GENERAL INTRODUCTION

The principal aim of this thesis is to discuss and evaluate the igneous petrology and geological setting of the Pigna Barney Ophiolitic Complex (Figs 0.1,1.1; new name - hereafter referred to as the PBOC) and of some associated Palaeozoic volcanic rocks from the southern part of the New England Orogen (Day *et al.*, 1976; Korsch and Harrington, 1981a) in northeastern New South Wales (Fig. 0.2).

The regional geology of the New England Orogen has been reviewed by various authors in Packham (1969) and by Voisey (1959), Harrington (1974), Leitch (1974), Runnegar (1974), Scheibner (1975,1976) Day *et al.* (1976,1978), Korsch (1977) and Korsch and Harrington (1981a). The New England Orogen extends north from the Queensland-N.S.W. border beneath Mesozoic cover to reappear as the Yarrol Orogen in southeastern Queensland. The geology of the Yarrol Orogen has been reviewed by Harrington (1974) and Day *et al.* (1976,1978).

In the following summary of the major geological features of the New England Orogen, and throughout the remainder of this thesis, the structural, stratigraphic (Fig. 0.1), and regional (Fig. 0.2) terminology of Korsch (1977) and Korsch and Harrington (1981a) is adopted, with some minor modifications. Age relations of the various stratigraphic associations of the New England Orogen (Fig. 0.1) are summarized in Table 0.1).

(1) Regional Geology of the NEO

The New England Orogen has been divided into two major parts by Leitch (1974) and subsequent authors. These parts are:

(i) The Gunnedah Basin and Tamworth Belt (Zone A) to the west, southwest and south of the Peel and Manning Fault systems (Fig. 0.2, see footnote,page 10); and

(ii) The Tablelands Complex (Zone B) to the east, northeast and north of the Peel and Manning Fault systems.

To the west and southwest of the Gunnedah Basin lies the (?)Late Proterozoic - Early Carboniferous Lachlan Fold Belt (e.g. Harrington, 1974).

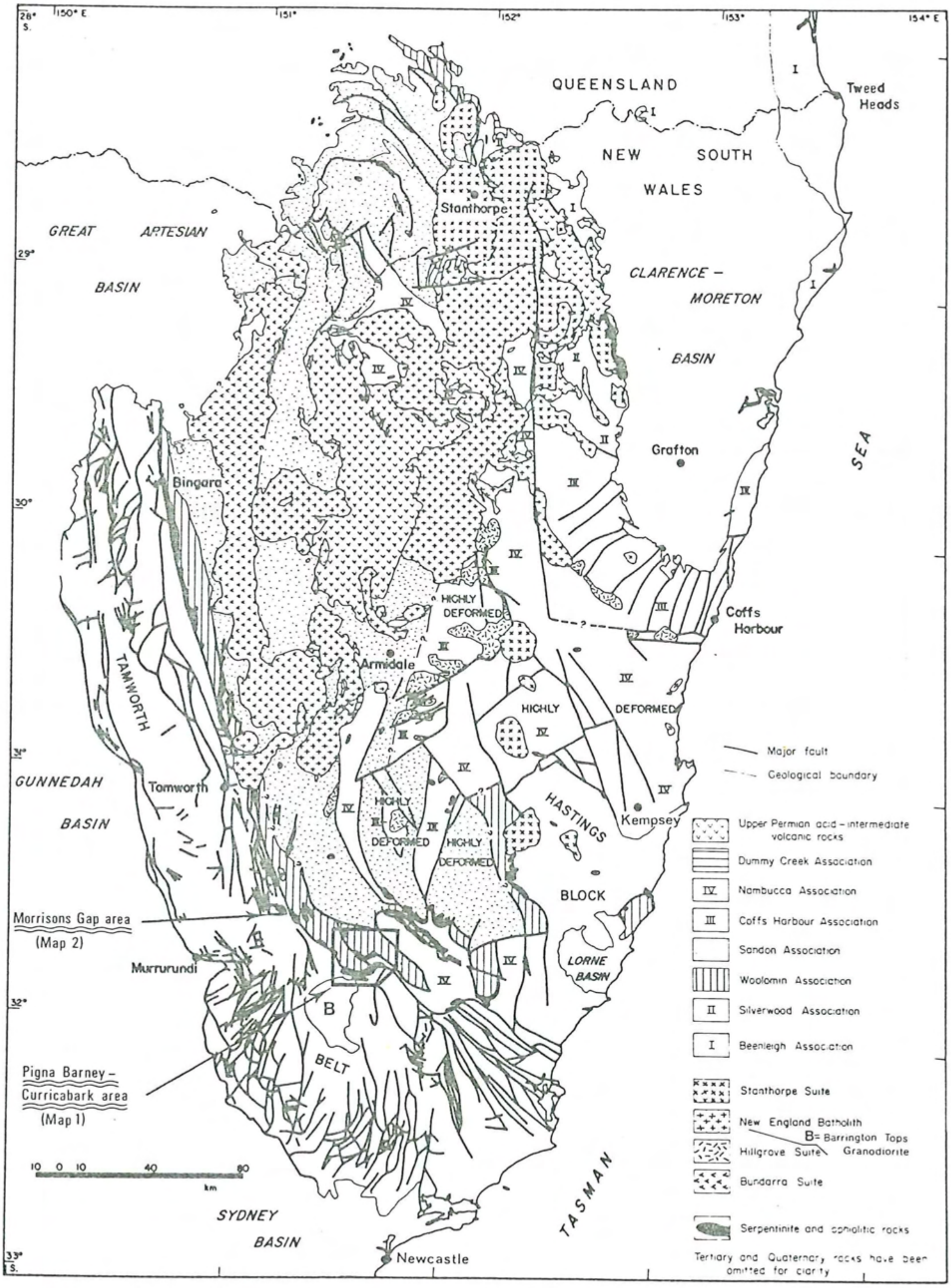

Fig. 0.1 Geological map of New England, from Korsch (1977). More recent work has shown that minor changes to the map are needed in the region N and NW of Stanthorpe. Inferred ages of the sedimentary associations are indicated in Table 0.1.

Fig. 0.2 Sub-provinces or domains in New England, with important place names referred to in the text.

1. Manning Province 2. Wollomombi Zone 3. Port Macquarie Block

At.= Attunga BAP = Bowling Alley Point

TABLE 0.1

System (U: Upper, M: Middle, L: Lower)	Stratigraphic units in the Tamworth Belt and ages of younger basins in Zone A	Stratigraphic Associations in the Tablelands Complex (Zone B), Clarence depression and southeast Queensland	Isotopic Ages (yrs x 10^6)	Plutonic Rocks and Isotopic Ages (yrs x 10^6)
Cainozoic	Sediments Basaltic volcanics	Sediments Basaltic volcanics		
Cretaceous U			80	
Cretaceous L				
Jurassic	Great Artesian Basin	Clarence - Moreton Basin / Moreton Basin		Upper Triassic Suite (205-215)
Triassic U		Clarence - Moreton Basin / Ipswich Basin	215	Stanthorpe Suite (216-230)
Triassic M			230	
Triassic L	Gunnedah Basin / Sydney Basin	Dummy Creek Association Acid-Intermediate Volcanics		New England Batholith (230-253)
Permian U	Gunnedah Basin / Sydney Basin		255	
Permian L	TAMWORTH BELT: Willow Tree CM Werrie Basalt Temi Group / Sydney Basin	Silverwood Assoc.(?) Nambucca Assoc. Coffs Harbour Association	300	Mt Ephraim Granodiorite } (270-280) Barrington Tops " Hillgrove Suite(s) (?270-300)
Carboniferous U	Currabubula Fm. Merlewood Fm. / Kuttung 'Group'	Coffs Harbour Association Beenleigh ? Association		Bundarra Suite (?270-?320)
Carboniferous L	Namoi Mudstone Tulcumba Sandstone *Orus Creek Unconformity* Tangaratta Formation Mandowa Mudstone Keepit Conglomerate	Sandon Association		Mt View Range Granodiorite in Zone A (336) Pola Fogal Hornblendite - Tonalite Suite (?331-?434)
Devonian U	*Bective 'Unconformity'*		345	
Devonian M, L	Baldwin Formation Tamworth Group	Woolomin Association		
Silurian Ordovician Cambrian	Cambrian and Ordovician limestone blocks (and epiclastics?)	Ordovician, Silurian (and Devonian) blocks and fault slivers		

TABLE 0.1. Sequences of Stratigraphic Associations and Plutonic Suites in the New England Orogen (modified from Korsch and Harrington, 1981a). CM = Coal measures; Fm. = Formation.

This thesis largely deals with rocks from both the Tamworth Belt and the Tablelands Complex adjacent to the Peel and Manning Fault systems in the Pigna Barney - Curricabark and Morrisons Gap areas (Fig. 0.1).

The Tamworth Belt consists of a thick (aggregate thickness ~12 km) stratified marine to terrestrial clastic sequence of argillites, siliceous argillites, volcanogenic epiclastics and limestones. Basaltic and keratophyric rocks are locally abundant towards the base of the sequence which ranges in age from possibly Cambrian (Cawood, 1976; see Fig. 1.1), but certainly Early Devonian, to Early Permian. This is generally considered to be a largely deep water fore-arc basin sequence (Leitch, 1974,1975,1979 ; Scheibner and Glen, 1972; Scheibner, 1976; Crook and Powell, 1976; Crook, 1980; Veevers *et al.*, 1982) or a shallow-water shelf sequence (McKelvey, 1974; Runnegar, 1974; Ellenor, 1975). However, Korsch (1982) and Harrington and Korsch (in prep.) have recently suggested that rocks of the Tamworth Belt accumulated in a back-arc setting.

The Tamworth Belt is characterized by dome and basin structures modified by faulting, and the intensity of deformation increases towards the Peel and Manning Fault systems. Much of the sequence has experienced low-grade burial metamorphism, not exceeding prehnite-pumpellyite facies.

The stratigraphy of the Tamworth Belt is summarized in Table 0.1. The main lithological units described in this thesis are briefly outlined in part (2) of this introduction and are discussed in more detail in Chapter 1.

The Tablelands Complex consists of a variety of stratigraphic associations and structurally distinct blocks or provinces (Figs 0.1, 0.2; and Korsch, 1977) whose geology is often poorly understood. Rocks from only two of these stratigraphic associations, the Woolomin Association and the Nambucca Association, have been investigated in this thesis.

The Woolomin Association forms a linear belt adjacent to the Peel and Manning Fault systems in,and to the northwest of,the Pigna Barney - Curricabark area (Fig. 0.1). To the east of this area,fragmented blocks of the Woolomin Association are known as the Myra beds and occur in fault contact with rocks of the Sandon and Nambucca associations and the Hastings Block. Relatively isolated blocks of this association also occur in the Thanes Creek and Port Macquarie areas (Figs 0.1,0.2).

The principal lithologies of the Woolomin Association are chert, impure chert and jasper, with lesser (but locally dominant) siliceous argillite, argillite, volcaniclastics and basaltic rocks. Rare limestones occur as fault-bounded blocks and these range in age from Late Ordovician to Early Devonian (Bradley, 1982). However, much of this association has the structural fabric of a tectonic melange and these ages are of uncertain significance (see Chapter 1).

The contact between the Woolomin and Sandon associations is typically faulted (Fitzpatrick, 1975; Cuddy, 1978). The Sandon Association consists largely of argillite and greywacke,with lesser chert, jasper and intermediate to basic volcanics,and rare limestones and conglomerates. These rocks probably range in age from Late Devonian to Early Carboniferous (see discussion in Korsch, 1977). Both the Woolomin and Sandon associations are composed predominantly of deep-water marine lithologies. These are complexly deformed, have suffered patchy low-grade regional metamorphism, and conceivably may constitute parts of a single tectono-stratigraphic association (Cross and Fergusson, 1983).

The Nambucca Association consists of the Nambucca Slate Belt (Fig. 0.2) and fault blocks widely distributed throughout the Tablelands Complex and in the Tamworth Belt close to the Peel and Manning Fault systems. It is characterized by marine diamictites, turbidites, conglomerates and rarer limestones and acid to basic volcanics. The rocks in the Nambucca Slate Belt (Fig. 0.2) are poorly fossiliferous, highly deformed (Leitch, 1978) and have experienced prehnite-pumpellyite to greenschist facies metamorphism (Leitch, 1975b). Elsewhere, fault blocks of the Nambucca Association are often richly fossiliferous, have not suffered significant regional metamorphism and typically are less deformed than in the Nambucca Slate Belt.

Other stratigraphic associations recognized by Korsch (1977) and depicted in Figure 0.1 (but not investigated in this thesis) are:-

Beenleigh Association - a moderately deformed Upper Carboniferous marine sequence of greywackes, argillites, cherts, and minor basic lavas and conglomerates varying from continental shelf deposits to deep water turbidites.

Coffs Harbour Association - a poorly fossiliferous Upper Palaeozoic flysh-like greywacke-argillite sequence, in part tectonic melange (Fergusson, 1982a), forming much of the Coffs Harbour Block and several fault blocks in the Wollomombi Zone (Fig. 0.2). Within the Coffs Harbour Block, rocks of this association have experienced at least two deformations (Korsch, 1981; Fergusson, 1982a) and prehnite-pumpellyite to low greenschist facies regional metamorphism with a low-grade thermal overprint (Korsch, 1978). Those in the Wollomombi Zone are generally highly deformed and more intensely metamorphosed than those in the Coffs Harbour Block.

Silverwood Association - consists of abundant andesitic volcanics, tuffs and volcaniclastics with volcanogenic sands, mudstones, chert and allochthonous(?) limestone; possibly a volcanic arc sequence of disputed Late Carboniferous-Early Permian or Early Devonian age (see discussions in Korsch, 1977; Korsch and Harrington 1981a,b; Strusz, 1981). Deformation and metamorphism is comparable to that of the Coffs Harbour Association nearby.

Dummy Creek Association - flat lying to moderately dipping terrestrial and shallow marine conglomerates with minor sandstones and mudstones. This association is possibly Late Permian to Early Triassic in age and it unconformably overlies Woolomin, Sandon, Coffs Harbour and Nambucca associations.

The Hastings Block (Figs 0.1,0.2) is lithologically and structurally similar to the southeastern part of the Tamworth Belt and, indeed, some workers consider it to be a displaced or distal portion of that belt (e.g. Scheibner and Glen, 1972; Runnegar, 1974; Scheibner, 1974,1976; Pogson and Scheibner 1976; Leitch, 1979a). However, Korsch and Harrington (1981a) include the Hastings Block in the Tablelands Complex. Rock-types in this block include basaltic and andesitic volcanics, argillites, sandstones, minor conglomerate and extensive Early Permian limestones (absent from the Tamworth Belt). These rocks range in age from Devonian to Early Permian and are intruded by Late Permian-Triassic granitoids (Leitch, 1979).

The Tablelands Complex has been intruded by Upper Carboniferous to Lower Permian S-type granitic plutons of the Bundarra and Hillgrove Suites and by Upper Permian and Triassic I-type granitoids belonging to the

New England Batholith *(s.s.)* and the Stanthorpe Suite (Fig. 0.1, Table 0.1). Some minor I-type plutons may be as young as Upper Triassic or Lower Jurassic. Plutons of the New England Batholith also intrude the Tamworth Belt near Tamworth, Nundle and in the Barrington Tops area (Figs 0.1,0.2). A Lower Carboniferous granodiorite (Mt View Range) of unknown affinities intrudes sediments of Zone A near Cessnock (Fig. 0.2). Acid to intermediate volcanics related to the epizonal New England Batholith *s.s.* cover much of the southern part of the Texas-Inverell province (Figs. 0.1,0.2).

Korsch (1977) and Korsch and Harrington (1981a) grouped granitic plutons in the New England Orogen into the above suites solely on the basis of their radiometric ages and spatial distribution. Shaw and Flood (1981) have proposed further subdivisions which are based on geochemical variations.

Weakly deformed Upper Palaeozoic to Mesozoic basins containing shallow marine and fluvial quartzose sediments, coal measures and rare volcanics and tuffs are faulted against, or unconformably overlie, the New England Orogen on all but its eastern margin (Fig. 0.1).

Remnants of once-extensive Tertiary basalt lava piles (Wilkinson, 1969b; Sutherland, 1981) and associated terrestrial sediments unconformably overlie parts of the New England orogen, especially in the southern part of the Texas-Inverell province, in the Wollomombi Zone and in the Murrurundi-Barrington Tops-Nundle-Nowendoc area (Figs 0.2,1.1). Remnants of large central volcanoes occur northwest of Woodsreef (Nandewar Volcano; Abbott, 1969) and in the northeastern corner of the orogen (Tweed Shield Volcano; Duggan 1974; Wellman and McDougall, 1974).

(2) Components of the Thesis

Because this study focuses on specific aspects of the geology of the Pigna Barney - Curricabark and Morrisons Gap areas (see below), the general geology of these areas is summarized in this introduction (section 4). The remainder of the thesis is divided into seven chapters, two of which (Chapters 3 and 5) embody almost all of the detailed work presented. These chapters are grouped into three parts:

PART I (Chapters 1-4) outlines the more fundamental aspects of the geology of the study areas, with particular emphasis on the field relations, petrology and intrinsic magmatic affinities of basaltic rocks in the Myra beds and Tamworth Belt (Chapter 3), and their implications for the geological evolution of these areas.

PART II (Chapters 5 and 6) deals with the internal field relations and petrology of the PBOC. Ophiolitic members of the PBOC are examined in some detail in Chapter 5 and exotic members are described briefly in Chapter 6.

PART III (Chapter 7) discusses some implications of this study for the original tectonic setting of the PBOC and associated basaltic rocks.

Appendices A-F, H and I contain a substantial part of the analytical data acquired during this study. Some critical chemical analyses reported in these appendices have been included in appropriate chapters in the text. Appendices G and K summarize laboratory and field techniques, and J lists the localities for samples referred to in the text. Appendix L includes a glossary of the more common abbreviations used in the text.

Throughout the thesis, samples are referred to by a three-figure number which corresponds to the last three digits of the U.N.E. Geology Department sample reference number. The two numbering systems may be correlated by prefixing each sample number in this thesis by R49. To avoid possible confusion all grid references in the text are prefixed by the letters GR.

Geological maps of the Pigna Barney - Curricabark (Map 1) and Morrisons Gap (Map 2) areas, at scales of 1:50,000 and 1:25,000 respectively, are included in a map pocket.

(3) Locations and Geography of Study Areas

(i) The Pigna Barney - Curricabark area:

The Pigna Barney - Curricabark area (Fig. 0.1, Map 1) encompasses the rugged headwater regions of the Pigna Barney, Curricabark and Manning rivers and is drained in the northern part by the Barnard River. The area forms part of the eastern scarp of the Mount Royal Range immediately north of the Barrington Tops State Forest. Although the area is deeply dissected, with up to 700m local relief, a high degree of shearing throughout much of it has resulted in deep weathering and relatively poor outcrop.

Much of the central, southern and western highlands is heavily timbered and only the river valleys and the more undulating country have been cleared for grazing. There are no towns in the area, graziers being the only permanent settlers. It is now served by all-weather roads from Gloucester and Scone and these have been up-graded considerably since the fieldwork for this thesis was terminated (see section 6). At that time access and mobility during wet weather was extremely restricted. The western part of the area must still be entered with some caution in wet weather.

Relevant topographic maps of this area are listed in Appendix K.

(ii) The Morrisons Gap area:

For the purposes of this thesis the area to the south and south-east of Nundle (Fig. 0.2), straddling the divide between the headwaters of the Peel River to the west and the Barnard River to the east, has been termed the Morrisons Gap area (Fig. 0.1, Map 2). The name is derived from a section of the Liverpool Range running north-south through the central part of the area. The western watershed is undulating cleared grazing country with all-weather access from Nundle. The eastern watershed is rugged, heavily timbered country accessible in dry weather *via* tracks leading from the Morrisons Gap road which runs south along the divide from Hanging Rock (Fig. 0.2). A geological map of part of the Hanging Rock area is included in Appendix I (Fig. I-1).

Relevant topographic maps of this area are listed in Appendix K.

(4) General Geology of the Study Areas

The regional and local geological settings of the Pigna Barney - Curricabark and Morrisons Gap areas and the PBOC are outlined in Figures 0.1,0.2 and 1.1. Maps 1 and 2 present the geology of these areas in more detail and cover parts of the Tamworth 1:250,000 scale Geological Series Sheet SH56-13 (Offenberg, 1967) and the Hastings 1:250,000 scale Geological Series Sheet SH56-14 (Brunker *et al.*, 1970). A 1:500,000 scale geological map covering much of the New England Orogen has been compiled by the N.S.W. Department of Mines (Pogson and Hitchins, 1972).

(i) The Pigna Barney - Curricabark area:- straddles the Peel Fault System where this fault system abruptly adopts a more eastward trend, a rather more complex form, and then (?)terminates against the Manning Fault System (Figs 0.2,1.1, see footnote page 10). The area consists of juxtaposed fault blocks of Woolomin Association, Tamworth Belt and Nambucca Association rocks, overlain unconformably to the west and southwest by Tertiary sub-horizontal flows of alkali basalt and associated terrestrial gravels and sands of the Liverpool Range beds (Crook, 1961c; Fig. 1.1).

In the Pigna Barney - Curricabark area the Woolomin Association is represented by the Myra beds (Mayer, in Brunker *et al.*, 1970; Mayer, 1972), which is here interpreted as a melange consisting predominantly of tectonically disrupted jasper, chert and siliceous argillite blocks in a less abundant matrix of sheared argillite. Other rock-types in the Myra beds include silicic vitric tuffs, basaltic volcanics and minor volcaniclastics and limestones. The age of the Myra beds is equivocal, but is probably pre-Lower Devonian (see discussion in Chapter 1). In this area the Myra beds are separated from rocks of the Tamworth Belt by the Peel and Manning Fault systems.

Much of the Peel and Manning Fault systems in the Pigna Barney - Curricabark area are delineated by a mafic-ultramafic (largely serpentinized) melange, here termed the Pigna Barney Ophiolitic Complex (PBOC; Fig. 1.1, Map 1). In many respects the PBOC is petrologically distinct from other mafic and ultramafic rocks associated with the Peel and Manning Fault systems elsewhere in northeastern N.S.W. Tonalitic and granodioritic plutons of Lower Carboniferous age, or older (see Chapter 4) also show a close spatial association with the Peel Fault System in this area and in the Glenrock Station area (Bayly, 1974).

The Tamworth Belt in the Pigna Barney - Curricabark area includes rocks of diverse character and age. It includes Lower to Mid-Devonian coarse volcaniclastics and sandstones, siliceous argillites and argillites, limestone and basaltic intrusives and extrusives of the Glen Ward beds, and Mid-Devonian volcanogenic sandstones, conglomerate and laminated argillites of the Cravens Creek beds. Possibly the youngest unit is represented by the Pitch Creek Volcanics, an andesitic to silicic volcanic pile of equivocal age (possibly Upper Devonian or Lower Carboniferous) and field relations (see Chapter 4).

The internal stratigraphy of the Tamworth Belt has been considerably disrupted by faulting and along the Peel and Manning Fault systems the Tamworth Belt rocks are faulted against Myra beds, the PBOC and the Nambucca Association. In the southern part of the area the Glen Ward beds are intruded by the Lower Permian Barrington Tops Granodiorite and associated silicic to intermediate dykes (Fig. 0.1, Map 1).

Nambucca Association rocks in the Pigna Barney - Curricabark area belong to the Manning Group of Mayer (1972) and are Lower Permian in age. They include diamictite, polymictic conglomerate, pebbly mudstone, interbedded fine sandstones and mudstones, massive and bedded limestone, silicic volcanics and volcaniclastics. For the most part they are marine mass flow deposits with some turbidite horizons. Marine shelly fossils are common.

Fault blocks of the Manning Group lie along parts of the Peel and Manning Fault systems and the Curricabark Fault Zone in this area, and also occur among the Glen Ward beds (Fig. 1.1, Map 1). Internally, these blocks are highly disrupted by faulting, and largely for this reason the Manning Group has not been subdivided in this thesis.

(ii) The Morrisons Gap area:- lies wholly within the Tamworth Belt and includes the only significant body of serpentinite within the belt. To the west of the serpentinite is a faulted section of undifferentiated Lower to Mid-Devonian siliceous argillites, volcanogenic epiclastics and basaltic intrusives and extrusives of the Tamworth Group (Crook, 1960, 1961a; see Chapter 1).

In this area the Tamworth Group is successively overlain by Upper Devonian andesitic epiclastics and argillites of the Baldwin Formation, and Upper Devonian to Lower Carboniferous laminated siltstones, mudstones, volcanogenic sandstones and conglomerates, and rare limestones of the Mandowa Mudstone or Gangaratta Formation (see Table 0.1, Fig. 0.1). To the east, a fault sliver of Nambucca Association separates the serpentinite from undifferentiated Tamworth Group.

The (?)Lower Permian Mount Ephraim Granodiorite and a number of minor felsic intrusives have contact metamorphosed much of the Upper Devonian succession. This hornfelsing was not recognised as such by previous workers and has led to misinterpretation of the stratigraphy in the past (see Part (5) below, and Chapter 1).

The southeastern part of the Morrisons Gap area appears to have been offset to the west relative to the northwestern part - presumably along a northeasterly trending fault obscured by the Tertiary sub-horizontal gravels and alkali basalt flows and sills of the Liverpool Range beds (Map 2).

(5) Previous Work

(i) The Pigna Barney - Curricabark area

Serpentinite in the Curricabark area was first reported by Andrews (1905), and from the vicinity of the Polly Fogal (now Pola Fogal) gold diggings on the Pigna Barney River by Benson (1918). Benson (1913, 1914a,b, 1915,1918) had previously mapped a major fault zone in north-eastern New South Wales which extends from Warialda in the north to Nundle in the southeast (Figs 0.1,0.2). This fault zone separates two Palaeozoic terranes possessing distinctive lithologies and structural styles. Along much of its length it is characterized by elongate lenses of serpentinite, forming the Great Serpentine Belt of New South Wales.*

Benson (1918) predicted that the Great Serpentine Belt would eventually be traced south from Nundle through Barry and Glenrock stations, across the headwaters of the Manning River and thence to the coast (see Fig. 0.2). He noted, however, that the distribution of serpentinites

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* This structure has been more recently termed the Peel Thrust (Carey and Browne, 1938; Scheibner 1974,1975 and 1976; Scheibner and Glen, 1972; Glen and Heugh, 1973; Ramsay and Stanley, 1976) and the Peel Fault System (Chappell, 1961; Crook, 1961a,1964). However, the majority of workers now refer to it as the Peel Fault or Peel Fault System (Leitch, 1974,1979a,b; Harrington, 1974; Korsch, 1977; Day *et al.*, 1978; Evans and Roberts, 1980; Korsch and Harrington, 1981a; this thesis). The terms Peel and Manning Fault systems as used in this thesis correspond to the Great Serpentine Belt - Manning River Fault System structure of Voisey (1959) and the Peel Fault System - Manning Fault System of Korsch and Harrington (1981). The structure referred to as the Peel Fault System in this thesis terminates against the Manning Fault System in the Pigna Barney - Curricabark area (see Chapter 1, Fig. 1.1).

throughout this area was more erratic than to the north of Nundle and this has been confirmed by later workers.

Osborne (1950) produced a regional map (approx. 1:560,000 scale) of the southeastern portion of the Tamworth Belt and this included part of the Pigna Barney - Curricabark area. He reported a serpentinized "harzburgite, dunite, hypersthenite" complex in this area and subdivided it into the Curricabakh (now Curricabark) Complex and the Pigna Barney Fault - a discontinuous line of ultramafic and mafic intrusives extending from Glenrock Station (Fig. 0.2) southeast through the valley of the Pigna Barney River. Voisey (1939) mapped the eastern part of the Manning Fault System and he subsequently correlated it with the Pigna Barney Fault of Osborne (1950) and the Great Serpentine Belt to the northwest (Voisey, 1959,1969).

Mayer (1972, and in Brunker *et al.* 1970) produced the first regional geological map of the Manning province (Fig. 0.2) and described the stratigraphy, structure and sedimentology of this region and part of the Tamworth Belt to the south. For the most part, stratigraphic and sedimentological data presented in Chapters 1,2 and 4 of this thesis simply reaffirm most aspects of the earlier work of Mayer (1972). He renamed the Pigna Barney Fault and Curricabakh Complex (Osborne, 1950) the Pigna Barney Fault Zone and the Curricabark Fault Zone respectively, and assigned all the fault-related igneous rocks of the region to the Pigna Barney Igneous Complex. Although he noted that the greatest diversity of rock types in the Pigna Barney Igneous Complex is associated with the Pigna Barney and Curricabark Fault Zones he undertook only a brief examination of their petrography.

The terminology of the Curricabark Fault Zone has been retained in this thesis (Fig. 1.1, Map 1, Chapter 1). However, as the Pigna Barney Fault Zone is equivalent to the Peel Fault System in the Pigna Barney - Curricabark area, the latter term has precedence.

The Glenrock area has been mapped by Williams (1979) and Offler (1978,1979). Williams (1979) examined the internal fabric of some serpentinite masses and Offler (1978,1979,1982) investigated the chemistry and mineralogy of basaltic rocks from the Woolomin Association and Tamworth Belt in that area.

Base-metal mineralization in the Pigna Barney - Curricabark and

Glenrock areas was investigated by Tippett (1974) and the Tomalla Gold Mine (Map 1, GR 640,804) was described by Suppel (1966).

(ii) The Morrisons Gap area

The western part of this area was first mapped by Benson (1914a) who subdivided it into the upper Bowling Alley Series of "banded radiolarian claystones, tuffs and breccias" (which he correlated with his Tamworth Series; Benson, 1913), overlain to the west by laminated mudstones and feldspathic sandstones of the Nundle Series, correlatives of his Barraba Mudstone (Benson, 1913). He also reported the occurrence of "granite" at Mount Ephraim.

Crook (1961a) remapped the area and assigned much of it to the Hawks Nest beds, a supposedly fault-bounded sequence of "interbedded black pyritic shales and greywackes, with occasional thick greywacke beds" and "some rudite". Crook (1961a,1964) also noted that the Hawks Nest beds contain carbonized plant fragments (simulating graptolites) and he concluded that these rocks accumulated in a euxinic environment, different from that of other Tamworth Belt sediments. However, the dark colour of the pyritic shales and the presence of carbonized plant fragments largely reflects low grade contact metamorphism by the Mount Ephraim Granodiorite and associated intrusives.

Crook (1961a) stated that the age of the Hawks Nest beds was unknown but is probably Lower Devonian. Voisey and Packham (1969) suggested that the Hawks Nest beds occur low in the Tamworth Group section and their age has been variously considered to be Ordovician to Devonian (Offenberg, 1967), Ordovician to Silurian (Crook and Powell, 1976), Silurian (Pogson and Hitchins, 1973) or Late Silurian to Early Devonian (Bradley, 1982). I suggested that the Hawks Nest beds are mostly Middle to Upper Devonian in age (Cross, 1974), a proposal based on the occurrence of a single poorly-preserved specimen of *Leptophloeum australe* (?). This suggestion has now been confirmed by further mapping (this thesis) and the Hawks Nest beds have been correlated with other units (undifferentiated Tamworth Group, Baldwin Formation and undifferentiated Mandowa Mudstone-Tangaratta Formation; see Map 2) of the Tamworth Belt.

Previous work in the eastern part of the Morrisons Gap area consists of a reconnaissance study by Heugh (1971), and a more detailed investigation by Cross (1974) who interpreted it to be an upthrust block of ophiolitic basement. This interpretation is re-evaluated and ultimately discounted in the light of more detailed investigations (this thesis).

(iii) Related studies

Other workers who have investigated areas along the Peel and Manning Fault systems south of Nundle are; Glen and Heugh (1973) and Moore (1973) in the Barry Station area, (Fig. 0.2) and Bayly (1974) in the Glenrock Station area.

Mafic-ultramafic complexes associated with the Peel or Manning Fault systems have been described by (in addition to authors previously mentioned) Proud and Osborne (1952), Wilkinson (1969a), Glen (1971), Paull (1975), Leitch (1979) and Herbert (1981).

Ramsay and Stanley (1976) determined an easterly dip of 65^{o} for the Peel Fault System near Woodsreef (Fig. 0.2) from a magnetic survey. No other detailed geophysical work on this structure has been reported.

(6) History of this Research Project and Some Major Problems Encountered

The nature and thrust of the research reported in this thesis changed markedly several times during candidature.

Initially the project was intended to be a predominantly field-oriented regional tectonic study concentrating on several major structural features of the New England Orogen. Principal objectives were to evaluate the roles played by the Peel and Manning Fault systems, the Mooki Fault System, the Hunter Thrust System and the Wollomombi Zone (Fig. 0.2) in the tectonic evolution of the New England Orogen.

Following a study of neotectonics and the tectonic evolution of orogens elsewhere, working hypotheses and models were developed to the stage where they could be tested in the field. Initial objectives were:

(i) to investigate in more detail the possibility that basaltic rocks in the Tamworth Group and Woolomin Association exposed along the Peel and Manning Fault systems represent oceanic basement to one or both of these rock associations (as suggested by Glen and Heugh, 1973; Cross, 1974; Crook and Felton, 1975).

(ii) to investigate the gross structure of the Woolomin and Sandon associations in order to examine the possibility that one or both represent a subduction complex* (as previously implied by Solomon and Griffiths, 1972; Scheibner, 1973; Leitch, 1974).

Reconnaissance work along the Peel Fault System indicated that the Pigna Barney - Curricabark area offered the greatest potential for a study of ophiolitic rocks associated with that fault system. I commenced mapping that area in detail late in 1975.

Fifteen weeks were spent in the field during the following seven months. Extraordinarily high rainfall, persistent ground-level cloud and three major floods in the area during this period considerably hampered fieldwork. Wet weather access to much of the area was extremely poor and on several occasions after being "rained in" I was unable to move my vehicle for periods in excess of one week. Some reconnaissance work was carried out along the Peel Fault System north of Nundle and in the Wollomombi Zone, and the Morrisons Gap area was mapped during some periods when the Pigna Barney - Curricabark area was inaccessible.

The Morrisons Gap area was investigated primarily to establish the stratigraphic position of the Hawks Nest beds with respect to the supposed ophiolitic rocks of the Tamworth Group (Cross, 1974; Crook and Felton, 1975), and as a first stage in the proposed mapping of poorly-understood sections of the Peel Fault System between Nundle and the Pigna Barney - Curricabark area. Of the geology of the Morrisons Gap area, only the basaltic rocks are discussed in any detail in this study.

The recognition of an unusual ophiolitic association in the Pigna Barney - Curricabark area and the poor initial field season led to a review of the original thesis aims, limiting the study to the Peel and Manning Fault systems, and allowing for a more detailed investigation of the adjacent rock associations. Fieldwork the following spring was again

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* The term 'subduction complex' (*cf.* Seely, 1979) as used here is synonymous with the 'accretionary prism' or 'accretionary wedge' of some recent workers (e.g. Karig and Sharman, 1975; Raymond, 1980).

hampered by unusually wet weather and was terminated in November by a spinal injury incurred in the field. This injury required major surgery.

I recommenced work on this thesis in April, 1978 but was physically unable to do further fieldwork at that time. Consequently the project was largely restricted to a petrological investigation of material at hand. In the period 1978-1982 a prolonged illness and a debilitating ear injury suspended progress in this study for a total of almost two years.

PART I

CHAPTER 1

STRATIGRAPHY AND STRUCTURE

General aspects of the stratigraphy and structure of the Woolomin Association and Tamworth Belt are outlined briefly in the General Introduction (pp.2-3). Figure 1.1 shows the gross structural relations of the principal stratigraphic associations at the southern end of the Peel Fault System.

Insofar as the Peel Fault System (see footnote, p.10) marks the juncture of the Woolomin Association and the Tamworth Belt, this major structure appears to be truncated by the Curricabark Fault Zone near the eastern limits of the PBOC (Fig. 1.1). Because the Curricabark Fault zone is simply one of the more prominent structural breaks in a terrane characterized by widespread and locally intense shearing, (see below) the structural implications of this 'termination' of the Peel Fault System (*s.s.*) are somewhat enigmatic. Some workers (e.g. Scheibner, 1973,1976; Runnegar, 1974) variously extend the 'Peel Fault System' to include faults bounding the Myra beds and the Manning Group (e.g. Dewitt and Kauthi faults and the serpentinite belts near Nowendoc, Fig. 1.1) to the east of the Pigna Barney-Curricabark area. Unless the Manning Group in this area is largely underlain by Tamworth Group lithologies, and this is considered unlikely, it is perhaps more prudent to suggest that the Peel Fault System 'blends' into the Manning Fault System *via* the Curricabark Fault Zone and subsidiary faults related to the latter. Data collected for this study place few tangible constraints on the detailed structural history of the Peel Fault System as a whole.

1.1 Myra Beds

The Myra beds (Mayer in Brunker *et al.*, 1970) are direct correlatives of the Woolomin beds (Crook, 1961a; Fig. 1.2) and form the southeastern part of the Woolomin Association of Korsch (1977; see General Introduction, p.2). Along the Peel Fault System in the Pigna Barney-Curricabark area they are faulted against members of the PBOC, intrusives of the Pola Fogal Hornblendite-Tonalite suite (see Chapter 4), and Tamworth Belt lithologies (Map 1). In this area they are also in

FIG. 1.1

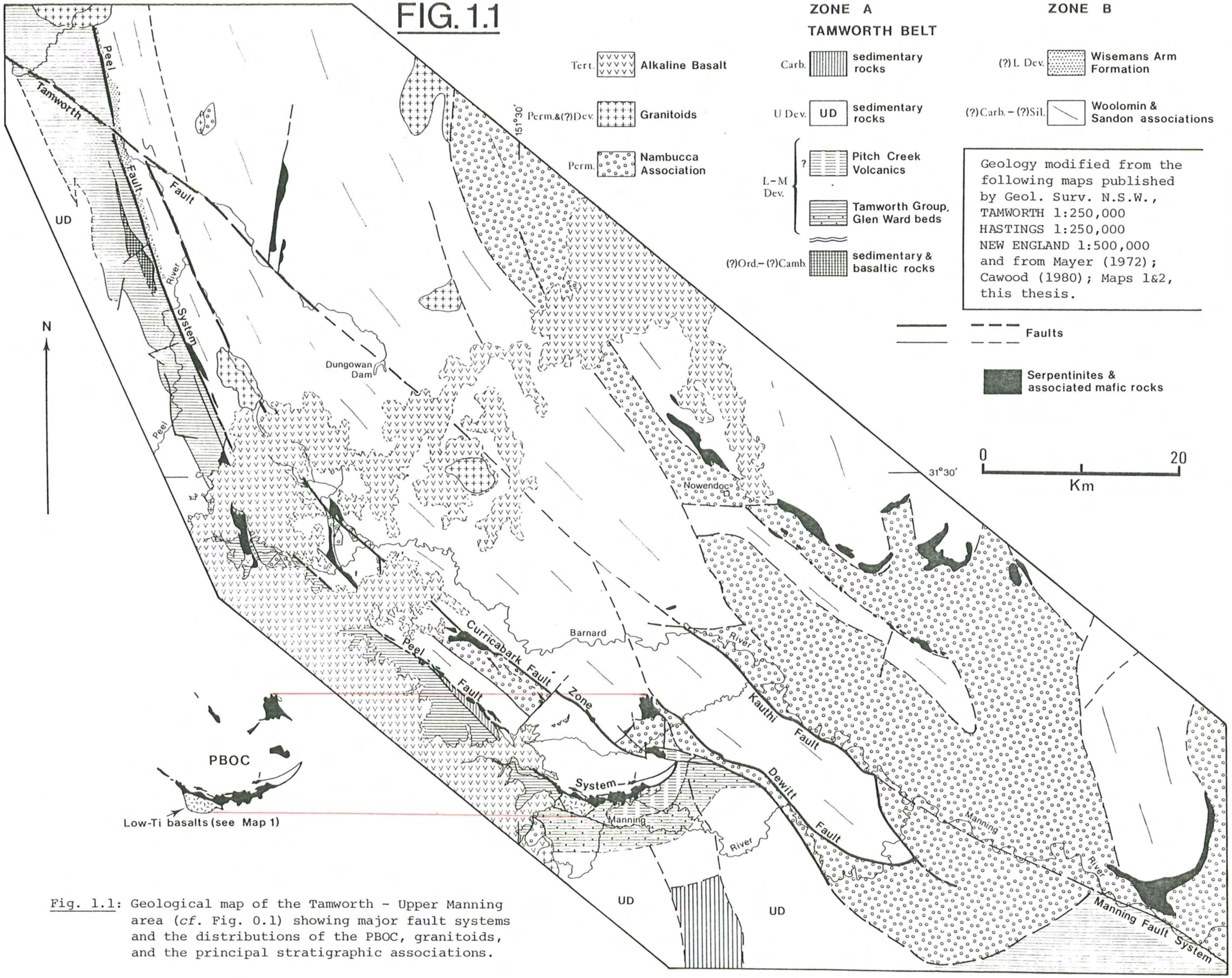

Fig. 1.1: Geological map of the Tamworth - Upper Manning area (*cf.* Fig. 0.1) showing major fault systems and the distributions of the PBOC, granitoids, and the principal stratigraphic associations.

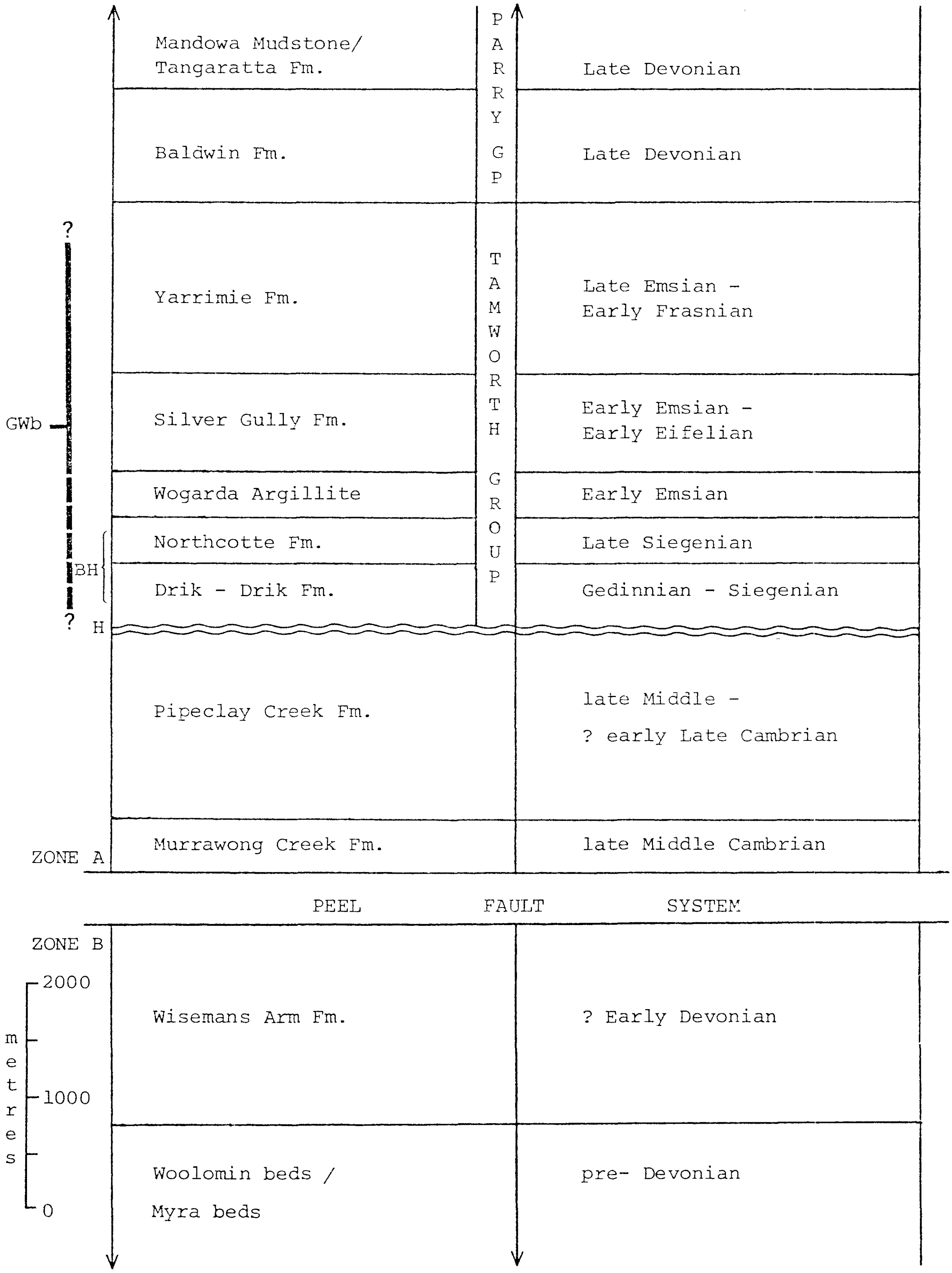

Fig. 1.2: Nomenclature, ages, and approximate thicknesses of principal stratigraphic units in the lower Tamworth Belt and Woolomin Association (modified from Cawood, in press).
H = Haedon Fm. (Mid - Late Ordovician).
BH = Bog Hole Fm. (Siegenian). GWb = Glen Ward beds

fault- and perhaps depositional contact (see Section 1.4) with blocks of the Nambucca Association (Manning Group). All faults bounding the Myra beds in this area are, or appear to be, sub-vertical.

To the north of Woolomin (Fig. 0.2) chaotic rocks termed the Wisemans Arm Formation (Fig. 1.2) by Leitch and Cawood (1980) occur along the western margin of the Woolomin Association (Fig. 1.1). Leitch and Cawood (1980) and Cawood (1982b, in press) consider these to be olistostromal deposits derived from the Tamworth Belt and the Woolomin Association. Analogous rocks have not been found in the Pigna Barney-Curricabark area.

Prior to this study little was known of the structure of the Myra beds. In particular, it was not recognized that they constitute a tectonic melange. The following general description and discussion aims to: (i) provide evidence to substantiate this interpretation; and (ii) place the possible implications of this interpretation into perspective. These interpretations must inevitably be constrained by limitations in current knowledge of the complex and, by analogy with accretionary terranes elsewhere, probable highly disordered structural history of Zone B.

Internally, the Myra beds largely consist of steeply-dipping mesoscopic- to kilometre-sized blocks or slabs (Plate 1.1A,B) of bedded and massive jasper, chert, siliceous argillite, relatively rare basaltic rocks, and very rare limestone, which are arranged in a more-or-less imbricate fashion (Fig. 1.3) in a matrix variably consisting of moderately-highly disrupted equivalent lithologies (siliceous matrix; Plate 1.1C,D) and/or highly sheared argillite (Plate 1.1E). Both the argillite matrix and the more highly disrupted and disaggregated of the siliceous variants (Plate 1.1D) are poorly exposed (Plate 1.1B). On occasion (? perhaps as a general rule) areas of poor outcrop which are underlain by the latter may be identified *via* the presence of abundant pebble- and cobble-sized fragments of highly siliceous lithologies in the soil profile (*cf.* Plate 1.1D). Some localized mixing of jasper and chert may be evident in the siliceous matrix (Plate 1.1C,F) but, because these lithologies are interbedded on millimetre- to metre-scales at a number of localities (e.g. GR 7660,9115; GR 7750,9183; sample 388), this mixing need not imply substantial tectonic transport. In the siliceous argillites the

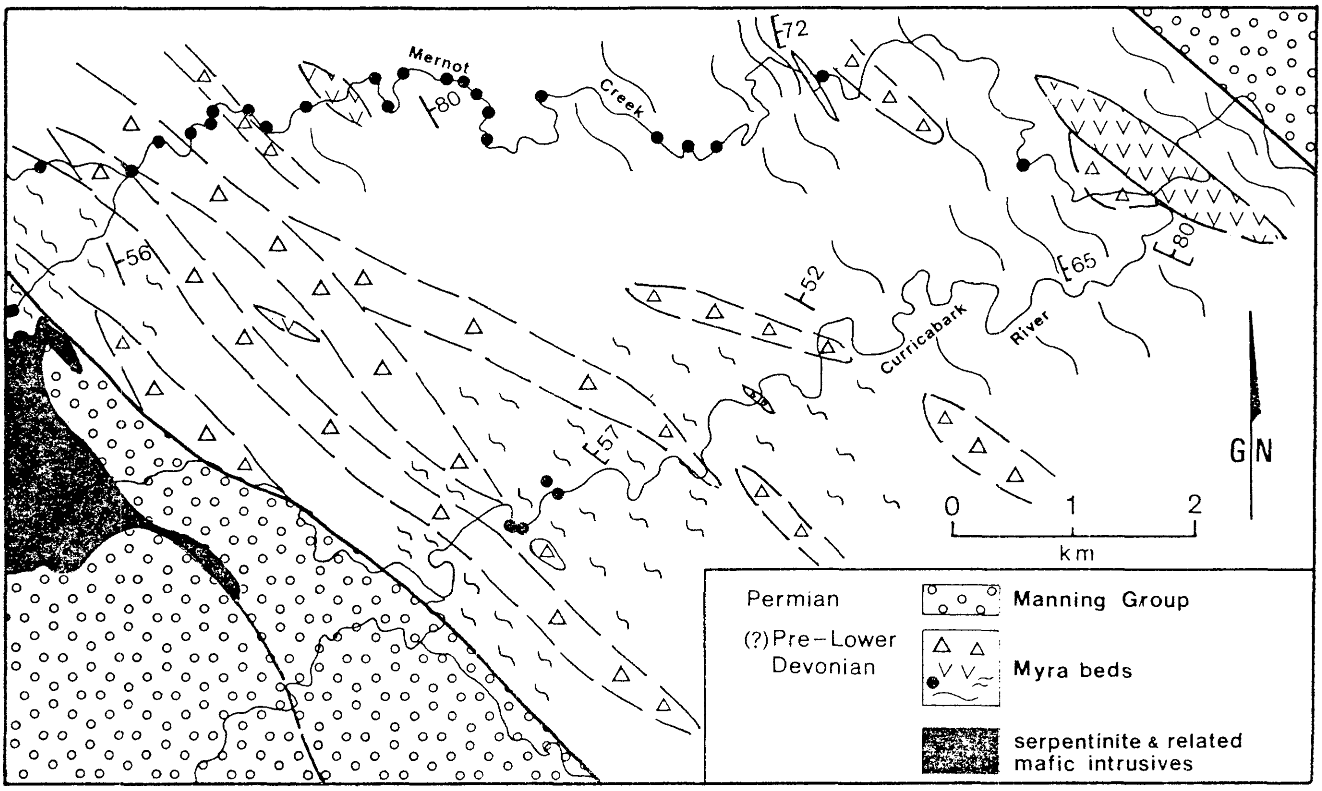

Fig. 1.3: Generalized interpretation map showing the approximate distributions of relatively undeformed blocks and sheared matrix in the vicinity of the type section of the Myra beds.

△△ jasper

∨∨ ● basaltic rocks

~~ pervasively sheared argillite

prominent bedding-parallel shear in siliceous argillites distinction between what might be termed 'sheared matrix' and comparatively unsheared 'blocks' is somewhat less clear-cut than in the jaspers and cherts (see page 20).

Because my mapping in the Myra beds did not proceed far beyond a fairly thorough 'familiarization stage' [see General Introduction, section (6)], the spatial distributions and relative proportions of the various blocks, lithologies, and matrix types are not known in any great detail. In general terms, jasper ± chert are the dominant block and matrix lithologies in domain 1 of Figure 1.4, and siliceous argillite predominates in the northeastern one-third of domain 2 (Fig. 1.4). These lithologies are irregularly mixed in the intervening areas. Areas of relatively abundant argillite matrix are shown in Figure 1.3 and the distribution of basaltic rocks is displayed on Map 1 and in Figure 1.3.

Basaltic outcrops commonly have sheared margins and may be pervasively sheared. Most of the highly-sheared basaltic rocks are relatively incoherent and crop out only poorly (e.g. GR 7519,9083). However, some highly-sheared examples are pervasively recrystallized (largely to chlorite ± epidote assemblages) and these outcrops are relatively coherent (Plate 1.2G). A semi-schistose microfabric (chlorite foliation) is developed in the latter variants (e.g. 249) suggesting that they were deformed at somewhat higher temperatures than were the former. The field relations of Myra basaltic rocks are discussed in more detail in Chapter 3 (Section 3.2.1).

In the blocks and sheared matrix, bedding attitudes and shear foliations generally trend NW-SE and dip steeply to the NE or, less commonly, to the SW (Fig. 1.4). Along the southern margin of domain 1 (see Figure 1.4), these s-surfaces are oriented (? transposed) sub-parallel to the Peel Fault System. Limited and somewhat equivocal evidence (? sharp "bases" and diffuse "tops" of thin siliceous argillite beds) suggests that the NW-SE trending rocks typically face to the NE and individual blocks probably young in this direction. However, because the prominent bedding-parallel shear might reflect the development of a more-or-less disrupted imbricate structure, the overall younging direction in the Myra beds remains uncertain.

The gross structural fabric of the Myra beds is that of a tectonic melange which is largely autoclastic in origin and is dominated more by

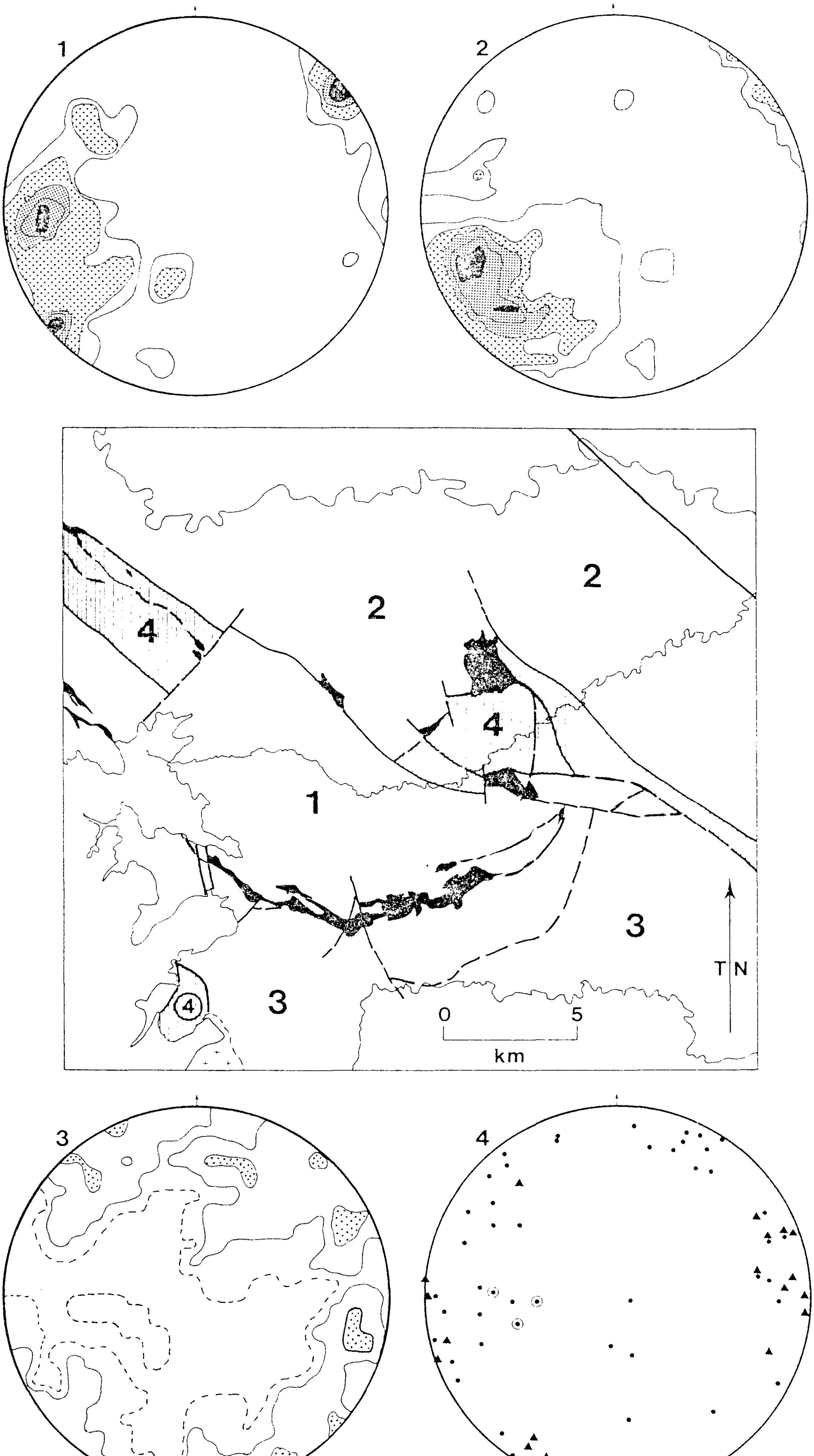
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PLATE 1.1

Structural Characteristics of the Myra beds : 1

A. Large, relatively coherent blocks and slabs of jasper and jasperoidal chert in a matrix largely consisting of similar, but more highly disrupted lithologies (siliceous matrix ; areas of relatively low relief). The slabs dip steeply ($> 70^{0}$) and are slightly divergent in strike ($\sim$E-W) . [GR634,968].

B. As above (blocks arrowed strike $\sim$ NW-SE). Note the scarcity of outcrop in the low-lying foreground area which largely consists of mixed siliceous- and argillite matrix. [GR771,905].

C. Angular pale grey-green cherty blocks in a highly disrupted and, in part, highly sheared matrix which consists of originally thin-bedded jasper and minor chert. Relatively small jasper and chert phacoids (in this case, isolated boudins and brittle pull-aparts) are abundant in the matrix. [GR6322,8532].

D. Semi-disaggregated and poorly coherent fabric in originally well-bedded jasper (e.g. centre right). This fabric is typical of much of the Myra siliceous matrix, and is largely accountable for its poor exposure. [GR7510,9070].

E. Pervasive small-scale fracturing and shearing in a relatively coherent part of a generally more highly sheared and intensely weathered outcrop of Myra 'argillite matrix'. The prominent relict bed forms part of an atypical fine-grained sandstone layer. [GR7510,9070].

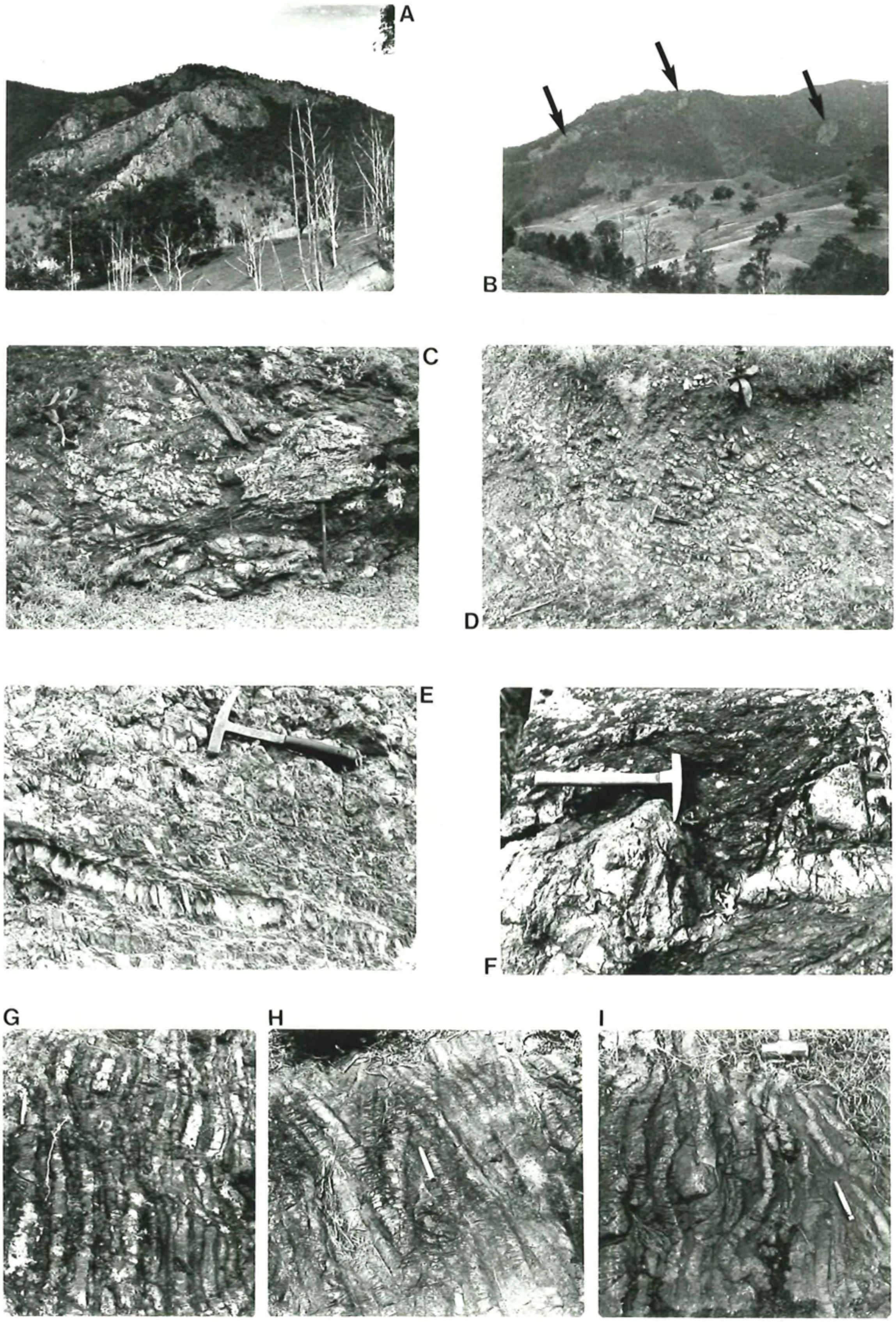
F. Pull-apart blocks of chert in a matrix consisting of highly sheared, originally well-bedded jasper. Note attenuation of lensoidal jasper phacoids (e.g. above, above right of hammer. [$\sim$GR650,822].

G. Well-bedded and little-deformed (at least on the mesoscopic scale) Myra jasper. Pen is 1.5cm in diameter. White patches are lichen. [GR6503,8460].

H. Mesoscopic chevron folds in well-bedded Myra jasper [GR6503,8460].

I. Disrupted folds in bedded jasper. The relatively low-relief, darker-grey areas are sheared jasper which appears to have subsequently recrystallized to a very slight degree. [GR6517,8492].

PLATE 1·1



bedding-parallel shear than by chaotic mixing (*cf.* Hsu, 1968; Hsu and Ohrbom, 1969; Cowan, 1981). In many respects this fabric is similar to that developed in some tectonic melanges along the Pacific margin of North America; in particular, types (IV) and (V) of Cowan (1981). In Cowan's (1981) terminology; type (IV) melanges are "bedded sequences ..... displaying progressive stratal disruption promoted by ductility contrasts in partly consolidated sediments undergoing layer-parallel shear". Type (V) melanges are "brittle fault- or schuppen-zones characterized by lenticular kernels and anastomosing, sub-parallel shear fractures formed in consolidated rocks".

In the Myra beds and in at least some other parts of the Woolomin Association (e.g. the Bingara-Barraba area; see Fig. 0.2), areas dominated by the more highly siliceous lithologies are generally characterized by predominance of type (V) fabrics on the mesoscopic and larger scales, and type (IV) fabrics on macroscopic and smaller scales. Thus, blocks of well-bedded jasper (Plate 1.1G), sometimes containing tight mesoscopic folds (Plate 1.1H) and partially disrupted folds (Plate 1.1I), may display:

(i) All gradations of bedding-parallel shear ranging from incipient stratal disruption to strong boudinage and ultimately the development of a dispersed block-in-matrix fabric (Plate 1.2A-D, see also Plate 1.1C), and/or

(ii) Significant internal brittle faulting and localized reorientation of sub-blocks (Plate 1.2E).

Discrete post-shear faults are usually evident only in the slightly sheared outcrops (Plate 1.2A). From the extent of well-developed mesoscopic brittle fracturing displayed by phacoids of jasper and chert it would appear that these sediments were well-lithified prior to initial deformation. In fact, a two-fold mechanism of shear superimposed on brittle fracturing may have contributed significantly to the formation of the more highly disrupted variants. In seemingly undeformed outcrops, shearing often may be localized in sub-millimetre-thick zones along the more sharply-defined bedding planes, and throughout less-siliceous (more ductile) horizons. Preferential shearing and tectonic mixing may be particularly evident where jasper and manganiferous- or highly ferruginous jasper are interbedded (Plate 1.2F; see Chapter 2), and where highly siliceous- and relatively more ductile lithologies are juxtaposed (e.g. jasper-basalt contacts, Plate 1.2G).

Type (IV) fabrics predominate in the areas largely consisting of siliceous argillites and/or interbedded argillite and siliceous argillite (see above). Some small-scale faulting does occur, especially in the relatively siliceous variants (e.g. Plate 1.2H), but few outcrops are extensively disrupted by faulting and/or fracturing (*cf.* jaspers, Plate 2.1E). However, some variants contain thin, highly sheared mafic (?) tuffaceous laminae (e.g. 397) whose ductile response to stress has led to brittle disruption of the interbedded siliceous argillite (? silicic tuff, see Chapter 2; Plate 1.2I).

On close examination, most apparently undeformed outcrops of bedded siliceous argillite (e.g. Plate 1.2J) display evidence of slight shearing along at least some bedding planes, and the relatively massive types contain numerous microshears. Most well-bedded variants have experienced significant bedding-parallel shear resulting in attenuation, pinch-and-swell, and boudinage (Plate 1.3A). Individual beds are typically attenuated in plan and in cross-section, and boudins are grossly discoidal in shape (Plate 1.3B). Where siliceous argillites and argillites are interbedded, shearing is strongly localized within the latter (Plate 1.3C,D). Lensoidal and lenticular fragments of former thin siltstone and siliceous argillite laminae are commonly perserved in this sheared argillite (Plate 1.3D).

Significant deformation gradients may occur within individual outcrops of siliceous argillite and the interbedded siliceous argillite-argillite variants. With increasing strain in both types, boudins and mesoscopic fold hinges (rare) become increasingly isolated in the sheared matrix (Plate 1.3E-G) and, ultimately, the original bedding is largely obliterated (Plate 1.3H).

For the most part, even the highly sheared siliceous argillite matrix displays a high degree of physical coherence and perhaps concomitant recrystallization compared with most other varieties of sheared matrix in the Myra beds (see above). Consequently, the relatively clear-cut distinction between topographically prominent blocks and low-lying, poorly exposed matrix which is commonly observed in the jasper-dominated

<u>PLATE 1.2</u>

Structural Characteristics of the Myra beds : 2

A. Incipient bedding-parallel shear and related boudinage in well-bedded Myra jasper. Note minor cross-cutting fault (arrowed). Pen is 1.5cm in diameter. [GR6504,8475].

B. Disruption of bedding in Myra jaspers as a result of significant bedding-parallel shear. [GR7725,9160].

C. As above (B), showing minor secondary shearing slightly oblique to relict bedding. [GR7433,9068].

D. An advanced stage of bedding-parallel shear in a Myra siliceous argillite-chert association. Note well-developed block (chert)-in - matrix (siliceous argillite) fabric. [GR7725,9160].

E. Brittle faulting in well-bedded Myra jasper. Individual fault blocks have been significantly reoriented during faulting and (?)associated warping (e.g. bedding in the wedge-shaped block on the lower left is ∿ 305/78NE, whereas bedding in the block on which the hammer is standing lies in the range 340/12E - 285/18N). [GR7226,9351]

F. Deformed jasper specimen displaying semi-ductile to brittle behavoir of 'normal' jasper (sample 392, pale-dark grey layers and angular blocks) and ductile behavior of interbedded relatively Fe+Mn-rich 'jasper' (sample 393,wispy dark grey/black layers and fracture fillings). [GR7506,9068]

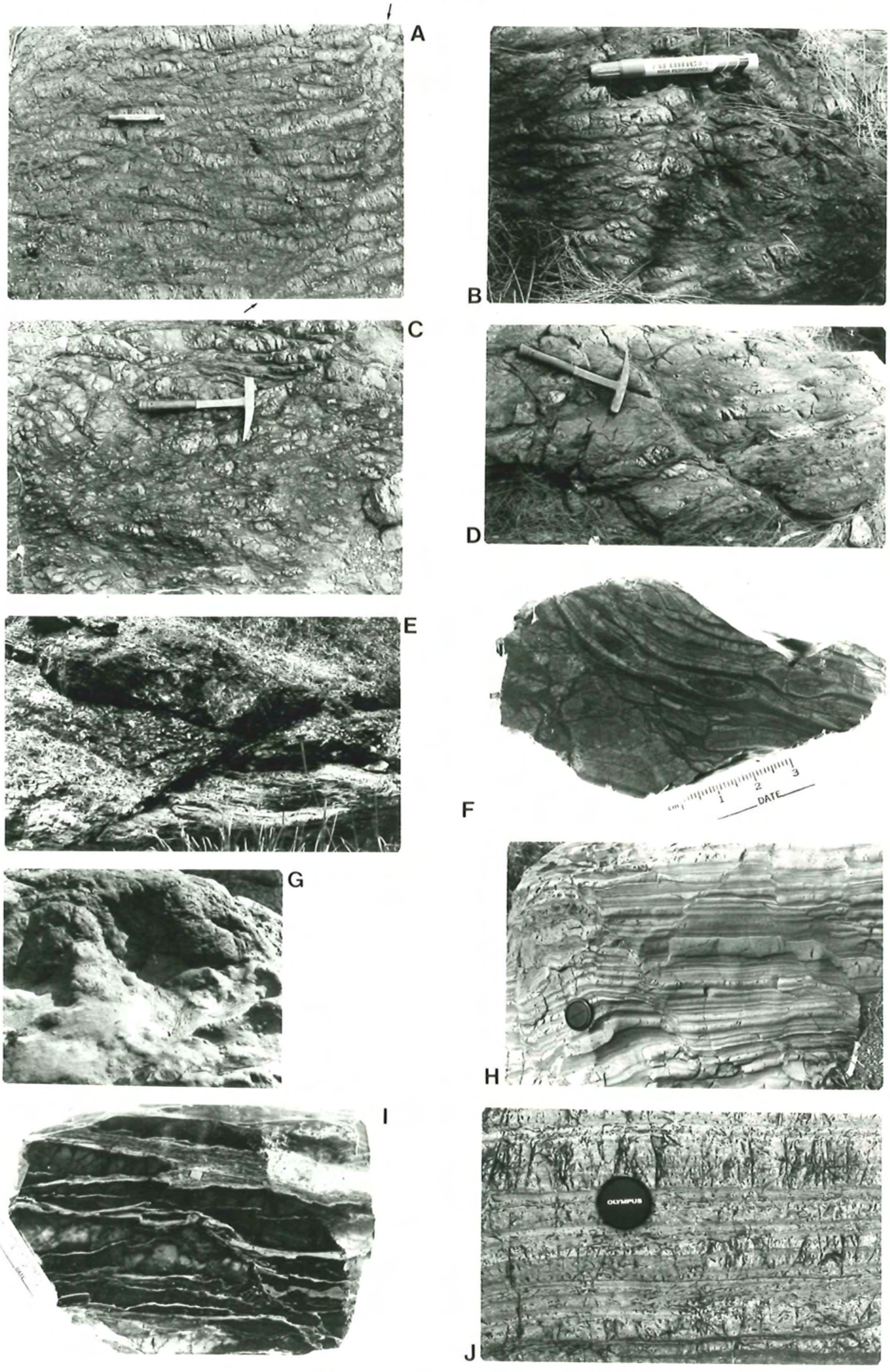
G. 'Moulded' tectonic contact between jasper (dark grey, upper background) and a highly sheared (?)basaltic unit (very fine-grained chlorite schist). Note small blocks of jasper (relatively high relief) which are incorporated in the chlorite schist (low relief, foreground). [GR649,827]

H. Small-scale faulting in well-bedded, comparatively little-deformed siliceous argillite. [∿GR801,927]

I. Highly sheared (?)mafic tuffaceous laminae (pale coloured and streaky; note pyrite euhedra, e.g. upper centre) smeared along (?)bedding planes and fractures in disrupted siliceous argillite (? silicic-intermediate tuff). [GR8038,9229]

J. Well-bedded, seemingly undeformed siliceous argillite which nevertheless displays some incipient shearing along some bedding planes [e.g. prominent dark bedding plane several mm above the lower margin of the photograph, and less prominent example approximately 1cm (photograph scale) above it]. [GR8004,9269].

PLATE 1·2



<u>PLATE 1.3</u>

Structural Characteristics of the Myra beds : 3

A. Incipient boudinage and pinch-and-swell structures in well-bedded siliceous argillites and minor argillites. Shearing is largely localized along bedding planes, although in some cases low-angle shears cross-cut the more highly attenuated beds. [GR7813,9105].

B. Same outcrop as in A, in cross-section. Note pinch-and-swell structures in down-dip and along-strike directions (*cf.* A.). The darker-coloured, plastically deformed beds appear to have a greater argillaceous component than the lighter-coloured, more siliceous variants. Discoidal boudins, especially of the more resistant beds, are a common feature of this style of deformation. [GR7813,9105].

C. Interbedded siliceous argillite/minor argillite in which bedding-parallel shear is largely confined to the more argillaceous (darker-coloured, low relief) layers. [GR7824,9211].

D. Well-developed shear foliation in argillite interbedded with more resistant siliceous argillite. Note attenuated laminae and lensoidal fragments of relatively pale-coloured siltstone and fine-grained sandstone in the sheared argillite (e.g. above and below cap of pen), and the 'pinched out' argillite horizon (∿1cm above lower left corner of photograph). [GR7813,9105].

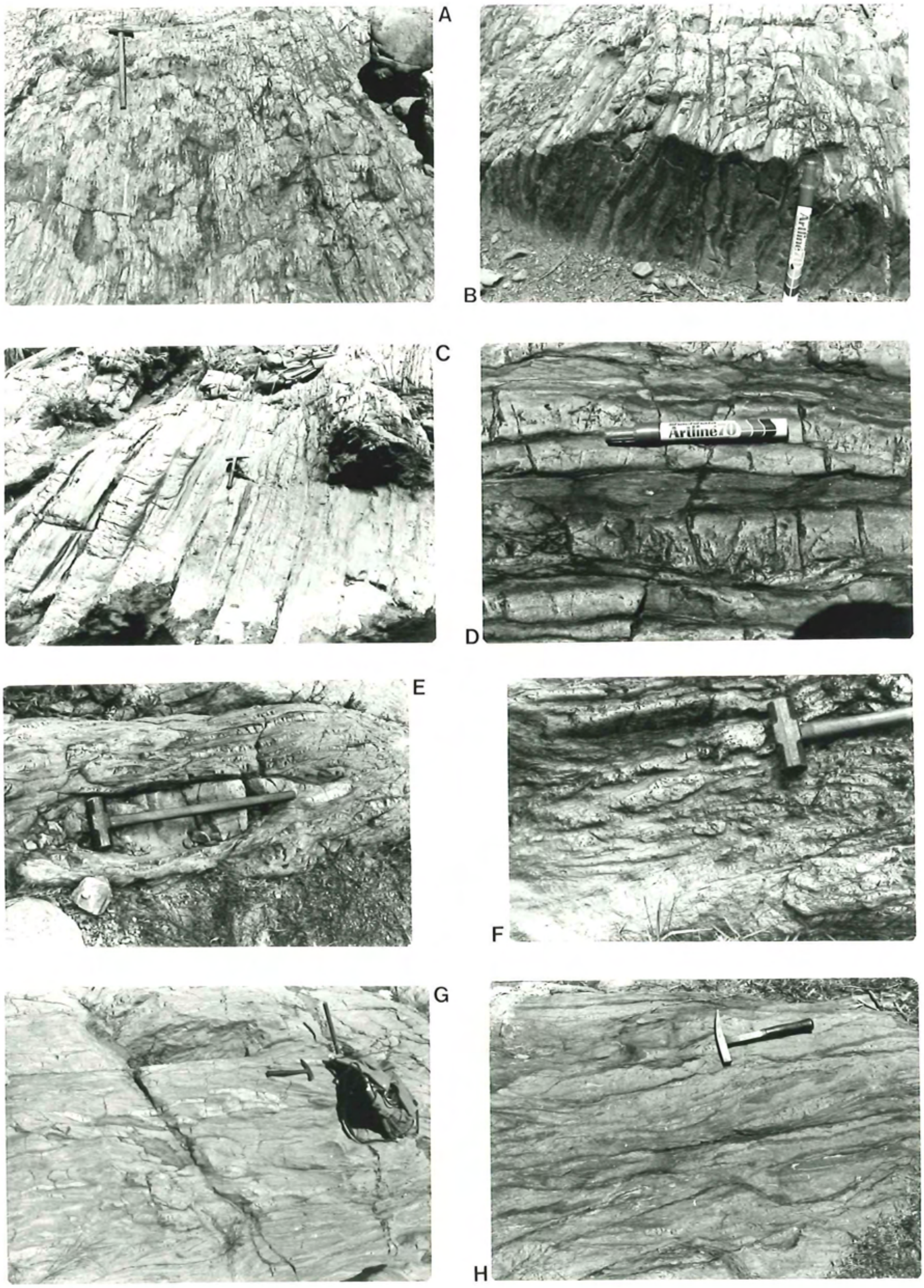
E. A lensoidal block of diffusely-bedded siliceous argillite isolated in a matrix of variably sheared, relatively well-bedded siliceous argillite. Note shear foliation wrapping around the larger block (e.g. near the end of the hammer handle). [∿GR802,926].

F. Siliceous argillites displaying an abrupt transition in fabric from a domain of incipient bedding-parallel shear (top) to one of intense shearing where original bedding is largely obliterated (bottom). [GR808,937].

G. Highly sheared siliceous argillites in which only lenticular fragments of original bedding are preserved. Note isolated fold hinge (centre) and dispersed fragments of similarly resistant beds. [GR7825,9218].

H. Intensely sheared siliceous argillite/argillite. [GR7824,9211].

PLATE 1·3



areas (e.g. Plate 1.1A,B; Fig. 1.3) is generally less evident in areas where siliceous argillite predominates. Somewhat more gradual deformation 'gradients' in the latter areas also contribute to a blurring of boundaries between high-strain and low-strain domains. Clearly, the block-in-matrix concept (*cf.* Hsu, 1968; Berkland *et al.*, 1972; Cowan, 1974; Silver and Beutner 1980) is directly applicable to these particular rocks only on macroscopic- and smaller scales.

Discussion

In the Woolomin beds between Woolomin and Kootingal (Fig. 0.2), Cawood (1982a) has mapped an imbricate stack of seemingly relatively coherent, westerly-dipping fault slices. In each of these slices a west-facing, crude oceanic layer 1-layer 2 (?) stratigraphy is variably developed (Fig. 3 of Cawood, 1982a). On the basis of this overall structure and lithological make-up, Cawood (1982a) has interpreted the Woolomin beds (his 'Woolomin Formation') to be an accretionary prism (subduction complex) formed during more-or-less west-dipping subduction along the line of the Peel Fault System.

Although the Woolomin beds in the Woolomin-Kootingal area and the Myra beds in the Pigna Barney-Curricabark area are almost certainly tectonostratigraphic equivalents, and both are most reasonably interpreted as accretionary complexes, they differ significantly in overall structure and deformational style. Much of the strain in these Woolomin beds appears to have been localized along thrust faults (Cawood 1982a) whereas in the Myra beds, intense shearing is relatively more widespread and incipient shearing is pervasive. Repetition of clearly-defined stratigraphic sequences is not evident in the Myra beds and, for the most part, s-surface dip steeply-moderately to the NE.

Apart from those localized melange zones specifically related to the major thrusts, such melange-like fabrics (e.g. transposition structures of Cawood, 1982a) as are developed in the Woolomin beds in the Woolomin-Kootingal and other areas (Cawood, 1982a, p.388; my personal observations, 1974-1982) are interpreted by Cawood (1982a,c) to relate to 'Early Permian regional orogenic deformation' in the NEO (*cf.* Leitch, 1974,1975). This assumption is based largely on his observations that similar melange fabrics are developed in: (i) the pre-Lower Devonian Woolomin Formation;

(ii) the Wisemans Arm Formation (see Fig. 1.1) of probable Early Devonian age (Cawood 1982b, in press); and in (iii) the (?) Late Devonian- (?) Early Carboniferous Cockburn Formation occurring to the east of the Woolomin Formation (beds) in the Woolomin-Kootingal area (see Fig. 2 of Cawood, 1982a). However, with the possible exception of the Wisemans Arm Formation (Leitch and Cawood 1980; Cawood, 1982b, in press), the absolute ages of these rocks do not appear to be well-established and the timing of the melange-forming event is poorly constrained (see below).

Although deformation of Permian age is widespread throughout the NEO (e.g. Leitch 1974; Korsch, 1977; Korsch and Harrington 1981a), the mechanism is somewhat obscure whereby post-subduction 'orogenesis' (Leitch, 1975; Cawood, 1982a,c) might have produced fabrics dominated by folding in Zone A and shearing in Zone B. If, as Cawood (1982a,c) suggests, subduction-related accretion in Zone B took place from the (?) Cambrian until the Early Permian (oldest rocks presumably subducted) or, at the very least, during the Upper Palaeozoic (*cf.* Korsch, 1975; Leitch, 1975; Crook, 1980a; Korsch, 1982), there would seem to be no necessity to invoke a discrete melange-producing event affecting Zone B in the Permian.

Indeed, because stress fields at convergent plate margins are likely to be at least somewhat dynamic and, on occasion, highly dynamic*, deformation displayed by subduction complexes with a long history of accretion (such as Zone B, NEO) is likely to be time-transgressive in both style and intensity, and perhaps even locally or regionally diachronous and/or multistage (e.g. see Dewey, 1975,1976,1977 for reviews and speculations on complexities at plate margins; and see Maxwell, 1974; Jones *et al.*, 1978; Coney *et al.*, 1980; Crook 1980a,b; Howell, 1980; Williams and Howell, 1982 for reviews of complexities in accretionary terranes). Subduction-related deformational fabrics developed in subduction complexes also may be a function of: (i) the rate of sediment influx to the trench (from the fore-arc region and/or the subducting plate) and the rate of subduction (e.g. Moore, 1973,1979; Moore and Karig

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* e.g. in close proximity to migrating triple junctions (*cf.* McKenzie and Morgan, 1969) and during complex interaction of microplates (e.g. Silver, 1971; Krause, 1973).

1980) and (ii) the mode of subduction (i.e. tensional or compressional, see Uyeda, 1982).

Differences in lithological make-up and deformational style are apparent between various accretionary tectonostratigraphic units in the NEO [e.g. the Woolomin and Sandon associations, at least parts of the Coffs Harbour Association and perhaps parts of the Nambucca Association (Crook, 1980a; Fergusson, 1982b; Flood and Fergusson 1982; Cross and Fergusson 1983)] and indeed, even within the Woolomin Association alone (see above). The accretionary history of the NEO appears to have been long and complex. By comparison with relatively well accepted models for deformation in accretionary prisms (e.g. Karig and Sharman, 1975; Seely, 1978; Moore, 1979; Scholl *et al.*, 1980), when viewed in isolation the overall structure of the Myra beds in the Pigna Barney-Curricabark area might suggest that they reflect accretion during generally westward-or southwestward-dipping subduction. Alternatively, this structure might be interpreted to reflect more-or-less imbricate overthrusting in a westward or southwestward direction. Whatever the local implications, these results are strongly at variance with the work of Cawood (1982a, see above). Bearing in mind the potential complexities of the as yet little-understood accretionary history of Zone B as a whole, it would be highly premature to speculate on the regional implications of the structure of that portion of the Myra beds examined here. For the purposes of this study it is important to emphasize that the PBOC in part borders, and is part incorporated in, one relatively small and structurally distinctive segment of an exceedingly complex, and as yet little understood, accretionary terrane.

1.2 Pigna Barney Ophiolitic Complex

The PBOC is an ophiolitic melange largely confined to the Peel Fault System and Curricabark Fault Zone in the Pigna Barney-Curricabark area (Fig. 1.1). It is everywhere in fault contact with adjacent stratigraphic associations and non-tectonic contacts between its various component lithologies are exceedingly rare. A crude internal ophiolitic stratigraphy is developed and, at least on present orientation, this consistently faces towards the Tamworth Belt. On the basis of general field associations the PBOC is possibly Early Devonian in age. However, this age is not well constrained. The internal structure of the PBOC is described in detail in Chapter 5.

1.3 Tamworth Belt

Tamworth Group and Glen Ward Beds

Following the work of Crook (1961a) and Cawood (1976,1980, in press), the stratigraphy and structure of the lower Tamworth Belt to the north of Bowling Alley Point (Fig. 0.2) are relatively well known. Crook (1961a) included all of the pre-Late Devonian rocks in the Tamworth Belt in his Tamworth Group which he considered to range in age from Lower-Upper Devonian. However, Cawood (1976) found Cambrian and Ordovician faunas in allochthonous limestone blocks in the basal units of Crook's (1961a) Tamworth Group (Drik Drik and Pipeclay Creek Formations). On the assumption of more-or-less contemporaneous age relationships between the faunas in these blocks and the deposition of their coarse-grained volcanogenic epiclastic hosts, Cawood (1980, in press) revised the lower Tamworth Belt stratigraphy to include three Lower Palaeozoic formations (Fig. 1.2). The known distribution of these (?) Lower Palaeozoic rocks is shown in Fig. 1.1.

To the south of Bowling Alley Point the pre-Upper Devonian stratigraphy of the Tamworth Belt is highly disrupted by faulting and, to some extent, blurred by an increased abundance of penecontemporaneous basaltic rocks (see Chapter 3). In the Nundle, Morrisons Gap, Glenrock, and Pigna Barney-Curricabark areas (Figs 0.1,0.2), discrete lithological units are rarely mappable for distances in excess of several hundred metres. Major lithological contacts commonly are faulted and/or poorly exposed. The intensity of faulting, especially outcrop-scale micro-faulting and shearing, is generally greatest in the vicinity of the Peel Fault System. This is most evident in the Pigna Barney-Curricabark area where rotation or 'jumbling' of relatively small fault blocks (on all scales) has produced a broad scatter in bedding orientations (Fig. 1.4, area 3). In general, however, overall bedding trends are sub-parallel to the Peel Fault System and dips are usually steep. Only the major faults are depicted on Maps 1 and 2. Folds are rarely developed in these rocks. Those few observed are tight mesoscopic types apparently confined to well-bedded siliceous argillite sequences (e.g. GR 2897,0510).

Because of the structural and perhaps stratigraphic complexities of the lower Tamworth Belt rocks adjacent to the Peel Fault System south of Bowling Alley Point, attempts to correlate in any detail between these rocks and the succession further to the north (Fig. 1.2) have met with only limited success (e.g. Crook, 1961a; Mayer, 1972; Offler, 1982). Mayer (1972) found Emsian and perhaps slightly older corals in Glen Ward limestones from the eastern part of the Pigna Barney-Curricabark area (see Map 1) suggesting that the associated volcanogenic epiclastics are possibly correlatives of the Silver Gully Formation (Fig. 1.2). In fact, coarse-grained volcanogenic epiclastics similar to those in the Silver Gully Formation and argillites closely resembling those in the Yarrimie Formation may occur at all structural and (?) stratigraphic levels in the lower Tamworth Belt 'sequence' in this area. Consequently, I have been unable to refine Mayer's (1972) correlations with any confidence. If correlatives of the Tamworth Belt (?) Lower Palaeozoic sequence do occur in the Pigna Barney-Curricabark area, then perhaps localized limestone-boulder conglomerates (containing rounded limestone boulders up to 1 metre in diameter, Plate 2.1) at GR 5954,9395 are the most likely candidates. I have not observed any fossils in this outcrop and I was unsuccessful in attempts to collect limestone samples for laboratory investigation. Throughout this area, limestone cobbles in the (?) Silver Gully Formation are typically unfossiliferous and the limestone-boulder conglomerate might simply be a coarse-grained variant of this formation.

Because the stratigraphy and general age-relations of lower Tamworth Belt rocks in the Pigna Barney-Curricabark area are incompletely known, and because it is convenient for the purposes of description, the informal terminology Mayer (1972) applied to these rocks (*viz.* Glen Ward beds) is retained (Fig. 1.1, Map 1).

Mayer (1972) suggested that a pile of keratophyric volcanics, which he termed the Pitch Creek Volcanics, underlie the Glen Ward beds and are therefore perhaps Lower Devonian in age. However, these volcanics unconformably overlie Glen Ward argillites, volcanogenic sandstones and doleritic rocks in the vicinity of GR 716,805 (see Map 1) and they appear to be faulted against the Glen Ward beds at other localities (e.g. GR 7324,8132). The volcanics display a close field association with members of the Pigna Barney Hornblendite-Tonalite suite and might be similar in age (see Chapter 4).

Undifferentiated Tamworth Group sedimentary rocks in the Morrisons Gap and Nundle areas are also lithologically similar to those in the Silver Gully and Yarrimie formations and are probably similar in age. In fact, rare Early-Mid Devonian corals (identified by J.S. Jell) do occur in a localized limestone breccia near Hanging Rock (*Sinospongophyllum*, UNEF 14095; see Fig I-1) and in a cobble in coarse-grained volcanogenic epiclastics in McDivitts Creek, GR 2835,0700 (*Xystriphyllum*, UNEF 14096).

Parry Group

In the Morrisons Gap area, undifferentiated Tamworth Group rocks appear to be conformably overlain by contact metamorphosed (see General Introduction) volcanogenic sandstones and argillites of the Baldwin Formation (Map 2). The Baldwin Formation is in turn overlain with apparent conformity by the Mandowa Mudstone (Tangaratta Formation). With complete continuity, both of these Parry Group units were traced from north of Nundle, where their stratigraphy is well-established (Crook, 1961a), into the Morrisons Gap area where they were previously mapped as the Hawks Nest beds (Crook, 1961a; see General Introduction). They are intruded by numerous leucocratic sills and dykes (Map 2) which, in hand specimen at least, closely resemble those intruding the Glen Ward beds in the vicinity of the Barrington Tops Granodiorite (Map 1).

Reticulate- and spaced cleavages are prevalent throughout much of the Parry Group in the Morrisons Gap area. Bedding-cleavage intersections and mesoscopic fold axes plunge to the NNE and SSW (Fig. 1.5). Although a synoptic plot of bedding in the area (Fig. 1.5) is broadly consistent with NNE-SSW trending folds, the general map pattern (Map 2) suggests that localized faulting may be the principal factor influencing bedding attitudes. In gross terms, the structural characteristics of this area are not unlike those of the Parry Group further to the north (*cf.* Crook, 1962).

Because the Late Devonian age of these Tamworth Belt rocks has been well established by simple stratigraphic continuity (see above) and the widespread occurrence of *Leptophloeum australe* (see Map 2; UNEF 14097;

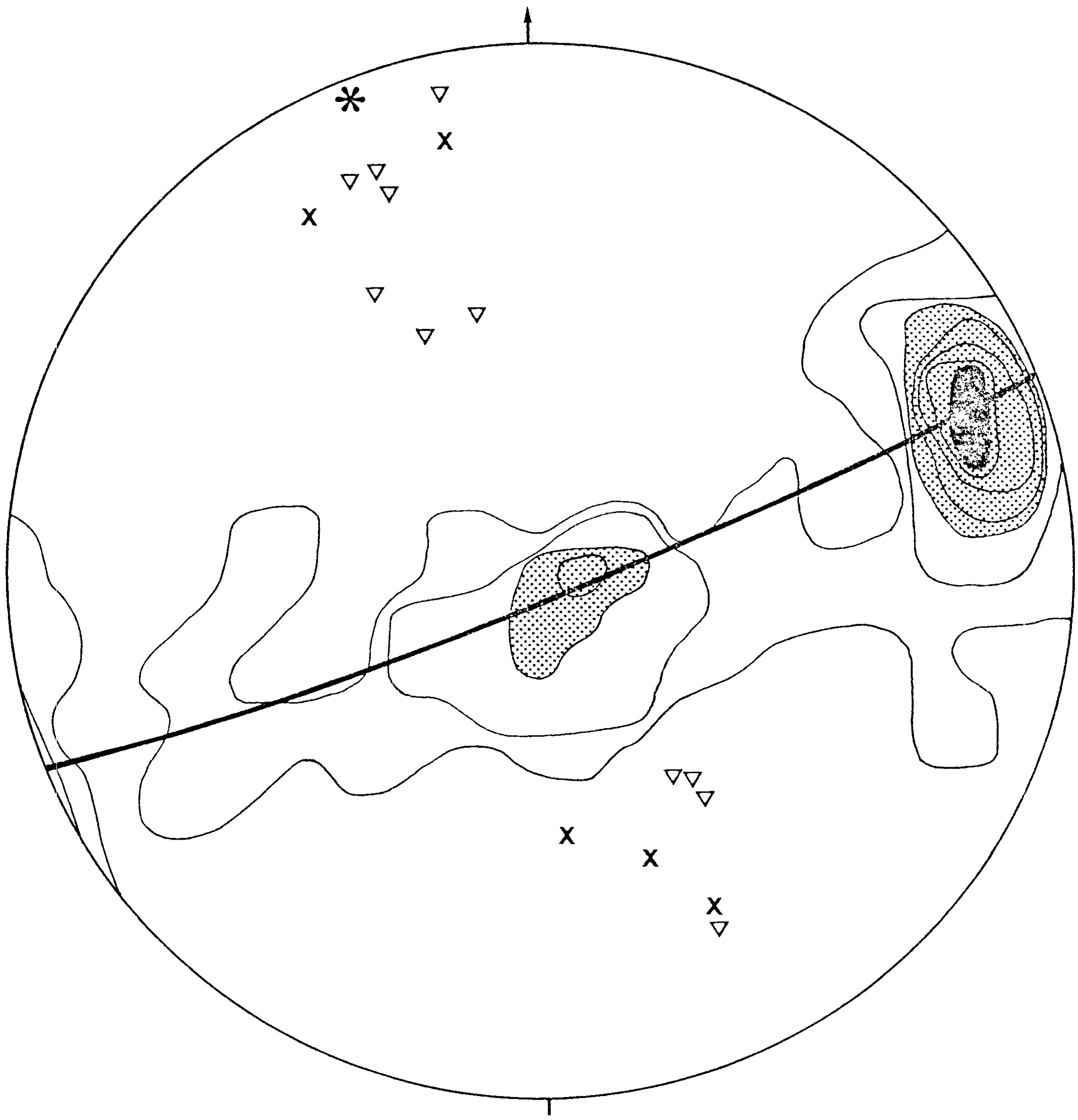

Fig. 1.5: Synoptic stereogram of 199 poles to bedding in the Morrisons Gap area.

Contours: 1:2.5:5:7.5:10:12.5:15% per 1% area.

✱ π axis $5^o/340^o$

▽ mesoscopic fold axes

X bedding-cleavage intersections

cf. Voisey and Packham 1969), and their stratigraphic position is no longer considered anomalous (see General Introduction), they are not discussed in any detail in the remainder of this thesis.

1.4 Nambucca Association

These rocks occur as minor fault blocks in the Glen Ward beds (Map 1) and Tamworth Group (Map 2), and as extensive fault blocks in Zone B (Map 1). They crop out poorly in the Pigna Barney-Curricabark area where they belong to the Lower Permian Manning Group of Mayer (1972). They have not been examined in any detail in this study. Some general observations on their structure and field relations are listed below.

(1) For the most part Manning Group lithologies in the Pigna Barney-Curricabark area are highly disrupted by intense faulting. In many areas, especially in the vicinity of major faults (e.g. GR 731,880), the finer-grained lithologies are strongly cleaved. Bedding and cleavage are usually steeply-dipping (Fig. 1.4). Rare clastic limestone horizons outline some disrupted folds (Map 1), but their structural significance is poorly known.

(2) On the basis of general lithological similarities, clastic rocks in the area to the northwest of McKenzies Creek (Map 1) are tentatively correlated with the Manning Group. Compared with the Manning Group elsewhere, however, silicic volcanics and volcaniclastics, and doleritic rocks are uncharacteristically abundant in this area (Map 1). In the vicinity of GR 576,940, conglomerate rocks seemingly derived from proximal silicic volcanics appear to rest unconformably on schistose serpentinite. Elsewhere in this area contact relationships between the various lithologies are poorly exposed. In their petrography and phyroxene- and bulk chemistries, at least some of the doleritic rocks resemble those nearby in the Woolomin Association (Offler, 1979,1982). If indeed these are Woolomin Association doleritic rocks, and this would seem likely, then perhaps: (i) Offler (1979,1982) is correct in assuming that the associated silicic volcanics and clastic rocks (conglomerates, poorly-lithified mudstones and

pebbly mudstones, lithic sandstones) are (exceptionally unusual) variants of the Woolomin Association; or (ii) the doleritic rocks are unroofed basement high in (?) underlying Woolomin Association; or (iii) the doleritic rocks are fault blocks introduced from (?) underlying or adjacent Woolomin Association. Because the assemblage in question appears to have at least some depositional contacts with underlying serpentinite (see above), and possibly with dolerite at GR 612,922. I tentatively favour possibility (ii) as a likely mode of origin for the doleritic rocks in this area (see Map 1). The structural and stratigraphic significance of highly altered mafic rocks poorly exposed GR 7040,8863 is similarly enigmatic.

(3) Near the southwestern corner of the Pigna Barney-Curricabark area (Map 1) a fault block of Manning Group diamictites containing poorly-preserved shelly fossils [e.g. *Deltopecten* (?)] is hornfelsed by the Barrington Tops Granodiorite. This indicates that the age of these particular rocks is at least 280 m.y. (see Chapter 4), and that they occupied their present structural position prior to the intrusion of the granodiorite. To some extent this reinforces Mayer's (1972) suggestion that the Manning Group occupies fault grabens in the Devonian and older rocks in the southern part of the NEO. These (?) grabens conceivably might represent: (i) pull-apart or tipped-wedge basins (*cf.* Emmons, 1969; Crowell 1974a,b; Aydin and Nur 1982; Norris and Carter 1982) related to possible (?) Upper Carboniferous-Lower Permian strike-slip movements along the Peel and/or Manning fault systems (e.g. Corbett, 1976; Cawood, 1982c) or, in Zone B at least; (ii) basins formed during differential uplift and shoaling of the Woolomin-Myra (?) accretionary prism (*cf.* Cawood, 1982a). Field relations in the Pigna Barney-Curricabark area place few tangible constraints on the above suggestions [*cf.* point (2) above] and a more specific and wide-ranging study than that achieved here is necessary to further elucidate the intrinsic structural history (-ies) of these fault blocks.