CHAPTER 20

PALAEOGEOGRAPHIC SYNTHESIS AND CONCLUSIONS

PALAEOGEOGRAPHIC SYNTHESIS AND CONCLUSIONS

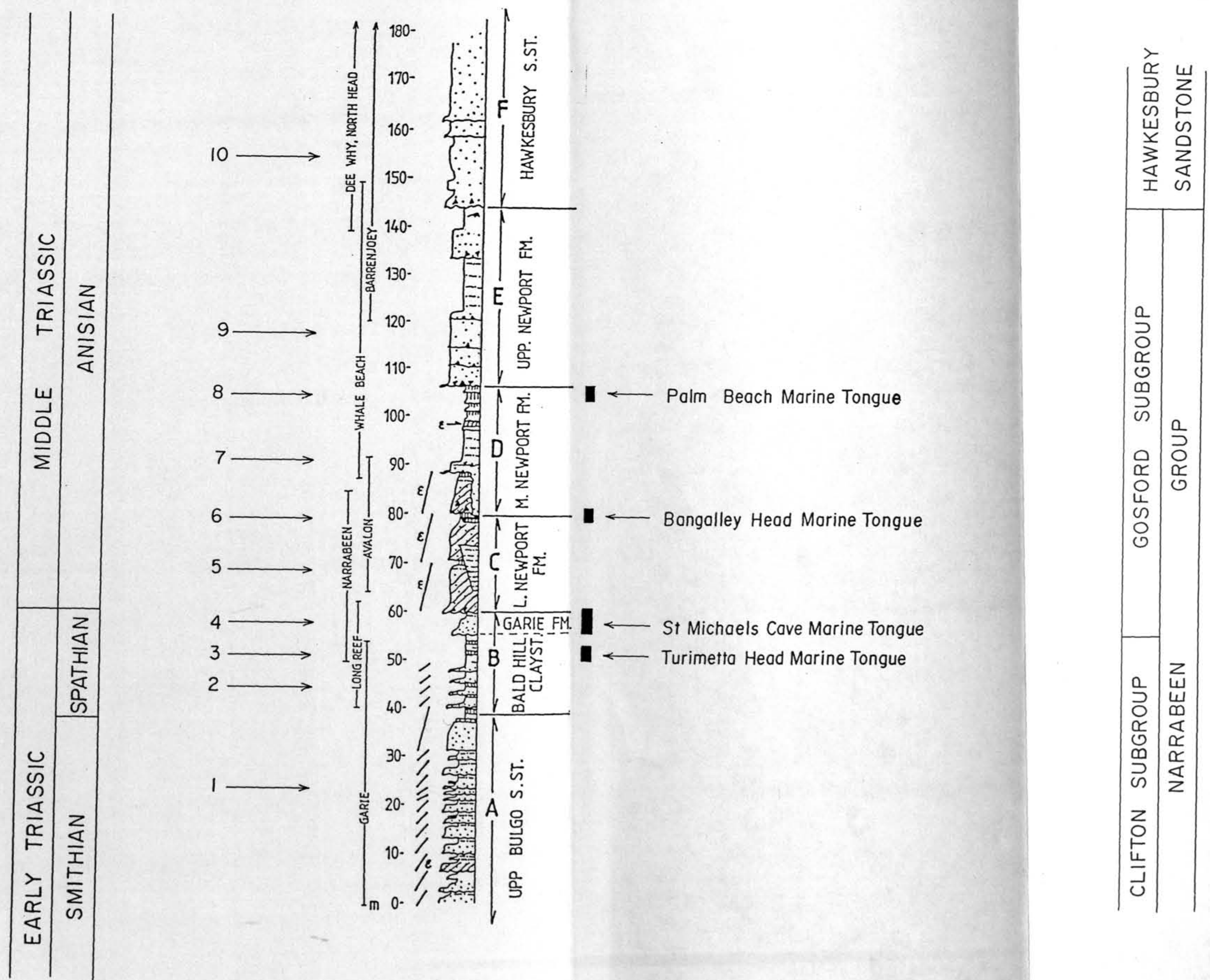
20.1. PALAEOGEOGRAPHIC SYNTHESIS

20.1.1. Introduction

The palaeoenvironmental differentiation of the uppermost Narrabeen Group succession into alternating fluvial and brackish shallow-marine stratigraphic intervals on the basis of their contained trace fossils and body fossils (cf. Text-Figs. 4.1, 4.3, 5.3, 5.4 & 20.1) permits further refinement of the changing palaeogeography of the north- and central-eastern parts of the Sydney Basin for the late Early and early Middle Triassic, starting with the reconstructions of Conaghan et al. (1982) and Cowan (1985), cf. Text-Fig. 1.12 herein. As described in this chapter, these palaeogeographic reconstructions and conclusions constitute a modified version of a manuscript by P.J. Conaghan, and T. Naing, appended here as Enclosure III.10.

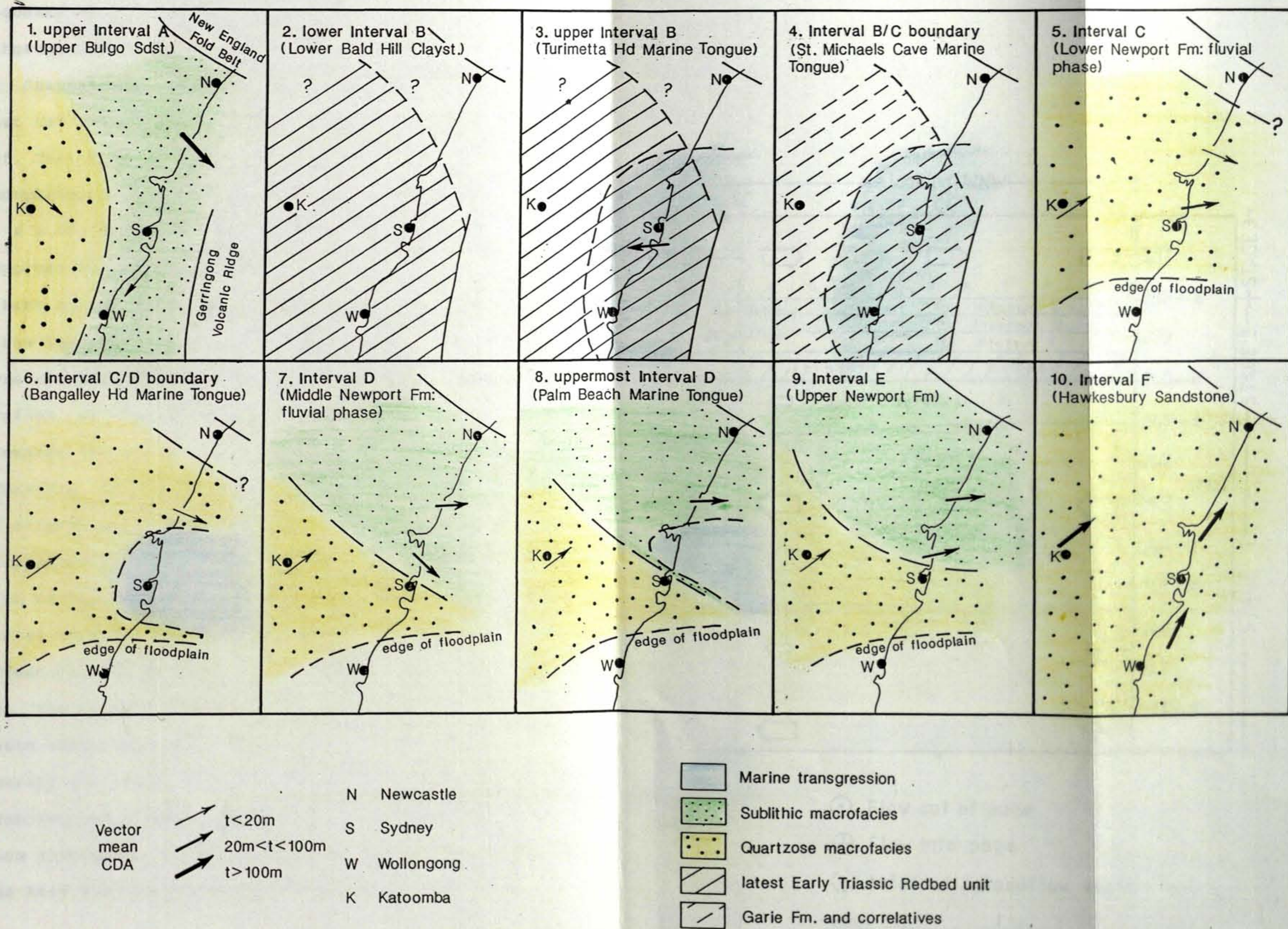
Text-Fig. 20.2 depicts ten frames or 'time-slices' that portray the main sequence of events in the changing palaeogeography of the latest Early and early Middle Triassic history of the northeastern part of the Sydney Basin, each 'time-slice' being defined stratigraphically in Text-Fig. 20.1. The regional palaeogeographic framework and palaeodrainage in each 'time-slice' are based on Cowan's earlier series of 'time-slices' (cf. Cowan, 1985, fig. 6.2, reproduced herein as Text-Fig. 1.12) for each of his stratigraphic intervals A to F, and based in turn on a time-space reconstruction for the central & eastern parts of the basin by Cowan (1985, fig. 6.1; reproduced here as Text-Fig. 20.3). Several of Cowan's palaeogeographic frames are repeated in Text-Fig. 20.2 because of the circumstances that several 'time-slices'

TEXT-FIG. 20.1. Stratigraphy of the Triassic rocks of the study area (from Cowan, 1985, fig. 2.1) showing stratigraphic position and extent of the four marine tongues (at right), and the stratigraphic location of the 'time-slices' (at left) depicted in the palaeogeographic reconstructions of Text-Fig. 20.2.


EARLY TRIASSIC
MIDDLE TRIASSIC
SMITHIAN
SPATHIAN
ANISIAN
1
2
3
4
5
6
7
8
9
10
GARIE
LONG REEF
NARRABEEN
AVALON
WHALE BEACH
BARRENJOEY
DEE WHY, NORTH HEAD
m
0-
10-
20-
30-
40-
50-
60-
70-
80-
90-
100-
110-
120-
130-
140-
150-
160-
170-
180-
A
B
C
D
E
F
UPP BULGO S.ST.
BALD HILL CLAYST.
GARIE FM.
L. NEWPORT FM.
M. NEWPORT FM.
UPP. NEWPORT FM.
HAWKESBURY S.ST.
Palm Beach Marine Tongue
Bangalley Head Marine Tongue
St Michaels Cave Marine Tongue
Turimetta Head Marine Tongue
CLIFTON SUBGROUP
GOSFORD SUBGROUP
NARRABEEN GROUP
HAWKESBURY SANDSTONE

TEXT-FIG. 20.1.

TEXT-FIG. 20.2. Latest Early and early Middle Triassic development of the central-eastern Sydney Basin in respect of 10 'time-slices' defined stratigraphically in Text-Fig. 20.1. The frames, some of which (2-4; 5 & 6; 7 & 8) are repeated here, with revisions, are taken from Cowan (1985, fig. 6.2), and are based on Cowan's (1985) time-space transect shown here as Text-Fig. 20.3. The major revisions to Cowan's diagrams involve the addition of the marine incursions shown in frames 3, 4, 6 and 8, based on the present work. Primary sources of palaeocurrent, petrographic, and sediment thickness (t) data are given in Cowan (1985, p.123). Palaeogeographic details in frames 3, 4, 6 and 8 are revised from Cowan's (1985, fig. 6.2) frames E, F and G; palaeogeographic details in other frames (1, 2, 5, 7, 9, 10) are as shown in Cowan's (1985) fig. 6.2. Geographic extent of Turimetta Head Marine Tongue (frame 3) is based on isopach and mineralogical patterns of the Bald Hill Claystone documented by Goldbery & Holland (1973, figs. 6 & 13); palaeocurrent (= sediment dispersal) vector shown in this frame is based on palaeocurrent data from the Bald Hill Claystone in Cowan (1985, fig. 2.1), isopach data for the Bald Hill Claystone (Goldbery & Holland, 1973, fig. 13), and considerations of the likely easterly provenance of sediment in the Bald Hill Claystone based on regional patterns in its mineralogy (cf. Goldbery & Holland, 1973, fig. 6; see also text for additional discussion). Rationale of likely geographic extent of the other marine tongues is given in the text.


1. upper Interval A (Upper Bulgo Sdst.)
New England Fold Belt
Gerringong Volcanic Ridge
2. lower Interval B (Lower Bald Hill Clayst.)
3. upper Interval B (Turimetta Hd Marine Tongue)
4. Interval B/C boundary (St. Michaels Cave Marine Tongue)
5. Interval C (Lower Newport Fm: fluvial phase)
6. Interval C/D boundary (Bangalley Hd Marine Tongue)
7. Interval D (Middle Newport Fm: fluvial phase)
8. uppermost Interval D (Palm Beach Marine Tongue)
9. Interval E (Upper Newport Fm)
10. Interval F (Hawkesbury Sandstone)
edge of floodplain
N
S
W
K
?
Vector mean CDA
t<20m
20m<t<100m
t>100m
N Newcastle
S Sydney
W Wollongong
K Katoomba
Marine transgression
Sublithic macrofacies
Quartzose macrofacies
latest Early Triassic Redbed unit
Garie Fm. and correlatives

TEXT-FIG. 20.2

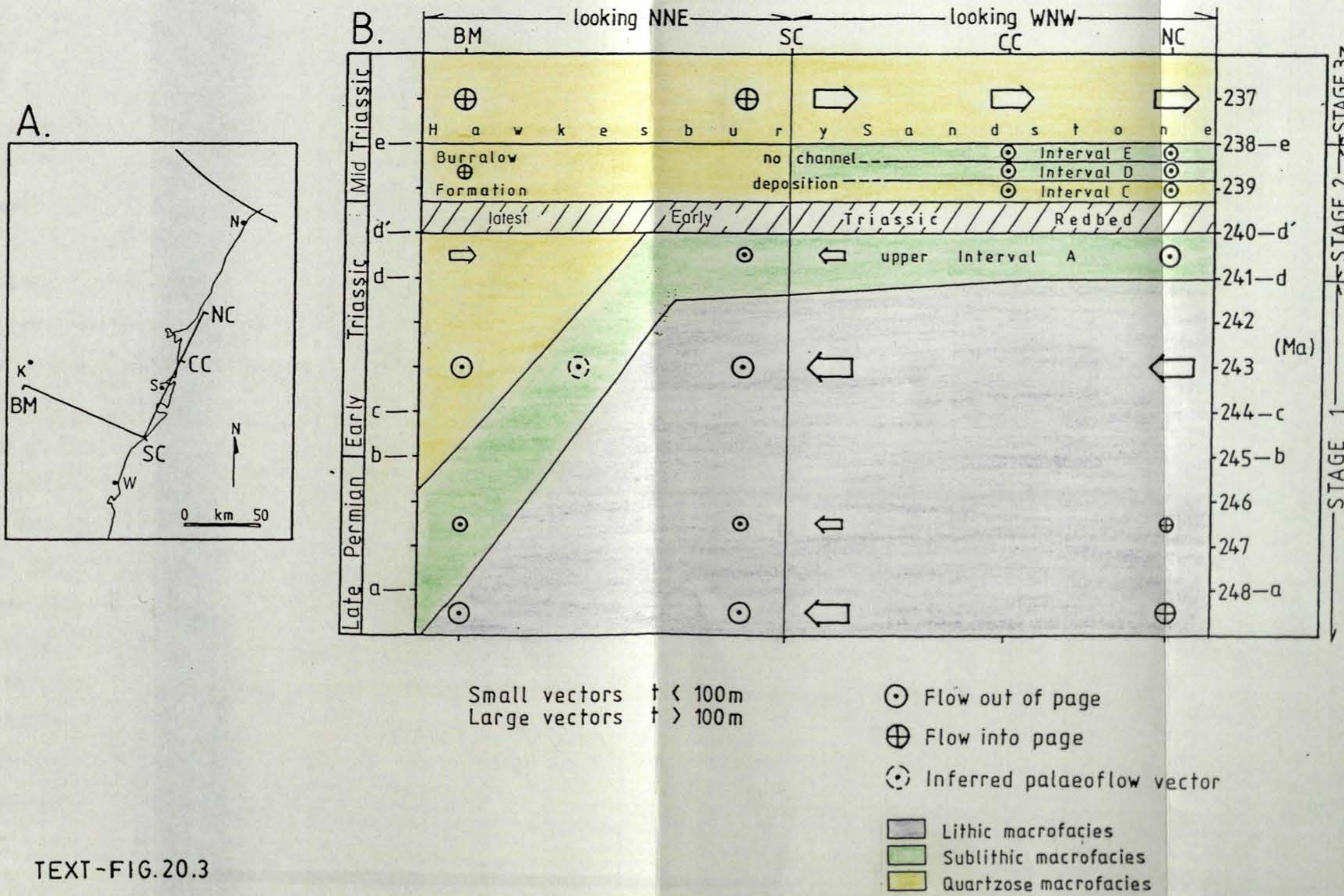
are sampled in some intervals in order to depict the rapidly changing palaeogeography (cf. Text-Fig. 20.1).

20.1.2. Sequence of palaeogeographic events

Clifton Subgroup (Text-Fig. 20.2, frames 1-3): As earlier explained in Chapter 1, the piedmont of orogen-derived labile sediment that had advanced towards the southwest during the Late Permian (cf. Text-Figs. 1.9; & 1.12, frames A & B) began to retreat geomorphologically during the Early Triassic (cf. Text-Figs. 1.9; & 1.12, frames C & D; Text-Fig. 20.3), as manifested by the progressive encroachment of craton-derived quartzose sediments back across the basin from the southwest towards the now waning New England Fold Belt. The advance and retreat of this piedmont was characterized by a southerly-flowing trunk stream the orientation of which swung progressively more towards the southeast towards the end of the Early Triassic (Text-Fig. 1.12, frame D; Text-Fig. 20.2, frame 1; Text-Fig. 20.3). The presence of abundant altered mafic volcanic rock-fragments associated with southwesterly palaeoflow structures in the upper Bulgo Sandstone at and south of Garie on the southern limb of the basin (Ward, 1972) indicates that the Gerringong Volcanic Ridge was present at this time (Text-Fig. 20.2, frame 1). In terms of sediment accumulation rate the basin's depocentre still lay in the northeast near Newcastle (Text-Fig. 20.2, frame 1).

During the latest Early Triassic (Spathian) the retreat of the orogen-sourced piedmont culminated in a period of starved sedimentation throughout the basin and resulted in the accumulation of the Bald Hill Claystone (Text-Fig. 20.2, frames 2 & 3;

TEXT-FIG. 20.3. A: Location of time-space transect shown in B. N = Newcastle, S = Sydney, W = Wollongong, K = Katoomba. NC = north coast, CC = central coast, SC = south coast, BM = Blue Mountains. NC - SC segment is orientated orthogonally to the northern (onshore) sector of the New England Orogen and parallel to the inferred southern extension of the New England Foldbelt (cf. Jones et al., 1984, 1987). SC - BM segment orientated parallel to the northern sector of the New England Orogen and orthogonal to the southern extension of the New England Orogen.
B: Time-space diagram incorporating data from Conaghan et al. (1982, fig. 3) for the microfloral boundaries \`a'-\`c'. Time-stratigraphy data of Cowan's (1985) figure 5.2 were used to construct the upper half of the diagram. Solid palaeoflow vectors based on the data of Conaghan et al. (1982), McDonnell (1983) and Cowan (1985). The size of the vectors denotes the thickness of sediment (t) that accumulated during the following time intervals: up to \`a', \`a' - \`b', \`b' - \`d', \`d' - \`d'', during interval C deposition, during interval D deposition, during interval E deposition, during Burralow Formation deposition and during Hawkesbury Sandstone deposition. Equal time spans are attributed to intervals C-E since, together with interval B, they all fall within a single microfloral zonule (At2). Absolute ages cf. data of Jones et al. (1984, fig. 166, and tables 10 & 11). Stages 1-3 (discussed in text) are defined at right. From Cowan (1985, fig. 6.1), with slight revision.


A.
N
NC
CC
K
S
BM
SC
W
N
0 km 50
B.
looking NNE
looking WNW
BM
SC
CC
NC
Mid Triassic
Early Triassic
Late Permian
e
d′
d
c
b
a
H a w k e s b u r y S a n d s t o n e
Burralow Formation
no channel deposition
Interval E
Interval D
Interval C
latest Early Triassic Redbed
upper Interval A
237
238—e
239
240—d′
241—d
242
243
244—c
245—b
246
247
248—a
(Ma)
STAGE 3
STAGE 2
STAGE 1
Small vectors t < 100m
Large vectors t > 100m
Flow out of page
Flow into page
Inferred palaeoflow vector
Lithic macrofacies
Sublithic macrofacies
Quartzose macrofacies

TEXT-FIG. 20.3

Text-Fig. 20.3), a redbed interval probably derived through the erosion of a deeply-weathered and lateritized landscape (Loughnan et al. 1964; Goldbery & Holland, 1973). Limited palaeocurrent data (cf. Goldbery & Holland 1973; and Cowan 1985) and regional patterns of the mineralogy within the Bald Hill Claystone and its correlative in the Blue Mountains (Goldbery & Holland 1973, fig. 6) suggest that this redbed unit was derived from the east (from the Gerringong Volcanic Ridge, cf. Text-Fig. 20.2, frames 2 & 3) in the eastern part of the basin, and from the west in the western parts of the basin. The first of the marine transgressions, represented by the Turimetta Head Marine Tongue, occurred towards the end of the Spathian (Text-Fig. 20.1) and the shallow sea or lagoon so formed was probably separated from the open sea to the east by the Gerringong Volcanic Ridge from which the lateritic sediment was still being shed (Text-Fig. 20.2, frame 3; see also Text-Fig. 1.11). The inland extent of the Turimetta Head marine transgression depicted in Text-Fig. 20.2 (frame 3) is much less than the area of development of the Bald Hill and Wentworth Falls Claystones and approximates that area of the redbed interval that is thickest and quartz-deficient, and hence of probable eastern rather than western provenance (cf. Goldbery & Holland, 1973, figs. 6 & 13). The Turimetta Head marine transgression then withdrew (Text-Fig. 20.1) and red palaeosols developed in areas such as Long Reef Point (Retallack, 1977a, b). This period of time is represented by trace fossil subintervals IC4 and IC5 (cf. Text-Fig. 5.3) and brought to a close sedimentation of the Clifton Subgroup (Text-Fig. 20.1).

Gosford Subgroup (Text-Fig. 20.2, frames 4-9): At the close of the Spathian water-tables began to rise once more as a shallow brackish-marine transgression inundated the central-eastern part of the basin, cannibalising and leaching the clayey land surface of the underlying Bald Hill Claystone to produce the clay-oolite/pisolite and clay-breccia textures of the (flint-clay) Garie Formation (cf. Bunny & Herbert, 1971; Retallack 1977b; Herbert, 1980a, p.46-48). This event is manifested by the St. Michaels Cave Marine Tongue (Text-Figs. 5.3, & 20.2 frame 4) which approximates the Early-Middle Triassic boundary and extends stratigraphically up slightly above the base of the Newport Formation (Text-Figs. 5.3 & 20.1). As mentioned in Chapter 1, the most laterally continuous and also thickest development of the Garie Formation is in the southern-eastern part of the basin (south of and inland from Botany Bay) where Bunny & Herbert (1971, fig. 5) record its maximum thickness to be 11 m. In the Sydney Northshore coastal exposures its development is laterally discontinuous, commonly present as channel-form deposits of highly altered volcanic rock-fragments and clay pellets, and has a maximum thickness of 7.6 m (Herbert, 1983b, p.13). Although the residual topographic feature of the Gerringong Volcanic Ridge was still present during this time (Text-Figs. 1.11 & 20.2 frame 4) there is little evidence that it shed much sediment into the shallow seaway to its west since the Garie Formation and its correlatives are thin over most of basin and can be accounted for by derivation mainly from the underlying Bald Hill - Wentworth Falls Claystone land surface (Herbert, 1980a, p.46-48). However, the highly altered volcanic-rock fragments that comprise up to

58% of the Garie Formation in the channel-form deposits of the Sydney Northshore area (Retallack, 1973; Herbert, 1983b, p.13) evidently were derived from the Gerringong Volcanic Ridge since they appear to be of mafic rather than silicic volcanic provenance unlike the volcanic rock-fragments present in the overlying Newport Formation (Conaghan, unpublished observations; Cowen 1985). The inland extent of the St. Michaels Cave marine transgression depicted in Text-Fig. 20.2 (frame 4) is restricted to much the same area as that depicted for the earlier Turimetta Head marine transgression on the basis of evidence in the Blue Mountains area that the correlative flint-clay unit there (i.e., the Docker Head Claystone Member of the Banks Wall Sandstone; cf. Text-Fig. 1.8) is of fluvial rather than marine origin (Loughnan et al., 1974; see also Loughnan & Goldbery, 1971).

Disappearance or eastward retreat of the St. Michaels cave marine transgression coincided with a weak resurgence of clastic bed-load alluviation of craton-sourced quartzose sand which advanced to the east and east-southeast across the northern and western parts of the basin (Text-Fig. 20.2 frame 5) and resulted in deposition of the Lower Newport Formation (Cowan's interval C). For the first time in the basin's Triassic history, there is now no longer any evidence of the existence of the Gerringong Ridge as a topographic feature, and the easterly course of the regional palaeodrainage system (Text-Fig. 20.2 frame 5) suggests that this ridge was either breached in the north or perhaps wholly buried by sediment laid down at this time (see also Retallack, 1977b). This phase of deposition terminated in the third marine transgression represented by the Bangalley

Head Marine Tongue (Text-Fig. 20.2, frame 6) whose inland extent is completely speculative. The inland extent of this marine transgression is depicted in Text-Fig. 20.2 (frame 6) to be considerably less relative to those of the two earlier transgressions on account of the likely influence of the presumed higher rates of coeval clastic alluviation than had prevailed during the period of the earlier two marine transgressions (Text-Fig. 20.2).

The briefly-lived Bangalley Head Marine Tongue straddles the Lower Newport and Middle Newport boundary (Text-Figs. 5.3 & 20.1) and heralds the advance of a sheet of sublabile sand of probable orogen or mixed craton-orogen provenance (Text-Fig. 20.2, frames 6 & 7), the only sediment sheet of such provenance in the Gosford Subgroup and the last sediment of such provenance in the Narrabeen Group as a whole. Cratonic quartzose sand continued to enter the basin from the southwest during this phase, as before, and the regional drainage in the northeastern part of the basin continued to be directed towards the east and southeast. This phase led to deposition of Cowan's interval D (the Middle Newport Formation) which terminates in the fourth and final brief marine transgression represented by the Palm Beach Marine Tongue (Text-Figs. 5.3, 20.1 & 20.2 frame 8). The inland extent of this brief marine transgression is also unknown and its geographic area depicted in Text-Fig. 20.2 (frame 8) is also small on the basis of the same rationale as was argued for the Bangalley Head marine transgression. A speculative east-west axis of elongation is depiction in Text-Fig. 20.2 in respect of both the Palm Beach and Bangalley Head Marine Tongues in sympathy with the east-west orientation of the longitudinal palaeodrainage that prevailed throughout Gosford Subgroup time, and which Cowan & Conaghan (1988, 1989) relate to southwestward thrusting in the onshore segment of New England Orogen during this time.

The last phase of Gosford Subgroup sedimentation (Cowan's interval E) saw the Palm Beach marine transgression over-run by continued deposition of sublabile sand that entered this central-eastern part of the basin from the west (and the central-northern part of the basin from the north; cf. data in Gregory, 1990) and with craton-sourced quartz sands continuing to enter the basin from the southwest (Text-Fig. 20.2, frame 9). This brought to a close sedimentation of the Narrabeen Group throughout the basin.

Hawkesbury Sandstone (Text-Fig. 20.2, frame 10): The final phase of Triassic sedimentation represented by the Sydney Northshore exposures is that of the Middle Triassic Hawkesbury Sandstone (Cowan's interval F; see Text-Figs. 5.3, 20.1 & 20.3). This phase occupies the early late Anisian and witnessed the development of a system of very large-scale low-sinuosity rivers that over-ran the basin from the southwest to emplace a maximum of about 260 m of craton-sourced quartz sand (Conaghan & Jones 1975; Conaghan 1980). The rare but relatively rich fauna of vertebrate and invertebrate body fossils that occur in the Hawkesbury Sandstone (cf. Branagan, in Packham, 1969, p. 415-417), as well as its abundant plant microfossils (Helby, in Packham, 1969, p.417) and rare trace fossils (Webby, 1970) occur within mudrock lenses and sheets that accumulated in ponded-water areas such as abandoned channels and flood-basins.

20.1.3. Palaeogeographic overview

Recent palaeogeographic reconstructions of the Sydney Basin and coeval New England Orogen to which it was yoked have pointed to the likelihood that the orogen, which approaches the present coastline from the northwest (Text-Fig. 1.1), turned to the south just offshore from the location of Newcastle and continued southward from there approximately parallel to the present coastline (Ward, 1972, 1980; Jones et al., 1984, 1987). Cowan's (1985) palaeogeographic reconstructions of the Sydney Basin shown here as Text-Fig. 1.12, based in turn on his time-space plot (Text-Fig. 20.3 herein), incorporate this notion. This idea that the onshore segment of the New England Orogen passed laterally into a southerly-trending offshore segment is explicit in the much earlier palaeogeographic reconstruction of David (1907) but had been long overlooked by most workers in the intervening period.

Cowan's reconstruction of the Late Permian, and Early and Middle Triassic history of the Sydney Basin involved a revision of Conaghan et al's (1982) earlier reconstruction and involved three stages (stages 1 to 3 in Text-Fig. 20.3; see also Text-Fig. 1.12).

(1) A Late Permian to latest middle Early Triassic phase of piedmont expansion and retreat, involving voluminous volcanogenic labile sediment influx to the basin from the east and northeast and the southward dispersal of this sediment in a regional trunk-stream system orientated parallel to the offshore segment of the New England Orogen. Craton-sourced

quartzose sediment entered the basin in significant amounts from the southwest only during the Early Triassic retreating phase of the piedmont (Text-Fig. 1.12, frames A-C; Text-Fig. 20.3).

(2) A latest Early and early Middle Triassic phase that witnessed the wholesale reorientation of the regional palaeodrainage net towards the southeast and then progressively more towards the east and east-northeast, concomitant with influx of craton-sourced quartzose sediment from the west and southwest and influx of labile/sublabile sediment from the orogen in the north except during Lower Newport Formation time (Cowan's interval C) when only cratonic quartzose sediment evidently entered the basin (Text-Fig. 1.12, frames D & F-H). This pattern of sedimentation was interrupted at the very end of the Early Triassic by the brief period of sediment starvation, deep lateritic weathering, and mobilization of this weathering mantle to form the basin-wide redbed marker unit, the Bald Hill and Wentworth Falls Claystones (Text-Fig. 1.12, frame E; Text-Fig. 20.3). A major contrast between this stage and the earlier one (stage 1) is the wholesale reduction of the offshore segment of the orogen as a sediment source for the basin and its progressive demise as a topographic feature. Instead, the easterly-directed palaeodrainage net parallel to the onshore segment of the orogen, and the evident northerly provenance of the labile/sublabile sediment during this stage (cf. Gregory, 1990) both manifest the influence of this segment of the orogen.

(3) A Middle Triassic pulse of craton-sourced quartzose sediment (i.e., the Hawkesbury Sandstone) laid down by large-scale powerful river that over-ran the basin from the southwest in an episode that was wholly unrelated either in time or space to the previous stage (Text-Fig. 1.12, frame I; Text-Fig. 20.3).

These reconstructions of Cowan (1985) remain essentially valid but can now be revised in detail on the basis of the palaeoenvironmental, and hence palaeogeographic implications that stem from the palaeoichnological work embodied in the present report (cf. Text-Fig. 20.2).

20.2. CONCLUSIONS

This study of the trace fossils in the Triassic rocks of the Sydney Northshore permits the identification of four brief, brackish, shallow-marine incursions in strata of the uppermost Narrabeen Group in that area. This finding confirms the rather speculative suggestion of several earlier workers that the uppermost two formations of the Narrabeen Group, i.e., the Garie Formation and the Newport Formation, are marine-influenced. Moreover, the study also shows that such marine-influence is also present in the underlying formation, the Bald Hill Claystone. Reference to Haq et al's (1988) compilation of chronostratigraphy and cycles of sea-level change shows that the Spathian and Anisian, when these brief marine incursions occurred in the central-eastern Sydney Basin (cf. Text-Fig. 20.1), were characterized by several short-term minor episodes of coastal onlap (Haq et al., 1988, fig. 17). Whether these onlap events were responsible for the Sydney Basin marine incursions, or whether they instead manifest local tectonic events that are also manifested by the evident major changes in sediment provenance and basin palaeo-drainage during this interval of the basin's history (cf. Text-Figs. 20.2 & 20.3) are presently unresolved.