Stratigraphy and Depositional Environments of the Northern Capertee High

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PEMBERTON, J. W., COLQUHOUN, G. P., WRIGHT, A. J., BOOTH, A. N., CAMPBELL, J. C., COOK, A. G., & MILLSTEED, B. D. Stratigraphy and Depositional Environments of the Northern Capertee High. *Proc. Linn. Soc. N.S.W.* 114 (4): 195-224 (1994).

Near the northeast margin of the exposed Lachlan Fold Belt, in the Cudgegong-Mudgee-Rylstone-Kandos district, the northern Capertee High was a shallow marine to subaerial palaeogeographic entity from the Late Silurian until the earliest Middle Devonian. Rocks of the former Capertee High are preserved in the Capertee Anticlinorium, together with Late Ordovician basement, Late Devonian fluvial to shallow marine sediments of the Lambie Group, Middle Carboniferous granitic intrusions and to earliest Permian silicic pyroclastics, lavas and epiclastics of the Rylstone Volcanics. The Permo-Triassic Sydney Basin succession conceals eastern portions of the Capertee High.

The Late Ordovician Cudgegong Volcanics are the products of basaltic and andesitic submarine volcaniclastic debris flows; geochemical data indicate an affinity with calc-alkaline lavas erupted in island arc settings. By comparison, coeval units to the east (Coomber Formation and Lue beds) represent deep water volcaniclastic and quartz-rich turbidites and debris flows, with radiolarian chert. Ordovician strata may represent rifted basement for the Capertee High which was established at the same time as the opening of the Hill End Trough.

Following an Early Silurian hiatus, voluminous shallow water silicic volcanics and associated epiclastics dominated the emerging Capertee High. In the Cudgegong-Mudgee district, a Wenlockian to Ludlovian, shallow marine to emergent succession of clastics and carbonates (Willow Glen Formation) is overlain by thick subaerial dacite lava and breccia (Windamere Volcanics) and laterally equivalent, shallow marine volcaniclastics (Toolamanang Formation), with an uppermost shallow marine shelf unit (Millsville Formation). Coeval shallow marine sequences to the east and northeast (Moonbucca Formation and Dungeree Volcanics) formed in a siliciclastic/carbonate mass flow apron which interdigitated with a dacitic volcanic pile.

Extensive Early Devonian strata on the platform areas of the northern Capertee High were dominated by the early Lochkovian to middle Emsian Kandos Group, 4000 m of fine- to coarse-grained clastics, carbonates and silicic volcanics deposited in a variety of shallow marine and subaerial environments which were affected by a number of transgressions and regressions. The Kandos Group is best exposed in the Cudgegong-Rylstone-Kandos district; however, upper units of the Kandos Group identified from the Capertee Valley in the south to the Mount Knowles-Mount Frome area in the north, indicate the Capertee High was an elongate entity persistent during the Early Devonian. Conodont data suggest that sedimentation in the Mount Frome Limestone continued into the earliest Eifelian (Middle Devonian).

By comparison, the late Lochkovian to late Emsian sequences of the Queens Pinch Belt were deposited in fans and aprons adjacent to the western margin of the northern Capertee High and are characterised by mass flow volcaniclastics, siliciclastics and carbonates, with thick mudstone intervals. Vast volumes of detritus were transported to the west across the platform and were redeposited marginal to the Capertee High as well as providing fill for the Hill End Trough.

Regression in the earliest Middle Devonian effectively terminated deposition on the northern Capertee High, although major deformation of the strata did not occur until the Early Carboniferous.

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INTRODUCTION

Rocks of the Capertee High occur at the northeast margin of the exposed Lachlan Fold Belt (Fig. 1) and are now largely preserved in the Capertee Anticlinorium.

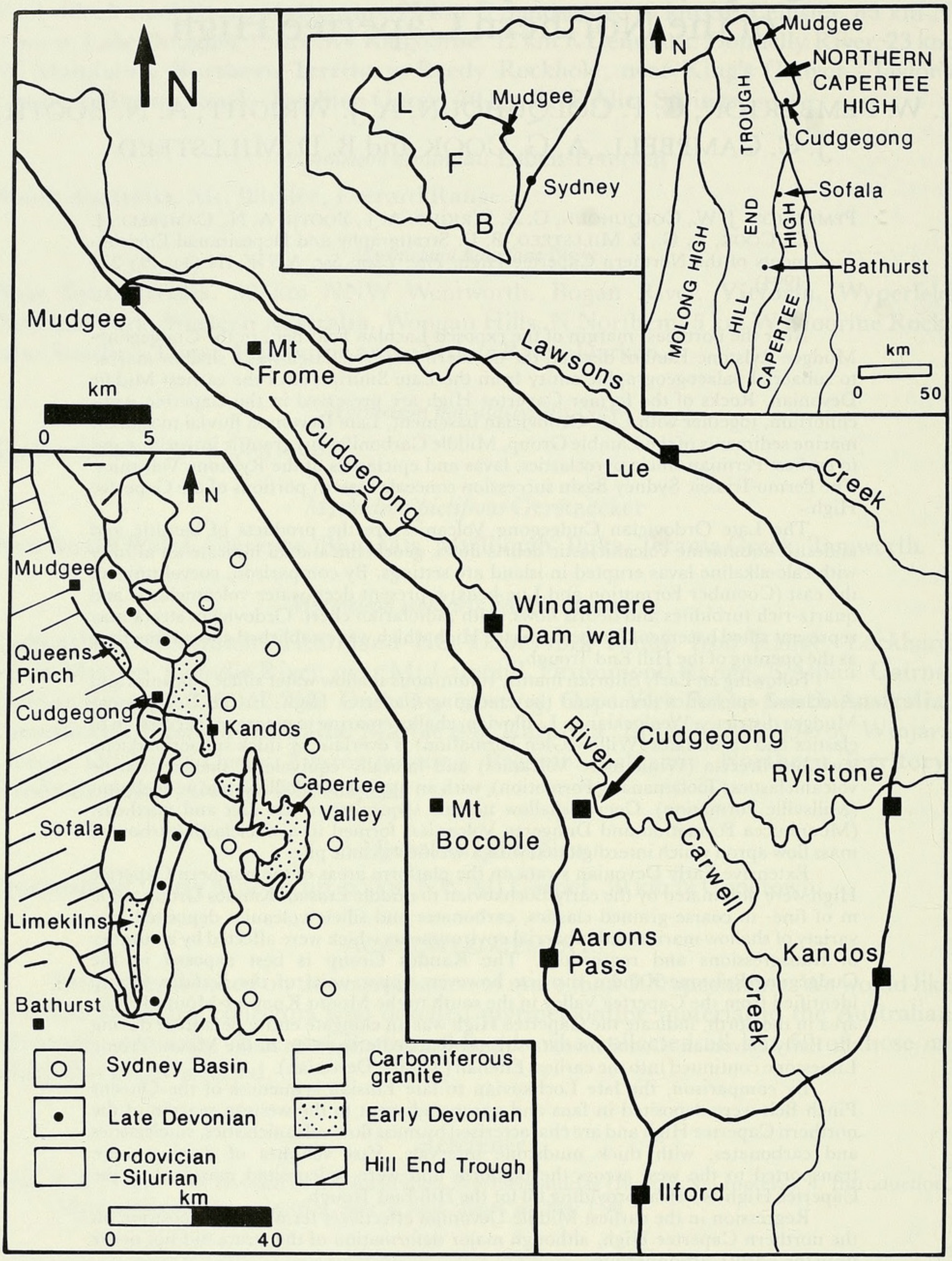

Fig. 1. Regional setting for the northern Capertee High, together with localities in the Mudgee-Cudgegong-Rylstone-Kandos district.

Packham (1960, 1968, 1969) originally defined the Capertee Geanticline as a discontinuous belt of Late Silurian to Early Devonian shallow marine strata from the Mudgee-Cudgegong district in the north (herein described as the northern Capertee High)

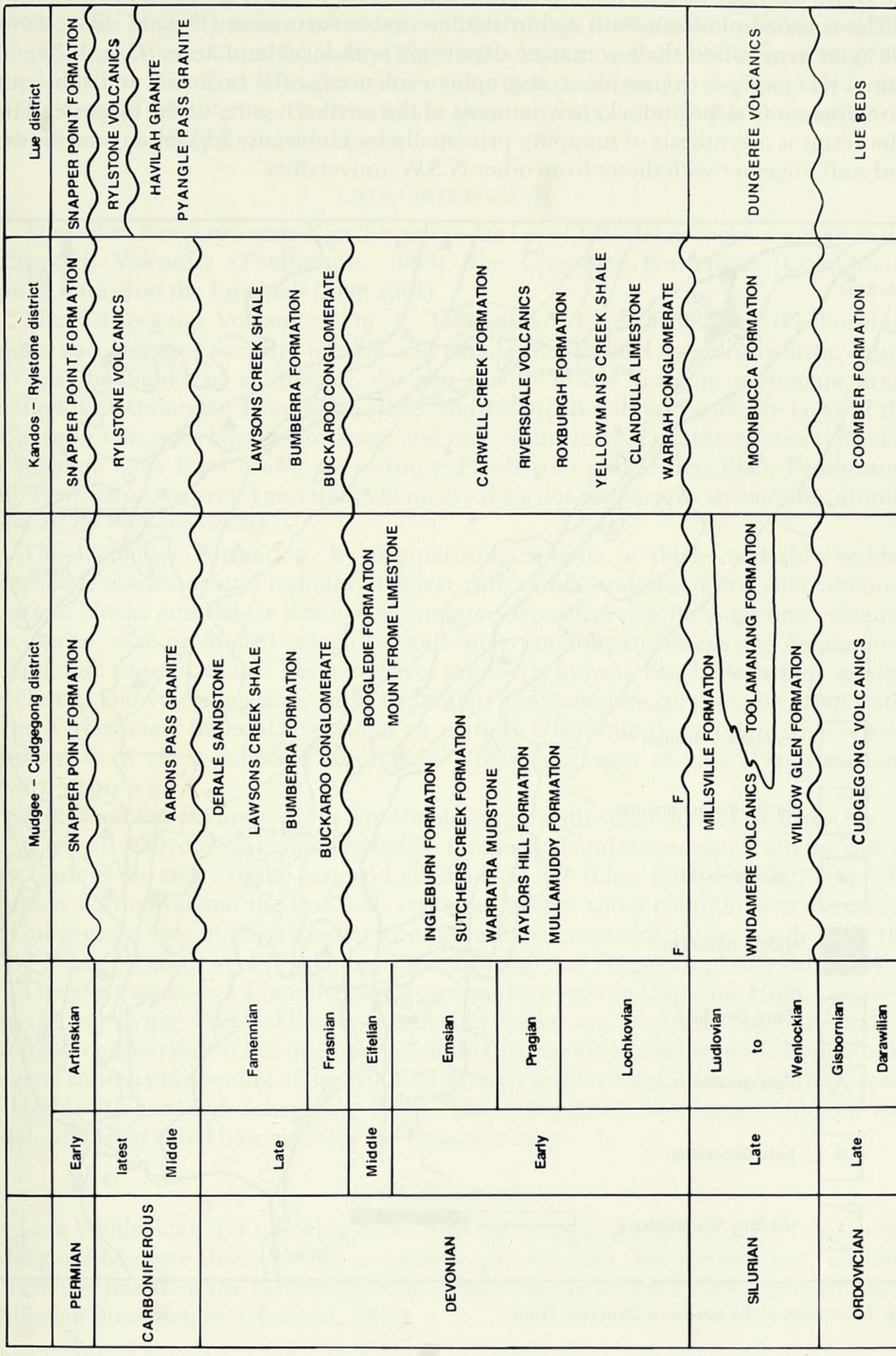

Fig. 2. Stratigraphic sequences on the northern Capertee High.

extending to the south through the Sofala district. Subsequent authors have referred to the Capertee High as a series of volcanic islands with fringing carbonate areas (Powell, 1984); a broad platform with a thin shallow water succession (Pickett, 1982; Powell, 1984); or generalised shallow marine deposition with local land areas (Cas, 1983). The aim of this paper is to provide stratigraphic evidence for the existence and subsequent development of depositional environments of the northern parts of the Capertee High. The result is a synthesis of mapping principally by University of Wollongong students and staff, together with theses from other N.S.W. universities.

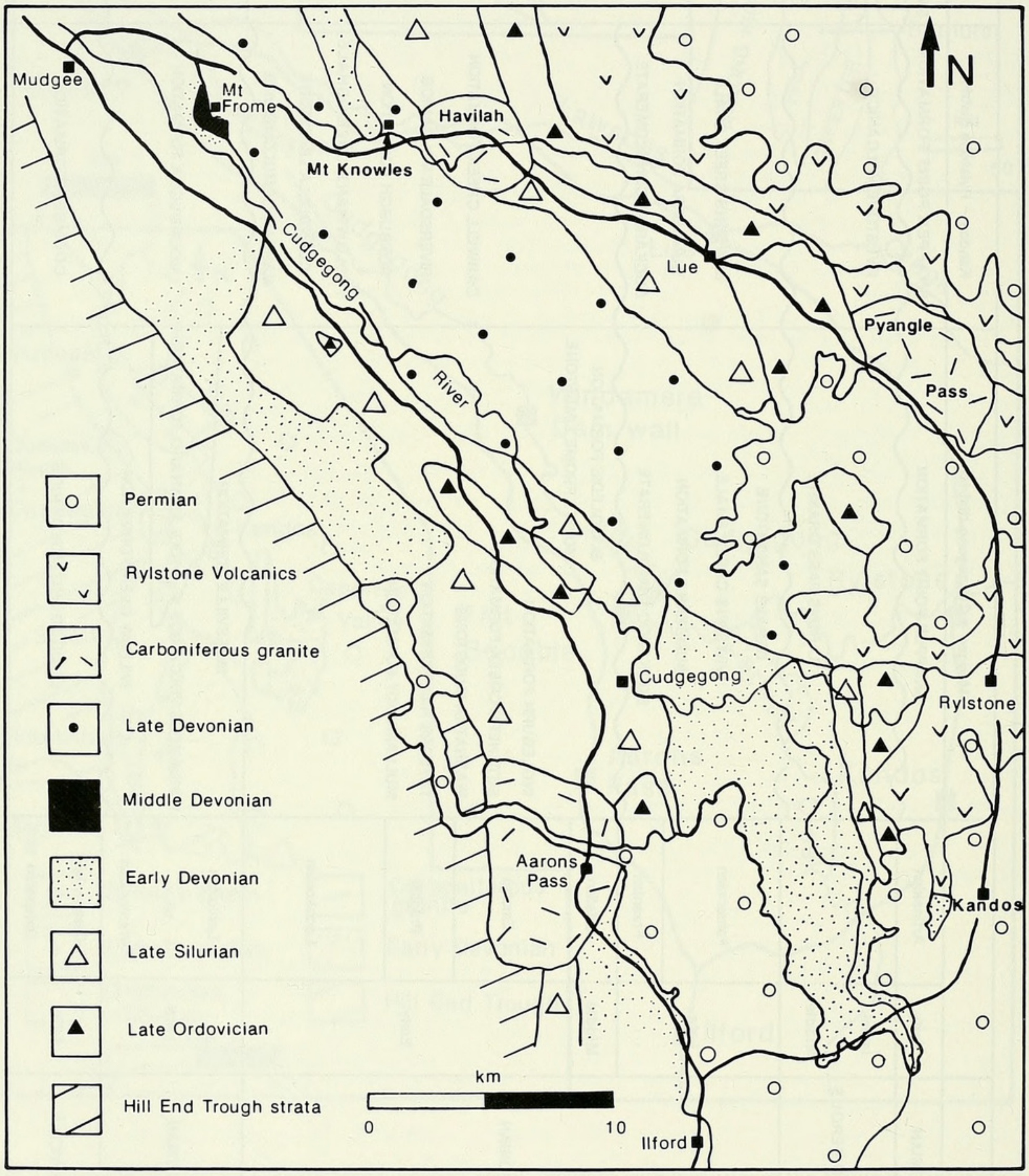

Fig. 3. Geology of the northern Capertee High.

The northern Capertee High (Pemberton *et al.*, 1991) encompasses Late Ordovician basement, together with Late Silurian to earliest Middle Devonian sequences (Fig. 2) best known from Mudgee in the north to the Cudgegong-Rylstone-Kandos district in the southeast (Fig. 3). The district is traversed by the Cudgegong River and the village of Cudgegong now lies under Lake Windamere.

Capertee High strata continue to the south through the Sofala-Limekilns area and to the southeast in the Capertee Valley (Fig. 1). Rocks of the northern Capertee High are faulted against Hill End Trough strata to the west; overlain by the Late Devonian Lambie Group; intruded by Carboniferous granite; and overlapped in the east by the Permo-Triassic Sydney Basin succession.

LATE ORDOVICIAN

The oldest strata recognised in the region are Late Ordovician rocks assigned to the Cudgegong Volcanics (Pemberton, 1989), the Coomber Formation (Colquhoun, unpubl. data) and the Lue beds (Day, 1961).

The Cudgegong Volcanics (Fig. 4; Table 1) are Late Ordovician (Gisbornian) basaltic and andesitic arenite, breccia and rare lava deposited by volcaniclastic debris flows on the flanks of submarine volcanoes with minor fringing carbonate areas [detailed descriptions in Pemberton (1989 and 1990)]. Basalt and andesite lavas of the Cudgegong Volcanics have major, trace and rare earth element characteristics typical of calc-alkaline lavas from island arc settings (Pemberton and Offler, 1985; Pemberton, 1990; Pemberton, in prep.) and their chemistry does not support the shoshonitic affinity proposed by Wyborn (1992).

The Coomber Formation, by comparison, consists of thick- and thin-bedded volcarenite, mudstone and radiolarian chert with minor andesite flows, allochthonous limestone blocks and debris flow conglomerate, deposited as a deep marine volcaniclastic apron, with prolonged pelagic periods interrupted by turbidites and debris flows (Colquhoun, unpubl. data). The extensive, yet poorly known, Lue beds include quartz-rich clastics and volcaniclastics, chert and minor conglomerate, of probable deep water origin. Ordovician (latest Darriwilian to earliest Gisbornian) conodonts have been identified from chert collected from Bara Creek, just west of Lue (Fergusson and Stewart, in prep.).

The Coomber Formation was a probable lateral equivalent of the Lue beds (Fig. 4) and its tentative Ordovician age is based on lithological and stratigraphic similarities to other Ordovician strata in the eastern Lachlan Fold Belt (Cas, 1983; Powell, 1984). The Coomber Formation and the Lue beds represent deeper water conditions to the east of the Cudgegong Volcanics. A similar configuration is reported to the south from the Sofala-Palmers Oakey area (Packham, 1968; Bischoff and Fergusson, 1982; Fell, 1984).

There are no known Llandoverian strata on the northern Capertee High. Contacts with the overlying Wenlockian to Ludlovian rocks are probably unconformable, although not observed. It has been proposed that rifting associated with the Benambran Orogeny caused the opening of the Hill End Trough and the establishment of the Capertee High (Gilligan and Scheibner, 1978). The Cudgegong Volcanics would, in this model, represent rifted basement for the Capertee High.

LATE SILURIAN

Late Wenlockian to Ludlovian rocks crop out in the Carwell Creek area and in the Cudgegong-Mudgee district. The sequences are recorded, for convenience, as Late Silurian age based on the twofold division of the Silurian by the IUGS subcommission on Silurian Stratigraphy (Holland, 1985).

Carwell Creek area

The Moonbucca Formation (Figs 4 and 5; Table 2) consists of mass flow- to suspension-deposited clastics, including basal conglomerate (with clasts of the Coomber

TABLE 1 LATE ORDOVICIAN BASEMENT ROCKS ON THE NORTHERN CAPERTEE HIGH

	thickness/rock types	age	environment	structures
CUDGEGONG VOLCANICS (McManus *et al.*, 1965; Pemberton, 1989)	1600m - basalt lava (SiO_2 47-51%), fine- to coarse-grained basaltic arenite and basaltic breccia; andesite lava (SiO_2 55-56%) and fine- to medium-grained arenite; mudstone. Type section: GR587738 to GR570730	Thin autochthonous marl horizon contains coral (*Plasmoporella*), alga (*Vermiporella*). Gisbornian age	Volcaniclastic debris flows on flanks of submarine volcanoes with minor fringing carbonate areas	Rare fine laminations, pillow lavas, reworked top of andesite lava provides facing
COOMBER FORMATION (new name) (Campbell, 1981; Colquhoun, unpubl. data)	1750m - volcaniclastic arenite and mudstone, with radiolarian chert and rare andesite lava, conglomerate and allochthonous limestone blocks. Rep. section: GR748652 to GR731642	Correlated with Late Ordovician deep water sequences	Thick mass flow and suspension deposits in deep marine setting with pelagic periods interrupted by turbidites and debris flows	Slumping, flutes, Bouma AE and ABE
LUE BEDS (Day, 1961; Evans, 1968; O'Donnell, 1972; Southgate, 1975)	1000m - slate, quartz-rich arenite, chert, conglomerate, rare andesite lava	Ordovician (Darriwilian) conodonts in chert (Fergusson and Stewart, 1993)	Proposed deep water	Bouma CDE, graded beds

TABLE 2 LATE SILURIAN ROCKS ON THE NORTHERN CAPERTEE HIGH

	thickness/rock types	age	environment	structures
MOONBUCCA FORMATION (new name) (Campbell, 1981; Colquhoun, unpubl. data)	610m - conglomerate (clasts of Coomber Formation), limestone breccia, mudstone, jasper; dacitic lava and arenite. Rep. section: GR732645 to GR720643	Late Silurian coral (*Phaulactis*, *Tryplasma*, *Zenophila*, *Propora*), trilobite (*Pacificurus* cf. *mitchelli*) fauna	NW-facing shallow marine setting with terrigenous/ carbonate slope and base of slope deposits with subaqueous lava and volcaniclastics	Graded beds, imbricated pebbles, geopetals

TABLE 2 (Continued) LATE SILURIAN ROCKS ON THE NORTHERN CAPERTEE HIGH

	thickness/rock types	age	environment	structures
DUNGEREE VOLCANICS (Offenberg *et al.*, 1971; O'Donnell, 1972)	1000m - dacite and rhyolite lava and volcaniclastics, mudstone, rare limestone	No distinctive fauna	Possibly shallow water to subaerial	None recorded
MILLSVILLE FORMATION (Pemberton, 1980b; Pemberton, 1989)	250m - breccia (limestone, dacite and rhyolite clasts), limestone, dacitic conglomerate. Rep. section: GR501795 to GR497794	Coral (*Phaulactis*, *Halysites*), trilobite (*Pacificurus mitchelli*), brachiopod (*Kirkidium*, *Eospirifer*, *Leptaena*, *Rhizophyllum*) fauna of Wenlockian to Ludlovian age	Shallow marine shelf with bank, lagoon and beach deposits affected by limestone bank collapse	Geopetals
TOOLAMANANG FORMATION (Pemberton, 1980a; Pemberton, 1989)	3000m - fine- to coarse-grained arenite (dacitic detritus) with black mudstone and fragmental basalt blocks	Lateral equivalent to, and fragmental version of, Windamere Volcanics	Dense, gravity-driven volcaniclastic ash and mudflows incorporating basement blocks	Slumping, loading
WINDAMERE VOLCANICS (Pemberton, 1980b; Pemberton, 1989)	1500m - dacite lava (SiO_2 65-69%), arenite and breccia; rhyolite lava. Rep. section: GR530793 to GR521766	Conformably overlies Willow Glen Formation and overlain by Millsville Formation - both Wenlockian to Ludlovian age	Possible thick lava dome in very shallow marine to subaerial environment	Localised ripple marks, cross beds and scour and fill in arenite
WILLOW GLEN FORMATION (Pemberton, 1980a; Pemberton, 1989)	1000m - conglomerate, pebbly litharenite and litharenite; fossiliferous mudstone and limestone. Type section: GR627676 to GR636720	Coral (*Phaulactis*, *Halysites*, *Pycnostylus*, *Desmidopora*), trilobite (*Pacificurus mitchelli*), brachiopod (*Morinorhynchus*, *Maoristrophia*, *Kirkidium*) fauna of Wenlockian to Ludlovian age	SE-facing coastal zone includes fluvial channels; subtidal to supratidal flats, affected by transgressive-regressive cycles; and open marine conditions	Fining-up sequences, cross-beds, scour channels, imbricated pebbles, geopetals, evaporites

Formation), litharenite, limestone breccia and calcarenite (with a late Wenlockian to Ludlovian fauna), mudstone and allochthonous jasper and limestone blocks. These lithologies interdigitate with a northward thickening unit of dacite lava, autoclastics and intraformational volcarenite (Colquhoun, unpubl. data). The depositional setting was a subaqueous mass flow apron with an associated silicic volcanic pile which accumulated at shallow depths on a northwest facing slope. Poorly known dacite lava and volcaniclastics, with minor mudstone, conglomerate and limestone, near Lue (the Dungeree Volcanics) are probable lateral equivalents of the Moonbucca Formation (Fig. 4).

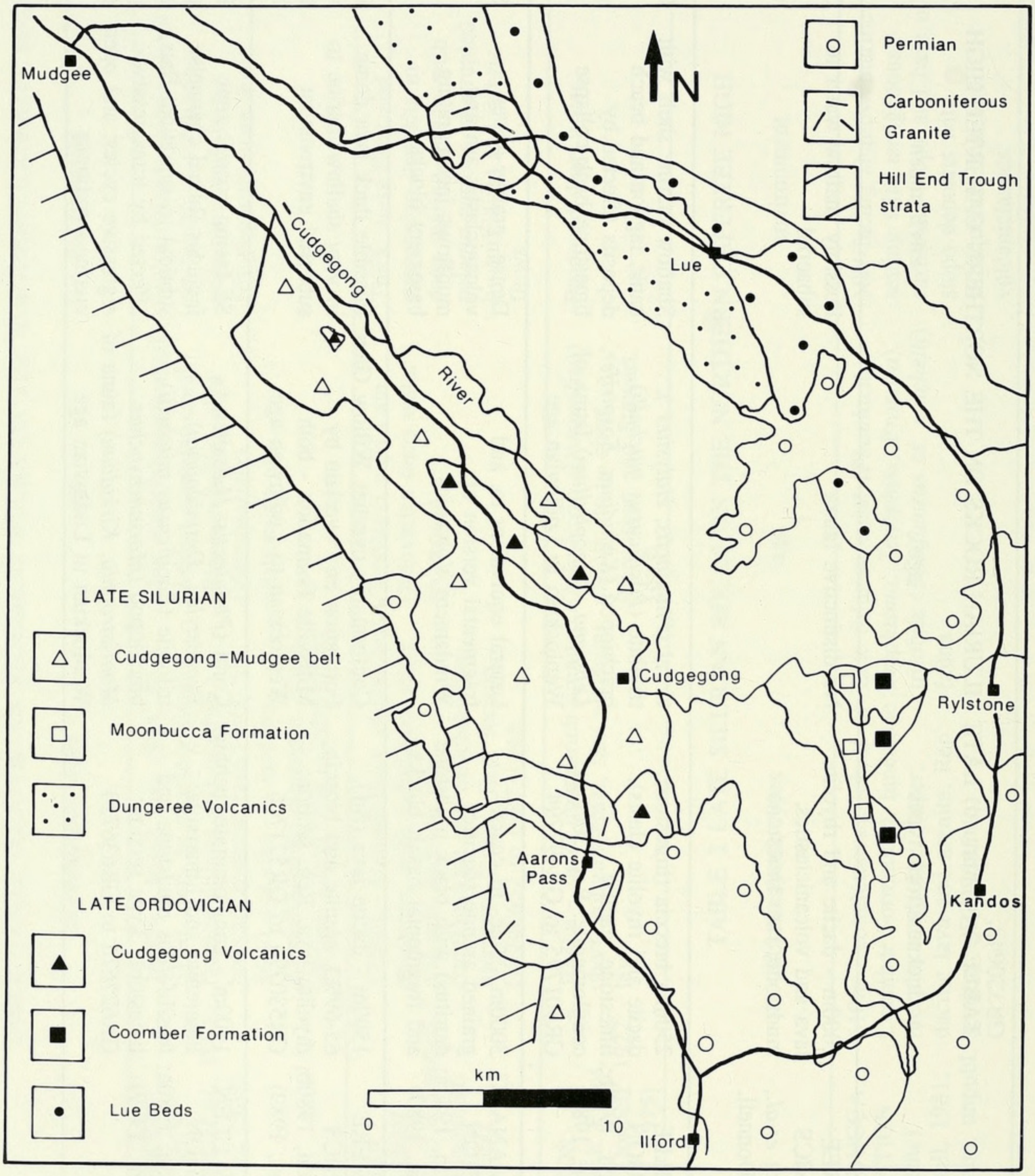

Fig. 4. Late Ordovician and Late Silurian units on the northern Capertee High.

Cudgegong-Mudgee district

A similar, yet much thicker, succession of conformable Wenlockian to Ludlovian shallow marine to probably emergent units occurs in the Cudgegong-Mudgee district

[Figs 4 and 5; Table 2; detailed descriptions in Pemberton (1989 and 1990)]. The Willow Glen Formation (conglomerate, pebbly arenite and arenite; mudstone and limestone with a late Wenlockian to early Ludlovian fauna) was deposited in a southeast-facing coastal zone which included fluvial channels, subtidal to supratidal flats (Jones *et al.*, 1987) and more open marine shelf conditions (Fig. 6A).

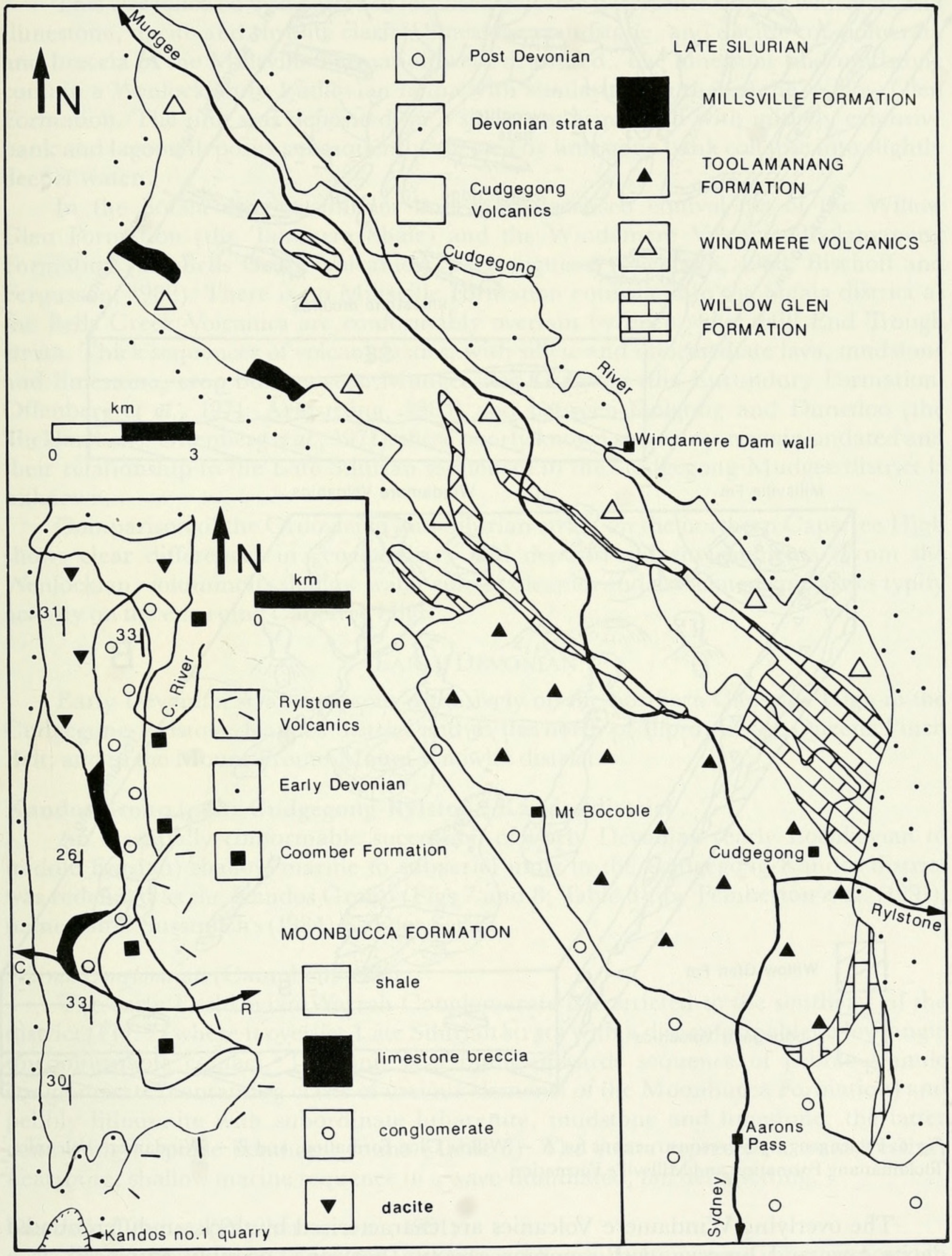

Fig. 5. Geology of the Cudgegong-Mudgee Belt and the Moonbucca Formation (inset).

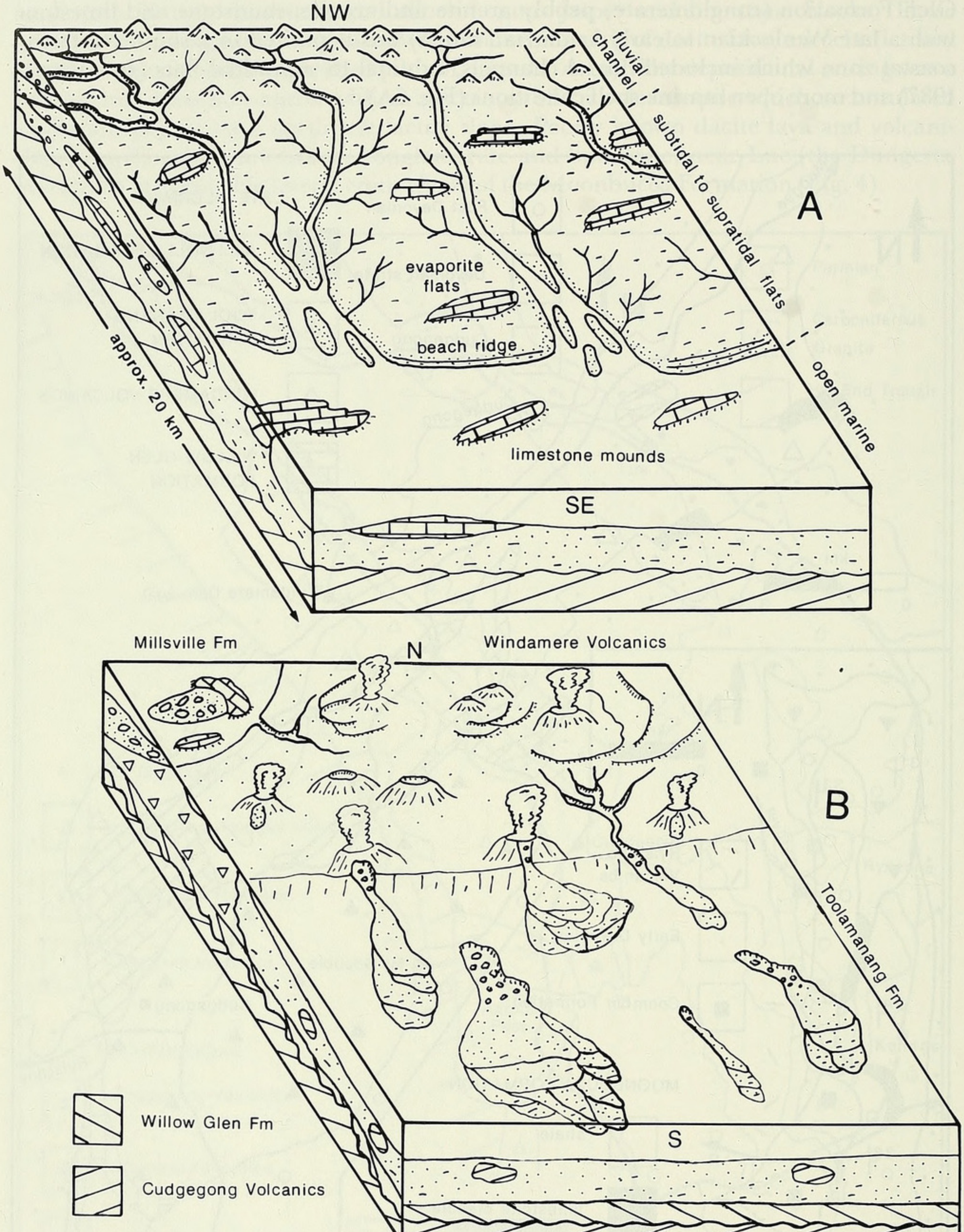

Fig. 6. Palaeogeographic reconstructions for A — Willow Glen Formation; and B — Windamere Volcanics, Toolamanang Formation and Millsville Formation.

The overlying Windamere Volcanics are characterised by thick, undifferentiated dacite lava and breccia, with common rhyolite horizons, possibly emplaced as a subaerial to very shallow marine lava dome or perhaps cryptodome. The Toolamanang

Formation is a thick succession of fine- to coarse-grained lithic arkose to feldspathic litharenite with common very fine ash-sized horizons, fine-grained breccia and sporadic basaltic blocks. The unit is considered a lateral equivalent to, and a fragmental version of, the Windamere Volcanics produced by dense, gravity-driven, shallow marine volcaniclastic flows of ash-sized dacitic detritus, with associated mudflows of the finer detritus, both of which incorporated some eroded basement material (Fig. 6B).

This was followed by a period of localised volcanic quiescence during which breccia (limestone, dacite and rhyolite clasts), limestone, mudstone, and dacitic conglomerate and breccia of the Millsville Formation were deposited. The limestone and mudstone contain a Wenlockian to Ludlovian fauna with similarities to that of the Willow Glen Formation. The unit was deposited on a shallow marine shelf with initially extensive bank and lagoon deposits subsequently affected by limestone bank collapse into slightly deeper water.

In the Sofala district, thinner and more localised equivalents of the Willow Glen Formation (the Tanwarra Shale) and the Windamere Volcanics-Toolamanang Formation (the Bells Creek Volcanics) are recognised (Packham, 1968; Bischoff and Fergusson, 1982). There is no Millsville Formation equivalent in the Sofala district as the Bells Creek Volcanics are conformably overlain by deep water Hill End Trough strata. Thick sequences of volcaniclastics, with silicic and intermediate lava, mudstone and limestone, crop out between Mudgee and Gulgong (the Eurundury Formation; Offenberg *et al.*, 1971; Armstrong, 1983) and between Gulgong and Dunedoo (the Tucklan beds; Offenberg *et al.*, 1971); these poorly known sequences remain undated and their relationship to the Late Silurian sequences in the Cudgegong-Mudgee district is unknown.

Comparison of the Ordovician and Silurian strata on the northern Capertee High shows clear differences in geochemistry and depositional environments. From the Wenlockian, voluminous shallow water silicic volcanics and associated epiclastics typify activity on the emerging Capertee High.

EARLY DEVONIAN

Early Devonian strata crop out extensively on the northern Capertee High in the Cudgegong-Rylstone-Kandos district and to the north of Ilford; in the Queens Pinch Belt; and in the Mount Frome-Mount Knowles district.

Kandos Group in the Cudgegong-Rylstone-Kandos district

An essentially conformable succession of Early Devonian (early Lochkovian to middle Emsian) shallow marine to subaerial units in the Cudgegong-Kandos district was redefined as the Kandos Group (Figs 7 and 8; Table 3), by Pemberton *et al.* (1991), named after Sussmilch's (1934) Kandos Series.

Warrah Conglomerate (Campbell, 1981)

The early Lochkovian Warrah Conglomerate is restricted to the southeast of the district (Fig. 7) where it overlies Late Silurian strata with a disconformable to low-angle unconformable contact. The unit is a fining-upwards sequence of pebble-granule conglomerate (containing clasts of various elements of the Moonbucca Formation) and pebbly litharenite with subordinate litharenite, mudstone and limestone, the latter containing a sparse benthonic fauna (Table 3). The strata represent a transgressive, nearshore, shallow marine sequence in a wave-dominated, fan delta setting.

Clandulla Limestone (Pemberton *et al.*, 1991)

The overlying early to middle Lochkovian Clandulla Limestone is best exposed in the Kandos quarries (Fig. 7) where conformable contacts with the underlying Warrah

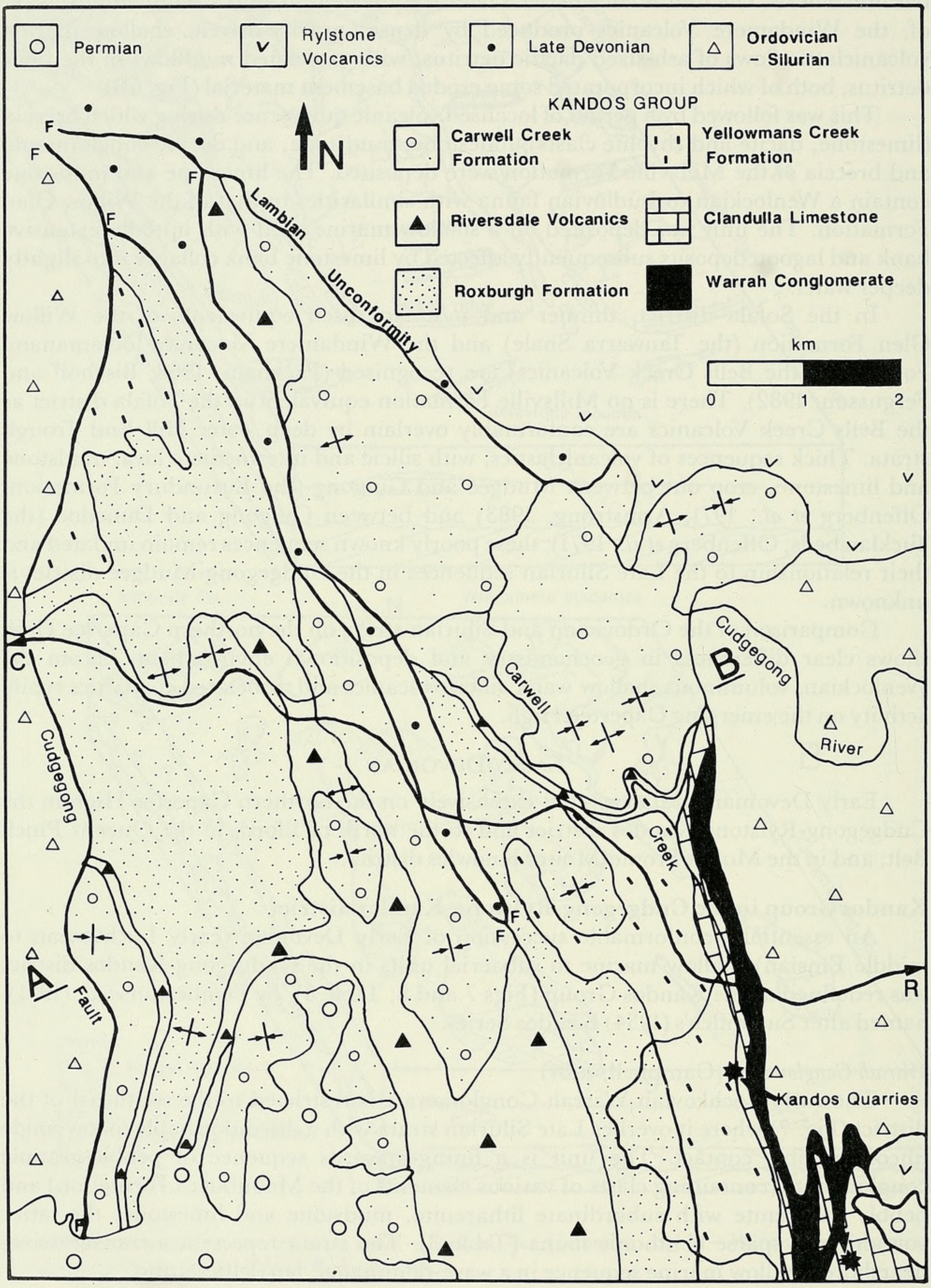

Fig. 7. Geology of the Kandos Group between Cudgegong and Rylstone.

Conglomerate and overlying Yellowmans Creek Formation, and the succession through the formation, are evident (Cook, 1988b). The unit comprises extensive shallow marine (depths of 0 to 24 m) carbonate deposition with biostromal and biohermal buildup dominated by stromatoporoid-*Thamnopora* communities and associated lagoon muds, forereef, interreef and backreef facies. The formation grades upwards into the Yellowmans Creek Formation reflecting deepening and a transition to more clastic sedimentation.

Yellowmans Creek Formation (Millsteed, 1985)

The middle Lochkovian Yellowmans Creek Formation crops out extensively in the Carwell Creek valley and to the east of Cudgegong as mudstone, calcareous mudstone, limestone, sublitharenite and volcaniclastic arenite and breccia. The sequence indicates fairweather suspension deposition of fine-grained siliciclastic detritus, together with carbonate mounds, periodically interrupted by distal storm-generated incursions of quartz-rich sand and minor volcaniclastic debris flows on a low energy, subtidal muddy shelf. The formation represents the peak of the transgressive cycle which began during deposition of the Warrah Conglomerate and continued through the Clandulla Limestone. An increasing proportion of coarser grained clastics near the top of the unit indicates shallowing associated with initiation of regressive conditions which continued during deposition of the overlying sandstone-dominated Roxburgh Formation.

Roxburgh Formation (Pemberton, 1980a)

The late Lochkovian-?early Pragian Roxburgh Formation occurs to the east of Cudgegong, along the Carwell Creek valley and to the north of Ilford (Colquhoun, in prep.). The formation thickens remarkably from 50 m in the east at an offlap contact with the Yellowmans Creek Formation near Carwell Creek (Fig. 8B) to a maximum of 750 m just east of Cudgegong (Fig. 8A). Lithologies include quartzarenite and sublitharenite with subordinate mudstone, litharenite, conglomerate, accretionary lapilli tuff and rare limestone. The unit yields, at several localities, an abundant shallow marine fauna dominated by brachiopods (Table 3).

Facies relationships indicate numerous cycles of small-scale (4 to 60 m thick) progradation and minor retrogradation superimposed on an overall upward-shallowing (regressive) trend (Colquhoun, in prep.). The depositional setting was a storm-dominated, southwest-sloping, shallow marine shelf, with outer to inner shelf, shoreface and coastal plain environments, flanked to the east by an eroding silicic volcanic terrain with some active volcanism, albeit distal to the setting. Palaeocurrent data indicate storm waves approached from the west-northwest producing dominantly southeast-directed longshore (on the shoreface) and southwest-directed offshore return currents over the shoreface and shelf.

Riversdale Volcanics (Wright, 1966)

The Pragian Riversdale Volcanics crop out extensively in the south of the district (Fig. 7) as dominantly welded, and lesser non-welded, purple dacitic ignimbrite (Fig. 8A). The unit thins very markedly to the west and north where it consists of dacite lava, immature coarse epiclastics and airfall tuff. Variation in both thickness and facies suggests emplacement of thick silicic intracaldera ignimbrites, with an explosive source to the south, which pass laterally to thin, coeval, shallow marine outflow equivalents. The base of the Volcanics is locally disconformable and implies a period of subaerial exposure prior to deposition of the thick subaerial ignimbrites. Towards the top of the sequence, reworking of dacitic detritus in a fan delta setting indicates the start of

TABLE 3 EARLY DEVONIAN ROCKS OF THE KANDOS GROUP

	thickness/rock types	age	environment	structures
CARWELL CREEK FORMATION (Offenberg *et al.*, 1971; Pemberton, 1980a; Booth, 1990; Cook, 1988a, 1990; Millsteed, 1985, 1992; Colquhoun, unpubl. data)	Glendale Limestone Member - basal 180m - limestone, dolomitised limestone, conglomerate - overlain by 1050m litharenite, crinoidal litharenite, conglomerate, limestone, dacitic ignimbrite. Rep. section: GR681685 to GR688687	Non-diagnostic corals (favositids) and stromatoporoids. Earliest Emsian brachiopods (*Buchanathyris*, *Spinella*). Early Emsian conodonts from 'Erang', south of Kandos Quarries and 'Riversdale' (Colquhoun *et al.*, in prep.)	Backreef to lagoon interrupted by volcaniclastic mass flows Shoreface to offshore storm-influenced setting with shoalwater limestone and minor volcanics	Low angle cross-beds Low angle tabular and trough cross-beds, hummocky cross stratification (HCS), wave ripples, bioturbation
RIVERSDALE VOLCANICS (Wright, 1966; Pemberton, 1980a; Cook, 1988a, 1990; Millsteed, 1985, 1992; Colquhoun, unpubl. data)	1250m - purple dacitic ignimbrite with minor lava, litharenite, conglomerate, accretionary lapilli tuff. Type section: GR709607 to GR690603	Early Devonian brachiopods (*Iridistrophia*) in litharenite near top	Thick subaerial intra-caldera ignimbrites passing laterally to thin outflow ignimbrites, epiclastics and lava. Marine incursion towards top	Localised erosional base; accretionary lapilli; fiamme; cross-bedded, bioturbated, laminated litharenite
ROXBURGH FORMATION (Pemberton, 1980a; Booth, 1990; Cook, 1988a, 1990; Millsteed, 1985, 1992; Colquhoun, in prep.)	750m - quartzarenite, litharenite, mudstone, conglomerate, accretionary lapilli tuff near base. Rep. sections: GR669629 to GR657629, GR719613 to GR709607	Early Devonian brachiopod-conodont-trilobite-mollusc fauna. Full faunal list in Colquhoun (in prep.)	Upward shallowing storm-dominated siliciclastics from middle-outer shelf to subaerial coastal plain setting	Low- to high-angle cross-beds, graded storm beds with rippled tops and scoured bases, intense bioturbation, abundant HCS

TABLE 3 (Continued) EARLY DEVONIAN ROCKS OF THE KANDOS GROUP

	thickness/rock types	age	environment	structures
YELLOWMANS CREEK FORMATION (Millsteed, 1985; Campbell, 1980; Cook, 1988a, 1990; Millsteed, 1992; Colquhoun, unpubl. data)	500m - calcareous mudstone, limestone, interbedded mudstone and litharenite, breccia. Type section: GR723616 to GR719613	Early Devonian brachiopods including (*Cyrtina*, *Anastrophia*, *Skenidiodes*) and trilobites (*Apocalymene*) with ?middle Lochkovian (*eurekaensis* Zone) conodonts (Colquhoun *et al.*, in prep.)	Quiet subtidal conditions with distal storm beds and carbonate deposition. Near top change to regressive cycle with storm deposits and very shallow conditions	Ripples, HCS in upper parts, bioturbation
CLANDULLA LIMESTONE (new name) (Campbell, 1981; Cook, 1988b, 1990; Colquhoun, unpubl. data)	170m - carbonate mudstone and variety of limestone types. Type section: GR735600 to GR736598	Early Devonian corals, stromatoporoids (*Amphipora*); brachiopods (*Machaeraria*, *Cyrtina*, *Salopina*, *Isorthis*). *woschmidti* to *eurekaenensis* zone conodonts (Colquhoun *et al.*, in prep.)	Transgressive reef development from lagoon carbonate muds through colonisation stage of extensive bioherms and forereef, interreef and backreef facies	Biostromal to biohermal buildup flanked by well bedded limestones
WARRAH CONGLOMERATE (new name) (Campbell, 1981; Booth 1990; Colquhoun, unpubl. data)	280m - conglomerate (Late Silurian clasts), pebbly litharenite, litharenite, mudstone and limestone lenses. Rep. section: GR726610 to GR725609	Favositid corals and stromatoporoids (*Amphipora*)	Transgressive nearshore shallow marine sequence in a wave-dominated fan delta	Low angle cross-beds, normal grading, wave ripples, bioturbation

another transgressive cycle. The reworked horizon contains the brachiopod *Iridistrophia*, which is found throughout the late Lochkovian-?early Pragian Roxburgh Formation, suggesting that any hiatus between the units was not prolonged. Furthermore, the Volcanics pass conformably into the Emsian Carwell Creek Formation, thereby constraining the age of the Volcanics to Pragian-early Emsian.

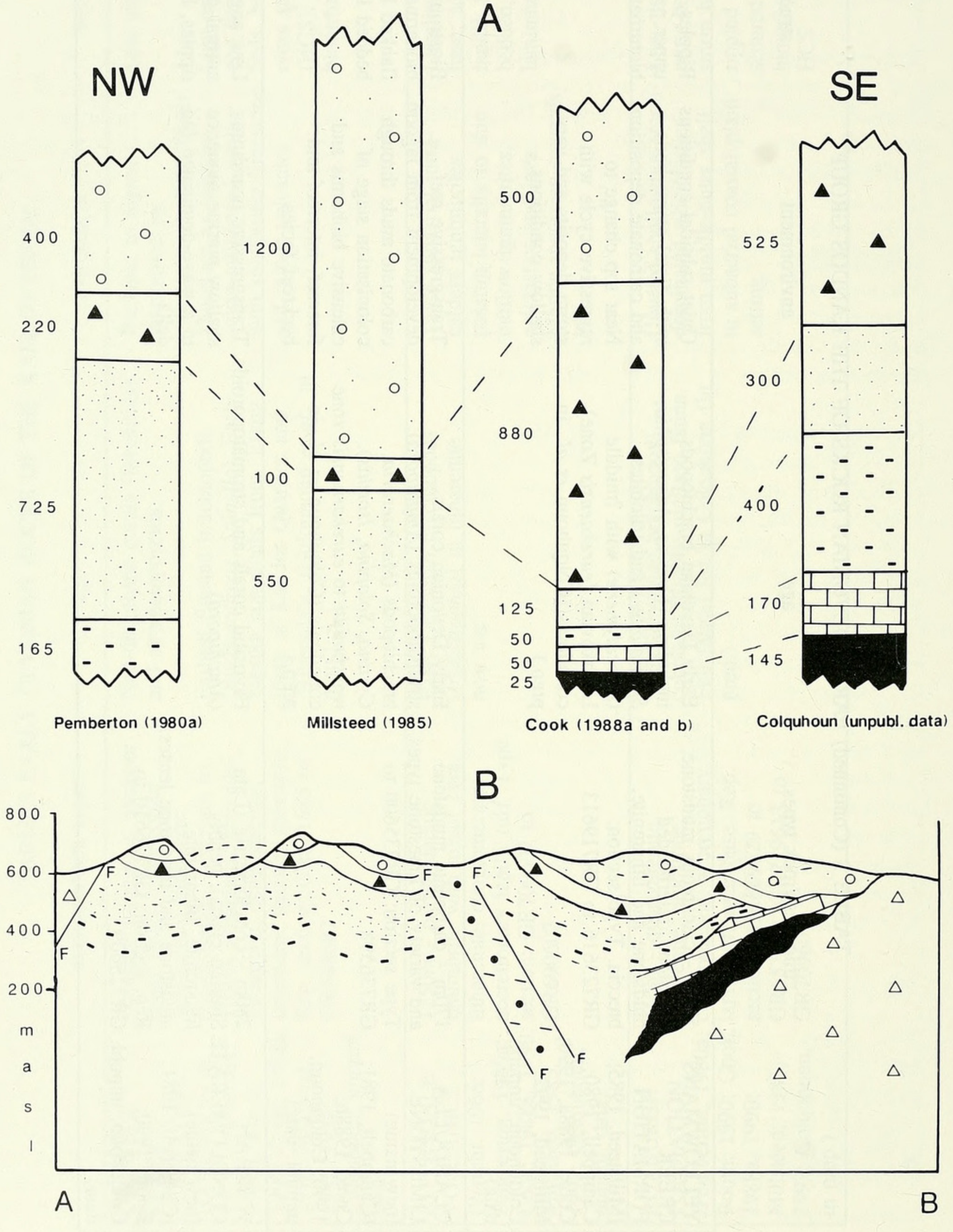

Fig. 8. A — sections through the Kandos Group. B — cross-section across the Kandos Group. Legend as in Fig. 7. Thickness in m.

Carwell Creek Formation (Offenberg *et al.*, 1971)

Stratigraphically the highest and most areally extensive unit of the Kandos Group, the early to middle Emsian Carwell Creek Formation crops out widely through the Cudgegong-Kandos district (Fig. 7) with probable equivalents to the south in the Capertee Valley and north as far as Mount Knowles. A discontinuous series of basal limestone and dolomite is defined herein as the Glendale Limestone Member (Table 3). The member and its lateral equivalents conformably overlie the Riversdale Volcanics, except in the east where the Carwell Creek Formation onlaps both the Clandulla Limestone and Late Silurian rocks (Fig. 8B). Maximum preserved thickness is 1230 m in the northeast; however, the top of the formation is nowhere exposed.

Lithologies include litharenite, crinoidal litharenite, pebbly litharenite and conglomerate as well as limestone and dolomite. The unit contains an abundant shallow marine fauna. The brachiopods *Buchanathyris* and *Spinella* suggest an earliest Emsian (*dehiscens* Zone) age (Garratt and Wright, 1988) and, in addition, *dehiscens* to *perbonus* Zone conodonts have been recovered from a number of localities (Table 3). The strata represent foreshore to inner shelf deposits influenced by fairweather- and storm-wave activity. The Glendale Limestone Member was mostly deposited in a restricted lagoon, suggesting a system of barrier islands and carbonate banks sheltering parts of the coastline. The setting was a broad, gently southwest-sloping shelf with rapid erosion of the Ordovician basement and the Riversdale Volcanics to the east and south. Some dacitic volcanoes remained active, possibly forming islands in the shallow shelf. The depositional phase was dominantly transgressive punctuated by brief regressive intervals and apparently long periods approaching aggradation.

Transgressive/regressive patterns recorded from the Kandos Group are similar to patterns recorded from various Australian basins, as well as on a world wide scale. Precise correlation of these trends, based on on-going conodont studies (Colquhoun), with eustatic sea level curves suggests a strong eustatic rather than tectono-sedimentary control on sedimentation patterns (Colquhoun *et al.*, in prep.).

Kandos Group north of Ilford

Early Devonian strata containing elements of both the Kandos Group and marginal Capertee High successions crop out in limited exposures to the north of Ilford (Booth, 1990; Colquhoun, unpubl. data). The strata are faulted against the Toolamanang Formation in the west and unconformably overlain by Permian strata in the north, east and south (Fig. 9). The basal Warrah Conglomerate comprises up to 280 m of pebble-granule conglomerate, with litharenite horizons, deposited in a fluvial to shallow marine setting. The unit is ?conformably overlain by the Roxburgh Formation, 325 m of quartzarenite, sublitharenite and mudstone. Equivalents of the Clandulla Limestone and Yellowmans Creek Formation are missing from the Ilford area, 8 km south of the Carwell Creek area.

The Roxburgh Formation is apparently faulted against the Kingsford Formation (new name; Colquhoun, unpubl. data), at least 250 m of slope-deposited, mass flow volcaniclastic arenite and limestone breccia, with hemipelagic mudstone, and allochthonous and possibly autochthonous limestone. A thin clastic horizon towards the top of the formation contains a rich benthic fauna including the zonal brachiopod *Boucotia australis* (Booth, 1990) suggesting a late Lochkovian age (Garratt and Wright, 1988). Preliminary conodont studies (Colquhoun *et al.*, in prep.) suggest a latest Lochkovian to early Pragian age (*pesavis* to *sulcatus* Zone). The Kingsford Formation is apparently a correlative of the lower parts of the Mullamuddy Formation of the Queens Pinch Belt, approximately 25 km to the northwest.

TABLE 4 EARLY DEVONIAN ROCKS OF THE QUEENS PINCH BELT

	thickness/rock types	age	environment	structures
INGLEBURN FORMATION (Wright, 1966, 1969)	600m - dacite lava and breccia, mudstone, quartzarenite, arkose, litharenite, conglomerate (dacite and arenite clasts)	Coral and brachiopod fauna indicates late Pragian to early Emsian. Conodonts including *Polygnathus inversus* indicate middle Emsian age (*inversus* Zone)	Shallow water slope setting with mass flow conglomerate and silicic volcanics	Finely laminated mudstone, cross bedded arenite at top of unit. Strongly cleaved mudstone
SUTCHERS CREEK FORMATION (Wright, 1966, 1969; McCracken, 1990)	180m - mudstone to pebbly mudstone with allochthonous limestone blocks	Abundant tetracoral and brachiopod fauna. *perbonus* Zone (*Polygnathus perbonus*) and *serotinus* Zone (*P. serotinus, P. inversus*) conodonts; at the top *Pandorinellina* cf. *steinhornensis steinhornensis* (McCracken,1990)	Carbonate debris flow apron with extensive hemipelagic periods	Finely laminated mudstone with convoluted bedding. Graded arenite (Bouma AE and ABE)
WARRATRA MUDSTONE (Wright, 1966; McCracken, 1990)	120m - mudstone	Abundant brachiopod fauna including *Spinella* indicates latest Pragian to earliest Emsian	Hemipelagic suspension deposits	Finely laminated, strongly cleaved mudstone
TAYLORS HILL FORMATION (Wright, 1966, 1969)	240m - mudstone, volcarenite, basaltic conglomerate, allochthonous limestone	Small coral, brachiopod and conodont fauna, including *Nadiastrophia* and *Martinophyllum*, indicates middle to late Pragian age	Prolonged hemipelagic suspension periods interrupted by turbidity currents and mass flows	

TABLE 4 (Continued) EARLY DEVONIAN ROCKS OF THE QUEENS PINCH BELT

	thickness/rock types	age	environment	structures
MULLAMUDDY FORMATION (Wright, 1966, 1969; McCracken, 1990)	780m - volcaniclastic arenite and conglomerate (clasts of dacite, limestone [some of which are Silurian] and basalt), mudstone, basaltic lava and breccia	Brachiopod, coral and trilobite fauna. Basal fauna of *Cyrtinopsis, Dolerorthis, Plectatrypa* (late Lochkovian). Higher beds include *Nadiastrophia*. Allochthonous limestone early Pragian (*sulcatus* Zone) conodonts (*Eognathodus*).	Submarine volcaniclastic apron, with mass flow deposits alternating with hemipelagic muds, and basalt lava and reworked material	Finely laminated mudstone, graded bedding in arenite, Bouma ADE and AE beds, pillows in basaltic material

TABLE 5 EARLY TO MIDDLE DEVONIAN ROCKS OF THE MOUNT FROME AREA

	thickness/rock types	age	environment	structures
BOOGLEDIE FORMATION (Wright, 1966; Offenberg *et al.*, 1971; Hewitt, 1975; Lyons, 1976; Malnic, 1978)	950m - fine- to coarse-grained litharenite, quartzarenite, crinoidal litharenite, pebbly litharenite, conglomerate, mudstone, limestone	Coral and brachiopod fauna includes *Spinella* and *Malurostrophia*, and *perbonus* Zone (late early Emsian) conodonts	Mixed siliciclastic and carbonate shelf and nearshore conditions	Cross-beds (small and large scale), symmetrical and asymmetrical ripples, well laminated
MOUNT FROME LIMESTONE (Wright, 1966, 1969, 1981; Pickett, 1978; 1987)	178m - calcarenite with silty calcareous interbeds	Rich tabulate and rugose coral fauna. Conodonts (Colquhoun *et al.*, in prep.) demonstrate beds represent most of Emsian up to earliest Eifelian (*perbonus* to *partitus* Zones)	Biostromal setting. Birdseye and fenestral textures suggest intertidal or supratidal conditions at times	Well laminated

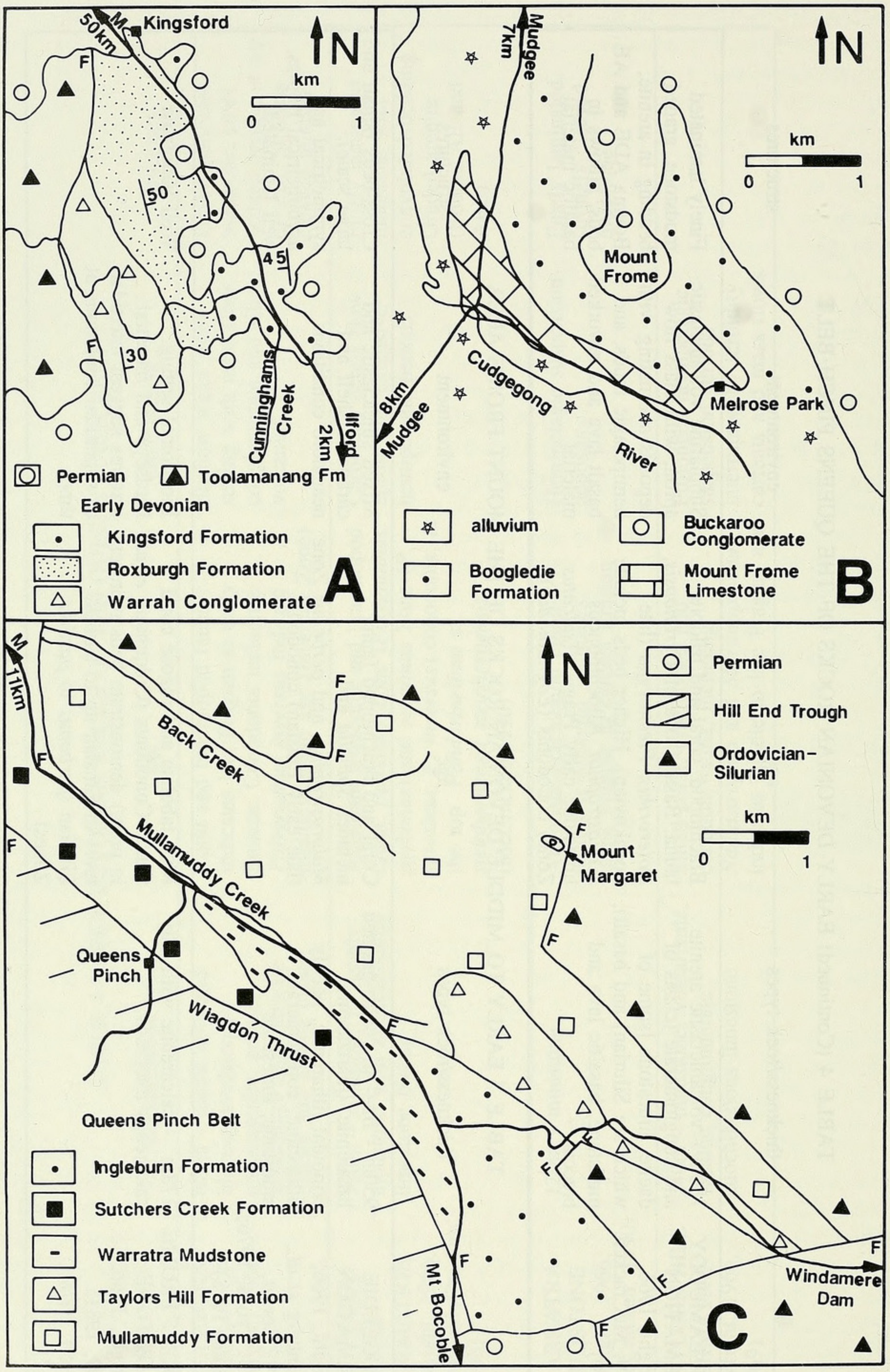

Fig. 9. Geology of A — the Kandos Group north of Ilford; B — the Mount Frome area; and C — the Queens Pinch Belt.

Queens Pinch Belt

The Queens Pinch Belt of Early Devonian strata, centred 16 km southeast of Mudgee, is separated from the Hill End Trough sequence to the west by the Wiagdon Thrust, and to the east and south by faulted and locally disconformable contacts with Late Silurian rocks (Fig. 9). The sequence at Queens Pinch consists of sedimentary and volcanic rocks which were mostly deposited in slope and base of slope settings along the western margin of the northern Capertee High. The Devonian sequence is preserved in a number of fault-bounded, wedge-shaped blocks which are internally characterised by numerous, open to tight, gently plunging folds, with local overturning on the limbs (Wright, 1966). A number of stratigraphic, often fault-bounded and richly fossiliferous units have been recognised.

Mullamuddy Formation (Wright, 1966)

The formation consists of approximately 780 m of thickly bedded volcaniclastic arenite and conglomerate, lenses of conglomerate containing limestone blocks, mudstone, and a basalt lava horizon and fine- to very coarse-grained fragmental equivalents (Wright, 1966; Powis, 1975; McCracken, 1990). The basalts are petrographically and chemically similar to basalts from the Ordovician Cudgegong Volcanics.

Mainly brachiopod faunas have been recorded from two horizons (Wright, 1966, 1969). The lower fauna is indicative of a late Lochkovian age (*australis* Zone; Garratt and Wright, 1988). Conodonts obtained by McCracken from limestone clasts from stratigraphically higher conglomerates indicate a maximum age of *sulcatus* Zone (early Pragian). The higher of the two shelly faunas contains the stratigraphically important brachiopod *Nadiastrophia*, indicative of the Pragian *Nadiastrophia-loyolensis* zone (Garratt and Wright, 1988).

The depositional environment is envisaged as a volcaniclastic apron with mass flows of arenite, conglomerate, and limestone blocks alternating with quieter periods dominated by hemipelagic suspension deposition of mud. The unit was deposited during a period of major subaerial silicic volcanism on the platform of the Capertee High, accounting for the sporadic, high volume influxes of volcaniclastic sediment. The unit probably formed part of a low stand system tract apron or fan which formed along the western Capertee High margin during the early to middle Pragian as volcanic material was rapidly redeposited from the largely subaerial shelf areas.

Taylors Hill Formation (Wright, 1966)

The formation conformably overlies the Mullamuddy Formation and comprises up to 240 m of dark mudstone, thinly bedded volcarenite, lenses of basaltic conglomerate and fossiliferous, massive to well-bedded, allochthonous and possibly also allodapic limestone (Wright, 1966, 1969). Good, although comparatively small, faunas were obtained by Wright (1966) from the base and near the faulted top of the unit, and may both be correlated (due to the presence of *Nadiastrophia* and the tetracoral *Martinophyllum*) with the *Nadiastrophia-loyolensis* assemblage of Garratt and Wright (1988), which spans most of the Pragian. In addition, a Pragian (possibly *sulcatus* to *kindlei* Zones: Garratt and Wright, 1988) conodont fauna is known from this unit. Depositional environments were similar to the Mullamuddy Formation with relatively prolonged periods of hemipelagic suspension and only minor turbidity currents of arenite. The decrease in volcanic material may indicate a cessation of volcanism, and possibly higher sea levels, on the platform areas of the Capertee High.

Warratra Mudstone (Wright, 1966)

This unit was originally defined by Wright (1966) as 120 m of grey mudstone underlying the Sutchers Creek Formation. McCracken (1990) altered the definition to include limestone conglomerate, lithic arenite and mudstone which Wright had placed in the overlying Sutchers Creek Formation. Here we recognise the two formations in their original sense. The Warratra Mudstone has a sparse macrofauna including rare *Spinella*; which is important in indicating a *dehiscens* Zone (earliest Emsian) age (Garratt and Wright, 1988). The unit was deposited during a major transgressive phase, which was responsible for deposition of part of the Carwell Creek Formation and its correlatives.

Sutchers Creek Formation (Wright, 1966)

The formation consists of up to 180 m of limestone conglomerate and blocks, usually commencing with an arenaceous turbidite unit; pebbly mudstone intervals and allodapic limestone are equally characteristic of the unit, which conformably overlies the Warratra Mudstone (Wright, 1966; McCracken, 1990). Wright (1966, 1969) listed extensive tetracoral and brachiopod faunas. Garratt and Wright (1988) noted *perbonus* Zone conodonts whereas McCracken recorded *perbonus* to early *serotinus* Zone conodonts from allodapic limestone, thus indicating a longer age span for the unit. Depositional environments were similar to those of the Warratra Mudstone yet with more and coarser lithic and limestone detritus; that is, a carbonate debris flow apron with extensive periods of hemipelagic sedimentation. The increase in carbonate detritus probably reflects regression and subsequent erosion of platform carbonate from the shelf areas of the Capertee High providing detritus for the Sutchers Creek Formation.

Ingleburn Formation (Wright, 1966)

The unit crops out as a fault-bounded block which contains 550 to 600 m of basal dacite lava, fossiliferous mudstone, conglomerate (with dacite clasts), andesite lava, cross-bedded quartzarenite and conglomerate (with dacite and quartzarenite clasts) at the top (Wright, 1966, 1969). Original age determination based on coral and brachiopod faunas (Wright, 1966, 1969) suggested a position in the sequence between the Taylors Hill Formation and the Warratra Mudstone (i.e., late Pragian-earliest Emsian). Garratt and Wright (1988) subsequently recorded *inversus* Zone (middle Emsian) conodonts, thus indicating partial equivalence with the Sutchers Creek Formation. The sampled limestone may be allochthonous and hence would give a maximum age for the unit. The depositional environment was at most an outer shelf/slope setting dominated by mass flows producing conglomerate and arenite, alternating with suspension sedimentation. This unit contains the youngest primary volcanics on the Capertee High as no correlatives from the platform areas are known; thus volcaniclastic deposition marginal to the Capertee High continued until very late in the Early Devonian.

Mount Frome-Mount Knowles area

In the vicinity of Mount Frome (Fig. 9), a distinctive Early to Middle Devonian sequence was recognised by Wright (1966), consisting of two formations: the lower Mount Frome Limestone, and the overlying Boogledie Formation (originally named the Melrose Formation).

Mount Frome Limestone (Wright, 1966)

The Mount Frome Limestone (6 km east of Mudgee) has been accorded either formation status (Wright, 1966) interdigitating with the Boogledie Formation or member status in the Boogledie Formation (Hewitt, 1975; Malnic, 1978; Powell and

Edgecombe, 1978). Some authors (e.g., McCracken, 1990) suggested that the limestone may be allochthonous; however, conformable, autochthonous relations with surrounding sediments can be demonstrated. The Mount Frome Limestone is between 178 m (Wright, 1966, 1981) and 238 m (Pickett, 1978, 1987) thick, depending on whether separate outcrops near the Cudgegong River are included. The unit consists of beds of dark blue-grey calcarenite, from several cm to at least 6 m thick, separated by thick, sparsely fossiliferous, silty calcareous intervals. The Limestone contains rich tabulate and rugose coral and subordinate brachiopod faunas. A biostromal depositional environment, rich in food and oxygen, is envisaged (Wright, 1966). Birdseye textures are present, typically in the middle and lower parts, indicating ephemeral intertidal or supratidal conditions. Conodont studies (Philip, 1974; Pickett, 1978, 1987; Wright, 1981; Wright and Flory, 1981; Garratt and Wright, 1988; Strusz *et al.*, 1988) collectively indicate the Mount Frome Limestone spans most of the Emsian with ages ranging from *perbonus* Zone (late early Emsian) for the basal beds, extending probably into the *partitus* Zone of the earliest Eifelian (Middle Devonian) in the uppermost 25 to 30 m.

Boogledie Formation (Offenberg *et al.*, 1971)

A sequence largely consisting of clastic strata occurs to the east and northeast of Mudgee; this has been collectively assigned to the Boogledie Formation (Offenberg *et al.*, 1971; and subsequent workers), a formation recognised initially on the basis of outcrops on the western side of the Mount Frome syncline and extended by later workers to include extensive outcrops around Eurundury, Budgee Budgee and Home Rule to the north. At Mount Frome, the unit has been interpreted as exhibiting a low angle unconformable contact with the Late Devonian Buckaroo Conglomerate (Powell and Edgecombe, 1978; Pickett, 1978). The base of the unit is poorly exposed, but locally developed unconformable contacts with poorly known Siluro-Devonian units have been reported with the Tingha Formation (Armstrong, 1983) and the Budgee and Eurundury Formations (Malnic, 1978). At Mount Frome, the formation interdigitates with the upper beds of the Mount Frome Limestone.

The Boogledie Formation consists of up to 950 m of fine- to coarse-grained, rarely fossiliferous, litharenite and quartzarenite (with small- and large-scale cross bedding and both symmetrical and asymmetrical ripple marks), lenses of pebbly arenite and pebble to cobble conglomerate, mudstone, and numerous small and large lenses of limestone, dolomitic limestone and dolomite (Wright, 1966; Hewitt, 1975; Lyons, 1976; Malnic, 1978).

Strata in the vicinity of Mount Knowles are included in the Boogledie Formation by Offenberg *et al.* (1971). The Mount Knowles Member (Wright, 1966; Hewitt, 1975) consists of lenses of thick or thin bedded limestone and dolomite (up to 120 m thick) and impure sandy limestone which crop out in the upper parts of the formation. Faunas vary from sparse (in the dolomite) to abundant (in the limestone) and are dominated by tabulate corals, stromatoporoids, receptaculitids, and minor tetracorals, with brachiopods locally abundant in thin beds; important brachiopods include *Spinella* and *Maluro-strophia.* Pickett (1972) reported a probable *perbonus* Zone (late early Emsian) conodont fauna from the member, and further studies are in progress (Colquhoun). However, at Mount Knowles, the development of dolomite and quartz-rich crinoidal arenite are strongly reminiscent of the Carwell Creek Formation and the Mount Knowles member is probably a correlative of the Carwell Creek Formation which has been traced as far north as west of Lue (Rogis, 1974; Southgate, 1975; Lyons, 1976) and the 'Erang' property near Windamere Dam wall (Wright *et al.*, in prep.).

The Boogledie Formation represents a mixed siliciclastic/carbonate shelf and nearshore sequence, probably an environment similar to that of the Carwell Creek

TABLE 6 LATE DEVONIAN ROCKS ASSOCIATED WITH THE NORTHERN CAPERTEE HIGH

	thickness/rock types	age	environment	structures
DERALE SANDSTONE (Wright, 1966; Killick, 1987)	800m - quartzarenite and sublitharenite	Late Devonian brachiopods	Storm-dominated shallow marine shelf	HCS, low angle cross-beds with palaeocurrent directions to east
LAWSONS CREEK SHALE (Wright, 1966; Killick, 1987; Millsteed, 1985, 1992)	400m - thinly bedded mudstone with subordinate quartzarenite	Late Devonian brachiopods (cyrtospiriferids, *Mucrosprifer*) and *Leptophloeum* flora	Upper offshore to shallow muddy shoreface with storm sand beds	Intensely bioturbated and well laminated with rare ripples, cross-beds, HCS. Palaeocurrent directions to east and northeast
BUMBERRA FORMATION (Wright, 1966; Killick, 1987; Cook, 1988a, 1990; Millsteed, 1985, 1992)	400m - sublitharenite, quartzarenite and mudstone	Late Devonian (?Fammenian) fauna (cyrtospiriferid, chonetid and productid brachiopods)	Tidal flats (subtidal, intertidal and tidal channels) and wave-dominated foreshore to lower shoreface. Overall upward deepening trend	Cross-beds, ripples, parallel lamination, flaser bedding, bioturbation. Palaeocurrent directions to northeast
BUCKAROO CONGLOMERATE (Wright, 1966; Killick, 1987; Cook, 1988a, 1990; Millsteed, 1985, 1992)	420m - purple conglomerate (chert, silicic volcanics, quartzarenite clasts) to pebbly litharenite and mudstone	?Frasnian	Fluvial, braided river	Cross-beds, fining upwards cycles, red non-bioturbated mudstone with mudcracks. Palaeocurrent directions to northeast

Formation. Provenance is similarly a mixed volcanic/cratonic source (Wright, 1969; Hewitt, 1975; Lyons, 1976). Thick accumulations of richly fossiliferous, mainly biostromal carbonate indicate areas and times of limited clastic supply and suggest that, in general, more open marine, less restricted conditions prevailed than was the case in the Carwell Creek Formation carbonates.

Late Devonian Strata

The Late Devonian Lambie Group is represented by a transgressive-regressive sequence at least 1700 m thick, of basal Buckaroo Conglomerate conformably overlain by a ?Famennian succession of Bumberra Formation, Lawsons Creek Shale and Derale Sandstone which crops out in a southeast-plunging syncline (the Pine Ridge syncline) from Mudgee to the west of Rylstone (Fig. 3; Wright, 1966; Killick, 1987).

The Buckaroo Conglomerate (Table 6) includes several fining-upwards cycles of red-purple conglomerate overlain by medium- to fine-grained litharenite and red mudstone (with mudcracks) and represents braided river deposits (Killick, 1987). The gradational contact with the overlying Bumberra Formation represents a transition to nearshore marine conditions. The Bumberra Formation consists of sublitharenite with thin mudstone interbeds and contains a possible Famennian fauna including cyrtospiriferid, and rare chonetid and productid brachiopods (Wright, 1966; Killick, 1987). The fauna, common bioturbation and abundant traction current structures (Table 6) indicate a shallow marine environment including tidal flats, foreshore and shoreface conditions. Thinly bedded mudstone with minor interbedded quartzarenite (the Lawsons Creek Shale) represent a rapid decrease in bed thickness, grain size and sand:silt ratio through the transgressive cycle. Abundant bioturbation and a brachiopod fauna including cyrtospiriferids and *Mucrospirifer* indicate deposition in a quiet, deepening environment of upper offshore to muddy lower shoreface conditions. The youngest unit of the Lambie Group in the Mudgee district, the regressive richly fossiliferous Derale Sandstone, represents thick sublittoral sheet sandstones deposited on a storm-dominated shallow marine shelf.

Palaeogeographic models for the Late Devonian (Killick, 1987) depict a northwest-southeast trending strandline, extending as far west as Parkes at the height of the transgression, with quartz-rich sediment derived from uplifted highlands to the west and southwest. Correlatives of the marine units in the Mudgee district are known from the Dulabree Syncline in the Ilford-Running Stream-Upper Turon area to the immediate south and elsewhere in the Lambie Group. However, the Buckaroo Conglomerate is apparently unique to the Mudgee-Cudgegong district. There are similar marine sequences in the Late Devonian Catombal Group on the Molong High (Killick, 1987) and it is apparent the ?Famennian marine transgression affected the majority of the northeast Lachlan Fold Belt (Webby, 1972).

A low-angle discordance (5 to 25°) between the Lambie Group and a variety of older rocks [the Lambian Unconformity of Powell and Edgecombe (1978)] has been recorded from numerous localities in the northeast Lachlan Fold Belt. The unconformity surface is exposed at several localities between Windamere Dam and the White Rock area (10 km northwest of Rylstone; Fig. 3). Recognition of the continuation of shallow marine sedimentation into the Middle Devonian at Mount Frome, together with the low-angle discordance of the Lambian Unconformity suggested by Powell and Edgecombe (1978), indicate that the Tabberabberan Orogeny had only mild effects on the northeast Lachlan Fold Belt.

TABLE 7 CARBONIFEROUS AND PERMIAN ROCKS ASSOCIATED WITH THE NORTHERN CAPERTEE HIGH

	thickness/rock types	age	environment	structures
AARONS PASS GRANITE (Offenberg *et al.*, 1971; Pemberton, 1990; Greenfield, 1992)	Massive, post-kinematic, minimum-melt, I-type biotite granite intruded at high crustal levels. Compositionally homogeneous yet considerable textural variation including pressure-quenched porphyritic granite. Associated with aplite dykes and veins, pegmatite and granophyre	Middle Carboniferous - 327Ma from biotite (Rb/Sr) cf. 320Ma from outlier immediately west (Vickary, 1983). Geochemically similar to Bathurst, Gulgong and Oberon plutons. Petrographically similar to Havilah and Pyangle Pass granites	Elliptical-shaped aureole, up to 1.5km wide, displays four prograde zones in pelites and psammites which are correlated with zones in calcareous hornfels (marble, calc-silicate, skarns) and metabasites	Intrudes Ordovician and Silurian units. Suspected faulted western contact. Nonconformably overlain by Permian rocks
RYLSTONE VOLCANICS (Day, 1961; Campbell, 1980; Langworthy, 1986; Dicker, 1989; Shaw *et al.*, 1989; Kuoni, 1991; Millsteed, 1992; Colquhoun, unpubl. data)	300m - rhyolitic to dacitic ignimbrite sheets with flow layered lava; interbedded tuffaceous arenite and mudstone; and localised breccias (both basement and co-ignimbrite)	Latest Carboniferous to earliest Permian - 292Ma from biotite (Rb/Sr). Indeterminate plant fossils in basal mudstone	Proximal intracaldera facies with subaerial ignimbrite sheets, co-ignimbrite breccias, lava dome growth and subordinate airfalls and ashflows. Shallow water (?lacustrine) reworking and fluvial channels drain basement	Shallow dipping sheets with broad, gently plunging folds. Fiamme, columnar jointing. Ripples, cross-beds, parallel laminations, flutes and accretionary lapilli in mudstone
SNAPPER POINT FORMATION (Bembrick, 1983; Bamberry, 1984; Pemberton, 1990)	160m - basal polymictic conglomerate (clasts of immediately underlying basement) grading to pebbly arenite and litharenite	Late Early Permian (middle to late Artinskian) brachiopods to north and south of Rylstone (Brown, 1974; Langworthy, 1986)	Sandy transgressive shoreline with beach, nearshore and offshore environments. Fluvio-glacial character	Thin, flat-lying outliers throughout the Cudgegong-Mudgee district. Arenites contain bioturbation, cross-beds, ripple marks

Deformation of the Pre-Carboniferous Rocks

The pre-Carboniferous rocks crop out in northwest-southeast trending, shallowly plunging, open, cylindrical, asymmetric folds, with well-developed axial plane cleavage; in the Late Ordovician strata, folding cannot be recognised. In particular, the Late Devonian strata are as intensely deformed as, and have similar structural characteristics to, the older rocks. This apparently indicates that the major folding and cleavage-forming deformation which affected strata on the northern Capertee High occurred in the Early to Middle Carboniferous, coinciding with the timing of the Kanimblan Orogeny (Powell and Edgecombe, 1978; Cas, 1983).

Aarons Pass Granite

The Aarons Pass Granite, to the southeast of Cudgegong, is an I-type, biotite granite stock, intruded at high crustal levels (Fig. 3; Table 7). The body is compositionally homogeneous yet the rocks show considerable textural variation including marginal phases which display probable pressure-quenched textures. The granite is associated with late stage aplite dykes, pegmatite and granophyre (Greenfield, 1992). A 328 Ma (Middle Carboniferous) age has been determined from Rb/Sr ratios of biotite separates (Pemberton, 1990). The intrusion produced an aureole up to 1.5 km wide, with four prograde zones identified in pelites and psammites. Other small I-type granite stocks occur at 'Havilah' and Pyangle Pass (Fig. 3).

Rylstone Volcanics

The Rylstone Volcanics are an extensive sequence of silicic pyroclastics, lavas and epiclastics (Table 7) which crop out for over 45 km along the western margin of the Sydney Basin (Fig. 3). They consist of thick sheets of subaerial dacitic and rhyolitic ignimbrite, with possible rhyolitic lava domes and interbedded volcaniclastics and basement-derived epiclastics (Langworthy, 1986). The facies association and volume of the ignimbrite sheets are consistent with the products of a small- to medium-volume ash flow caldera (Dicker, 1989; Kuoni, 1991). Radiometric data (Shaw *et al.*, 1989) indicate an age of 292 Ma (earliest Permian; Roberts, *et al.*, 1993). This evidence, together with nonconformable contacts with the Pyangle Pass Granite (Langworthy, 1986), refutes earlier proposals (Day, 1961; Ranocchia, 1981) that the Rylstone Volcanics and nearby Carboniferous stocks were synchronous and comagmatic.

Early Permian Strata

Permian rocks in the Cudgegong-Mudgee district are restricted to thin, flat-lying, conglomeratic veneers which overlie older rocks with angular unconformity. They represent the basal unit of the Snapper Point Formation, the lowermost member of the Shoalhaven Group at the extreme western margin of the Sydney Basin (Bembrick, 1983). The formation represents a sandy transgressive shoreline deposit with beach, nearshore and offshore environments under apparent fluvio-glacial conditions (Dulhunty and Packham, 1962; Bamberry, 1984). At Kandos and surrounding areas (Fig. 3) the sequence extends up into the Berry Siltstone and the Illawarra Coal Measures.

Acknowledgements

Some of the University of Wollongong research documented here has been funded by grants to the Tasmanides Research Group from the University of Wollongong. We thank:— various University Geology Departments for access to Honours, Masters and PhD theses; Des Strusz and John Pickett for faunal identifications, and John for his comments on the manuscript. Many farmers along the Cudgegong River valley and surrounds granted access to their properties as did the Department of Conservation and Land Management to their holdings associated with Cudgegong Waters State Recreation Park.

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