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Some new fossil records and *notabilia* from the Falkland Islands

P. Stone[1, 2] and A. W. A Rushton[3]

1. Department of Mineral Resources, Stanley, Falkland Islands
2. British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA
3. Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD

During recent geological investigations in the Falkland Islands new fossil material, including some previously unrecorded species, was collected at several stratigraphical levels. The sedimentary rock sequence preserved in the islands (Figure 1) comprises marine but near-shore, clastic strata in the lower part, the West Falkland Group of Siluro-Devonian age, succeeded by marine to lacustrine clastic lithologies of the Lafonia Group, of Carboniferous to Permian age (Aldiss and Edwards 1999). At the base of the Lafonia Group is a glaciogenic unit, the Fitzroy Tillite Formation. The sequence is broadly comparable to those present in the originally adjoining parts of the Gondwana supercontinent now fragmented into South America, Africa and Antarctica. Particularly close stratigraphical similarities are seen between the Falklands and the Cape Fold Belt and Karoo Basin of southern Africa.

In the lower part of the West Falkland Group, the Port Stephens Formation quartzite contains various trace fossils, some of which are abundant and on a large scale, but no body remains. In contrast, the lithic sandstone and mudstone of the succeeding Fox Bay Formation contain a rich fossil shelly fauna of mid-Devonian (Emsian) age. All species then known from this unit were included in the faunal list compiled by Aldiss and Edwards (1999) though some of the nomenclature may now be superseded. The fossil assemblage is dominated by brachiopods, with trilobites, bivalves and gastropods all well represented; it is the fauna of the so-called “Malvinokaffric Realm”, found along the now-dispersed coastal fragments of Gondwana from Antarctica, through South Africa and into South America. Fossil plant material appears at the top of the Fox Bay Formation and is the dominant fossil type in the

succeeding Port Philomel Formation, although the host lithology is broadly similar. Rare fossil plant fragments also occur in the basal beds of the Port Stanley Formation, the youngest component of the West Falkland Group and composed dominantly of quartzite, but otherwise it is unfossiliferous.

Above the basal marine and glaciogenic beds, Permian lacustrine sandstone and mudstone comprise the majority of the Lafonia Group. They contain much fossil plant material with leaf and stem impressions well preserved locally; fragments of petrified wood are widespread – though not common. There is also a wide range of trace fossils, including extraordinary and recently-described fish trails (Trewin 2000) but no animal body fossils have been previously reported, with the exception of a remarkable insect wing impression found by T. G. Halle during the Swedish Magellanian Expedition (1907-08).

The Fox Bay Formation

This Early Devonian assemblage of sandstone and mudstone is the most richly fossiliferous part of the Falklands succession and was deposited about 400 million years ago. The fauna was originally discovered and collected by Charles Darwin in 1833 at localities around Port Louis Harbour. Subsequent collections brought back to Britain were obtained from the same general area, by members of the *Challenger* Expedition (1873-76) and the Scottish National Antarctic Expedition (1902-04). Preservation of the fossils from Port Louis is not particularly good, but when the outcrop of the Fox Bay Formation was found to extend across into West Falkland, much better fossil specimens were obtained. In particular, a site on Pebble Island was discovered wherein a mudstone contained carbonate concretions nucleated on fossils, many of which were trilobites. Patience and great care is required to extract the fossils undamaged from the hard concretions, but when this is successfully done the standard of preservation is exquisite.

The Pebble Island site was extensively collected in the early 20th century by Constance Allardyce, wife of the then Governor, who dispatched specimens to various museums and provided a fine collection that were described in detail by John M. Clarke in a monograph published in 1913 under the auspices of the *Servicio*

Geologico e Mineralogico do Brasil (not as odd as it sounds; remember the Gondwana connections). Those specimens ended up in the New York State Museum, of which Clarke was Director. Clarke also had access to specimens collected by J. G. Andersson during the Swedish South Polar Expedition (1901-03) and by T. G. Halle during the Swedish Magellanian Expedition (1907-08). More recently, in early 2000, another New York institution, the American Museum of Natural History, mounted a palaeontological expedition led by John Maisey. His group re-visited the Pebble Island locality and examined many other sections through the Fox Bay and Port Philomel formations. The extensive collections obtained are currently being studied but Maisey et al. (2002) have published briefly on fragmentary fish remains (spines, plates and tooth whorls) from localities in West Falkland. These include the first vertebrate remains to have been found in the Fox Bay Formation.

Two other aspects of the fossil fauna from the Fox Bay Formation can be illustrated from material collected recently at Pebble Island by one of the authors (PS). Snails are a well-known part of the fauna but we have found examples (Fig. 2a) of the genus *Naticopsis*, identified by Dr N. J. Morris, overgrown by a Trepostome Bryozoan, identified as such by Dr P. D. Taylor; sincere thanks to both of these specialists from The Natural History Museum, London. The previously unreported bryozoan would have grown on the shell once the snail had died; such growths are not generally present, as is the case in the second snail specimen (Fig. 2b) which is sufficiently well preserved for the growth lines on the shell to be clearly seen. Apart from this example, the quality of preservation in the Pebble Island fauna is also well illustrated by a carefully prepared cephalon (or head-shield) of the calmoniid trilobite *Bainella nilesi* (Fig. 3). The front and side views show a prominent occipital spine and, remarkably, the individual lenses on the elevated eye. These features are usually broken off by anything other than the most careful collecting.

The quality of preservation and varied fauna of the Pebble Island site clearly provides great potential for further discoveries. The fossiliferous outcrop has a limited area, largely littoral and subject to active marine erosion that removes the concretions from the host mudstone so that they can be readily collected. Casual extraction of the fossils invariably destroys much of their fine detail. With these features in mind, it

might be appropriate to consider giving the site a protected status as one of unique and particular scientific interest.

The Fitzroy Tillite Formation

The Fitzroy Tillite Formation is the representative in the Falkland Islands of the late Carboniferous to early Permian glaciogenic rock unit that is widespread across the fragments of Gondwana, recording a glacial episode about 290 million years ago. Gondwana began to break up about 200 million years ago and continental fragments were dispersed around the Southern Hemisphere, each fragment with its own part of the once-contiguous tillite succession: the Dwyka Tillite in South Africa, the Sauce Grande Formation in northern Argentina, the Whiteout Conglomerate in the Ellsworth Mountains, Antarctica etc.

The Fitzroy Tillite Formation of the Falkland Islands (Fig. 1) has recently been reviewed and formally defined by Aldiss & Edwards (1999). In West Falkland, a dark, sandy mudstone matrix contains and supports a variety of exotic rock fragments, mostly as small pebbles but ranging up to boulders 7 m across; this is regarded as a terrestrial, sub-glacial deposit. In the east, a dark grey and fine-grained muddy matrix contains a sparser assemblage of fragments that also tend to be smaller and of a more restricted lithological range than is seen in the west. The East Falkland tillite was probably deposited in marine conditions under a floating ice sheet.

The fragments in the Fitzroy Tillite were derived from a wide range of lithologies, most commonly quartzite, various granites and metamorphic rocks, and were carried into the depositional area by ice. Some may have been originally eroded from a Gondwanan source that is now some considerable distance away from the Falklands. Limestone fragments are relatively scarce but in some of those from West Falkland fossil archaeocyathids have been found. Archaeocyathids were a group of organisms, now extinct, that were closely related to the sponges. They had a calcareous skeleton usually consisting of two cones, one inside the other, connected by vertical and sometimes horizontal plates. They lived in a tropical, shallow-water environment. Fossil archaeocyathids range in size from only 1 or 2 mm to over 50 cm, but typically both their diameters and lengths lie between 0.5 and 3 cm. The first examples

appeared about 530 million years ago during the Lower Cambrian and archaeocyathids then diversified rapidly into hundreds of species that were important contributors to the construction of the first reefs. Despite their success they were a relatively short-lived group and were extinct well before the end of the Cambrian Period, less than 25 million years after their first appearance.

The first discovery of an archaeocyathid-limestone fragment, at Port Purvis, was entirely fortuitous. It was found early in 2002 by Judith Clay and Sue Macaskill during a visit to the gentoo penguin colony there whilst they were on holiday from the UK. They recognized the specimen as highly unusual and arranged for its recovery to Port Howard whence, through the good offices of Hattie Lee, it was sent on to the Department of Mineral Resources in Stanley for identification. A subsequent search of the West Falkland tillite outcrops by one of the authors (PS) led to the discovery of several more archaeocyathid-limestone fragments at Fox Point, near Hill Cove. Despite these more recent discoveries, the original specimen remains the most striking, clearly showing the fossils' fine detail on two wind-polished surfaces (Fig. 4 a&b).

Archaeocyathids are restricted to early Cambrian rocks, usually limestones, and there are neither rocks of that age nor that lithology within the rock sequence of the Falkland Islands. The limestone fragments in the tillite are therefore exotic to the Falklands, transported to the site of their deposition by an ice sheet during the latest Carboniferous to earliest Permian glacial episode. In terms of the original geography of Gondwana, the source of the limestone would most likely lie in areas that are now parts of Antarctica.

The Lafonia Group

The sandstone and mudstone of the Permian Lafonia Group were deposited in a huge inland lake about 275 million years ago. Plant fossils have been well known since the pioneering work of J. G. Andersson, during the Swedish South Polar Expedition (1901-03), and T. G. Halle during the Swedish Magellanian Expedition (1907-08); Halle also recovered the impression of an insect wing. The crawling and browsing trails made by lacustrine animals are also widespread (e.g. Trewin, 2000) but only

recently was the first body fossil of a lake-dwelling animal found by one of the authors (PS) at Rory's Creek on the south side of Victoria Harbour, Choiseul Sound. It is the impression in fine-grained sandstone of the conjoined shells of a small bivalve (Fig. 5). The stratigraphic level at which the fossil was found lies very close to the boundary of the Brenton Loch and Bay of Harbours formations, respectively the lower and upper components of the post-glacial, lacustrine sequence.

The preservation of the bivalve shells is too poor to allow formal identification, but their occurrence raises the hope that more fossils in better condition will be found in the future. In the South African Karoo sequence, with which the Lafonia Group is equivalent, some bivalve faunas have been recorded and are taken to indicate marine incursions into the otherwise freshwater inland basin. Additional fossils from the Lafonia Group might therefore aid regional correlation between these two fragments of the ancient Gondwana continent.

An overview of Falklands fossils

This article has concentrated on recent discoveries of fossils that were not previously known from the Falkland Islands. Apart from those described, there is a wealth of fossils, particularly in the Fox Bay Formation, forming an important part of the islands' scientific heritage. The most comprehensive recent account is in the report by Aldiss and Edwards (1999) that accompanies the 1:250 000 scale geological maps of the Falklands, and include a comprehensive bibliography. For those with a more general interest a full-colour brochure, *Fossils from the Falkland Islands*, has been produced recently by the Department of Mineral Resources, Stanley. Details are as follows:

Stone, P. and Aldiss, D. T. 2002. *Fossils from the Falkland Islands*. British Geological Survey for Department of Mineral Resources, Falkland Islands Government. Keyworth, Nottingham, NG12 5GG. ISBN 0-85272-447-0. Price £2. The brochure can be obtained from various outlets in Stanley, including the Department of Mineral Resources, or from the British Geological Survey offices in Keyworth and Edinburgh, UK.

Acknowledgements

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Specimens illustrated in figures 2, 3 and 4 are now in the palaeontology collection of The Natural History Museum, London. The specimen illustrated in figure 5 is held by the British Geological Survey, Keyworth, Nottingham.

References

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Maisey, J. G., Borghi, L and De Carvalho, M. G. P. 2002. Lower Devonian fish remains from the Falkland Islands. *Journal of Vertebrate Paleontology*, Vol. 22, 708-711.

Trewin, N. H. 2000. The ichnogenus *Undichna*, with examples from the Permian of the Falkland Islands. *Palaeontology*, Vol. 43, 979-997.

Figure captions

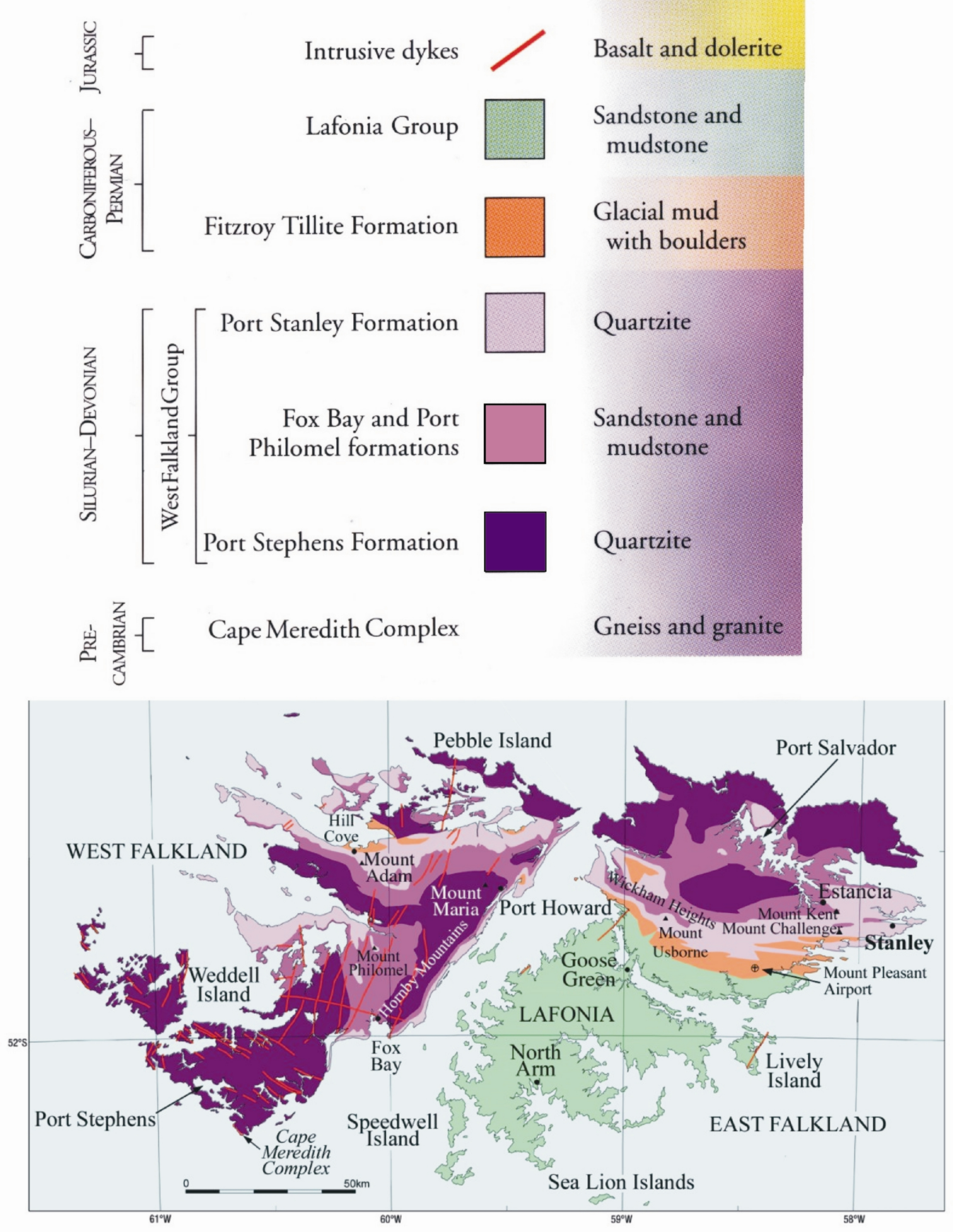
1. Outline geology of the Falkland Islands showing the location of the fossil sites.

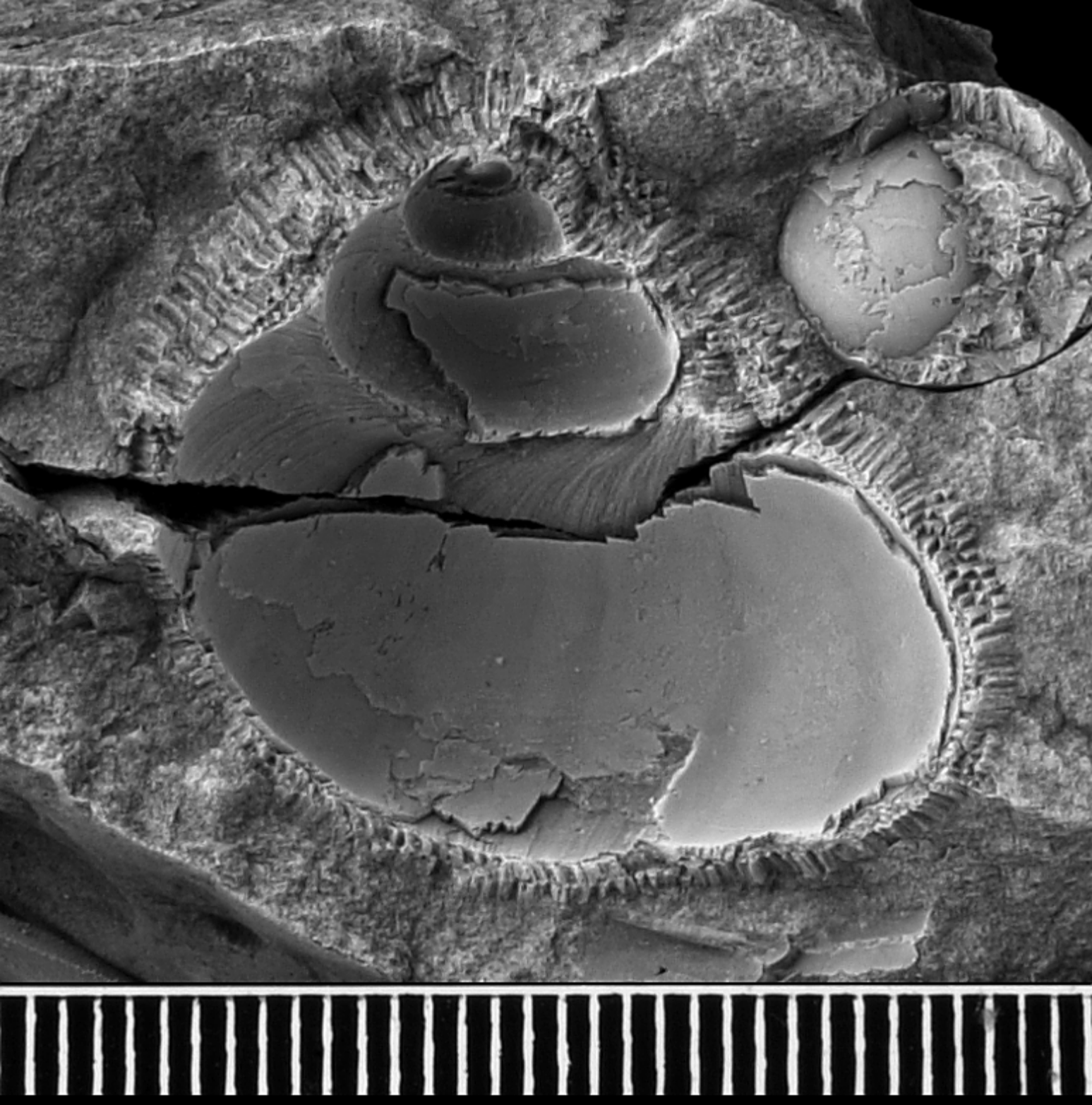
2. Snails from the Fox Bay Formation, Pebble Island: a. shell with overgrowth of bryozoa, scale in mm. Natural History Museum photograph; b. shell showing growth lines (also faintly visible in a), scale as for a. British Geological Survey photograph P511918.

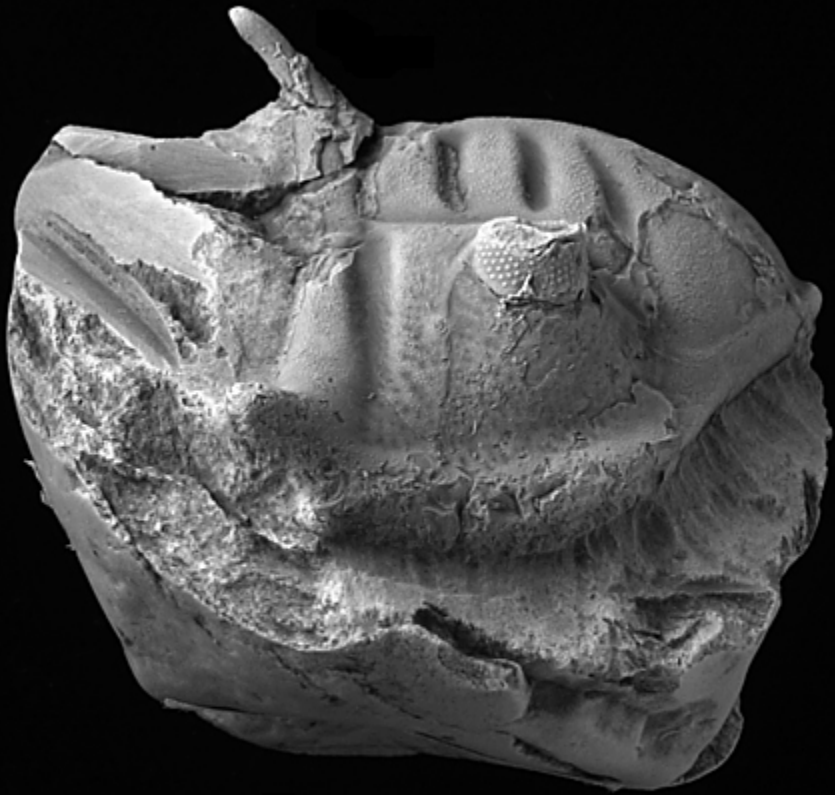
3. Trilobite cephalon from the Fox Bay Formation, Pebble Island; plan, front and side views, the latter two showing in particular the occipital spine and lenses on the eye. Scales in mm. Natural History Museum photographs.

4. Archaeocyathids from a limestone cobble in the Fitzroy Tillite Formation, Port Purvis: a. cross-sections showing circular wall surrounding a central cavity, at least two different species are present; b. lateral section showing detail of stucture within the perimeter wall. The 2 pence coin is 2.5 cm in diameter. British Geological Survey photographs P511905 & 6.

5. Impressions of conjoined shells of a small bivalve in fine grained sandstone of the Lafonia Group, Rory's Creek. British Geological Survey photograph P532008.


JURASSIC
Intrusive dykes
Basalt and dolerite
CARBONIFEROUS–PERMIAN
Lafonia Group
Sandstone and mudstone
Fitzroy Tillite Formation
Glacial mud with boulders
SILURIAN–DEVONIAN
West Falkland Group
Port Stanley Formation
Quartzite
Fox Bay and Port Philomel formations
Sandstone and mudstone
Port Stephens Formation
Quartzite
PRE-CAMBRIAN
Cape Meredith Complex
Gneiss and granite
Pebble Island
Port Salvador
Hill Cove
WEST FALKLAND
Mount Adam
Mount Maria
Port Howard
Wickham Heights
Mount Usborne
Mount Kent
Mount Challenger
Estancia
Stanley
Mount Philomel
Hornby Mountains
Weddell Island
Goose Green
Mount Pleasant Airport
LAFONIA
52°S
Fox Bay
North Arm
Lively Island
Port Stephens
Speedwell Island
EAST FALKLAND
Cape Meredith Complex
0
50km
Sea Lion Islands
61°W
60°W
59°W
58°W






2
FALKLAND ISLANDS 1987


2
FALKLAND ISLANDS
1981


1 cm