Noel P. James
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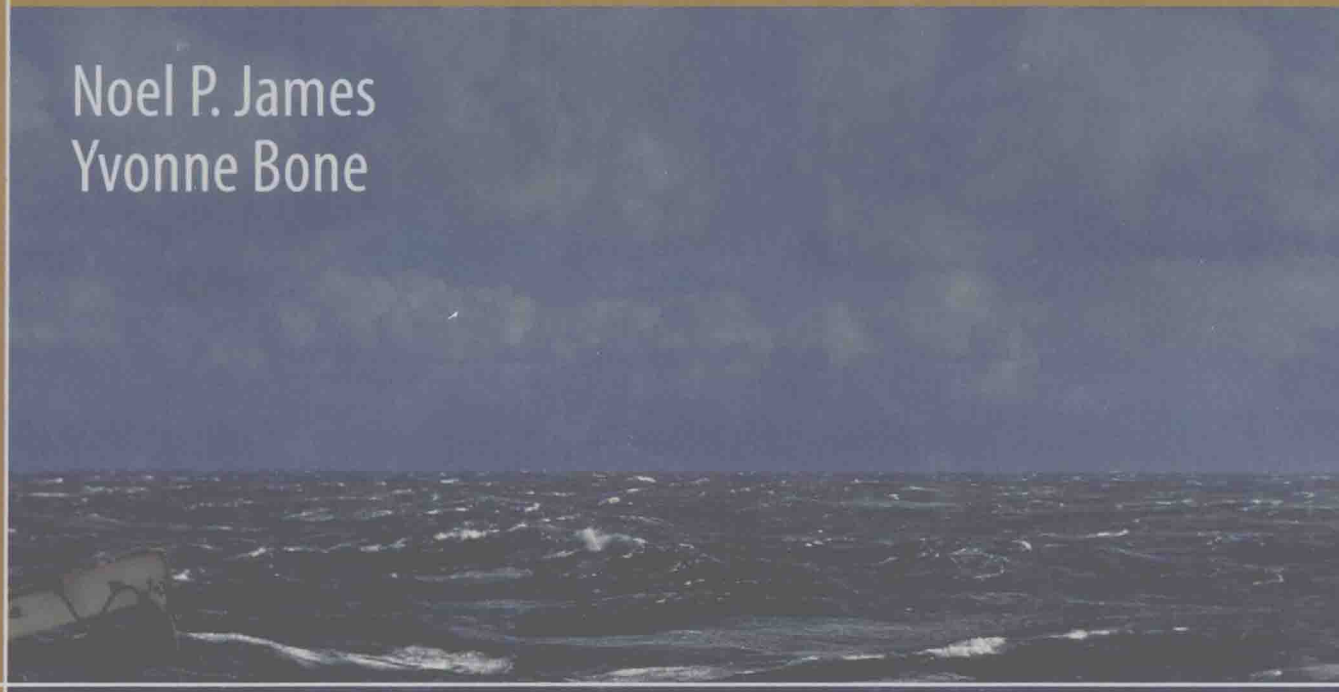

Neritic Carbonate Sediments in a Temperate Realm

Southern Australia

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Cover illustration: Force 6, the Southern Ocean, Great Australian Bight, October 1998 from RV *JOIDES Resolution*. The seafloor beneath these cold, stormy waters is the site of prolific temperate water carbonate sediment production and accumulation.

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To
Vic Gostin & Chris von der Borch

The Pioneers

Preface

Carbonate sediments deposited on shelves and ramps across the globe and in the geological record have traditionally been viewed as tropical, warm-water deposits (Bathurst 1975; Wilson 1975; Tucker and Wright 1990; James and Kendall 1992). Although it has been recognized for more than 50 years that carbonate sediments do accumulate in cool-water temperate and cold, polar environments (Chave 1952), it is only in the last several decades that these sediments have been studied seriously in the modern ocean (Nelson 1988a; James 1997; Pedley and Carannante 2006). This relative neglect is largely because they occur in environments that are difficult to document. The mid latitudes are stormy and the waters are cool but above all the shelves are mostly deep and so not amenable to research using SCUBA. The system must, as a result, be studied by remote sensing, chiefly through shipborne sampling, acoustic profiling, towed imaging and tethered water characterization. Scientific appreciation of the temperate carbonate depositional realm has thus lagged behind our understanding of the warm-water tropical environment. A direct consequence of this knowledge gap is that actualistic cool-water depositional models are not being routinely considered when interpreting the older rock record.

The Australian continent with its old, topographically subdued landscape, has a continental shelf that is almost entirely covered with carbonate sediment. The southern part of the continental shelf is the largest area of temperate, cool-water carbonate deposition in the modern world. Sediments in this vast southern region, in environments ranging from paralic to deep sea, have been examined by a variety of workers but the resultant information is scattered throughout the scientific literature (von der Borch et al. 1970; Wass et al. 1970; Belperio et al. 1988; James et al. 1992; Boreen et al. 1993; James et al. 1994; James et al. 1997; James et al. 2001; James et al. 2008), or presented as short, general summaries in special publications (James and Clarke 1997) and textbooks (Tucker and Wright 1990).

The purpose of this volume is to amalgamate and synthesize most of this information in one place, utilizing the studies of others, our own surveys, and unpublished data, to arrive at an overall synthesis of this critical region. The focus is on the continental shelf and its deposits. It is designed to serve as (1) a core of information for modern environmental studies, (2) a springboard for future marine geological research, and (3) a solid foundation upon which to build sedimentary facies and sequence stratigraphic models that are applicable to the interpretation of the older rock record.

This research has been funded by grant agencies from two countries, specifically the Natural Sciences and Engineering Research Council of Canada (NPJ), the Australian Research Council (YB), the Commonwealth Scientific and Industrial Research

Organization Division of Oceanography ship funding program, Geoscience Australia, and the University of Adelaide.

This science would not have been possible without the ceaseless efforts of officers and crews of CSIRO and Geoscience Australia vessels often under extremely difficult conditions. We are particularly grateful to Captain Neil Cheshire who skillfully guided us through many trying times and raging seas.

Our colleagues at sea and in the laboratory, Tom Boreen, Lindsay Collins, David Feary, Vic Gostin, Steve Hageman, Lisa Hobbs, Kurt Kyser, Jeff Lukasik, John Marshall, and Chris von der Borch are all silent partners in this endeavour.

The research at sea would have been impossible without the tireless efforts of Tony Belperio, Phil Bock, Kirsty Brown, Frank Brunton, Ric Daniels, Vicky Drapala, Margaret Fuller, Kieth Gaard, Paul Gammon, Karen Gowlett-Holmes, Graham Heinson, Alexandra Isern, Andrew Levings, Bobby Rice, Sam Ryan, Paul Scrutton, Rolf Schmidt, and Tony White. The exacting laboratory analyses were carefully performed by Christina Bruce, Elizabeth Campbell, Morag Coyne, Alexandra Der, Christa Kobernick, Heather Macdonald, and Rowan Martindale. Special thanks go to Isabelle Malcolm whose attention to detail, editing, analysis, and photographic skills helped greatly during the final stages of book production.

We are indebted to Peter Davies, Qianyu Li, Brian McGowran, Paul Taylor, and John Rivers for continuing discussions about our interpretations. Seafloor images from NW Tasmania were acquired with the help of Alan Williams and Bruce Barker.

The original manuscript was kindly read and criticized by Vic Gostin, Brian Jones, Andrew Levings, and John Middleton, to whom we are very grateful for their careful, insightful, and helpful suggestions.

Contents

Chapter 1
Introduction

1.1 Scientific Approach

Global carbonate sedimentation is partitioned into discrete marine realms whose character is determined by seawater temperature (Fig. 1.1). The latitude 25° S, which bisects the Australian continent, is the boundary between tropical, warm-water deposits in the north (e.g. the Great Barrier Reef) and temperate, cool-water sediments in the south (Fig. 1.2). Southern Australia is a classic area of shallow and marginal marine carbonate sedimentation (see review in Gostin et al. 1988). As such, it is one of a suite of modern settings that has been repeatedly utilized, along with Florida, the Bahamas, Caribbean islands, Pacific atolls, the Persian Gulf, and western Australia, as modern analogues for the interpretation of the carbonate rock record throughout geologic time. Thus, southern Australia is a touchstone for those scientists wishing to understand how carbonate sedimentation takes place today but also how it took place throughout geologic history. What has been lacking to date is a synthesis of the modern neritic carbonate sedimentary system that lies offshore from the well-studied marginal marine settings of southern Australia.

The purpose of this book is to document and interpret the origin, distribution, and diagenesis of surficial sediments on this immense cool-water carbonate shelf. It is perhaps useful to recall that the length of this environment is the same as the distance between New York to San Francisco or from the English Channel to the Caspian Sea.

The deposits across this shelf are, to a first degree, the products of modern oceanography, the Pleistocene prehistory of the region, and the organisms that produce the sediment. The first part of the book, comprising four chapters, is devoted to each of these aspects. In order to place the resultant neritic carbonates in a holistic context it is also necessary to describe the numerous coeval marginal marine depositional systems, most of which have been documented by others and are here the subject of a separate following chapter. The core of the book is, however, the chapters on neritic facies and depositional environments, many of which are unique to this continental margin. Yet, despite the universality of these facies and environments, each segment of the shelf has a unique suite of attributes. Thus, later chapters are devoted to analyzing the three major sectors of the southern Australian margin. Although the focus is on deposition, the sediments do not enter the rock record as simple biogenic particles, they undergo profound alteration on and just below the modern sea floor; early diagenesis plays an important part in this system and so a separate chapter is devoted to such matters. Finally, all of these aspects are assessed and discussed, both in terms of the modern sedimentary system and the applicability of our findings to global carbonate sedimentation.

1.2 Scope

The character of the sediments is interpreted in light of our current perception of the modern and late Quaternary biota, climate, oceanography, and geohistory of the area. The vast, latitude-parallel continental margin described herein extends some 4000 km from Cape Leeuwin, Western Australia to South West Cape at the southern tip of Tasmania (Fig. 1.3a). Over this distance there are a myriad of marine environments, each of which has a distinctive array of organisms and carbonate deposits. At the broadest scale, it is made up of a Southwestern

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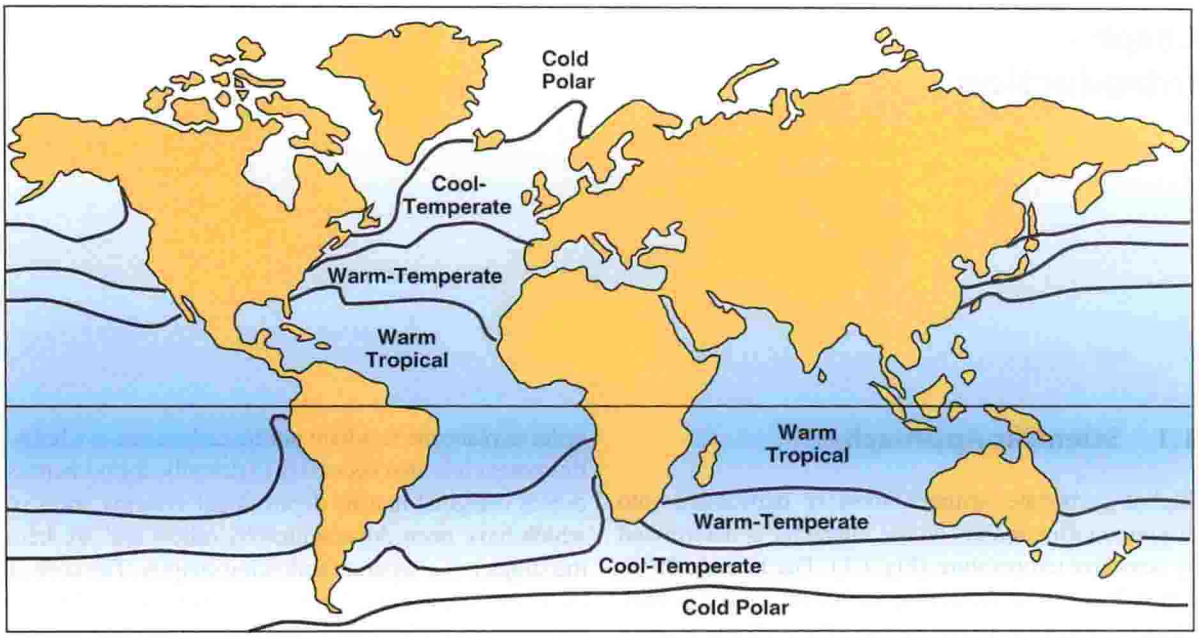

Fig. 1.1 A global map of average surface seawater isotherms delineating different modern carbonate depositional realms. The cool-water realm is differentiated into warm-temperate (15–20°C) and cool-temperate (5–15°C). (After James and Lukasik 2010)

Continental Margin and a Southeastern Continental Margin that pass from one to the other across a complex region of islands and large embayments called the South Australian Sea (Bye 1976) (Fig. 1.3b).

The Southwestern Continental Margin extends from Cape Leeuwin to southern Eyre Peninsula and includes the somewhat narrow Albany Shelf in the very west, but is dominated by the extensive Great Australian Bight. The Bight is, for purposes of documentation, divided into, from west to east, the Baxter, Eyre, and Ceduna sectors. The South Australian Sea is made up of Spencer Gulf, Gulf St. Vincent, Investigator Strait,

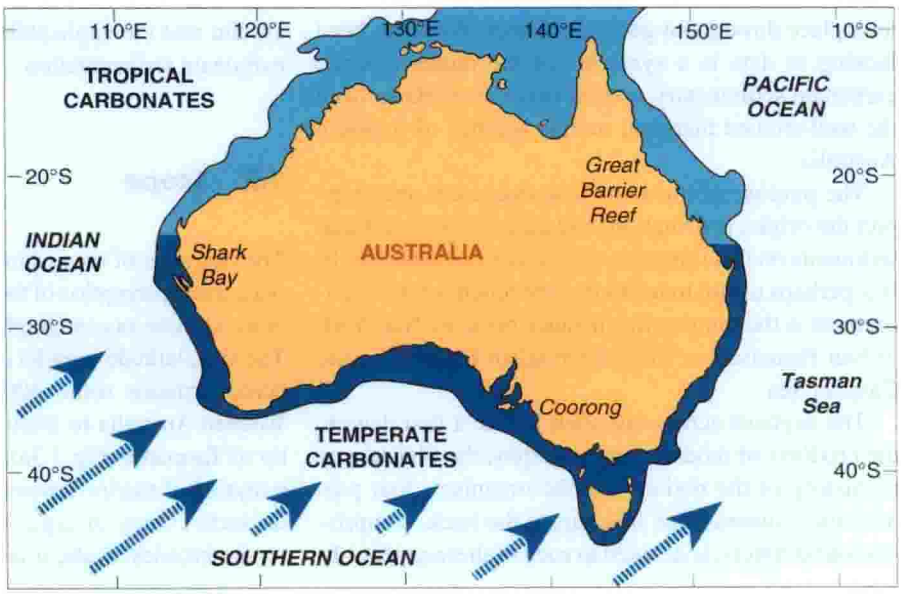

Fig. 1.2 A map of Australia illustrating the surrounding oceans, different neritic carbonate depositional realms (separated by the ~25° S latitude) and the direction of main wave approach (*dashed arrows*). Shark Bay, the Great Barrier Reef, and the Coorong are well known and intensively studied regions of carbonate deposition

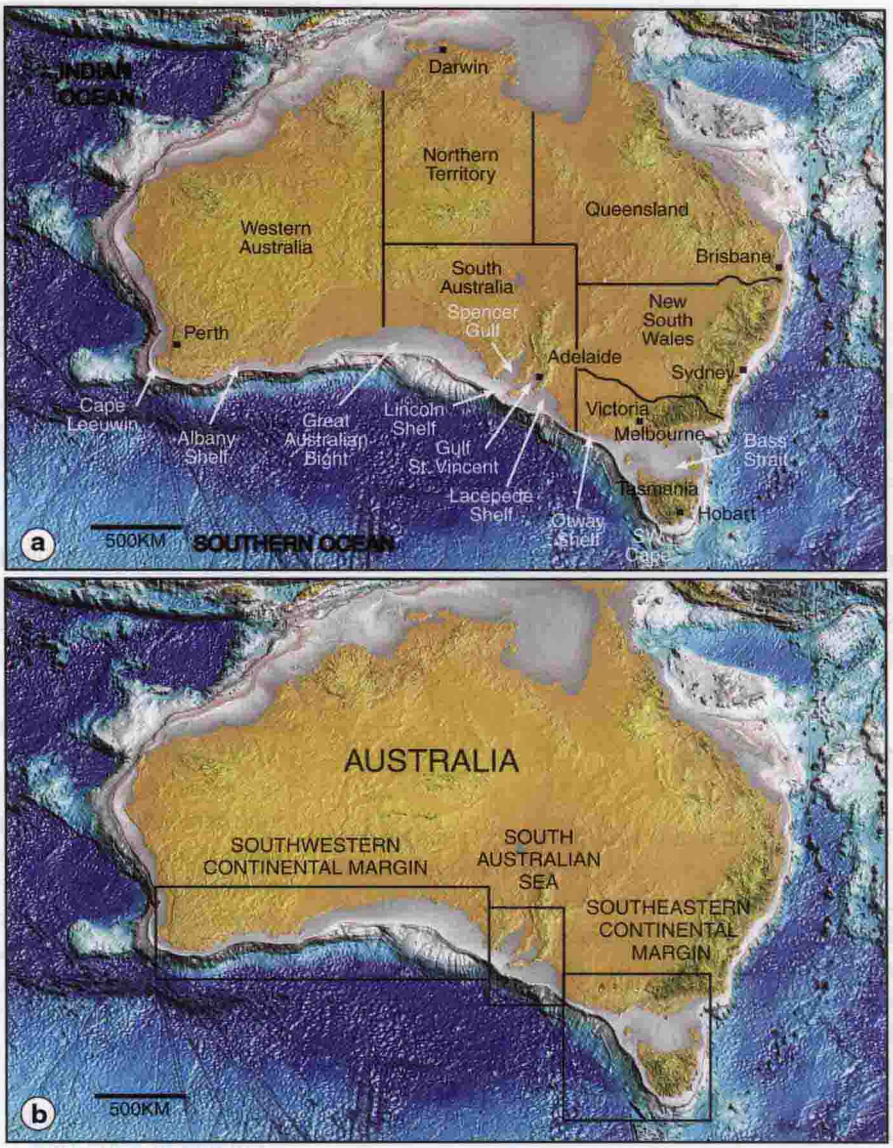

Fig. 1.3 (**a**) A map of Australia and surrounding oceans illustrating the states, major cities, and locations along the southern coast that are noted in this book. (**b**) Map of Australia showing the major sectors of the southern Australian continental shelf discussed in this book. Image courtesy of Geoscience Australia

the Lincoln Shelf, and the expansive Lacepede Shelf. The relatively narrow Southeastern Continental Margin fringes the west coast of Victoria as the Otway Shelf and swings southward along Bass Strait to flank Tasmania as the Western Tasmania Shelf. The scope does not specifically include the continental margin off Western Australia that faces the Indian Ocean or the eastern continental margin off eastern Tasmania, eastern Victoria and New South Wales that face the Tasman Sea.

The environments of sediment accumulation although numerous and varied, can be detailed and integrated under a few broad headings. At the core of this system is the subtidal, open marine seafloor and overlying water column. It is in this neritic sediment factory that stretches from the shoreface to the mid-slope, that most of the carbonate sediment is produced and redistributed. In spite of its largely latitude-parallel orientation, the shelf traverses nearly 15° of latitude, from ~31.5° to ~46° S, and ranges from warm temperate in the west to cool temperate in the east. This sediment factory is also active in the large gulfs and embayments, but because of local oceanographic and climatic constraints it is somewhat different from the open shelf factory. The important marginal marine settings range from spectacular high-energy cliffs to

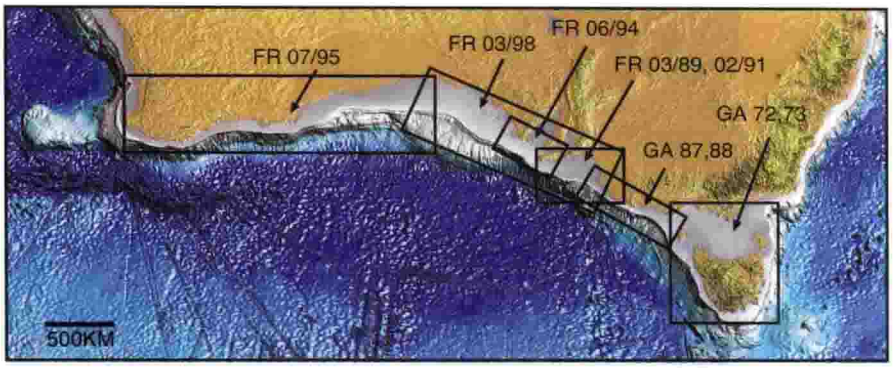

Fig. 1.4 A map of southern Australia. Research cruises (no. = month per year), mainly aboard *RV Franklin*, that enabled complete coverage of the southern continental margin of Australia. Some cruises overlapped previous areas so that seasonal changes in distribution and diversity of the major carbonate producers could be assessed. It also allowed sampling of sites that were not sampled due to weather extremes on previous cruises. Image courtesy of Geoscience Australia

protected muddy tidal flats to strandline dunes and associated saline lakes to fluvial-dominated beaches. Sediment in all of these settings undergoes moderate to significant diagenesis.

1.3 Data Base

The information in this volume comes from documentation of a series of local areas by ourselves, our students, and others over a period of more than 20 years. Research was mainly undertaken during a series of research cruises (Fig. 1.4). The open shelf environment has been documented by James et al. (1992), Boreen et al. (1993), James et al. (1997, 2001, 2008). The slope and associated mounds were described in Passlow (1997), James et al. (2004), von der Borch and Hughes-Clarke (1993), James et al. (2004), Hill et al. (2005), and Exon et al. (2005). The large embayments and their associated marginal facies have been intensively studied (see review for South Australia in Belperio 1995). More terrestrial settings, especially the saline lakes, are also reviewed in Belperio (1995) and Last (1992).

1.4 Data Acquisition and Methodology

The synthesis is principally based on analysis of seafloor sediment samples obtained using CSIRO *RV Franklin* (Fig. 1.5a). These research cruises took place between 1989 and 1998. The first expeditions were to the Lacepede Shelf in 1989 and again in 1991, with the latter focusing on the shelf margin and upper slope. This work was followed by a cruise to the Lincoln Shelf and southeastern Great Australian Bight in 1994. Work in the Great Australian Bight proper began in 1995 by documenting the western half of this huge area. This study was augmented in 1998 by a cruise that collected information from the Lacepede and Lincoln shelves but focused on the eastern part of the Bight. We have not collected samples from the eastern continental shelf ourselves but have generously been given material from the Tasmania continental margin and the Otway Shelf by Geoscience Australia who acquired sediments there in 1971–1972 and 1987–1988 respectively.

Research is based on a total of 1096 sediment samples (Table 1.1). Most of our material was obtained using either a simple pipe dredge (Bleys Dredge) with a volume of ~20 l (Fig. 1.5b), a large epibenthic sled with a 15 cm gape and volume of ~220 l (Fig. 1.5c), a beam trawl (Fig. 1.5d), or occasionally a Smith-McIntyre grab sampler (Table 1.1). Water depths are mostly >30 m, the shallowest operating depth for *RV Franklin*. The pipe dredge and sled were set on the bottom and towed at a speed of 2 knots for 3–5 min, at which time the vessel was stopped and the device retrieved. All sediment samples are, therefore, a mixture of surface and subsurface material to a depth of ~10 cm. A minor amount of the mud fraction may have washed out during retrieval, but enough samples with significant amounts of mud were recovered to indicate that such loss was minimal.

Fig. 1.5 **(a)** *RV Franklin*, the platform used to collect most of the samples and other marine information used in this book, **(b)** the pipe dredge (Bleys Dredge) used to collect most of the bottom sediment samples; hammer is 15 cm long, **(c)** the epibenthic sled being retrieved after sampling; the bag in the center is half full of sediment, **(d)** the material, seafloor biota, and sediment recovered by a beam trawl, **(e)** sediment being analyzed on the stern deck of *RV Franklin*. (Paul Gammon and Kirsty Brown)

Table 1.1 Samples

	Tasmania	Otway Rig Seismic 1987–1988 FR 02-91	Lacepede FR 3-89 FR 2-91	Eucla Rig Seismic 1992	Lincoln FR 06-94	Gab West FR 07-95	Gab East FR 03-98	Total
Grab	272	116	10	11	2	7	1	419
Bleys Dredge	0	0	149	0	52	91	19	311
Epibenthic Sled	0	0	0	0	15	103	91	209
Vibracore	0	24	0	11	0	0	0	35
Garvity Core	0	119	1	0	0	0	0	120
Piston Core	0	0	2	0	0	0	0	2
Total	272	259	162	22	69	201	111	1096