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COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

RECORDS.

1962/49

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ADDITIONAL NOTES ON THE GEOLOGY OF THE CAMOOWEAL 4-MILE SHEET AREA.

by

M.A. Randal and G.A. Brown.

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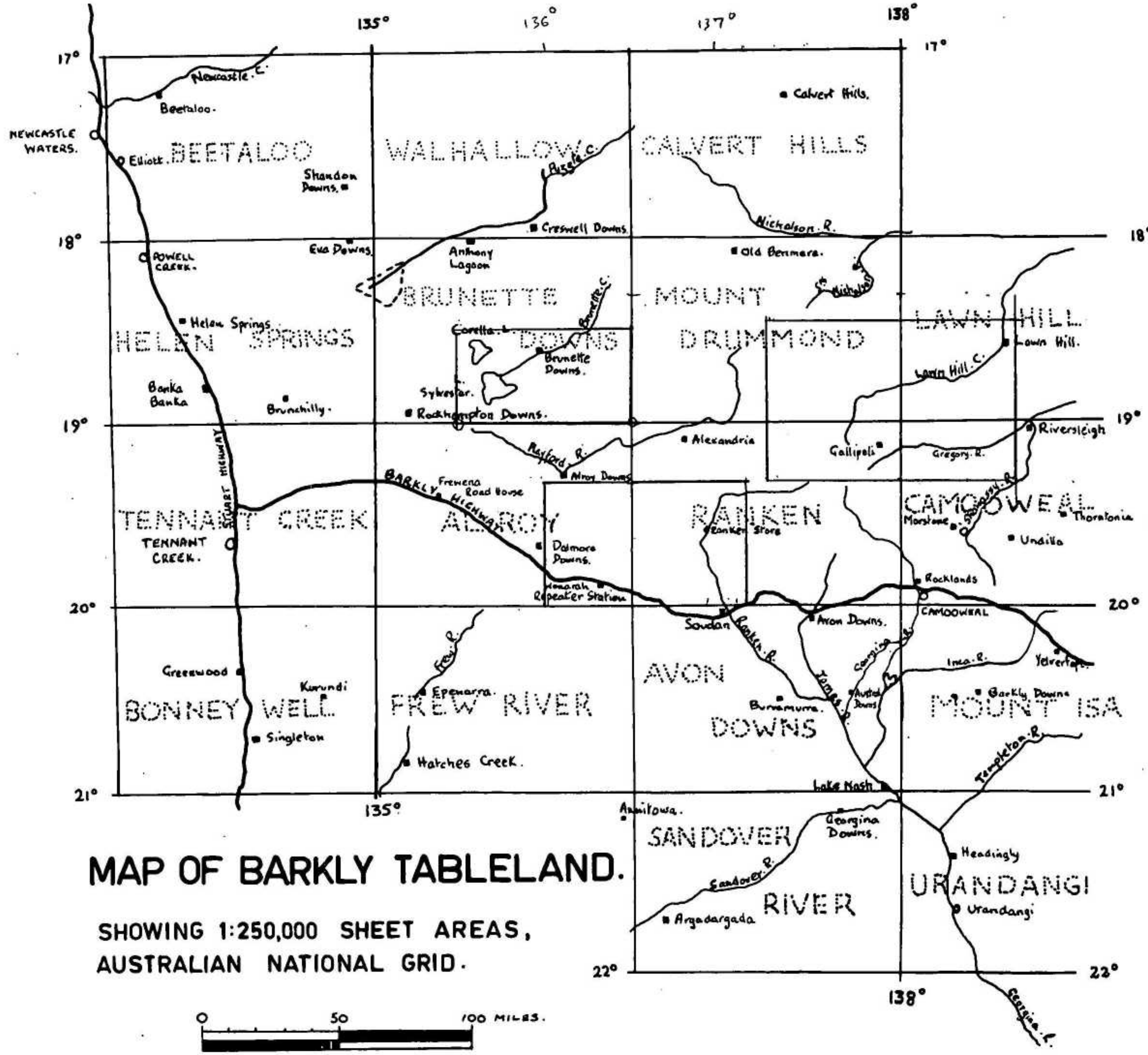
ILLUSTRATIONS

FIG. 1.



MAP OF BARKLY TABLELAND.

SHOWING 1:250,000 SHEET AREAS, AUSTRALIAN NATIONAL GRID.

0 50 100 MILES.

Bureau of Mineral Resources, Geology & Geophysics. April, 1962

To accompany Records 1962/49, 55, 56, 61.

ADDITIONAL NOTES ON THE GEOLOGY OF THE CAMOOWEAL 4-MILE SHEET AREA

by

M.A. Randal and G.A. Brown

RECORDS 1962/49

SUMMARY

The Bureau of Mineral Resources mapped the Ranken and Avon Downs 1:250,000 Sheet areas in 1961 and, during this survey, the western part of the Camooweal Sheet area was re-examined; these areas, which make up the north-eastern part of the Georgina Basin, also form the eastern part of the Barkly Tableland (Figure 1). The geology of the Ranken and Avon Downs areas is contained in other Records - Randal and Brown (1962a and b).

The Lower Palaeozoic carbonate sequence in the Camooweal area was examined to try to clarify the relationship of the Age Creek Formation with both the Camooweal Dolomite to the west and the limestone rocks of the Undilla Basin to the east. Whitehouse (1931,1936) regarded the dolomite as part of the Cambrian sequence of the Georgina Basin but Öpik's (1954, 1957) interpretation was that it was older than the Middle Cambrian and was a "high" separating the Georgina Basin and the Undilla Basin. Later work by the Bureau of Mineral Resources shows that the dolomite interfingers with Middle Cambrian rocks in the Morstone area, and that similar lithologies to the Camooweal Dolomite occur in the Cambrian-Ordovician sequence in the south-eastern part of the Georgina Basin.

The main lithology of the Camooweal Dolomite is a crystalline dolomite, in part friable and cavernous, with some beds of dense hard brown dolomite. Chert nodules and bands are common. Bedding ranges from medium to very thick. Near George Creek and Goonooma Creek, interbeds of medium pellet dolomite occur in medium and thick bedded crystalline dolomite. The total thickness of the Camooweal Dolomite is not known; west of New Norfolk Homestead 120 feet has been measured, but bore data suggest a thickness of 800-1000 feet. No fossils have been found in the Camooweal Dolomite.

The Age Creek Formation crops out as rugged karst topography and consists mainly of pellet dolomite with some crystalline dolomite and pellet dolomite containing terrigenous material. Chert bands and nodules are rare, but are present near the contact of the formation with the Camooweal Dolomite. Sections measured in Ada Creek indicate the formation is more than 4000 feet thick, but it is doubtful that the entire thickness is present at any one point. The prevalance of cross beds prevents an accurate appraisal of the thickness.

The Age Creek Formation appears to interfinger with rocks which have previously been regarded as Camooweal Dolomite in Ada Creek, west of Marion Bore, and in Frith and Labortion Creeks, near Morstone.

In the upper reaches of Argus Creek cross beds are developed in pellet dolomite which dips at low angles to the south. Between Corkwood Creek and Stoney Creek outcrops of pellet dolomite appear to dip 10° to the east but underlying marly limestone dips south-east at 2°. This indicates the strong development of cross beds in the coarse lithologies of the Age Creek Formation and makes dip measurements on isolated outcrops unreliable.

The carbonate sequence was deposited in warm seas which deepened to the east. The Camooweal Dolomite was deposited in an area of strong evaporation, with currents from the east or north-east supplying a constant flow of carbonate laden water. The more saline water from the interior of the area returned as a bottom current. Strong currents from the north-east met the physical barrier of shallowing water and opposing saline bottom currents and were deflected to the south-east, and deposited the cross-bedded sequence of the Age Creek Formation on the western side of the basin.

INTRODUCTION

General

The Camooweal Sheet area lies between longitudes 138° E and 139°30' E and between latitudes 19° S and 20° S, in Queensland, and adjacent to the Northern Territory; it lies in the north-eastern part of the Barkly Tableland (Figure 1).

In 1961 the Bureau of Mineral Resources published the Camooweal Sheet in the Four-mile Geological Series.

The Camooweal Sheet area contains rocks of Proterozoic, Cambrian, Mesozoic and Tertiary ages. This Record is concerned solely with the Cambrian rocks which crop out in the western part of the area.

The problem of the Camooweal Dolomite

Öpik (1954) considered that the Middle Cambrian rocks, which occupied a basin centred on Undilla, north-east of Camooweal, are unconformably underlain by a white crystalline pre-Middle Cambrian dolomite (Camooweal Dolomite) which crops out to the west. This was in reverse to the interpretation of Whitehouse (1936) who regarded the dolomite as the upper beds of the Georgina Limestone and part of the Georgina Basin. Öpik (1957) disagreed that it formed part of the Georgina Basin, and he showed the Camooweal Dolomite to extend from Lawn Hill southwards through Camooweal to beyond Urandangi (Figure 1); it is shown as far west as Alexandria Homestead.

Subsequent mapping in the Georgina Basin and in the northern part of the Barkly Tableland cast some doubt on the validity of a pre-Middle Cambrian age for some of the rocks shown as the Camooweal Dolomite. In the Huckitta and Tobermorey Sheet areas to the south an identical dolomite lithology was found in a number of horizons in the Cambrian-Ordovician sequence (Smith et al 1961). On the Mount Drummond and Lawn Hill Sheet areas to the north, what has been interpreted as the Camooweal Dolomite overlies Middle Cambrian sediments (Smith & Roberts, 1960). Condon (1961) briefly visited the area in 1960 and considered the Camooweal Dolomite was the lateral equivalent of the Middle Cambrian Age Creek Formation, and that this formation was in turn a variant of the fossiliferous limestone sequence further east. He considered there was a lateral change from limestone in the east to dolomite in the west and that regional dips were south-westerly which indicated that the sequence did form part of the Georgina Basin. His view was supported by Mulder (1961) whose photo-geological maps showed prevailing south-westerly dips in the Undilla area; Mulder also doubted the existence of the Undilla Basin.

During 1961, M.A. Randal and G.A. Brown re-examined the carbonate sequence in the western part of the Undilla Basin in an attempt to clarify the relationship of the Camooweal Dolomite to the Age Creek Formation, and to see the best exposures of units which they expected in their mapping to the west.

Previous Work

The Cambrian geology of this Sheet area cannot be considered as an entity; it involves the Cambrian stratigraphy of the north-western part of Queensland and the eastern part of the Northern Territory. Consequently, previous work in the Barkly Tableland and its south-eastern environs is relevant to the geological problems in the Camooweal area.

Cambrian fossils were first found in the Barkly Region by H.Y.L. Brown (1895) who found Middle Cambrian trilobites in the spoil from an old well near Alexandria Homestead. The fossils were originally described by Etheridge (1897) as Olenellus, but have since been identified as Xystridura browni. This find was followed in 1898 by Davidson's discovery of Pagetia significans and Peronopsis elkedraensis (Etheridge 1902), south-east of Elkedra station.

Danes (1911) visited Rocklands cattle station and because of the probable great thickness of the "limestones" he considered they represented more than one geological period. Both Woolnough (1912) and Jensen (1914) passed through the Barkly area and commented on the flat-lying Cambrian limestones and quartzites. In 1913 Dunstan mapped the area from Camooweal northwards to Riversleigh. He named some of the limestones the Barkly Series; other rocks, including those now mapped as Camooweal Dolomite, were named the Lawn Hill Series of Devonian age. He later (1920) revised the age of these rocks to Jurassic and thought they were the intake beds for the Queensland Great Artesian Basin. Etheridge (1919) described Middle Cambrian trilobites from Alroy Downs which Jensen (1915) had figured earlier. Jensen (1923 and 1944) referred to the Cambrian rocks as the Barkly Tableland Series. Saint-Smith (1924) described Lower Cambrian trilobites from the Templeton River, south of Camooweal; these fossils were the first Cambrian ones found in Queensland and were later redescribed and assigned to the Middle Cambrian by Whitehouse (1927). In addition to specimens from the Thornton River, Chapman (1929) described Middle and Upper Cambrian fossils from the Templeton River. Whitehouse (1930) referred to these fossiliferous rocks as the Templeton Series, and after Ogilvie's discovery of fossiliferous limestone at Glenormiston, he erected the term Georgina Limestones for the rocks overlying the Templeton Series. This name has appeared in later publications as Georgina Limestone Series or Georgina Series. From 1931 to 1949 Whitehouse worked on the palaeontology and stratigraphy of the area.

In 1947-48 the C.S.I.R.O. survey of the Barkly Region (C.S.I.R.O., 1954) covered parts of north-western Queensland; the geological aspects of this survey were covered by Noakes and Traves who referred to the Cambrian rocks on the Barkly Tableland as the Barkly Group (Noakes, 1951; Noakes and Traves in C.S.I.R.O., 1954). The Barkly Group included rocks which Öpik (1954) later called the Camooweal Dolomite. Since 1948 A.A. Öpik has made a number of visits to the Barkly Tableland and has made many fossil collections. The results of this work are contained in a number of unpublished reports which form the basis of papers by Öpik (1957). In 1953, Öpik mapped and collected from the Cambrian rocks in the Mt. Isa and Camooweal region and erected a stratigraphy which in this region superseded that of Whitehouse (Öpik 1954).

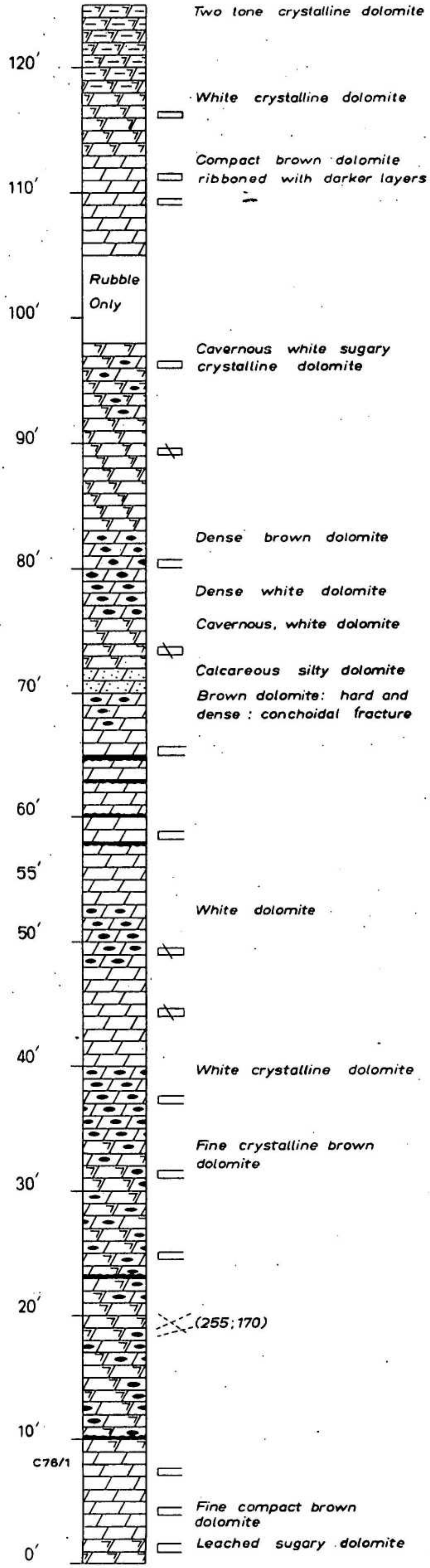
Fig. 3. Canyon topography in medium and thick bedded Camooweal Dolomite. Goonooma Creek, west of New Norfolk. (M/146).

Fig. 2

SECTION IN CAMOOWEAL DOLOMITE

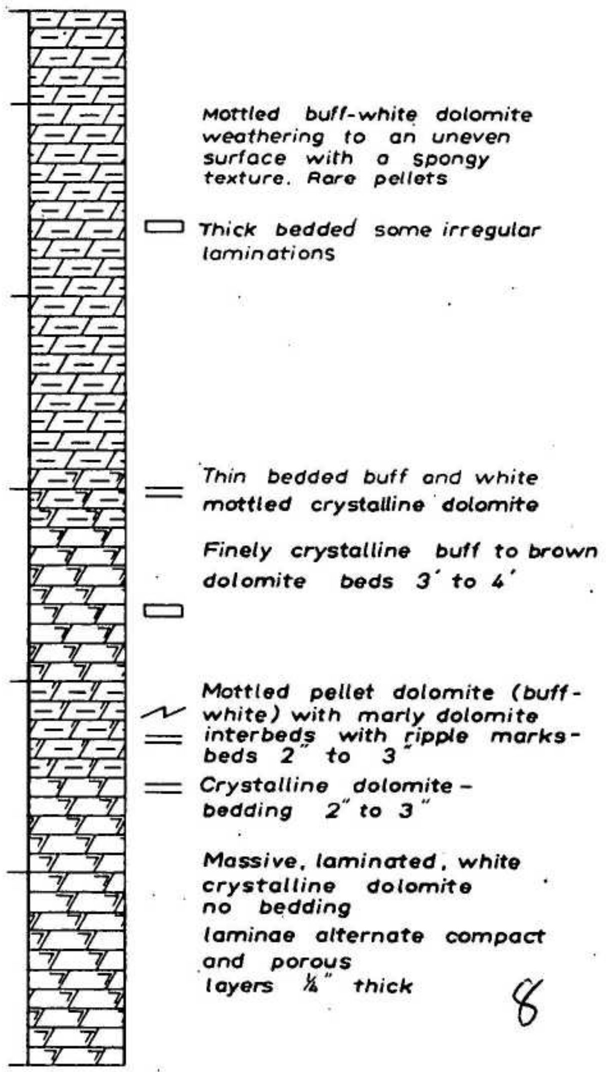
GOONOOMA CREEK

4 MILES WEST OF NEW NORFOLK STATION



SECTION MEASURED IN SINKHOLE 2 MILES EAST OF CAMOOWEAL IN CAMOOWEAL DOLOMITE

For Reference see Plate 2



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GEOLOGY

General Considerations

Whitehouse (1936) considers the carbonate rocks in and about the valley of the Georgina River are part of the Georgina Limestone, which is the uppermost part of his Cambrian succession in this area. Öpik (1957, 1960) considers the reverse is the case; he suggests the Georgina Limestone refers only to rocks near Glenormiston, and for the unfossiliferous dolomite which crops out about the valley of the Georgina River he uses the name Camooweal Dolomite. Öpik regards the Camooweal Dolomite as older than the Middle Cambrian rocks and in support of this, discusses its relationships with other Middle Cambrian rocks in the Alexandria-Soudan region on the adjoining Ranken Sheet area (Öpik 1957). This is further discussed in Randal and Brown (1962a and b). Recent workers have tended to follow Whitehouse's interpretation of the dolomite and regard it as part of the Middle Cambrian to Ordovician sequence of the Georgina Basin but in the Camooweal area it is probably no younger than Middle Cambrian.

The rocks involved are the Camooweal Dolomite, the Age Creek Formation and the limestone rocks west of Undilla. The carbonate rocks in the eastern and central parts of the Undilla Basin were not examined in detail during this survey; the nomenclature and the descriptions of the formations are given by Öpik (1954, 1957, 1960). Detailed petrological examinations of rocks from the Camooweal Dolomite and the Age Creek Formation have been done by G.A. Brown (Brown, 1962).

Camooweal Dolomite.

The Camooweal Dolomite crops out to the west of a longitudinal line through Morstone Homestead; it extends to the north onto the Mount Drummond and Lawn Hill Sheet areas , to the west onto the Ranken Sheet area, and to the south onto the Avon Downs and Mt. Isa Sheet areas.

The type area is the Georgina River between Lakes Mary and Francis near Camooweal township (Öpik, 1954); no type section has been described, however two representative sections are shown in Figure 2.

The unit crops out as scattered slabs and boulders in the black soil downs adjacent to the Northern Territory border, south of Herbert Vale Outstation. Canyon topography (Figure 3) is common north of Herbert Vale and north of Marion Bore where streams of the Gulf Drainage System have deeply incised the edge of the Tableland. Small gorges and stoney watercourses occur south of Morstone Homestead.

The Camooweal Dolomite is described by Öpik (1957) as "a bedded dolarenite with nodules, stringers and small lenticles of chert; some admixed fine quartz sand and interbeds of quartz sandstone occur at its base and locally thin beds of limestone and dolomitic limestone occur at various horizons". In the section measured in Goonooma Creek (Figure 3), chert forms a high percentage of the rock, and thin chert bands extend laterally for several hundred feet (Figure 4). Chert bands are laminated (Figure 4a) and show carbonate textures; in some localities nodules grade imperceptibly into carbonates.

The Camooweal Dolomite is variable in colour: buff, light brown, cream and white. The white rocks are dominant and generally are more coarsely crystalline than the darker ones. White dolomite is usually sugary and even friable. Intraformational conglomerates are present in the eastern part of the adjoining Ranken Sheet area. Pellet dolomite has been noted near the contact with the Age Creek Formation; fine-grained dolomites which have not been recrystallised contain small pellets, and in a

Fig. 4a. Laminated chert bands in Camooweal Dolomite. Goonooma Creek, west of New Norfolk. (M/146).

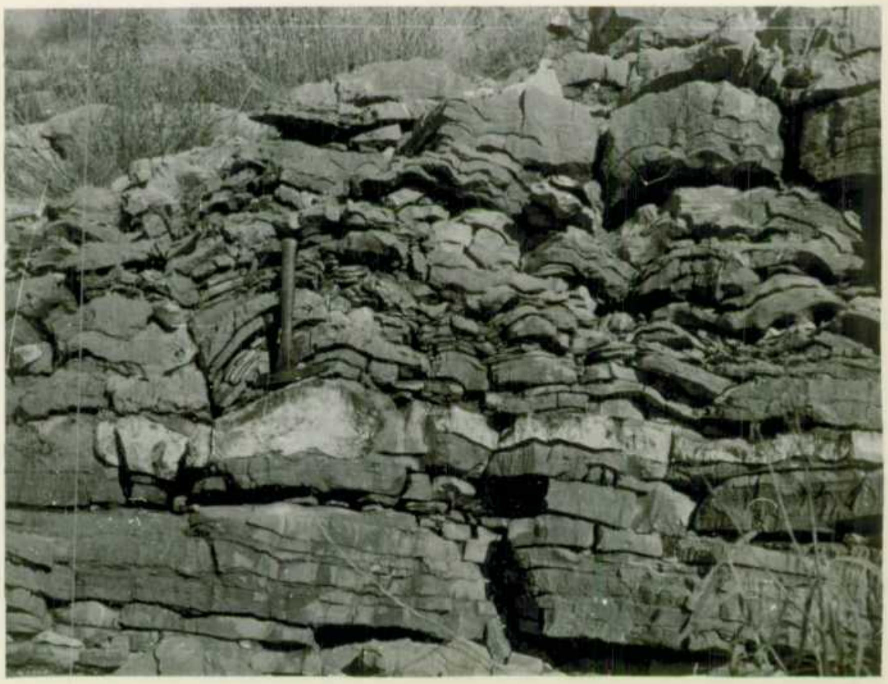


Fig. 4b. Chert bands in medium and thin bedded Camooweal Dolomite. Goonooma Creek. (M/146).

sinkhole east of Camooweal, pellet dolomite is ripple marked (Figures 2, 5). The pellets are about 0.05 mm. in diameter; they are spherical and are composed of dark dolomitic material. Near the boundary with the Age Creek Formation, composite pellets about 1 mm. in diameter occur.

The dolomite contains some terrigenous material, angular quartz and feldspar grains about 0.05 mm. in diameter, smaller rounded grains of tourmaline and spinel, and mica. The quartz grains are larger (0.6 mm.) near the contact with the Age Creek Formation and are well rounded and spherical. No quartz sandstone beds are known in the Camooweal area, but they have been observed on the Urandangi, Ranken and Avon Downs Sheet areas. (Opik 1960, Randal and Brown, 1962a and b). Sandstone boulders in the Avon Downs area contain the same heavy minerals as the Camooweal Dolomite.

Bedding is variable from thin to very thick, but the medium and thick bedded rocks are the commonest (Figures 3, 4b). Individual beds are internally laminate (Figure 4a); laminations are wavy, straight, and in places cross-bedded (Figure 7). The cross-bedded laminations are restricted to the eastern part of the unit, near its boundary with the Age Creek Formation; they are accompanied by extensive scour and fill structures (figure 6), which also occur in the western part of the Age Creek Formation.

The Camooweal Dolomite is generally flat-lying, except near its contact with the Age Creek Formation, between Marion Bore and Bauhinia Creek, where some shallow dips to the south and south-east have been seen. Shallow westerly dips occur in Goonooma Creek, west of New Norfolk Homestead. Shallow dips have been recorded in the adjoining areas (Randal & Brown, 1962a and b).

The relationship of the Camooweal Dolomite with the Age Creek Formation is a complex one. A lithological boundary can be traced from Morstone Homestead southwards to Labortion Creek. Its position approximates that of the Camooweal Dolomite-Age Creek Formation boundary as shown on the current Geological Map (Plate 3). East of the boundary the rocks are a pellet dolomite; near the boundary pellet dolomite forms lenses within a crystalline dolomite; west of the boundary the rocks are cross laminated, white or mottled porous crystalline dolomite. The boundary extends northwards along the eastern side of the watershed between Nankivel Creek and Ada Creek.

Along this contact, the Age Creek Formation interfingers with the Camooweal Dolomite; large tongues of detrital pellet dolomites are interbedded with lenses of chemically deposited crystalline dolomite. Immediately north of the northern boundary of Morstone, interbeds of pellet dolomite commonly occur in the crystalline dolomite; they form characteristic rugged black outcrops which are easily distinguished on aerial photographs from the lighter coloured crystalline dolomite.

At point C73 (Plate 1) in Ada Creek, north of Marion Bore, twenty-five feet of medium bedded pellet dolomite occurs as an interbed in medium and thick bedded crystalline dolomite with chert nodules; this section can be traced eastward into definite Age Creek Formation along Marion Creek. The Age Creek Formation contains 20 feet thick interbeds of crystalline dolomite and chert near the confluence of Ada and Marion Creeks.

At point C67, north-west of Marion Bore, pellet dolomite is interbedded with a sugary crystalline dolomite containing chert nodules and bands. Interbeds of pellet dolomite in Camooweal Dolomite lithology have been seen in small tributaries of Goonooma Creek, north of New Norfolk and in Dariel and George Creeks, north of Herbert Vale, and in Frith and Labortion Creeks, in the Morstone area.

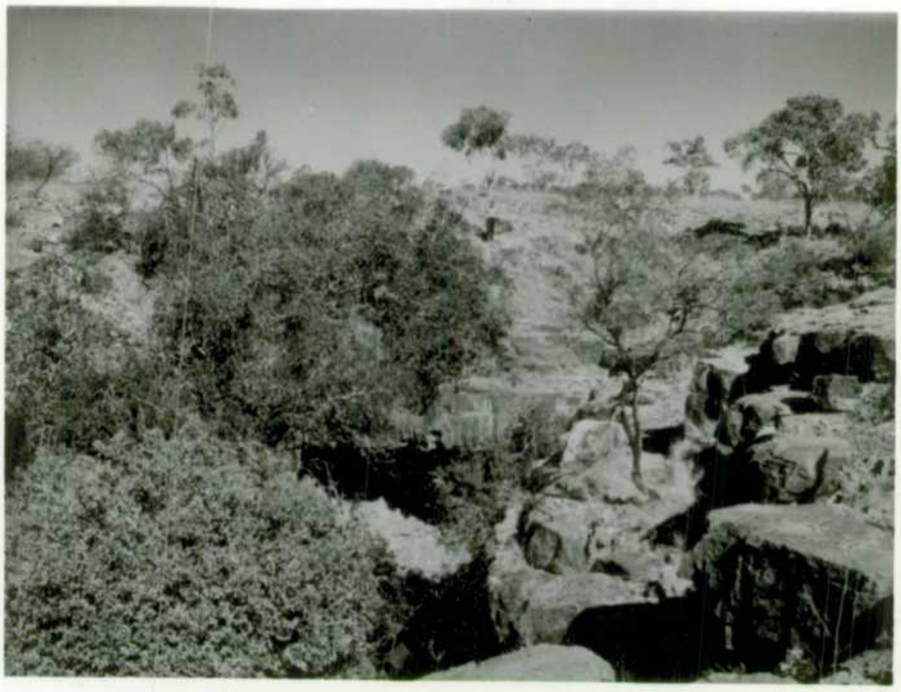
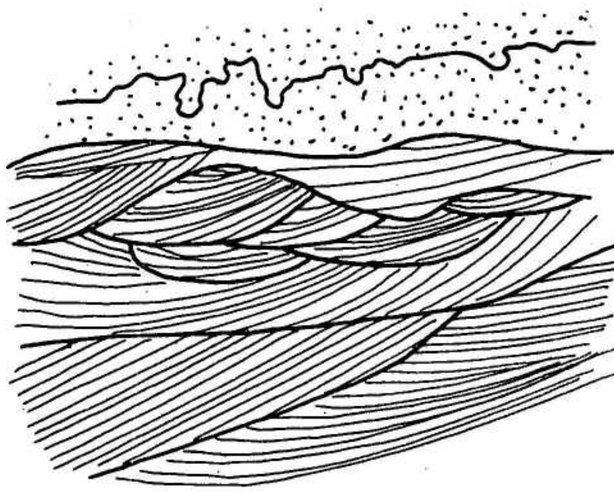


Fig. 5. Sinkhole in Camooweal Dolomite, 2 miles east of Camooweal. (G4446).

Fig. 6. Cross-bedded laminations in Camooweal Dolomite. Note the scour and fill structure near the point of the hammer. Bauhinia Creek. (G4432).



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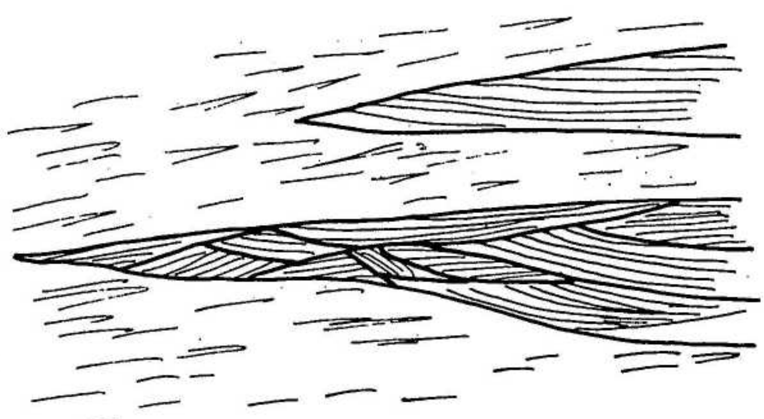

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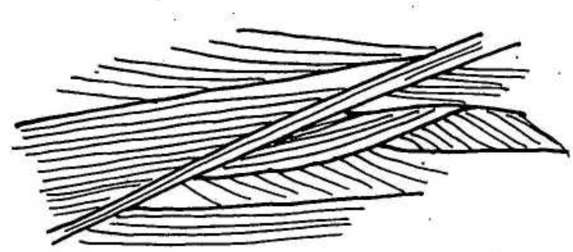

C110

Cross-laminations in the Camooweal Dolomite.

13

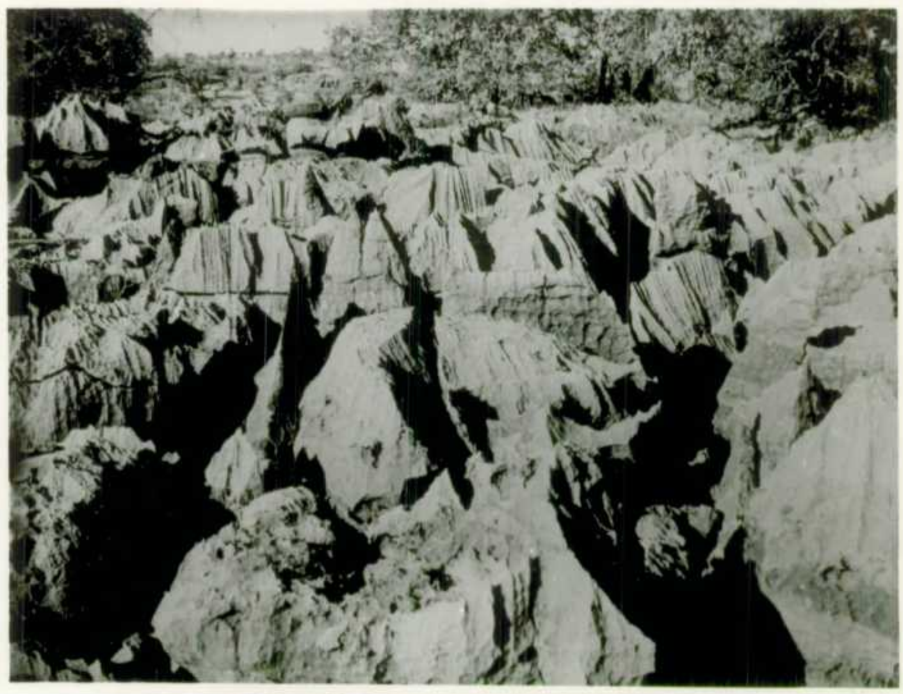

Fig. 8. Massive karst outcrop of the Age Creek Formation. Near Old Morstone. (G4443).

Fig. 9. Massive cross-beds in the Age Creek Formation. Argus Creek (G4449).

The Camooweal Dolomite extends in continuous outcrop from the Ada Creek area to Border Waterhole on the boundary between the Lawn Hill and Mount Drummond Sheet areas, where the dolomite overlies the Middle Cambrian Currant Bush Limestone (Smith & Roberts, 1960). Öpik (in Carter & Öpik, 1961) postulated a fault between the two units in this area; however, Smith and Roberts (1960) regard the contact as simple superposition. At this locality the Currant Bush Limestone ranges from the Ptychagnostus gibbus zone to the P. gibbus - atavus zone (Figure 13a) whereas in the Undilla Basin it continues upward into the P. punctuosus zone (Öpik 1960). However, the Age Creek Formation has a larger range; it extends from the Xystridura zone to the Ptychagnostus nathorsti zone. Consequently, the dolomite mass which interfingers with the Age Creek Formation in the south, and overlies the Currant Bush Limestone in the north, may not necessarily extend above or below the Middle Cambrian.

On the other hand in the Lawn Hill area the Thorntonia Limestone which is the lowermost Middle Cambrian unit, rests on a dolomite which is lithologically similar to the Camooweal Dolomite (Öpik in Carter & Öpik, 1961). Furthermore, Öpik records anomalous chert and limestone boulders containing Middle and Upper Cambrian fossils, which are scattered over the surface of the Camooweal Dolomite and which he regards as remnants of a younger sequence. To the south of the Camooweal area, the dolomitic rocks of the Ordovician Ninmaroo Formation (Smith et al 1961) are lithologically similar to the dolomite around Camooweal.

The areal extent of the Camooweal Dolomite was originally based on the uniformity of the lithology (dolomite with chert) and its topographic expression (downs country) as seen on air-photographs. This may have been misleading and resulted in the apparent anomaly of different stratigraphic positions for the unit. But this of course may be true; the dolomite may represent an environment which was diachronous and which ranged from the pre-Middle Cambrian into the Lower Ordovician. This cannot be proved at present because of the lack of continuous outcrop south and west of Morstone, and the stratigraphic position of the Camooweal Dolomite in the Morstone area need not be the same as elsewhere. Consequently the presence of pre-Middle Cambrian dolomite in the Camooweal area cannot be ignored and until it is established whether or not the Middle and Upper Cambrian fossiliferous floaters are in sequence with the dolomite or are in fact remnants, the age of the Camooweal Dolomite around Camooweal remains open. However, it is reasonable to regard the white crystalline dolomite north of Morstone as Middle Cambrian or younger. No fossils have been found in situ in these rocks other than stromatoliths (Smith & Roberts, 1960).

Stratigraphic drilling could provide a solution to the problem and subsequently it may be found necessary to redefine the unit and restrict its areal extent.

The depositional environment of the Camooweal Dolomite is discussed on page 9. Bore data indicates its thickness is 800-1000 feet.

Age Creek Formation

The name "Age Creek Formation" was published by Öpik (1957), and later (1960) defined as a "calcareous formation consisting of sandy clastic dolomite and limestone with interbeds of calcareous sandstone ... (it) is the slope deposit of the Undilla Basin and is confined to the Basin". Öpik considered it was 4000 feet thick.

The type locality for the Age Creek Formation is at the confluence of Age Creek with the O'Shannassy River, downstream from Old Morstone (Öpik, 1954). The dominant rocks are pellet dolomite (dolarenite), calcarenites and dolomitic limestone; the rocks are frequently oolitic. No type section has been described, but during the 1961 survey, sections totalling over 4000 feet were measured in Ada Creek, north of Old Morstone (Plate 2).

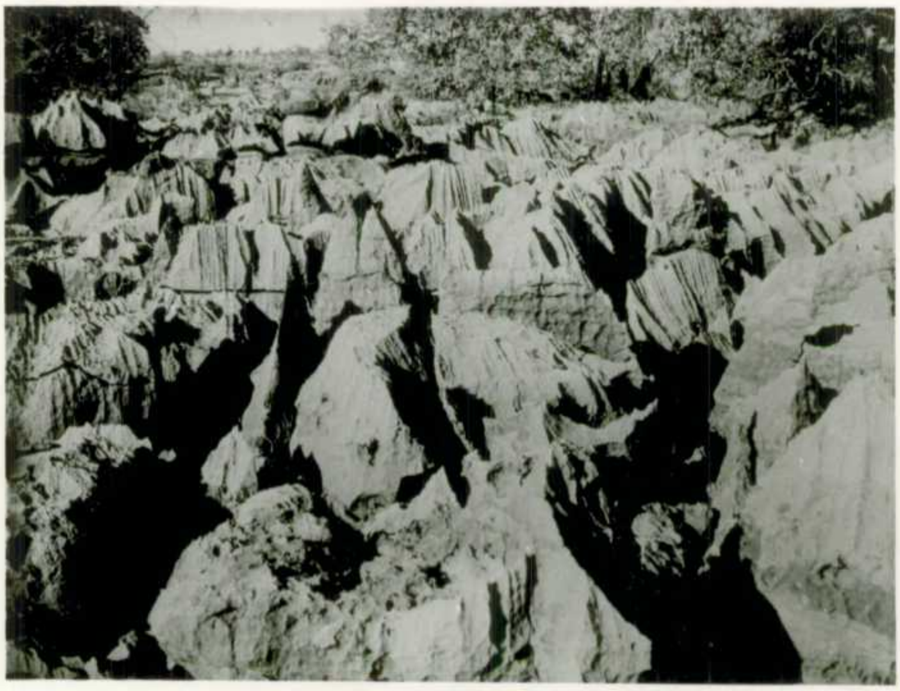

Fig. 8. Massive karst outcrop of the Age Creek Formation.
Near Old Morstone. (G4443).

Fig. 9. Massive cross-beds in the Age Creek Formation.
Argus Creek (G4449).

The Age Creek Formation crops out as linear belts" around the western, northern and north-eastern margins of the Undilla Basin (Öpik, 1954). On the western side of the basin it extends northwards from Bauhinia Creek to Ada Creek; on the eastern side it extends from Redbank Creek north-west to Ada Creek, where the two belts merge, and on the Geological Map, are shown as a syncline open to the south. However, it has been found that the Age Creek Formation interfingers with the Camooweal Dolomite in this area, and that "Age Creek lithologies" are present in the gorges north of New Norfolk and Herbert vale. Therefore, the swing in strike of the formation, north of Morstone, may not be as important a feature as shown on the Geological Map; the formation may continue into the area of the Camooweal Dolomite north of Herbert vale and eventually lens out. Patches of Age Creek Formation occur in the V-creek Limestone north-east of Undilla Homestead.

The typical outcrops of Age Creek Formation are rough dissected karst country, deeply incised by steep-sided creeks and rivers. The top of the outcrops consist of black blocks which show solution effects (Figure 8). The blocks are separated by irregular joints and cracks, up to 20 feet deep. Away from the watercourses, the formation is less dissected and forms black soil plateaux similar to those on the Camooweal Dolomite. It supports spinifex and mitchell grass, but is not suitable for grazing because of the rough terrain, the lack of underground water, and the sparse vegetation.

The Age Creek Formation consists of pellet dolomite, dolomite with pellets, crystalline two-tone dolomite and minor calcarenite. Chert nodules and bands are uncommon except in Opal Creek (Öpik, 1954) and near the contact with the Camooweal Dolomite. In Ada Creek, chert nodules occur in crystalline dolomite interbeds in the Age Creek Formation; the hills are covered with chert scree.

The pellet dolomite of the formation contains detrital grains made up of dolomitic pellets, oolites, algal material, and fragments of quartz, chert and feldspar. The diameter of the pellets ranges from 0.1 mm. to 2.0 mm. and are well rounded and ellipsoidal; composite pellets contain pellets 0.05 mm. in diameter. Some composite pellets are themselves incorporated in composite pellets; this suggests that the original sediment has undergone more than one period of erosion and sedimentation. Over half the rocks examined contain oolites, many of which have been recrystallised, presumably during dolomitisation. The oolitic rocks mainly contain subordinate pellets, but rocks, in which the oolites are subordinate, contain considerable quantities of quartz and chert grains which suggests the accumulation of particles from several source areas.

Coarse terrigenous material is generally confined to the western part of the formation near its contact with the Camooweal Dolomite. The quartz shows evidence of straining and it is suggested (Brown 1962) that it is derived from a metamorphic quartzite. On the other hand herring-bone fractures in individual quartz grains are parallel and this suggests the quartz has been subjected to some strain in the sediments.

Chert fragments occur mainly in the rocks near Ada Creek; the fragments are usually well rounded but some are angular. There is no evidence to suggest they are replacing carbonate pellets in situ.

Brown (1962) has recognised two types of cement in the pellet dolomites. The first is a coarse mosaic of dolomite crystals resulting from the recrystallisation and dolomitisation of an original calcareous cement. The second type consists of euhedral dolomite rhombs growing outwards from and perpendicular to the pellets in the same manner as a sparry calcite cement. This may represent an original dolomite cement.

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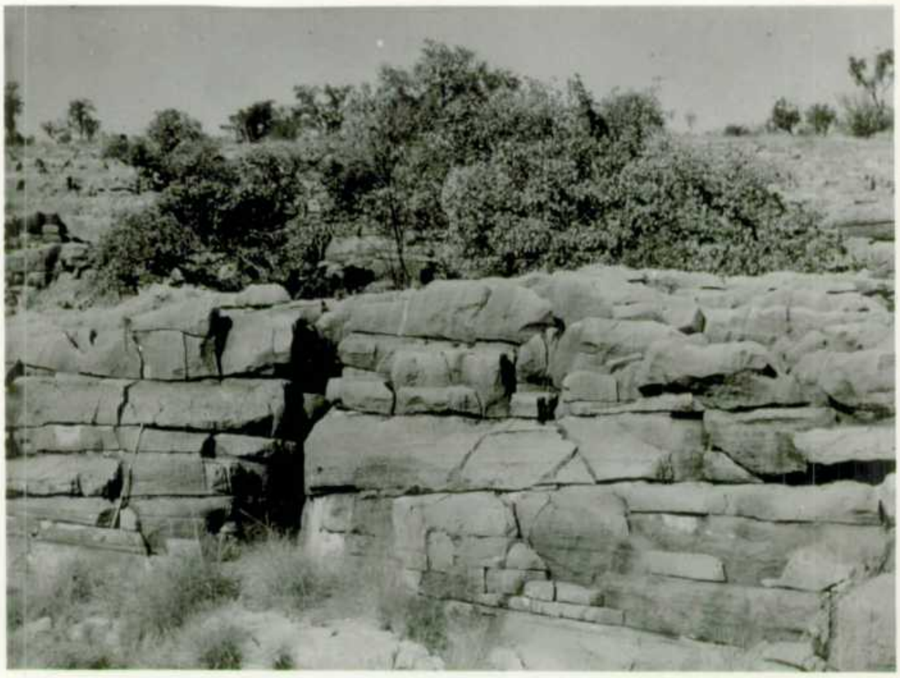

Fig. 10. Low angle cross beds in Age Creek Formation near Stoney Creek. (G4440).

Fig. 11. Cross-beds in the Age Creek Formation. O'Shanassy River near Old Morstone. Massive foresets and topsets in the top right of the photo are partially obscured by the trees. (G4441).

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The Age Creek Formation is mainly medium and thick bedded, but thin calcareous beds and massive beds have been seen. The formation is cross-bedded, with foresets up to fifty feet thick (Figure 9). The foresets are thin to thick bedded; they dip at angles up to 30° but mainly at 10° or less (Figure 10). Lenses of fine grained, thin bedded, flat-lying fossiliferous dolomite and limestone grade laterally into thick bedded pellet dolomite foresets.

In the upper reaches of Argus Creek, cross-beds (with foreset dips of 25°) are developed in pellet dolomite which dips at low angles to the south and south-east. Cross beds first appear where the terrigenous quartz content drops considerably and where crystalline dolomite with pellets grades eastwards into pellet dolomite. This is the boundary between the Age Creek Formation and the Camooweal Dolomite as shown on the Geological Map. A lithological boundary is present, but it is not necessarily a formational one. Between Corkwood and Stoney Creeks, outcrop of a medium bedded pellet dolomite appear to dip 10° to the east, but the underlying marly limestone and dolomite dips south-east to south at angles of less than 2°. Similar cross-beds are developed in rocks along the O'Shanassy River, downstream from Old Morstone (Figure 11).

Thus, there is a strong development of cross-beds in the coarse lithologies of the western Undilla Basin which, together with the occurrence of collapsed Karst outcrops and slumping, makes dip measurements in isolated outcrops unreliable.

The structure of the Age Creek Formation is confused by the prevalance of the cross-beds. High dips measured on isolated outcrops appear to be anomalous and in most cases their validity is suspect. High dips shown on the Geological Map have been examined in the field and appear to have been measured on large scale foresets. Mulder (1961) doubted the existence of the Undilla Basin, but the regional disposition of the rocks near Morstone indicates a basin does exist. In the Corkwood Creek area the top and bottom sets of marly limestone and dolomite dip between 2-5° to the south-east. The thickness of sediments in the basin is probably less than is implied on the Geological Map; it may be determined by a deep stratigraphic bore positioned near Wim Well in the centre of the basin.

Seismic work in the area (Robertson, in preparation) has indicated reflecting layers deeper than 4000 feet in the centre of the basin, but no reliable estimate can be made from the poor results obtained.

Strong trend lines which are apparent on the air-photographs, swing from the south-east to the south-west, north of Marion Bore. There is a shift in the direction of the cross-beds in this area and these trends appear to be strike lines of the foresets, rather than major trends of the bedding. As pointed out previously, the Age Creek Formation continues to the north-west into the Camooweal Dolomite where it may form part of a sequence which dips south-west and forms part of the Georgina Basin.

The Undilla Basin may be a small basin to the east of the Georgina Basin and partly separated from it by a small "high" in the Precambrian basement near Camooweal. This possibility and the relationships of the units are illustrated in Figure 13. Time lines have been drawn in this figure illustrating the possible range of the Camooweal Dolomite from pre-Middle Cambrian to Lower Ordovician, but at present there is no evidence for Ordovician rocks in the Camooweal area; the eastern part of the figure is after Öpik (1954).

The stratigraphic range of the Age Creek Formation extends from the Xystridura to the Ptychagnostus nathorsti zones of the Middle Cambrian (Öpik, 1954, 1960).

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Fig. 12. Slump structures in the Age Creek Formation near Old Morstone. (G4430).

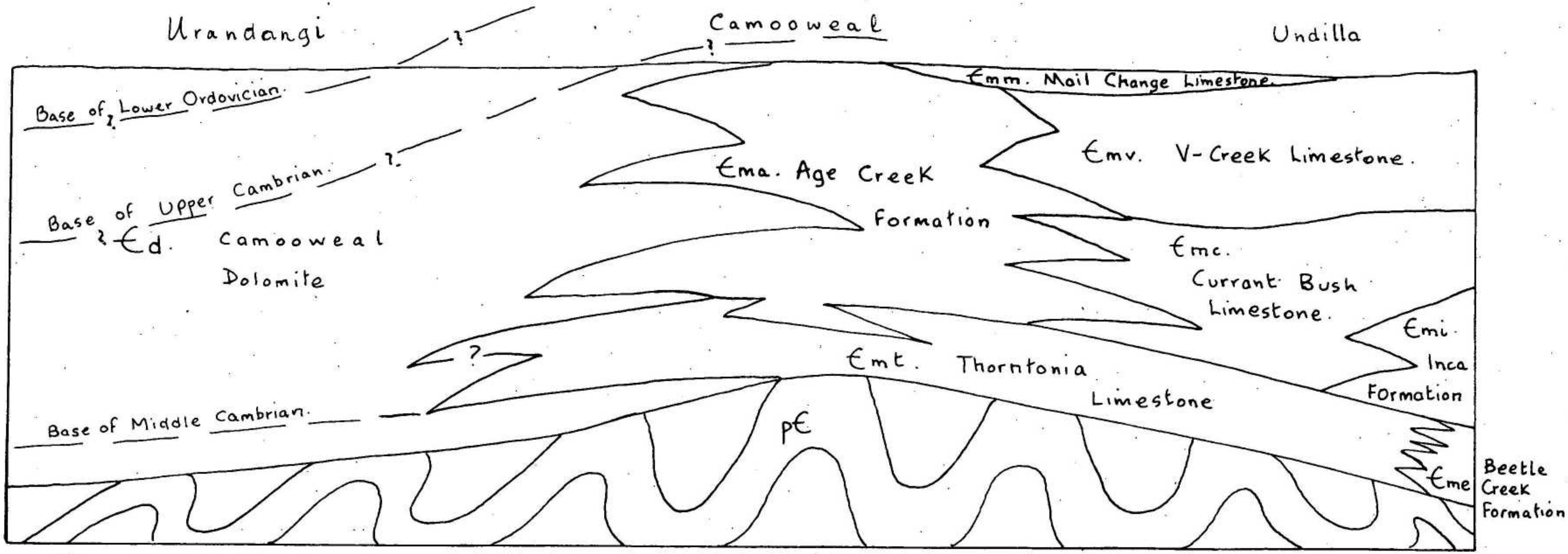

FIG. 13. Showing the probable relationship of Rock Units in the western part of the Undilla Basin and Southwards to Urandangi. (Diagrammatic, not to scale).

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Bureau of Mineral Resources, Geology and Geophysics, May 1962

In the area north of Morstone the Age Creek Formation and the Camooweal Dolomite interfinger. A similar relationship is seen on the eastern boundary of the Age Creek Formation with the limestone formations of the Undilla Basin.

Öpik (1954) regards the relationship as "an edgewise intertonguing and interbedding". Interbeds of "Age Creek lithology" occur in the V-Creek Limestone near Undilla. Öpik (1954) considered that the Mail Change Limestone was in part interbedded with the top of the Age Creek Formation and also overlapped it. However Öpik (pers. comm.) believes that on the western side of the basin the "normal limestone rocks" which are interbedded with the Age Creek Formation are part of the V-Creek Limestone. Some outcrops in this area are shown on the Geological Map as Mail Change Limestone, but as Öpik (1954) points out "Mail Change" type lithologies occur in the upper part of the V-Creek Limestone.

East of the track from Wim Well to Old Morstone 55 feet of section is exposed from the bed of a creek to the top of a small ridge. In the creek massive beds of mottled calcilutite are overlain by friable mottled calcarenite. This is overlain by crystalline dolomite which passes upwards into pellet dolomite at the top of the ridge. The limestone is similar to the lithologies of both the Mail Change Limestone and the V-Creek Limestone. The following section is exposed in Stoney Creek in a cliff, west of the track.

	Top
25 feet	Medium bedded crystalline dolomite with quartz grains.
5 feet	Thick bedded pellet dolomite with quartz.
10 feet	Laminated calcareous siltstone with bands of calcarenite.
1 foot	Dolomite with pyrites.
6 feet	Calcareous siltstone with interbeds of pellet dolomite.
3 feet	Silty limestone
4 feet	Blue-grey calcilutite.

The spoil from an old well downstream from here is a blue calcarenite and calcareous siltstone similar to "V-Creek" lithology. The surface outcrops consist of pellet dolomite.

Although it is uncertain whether the rocks which interfinger with the Age Creek Formation are the Mail Change Limestone or the V-Creek Limestone, there is little doubt that the Age Creek Formation interfingers with the limestone rocks of the Undilla Basin.

<u>Environment of Deposition in the Western Undilla Basin</u>

The depositional environment of the Camooweal Dolomite, the Age Creek Formation and the limestones of the Undilla Basin, is illustrated in Figure 14. The Thorntonia Limestone has been omitted for clarity.

The Camooweal Dolomite was deposited in shallow normally quiet seas - as evidenced by ripple marks and laminations. Massive, internally laminate, sediments deposited during long stable periods under an arid climate, remained at the water/sediment interface or just below it for long periods during which time dolomitisation of the sediments took place; however, part of the dolomite may be the result of direct precipitation of a dolomite mud.

The Age Creek Formation was deposited in an area of strong currents in warm sea water; shallow water conditions which favoured the formation of oolites, existed in most areas of deposition. The currents deposited carbonate pellets on a slightly sloping sea floor as massive cross beds. Some of the composite pellets in the formation suggest pellets were derived from the area where the Camooweal Dolomite was being deposited; but north of Marion Bore the cross-beds suggest a source to the north-east.

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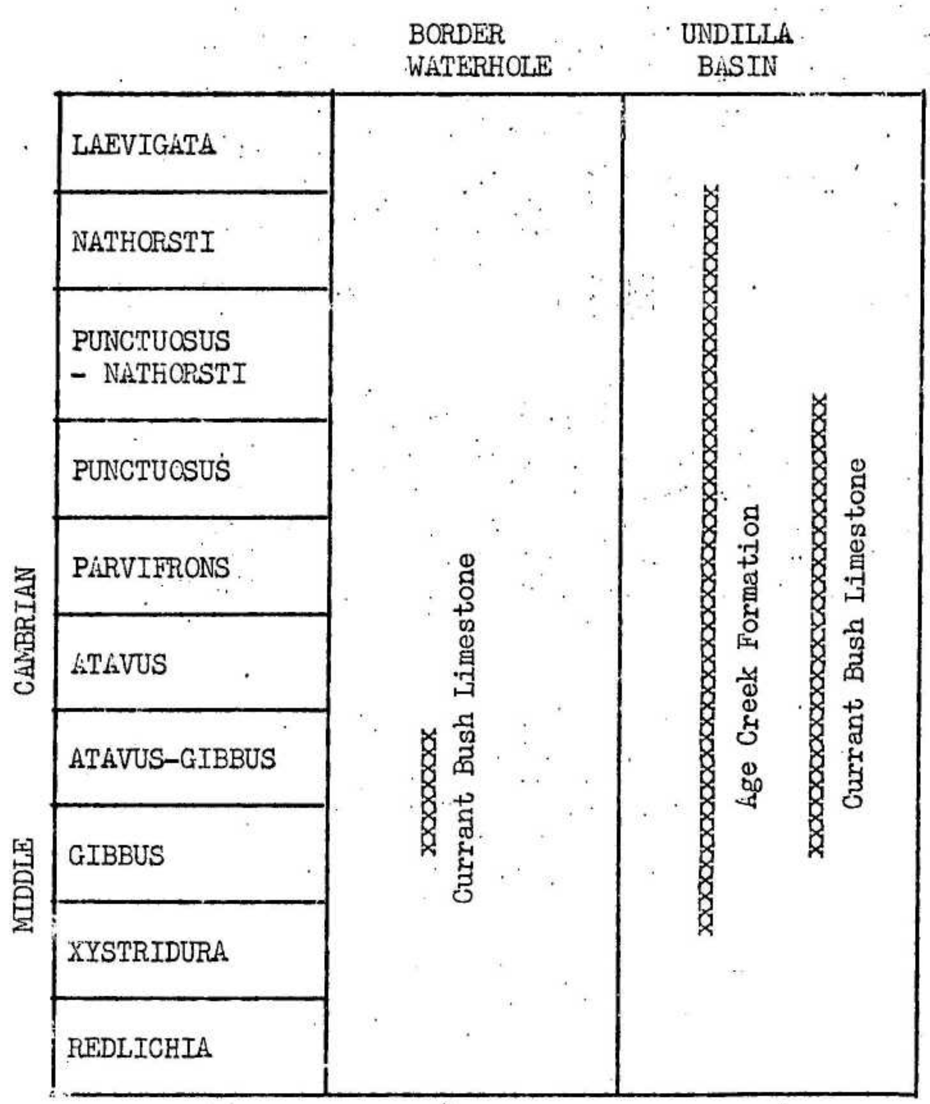


Fig. 13a. Stratigraphic range of Currant Bush Limestone and Age Creek Formation.

FIG. 14.

BLOCK DIAGRAM TO ILLUSTRATE THE DEPOSITIONAL CHARACTERISTICS OF THE FORMATIONS OF THE WESTERN UNDILLA BASIN

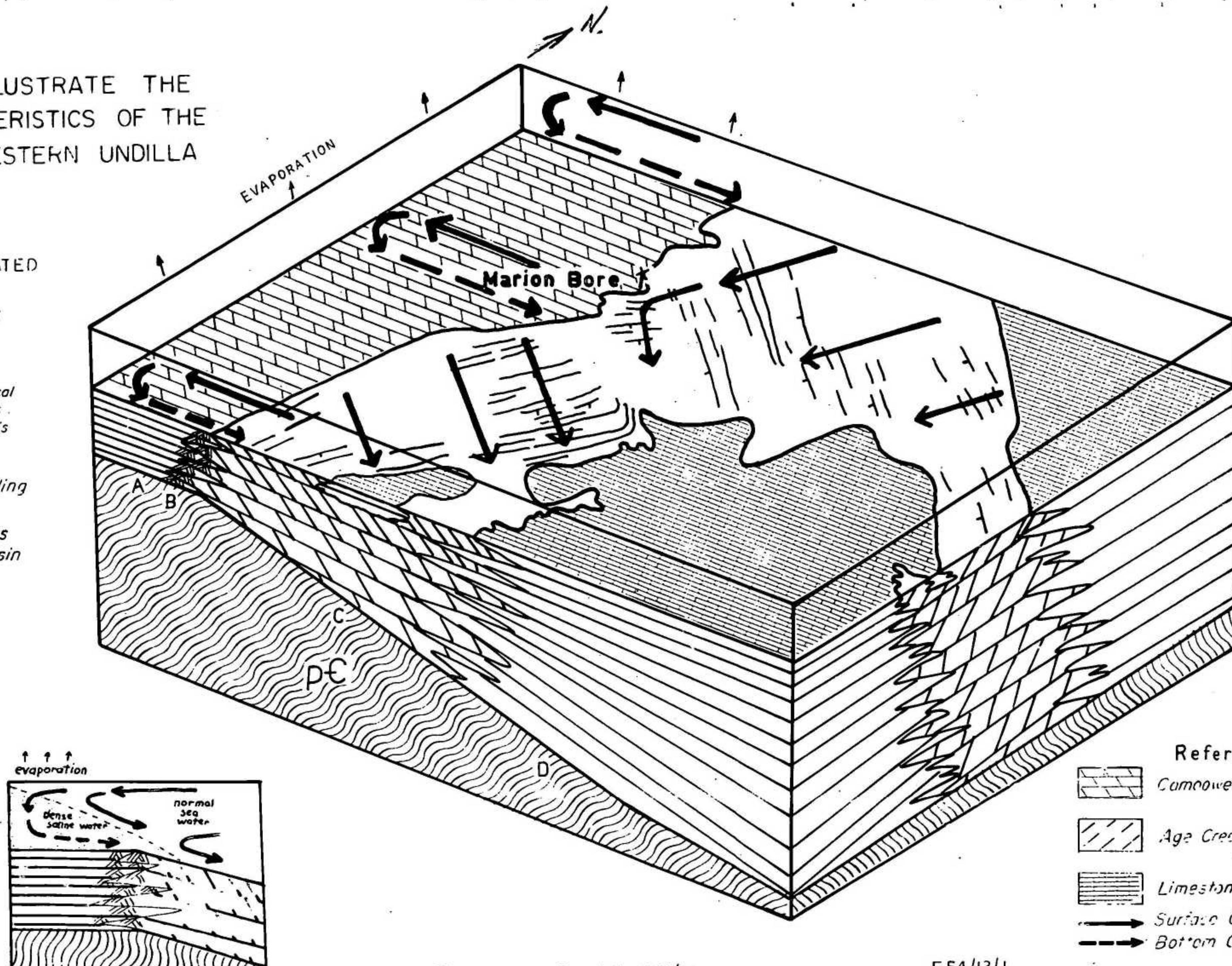
FEATURES ILLUSTRATED

A *Horizontal Bedding*

B *Cross Laminations*
(Note: There is no Geological or Geophysical evidence for the break in Basement Slope it is purely theoretical)

C *Massive Cross Bedding*

D *Shallow Dips towards the centre of the Basin*



Reference

Camooweal Dolomite

Age Creek Formation

Limestone Sequence

Surface Currents

Bottom Currents

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G.A.P.

Terrigenous material suggests a source from a granitic or metamorphic province. Two types of terrigenous material are present: angular grains of sand and silt size particles and well rounded grains of coarse and medium sand size particles. The terrigenous grains are concentrated along the boundary between the Camooweal Dolomite and the Age Creek Formation, but south of Morstone the coarser grains spread out east of the boundary.

The foresets in the Age Creek Formation (Figure 14) give a clue to the prevailing currents at the time. North-east of Old Morstone they dip to the south-west; near Marion Bore they dip to the south, and near Morstone they dip to the south-east. It appears that currents flowing from the north-east were deflected by some physical barrier which trended north-south through a point near Morstone Homestead. This barrier may have had two components; 1) very shallow water in the area where the Camooweal Dolomite was being deposited, caused by a gentle upwarp in the underlying basement (Figure 13); 2) east-flowing currents from the area where the Camooweal Dolomite was being deposited. Surface currents bringing carbonate rich waters into the area, on evaporation would precipitate the carbonates of the Camooweal Dolomite. Because of evaporation the salinity of the water would increase, its density rise and the water sink. During precipitation, some of the denser water may have flowed eastwards mainly as bottom currents, carrying with it pellets of carbonate mud. The presence of salinity currents in areas of strong evaporation has been described by Emery and Stevenson (1957).

Interference effects between the south-westerly and the easterly flowing currents may be the explanation for the cross laminations and scour and fill structures seen along the boundary between the Camooweal Dolomite and the Age Creek Formation. The swing of these currents is illustrated in Figure 14. The features extend into the western part of the Age Creek Formation, but quickly give way to massive cross-bedding further east.

Notes on the Split Rock Sandstone

Öpik (1954) recognised a sandy formation in the southern part of the Undilla Basin, with scattered outliers in the eastern and central parts of the Basin. The formation was named the Split Rock Sandstone and described as having a wide stratigraphical range because of its rising contact with the V-Creek Limestone and the Mail Change Limestone. The upper parts of the Split Rock Sandstone overlie the carbonate sequence and Öpik considers it is the topmost Middle Cambrian in the area.

During a reconnaissance trip in the area, Condon (1961) examined outcrops of the Split Rock Sandstone near the Burketown Road; he regarded the sandstone as the skeletal residual rock resulting from the leaching of carbonates. Because of this he considered the Split Rock Sandstone had no validity as a formation, and was in reality the weathered rocks of the Mail Change Limestone and the V-Creek Limestone. During the 1961 survey samples of Split Rock Sandstone were collected from the type area and a sample of Mail Change Limestone was collected near Old Morstone. The samples were forwarded for petrological examination; the attached descriptions by L.V. Bastian suggests that in the type-area at least, the Split Rock Sandstone is a distinct formation.

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APPENDIX I

PETROLOGICAL EXAMINATION OF SPECIMENS FROM THE CAMOOWEAL AREA, NORTH QUEENSLAND

by

L.V. Bastian

Eight specimens, R9250 - R9256, and R9326, were submitted by Dr. N.H. Fisher for petrological examination. They were collected from Split Rock Waterhole, about 25 miles east of Camooweal in zone 6/210 (Hanging Rock 1-mile Sheet). R9250 - R9256 represent a section of Mail Change Limestone/Split Rock Sandstone, with R9250 the lowermost and R9256 the uppermost, while R9326 is from the Mail Change Limestone, $2\frac{1}{2}$ miles south of Old Morstone, on the Mail Change road. They were mapped as two different lithological types, but it was thought that the sandstone representatives (R9251 - R9256) could have possibly been derived from R9250 (Mail Change Limestone) by secondary surface chemical processes.

R9250 (T.S. 7333) is a gritty limestone, which shows on the freshly cut surface strongly contorted patches of cream and light brown colours, caused by plastic movement of two distinct sediment types whilst unconsolidated, the paler material being poorer in silicate detrital minerals. In thin section it is made up of a variable percentage of silicate detritals, ranging from 20% to 45% in different patches, much detrital carbonate, and a few fossil fragments , in a recrystallized calcilutite matrix. Some minor fractures are filled with calcite. The silicate detritals are mainly angular and subangular grains of quartz with lesser amounts of feldspars, micas, and a variety of heavy minerals. The detrital carbonate occurs as well-rounded grains and appears to constitute most of the carbonate content of the rock. A staining test carried out on this specimen identified the carbonate as calcite, and showed up the considerable plastic deformation that took place in the soft sediment before consolidation.

R9251 - R9253 (T.S. 7334 - 7336) are yellow-grey fine silty sandstones, with a much higher percentage (about 80%) of silicate detritals than in the previous specimen. The assemblage is similar to the above, but detrital or cementing carbonate is absent. The matrix is a reticulate network of a pale brown clay mineral, and there are also occasional patches of black carbonaceous matter. Although many of the grains interlock with suturing on their contacts, there is no important addition of secondary silica. The high percentage of primary insoluble material rules out the possibility that the rock was originally a gritty limestone, without envisaging secondary concentration of the insolubles as an accompaniment to weathering. Primary bedding, however, appears to have been retained, and the framework of insolubles almost certainly has not undergone such a secondary packing.

R9254 and R9255 (T.S. 7337 & 7338) are porous yellow fine sandstones, with a fairly even colour banding in hand-specimen. They carry a similar detrital assemblage to the above, with less than 10% clay matrix, and authigenic enlargement of quartz is common. Hydrated iron oxides occur throughout the rocks, but are concentrated in the brown bands.

R9256 (T.S. 7339) is a very porous brick-red fine sandstone, with a close and regular primary bedding lamination. In thin section it is made up of the same silicate detrital assemblage, with a matrix consisting of a pleochroic red-brown, translucent clay mineral, optically length-slow, laden with hydrated iron oxide inclusions, a common feature when found in weathered rocks. There is little doubt that this is a secondary product, and that the lighter coloured sandstones represent material from a pallid zone beneath this rock. Quartz detritals have been enlarged by authigenic outgrowth, and many grains, originally subangular or moderately rounded, now interlock closely. If the pore-space was created by dissolution of carbonates, this 25 could indicate a rock which was originally of calcareous sandstone or sandy limestone composition.

R9326 (T.S. 7350) is a pale grey gritty limestone similar to R9250 in hand-specimen, with a strongly contorted structure consisting of two distinct sediment types. A thin shell of brown sandy material forms the surface of the rock, and the problem was to determine whether this outer shell was a sandstone or merely a weathered product of the main rock type. At the outset it seemed obvious that this was a weathered surface; an inspection with the stereoscopic microscope showed that the outer layer was very porous, the porosity commencing about 3 mm. in and increasing markedly towards the surface.

The thin section examination supports this conclusion. The limestone is non-porous and very sandy, with insoluble detrital minerals ranging from about 40% in some parts to over 50% in other parts of the rock. The porosity is due to solution cavities which appear in the carbonate near the surface; at the surface all the carbonate has been removed. Some minor hydrated iron oxide imparts the brown colouration to the outer shell. The most conclusive feature is that there is no accompanying increase in the percentage of sand, i.e. the main body of the limestone is no less sandy than the (apparently sandier) outer shell. This evidence clearly indicates that the brown surface layer is a product of weathering.

Discussion

The porous outer layer of R9326 closely resembles the very porous sandstones R9254-5-6, and suggests strongly that they were calcareous. Of these, however, only R9256 is nearly as porous, the others having notably higher detrital content. R9256 and R9326 may thus be considered as "borderline" rocks between sandstone and limestone, and the remainder sandstones.

Although the existence of a surface ferruginous zone and an underlying pallid zone is indicated, there is an obvious inconsistency which precludes the likelihood of most of the sandstones having been derived from the limestone. Firstly there is no disturbance of bedding in any of the sandstones; therefore any secondary alteration must have been of an interstitial type, not involving repacking of the framework of insoluble minerals. Secondly the sandstones are composed dominantly of primary detrital grains, which shows that the rock must have been considerably repacked if it was originally a limestone containing only small amounts of insolubles. R9256 is the only specimen which could have started with an important carbonate content, on the basis of no residual packing of insolubles.

Two further features are pertinent. Firstly the petrological work shows that much of the carbonate in the limestone occurs as well-rounded grains which were carried in the original sediment load. Secondly the strong plastic deformation in the limestone is not present in the other rocks: had the carbonate in this limestone been replaced, the deformation structure should have still persisted. The absence of detrital carbonate in the sandstones, and the change of structure from highly contorted to evenly bedded, can be best explained as the product of normal sedimentary processes.

It is concluded that specimens R9251 - R9256 were originally sandstones, and should be considered as a different rock-type from R9250, although a small variable percentage of carbonate is likely to have been present in these rocks.

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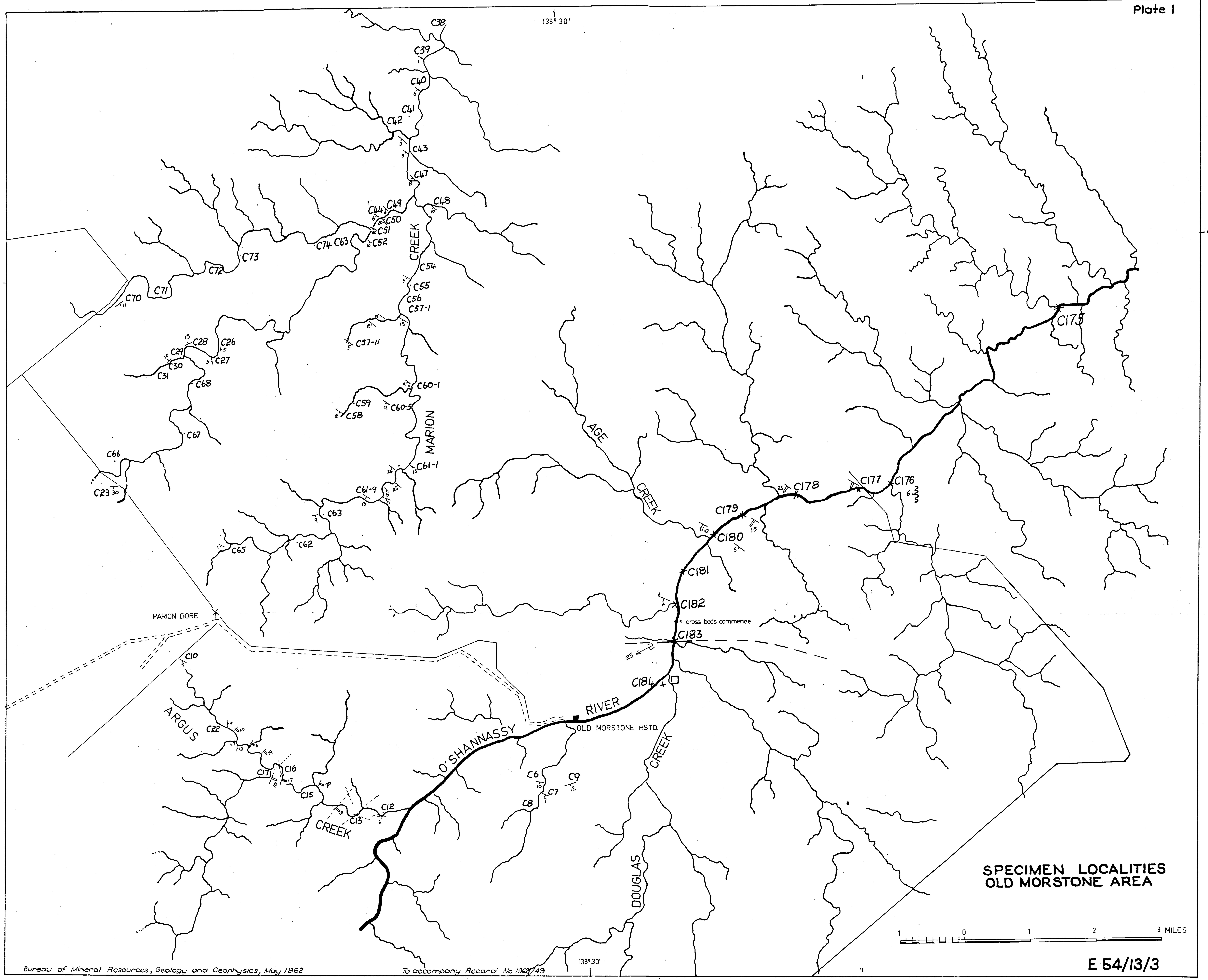
Plate I



Bureau of Mineral Resources, Geology and Geophysics, May 1962

To accompany Record No 1962/49

E 54/13/3

SECTIONS MEASURED IN ADA AND MARION CREEKS

AGE CREEK FORMATION

"C" numbers refer to localities on Plate 1

SECTION IN AGE CREEK FORMATION SOUTH-WEST OF MORSTONE HOMESTEAD