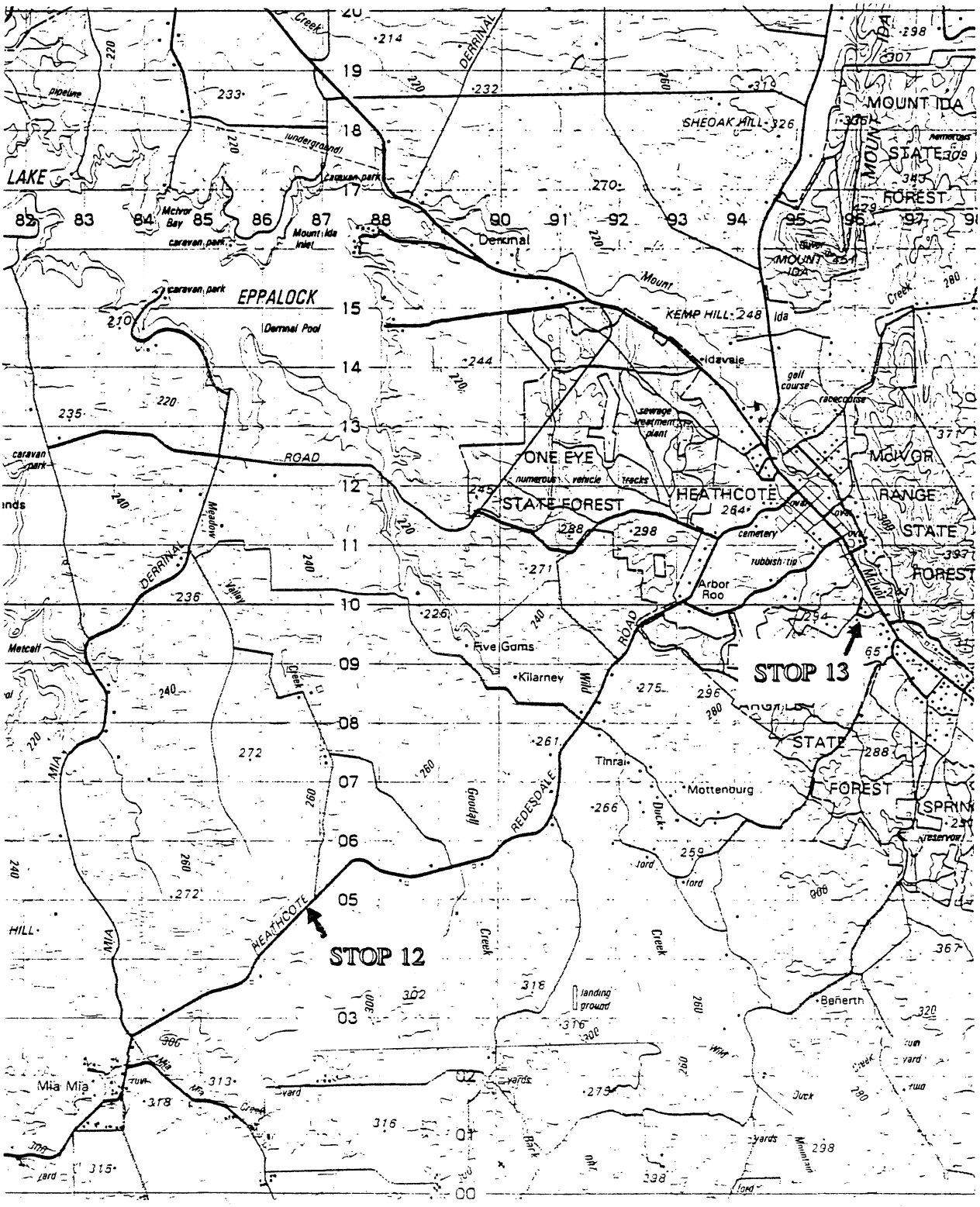

Fig. 12: Locality map, Heathcote - Mia Mia region. Scale = 1:100,000.

Stop 13: Heathcote Fault at Heathcote (Fig. 12).
The Heathcote Fault is one of a system of bedding-parallel faults along the Heathcote Greenstone Belt, that separate the Bendigo-Ballarat Zone from the Melbourne Zone. The Heathcote Fault is at the top of the Cambrian and is well-exposed in the 'badlands' at Heathcote, where gold mining activity has led to extensive erosion and removal of soil. The main fault, at the base of the Cambrian, lies in a valley and is not exposed.

These faults dip very steeply at surface, but a seismic traverse shows them to be strongly listric, becoming gently west-dipping at a few km depth. The Heathcote Greenstone Belt is thus a thrust system, with Cambrian and Ordovician thrust eastwards over the Silurian and Early Devonian of the Melbourne Zone. The thrusting probably occurred during the Middle Devonian Tabberabberan Deformation, although there is evidence that Cambrian greenstone was exposed somewhere along here or farther west much earlier than this: the late Llandovery Springfield Sandstone near Romsey contains large amounts of basaltic detritus.

In transit: visit McIvor Winery at Heathcote en route.

STOP 14: EASTONIAN, ENOCH'S POINT

Stop 14: Eastonian (Ea1-Ea2) Mount Easton Shale, Enoch's Point (PL1300s).

The locality is a long road cutting (Fig. 13) along Big River Valley Road, about 4 km south of Enoch's Point. Most of the road from Eildon is unsealed, and the last section along Big River Road is quite rough. Big River Road continues and ultimately joins the Yarra Track (Warburton-Wood's Point Road) at Cumberland Junction, but it has a kilometre-long section that is only passable by 4WD vehicle.

The road cutting, which is more than 1 km long, is entirely in (mostly bleached) shale, with no interbedded sandstone. This is typical of most outcrops of Mount Easton Shale. There is a pervasive slaty cleavage but in the Ea1-Ea2 section to be sampled this is unobtrusive and does not interfere with the very good bedding-parallel splitting property of the shale. There is also no distortion of the graptolites, other than flattening along bedding. In the younger (Ea3-Ea4) section farther east, the cleavage becomes much stronger and renders the shale much harder to split on bedding.

Most of the shale in this section is bleached to pale brown colours. Graptolites are quite delicately preserved as grey stains, with only solid structures such as apertural selvages in the climacograptids and amplexograptids, and virgellar spines, preserved in slight relief. In some places the shale is still black, in which case the graptolites occur as black shiny films, which do not show much detail. Note the very fine shaly lamination, and the total absence of burrow marks, both typical of the upper Ordovician black shale facies in the southeastern Lachlan Fold Belt.

Details of the section and fauna were given by VandenBerg & Stewart (1983) and are reproduced here (Figs 13 and 14). The updated faunal list is as follows, with range indicated by [1] for Ea1 and [2] for Ea2: *Corynoides americanus* Rued. [1], *C. australis* Harris & Thomas [1,2], *C.* cf. *calicularis* [1,2], *C. curtus* Lapw. [1?,2], *C. ultimus* Rued. [2],

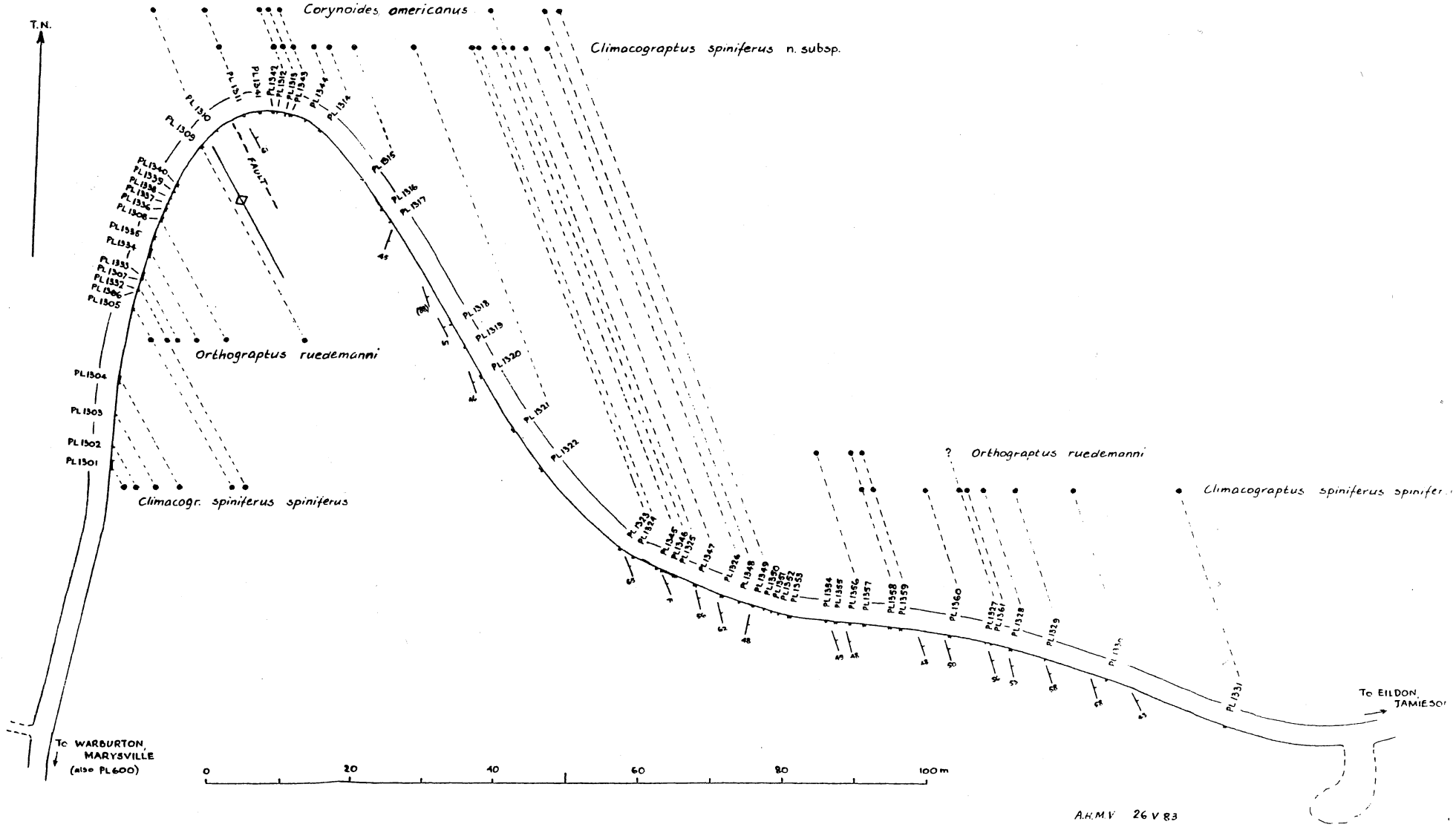

Fig. 13: Detailed map of fossil localities, near Enoch's Point.

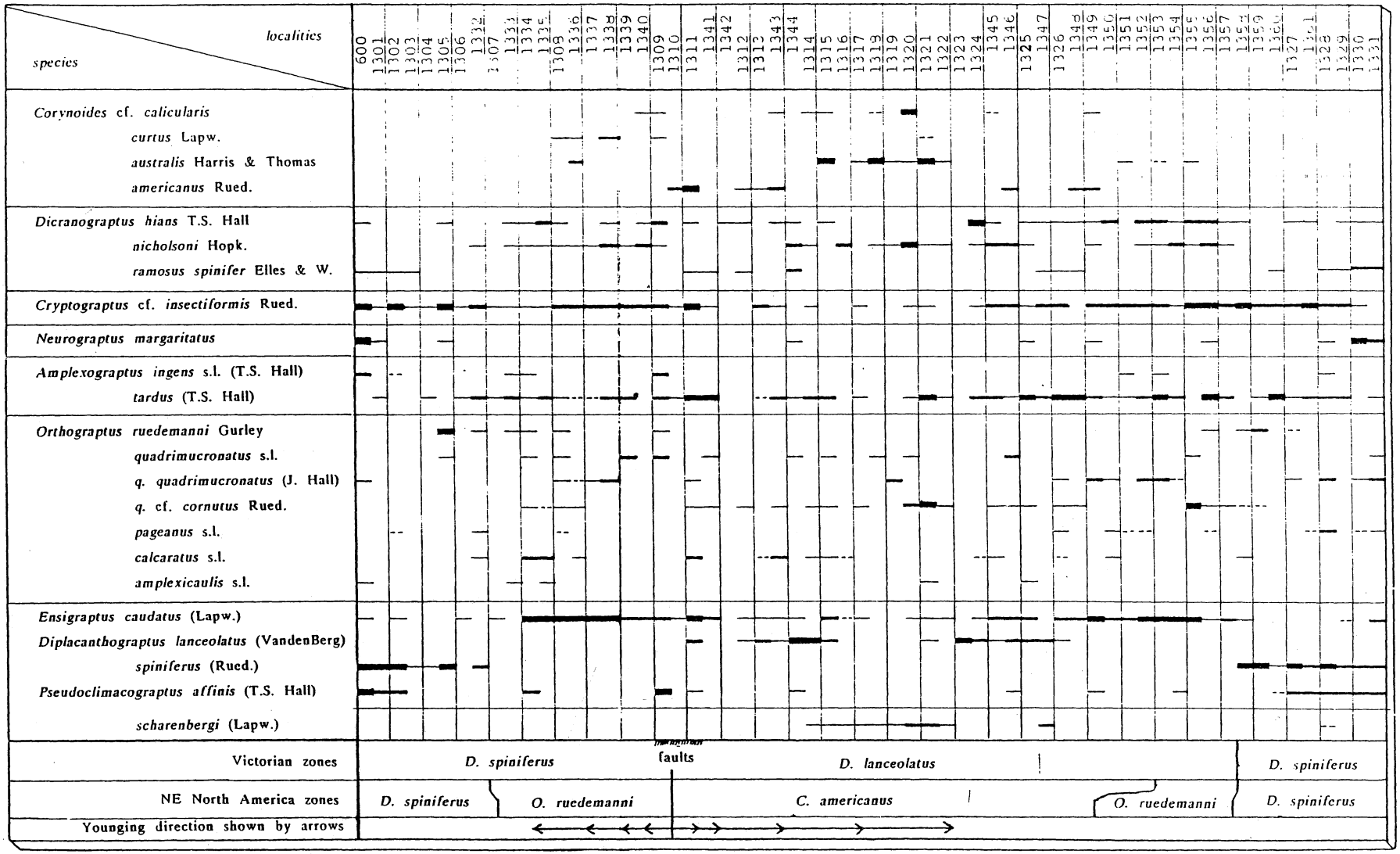

Fig. 14: Distribution of main graptolite species, Enoch's Point section.

Cryptograptus cf. *insectiformis* [1,2], *Dicranograptus nicholsoni* Hopk. [1,2], *D. hians* T.S. Hall [1,2], *D. ramosus spinifer* Elles & W. [1,2], *Dicellograptus caduceus* Lapw. [2], *D. flexuosus* Lapw. [2], *Neurograptus margaritatus* Lapw. [1,2], *Amplexograptus ingens ingens* (T.S. Hall) [2], *A. i. wellingtonensis* (Harris & Thomas) [1,2], *A. tardus* (T.S. Hall) [1,2], *A.* n. sp. [1] (wrongly figured as *A. tardus* in VandenBerg & Stewart (1983, fig. 47); *A. tardus* is the senior synonym of *A. praetypicalis* Riva), *Climacograptus? baragwanathi* T.S. Hall [2], *Diplacanthograptus lanceolatus* (VandenBerg) [1], *D. spiniferus* (Rued.) [2], *Ensigraptus caudatus* (Lapw.) [1,2], *Orthograptus amplexicaulis* s.l. [1,2], *O. pageanus pageanus* Lapw. [1,2], *O. p. spinosus* Harris & Thomas [1,2], *O. quadrimucronatus quadrimucronatus* (J. Hall) [1,2], *O. q.* cf. *cornutus* Rued. [1,2], *O. q. spinigerus* Lapw. [2], *O. ruedemanni* Gurley [topmost Ea1 to Ea2], *O.* n. sp. A (Fig. 35 in VandenBerg & Stewart, 1983) [1], *Pseudoclimacograptus affinis* (T.S. Hall) [1,2], *P. scharenbergi* (Lapw.) [1], *P.* n. sp. A (Fig. 26 in V. & S. 1983) [1], *P.* n. sp. B (Fig. 30 in V. & S. 1983) [2], *Glyptograptus brevis brevis* (Elles & W.) [1] and *G. brevis strictus* (Rued.) [1].

Several points are worth emphasizing. The early Eastonian (Ea1+2) is an easily recognizable assemblage, characterized by *D. hians, N. margaritatus, A. ingens* and *E. caudatus*, all of which are distinctive and do not extend beyond the interval. Zone Ea1 in southeastern Australia is entirely without *Dicellograptus*, and the difference in thecal form between the Gisbornian species (*D. sextans* etc.) and the later species is such that *Dicellograptus*, as presently defined, may be a polyphyletic taxon. Lastly, in addition to several thousand graptolites which have been collected from this section, there have been two or three conodont elements, and two straight nautiloids.

July 25 (Thur.) Travel from Eildon to Melbourne via Yea, to visit the oldest *Baragwanathia* locality (Ludlow). Arrive in Melbourne mid-afternoon. If Devilbend Quarry is accessible, the alternative is to take those needing to catch a plane on July 25th to Tullamarine and the rest to Devilbend Quarry to spend the entire afternoon there; this is only feasible for persons not needing to fly home on July 25th. Devilbend Quarry is about 2 hours travel beyond Melbourne (it is on the 'wrong' side, southeast of Melbourne), and 2½ hours from Tullamarine. Eildon to Devilbend is about 4 hours travel.

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