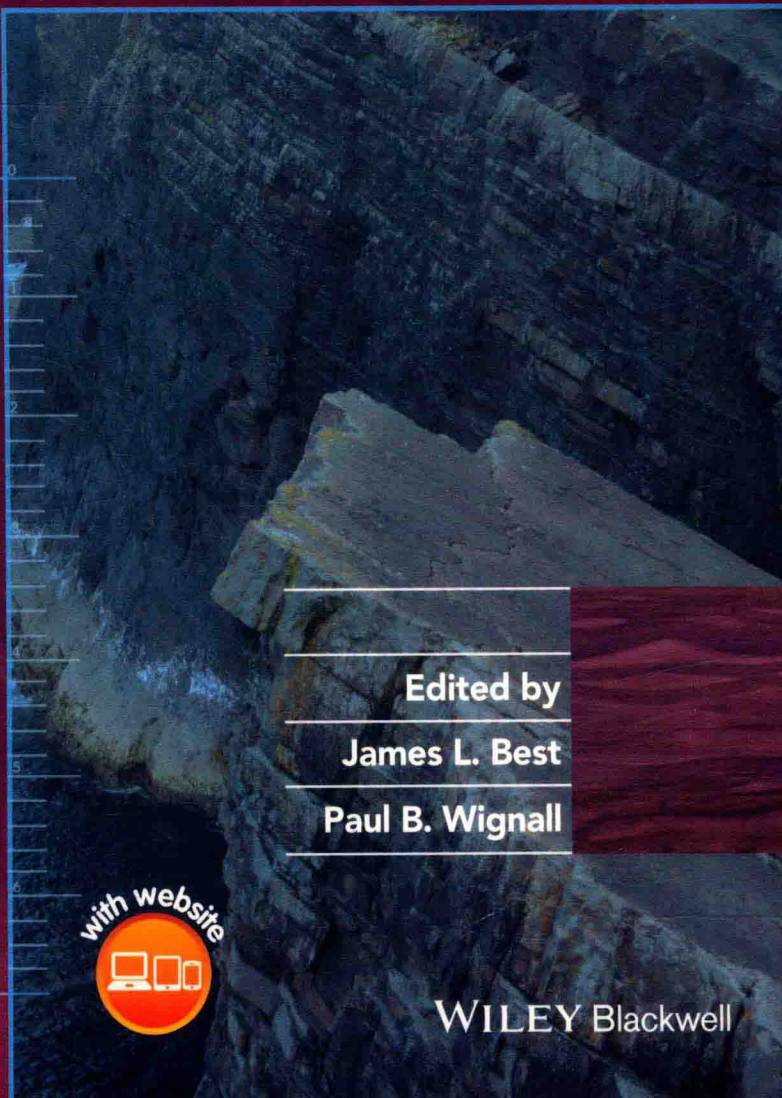


**A Field Guide**  
to the **Carboniferous Sediments**  
of the **Shannon Basin, Western Ireland**

International Association of Sedimentologists Field Guide



**Edited by**  
**James L. Best**  
**Paul B. Wignall**



**WILEY** Blackwell

# **A Field Guide to the Carboniferous Sediments of the Shannon Basin, Western Ireland**

Edited by

JAMES L. BEST & PAUL B. WIGNALL

**WILEY** Blackwell

This edition first published 2016  
© 2016 by the International Association of Sedimentologists

*Registered Office*

John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

*Editorial Offices*

9600 Garsington Road, Oxford, OX4 2DQ, UK  
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK  
111 River Street, Hoboken, NJ 07030-5774, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at [www.wiley.com/wiley-blackwell](http://www.wiley.com/wiley-blackwell).

The right of the author to be identified as the author of this work has been asserted in accordance with the UK Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

**Limit of Liability/Disclaimer of Warranty:** While the publisher and author(s) have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that the publisher is not engaged in rendering professional services and neither the publisher nor the author shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

*Library of Congress Cataloging-in-Publication data applied for*

ISBN: 9781119257127

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: James L. Best and Paul B. Wignall

Set in 9.25/11.5pt Times New Roman by SPi Global, Pondicherry, India  
Printed and bound in Malaysia by Vivar Printing Sdn Bhd

Field Guide to the  
Carboniferous Sediments of the  
Shannon Basin, Western Ireland

## Contributors

### Editors

**Jim Best**, *Jack and Richard Threet Chair in Sedimentary Geology, Departments of Geology, Geography & GIS, Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory, University of Illinois at Urbana-Champaign, 605 East Springfield Avenue, Champaign, IL 61820, USA.*

**Paul B. Wignall**, *School of Earth and Environment, University of Leeds, Leeds, West Yorkshire, LS2 9JT, UK.*

### Contributors

**Karen Braithwaite**, *School of Earth and Environment, University of Leeds, Leeds, West Yorkshire, LS2 9JT, UK. now at: School of Veterinary Medicine and Science, University of Nottingham, College Road, Sutton Bonington, Loughborough, Leicestershire, LE12 5RD, UK.*

**Alex Bryk**, *Department of Geology, University of Illinois at Urbana-Champaign, 605 East Springfield Avenue, Champaign, IL 61820, USA; now at: Department of Earth and Planetary Science, University of California Berkeley, 307 McCone Hall, Berkeley, CA 94720, USA.*

**John Graham**, *Department of Geology, Museum Building, Trinity College Dublin, Dublin 2, Ireland.*

**Eric Obrock**, *Department of Geology, University of Illinois at Urbana-Champaign, 605 East Springfield Avenue, Champaign, IL 61820, USA; now at: ExxonMobil, 22777 Springwoods Village, Parkway, Spring, TX 77389, USA.*

**Jeff Peakall**, *School of Earth and Environment, University of Leeds, Leeds, West Yorkshire, LS2 9JT, UK.*

**David R. Pyles**, *EOG Resources, 600 17<sup>th</sup> Street Suite 1000N, Denver, CO 80202, USA. Formerly at: Chevron Centre of Research Excellence, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401, USA.*

**Jessica Ross**, *School of Earth and Environment, University of Leeds, Leeds, West Yorkshire, LS2 9JT, UK.; now at: Maersk Oil North Sea UK, Maersk House, Crawpeel Road, Aberdeen, AB12 2LG, UK.*

**Lorna J. Strachan**, *Earth Science Programme, School of Environment, University of Auckland, Auckland 1142, New Zealand.*

**Eleanor J. Stirling**, *BP Exploration Operating Company Ltd., Chertsey Road, Sunbury-on-Thames, Middlesex TW16 7LN, UK.*

**Ian D. Somerville**, *School of Earth Sciences, Science Centre West, University College Dublin, Belfield, Dublin 4, Ireland.*

## Acknowledgements

We are very grateful to a whole host of people who have inspired and helped us in our research in Western Ireland over the past twenty-five years and also provided enthusiasm and assistance in completing this field guide.

Firstly, we are grateful to all of the contributors to this book in its long journey from inception to publication and thank them for their input, patience and dedication to producing a field guidebook to a region of globally-renowned and important geology that will hopefully be very widely used. We have also benefitted from visiting this area with many people over the years and are very grateful for the insights and expertise provided by Jeff Peakall (University of Leeds), Drew Phillips (Illinois State Geological Survey), Steve Marshak and Michael Stewart (University of Illinois), Jeff Nittrouer (Rice University) and Owen Sutcliffe (Neflex). We would also like to thank several generations of Leeds University and University of Illinois undergraduates and postgraduates who have worked in the region and greatly contributed to our understanding of the geology; especially Dan Bell, Alex Bryk, Karen Braithwaite, Rachael Dale, Heather Macdonald, Eric Obrock and Eleanor Stirling. We are thankful to Dan Bell for data that helped construct the geological map of Kilkee. We are also grateful for the help of the IAS Special Publications editors we have worked with – Ian Jarvis, Tom Stevens and Mark Bateman – for their encouragement and perseverance; and also to the IAS and the Jack and Richard Threet Chair in Sedimentary Geology at the University of Illinois for funding the final graphics compilation. We are indebted to Chris Simpson for his superb work on the final graphics that ensured the consistency of all illustrations in the guide and made them available for online download. Ian Francis, Kelvin Matthews, Delia Sandford and Radjan Lourde Selvanadin at Wiley Blackwell are thanked for their guidance and work in bringing this guide to publication.

We have also been incredibly fortunate to make lasting friends in County Clare in our many years working there and these people have provided a constant source of knowledge, help, good humour and true friendship. We are especially grateful to Patrick Blake and Patrick Egan (Liscannor), Orla and Mark Vaughan (Kilfenora Hostel and Vaughan's Pub, Kilfenora),



Brian Farrell (Burren Coaches, Ballyvaughan) and Geoff and Susanne Magee (Dolphinwatch, Carrigaholt) for their friendship and help.

Finally, we would like to dedicate this field guide to the memory of Trevor Elliott, who sadly passed away on 28<sup>th</sup> January 2013. Trevor was an inspirational field geologist who fostered the interest of many geologists, including us, in the Shannon Basin. His seminal work on many parts of the basin fill, his mentoring of colleagues in the region and his leadership of many industrial trips to these rocks have left a permanent imprint on many of us who were lucky enough to know and meet Trevor. We, and his many friends in this area of Western Eire, will sorely miss the sight of Trevor striding across the cliff top paths in his brightly coloured field clothes and discussing the geology with him over a Guinness in the evenings. His kindness and inspiration will remain with us for many years to come.

Jim Best and Paul B. Wignall,  
January 2016



## About the Companion Website

This book is accompanied by a companion website:

**[www.wiley.com/go/best/shannonbasin](http://www.wiley.com/go/best/shannonbasin)**

The website includes:

- All figures from the field guide in PowerPoint format for use in teaching.
- GigaPan Images from various sites that are referred to in the field guide.
- All outcrop locations, as both kmz files and text files (UTM Zone 29U and OSI Grid co-ordinates).
- Web addresses for the Ordnance Survey of Ireland and Geological Survey of Ireland.
- Details of accommodation and travel in the region.

# Contents

**Contributors, vii**

**Acknowledgements, ix**

**About the Companion Website, xi**

**1 Introduction to the Field Guide, 1**

*Jim Best & Paul B. Wignall*

**2 The Shannon Basin: Structural Setting and Evolution, 16**

*John Graham*

**3 Basin Models, 35**

*Paul B. Wignall & Jim Best*

**4 Lower Carboniferous of the Shannon Basin Region, 48**

*Ian D. Somerville*

**5 Viséan Coral Biostromes and Karsts of the Burren, 79**

*Ian D. Somerville*

**6 The Clare Shales, 97**

*Paul B. Wignall, Ian D. Somerville & Karen Braithwaite*

**7 Architecture of a Distributive Submarine Fan: The Ross Sandstone Formation, 112**

*David R. Pyles & Lorna J. Strachan*

**8 Evolving Depocentre and Slope: The Gull Island Formation, 174**

*Lorna J. Strachan & David R. Pyles*

- 9 The Tullig and Kilkee Cyclothem in Southern County Clare, 240**  
*Jim Best, Paul B. Wignall, Eleanor J. Stirling, Eric Obrock & Alex Bryk*
- 10 The Tullig and Kilkee Cyclothem of Northern County Clare, 329**  
*Paul B. Wignall, Jim Best, Jeff Peakall & Jessica Ross*
- 11 The Younger Namurian Cyclothem around Spanish Point, 350**  
*Paul B. Wignall & Jim Best*
- Appendix: List of *GigaPan* Images, 361**
- References, 362**
- Index, 371**

# Chapter 1

## Introduction to the Field Guide

JIM BEST & PAUL B. WIGNALL

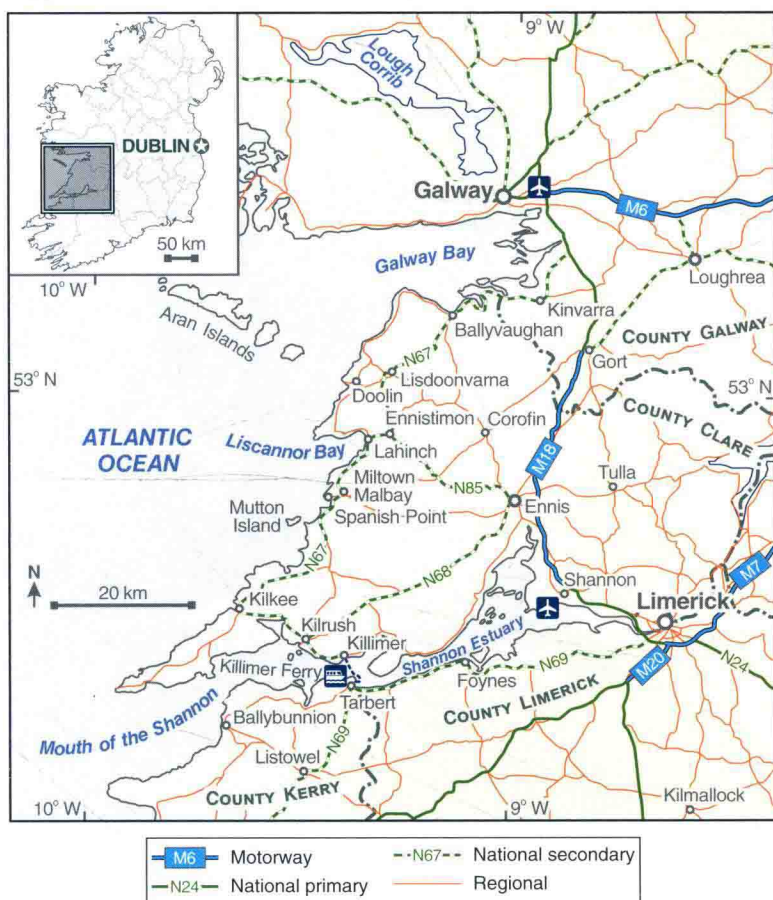
### 1.1 The Aim of this Field Guide

This field guide provides a detailed account of the Carboniferous geology of the Shannon Basin, principally in County Clare and County Kerry, Western Ireland. This region has become a classic destination for field groups from across the world in the past 25 years due to its stunning exposures of a wide range of Carboniferous depositional environments – from carbonate platform to deep sea turbidites, from black shales to delta slope and from shallow marine environments to fluvial channels – that can be viewed on a wide range of spatial scales up to those of interest within hydrocarbon reservoir modelling. The region has become a testing ground for concepts within basin analysis and sequence stratigraphy and has been used as a source of outcrop analogues for many hydrocarbon reservoir studies across the globe. This guide provides a summary of both past work and ongoing debate on the interpretation of these exceptional outcrops, through description of the principal localities and their major features. We hope the guide will be valuable to both professional and amateur geologists, as well as a broader audience who want to know more about the rocks that form this beautiful landscape. This guide thus provides both an account of the deep-time evolution of this region in the Carboniferous some 320 million years ago, as well as setting the stage for a landscape that has a fascinating history of human settlement over the past 6000 years (Jones, 2004, 2007). The guide assumes a basic knowledge of geology but also includes some terminology associated with specific areas and topics, such as palaeontology and sequence stratigraphy.

Perhaps what strikes one most when walking over and examining the rocks described in this field guide is the incredible variety and wealth of superbly-preserved geological features present. These outcrops have provided the materials for a range of detailed research papers over a 60-year period and have led to this region being perhaps one of the most visited destinations by geological field parties in a global context; and for specialities that include sedimentology, palaeontology, structural geology, geophysics and reservoir geology. Yet, despite this extensive study, the Shannon Basin continues to reveal new features, to stimulate new interpretations and debate and there are many questions that remain to be answered about these sedimentary sequences. This field guide thus not only aims to provide details about many of the key localities, but also highlights areas of ongoing debate and discussion, in the hope that it will provide a synthesis and starting point for future study and teaching.

## **1.2 Background to the Area**

The Carboniferous-age Shannon Basin encompasses an area within Western Ireland that includes the majority of County Clare and parts of County Kerry and County Limerick. The area lies along the Atlantic coast of Western Ireland (Fig. 1.2.1) and encompasses regions both to the north and south of the Shannon Estuary, a waterway whose trend has considerable geological importance as regards the formation and evolution of the Shannon Basin (Graham, Chapter 2). The topography of the area (Fig. 1.2.2) consists of higher terrain to the north in the limestone hills and karst terrain of the Burren and gently rolling hills of the Loop Head Peninsula that lies to the north of the Shannon Estuary, the mouth of Ireland's largest river. The Atlantic coast often possesses high and dramatic vertical cliffs that afford superb exposures within the Carboniferous sediments, but inland on the Loop Head Peninsula and in Counties Kerry and Limerick the exposures are far more limited. The area contains the world heritage area of the Burren in the north that comprises Lower Carboniferous limestones that also make up the Aran Islands (Fig. 1.2.1), and which exhibits superb geomorphology (Simms, 2006), natural history (D'Arcy & Hayward, 1991; Nelson, 2008) and archaeology (Jones, 2004, 2007). The region also contains the world famous Cliffs of Moher that display a section through part of the Carboniferous clastic basin fill, and the striking coastal scenery of the Loop Head Peninsula. The geology of the area allows access to a wide range of sediments that document the formation, fill and later deformation of the Carboniferous Shannon Basin, with many exposures being located along the western Irish Atlantic coast.



**Fig. 1.2.1.** Map of the region detailed in this field guide, with principal towns, roads and airports marked.

Tectonic deformation of the area occurred during the Variscan Orogeny, with compression from the south producing broadly west-east oriented fold structures, which decrease in their intensity further north. Thus, the limestones and sandstones of northern County Clare, that gently-dip at a few degrees to the south, are increasingly replaced by more intensely folded and faulted sediments further south on the Loop Head Peninsula and south of the Shannon Estuary, where pervasive pressure solution cleavage is also developed. Indeed, the degree of low-grade metamorphism also increases into the outcrops across the Shannon Estuary to the south.



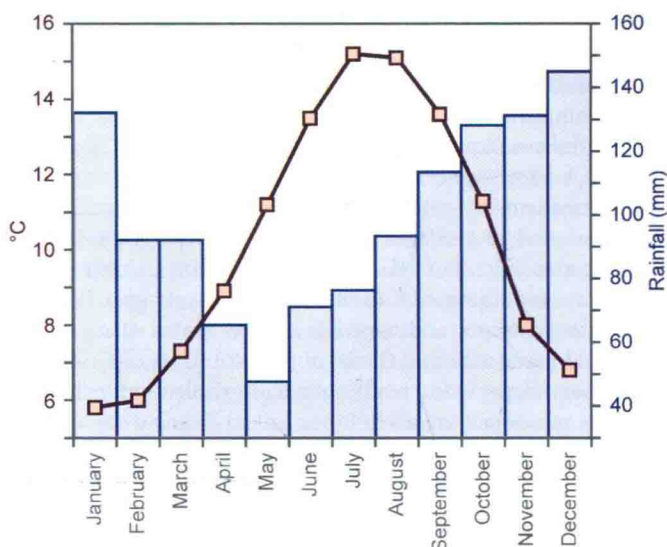


**Fig. 1.2.2.** Topographic map of the region, derived from Shuttle Radar Topography Mission (SRTM) data (from <http://photojournal.jpl.nasa.gov/catalog/?IDNumber=PIA06672>). Colour coding is directly related to topographic height, with green at the lower elevations, rising through yellow and tan, to white at the highest elevations.

### 1.3 Climate

The present-day climate in Western Ireland (Fig. 1.3.1) is mild, being dominated by the weather systems that track across the Atlantic and providing conditions that are seldom very cold but are often rainy. Weather conditions can range from large Atlantic storms that strike the coast and bring considerable rain, high seas and gale force winds, through to summer anticyclones that yield warm, dry periods. July is the warmest month (at Kilkee (Fig. 1.3.1), the average is 15.2°C (59.4°F) with January being the coldest (Kilkee average = 5.8°C or 42.4°F)). June and December are the





**Fig. 1.3.1.** Average monthly temperature and rainfall at Kilkee, County Clare (see location on Fig. 1.2.1).

driest and wettest months (at Kilkee, 71 and 154 mm rainfall, respectively). However, rainfall occurs in all months (Fig. 1.3.1) and thus it is always worthwhile packing waterproof clothes for fieldwork in the area, as well as sun-block and sunhats for the summer months. It is also worthy of note that at this latitude the winter days are short (*c.* 7.5 hrs between sunrise and sunset at the winter solstice) but you are rewarded by long days and light evenings in the summer (*c.* 17 hrs between sunrise and sunset at the summer solstice).

## 1.4 Accommodation, Travel and General Facilities

The field area can be reached easily by car or bus from Dublin (*c.* 4 hours by car) or visitors may also fly direct to either Shannon Airport, which is *c.* 1.5 hrs away from the town of Kilkee (Fig. 1.2.1), or Galway Airport that is *c.* 1.5 hrs away from Lahinch (Fig. 1.2.1). In-field transport along often small roads is easier by car or minibus. Larger coaches can negotiate the small roads that lead to the vast majority of the outcrops detailed herein, but it is essential to discuss the localities to be visited with the local coach operators. Most of the sites can be accessed easily and the local landowners are very gracious and obliging in allowing geologists to visit

these localities. However, it is recommended that visitors ask permission for access to any areas where it is obvious that you are walking across private land and fields.

Tourism is important to the local economy in most of the coastal areas to be visited and consequently accommodation in the area is easily available through a host of options. A range of hotels is available in the larger towns, with excellent bed-and-breakfast guest houses also to be found in towns, villages and in the countryside. In addition, several hostels are present in the area (such as in Kilfenora, Doolin and Lahinch in northern County Clare) and these can cater for student groups. Besides these options, houses, cottages and caravans can be rented at many localities within the field guide area and the local tourist offices of Counties Clare, Kerry and Limerick provide a ready source of excellent information. Some useful sources of contact are given in the linked online website.

## 1.5 Safety

The field area is generally safe and many of the localities can be visited by large groups, with the extensive exposures providing easy access. However, a series of hazards, some potentially fatal, are present and should be borne in mind when planning visits to these localities. Some of the localities detailed herein are also weather dependent (slippery rocks, high winds, tides) and thus the visitor should always, at each outcrop, conduct a careful safety assessment of local conditions and hazards before proceeding to access the localities described in this field guide. A list of the principal hazards is given below but additional factors and hazards may be present at individual sites.

**High cliffs:** Some of the coastal outcrops are adjacent to high cliffs that call for great care, especially if the rocks are slippery when wet, as they often are, and when there are high winds, which may be stronger near the cliff edges. All such localities must be approached with extreme care and cliff edges should not be approached due to potential undercutting and instability of any overhanging ledges.

**Slippery rocks:** One of the most frequent hazards in this region is slippery rocks, caused by either rain or sea-water. Slippery surfaces are often worse in intertidal areas where seaweed and water can make the outcrops truly treacherous. Extreme care should be taken in this regard, with the limestones also providing sharp surfaces on which cuts can be sustained easily during any falls.

**Loose rocks:** Some localities possess high outcrops and cliffs that have loose rocks overhead and thus, as always, the wearing of hardhats is essential at these localities.