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The Garra Formation (Early Devonian) at Wellington, N.S.W.

Brian D. Johnson

Abstract—Andesitic volcanics, often regarded as Ordovician, but here referred to the Early Devonian Cuga Burga Volcanics, out-crop in a much faulted, north plunging anticline in the Wellington Caves area. The volcanics are overlain by the Garra Formation. The latter commences with an apparently transgressive sequence of volcanically derived sediments grading from conglomerates and siltstones through to marine shales and these in turn into limestones at the base of a carbonate sequence some 970 metres in thickness. It is contended that a complete sequence of the Garra Formation exists in the Wellington area and that this can be informally divided into 20 units. After the initial transgressive phase, subtidal marine carbonates were deposited on a shallow platform ; the upper half of the formation is characterized by extensive sabkha style deposition on intertidal and supratidal flats. Conodonts indicate correlation of the basal Garra limestones with the limestones at the base of the Mandagery Park Formation (late Lochkovian-early Praguian).

Introduction

Richly fossiliferous horizons have long been known to occur in the limestones of the Garra Formation near the Wellington Caves, south of Wellington, N.S.W., but their stratigraphic sequence and faunal composition have not been detailed ; with the exception of the corals, (Strusz, 1965*b*, 1966, 1967*b*, Strusz and Jell, 1970) the diverse invertebrate faunas have received little attention. Mapping of the Wellington Caves area was undertaken to determine the field relationships of the Garra Formation to contiguous units and to establish the stratigraphic and lithologic sequence as a basis for palaeoecological analysis of the faunas.

The area (Figure 1) forms part of the eastern flank of the Molong High. The oldest outcrops in the region are Ordovician spilites and graptolitic shales (Oakdale Formation) overlain by fossiliferous Silurian limestones (Narragal Limestone) and graptolitic shales (Barnby Hills Shale). Andesitic vulcanism, with extensive intermediate lavas and detrital deposits, commenced at or about the close of the Silurian and continued into the Early Devonian (Cuga Burga Volcanics). All the above outcrop typically along the Oakdale Anticline (Strusz, 1960) to the east of the Caves area.

The oldest outcrops within the area mapped are lavas, herein assigned to the Cuga Burga Volcanics. These are overlain by a thick sequence of Early Devonian limestones representing an eastward extension from a major meridional belt of limestones, the Garra Formation (Strusz, 1965*a*), and physically separated from it by a synclinal belt of Late Devonian quartz rich clastics, the Catombal Group (Conolly, 1963 ; Roberts *et al.*, 1972). There is no further sedimentary record of events until the late Cainozoic when the various alluvials of the present drainage system accumulated.

Stratigraphy

Cuga Burga Volcanics

Andesitic lavas, tuffs and detrital sediments of volcanic derivation, previously regarded as Ordovician in age (e.g. Adrian, 1971) and so indicated on the Dubbo 1 : 250,000 geological sheet (Offenburg *et al.*, 1968), are here assigned to the Cuga Burga Volcanics as defined by Strusz (1960) ; this assignment has been implied previously by Strusz (1967*a*), Savage (1968) and Druce (1970). Correlation is indicated by the close petrographic similarities to the typical Cuga Burga outcrops mapped by Strusz (1960) and, more important, by field relationships in the area north of Newrea (south east of the Wellington Caves) where these volcanics are seen to be underlain by the Late Silurian Barnby Hills Shale.

Owing to the weathered nature and lack of stratification in most outcrops, precise relationships and thicknesses are not clear. The better exposures to the south (' Camelford Ridge ') are massive and strongly jointed, making bedding difficult to determine. The lowest outcrops are a suite of breccias with coarse angular, andesitic clasts and minor red lithic tuffs. They are overlain by green andesites grading into dark red and purple andesites with quartz veins and disseminated copper.

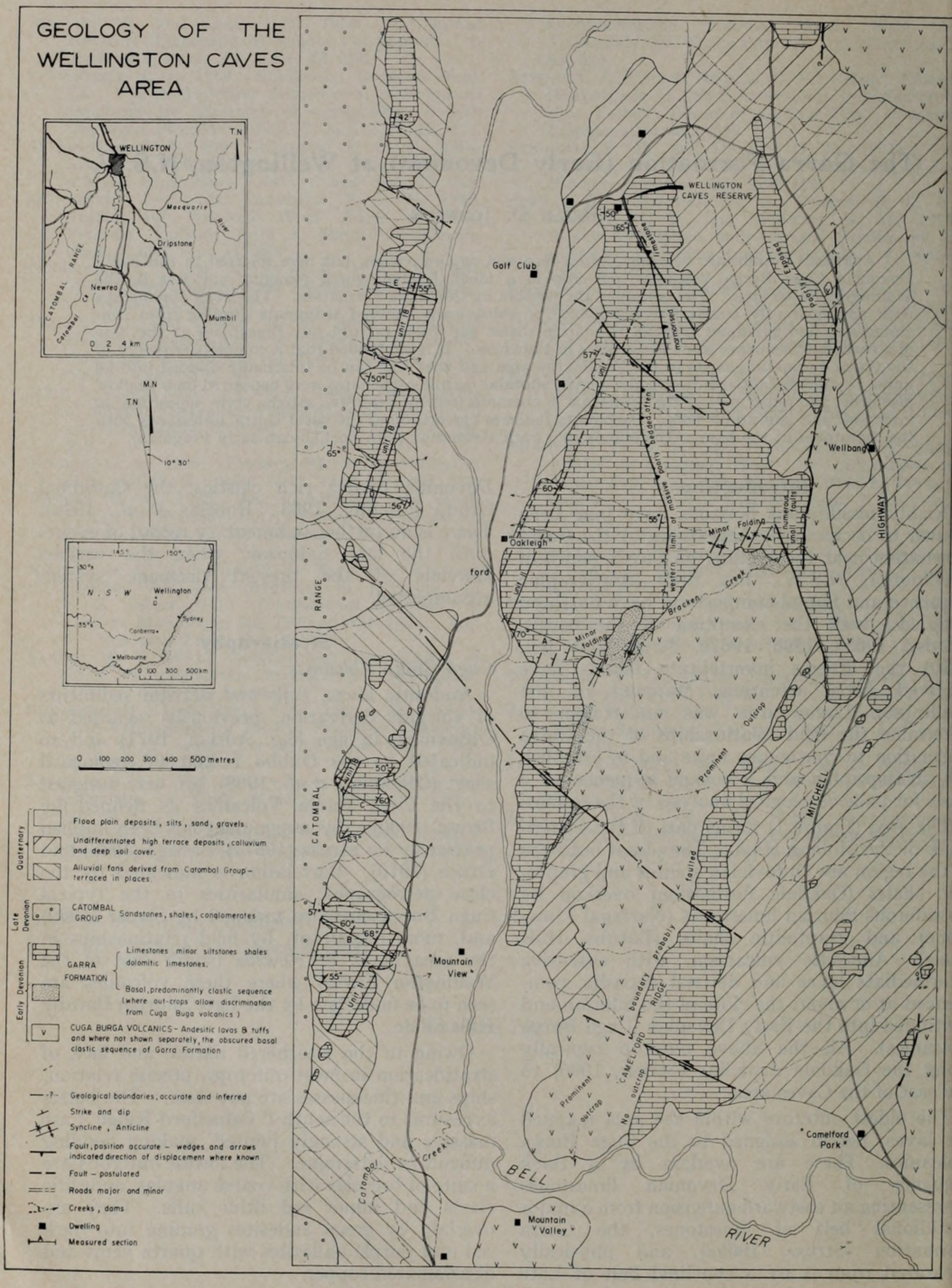

GEOLOGY OF THE WELLINGTON CAVES AREA
WELLINGTON
T.N
Macquarie River
Dripstone
CATOMBAL RANGE
Newrea
Catombal Ck
Mumbil
0 2 4 km
M.N
T.N
10° 30'
145°
150°
30°s
N. S. W
Wellington
35°s
Canberra
Sydney
Melbourne
0 100 300 500 km
0 100 200 300 400 500 metres
Quaternary
Flood plain deposits, silts, sand, gravels.
Undifferentiated high terrace deposits, colluvium and deep soil cover.
Alluvial fans derived from Catombal Group - terraced in places.
Late Devonian
CATOMBAL GROUP
Sandstones, shales, conglomerates
Early Devonian
GARRA FORMATION
Limestones minor siltstones shales dolomitic limestones.
Basal, predominantly clastic sequence (where out-crops allow discrimination from Cuga Burga volcanics)
CUGA BURGA VOLCANICS - Andesitic lavas & tuffs and where not shown separately, the obscured basal clastic sequence of Garra Formation
Geological boundaries, accurate and inferred
Strike and dip
Syncline, Anticline
Fault, position accurate - wedges and arrows indicated direction of displacement where known
Fault - postulated
Roads major and minor
Creeks, dams
Dwelling
Measured section
WELLINGTON CAVES RESERVE
Golf Club
limestone
marmorised
poorly bedded, often
western limit of massive poorly bedded
unit 8
unit 18
unit 11
unit 18
unit 11
Poorly Exposed
Wellbang
HIGHWAY
MITCHELL
Oakleigh
ford
Minor Folding
numerous small faults
Bracken Creek
Minor folding
RANGE
CATOMBAL
Prominent outcrop
faulted
probably
boundary
CAMELFORD RIDGE
No outcrop
Prominent outcrop
Mountain View
Camelford Park
Catombal Creek
BELL
RIVER
Mountain Valley
A
B
C
D
E

FIGURE 1.

Garra Formation

The above, essentially volcanic unit (approx. 200 metres), is overlain by 30–50 metres of polymictic conglomerates, siltstones and shales, compositionally consistent with derivation from earlier erupted lavas. These sediments are best exposed in deeply weathered, discontinuous outcrops along Bracken Creek. The conglomerate has well rounded clasts, imbricated in part, in a claret coloured siltstone matrix. Alternating siltstones and shales overlie the conglomerate ; these grade into approximately 10 metres of fine silty shales with discontinuous, thin, contorted laminae of limestone and several recessive biostromes composed of abundant rugose and tabulate corals, stromatoporoids and crinoid columnals, with interstitial mudstone. The first laterally persistent limestone bed of the Garra Formation occurs approximately two metres above the highest of these biostromes.

Definition of the top of the Cuga Burga Volcanics and the base of the Garra Formation is open to variant interpretation. The cessation of vulcanism and subsequent deposition of detritus from the reworked lavas and tuffs in an apparently transgressive sequence of basal conglomerate, siltstone, shale, limestone, may be regarded as either representing the close of ' Cuga Burga ' or the commencement of ' Garra ' events ; the latter is suggested here. Formal naming of this member has been deferred pending accumulation of data over a wider area. The appearance of marine biota and the transition to a carbonate sequence indicates an important change in depositional environment ; this horizon has been used as the base for measurement of the stratigraphic column (Figure 2). As both the conglomerate and biostromes outcrop very poorly, the first laterally persistent limestone bed has been used, for the purposes of mapping (Figure 1), as an approximation to the base of the Garra Formation.

Strusz (1965*a*), in describing the Garra Formation, estimated its thickness to be between 915 and 1,200 metres, but due to sporadic outcrop, rapid facies changes, thickness variations and an apparent absence of a complete sequence at any locality, did not propose formal subdivision. It is here suggested that a complete sequence is developed in the Wellington Caves area.

Within the mapped area, five sections were measured (see locations Figure 1) ; close lithological and faunal correlation has enabled compilation of a stratigraphic column (Figure 2). This correlation demonstrates that faulting and/or folding has caused offsetting and some apparent increases in thickness between the marker horizons—Units 11 and 18 of Figure 2.

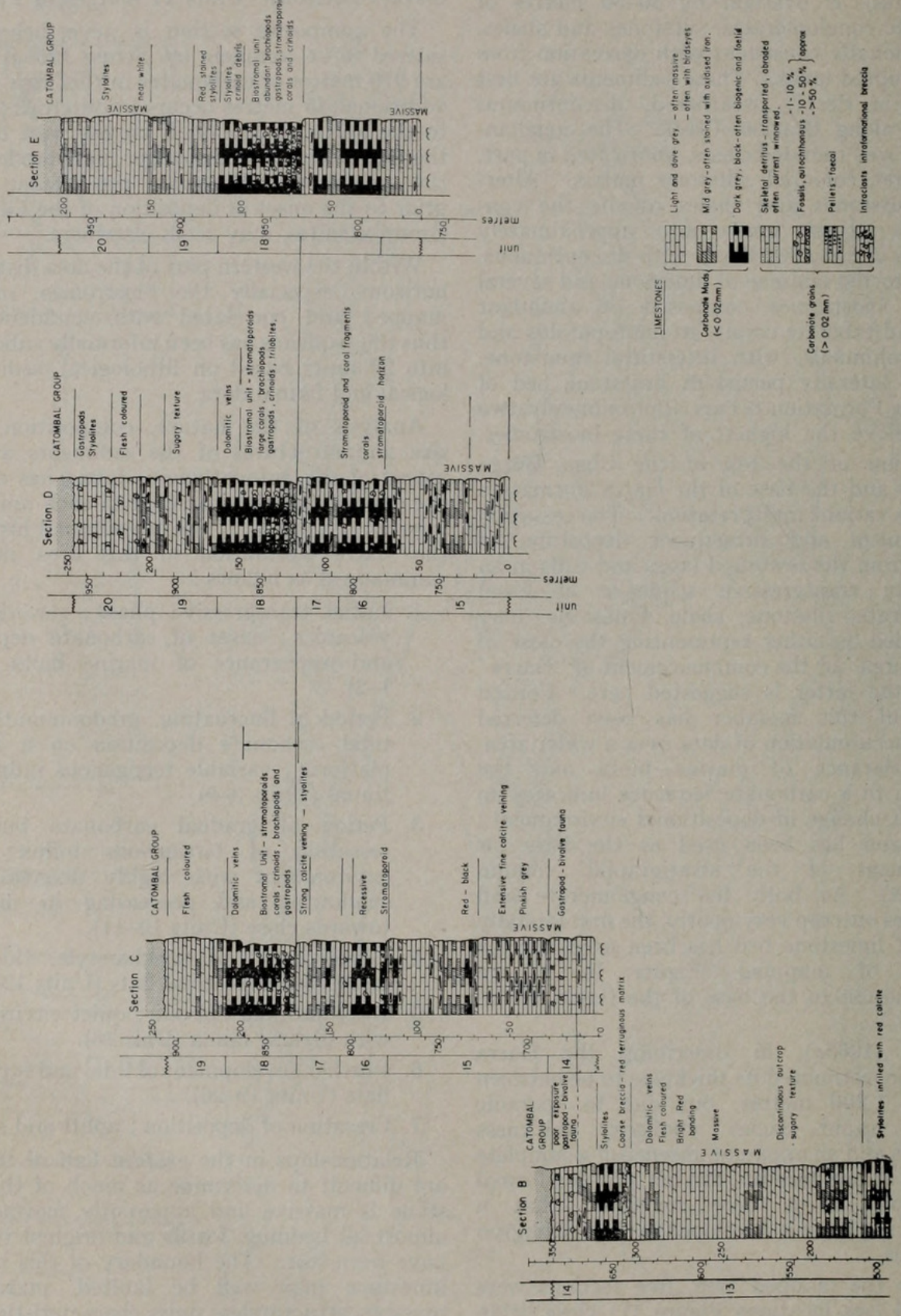
The composite section is nevertheless considered to be complete (*cf.* Strusz 1965*a*) ; there are 970 metres of carbonates in this area, but an additional 45 metres occurs in outcrops 2·5 km to the north of Section E on the west bank of the Bell River. Still younger units eroded from the area in post-Praguian, pre-Fasnian times, prior to the onset of deposition of the Catombal Group arenites, may occur elsewhere.

Within the western part of the area distinctive horizons, especially the biostromes, may be mapped and correlated with confidence and thus the sequence has been informally subdivided into 20 units based on lithological, sedimentological and faunal data.

Analysis of the nature, composition, grain size and structures of the sediments and the aspect of the autochthonous fauna has enabled the depositional environment of each unit to be inferred (Figure 3). The depositional history of the Garra Formation in this area may be summarized as follows :

1. Initial transgressive phase ; reworking of volcanics ; onset of carbonate deposition and appearance of marine biota (Units 1–2).
2. Period of fluctuating, predominantly subtidal carbonate deposition on a shallow platform ; variable terrigenous influx continues (Units 3–9).
3. Period of gradual carbonate build-up ; cessation of terrigenous influx ; quiet environment with highly diverse fauna, shallowing and decreasing in diversity towards close (Units 10–11).
4. Development of sabkha-style, tidal and desiccated supratidal flats (Units 12–17).
5. Brief subtidal episode ; quiet environment with diverse fauna (Unit 18).
6. Further development of tidal and supratidal flats (Units 19–20).
7. Cessation of deposition ; uplift and erosion.

Relationships in the eastern half of the area are difficult to determine as much of the limestone is massive and apparently marmorized ; almost all bedding, fossils and original textures have been lost. The boundary of this massive limestone may well be faulted, juxtaposing massive, structureless units characteristic of the upper part of the sequence against the well bedded lower units (e.g. in the Fault Wall of the Cathedral Cave).


Section E
CATOMBAL GROUP
Stylolites
near white
Red stained stylolites
Stylolites
crinoid debris
Biostromal unit abundant brachiopods gastropods, stromatoporoids corals and crinoids
MASSIVE
Section D
CATOMBAL GROUP
Gastropods
Stylolites
Flesh coloured
Sugary texture
Dolomitic veins
Biostromal unit – stromatoporoids large corals, brachiopods gastropods, crinoids, trilobites.
Stromatoporoid and coral fragments
corals
stromatoporoid horizon
MASSIVE
Section C
CATOMBAL GROUP
Flesh coloured
Dolomitic veins
Biostromal Unit – stromatoporoids corals, crinoids, brachiopods and gastropods
Strong calcite veining – stylolites
Recessive
Stromatoporoid
Red – black
Extensive fine calcite veining
Pinkish grey
Gastropod – bivalve fauna
MASSIVE
Section B
CATOMBAL GROUP
poor exposure gastropod – bivalve fauna
Stylolites
Coarse breccia – red ferruginous matrix
Dolomitic veins
Flesh coloured
Bright Red bonding
Massive
Discontinuous outcrop
sugary texture
MASSIVE
Stylolites infilled with red calcite
metres
unit
LIMESTONES
Light and dove grey – often massive – often with birdseyes
Mid grey – often stained with oxidised iron.
Dark grey, black – often biogenic and foetid
Skeletal detritus – transported, abraded often current winnowed.
Fossils, autochthonous – 1 - 10 % – 10 - 50 % – >50 % } approx
Pellets – faecal
Intraclasts intraformational breccia
Carbonate Muds (< 0 02mm)
Carbonate grains (> 0 02 mm)

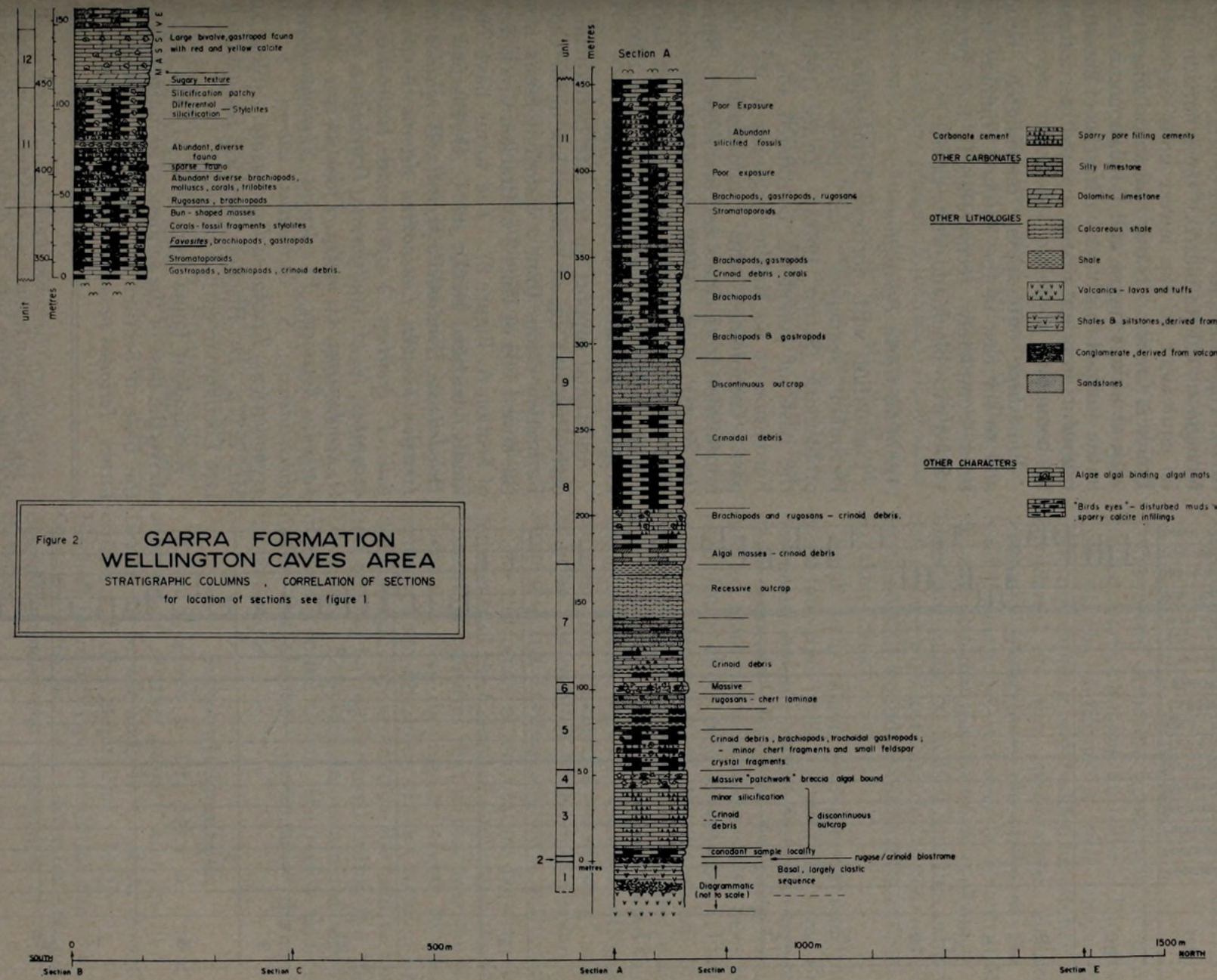
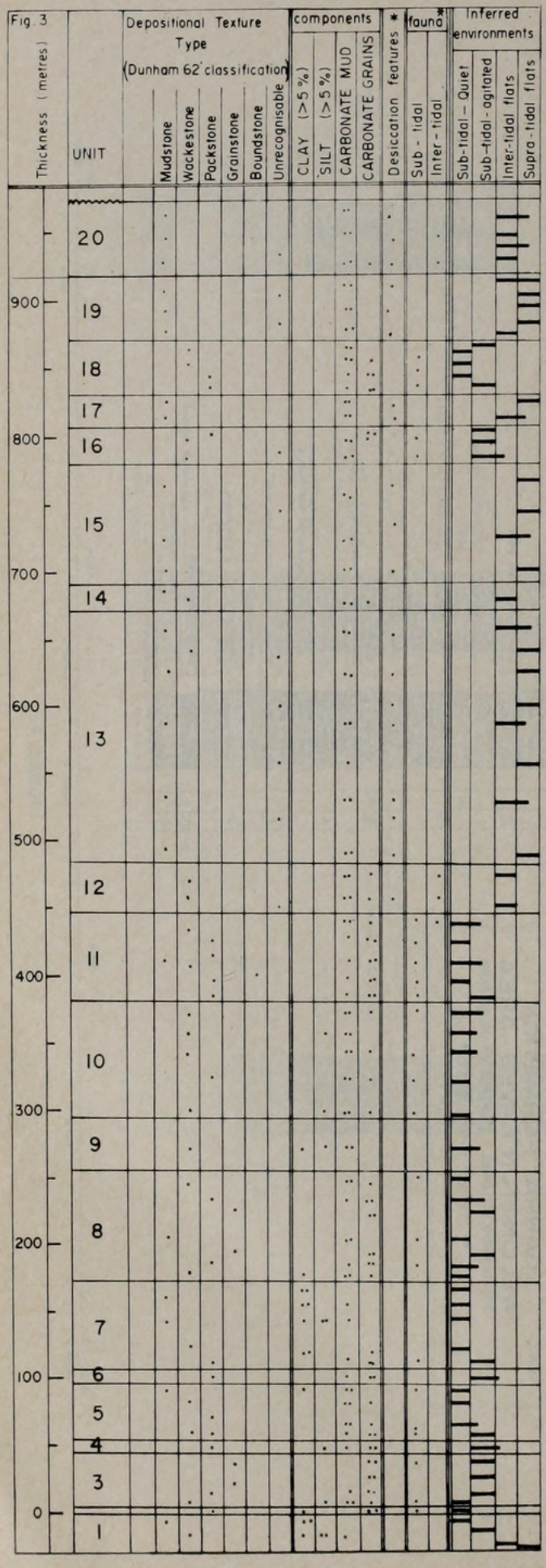


Figure 2. GARRA FORMATION WELLINGTON CAVES AREA

STRATIGRAPHIC COLUMNS, CORRELATION OF SECTIONS

for location of sections see figure 1

FIGURE 2.



Limestones along the eastern flank of ' Camelford Ridge ' are marmorized and dolomitized but retain some of their primary character. The outcrops to the volcanics in the south are rich in rugosans and crinoid debris, set in a red ferruginous calcite matrix ; these horizons may be equivalent to the lowest units exposed in Bracken Creek. Creamy dolomitic limestones with abundant rugose and tabulate corals occur in the north of this block. Breccias of limestone fragments in bright orange and red ' terra rossa ' are common.

Limestone outcropping immediately beside and to the east of the Mitchell Highway have been completely recrystallized and heavily veined with black and white calcite.

Age of the Garra Formation

Correlation with northern hemisphere Early Devonian sequences has been somewhat problematic (Strusz, 1967*a*). Druce (1970), on the basis of conodonts considered the Garra Formation to be Middle Siegenian in its lower part. Combining this information with information from corals and brachiopods, Strusz (in Strusz *et al.*, 1972) considers the Garra Formation as extending from the latest Lochkovian or earliest Praguian at the base, through Praguian, probably into Zlichovian.

Additional support for the late Lochkovian—early Praguian age of horizons low in the Garra Formation comes from a conodont fauna from the lowest bed of Unit 3 in Bracken Creek (base of Section A, Figure 2). The forms have been kindly identified by Dr. G. C. O. Bischoff as : *Belodella* sp, *Hindeodella priscilla*, H. *equidentata*, *Icriodus pesavis*, *Lonchodina detorta*, *L. cristagalli*, *L. greilingi*, *Neoprioniodus bicurvatus*, *N. excavatus*, *N.* cf. *multiformis*, *Ozarkodina typica*, *O. denckmanni*, *O. media*, *Paltodus* sp., *Plectospathodus flexuosus*, *P. extensus*, *Spathagnathodus remcheidensis*, *S. inclinatus wurmi*, *S.* aff. *asymmetricus*, *Trichonodella excavata*. (Slide No. MU 7277). Dr. Bischoff considers the age to be late Lochkovian-early Praguian.

A conodont fauna from Unit 11, 410 metres above the base of the sequence (70 metres above the base of Section B, Figure 2) includes the forms : *Icriodus pesavis*, *Ozarkodina denckmanni*,

FIGURE 3.

(*a*) Dessication features :—' bird's eyes ', mud cracks, algal mats, vadose silts ; for distribution of dolomites see Figure 2.

(*b*) Discrimination of faunal aspect based on the generalization that brachiopods, corals, bryozoans, crinoids, stromatoporoids were unable to survive subaerial desiccation in the intertidal zone.

Spathagnathodus exiguus philipi, *S. optimus*, *S. sulcatus*. (Slide No. MU 7278). Dr. Bischoff considers the age of this fauna to be early Praguian. Interestingly, the fauna includes *Spathagnathodus sulcatus* and *Icriodus pesavis*, shown by Savage (1973*a*, *b*) as having mutually exclusive ranges.

Units higher than Unit 11 have so far failed to yield conodonts in the mapped area though conodonts are abundant in samples from roadside outcrops of dark grey, highly fossiliferous limestones underlain and overlain by light grey massive algal limestones on the Mitchell Highway 19 km NNE of Wellington (the fauna and lithological sequence suggest probable correlation with Unit 18). *Spathagnathodus exiguus philipi*, *S. optimus*, *Ozarkodina denckmanni*, *O. typica australis*, *Plectospathodus extensus* are prominent (Slide No. MU 7279) but in spite of quite high yields *S. sulcatus* and definitive younger forms such as *S. exiguus exiguus* or species of *Polygnathus* were not obtained.

On the similarity of the conodont faunas and regional relationships, I suggest correlation of the basal Garra Formation with the basal limestones of the Mandagery Park Formation (Savage, 1968, 1973*a*, *b*) ; the latter is interpreted as a tongue of Garra extending out into the Cowra Trough.

According to my analysis, previously listed coral, conodont and brachiopod faunas from the Wellington area have come from the following horizons :

Strusz, (1965*b*, 1966, 1970) rugose corals, Localities Cr 103, 106, $BR^3/200$, $BR^3/214$, =Unit 11. Localities Cr 100, 94, 89, 111, 113, $BR^1/177$ =Unit 18.

Also assignable to this unit are localities Cr 1, 2, and 77, just outside the mapped area.

Druce, (1970) conodonts, Locality WC5=Unit 10.

Strusz, (in Strusz *et al.*, 1972) Brachiopods Locality Wellington Golf Course=Unit 10, 11

Unpublished details of Dr. Strusz's sections are given in his Ph.D. thesis (Strusz, 1963), (his BR^3=Section B, BR^2=Section D, BR^1= Section E).

Catombal Group

The lowest units of the Catombal Group in the area are red to white, medium grained sandstones (orthoquartzites) of the Brymedura Sandstone (Conolly, 1963). There is a marked angular discordance of strike between the Garra limestones and Catombal clastics in the south of the area, the angle of discordance gradually decreasing northwards.

There is no evidence of Middle Devonian sedimentation, either in the Wellington area or for that matter in central N.S.W. (Pickett, 1972).

Structure

The broad structure appears to be a much faulted, north-plunging anticline. The western limb of the antiform is well preserved in uniformly dipping, well bedded limestones. The boundary of the marmorized limestones angularly transgresses the strike of the well bedded limestones and may be a fault. Many of the boundaries between volcanics and limestone could be faulted but this cannot be determined with certainty due to poor outcrops ; an unfaulted boundary nevertheless occurs in Bracken Creek.

Small tight minor folds are common in the basal limestone units (i.e. near the Cuga Burga Volcanics) but are absent from the remainder of the sequence. Evidence of faulting has been inferred from the measured sections more often than from direct field observation. Faulting prior to deposition of the Catombal Group produced a number of fault slices causing offsetting ; either faulting or undetected folding has increased the apparent thicknesses (Figure 1) between the distinctive biostromes and in addition has resulted in minor discordances in strike direction between sequences in the blocks.

The difference in orientation between basal sediments of the Catombal Group and the Garra Formation indicates that in this area the Garra Formation was dipping at about 15° north-easterly when deposition of the Catombal Group commenced ; this is evidence for mild tectonism and erosion having occurred during the Middle Devonian. Following the cessation of deposition of the Catombal Group, the region underwent major deformation, presumably during the Carboniferous.

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Addendum

The stratigraphic position of limestones along the eastern flank of Camelford Ridge is currently

under review; conodonts recently discovered indicate a pre-Garra age. A paper discussing these findings and their significance is in preparation.

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School of Earth Sciences,
Macquarie University,
North Ryde, N.S.W., 2113.

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