This book is about the way the coast evolves. It outlines the latest concepts in terms of deposition and erosion of shorelines and their dynamics over the last Ice Age. There are reviews of how deltas, reefs, estuaries, cliffs, polar and other coasts change with time, and how conceptual models can be extended to include shorelines modified by human influence.

*Coastal Evolution* is aimed at undergraduates studying coastal geomorphology, geologists who are mapping coastal sedimentary sequences, and environmental scientists, engineers, planners and coastal managers who need to understand the processes of change that occur on shorelines.
COASTAL EVOLUTION
Late Quaternary shoreline morphodynamics
COASTAL EVOLUTION

Late Quaternary shoreline morphodynamics

Edited by

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a contribution to IGCP Project 274: Coastal Evolution in the Quaternary
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Richard William (BILL) Gale CARTER
1946–1993

The sudden death of Bill Carter in July 1993 from cancer has robbed coastal geomorphology of one of its leading luminaries and taken from a wide circle of friends and colleagues a person of great stature, intellectual ability and unfailing support. His early death at 47 has deprived the discipline of someone who was just approaching the height of his powers and who had so much more potential to give.

Bill was born in the old coastal town of Bristol, south-west England, and remained a west-country man to the end. His childhood home at Portishead lay only a stone’s throw from the Severn estuary and during his early years the shoreline was an ever-changing back-cloth to his deep interest in the natural world. Those who stayed with Bill at his mother’s home, quickly sensed his delight in showing those sites along the estuary where he had first played and later studied as an undergraduate. Those early years also bred into him a deep and steadfast belief in family life which became a hallmark characteristic of Bill the person.

He studied Geography for his first degree at Aberystwyth, where he was influenced by Clarence Kidson and Brian McCann. He graduated in 1968, winning the University of Wales Prize for Geography *en route*. Due to
personal reasons he was unable to take up a studentship offered to him to work under the late Prof. Joe Jennings at ANU Canberra, and instead had to scramble to find a research studentship in the UK towards the end of the yearly grant-round. After writing to several institutions he was offered a chance to 'do something geomorphological' by Frank Oldfield, at a multidisciplinary School of Biological and Environmental Science in a new university that had just opened in a small country town near the north coast of Northern Ireland. Bill went to Coleraine and, except for a brief excursion to London for a year, remained there as postgraduate student (1968–71), lecturer (1972), senior lecturer (1981), reader (1987), professor (1991) and head of department (1989–92). In many ways the strength and vivacity of the Environmental Studies department at Ulster University is a reflection of the input of Bill, who became a mainstay of departmental life and direction.

These early years in Ireland saw the foundations laid of his coastal life with his perceptive and transformational study of Magilligan Foreland for his doctoral thesis (1972). This formed the cornerstone of his later research, giving direction to mesoscale approaches to morphosedimentary environments, the appreciation of shoreline development through morphodynamics, and the stimulus for his eolian work: research that is also a foundation for this present volume on coastal evolution. Those early years in Ireland also saw the establishment of the other force in his life, that of his family, when he met and married Clare Binney, also a postgraduate student at Coleraine.

It is no overstatement to say that Bill transformed coastal studies in Ireland. Before him, the coasts were regarded as stratigraphical sections to aid interpretation of Quaternary sea-level movement as a key to glaciation chronology. His interests in sea-level change and his realisation that the coastal stratigraphy and beach state had a process story to tell that was explicitly important for coastal studies were witnessed by the string of publications in the 1970s and 1980s which identified these themes. Magilligan, the north coast of Ulster and even the freshwater source of Lough Neagh offered a variety of unstudied shoreline features for Bill to work on. In particular, the work that Bill undertook on the structure and dynamics of swash bars and nearshore bars at a time preceding the emergence of the morphodynamics models of Short and Wright is an instructive example of how he recognised that the dynamics of coastal systems could be coupled with morphology in other than a descriptive fashion. His work on process did not deny his long-standing interest in Quaternary-scale coastal change. He was a strong contributor to the UK element of the IGCP 200 programme and his establishment of a sea-level curve for Northern Ireland set a standard for an approach to coastal problems. Although not a palynologist or palaeoecologist by training, he had the ability
Dedication: Bill Carter

to synthesise the essentials of their work and had the foresight to be able to recognise the reality of coastal environments, rather than ‘hopeful’ thinking, when translating the results of such work into the context of actual sea-level indicators. In this respect his ability to recognise the three-dimensionality and continuity of coastal process and responses gave him a head start over other more traditional workers on the Irish coastline.

The work on the northern coast of Ireland was followed by a successful phase in the early 1980s when the mixed sand and gravel barriers of south-east Ireland were studied in association with me. The realisation that the plethora of publications on US coastal barriers during the 1970s excluded a wide range of coarse clastic barriers, only served to entice him into studying the wider world of barrier features occurring around the mid- and upper-latitudes as reworked remnants of the Pleistocene inheritance. Bill’s main international co-operation dates from this period when he and I were lured to Canada by Don Forbes and Bob Taylor (Bedford Institute of Oceanography) to involve ourselves in the marvellous Holocene shorelines of the Eastern Shore, Nova Scotia. Bill readily identified with both this coastal environment and with the welcoming hearths of many Nova Scotian homes. He returned every year, sometimes with his growing family (son Ben and daughter Helen), for nearly a decade, always discovering something new each time. A painting of Chezzetcook Inlet (at the heart of the Eastern Shore study) still takes pride of place over his family hearth. Much of the success in unravelling the bewildering context of Holocene shoreline development of this barrier-dominated coastline came from the incisive and constantly fertile mind of Bill. Indeed, much of the background to this volume comes from his attempts to organise the diversity of barrier and beach forms that he saw in Nova Scotia. The stability and dominance of certain forms, the way in which those forms attempted to minimise their variation through feedback structures and the possibilities of indeterminacy in a complex morphosedimentary environment, all arose through this period of close contact with the coarse clastic shorelines of Nova Scotia. This Ulster link with Nova Scotia was further cemented, to the delight of Bill, by the appointment of John Shaw, one of Bill’s postgraduates, to the Bedford Institute.

It is difficult to state which coastal morphology intrigued Bill the most. He was unusual in some senses in that he had expertise in several areas of coastal studies, in that his name will be linked with gravel-dominated barriers, with sea-level studies, with sand beach morphodynamics and with coastal dunes. It was in the last field that he had other close international ties. In particular, Karl Nordstrom and Norbert Psuty and their associates through Rutgers University proved to be a fertile source of association for Bill in his dune studies.
Julian Orford

Although keenly interested in dunes as a morphology interesting in its own right, Bill regarded them as an integral element of a dynamic coastal system and was just about to undertake a major research project on the interaction of beach, dune and sea-level forcing when his last illness occurred.

During 1981, Bill was unfortunately sidelined by the need for major surgery. While convalescing he started two long-term commitments; one was to discover that he enjoyed cooking ‘real’ bread, the other was to discover the enjoyment of writing a book. Coastal Environments (1988) will stand as a lasting testament to his pertinence, incisiveness and comprehension that became the hallmark of his work. This book departed radically from what had gone before in that it included an explicit identification of the problem and prospects presented by human involvement with the coast. This holistic theme was a product of the environmental tradition that Bill discovered at Coleraine and which he willingly embraced. He felt that coasts had to be managed if they were to survive as functioning elements of the natural world. It pained him that his own country, with such great past maritime allegiances, seemed to make all of the fundamental mistakes in using and abusing the coast, and despite being told still would not recognise this fact. He spent considerable time involving himself in unpaid coastal advisory work for the National Trust (the largest private charity landowner of UK coastline) and would always oblige coastal landowners and managers, regardless of status and size, with his views on management. His was a voice not always welcomed by coastal engineers in that he felt that coastal engineers were too partisan over engineering structures for the good of the coast, but his integrity and purpose were respected by them, and he kept being invited back to talk at their meetings.

On an individual basis, Bill was a professional to his finger-tips when it came to matters coastal. He often gave the appearance of being aloof and possibly cool towards others he did not know. This was because he had a shyness which he fought all the time. I can well remember my first meeting with him as an unexpected visitor to the north coast of Ireland, after ten minutes I wondered how on earth I was going to survive the rest of the day with him! After one day with him, I realised that I had found a colleague bursting with ideas and knowledge. After fifteen years of working closely with him, I know I had a friend for life. He was well known for his verbal explosions but it all related to one aspect; he admired all who tried honestly, but would not suffer fools and charlatans. If you admitted you did not know then he was the soul of help. I know for certain that he agonised over all the material that came his way to be read. Bill was a glutton for work, his output was prodigious, somewhat in excess of 120 papers and four books in two decades. He never stopped still for a moment, always jotting something down or planning the next
Dedication: Bill Carter

paper. He was an avid traveller, always looking for new coasts to see. He kept
the tourist card industry and postal services in business around the world! His
early disappointment at missing out on Australia was somewhat mollified by
the last trip he made when he visited there in November 1992 in order to work
on the editing of manuscripts for this book. He took the opportunity to visit
most of the centres of coastal excellence that have appeared over the last two
decades and was greatly impressed with the variety of coasts he saw and the
friendliness of all whom he met. One of his comments to me after this trip was
his sadness that the UK had never recognised the importance of the coastal
environment as had Australia.

Bill’s illness was diagnosed early in 1993. His fortitude and courage would
have been a revelation to those who did not know him before his illness. To
those who did know him he was just the same Bill, going about life’s
adversities with his usual commonsense and down-to-earth approach. I doubt
if he ever realised the admiration and awe that he engendered in his friends
over the last few months of his life. He had to undergo a series of
chemotherapy cycles which clearly took a toll of him physically, although
mentally he was in total command, endeavouring to do more work than ever.
He wrote several papers, two major end-of-grant reports, completed his share
of editing papers for this IGCP 274 volume and answered numerous enquiries
about his health from his very wide circle of correspondents. He often likened
himself to the spider at the centre of a web, he only had to twitch and we came
running! He talked often about new ideas about existing work and new
projects. However, it was not to be, as eventually the cancer took its toll and
Bill died on July 17th 1993. This book, which engenders so many of the ideas
and themes upon which Bill worked so hard, is dedicated to the memory of him
as an outstanding worker, a selfless colleague and a firm friend to all in the
coastal environment.

Belfast, 1993           Julian Orford
Foreword

The International Geological Correlation Programme (IGCP) is concerned with networking and research projects of continental to global scale and scope. In the case of IGCP Project 274, ‘Quaternary coastal evolution: case studies, models and regional patterns’ (short title: ‘Coastal evolution in the Quaternary’), much of the initial network and research focus came forth from two previous IGCP Projects: No. 61 (1974 to 1982) and, in particular, No. 200 (1983 to 1987). These two earlier Projects dealt primarily with the global variation in relative sea-level (RSL) changes during the last 15,000 and 200,000 years respectively. At the final meeting of Project 200 (held in Halifax and Ottawa Canada in 1987) an overwhelming majority favoured continuation of sea-level and coastal research under the stimulating IGCP umbrella of UNESCO and IUGS. Project proposal No. 274 was submitted in October 1987 and endorsed as Project No. 274 in March 1988 to run until 1992 (later extended to 1993). The inaugural meeting was held on 22 September 1988 during an International Symposium on ‘Theoretical and applied aspects of coastal and shelf evolution, past and future’, held in Amsterdam from 19 to 24 September 1988.

The topic ‘coastal evolution’ was generally considered the natural choice for a follow-up project given the focus and results of the two foregoing IGCP sea-level projects. While much of the RSL database was being put to good use in validating regional and global models of earth crustal movements and ice-melt histories, available RSL change records remained to be analysed with respect to the effects, in space and time, on different coastal environments and the importance of this factor relative to other controlling variables such as energy regime, sediment supply and characteristics, basement topography, freshwater input, and internal controls and feedback mechanisms operating within any evolving depositional system. Within two years of the initiation of the Project over 400 coastal researchers from more than 50 countries were involved in palaeo-, actuo- and/or predictive studies of a wide range of coastal
Orson van de Plassche

environments and, equally important, the continental shelf which provides a framework for coastal evolution. As the Project ends, its membership list numbers well over 600 participants from 70 countries.

Essential for the growth and maintenance of this network were the efforts by the National Representatives and Correspondents, the organisers of the many national and international symposia, conferences, workshops, fieldtrips and business meetings (Fig. 1), and the editors of a significant number of acknowledged contributions to the Project (see list below). Several of the international meetings were co-sponsored by Sub-Commissions of the INQUA Commission on Quaternary Shorelines. The generous offer by 24 radiocarbon laboratories from 17 countries to carry out limited numbers of free datings for Project participants from developing nations provided a much-appreciated extra stimulus. An IGCP Project on Quaternary coastal evolution was justified for several reasons:

One, it would promote (a) further compilation and critical evaluation of existing RSL records and collection of new, much-needed, high-resolution sea-level data, and (b) analysis of coastal records for proxy data of past climate conditions and oceanic influences and of seismotectonic events. (A measure of the importance of coastal records research is found in the fact that UNESCO and the IUGS have endorsed, within their new joint international programme entitled ‘Earth Processes in Global Change’, a Pilot Project called ‘Climates of the Past’ (CLIP). The primary objective of CLIP is to determine and understand the natural variability of climate in the tropical belt, through

![Figure 1. Meetings of IGCP Project 274 ‘Coastal Evolution in the Quaternary’, 1988–1993.](image-url)
observation of high-resolution dating of geological records in coastal areas, noting that such records are one key to interaction of changing oceanic and atmospheric patterns.)

Two, in many parts of the world the coastal environment is under increasing pressure; the questions whether and, if so, how coastal environments should be managed must be based on the best possible understanding of shelf and coastal dynamics and interaction, as well as on adequate knowledge of the state or mode and sensitivity of a system, the controlling factors, the scale on which these operate (or operated) and the direction into which they are likely to change in the near future.

Three, the variety in coastal environments, the range in stages of research reached in different areas and the need for reliable prediction called for generalisation, coherent classification, and education and for further development of conceptual and numerical models of coastal/shelf processes and evolution.

On the basis of these considerations it was agreed that the primary objectives of Project 274 would be: (i) to document and explain local to global variations in coastal and continental-shelf evolution, incorporating knowledge of coastal and shelf processes and environments with geodynamic, climatic, oceanographic and other data to produce local and regional models, ranging from descriptive to numerical, leading to better understanding of interactive forces responsible for past, present, and future changes of coastlines; (ii) to promote specified thematic studies, which are necessary to solve problems of coastal change affecting human occupation of the coastal zone (e.g., assessment of the impacts of past and future sea-level change on coastal environments); (iii) to develop a globally coherent framework for integrated analysis and prediction of coastal change on different spatio-temporal scales, concentrating on the last 125 000 years; and (iv) to promote education on matters concerning coastal evolution.

The study of the evolution of a given coastal or shelf area requires independent and sufficiently accurate documentation of at least the RSL and tidal-range histories for that area and of the changes in the position and characteristics of the shoreline and coastal (sub)environments through space at time scales of millennia, centuries, and, if possible, decades with special attention to the influence of high-energy events. In view of the fact that large parts of the continental shelves and coastlines of the world have not been mapped in any detail and given the time-consuming and labour-intensive nature of coastal and shelf mapping and sample collection, it is no surprise that regional and global syntheses of coastal evolution remain a long-term goal. An important general achievement of IGCP Project 274 is, however, that through the many international meetings and the numerous individual and collective publications, coastal researchers the world over have obtained a supra-local
Orson van de Plassche

scope of their field of research. At the same time it is now generally appreciated that while a coherent regional to global analysis of the spatiotemporal hierarchy of controlling factors is both possible and important, this cannot be achieved without carefully conducted local studies that can be compared and analysed for similarities and differences in influence of RSL change and other parameters.

One of the first major contributions to Project 274 (and to several other international activities) was the World Atlas of Holocene Sea-level Changes (Pirazzoli, 1991). This atlas of some 800 field and 100 model-predicted RSL curves is at once a milestone and a millstone in that it brings out not only the global effort of sea-level researchers over the past 30 years, but also the weight of the question as regards the independency and accuracy of each curve when it comes to explaining general or specific aspects of shelf or coastal evolution during the past 10000 years. Indeed, a well-documented history of coastal evolution generates its own demands on (existing) sea-level, palaeo-tide, and other parametric data. Conversely, as this atlas invites a global first-order analysis of the relation between variation in RSL change and in coastal evolution during the Holocene, it challenges the coastal researcher to define accurately first-order features of shelf and coastal depositional histories.

Relative sea-level change never is, of course, the only operating variable. For a given rate and sign of RSL change the effect is strongly dependent on other system parameters, such as substrate topography (accommodation space), rate of sediment supply, biogenic productivity and fluvio-tidal balance. Thus, adjacent estuaries, which experienced the same RSL influence, nevertheless can have markedly different records of environmental change. On the other hand, patterns of Quaternary evolution of coastal and lowland riverine plains can be broadly similar across a region as large as Southeast Asia to northern Australia.

The natural variability and complex nature of coastal systems requires careful and systematic documentation and analysis of depositional records and calls for evolutionary morphosedimentary models and general concepts that may be applied or serve as useful working hypotheses in other, less-well-studied areas. Fine examples can be found in many of the Project 274 contributions listed below, or among the hundreds of individual papers produced by Project participants over the past six years. The present book on Coastal Evolution, born out of that very idea of model and concept transfer, will be a source of inspiration to many.

Project Leader
Amsterdam, 1993

Orson van de Plassche
Foreword

Selected contributions to IGCP Project 274


