University of Queensland

DEPARTMENT OF GEOLOGY

VOLUME IV 1953 NUMBER 4

Upper Palaeozoic Formations in the Mt. Morgan District—Stratigraphy and Structure

By

W. G. H. MAXWELL, B.Sc., Ph.D.
Department of Geology, University of Queensland

Price: Three Shillings

THE UNIVERSITY OF QUEENSLAND PRESS
BRISBANE

DATE OF PUBLICATION
20th September, 1953

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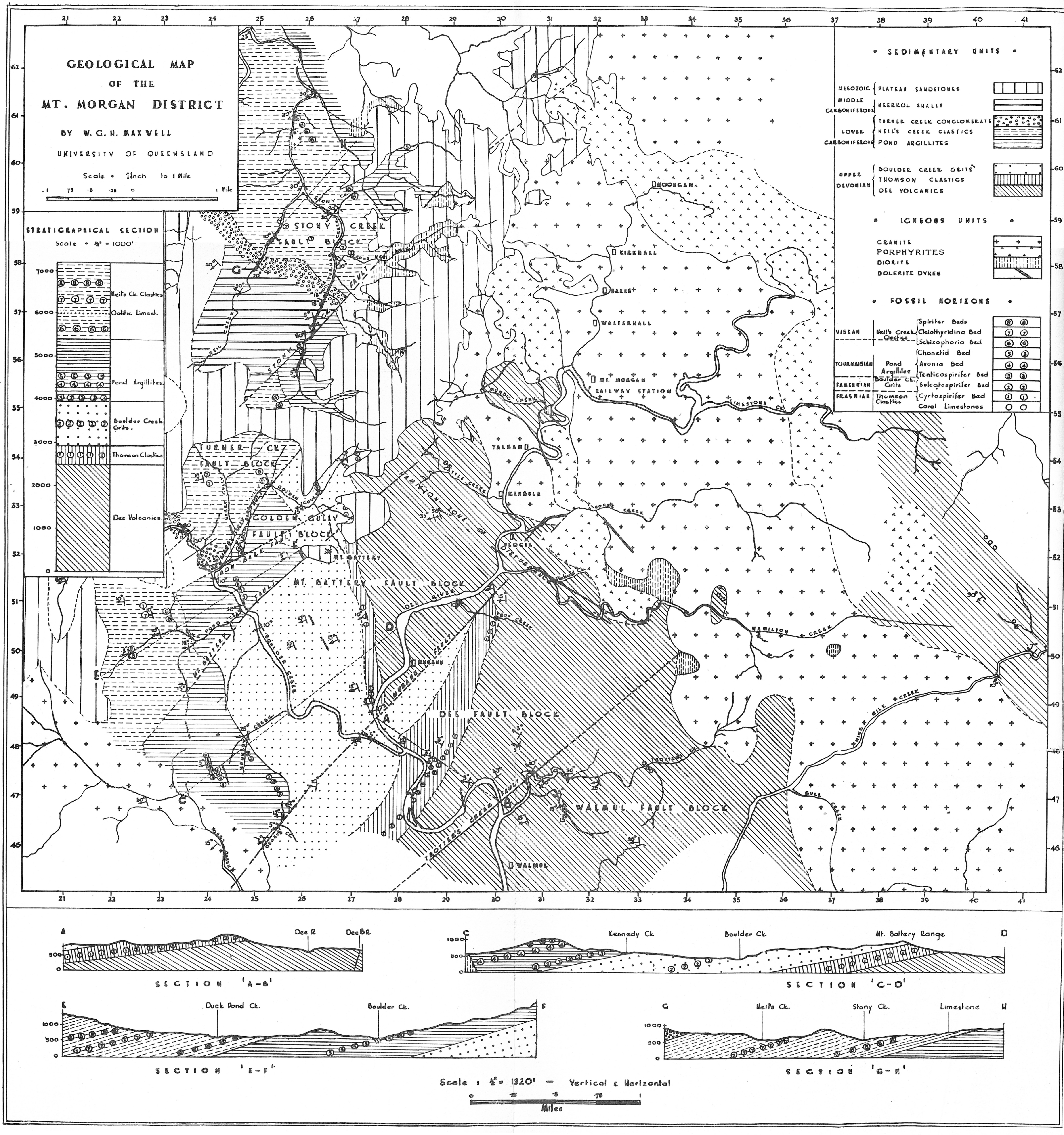
Registered at the General Post Office, Brisbane,
for transmission by Post as a Book.

Wholly set up and printed in Australia by
WATSON, FERGUSON AND COMPANY
Brisbane, Q.


GEOLOGICAL MAP
OF THE
MT. MORGAN DISTRICT
BY W. G. H. MAXWELL
UNIVERSITY OF QUEENSLAND
Scale • 1 Inch to 1 Mile
STRATIGRAPHICAL SECTION
Scale • ½" = 1000'
Neil's Ck. Clastics
Oolitic Limest.
Pond Argillites
Boulder Creek Grits.
Thomson Clastics
Dee Volcanics
SEDIMENTARY UNITS
MESOZOIC PLATEAU SANDSTONES
MIDDLE CARBONIFEROUS NEERKOL SHALES
LOWER CARBONIFEROUS TURNER CREEK CONGLOMERATE NEIL'S CREEK CLASTICS POND ARGILLITES
UPPER DEVONIAN BOULDER CREEK GRITS THOMSON CLASTICS DEE VOLCANICS
IGNEOUS UNITS
GRANITE
PORPHYRITES
DIORITE
DOLERITE DYKES
FOSSIL HORIZONS
VISEAN
Neil's Creek Clastics
Spirifer Beds
Cleiothyridina Bed
Schizophoria Bed
TOURNAISIAN
Pond Argillites
Chonetid Bed
Avonia Bed
Tenticospirifer Bed
FAMENNIAN
Boulder Ck. Grits
Sulcatospirifer Bed
FRASNIAN
Thomson Clastics
Cyrtospirifer Bed
Coral Limestones
STONY CREEK FAULT BLOCK
TURNER CK. FAULT BLOCK
GOLDEN GULLY FAULT BLOCK
MT. BATTERY FAULT BLOCK
DEE FAULT BLOCK
WALMUL FAULT BLOCK
HAMILTON ZONE OF
MT. BATTERY
MT. MORGAN RAILWAY STATION
MOONGAN
KIRKHALL
WALTERHALL
TALGAI
KENBULA
WALMUL
MURAND
DEE RIVER
LIMESTONE CK.
HAMILTON CREEK
MUNDIC CREEK
BOULDER CREEK
TROTTER'S CREEK
BULL CREEK
SECTION 'A-B'
Dee R
Dee B2
SECTION 'C-D'
Kennedy Ck.
Boulder Ck.
Mt. Battery Range
SECTION 'E-F'
Duck Pond Ck.
Boulder Ck.
SECTION 'G-H'
Neil's Ck.
Stony Ck.
Limestone
Scale : ½" = 1320' — Vertical & Horizontal
Miles

CONTENTS

Upper Palaeozoic Formations in the Mount Morgan District—Stratigraphy and Structure

By W. G. H. MAXWELL, B.Sc., Ph.D.
Department of Geology, University of Queensland.

(with 1 text-figure, 2 tables, 1 map).

Abstract.—In the Mt. Morgan district the Upper Palaeozoic sediments of the northern portion of the Yarrol Basin are exposed. By means of the several fossil horizons contained in them, the sequence has been divided into seven faunal zones ranging in age from Frasnian to late Visean. The individual formations are described, and the progressive change in their lithology from strongly felspathic to more quartzose rocks, has been used in an interpreation of the tectonic factors which controlled this sedimentation. A narrow granite batholith and associated hypabyssal material is intruded into the sedimentary formations. The whole area has been affected by two systems of normal faults; the N.E. system caused the downthrow of the northern blocks, resulting in the eastward displacement of the gently dipping northern beds. Fresh-water Mesozoic sediments were deposited unconformably on the older beds in the basin so formed.

INTRODUCTION

The Upper Palaeozoic formations deposited in the northern portion of the Yarrol Basin are exposed on the western slopes of the Mt. Morgan plateau, which is bounded on the north and east by the Razorback and Dee Ranges. Further north in the Fitzroy valley and Westwood district these formations are covered largely by alluvium. The Dee and Razorback Ranges exceed 1,500 feet, and are the source areas of the Dee River and its two main tributaries, Boulder Creek and The Nine Mile. These streams flow southwards through a terrain of granite, Mesozoic and Palaeozoic sediments, the Mesozoic rocks forming high sandstone ridges which separate this drainage system from that of the northerly flowing Neerkol Creek system. The main exposures of Carboniferous rocks are found in the mountainous region west of this divide, while Devonian sediments are more abundant to the east. Jardine (1927) and Sussmilch (1938) have discussed the physiography of this region, the former regarding it as part of the main dissected plateau of the Rockhampton district, its northern scarps marking the " limit of dissection of the plateau by the Fitzroy system." He believed differential erosion to have been the controlling factor in the physiographic development of the region. Sussmilch, on the other hand, emphasised the importance of block faulting, and described the Dee and Razorback Ranges as fault scarps. Field investigations have revealed two fault systems in this area, and they appear to have had considerable influence on the geomorphological history. However, the relative importance of faulting and differential erosion is difficult to evaluate and beyond the scope of this paper.

Previous detailed work on this region is negligible. Towards the end of the last century, Rands, Gibb Maitland, Jack and Dunstan surveyed the Stanwell Coal Measures further north. Reports on the mineralised area of Mt. Morgan have been furnished by Jack (1898), Newman and Campbell-Brown (1911), Fraser (1914, unpublished), Shepherd (1938), and Reid (1948). Hart (1912) carried out preliminary mapping of the area to the south and east of Mt. Morgan, and since that time there have been no further publications on the regional geology.

The first fossils from this area were given to the author by Mr. H. R. E. Staines, geologist to Mt. Morgan Ltd., who collected them during a survey of a mining lease. Further collections were made when the Upper Palaeozoic formations were being mapped. I am indebted to the members of the Department of Geology, University of Queensland, for their assistance while carrying out this research; in particular, to Dr. D. Hill for valuable advice and discussion. My thanks are due to Mr. H. R. E. Staines for the use of material; to Messrs. K. S. W. Campbell, K. Lodwick and K. Smith, for assistance in the field; to Dr. G. Thomas, for reading the manuscript. A Research Grant from the University of Queensland enabled this work to be done.

STRATIGRAPHY

I. INTRODUCTION.

This investigation was concentrated on those formations ranging in age from early Upper Devonian to Middle Carboniferous, and occurring to the west of the Mt. Morgan granite. Beds of Middle Devonian age occur to the east of the granite, and volcanic complexes of Permian age occur to the west of the area investigated. Throughout the entire stratigraphical succession the role of vulcanicity has been important, the earliest beds consisting wholly of pyroclastic material and flows. Clastic sediments increase in abundance in the higher formations, although volcanic rocks once again dominate the top of the sequence. Fossiliferous horizons are most abundant in Carboniferous rocks, the increase in their abundance being accompanied by a corresponding decrease in the proportion of pyroclastic materials. Brachiopods are dominant in the faunas; crinoids, corals, gastropods, polyzoans and trilobites are found in smaller numbers.

The whole area was faulted towards the end of Palaeozoic times, with two dominant systems of normal faults. From north-west to south-east, six faults blocks can be recognised, viz.:—Stony Creek, Turner Creek, Golden Gully, Mt. Battery, Dee, and Walmul Blocks. Associated with the faulting was the emplacement of the main granite mass. The subsequent deposition of Mesozoic formations has hidden much of the Palaeozoic succession in the north. The non-marine Mesozoic sediments consist of kaolinitic clays and non-calcareous sandstones, with conglomerate and tuffaceous material near the base of the sequence. Fossils of Valanginian age have been found in a marine intercalation in the Stanwell district further north (Whitehouse, 1946), suggesting that the greater part of these sediments are of Cretaceous age.

Stratigraphical Succession.

TABLE 1—Stratigraphical Chart.

Middle Carboniferous shales	Mudstones Shales		
Turner Ck. conglomerate	Conglomerate		
Neil's Creek clastics ..	Calc. argillites and limestones	*Spirifer* zone	VISEAN
	Argillaceous limestone, subgraywacke Oolitic limestone	*Cleiothyridina* zone	
	Subgraywacke & chert Limestone	*Schizophoria* zone	TOURNAISIAN
Pond argillites	Argillite Felspathic siltstones, claystones	*Chonetes* zone	
	Felspathic siltstones	*Tenticospirifer* zone	
Boulder Creek grits	Tuffaceous grits Shales Tuffs	*Sulcatospirifer* zone	FAMENNIAN
Thomson clastics	Calc. tuffs Felspathic tuffs	*Cyrtospirifer* zone	FRASNIAN
Dee volcanics	Tuffs Tuffs & limestone Agglomerate Lavas, tuffs		

II. STRATIGRAPHICAL SUMMARY.

A volcanic formation, the Dee volcanics, occurs at the base of the Upper Palaeozoic sequence, the early members of which are andesitic lavas, the larger remaining portion consisting of water-lain andesitic tuffs and agglomerates, with fragments and lenses of limestone occurring in the lower beds. They are succeeded by the Thomson clastics which are fossiliferous, tuffaceous sediments of Frasnian age. These are also overlain by tuffaceous sediments, the Boulder Creek grits, which contain an interbedded fossiliferous tuffaceous shale layer of Famennian age. Gastropods occur near the top of the Boulder Creek grits, which are succeeded by the Pond argillites, containing fossils of Carboniferous age. The main development of Carboniferous sediments, the Neil's Creek clastics, then follows without angular discordance. Several fossiliferous horizons ranging in age from Upper Tournaisian to Visean occur in this formation. The sediments consist largely of alternating bands of subgraywacke and chert, with limestones and calcareous rocks becoming more abundant near the top. The Turner Creek conglomerate rests conformably on the Neil's Creek clastics, and is succeeded in turn by polyzoan mudstones and shales, probably equivalent to the Middle Carboniferous Neerkol beds which occur seven miles further north in the Stanwell district.

TABLE 2—Range chart showing the stratigraphic distribution of the Mt. Morgan faunas.

The species are arranged in ascending order of appearance in the stratigraphic column, the oldest ones occurring at the top of the chart, the youngest ones at the bottom.

SPECIES	ZONES						
	Cyrto-spirifer	*Sulcato-spirifer*	*Tentico-spirifer*	*Chonetes*	*Schizoph-oria*	*Cleiothy-ridina*	*Spirifer*
Productella cf. *lachrymosa* Conrad	▬						
Cyrtospirifer reidi Maxwell	▬	▬					
Sulcatospirifer primus sp. nov.		▬					
Camarotoechia cf. *contracta* Hall & Clarke		▬	▬				
Productella sp.			▬				
Tenticospirifer grandis sp. nov.			▬				
Mucrospirifer kennedius sp. nov.			▬				
Dimegelasma elegans sp. nov.			▬				
Sinospirifer morganensis sp. nov.			▬	▬			
Camarotoechia sp.				▬			
Chonetes kennedia sp. nov.				▬			
C. tenuistriata sp. nov.				▬			
Avonia kennedia sp. nov.				▬			
Dimegelasma kennedia sp. nov.				▬			
Brachythyris campbelli sp. nov.				▬			
Schizophoria aff. *resupinata* Martin					▬	▬	
S. cf. *resupinata* var. *lata* Demanet					▬		
Leptaena cf. *analoga* Phillips					▬		
Avonia cf. *kennedia*					▬		
Productus cf. *minutus* Muir Wood					▬		
Prospira prima gen. et sp. nov.				▬	▬		
Prospira typa sp. nov.					▬	▬	
Syringothyris australis sp. nov.					▬	▬	
Brachythyris cf. *campbelli*					▬		
Brachythyris sp.					▬		
Cleiothyridina australis sp. nov.					▬		
Phricodothyris lineata Martin					▬	▬	
Chonetes kennedia var. *magna* var. nov.						▬	▬
Chonetes cf. *zimmermanni* Paeckelmann						▬	▬
Prospira sp.						▬	▬
Cleiothyridina transversa sp. nov.						▬	
Cleiothyridina sp.						▬	
Cleiothyridina biconvexa sp. nov.						▬	
Brachythyris cf. *pinguis* Sowerby						▬	▬
Spirifer cf. *liangchowensis* Chao.							▬

III. FAUNAS.

Seven faunal zones have been recognised in the Upper Palaeozoic succession. Their constituent species are listed in the range chart on page 3. The *Cyrtospirifer* and *Sulcatospirifer* zones are the earliest, occurring in upper Devonian sediments. The Tournaisian rocks contain the *Tenticospirifer*, *Chonetes* and *Schizophoria* zones, although the early part of the *Tenticospirifer* zone may be of Famennian age, and the upper part of the *Schizophoria* zone is probably of Visean age. The *Cleiothyridina* and *Spirifer* zones are of Visean age.

IV. FORMATIONS.

1. The Dee volcanics.

(*a*) *Distribution.*—The Dee volcanics, which are the oldest rocks in the succession, are most extensively exposed, and attain a thickness of approximately 2,500 feet, the greatest of all the Palaeozoic formations. They are best exposed in the northern part of the Mt. Battery, Dee and Walmul fault blocks, and particularly in the valley of the Dee River, after which they have been named. The type section of this formation extends along the railway from Ulogie to Muranu. Along their north-eastern edge these volcanics are intruded by the Mt. Morgan granite. The earliest members consist of interbedded lavas and tuffs of andesitic character. These are succeeded by coarser tuffs and agglomerates, containing limestone fragments in which corals, probably of Givetian age, have been found. Overlying them are coarser tuffs and interbedded tuffaceous mudstones. The latter rocks are not extensively developed and in many cases have been silicified. The formation terminates with coarse tuffaceous rocks.

Exposures of the earliest tuffs and lavas are found east of Cattle Creek, near the granite contact; at the junction of Horse Creek with the Dee River; in Piebald Creek (31.4 E.-51.5 N., see map), Hamilton Creek (31.1 E.-50.7 N.), and at various points along Trotter's Creek. Tuffaceous rocks containing limestone fragments occur in Cattle and Trotter's Creeks (see map). Similar rocks have been found on the eastern edge of the Mt. Morgan granite. The tuffaceous mudstones outcrop on the S.W. slopes of the Cattle Creek valley (28.5 E.-53.0 N.); in the Dee River between the junctions of Horse and Hamilton Creeks (30.0 E.-52.3 N.); and in the western end of Trotter's Creek. The main development of coarse tuffs in the upper part of the sequence is exposed on the western slopes of the Cattle Creek valley, Hamilton Creek (lower reaches), and in the mountainous regions east of Muranu and north-east of Walmul. Rocks similar to the oldest members of this formation occur in the mineralised area of Mt. Morgan, where silicified tuffaceous mudstones, altered tuffs and limestone have been recorded.

(*b*) *Lithology and Sedimentary Environment.*—The tuffs are dominantly lithic, the rock fragments consisting of andesite, with subordinate chert. Crystalline material is common, being mainly euhedral orthoclase crystals, whereas glass shards are almost entirely lacking. Secondary calcite has been found in all the specimens sectioned. The characteristic green colour of these volcanics has resulted from the extensive development of chlorite in both lavas and tuffs. The angularity of the rock fragments, together with the absence of sorting and bedding, the presence of limestone inclusions, and the occurrence of marine fossil bands indicate that the volcanic material was rapidly deposited under marine conditions, during a period when the area of deposition, except for intermittent fluctuations, was subsiding rapidly. It is probable that the source area was not far from that of deposition, and was a region of intensive vulcanicity.

(*c*) *Fauna and Correlation.*—In the limestone inclusions, indeterminate corals and crinoids have been found. Lithologically the formation is similar to the Silverwood series in the Warwick district, this series being of Lower and early Middle Devonian age. However, the Dee volcanics overlie the Struck Oil limestones in the north, which contain corals of Givetian age. The succeeding beds contain brachiopods of Frasnian age. Thus, the age of the Dee volcanics probably ranges from late Givetian to Frasnian.

2. The Thomson clastics.

(*a*) *Distribution.*—These beds, which rest conformably on the Dee volcanics, may attain a thickness of 500 feet, and are the first richly fossiliferous sediments in the Upper Palaeozoic sequence. They are best exposed in the Golden Gully, Mt. Battery and Dee fault blocks, particularly on the S.E. slopes of Mt. Battery, S.W. of Muranu on the eastern slopes of the Mt. Battery Range, and along the railway south of the junction of Boulder Creek and the Dee River. Other exposures occur in Golden Gully, Box Creek and on the eastern slopes of the mountain range which runs parallel with the Dee River south of Muranu. The type section (see A-B on map) extends from the mouth of Boulder Creek south-eastwards to the Dee volcanics north of Trotter's Creek.

(*b*) *Lithology and Sedimentary Environment.*—The sediments are variable in appearance, but are distinguishable from the underlying and overlying formations by the finer, more uniform grain size. In colour, they vary from black to green and grey, depending on the relative abundance of argillaceous and calcareous material. The rocks are marine-laid tuffs, with an average grain size from 0.1 to 0.3 mm., although grains up to 0.6 mm., as well as finer material, are present. The main constituent, orthoclase (forming from 20-40 per cent. of the rock) is usually fresh in appearance, but slightly rounded in outline. Epidote, calcite and chlorite occur in varying proportions, both as subrounded grains and as finer interstitial material. Quartz never exceeds 6 per cent., and rock fragments of chert and andesite are present in small amounts. The interstitial material, which is mainly chloritic in the earlier beds, suggests an originally argillaceous matrix. In the higher members the matrix is calcareous, consisting of finely divided calcite. There is no evidence of sorting or grading, and bedding only becomes apparent in the younger sediments. The absence of sorting suggests rapid deposition in comparatively shallow water, followed by subsidence. The increase in calcareous material and the relative decrease of the felspathic content, together with the development of bedding, suggests a slowing down of both sedimentation and subsidence.

(*c*) *Faunal Zones and Correlation.*—Two horizons have been recognised in this formation, the first being in the felspathic tuffs and containing *Cyrtospirifer reidi* and *Productella* cf. *lachrymosa,* the second in the calcareous tuffs containing only *C. reidi*. These horizons constitute the *Cyrtospirifer* zone which is of late Frasnian age, and ranges from the base of the Thomson clastics to their junction with the Boulder Creek grits. The fossils have been compared with similar species from the Dotswood and Lambie beds of Eastern Australia, and with other foreign forms.

3. The Boulder Creek grits.

(*a*) *Distribution.*—The main exposures of this formation occur in the Mt. Battery and Dee fault blocks, particularly on the western slopes of the Mt. Battery Range where the regional dip approximates the gradient of these slopes. It attains a thickness of almost 1,000 feet. The type section (see C-D on map) extends from the Mt. Battery Range south-west to Kennedy Creek. The formation is named after the largest stream which flows through the main part of its outcrop.

(*b*) *Lithology and Sedimentary Environment.*—The greater part of the formation consists of andesitic lapilli tuffs, fragments of which exceed 15 mm. in diameter. The main constituents are fragments of andesite, chert and porphyry, and grains of epidote, felspar and chlorite. The rock is unsorted, and carries little matrix. A fossiliferous band of tuffaceous mudstone is interbedded with the main tuffaceous beds. This band contains the *Sulcatospirifer* zone. The tuffaceous fraction decreases progressively towards the top of the formation, while clastics become more abundant. The youngest beds contain poorly preserved impressions of gastropods. The occurrence of marine fossils within the formation indicates marine conditions during deposition, and the lack of sorting suggests that the rates of deposition and subsidence were rapid.

(*c*) *Faunal Zones and Correlation.*—The *Sulcatospirifer* zone is defined by the upper and lower limits of the tuffaceous mudstone in which the fauna is found. *Sulcatospirifer primus* and *Camarotoechia* cf. *contracta* are the two characteristic species of this zone. They have been equated with early Famennian forms in Asia and America, and the occurrence of early Carboniferous and Frasnian formations above and below respectively, confirms this determination. A gastropod horizon occurs in the uppermost beds, but their poor preservation prevented determination.

4. The Pond argillites.

(*a*) *Distribution.*—This formation conformably overlies the Boulder Creek grits and exceeds 1,000 feet in thickness. Its sediments gradually become coarser and less tuffaceous towards the top. The Pond argillites are best exposed in the Turner Creek, Golden Gully and Mt. Battery fault blocks. Fossiliferous strata are exposed near the head-waters of Turner Creek (25.8 E.-56.4 N.), in Iron Bark Creek (24.6 E.-51.8 N.), at the Duck Pond in Boulder Creek and along the divide between Oaky and Kennedy Creeks. The formation also outcrops in the upper reaches of Stony Creek. The type section (E-F on map) passes through the Duck Pond after which the formation has been named.

(*b*) *Lithology and Sedimentary Environment.*—The lowest beds in the formation contain the *Tenticospirifer* fauna, and are felspathic silt-stones possibly derived from a redistributed marine tuff. The fine-grained matrix, which is the dominant feature of the rock, contains calcite, felspar, quartz and clay minerals. Small subangular grains of quartz, felspar and calcite and rarer fragments of lava are set in this matrix. The younger sediments show a gradual increase in grain size, and those containing the *Chonetes* zone are quartzose argillites with an average grain size of approximately 0.7 mm. The grains are equant, only the felspars tending to become elongate. They vary in outline from subangular to subrounded. Quartz constitutes 30-40 per cent. of the rock, plagioclase and rock fragments being present in smaller amounts. Some orthoclase and epidote are present, and calcite occurs as crystalline aggregates (probably derived from shell detritus), and as finer material disseminated throughout the matrix. The interstitial material is chloritic and calcitic, indicating an originally argillaceous-calcareous mud. Bedding is weakly developed in these sediments, and there are slight indications of sorting.

The calcareous-felspathic siltstones found in the lowest beds of this formation are characteristic of a mildly unstable shelf region, the source area of the sediments varying from stable to mildly epeirogenic. The uppermost quartzose argillites indicate somewhat similar conditions. Their composition suggests that they were derived by the redistribution of tuffaceous material in a shallow, slowly subsiding region. The reworking of the tuff was not sufficient to eliminate the felspars, nor to produce any high degree of rounding. This, together with the weakly developed bedding and sorting, and the small amount of matrix, suggests a slowly subsiding environment of deposition, similar to that found in the later stages of a geosyncline.

(*c*) *Faunal Zones and Correlation.*—Three faunas are present in the Pond argillites. In the early calcareous-felspathic siltstones, the *Tenticospirifer* zone occurs. The age of this zone is suggested as early Tournaisian, although the presence of genera characteristic of the Upper Devonian faunas of China suggests that the early part of this zone may be of late Famennian age. It extends from the base of the Pond argillites to the base of the *Avonia* horizon. The thickness of sediments deposited in this zone is approximately 150 feet.

The *Avonia* horizon is the basal unit of the Chonetes zone. Species of early Tournaisian age occur in this horizon, and 70 feet above, the *Chonetes-Brachythyris* assemblage is found in quartzose argillites. This assemblage characterises the upper part of the *Chonetes* zone and extends to the base of the Neil's Creek clastics. The complete faunal list of this zone is given in Table 2. The *Tenticospirifer* fauna has many late Devonian affinities, and may be regarded as transitional in many respects. Its early Carboniferous characters would suggest that the *Tenticospirifer* zone is partly equivalent to the K zone of the British sequence. The *Chonetes* zone is correlated with the later part of the K zone and the early part of the Z zone.

5. The Neil's Creek clastics.

(*a*) *Distribution.*—This is the largest formation in the Carboniferous sequence, with a thickness of 2,000 feet. It follows the Pond argillites conformably, and is best exposed in the Stony Creek and Turner Creek fault blocks. Fossiliferous horizons outcrop frequently in the Golden Gully-Harry Gully section, in Duck Pond Creek and in Stony Creek and its tributaries. The type section is exposed in Neil's Creek and on the western slopes of the Stony Creek valley (see section G-H on map).

(*b*) *Lithology and Sedimentary Environment.*—The lithology is variable, but is generally strongly felspathic. The sediments are well graded, the greater part consisting of alternating bands of subgraywacke and chert. Interbedded with these are bands of calcareous sediments, limestones and occasional grits. The base of the formation is defined by a limestone which is exposed for several miles in the northern region. It is almost purely calcareous, bedded and poorly fossiliferous. Fine cloudy mosaics of calcite form the matrix, enclosing larger crystals of calcite, many of which are of secondary origin, having formed by crystallisation around crinoidal detritus. The purity of this poorly fossiliferous limestone may have resulted from the precipitation of carbonate derived from the overlying fossiliferous beds which are now partly decalcified. The environmental significance of this limestone is difficult to evaluate. One might infer that its deposition occurred during an interval when clastic sedimentation was at a minimum, possibly during a temporary rise of sea-level.

The fine-grained argillaceous rocks succeeding this limestone are composed of quartz, felspar and lava fragments, set in a cryptocrystalline matrix, which constitutes the principal part of the rock. Calcite, partly of secondary origin, occurs both as grains and as part of the matrix. The rock is a calcareous argillite. These sediments merge into argillaceous limestones and calcareous argillites which contain the *Schizophoria* fauna. They grade imperceptibly into the main development of chert and subgraywacke so characteristic of this formation. These alternating bands vary in thickness from a few millimetres to several centimetres. The chert consists of a cryptocrystalline matrix, enclosing minute grains of quartz and felspar arranged in fine laminae. The bounding surfaces of the chert and subgraywacke are sharply defined. Graded bedding occurs in the subgraywacke, the coarser varieties of which have an increased felspathic fraction, whereas the finer ones are more quartzose. This rock differs from the Neranleigh graywacke in its finer grain size, paucity of argillaceous material and its higher arenaceous fraction. The tectonic implication of this rock is one of mildly unstable source and depositional areas, such as are found on the margins of shelf regions, or in the later phases of a geosyncline, prior to uplift.

Limestones are again developed towards the top of the sequence. One oolitic limestone in particular has a considerable areal extent; it is several feet thick and contains a high proportion of crinoidal debris. Its occurrence suggests the stabilising of this region of sedimentation, since oolitic limestones are characteristic of shelf environments. Subgraywacke and chert occur above this bed, but higher in the sequence the carbonate fraction increases, and another limestone composed of organic detritus (crinoidal, molluscan, brachiopodan and coralline) occurs. Small quantities of argillaceous material are also present. These beds contain the *Cleiothyridina* fauna, of Visean age. The *Spirifer* horizon occurs 350 feet higher in the sequence, in an argillcaeous limestone, which marks the base of the *Spirifer* zone. This limestone is well bedded and low in felspathic content. Calcareous grits and sandstones (slightly felspathic) terminate this formation, and the Turner Creek conglomerate follows without apparent angular discordance.

Consideration of the progressive change in the composition of these sediments indicates the importance of this formation in the interpretation of the tectonics of the region. The marked decrease in the vulcanicity which had been prevalent in earlier times is reflected in the decline of the felspathic fraction and the increase in the carbonate and normal clastic content. Pure quartzose sandstones are not developed, but the sedimentary environment would appear to have approached conditions found on mildly unstable shelf margins. Rapid and intermittent subsidence seems to have terminated after the deposition of the subgraywacke and chert.

(c) *Faunal Zones and Correlation.*—The *Schizophoria* zone, characterised by a fauna of Upper Tournaisian age, extends from the base of the formation to the oolitic limestone. The richly fossiliferous part of the zone extends through a thickness of 70 to 100 feet, in the calcareous argillites above the first limestone. The generic constitution of its fauna is characteristic of the Upper Tournaisian faunas of most countries, viz.—*Leptaena, Avonia, Schizophoria, Syringothyris, Brachythyris, Phricodothyris* and *Cleiothyridina*.

The fauna of the succeeding *Cleiothyridina* zone has strong early Visean affinities. It occurs in the sediments extending from the oolitic limestone to the base of the *Spirifer* horizon. This fauna is not rich in brachiopods, the most abundant fossils being crinoids (columnals), gastropods and polyzoans.

The youngest fauna is found in the *Spirifer* zone, so named because of the occurrence of *S.* cf. *liangchowensis*. This zone extends to the base of the Turner Creek conglomerate. The youngest strata in this zone have not been well exposed and consequently little is known about them. Limestones containing shell and crinoidal detritus occur, but due to the paucity of exposures, fossil collections are difficult to obtain. Their stratigraphical position, however, favours correlation with the Lion Creek limestone of the Stanwell district, the age of which has been determined as upper Visean (possibly D_2).

Some of the faunas of this formation have their equivalents in other parts of Australia. The *Schizophoria* fauna has been recognised in the Fairy Bower beds near Rockhampton, in the sediments of Cania, and to a lesser extent in the Hilldale and Clarencetown beds in New South Wales. However, the faunas of New South Wales and Queensland have few genera and species in common. In the Mundubbera district, an impoverished *Cleiothyridina* fauna occurs, and has been equated with that of the Neil's Creek clastics.

6. The Turner Creek conglomerate.

(a) *Distribution.*—The most extensive outcrops are in the Stony Creek fault block, the best occurring in Turner Creek and Neil's Creek (25.1 E.-58.3 N. and 24.1 E.-59.2 N.). There is no angular discordance between this and the preceding formation.

(b) *Lithology and Sedimentary Environment.*—The conglomerate shows marked variation in thickness as it is traced southwards. Its main components are igneous—dioritic and poprhyritic boulders, together with fragments of chert, all of which are well rounded. Lack of sorting and grading is evident. The large unsorted boulders, together with the great thickness of the deposit might suggest glacial origin, but the absence of faceted and striated boulders does not support this interpretation. The great thickness and the massive rounded fragments indicate important movements at the close of Lower Carboniferous times. Although concordant with the Neil's Creek clastics, the characters of the conglomerate suggest uplift of both the marine basin and the surrounding highlands, such uplift being of an epeirogenic rather than of an orogenic nature.

(c) *Correlation.*—Its stratigraphic position and lithological characters suggest that this formation is equivalent to the basal conglomerate of the Middle Carboniferous Neerkol beds of the Stanwell district.

7. Middle Carboniferous Shales and later Formations.

These beds outcrop on the western margin of the area and their contact with the earlier formations has been found only at one locality. Unfortunately their true relation here has been marred by faulting. They have been equated with the Neerkol beds on the basis of their lithological similarity, the presence of polyzoan remains, and their stratigraphical position. The Neerkol brachiopod assemblage has not been found. West of the area investigated, freshwater mudstones followed by volcanics have been found. This sequence is similar to that of Stanwell, where the Dinner Creek freshwater beds and the lower Permian volcanics are found.

V. AN INTERPRETATION OF THE SEDIMENTARY ENVIRONMENTS.

The tectonic factors controlling sedimentation in this region are reflected in the various components of these Upper Palaeozoic formations. The sequence began with a phase of intensive vulcanicity during which the Dee volcanics were deposited under marine conditions, in what seems to have been a rapidly subsiding trough. During a period of lesser volcanic activity and slower subsidence, the Thomson clastics were formed, and prolific marine life developed. This interlude was followed by renewed vulcanicity, during which the Boulder Creek grits were rapidly deposited and buried and, except for the quiescent phase when the fossiliferous *Sulcatospirifer* beds were formed, this activity continued with gradually decreasing intensity until the Pond argillites were deposited. The latter sediments, which are less felspathic and weakly bedded and sorted, suggest an almost complete lack of active volcanism, the sediments being derived by normal processes of erosion on a tuffaceous terrain. Their deposition would appear to have occurred in a slowly subsiding region where a minor degree of reworking was possible. The continued decline of felspathic material and the corresponding increase in carbonates and marine fossils is even more apparent in the Neil's Creek clastics. Alternations of chert and subgraywacke indicate that although the volcanic activity of the source area had almost ceased, movements in both source and site were still frequent. The occurrence of oolitic limestone, so characteristic of stable shelf conditions, suggests that even these movements had diminished after the deposition of the subgraywacke and chert. However, movements of considerable magnitude must have been responsible for the formation of the Turner Creek conglomerate. Although angular discordance was not produced between it and the earlier formations, marked changes in the topography of land and depositional area must have resulted. A quiet phase of sedimentation succeeded this movement, during which the Middle Carboniferous shales were deposited, and the environment gradually changed to one of freshwater when the later sediments were deposited. Finally, vulcanicity once again became dominant.

Thus, in summary, there was firstly a rapidly subsiding trough into which large quantities of volcanic material were being deposited. During short periods of quiescence normal clastic sediments formed and the rate of subsidence decreased. The initial intensity of the vulcanicity declined, and still more clastics were deposited while the rate of subsidence of the trough fluctuated considerably. Later, a temporary stability was achieved and carbonate and clastic sediments accumulated. This phase was followed by movement of an epeirogenic nature, and great thicknesses of conglomerate formed. As this movement subsided, marine conditions were gradually replaced by a freshwater environment, and finally another phase of vulcanicity began. Thus the early characters of this trough are geosynclinal, but as sedimentation progressed, a "semi-shelf environment" developed which was destroyed finally by uplift and vulcanicity. Such a history suggests that the region of deposition was an idiogeosyncline or an intramontane basin.

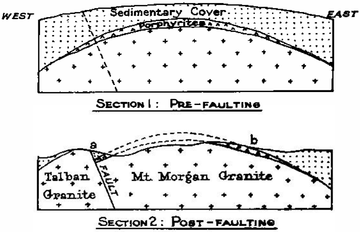
STRUCTURE

I. INTRODUCTION.

The structure of the Mt. Morgan district may be summarised as follows: A long narrow granite batholith, the Mt. Morgan granite, is exposed along the axial part of a slightly arched development of Upper Palaeozoic sediments. The general grain of the sediments is N.N.W., those to the west of the granite dipping very gently westwards. The whole region has been affected by normal faulting movements, firstly by fractures trending N.W., and then by a N.N.E. system, the latter producing fault blocks which were downthrown towards the north-west. Thus the beds appear to have been stepped north-eastwards, due to the combined effects of faulting and erosion. Associated with both phases of movement were periods of hypabyssal activity, during which dolerite and andesitic dykes were injected along planes parallel to those of the faults. Mesozoic sediments rest unconformably on the Palaeozoic sediments and the granite. The salient structural features are the fault blocks which resulted from the N.N.E. fracturing. The various structural units will be considered in the following sequence:—Granites, diorites and porphyrites; N.W. fault system; N.N.E. fault system; Hypabyssal intrusives.

II. THE GRANITES, DIORITES AND PORPHYRITES.

The Mt. Morgan granite, an elongate batholith trending concordantly with the grain of the Upper Palaeozoic sediments, extends for more than fifteen miles in a N.N.W. direction, but is less than three miles in width. In the south it intrudes sediments of late Middle Devonian and early Upper Devonian age. Its relation to the Lower Carboniferous sediments further north has not been established. Two smaller granites—the Talban and the Moonmera—are separated from the main batholith by " corridors " of porphyrite and altered sediments, while a third igneous mass with aplitic affinities occurs in Oaky Creek where it intrudes Lower Carboniferous sediments. Small intrusions of a similar nature intrude these sediments in Stony Creek. Around the margins of the granites, particularly where they have intruded the pyroclastic rocks of Devonian age, large developments of porphyrite are found. Petrologically, this porphyritic rock varies from quartz porphyry to felspar porphyrites. This variation and their mode of occurrence suggest that they belong to that group of rocks originally described by Gumbel (1874) as Keratophyres. In some localities dioritic rocks are found along the granite margin, particularly where the granite has intruded the more calcareous sediments in the north-east and south-west.



The Talban and Moonmera granites appear to have been faulted off the main batholith, from which they are now separated by belts of porphyrite and altered sediments. The Talban granite has been uplifted relative to the Mt. Morgan granite, along a normal fault of the N.W. system. Evidence of this faulting along its eastern margin is quite strong, and the Hamilton zone of disturbance which trends N.W. occurs not far from its western margin. The structural relation of this granite " block " to the batholith is illustrated diagrammatically in fig. 1. The interaction of the two main fault systems has produced an embayment in its eastern margin, into which the sediments of the Mt. Morgan mine area were dropped, and later mineralised by the hypabyssal activity which accompanied and succeeded the movement. Similar faulting has separated the Moonmera granite further north.

III. THE NORTH-WEST FAULT SYSTEM.

This system is best revealed in the mineralised region of Mt. Morgan, where numerous small dykes have been displaced by it. The presence of a zone of disturbance trending north-westwards from the lower reaches of Hamilton Creek to the north-east of Mt. Victoria is indicated by widespread brecciation, variations in strike and discontinuity of beds. The exact nature of this zone has not been determined, but it appears to have been associated with subsidence during the periods of faulting. The hypabyssal intrusions associated with this system are numerous, being in the main doleritic dykes which trend in the same direction as the faults. The effect of this first movement does not appear to have been as severe as that of later movements.

IV. THE NORTH-NORTH-EAST FAULT SYSTEM.

This system probably originated at the same time as the previous one, but movement along its fault planes continued after the earlier activity had ceased. Five major faults have been recognised—Stony Creek, Harry Gully, Mt. Battery, Muranu and Trotter's Creek faults. Subsidiary movements have occurred along smaller fault planes within the main blocks. The overall effect has been the progressively increased subsidence of the blocks towards the north, the Stony Creek fault block having dropped more than 3,000 feet in relation to the Mt. Battery block.

1. The Stony Creek Fault Block.

The north-western limit of this block is determined by another normal fault outside the area described in this paper. In the north-east and east its relation with the Mt. Morgan granite is obscured by Mesozoic sediments. The Middle Carboniferous shales, Turner Creek conglomerate, Neil's Creek clastics and the upper part of the Pond argillites are found in this block, the regional strike of these sediments being 330°, the dip varying from 10° to 30° S.W. (but averaging 17° S.W. in the greater part of the block). Small granitic intrusions similar to that in Oaky Creek are found intruding sediments of Carboniferous age in Stony Creek. The Stony Creek fault along the S.E. edge of the block has been a zone of severe disturbance, the relative vertical displacement of the blocks on either side of the fault being considerable.

2. The Turner Creek Fault Block.

The Neil's Creek clastics and Pond argillites occur in this unit. Large exposures of Mesozoic sediments obscure the earlier formations and the granite contacts. The regional strike approximates 355°, the dip 10° W., thus indicating a slight divergence from the attitude of the sediments in the northern block. Along the south-eastern margin is the Harry Gully fault.

3. The Golden Gully Fault Block.

The sequence here contains the early part of the Neil's Creek clastics, the Pond argillites, Boulder Creek grits and Thomson clastics, the regional strike being 345°, the dip being 12-15° S.W. The Iron Bark Creek fault has disturbed the beds within this block, but displacement has not been great. Hypabyssal activity has resulted in the intrusion of numerous dolerite dykes, all trending N.W. Andesitic dykes trending N.E. are less numerous.

4. The Mt. Battery Fault Block.

This is defined by the Mt. Battery fault in the north and the Muranu fault in the south. The sequence extends from the lower part of the Dee volcanics into the Pond argillites. The Hamilton zone of disturbance trends north-westwards across this block, just south of Cattle Creek. This has been a region of severe disturbance and fracturing, probably associated with the uplift of the Talban granite. The regional strike of the sediments to the south of the Hamilton zone is 335°, and to the north it is 330°, this variation being due to the greater degree of uplift in the northern part of the Talban granite. The regional dip is 15° S.W., but this increases in the north. Dolerite dykes trending N.W. are abundant, and in the Oaky Creek region the aplitic granite mass is exposed.

5. The Dee Fault Block.

The Boulder Creek grits, Thomson clastics and Dee volcanics are exposed in this block. The Hamilton zone of disturbance is the main structural feature; the variations in strike and dip about this zone indicate that the movement associated with the Muranu fracturing resulted in the tilting of the block towards the north-west, this tilting being terminated at the Hamilton zone and reversed to the north of it, *i.e.*, tilted towards the south-west. In effect, the Hamilton zone appears to be a region of subsidence, caused by the upward movement of the extremities of the Dee fault block. In the south, the regional strike is 35°, and the dip 5° N.W., while in the north the strike approximates the regional grain of the whole area, viz., 330°. Only a small degree of tilting would be necessary to effect this large difference in the strikes of gently dipping beds. The Muranu fault extends north-eastwards through the mouth of Horse Creek and has been responsible for the truncation of the southern part of the Talban granite, which it separates from the porphyrites to the south of Horse Creek. Movement along the N.W. fractures in the northern part of the Dee block has prevented the effects of the N.N.E. dislocations in the granite from being as apparent as they are further south. Dolerite dykes are numerous, and in most cases they have been displaced by N.N.E. faults.

6. The Walmul Fault Block.

Separated from the Dee block by the Trotter's Creek fault, this is the most southerly unit of the area investigated. It is composed almost entirely of Dee volcanics. The Trotter's Creek fault zone has been a region of very severe disturbance. Minor fracturing within the Walmul fault block has introduced further complexities and a clear understanding of its structure is not yet possible.

V. THE HYPABYSSAL INTRUSIVES.

The most common dykes are dolerites, and except in the Dee fault block, they follow a constant N.W. trend. They appear to be associated with the N.W. system of faults, having been displaced by later movements along the N.N.E. fault planes. The dykes intrude all the Palaeozoic formations, but are never found in the Mesozoic sediments. They are particularly abundant in the mineralised area of Mt. Morgan, where the effects of the N.N.E. faulting are clearly reflected in their displacements. In the Stanwell area, similar dykes intrude the Middle Carboniferous sediments. Andesitic dykes, trending N.N.E. also intrude the Palaeozoic formations. These are most abundant in the Boulder Creek-Iron Bark Creek section.

VI. STRUCTURAL DEVELOPMENT OF THE LATE PALAEOZOIC FORMATIONS.

Towards the end of the Palaeozoic era, the sediments of the Mt. Morgan area were gently domed and subjected to igneous activity—firstly the keratophyres, then the main granitic batholith, and finally the hypabyssal dykes were intruded. Faulting associated with the final phase of hypabyssal activity was of the normal type, possibly resulting from the " post-granite " settling of the area. The two fault systems may have originated simultaneously, but movements along the N.N.E. planes persisted, and their influence on the structural history of the area was most marked. The degree of subsidence of the blocks increased progressively towards the north, and it was in the basin so formed that the Mesozoic sedimentation occurred.

The effect of the interaction of the two fault systems is seen in the mineralised area, where a segment of keratophyre and sediments subsided in an embayment in the Talban granite margin. When the surface cover of the granites had been completely eroded, this segment remained. It was the site of intense hypabyssal activity as well as severe normal faulting, the whole area now presenting an intricate complex of dykes and faults. The age and nature of the mineralisation of this region has not been thoroughly investigated, but it seems highly probable that the hypabyssal intrusives, which are so closely related to the hydrothermal and pneumatolytic phases of granitic activity, may have played a major role.

VII. REGIONAL TECTONICS—SOME OBSERVATIONS.

1. *The Yarrol Basin.*—The Mt. Morgan-Rockhampton district occupies the northern end of the Yarrol basin, which is bounded on the west by the Gogango High and on the east by the South Coast High. These terms were introduced by Hill (1951, p. 18), who also described the Yarrol basin as a long intramontane marine basin, originating at the beginning of Upper Middle Devonian times.

The early tectonic history of this region is reflected in the bounding highs, which consist of metamorphosed rocks intruded by large granitic masses. The elongate trough between the two highs contains the sedimentary formations ranging in age from late Middle Devonian to Permian. These deposits show a diversity of lithologies, grading from andesitic lavas and tuffs in the early beds to chert, subgraywacke, shales, grits, sandstones and limestones in the younger formations. In the southern part of the basin the beds have been steeply folded, while further north in the Mt. Morgan district there is no evidence of folding, the beds dipping gently to the south-west. Although the nature of the margins of the basin has not been determined, Hill (1951, p. 18) regards present evidence as suggestive of an overthrust in the west. Serpentine has been intruded along the eastern margin, between the sediments of the basin and Lower Devonian limestone of the high.

2. *Anomalies in the north.*—The lithological sequences in the north are somewhat similar to those further south, with perhaps a greater proportion of tuffaceous material in the former. The trough narrows considerably and there is no evidence of folding in this region. The whole sequence, which is gently domed, has been intruded by a narrow batholith concordant with the N.N.W. grain of the sediments. The intrusion of N.W. trending dolerite dykes, the normal N.W. faulting and the later N.N.E. faulting which resulted in the downthrow of blocks towards the Stanwell region, are features which are not in harmony with the general character of the basin further south.

3. *Comparison of Yarrol Structures with Similar Features Elsewhere.*—The diversity of facies, the abundance of eruptive rocks and the variable response of the different parts of the basin to compressive forces are features which are characteristic of many of the intramontane troughs of the European Variscides (Umbgrove, 1948), and the East Indian troughs (van Bemmelen, 1949). The elongate structure of the Yarrol basin is also typical of such troughs. The occurrence of serpentine along the eastern margin of the basin, in association with early Devonian limestones of the South Coast High, might suggest that this intrusion belonged to the earlier phase of orogeny which terminated with the Lower Middle Devonian. In the north the gentle warping of the Upper Palaeozoic beds, the injection of a long narrow batholith, the prolific development of volcanic rocks, and the narrow width of the trough are features frequently associated with block faulting and rift valleys.

4. *Possible Causes of Anomalies.*—During late or post-Permian times the areas of marine sedimentation along eastern Australia suffered orogenic disturbances resulting in their uplift and, in most cases, folding and thrusting. This movement has been interpreted by various authors as one of compression, the compressive forces acting from the east. The evidence of thrusting has been described from the northern apex of the Bowen basin, and from several regions in New South Wales, while the beds in the southern part of the Yarrol basin are steeply folded. It is remarkable, then, that no evidence of this compressive phase is revealed in the northern region. In fact, tensional forces might be suggested by the normal faulting, gentle dips, axial granite, vulcanicity and, in the Mt. Morgan area, the absence of ultrabasic rocks. It is possible that some structural factor might have shielded the region from the normal deforming stresses, and since certain features characteristic of rift valleys and graben are found in the area, the possibility of rifting cannot be overlooked. If such were the case, then the tangential stresses may have been dissipated by vertical adjustments of the graben, these adjustments being accompanied by volcanic activity.

It is suggested that the Yarrol basin may represent a trough formed by the axial collapse of the Gogango-South Coast Geanticline in early Devonian times. This collapse was effected by rifting in the north and by normal subsidence in the south, these differences in origin being responsible for differences in their subsequent reaction to the compressive forces of the Permian.

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