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Devonian and Permian fossils from the Falkland Islands in the biostratigraphy collection of the British Geological Survey

Marine Geosciences Programme

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BRITISH GEOLOGICAL SURVEY

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P Stone

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Keywords

Brachiopod, bivalve, trace fossil, West Falkland, East Falkland, Lafonia, Fox Bay Formation, Brenton Loch Formation.

Front cover

Impressions of the Devonian brachiopod Australospirifer hawkinsii in fine-grained sandstone of the Fox Bay Formation, West Falkland Group. Collected at Canard Cove, Port Louis Harbour, East Falkland [51° 33’ South, 58° 09’ West]. BGS image number P511901. The two-pence coin is 2.5 cm in diameter.

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Foreword

This report provides details, background information and illustrations for Devonian and Permian fossil specimens collected in the Falkland Islands, South Atlantic Ocean, and now lodged in the biostratigraphy collections of the National Geoscience Data Centre, British Geological Survey, Keyworth, Nottingham. The specimens were recovered during geological fieldwork by the British Geological Survey (BGS) as part of a geological consultancy programme led by Dr Phil Richards in support of the Department of Mineral Resources, Falkland Islands Government. Some of these fossils have subsequently been figured in both BGS publications and external publications in the broader scientific literature. They are mostly Devonian brachiopods from the Fox Bay Formation, West Falkland Group, and Permian bivalves from the Brenton Loch Formation, Lafonia Group.

Acknowledgements

Palaeontological advice was provided by Adrian Rushton and Robin Cocks of The Natural History Museum, London, and by Peter Brand, British Geological Survey, Edinburgh. The images of the fossils were produced by Fergus MacTaggart and Brian McIntyre and the specimens were curated by Sally Wild, all of the British Geological Survey, Edinburgh. In the Falkland Islands, logistical support was provided by the Department of Mineral Resources directed by Mrs Phyl Rendell.

Contents

Summary

A number of fossil specimens were collected in the Falkland Islands (South Atlantic Ocean) between 1998 and 2008 during geological fieldwork by the British Geological Survey (BGS) in support of the Department of Mineral Resources, Falkland Islands Government. The specimens have now been lodged in the biostratigraphy collections of the National Geoscience Data Centre, British Geological Survey, Keyworth, Nottingham, and this report provides background information on the collection and their geological setting, and illustrates some of the specimens. Two assemblages are present. Devonian fossils, mostly brachiopods, were recovered from the Fox Bay Formation, West Falkland Group; Permian fossils, sparse bivalves and representative examples of bioturbation, were recovered from the Brenton Loch Formation, Lafonia Group. The Devonian fauna is relatively well known, having been first discovered in 1833 by Charles Darwin during his voyage on HMS *Beagle*. The Permian fauna is very rare, with a few small bivalves known only from a single locality that was discovered during BGS fieldwork in 2001.

1 Introduction

A number of fossil specimens were collected by the author in the Falkland Islands (South Atlantic Ocean) between 1998 and 2008 during geological fieldwork by the British Geological Survey (BGS) in support of the Department of Mineral Resources, Falkland Islands Government. Some of these fossils have subsequently been figured in both BGS publications and external publications in the broader scientific literature. The specimens have now been lodged in the biostratigraphy collections of the National Geoscience Data Centre, British Geological Survey, Keyworth, Nottingham. This report provides background information on the fossil specimens themselves and on their geological setting, and illustrates some of the specimens. Two assemblages are present. Devonian fossils, mostly brachiopods, were recovered from the Fox Bay Formation, West Falkland Group; Permian fossils, sparse bivalves and representative examples of bioturbation, were recovered from the Brenton Loch Formation, Lafonia Group.

The Devonian fauna is relatively well known, having been first discovered in 1833 by Charles Darwin during his voyage on HMS *Beagle*. It is dominated by brachiopods, commonly in 'death assemblage' coquinas contained in micaceous sandstone where the fossils are preserved as internal moulds and external impressions, the shell material having been dissolved. Crinoids, tentaculitids and trilobites are abundant locally, with gastropods, bivalves and orthocones less common though widely present, accompanied by rare bryoza and conularia; a single starfish has been found. The more varied fauna is generally preserved in mudstone interbeds where the fossils may be exceptionally well preserved in carbonate-rich concretions. Bioturbation is widespread. The material deposited in the BGS collection mainly comprises brachiopod assemblages seen as impressions and moulds in fine grained sandstone.

The Permian fauna is very rare. The thick sequence of Permian sandstone and mudstone contains an abundance of plant material, including a distinctive *Glossopteris* flora, but until recently the only known animal fossil was the impression of an insect wing. A few small bivalves have now been recovered from a single locality during BGS fieldwork in 2001 and 2004.

A comprehensive modern geological account of the Falkland Islands is provided by Aldiss and Edwards (1999); more general, popular descriptions are given by Stone, Aldiss and Edwards (2005) and Stone (2010). The oldest Falkland Islands rocks are the *ca* 1000 million years old, granite and gneiss of the Proterozoic **Cape Meredith Complex**, which has a very small outcrop on the southernmost point of West Falkland (Figure 1). This 'basement' complex is unconformably overlain by the **West Falkland Group**, a thick succession of marine, near-shore clastic strata, definitively Devonian in part but possibly ranging in age from Silurian to Carboniferous: a fossiliferous unit in the middle of the group (Fox Bay Formation, about 400 million years old), was the source of the Devonian fossils described in this report. The West Falkland Group underlies most of West Falkland and the northern part of East Falkland. In the southern part of East Falkland a younger succession of strata, the **Lafonia Group**, has near its base a Permo-Carboniferous glacigenic unit (Fitzroy Tillite Formation, about 300 million years old, which passes upwards into a thick succession of Permian, mainly lacustrine strata. The lower part of the lacustrine succession (Brenton Loch Formation) was the source of the bivalve fossils described in this report. The metamorphic and sedimentary rocks are cut by a multitude of Jurassic and Cretaceous dolerite dykes ranging in age between about 180 and 120 million years.

The geology of the Falkland Islands correlates closely with that of South Africa because the two areas were adjacent within the immense Gondwana supercontinent prior to its break-up from about 150 Ma onwards. The West Falkland Group relates to part of the Cape Supergroup, with the Fox Bay Formation of the former being the equivalent of the Bokkeveld Group of the latter. The Lafonia Group relates to part of the Karoo Supergroup: the Fitzroy Tillite Formation of the former is the direct equivalent of tillites with the Dwyka Group of the latter; the Brenton Loch Formation of the former correlates with the upper part of the Ecca Group of the latter.

2 West Falkland Group

The group comprises four formations:

Port Stanley Formation	White quartzite and quartz-arenite with some siltstone and carbonaceous mudstone
Port Philomel Formation	Sandstone and mudstone with plant debris
Fox Bay Formation	Sandstone and mudstone with a widespread shelly fossil fauna
Port Stephens Formation	White quartzo-feldspathic arenite, locally conglomeratic

Within the Devonian Period, the shelly fauna from the Fox Bay Formation defines a Pragian-Emsian age, whilst miospores from the top of the Port Stanley Formation define a Famennian age. It is possible that the unfossiliferous Port Stephens Formation ranges down into the Silurian.

A number of historically important fossil collections have been recovered from the Fox Bay Formation and are held in British museums. Specimens obtained by Charles Darwin during the *Beagle* expedition (1831-36), and described by Morris and Sharpe (1846), are held mostly by The Natural History Museum, London, with a few at the Sedgwick Museum, Cambridge. The Natural History Museum also holds specimens collected when the James Clark Ross *Erebus & Terror* expedition over-wintered in the Falkland Islands in 1842, and a selection of other specimens acquired at various times since then from multiple donors (Rushton and Stone 2011; Stone and Rushton 2007, 2012). A small number of specimens acquired by the Scottish National Antarctic Expedition (1901-1903) are held in Edinburgh by National Museums Scotland (Newton 1906). The Hunterian Museum, Glasgow University, holds a small collection donated in 1915 by the Salvesen Whaling Company, which had been acquired during mineral prospecting work undertaken on the company's behalf by D Ferguson. Specimens collected by H. A. Baker in 1921-22, during the first attempt at a systematic geological survey, were split between The Natural History Museum and Imperial College, London (Stone and Rushton, 2006).

Important collections are held overseas in Stockholm, and New York. The Stockholm collections, at the Natur Historiska Riksmuseet, were obtained during the Swedish South Polar Expedition (1901-1903) and the Swedish Magellanic Expedition (1907-1908), see Andersson (1907) and Halle (1912) respectively. The New York collections are held by the American Museum of Natural History (AMNH) and the New York State Museum at Albany, NY. The Albany collection was initiated through collaboration between the eminent palaeontologist John Clarke and a local enthusiast, Mrs Constance Allardyce, wife of William Allardyce, Governor of the Falkland Islands from 1904 to 1915 (Stone 2009). Clarke (1913) remains the fundamental account of the Devonian palaeontology of the Fox Bay Formation. The AMNH collection has been acquired more recently, and recently-collected specimens are also held by the University of Sao Paulo, Brazil, and the University of Western Australia.

It is highly likely that collections of Devonian fossils from the Falkland Islands are held in Argentina, but as originating from Las Islas Malvinas and related to an independent lithostratigraphical nomenclature that is applied, albeit inconsistently, in the Argentine literature (e.g. Limarino et al. 1999; Mendía et al. 2008). In the Malvinas archipelago the two main islands become Gran Malvina (West Falkland) and Isla Soledad (East Falkland) and these names are applied to the West Falkland and Lafonia groups respectively. In the Grupo Gran Malvina, the Fox Bay Formation commonly appears as the partial translation Formación Bahia Fox. During the brief Argentine military occupation of the islands in 1982, Port Stanley was renamed Puerto Argentino. The usage has been maintained in Argentine literature and accordingly the Port Stanley Formation is commonly disavowed, Formación Caleta Shag being preferred (a partial translation of Shag Cove, a location in 'Gran Malvina').

The specimens of Devonian fossils from the Fox Bay Formation that have been lodged with the British Geological Survey are listed below.

LX1011 (Plate 1) … Internal moulds of the brachiopod *Schellwienella sulivani* and the smaller species *Australocoelia palmata*. Fox Bay, West Falkland [51° 57' South, 60° 05' West]. BGS image number P100659. Illustrated in figure 13 of Stone and others (2005).

LX1012 (Plate 2) … Various impressions and moulds mostly of the brachiopods *Schellwienella sulivani* and *Australospirifer hawkinsii* with a few examples of *Australocoelia palmata*; crinoids are also present. Canard Cove, Port Louis Harbour, East Falkland [51° 33' South, 58° 09' West]. BGS image number P549542. Illustrated in figure 13 of Stone and others (2005).

LX1013 (Plate 3) … Impressions and moulds of the brachiopod *Australocoelia palmata*, with one large example of *Australospirifer hawkinsii* (with partial counterpart) and the thorax and pygidium of a small calmoniid trilobite (at lower right). Saddle Quarry, West Falkland [51° 38' South, 59° 52' West]. BGS image numbers P549540, P549541 and P549543. Illustrated in figure 13 of Stone and others (2005).

LX1014 (Plate 4) … Internal moulds and external impressions of the brachiopod *Pleurothyrella falklandica*, with the pygidium of a small calmoniid trilobite. Dan's Shanty Creek, Port Salvador, East Falkland [51° 32' South, 58° 12' West]. BGS image number P573120. Illustrated in figure 13 of Stone and others (2005).

LX1015 (Plate 5) … A flattened example of the brachiopod *Orbiculoidea falklandensis*. Caneja Creek, Port Salvador, East Falkland [51° 51' South, 58° 16' West]. BGS image number P511907. Illustrated in figure 13 of Stone and others (2005).

LX1016 & 1017 … Two examples of the brachiopod *Orbiculoidea falklandensis* preserved in three-dimensions in small carbonate-rich concretions. South coast of Pebble Island, West Falkland [51° 18' South, 59° 41' West].

LX1018 (Plate 6) … The impressions of tentaculitids and a few brachiopods, mostly *Schellwienella sulivani*. Geordies Valley, Port Salvador, East Falkland [51° 31’ South, 58° 13’ West]. BGS image number P511896. Illustrated in figure 22 of Stone and others (2005).

LX1019 … Part and counterpart of brachiopods, most probably *Pleurochenetes falklandicus*. Caneja Creek, Port Salvador, East Falkland [51° 51’ South, 58° 16’ West].

LX1020 … Various impressions and moulds mostly of the brachiopods *Schellwienella sulivani* and *Australocoelia palmata*; crinoids are also present. Canard Cove, Port Louis Harbour, East Falkland [51° 33’ South, 58° 09’ West].

LX1021 … Impressions and moulds of various brachiopods, most notably a large example of *Australospirifer hawkinsii*. Part and counterpart. Canard Cove, Port Louis Harbour, East Falkland [51° 33’ South, 58° 09’ West].

LX1022 … Part and counterpart (in three pieces) of a large brachiopod, *Australospirifer hawkinsii*, demonstrating tectonic deformation. Canard Cove, Port Louis Harbour, East Falkland [51° 33’ South, 58° 09’ West].

LX1023 … A carbonate-rich concretionary layer preserving an assemblage of brachiopods, gastropods and crinoids. South coast of Pebble Island, West Falkland [51° 18’ South, 59° 41’ West].

LX1026 (Plate 7) … Bioturbated Fox Bay Formation sandstone with large (up to 12 mm diameter), concentrically segmented burrows. Port Howard, West Falkland. [51° 36’ South, 59° 31’ West].

3 Lafonia Group

The group comprises five formations:

Bay of Harbours Formation	Sandstone, siltstone and mudstone
Brenton Loch Formation	Sandstone, laminated siltstone and mudstone
Port Sussex Formation	Mudstone (some carbonaceous) and siltstone with minor sandstone and glacigenic diamictite
Fitzroy Tillite Formation	Glacigenic diamictite
Bluff Cove Formation	Sandstone, siltstone and mudstone

The Fitzroy Tillite Formation is the local representative of the widespread deposits arising from the latest Carboniferous to earliest Permian Gondwanide glaciation. A Permian *Glossopteris* flora is widespread in the Brenton Loch and Bay of Harbours formations.

A curiosity of the Fitzroy Tillite Formation is the presence within it of erratic clasts of Early Cambrian limestone; neither strata of that age nor rocks of that lithology are present in the Falklands. Overall, a wide range of lithologies is represented by the clasts within the tillite (mostly gneiss, schist, granite, quartzite and a variety of porphyritic hypabyssal rock types), with much previously described as having a relatively local origin within the Devonian sedimentary succession or its igneous and metamorphic basement (the Cape Meredith Complex). However, fossiliferous clasts of Fox Bay Formation sandstone are conspicuous by their absence, and the Cambrian limestone is the only fossiliferous material to have been recovered. The fossils are archaeocyaths and trilobites, a highly unusual assemblage for which the Transantarctic Mountains are the most likely source (Stone and Thomson, 2005). This is not as unlikely as it sounds since at the time of glaciation, ca 300 million years ago, the southern continents were united in the immense Gondwana landmass, with the Falklands microplate adjacent to areas that now comprise East Antarctica and South Africa. Significantly, the regional correlatives of the Fitzroy Tillite Formation – the Dwyka Group in South Africa and the Sauce Grande Formation in Argentina – both contain archaeocyathan limestone clasts with a similar fauna to that in the Falklands examples. Specimens of archaeocyathan limestone clasts from the Fitzroy Tillite Formation, along with a range of the more common clast lithologies have been lodged in the BGS rock collection (Stone 2011); the limestone clasts are numbered LX1004-1 to LX1004-5, LX1006-19 and LX1008-1 to LX1008-5. Their presence must cast some doubt on the supposed local provenance of many of the other clasts.

The *Glossopteris* flora was discovered during the Swedish South Polar Expedition (1901-1903) and much extended during the Swedish Magellanic Expedition (1907-1908); see Andersson (1907) and Halle (1912) respectively. Collections are held in London at The Natural History Museum, and in Stockholm at the Natur Historiska Riksmuseet. Remarkably, Halle also found the impression of an insect wing, described as being from a damselfly by Tillyard (1928). Plant fossil specimens collected by H. A. Baker in 1921-22, during the first attempt at a systematic geological survey of the Falkland Islands, were described by Seward and Walton (1923) and split between The Natural History Museum and Imperial College, London (Stone and Rushton, 2006).

The Permian bivalve fauna was discovered at Rory's Creek (Figure 1) on the south side of Choiseul Sound. The shells are contained in a laminated siltstone close to the top of the Brenton Loch Formation within its Saladero Member; a few bivalve specimens are closed and apparently in life position but most are splayed open or "butterflied" (Plates 8 and 9). Most of the shells have suffered slight tectonic deformation. The BGS collection comprises 6 specimens (LX 1010a to LX1010h – two specimens are represented by part and counterpart). The first was collected in 2001 (Plate 8) and the remainder in 2004; examples were figured by Stone and Rushton (2003) and by Stone and others (2005) without formal identification. Subsequent collecting by Brazilian palaeontologists in 2011 yielded a further 5 specimens which are held in the collection of the Laboratório de Paleontologia e Sistemática, Institute of Geosciences, University of Sao Paulo, Brazil. Both collections were then jointly described and figured by Simões and others (in press) who recognized a single taxon: *Palaeanodonta* cf. *P. dubia* (Amalitsky). *Glossopteris* leaves are present at the same stratigraphical level as the bivalves, and a variety of trace fossils are also present there and are widespread throughout the Lafonia Group (Plate 10).

The specimens lodged with the British Geological Survey are listed below. All were collected at Rory's Creek, Lafonia, East Falkland [51° 55' 44" South, 58° 53' 48" West].

LX1010a (Plate 8) … Concave impression of a splayed pair of conjoined bivalve shells. BGS image number P511904.

LX1010b (Plate 9) … Concave impression of a splayed pair of conjoined bivalve shells. BGS image number P573117.

LX1010c … Convex impression of a splayed pair of conjoined bivalve shells, counterpart of LX1010b. BGS image number P573118.

LX1010d … Convex impression of a splayed pair of conjoined bivalve shells.

LX1010e … Partial convex impression of a single shell.

LX1010f … Closed pair of shells, joined and preserved in life position.

LX1010g … Partial counterpart of LX1010f

LX1010h … Convex impression of a splayed pair of conjoined bivalve shells.

In addition to the above, two examples of Permian trace fossils have been lodged in the BGS collection. Bioturbation in a black mudstone (Plate 10) from the Terra Motas Member, Brenton Loch Formation was collected at Canada Runde Quarry, East Falkland [51° 49' South, 58° 41' West] and has the specimen number LX1024, BGS image numbers P549537, 8 and 9. Illustrated in figure 39 of Stone and others (2005). A branching trail from the Bay of Harbours Formation was collected at New Haven, Lafonia, East Falkland [51° 45' South, 59° 12' West] and has the specimen number LX1025.

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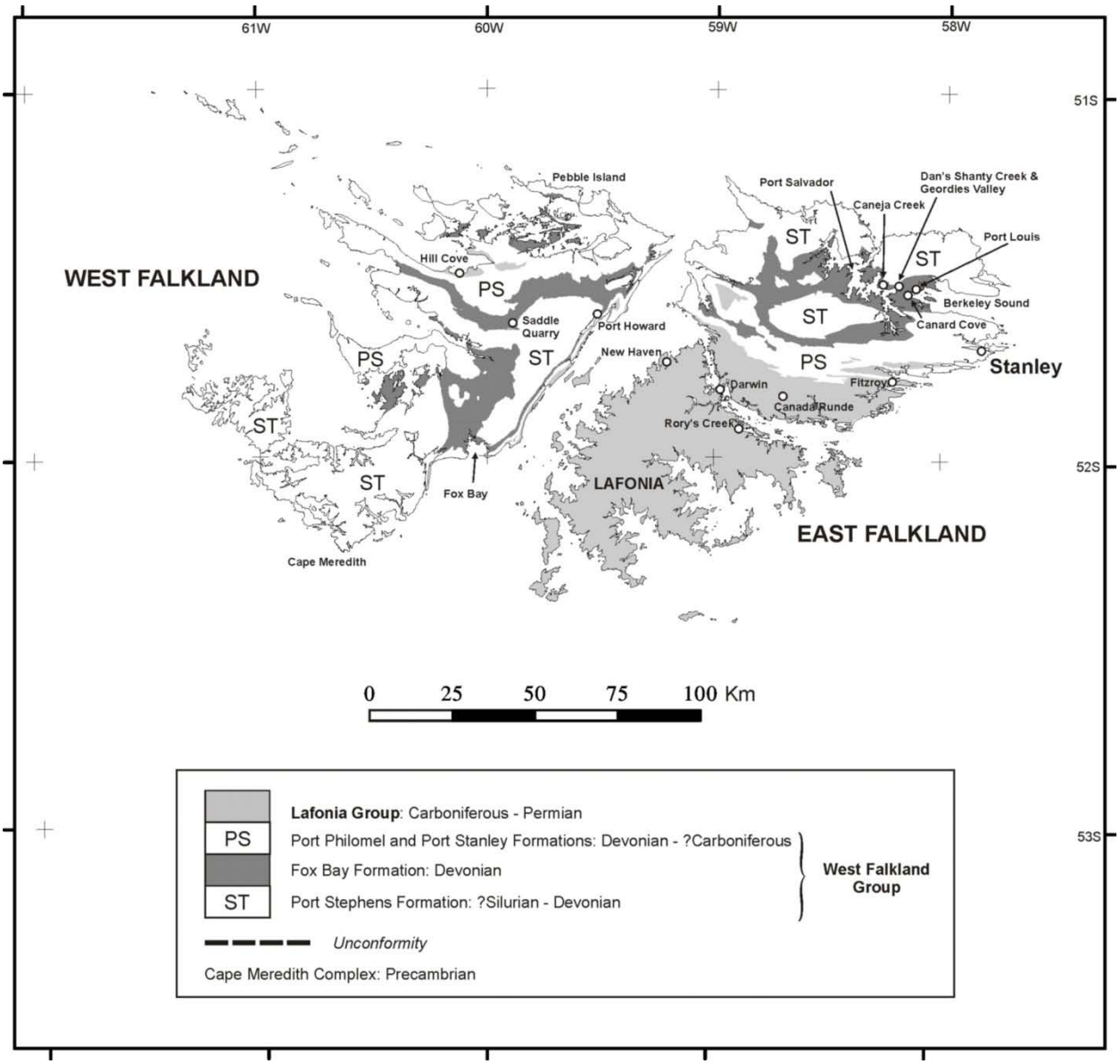

Figure 1. Outline geological map of the Falkland Islands showing locations from which fossils were collected

Plate 1. LX1011. Internal moulds of the brachiopod *Schellwienella sulivani* and the smaller species *Australocoelia palmata*. Devonian, Fox Bay Formation. Fox Bay, West Falkland [51° 57' South, 60° 05' West]. BGS image number P100659. Illustrated in figure 13 of Stone and others (2005). Coin is 2.5 cm in diameter.

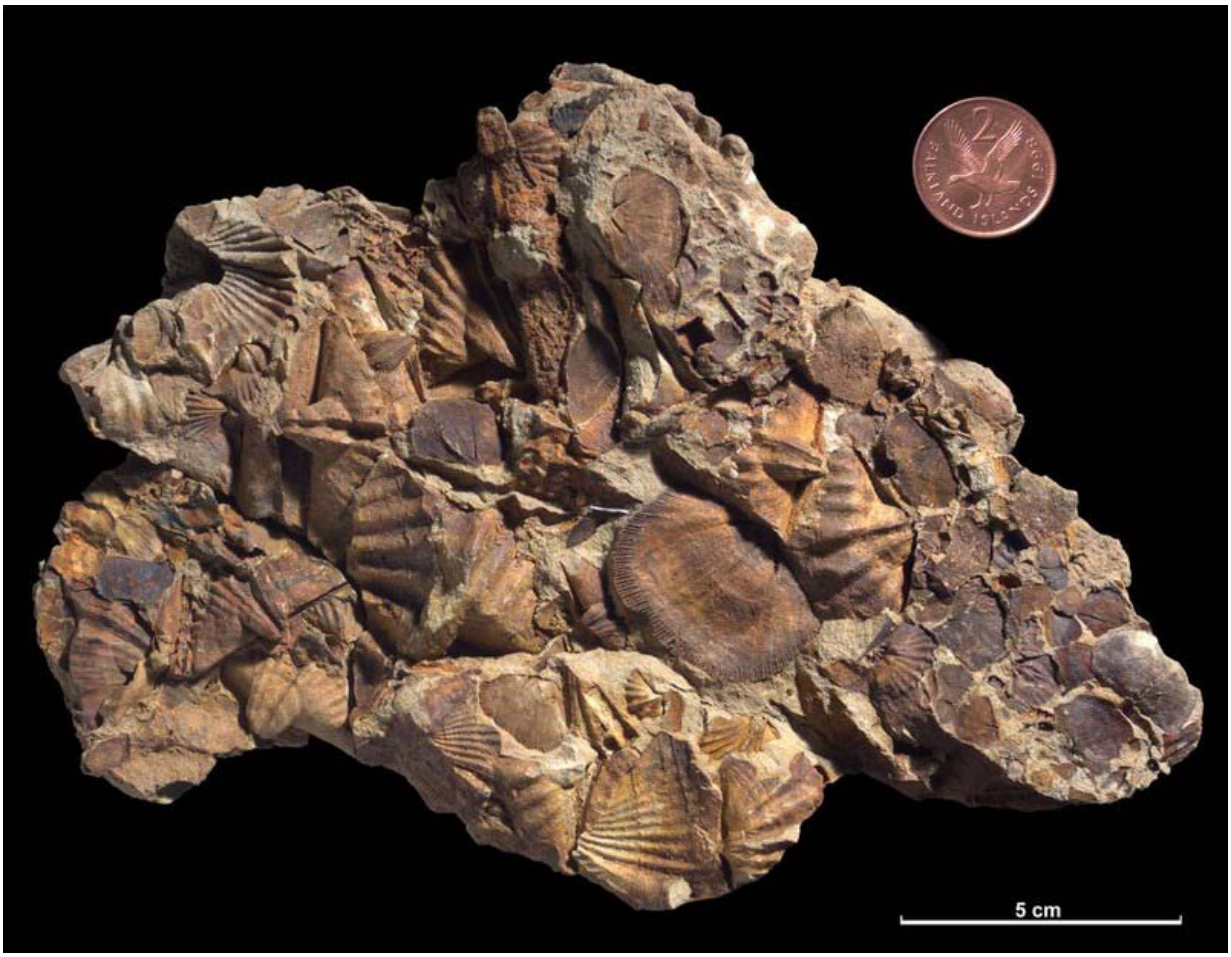

Plate 2. LX1012. Various impressions and moulds mostly of the brachiopods *Schellwienella sulivani* and *Australospirifer hawkinsii* with a few examples of *Australocoelia palmata*; crinoids are also present. Devonian, Fox Bay Formation. Canard Cove, Port Louis Harbour, East Falkland [51° 33' South, 58° 09' West]. BGS image number P549542. Illustrated in figure 13 of Stone and others (2005). Coin is 2.5 cm in diameter.

Plate 3. LX1013a. Impressions and moulds of the brachiopod *Australocoelia palmata*, with one large example of *Australospirifer hawkinsii* and the thorax and pygidium of a small calmoniid trilobite. Devonian, Fox Bay Formation. Saddle Quarry, West Falkland [51° 38' South, 59° 52' West]. BGS image numbers P549540,1 and P549543. Illustrated in figure 13 of Stone and others (2005). Coin is 2.5 cm in diameter.

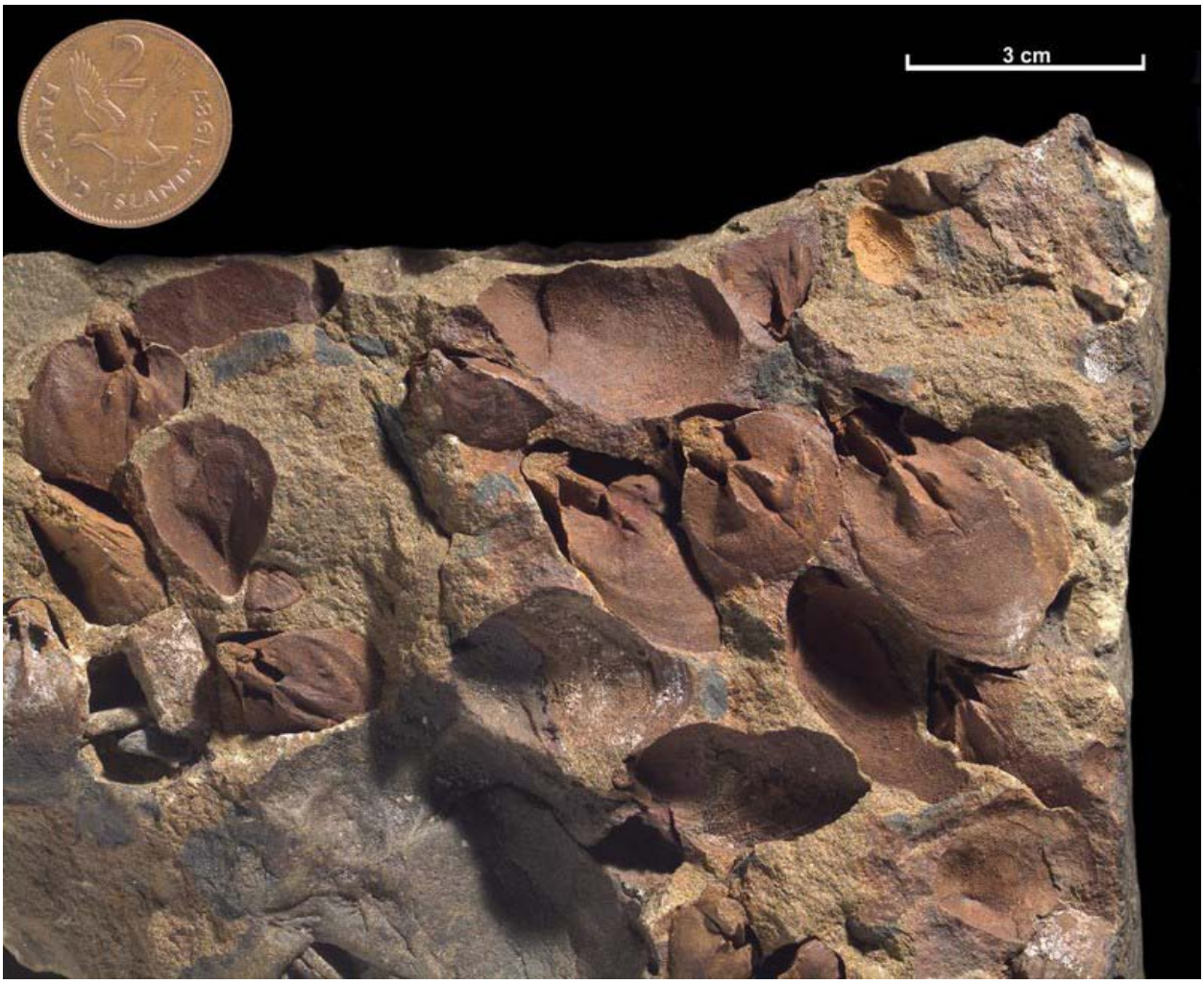

Plate 4. LX1014. Internal moulds and external impressions of the brachiopod *Pleurothyrella falklandica*, with the pygidium of a small calmoniid trilobite. Devonian, Fox Bay Formation. Dan's Shanty Creek, Port Salvador, East Falkland [51° 32' South, 58° 12' West]. BGS image number P573120. Illustrated in figure 13 of Stone and others (2005). Coin is 2.5 cm in diameter.

Plate 5. LX1015. A flattened example of the brachiopod *Orbiculoidea falklandensis*. Devonian, Fox Bay Formation. Caneja Creek, Port Salvador, East Falkland [51° 51' South, 58° 16' West]. BGS image number P511907. Illustrated in figure 13 of Stone and others (2005). Coin is 2.5 cm in diameter.

Plate 6. LX1018. The impressions of tentaculitids and a few brachiopods, mostly *Schellwienella sulivani*. Devonian, Fox Bay Formation. Geordies Valley, Port Salvador, East Falkland [51° 31' South, 58° 13' West]. BGS image number P511896. Illustrated in figure 22 of Stone and others (2005). Coin is 2.5 cm in diameter.

Plate 7. LX1026. Bioturbated Fox Bay Formation sandstone with large, concentrically segmented burrows. Port Howard, West Falkland. [51° 36’ South, 59° 31’ West]. Author’s photograph. Scale in mm.

Plate 8. LX1010a. Concave impression of a splayed pair of conjoined ("butterflied") bivalve shells: *Palaeanodonta* cf. *P. dubia* (Amalitsky). Permian, Brenton Loch Formation. Rory's Creek, Lafonia, East Falkland [51° 55' 44" South, 58° 53' 48" West]. BGS image number P511904. Illustrated in figure 5 of Stone and Rushton (2003). Coin is 2.5 cm in diameter.

Plate 9. LX1010b. Concave impression of a splayed pair of conjoined ("butterflied") bivalve shells: *Palaeanodonta* cf. *P. dubia* (Amalitsky). Rory's Creek, Lafonia, East Falkland [51° 55' 44" South, 58° 53' 48" West]. BGS image number P573117. Illustrated in figure 38 of Stone and others (2005).

Plate 10. LX1024. Bioturbated black mudstone from the Terra Motas Member, Brenton Loch Formation. Canada Runde Quarry, East Falkland [51° 49’ South, 58° 41’ West]. BGS image number P549538. Illustrated in figure 39 of Stone and others (2005). Coin is 2.5 cm in diameter.