GEOLOGIE EN MIJNBOUW© VOLUME 57 (1), p. 25-32 1978

NEW DATA ON EARLY DINANTIAN (EARLY CARBONIFEROUS) STRATIGRAPHY AND SEDIMENTATION IN SOUTH CORK, IRELAND[1]

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Van Gelder, A. & G. Clayton (1978). New data on Early Dinantian (Early Carboniferous) stratigraphy and sedimentation in south Cork, Ireland. Geol. Mijnbouw, 57, p. 25-32.

The sedimentology and stratigraphy of the Dinantian (Lower Carboniferous) Kinsale Formation are described from ten major coastal sections in south Cork, Republic of Ireland. Palynological correlations between the sections are outlined, and subdivision of the Kinsale Formation into three members is proposed. Members 1 and 3 are dominated by mudrocks, and are separated by the more sandy member 2. Sediments assigned to member 1 were deposited in a deep-water, marine environment below wave base, whereas members 2 and 3 were deposited on a shallow marine, muddy platform, where sandy shoals built up. The latter are especially well developed in member 2.

INTRODUCTION

During the summers of 1973 and 1974 the authors carried out a sedimentological and palynological study of Lower Carboniferous (Lower Dinantian) strata in coastal exposures between Seven Heads Peninsula and Cork Harbour. The present paper deals mainly with the lowermost part of the Dinantian sequence, namely the Kinsale Formation (NAYLOR ET AL., 1974), which consists entirely of fine terrigenous clastics, deposited in a shallow marine, wavedominated environment. The Kinsale Formation in the studied area ranges in thickness from 700 to 1400 m. Its sedimentological interest derives mainly from the remarkable sediment-structural and sequential characteristics of the sandy successions in the lower part of the formation. In this paper the general stratigraphical and sedimentological aspects of the Kinsale Formation, and some characteristics of the overlying formations will be described. The higher formations have not been studied in detail; they have been added to the columns of Fig. 2 only for the sake of completeness.

Detailed sedimentological information on selected sections from the Kinsale Formation has been presented by DE RAAF ET AL. (1977). The present work is a sequel to previous sedimentological and palynological investigations (KUIJPERS, 1971, 1972; LEFLEF, 1973 a,b; VAN GELDER, 1974; CLAYTON ET AL., 1974) of the underlying Upper Devonian complex, which is characterized by a (partly lateral) facies change from fluvial, continental (Old Red) to tidally influenced, shallow marine deposits (Old Head Sandstone Formation: NAYLOR, 1966).

LITHOSTRATIGRAPHY

In order not to add to the already existing multiplicity of names, Naylor's comprehensive system of lithostratigraphic nomenclature for South Cork (NAYLOR ET AL., 1974, p. 78) is followed. His formation and member names are generally used but are occasionally supplemented or changed as a result of our more recent data.

The tectonic framework of the area (Fig. 1) is fundamentally that outlined by NAYLOR (thesis 1964; 1966, 1969). The only major modification concerns the sections between Flat Head and Coolmain Bay, where on palynological evidence sandy rocks (e.g. those exposed at the entrance of Kinsale

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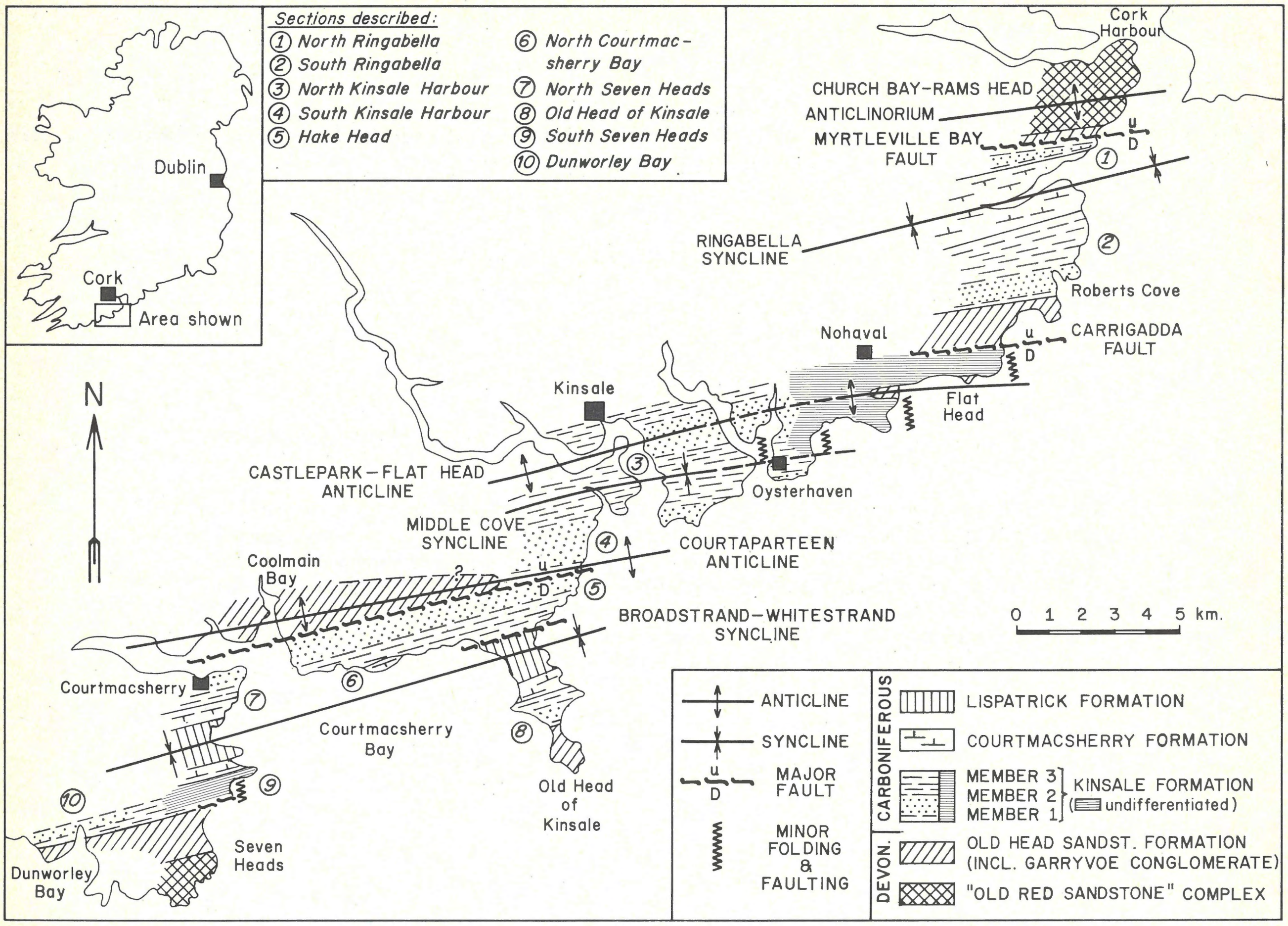

Fig. 1
Outline geology of investigated area, South Cork. Data partly from NAYLOR (1969) and NAYLOR ET AL. (1969).

Harbour and in the Oysterhaven estuary) are correlated with the Kinsale Formation instead of with the Old Head Sandstone Formation as suggested by NAYLOR (1969, Fig. 3).

Upper and lower boundaries of the Kinsale Formation

In the South Cork area the Kinsale Formation comprises a thick succession of predominantly muddy, non-calcareous strata overlying NAYLOR's (1969) Quartz Conglomerate Formation, which approximately equates with the Garryvoe Conglomerate Formation of MACCARTHY ET AL. (1971). The Kinsale Formation (see Figs. 1, 2) is succeeded conformably by the Courtmacsherry Formation, the base of which is defined by the appearance of calcareous mudstones (NAYLOR ET AL., 1974).

Following MATTHEWS & NAYLOR (1973), the base of the Courtmacsherry Formation in both Ringabella sections has been drawn at the base of the lowermost recognizable calcareous beds in the section, so that the formation begins with slightly calcareous, laminated mudstones containing occasional limestone lenses. In the upper part of the Courtmacsherry Formation crinoidal, calcarenitic beds and lenses up to a few dms thick are frequently intercalated.

The definition of the base of the Kinsale Formation adopted by the present authors differs in one major respect from Naylor's definition (NAYLOR, 1964; NAYLOR ET AL., 1974), in that we consider that the mud-dominant sediments underlying the Quartz Conglomerate, such as the 'Ballinluska Formation' and 'Tower Formation' (NAYLOR, 1969; p. 314, 318) should not be considered time-equivalent to the Kinsale Formation, based on the palynological dating of these units (CLAYTON ET AL., 1974).

Subdivision of the Kinsale Formation

The Kinsale Formation can be subdivided into three units which can be recognized in most of the sections investigated (see Fig. 2). Seventy kilometres to the west, in Dunmanus Bay, NAYLOR (1975) established an almost identical threefold subdivision. Similarly in the Toe Head-Galley Head area, GRAHAM (1975) was able to differentiate between three members.

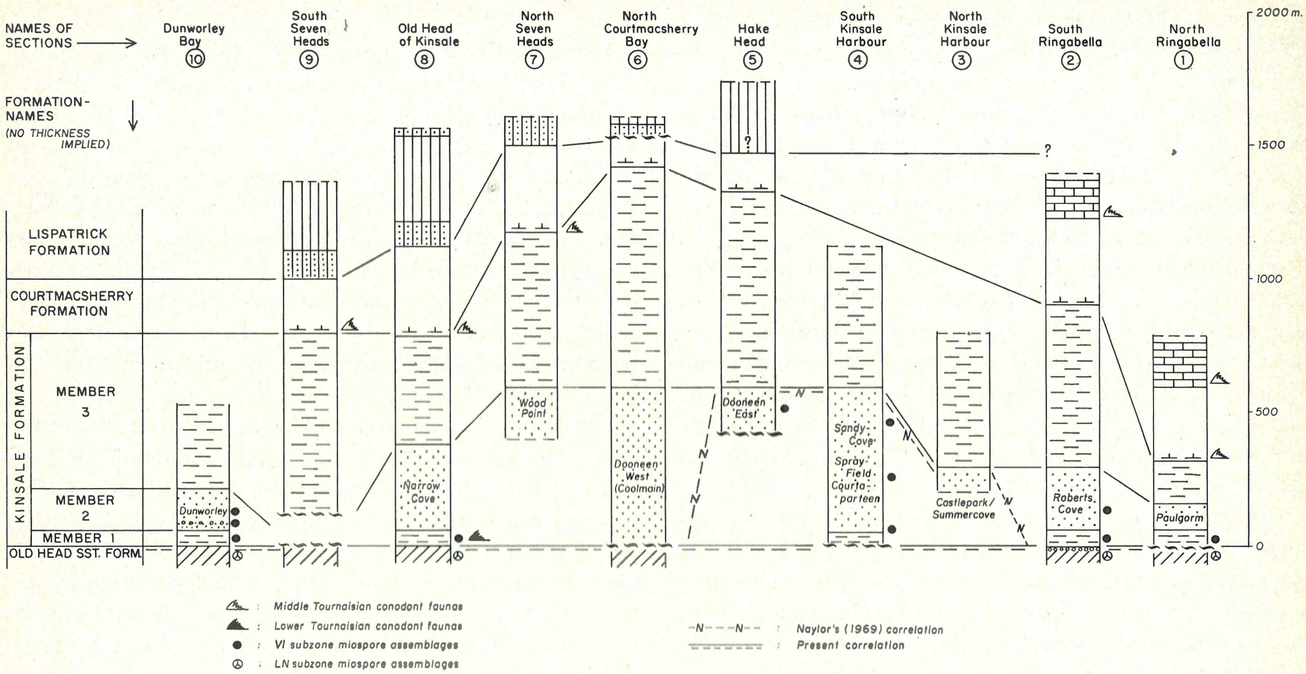

Fig. 2
Lithological and biostratigraphic correlations of coastal sections, South Cork. Conodont stratigraphy in sections 1, 2, and 8 according to MATTHEWS & NAYLOR (1973); in sections 7, and 9: G. D. SEVASTOPULO (unpublished). Only selected miospore samples are indicated. Thicknesses calculated from dip-measurements. For location of sections see Fig. 1.

Since palynological correlation between these sections has not revealed any diachronism, the present authors have adopted the same basic subdivision.

Member 1 overlies the Old Head Sandstone Formation and is strikingly mud-dominant, almost to the total exclusion of sand. It is identical to NAYLOR's (1966) Castle Slate Formation.

Member 2 (NAYLOR's (1966) Narrow Cove Formation) differs from members 1 and 3 by the much higher sandstone content, which locally even becomes dominant. Its lower boundary is gradational, but it is followed rather abruptly by member 3.

Member 3 (NAYLOR's (1966) Pigs Cove and Coosduff Formations) is again mud-dominant, though less so than member 1. Lenticular bedded, flaser bedded and evenly bedded sandy intercalations may make up considerable intervals; towards the top of some sections to the extent that the definition of a fourth sandy member could be possible.

The three members distinguished above encompass numerous local 'formations' and 'members', defined by NAYLOR (1964, 1966, 1969). Recent palaeontological work (MATTHEWS & NAYLOR, 1973; CLAYTON ET AL., 1974) has provided a basis for correlation of the different sections, thus permitting rationalisation of the lithostratigraphic nomenclature. Subdivision of the VI Miospore Subzone has so far not been achieved, thus rendering palynological correlation of the constituent members of the Kinsale Formation impossible. The boundaries between the three members in stratigraphical columns may therefore be somewhat diachronous. Lateral changes of lithofacies and thickness of members are probably not only related to differential subsidence but also to primary indentation of the facies belts along the early Carboniferous coastline.

The lower boundary of member 3 in the Dunworley section is very gradational and has therefore arbitrarily been drawn at the level where the formation becomes mud-dominant (> 50% overall mudcontent). The same applies to the North Ringabella section. NAYLOR (1964, 1969) did not recognize a separate sandy subdivision here and grouped members 2 and 3 of the present authors together as the 'Paulgorm Formation'.

Approximately 100 m. above the base of Naylor's Paulgorm Formation a change of lithofacies occurs which can probably be correlated with the boundary between members 2 and 3 in the other sections in the area. Below this level several small coarsening upwards sequences and sharp based, even-laminated sandstones occur, alternating with relatively pure, silt-streaked muds. Above this level, in member 3, the lithology is more monotonous, consisting of sand-streaked muds and linsen beds which are only rarely interrupted by evenly-laminated sandstones a few centimetres in thickness.

Towards its top member 3 becomes slightly more sandy with some thicker even- laminated sandstones (up to a few dm.). The latter have been interpreted as representing the products of rough weather (storm) conditions (see also DE RAAF ET AL., 1977).

Member 1 – This member is synonymous with NAYLOR's (1966, 1969) Castle Slate, Nohaval Mudstone and Myrtleville Formations, and is of rather uniform thickness, varying from 75 m. in the North Ringabella section to approximately 50 m. in Dunworley Bay. In many sections member 1 is absent due to faulting, caused partially by the strong lithological contrast between member 1 of the Kinsale Formation and the underlying Old Head Sandstone Formation.

Member 1 is entirely mud-dominant. Thin silt or very fine sand laminae, often graded, may be present but never form an important constituent. Decalcified crinoid ossicles are encountered, especially in the basal part of the member, immediately overlying the Old Head Sandstone Formation. Lens-shaped siliceous and silico-phosphatic nodules are common throughout member 1 (NAYLOR, 1966), though not lacking in the other members.

The strong predominance of mud and the paucity of wave-ripple cross-lamination in member 1 suggest deposition in fairly deep water below average wave base. Even lamination and slight positive grading in the silt/fine sand laminae indicate that deposition was mainly from suspension, probably from turbulent clouds whirled up during storms.

Towards the top of member 1 the number and thickness of silt/sand intercalations increases as does the amount of wave-ripple cross-lamination. There is a completely gradational transition to member 2, the base of which is defined as the first sand-dominant (> 50%) flaser/linsen bed.

Lateral lithologic variability in member 1 is generally slight. In North Ringabella (Myrtleville) however, member 1 appears to contain more small lenticular silt/sandstone beds than elsewhere, though intense tectonic deformation makes it difficult to ascertain whether this is a primary depositional or a secondary diagenetic feature.

Member 2 – The sedimentological details of the South Kinsale Harbour section have been dealt with extensively by DE RAAF ET AL. (1977). The most conspicuous features are summarised below.

On the basis of sedimentary structures and sand/mud ratio a great variety of rocktypes can be recognized, ranging from parallel-laminated silt/sandstreaked muds via cross-laminated linsen and flaser beds to cross-laminated/bedded or even-bedded sandstones. The primary structures are almost invariably wave generated. Structural bimodality of the type indicative of wave action (i.e. different foreset directions within one coset) occurs commonly. 'Herringbone' structures (continuously opposing foresets) are rare, as are unimodal current structures. Currents, if present at all, were of a very ephemeral character and mostly derived from wave action.

Although the other sections have not been investigated in such detail as the South Kinsale Harbour section, a general predominance of wave-deposited rocktypes seems to be characteristic of the entire Kinsale Formation. This is in strong contrast to the underlying Old Head Sandstone Formation in which tidal deposits appear to play an important role (KUIJPERS, 1972).

The sand-rich rocks of member 2 of the Kinsale Formation are sometimes arranged in coarsening upwards (CU) sequences of several metres thickness, but mostly they do not form a predictable sequential order. In rare cases, fining upwards (FU) sequences have been encountered (e.g. Sandy Cove). Deep scouring channels are notably absent, as are any structures pointing to strong current erosion. On the other hand evenly laminated sandstones indicating high-energy wave-activity occur frequently. They may form either the top of a CU sequence or the central part of a CUFU (i.e. a more or less symmetrical sequence: coarsening upwards immediately followed by fining upwards).

The depositional environment has been envisaged (DE RAAF ET AL., 1977) as a shallow, gently sloping submarine platform with longshore directed shoals building up to different heights (emergent or submerged) and structural content, depending on the energy level of the wave processes and availability of sand. The general coastline trend, as deduced from ripple-crest directions, must have been NE-SW with the open sea lying to the (present) SE. This is in reasonable accordance with the Tournaisian palaeogeography outlined by NAYLOR ET AL. (1974). The NE-SW trend suggests that the westwards lying 'Glandore High' (NAYLOR ET AL., 1974) existed in early Tournaisian times.

Lateral variation within member 2 – Member 2 of the Kinsale Formation shows a considerable thickness variation, ranging from 100 to 150 metres in the extreme NE (North Ringabella) and SW (Dunworley Bay) to almost 600 metres in the central area (North Courtmacsherry Bay, South Kinsale Harbour).

In North Ringabella (Paulgorm) the fact that member 2 is very thin, containing only a few thick sandstones seems to point to a marginal position in the basin, relatively remote from the main source of sand supply. The even lamination and wave ripples in the rare thick sandstones nevertheless indicate deposition at shallow depths.

In South Ringabella member 2 (Naylor's Roberts Cove Sandstone Formation) forms a transition into the Kinsale Harbour equivalents in many respects. Sand-sized material is present in such quantities that it is locally dominant. The rocks are generally arranged in sequences of CU/FU and random character: in the former case a central portion of sandstone sandwiched between flaser and linsen beds can be distinguished. Beds are often intensely burrowed, indicating a relatively slow rate of deposition.

The North and South Kinsale Harbour sections as well as the Hake Head section are similar in lithological and sequential character. They have an approximately equal overall sand/mud ratio with thick intervals of mud-dominant rocks alternating with sandy intervals. The latter may occur as random intercalations, as CU/FU, or as CU sequences. In the uppermost part of the South Kinsale Harbour section a FU sequence has been observed. Detailed logs covering a large part of the South Kinsale Harbour section have been described by DE RAAF ET AL. (1977).

The North Courtmacsherry Bay (Coolmain Bay) area, situated further west, shows a similar pattern. The most notable differences are the presence of coarser-grained material (up to medium sand) especially in the middle part, and conspicuous bioturbation. Locally the size and shape of burrow tubes is remarkable. Strongly winding trails several centimetres in diameter and decimetres long have been observed on bedding planes in the middle part of member 2. The lower part of member 2 in the North Courtmacsherry Bay area (Coolmain Bay) is made up of relatively small CU/FU sequences, whilst in the upper part they are generally of larger size with a more pronounced CU tendency.

On North Seven Heads (Wood Point) only the uppermost part of member 2 is exposed. The junction with the overlying member 3 is very abrupt and probably faulted. Despite its proximity to the North Courtmacsherry Bay section, along the strike no clear correlations can be made. CU-, FU and CU/FU tendencies (at m-scale) as well as random intercalations are present in this area.

In the South Seven Heads section no strikingly sandy intervals have been observed. Intensive small-scale folding and faulting occurs near the junction of the Kinsale and Old Head Sandstone Formations. It has therefore been assumed that both member 1 and member 2 have been faulted out (see Fig. 2), though in addition to the tectonic complications the situation is difficult to assess on account of the inaccessibility of the high cliffs along this part of the coast.

In Dunworley Bay there is, unlike in most other sections, a very gradual transition from member 2 to member 3. The boundary has been drawn arbitrarily at the level where the formation becomes mud-dominant. CU sequences as well as CU/FU's and random intercalations are present in member 2. Most of the structures in the sandstones are of the wave cross-laminated/even-laminated type, indicating either deposition on shoals or as storm sands deeper in the basin (see DE RAAF ET AL., 1977). Current formed cross-lamination indicating supply from westerly or north-westerly directions occurs more commonly in Dunworley Bay than in other sections.

Some 40 metres above the base of member 2, which is drawn where the lowermost CU becomes sand-dominant, there are some thin, laterally wedging-out lenses of clay pebbles of apparently local origin embedded in a matrix of coarse sand (around 1 mm). The uppermost of these lenses contains well rounded quartz pebbles exceeding the 2 mm. grade. MAC CARTHY ET AL. (1971) assigned these beds to their "Garryvoe Conglomerate Formation". Palynological data however indicate a position within the VI Subzone (see Fig. 3) and substantially younger therefore than the LN/VI Subzone boundary immediately below which this "formation" usually occurs. We consider therefore that these levels are local lithological variants of member 2, especially since relatively large grain-sizes are also present in the nearby sections of North Courtmacsherry (Coolmain) Bay and the Old Head of Kinsale, within member 2.

On the Old Head of Kinsale (at Narrow Cove) a four metres thick, evenly laminated and low-angle cross-bedded sandstone, randomly intercalated in the middle part of member 2 shows coarse sand grades as well as unusually large amounts of mud flakes and ferruginous matrix (see also DE RAAF ET AL., 1977). Apart from this strikingly coarse and poorly sorted sandstone there are notably fewer thick sandstone sequences in member 2 on the Old Head of Kinsale than in the more northerly sections such as Courtmacsherry Bay and Kinsale Harbour. Sequential regularity is hardly evident in the main part of the Narrow Cove section. Only the middle part of member 2 shows some coarsening upwards tendencies. The wave cross-laminated and evenly-laminated sandy beds in the upper part of member 2 are mostly intercalated at random in the mudstone facies.

BIOSTRATIGRAPHY

Very few macrofossils have been recorded from the Old Head Sandstone Formation or Kinsale Formation in the area investigated, but miospores occur abundantly at many levels, and have been used effectively for correlation purposes. The relevant section of the Dinantian miospore zonation, modified from work by NEVES ET AL. (1972) and CLAYTON ET AL. (1974) is summarized in Fig. 3. Conodonts have been described from several localities, mainly in the Courtmacsherry Formation (MATTHEWS & NAYLOR, 1973).

Within the area investigated the formation boundaries selected can be shown to be synchronous palaeontologically, though diachronism may occur when these are traced over a wider area. On palynological evidence the Old Head Sandstone Formation is late Devonian in age (probably Tn 1a-lower Tn 1b in terms of the Belgian succession), whereas the overlying Kinsale Formation is early Carboniferous (upper Tn 1b-Tn 2). The base of the Kinsale Formation is approximately the base of the Carboniferous system in the area.

Dunworley Bay (section 10, Figs. 1 and 2)

A shale intercalation 20 m. below the top of the Old Head Sandstone Formation yielded a LN Subzone miospore assemblage. A pyritized VI Subzone assemblage of restricted composition was obtained from close to the base of member 1 in the overlying Kinsale Formation, and closely resembles assemblages from low in member 1 on the Old Head of Kinsale. Three VI Subzone assemblages were also obtained from member 2.

Seven Heads (sections 7 and 9)

Several LN Subzone miospore assemblages have been obtained from the upper part of the Old Head Sandstone Formation at South Seven Heads. There is no direct palaeontological evidence at present concerning the age of the Kinsale

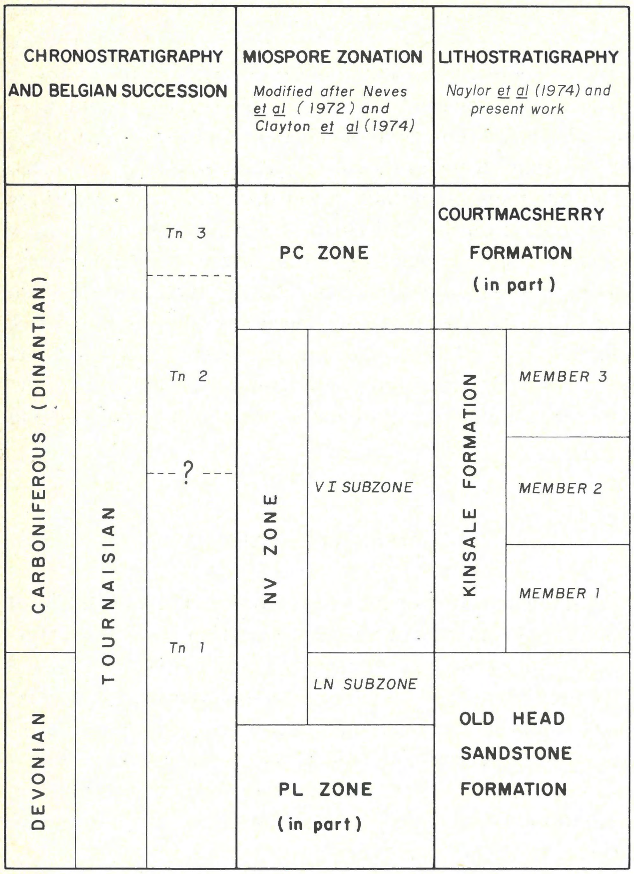

Fig. 3
Summary of the chrono-, bio-, and lithostratigraphy of South Cork (no scale implied).

Formation, but limestone lenses at the base of the overlying Courtmacsherry Formation in both the North and South Seven Heads sections have yielded conodont faunas similar to those described by Matthews and Naylor from the base of the Courtmacsherry Formation at North Ringabella, and which indicate a mid-Tournaisian age (G. D. Sevastopulo *pers. comm.*).

Old Head of Kinsale (section 8)

The boundary between the LN Subzone and the VI Subzone coincides precisely with the boundary between the Old Head Sandstone Formation and the Kinsale Formation. Both the lithological and the palynological changes are so abrupt at this level that a non-sequence may be present, though palynological correlation with sections elsewhere in Ireland suggest that the stratigraphic extent of any such break in the succession would be minimal. Conodont faunas from member 1 confirm a probable early Dinantian age (MATTHEWS & NAYLOR, 1973).

Miospore assemblages throughout the Kinsale Formation were assigned to the VI Subzone, but two samples from the lower part of the Courtmacsherry Formation yielded PC Zone assemblages. Conodont faunas from the base of the Courtmacsherry Formation suggest a mid-Tournaisian age (MATTHEWS & NAYLOR, 1973).

North Courtmacsherry Bay, Hake Head and Kinsale Harbour (sections 6, 5, 4 and 3)

Shale samples collected by KUIJPERS (1972) from the basal, sand-dominant beds on the south limb of the Courtaparteen Anticline (Naylor's 'Dooneen Formation') yielded VI Subzone miospore assemblages. Samples from the basal sandy beds on the north limb of the same anticline in the southern Kinsale Harbour section (4) also yielded VI Subzone assemblages, supporting the assignment of the sandy strata in the core of the Courtaparteen Anticline to member 2 of the Kinsale Formation, rather than to the Old Head Sandstone Formation as suggested by NAYLOR (1969). Undated calcareous shales define the base of the Courtmacsherry Formation in the Hake Head and North Courtmacsherry sections.

VI Subzone miospore assemblages were obtained from several samples in the sandy succession exposed in the Summercove and Castlepark sections in North Kinsale Harbour, and also in the Oysterhaven inlet. The wave-governed, sand-dominant beds in sections 3 and 4 are therefore assigned to member 2 of the Kinsale Formation.

The geology of the area between Oysterhaven and Flat Head is difficult to elucidate due to numerous minor folds and to the inaccessibility of critical parts of the sequence. The Castlepark Anticlinal Axis has however been tentatively joined with the anticline exposing the highest strata of the Old Head Sandstone Formation on Flat Head and in Nohaval Cove (Fig. 1; see also NAYLOR, 1969; MACCARTHY ET AL., 1971).

North and South Ringabella (sections 1 and 2)

As on the Old Head of Kinsale, the boundary between the LN and VI Subzones coincides with the boundary between the Old Head Sandstone Formation and the Kinsale Formation. Preliminary results from these sections were published by CLAYTON ET AL. (1974), and further data indicating a VI Subzone age for the Kinsale Formation and a PC Zone age for the lower part of the Courtmacsherry Formation were presented by HIGS (unpublished thesis, 1975). MATTHEWS & NAYLOR (1973) recorded mid-Tournaisian conodonts from the base of the Courtmacsherry Formation.

CONCLUSIONS

Apart from local tectonic complications, the three formations distinguished by NAYLOR ET AL. (1974), viz. the Kinsale, Courtmacsherry and Lispatrick Formations, are recognizable throughout the Cork Harbour-Seven Heads area of South Cork. All are essentially Dinantian in age, though the uppermost beds of the Lispatrick Formation may extend into the

Namurian. The base of the Kinsale Formation is marked by the occurrence of an almost pure shaly lithology (member 1), which was deposited below wavebase. The base of the Kinsale Formation coincides with the boundary between the LN and VI Miospore Subzones, and approximates to the Devonian/Carboniferous boundary. Member 1 contrasts strongly with the shallow water wave and tide dominated sandstones of the underlying Old Head Sandstone Formation. Mud-rich strata which at Ringabella underlie the 'Garryvoe Conglomerate Facies' (GARDINER & HORNE, 1976) have yielded LN Subzone miospore assemblages. These mudrocks are therefore demonstrably older than the base of the Kinsale Formation on the Old Head of Kinsale, and are assigned to the Old Head Sandstone Formation (CLAYTON ET AL., 1974).

The most westerly outcrops of the conglomeratic facies developed at the top of the Old Head Sandstone Formation are seen in the Nohaval-Flat Head area; further west, only coarse sandstones occur at this level. The abrupt change of lithology at the base of the Kinsale Formation may indicate the presence of a minor non-sequence. The thin conglomeratic horizons within member 2 of the Kinsale Formation in Dunworley Bay are considerably younger than the conglomerates at the top of the Old Head Sandstone Formation, and are only locally developed. This impersistence of conglomeratic horizons within the marine sequences of Upper Devonian and Dinantian age in south Cork further supports the view expressed by CLAYTON ET AL. (1974), that correlations of these horizons without biostratigraphic control tend to be erroneous. The use of lithostratigraphic classifications of the type proposed by MACCARTHY ET AL. (1971) and GARDINER & HORNE (1976), which incorporate units defined or delimited by the presence of conglomerates is therefore rejected by the present authors.

The calcareous base of the Courtmacsherry Formation can be recognized throughout the area investigated, though this becomes less easy in some of the more westerly sections. The shales overlying the thin basal limestones are often lithologically indistinguishable from the mud-dominant strata of member 3 of the underlying Kinsale Formation. The limestones die out laterally to the west of Seven Heads, and there the distinction between the Kinsale Formation and the Courtmacsherry Formation becomes impossible (GRAHAM & REILLY, 1976).

Three members can be distinguished within the Kinsale Formation, and these have been recognized in all but one of the sections described. This subdivision parallels that proposed by NAYLOR (1975) for Dunmanus, and by GRAHAM & REILLY (1976) for Clonakilty Bay. The Kinsale Formation as a whole, and member 2 in particular, shows marked thickness variations in the area investigated. The thickest sequences are found in the Kinsale Harbour and North Courtmacsherry Bay sections. Proximity to the source of clastic supply and a greater rate of subsidence are probably jointly responsible. VI Subzone miospore assemblages from the thick sandy sequences around Kinsale Harbour suggest that these strata should be assigned to member 2 of the Kinsale Formation, rather than to the Old Head Sandstone Formation as proposed by NAYLOR (1969, fig. 4).

Member 1 was mainly deposited in a deep water environment, below wavebase, though there is evidence of gradually shallowing conditions towards the top of the member. The depositional environment of member 2 is envisaged as a muddy, shallow marine platform, where, under varying degrees of wave influence, sandy shoals built up, sometimes becoming emergent (DE RAAF ET AL, 1977). Neither tidal nor fluvial influence was significant during the deposition of the Kinsale Formation. There was a gradual shallowing of the seabed towards the palaeo-coastline, which lay to the northwest, though its precise position is unknown. Sandstones with structures similar to those in member 2 are encountered in member 3, suggesting affinities in depositional process.

ACKNOWLEDGEMENTS

The fieldwork in Ireland was financed by a NATO Research Grant (no. 638), which is gratefully acknowledged, as are research grants from Z.W.O. and N.E.R.C. The authors are much indebted to Professor J. F. M. DE RAAF for his stimulating advice and help in the field as well as during preparation of the manuscript. Thanks are also due to Dr. J. R. BOERSMA, Dr. K. HIGGS, Dr. D. NAYLOR and Dr. G. D. SEVASTOPULO for helpful discussions and access to unpublished data.

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