Holocene Sea-level and Sedimentary Changes on the South Coast of Ireland

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ABSTRACT


Studies of Holocene relative sea-level (RSL) data on Ireland's southern coast indicate possible long-term E-W Earth crustal movements. New long sedimentary records of coastal environmental changes from the central south coast now provide critical sites for the evaluation and validation of such crustal movements and the regional patterns of RSL changes. Data from one such site at Timoleague, Courtmacsherry Bay are presented. These show marine inundation of the inner coastal areas post c. 7400 cal yr BP at -5.7 m ODM. This initial marine flooding episode is followed by the recording of 3 main 'cyclic' sedimentary phases of alternating tidal - sub-tidal mudflat conditions followed by the development of salt marsh and fresher high marsh environments. These 'cycles' suggest significant changes in the influence of tidal levels at the site, probably independent of the wider trends in RSL change. The mid-late Holocene position of RSL for the inner Bay had reached -0.63 m ODM by c. 3100 cal yr BP.

ADDITIONAL INDEX WORDS: Coastal erosion, marsh accretion, diatoms, tidal changes, Earth crustal movement.

INTRODUCTION

An established record of Holocene sea-level changes for Ireland exists (e.g. CARTER et al., 1989; DEVOTOY et al., 1996). This shows an uneven spatial coverage in knowledge, together with continuing uncertainties concerning the significance of extreme events (e.g. high magnitude surges, tsunamis) in determining coastal signatures (DUFFY and DEVOY, 1999), or particularly of Earth crustal (land) movements and tidal changes as components of relative sea-level (RSL) changes. These uncertainties are of wider concern for most world coasts, in terms of quantifying coastal functioning at micro- to meso-scales (temporal and spatial) (SMITH et al., 2000).

Before the 1980s little focused sea-level work had been undertaken on Ireland's southern coasts. Subsequently, over 40 ⁰C Holocene sea-level index points have been established for this coastline (SINNOTT, 1999). In addition, geophysical modelling has also developed expected patterns of long-term RSL changes for the region (e.g. LAMBECK, 1993; PELTIER, 1998; LAMBECK and PURCELL, 2001). The empirical data show RSL rising from below -15.3 m Ordnance Datum Malin (ODM) at c. 9000 cal yr BP to the present day at -2 m ODM. This RSL trend is supported by the geophysical work (DEVOY, 1995). The time and spatial distribution of the index points also suggest a possible differential EW height pattern, which may indicate long-term Earth crustal movement, as evidenced by earlier interglacial RSL records (DEVOY and SINNOTT, 1997).

In establishing the RSL data for this coastline then little information has been retrieved from the central south coast. This region is critical in helping evidence the existence of any E-W differential crustal movements and in helping to further validate the geophysical models for the regional reconstruction of shoreline patterns and associated Earth rheology. Former studies of coastal sites in the region (DEVOY, 1983; CARTER et al., 1989) have shown either only relatively shallow (<5 m thick) late-Holocene sedimentary sequences, or thicker, clastic-dominated estuarine sediments which lack well defined sea-level change index points.

Recent investigations (post 2000 A.D.) of a series of N-S aligned estuaries and incised valleys close to Cork (Figure 1), developed in deep (>30 m) former glacialfluviatile channels, have provided now longer Holocene sedimentary records. These show 8-15 m of interleaved inorganic (clay-silts and sands) and biogenic (wood and monocot peats) sediments. This study presents the stratigraphic data from one of these new key central south coast locations, at Timoleague (Figure 1c).

STUDY AREA

The Timoleague site lies close to the entrance of the Argideen River into the upper (western) end of Courtmacsherry Bay (Figure 1). Other similar small N-S draining river catchments enter the Bay from the north as well. These have also been found to contain Holocene sedimentary records comparable with those at the study site.

At Timoleague this Bay-estuary complex narrows progressively westward to form intertidal mudflats, which grade vertically into salt marsh and higher freshwater marsh environments. The Spring tidal range in the area is between c. 3.5-3.9 m. A series of small streams, developed in former glacialfluviatile channel systems, feed locally into the marshes. The glacialfluviatile channels, which underlie the site and are also developed in the Argideen valley and elsewhere in the Bay, contain interbedded sands, gravels and cobble sized sediments, capped by finer-grade heterogeneous glaciogenic sediments. These sequences are developed below c. -8 to -15 m ODM beneath the Holocene sediments in these inner parts of the Bay. Seismic and sidescan sonar studies from the outer Bay (WHEELER et al., 2001 and pers. comm.; SUTTON, 2002) show the channels to link up southwards and to be cut into bedrock (Devonian sandstones, slates and shales), exiting S-SW through Courtmacsherry Bay at depths below c. -30 m ODM.

Contemporary and ongoing sedimentary and hydrodynamic process studies at Timoleague and other sites in Courtmacsherry Bay show variable patterns of marsh accretion and erosion (DUFFY and DEVOY, 1999; SWIFT et al., 2003). Overall, inner marsh areas appear to be building-up, showing averaged annual vertical accretion rates of c. 4.6 mm yr⁻¹. This compares with longer-term Holocene rates for low energy coastal sites in southwest Ireland of 1-2 mm yr⁻¹ (DEVOY et al., 1995). Studies of the dynamics of the higher energy open coasts composed of 'soft' sediments in Courtmacsherry and adjacent areas are shown to be eroding at averaged rates of c. 0.5-1.0 m yr⁻¹ (DEVOY, 2000). Storm, wave and erosion modelling of these coasts are ongoing from European Union Framework 5 (HIPOCAS, STORMINESS) and national (HEA, Coastal Erosion and Coastal Flooding) research projects.

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TIMOLEAGUE SALT MARSH

Investigation and Methods

The stratigraphy from Timoleague has been examined from >40 continuous gouge-auger cores taken in a grided-series of N-S and E-W transects. The main across-marsh and estuary stratigraphy was reconstructed from 15 cores taken along a 350 m transect, that extends N-S across the widest portion of the salt marsh system (Figure 2). This transect includes the main tidal tributary that drains to Courtmacsherry Bay and three secondary tidal channels. All cores were levelled (by EDM Total Station) relative to mean sea level (ODM), established from temporary local benchmarks set to chart datum in Cobh, the nearest standard port. A high resolution differential GPS was used to establish the benchmarks. Sample cores were taken using a combination of wide-bodied gouge-auger and piston samplers (1m x 0.05 m Ø).

Core 8 (Figure 2) was identified as representative of the long-term sedimentation history at the site and was selected for initial grain size analysis, diatom study and radiocarbon dating. Further work on the pollen and vegetational changes is being undertaken. Grain size measurements on 38 samples were taken at 20 cm intervals and made using a Malvern Mastersizer, with results reported here as mean values. Sampling for diatom analysis was conducted at 10 cm intervals with 63 samples prepared following the standard hydrogen peroxide and centrifuge method (DEVOY, 1979; BATTARBE, 1986). Fossil diatoms were mounted in Naphrax and examined using light microscopy with an x100 oil immersion objective (at magnification of x1000). A minimum count sum of 350 diatom valves was made on each sample. The identification of 218 diatom taxa and palaeoenvironmental interpretation was based upon established floras and other texts, including VAN DER WERFF and HULS (1957-1974), KRAMMER and LANGE-BERTALO (1986-1991), FOGED (1977, 1978) and JOHN (1983). Results are presented as a percentage frequency diagram, showing the key diatom species within salinity (Halobion) groupings assigned using DENYS (1991a, b).

Radiocarbon age determinations in core 8 were made on six peat samples, submitted to Beta Analytic Laboratories (USA) (Table 1). Additional 14C samples submitted to Waikato University Radiocarbon Laboratory (New Zealand) were also obtained for other cores. All results are reported as calibrated ages.

Figure 2. Generalised stratigraphic cross-section for Timoleague salt marsh - mudflats. Cores are shown in relation to the sediment surface. The positions of mean sea level (ODM) and mean high water mark of spring tides (MHWST) are also shown.
Table 1. Radiocarbon and height data from Timoleague.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Date yr BP(Conv.)</th>
<th>Date yr BP(2 Cal.)</th>
<th>Core Number</th>
<th>Material Type &amp; Boundary</th>
<th>Rel. Level to MHWS (m)</th>
<th>Rel. Level to OD Malin (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Modern</td>
<td>260</td>
<td>4</td>
<td>Shell, above buried tidal-flow channel</td>
<td>-1.62</td>
<td>40.38</td>
</tr>
<tr>
<td>2</td>
<td>1690 70</td>
<td>1575 (1415-1735)</td>
<td>8A</td>
<td>Peat (top)</td>
<td>-1.20</td>
<td>+0.80</td>
</tr>
<tr>
<td>3</td>
<td>2940 60</td>
<td>3118 (2925-3310)</td>
<td>8B</td>
<td>Peat (base)</td>
<td>-2.63</td>
<td>-0.63</td>
</tr>
<tr>
<td>4</td>
<td>3830 60</td>
<td>4210 (4005-4415)</td>
<td>8B</td>
<td>Peat (top)</td>
<td>-3.82</td>
<td>-1.82</td>
</tr>
<tr>
<td>5</td>
<td>4190 50</td>
<td>4702 (4555-4850)</td>
<td>8B</td>
<td>Peat (base)</td>
<td>-4.06</td>
<td>-2.06</td>
</tr>
<tr>
<td>6</td>
<td>4590 60</td>
<td>5310</td>
<td>19</td>
<td>Peat (erosion contact)</td>
<td>-4.20</td>
<td>-2.20</td>
</tr>
<tr>
<td>7</td>
<td>5040 60</td>
<td>5778 (5635-5920)</td>
<td>8A</td>
<td>Peat (top)</td>
<td>-5.35</td>
<td>-3.35</td>
</tr>
<tr>
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<td>5130 60</td>
<td>5490</td>
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</tr>
<tr>
<td>9</td>
<td>5570 60</td>
<td>6373 (6280-6465)</td>
<td>8A</td>
<td>Peat (base)</td>
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</tr>
<tr>
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<td>7490</td>
<td>25</td>
<td>Peat (erosion contact)</td>
<td>-7.70</td>
<td>-5.70</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Stratigraphic Setting

All 15 cores on the across-marsh transect penetrated the basal glaciogenic surface, providing a complete record of sedimentation during Holocene time (Figure 2). Depth to the ‘glaciogenic-base’ ranges from c. +1.0 m ODM at the valley sides to c. -6.0 m ODM adjacent to the main tidal channel (e.g. core 25). Nine cores, including core 8, recovered a basal deposit of sandy and gravely silt that is 0.1-0.5 m thick. Multiple units of interbedded silts and fine sands overlie this deposit, with bed thickness ranging from 1 to 3 m. Within the central section of the core transect, these silt and sand beds are interleaved with well-preserved organic-rich sediments (peats). Core 8 contains four organic beds, one c. 1.4 m thick, composed predominantly of well-humified grasses and sedges (monocot peat), with a smaller and varying clay-silt fraction present in some of the beds.

In contrast, the southern section of the salt marsh is characterised by 1-3 m thick beds of silty medium sand (cores 2-6, Figure 2). Stratigraphic correlation between cores suggests this sand bed is laterally continuous for at least 100 m and most likely represents the infill of a palaeo-tidal channel. A radiocarbon age of 260 cal yr BP on articulated cockle shell (Cardium edule, core 4) deposited above this channel fill indicates that channel abandonment was relatively recent and most likely related to the construction of walls and a causeway across the estuary during the late eighteenth and mid-nineteenth centuries.

Palaeoenvironmental Changes

The most complete record of Holocene sedimentation and relative sea-level change in this area is provided by core 8 (Figure 2). (Descriptions of the Troels Smith stratigraphic and sedimentary classification of this and other the cores are available.) Sedimentation in this core began with the deposition of c. 0.5 m of sandy silt and clay above the bottom glacigenic sediments. A radiocarbon date on organic-rich silt-clay at the upper surface of this basal Holocene unit gives an age of 6280-6465 cal yr BP. The shell remains indicate deposition took place in a salt marsh creek - estuarine mudflat setting. Examination of the diatom record shows the dominance of polynhalobous diatom species in these sediments at >80% Total Diatoms (TD), indicating strong tidal, brackish water to near marine palaeo-salinity conditions during this opening Holocene sedimentary phase (Figure 3). An earlier radiocarbon age of c. 7490 cal yr BP at -5.7 m ODM (core and 25) was obtained for the junction of a wood and monocot peat with this overlying marine - brackish water clay-silt. This unit contains shells of Scrobicularia plana and Hydrobia spp. and evidences an earlier phase of the marine inundation of this inner zone of Courtmacsherry Bay.

This phase was followed by approximately a 2 k yr period of predominantly clay-silt deposition, spanning until 4075-4415 cal yr BP, during which time the sediment surface accreted to c. 1.8 m below present mean sea level, assuming minimal post-depositional compaction. This interval is characterised by successive beds of organic silt, silty clay with an upward increase in organic content and closing with the development of a monocot peat at c. 3.8 m depth. Diatom salinity groups in this phase record an overall decline in abundance of polyhalobous types to 20% TD and an increase in oligohalobous to mesohalobous forms (Figure 3). This evidences a decline in palaeo-salinity levels during this interval.

A 0.5 m thick bed of organic-rich silty clay overlies the '4 k yr palaeo-tidal bed' (3.45-3.98 m depth). This return to clastic-dominated sedimentation is associated with a rise in polyhalobous diatom taxa to c. 40% TD abundance, indicating return to a stronger marine influence at the site. The cause may be from local tidal and sedimentary changes alone, or may relate to the influence of the wider, ongoing Holocene relative sea-level rise. The timing of this shift is unknown. But it was probably a relatively short episode, as this phase of sedimentation is interleaved with 0.2 m of monocot peat. This records a return to more brackish water conditions, as indicated by a local increase in the mesohalobous diatom group.

The lower facies succession of clastic- (silt-clay) to organic-dominated (peat) sedimentation is repeated through the next 2 m in core 8, above c. 3.45 m depth. At c. -0.63 m ODM clay-silt deposition is replaced by the development at the site of >1.4 m of monocot peat, spanning an interval from 3310-3305 cal yr BP to 1735-1415 cal yr BP. Again, the diatom record indicates a brief rise of polyhalobous species (>50% TD) within the clastic-rich sediments. This is followed by a return to the dominance of mesohalobous and oligohalobous diatoms (>70% TD) as plant growth and peat formation began again. However, diatom preservation becomes poor within the upper 0.7 m of the peat bed, precluding a clear reconstruction of local palaeo-salinity in this interval, though brackish water conditions appear to be dominant.

Accretion to the modern salt marsh surface is recorded in the upper 0.8 m of silty clay, indicating a recent (post c. 1.5 kyr BP) return to clastic-dominated sedimentation. However, this shift is not associated with an increase in the values of polyhalobous diatoms. Rather mesohalobous and oligohalobous indifferent groups are most abundant (>80% TD), signalling a shift to a brackish and a significantly greater freshwater influence at the site, with oligohalobous indifferent species comprising >35% TD.

As evidenced by movements in the present marsh creeks and tide-ebb channel, and from the former tide channel (cores 2-6), lateral erosion has removed phases of the earlier Holocene marsh stratigraphy in many locations. The former extent of the biogenic and associated clay-silt sequences would probably have been far greater than is shown in the cores. If so, then the more extensive development of freshwter plant communities at the site would suggest long phases of reduced
tidal and marine influence in the area, as supported by the diatom data. The apparent 'cycles' of marsh and biogenic sedimentary development, followed by brackish-marine water and tidal inundation, appear similar to those modelled by ALLEN (2000) and recorded in the Severn estuary, UK (ALLEN and HASLETT, 2002). Future modelling work at the Timoleague site would be valuable in examining the interplay between rates of RSL rise, tidal change and sediment supply as controls in developing this marsh environment.

CONCLUSIONS

At Timoleague and from neighbouring estuary sites in Courtmacsherry Bay ≥15 m of interleaved biogenic and inorganic sediments provide a record of Holocene RSL changes in an open Bay - estuary system. Results of detailed lithostratigraphic - sedimentological and biostratigraphic work at this site (e.g. grain size, diatom, pollen) show an early-to-mid-Holocene littoral-marine invasion of this shallow upper-end of Courtmacsherry Bay after c. 7400 cal yr BP. Phases of reduced marine salinity removal and the establishment of fresh - brackish water marsh conditions are recorded in the subsequent rise of sea level. The sedimentary record in core 8 comprises three 'cycles' of clastic-dominated to organic-dominated sedimentation styles, with each associated with clear fluctuations in palaeo-salinity. Clastic-dominated deposition appears to be linked with a rise in salinity (due possibly to increased tidal access - RSL rise episode). Times of increased

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organic deposition - monocot peat growth are associated with brackish to more freshwater conditions (times of reduced tidal activity and/or possibly relative sea-level stillstand). Radiocarbon dating of these sediments provides a series of potential RSL index points from Timoleague for the central south coast of Ireland. Fluctuations in the marine influence recorded through suggest that factors of sediment supply and autogenic marsh growth may have been important in modifying the strength of the tidal and related marine influence at the site.

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LITERATURE CITED


