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FACIES CHANGES IN THE UPPER DEVONIAN AND LOWER CARBONIFEROUS OF SOUTH CORK, IRELAND — A RE-ASSESSMENT[1]

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ABSTRACT

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The North Ringabella section, critical to an understanding of the sub-carbonate facies changes in south Co. Cork, is redescribed. Three successive formations are detailed: the alluvial West Cork Sandstone Fm. (800+ m), the shallow-marine Coomhola Fm. (96+ m) and the fault-based Kinsale Fm. (340+ m), here a pro-delta and shallow-marine sequence. This is overlain by the calcareous Courtmacsherry Fm. The Devonian/Carboniferous boundary occurs about the base of the Kinsale Fm.

Comparison with adjacent sections reveals a complex transgressive-regressive interplay. Four cycles are recognised. The first, in the Late Devonian, was affected by differential subsidence and was initially localised. The second, at the base of the Carboniferous, abruptly cut across earlier deltaic depositional patterns. Further delta growth in the Cork Harbour area was terminated by the third transgression, while the fourth marked the end of deltaic activity and the formation of a low-energy platform area around Cork Harbour upon which carbonate reefs ('Carboniferous Limestone') were subsequently developed.

INTRODUCTION

The striking north-south geological contrast across a line between Kenmare and Cork Harbour, with Lower Carboniferous limestones absent on the southern side, has been known since the pioneer work by GRIFFITH (1838, 1839). Although subsequent workers (e.g. JUKES, 1864; TURNER, 1939, 1952) in the Cork City area identified this as reflecting lateral facies changes, opinions differed until the recent study by NAYLOR & JONES (1967) and NAYLOR (1969). They recognised that the section at North Ringabella (Fig. 1) was critical, supplied lithostratigraphical data and by comparison with adjacent sections reached several major conclusions. Firstly, that thick Late Devonian red-bed continental sequences at North Ringabella were abruptly laterally equivalent to marine sequences at the next section to the south (South Ringabella, Fig. 1). Secondly, that there was a relatively thin (<70 m) marine Late Devonian sequence at North Ringabella compared to 1000+ m at South Ringabella. Thirdly, that the succeeding Early Carboniferous clastic sequences were essentially deposited under shallow-marine conditions and show a southerly thickening between North and South Ringabella. Fourthly, that thick Early Carboniferous limestones in the Cork Harbour area are replaced to the south by a thick argillaceous facies.

The diachronous nature of the Late Devonian marine transgression between the North and South Ringabella sequences was subsequently confirmed on miospore evidence (CLAYTON ET AL., 1974) and the facies changes proposed by NAYLOR (1969) were followed in subsequent regional reconstructions (NAYLOR ET AL., 1974; GARDINER, 1975). The lithological details as supplied by NAYLOR (1969) were accepted by subsequent workers for correlation purposes. However, recent work in the Cork Harbour area (MACCARTHY, 1974; MACCARTHY ET AL., 1978) revealed lithostratigraphical and sedimentological correlation problems with the published description of the North Ringabella sequence underlying the Courtmacsherry Fm. The authors therefore carried out a detailed study of this part of the latter section (Fig. 1). The results obtained show striking differences with the earlier studies and, in addition to clarifying lithostratigraphical problems, have revealed a previously unrecognised complex interplay of transgressive/regressive facies changes in the Upper Devonian – Lower Carboniferous of this area.

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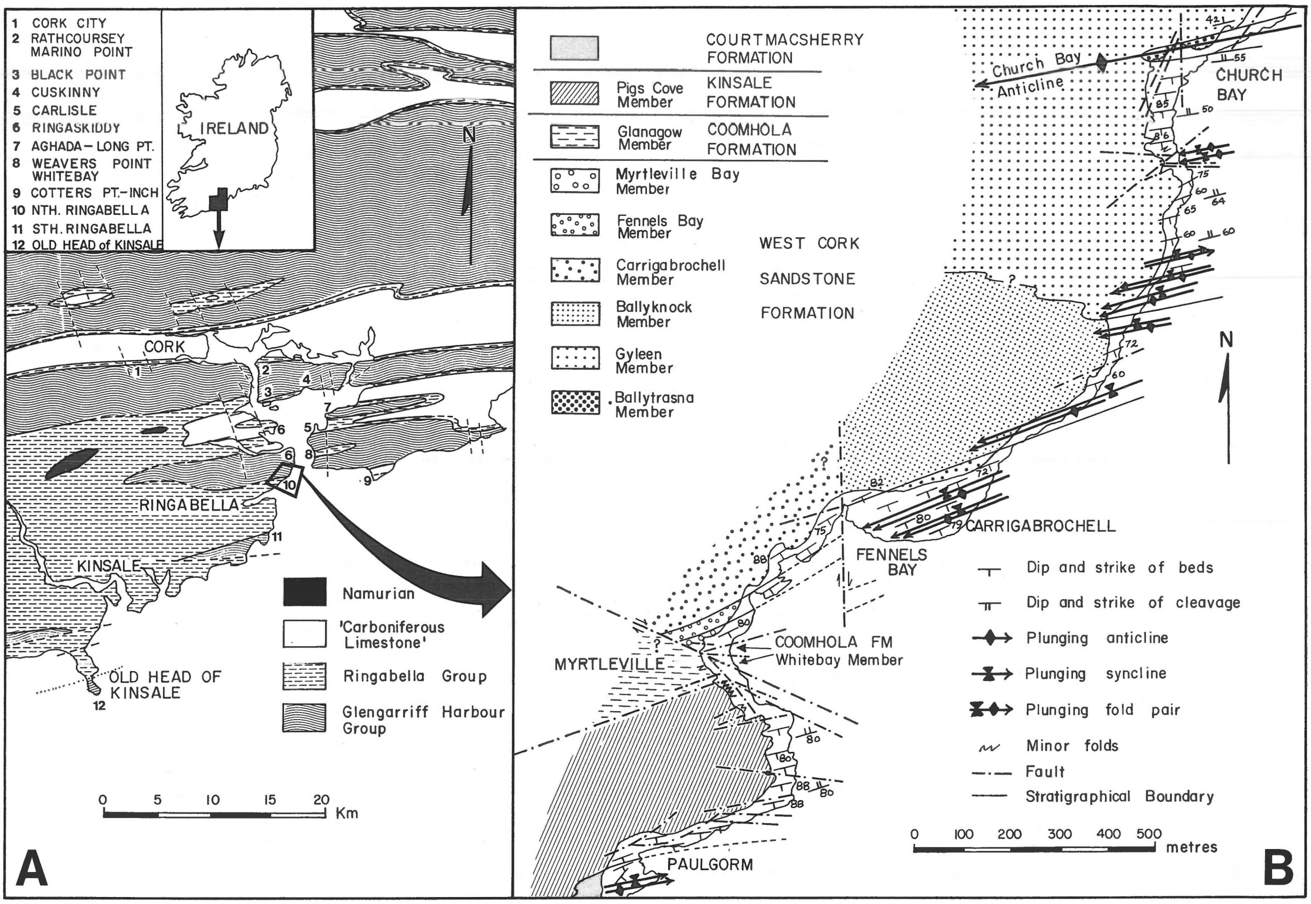

Fig. 1
A: Sketch map showing the generalised geological setting of the North Ringabella section and the location of other documented sequences.
B: Geological map of the North Ringabella sequence between Church Bay and Paulgorm, showing the location of the lithostratigraphical units described in the text.

PREVIOUS WORK AND STRATIGRAPHICAL NOMENCLATURE AT NORTH RINGABELLA

NAYLOR & JONES (1967) and NAYLOR (1969) were the first to identify formal stratigraphical units and to make correlations with other known sequences. Parts of this lithostratigraphical terminology, downgraded in rank, were subsequently utilised by GARDINER & HORNE (1972, 1976) in a regional lithostratigraphy. There is now general agreement over units of formation level in the marine sequences, but there are still two lithostratigraphical schemes in the Cork Harbour area with differences in terminology and detail. Thus, for the North Ringabella section (Fig. 2), nine different schemes have been applied to date. However, only LEFLEF (1973-a, b), CLAYTON ET AL. (1974) and VAN GELDER & CLAYTON (1978) have carried out further specific work on the section. LEFLEF (1973-a, b) was concerned with the detailed sedimentology of a limited red-bed sequence; CLAYTON ET AL. (1974) were concerned with palynological investigations, while VAN GELDER & CLAYTON (1978) briefly assessed the uppermost part of the sequence for correlation purposes. All others relied on the lithological data supplied by NAYLOR & JONES (1967) and NAYLOR (1969).

In order to evaluate the accuracy of the various correlative proposals the entire section was remapped on a scale of 1:2500 and the sequence measured on a scale of 1:100. Several laterally equivalent sections were logged in order to assess sedimentological geometry. All original maps and sections are housed at University College, Cork.

In presenting this data, the regional nomenclature proposed by GARDINER & HORNE (1972, 1976) was selected for two reasons. Firstly, because detailed descriptions using this scheme for all adjacent sections to the north and east of North Ringabella were now available (MACCARTHY ET AL., 1978), facilitating lateral comparisons. Secondly, because definition agreement of the redefined base of the Old Head Sandstone Fm. (Group) of NAYLOR (1969) has still to be reached. Initially taken at the top red-bed (NAYLOR, 1966; 1969; MATTHEWS & NAYLOR, 1973; NAYLOR ET AL., 1974; etc), current supporting authors of this name recognise its base as either the 'first appearance of heterolithic lithologies' (GRAHAM, 1975) or at the 'entry of significant amounts of lens bedding and flazer bedding' (SLEEMAN ET AL., 1978, p. 168), or both (NAYLOR, 1975, p. 323 and p. 325). Further confusion is avoided if this name is not used in this study.

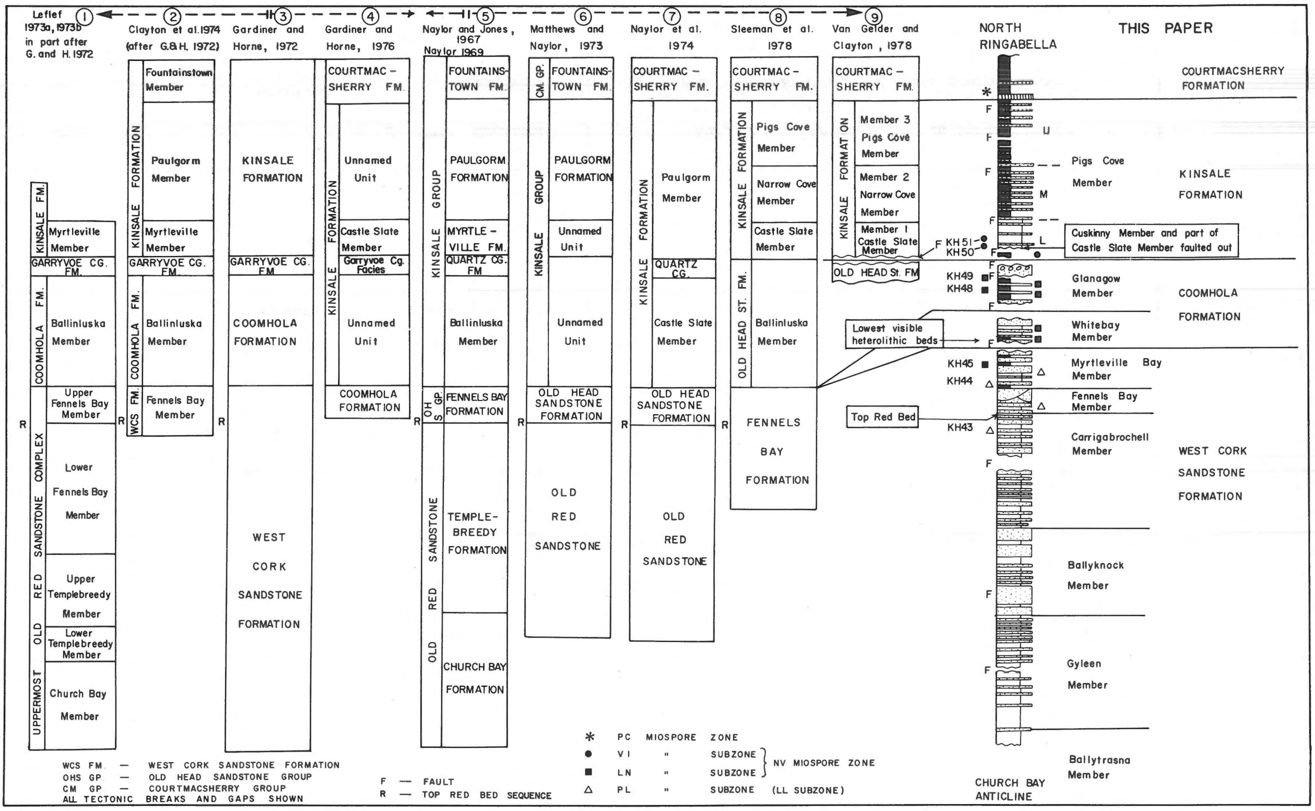

Fig. 2

Schematic representation of the North Ringabella sequence, showing bulk vertical lithological variation and the lithostratigraphical units recognised in this paper. Vertical thickness not uniform. Palynological data on L H S from Clayton et al., (1974); on RHS from Van Veen (pers. comm.). Columns 1-9 give the lithostratigraphical terminology as applied by workers since 1969 specifically to the North Ringabella sequence, with their unit boundaries related directly to the schematic section for comparative purposes. Columns 2-4, 5-8, incl., based on data from Naylor (1969). Arrows indicate derivation of lithostratigraphic nomenclature.

THE NORTH RINGABELLA SECTION

This extends from the core of the Church Bay Anticline (Fig. 1) to Ringabella Creek and encompasses four formations (Fig. 2): the West Cork Sandstone Fm., the Coomhola Fm., the Kinsale Fm. and the Courtmacsherry Fm. of GARDINER & HORNE (1972, 1976). The Devonian/Carboniferous junction approximates to the LN/VI miospore boundary (GEORGE ET AL., 1976), which is probably faulted out on this section (Fig. 2).

The effect of structural deformation has been greatly underestimated or overlooked in previous accounts. Parts of the stratigraphical changes proposed here have arisen because of the recognition of significant fault effects.

STRUCTURAL GEOLOGY

The sequence occurs on the steeply dipping southern limb of the major ENE trending Church Bay Anticline, with a locally penetrative cleavage fabric occurring at incompetent levels, particularly in minor fold hinges. Minor parasitic folds are sporadically developed, generally plunging at low angles to the west but with some plunge reversals (Fig. 1). The strata essentially young southwards.

The fault pattern is shown in figures 1 and 3, and is here only considered in so far as the stratigraphy has been affected. Of the 48 faults identified, only F1, F4, F6, F10, and F18 appear stratigraphically important. These are in the Fennels Bay – Paulgorm section (Fig. 3) and show dextral movement, although the amount of displacement is unknown. NAYLOR (1969) recorded six faults which did not apparently include F1, F4 or F10, while F6 and F18 were shown as having no stratigraphical effect. LEFLEF (1973-a, b) only recognised F1, F2 and F10 in the same area and inserted an additional fault which could not be located. VAN GELDER & CLAYTON (1978) in a generalised map show one major fault (F18, Fig. 3).

The fault at Fennels Bay (F1) has a dextal throw of at least 200 m. Its omission by NAYLOR (1969) allied with incorrect bedding-strike plots between F1 and F3 (see Fig. 3 as compared to Fig. 3 of NAYLOR, 1969) appears to be the cause of his failure to recognise the distinctive Carrigabrochell Member.

F4 separates the West Cork Sandstone Fm. from the Coomhola Fm., while F6 and F10 juxtapose the Whitebay and Glanagow Members (Coomhola Fm.). Faulted bounderies

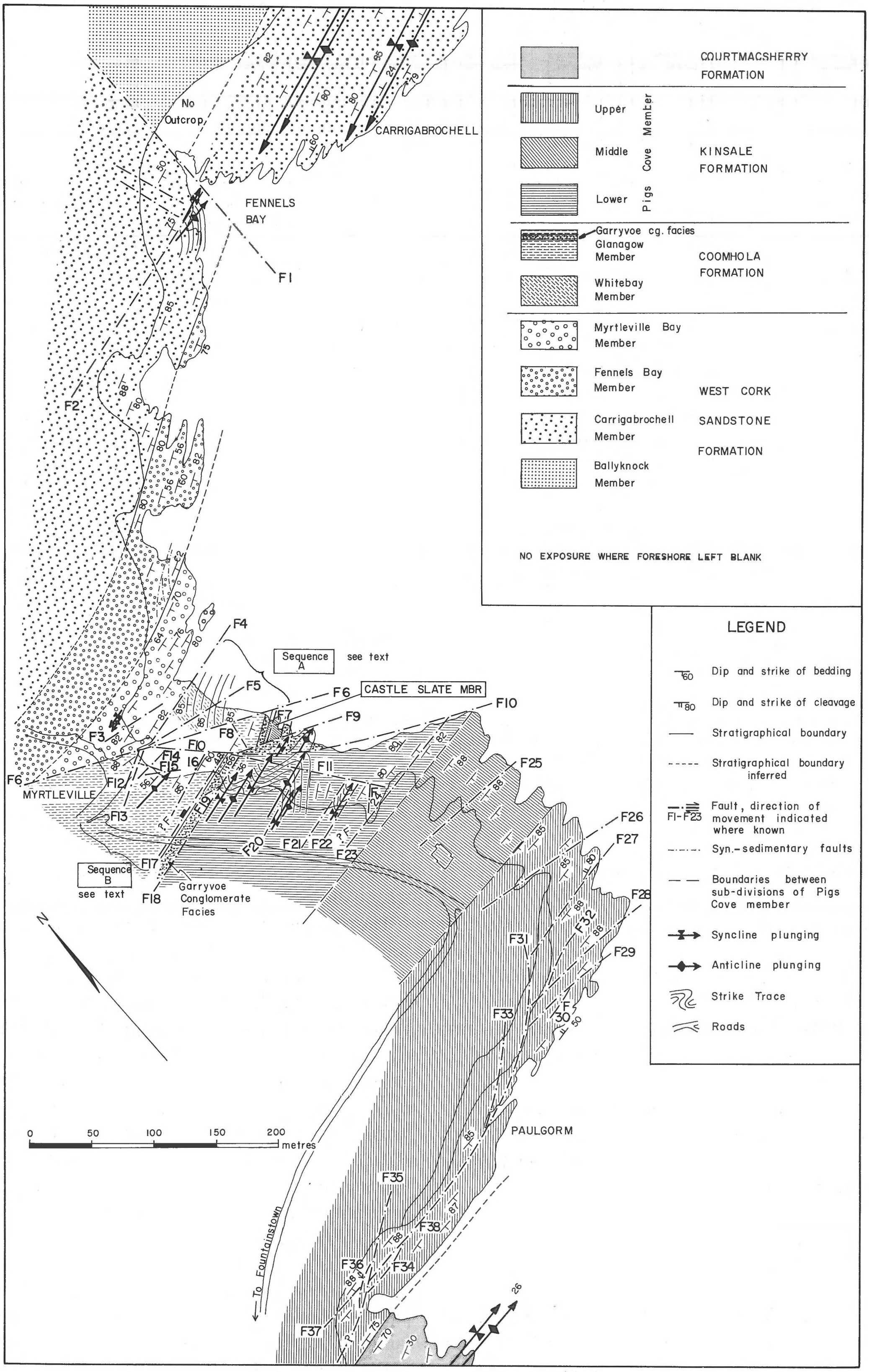

Fig. 3
Detailed geology of the Fennels Bay – Paulgorm coastal section. Note effect of faulting on the stratigraphical sequence.

preclude any total thickness measurement for the Coomhola Fm. The base of the Kinsale Fm. is not seen due to faults F7, F10 and F18.

STRATIGRAPHY

West Cork Sandstone Fm. (800+ m)

The base is not exposed while its top, defined by the incoming of heterolithic beds (GARDINER & HORNE, 1972), is faulted out (F4 and F6 in Fig. 3). Three regionally traceable members within this formation recognised by MACCARTHY ET AL. (1978) in adjacent sections also occur in North Ringabella (Ballytrasna, Gyleen and Ballyknock Mbrs.). These comprise the lower part of the sequence and are succeeded by three members unique to this section.

Ballytrasna Mbr. (23+ m) – This member comprises a thick succession of sandstone-laminated, red siltstone with isolated claystone levels. Only the uppermost 23 m of the member are exposed here (Fig. 1).

Gyleen Mbr. (approx. 300 m) – The base of this member is marked by the lowermost scourbased sandstones and comprises a succession of rhythmic fining-up units (cf. ALLEN, 1965). Each unit contains a cross-cutting surface and consists of a thick (1-4 m) green, grey or red sandstone fining up to a thick (5-20 m) red siltstone. The top of the member is taken at the top of the uppermost thick siltstone which caps the rhythmically organised sequence (MACCARTHY ET AL., 1978). The lower part of the member is distinguished in containing relatively minor thin (1-2 m) sandstones. Thick pale green-grey sandstones characterise the upper part. There is a bulk coarsening-up through the member.

Ballyknock Mbr. (approx. 200 m) – This member is dominated (75%) by thick, parallel-sided, green sandstone-laminated siltstones, alternating with red siltstones of variable thickness. Its boundaries are defined by thick units of rapidly alternating sandstones and siltstones which are usually green or grey. The member contains a complex array of small-scale rippled sandstones and siltstones (LEFLEF, 1973-b).

Carrigabrochell Mbr. (184+ m) – This is distinguished by thick epsilon cross-stratified scour-based sandstones, interleaved with regularly alternating, cross-stratified and rippled sandstones and thicker red siltstones. The type section is located at Carrigabrochell and West Fennels Bay (Figs. 3, 4). The top of the member is taken at the uppermost thick (5 m) siltstone which coincides approximately with the uppermost redbed, although minor redbeds occur above this level.

Fennels Bay Mbr. (27 m) – This is characterised by thick complex, greenish down-cutting channel-fill sandstone units, of which a number contain an unusual array of synsedimentary faults. The channel units are separated by thin, yellowish-green siltstones; thin lenticular siltstones also occur within some channel units (Fig. 4).

Myrtleville Bay Mbr. (65+ m) – The base is marked by the first thick (7 m) mudstone in the sequence. This coarsens up from claystone to siltstone with sparse thin sandstones (Fig. 4). The member essentially consists of four such thick (4-7 m) mudstone units, alternating with thick sandstone/siltstone channel-fill complexes with a few interleaved claystone levels. The siltstones are mostly pale yellow-greyish and contain numerous thin sheet and lenticular wave-rippled sandstones; at several levels they infill major channels. Shrinkage cracks occur while bioturbation is evident in the uppermost mudstone unit. Lenticular epsilon cross-stratified sandstones overlie two siltstone units. A striking feature of the lower part of the member is the abundance of sedimentary deformation.

Coomhola Fm. (96+ m)

The base of this formation is marked by the incoming of heterolithic beds, while its top is delimited by the base of the first significant claystone unit (GARDINER & HORNE, 1976). There has been confusion concerning the location of this unit at North Ringabella (Fig. 2).

The present study has shown that the lowest heterolithic beds occur to the south of fault F4 (Fig. 3). Since heterolithic units occur within 4 m of the fault contact (Fig. 4), it is here considered that the base of the Coomhola Fm. is not exposed.

The Coomhola Fm. is therefore restricted to the fault-bounded block between F4 and F18 of figure 3. NAYLOR (1969) indicated a lateral continuity in this zone (his 'Ballinaluska Formation'), but there are two contrasting sequences (A and B in Fig. 3) in fault juxtaposition. Detailed logging (Fig. 4) shows that sequence A is sand dominant, while sequence B is siltstone/clay dominant. Miospore evidence (Drs. P. van Veen, pers. comm., see Fig. 2) indicates that sequence A is within the LN subzone and hence older than the Kinsale Fm. in this area (CLAYTON ET AL., 1974).

Sequence A matches the Whitebay Mbr. while sequence B is comparable to the Glanagow Mbr. as described in MACCARTHY ET AL. (1978). In view of the regional thickening of this formation south-westwards (GARDINER, 1975; MACCARTHY, 1979), it should be at least as thick or thicker than in Cork Harbour, where it is 203 m thick (MACCARTHY ET AL., 1978). This suggests that at least 50% of the formation is cut out by faulting.

Whitebay Mbr. (39+ m) – This is a sandstone-dominant unit typified by coarsening-up units (MACCARTHY ET AL., 1978). It consists here of an alternation of linsen-bedded mudstones and parallel-laminated or rippled sandstones with minor internal scouring, arranged in seven crude coarsening-upward units (Fig. 4). The coarsening-upward units are more pro-

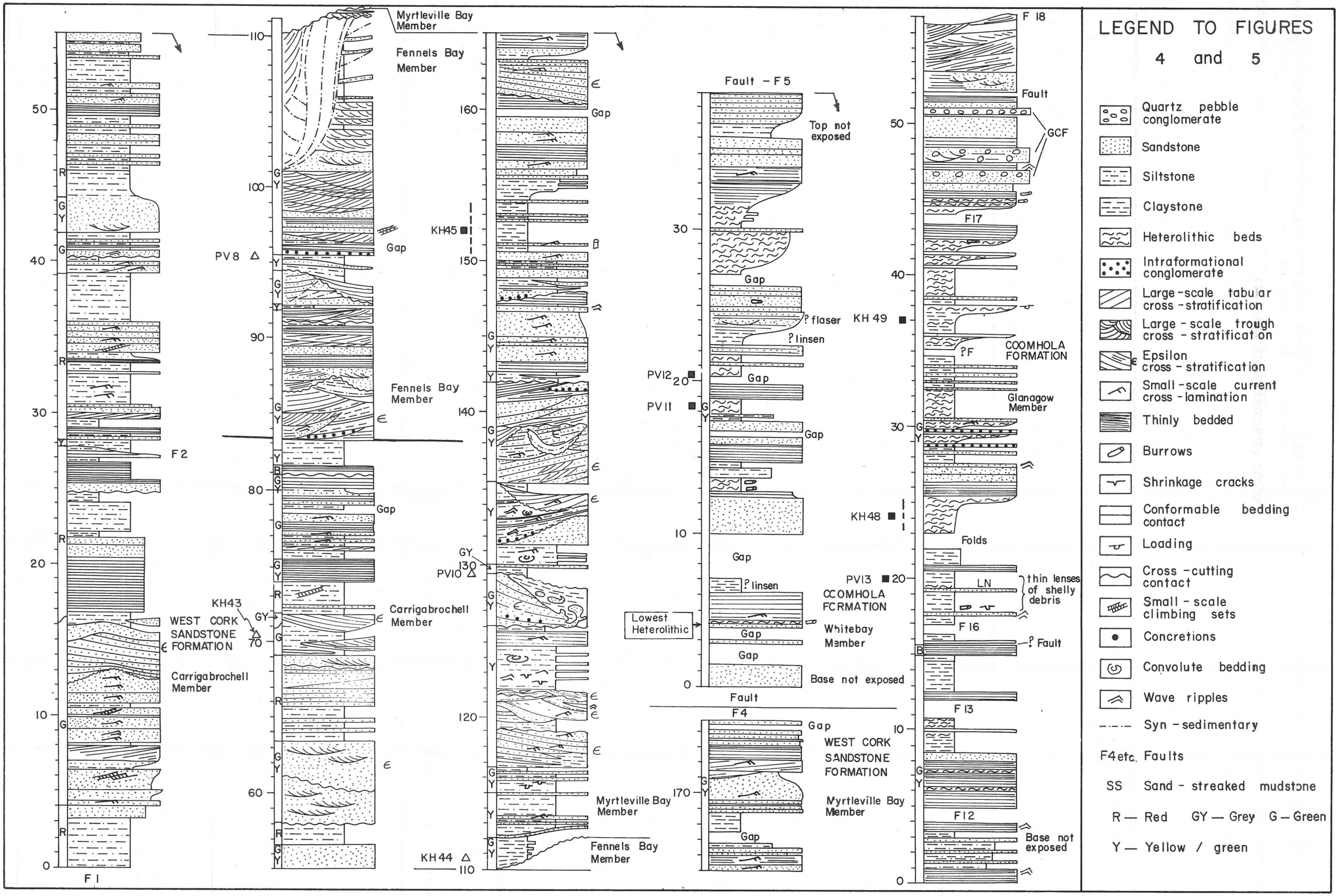

Fig. 4
Detailed stratigraphical log of the upper part of the West Cork Sandstone Fm. and Coomhola Fm. between Fennels Bay and S. Myrtleville strand.

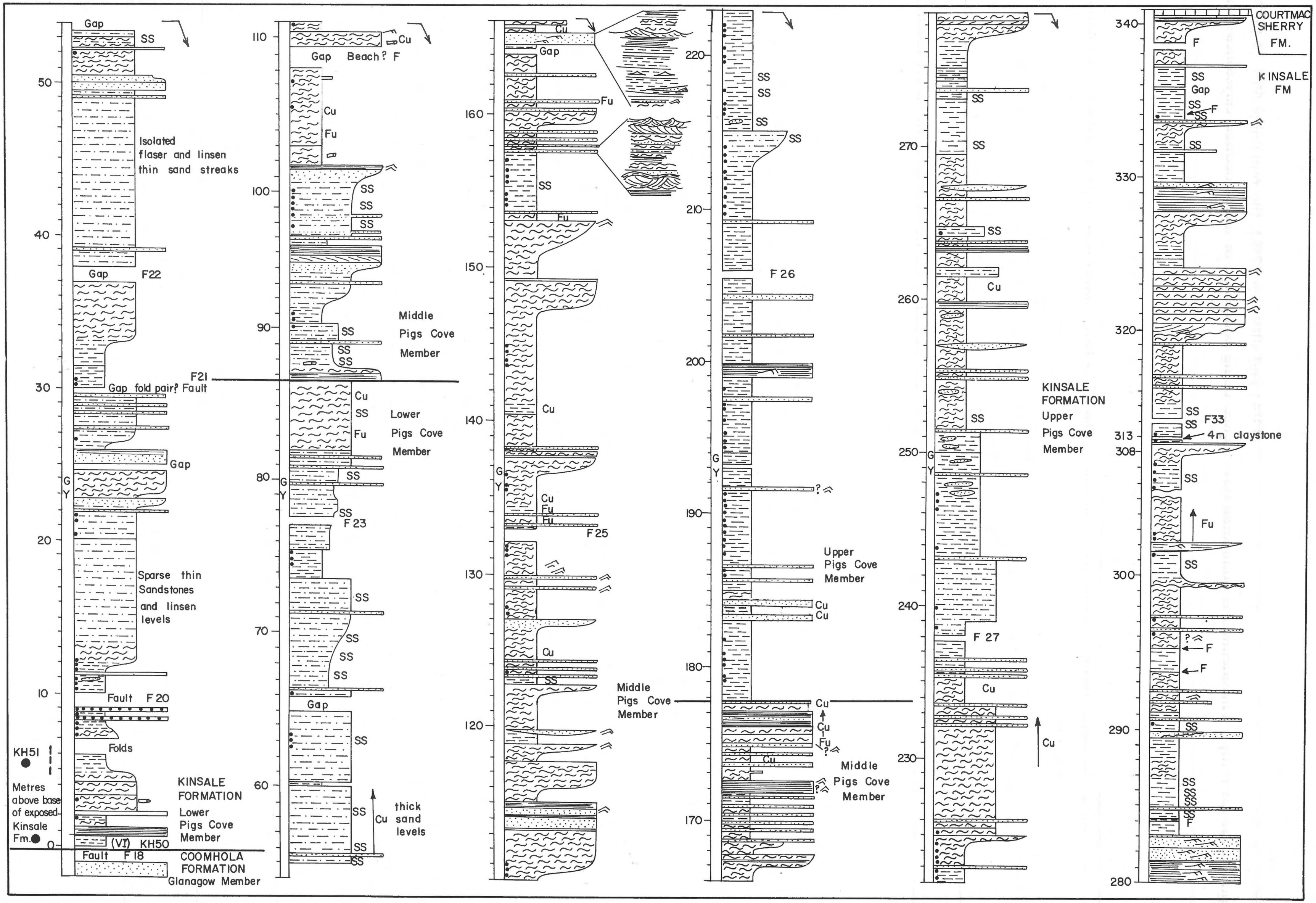

Fig. 5
Detailed stratigraphical log of the Kinsale Fm. at North Ringabella.

nounced in the upper part of the exposed member. Minor bioturbation is evident.

Glanagow Mbr. (57+ m) – This member is dominated (60-70%) by linsen-bedded or homogeneous claystones. The remainder of the sequence is composed of parallel-laminated, rippled and large-scale cross-stratified sandstones (Fig. 4).

The member shows an overall bulk coarsening-upward pattern with the upper 12 m essentially consisting of parallel-bedded or large-scale cross-stratified sandstones, within which are three pebbly sandstone levels with subrounded quartz pebbles (Garryvoe Conglomerate Facies of GARDINER & HORNE, 1976). In addition, eight minor coarsening-up units (0.5 to 4.5 m thick) occur within the middle part of the member. Thin lenses of shelly debris occur between the 18 m and 20 m levels. Wave ripples and burrowing occur sporadically.

Kinsale Fm. (340+ m)

This is delimited by the incoming of the first significant claystone unit in the sequence and the base of the first calcareous beds of the succeeding Courtmacsherry Fm. (NAYLOR, 1975; GARDINER & HORNE, 1976).

Due to earlier lack of uniformity in defining the base, two different levels have been selected in the past at North Ringabella (Fig. 2). We accept the positioning by SLEEMAN ET AL. (1978) and VAN GELDER & CLAYTON (1978), as the Glanagow Mbr. is lithologically heterogeneous with no significant claystone unit. Further, the LN/VI miospore zone boundary occurs approximately at the base of the Kinsale Fm. in south Co. Cork (CLAYTON ET AL., 1974). Only LN miospores have been obtained from the Glanagow Mbr. (Figs. 2, 4), which is therefore older than the base of the Kinsale Fm. (VAN GELDER & CLAYTON, 1978).

VAN GELDER AND CLAYTON (1978) and SLEEMAN ET AL. (1978) recognised three widespread members here in the Kinsale Fm.: the Castle Slate, Narrow Cove and Pigs Cove Members (Fig. 2). We feel that only part of the Castle Slate Mbr. and the Pigs Cove Mbr. are present, for reasons discussed after the lithological description.

Castle Slate Mbr. (10+ m) – This occurs as a fault-bounded unit located immediately to the north of F9 (Fig. 3). The member here consists exclusively of dark grey claystone with a maximum exposed thickness of 10 m.

Pigs Cove Mbr - lower part (approx. 87+ m) – This is an intensely faulted sequence with several minor northeastward plunging parasitic folds (Fig. 3). The succession is dominated by siltstone (65%). Other lithologies present are linsen units (17%), with minor amounts of sandstone (8%), flazer-bedded units (1%) and claystone (9%). Sandstones are spread evenly throughout the sequence. A number of fining and coarsening-up units occur at various levels (Fig. 5).

Pigs Cove Mbr. - middle part (approx. 91 m) – The succession consists of minor (14%) sandstones, flazer-bedded sandstones (13%) and siltstones (7%), the remaining 66% of the sequence being composed of linsen-bedded claystones or mudstones. These lithologies are arranged in a succession of coarsening-up units each of which is capped by a thin (<1.5 m) sandstone which may be flazer-bedded (Fig. 5). Wave-generated ripples are a prominent feature.

Pigs Cove Mbr. - upper part (approx. 162 m) – This part of the member is characterised by thick nodule-bearing claystone or linsen-bedded units (Fig. 5). Minor, sheet and lenticular sandstones are dispersed throughout with thicker brownish weathering sandstones occurring in the upper part of the unit. These contain wave- and current-ripple cross-lamination. Linsen-bedded claystones are mostly confined to the upper 60 m of the member. Coarsening-upwards units occur at 10 levels.

Member identification at North Ringabella

The tripartite subdivision of SLEEMAN ET AL. (1978) and VAN GELDER & CLAYTON (1978) appears comparable to that recognised in this study (Fig. 5), although the top of the Castle Slate Mbr. was drawn at the 74 m level (following NAYLOR, 1969). This lower part (between F18 and F23) is, however, significantly different from any other occurrence of the Castle Slate Mbr. in southern Ireland. It is markedly heterogeneous, is siltstone dominant and contains only 9% claystone in contrast to 90% claystone in the Castle Slate Mbr. The earlier lithological correlation therefore cannot be sustained and it is concluded that apart from its occurrence adjacent to F7, the Castle Slate Mbr. is faulted out.

The Narrow Cove Mbr., as traced from Old Head of Kinsale, has a marked sandstone content and may be locally sandstone dominant (SLEEMAN ET AL., 1978; VAN GELDER & CLAYTON, 1978). There is, however, no significant increase in sandstone until the 82 m level at North Ringabella (Fig. 5) and the sequence of thin sandstone and mudstones above this level is in strong contrast to the unit above the Castle Slate Mbr. between South Ringabella and Cork Harbour. This is a distinctive sandstone-dominant sequence (Cuskinny Mbr, MACCARTHY ET AL., 1978) which is also recognisable at South Ringabella (Roberts Cove Sandstone Fm. of NAYLOR, 1969). If the sequence at North Ringabella were part of the Narrow Cove Mbr., major lateral changes would have to be proposed (Fig. 6a). In the absence of any other data, a simpler alternative interpretation is that only the Pigs Cove Mbr. is represented here (Fig. 6b). In this context, facies in the Pigs Cove Mbr. were examined in adjacent sections. Unfortunately, the inferred Pigs Cove Mbr. at South Ringabella is largely inaccessible (NAYLOR, 1969) and details are not available. This study revealed that the member is divisible into three parts (Fig. 7), which match the exposed Kinsale Fm. at North Ringabella (Fig. 5).

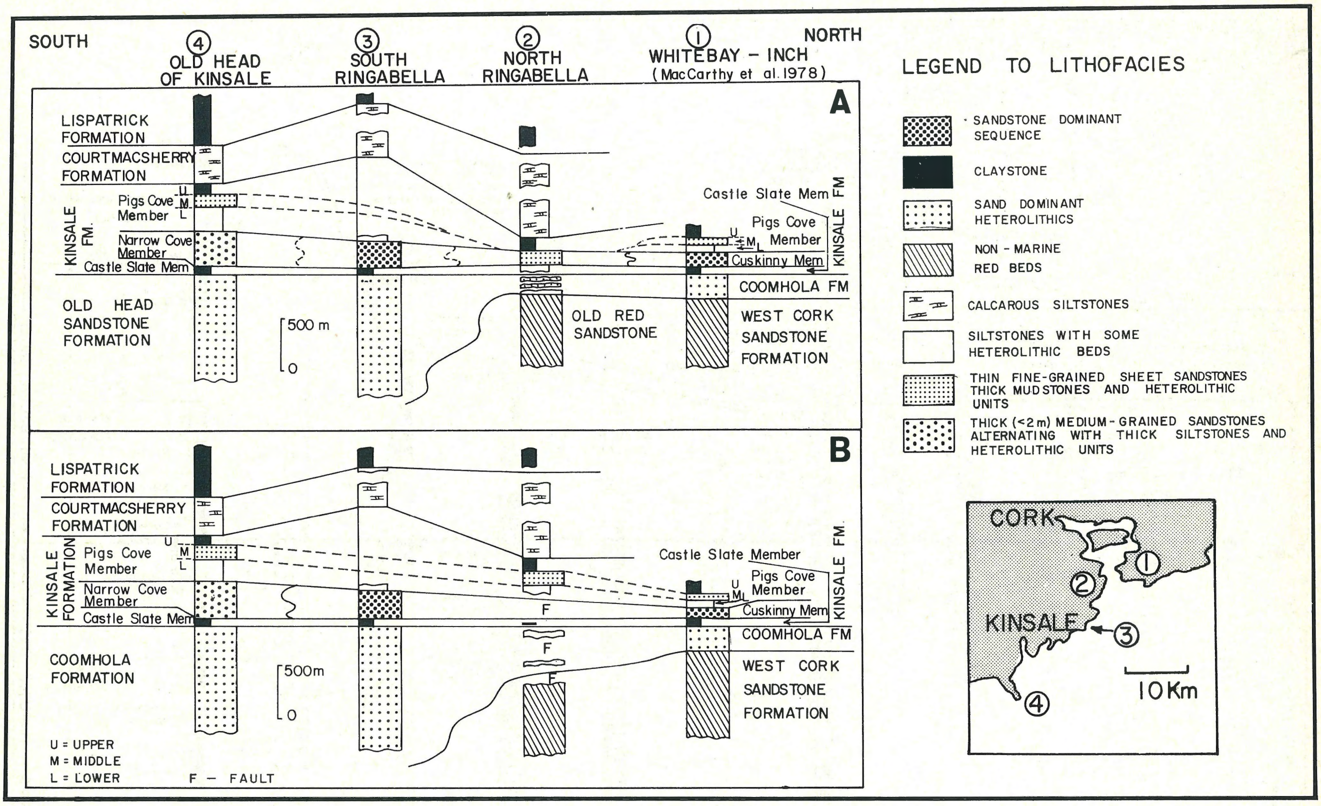

Fig. 6
Alternative lithological correlations of the Kinsale Fm. between North Ringabella and adjacent sections. Inaccessible part of South Ringabella sequence represented by straight line.
A: after Sleeman et al. (1978) and Van Gelder & Clayton (1978).
B: this study.

On this basis, it is considered that only the Pigs Cove Mbr. is exposed in the continuous sequence to the south of F18 at North Ringabella. The other two members are faulted out. This harmonises with the adjacent sequences (Fig. 6b) and also explains the anomalous thinning of the Kinsale Fm. arising from previous correlations (Fig. 6a).

BIOSTRATIGRAPHY

Macrofossil occurrences are sparse in the Devonian-Carboniferous succession in this region. Conodonts have been recorded from a few localities, largely from the Courtmacsherry Fm.; records of these and goniatites from the North Ringabella sequence are summarised in GEORGE ET AL. (1976).

Miospores, however, provide a valuable correlation tool in the non-carbonate sequences overlying the redbeds. CLAYTON ET AL. (1974) obtained assemblages from several levels in this sequence and related them to a miospore zonation spanning the Devonian-Carboniferous boundary. They recognised the PL, NV and PC Zones, with the NV Zone divided into the LN and VI Subzones. The Devonian-Carboniferous boundary occurs approximately at the LN/VI Subzone boundary, which is mid-Tn1b in terms of the Belgian succession (VAN GELDER & CLAYTON, 1978). Their sampled levels are indicated in Figs. 2, 4 and 5, based on ground collection map data supplied by Dr. K. Higgs (pers. comm).

The PL zone was subsequently divided by KEEGAN (1977) into the LL and LE Subzones, the base of the LE Subzone being distinguished by the presence of *H. explanatus*. This is not present in the PL Zone assemblages described by CLAYTON ET AL. (1974) from North Ringabella, but their samples were widely spaced, with a 40 m gap in which the LE Subzone could be present (Fig. 4).

In view of the large stratigraphical gaps between the known assemblage levels described by CLAYTON ET AL. (1974) and the possibility of error in stratigraphical positioning because of the unrecognised structural complexity, parts of the succession were resampled. The miospore assemblages were determined by Drs. P. Van Veen (pers. comm.), the sample positions and zonal allocations being given in Figs. 2, 4 and 5. These results confirm and amplify the work of CLAYTON ET AL. (1974). The LE Subzone was not recognised, but the gap in which it could be present has been reduced to 21 m. The previously palaeontologically unknown fault-bounded Whitebay Mbr. yielded two LN Subzone miospore assemblages.

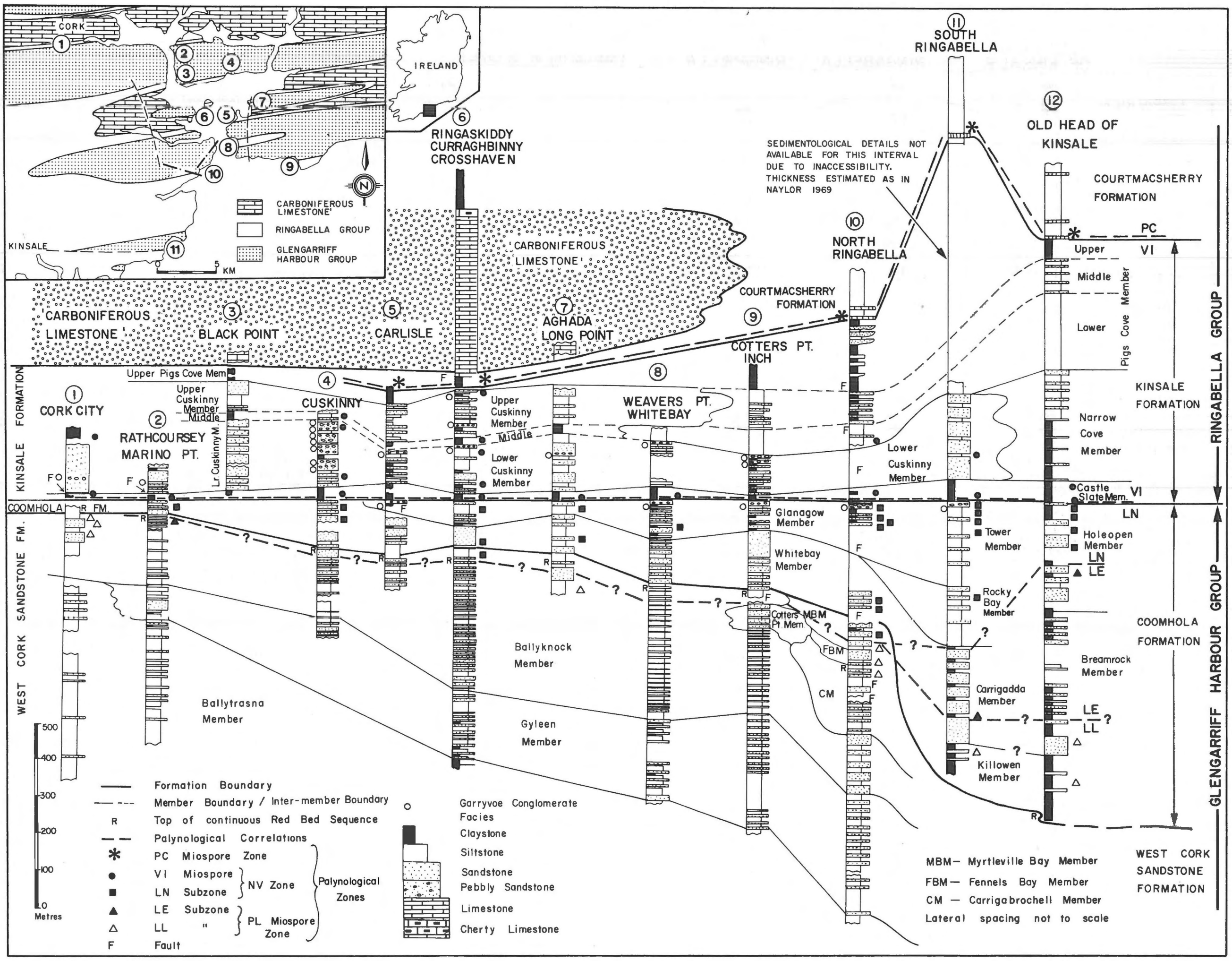

Fig. 7
Lithostratigraphical and palynological correlations between North Ringabella and selected adjacent sequences. Lithological data for sections 1-9 from MacCarthy et al., 1978; 11-12 from Naylor, 1969. Palynological data from Clayton et al., 1974; Keegan, 1977; Sleeman et al., 1978; Van Gelder & Clayton, 1978; Van der Zwan & Van Veen, 1978; Van Veen (unpublished). Data for Aghada/Long Point section from K. Higgs (pers. comm.)

LATERAL CORRELATIONS AND STRATIGRAPHICAL CONCLUSIONS

In order to assess the lateral variations and significance of the north-south facies changes, adjacent sequences were taken for correlation purposes (Fig. 7). The following features are significant.

Firstly, the exposed part of the West Cork Sandstone Fm. at North Ringabella continues the progressive southerly thickening as recognised in MACCARTHY ET AL. (1978). The Myrtleville and Fennels Bay Mbrs. are of comparable facies to the Cotters Points Mbr. to the east, so that there is a major facies change at this level between North Ringabella and the sequences to the north (Fig. 7).

Secondly, the position of the LL/LE Subzone boundary indicates that only the lowest part of the marine Coomhola Fm. at South Ringabella may be time equivalent to the North Ringabella red-bed sequences. The contention by NAYLOR (1969) that some 870 m of marinc scdimcnts at South Ringabella are equivalent to red-bed sequences at North Ringabella cannot be supported.

Thirdly, that there was a striking differential net accumulation of sediment during the LE Subzone period. While thick deposits (probably 400+ m) accumulated at the Old Head of Kinsale, the subzone is either not preserved at North Ringabella or at most consists of 21 m of the sequence.

Fourthly, that the Coomhola Fm. at North Ringabella is considerably thicker than indicated by data presented in NAYLOR (1969). It is probably over 200 m thick and is time equivalent to the upper half of the formation at South Ringabella.

Fifthly, that the Kinsale Fm. at North Ringabella is only

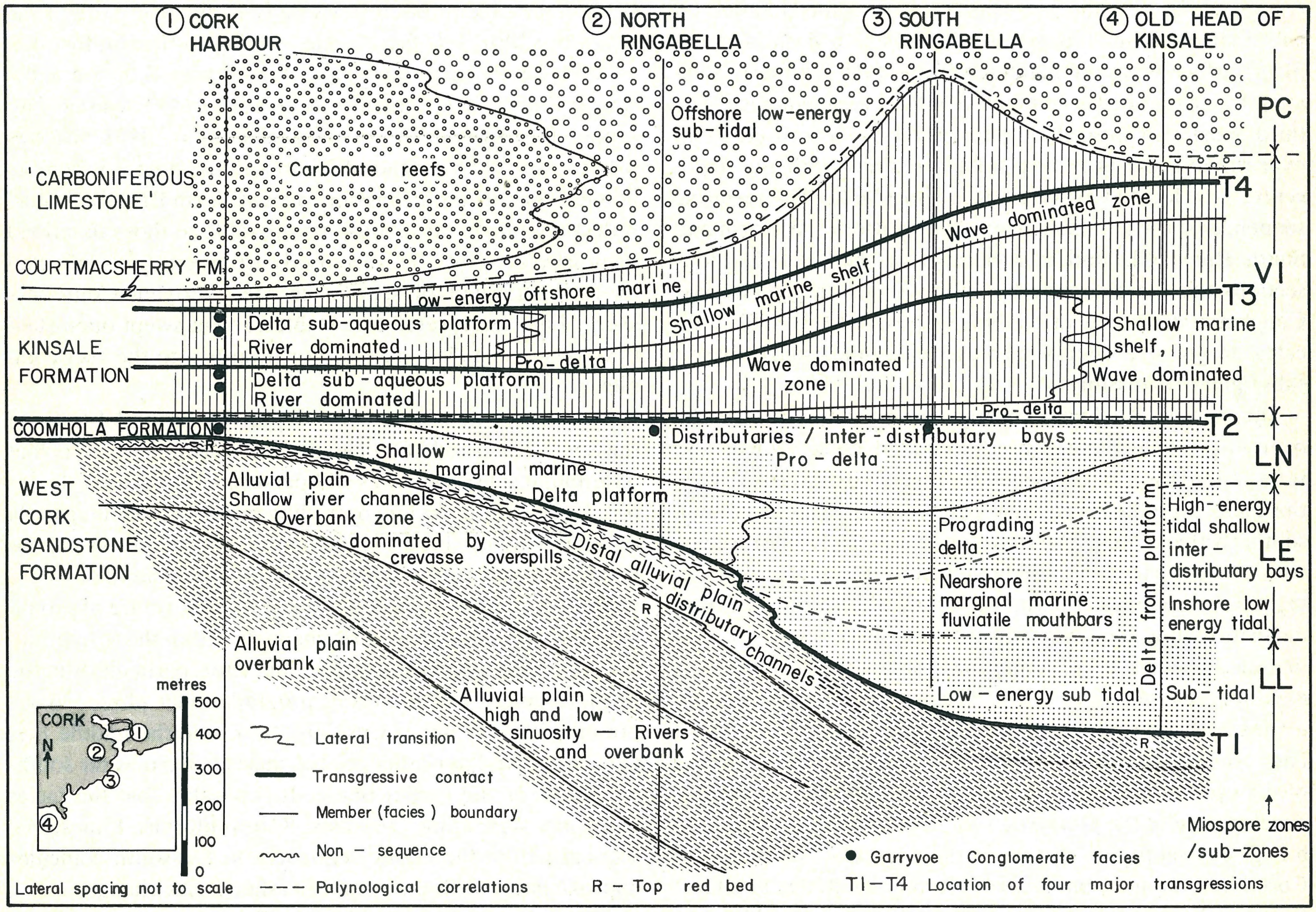

Fig. 8
Generalised correlations of inferred depositional environments between Cork Harbour and the Old Head of Kinsale in Late Devonian-Early Carboniferous times. Time planes dashed. Transgressions shown by heavy lines.

represented by the Pigs Cove Mbr. and the thin fault-bounded Castle Slate Mbr. The tripartite subdivision of the Pigs Cove Mbr. can be traced into adjacent sections and shows a northward lateral transition into the upper part of the Cuskinny Mbr. of MACCARTHY ET AL. (1978). On a comparative basis, the thickness of the Kinsale Fm. at South Ringabella (NAYLOR, 1969) appears anomalous; it may well be an overestimate.

REGIONAL PALAEOGEOGRAPHICAL INTERPRETATIONS

Previous studies in this area have interpreted the Upper Devonian - Lower Carboniferous facies changes either as reflecting a relatively uniform Late Devonian major marine transgression (e.g. NAYLOR ET AL., 1974) or containing abrupt changes in depositional patterns (MACCARTHY ET AL., 1971; GARDINER, 1975). The present revision of the North Ringabella sequence, integrated with other recent studies, provides further information on this problem.

The model shown in figure 8 summarises the interpretation presented in this study. The local environmental suggestions are based on the work of NAYLOR (1966; 1969), NAYLOR ET AL. (1974), VAN GELDER (1974), KUIJPERS (1972), DE RAAF ET AL. (1977) and MACCARTHY ET AL. (1978). The most significant features of this model are the recognition of four important transgressive/regressive cycles, overprinted on a pattern of progressively reducing differential subsidence between Cork Harbour and the Old Head of Kinsale.

The transgressive phase of the first cycle (T1 in Fig. 8) is marked by the base of the Coomhola Fm. However, the southward thickening of members within the underlying West Cork Sandstone Fm. suggests that differential subsidence may have been initiated before deposition of the Coomhola Fm. and may have controlled sedimentation patterns in most of the red-bed sequences (GARDINER ET AL., in prep.). This transgression was three phased. Initially, (LL Subzone) low-energy subtidal conditions established at South Ringabella (VAN GELDER, 1974) and the Old Head of Kinsale (KUIJPERS, 1972) passed northwards into a distal alluvial plain at North Ringabella. Subsequently (LE Subzone), there was net accumulation at the Old Head of Kinsale, with a progressive increase in the energy gradient, while between North Ringabella and Cork City there was, in contrast, a relative stable distal alluvial-plain surface with abundant reworking (and southerly sediment transport) with a condensed or local non-sequence. The third phase (LN Subzone) initiated the major transgression, over-running the northerly stable area and with the depocentre now located around South Ringabella. The resulting sequences show a bulk coarsening-up pattern. At North and South Ringabella and in a number of the Cork Harbour sections these are capped by pebbly sandstones (Garryvoe Conglomerate Facies of GARDINER & HORNE, 1976). This indicates progressive energy increase with time, suggestive of subsequent regression.

The abrupt lithological change to the claystones of the overlying Castle Slate Mbr. terminated delta growth and reflects initiation of the second transgressive cycle (T2). In this cycle, both the transgressive and regressive phases show a southerly thickening. The widespread, relatively synchronous basal contrast is here thought to result from a sudden deepening of the depositional basin, the Castle Slate Mbr. reflecting deposition in a deep-water (prodelta) environment (cf. VAN GELDER & CLAYTON, 1978) rather than the shallow-water setting envisaged by GRAHAM (1975). The upper part shows some evidence of shallower conditions (VAN GELDER & CLAYTON, 1978) and is overlain by the coarser shallow-marine regressive part of the cycle (Cuskinny and Narrow Cove Mbrs.). A further development of the Garryvoe Conglomerate Facies occurs as a bulk coarsening-up feature in this regressive phase in the Cork Harbour area, but is absent further south due to lateral fining and seabed deepening, although at the Old Head of Kinsale there is a good coarsening-up sequence capped with sandstones (NAYLOR, 1966) (Fig. 6).

The fine-grained middle Cuskinny Mbr. and lower Pigs Cove Mbr. (Fig. 7) are interpreted as another widespread prodelta sequence arising from the third marine transgression (T3). The contact is abrupt at the Old Head of Kinsale (NAYLOR, 1966), This cycle is sedimentologically similar to the underlying one and shows a similar lateral thickness variation. There is also a reduction of coarse clastic material in the regressive phase, although the Garryvoe Conglomerate Facies is still locally developed in the Cork Harbour area (Fig. 7). At the Old Head of Kinsale the cycle is taken as ending at the top of the middle sand-dominant unit of the 'Coosduff Fm.' of NAYLOR (1966), within which onlap-offlap cycles have been recognised (DE RAAF, 1970). The upward coarsening from the middle Cuskinny to the top of the upper Cuskinny Mbr. is essentially a recurrence of the earlier pattern of transgression followed by regression. These recurring CU patterns are comparable to those generated in several modern and ancient deltas (COLEMAN, 1976; GOULD, 1970; ELLIOTT, 1978). The Narrow Cove Mbr. and much of the Pigs Cove Mbr. in the southwestern sections accumulated in a shallow marine shelf on which wave activity was pronounced (DE RAAF ET AL., 1977). The alternation of delta progradation and transgressive events in the northern sections is reflected in vertical and lateral facies distribution in laterally equivalent parts of the Pigs Cove Mbr. (cf. Figs. 7 and 8) lying to the southwest.

A further marine incursion (T4) is indicated by the widespread fine-grained sequence at the top of the Kinsale Fm. (upper Pigs Cove Mbr. of MACCARTHY ET AL., 1978 and this paper). At the Old Head of Kinsale the sequence is coarser grained and the coarsening-up cycles at North Ringabella may reflect migrating bar features comparable to those described by DE RAAF ET AL. (1977). Increased current energy is reflected by cross-stratified biosparites in the overlying Courtmacsherry Fm., interpreted as a stable current-swept open shelf (NAYLOR ET AL., 1974), passing northwards into the reef complex.

The thickening of sediments deposited during VI times in the South Ringabella/Old Head of Kinsale area suggests that differential subsidence was still persistent in this area. It was not, however, the major controlling factor in modelling delta development as there are no marked thickness variations within this unit to the north of Ringabella. The deltas were probably river-dominated, in view of the occurrence of prominent thin CU units capped by channels within the formation, but wave influence was an important factor, particularly in the offshore zone. The following progradational phase, as represented by the upper Cuskinny Mbr. and the middle Pigs Cove Mbr., did not influence the facies pattern as far southwestwards as the earlier phase. It is notable that the facies boundary separating the thick 'Carboniferous Limestone' sequence from the clastic sequences to the south coincides approximately with the zone of earlier facies changes.

All four cycles occur within the first major eustatic cycle recognised by RAMSBOTTOM (1973) in the British Dinantian, with the reef development assigned to the regressive phase. In view of the evidence for tectonic control of sedimentation in this area (MACCARTHY ET AL., 1971; GARDINER, 1975), it seems unlikely that eustatic changes were the sole cause. The second cycle (T2) was clearly the most important, the first cycle being largely the effect of localised differential subsidence (see also GARDINER, 1975). It may well be that T2 marks the base of the first major eustatic cycle in this area, rather than T1 as has been presupposed in the past. Certainly the major transgression initiated in the Late Devonian was far from uniform. A further understanding will be enhanced by the tracing of fine-grained transgressive units as well as diagnostic pebbly regressive facies as recognised by MACCARTHY ET AL. (1971).

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