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GEOLOGICAL SURVEY REPORT

NUMBER 1971/1

EXPLANATORY NOTES ON THE
RINGWOOD 1:63,360 GEOLOGICAL MAP

by A.H.M. VANDENBERG

MINES DEPARTMENT VICTORIA

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NOTE: Figure 3 is modified from Neilson 1970, and Table 3 is after Neilson 1970

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1:63,360 GEOLOGICAL MAP

by A.H.M. Vandenberg

PART ONE

INTRODUCTION

The area described totals approximately 1200 km^2, and includes the eastern and southeastern suburbs of Melbourne, the Dandenong Ranges, the Harkaway Hills and the Silvan and Macclesfield districts. It coincides with the 1:50,000 military maps of Monbulk and Ringwood, which were used as a base. Topographically, the area is dominated by the Dandenong Ranges, composed of Devonian volcanics; these are flanked to the east and west by a maturely dissected hilly terrain of Lower Palaeozoic sedimentary rocks, and to the south by a hilly terrain of granodiorite. In the southwestern part of the area, the coastal plain of the Brighton area merges with the Carrum Swamp to the south.

ACKNOWLEDGEMENTS

The mapping of the Ringwood 1:63,360 geological map was carried out by the author during 1968 and 1969, as part of a regional mapping project for the Geological Survey of Victoria. The author is indebted to Dr D. Spencer-Jones, Director of Geological Survey, and to Mr G. Bell and Dr J.G. Douglas for their encouragement. During the field work, emphasis was laid on the study of the Lower Palaeozoic sedimentary rocks, and in this the author benefited from discussions with Mr M.J. Garratt and Mr N.W. Schleiger, both of whom co-operated in some of the field work. Dr D.E. Thomas, and Messrs P.R. Kenley and T.A. Darragh generously provided valuable information on the eastern part of the area. The author is also indebted to Mr Kenley for discussion and suggestions on the Tertiary geology, and for editing this paper. Messrs J.L. Neilson and J.B. Coulsell provided the author with information on the geology of the MMBW tunnels along North Road, and from East Malvern to Braeside. Dr A. Cundare (Geology Dept, Melbourne University) kindly provided the revised petrography of the Devonian volcanic rocks. Sincere thanks are due to the Draughting Branch of the Mines Department for the draughting and reproduction of the geological map.

The early observations of Dr A.R.C. Selwyn served as a source of inspiration throughout the course of this project.

PART TWO: GEOLOGY

SECTION A: THE LOWER PALAEOZOIC SEDIMENTARY ROCKS

The oldest rocks known in the area are of Lower Silurian to Lower Devonian age. They consist of a conformable sequence of sedimentary rocks laid down in a geosynclinal trough, and reach a thickness of about 8,200 m. They have been subdivided into four formations:

youngest:	Dlc	Cave Hill Sandstone	30-60 m
	Dlh	Humevale Formation	4,300+ m
	Sud	Dargile Formation	1,700 m
oldest:	Sla	Anderson Creek Formation	2,300+ m

The lower three formations show gradational boundaries.

In marine trough environments, two types of sediment can be recognised:

(a) argillites, resulting from the accumulation of mud settling in a quiet water environment;

(b) arenites - rudites, resulting from ephemeral sediment-laden turbidity currents, which carry large amounts of sediment from the continental slope far into the trough. The typically poorly sorted sediments (greywackes) deposited by turbidity currents are called turbidites. They show a rhythmic succession of bedding structures, which Bouma (1962) summarised as follows:

top: Unit 'e': massive mudstone
Unit 'd': laminated mudstone, siltstone, or fine sandstone
Unit 'c': current-bedded sandstone
Unit 'b': laminated greywacke or sandstone
Unit 'a': massive greywacke, grading from coarse to fine upwards; this may include poorly sorted conglomerates
Units 'a' to 'd' represent sediments deposited by a single passing turbidity current, and reflect the decrease in turbulence as the current passes. Unit 'e' represents pelagic mud deposited under quiet water conditions. Turbidites are further characterized by sole marks such as flute casts and bounce marks, and by the presence of current ripple marks or antidunes.

Sla: ANDERSON CREEK FORMATION (Selwyn 1854-5) (='Unnamed Formation', Moore 1965).

Selwyn gave the name Anderson's Creek Beds to a sequence of siltstone, greywackes, and conglomerates outcropping in Anderson Creek. The author has extended the name to include the thick sequence of similar rocks overlying the Anderson Creek sediments. Sediments of similar lithology in the Macclesfield area are correlated with this unit.

Age: Upper Llandoverian to Lower Ludlovian.
Estimated thickness: 2,300+ m (base not exposed).

LITHOLOGY: The Anderson Creek Formation consists almost entirely of massive mudstones and minor siltstones ('e' units). Bed thicknesses range from a few cm to about a metre; 15 to 30 cm is most common. The mudstones are predominantly claystones to silty claystones. They show a great abundance of worm burrows parallel to the bedding. When fresh, the mudstones are dark grey and the burrows black. The mudstones are invariably interbedded with thin to very thin sandstones, ranging between 3 and 12 mm, which show prominent current bedding, sometimes also laminations. These represent 'b' and 'c' units. The current bedding indicates a predominantly westerly source of the sediments. When fresh, the sandstones may be difficult to distinguish from the mudstones in outcrops.

On weathering, the mudstones may become olive green and indurated, or may become yellow, red, pink, orange, or brown, and soft. In the latter case, the worm burrows and thin sandstones become impregnated with iron oxides, so that they tend to weather in relief.

Thick repetitive turbidite sequences are found at numerous intervals in the Anderson Creek Formation. Bed thicknesses range from a few cm to more than 3 m; 15 to 60 cm is most common. Unit 'a' generally predominates, while 'b' and 'c' units are generally only thin or completely absent. The 'a' units sometimes include poorly sorted irregular conglomerate bands, with well rounded pebbles up to 10 cm in diameter, of white quartz, quartzite, sandstone and chert in a matrix of angular coarse sand or fine gravel. Other conglomerates consist of large elongate pebbles or boulders (clasts) up to 15 cm long, of mudstone set in a fine gritty matrix. Grit beds, generally less than 12 mm thick, are sometimes found about 12 mm above the base of the 'a' units. Near the crest of the Warrandyte Anticlinorium a number of conglomerates outcrop. The thickest of these reaches about 6 m (Jutson 1911b), and has been named the Warrandyte Conglomerate Member (Moore 1965). The type locality of this conglomerate is the Warrandyte South quarry (co-ords 255 433). Other localities where the features described above are well exposed include the road cuttings on the Ringwood-Warrandyte road between Wellesley and Hall roads (Co-ords 2630 4075 to 2610 4150), and the small quarries on Gold Memorial road (co-ords 2425 4420 and 2445 4425).

Fresh outcrops of conglomerate have not been found, although hard, indurated conglomerate beds outcrop in the bed of Anderson Creek. It weathers to a yellow or pale brown rock, from which the pebbles can be easily extracted. The greywackes, when fresh, are dark grey, and very hard. They weather to shades of green, brown, yellow, and white and may become very soft and friable. In the Macclesfield area, many of the greywackes have been silicified, and are dense and tough.

PALAEONTOLOGY: The Anderson Creek Formation is only sparingly fossiliferous. The list below includes the significant fossils so far discovered.

(1) Macclesfield area (Locs. T 22, T 23, T 39): *Monograptus marri, M. priodon, M.* cf. *spiralis* (T.S. Hall 1914; Thomas 1939; Thomas & Kenley 1954-5).

(2) Warrandyte area: The Warrandyte Conglomerate Member has yielded a number of fossils, which have not been described. *Monograptus* aff. *priodon* has been found in a small quarry at Warrandyte (Gill 1952).

(3) Templestowe area: The trilobite *Thomastus jutsoni* (Chapman) was found in an old quarry, now built over, at co-ords 1160 4210, and also at No.14 Hill Rd, North Balwyn.

The graptolites indicate an Upper Llandoverian age for the beds of Warrandyte and Macclesfield, while the trilobite can be compared with *Thomastus* spp. from the Upper Llandoverian *'Illaenus'* Band of the Heathcote area (Öpik 1953, Talent 1965b). The age of the upper part of the formation is poorly known. Wenlockian fossils have yet to be found, but *Monograptus bohemicus* occurs near the top of the formation in the Eltham area (Schleiger, pers. comm.), indicating a Ludlovian (probably lowermost Ludlovian) age for the top.

Sud: DARGILE FORMATION (Thomas 1937) (= Christmas Hills Formation of Gill 1965; Moore 1965; and Yan Yean Formation of Williams 1964).

Thomas gave the name Dargile Beds to a sequence of sandstones and shales of Ludlovian age, occurring in the Heathcote district. Recent mapping by Schleiger (MS), Williams (1964), Garratt (in prep.) and the author, has shown that this formation extends southwards into the Melbourne area.

Age: Ludlovian (? to Lower Gedinnian).
Estimated thickness: 1,700 m

LITHOLOGY: The Dargile Formation consists of rhythmically interbedded thin mudstones, siltstones, shales, and sandstones. Bed thicknesses vary between 12 mm and 30 cm; 25 mm to 50 mm is most common. The formation is typified by rhythmic sequences of 'b' and 'c' units; the 'a' units so common and thick in the turbidites of the Anderson Creek Formation are rare and thin in the Dargile Formation. The 'e' units (mudstones) are usually very thin. The current bedding in the abundant 'c' units indicates a westerly source of the sediments. Petrologically, the argillites are claystones or silty claystones. The argillites form the largest component of the formation, i.e. approx. 75 to 80% of the total thickness.

When fresh, the rocks are dark-grey to black, often with pale grey laminae of sand. The bedding features are best observed in weathered sections, where the rocks have become softer, and show shades of light grey, green, brown, and yellow. The weathered sandstones become very soft and friable, and split easily along the laminations. In sequences where thicker mudstones predominate, the thin sandstones become impregnated with iron oxides, and are resistant to weathering. In the area north of Heathmont, the upper 150 m of the formation has been silicified, rendering the rocks very hard so that they form a prominent strike ridge.

A narrow, gently dipping belt of gritty sandstones and fine shales occurs along the northern side of the Yellingbo Fault. This has been tentatively included in the Dargile Formation, although fossils from these sandstones are largely indeterminable. Close to the fault, the sandstones have been metamorphosed by the Yellingbo Dyke to form tough quartzites.

PALAEONTOLOGY: In the Dargile Formation, few fossil localities are known. The most significant are listed below.

(1) Studley Park (co-ords 040 383): *Monograptus dubius*, *M. varians*, *M. chimaera*, *M. colonus*, *M. crinitus*, *M. roemeri*; the ophiuroids *Urosoma bakeri* (Withers & Keble), *Sturtzura brisingoides* (Gregory); the arachnid *Hemiaspis tunnecliffei* Chapman; and the brachiopods *Stegerhynchus* sp. and *'Chonetes' melbournensis* Chapman.

(2) Williamsons Rd, Doncaster (co-ords 157 409): the brachiopods *'Nucleospira'* sp. and *'Chonetes'* sp. (Gill 1942).

(3) Yarra Rd, Wonga Park (co-ords 299 440): the brachiopod *Notanoplia* sp., and the trilobite *Phacops* sp. (Gill 1940).

The fossils from Studley Park indicate a Lower Ludlovian age. *Notanoplia* has so far only been recognized from Lower Devonian rocks in Victoria. It is, however, doubtful that the Yarra Rd locality is of Lower Devonian age. The upper age limit of the formation cannot yet be accurately established, owing to the unfossiliferous nature of the Dargile Formation and the lower part of the Humevale Formation in the Ringwood area.

Dlh: HUMEVALE FORMATION (Williams 1964) (= Ruddock Siltstone of Gill 1965, Moore 1965)

Williams gave the name Humevale Formation to a thick sequence of siltstones outcropping in the Kinglake district. Gill and Moore gave the name Ruddock Siltstones to a sequence of similar sediments outcropping in the Lilydale district. Recent mapping by Garratt (in prep.) and the author has shown that the two names apply to the same rock unit. The use of the name 'Yeringian", which has long been applied to Lower Devonian rocks of central Victoria, was considered inadvisable by the author, since it has been used at various times to denote a time unit (Gregory 1903, Chapman 1913, Thomas & Keble 1933, Gill 1940, 1942, 1946); a time-rock unit (Gill 1941, 1942), and also to indicate the Lower Devonian shelly facies (Gill 1938, Thomas 1937). Chapman included Wenlockian graptolitic rocks from the Keilor area (Chapman 1913), and Upper Ordovician shelly fossils from the Deep Creek area west of Melbourne (Chapman 1932) in the Yeringian. Gill (1965) included the Ruddock Siltstone, Lilydale Limestone, and Cave Hill Conglomerate as three formations in the Yering Group. Talent (1965b, and Talent & Banks 1967) showed that the inclusion of the Cave Hill Conglomerate in the Yering Group contravenes the Code of Stratigraphic Nomenclature, since it unconformably overlies the Lilydale Limestone. The present author considers the Lilydale limestone is too limited in extent to warrant giving it formation status; it is here considered to be a limestone lens within the Humevale Formation.

The sandstone member outcropping in the Seville East area has been left unnamed, since further field work is needed to confirm possible correlation with the Flowerdale Member of Williams (1965).

Age of the Humevale Formation: ?Lower Gedinnian to ?Emsian.
Estimated thickness: 4,300+ m

The Humevale Formation contains two members:

Dll: Lilydale Limestone Lens, approx. 220 m, ?Emsian age.
Dlu: Unnamed sandstone member, approx. 460 m thick, exact age not established, but probably early Emsian.

LITHOLOGY: The Humevale Formation includes a variety of rock types. In the Kilsyth-Bayswater area, massive siltstones predominate, which characteristically contain small flakes of mica. Beds are often in excess of 3 m thick, and, where present, bedding is difficult to detect. Towards the top of the sequence, intervals of thinly bedded fossiliferous siltstones become common. The fossils are often found in thin, porous beds, suggesting they were deposited as coquinas from which the shell material has since been dissolved out.

In the eastern part of the area, sequences of thick, massive siltstones alternate with sequences of rhythmically interbedded mudstones and thin greywackes. Thick repetitive turbidite sequences, outcropping as white sandstones, have been found in some localities, e.g. at co-ords 499 387 and 494 387. Towards the top of the sequence in this area, the greywackes disappear, and siltstones and mudstones predominate. At Seville (co-ords 484 416) a thick sequence of thinly bedded (12 to 40 mm) black pyritic siltstones outcrop. Between Seville and Seville East, the sequence consists of well bedded fossiliferous siltstones, becoming quite coarse towards the top. The fossils in the coarse siltstones often occur as small porous pockets, suggesting they were introduced in the form of shelly mud pellets, from which the shell matter has since been dissolved out.

Fresh rocks are rarely exposed in the area. The weathered siltstones are chocolate brown to pale brown, grey, and white, and are easily broken into very small pseudo-conchoidal fragments. The weathered mudstone-greywacke sequences become pale grey and brown, while the thin greywackes may become impregnated with iron oxides. In some areas, the siltstone has become indurated to form a hard, brittle, dark green rock, which typically shows a splintery jointing.

Dlu: Unnamed Sandstone Member: A prominent development of turbidite sandstones overlies the fossiliferous siltstones in the Seville East area. The sandstone beds, ranging between 50 mm and 30 cm thick, consist of well developed 'b' to 'd' units, and are interbedded with mudstones. Two thin quartz-conglomerate beds outcrop in a road cutting at co-ords 5090 4140.

Fresh outcrops of the unnamed sandstone member have not been found. In the weathered state, the sandstones may be hard or soft, and have shades of white or pale brown. The lamination of the 'b' units render the rock very fissile, giving it a flaggy appearance. Surface silicification has made the sandstones tough and brittle in some localities.

The sandstone member has only been found in the eastern part of the area. It is possible that it occurs in the Lilydale - Scoresby area, but outcrops in that area are poor and prevent a detailed study of the stratigraphy. From stratigraphic evidence the sandstone member is considered to predate the Lilydale Limestone Lens.

TABLE 1. FAUNAL LIST OF HUMEVALE FORMATION

LOCALITY	1	2	6	7	9	13	18	29	36	37	38	50	52	69
CO-ORDINATES	359429	365438	364424	361432					509415	499414	498415			
COELENTERATA														
Stromatoporida														
Actinostroma compactum Ripper			x											
A. verrucosum Ripper			x											
A. altum Ripper			x											
Clathrodictyon regulare cylindriferum Ripper			x											
C. chapmani Ripper			x											
C. calamosum Ripper			x											
Syringostroma aff. *niagarensis* Parks			x											
S. aff. *ristigouchense* (Spencer)			x											
S. densum Nicholson			x											
Stromatopora foveolata (Girty)			x											
S. aff. *hüpschi* (Bargatzky)			x											
S. bücheliensis (Bargatzky)			x											
S. bücheliensis digitata Nicholson			x											
S. lilydalensis Ripper			x											
Stromatoporella granulata (Nicholson)			x											
S. cf. *damnionensis* Nicholson			x											
Idiostroma oculatum Nicholson			x											
Hermatostroma episcopale Nicholson			x											
Tabulata														
Alveolites victoriae Chapman			x											
A. regularis Chapman			x											
Heliolites daintreei			x											
Favosites grandiporus Etheridge			x											
F. forbesi Edwards and Haime			x											
Coenites sp.			x											
Thamnopora sp.			x											
Roemeria thomii (Chapman)			x											
R. progenitor (Chapman)			x											
Pleurodictyum megastoma McCoy				x		x								
Rugosa														
'Spongophyllum' stevensi (Chapman)			x											
Lyrielasma subcaespitosum subcaespitosum (Chapman)			x											
Sterictophyllum cresswelli (Chapman)			x											
Paradisphyllum ops (Philip)			x											
P. n. sp.			x											
'Acervularia' chalkii (Chapman)			x											
Loomberaphyllum n. sp.			x											
Tryplasma n. sp.			x											
BRACHIOPODA														
Plectodonta bipartita (Chapman)							x	x						
Maoristrophia keblei Gill	x					x								
'Chonetes' robusta Chapman		x				x								
'C.' cresswelli Chapman	x	x				x								
'C.' bowieae Gill	x			x						x				
'C.' ruddockensis Gill													x	
'C.' micra Gill		x				x								
'C.' killarensis Gill				x										
Boucotia australis (Gill)						x							x	
'Hipparionyx' aff. *minor* Clarke	x	x		x		x								
Sphaerirhynchia globularis Talent				x										
Megakozlowskiella cooperi (Gill)		x	x			x		x						x
Acrospirifer lilydalensis (Chapman)	x					x								

LOCALITY	1	2	6	7	9	13	18	29	36	37	38	50	52	69
CO-ORDINATES	359429	365438	364424	361432					509415	499414	498415			
MOLLUSCA														
Monoplacophora														
Vallatotheca elegantula (Chapman)			x											
Gastropoda														
Bellerophon cresswelli Etheridge			x											
Phanerotrema australis Etheridge			x											
Michelia brazieri (Etheridge)			x											
'Mourlonia' subaequilatera Chapman			x											
Straparollus (Euomphalus) northi (Etheridge)			x											
Scalaetrochus lindstroemi Etheridge			x											
'Cyclonema' lilydalensis Etheridge			x											
'C.' australis Etheridge			x											
'Craspedostoma' lilydalensis (Cresswell)			x											
Loxonema australis Chapman			x											
Bivalvia														
Conocardium cresswelli Talent and Philip			x											
C. costatum Cresswell			x											
'Ambonychia' acuticostata McCoy			x											
Ctenodonta portlocki Chapman		x												
Goniophora australis Chapman						x								
ARTHROPODA														
Trilobita														
Calymene killarensis Gill										x	x			
Gravicalymene angustior (Chapman)					x									
Acaste longisulcata Shergold							x					x		
Acastella frontosa Shergold	x	x												
Acanthopyge australis (Gill)				x					x					
Scutellum enorme (Etheridge)						x								
Ostracoda														
Velibeyrichia wooriyallockensis (Chapman)						x								
AFFINITIES UNKNOWN														
Conodonta														
Eognathodus sulcatus Philip			x											
Hindeodella sp.			x											
Lonchodina greilingi Walliser			x											
Neoprioniodus bicurvatus (Branson and Mehl)			x											
Ozarkodina typica denckmanni Ziegler			x											
Panderodus simplex (Branson and Mehl)			x											
Plectospathodus cf. *flexuosus* Branson and Mehl			x											
Spathognathodus steinhornensis steinhornensis Zeigler			x											
Trichonodella inconstans Walliser			x											
Tentaculitidae														
Nowakia matlockiensis					x									
Styliolina fissurella				x	x				x					

Dll: Lilydale Limestone Lens (= Lilydale Limestone of Gill 1965, Moore 1965).

A lens of limestone, approximately 220 m thick, and traceable along strike for about 1.6 km (Crohn 1953) forms the highest horizon of the Humevale Formation in the area. It is possible that the limestone is overlain by siltstones (Crohn 1953). The limestone beds range from about 10 cm to 1 m or more in thickness, and show only minor lensing. The limestone is composed of beds of finely comminuted detrital shell fragments, and oolitic limestone, with particles of sand size. Boulders of stromatoporoids and tabulate corals occur frequently within the detrital beds. The limestone represents a typical detrital-biostromal deposit, with no indications of the presence of a reef in the vicinity.

The fresh limestone is dark grey, hard, and shows evidence of recrystallization. Surface weathering has rendered the rocks porous and friable near the surface, due to a partial solution of calcium carbonate.

PALAEONTOLOGY: The lower part of the Humevale Formation is poorly fossiliferous. Richly fossiliferous horizons occur only in the upper part, where they are interbedded with thick sequences of poorly fossiliferous rock. The limestone is richly fossiliferous. The unnamed sandstone member has also yielded a number of fossils. Only a small part of the fauna has been described in detail, and most of the early determinations are in need of revision. For the sake of completeness, most of the described fossils are listed in Table 1.

There is still some uncertainty as to the precise age limits of the Humevale Formation. The majority of the fossils listed above have been recovered from the upper part of the formation. Ripper (1938) first recognised the Lower Devonian age of the Lilydale Limestone Lens, which was confirmed by Hill (1939), although she states that the coral fauna showed strong Middle Devonian affinities. Talent (1965b) correlated the rich shelly faunas of the upper part of the siltstones with the Upper Siegenian and Emsian stages of Europe. Philip & Pedder (1967a, b, c) however, gave a Lower Siegenian age for the Lilydale Limestone, basing their age on the rugose corals and conodonts; Shergold (1968) gave a late Gedinnian to early Siegenian age for the upper part of the formation. The age of the lower part of the formation is less well known. In this paper, the top of the Dargile Formation is arbitrarily placed at the Silurian - Devonian boundary.

Dlc: CAVE HILL SANDSTONE (= Cave Hill Conglomerate of Gill 1965, Moore 1965; Cave Hill Sandstone of Talent 1965b).

Age: ?Emsian
Estimated Thickness: 30 to 60 m

The lithology and contact relationships of this formation have been described in detail by Crohn (1953). The Cave Hill Sandstone overlies the Lilydale Limestone Lens with angular unconformity. Although both units dip east, the dip of the Cave Hill Sandstone is about 15° less than that of the Lilydale Limestone Lens. The two units also show a small difference in strike direction. The contact between the two units is exposed in the Cave Hill limestone quarry (co-ords 363 425). It is highly irregular, and shows numerous small, steep pinnacles of limestone completely surrounded by sandstone.

LITHOLOGY: The Cave Hill Sandstone consists of sandstones, with minor interbedded clays, and poorly sorted conglomerates. The sandstones are typically laminated, with laminae a few mm thick. The laminations are due to subtle changes in clay and sand content. The sandstones are fine to very fine grained, and rather poorly sorted. Bedding, apart from the prominent laminations, is ill-defined. A large number of thin (25 to 50 mm) conglomerate beds occur in the sequence. They are poorly sorted, and have a fine sandy matrix. The smooth, well-rounded pebbles (5 to 15 mm) consist mainly of light grey quartzite, and are often sheared or broken.

No fresh rocks have been found. The weathered sandstone is soft and powdery, light grey to white. Some beds are silicified, and are tough and brittle. Surface silicification has given the rock a superficial coat of hard, tough, light grey quartzite, which obscures the bedding.

PALAEONTOLOGY: The rock has yielded indeterminable Spiriferid remains. Although these prove the rock to be marine, and of Devonian age, precise age determination is impossible.

PALAEOENVIRONMENT OF THE LOWER PALAEOZOIC SEDIMENTS

The north-south trending geosynclinal basin in which the Siluro-Devonian sediments were deposited is known as the Melbourne Trough (Packham 1960).

The sediments that filled this trough indicate that deep water conditions prevailed during the Silurian and Lower Devonian. However, two distinct periods of tectonic activity are indicated by the presence of thick sequences of turbidites. The first occurred at Upper Llandoverian times, and resulted in the deposition of the Warrandyte Conglomerate Member and the turbidites associated with it, and the Springfield Conglomerate of the Lancefield area (Thomas 1960). In the Heathcote area, tectonic uplift was responsible for the deposition of the shallow-water '*Illaenus*' Band, interbedded in poorly fossiliferous deep-water sediments. The second period of tectonic activity occurred in Ludlovian times, and resulted in the deposition of the Dargile Formation. In the Heathcote area, the Ludlovian tectonic uplift persisted, and the Lower Devonian sequence overlying the Dargile Formation is composed of neritic fossiliferous coarse-grained sediments. In the Ringwood area, shallow-water deposits occur only near the top of the Lower Devonian sequence. Although Talent (1965b) suggests that this is a result of the almost complete filling of the trough, it is possible that tectonic uplift occurred as well. This ?Emsian period of tectonic uplift could be the cause of the turbidity currents that deposited the unnamed sandstone member.

The deposition of the Lilydale Limestone Lens marks the end of continuous marine deposition. The unconformable contact between the limestone and the overlying Cave Hill Sandstone shows that some folding, uplift, and erosion took place prior to the deposition of the sandstone. The Cave Hill Sandstone represents the last brief interval of marine deposition during Palaeozoic times in the area. Subsequently, the marine sediments were folded, uplifted, and eroded, before the extrusion of the next major suite of rocks, the Mount Dandenong Volcanics.

SECTION B: THE DEVONIAN IGNEOUS ROCKS

The tectonic activity responsible for the folding of the Siluro-Devonian sediments culminated in a period of igneous activity, during which a thick sequence of acid volcanics was extruded, and a variety of acidic rocks intruded.

THE MOUNT DANDENONG VOLCANICS

This group consists of a thick sequence of terrestrial acid volcanic rocks, extruded into a cauldron subsidence. Because of the lack of bedding in much of the rock, the structure and thicknesses are imperfectly known. The volcanics of the Lilydale - Mount Evelyn area were first described in detail by Morris (1914); this study was revised and expanded to cover the whole of the Dandenong Ranges by Edwards (1956). The description of the rock types has been largely adapted from these authors.

Apart from fragmental plant fossils found in some tuff beds (Hills 1941b), no other fossils have been found. Consequently, the precise age of the volcanics is not known. They are assumed to be Upper Devonian in age by analogy with similar volcanic sequence in other parts of the state, which have been dated from fossil fish (Hills 1931, 1935).

The sequence has been subdivided into four formations:

youngest:	Dvf	Ferny Creek Rhyodacite
		- Thin tuff horizon -
	Dvk	Kalorama Rhyodacite
		- Thin tuff horizon -
	Dve	Mount Evelyn Rhyodacite
oldest :	Dvc	Coldstream Rhyolite

Dvc: COLDSTREAM RHYOLITE (= lower toscanite + upper toscanite of Morris 1914, Edwards 1956).

Morris and Edwards subdivided this formation into two units, a lower toscanite, and an upper toscanite. This subdivision was based mainly on the presence (in the lower toscanite) or absence (in the upper toscanite) of flow layering. The author found that flow layering, although not common, occurs throughout the unit, and prefers to regard the sequence as a single stratigraphic unit.

LITHOLOGY: When fresh, the rock is dark greenish to bluish grey, to bluish black. It weathers to various shades of grey, buff, cream, or white. Flow layering is best exposed in Black's Quarry, Coldstream, which is designated as a type locality. The flow layering is rather fine, with flow laminae 2 to 5 mm thick, and causes the rock to break into platy fragments. Excellent exposures of flow-banded rhyolite also occur at co-ords 384 428, near the top of the formation. Throughout most of the section, flow banding is absent, or difficult to observe, and the rock then shows small blocky jointing. Fragmental or agglomeratic rocks are common near the northern rim of the outcrops (e.g. at co-ords 425 435).

In thin sections, the rock shows sporadic blocky phenocrysts of andesine (ab60) between ½ and 2 mm across, set in a cryptocrystalline groundmass of felspar, chloritized biotite, and a little quartz. The groundmass felspar occurs in the form of more or less rectangular crystals of orthoclase up to 20 microns in size, and of lath-like microlites. The crystals show flow alignment to varying degrees. The biotite occurs as minute flakes, usually completely altered to green chlorite. The biotite is distinctly concentrated into parallel strings and drawn-out lenses, giving rise to the closely spaced platy flow layering. Although minor variations are found, the formation shows a marked chemical uniformity (see Edwards 1956, p.116).

Dve: MOUNT EVELYN RHYODACITE (= lower dacites of Morris 1914, Edwards 1956)

The contact between the Coldstream Rhyolite and Mount Evelyn Ryodacite is exposed in the Montrose quarry (co-ords 354 364), where these two formations are separated by a 10 m sequence of well bedded argillaceous and arenaceous tuffs. Elsewhere in the area, the contact could not be found. The Mt Evelyn Rhyodacite probably consists of a large number of flows.

LITHOLOGY: The rocks are characterised by a grey, greenish grey, or green colour, and by the presence of abundant phenocrysts of quartz. Numerous angular rock fragments of hornfels, Coldstream Rhyolite, and rhyodacite are included in the rock, sometimes so abundantly that the rock becomes an agglomerate. Rock fragments become rare near the top of the sequence. A number of thin tuffs are interbedded in these lavas (e.g. at the Fern Tree Gully quarry, co-ords 329 276, and along York Rd, co-ords 404 389; Hills 1941b, Edwards 1956).

When fresh, the rock is hard and tough. The weathered rocks are soft and friable, and in extreme cases have been altered to sticky clays.

In thin sections, the Mount Evelyn Rhyodacite shows a gradation from rhyolite to rhyodacite. The basal rhyolites and fragmental rhyolites contain numerous embayed phenocrysts of quartz, fewer phenocrysts of orthoclase, and occasional corroded pink garnets, set in a glassy to cryptocrystalline groundmass showing flow structure. These grade upwards into true rhyodacite about 60 to 100 m above the base. The rhyodacites contain phenocrysts of orthoclase and oligoclase more numerous than the quartz phenocrysts, and pink garnets about 2mm across. The groundmass is slightly more crystalline. In the top 60 to 100 m of the formation, there is an abundant development of plagioclase, while the ferromagnesian minerals have been converted to a bright green chlorite, giving the rock a green colour.

Dvk: KALORAMA RHYODACITE (= middle dacite of Morris 1914, Edwards 1956)

The Kalorama Rhyodacite is separated from the underlying Mount Evelyn Rhyodacite by a thin sequence of argillaceous tuffs, totalling some 3 to 10 m. When fresh, these tuffs are dark grey to black, and very hard (as at co-ords 3295 2770); however, almost all outcrops show weathered, soft, greenish to brownish grey material resembling mudstone. Fragmental plant fossils occur in this tuff on the Mt Dandenong Rd, at co-ords 397 372 (Hills 1941b). The type locality of the Kalorama Rhyodacite is a series of road cuttings on the Mt Dandenong Rd, between co-ords 397 372 and 403 373. The road cuttings show an almost continuous section through the upper part of the Mount Evelyn Rhyodacite, the Kalorama Rhyodacite, and the chilled base of the Ferny Creek Rhyodacite, as well as the tuff beds separating these formations. The formation is approximately 250 to 300 m thick, though the thickness varies from place to place.

LITHOLOGY: The fresh rhyodacite has a black glassy appearance, and is characteristically porphyritic. On weathering, the rock becomes soft and friable, light-grey, and has a silty texture.

In thin sections, the rhyodacite is composed of phenocrysts of quartz, garnet, biotite, and felspar, set in a glassy black groundmass, which consists of quartz, felspar, and minute biotite flakes.

Dvf: FERNY CREEK RHYODACITE (= upper dacite of Morris 1914, Edwards (1956)

The Ferny Creek Rhyodacite is separated from the underlying Kalorama Rhyodacite by a tuff band about 1½ m thick in the Mt Dandenong Rd Section. This tuff can be traced to Fern Tree Gully, and may reach a thickness of about 10 m in some areas. The type locality of the Ferny Creek Rhyodacite is Mt Dandenong Road, in cuttings between Upper Fern Tree Gully and Ferny Creek. The thickness of the formation is unknown, but it is the thickest unit of the Mount Dandenong Volcanics. Apart from the lower 60 m, which is chilled, the formation is remarkably homogeneous, suggesting it is a single flow.

LITHOLOGY: The chilled base is black to blue-black and fine grained, grading up into a lighter coloured grey rock, in which small phenocrysts of felspar, hypersthene, and biotite are visible. Surface weathering gives the rock a thin light brown coat, while more complete weathering renders it very soft, with a light grey fine mottled appearance. In thin section the chilled base shows phenocrysts of zoned plagioclass with labradorite cores, and hypersthene, set in a dense glassy groundmass. In the normal, unchilled part of the sequence, abundant biotite and rare quartz phenocrysts are present. The biotite is a result of chemical reaction between the hypersthene and orthoclase.

Dvf-m: FERNY CREEK RHYODACITE - SCHISTOSE BELT

The extrusion of the Ferny Creek Rhyodacite marked the end of the volcanic activity. Subsequently, the volcanics were downfaulted and warped in a cauldron subsidence.

The contact between the Ferny Creek Rhyodacite and the Lysterfield Granodiorite is marked by a belt of altered rhyodacites. Skeats (1910a,b) thought that the alteration of the dacite was due to thermal metamorphism, but Berger (1961) concluded that most of the alteration is due to faulting.

The schistose belt can be subdivided into three zones (Berger 1961).

Zone 1: zone of coarse-grained foliated rhyodacites. This zone is restricted to the eastern part of the schistose belt, outcropping east of the 410 co-ordinate. It consists of fairly uniform coarse-grained, rather indistinctly foliated rhyodacite, which grades into normal rhyodacite to the north. The rocks contain phenocrysts of corroded plagioclase and biotite, set in a fairly coarse (0.5 to 0.15 mm) allotriomorphic - granular groundmass of quartz and felspar.

Zone 2: zone of schistose rhyodacites. This zone is restricted to the western part of the schistose belt, outcropping west of the 372 co-ordinate. It consists mainly of schistose rhyodacites and minor schists. To the north, this zone is apparently sharply separated from the normal Ferny Creek Rhyodacite. The majority of the rocks within the zone are schistose rhyodacites, retaining the general appearance of the parent rock, and are similar to the coarse-grained rocks of zone 1. They are very well foliated, and show numerous rust-coloured crystals of partly altered hypersthene. In many cases, the hypersthene has been wholly or partially converted to biotite. Other rocks within zone 2 approach the texture and composition of the schists of zone 3.

Zone 3: zone of schists. This zone is restricted to the central part of the belt, outcropping between the 372 and 410 co-ordinates. It shows a sharp boundary with the normal rhyodacite to the north, and with the Lysterfield Granodiorite to the south. The boundaries with zones 1 and 2 appear to be transitional. The rocks within zone 3 are medium to coarse-grained quartz-biotite-felspar schists, characterised by the development of blastoporphyritic textures. They have all experienced a fairly high degree of recrystallisation, and augen are present.

PETROGENESIS OF THE MOUNT DANDENONG VOLCANICS.

The geochemistry of the Mount Dandenong Volcanics has been studied in detail by Valiullah (1964), who concluded that the increasingly basic trend displayed from the base to the top of the sequence is due to crystal fractionation. Prior to extrusion, the crystallising rocks within the magma chamber are considered to have been layered in the following fashion:

top:	rhyolite	(Coldstream Rhyolite)
	rhyolite - rhyodacite	(Mount Evelyn Rhyodacite)
	biotite - rhyodacite	(Kalorama Rhyodacite)
bottom:	hypersthene rhyodacite	(Ferny Creek Rhyodacite).

This layering resulted from the sinking of the relatively heavy hypersthene and basic plagioclase (labradorite) crystals, which were the first minerals to crystallise from the magma. The sinking of these minerals (which are dominant among the phenocrysts of the Ferny Creek Rhyodacite) had the effect of reducing the content of Fe, Mg, Al, and Ca in the higher levels of magma chamber. With the progress of crystallisation, a residuum rich in Si and K was produced. Rapid cooling of the magma within the chamber prevented the basic plagioclase from establishing a chemical equilibrium with the magma, so that the plagioclase phenocrysts are strongly zoned. Edwards (1937) suggested that a tholeiitic magma (a basaltic magma low in alkalies and high in silica) would on digestion of argillaceous sediments, produce an acid magma capable of forming the calc-alkaline rock types of the Mount Dandenong Volcanics. The Coldstream Rhyolite, however, displays chemical peculiarities (it is relatively low in Mg and Ca, and high in Fe) that led Edwards (1956) to believe it has been more strongly affected by the assimilation of argillaceous sedimentary rocks within the upper part of the magma chamber.

THE UPPER DEVONIAN INTRUSIVE ROCKS

During and after the downwarping of the Mount Dandenong Volcanics, a variety of acid igneous rocks were intruded into the Palaeozoic sediments and volcanics. The age of this intrusive period is assumed to be late Upper Devonian, by analogy with similar intrusives found elsewhere in central Victoria. The intrusives are listed below, but are not arranged in chronological sequence:-

Dgl	Lysterfield Granodiorite
Dgs	Silvan Granodiorite
Ddp	Porphyrite intrusions
Ddq	Yellingbo dyke
Ddn	Narree Worran porphyrite dyke swarm
Ddt	Tally Ho Quartz Diorite
	Other intrusions

Dgl LYSTERFIELD GRANODIORITE (Edwards 1956)

The Lysterfield Granodiorite, a small batholith, is the largest intrusion exposed in the area. It is situated in the south-east, where its comparative resistance to erosion has given rise to smooth, rolling hills in the west, and a rather rugged topography in the east. It has a well developed contact metamorphic aureole of hornfels in the Palaeozoic sediments, and has also imparted a weak metamorphism to the southern margin of the Ferny Creek Rhyodacite.

LITHOLOGY AND PETROLOGY: The Lysterfield Granodiorite is essentially a medium-grained biotite granodiorite, consisting of quartz, oligoclase, orthoclase, and biotite, with local accumulations of hornblende. Xenoliths are present only in small numbers. Small, thin veins of aplite-pegmatite are quite common, with all stages from aplite to graphic pegmatite generally visible within the same vein.

Fresh granodiorite is rarely found in outcrop. Instead, the rock occurs as large, rounded blocks, the result of exfoliation. In the western part of the granodiorite mass, the rock is often completely weathered to soft, sandy clay.

Hornfels is best exposed in quarries in the Lysterfield Hills, where it is fresh, dense, dark blue-grey, and closely jointed. In the Emerald-Cockatoo area, the hornfels has been weathered to a soft fine-grained rock which closely resembles mudstone. Bedding features have been destroyed in all but the outer parts of the aureole.

Dgs SILVAN GRANODIORITE (Edwards 1956)

In contrast with the Lysterfield Granodiorite, the Silvan Granodiorite is rarely found in outcrop. Scattered small outcrops occur in the Olinda Creek area, just north of the Silvan damsite. Gill (1942b) records a small outcrop of granodiorite porphyrite jutting through the Older Volcanics in the Wandin North area. This has since been removed to enable farming of the area.

The hornfels aureole of the Silvan Granodiorite and associated porphyrite plugs is very extensive, suggesting that the granodiorite is part of a ring dyke system.

LITHOLOGY: The Silvan Granodiorite is a porphyritic biotite granodiorite, consisting of plagioclase, quartz, orthoclase, and biotite phenocrysts in a groundmass of quartz and orthoclase. It contains numerous xenoliths.

The metamorphic aureole consists of hornfels, invariably weathered in outcrops to a fine-grained rock resembling mudstone. Bedding is sometimes preserved even in weathered outcrops. In the Olinda Creek area, the Ferny Creek Rhyodacite is schistose at the contact with the Silvan Granodiorite (Morris 1914).

Ddp PORPHYRITE INTRUSIONS (Edwards 1956)

Two 'plugs' of quartz porphyrite outcrop in the Dandenong Ranges. One occurs at the north-eastern extremity of the Kalorama Rhyodacite outcrop; the other occurs just west of the Silvan Reservoir. A third plug was located in test pits near the Silvan dam site (Summers 1929), but this has since been covered.

LITHOLOGY: The rock from the southern 'plug' is porphyritic, consisting of phenocrysts of quartz, plagioclase, and ragged biotite, set in a coarsely microcrystalline groundmass of quartz, blocky orthoclase, and a little biotite. The rock from the northern 'plug' is dense black, and is studded with white to greenish white prisms of zoned plagioclase, up to 3 mm long, and a few smaller rounded and embayed quartz phenocrysts.

Ddq YELLINGBO DYKE (Thomas & Kenley, 1954-5)

A quartz porphyrite dyke of considerable proportions has been intruded along the Yellingbo Fault. Fresh rock is rarely exposed; and the position of the dyke is generally marked by an abundance of weathered floaters, or by clay with large euhedral quartz crystals.

LITHOLOGY: The only fresh sample obtained (at co-ords 477 324) is a quartz porphyrite, a tough, red, porphyritic rock with a fine groundmass. Phenocrysts of quartz and plagioclase are set in a fine groundmass of quartz, plagioclase, orthoclase, and some altered biotite.

Ddn NARREE WORRAN PORPHYRITE DYKE SWARM (= Lysterfield dyke swarm, Edwards 1956)

A small dyke swarm of felspar-hornblende porphyrite intrudes the northwestern part of the Lysterfield Granodiorite and the surrounding rocks. Within the granodiorite, the dykes trend north-south, parallel with the principal joint direction of the granodiorite, but swing northeasterly as the hornfels aureole is approached. The dyke rocks have resisted erosion, with the result that fresh outcrops can be traced for considerable distances. In road cuttings, the dykes are rarely more than 60 cm thick, but on hill slopes the rocks have spread, giving an impression of greater thickness. At the surface, the rocks occur as joint blocks. They are often very tough, and only rarely weather to softer material.

LITHOLOGY: The rocks vary between dark green felspar-hornblende porphyrites and light grey-green porphyrites.

The felspar-hornblende porphyrites show light grey to white corroded and embayed phenocrysts of zoned plagioclase (labradorite to andesine or oligoclase), with occasional sericitised zones, and prisms or blades of dark green hornblende set in a fine-grained groundmass of zoned prisms or blades of plagioclase, somewhat lesser amounts of orthoclase and quartz, and fine needles and irregular patches of hornblende.

The felspar porphyrites have smaller phenocrysts of zoned plagioclase and hornblende; the plagioclase phenocrysts are also more commonly sericitized. The groundmass is more quartz rich, showing abundant granophyric intergrowths of quartz and orthoclase. Biotite is also present in the groundmass.

Ddt TALLY HO QUARTZ DIORITE

A small plug of quartz diorite occurs near the junction of Springvale and Highbury roads, Glen Waverley. It was quarried for road metal for many years, but the quarry has recently been filled in. The only material available in outcrop is weathered, soft, crumbly, light green rock.

LITHOLOGY: The rock consists of medium grained orthoclase, hornblende, and rare quartz.

OTHER INTRUSIONS

A number of small acidic dykes has been intruded into the Siluro-Devonian sedimentary rocks. With few exceptions, these dykes are completely weathered to white, soft clay, in which the presence of small quartz grains shows the original acidic nature.

Recent drilling by the MMBW has shown the presence of a small intrusion of granitic rock under the Tertiary sediments in the Heatherton area. This rock is entirely weathered to the depth penetrated by the drilling.

THE POST-UPPER DEVONIAN TO PRE-TERTIARY RECORD

The intrusion of the Upper Devonian acidic igneous rocks marks the last documented Palaeozoic event in the area. During the Mesozoic, the area underwent prolonged erosion, and rocks of this era are absent.

Section C: THE CAINOZOIC ROCKS

The Cainozoic era is represented by a variety of thin terrestrial and marine sediments, and basaltic lavas of two distinct periods of volcanic activity. The main rock units are listed below in chronological order:-

youngest:			Recent alluvial and colluvial deposits
		Qvn	Newer Volcanics
	Brighton Group	Tpr	Red Bluff Sands
		Tpb	Black Rock Sandstone
		Tmn	Newport Formation
		Tvo	Older Volcanics
oldest:		Tew	Sub-Older Volcanic sediments

The Cainozoic rocks of the Melbourne area have been described in detail in Bulletin 59 'Geology of the Melbourne District', from which part of the following information has been extracted.

Tew SUB-OLDER VOLCANIC SEDIMENTS

The oldest Cainozoic rocks of the area (mistakenly labelled 'Werribee Formation' on map) consist of thin, widely scattered fluviatile deposits. They are rarely more than 3 m thick and represent the stream deposits of valleys which subsequently became filled with Older Volcanic basalts. These basalts protected them from subsequent erosion.

The deposits are of probable Eocene age, since they can be correlated with similar deposits in the Berwick area, which contain Eocene plant fossils (Deane 1902).

LITHOLOGY: The sediments vary in lithology from coarse, poorly sorted conglomerates, to sands and clays. Bedding is generally absent, and fossils are rarely found.

Tvo OLDER VOLCANICS

During the early Tertiary, the area was subjected to a period of volcanic activity. Basalts filled some of the existing stream valleys, and basaltic dykes were intruded into Palaeozoic sediments throughout the area.

The basalts reach a maximum thickness of about 36 m in the Silvan area, and about 60 m in the Lilydale area, but are much thinner elsewhere.

Although no definite age can be established for the Older Volcanics occurring within the area, evidence from the Altona area shows that the Older Volcanics there are of Upper Eocene to Lower Oligocene age. In the Mordialloc area, the Older Volcanics are overlain by marine Tertiary silts of Miocene age.

LITHOLOGY: Fresh basalt rarely outcrops, but can be found at shallow depths. It is exposed in a number of quarries in the Narre Warren area, where it is very fine grained to glassy, and has a blue-black colour. It is very tough. Close columnar jointing is common. Weathered basalts, as exposed in the Lilydale limestone quarry, have a dark brown to greenish-brown colour, and are crumbly, showing typical onion weathering. The soils are typical deep red basaltic clays.

The basic dykes are almost always weathered to clay, in which the absence of quartz suggests their basic nature. Studies on fresh dyke rocks (Hills 1941a; Edwards 1934, 1939) show that there is a variety of rock types present, including alkaline dykes, lamprophyres, and limburgite.

In thin sections the basalts are fine-grained olivine basalts (Edwards 1939) with microphenocrysts of more or less corroded olivine, sometimes accompanied by microphenocrysts of augite and labradorite, set in a groundmass of olivine, augite, labradorite, iron ore and glass.

The alkaline dykes of Studley Park (Hills 1941a) are porphyritic, showing large white felspar phenocrysts and biotite in a mottled groundmass. The felspar is simply twinned anorthoclase. Altered phenocrysts of pyroxene are visible in thin sections. The groundmass consists of closely packed laths of sanidine and specks of iron ore in a chloritic and serpentinous base.

Chapman & Thiele (1911) have described a plug of limburgite which occurs near the intersection of Clifton and Sweyn streets, Balwyn. The rock, which was exposed over an area measuring some 70 m by 30 m, has since been covered by housing development. The rock is dark blue or black, and dense, consisting of numerous olivine and occasional augite phenocrysts, set in a groundmass of augite, labradorite, and brown glass.

Tmn NEWPORT FORMATION (Thomas & Baragwanath 1950).

During the Miocene, the south western part of the area was submerged, and a thin veneer of marine sediments was deposited. These sediments reach a maximum thickness of approx. 60 m near the coast, south of the Beaumaris Monocline. They are much thinner on the northern side of this monocline, and gradually thin out towards the north and east, until they disappear just west of the Dandenong railway line.

The sediments are fossiliferous, the fossils indicating a Miocene age. Foraminifera of the Batesfordian, Balcombian, and Bairnsdalian stages have been recorded from numerous bore samples (Abele, see below; Kenley, 1967).

LITHOLOGY: The Newport Formation consists almost entirely of dark grey-green and green glauconitic silt, with few macrofossils, but an abundance of microfossils. Towards the northern limits of the formation, thin pockets of silty bryozoal limestone and silty sand occur at the base. The unconformable contact between the Silurian sediments and the Newport Formation has recently been exposed for some length in the construction of the Caulfield Intercepting sewer along North Road (Coulsell, 1969). This shows small, thin, discontinuous pockets of silty limestone, frequently containing boulders of Silurian rock, surrounding steep rock stacks of Silurian mudstone - a typical shoreline environment.

The top 6 m or so of the Newport Formation has been extensively oxidised throughout the area. The dark green colour gradually changes upwards to a pale brown colour at the top. This shows that the silts were subjected to prolonged subaerial weathering prior to the deposition of the overlying sediments.

The only outcrop of the Newport Formation in the area occurs at Beaumaris, just offshore from the cliff, opposite the Dog Tooth beacon (co-ords 087 154), where it is exposed only at very low tides.

Faunal list of the Newport Formation

The following faunal lists were contributed by Dr C. Abele and Mr T.A. Darragh.

The foraminifera listed below were collected from a number of bores in the Brighton - Springvale - Mordialloc area. Foraminifera of Faunal Units 9,10 and 11 (Carter 1964) are present, indicating an age range from Batesfordian to Bairnsdalian, or Middle to Upper Miocene.

FORAMINIFERA (list contributed by Dr C. Abele)

Orbulina universa d'Orbigny
O. suturalis Bronnimann
Globigerinoides bisphericus Todd
G. trilobus (Reuss)
Cibicides victoriensis Chapman, Parr and Collins
C. perforatus (Karrer)
Lepidocyclina howchini Chapman and Crespin
Anomalina macraglabra Finlay
Anomalinoides procolligera Carter
Astrononion australe Cushman and Edwards
Siphonina australis Cushman
Operculina victoriensis Chapman and Parr
Sphaeroidina bulloides (d'Orbigny)
Pullenia quinqueloba (Reuss)

MACROFOSSILS

The following list and comments have been contributed by Mr T.A. Darragh.

The mollusca listed below have been collected from spoil derived from test shafts and tunnelling of the Southeastern Trunk Sewer between the Braeside Shaft and the northeastern corner of Boundary and Junction roads.

'Macrofossils are not abundant and the list should be regarded as tentative, though most of the common species are listed. The age of this fauna is Balcombian, and it has considerable affinity with the mollusca of the Muddy Creek Formation in western Victoria. It should be noted that many of the bivalves are also recorded from the lower part of the Black Rock Sandstone (see below), and that this relationship would be further strengthened if a full census of the bivalvia were made from both formations.'

MOLLUSCA

Cephalopoda

Aturia australis McCoy

Bivalvia

Scaeoleda woodsi (Tate)
Glycymeris cainozoica (Tenison Woods)
Cucullaea corioensis McCoy
Patinopecten murrayanus (Tate)
Eotrigonia semiundulata lutosa (Pritchard)
Eucrassatella eupontica Darragh
Electromactra howchiniana (Tate)
Notocorbula ephamilla Tate

Gastropoda

Maoricolpus murrayanus (Tate)
Umbilia eximia (G.B. Sowerby I)
Zoila platypyga McCoy
Globisinum pritchardi (Cossmann)
Concholepas cf. *antiquata* (Tate)
Tudicla turbinata Tate
Phos tardicrescens Tate
Baryspira tatei (Marwick)
Pterospira alticostata (Tate)
Pseudocymbiola strophodon (McCoy)
Notovoluta cathedralis (Tate)
Marginella propinqua Tate
Micantapex rhomoidalis (Tenison Woods)
Conus cuspidatus Tate
Nototerebra platyspira (Tate)

BRIGHTON GROUP (See Kenley 1967) (= Sandringham Sands, Gill 1950a)

The Newport Formation is disconformably overlain by a thin sequence of arenaceous sediments, collectively known as the Brighton Group. The group has been subdivided into two formations, which show a disconformable contact. For a detailed description of the Brighton Group, see Kenley (1967).

Tpb BLACK ROCK SANDSTONE (Gill 1957)

Outcrops of the Black Rock Sandstone are restricted to the coastline. It forms a series of shore platforms stretching from Elwood to Ricketts Point, then disappears as a result of the downthrow on the Beaumaris Monocline, and reappears as shore platforms in the Parkdale area. The sandstone forms the lower parts of the cliffs in the Beaumaris area.

The contact between the Newport Formation and the Black Rock Sandstone is disconformable, and is marked by a nodule bed about 8 cm thick, consisting of quartz grit and gravel containing numerous rounded phosphatic concretions, abraded shark teeth, and pieces of whale bone. The total thickness of the formation at Beaumaris is 12 to 14 m. Proceeding inland, the formation has been recognised from excavations in North Brighton and Bentleigh. Farther east, it is apparently absent.

The richly fossiliferous basal 6 m of the Black Rock Sandstone at Beaumaris is the type section of the Cheltenhamian (uppermost Miocene) (Singleton 1941). Singleton regarded the upper, poorly fossiliferous part, as Kalimnan (Lower Pliocene).

LITHOLOGY: In outcrop, the formation consists of yellowish-red and reddish-brown ferruginous sandstones and marly sands, with local development of ironstone bands. In bores, the sediments consist largely of glauconitic silty sands and shelly sands. The formation is reasonably well stratified, and shows only minor development of current bedding.

Faunal list of Black Rock Sandstone

The following comments and list of mollusca have been contributed by T.A. Darragh.

'The mollusca recorded below have been identified from three localities:

No. 1: Cliff at Beaumaris immediately above 'Nodule bed'
No. 2: Ironstone in cliff at Beaumaris about 6 to 10 m above beach
No. 3: Sewer tunnel, north of Centre Rd, 12 m below Wright St, Bentleigh.

TABLE 2. FAUNAL LIST OF BLACK ROCK SANDSTONE

Scaphopoda	1	2	3
Dentalium (Laevidentalium) largicrescens Tate	x		
Cadulus (Gadila) infans Tate			x
Bivalvia			
Ennucula kalimnae (Singleton)	x		x
Scaeoleda woodsi (Tate)	x		
" " *acinacaeformis* Tate		x	x
Tucetona convexa (Tate)	x		
Limopsis beaumariensis Chapman	x		
Trichomya hamiltonensis (Tate)			x
Pododesmus tatei (Chapman and Singleton)	x		
Neotrigonia acuticostata (McCoy)	x		
Callucina balcombica (Cossmann)			x
Divalucina cumingi (A. Adams)		x	x
Miltha dennanti Wilkins		x	x
Montacuta sericea Tate			x
Glans kalimnae Crespin	x		
Eucrassatella eupontica Darragh	x		
Zenatiopsis phorca Gill and Darragh	x		
Mactra hamiltonensis Tate		x	x
Electromactra howchiniana Tate	x		
Anapella variabilis (Tate)			x
Plebidonax depressa (Tate)		x	x
Tellina albinelloides Tate	x		
Macomona ralphi (Finlay)	x		
Tawera propinqua (Tenison Woods)	x		x
Placamen sp.	x	x	x
Proxichione moondarae Darragh	x		
Bassina paucirugata (Tate)			x
Kereia johnstoni (Tate)	x	x	x
Pullastra aff. *fabagella* (Deshayes)			x
Venerupis paupertina Tate			x
Claudiconcha cumingi (Deshayes)			x
Notocorbula ephamilla (Tate)	x		x
" " aff. *flindersi* (Cotton)			x
Myadora aff. *australis* Johnston			x
Cephalopoda			
Aturia australis McCoy	x		x

Gastropoda	1	2	3
Patellidae			x
Astele millegranosa Pritchard	x		
Phasianotrochus aff. *subsimplex* Ludbrook			x
Bankivia fasciata (Menke)			x
Leiopyrga sayceane Tate	x	x	x
Subinella grangensis (Pritchard)			x
Phasianella dennanti Crespin			x
Melamerita melanotragus (Smith)			x
Colpospira aff. *tristira* (Tate)	x		
Ctenocolpus aff. *pagodulus* (Tate)	x		
Gazameda aff. *victoriensis* (Cotton and Woods)	x		
Amaea triplicata (Tate)	x		x
Tylospira coronata (Tate)	x		x
Zeacrypta immersa (Angas)			x
Sigapatella tatei (Finlay)			x
Umbilia tatei (Cossmann)	x		
Polinices (Conuber) subvarians (Tate)	x		x
Austrocochlia cf. *substolida* (Tate)	x		
Tanea hamiltonensis (Tenison Woods)	x		
Sigaretotrema infundibulum (Tate)	x		x
Semicassis cf. *transenna* (Tate)	x		x
Sassia sp.	x		
Columbarium sp.			x
Pterynotus trinodusus (Tate)			x
Dicathais abjecta Tate			x
" " aff. *baileyana* (Tenison Woods)			x
Baryspira aff. *pseudaustralis* Tate			x
Alocospira aff. *orycta* (Tate)	x		
Amorena undulata (Lamarck)			x
Marginella aff. *cassidiformis* Tate			x
Austroginella aff. *muscaria* (Lamarck)			x
Conus cuspidatus Tate	x		
Acuminia aff. *brazieri* (Angas)	x		x
Noditerebra geniculata (Tate)			x
Acteon cf. *funiculifer* (Cossmann)	x		x
Acteocina aff. *aptycha* (Cossmann)			x
Cylichna aratula (Cossmann)	x		
Cylichnania exigua (Tenison Woods)	x		

'The molluscan faunas of the three localities are of similar age, but localities 2 and 3 have a somewhat different suite of molluscs from loc 1. The faunas from localities 2 and 3 are comprised of molluscs which lived in very shallow water in or on a fine sandy bottom, as found off many present-day Victorian sandy beaches. At loc 3 there are several species which live on rocks in the littoral and sublittoral zone, which suggests the occurrence of rocky outcrops nearby as many of these specimens are little worn and have not been transported a great distance. A similar fauna of the same age is found in the upper beds of the Royal Park railway cutting. The molluscs of loc 1 indicate deeper water conditions, perhaps down to 20 or 30 m which, with the evidence of the fauna from loc 2, demonstrate a progressive shallowing of water with time during the deposition of the Black Rock Sandstone.'

Tpr RED BLUFF SANDS (Gill 1957)

The Red Bluff Sands outcrop extensively in the western part of the area. They form a thin sheet of sediments, with a gentle south-westerly dip, which outcrops continuously south of Gardiners Creek and west of Dandenong Creek. North of Gardiners Creek, the formation is restricted to the higher parts of the dissected hilly country. Good outcrops of the formation occur in railway cuttings along the Frankston and Sandringham railway lines, in numerous sand pits in the Clayton area, and in the coastal cliffs. The formation reaches a maximum thickness of about 30 m in the Brighton Coastal Plain, and thins out very gradually to the north and east. The Red Bluff Sands are almost devoid of fossils. Fossil wood, pollen, and a hystrichosphaerid have been found at Red Bluff, Sandringham. The sediments are probably of middle to upper Pliocene age (Singleton 1941).

LITHOLOGY: The Red Bluff Sands consists of poorly consolidated sands, fine sands, grits, and gravel, with pale yellow or brown colours predominating. Bedding is poor, and undulating. Surface weathering often produces hard limonitic bands. Gill (1957) suggested a partly fluviatile, partly near-shore lagoonal or paludal origin for the unit. The absence of thick silts and clays, however, points more to a fairly active fluviatile environment, probably contributed to by a number of streams. A lagoonal or paludal environment would be characterised by black muds, which are absent. No typical overbank deposits such as characterise flood plains have been recognised.

Qvn NEWER VOLCANICS

The last volcanicity in the area took place in Pleistocene times when the basalts of the Newer Volcanics were extruded. By that time the Brighton Group had been entirely removed in the Collingwood area. The basalt in this area is a valley flow, which filled the pre-Holocene valley of the Darebin Creek, Yarra River and Gardiners Creek. Pleistocene alluvium of the Yarra River has been found below the basalt in quarries in the Clifton Hill area. The Newer Volcanics form a low plain, with isolated hills of Silurian rocks capped by Brighton Group sediments jutting through the basalt sheet.

Radiometric dating (Page 1968) shows that the basalts are of Pleistocene age. Six radiometric dates have been obtained for basalt samples from a quarry at Alphington (co-ords 069 412); these gave an average of 0.81 million years. In contrast, basalt from a quarry some 2 miles west of this quarry (Melbourne sheet, co-ords 023 414) gave an age of 2.23 m.y.

LITHOLOGY: The basalts are usually vesicular or honeycombed. Jointing is either irregular, or occurs as widely spaced columnar jointing. The fresh basalts have a typical bluish-grey fine-grained appearance, and, apart from the large vesicles, also show a finely porous texture. Olivine phenocrysts are usually visible.

In thin sections, the basalts are normal olivine basalts, showing small phenocrysts of corroded olivine, sometimes altered to iddingsite, laths of labradorite or bytownite and occasional pyroxene prisms set in a groundmass of labradorite laths, pyroxene prisms, iron ore minerals, and green felspathic glass.

The Newer Volcanics quarries in Clifton Hill, Richmond and Burnley were for many years a source of excellent specimens of zeolite minerals and carbonates. These minerals were developed in the vesicles and along the joints in the basalts.

PLEISTOCENE TO RECENT ALLUVIAL AND COLLUVIAL DEPOSITS

These deposits can be conveniently grouped into four types, according to their mode of deposition:

Qra, Qrt	Alluvial deposits
Qrm	Swamp deposits
Qrc	Fan and slump deposits

The above list is not intended to convey an age or stratigraphical relationship.

Qra, Qrt ALLUVIAL DEPOSITS

Alluvial deposits make up the valley fill of the major streams and their tributaries. In the major streams, e.g. the Yarra River and Dandenong Creek, the alluvial deposits occupy broad river flats, but in the small tributaries, they are quite narrow.

The alluvial deposits are Pleistocene to Recent in age. They are generally thin, though may exceed 15 m in the alluvial flats of the Yarra River upstream from the Darebin Creek.

LITHOLOGY: In general, the alluvial deposits consist of poorly sorted sandy silts with interbedded minor sand and gravel lenses. The only good outcrops in the area are found in a series of low railway cuttings between Gardiner and East Malvern railway stations. These cuttings are in the high terraces, and show unconsolidated sands and silty sands.

Qrm SWAMP DEPOSITS

Swamp deposits are restricted to the Carrum Swamp and the Caulfield-Moorabbin area, and are usually only a metre or so in thickness. They directly overlie the Red Bluff Sands and range in age from ?Pleistocene to Recent.

LITHOLOGY: The predominant lithology is dark grey sandy clay. A large admixture of sand is often found, and is due to sand carried in from the surrounding Red Bluff Sands.

Qrc FAN AND SLUMP DEPOSITS

Fan deposits are restricted to the steeper slopes in the area. An excellent development of these deposits occurs on the western slopes of Mt Dandenong. They are generally thin and discontinuous, and display steep initial dips.

The age of the fan deposits is not precisely known, but on physiographic evidence is assumed to be Pleistocene to Recent.

LITHOLOGY: The lithology of the fan deposits depends largely on the source rocks. The fans on the steep western slopes of the Dandenong Ranges consist largely of boulders of Ferny Creek Rhyodacite, with rare boulders from the other volcanic units. Cuttings through the fan deposits occur at co-ords 382 367 on the Mt Dandenong Road near Montrose, and also along the Burwood Highway at Upper Fern Tree Gully (co-ords 337 272). The fans along the Brushy Creek escarpment are poorly exposed. They consist of poorly sorted conglomeratic material, with boulders of quartzite.

Slump deposits are restricted to the Silvan district, where small-scale slumping of the deep red clay soils occurs on the hill slopes.

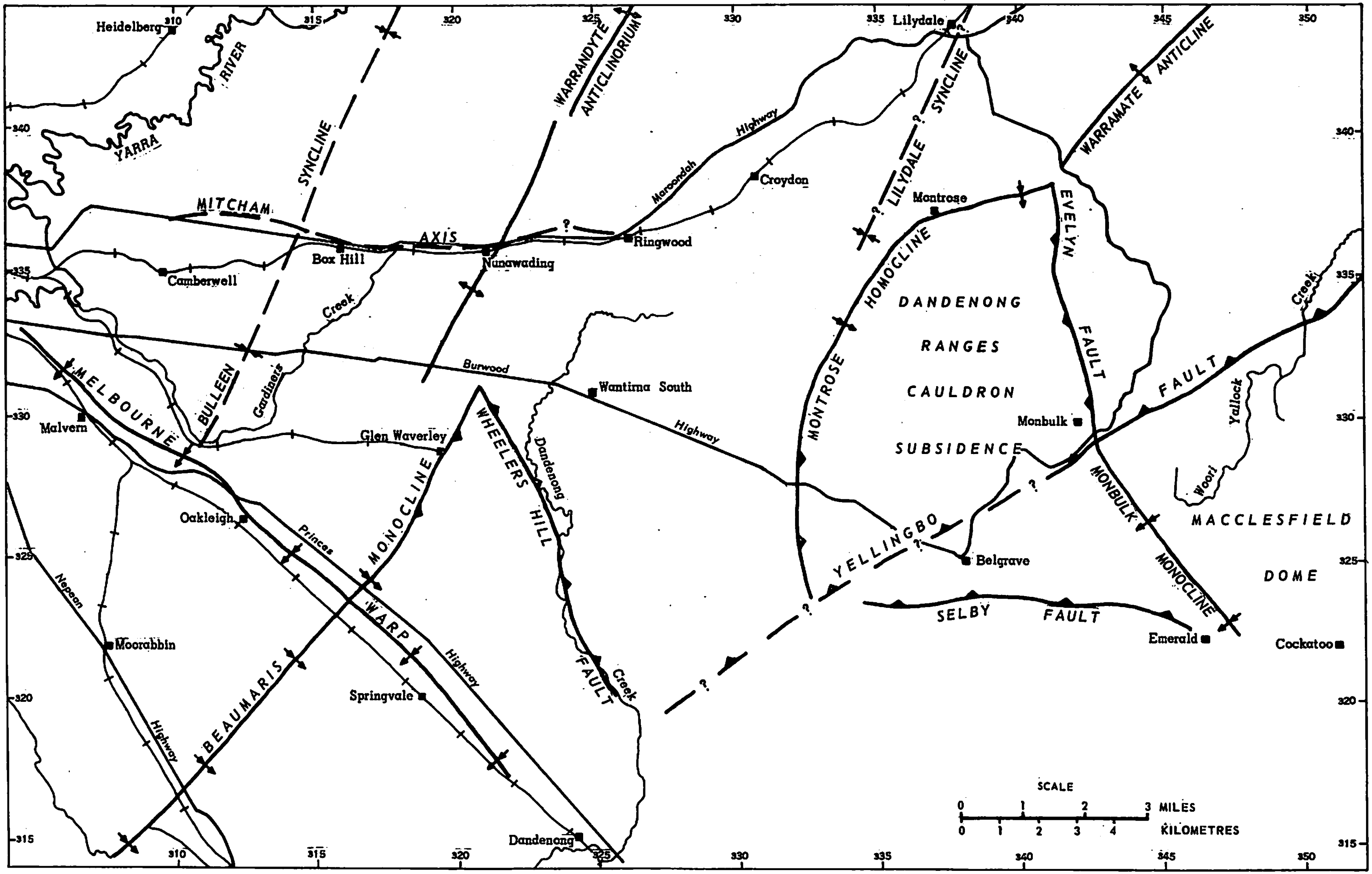


Fig. 1 Main Structural Features of the Ringwood 1:63,360 Geological Map

PART THREE: STRUCTURES

SECTION A: THE MIDDLE DEVONIAN FOLDING

The Lower Palaeozoic sedimentary rocks have been folded in a concertina style. With some exceptions, the folds trend approximately 20° east of north. In the western half of the area, the folds are quite closely spaced, with a wavelength of 1 to 2 km, but in the east this increases to approximately 8 km (see also Nicholls 1930, Whiting 1967).

The oldest rocks are exposed in three anticlinoria, or domes. In the Warrandyte Anticlinorium and Macclesfield Dome, the rocks are tightly folded, and exhibit slaty cleavage near the fold axes. The Templestowe Anticlinorium is a smaller structure, which lacks the tight folding and slaty cleavage of the other structures. In contrast, major synclinoria are absent. Instead, the youngest rocks outcrop in wide, open synclines. The largest of these is at Lilydale, where its precise position is hidden by the Mount Dandenong Volcanics. Another major syncline occurs at Seville East. The Bulleen Syncline forms a major structure in the western part of the area.

Plunges along any of the folds are difficult to establish from structural measurements alone, due to the variability of strike directions in most exposures, but large-scale plunges are clearly shown by the outcrop pattern. The Warrandyte Anticlinorium shows a strong southerly plunge between Warrandyte and Park Orchards, and then flattens out, and there is no appreciable plunge south of Park Orchards. The Bulleen Syncline is a trough-like structure, with strong northerly plunges between Mont Albert and Templestowe, and a strong southerly plunge north of Templestowe. The Warramate Anticline shows a strong southerly plunge between the Warramate Hills (Yan Yean sheet Garratt, in prep.) and Mount Evelyn and the Seville East Syncline plunges northerly south of Seville East. The plunges of the folds in the Macclesfield Dome cannot be determined, due to the poor exposures in that area.

In the western part of the area, west of the Bulleen Syncline, no pronounced plunges can be found, except for some minor southerly plunges on small anticlines, where the Anderson Creek Formation outcrops in the cores of the folds.

Small faults are present in the Siluro-Devonian sediments throughout the area, and can be observed in most of the quarries and road and railway cuttings. The faulting probably dates from the same period as the folding. It is always of minor scale,and has not visibly affected the outcrop pattern. The Yellingbo Fault, which is of younger age, is discussed below.

SECTION B: THE MIDDLE TO UPPER DEVONIAN CAULDRON SUBSIDENCE

Morris (1914) thought that the Mount Dandenong volcanics were flat-lying, and occupied a graben-like structure, bordered on the western side by the Montrose Fault, and on the eastern side by the Evelyn Fault. Hills (1941b) showed that the volcanics owe their preservation to original downwarping. Along the western margin, the downwarp is marked by the Montrose Monocline (Edwards 1956), while the Evelyn Fault marks the eastern margin. Hills regarded the main volcanic mass as a tilt block with a steep southeasterly dip. Edwards (1956) recognised two structural units within the volcanics:

(a) a shallow, broad, synclinal structure, called the Lilydale Hills Syncline, running north from Mt. Evelyn towards Coldstream;

(b) a main triangular trough-like structure, bordered on the western side by the Montrose Monocline, and on the eastern margin by the Monbulk Monocline and Evelyn Fault, and on the southern margin by the Selby Monocline.

Edwards postulated roof collapse of a magma chamber as a cause of the downwarping, and compared the structure with that of the Cerberean Cauldron subsidence. Berger (1961) showed that the southern border is faulted, and named this structure the Selby Fault. Zone 3 of the schistose rhyodacite belt, the zone of maximum metamorphism, coincides with the position of a synclinal axis. The intrusion of the Lysterfield Granodiorite postdates this faulting and downwarping.

The structure of the cauldron subsidence is in fact more complex than formerly thought. The tilt block, as envisaged by Hills (1941b), is the largest feature, but is separated from the southern synclinal structure by a westerly extension of the Yellingbo Fault. The structural elements described in this paper are shown in Fig. 4, and cross-sections are shown in Fig. 5.

The main structural elements within the volcanics are

(a) the Lilydale Hills Syncline (Edwards 1956), a broad, open synclinal structure with a

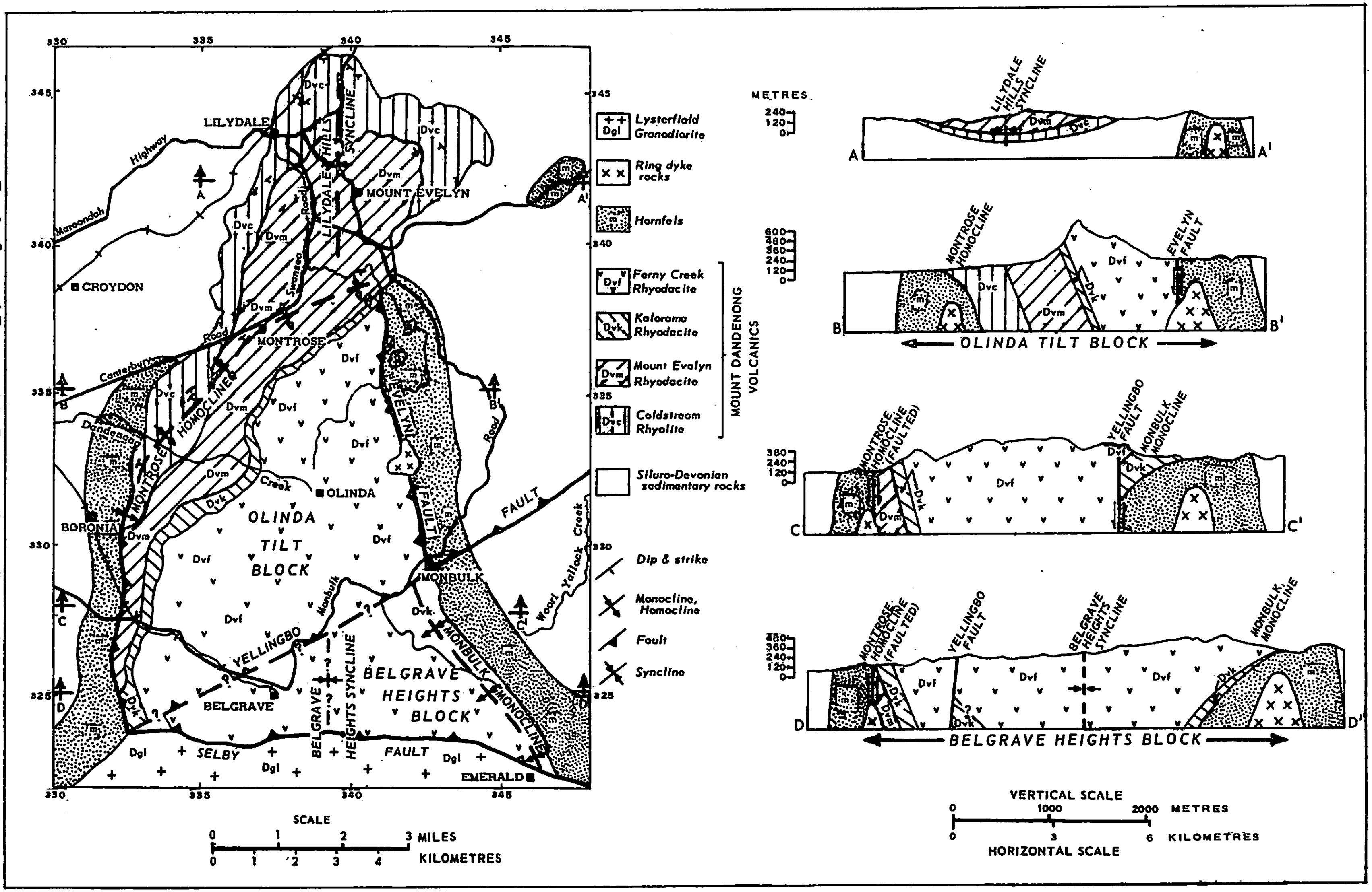


Fig. 2 Structural Features of the Dandenong Ranges Cauldron Subsidence

gentle southerly plunge. This lies north of the main cauldron subsidence.

(b) the Olinda Tilt Block, a structure bordered by the Montrose Homocline to the west, the Evelyn Fault to the east, and the Yellingbo Fault to the south.

(c) the Belgrave Heights Block, a synclinal structure bordered by the Yellingbo Fault to the north, the Monbulk Monocline to the east, and the Selby Fault to the south.

The Olinda Tilt Block and Belgrave Heights Block together make up the cauldron subsidence.

The western margin of the cauldron subsidence is marked by the Montrose Homocline. At the southern extremity, the structure becomes a fault (see also Berger 1961). The course of the homocline is shown in Fig. 2a. It is bordered on the western side by a pronounced ridge of hornfels developed in the Humevale Formation sediments. Bedding, which is still preserved in many areas, shows that the Lower Devonian sediments have not been affected by the homoclinal movements. Although no metamorphism has been found along the homocline where it crosses the volcanics, an intrusion of porphyrite occurs north of Kalorama, near its northern end.

The eastern margin of the cauldron subsidence is complex. North of the Yellingbo Fault, the relationships between the volcanics and Palaeozoic sediments are largely obscured, although at the northern extremity, the contact is clearly faulted (Morris 1914, Edwards 1956) along the Evelyn Fault. The rhyodacite is schistose where it comes into contact with the Silvan Granodiorite (Morris 1914). Morris attributed the schistosity to thermal metamorphism, but the author suggests that it may be due to faulting. South of this locality, contact relationships are obscured for a distance of about 3 km. Edwards (1956) interpreted this boundary as a monoclinal structure forming part of his Monbulk Monocline. In his view, the units pre-dating the Ferny Creek Rhyodacite are lacking because they never extended as far eastwards as this. The present author suggests that the boundary is a continuation of the Evelyn Fault. The block north of the Yellingbo Fault is a tilt block, as envisaged by Hills (1941b), and not a synclinal structure as shown by Edwards (1956, p.144).

South of the Yellingbo Fault, a volcanic unit predating the Ferny Creek Rhyodacite occurs along the eastern border of the volcanics. Interbedded tuffs show gentle southwesterly dips. The vocanic unit is underlain by thin tuffs, which in turn overlie Palaeozoic sedimentary rocks. This volcanic unit was tentatively correlated with the Kalorama Rhyodacite by Edwards. The gentle southwesterly dips are due to the Monbulk Monocline.

The southern margin of the cauldron subsidence is faulted, as shown by Berger (1961). The central zone of maximum metamorphism (zone 3) coincides with the position of the Belgrave Heights Syncline, a broad open syncline.

The Belgrave Heights Block is separated from the Olinda Tilt Block by the Yellingbo Fault. In the Macclesfield area, the position of this fault is marked by the thick Yellingbo Dyke, which was first mapped by Thomas and Kenley (1954-5) in the Yellingbo area. The suggested northerly throw of this fault is in the order of 3,000 m in the Macclesfield area. In the calculation of this large throw, it was assumed that the missing Wenlockian and Ludlovian beds are of similar thickness to those in the Ringwood area. The age of the Macclesfield graptolites is regarded as Upper Llandoverian, but this age is based on the provisional determination of *Monograptus* cf. *spiralis* (Thomas & Kenley 1954-5). The other graptolites (see above) have a slightly longer time range, so that the beds may be as young as middle Wenlockian. In the Monbulk area, the position of the fault is obscured by thick soils. A weathered acidic dyke has been located at Monbulk, but probably does not lie on the fault. Near the Patch, the contact between the Kalorama and Ferny Creek Rhyodacites is obscured by alluvial sediments. Within the Ferny Creek Rhyodacite, outcrops are generally obscured by thick soils, and the position of the fault has not been accurately established. Continuing in a south westerly direction, however, the contact between the Lysterfield Granodiorite and the hornfels of the Lysterfield Hills lies on the exact strike of the fault. Farther southwest, its position is hidden by Cainozoic sediments, but it appears to line up with the Selwyn Fault, which marks the western coastline of Mornington Peninsula. Asthama (1957) shows that this fault predates the Devonian granitic intrusions of the peninsula.

The eastern hornfels aureole of the Lysterfield Granodiorite continues north to Mt Evelyn running along the Monbulk Monocline and Evelyn Fault. This and the hornfels ridge along the Montrose Homocline are thought to mark the position of a ring dyke, which has been exposed in the Olinda Creek area (as the Silvan Granodiorite).

The faulting and warping associated with the cauldron subsidence at least partly postdate the extrusion and solidification of the youngest Devonian volcanics. Edwards (1956) stated that the likely cause of the subsidence is a collapse of the roof of the magma chamber, following on the withdrawal of magma to form the volcanics.

SECTION C: TERTIARY FAULTING AND FOLDING.

Small-scale faulting and folding have affected the Tertiary deposits in the western part of the area. These structures have been discussed in detail by Kenley (1967), and only a brief summary is given here.

MELBOURNE WARP

The Melbourne Warp is an exceedingly broad gentle flexure with the downthrown block lying to the southwest (Gill 1961). It is responsible for the low topographic escarpment which runs parallel to, and a little to the east of, the Oakleigh to Dandenong railway line, and for the pronounced lineation of the Tertiary - Silurian contact along Gardiners Creek. The total vertical displacement is approx. 40 m in the Oakleigh area. The Miocene shore line approximately parallels the Melbourne Warp. This suggests that repeated movement took place along the Melbourne Warp. During Cainozoic times the warp appears to have acted as a hinge separating a predominantly rising area in the northeast from a predominantly subsiding area in the south west.

BEAUMARIS MONOCLINE

This structure is seen in outcrop at Beaumaris, where the cliffs are locally parallel with the turnover of the Monocline. Flexing of the beds has produced dips of up to 30° to the southeast near Charman Road, and minor faulting is present at some places. Newport Formation sediments outcrop in the core of the Monocline at Beaumaris, although below sea level. The Beaumaris Monocline forms a low diminishing escarpment which can be traced inland from some distance to the northeast. This escarpment forms the divide between the Gardiners Creek and Dandenong Creek - Carrum Swamp drainage systems (The Notting Hill - Cheltenham axis, Hart 1913). In the Notting Hill area, the monocline occurs as a fault, with a southeasterly displacement of about 18 m. Subsurface data show that the monocline has been active at various times. The top of the Silurian rocks is faulted, with a displacement of about 60 m. On the other hand, the top of the Newport Formation shows a much smaller displacement, so that the thickness of the formation changes from about 25 m to about 60 m across the monocline. Instead of a faulted top, the Newport Formation surface shows a gradual southwesterly slope. Sandy sediments characterise the Newport Formation and overlying sediments on the monocline.

WHEELERS HILL FAULT

A prominent escarpment forms the western margin of the Dandenong Creek valley between Glen Waverley and Dandenong. Although no definite evidence of faulting has been found along this escarpment, it is probably due to a post-Pliocene fault. Maximum displacement probably occurred in the Glen Waverley area. From here to the southeast, the escarpment gradually becomes lower, until it disappears about 1.6 km north of Dandenong. At its northern extremity the fault terminates against the Beaumaris Monocline.

The downward erosion of Dandenong Creek has greatly exaggerated the relief along the escarpment, especially in the north, where a maximum relief of 90 m occurs. The maximum downthrow in that area probably did not exceed 45 m.

FOLDING

Kenley (1967) has mapped a number of small fold-like ridges within the Tertiary sediments in the Brighton - Beaumaris area. These 'folds' have small amplitudes and are rather closely spaced, and sub-parallel. Kenley considered they post-date the deposition of the Black Rock Sandstone, but predate the Red Bluff Sands, since the latter are not affected by jointing which is well-developed in the Black Rock Sandstone. The present author considers that they probably post-date the deposition of the Red Bluff Sands, since in his view their present topographic expression cannot be explained by differential compaction, nor by drainage, which is poorly developed. The absence of joints is thought to be due to the uncompacted nature of the Red Bluff Sands at the time the structures were formed.

On this interpretation the last movements on the monoclinal structures, and the folding of the Tertiary sediments, took place after the deposition of the Brighton Group sediments, and probably coincided with the Kosciusko Uplift (Hills, 1940), of late Pliocene to Pleistocene age. Kenley (pers.comm.) no longer regards the structures in the top of the Black Rock Sandstone as folds. From recent studies he now considers them to be syn-depositional ridges akin to sand waves in morphology (Off, 1963).

PART FOUR: ECONOMIC GEOLOGY

A brief summary of the rock types and their uses is given below. For a more detailed account, see Bell *et al.* (1967).

CRUSHED ROCK AGGREGATES (used as concrete aggregates and road metal)

The fresh hornfels of the Lysterfield area form the largest single supply of rock aggregate in the area. Its toughness and close jointing make it ideally suited for crushing. In other areas, the hornfels is too deeply weathered and soft to be suitable, although small disused quarries are widely scattered in the area.

The Coldstream Rhyolite and Mount Evelyn Rhyodacite are quarried at Montrose and Fern Tree Gully respectively. Most of the Upper Devonian volcanic rocks are either too weathered or too massive to be quarried conveniently.

The Older Volcanics form a source of rock aggregate in the Narre Warren area, where they are fresh and dense, and closely jointed. Elsewhere, the Older Volcanic residuals are too deeply weathered, and quarrying is uneconomic.

The quality of the Newer Volcanics is extremely variable, due to deep weathering and the presence of vesicles. It was formerly quarried in the Clifton Hill and Burnley areas, where availability is now limited by the extensive residential developments.

The sedimentary rocks are generally not suitable as aggregates, due to their lack of cohesion. Fresh greywacke, however, is quarried in the Templestowe area, and the Lilydale Limestone finds limited use as road metal.

CLAY AND SHALE (used for brick and pipe manufacture)

The Silurian sedimentary rocks provide an unlimited, readily available source of clay and shale, both in the weathered and fresh states. A large number of quarries are scattered throughout the eastern suburbs, where both weathered and fresh mudstones are used as brick clay. Plastic clay deposits suitable for red tile and pipe manufacture are quarried in the outer eastern suburbs (Blackburn, Mitcham, East Burwood, and Scoresby). These clays are either deep residual clays, formed by prolonged weathering, or Cainozoic valley fill, largely derived from the residual clays.

FIRECLAY (used in the production of firebrick and other refractory materials)

Deep weathering of the Lysterfield Granodiorite near Dandenong has resulted in the formation of small deposits of fireclay (kaolinite). This was formerly quarried for the production of fire bricks (Knight 1952). No other likely areas of fireclay have been found during the present survey.

SAND DEPOSITS

The extensive sand deposits of the Red Bluff Sands have been quarried in the Springvale - Oakleigh - Clarinda area. These sands are used as concrete sand, brick sand, and, to a minor extent, as glass sand. Reserves of useable sand deposits are now limited largely by housing development.

LIMESTONE DEPOSITS

The only commercial limestone deposit in the area, the Lilydale Limestone Lens, has long been quarried as a source of agricultural lime. Small quantities have also been used for ornamental stonework, and for road metal.

METALLIFEROUS DEPOSITS

Victoria's first gold discovery was made at Anderson Creek, south of Warrandyte. Auriferous quartz veins were also discovered on the Templestowe Anticline, near North Balwyn, and on the Ringwood Anticline at Ringwood. Antimony and copper were found associated with the gold at Anderson Creek, and antimony was also present at Ringwood. Mining of these deposits continued for some time, but accurate yields are not available. Minor gold discoveries in the area are listed by Whiting (see Bell *et al.* 1967).

UNDERGROUND WATER

In general, only small supplies of poor quality water occur, although good supplies of good quality water are obtainable from the lower parts of the Newport Formation in the southwestern part (Braeside-Mordialloc area) and from the sub-Older Volcanic sediments in the Silvan area.

PART FIVE: PHYSIOGRAPHIC EVOLUTION

The evolution of the present topography of Victoria can be traced back to Mesozoic times when long, continued erosion of the Palaeozoic rocks had produced a great peneplain, which extended over most of Victoria. Hills (1955) has suggested that peneplanation was completed during the Triassic. The country between Warburton, Healesville, Marysville, and Mount Torbreck is a remnant of this Triassic erosion surface (Hills 1934a). In the area studied, Mount Dandenong represents a remnant of the Triassic erosion surface, although it has been eroded to well below its former level. The present elevation of Mount Dandenong and surrounding ranges is due to the resistance to erosion of the Ferny Creek Rhyodacite.

During the Mesozoic (?Triassic) the Triassic erosion surface was faulted and uplifted, and a new cycle of erosion started which led to the development of much of the present topography. By Eocene times it had produced a maturely dissected terrain, such as that occurring east of Mount Dandenong, where its original relief can be observed beneath the abundant residuals of Older Volcanics. The main divide during the Eocene was very close to its present position. The area between Mt Dandenong and Fern Tree Gully formed high ranges, from which the divide ran north to Coldstream, and east to Emerald and Gembrook.

South of the Eocene divide, the base of the Older Volcanics shows a drop of about 120 m in 10 km. In comparison, the youthful tract of the present Cardinia Creek drops about 120 m in 8 km (measured in a straight line from its headwaters near Emerald to about 2½ km north of Upper Beaconsfield). To the north of the Eocene divide, the ancestral Woori Yallock Creek had eroded a drainage basin very similar to that of the modern Woori Yallock Creek (Edwards 1940). Immediately north of the divide, the pre-Older Volcanics terrain shows a drop of about 60 m in 5 km, indicating youthful valley tracts. Farther downstream, the extensive basalts in the Silvan and Wandin North areas cover a wide, open, maturely dissected drainage system. The relief becomes much gentler, showing a drop of about 60 m in 15 km between Macclesfield and Seville. The Eocene divide also forms the boundary between the Flinders and Berwick types of Older Volcanics (Edwards 1939), the former occurring north of the divide at Emerald and Lilydale, while the latter occurs south of the divide at Mt Morton and Berwick. The comparisons between the Eocene and modern drainage systems clearly show the similarity of the topography at both times. It may be concluded that the Eocene and modern drainage systems were largely influenced by the relative resistance to erosion of the different Palaeozoic rock types, and that the extrusion of the Older Volcanics had little effect.

The only evidence of stream diversion caused by the Older Volcanics valley flows is found in the Silvan area, where the Olinda Creek and its tributaries, formerly part of the Woori Yallock system, were dammed back to produce a swamp. Subsequently, the creek cut a valley through the Eocence divide between Kalorama and Mt Evelyn and, although the headwaters still drain the eastern slopes of the Dandenong Ranges, it now flows through Lilydale and joins the Yarra River independently.

West of the Dandenong Ranges the Eocene topography is poorly known. Keble (1918) postulated a predominantly north-south drainage system, the 'Wurunjerri River', which had its origin northeast of Yarra Glen, and which flowed south through Lilydale into the ancestral Western Port. It was separated from the Port Phillip drainage system by a prominent mountain range, the 'Wurunjerri Range', which was composed of resistant quartzites (Dargile Formation of this report). He further postulated that the headwaters of this 'Wurunjerri River' were captured by a westerly flowing stream, giving rise to the present westerly flowing Yarra River. Gill (1942b, 1949) agreed with the main points of Keble's theory, but proposed minor modifications. Hills (1934) similarly did not question the existence of Keble's postulated features, although he pointed out the improbability of river capture as a cause of the diversion of the headwaters of the 'Wurunjerri River'. Instead, he thought that this diversion was caused by the extrusion of the Older Volcanics at Lilydale, which effectively blocked the river, causing it to find an outlet elsewhere. Each of these writers thought of the 'Wurunjerri Range' as an erosional feature. Jutson (1911a), however, gave an entirely different explanation of these features. He postulated a fault origin for the pronounced scarp (i.e. Keble's 'Wurunjerri Range' running from Yarra

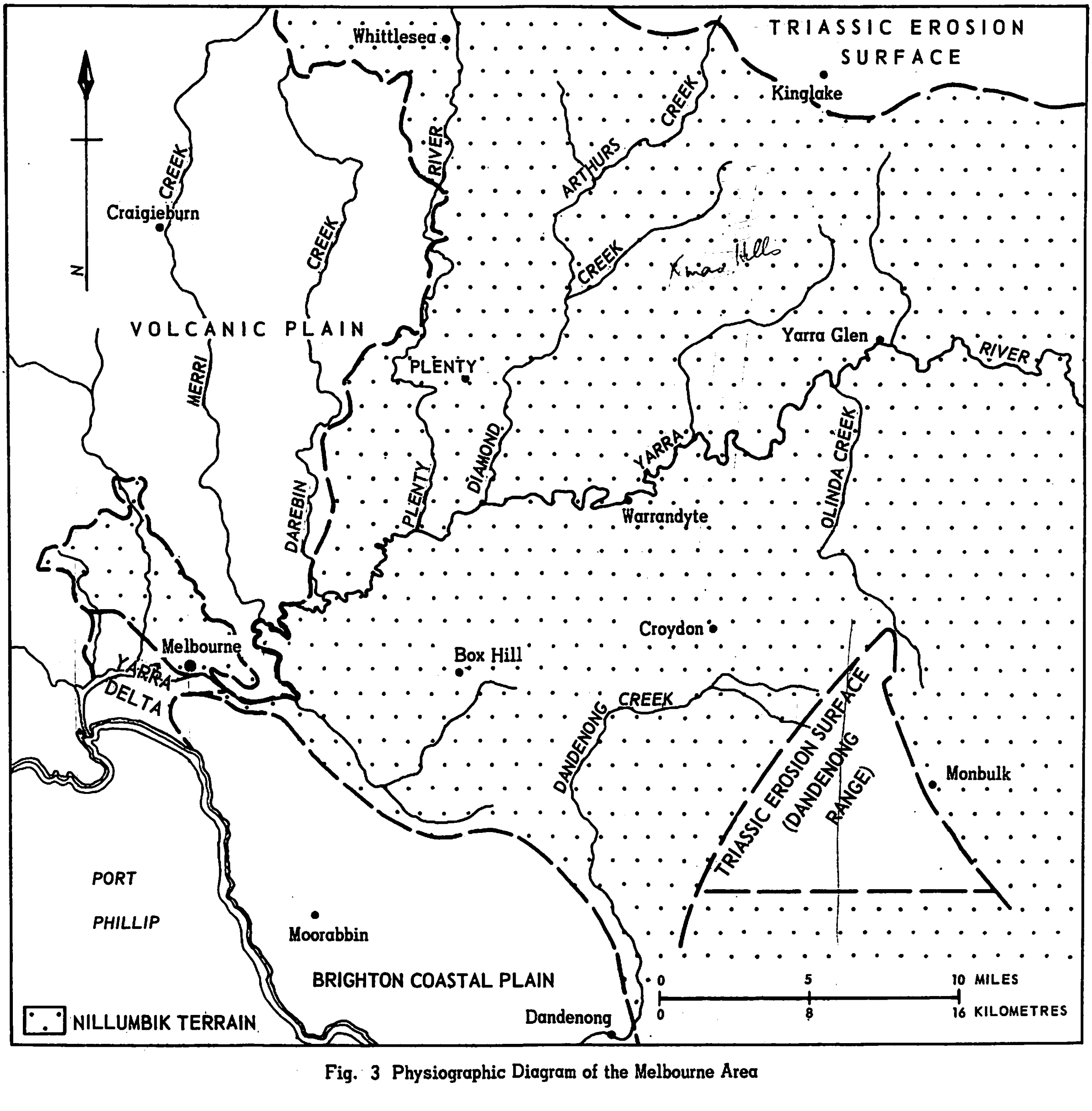


Fig. 3 Physiographic Diagram of the Melbourne Area

Glen to south of Croydon. The uplifted land surface was referred to as the Yarra Plateau, while the downfaulted portion was called the Croydon Sunkland, both features together comprising the Nillumbik Peneplain. He showed that these features, including the fault scarp, post-dated the Older Volcanics.

The present author, in collaboration with M.J. Garratt, has endeavoured to clear up the controversy that exists in the literature dealing with the physiographic evolution. Garratt (in prep.) has shown conclusive proof of the existence of Jutson's Yarra Fault, bordering the Yarra River flats in the Yarra Glen area. Furthermore, this fault is definitely a young feature, probably of post-Pliocene age. No evidence of the continuation of the fault south of Wonga Park has been found, and the author regards the prominent line of hills situated in the Dargile Formation between Wonga Park and Heathmont as an erosional feature. The author has examined the Older Volcanics of the Lilydale area in some detail, and has found nothing to support the existence of the 'Wurunjerri River'. The Tertiary sands underlying the Older Volcanics at the Lilydale limestone quarry could not form part of the alluvium of this 'Wurunjerri River', as suggested by Gill (1942b), as the Older Volcanics capping these sands are about 30 m higher than in other parts of the quarry. Furthermore, at their lowest point, the Older Volcanics directly overlie the Lilydale Limestone Member, and the Tertiary sands are thin or absent. The evidence shows that the Older Volcanics at Lilydale covered gently undulating hilly country, dissected by minor valleys. In the western part of the area, the Older Volcanics are of limited extent and shed little light on the Eocene physiography.

During late Eocene and early Miocene times, widespread subsidence took place over much of Victoria, and marine deposits were laid down in the low-lying areas. On the Ringwood sheet, the Miocene sea encroached as far east as Huntingdale, Springvale, and Keysborough. To the west of this line, the marine Newport Formation was laid down. On the land, the Mesozoic - Tertiary erosion cycle had produced an erosion surface of low relief, with a gentle seaward slope. Jutson (1911a) named this middle Tertiary surface the Nillumbik Peneplain. It is now generally referred to as the Nillumbik Terrain (Hills 1934, Neilson 1967, 1970). Remnants of this erosion surface are represented by the high, concordant, relatively flat hilltops in the Warrandyte - Doncaster - Nunawading area, and are typically underlain by deep soils. During the Pliocene, the streams draining the higher country to the east and north deposited a thin veneer of terrestrial sediments, the Red Bluff Sands, on the Nillumbik Terrain. These sediments are typically fluviatile, with only minor developments of fine-grained overbank deposits, indicating a rather active environment.

The Nillumbik Terrain, with its thin veneer of Red Bluff Sands, was uplifted between late Pliocene and early Pleistocene times (Hills 1934, Neilson 1967). Maximum uplift occurred along the Mitcham Axis (Jutson 1911a), running from Kew to Ringwood. The rejuvenated streams have since eroded through the thin Red Bluff Sands, exposing the underlying Silurian rocks.

During the late Pliocene and Pleistocene, basalts were extruded from eruption points north of the area. It has not been established whether or not the late Pliocene flow which filled the Merri Creek valley occurs on the Ringwood sheet. The Pleistocene flow, originating from Hayes Hill (Hanks, 1954), filled the valleys of Darebin Creek and the Yarra River downstream from Fairfield, and has influenced the post-Newer Volcanic physiography in this area. The Newer Volcanic rocks form the eastern margin of the volcanic plains, which extend into western Victoria.

The Tertiary events in the western part of the area had little effect on the physiography of the eastern part. There, the late Cretaceous - Tertiary erosion cycle has continued virtually uninterrupted to the present day. In the Woori Yallock basin, continued erosion reduced the extent of the Older Volcanics, which, due to their relative resistance to erosion, now form residual caps on the higher hills, while the streams have cut valleys in the softer Siluro-Devonian sediments.

DRAINAGE SYSTEMS

Three river systems drain the area. These are the Yarra River system in the north, the Dandenong Creek system in the southwest, and the Cardinia - Toomuc Creeks system in the southeast.

In the eastern part of the area, the drainage pattern is controlled by the relative resistance of the Mount Dandenong Volcanics and the Lysterfield Granodiorite. The tributaries of the Yarra River east of Mount Dandenong have northerly or northeasterly courses. Olinda Creek, which is an exception to this, has been displaced by the Older Volcanics. Olinda Creek, Wandin Yallock Creek, and Woori Yallock Creek occupy alluviated valleys, which are continuous with the extensive alluvial flats of the Yarra River farther downstream. To the west of Wonga Park, the westerly course of the Yarra River is attributed to the Mitcham Axis (Jutson 1911a), which forms the divide between Gardiners Creek and Koonung Creek. Mullum Mullum, Anderson, and Narrmeian Creeks drain the northern slopes of the Mitcham Axis in the Ringwood area. Their youthful tracts are due to the resistant mudstones and sandstones

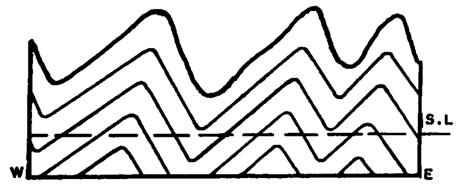
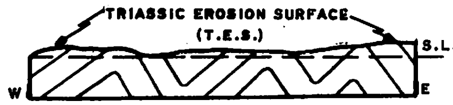
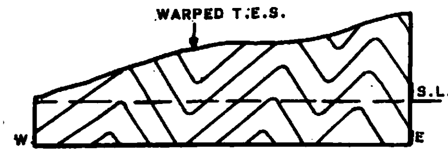
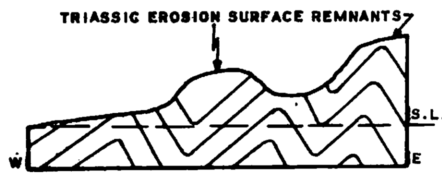
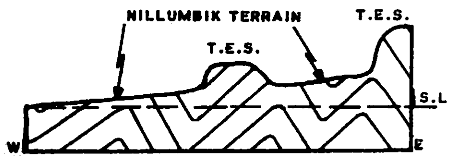
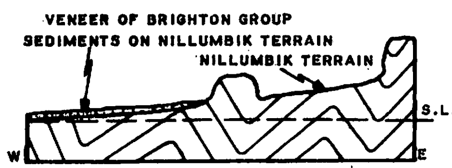
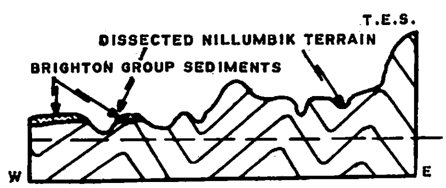
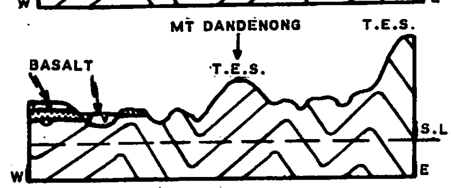
Geological Period	Event or Process	Products	Diagram
	Uplift and folding	Mountainous landscape	
Devonian to Triassic	Prolonged erosion	Landscape reduced to plane-like erosion surface 'Triassic Erosion Surface' (T.E.S.)	
Jurassic	Uplift and warping	T.E.S. warped into higher inland areas, and coastal basins of sedimentation in S.E. and S.W. Victoria	
Jurassic to Middle Tertiary	Weathering and erosion of uplifted T.E.S.	Residuals of T.E.S. only survive	
Middle Tertiary	Continued erosion produces an erosion surface at lower level than the T.E.S.	New erosion surface named the Nillumbik Terrain; it is surfaced by a thick mantle of residual clays	
Miocene	Deposition of sandy sediments by sea and streams on seaward part of Nillumbik Terrain.	Brighton Group sediments deposited	
	Lateritic weathering	Ferruginisation gives red colours, mottling and ironstone bands in Brighton Group, and mottling of clays in the weathered Silurian mantle	
	Uplift erosion	Valleys cut into Nillumbik Terrain. Brighton Group is eroded and survives mainly on hill tops	
Upper Pliocene–Pleistocene	Outpouring of basalt flows (Newer Volcanics)	Basalt fills some valleys and forms lava plains W. and N. of Melbourne	

Table 3 Erosional History of the Melbourne Area

through which they flow, and to the rapid drop north to the Yarra River. Northeast of Ringwood, the upper reaches of Mullum Mullum Creek flow in a southwesterly direction, in contrast with the prevailing northerly drainage of that area. Thiele (1906) has shown this to be due to river capture, in which the upper part of a stream originally draining into the Dandenong Creek system was captured by the actively eroding Mullum Mullum Creek. The original course is represented by a low gap about 90m east of Heatherdale railway station, and by a small tributary of Dandenong Creek south of this gap.

The Gardiners Creek - Scotchman Creek system drains to the southwest in its headwaters, but suddenly changes to a northwesterly direction at East Malvern. Keble (1931) thought the apparent diversion was due to a fault which ran along the southern bank of Gardiners Creek, with a downthrow to the north east. There is little evidence to support this theory - instead, the course of Gardiners Creek closely parallels the Melbourne Warp, which is downthrown to the southwest. The anomalous northwesterly direction closely parallels the well-developed ridges farther south west, and it is possible that a similar ridge determined the direction of flow of Gardiners Creek. Another feature supporting this theory is the lack of tributaries along the south bank of Gardiners Creek.

Another case of river capture occurs on Gardiners Creek. The old course is marked by a pronounced wind gap filled with alluvial sediments, just south of Alamein railway station. In this case, Gardiners Creek has been captured by Scotchman Creek, some distance upstream from the former junction of these creeks. This capture was probably facilitated by the lavas of the Newer Volcanics which occupy the Yarra valley farther downstream. These caused both creeks to deposit sediments, thus elevating the valley floor to a level at which the valleys joined. The floor of the wind gap is at the same level as the high-level terraces elsewhere along Gardiners Creek.

East of Studley Park, the Yarra River is a slow, meandering stream, with extensive developments of alluvial flats and isolated high level terraces along the valley. At Studley Park, the valley becomes youthful, with steep banks on both sides. These features are due to the damming of the Pleistocene Yarra River valley by lavas of the Newer Volcanics. The high level terraces represent the level to which the Pleistocene valley became filled with sediments. They reach a height only a little below the top of the basalts at Alphington. A similar development of dissected high level terraces and low alluvial flats occurs along Gardiners Creek; these originated in the same way.

The divide between the Yarra River and Dandenong Creek systems is due to a variety of factors. Parts of the divide are due to warping, e.g. in the southwest, where the Cheltenham Axis (Hart 1913) forms the (migrated) scarp of the Beaumaris Monocline. To the north, the divide occurs close to the Mitcham Axis, while in the east it occurs in the resistant Mount Dandenong Volcanics. The divide between the Dandenong Creek and Cardinia Creek systems has been determined by a valley flow of resistant Older Volcanics (see also Cranbourne 1:63,360 geological map).

Dandenong Creek occupies a long, broad valley, a feature which caused Jutson (1911a) to regard the valley as fault controlled. He proposed the name 'Croydon Senkungsfeld' for this feature. Keble (1918) thought that the valley represented the pre-Older Volcanic course of a large southerly draining stream. This theory has been discussed above. The author regards the valley as a post-Pliocene feature, since it has truncated the Pliocene Red Bluff Sands between Wheelers Hill and Dandenong. The field relationships in that area show that these sands were supplied from the northeast and east, which contradicts the existence of a large north-south valley prior to the Pliocene. A prominent escarpment forms the western margin of the Dandenong Creek valley between Glen Waverley and Dandenong. The probable faulted nature of this escarpment has been discussed above. In general, apart from this feature, the prominent Dandenong Creek valley is considered to be due to the ease of weathering of the Humevale Formation. The topography is very subdued, consisting of low, rounded hills. The extensive alluvial flats are attributed to lateral planation and alluviation during the Pleistocene when a shallow marine embayment in the Carrum Swamp area formed a temporary base level of erosion.

In contrast with the Dandenong Creek system, the Cardinia Creek and Toomuc Creek systems have youthful tracts, due to the resistant granodiorites through which they flow.

The drainage pattern reflects the structure of the underlying rocks in only a few areas. An example of this is the rectangular drainage pattern on the Eumemmering Creek system, which reflects the major north-south and minor east-west jointing of the underlying Lysterfield Granodiorite. A similar rectangular pattern occurs in the upper reaches of the Woori Yallock Creek system between Cockatoo and Monbulk, reflecting the prominent northwest-southeast and less prominent northeast-southwest jointing of the underlying hornfels and Lysterfield Granodiorite.

In the Brighton Coastal Plain, the porosity of the Red Bluff Sands has prevented the development of a normally dissected topography. The poorly developed drainage pattern shows a prominent northwest-southeast alignment, i.e. parallel with the coastline, rather than at right angles to it. This is considered to be a reflection of the structures in the underlying Tertiary sediments (Kenley 1967).

Table 4. Chemical analyses of the Mount Dandenong Volcanics

	(1)	(2)	(3)	(4)	(5)	(6)
SiO_2	69.10	73.85	65.85	66.18	68.09	63.49
Al_2O_3	15.00	14.45	15.50	15.60	15.75	15.96
Fe_2O_3	1.43	0.61	1.34	1.33	1.55	0.87
FeO	2.50	1.20	3.46	3.98	3.46	5.14
MgO	0.33	0.83	1.71	1.49	1.46	2.75
CaO	1.72	1.40	3.33	3.19	2.59	4.21
Na_2O	3.07	2.09	2.58	2.31	2.94	2.71
K_2O	3.98	5.19	2.57	3.62	2.70	2.85
H_2O+	1.05	0.21	1.53	1.12	0.30	0.46
H_2O-	0.39	0.10	0.23	0.09	0.05	0.16
CO_2	0.64	nil	0.56	0.18	nil	nil
TiO_2	0.33	0.28	0.66	0.74	0.78	1.09
P_2O_5	0.07	tr	0.20	0.25	0.29	0.20
MnO	0.08	0.10	0.05	0.06	0.07	0.02
Cl	tr	-	nil	tr	nil	nil
SO_3	tr	-	tr	tr	tr	nil
FeS_2	-	-	0.10	0.10	nil	0.23
BaO	0.29	-	0.20	0.13	-	-
Total	99.98	100.31	99.87	100.37	100.03	100.14

(1) Coldstream Rhyolite, average of 6 analyses (Edwards 1956, p. 116, Nos. 1 to 6)

(2) Mt Evelyn Rhyodacite, basal rhyolitic phase (ibid., p. 121, No. 7)

(3) Mt Evelyn Rhyodacite, average of 3 analyses (ibid., p. 121, Nos. 8 to 10)

(4) Kalorama Rhyodacite, average of 3 analyses (ibid., p. 125, Nos. 11 to 13)

(5) Ferny Creek Rhyodacite, chilled base, average of 2 analyses (ibid., p. 127, Nos. 14, 15)

(6) Ferny Creek Rhyodacite, average of 4 analyses (ibid., p. 127, Nos. 16 to 19)

Table 5. Chemical analyses of the Upper Devonian intrusive rocks.

	(1)	(2)	(3)	(4)	(5)
SiO_2	69.51	66.20	67.66	69.15	65.84
Al_2O_3	14.30	15.24	15.36	14.52	15.26
Fe_2O_3	1.89	0.92	0.74	1.26	1.77
FeO	1.34	3.67	3.84	2.64	3.26
MgO	1.08	2.33	1.52	1.07	2.12
CaO	2.65	3.74	3.24	3.66	4.17
Na_2O	2.92	3.34	3.02	2.75	2.34
K_2O	3.25	2.91	2.24	3.12	3.67
H_2O+	0.94	0.80	1.42	0.76	0.75
H_2O-	0.26	0.08	0.04	0.11	0.11
CO_2	tr	0.03	0.06	0.03	nil
TiO_2	0.44	0.64	0.62	0.61	0.48
P_2O_5	0.17	0.06	0.24	0.27	0.27
MnO	tr	0.03	0.06	0.07	0.09
Cl	tr	tr	0.01	tr	tr
SO_3	tr	tr	0.01	tr	tr
FeS_2	0.05	-	-	-	-
BaO	-	-	-	-	-
Total	98.80	99.99	100.08	100.02	100.13

(1) Silvan Granodiorite, average of 2 analyses (Edwards 1956, p. 131, Nos. 25,26)

(2) Lysterfield Granodiorite, average of 2 analyses (ibid., p.131, Nos. 27, 28)

(3) Felspar porphyrite 'plug' (co-ords 405 383) (ibid., p. 134, No. 32)

(4) Narree Worran dyke swarm, hornblende porphyrite dykes, average of 2 analyses (ibid., p. 134, Nos. 30, 31)

(5) Narree Worran dyke swarm, felspar-hornblende porphyrite dyke (ibid., p. 134, No. 33)

Table 6. Chemical Analyses of Cainozoic igneous rocks

	(1)	(2)	(3)
SiO_2	45.56	45.64	47.80
Al_2O_3	13.32	14.35	18.02
Fe_2O_3	2.30	2.08	1.77
FeO	9.68	10.32	9.46
MgO	11.12	9.50	3.96
CaO	8.77	7.87	8.54
Na_2O	3.02	2.17	3.74
K_2O	1.53	1.23	1.12
H_2O+	1.28	1.29	1.15
H_2O-	0.27	1.92	-
CO_2	nil	0.47	-
TiO_2	3.00	2.74	3.53
P_2O_5	0.71	0.42	0.27
MnO	0.19	0.13	0.30
Li_2O	nil	-	-
SO_3	nil	nil	-
S	-	0.14	-
BaO	-	nil	-
Cl	0.05	0.02	-
NiO, CoO	0.01, tr.	-	-
Cr_2O_3	0.06	0.01	-
Other		0.10	
Total	100.87	100.40	99.66

(1) Limburgite plug, Balwyn. (Chapman & Thiele 1911, p. 133).

(2) Older Volcanics, Flinders type (although the analysis is from Royal Park, Melbourne, it is typical of the Older Volcanics of Emerald and Lilydale)(McCance 1932, in Edwards 1938, p. 288, Table 8, No. 4).

(3) Newer Volcanics, olivine basalt, Clifton Hill (Richards 1917, in Edwards 1938, p. 278, Table 5, No. 1).

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