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# RECONNAISSANCE GEOLOGY OF THE SURAT BASIN QUEENSLAND AND NEW SOUTH WALES

BY

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UNION OIL DEVELOPMENT CORPORATION

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# FOREWORD

The geological surveys here reported were not subsidized under the Petroleum Search Subsidy Acts. As the data, nomenclature and interpretations presented in this report form an essential reference to the many reports on subsidized geophysical and drilling operations, Union Oil Development Corporation, on behalf of Union Oil Company of California, Kern County Land Company and Australian Oil and Gas Corporation Limited, offered the report for publication. This offer was accepted and the report included in the P.S.S.A. Publications series because of its direct relevance to the companies' subsidized operations.

J. M. RAYNER
DIRECTOR

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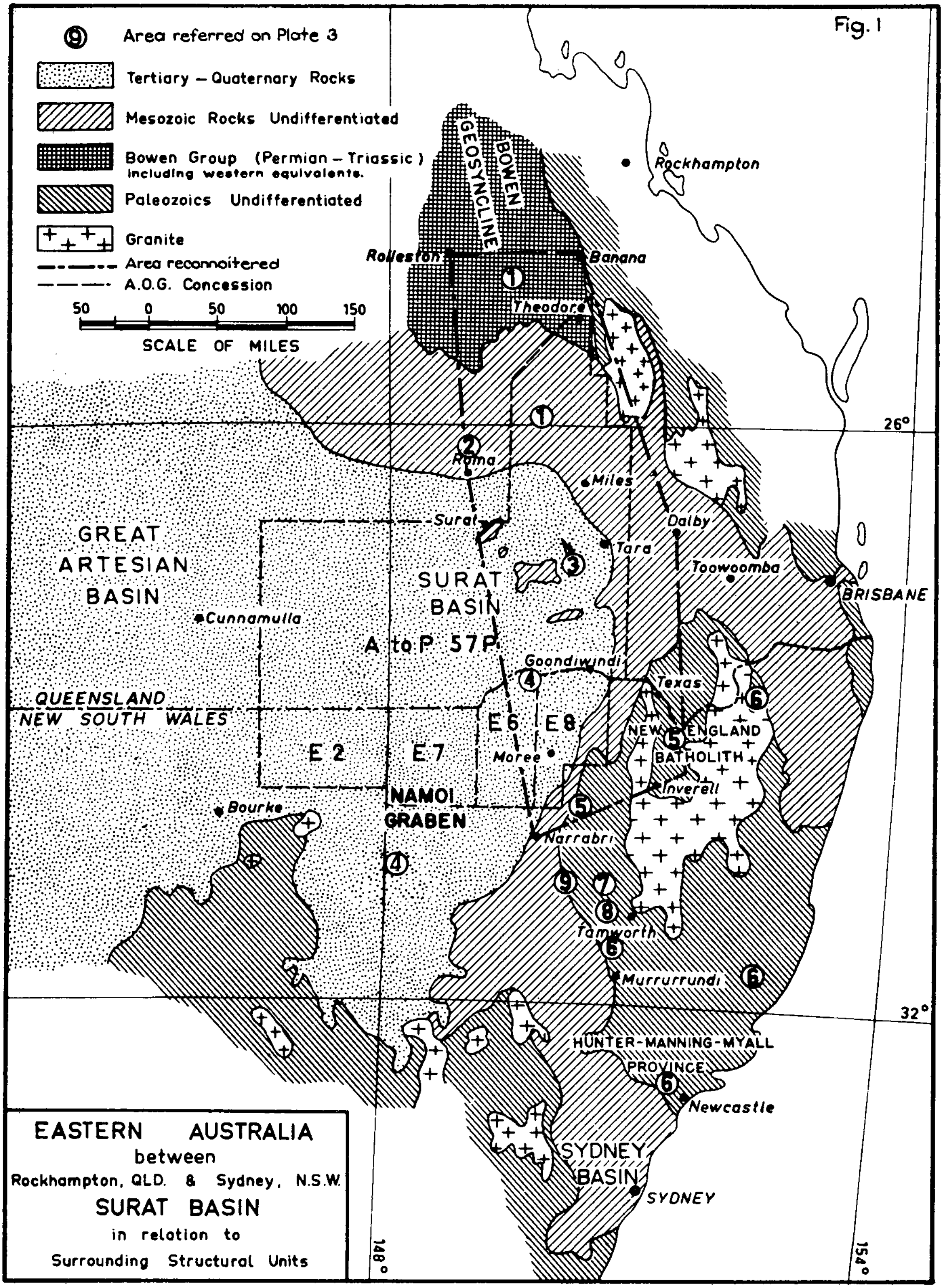
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9 Area referred on Plate 3
Tertiary – Quaternary Rocks
Mesozoic Rocks Undifferentiated
Bowen Group (Permian – Triassic) including western equivalents.
Paleozoics Undifferentiated
Granite
Area reconnoitered
A.O.G. Concession
50 0 50 100 150
SCALE OF MILES
BOWEN GEOSYNCLINE
Rockhampton
Rolleston
Banana
Theodore
26°
Roma
Miles
Surat
Dalby
Tara
Toowoomba
BRISBANE
GREAT ARTESIAN BASIN
SURAT BASIN
Cunnamulla
A to P 57P
Goondiwindi
Texas
QUEENSLAND
NEW SOUTH WALES
E6
E8
E2
E7
Moree
NEW ENGLAND BATHOLITH
Inverell
NAMOI GRABEN
Bourke
Narrabri
Tamworth
Murrurundi
32°
HUNTER-MANNING-MYALL PROVINCE
Newcastle
SYDNEY BASIN
SYDNEY
148°
154°
EASTERN AUSTRALIA
between
Rockhampton, QLD. & Sydney, N.S.W.
SURAT BASIN
in relation to
Surrounding Structural Units

## INTRODUCTION

In late 1959, Union Oil Development Corporation, a wholly owned subsidiary of Union Oil Company of California, and the Kern County Land Company, also of California, entered into an agreement with Australian Oil and Gas Corporation Limited to conduct an exploration programme on lands of Authority to Prospect 57P, Queensland, and Petroleum Exploration Licences E2, E6, E7, and E8, New South Wales. As part of the programme, surface geological studies were made of the concessions and adjoining areas. This report is concerned primarily with this aspect of the exploration.

The surface reconnaissance was carried out intermittently from November, 1960 to October, 1961. The area reconnoitred, approximately 40,000 square miles, is bounded roughly by the towns of Rolleston and Banana in Queensland and Narrabri and Inverell in New South Wales (Fig. 1). The region is accessible by several major paved highways and a connecting network of dirt roads and stock trails. Department of the Army 1:250,000 sheets were used as a base map for the work; planimetric control was by car odometer and elevation control, where required, by aneroid barometer. Field samples, both lithologic and palaeontologic, are indexed on the geological maps and are stored at the offices of Union Oil Development Corporation, Toowoomba, Queensland.

## REGIONAL SETTING

Within the region reconnoitred, the geological record clearly marks major differences in the stratigraphy, related to three distinct structural units; from oldest to youngest, the Tasman Geosyncline, the Bowen Basin, and the Great Artesian Basin. The Tasman Geosyncline was the focus of marine deposition in eastern Australia from the end of Ordovician to the end of Carboniferous time. During early Permian time, this geosyncline was broken up and, in New South Wales, stabilized as a positive element by intrusion of the New England Batholith. As compensation for intrusion of the batholith, a large block was downdropped west of it to form the Namoi Graben.

The Bowen Basin is a major miogeosynclinal downwarp which culminated in early Triassic time. The southern margin of this basin is within the northern end of the Namoi Graben. Downwarp of the miogeosyncline was buttressed by the New England Batholith on the south-east. Granitic intrusions, such as the Auburn Complex, were intruded along the easterly mobile front of the geosyncline during its evolution. A relatively stable shelf, in the Roma-Springsure district of Queensland, bordered the actively downwarping geosyncline on the west.

The Great Artesian Basin is a vast Mesozoic downwarp which had its inception in late Triassic time. An eastern lobe of the Great Artesian Basin, the Surat Basin, overlaps the southern end of the Bowen Basin.

## STRATIGRAPHY

The oldest rocks mapped in this survey are marine clastics of questionable Silurian/Lower Devonian age which have been subjected to low-grade metamorphism. Apart from these rocks, three major phases of sedimentation have been recognized, one related to the development of the Tasman Geosyncline during late Devonian to early Permian time, one to the development of the Bowen Basin, and the other to the development of the Great Artesian

Basin. The Upper Devonian/Lower Permian rocks of the Tasman Geosyncline are included within the Horton Group and subdivided into two formations. Three formations are recognized in the Permian/Lower Triassic Bowen Group on the eastern flank of the Bowen Basin. On the western flank of the Bowen Basin additional rock units have been defined in the Lower Triassic sediments. These formations tongue out eastward and are equivalent to the Triassic rocks of the Bowen Group (Pl. 3). Within Queensland sedimentary rocks of the Great Artesian Group are subdivided into four formations which range in age from late Triassic to early Cretaceous. South of the Darling-Brisbane Shear Zone, in New South Wales, these four units were not recognized, and only one formation was mapped in the Great Artesian Group.

The Horton Group consists of an intertonguing sequence of shallow marine tuffaceous clastics and continental tuffaceous clastics, volcanic conglomerates, lava flows, and tuffs. The Permian rocks of the Bowen Group grade upward from shallow marine tuffaceous clastics to non-marine tuffaceous clastics and coal. The Triassic rocks of this group are tuffaceous, coarse clastic, fill deposits which probably give way to variegated shales along the southern margin of the Bowen Basin. A period of base level was reached in the Bowen Basin within Triassic time. This period marked the end of Bowen sedimentation and set the stage for the deposition of the Great Artesian rocks. Rocks of the Great Artesian Group are predominantly continental clastics deposited in shallow inland seas and swamps. At the top of the group a marine transgression is represented by rocks of the Roma Formation.

On the south-east margin of the Surat Basin, a Permian granite pluton, the New England Batholith, intrudes rocks of the Horton Group and is onlapped by rocks of the Great Artesian Group. Permian (?) volcanics, the Scrubhut Volcanics, overlie a spur of this batholith. On the eastern flank of the Bowen Basin, a Triassic granite intrusive, the Auburn Complex, intrudes volcanics which underlie the Bowen Group and is onlapped by rocks of the Great Artesian Group. North of the Darling-Brisbane Shear Zone, lateritized Tertiary clastics rest unconformably on the Great Artesian rocks. Tongues of Tertiary basalt cap the older rocks in the south-east and crop out locally in the north.

## Questionable Silurian/Lower Devonian rocks

Rocks of questionable Silurian/early Devonian age crop out in the vicinity and north of the Warwick-Inglewood Highway. These rocks consist of siliceous argillite, chert, slate, phyllite, and minor quartzite. Originally they were tuffaceous, argillaceous, marine clastics with some interbedded acidic tuffs. At Cement Mills, south of Gore, a lens of massive light grey to blue-grey, fine crystalline limestone was mapped within this sequence; and north of Mount Bodumba along Mosquito Creek, an andesite flow is interbedded in the sequence.

The age of these rocks is based on meagre palaeontological data and tenuous lithological correlations. A coral specimen, reportedly collected from the limestone at Cement Mills and since lost, was identified as *Heliolites* sp. (Ordovician-Devonian) (Hill et al., 1960, p. 140). On the basis of lithological similarity, previous workers have correlated the Neranleigh-Fernvale group of the Brisbane area with these rocks. This group 'may be Silurian' and is considered so on evidence 'other than palaeontologic' (Hill et al., 1960, p. 116, 137). Also because of lithological similarity various workers have correlated radiolarian jasper cropping out at Bald Hills, north of Gore, with jasper in the upper part of the Neranleigh-Fernvale group and with the Bald Mountain Jaspers of the Silverwood district, south of Warwick. The Bald Mountain Jaspers have been placed in the Lower Devonian since they underlie the Middle Devonian Silverwood series (Richards & Bryan, 1928, p. 290).

The only marked lithological difference between the questionable Silurian/Lower Devonian rocks and rocks of the Bangheet Formation exposed immediately to the south is the degree of metamorphism: the older rocks have a phyllitic aspect not common to the Bangheet, which suggests a greater degree of deformation. If the increased metamorphism is due solely to the position of the rocks in the Darling - Brisbane Shear Zone, they could well be considered as part of the Bangheet Formation; but it is also possible that they were involved in an orogeny before the Bangheet Formation was laid down.

## Horton Group

The Horton Group is used in the present report for an intertonguing sequence of marine and terrestrial sediments which range in age from Devonian to early Permian and are well exposed in the drainage basin of the Horton River of north-eastern New South Wales, Australia. The group is subdivided into marine and terrestrial rocks, the Bangheet and Kuttung Formations respectively. A representative section of the group can be seen along the road from Bingara to Narrabri, New South Wales, where approximately 18,000 feet of the Bangheet and 12,000 feet of the Kuttung Formation are exposed in a series of large, meridional trending, parallel folds (Pl. 6).

Benson (1913), in a study of the rocks in the Barraba-Tamworth district of New South Wales, subdivided the Carboniferous sequence into a marine 'Burindi Series' and an overlying, terrestrial 'Rocky Creek Conglomerate'. He described the Burindi as mudstones with bands of andesitic tuff, occasional coarse breccias, and locally thin bands of crinoidal and oolitic limestone. The Rocky Creek Conglomerate he defined as conglomerates and tuffaceous sandstones with interbedded rhyolite, trachyte, and andesite tuffs and flows. Sussmilch and David (1919) retained Benson's 'Burindi Series' for the marine Carboniferous rocks of the Hunter River district of New South Wales but proposed the name 'Kuttung Series' for the overlying terrestrial rocks. Osborne (1922) established the Paterson-Clarencetown district of New South Wales as type area for the 'Kuttung Series'. Carey and Browne (1938, p.591-594) demonstrated that the upper part of the 'Burindi Series' was equivalent to the lower part of the 'Kuttung Series' and also noted that Benson's Rocky Creek Conglomerate in the type area was 'Upper Kuttung'. Subsequent workers have used the terms 'Kuttung' and 'Burindi' both in the sense of rock units and of time-rock units. In the present report, the Kuttung is considered as a rock unit. Normally, the author would have used the name 'Burindi' as a rock unit encompassing the marine rocks of the Horton Group as he considers these rocks the lithological correlative of the Burindi in the type area. However, the Stratigraphic Nomenclature Committee of New South Wales, although they recognize the Kuttung as a rock unit, have indicated that they are reserving the name 'Burindi' as a time-rock unit. To avoid complications in nomenclature, the name Bangheet Formation is applied to the marine rocks of the Horton Group (Pl. 3). The name is after the Bangheet photo survey area, No. 8-280, of the Central Mapping Authority, New South Wales Department of Lands, within which these rocks are well exposed.

### Bangheet Formation:

In the Warialda-Narrabri district, the Bangheet Formation consists of tuffaceous, partly calcareous, well indurated claystone, siltstone, sandstone, and minor oolitic limestone (Pl. 4). The claystone and siltstone are blue-grey to dark olive-green, thin-bedded to massive and, locally, laminated and banded with stringers and blebs of sandstone. Sub-spheroidal, blue-grey to blue-black, dense limestone concretions were noted in the more calcareous claystone, and in places fossil bryozoa, algae, crinoids, and small pelecypods were collected from these claystones. The sandstone of the formation is best developed to the west, and its modal size increases in this direction. It is blue-grey to olive-green, varies from fine-grained to granule-pebble size, is poorly sorted, consists of grains of well indurated mudstone and acidic tuffs and flows, is generally tightly cemented with calcite, and weathers in sub-spheroidal balls. Sporadic lenses of blue-grey to brown oolitic limestone interrupt the sandstone. These lenses grade laterally into the sandstone and are composed of oolites and shell detritus in a dense limestone matrix. An abundant fossil fauna of corals, brachiopods, crinoids, bryozoa, and small pelecypods was collected from these lenses. Near the Bingara Fault Zone and the western margin of the New England Batholith, the Bangheet mudstone is highly siliceous, and the sandstone is quartzitic and very hard. Silicification decreases westward, away from the fault zone and intrusion.

North-east of the Warialda-Narrabri district, the Bangheet Formation has been deformed by the intrusion of the New England Batholith. On the west flank of the Ashford Spur of this batholith, the formation consists of blue-black to dark olive-green siliceous argillite with minor quartzitic, very hard, blue-grey, fine to medium-grained sandstone. These rocks are steeply dipping, sheared, and cut by quartz veins. In Limestone Creek, massive, white to blue-grey, lithographic limestone is interbedded in this sequence. Towards the margin of the granite, this limestone is marmorized, and the granite contact is coarsely crystalline. On the east flank of the Ashford Spur, siliceous argillite is also the dominant rock type; however, here, more sandstone as well as microbreccias and silicified acidic tuffs were mapped within the formation, and they increase in predominance eastwards. The sandstone is olive-green to blue-grey, quartzitic, fine to coarse-grained, and tuffaceous. The microbreccias consist of angular fragments, up to pebble size, of argillite, quartzite, and acidic tuffs, in a blue-black, dense, siliceous argillite matrix.

Farther north in the Taxas-Glenlyon area, the Bangheet Formation has been complicated by faulting coincident with the intrusion of the New England Batholith. Here the formation is mainly olive to yellow-green, tuffaceous, well indurated mudstone, blue to blue-black and dark olive-green, hard, dense siliceous argillite, blue-grey to olive-green quartzite, and silicified rhyolitic tuff. These beds are steeply dipping, sheared, and cut by quartz veins. Massive, light grey to blue-grey, dense, hard, lithographic to sub-lithographic limestone is interbedded in the Bangheet east of Limevale and along Pike and Little Plains Creek. In the vicinity of Little Plains Creek, this limestone is underlain by a purple-weathering amygdaloidal andesite flow. The amygdales are filled with calcite. About two miles east of Texas, on the Stanthorpe Road, fragments of a similar limestone were seen in a purple-weathering andesite flow (AMa. 189 Li). In the Hetherington Fault Zone, a purple andesitic volcanic conglomerate (AMa. 219 Li) was mapped interbedded with tuffaceous quartzitic sandstone and silicified mudstone of the Bangheet Formation.

The youngest beds of the formation mapped in this survey are exposed in the Silver Spur and Glenlyon area. Near Silver Spur, these beds consist of dark blue-grey to olive-green, tuffaceous, partly calcareous, well indurated to silicified, sandy to pebbly mudstone, fine to coarse-grained tuffaceous sandstone, granule-pebble conglomerates, and, north of the Silver Spur Mine, highly sheared pebble-cobble conglomerate. The conglomerate contains clasts of quartz, quartzite, quartzitic tuffaceous sandstone, and siliceous argillite. A fossil fauna of brachiopods, corals, pelecypods, gastropods, crinoids, and bryozoa was collected from these beds. At Glenlyon and south-east of Glenlyon, a similar sequence was mapped; however, here conglomerates are more prevalent, and they thicken and become coarser to the south-east. The conglomerates consist of angular to rounded clasts, from granule to cobble size (up to 8"), of dark-blue argillite, quartz, quartzite, tuffaceous sandstone, minor green chert, and silificied acidic tuff, and a trace of granite, in a matrix of silificied tuffaceous mudstone. At Glenlyon, brachiopods, bryozoans, crinoids, gastropods, and pelecypods have been collected from these rocks, and fragments of a brown limestone with bryozoa were noted in a pebble conglomerate here (AMa. 212F). South-east of the homestead a lens of crinoidal, partly recrystallized limestone (AMa. 213F) is interbedded in this sequence.

In the Warialda-Narrabri area, diagnostic fossils were collected from both the Bangheet and Kuttung Formations near their intertonguing contact. These fossils indicate an early Carboniferous age, probably basal Viséan or upper Tournaisian, for the rocks at this horizon (see Palaeontological Appendix). The great thickness of Bangheet sediments exposed on the north flank of the Pallal Anticline east of the Kuttung contact suggests a still older range for these rocks. The Bangheet exposed in the crestal region of this anticline is continuous with and lithologically similar to the Barraba 'series' mapped by other workers south of the area reconnoitred (Pl. 3). The Barraba has been assigned a late Devonian age on the basis of casts of the plant Lepidodendron australe (David, 1950, p.252). L. australe is reported from the marine Lower Carboniferous Tellebang Formation of the Yarrol Basin (Maxwell, 1960) and above beds with Tournaisian marine fossils fron the Upper Burdekin Valley (Wyatt & White, 1960).

On the basis of corals collected in limestones north-west of Ashford in Limestone Creek, Raggatt (1941, p.170-171) assigned a Viséan age to the rocks here. The limestones in the Texas-Limevale area have been dated as Viséan on the basis of corals such as Lithostrotion stanvellense and Amygdalophyllum inopinatum (Wade, 1941, p.17). The fossil fauna collected from the Bangheet rocks in the Silver Spur and Glenlyon districts indicates an early Permian age (Palaeontological Appendix).

Kuttung Formation:

In the Warialda-Narrabri district, the Kuttung Formation consists mainly of coarse-grained tuffaceous sandstone, microbreccias, volcanic conglomerates, breccias, tuffs, and flows (Pl. 4). The contact of the Kuttung with the Bangheet is a facies relationship and was picked at the point where coarse conglomerates interrupt the Bangheet sequence. The contact approximates a shoreline with the marine Bangheet to the east and terrestrial Kuttung to the west.

Lenses of oolitic limestone, similar to those described in the Bangheet Formation, occur in the Kuttung Formation near its intertonguing contact with the Bangheet. These lenses are interbedded with tuffaceous sandstone, microbreccias, brecciated water-worked tuffs, thin rhyolite flows, and pebble to small boulder conglomerate. To the west and higher in the section rhyolite to dacite tuffs and flows, conglomerates, and breccias increase at the expense of sand and shale. The tuffs and flows are brecciated locally and contaminated with scattered pebbles and cobbles of similar composition. The conglomerates and breccias consist of clasts, ranging in size from pebbles to small boulders, of dacite and rhyolite tuffs and flows in a matrix of tuffaceous sandstone. Locally, purple to green tuffaceous shale and sandstone are interbedded with green, pink, and lavender tuffs and conglomerates. The colour and aspect of these rocks suggest deposition in an oxidizing environment.

Farther west, thin coal beds and coaly shale with plant fragments (AMa. 308 mf) were mapped within the Kuttung. These coals are interbedded with white to greenish-white tuffaceous sandstone, siltstone, massive pink to white rhyolite tuff, and minor volcanic pebble-cobble conglomerate. This predominantly tuff sequence persists stratigraphically higher in the formation. South of Narrabri, between Baan Baa and Boggabri, the youngest beds of the Kuttung Formation are exposed. They consist of massive white rhyolite tuff interbedded with amygdaloidal basalt flows.

As noted in the discussion of the Bangheet Formation, diagnostic fossils indicative of an early Carboniferous age were collected from the Kuttung near its contact with the Bangheet. Leaf fossils, collected from coals in the formation near the crest of the Nandewar Range, suggest a late Carboniferous or Permian age for the Kuttung at this horizon (Palaeontological Appendix). The basalts and tuffs near Boggabri may be equivalent to the Lower Permian Temi Group and Werrie Basalts which are exposed farther to the south (Hanlon, 1953, p. 6-18).

An eastern shoreline of the 'Bangheet sea' may have run south-east of the present outcrop of the New England Batholith in late Carboniferous and early Permian time. Terrestrial rocks similar to the Kuttung would have been deposited east of this shoreline. There is some evidence to support this hypothesis: as discussed earlier, tuffs and microbreccias are progressively more prevalent in the Bangheet east of Ashford, and conglomerates in the Lower Permian Bangheet beds thicken and become coarser south-east from Glenlyon.

## Cracow Formation

In outcrop on the eastern flank of the Bowen Basin, volcanic rocks of earlier Permian (?) age underlie the Bowen Group. These volcanics, the Cracow Formation, are considered equivalent to the upper part of the Kuttung Formation of the Horton Group.

Denmead (1933) named a sequence of tuffs and breccias overlying dacite and rhyolite lavas near Cracow, Queensland, as the 'Cracow Series' and assigned to them an early Triassic age. A fossil flora collected from shale immediately and 'conformably' overlying the volcanics is considered by Jones (1948) as Triassic-Jurassic. Jones and later Whitehouse (1955) have equated these shales with beds of the Bundamba Group (Hill et al., 1960, p.282).

Shell (Queensland) Development Pty Limited (Schneeberger, 1951) applied the name 'Cracow Series' to volcanics which form the country rock of the gold fields at Cracow. Flora collected by Shell from an intercalation of ashy shale in the volcanics indicated a Permian age for these rocks. It is inferred that Shell included the tuffs and breccias of Denmead's 'Cracow Series' in a continuous sequence with the underlying flows and did not relate them to the overlying Great Artesian rocks. The author also believes that the tuffs and breccias are integral with the Permian volcanics and consequently thinks that the overlying shales are unconformable with the 'Cracow Series' as defined by Denmead.

The Cracow Formation consists of purple, green, reddish-brown, and grey to black andesite to rhyolite flows, agglomerates, tuffs and breccias, with andesite flows predominant. The andesites are locally amygdaloidal, and the amygdales are generally filled with a white zeolite. The Cracow Formation has been intruded by rocks of the Auburn Complex: the thickness of the volcanics is unknown as the intrusion masks the lower contact of the formation. In outcrop no evidence of unconformity was noted between the Cracow and the overlying Back Creek Formation.

An isolated outcrop of andesite was mapped three miles east of Kianga Homestead. Field relations suggest that it is a flow interbedded in olive-green tuffaceous mudstone of the

Back Creek Formation. This flow is tentatively considered a younger tongue of the Cracow Formation. In Prospect Creek, on the eastern flank of the Auburn Complex, Shell (Queensland) mapped sandstone, siltstone, and shale overlying the Cracow Formation and interbedded with volcanics similar to those of the Cracow Formation. A faunal assemblage collected from these beds suggests that they are equivalent to the lower part of the Back Creek Formation in the Cracow district (Schneeberger, 1951).

In Union-Kern-A.O.G. Cabawin No. 1, purplish-grey to green weathered andesite was drilled below the Back Creek Formation at 11,662 feet (K.B.) and assigned to the Cracow Formation. The company's aeromagnetometer survey indicates that the Cracow volcanics are continuous in the subsurface from outcrop to well. There was no fossil evidence in the well on which to assign an age to the Cracow in this part of the Bowen Basin. In the well the lower part of the Back Creek Formation is missing, and in contrast to the type area of the Cracow, the Cracow/Back Creek contact is unconformable.

In Union-Kern-A.O.G. Moonie No. 1, approximately 20 miles south of Cabawin No. 1 tuffaceous clastics and weathered dacite tuffs were drilled beneath the overlapping Bundamba Formation of the Great Artesian Group. These rocks were assigned to the Kuttung Formation of the Horton Group.

## Scrubhut Volcanics

The Scrubhut Volcanics are defined as a relatively flat-lying sequence of rhyolite to dacite tuffs, lapilli tuffs, and minor flows which overlie a spur of the New England Batholith and form a tableland east of Ashford, New South Wales, and south of the Hetherington Fault Zone. The formation was named after Scrubhut Creek, which flows through the volcanics and is a tributary of the Severn River. A Permian age is suggested for these volcanics; they were deposited after the intrusion of the New England Batholith, and, probably, before the deposition of the Ashford Formation.

The tuffs consist of small phenocrysts (1-4 mm) of clear quartz and orthoclase in a white to pink-grey and pink silicified ash groundmass. Lapilli are of similar composition to the tuff and are generally flattened and strung out in sub-parallel bands, suggesting that the tuffs are welded. The flows consist of phenocrysts of quartz, feldspar, and hornblende in a greyish-pink to pink felsite matrix, and they are considered to be the extrusive phase of pink quartz-feldspar porphyry dykes which were mapped near the margins of the volcanics. The dykes, where mapped, are controlled by faults and seem to be related to a dyke set peripheral to the spur of the New England Batholith over which the Scrubhut Volcanics were deposited.

## Bowen Group

The term Bowen Group is used in the present report for a related sequence of marine to continental clastics deposited in the Bowen Basin during Permian to early Triassic time. The oldest rocks of the group are tuffaceous shallow-marine clastics of the Back Creek Formation, which grade upward into tuffs, coals, and tuffaceous clastics of the Kianga Formation. The Kianga Formation represents a transition from a marine to continental environment in the Bowen Basin and grades upward into tuffaceous, coarse clastic, 'fill' deposits of the Cabawin Formation, the youngest rocks of the Bowen Group.

The Ashford Formation, exposed on the north-west flank of the New England Batholith, is tentatively referred to the Bowen Group. Lithologically it is similar to the Kianga

Formation and is thought to represent sedimentation marginal to the southern end of the Bowen Basin during late Permian time.

Back Creek Formation:

The 'Back Creek Series' was established by Shell (Queensland) Development Pty Limited (Schneeberger, 1951) for approximately 5700 feet of tuffaceous, partly fossiliferous clastics with basal limestone beds exposed in Back Creek. This creek heads near Cracow, Queensland, and flows westward into the Dawson River. On the basis of megafossils, the 'series' was assigned a Permian age. Derrington et al., (1959) modified Shell's 'Back Creek Series' to 'Back Creek Group' and subdivided the unit into a number of formations. In this survey only one formation was differentiated in the marine Permian section of the Cracow-Banana area, and that closely parallels the 'Back Creek Series' as mapped by Shell. The name 'Back Creek' is retained for this unit, but it is downgraded from group to formational status.

The Back Creek Formation in outcrop conformably overlies the Cracow Formation and is conformable beneath the Kianga Formation. The Kianga/Back Creek contact is intertonguing and represents a change from marine to freshwater deposition. 5500 to 6000 feet of the formation are exposed in the Cracow-Banana area. To facilitate discussion, the formation is subdivided into informal units which are indexed to the stratigraphical columns of Plate 5.

The basal 400-600 feet of the Back Creek Formation consists of white silicified tuffs and silty tuffs with beds and lenses of shell coquina (Unit 1). The coquinas are made up of crinoids, brachiopods, pelecypods, gastropods, bryozoans, and sponge spicules. Different lenses at approximately the same stratigraphical horizon are often dominated by one faunal type i.e. crinoids in one, brachiopods in another.

Above the basal tuffs and coquinas are approximately 3200 feet of interbedded olive-green tuffaceous, calcareous claystone, siltstone, and sandstone (Unit 2). In the lower part of this interval, between Cracow and Theodore, sandstone is best developed, and minor silicified white tuff is interbedded in the sequence. Farther north and higher in this section, the rocks are progressively more argillaceous. Thin silty blue-grey limestone bands are prevalent locally in the upper part of this unit, and blue-grey calcareous concretions with fossils are common.

Overlying Unit 2 is approximately 250 feet of silicified white tuff, silty tuff, tuff granule conglomerate and tuffaceous sandstone (Unit 3). This tuff sequence serves as a rough marker horizon within the Back Creek outcrop.

In the Cracow-Theodore area, the Back Creek Formation above the tuff marker consists of approximately 1500 feet of interbedded tuffaceous claystone, siltstone, sandstone, and minor tuff granule conglomerate (Unit 4). Macerated carbonaceous debris is abundant in this unit, and fossil wood occurs locally in the granule conglomerates. The clastics vary from calcareous to non-calcareous, and blue-grey claystone with foraminifera (?) was mapped near the top of the interval. Farther north, between Theodore and Banana, the Back Creek Formation above the tuff marker is mainly siltstone and claystone, with minor sandstone. In this area questionable sponge spicules were collected from a silty tuff near the top of the unit.

The upper contact of the Back Creek Formation was picked at the top of Unit 4. The marine beds at the top of this unit are the same beds in which Shell (Schneeberger, 1951) collected pelecypods and which they considered the top of the 'Back Creek Series'. They are probably equivalent to the marine siltstone with foraminifera, productid spines, and crinoid ossicles drilled at the top of the Back Creek Formation in Union-Kern-A.O.G. Cabawin No. 1.

As discussed earlier, in Cabawin No. 1 only the upper part of the Back Creek Formation was encountered. The formation was penetrated from 10,358 to 11,662 feet (K.B.). The lower beds consist of tuff overlain by pyritic dark grey shale and tuffaceous fossiliferous sandstone and siltstone. Above these rocks a tongue of coal and sandstone, related to the overlying Kianga Formation, interrupts the marine sequence, and this is overlain by blue-grey fossiliferous claystone, siltstone and sandstone. The tuff at the base of the Back Creek Formation in Cabawin No. 1 is probably equivalent to the tuff marker approximately 1500 feet below the formation top in outcrop.

In Union-Kern-A.O.G. Cabawin East No. 1 the Back Creek Formation was penetrated at 11,197 feet (K.B.), and the well was abandoned in this formation at 12,091 feet (K.B.). More coal tongues were drilled within the Back Creek in this well than in Cabawin No. 1.

Kianga Formation:

The Kianga Formation was established by Union Oil Development Corporation in the Cracow-Theodore-Banana area of Queensland to include approximately 1800 feet of silicified tuff, coal measures, tuffaceous sandstone, and conglomerate. These rocks conformably overlie the Back Creek Formation and grade vertically into the overlying Cabawin Formation. The name of the formation was taken from the Kianga open-cut mine, 3 miles east of the Dawson Valley Railway siding of Kianga. The type section (Pl. 5) was constructed from a belt of outcrop extending from Back Creek to the area between Moura and Banana.*

The lowest 250 feet of the formation consists of interbedded olive-green to greenish-grey tuffaceous siltstone, sandstone, and silicified white tuff. Overlying the basal beds are about 200 feet of tuff, granule-pebble conglomerate with abundant macerated carbonaceous debris and brownish-black biotite. Above these clastics about 300 feet of silificied white tuff forms an excellent time-marker horizon. This tuff is expressed topographically as small resistant ridges, and its outcrop can be easily traced on aerial photomosaics of the region. Coal and shaly tuff with Glossopteris sp. occur locally as thin bands and beds in the tuff, and large fragments of fossil wood were noted towards the base of the tuff.

At Theodore, the section above the tuff grades from interbedded silicified white tuff and tuffaceous sandstone into yellow-green tuffaceous biotitic siltstone, sandstone, and granule conglomerate, with scattered macerated carbonaceous debris and minor quartz. North of Theodore, coal measures are well developed in the formation above the tuff marker. The coals are interbedded with tuffaceous sandstones which contain macerated carbonaceous debris and black biotite. The coal seams are mined at Kianga and at another open cut approximately 6 1/2 miles north-east of Moura. South of Theodore, although coals are also developed, there

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* Kianga Formation has been published, without definition, by Allen & Sanker (Ann. Rev. Qld Min. Dept 1960, p.87) in a summary of the stratigraphic section in Cabawin No. 1. Their use of the term was based on the definition published here.

The Kianga Formation, as defined above, includes the Baralaba - Kianga Coal Measures of Reid (Qld Govt Min. J., Oct. 1945), and probably corresponds to the same author's Baralaba Coal Measures and Calcareous Stage (Qld Govt Min. J., Dec. 1945).

is a progressive increase in the percentage of conglomerate above the tuff marker. The conglomerate contains clasts (up to large cobble sizes) of silicified tuff, and andesite and dacite flows in a tuffaceous sandstone matrix.

Owing to its gradational, intertonguing nature and poor outcrop, the upper contact of the Kianga Formation is difficult to map on the surface. The contact was picked where the rocks change from a sequence of interbedded tuffaceous clastics, coal seams, and white tuff to tuffaceous quartzose clastics. In Union-Kern-A.O.G. Cabawin No. 1 and Cabawin East No. 1, the formation top was picked on a similar change in lithology. In Cabawin No. 1, the formation was drilled from 9835 to 10,352 feet (K.B.) and in Cabawin East No. 1 from 10,600 to 11,197 feet (K.B.). The Kianga Formation in these wells consisted of coals, white silicified tuff, tuffaceous sandstone, and minor conglomerate. The sandstone and conglomerate are composed mainly of tuff detritus in an ash matrix. Coals are better developed in Cabawin East No. 1.

Flora collected by Shell (Queensland) Development Pty Limited (Schneeberger, 1951) in beds of what the author maps as Kianga Formation have been assigned to the Permian. On the basis of spores, N.J. de Jersey of the Queensland Geological Survey places coals from the Kianga mine in the Permian (Palaeontological Appendix). Spores from the Cabawin wells indicate a gradational change from Triassic to Permian floras across the Kianga-Cabawin contact. This change is in harmony with the gradational character of the lithological contact between these formations both in the Cabawin wells and in outcrop. De Jersey reports the first definite Permian age for spores in the Kianga Formation in Cabawin No. 1 at 9870 feet (K.B.). P.R. Evans of the Bureau of Mineral Resources considers spores from 9935 feet (K.B.) in Cabawin No. 1 to be Upper Permian and suggests a Permian age for spores from 9900 to 9910 feet (K.B.) in the well. De Jersey has demonstrated the probable age equivalence of coals from the Kianga mine with coals of the Kianga Formation in Cabawin No. 1.

Ashford Formation:

The Ashford Formation is exposed north of Ashford, New South Wales, in fault contact with the western margin of the Ashford spur of the New England Batholith. Geological and geophysical studies of the formation by the Bureau of Mineral Resources suggest that the bounding fault with the granite is high-angle reverse, with the fault plane dipping to the west (Owen et al., 1954). East of the fault, the formation lies with marked angular unconformity on the Bangheet Formation. The formation consists of coal seams interbedded with tuffaceous sandstone, conglomerate, and shale. The sandstone and conglomerate are whitish-grey, friable when weathered, and are composed of white to greenish-white tuff in a reworked tuff matrix. Locally these coarse clastics tongue laterally into blue-grey tuffaceous shale, with abundant plant remains and macerated carbonaceous matter. The coal is mined and supplied to the Ashford power plant. The formation has a maximum thickness of 550 feet in the colliery area (Owen et al., 1954, p.16). South of Ashford, near Arawatta and Arthur's Seat, a few scattered outcrops of coal, conglomerate, and shale have been mapped by other workers and equated with the Ashford Formation.

Although the Ashford Formation lies on the margin of a spur of the New England Batholith, it is not intruded by the batholith; whereas Lower Permian clastics of the Bangheet Formation, in the Silver Spur and Glenlyon areas, were affected by intrusion of the batholith. From these facts, it is inferred that the Ashford Formation is younger than the Lower Permian beds of the Bangheet and that it was deposited after the intrusion of the batholith. Spores in samples of the Ashford coal indicate a Permian age, but no species of restricted range within the Permian was identified to facilitate further zonation (Palaeontological Appendix).

Cabawin Formation :

The Cabawin Formation has been established by Union Oil Development Corporation to include 2195 feet of tuffaceous quartzose sandstone and conglomerate drilled in Union-Kern-A.O.G. Cabawin No. 1 Well from 7640 to 9835 feet (K.B.) This formation has been assigned a Triassic age on the basis of fossil flora.

In the well the type section consists of the following units as indexed to the depth from the kelly bushing (968 ft msl.) at which they were penetrated:

| | Depth (feet) | Thickness (feet) | Lithology |
|---|---|---|---|
| 1. | 7640-7674 | 34 | Shale, tuffaceous, dark reddish-brown and mustard coloured with bluish to greenish-grey streaks, dense, micromicaceous, and with scattered finely macerated carbonaceous debris. |
| 2. | 7674-8424 | 750 | Granule conglomerate, pale green to greenish-grey, tuffaceous, quartzose, with minor bands of pebbles; clasts of multicoloured quartz and chert in a fine to coarse-grained, poorly sorted, angular to subangular quartz sandstone with a matrix of green to whitish-green reworked ash. Porosities in this interval range up to 30 percent and permeabilities to 300 md; however, the porous zones average only 5 feet thick. |
| 3. | 8424-8810 | 386 | Pebbly sandstone to granule conglomerate, pale greenish-grey, tuffaceous, quartzose, poorly sorted, fine to granule-sized, angular to subangular grains of quartz and chert, with minor pebbles of quartz, chert, and silicified ash, in a matrix of white to green reworked ash. Porous zones in this interval have similar porosities and permeabilities to those in the unit above, but are approximately twice as thick. |
| 4. | 8810-8845 | 35 | Tuffaceous shale, chocolate-brown to mustard coloured, and minor grey siltstone with carbonaceous streaks. |
| 5. | 8845-9456 | 611 | Conglomeratic sandstone and conglomerate, grey to greenish-grey, tuffaceous, grains and clasts up to small cobble size of subangular to rounded multicoloured quartz, chert, quartzite, and silicified ash in a matrix of white to green reworked ash. The modal size of the conglomerate clasts increases from granules to pebble-cobble size towards the base of the interval. Porosities are negligible. |

| | Depth (feet) | Thickness (feet) | Lithology |
|---|---|---|---|
| 6. | 9456-9835 | 379 | Similar to unit above but with marked increase in amount of tuffaceous material. One thin coal bed at 9622 feet. |

In Cabawin No. 1, the Bundamba Formation disconformably overlies the Cabawin Formation. In outcrop the Cabawin Formation is overlain by the Bundamba with angular unconformity on the flanks of the Bowen Basin. Basinward the relationship between the formations is one of disconformity. Our seismic reconnaissance within the Surat Basin has confirmed this contact relationship. In Cabawin East No. 1, 2750 feet of the Cabawin Formation was drilled. The lithology of the formation in this well is monotonously similar to that in Cabawin No. 1; however, additional tuffaceous siltstone and sandstone are developed above the shale interval that was drilled at the top of the formation in Cabawin No. 1. In Cabawin East No. 1. ditch cuttings suggest that the Cabawin Formation grades transitionally upward into the basal sandstone of the Bundamba Formation. However, electric logs of the well show that the Bundamba-Cabawin contact is sharply marked by a change in character of the sandstone, suggesting a disconformable Bundamba-Cabawin contact in Cabawin East No. 1 as in Cabawin No. 1.

In the Surat Basin, seismic work along the Condamine Highway indicates approximately 7000 feet of Cabawin Formation along the axis of the Leichhardt Syncline.* Along this same line, the Cabawin Formation wedges out westward on the Roma "high" and eastward on the Auburn Complex. In the vicinity of Taroom, seismic survey suggests at least 17,000 feet of the Cabawin Formation along the axis of the Leichhardt Syncline. Although calculations are based on relatively few attitudes, at least 15,000 feet of the Cabawin Formation is exposed on the surface immediately north of the Bundamba overlap.**

The lithology of the Cabawin Formation on the surface closely parallels its expression in the Cabawin wells. Except in the Dawson Range, the formation is topographically expressed as low rolling rises and flats. On the eastern flank of the Leichhardt Syncline, the formation consists of olive to yellow-green, tuffaceous, quartzose siltstone, sandstone, conglomeratic sandstone, and conglomerate. These clastics contain grains and clasts of subangular to rounded quartz, chert, quartzite, and silicified ash in a matrix of white to green reworked ash. Reddish-brown biotite and macerated carbonaceous matter is common in these clastics, and, locally, the tuffaceous matrix is calcareous. Within this section more resistant beds, of similar clastics but more highly quartzose, underlie the Dawson Range. Near Glenmoral Homestead, the 'Dawson Range beds' are overlain by pebble to small boulder conglomerate which consists of rounded clasts of white tuff in a tuffaceous quartzose sand matrix. Farther north, the conglomerate contains clasts of silicified ash, andesite, rhyolite, quartzite, and chert.

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* The Leichhardt Syncline is probably continuous with the Mimosa Syncline (Hill et al., 1960, Fig. 27.)

** The Cabawin Formation has also been intersected in Union-Kern-A.O.G. Wandoan No. 1 Well, which is located 5 miles south-west of the town of Wandoan, Queensland.

On the western flank of the Leichhardt Syncline, the Cabawin Formation is lithologically similar to that on the east; however, the modal grain size of the sandstone is finer, silty, tuffaceous claystone is better developed, and conglomerate is less common.

Correlations within the Bowen Group :

Correlation of the Permian rocks of the Bowen Group in the Cracow-Banana district with those of the Springsure area and with the Permian drilled in the Surat Basin is suggested in Plate 5. D. Hill, University of Queensland, considers the fossiliferous beds with a Eurydesma-Taeniothaerus fauna exposed at the base of the Back Creek Formation near Cracow Homestead to be equivalent to the lower Cattle Creek Formation of the Springsure district (personal communication). The fossiliferous beds at the top of the Back Creek Formation in the Cracow-Banana area are probably equivalent to the Mantuan Formation of the Springsure district. I. Crespin, Bureau of Mineral Resources, on the basis of foraminifera suggests that the upper part of the Back Creek in Cabawin No. 1 is equivalent to the Mantuan Formation (personal communication).

The Bandanna Formation of the Springsure district is correlated with the Kianga Formation on the basis of similar lithology and a like stratigraphical position. The Kianga Formation in the Cabawin wells has been correlated on electric logs, similar flora, and relatively similar lithology with the Latemore Formation defined by Mines Administration Pty Limited in their wells in the Roma district. De Jersey, Queensland Geological Survey, on the basis of microflora suggests that the section around 9600 feet in Cabawin No. 1 can be correlated with the Pickanjinnie Formation of Mines Administration Pty Limited in the Roma area (personal communication).

On the western flank of the Bowen Basin, in the Springsure District, three formations crop out which probably tongue eastward into the Cabawin Formation, and are overlain by a tongue of the Cabawin Formation (Pl. 3). From oldest to youngest, these formations are the Rewan, Clematis, and Moolayember. Only the Clematis Formation was mapped in this survey. The Rewan Formation is described as 300 to 2300 feet of chocolate-red clay shale with sporadic beds and lenses of fine-grained sandstone and siltstone. The Clematis Formation, originally named by Jensen (1926), was mapped where it is exposed in the Expedition Range along the Rolleston-Moura Highway. It consists of highly porous, medium to coarse-grained, white (streaked with yellow, orange, and red), quartzose, angular to subangular, thick-bedded to massive, cross-bedded, friable sandstone and pebbly granule conglomerate. Thin intervals of thin-bedded, white, punky, siliceous shale interrupt the sandstone sequence.

The formation thins to the south and south-east. North of the Rolleston-Moura Highway, between Shotover and Planet Downs, the Clematis Formation is more than 1000 feet thick (Hill et al., 1960, p. 281). South of this highway, thickness of the formation varies from 250 to 400 feet. The Clematis Formation is the lateral equivalent of the tuffaceous quartzose clastics of the Cabawin Formation that underlie the Dawson Range on the eastern flank of the Leichhardt Syncline. Plant fossils in the formation indicate an early Triassic age (Hill et al., 1960, p.281). The Moolayember Formation is described as up to 1500 feet predominantly of olive-green to yellow-brown sandy tuffaceous shale with interbeds of calcareous yellow sandstone (Hill et al., 1960, p.181-182).

Depositional environment of the Bowen Group:

During deposition of the lower part of the Back Creek Formation in the Cracow-Theodore-Banana district, the area in which Cabawin No. 1 was drilled stood above the sea.

By late Back Creek time, the sea had transgressed into the southern end of the Bowen Basin; the southern margin of the sea was within the northern end of the Namoi Graben. Towards this shoreline, the Back Creek Formation is inferred to be progressively replaced by a coal, shale, and sandstone facies similar to the Kianga Formation. The tongues of coal drilled in the Back Creek Formation in the Cabawin wells are perhaps indicative of this facies change to the south.

In Kianga time, the sea regressed, and explosive vulcanism was more prevalent around the eastern and southern margins of the basin. Ash falls and clastics made up of reworked tuff eroded from highlands to the east and south-east intermixed with the 'Kianga' coals being formed in widespread, swampy lowlands in the basin.

By the end of Kianga time, intensive uplift had begun along the eastern side of the Bowen Basin. During Cabawin time, subsidence in the Basin reached its culmination. The tuffaceous detritus characteristic of the formation was derived largely from an eastern source. The lithological character of the lateral equivalents of the Cabawin Formation in the Springsure District suggests that this area was part of a stable shelf bordering the miogeosyncline on the west during Cabawin time. By the end of Cabawin time, the Bowen Basin had reached a state of isostatic equilibrium.

## Great Artesian Group

The Great Artesian Group includes the Mesozoic rocks deposited over much of eastern Australia in conjunction with the sag of the Great Artesian Basin. In the Surat Basin, the oldest rocks of the group are continental quartz clastics of the Bundamba Formation. This sandstone grades vertically into coal and shale of the Walloon Formation, and these in turn grade into the quartz sandstone of the Blythesdale Formation. The Blythesdale is transitional upwards into marine shale and sandstone of the Roma Formation, the youngest unit in the Great Artesian Group. Along the southern margin of the Surat Basin, the Great Artesian Group thins, older rocks of the group are progressively overlapped, and facies changes make the units mapped in the group to the north unrecognizable. In this area only one formation, the Intake Formation, was mapped in the Great Artesian Group.

### Bundamba Formation:

The name 'Bundamba' was first applied by Cameron (1907) to 'Trias-Jura' coarse grit and sandstone overlying the coal bearing Ipswich Beds near the town of Ipswich, Queensland. Later, the age of the Bundamba in the type area was shown to be Upper Triassic (Hill et al., 1960, p.257).

Reeves (1947) mapped sandstone at the base of the Great Artesian section in the Roma district of Queensland as the 'Bundamba series'. He considered these rocks Upper Triassic and subdivided the 'series' into four members from oldest to youngest as follows:

(i) Bundamba sandstone - 230 to 300 feet of coarse-grained to conglomeratic sandstone;

(ii) Bundamba shale - 200 to 250 feet of interbedded sandstone and shale;

(iii) Boxvale sandstone - 30 to 80 feet of fine-grained sandstone;

(iv) Hutton sandstone - 400 to 1000 feet of arkosic coarse-grained sandstone and conglomerate.

Whitehouse (1955) redefined the Bundamba in the Roma district. He placed Reeves' three lower members in the 'Bundamba Group', retained Boxvale Sandstone as a formation within the group and renamed Reeves' 'Bundamba shale' and 'Bundamba sandstone' as the 'Evergreen Shale' and 'Precipice Sandstone' respectively. He placed Reeves' 'Hutton sandstone' in the Marburg Formation.

In the northern part of the Surat Basin, the author mapped the Bundamba as a formation and subdivided it into three members, a lower sandstone, middle shale, and upper sandstone, which correlate roughly with the 'Precipice Sandstone', 'Evergreen Shale', and combined Boxvale Sandstone and Marburg Formation of Whitehouse in the Roma district. These members can be correlated with three similar units drilled in the Cabawin wells (i.e. Cabawin No. 1, 5444-6092 feet, 6092-6550 feet, 6550-7640 feet; and Cabawin East No. 1, 5294-6112 feet, 6112-6560 feet, 6560-7850 feet.)

The lower member of the Bundamba Formation is a cliff-forming, massive, coarse-grained to conglomeratic, subangular to rounded, friable, extremely porous, quartzose sandstone. This member is a major aquifer in the northern part of the Great Artesian Basin.

The middle member of the Bundamba Formation consists of interbedded claystone, siltstone, and sandstone. The claystone and siltstone are interbedded, laminated, blue-grey (white when weathered), platy-fracturing, and punky, and contain abundant macerated carbonaceous debris. The sandstones are fine to coarse-grained, quartzose, subangular to rounded, and locally have a matrix of clayey white reworked tuffaceous matter.

The upper member of the Bundamba Formation is white to buff fine to coarse-grained quartzose sandstone with granule conglomerate and thin siliceous shale intervals at the base. The upper part of this member consists of well-bedded, thin to thick-bedded, fine to medium-grained quartzose sandstone interbedded with clayey siltstone. In the Cockatoo Creek area, an interval of ferruginous shale and oolitic ferruginous sandstone can be traced as a marker in the lower part of the member. Farther west, concentrations of ferruginous matter in the sandstone near the base of the member may be correlative with the Cockatoo Creek marker.

The Bundamba Formation overlaps the Bowen Group across the Bowen Basin and is conformably overlain by the Walloon Formation. In the north-eastern part of the Surat Basin, the formation progressively overlaps the Auburn Complex to the east and south-east. On the basis of spores from the formation in the Cabawin wells, the Bundamba Formation ranges in age from Triassic to Jurassic.

Around the northern end of the New England Batholith, the Bundamba overlaps the Palaeozoic complex. Here, the formation consists of coarse-grained sandstone and granule-pebble conglomerate, which are considered equivalent to the upper member of the Bundamba in the northern part of the Surat Basin. The sandstone is white, subangular to rounded, poorly sorted, friable, and porous, and has a white, reworked, tuffaceous clay matrix. The conglomerate contains clasts of multi-coloured quartz, chert, and white silicified tuff in a sandstone matrix of similar composition. At the contact with the Palaeozoic rocks, these clastics are streaked locally with purple and red tints, and the conglomerate contains concentrations of small cobbles. On the basis of plant fossils collected in outcrop between Limevale and Inglewood, Wade (1941) dated the Bundamba in this district as basal Jurassic. The formation is onlapped by the Blythesdale Formation south of Millmerran.

Walloon Formation:

Gregory (1876) described coal deposits near Walloon, Queensland, which Cameron (1907) included within the 'Walloon beds'. Walkom (1917) definitely established a Jurassic age for these rocks. Reeves (1947) placed what he considered Jurassic rocks in the Roma district in the 'Walloon series' and subdivided this 'series' into numerous units. Whitehouse (1955) restricted the Walloon to Reeves' 'Lower Walloon'.

In the northern part of the Surat Basin, the author mapped Reeves' 'Middle' and 'Lower Walloon' as the Walloon Formation. North of the Great Dividing Range, the formation was subdivided into a lower and upper member equivalent to Reeves' 'Lower' and 'Middle' Walloon respectively. The Walloon crops out in a wide belt north of the Great Dividing Range and across this range to the south-east. The formation supports a growth of brigalow and belah trees in grey soil and is topographically expressed as subdued rolling rises and flats. The formation is conformably overlain by the Blythesdale Formation, and the contact is intertonguing. Spores from the formation in the Cabawin wells indicate a Jurassic age.

The lower member of the Walloon Formation consists of interbedded coal, coaly shale, siltstone, and sandstone, with the coal and shale sequence predominant. The sandstone is quartzose, fine to medium-grained, yellow-buff, hard, calcareously cemented, and contains abundant, finely macerated, carbonaceous matter; it is difficult to trace laterally and inferred to be discontinuous lenses and beds within the coal and shale sequence.

The upper member of the Walloon Formation, differentiated only in the area north of the Great Dividing Range, is interbedded clayey siltstone, sandstone, and conglomerate, which intertongue along the strike. The sandstone is yellow-buff, fine to coarse-grained, calcareously cemented, and contains finely macerated carbonaceous matter and, locally, large fragments of fossil wood. The conglomerate consists of clasts, ranging in size from granules to small boulders, of quartz, chert, quartzite, tuff, sandstone, and andesite (?) in a sand matrix. The coarser clasts occur locally as lenses and stringers in the conglomerate.

In the far south-eastern part of the Surat Basin, the Walloon Formation consists of coal, blue-grey shale, siltstone, and sandstone. The sandstone is yellow-buff, calcareously cemented, hard, fine to coarse-grained, and contains lenses with abundant fragments of fossil wood. Near the base of the formation granule-pebble conglomerate with fragments of fossil wood is interbedded with thin intervals of shale. South of Millmerran, the formation is progressively overlapped by the Blythesdale Formation and partly replaced by a sandstone facies mapped as part of the Blythesdale.

Blythesdale Formation:

Jack (1895) proposed the name 'Blythesdale Braystone' for a sequence of grits and conglomerates exposed along Blyth Creek a few miles north of the Blythdale Railway Station, Queensland. Reeves (1947) mapped Jack's Blythesdale as the 'Middle' and 'Upper' Walloon. Whitehouse retained Jack's nomenclature but considered the unit as the 'Blythesdale Group'. The author has restricted the Blythesdale to what Reeves mapped as the 'Upper Walloon' and has downgraded the unit to formational status.

The Blythesdale Formation forms the Great Dividing Range north of the Miles-Roma Highway, and here consists of thick-bedded to massive, medium to coarse-grained sandstone and granule-pebble conglomerate with minor shale intervals. The sandstone is white, quartzose, subangular to rounded, cross-bedded, friable, and has a matrix of reworked white tuffaceous clay. The conglomerate is similar in composition to the sandstone, and the shale is white and punky and contains scattered fine quartz grains. The sandstone of the Blythesdale Formation grades upward into marine shale of the Roma Formation. Spores from the formation in the Cabawin wells date the Blythesdale Formation as Jurassic/early Cretaceous.

The belt of Blythesdale outcrop swings southward at Miles and is continuous along the eastern side of the Surat Basin to the vicinity of the New South Wales border. The formation here does not vary from its expression to the north; however, near the base, white, siliceous, rounded, quartzose, pebble-cobble conglomerate was mapped locally. South of Millmerran the Blythesdale overlaps the Walloon and onlaps the Bundamba Formation. The Blythesdale sandstone is continuous across the New South Wales border with sandstone of the Intake Formation.

Roma Formation:

The 'Rolling Downs Formation' was originally defined to include all the Cretaceous beds of the Great Artesian Basin. Whitehouse (1955, p.10) elevated the 'Rolling Downs' to a group status and subdivided the marine rocks into two formations, of which the Roma included all the Aptian rocks. He suggested that the type area for the Roma was along Bungeworgorai Creek just north and south of the railway line east of Roma, Queensland.

The Roma Formation crops out near Roma and as inliers projecting through the Tertiary rocks near Surat, Coomrith, Dulacca-Drillham, and along the Weir River near Tarrawinebar Homestead. The formation consists of interbedded sandstone, siltstone, and shale, with shale predominant. The sandstone is quartzose, fine to medium-grained, calcareously cemented, and contains finely macerated carbonaceous matter. It is blue-grey, weathers yellow-buff, and fractures in tabular to platy blocks. The shale is calcareous, blue-grey, contains carbonaceous matter, and is laminated and banded with siltstone. The formation weathers to a grey soil and is topographically expressed by rolling downs. An Aptian microfauna has been collected from the formation in outcrop (Whitehouse, 1955, p.16), and the microfaunal assemblage from the formation in Cabwain No. 1 suggests an Aptian/Lower Albian age (I. Crespin, personal communication). South of the New South Wales border, sandstone similar to those in the Roma Formation was mapped near the top of the Intake Formation.

Intake Formation:

In New South Wales, off the western flank of the New England Batholith, David (1950, p.458) mapped the Great Artesian rocks as the 'Artesian Series' and equated them with the Walloon in Queensland. Whitehouse (1955, p.12, Fig. 4) refers to these rocks as the 'Marginal (Intake) Series' and correlates them with the Blythesdale Formation. The name 'Intake Formation' will be used informally in this report to refer to these rocks. The formation consists chiefly of medium to very coarse-grained sandstone and granule-pebble conglomerate, eroded to form cliffs and minarets where they onlap the Palaeozoic rocks. The sandstone is quartzose, white to yellow-buff, porous, friable, thick-bedded to massive, cross-bedded, subangular to rounded, with a white clay matrix. The conglomerate is similar in composition to the sandstone, but near the base of the formation contains scattered cobbles of silicified white tuff as well as quartz and chert. The basal conglomerate and sandstone are streaked locally with red to purple tints and have an abundant, white, reworked, tuffaceous clay matrix. Towards the top of the formation, there is a gradual transition from coarse sandstone to a section with more claystone and siltstone. The sandstone near the top is fine to medium-grained, yellow-buff, hard, calcareously cemented, and contains abundant macerated carbonaceous matter; it is similar to that in the Roma Formation.

Between Moree and Warialda, plant fossils collected from the formation indicate a Jurassic age (David, 1950, p.459). The similarity between the sequence near the top of the formation and the Roma Formation suggests that these rocks may range into the Lower Cretaceous. There is a suggestion that the formation wedges out in the southern part of the Namoi Graben.

## Tertiary-Quaternary rocks

In the Surat Basin, a sequence of Tertiary-Quaternary clastics in various stages of lateritization unconformably overlies the Great Artesian Group. Since subdivision of these rocks would not add appreciably to an understanding of the area, they are mapped simply as Tertiary-Quaternary rocks. They consist of silty shale, sandstone, and conglomerate. The sandstone is poorly sorted, massive, medium to very coarse-grained, pebbly, and has an abundant tuffaceous white clay matrix. Clasts in the conglomerate range in size from granules to small boulders and are mainly quartz, although most of the older rocks in the basin are also represented. The shale is white, siliceous, and punky. Where they overlie the Blythesdale, the Tertiary-Quaternary sandstones are difficult to differentiate from those of the Blythesdale Formation.

The Tertiary-Quaternary sandstone forms small ridges peripheral to the Roma Formation inliers. Between the Surat and Coomrith Inliers, a linear ridge of this sandstone, the Thomby Range, is thought to reflect a fault. Along the north flank of the Weir Inlier the sandstone forms an abrupt topographic break, which is continuous with a regional lineation, the Weir Lineament. North of this lineament, the Tertiary-Quaternary sandstone is well developed; whereas to the south the Tertiary-Quaternary rocks consist mostly of soil and alluvium.

Tertiary basalts cap the older rocks in a radial pattern north and west of Inverell, New South Wales. A thin patch of basalt caps the ridge west of Millmerran, Queensland. Farther north, a tongue of Tertiary basalt lies along the axis of the Leichhardt Syncline, and similar basalts crop out in the north-west between Rolleston and Bauhinia Downs.

## New England Batholith

The Ashford Spur of the New England Batholith is megascopically a white to grey, hypidiomorphic coarse to very coarse crystalline granite. Black biotite is generally a varietal mineral in the rock, and locally clusters of euhedral hornblende crystals were noted. The batholith is inferred to have been intruded during Permian time. The Lower Permian beds of the Bangheet Formation in the Texas-Glenlyon district are affected by the intrusion; whereas, the Upper (?) Permian Ashford Formation, on the flank of the Ashford Spur, is not intruded by the granite.

## Auburn Complex

The Auburn Complex, a granodiorite pluton, crops out on the eastern margin of the Bowen Basin. In the Cracow-Banana area, the pluton intrudes the Lower Permian Cracow

Formation. In the Prospect Creek area to the east, the pluton intrudes marine rocks considered partly equivalent to the Back Creek Formation (Schneeberger, 1951). The late Triassic/Jurassic Bundamba Formation progressively overlaps the Auburn Complex in the south-east. The intrusion of the pluton is suggested to have taken place coincident with active downwarp in the Bowen miogeosyncline during early Triassic time.

The granodiorite, where mapped east of Bungaban, Cockatoo Creek, and Dawsonvale, is associated with hypabyssal to extrusive andesite, dacite, and rhyolite along its western edge. Here, the complex relationship of granodiorite to hypabyssal and extrusive rocks suggests the marginal facies of a pluton. Farther north, in the Cracow-Banana area, Shell (Queensland) Development Pty Limited (Schneeberger, 1942), have also recognized a zone of hypabyssal to extrusive rocks related to the granodiorite.

## GEOLOGIC HISTORY AND STRUCTURE

The structure of the area reconnoitred is related to the successive evolution of three units, the Tasman eugeosyncline, the Bowen miogeosyncline, and the Great Artesian downwarp, of which the Surat Basin is a part (Pl. 2). Since rocks older than late Devonian were not investigated in the survey, the older history of the Tasman Geosyncline is not considered here; suffice it to say that the Queensland portion of the geosyncline probably originated at the end of the Ordovician (Hill et al., 1960, p. 6). Throughout most of the Palaeozoic, the Tasman Geosyncline was the focus of marine deposition in eastern Australia. During late Devonian to early Permian time, the axis of the geosyncline in New South Wales probably bisected the present position of the New England Batholith; this is suggested by the areal distribution of the Bangheet Formation in this region. Farther north in Queensland, the position of the axis during this time is speculative. It is suggested that the continuity of marine sedimentation across the Tasman Geosyncline in southern Queensland during the Carboniferous was broken by an archipelago extending north-north-west from the Inglewood-Warwick district to the northern end of the present outcrop of the Auburn Complex. The fact that Kuttung or Cracow volcanics were drilled in both Cabawin No. 1 and Moonie No. 1 in a position east of the palaeogeographic shoreline suggested along the Kuttung-Bangheet contact farther south supports this hypothesis.

Between the archipelago and the eastern side of the Springsure district, marine sedimentation was probably continuous in what was subsequently to become the Bowen Basin. The Kuttung-Bangheet 'strand line' is trending north-north-west where it disappears beneath the Great Artesian Basin between Warialda and Moree, New South Wales. If this line were extrapolated north under the Great Artesian Basin it would reappear along the eastern side of the Springsure district. The stratigraphy of the Carboniferous in the Springsure region lends validity to this extrapolation. South-east of Springsure, Carboniferous (?) paralic rocks were drilled in Oil Search Limited Hutton Creek No. 1, in a position unconformably below Permian rocks; whereas west of Springsure the exposed Carboniferous section is terrestrial volcanics and freshwater sediments considered equivalent to the Kuttung. Marine sedimentation was also continuous in the geosyncline east of the archipelago. This is suggested by a thick sequence of marine Carboniferous rocks exposed in the Yarrol-Rockhampton district of Queensland.

In late Carboniferous/early Permian time, the Tasman Geosyncline was disrupted. Uplift began south of an old line of weakness in the basement, the Darling-Brisbane Shear Zone, and to a lesser extent along the line of the old Carboniferous archipelago. Faulting took place along the shear zone and along subsidiary lines of weakness parallel and conjugate to the shear zone both in the uplifted area to the south and along a spine of land which replaced the old archipelago. This faulting resulted in a pattern of horsts and grabens. The emplacement of the New England Batholith and other Permian intrusives south of the shear zone was probably controlled by this block faulting. Large meridional folds were developed off the western flank of the New England Batholith concurrent with its intrusion. As compensation for intrusion of this batholith on the east and intrusion and uplift of the Brewarrina Spur on the west, a large block was downdropped to form the north-plunging Namoi Graben. Subsidiary block faulting within the Namoi Graben subdivided it into a series of parallel horsts and grabens.

During Back Creek time, the sea occupied the depositional axis of the marine Carboniferous west of the old archipelago. Gradually this sea encroached on the spine of land to the east and transgressed as far south as the northern end of the Namoi Graben: the lower part of the Back Creek Formation is missing in Cabawin No. 1, and the upper part lies on an old erosion surface. Tongues of Kianga Formation drilled in the Back Creek in the Cabawin wells suggest the approach to a shoreline in the south-east. By Kianga time, the Back Creek sea had withdrawn, and was relatively stable; the lithological facies of the Kianga and its relatively constant thickness over wide areas suggest stability.

By early Triassic time, as a result of compression from the east, uplift began along and east of the site of the old Carboniferous archipelago. Concurrently downwarp began in the Bowen miogeosyncline. The rocks of the Cabawin Formation were derived from the uplifted areas to the east; movement was renewed along old lines of weakness parallel and conjugate to the Darling-Brisbane Shear Zone. The intrusion of the Auburn Complex along the mobile front of the geosyncline was probably localized by this pre-existing fault pattern. The miogeosyncline was bordered on the west, in the Roma-Springsure district, by a relatively stable shelf and on the south-east, by the New England Batholith. To the south, within the Namoi Graben, folding and faulting were renewed. The intensity of deformation diminished southward up the plunge of the graben on the "positive" element stabilized during the breakup of the Tasman Geosyncline.

The downwarp of the Bowen miogeosyncline is mirrored by the Cabawin Formation: the lithological character of the formation suggests 'fill' deposition, and seismic survey shows that the relative thickness of the formation directly reflects the structural relief in the miogeosyncline. The stability of the Roma area during Cabawin time is confirmed by our seismic survey, which shows a marked thinning of the Cabawin Formation on to the Roma 'high'. Farther north, the lateral equivalents of the Cabawin Formation, the Rewan, Clematis and Moolayember Formations, suggest shelf-type sedimentation. In the south-east, the change in strike of structures from a northerly to north-east trend reflects the buttressing effect of the New England Batholith.

By the end of Cabawin time, isostatic equilibrium was reached in the Bowen Basin. The miogeosyncline had been base-levelled by reason of the fill of the Cabawin sediments, and the easterly mobile belt had been stabilized. Parts of the mobile belt as well as the New England Batholith and the Brewarrina Spur in the south stood above the base-levelled basin. In this setting, the rocks of the Great Artesian Group were deposited in widespread inland seas and swamps with varying amounts of overlap on to the high areas. Along the eastern margin of the Surat Basin, the outcrop pattern of the Bundamba Formation suggests a progressive overlap to the south-east. On the southern margin of the basin, rocks of the Great Artesian Group thin, the older rocks of the group are overlapped, and facies changes make the units mapped to the north unrecognizable.

In Tertiary time, basalts were extruded from local centres of vulcanism, and there was a slight rejuvenation of movement along zones of weakness parallel and conjugate to the Darling-Brisbane Shear Zone. The outcrop pattern of Tertiary sandstones locally reflects structure in rocks of the Bowen Group and suggests this rejuvenation.

## Faults

Darling-Brisbane Shear Zone and parallel trends: Hills (1955, p. 4-6) described the Darling Lineament as along the course of the Darling River across the western plains of New South Wales. To the south-west, he showed that a continuation of the lineament coincided with the boundary of Precambrian outcrop south of Broken Hill, and that here geophysics indicated a major fault continuous with the lineament. He further pointed out that between Wilcannia and Bourke, the geological boundaries between Palaeozoic and Mesozoic rocks lie approximately along the Darling River. Hills extrapolated this lineament farther east along the Darling River to St George and then to Chinchilla. The author considers Hills' lineament along the Darling River and to the south-west a valid structural line, but does not agree with his extrapolation of the line eastward. The Darling Lineament if extrapolated east roughly parallels the lower course of the Weir River and from there passes south of Millmerran and Brisbane. The lineament probably reflects an old zone of shearing and is therefore named the 'Darling-Brisbane Shear Zone' (Pl. 2).

In the southern part of the Surat Basin, the northern limit of the shear zone is defined by the Weir Lineament (Pl. 1). This lineament follows a topographic break across the northern end of the Weir Inlier and marks the southern limit of a relatively thick sequence of Tertiary sandstones. Farther east the lineament still follows the topographic break, and here the break is coincident with the Blythesdale contact along the southern flank of the Weir Anticline. In this vicinity the lineament also defines a drainage divide. Residents of the region note that south of the topographic break water can be drilled at shallow depth, whereas north of it there is an area of little shallow water. In the same district, Whitehouse (1955, p.14, Fig. 41) writes that the Weir River marks a prominent change in geology, since subsurface water pressures differ on either side of the river as also does the availability of shallow water.

Still farther east, the Darling-Brisbane Shear Zone is reflected by faulting in the ridge south-west of Millmerran and by the termination of the New England Batholith. In this vicinity, the structural grain of the Palaeozoic rocks is approximately east-west, in contrast to the predominant northerly grain farther south, and, as discussed earlier, these rocks are metamorphosed to a greater extent than those to the south. These changes in the Palaeozoic rocks may be evidence of the shear zone. Between the northern end of the New England Batholith and Brisbane, suggested offsets in Tertiary basalts and an offset in the Palaeozoic rocks near the coast are also possible indications of the shear zone (Tectonic map of Australia, 1960).

Near the northern end of the New England Batholith, a re-entrant in the granite south of Warwick suggests a possible east-west shear parallel to the major shear zone. Extrapolated east, this lineament is continuous with alignments of Tertiary basalt, and, extrapolated west, it is coincident with the zone where the structural grain of the Palaeozoic rocks changes from north-south to east-west. Farther south a parallel lineament follows a re-entrant in the granite margin near Drake, and, to the west, bounds a westward extension of the granite and is continuous with the Hetherington Fault Zone mapped in this survey (Pl. 1).

Along the eastern margin of the Bowen geosyncline, the structural hinge of the basin is offset locally by faults parallel to and genetically related to the Darling-Brisbane Shear Zone.

Faults conjugate to the Darling-Brisbane Shear Zone: Faults conjugate to the Darling-Brisbane Shear Zone strike in a northerly direction. This fault set localized the Namoi Graben. On the eastern side of the graben, seismic survey indicates a major north-striking normal fault (Goondiwindi Fault) in the Goondiwindi area (Pl. 1.), east of which and south of the Weir Lineament, the basement is probably at shallow depth. On the western side of the Namoi Graben, the Thomby-Walgett Lineament suggests a major fault marginal to the Brewarrina basement spur. This lineament strikes north-north-east and, farther north, controls the lower course of the Moonie River, is continuous with the Thomby Range, and marks the eastern margin of the Surat Inlier. West of the Surat Basin, the Nebine and Eulo Ridges also trend north-north-east and may have been uplifted along faults conjugate to the Darling-Brisbane Shear Zone.

Along the western margin of the New England Batholith, a north-striking zone of high-angle reverse faulting was mapped east of Bingara (Bingara Fault Zone). The zone has been mapped by other geologists from the vicinity of Warialda to Tamworth; belts of serpentine attest to the intensity of deformation.

Along the eastern margin of the Bowen Basin, a structural hinge separates the mobile front of the geosyncline from the miogeosynclinal belt. The hinge trends north-north-west and probably reflects an old line of weakness in the basement conjugate to the Darling-Brisbane Shear Zone. Seismic survey indicates that rocks of the Bowen Group are truncated along it. In the Surat Basin the hinge is presently masked by overlapping rocks of the Great Artesian Group.

North of the Surat Basin, the hinge roughly parallels the course of the Dawson River and the Auburn Complex, the north-north-west belt of folded Permian and early Triassic rocks marks the hinge area. These rocks are complicated by north-westerly reverse faults and by tear faults which trend at right angles to the reverse faults and are clearly marked in outcrop by offsets in the Permian rocks.

## Folds

Western flank of the New England Batholith: Large 'Appalachian type', parallel, north-striking open folds are reflected in the Horton Group along the western flank of the New England Batholith (Pl. 6). Westward off the batholith, the crests of these folds are at progressively lower structural positions, and the folds themselves become more open. Topographically, the flanks of the folds are expressed in long, elongate meridional ridges. Between Bingara and Narrabri, these folds are well defined and relatively unbroken except for two normal faults on the west flank of the Terragee Anticline. The folds plunge to the north, and farther north are complicated by numerous small subsidiary folds and minor faults. They are assumed to die out south of the Darling-Brisbane Shear Zone.

Southern part of the Bowen Basin: The major structural feature in the southern part of the Bowen Basin is the Leichhardt Syncline, whose axis reflects the axis of the Bowen miogeosyncline. The Syncline trends north to slightly west of north; north of the Miles-Roma road it is well defined by a progressive succession of outcropping older beds from the centre to the eastern and western flanks. Seismic survey indicates that beneath the Great Artesian overlap, the configuration of the Bowen miogeosyncline is that of two structural depressions which plunge north and south respectively off a line of culmination which approximates the position of the Great Dividing Range north of the Miles-Roma road.

Along the south-east margin of the Bowen Basin, there is a pronounced change in the strike of structures from a northerly to a north-easterly trend (Pl. 1). In this area, compressional forces acting from the north-east against the buttress formed by the New England Batholith produced complex faulting in rocks of the Bowen Group. Seismic survey shows that, here, folds in rocks of the Great Artesian Group are localized by fault blocks in the older rocks. These folds plunge to the south-west.

Inliers (Roma Formation): The Roma and Surat Inliers reflect shallow basement. Wells drilled in the Roma area have confirmed the presence of shallow granite, and potassium-argon dating of the granite marks an emplacement at about the base of the Middle Devonian. The Surat Inlier is coincident with the southward extension of the Roma "high". Seismic work indicates that the Dulacca-Drillham Inlier reflects an anticline in rocks of the Bowen Group. The significance of other inliers in the basin is not yet known.

## PETROLEUM SOURCE AND RESERVOIR ROCKS

The marine Back Creek Formation is the most probable source rock for any oil accumulation in the Surat Basin. The rocks of the marine Bangheet Formation, where undeformed in basinal positions, might also act as source beds.

On the basis of lithology, the porous quartzose sandstones of the Bundamba and Blythesdale Formations are the most favourable reservoir rocks. The Blythesdale Formation at present is not considered a target, because nowhere in our exploration to date has the formation been found in a setting favourable to the accumulation of oil. Wells drilled in the Surat Basin have proved the potential of the Bundamba Formation as an oil reservoir. Gas and minor amounts of condensate have been produced from the formation in wells on the Roma "high". On initial production tests of short duration Union-Kern-A.O.G. Moonie No. 1 on 23rd December, 1961 flowed at a rate of 2196 bbl/day of 48° A.P.I. crude from sandstones of the Bundamba Formation. Porosites in sandstones of the Bundamba Formation in the three initial wells drilled by Union-Kern-A.O.G., range up to 24 percent and permeabilities up to several hundred millidarcys.

Although the highly tuffaceous nature of the Kianga Formation does not suggest good reservoir rock, thin porous zones in the formation have accumulated oil. On sustained production tests, Union-Kern-A.O.G. Cabawin No. 1 produced 62 bbl/day of 48° A.P.I. crude from sandstone of the Kianga Formation. Several horizons of tuffaceous sandstone, similar to that in the Kianga, were mapped in the Back Creek Formation, and these could also be considered limited reservoirs. The Cabawin Formation has only limited reservoir potential, although thin porous streaks were drilled in the formation in the Cabawin wells. The sandstones and conglomerates of the formation have an abundant reworked ash matrix, and they lens in and out erratically along strike.

The Bangheet Formation in outcrop is not attractive as a reservoir rock. The massive Viséan limestones of the formation, where least affected by intrusion of the New

England Batholith, are dense, lithographic to sublithographic, and have no reservoir potential. The oolitic limestones, which crop out as erratic lenses near the Kuttung contact, show no porosity and tongue out laterally into tight tuffaceous sandstones. The sandstones of the formation, where unaffected by intrusives and faulting, are tight, poorly sorted, and have a dirty, tuffaceous matrix. The Kuttung Formation is not considered a suitable reservoir rock as volcanic flows, tuffs, and highly tuffaceous clastics characterize the unit.

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## PALAEONTOLOGICAL APPENDIX

Fossils collected in the course of the survey were determined by Professor Dorothy Hill, H.O. Fletcher, N.J. de Jersey, and J.E. Mack. The localities from which collections were made are shown on Plate 1.

### MACROFAUNA

#### Warialda-Narrabri district, N.S.W.

Determinations and comments by Professor Dorothy Hill*

AMa.244F Leptaena ? sp.
Algae and crinoidal fragments
Age: Lower Carboniferous.

AMa.245F Parallelodon sp.
Nuculana ? sp. (partial external mould)
Cladochonus sp. (external mould)
Prospira ? sp.
Yvania ? sp.
Age: This assemblage is Lower Carboniferous.

AMa.284F Crinoidal fragments
Rhipidomella australis - 2 specimens
Schellwienella sp. cf. merlewoodensis
Age: This association of brachiopods indicates a Lower Carboniferous age, probably upper Tournaisian or basal Viséan.

AMa.285F Aphrophyllum sp. cf. foliaceum
Michelinia sp.
Calical plate of crinoid
Cladochonus sp.
Cyathaxonia ? sp. - small solitary Rugosa with columella but without dissepiments - the cross-section somewhat resembles that of single corallites of Lithostrotion.
Barrandeophyllum ? sp.
Polyzoan.
Age: The association is Lower Carboniferous, and is probably somewhere near the boundary between Tournaisian and Viséan.

AMa.289F Echinoconchus gradatus
Schellwienella sp.
Age: Lower Carboniferous, possibly basal Viséan.

AMa.291bF Crinoidal columnal
Age: Indeterminate.

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* University of Queensland, Brisbane.

AMa.296F Indeterminate shell and crinoidal debris in oolitic limestone.
Age: Indeterminate.

AMa.297F Small solitary rugose coral with short thin minor septa, with dissepiments but without columella.
Age: Probably Lower Carboniferous.

## Texas-Glenlyon district, Queensland

(a) Determinations and comments by Professor Dorothy Hill

AMa.190F Anidanthus springsurensis (abundant)
Cancrinella sp.

This is the characteristic pair of the Lower Permian Silver Spur Beds of the Texas district. The fauna lies somewhere in the Dilly/Cattle Creek range of the Springsure district, and is probably a little younger than the Cracow Homestead fauna in the Dawson Valley, but older than the Flat Top and Orange Creek faunas.

AMa.191aF Gastropod - Keenia ?
Age: Probably early Permian.

AMa.191bF Spiriferid sp. indet.
Indeterminate solitary rugose coral
Fenestellids
Small Spiriferellina
Crinoidal detritus
Anidanthus springsurensis
Age: Lower Permian. Probably equivalent to Silver Spur Beds.

AMa.195F Spiriferid with triplicate ribs
Young lamellose spiriferid
Astartila ? sp. with concentric ribs
Age: Permian. Insufficient for giving position within the Period.

AMa.204F Streblochondria ? sp.
Indeterminate internal mould of spiriferid
Age: Probably Permian.

AMa.205F Crinoidal detritus
Age: Indeterminate.

AMa.212F Impure limestone with fenestellids and crinoid plates
Age: Indeterminate, Upper Palaeozoic.

AMa.213F Crinoidal detritus
Age: Indeterminate.

(b) Determinations and comments by Dr. H.O. Fletcher*

$AM^c$14F

Anidanthus springsurensis (Booker). Small shells about 10 mm high, 33 mm wide and 15 mm thick; maximum width along hinge-line, geniculate. Ornamented with even radiating costae.

This species appears to be abundant at locality $AM^c$14F. It has a wide distribution in the Lower Permian rocks of Queensland and New South Wales and it is most unlikely that it ranges into the Carboniferous.

It is common at Springsure at the top of the southern extension of the Dilly Beds in the Serocold Anticline and also at the top of the marine sequence of Yarrol, Burnett District. The species is also common in the First (or Phoenix or Maitland) Slate at Dawn Pocket on the Gympie Goldfield and in the somewhat higher Upper (or Top) Limestones of various localities. Other localities include Lake's Creek Quarry, Rockhampton, and near the base of the marine sequence at Mt Britton. It has also been recorded from a locality 4 miles east of Texas and nearby at Silverwood, where it occurs in the Stanthorpe Road Block near the base of the sequence. These localities are generally equivalent to the Dilly Beds of the Springsure area.

In New South Wales the species forms two well marked zones in the Lower Permian rocks of the Manning-Macleay Province, one below the Yessabah Limestone and one in the Warbro Stage above the limestone.

Spirifer sp. indet. A single specimen consisting of a small portion of an internal cast but indicating a Permian species.

Cancrinella farleyensis (Etheridge & Dun). Large concave-convex geniculate shells with transverse wrinkles strong on the umbonal slopes and ears and with numerous spines.

This species is represented by a single central valve, slightly larger than typical specimens, and showing little or no trace of spines (due to weathering).

The species is found in the Springsure district at Little Gorge Creek and Cattle Creek, in the southern extension of the Dilly Beds in the Serocold Anticline; at Mt Britton in association with A. springsurensis; and also with that species at several localities in the Middle Gympie Group of Dunstan, in the Top Limestone and First or Phoenix Slate; Cracow limestone at Cracow Homestead, Dawson River; Lake's Creek Quarry and vicinity at foot of Mt Beserker, Rockhampton district, and also at Yarrol Station, Burnett District.

In New South Wales the species is found in the Farley Stage and in the Macleay and Drake series of the Northern Rivers area.

$AM^c$15F

Anidanthus springsurensis (Booker). Remarks as above.
Crinoid stems. No stratigraphic significance.

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* Australian Museum, Sydney.

(c) Determinations by J.E. Mack

Fossil collection seen at Glenlyon Homestead (Specimens collected at the Homestead).

Eurydesma sp. (?)
Gastropod with subquadrate whorls
Spirifer sp.
Crinoid stems.

Cracow-Banana district, Queensland

(a) Determinations and comments by Professor Dorothy Hill

AMa.100 Crinoid columnals
Streblochondria ? sp.
Age: Permian.

AMa.101 Crinoid columnals
Age: Permian.

AMa.114 N.E. of Theodore on Lonesome Creek Road.
Terrakea sp. This is very like the species in Core No. 42 from Cabawin No. 1.
? Lissochonetes sp.
Age: Permian.

AMa.134F Cladochonus nicholsoni
Neospirifer sp. with unit ribs
Trigonotreta sp. as from Oxtrack Creek Limestone on road 1 1/2 miles west of Cracow Village.
Ingelarella sp. as from Oxtrack Creek Limestone.
Cancrinella sp.
Stenopora sp.
Fenestella sp.
Age: Permian. This fauna correlates well with that of the Oxtrack Creek Limestone outcropping on the road from Cracow to Theodore, 1 1/2 - 2 miles from Cracow Village.

Ama.135 Crinoid columnals
? Strophalosia
Fenestellid fragments
Age: Permian. May correlate with Oxtrack Creek Limestone as of AMa.134F, but evidence very weak.

AMa.139 Crinoid columnals.
Age: Permian. May correlate with Oxtrack Creek Limestone but evidence extremely weak.

AMa. 140F Stenopora sp.
Thamnopora wilkinsoni
Cladochonus nicholsoni

This collection is in the facies and has the fauna of the Ingelara Formation of the western side of the Bowen Basin. But being a facies fauna it could recur at different horizons. I consider it younger than the Cracow Homestead Limestone and probably older than the Oxtrack Creek Limestone.

AMa.142 Large crinoid columnals
Fenestella sp.
May correlate with Oxtrack Creek Limestone, but evidence is extremely weak.

AMa.143F Trachypora wilkinsoni
May correlate with AMa. 140F

AMa.144F Crinoid detritus
Age: Permian.

AMa.157F Crinoid detritus
Fenestellid detritus
Terrakea solida
Productid spines
Ingelarella sp.
Euryphyllum sp. indet.
May correlate with Oxtrack Creek Limestone, but evidence is weak.

AMa.171F Neospirifier sp. - transverse form similar to one from Mantuan Formation of Nardoo, on the western edge of the Bowen Basin.
Trigonotreta sp. - triple ribbed - a high form.
May correlate with Mantuan or Flat Top Formations.

AMa.172F Trigonotreta sp.
Terrakea sp.
Age: Permian.

AMa.176F Taeniothaerus subquadratus
Eurydesma ?

The Cracow Homestead Limestone at the base of the marine sequence of the Cracow area.

AMa.180F Trachypora wilkinsoni
Cladochonus nicholsoni
Indeterminate small lamellibranchs
May possibly correlate with AMa.140F.

AMa.181F Spirifer with plaited ribs
Crinoid columnals
Age: Permian.

(b) Fossil collections by Shell (Queensland) Development Pty Limited from type section of Back Creek 'Series' - determinations by Professor D. Hill (Schneeberger, 1951)

Basal, Back Creek (150 ft)-

Euryphyllum gregorianum (Eth.)
Euryphyllum reidi forma elongata nov.
Chonetes sp.
Horridonia mitis Hill
Martiniopsis sp. nov.
Martiniopsis subradiata
Neospirifer stokesi
Spirifer sp.
Spirifer tasmaniensis Morris
?Strophalosia sp.
Taeniothaerus subquadratus (Morris)
Terrakea pollex Hill
Astartila ? pusilla (McCoy)
Eurydesma cordatum Morris
Eurydesma cordatum var. sacculum
Eurydesma hobartense Johnston
Deltopecten ? illawarraensis
Modiola sp.
Platyschisma oculum Sowerby

Lower Back Creek (3000 ft) -

Cladochonus nicholsoni Eth.
Martinia sp.
Martiniopsis sp.
Neospirifer tasmaniensis Eth.
Strophalosia sp.

Middle Back Creek (600 ft) -

Corals

Upper Back Creek (1850 ft) -

Chaenomya mitchelli de Koninck
Streblochondria ? englehardti

FLORA

Ashford coal mine, near Ashford, N.S.W.

Determinations and comments by N. J. de Jersey*

$AM^c24Mf$ Inaperturopollenites sp.
Leiotriletes directus
Calamospora diversiformis
Granulatisporites trisinus
Granulatisporites micronodosus
Entylissa vetus

---

* Geological Survey of Queensland.

Verrucosisporites sp.

The presence of Granulatisporites trisinus, G. micronodosus, and Entylissa vetus indicates a Permian age for the sample. These species are all long ranged and have been recorded from both the Greta Coal Measures and Upper Coal Measures in New South Wales, so that no determination of the horizon of the sample within the Permian is possible. In the U-K-A. Cabawin No. 1 Well they were recorded from samples of Permian age, but did not extend up into the Triassic portion of the sequence.

AMa.230Mf Leiotriletes directus
Verrucosisporites sp.
Entylissa vetus
Calamospora diversiformis
Granulatisporites micronodosus
Nuskoisporites gondwanensis
Apiculatisporites sp.
Granulatisporites cf. trisinus
Inaperturopollenites sp.

None of the species listed above is of restricted range within the Permian. Consequently the additional material submitted has not furnished any palynological evidence on the suggested correlation of the Ashford seam with the Kianga coal measures.

Nandewar Range, along road from Bingara to Narrabri, N.S.W.

AMa.308 Mf, 308b Mf, 326b Mf

These three samples have been examined but unfortunately in each case the yield of spores and pollen has proved to be negligible. In one sample (AMa.308Mf) leaf remains comparable with the species Glossopteris browniana have been identified. However this is a long-ranged species extending from Upper Carboniferous to Upper Permian, so that no more precise evidence on the age of these samples is forthcoming.

Kianga Coal Mine, Queensland

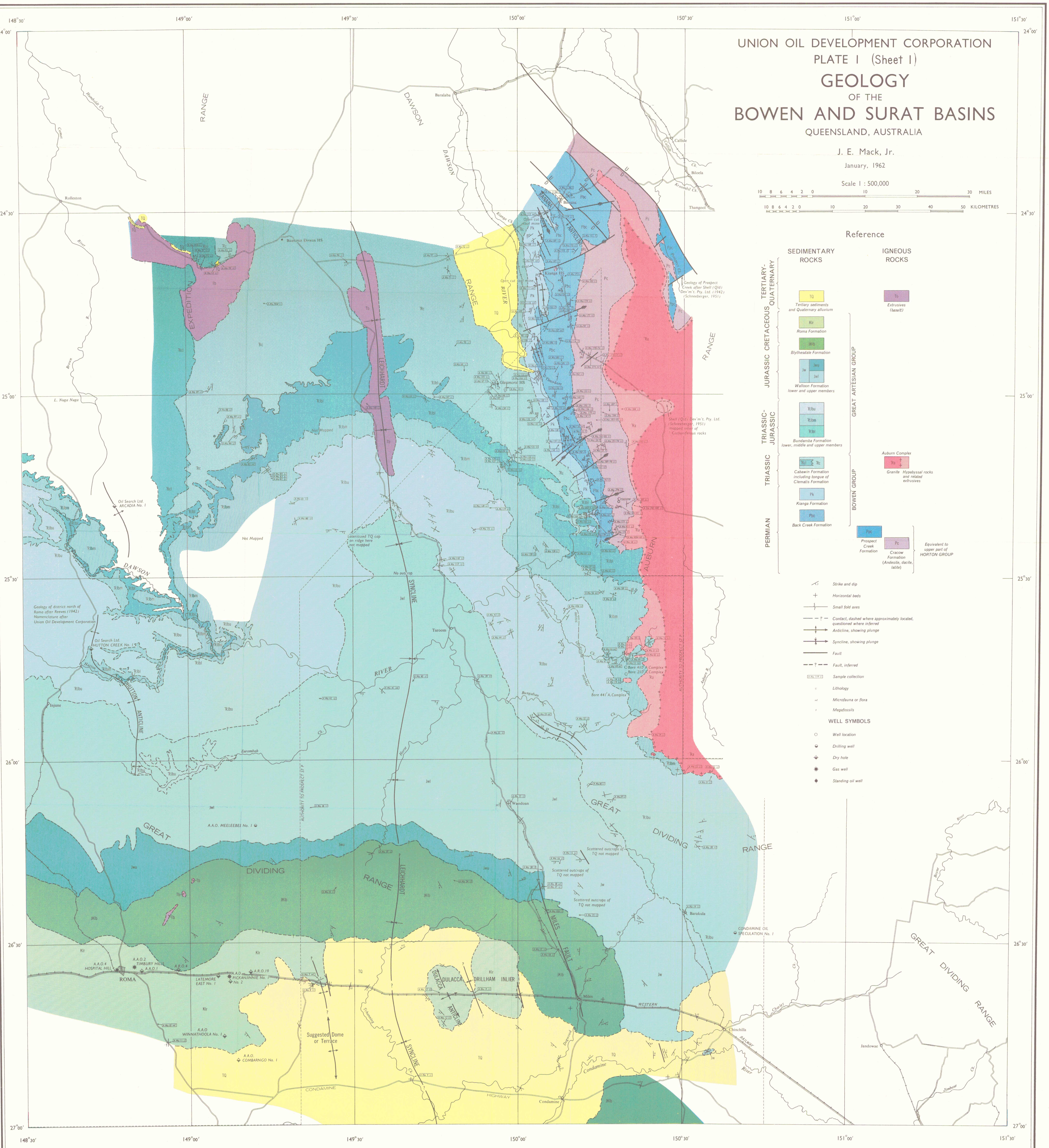
Two coal samples -

(a) Lueckisporites limpidus
Lueckisporites amplus
Lueckisporites cancellatus
Lueckisporites multistriatus
Apiculatisporites filiformis
Apiculatisporites levis
Acanthotriletes ericianus
Acanthotriletes cf. uncinatus
Entylissa vetus
cf. Pteruchipollenites sp.
Leiotriletes directus
Granulatisporites trisinus
Marsupipollenties sinuosus
Marsupipollenites triradiatus

This assemblage indicates a Permian age for the sample. The microflora is, in general character, similar to that of the Upper Bowen Coal Measures, with which the Kianga coals have been correlated.

(b) Lueckisporites limpidus
Lueckisporites amplus
Lueckisporites cancellatus
Apiculatisporites filiformis
Acanthotriletes ericianus
Entylissa vetus
Pteruchipollenites sp.
Leiotriletes directus
Marsupipollenites sinuosus
Marsupipollenites triradiatus
Verrucososporites cf. hamatus
Tuberculatisporites cf. modicus
Calamospora diversiformis
Florinites ovatus

This assemblage indicates a Permian age also for this sample. The slight differences between the assemblages from the two samples are not considered significant as species not common to the two lists are in all cases relatively rare and represented by only a few specimens. No species which are restricted to periods other than the Permian have been detected.




Drawn by Ruskin Cartographic Service, Melbourne

# UNION OIL DEVELOPMENT CORPORATION

PLATE I (Sheet 2)

# GEOLOGY

OF THE

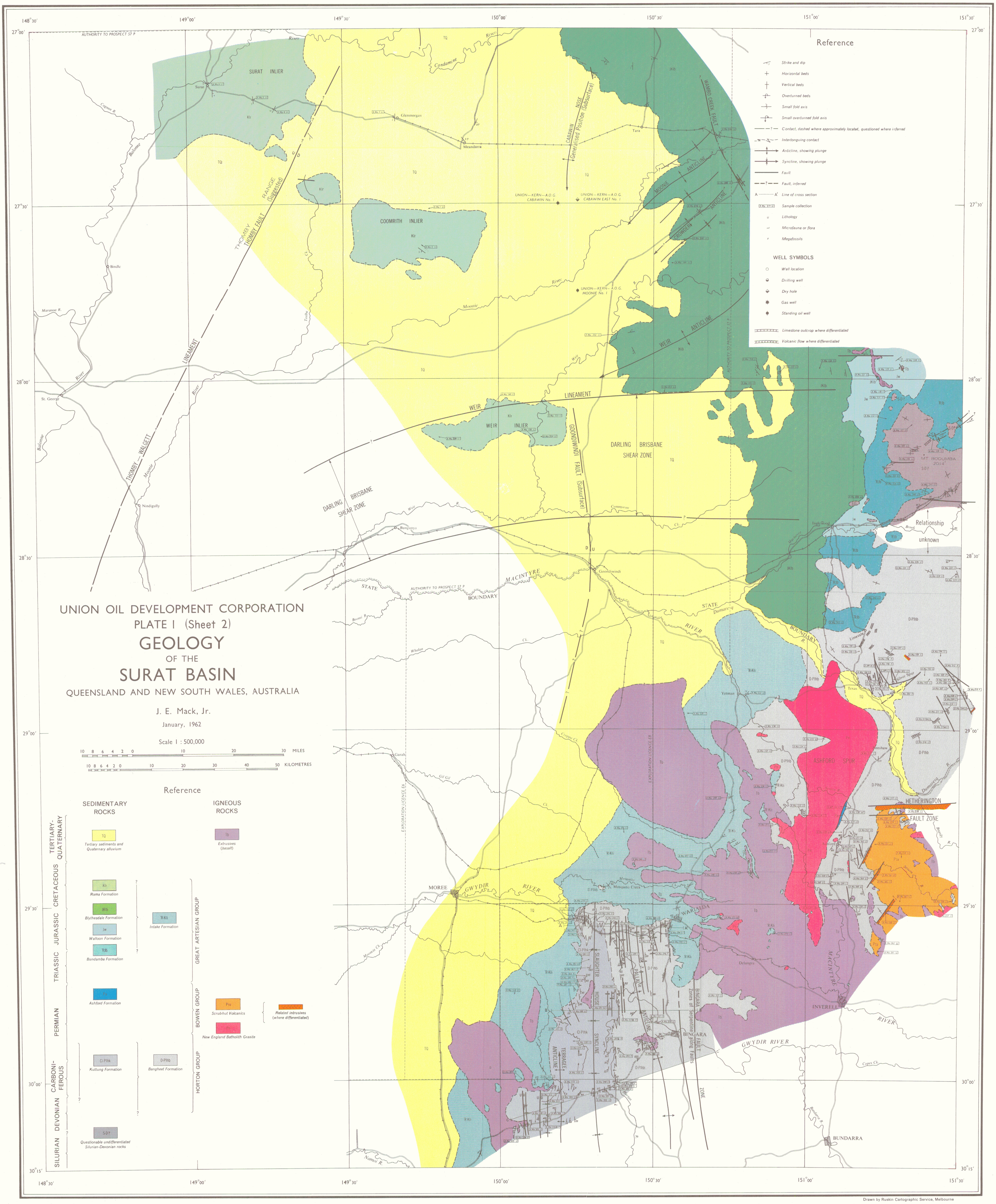
# SURAT BASIN

QUEENSLAND AND NEW SOUTH WALES, AUSTRALIA

J. E. Mack, Jr.

January, 1962

Scale 1 : 500,000




TQ Tertiary sediments and Quaternary alluvium

Klr Roma Formation

Jkb Blythesdale Formation

Jw Walloon Formation

Rb Bundamba Formation

TR-Kb Intake Formation

Pa Ashford Formation

Tb Extrusives (basalt)

Psv Scrubhut Volcanics

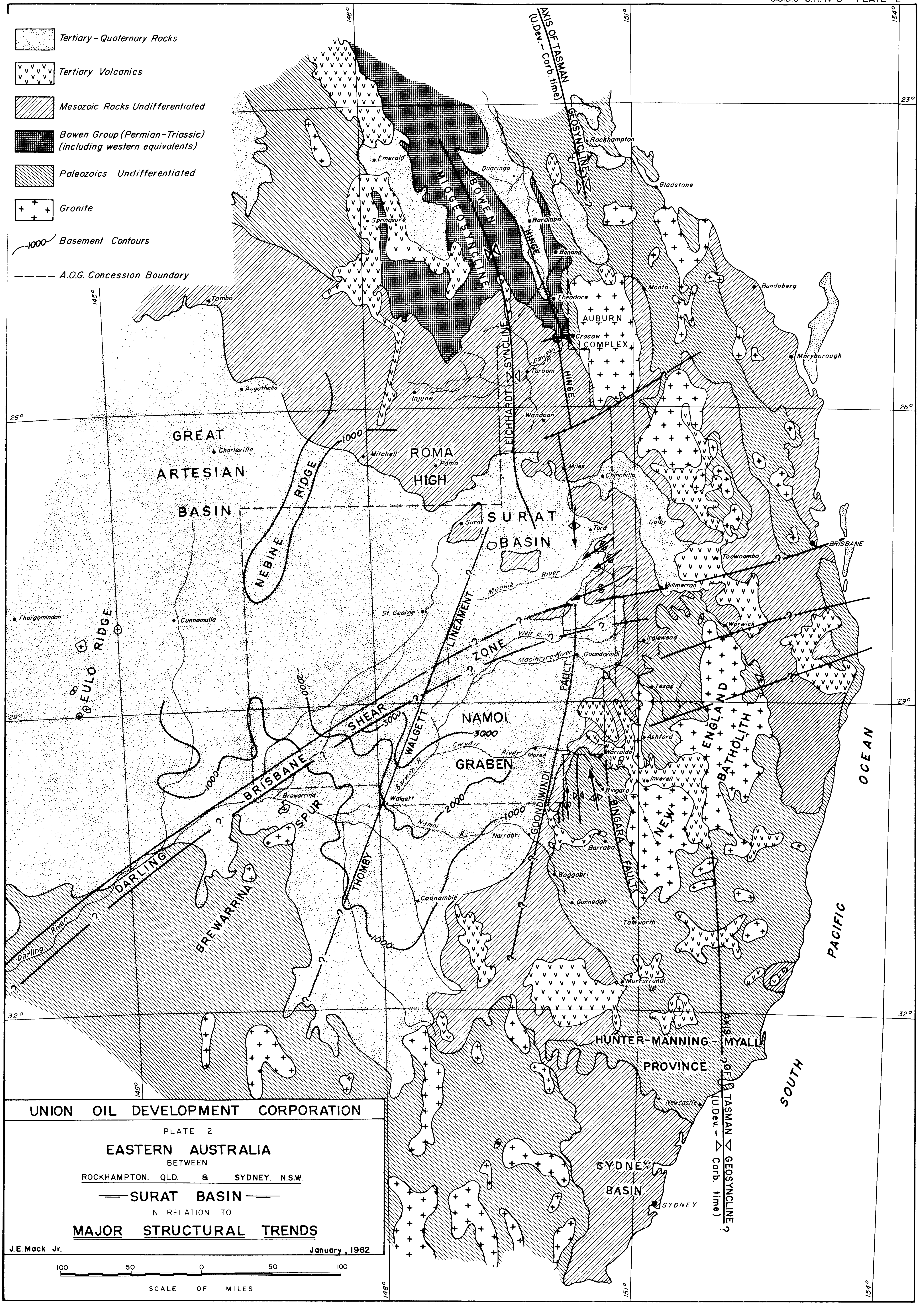
Png New England Batholith Granite

Related intrusives (where differentiated)

Cl-Plk Kuttung Formation

D-Pbb Bangheet Formation

SDY Questionable undifferentiated Silurian-Devonian rocks




UNION OIL DEVELOPMENT CORPORATION

PLATE 2

EASTERN AUSTRALIA

BETWEEN

ROCKHAMPTON. QLD. & SYDNEY. N.S.W.

—SURAT BASIN—

IN RELATION TO

MAJOR STRUCTURAL TRENDS

J.E.Mack Jr. January, 1962

100 50 0 50 100

SCALE OF MILES

UNION OIL DEVELOPMENT CORPORATION

# STRATIGRAPHIC CORRELATIONS in the SURAT BASIN and ADJOINING AREAS

U.O.D.C. GR. 8 PLATE 3

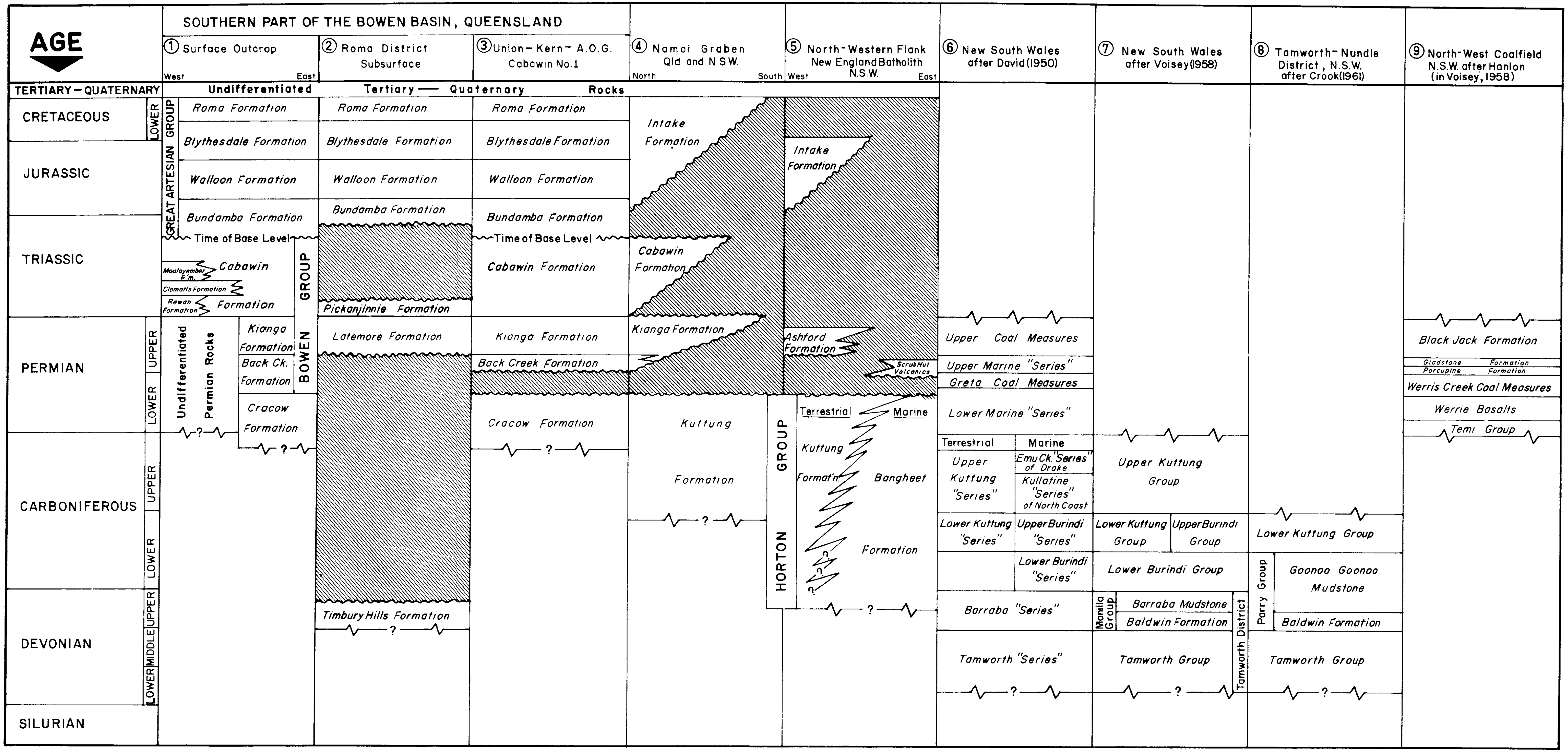
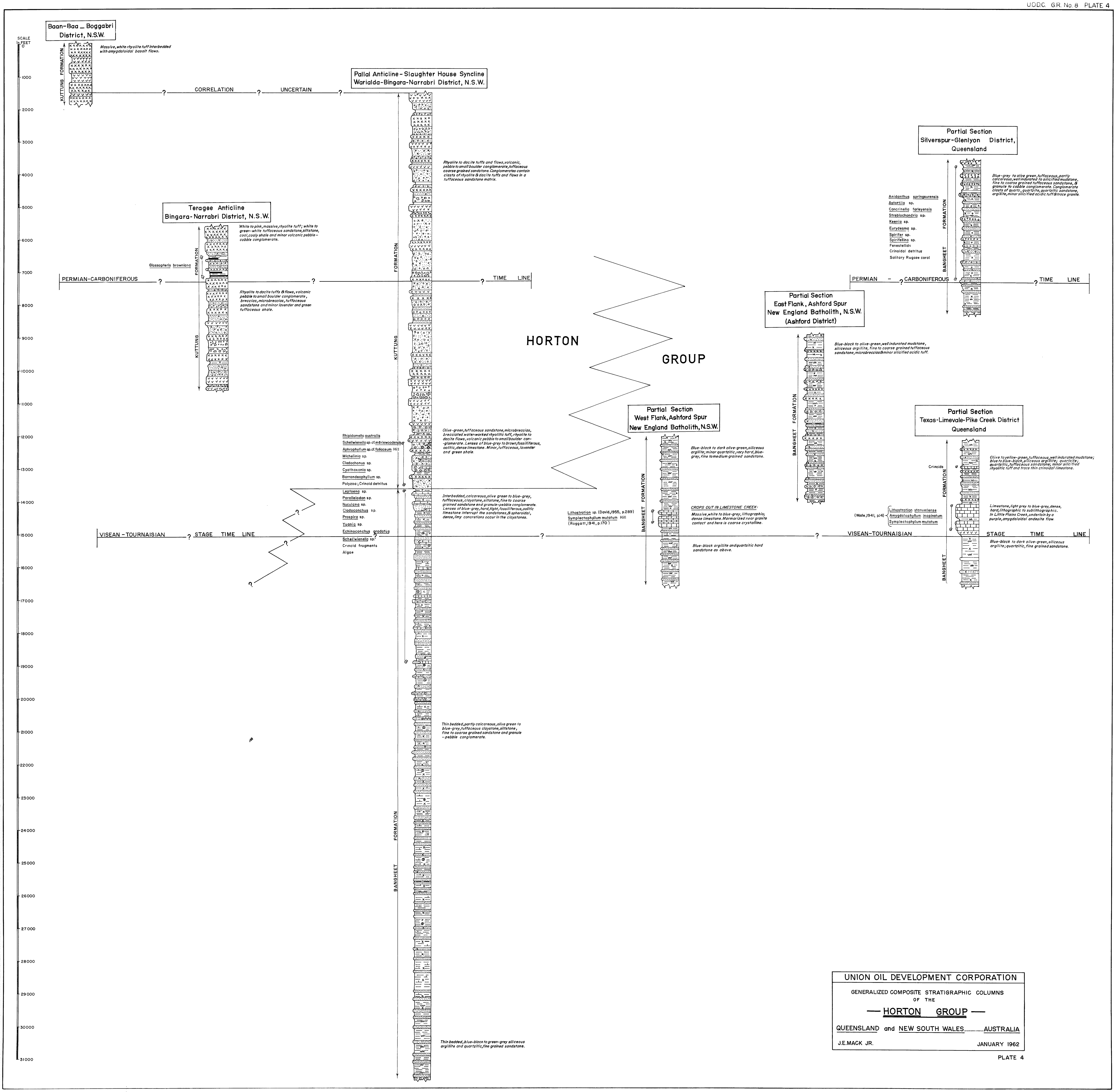



Fig. 1 is an index map to the correlation chart

J.E. MACK Jr. January, 1962


SCALE in FEET
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31000
Baan-Baa _ Boggabri District, N.S.W.
KUTTUNG FORMATION
Massive, white rhyolite tuff interbedded with amygdaloidal basalt flows.
? CORRELATION ? UNCERTAIN ?
Pallal Anticline - Slaughter House Syncline
Warialda-Bingara-Narrabri District, N.S.W.
Rhyolite to dacite tuffs and flows, volcanic, pebble to small boulder conglomerate, tuffaceous coarse grained sandstone. Conglomerates contain clasts of rhyolite & dacite tuffs and flows in a tuffaceous sandstone matrix.
Teragee Anticline
Bingara-Narrabri District, N.S.W.
White to pink, massive, rhyolite tuff; white to green-white tuffaceous sandstone, siltstone, coal, coaly shale and minor volcanic pebble-cobble conglomerate.
Glossopteris browniana
KUTTUNG FORMATION
PERMIAN-CARBONIFEROUS ? ? ? TIME LINE
Rhyolite to dacite tuffs & flows, volcanic pebble to small boulder conglomerate, breccias, microbreccias, tuffaceous sandstone and minor lavender and green tuffaceous shale.
KUTTUNG FORMATION
HORTON GROUP
Partial Section
Silverspur-Glenlyon District, Queensland
Blue-grey to olive green, tuffaceous, partly calcareous, well indurated to silicified mudstone, fine to coarse grained tuffaceous sandstone, & granule to cobble conglomerate. Conglomerate clasts of quartz, quartzite, quartzitic sandstone, argillite, minor silicified acidic tuff & trace granite.
Anidanthus springsurensis
Astartila sp.
Cancrinella farleyensis
Streblochondria sp.
Keenia sp.
Eurydesma sp.
Spirifer sp.
Spirifellina sp.
Fenestellids
Crinoidal detritus
Solitary Rugose coral
BANGHEET FORMATION
PERMIAN - ? CARBONIFEROUS ? TIME LINE
Partial Section
East Flank, Ashford Spur
New England Batholith, N.S.W.
(Ashford District)
Blue-black to olive-green, well indurated mudstone, siliceous argillite, fine to coarse grained tuffaceous sandstone, microbreccias & minor silicified acidic tuff.
BANGHEET FORMATION
Olive-green, tuffaceous sandstone, microbreccias, brecciated water-worked rhyolitic tuff, rhyolite to dacite flows, volcanic pebble to small boulder conglomerate. Lenses of blue-grey to brown, fossilliferous, oolitic, dense limestone. Minor, tuffaceous, lavender and green shale.
Rhipidomella australis
Schellwienella sp. cf. merlewoodensis
Aphrophyllum sp. cf. foliaceum Hill
Michelinia sp.
Cladochonus sp.
Cyathaxonia sp.
Barrandeophyllum sp.
Polyzoa; Crinoid detritus
Leptoena sp.
Parallelodon sp.
Nuculana sp.
Cladoconchus sp.
Prospira sp.
Yuania sp.
Echinoconchus gradatus
Scheilwienella sp.
Crinoid fragments
Algae
Interbedded, calcareous, olive green to blue-grey, tuffaceous, claystone, siltstone, fine to coarse grained sandstone and granule-pebble conglomerate. Lenses of blue-grey, hard, tight, fossiliferous, oolitic limestone interrupt the sandstones, & spheroidal, dense, limy concretions occur in the claystones.
Partial Section
West Flank, Ashford Spur
New England Batholith, N.S.W.
Blue-black to dark olive-green, siliceous argillite; minor quartzitic, very hard, blue-grey, fine to medium grained sandstone.
Lithostrotion sp. (David, 1955, p.289)
Symplectophyllum mutatum Hill
(Raggatt, 1941, p.170)
BANGHEET FORMATION
CROPS OUT IN LIMESTONE CREEK:
Massive, white to blue-grey, lithographic, dense limestone. Marmorized near granite contact and here is coarse crystalline.
Blue-black argillite and quartzitic hard sandstone as above.
Partial Section
Texas-Limevale-Pike Creek District
Queensland
Olive to yellow-green, tuffaceous, well indurated mudstone; blue to blue-black, siliceous argillite; quartzite; quartzitic, tuffaceous sandstone; minor silicified rhyolitic tuff and trace thin crinoidal limestone.
Crinoids
BANGHEET FORMATION
Lithostrotion stanvellense
(Wade, 1941, p.14) Amygdalophyllum inopinatum
Symplectophyllum mutatum
Limestone, light grey to blue-grey, dense, hard, lithographic to sublithographic. In Little Plains Creek, underlain by a purple, amygdaloidal andesite flow.
VISEAN-TOURNAISIAN ? STAGE TIME LINE ? ? VISEAN-TOURNAISIAN STAGE TIME LINE
Blue-black to dark olive-green, siliceous argilite; quartzitic, fine grained sandstone.
Thin bedded, partly calcareous, olive green to blue-grey, tuffaceous claystone, siltstone, fine to coarse grained sandstone and granule-pebble conglomerate.
BANGHEET FORMATION
Thin bedded, blue-black to green-grey siliceous argillite and quartzitic, fine grained sandstone.
UNION OIL DEVELOPMENT CORPORATION
GENERALIZED COMPOSITE STRATIGRAPHIC COLUMNS OF THE
— HORTON GROUP —
QUEENSLAND and NEW SOUTH WALES ......... AUSTRALIA
J.E. MACK JR.
JANUARY 1962
PLATE 4


UNION OIL DEVELOPMENT CORPORATION

CORRELATED STRATIGRAPHIC COLUMNS
OF THE

— PERMIAN ROCKS of the BOWEN GROUP —

QUEENSLAND AUSTRALIA

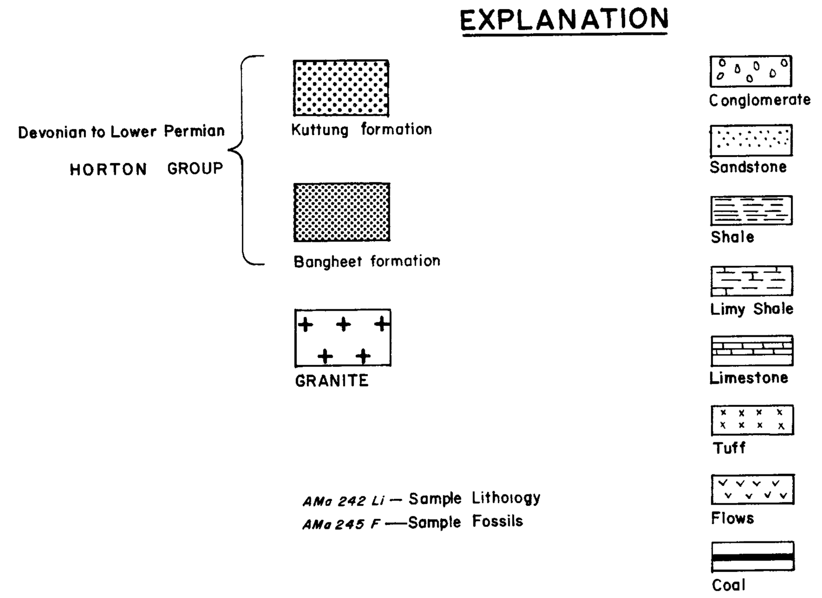
J.E. MACK JR. JANUARY 1962

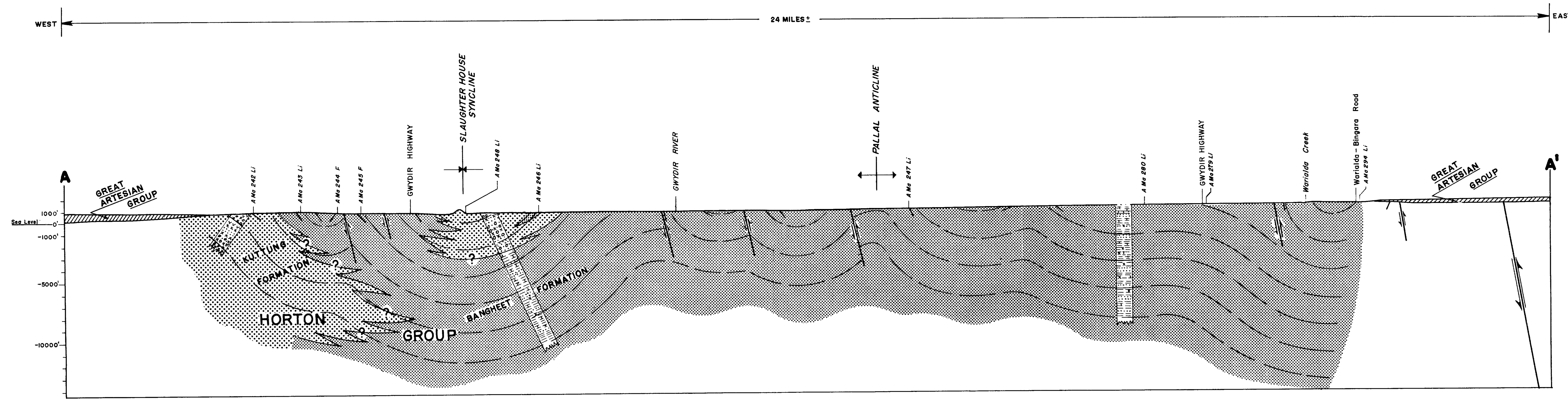
UNION OIL DEVELOPMENT CORPORATION

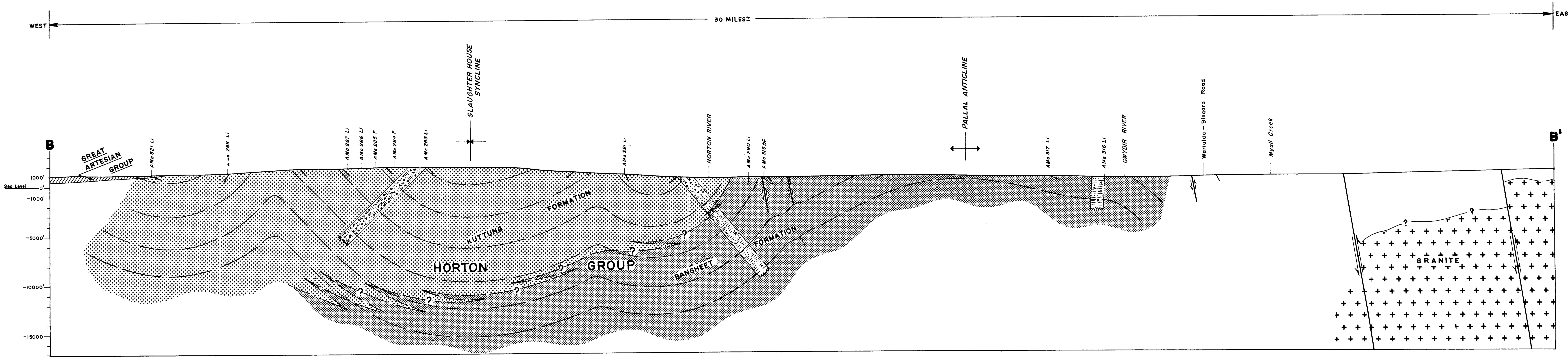
**STRUCTURAL CROSS-SECTIONS**
OF THE
**HORTON GROUP**
IN THE
**WARIALDA — NARRABRI AREA**
**NEW SOUTH WALES.............. AUSTRALIA**

J.E.MACK JR. JANUARY, 1962

## EXPLANATION





LOCATIONS OF SECTIONS SHOWN ON PLATE 1