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Charles Darwin's discovery of Devonian fossils in the Falkland Islands, 1833, and its controversial consequences

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Abstract

In March 1833 Charles Darwin discovered Devonian fossils in the Falkland Islands. He was excited by his find but could have had little premonition of the long-running geological controversy that he was initiating. Darwin's fossils matched a coeval South African fauna, and as further collections were made the association was apparently strengthened. A particularly important contribution arose around 1910 through collaborations between a local collector, Constance Allardyce, and professional palaeontologists: Ernest Schwarz in South Africa and John Clarke in the USA. The accumulating evidence was seized upon by the early proponents of 'displacement theory' – continental drift – notably Alexander Du Toit, who relocated the Falkland Islands northward for his 1927 South Atlantic reconstruction. A more radical, but geologically sounder proposal arose in 1952 when Ray Adie suggested that the Falkland Islands, rotated through 180°, had originated as the eastward culmination of the Cape Fold Belt and Karoo Basin. In effect, Adie had presciently described a rotated microplate, perhaps the first on record. An opposing view saw the Falkland Islands as part of a fixed, South American promontory, and argument around these two contrasting interpretations of South Atlantic geology continues to the present day.

During the 1831–1835 voyage of HMS *Beagle*, Charles Darwin (1809–1882) paid careful attention to the geology and palaeontology of the lands visited, inspired by his reading of the newly published *Principles of Geology* by Charles Lyell (1795–1875). Following the voyage, Darwin incorporated most of his geological observations in a series of books and only one locality was described independently: 'On the geology of the Falkland Islands' was presented at the Geological Society of London's meeting on 25 March 1846 and published in the Society's journal later that year (Darwin 1846). The paper was complemented by a description of the Palaeozoic fossils, mostly brachiopods, which Darwin had discovered there in 1833 (Morris and Sharpe 1846). These publications unwittingly initiated a geological controversy over the regional geological relationships of the Falkland Islands that remains unresolved.

The Falkland Islands (also known as *Islas Las Malvinas*) lie in the SW part of the South Atlantic Ocean, centred around 52° S. 60° W., about 500 km east of the South American mainland (Fig. 1a). Two large islands, East and West Falkland, are surrounded by a score of substantial subsidiary islands and myriad smaller islands, rocks and reefs, which together comprise a total land area of just over 12,000 km^2. In terms of the archipelago's geographical position, aspects of the geology appear ambiguous. There are compelling correlations with the stratigraphy and structure of the Cape Fold Belt and Karoo Basin in South Africa, and from this have arisen ideas of a Falklands microplate, detached and rotated during the break-up of Gondwana and the opening of the Atlantic Ocean. Conversely, other lines of evidence appeared to favour a fixed position for the Falkland Islands as a promontory from South America.

This paper traces the origins of the controversy back to Darwin's palaeontological discoveries in 1833, examines its subsequent development, and identifies the principal early contributions. The combination of these themes establishes a strong local geoheritage for the Falkland Islands, with the influence of that geoheritage impacting more widely on the history of continental drift and plate tectonic theories. The importance of Darwin's experiences in the Falkland Islands to the development of his broader scientific ideas, and the details of his geological fieldwork there, have been reviewed by Armstrong (1992) and touched upon by Herbert (2005, p. 301) in her wide-ranging account of *Charles Darwin, Geologist*. It is possible that the Falkland Islands were more influential on Darwin's evolutionary thinking than has been generally recognised (Grove 1985).

An outline of Falkland Islands geology

Falkland Islands geology (Fig. 1b) has been surveyed and described in detail by Aldiss and Edwards (1999) and reviewed by Stone (2016); both these publications provide comprehensive bibliographies. A Mesoproterozoic basement, c. 1000 Ma, is overlain by a possibly Silurian to unequivocally Devonian succession of fluvial to neritic and shallow marine quartzite, sandstone and mudstone (West Falkland Group). This is succeeded with minimal unconformity by an upper Carboniferous to largely Permian succession that, near its base, includes a glacigenic diamictite, and thence passes up into a succession of deltaic and lacustrine sandstone and mudstone (Lafonia Group). Deformation of the West Falkland Group into a south-verging fold and thrust belt resulted in deposition of the Lafonia Group in the structurally preceding foreland basin. Dyke swarms of early Jurassic age are mostly confined to West Falkland; a swarm of Early Cretaceous dykes is sparse but more widespread. The similarity of the lithostratigraphy and deformation to that of the Cape Fold Belt and Karoo Basin is striking, as is the similarity of the Jurassic dyke swarms to the Karoo dykes of South Africa both in age and composition. But against these geological commonalities must be set the tectonic difficulties of transferring the Falkland Islands microplate from South Africa to South America as the South Atlantic Ocean opened. Further, no convincing deep structural break has yet been detected between the Falklands and the South American mainland.

Charles Darwin and the Devonian fauna

HMS *Beagle* made two visits to the Falkland Islands, first in March 1833 and again in March 1834. Whilst there, the ship was mostly based in Johnson Harbour on the north side of Berkeley Sound, East Falkland, whence Darwin explored East Falkland. He was not impressed:

> "3 March 1833. Took a long walk; this side of the island is very dreary: the land is low & undulating with stony peaks and bare ridges; it is universally covered by a brown, wiry grass, which grows on the peat. … The whole landscape from the uniformity of the brown colour, has an air of extreme desolation" (Keynes 1988, p. 145) (Fig. 2).

Nevertheless, Darwin and several of his *Beagle* shipmates are now celebrated in Falkland Islands placenames: Darwin, Fitzroy, Mt Usborne, Mt Sulivan, Wickham Heights *inter alia* (Fig. 1b).

Darwin was initially disappointed by the apparently limited scientific opportunities that the islands afforded, but that changed dramatically in mid-March 1833 during an exploratory walk from Johnson Harbour to the small settlement at Port Louis (Fig. 1b). As he recorded in his diary (Keynes 1988, p. 146–147): "The whole aspect of the Falkland Islands, were however changed to my eyes from that walk; for I found a rock abounding with shells; and these of the most interesting æra." Darwin recognised the fossils, mostly brachiopods, as being unexpectedly similar to varieties from what were then known in Britain as 'Transition Era' rocks, approximately equivalent to the modern Lower Palaeozoic. Hence, the brachiopods were amongst the oldest of their kind that were then known

(Fig. 3). Many of Darwin's diary and notebook entries illustrate his excitement at the discovery, his speculations on their wider significance, and his desire to see the fossils compared with those of similar age from elsewhere in the world.

Darwin's fossils were collected from what is now known as the Fox Bay Formation of the West Falkland Group (Aldiss & Edwards 1999). This group and formation also have extensive outcrops in the northern part of East Falkland (Fig, 1b) and it was from the East Falkland outcrop that Darwin collected his fossils. The precise locations are not recorded, but some of Darwin's material was found in the vicinity of Port Louis (Armstrong 1992), whilst there are several locations on the shores of Johnson Harbour where fossils may be obtained. This collection from East Falkland was supplemented some years later by at least one specimen of similar brachiopods from West Falkland, sent to Darwin by his great friend Bartholomew Sulivan (1810–1890). Sulivan had been lieutenant aboard HMS *Beagle* and later, when in command of HMS *Arrow* and HMS *Philomel* during subsequent surveying voyages around the Falkland Islands between 1838 and 1845, he sent additional geological information and specimens to Darwin (Stone & Rushton 2013).

The relatively soft sandstone and mudstone of the Fox Bay Formation has very little inland exposure, but commonly forms low seashore cliffs (Fig. 4). At Darwin's collecting localities around Berkeley Sound, and in most other parts of the Fox Bay Formation outcrop, the fossils are preserved only as impressions and moulds, all the original shell material having been dissolved. They may occur individually but are commonly found accumulated into shell-drifts. A slight tectonic deformation affects many of the specimens from the Berkely Sound area.

Most of Darwin's fossils from the Falkland Islands, including the examples supplied by Sulivan, were identified and formally described by Morris and Sharpe (1846). John Morris (1810–1886) and Daniel Sharpe (1806–1856) were amongst the leading British palaeontologists of their time and from Darwin's collection they described nine species of brachiopods (subsequently revised, see Table 1), a bivalve, crinoid columnals and fragmentary trilobite remains; this material, about 40 fossiliferous specimens, is now held by The Natural History Museum, London. A smaller collection of about 20 specimens, brachiopods and crinoids that were probably regarded as inferior duplicates, is held by the Sedgwick Museum, University of Cambridge. All this material has been reviewed by Stone and Rushton (2013) who noted that the Sedgwick Museum also holds (in the Harker petrology collection) six specimens that had been enigmatically referred to by Darwin as *Gorgonia*. Recently rediscovered, these fossils prove to be articulated fragments of branching crinoid arms. Probably to Darwin's great disappointment, Morris and Sharpe were only prepared to give a generalised 'Silurian to Devonian' age for his Falklands fossils; Devonian is now the consensus, within the Pragian to Emsian stages.

Ten years after his work on Darwin's fossils from the Falkland Islands, Daniel Sharpe was involved in the description of another Devonian fauna from the southern hemisphere, this one from the 'Bokkeveld Beds' of South Africa (now the Bokkeveld Group). In respect of the brachiopods from a diverse fauna, Sharpe and Salter (1856) were surprised to note:

> "… the only locality where any of these South African species have previously been found is in the Falkland Islands; and it is very remarkable that, of the nine species brought back from those islands by Mr Darwin … five are contained in the collection from the Cape."

Sharpe and Salter also described trilobites, one of which, as noted by Herbert (2005, p. 301), had been initially assigned by Sir Roderick Murchison (1792–1871) to the lower part of his Silurian System, before he revised the age to Upper Silurian or Devonian (Murchison 1859, p. 455). By correlation with the Bokkeveld fauna, the same age could be applied to the Fox Bay Formation of the Falkland Islands.

Expanding Darwin's collection

Following Darwin's discovery, additional collections of fossils from the Berkeley Sound area were acquired during two other 19th century expeditions whose main focus was elsewhere: in 1842 during the James Clark Ross *Erebus* and *Terror* Antarctic expedition (1839–1843), and in 1876 during the oceanographical *Challenger* expedition (1872–1876). Senior surgeon aboard HMS *Erebus* was Robert McCormick (1800–1890) whose principal, if unfortunate, claim to fame is to have left HMS *Beagle* early in the voyage when he discovered that his anticipated role as ship's naturalist had been usurped by the youthful Charles Darwin (Steel 2011). McCormick's fossil collection was only passed to The Natural History Museum's predecessor on his death and has never been fully examined (Stone 2020). The *Challenger* fossils were described by Robert Etheridge Jnr (1885), but their value is diminished by uncertainty over their provenance, and the current whereabouts of the specimens is unknown (Stone & Rushton 2012). Both collections mostly comprised brachiopods and crinoids, duplicating Darwin's fauna, but Etheridge noted the first gastropod – a small bellerophontid gastropod is present in one of Darwin's specimens but was not recorded by Morris and Sharpe – and, unknowingly, McCormick collected tentaculitids (Stone & Rushton 2013).

At the beginning of the 20th century another small fossil collection was acquired in 1904 by the Scottish National Antarctic Expedition (1902–1904) which included trilobite fragments in addition to the more abundant brachiopods and crinoids (Newton 1906); the specimens are now held by National Museums Scotland. But it was fossil collections made at around the same time by two

Swedish geologists that finally confirmed the likelihood that the Fox Bay Formation of the Falkland Islands would contain trilobites corresponding to those from the Bokkeveld Group.

In 1902, Johan Gunnar Andersson (1874–1960) spent some time in the Falklands whilst waiting to rendezvous with the ship, *Antarctic*, supporting the 1901–1903 Swedish South Polar Expedition. He made extensive fossil collections from localities in both East and West Falkland (Andersson 1907), but sadly much of his material was lost when *Antarctic* was crushed by ice and sank. The surviving part of his collection, mostly brachiopods from Fox Bay, West Falkland, that had been left stored in Stanley, is held by Naturhistoriska Riksmuseet in Stockholm, Sweden. Andersson's work in the islands was extended by his colleague Thore Halle (1884–1964), who made considerable progress towards an overall geological understanding of the Falkland Islands in the 1907–1908 austral summer, during the Swedish Magellanic Expedition (Halle 1911). Much of Halle's specimen collection is also held in Stockholm but it does not appear to include his Devonian fossils from the Falkland Islands, the whereabouts of which remain uncertain.

The long-term value of Andersson's and Halle's collections is vested in their use by the eminent palaeontologist John Mason Clarke (1857–1925), Director of the New York State Museum, Albany, NY, USA, in a major review of the Devonian faunas of South America, particularly those of the Parana Basin of Brazil and Bolivia (Clarke 1913). This work remains the most comprehensive discussion of the Devonian fossils from the Falkland Islands, although Clarke did not re-examine Darwin's collection, relying instead on the descriptions by Morris and Sharpe (1846). However, there was one additional contributor to the material available to Clarke, a local collector living in Stanley. This was Mrs Constance Allardyce (1861–1919), the wife of the Governor, William Lamont Allardyce (Fig. 5). She and her husband had arrived in the Falkland Islands in 1904, and during Governor Allardyce's tenure of office, one initiative was the construction of a new Town Hall in Stanley; Constance Allardyce is credited with ensuring that the building contained facilities for a library and a museum.

Mrs Allardyce began a fossil collection for the museum and encouraged searches in the more distant parts of the archipelago. She actively supported Halle during his work in 1907-1908, as he acknowledged: "It was by means of these collections that I first learned of several finds which afterwards proved to be of great importance for our geological investigations" (Halle 1911, p. 6). At about the same time, knowing of the established similarity between Darwin's fossils and the coeval fauna from South Africa, she had embarked on a scientific collaboration with the South African palaeontologist Ernest Schwarz (1873–1928), exchanging information and specimens. Schwarz acknowledged her contribution in his book *Causal Geology*:

> "I have to thank Mrs. W. L. Allardyce; for sending me in exchange a collection of Devonian fossils from Pebble Island in the Falkland Islands; there are no differences in regard to the species, or the matrix they are in, between these Falkland Island fossils and those of the Bokkeveld beds of South Africa" (Schwarz 1910, p.160).

The Pebble Island fossil site had been discovered shortly after Halle had left the islands, during the 1908–1909 austral summer and most probably by the children of the local McAskill farming family (Stone 2009). In contrast to the residual impressions and moulds seen elsewhere, at Pebble Island the fossils are preserved complete in calcareous nodules and careful preparation reveals fine detail (Fig. 6).

Fortuitously for Clarke, his request to the Governor of the Falkland Islands for assistance in acquiring specimens of local fossils coincided with the discovery of the Pebble Island site. Naturally, Governor Allardyce passed the enquiry to his wife. The material that she sent to Clarke probably surpassed his wildest dreams and much correspondence between him and Mrs Allardyce is preserved in the Falkland Islands' Jane Cameron National Archive. One letter, dated 8 January 1910, was partially reprinted in the *Falkland Islands Magazine and Church Paper* for May 1910. It concludes: "I salute you, Mrs Allardyce, as the most successful of Falkland Islands geologists, not excepting Charles Darwin himself."

Clarke made a detailed analysis of the fossils sent to him by Constance Allardyce, some partly prepared and tentatively identified by her, and incorporated descriptions and illustrations in his extensive, bilingual monograph *Fosseis Devonianos do Paraná*, published by the Serviço Geológico y Mineralógico do Brasil (Clarke 1913). Therein, he lists 22 species identified from the Allardyce material, including trilobites, brachiopods, bivalves, gastropods, crinoids and orthocones. He named the trilobite *Metacryphaeus allardyceae* for her, and the gastropod *Diaphorostoma allardycei* for her husband, the Governor. In terms of the regional correlations of the Falkland Islands fauna, Clarke thought the trilobites to have stronger South African affinities than the more cosmopolitan brachiopods – a view of the brachiopods subsequently disputed, most recently by Penn-Clarke and Harper (2021) who found marked provincialism – but overall, he concluded:

> "The community of species in the Falkland Islands and South Africa is noteworthy … It is perhaps somewhat extraordinary that in both sedimentary facies and in fauna the resemblance of the Falkland Islands Devonian is closer to that of South Africa than to that of South America" (Clarke 1913, p. 56-57).

The Allardyce collection is still held in the New York State Museum, Albany, NY, and Clarke's monograph remains one of the most important reference sources for the Falkland Islands Devonian fauna. Clarke's long-standing respect for his erstwhile collaborator (whom he never met) is evident in the touching obituary he published in *Science* following her premature death (Clarke 1919), by which time her husband had been elevated to Sir William, and so she to Lady Allardyce. A sad epilogue to the story was the loss in 1944 of the entire Falkland Islands museum collection, including all the Allardyce fossils that had been retained locally, in a catastrophic fire which destroyed the Stanley Town Hall and associated buildings.

Continental Drift to Plate Tectonics

During Halle's geological work in the Falklands, he had recognised another important link with South African geology. At Hill Cove on the north coast of West Falkland (Fig. 1b) he identified a tillite, a glacial diamictite, and correctly suggested a correlation with the diamictites of the Dwyka Group in South Africa. Curiously, the same site had been described to Darwin by Sulivan in a letter dated 10 May 1843 (Darwin Correspondence Project, letter 675). Therein he described an unusual conglomerate from the south side of Byron Sound, on the north coast of West Falkland, as follows:

> "… it is nearly a hard clay, the colour yellow in one part & blue in another, yet everywhere containing boulders & Pebbles, of other rocks not found in the Islands - I never saw such a variety - beach at the foot of the low cliff is strewed with Pebbles of all sizes … from a marble to two or three feet in diameter. All appear to be primitive rocks. Granites of all shades and colours kneiss (I forget how to spell it) syanite [*sic*] and I know not what slate, basalt (at least I think so) &c &c. The cliff crumbles away fast and can almost be dug with a spade the Rock is so soft."

This is a perfect description of the cliff section exposing the Fitzroy Tillite Formation (Lafonia Group) at Hill Cove (Fig. 7). Darwin appreciated the association with ice, but at the time he interpreted such deposits as coastal accumulations of material drifted in by icebergs (Stone & Rushton 2013).

Halle's interpretation and correlation was confirmed when Herbert Arthur Baker (1885–1954) made the first attempt at a systematic geological survey between 1920 and 1922. Baker's remit was primarily a search for economic minerals and though unsuccessful in that respect his work was thorough and comprehensive (Baker 1924).

By that time, the palaeontological and geological similarities between the Falkland Islands and South Africa were being cited as evidence by the early proponents of 'displacement theory' – continental drift – and Baker was supportive of the idea. One notable champion was the eminent South African geologist Alexander Du Toit (1878–1948), who was the first to suggest a physical removal of the Falkland Islands to a position more compatible with their perceived relationship to the regional geology of Gondwana once South Africa and South America were reunited (Du Toit 1927, 1937). In his reconstruction the Falklands were moved about 1500 km to the north to lie between the western Cape Province of South Africa and the Sierra de la Ventana region of Argentina (Fig. 8), where similar successions of rocks had been recognised (Keidel 1916). Alfred Wegener (1880–1930), the principal architect of 'displacement theory', was broadly supportive of Du Toit's reconstruction in the 4th edition of his book *Die Ehtstehung der Kontinente und Ozeane* (Wegener 1929).

For the Falkland Islands, Du Toit's reconstruction proved untenable, but the issue was readdressed in a radical proposal by Adie (1952) who saw their geology as the eastward extension, and culmination, of the Cape Fold Belt and the Karoo Basin (Fig. 9). Raymond J. Adie (1925–2006), a South African geologist, had spent time in the Falkland Islands in 1950 whilst travelling north after geological work on the Antarctic Peninsula with the Falkland Islands Dependencies Survey (now British Antarctic Survey). He travelled widely around the islands, studying the geology, and collected fossils at numerous locations; with his South African background he immediately recognised the similarities. Adie's fossil collection is preserved in the Sedgwick Museum, University of Cambridge, and in his notes accompanying the specimens he simply uses the contemporary South African stratigraphical terms; hence his Falkland Island fossils are assigned to the Bokkeveld Series (Stone & Rushton 2012).

When Adie reconstructed the Falkland Islands to the east of South Africa he introduced the requirement for a reversal of their north-south orientation, on well-founded geological grounds. On the larger scale, in South Africa the Karoo Basin lies to the north of the Cape Fold Belt whereas in the Falkland Islands the relationship of the equivalent units is reversed, Lafonia hosts the Karoo equivalents and is south of the deformed strata that correlates with the Cape Fold Belt. Adie also noted the similarities of the Falkland Islands igneous dyke swarms to South African examples and included them all as 'Karoo dolerites'. On a smaller scale, Adie looked to the depositional details of the glacigenic diamictites, noting that in the Falklands these appeared to show ice movement from south to north, contrasting with the broadly north to south movement thought to apply in South Africa. All of this, together with a similarity in structural style was presented by Adie in support of his model which, he hoped, "will afford additional strength to the displacement hypothesis".

Adie envisaged that as the Atlantic Ocean opened there was considerable rotation of an independent Falkland Islands crustal block as it moved into its current orientation adjacent to South America. In effect, he had identified and described what would now be regarded as the independent movement of a microplate; that may well have been the first time such a phenomenon had been invoked. But this was 1952 and continental drift was mostly still thought of as fringe eccentricity. Adie's paper seems to have aroused little interest at the time and was largely forgotten for the next thirty years.

Despite the dismissal of continental drift as a mechanism for separating the Falkland Islands from South Africa, the geological similarities between the two areas remained an enigma. However, an alternative and strengthening view from South America saw things rather differently and was epitomised by a review of Falkland Islands geology by Borrello (1963), based largely on the work of Baker (1924), that stressed perceived correlations with the mainland of Argentina in preference to the South African connection. Borrello regarded the Falkland Islands (*Las Malvinas*) as part of a fixed continental promontory extending from South America into the Falkland Plateau (Fig. 1a), with the metamorphic rocks of the Deseado Massif in Argentina extending eastward to underlie the archipelago. By 1972, even Adie seems to have lost confidence in his South African reconstruction, apparently endorsing a fixed, South American connection in Greenway (1972). This, despite the advent of plate tectonics providing a respectable mechanism for microplate movement and rotation.

The dormant controversy was reignited when the first palaeomagnetic results from the Falkland Islands, from Jurassic dolerite dykes, were reported by Mitchell *et al*. (1986). These initial findings were taken to show substantial rotation of the dykes and their host rocks since their intrusion, an interpretation seemingly confirmed by a more detailed study (Taylor & Shaw 1989). This did not settle the matter. The palaeomagnetic results were challenged, lively debate has continued without reaching a consensus, and the geological complexities involved have been broadened by the increasing availability of offshore data from the surrounding parts of the South Atlantic. A substantial body of literature has been generated, recently reviewed by Stone (2015, 2016) and Stone and McCarthy (2021) with an acknowledged South African bias, whereas the South American link has been championed by Ramos *et al*. (2017, 2019) and accommodated in regional reconstructions such as that by Eagles and Eisermann (2020), a radical and challenging reinterpretation. Other assessments have considered the geometrical process by which a Falklands microplate might rotate away from an African origin: Marshall (1994), Storey *et al*. (1999), Johnston (2000) and Stanca *et al*. (2019, 2022). The last-named of these authors have slightly adjusted Adie's palaeogeography to meet a rotational history rigorously modelled from marine geophysical data.

From the Falkland Islands, we identify the following recent contributions as of particular importance to the continuing debate.

- Detailed studies of the Jurassic dykes by Mitchell *et al*. (1999) and Hole *et al*. (2016) reinforced correlations with the Karoo swarms of South Africa and the Ferrar swarm of East Antarctica.
- Curtis and Hyam (1998) described the close similarity in the style of folding and character of deformation between the Falklands and the Cape/Karoo system of South Africa, despite the opposing asymmetry, as currently positioned.
- Detailed stratigraphical correlations were drawn between parts of the Falkland succession and the coeval strata in the Cape Fold Belt and Karoo Basin of South Africa by Trewin *et al*. (2002) and by Hunter and Lomas (2003).
- Contrasting asymmetric aeromagnetic anomalies produced by the early Jurassic dykes and a subsequently discovered suite of early Cretaceous dykes were thought by Stone *et al*. (2009) to suggest intrusion of the older dykes before, and the younger ones after, a rotation of their common host rocks.
- A distinctive Cambrian fossil fauna in erratic limestone clasts from the Fitzroy Tillite Formation was described by Stone *et al*. (2012), who noted similarities with clasts from the Dwyka Group diamictites and proposed a source in the Transantarctic Mountains of East Antarctica. Craddock *et al*. (2019) also related the abundance of garnet grains in the Fitzroy Tillite to an Antarctic source.

Geoheritage and site status

The Falkland Islands geological sites identified in this article contribute to

geoheritage in both local terms and in respect of the scientific development of global geological theories. They provide a direct link with the 19th century explorers of the region, notably the British naturalists Charles Darwin and Robert McCormick, and the Swedish geologists Johan Gunnar Andersson and Thore Halle. Their observations and collections, enhanced by the work of the locally based amateur palaeontologist Constance Allardyce, once integrated into regional palaeobiogeography by the American palaeontologist John Clarke, then proved influential for the promotion of continental drift by Alfred Wegener and Alexander Du Toit. For that controversial proposal, the South Atlantic region provided a crucial case study.

The sites described are still accessible. Indeed, with the coastal tussock grass vegetation severely depleted by livestock grazing, the exposure is probably now more extensive than it was during the pioneering visits. The sites have no formal protection or conservation issues. They are on private land and are in relatively remote localities which are difficult to reach without the cooperation of the local community. Nevertheless, tourism is an increasingly important factor in the Falkland Islands economy with geology and geoheritage recognised as part of the islands' appeal to visitors (Falklands Conservation 2021). Site visits should therefore not be difficult to arrange. An export licence from the Falkland Islands Government is required for any geological specimens taken from the islands.

Epilogue

The controversy surrounding the regional geological relationships of the Falkland Islands, initiated by the fossil collection gathered by Darwin in 1833, continues unresolved, having played a generally unrecognised part in the evolution of 'displacement theory' – continental drift – into plate tectonics. Darwin, noting the varied background of the Falkland Islands settlers and the conflicting British and Argentinian territorial claims, observed that the islands were "a bone of contention between different nations" (Keynes 1988, p. 148), but nevertheless, he would most probably be astonished by the geological arguments that his discoveries set in motion.

Palaeontology was taken to provide the first indications of a South African geological connection for the Falkland Islands, albeit its importance has been reduced by more recent research and discoveries. Nevertheless, that early interpretation, together with the accumulation of other evidence during the first half of the 20th century, was seized upon by the early proponents of continental drift, notably Du Toit, who relocated the Falkland Islands northward for his 1927 South Atlantic reconstruction. Du Toit's reconstruction was soon rejected but led to the prescient interpretation by Adie (1952) which effectively viewed the Falkland Islands as a rotated microplate, some years before that concept was accommodated within the mechanisms of plate tectonics. Since Adie published, much additional data from the Falkland Islands has tended to support the broad premise of his proposal that they originated as the eastward culmination of the Cape Fold Belt and Karoo Basin. Conversely, an equally vigorous case has been made that the Falkland Islands lie on a fixed promontory from the South American mainland, with stress placed on the lack of evidence for a deep structural break to the west of the Falkland Islands. It seems unlikely that the issue will be resolved until unequivocal palaeomagnetic data are available.

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Archives

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Figure Captions

Figure 1

a. The location of the Falkland Islands in the South Atlantic Ocean.
b. Outline geology of the Falkland Islands after Aldiss & Edwards (1999) showing key localities.

British Geological Survey images © UKRI.

Figure 2

The view west from a position near Port Louis. The quartzite of the Port Stanley Formation is the source of the boulders in the foreground (part of a periglacial blockfield) and forms the ridge of hills in the far distance. The Fox Bay Formation underlies the low, middle ground and the Port Salvador embayment (a large ria system). Image by P. Stone. British Geological Survey image number P697169 © UKRI.

Figure 3

A specimen collected by Charles Darwin at Port Louis, East Falkland. The brachiopods *Australospirifer hawkinsii* (labelled b) and *Schellwienella sulivani* (labelled c and named after Lieutenant Bartholomew Sulivan of HMS *Beagle*) are associated with a scattering of crinoid columnals (B17794). The Falkland Islands 2 pence coin is 25 mm in diameter. © Trustees of the Natural History Museum, London, reproduced under the terms of a Creative Commons Attribution Licence (CC-BY 4.0)

Figure 4

A typical coastal exposure of the Fox Bay formation at the NE end of Port Salvador. Robert McCormick collected fossils in this vicinity in 1842. Image by P. Stone. British Geological Survey image number P1027059 © UKRI.

Figure 5

William Allardyce (Governor of the Falkland Islands) and Mrs Constance Allardyce (2nd and 3rd adults from the right) with their two children and guests in the Government House conservatory, Stanley, c. 1906. Image reproduced with permission from the Brandon Album, Jane Cameron National Archives, Stanley, Falkland Islands.

Figure 6

A cephalon of a calmoniid trilobite, probably *Bainella nilesi*, collected from Pebble Island and prepared by the authors (PS and AWAR, respectively) (It27132). The fine details of the fossil, including the individual lenses of the compound eye (arrowed), have been preserved in a carbonate-rich concretion: a - plan view; b - lateral view. Linear scale in mm. © Trustees of the Natural History Museum, London, reproduced under the terms of a Creative Commons Attribution Licence (CC-BY 4.0).

Figure 7

The beach at Hill Cove littered with exotic cobbles and pebbles eroded from the cliffs of Fitzroy Tillite Formation diamictite. Bartholomew Sulivan's description from 1843 is still apposite. Image by P. Stone. British Geological Survey image number P1027060 © UKRI.

Figure 8

The Early Permian position proposed for the Falkland Islands by Du Toit (1927, 1937) as a link between the Sierra de la Ventana (Argentina) and the Cape Fold Belt (South Africa) in his reconstruction of the Gondwana supercontinent. *Mesosaurus* is a distinctive terrestrial vertebrate fossil. After Du Toit 1937, fig. 13. British Geological Survey © UKRI.

Figure 9

The Early Permian position proposed for the Falkland Islands by Adie (1952, fig. 3) as the eastward culmination of the Cape Fold Belt and Karoo Basin of South Africa. Note the 180° rotation of the islands. British Geological Survey © UKRI.

Table Caption

Table 1 Taxonomic nomenclature applied to Darwin's fossil brachiopods

Morris and Sharpe (1846)	**Clarke (1913)**	**Cocks cited in Aldiss & Edwards (1999)**
Orthis sulivani	*Schuchertella sulivani*	*Schellwienella sulivani*
Orthis concinna	*Leptostrophia concinna*	*Protoleptostrophia concinna*
Orthis tenuis		*Australostrophia mesembria?*
Atrypa palmata	*Leptocoelia flabellites*	*Australocoelia palmata*
Chonetes falklandica	*Chonetes falklandicus*	*Pleurochonetes falklandicus*
Spirifer hawkinsii	*Spirifer hawkinsii*	*Australospirifer hawkinsii*
Spirifer antarcticus	*Spirifer antarcticus*	
Spirifer orbignii		
Orbicula (undetermined)	*Orbiculoidea baini*	*Orbiculoidea falklandensis*

Table 1

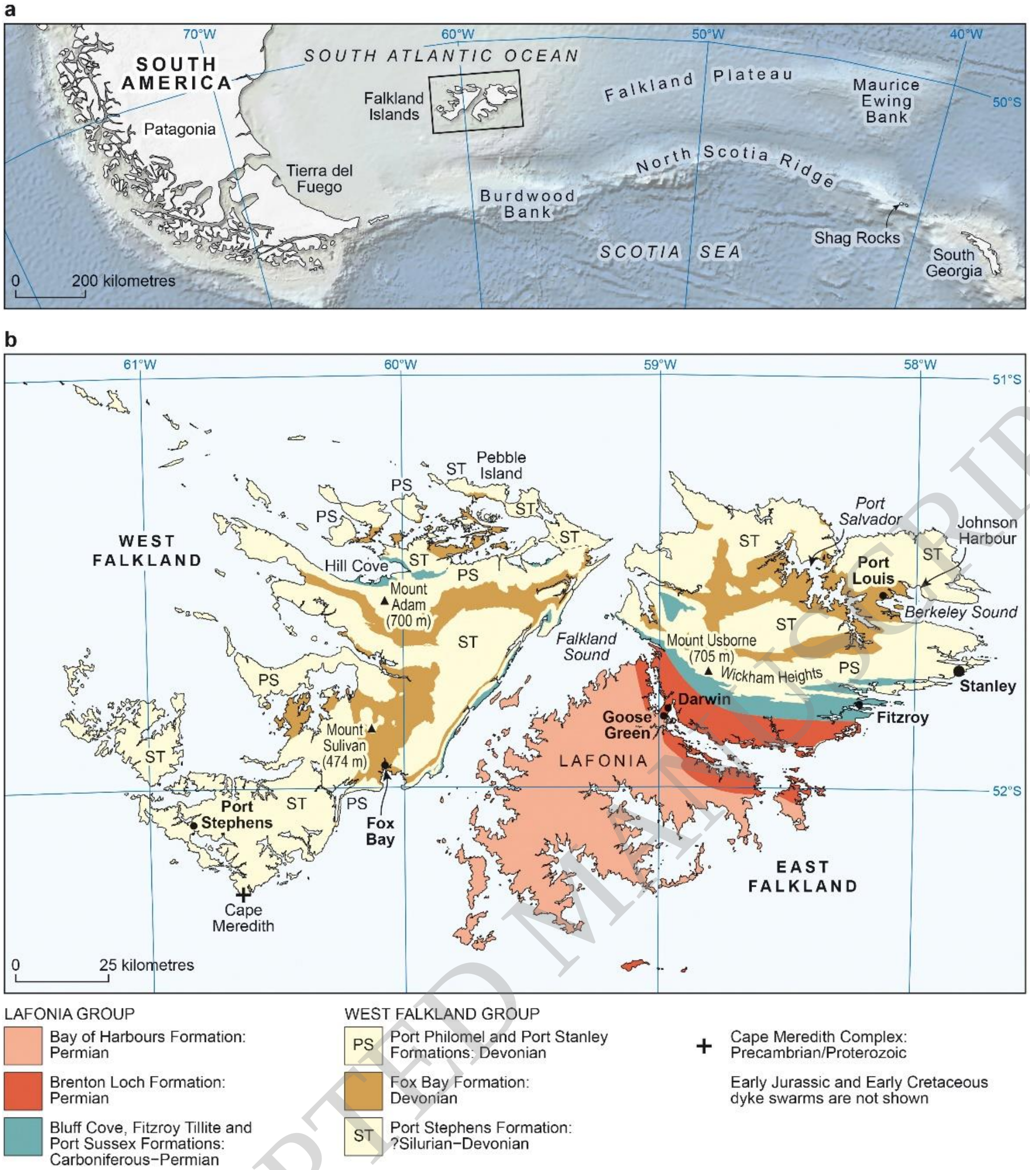
a
70°W
60°W
50°W
40°W
50°S
SOUTH AMERICA
SOUTH ATLANTIC OCEAN
Falkland Islands
Falkland Plateau
Maurice Ewing Bank
Patagonia
Tierra del Fuego
Burdwood Bank
North Scotia Ridge
Shag Rocks
South Georgia
SCOTIA SEA
0
200 kilometres
b
61°W
60°W
59°W
58°W
51°S
52°S
Pebble Island
WEST FALKLAND
Hill Cove
Mount Adam (700 m)
Port Salvador
Johnson Harbour
Port Louis
Berkeley Sound
Falkland Sound
Mount Usborne (705 m)
Wickham Heights
Stanley
Darwin
Goose Green
Fitzroy
LAFONIA
Mount Sulivan (474 m)
Port Stephens
Fox Bay
EAST FALKLAND
Cape Meredith
0
25 kilometres
LAFONIA GROUP
Bay of Harbours Formation: Permian
Brenton Loch Formation: Permian
Bluff Cove, Fitzroy Tillite and Port Sussex Formations: Carboniferous–Permian
WEST FALKLAND GROUP
PS Port Philomel and Port Stanley Formations: Devonian
Fox Bay Formation: Devonian
ST Port Stephens Formation: ?Silurian–Devonian
Cape Meredith Complex: Precambrian/Proterozoic
Early Jurassic and Early Cretaceous dyke swarms are not shown

Figure 1

Figure 2


2
FALKLAND ISLANDS 1987
c
b
Spirifer Hawkinsi, Morris & Sharpe, & Orthis Sulivani, M & S.
Lower Devonian
Falkland Islands
Fig.d Morris & Sharpe: Quart. Journ. Geol. Soc. 1846, Vol. 2 pl. 11 f. 1a-b, pl. 10 f. 1c, pp. 275-276.
[B.17794] + BD6660-1 Charles Darwin Collection
Transf. M.P.G. 1880.

Figure 3

Figure 4

Figure 5

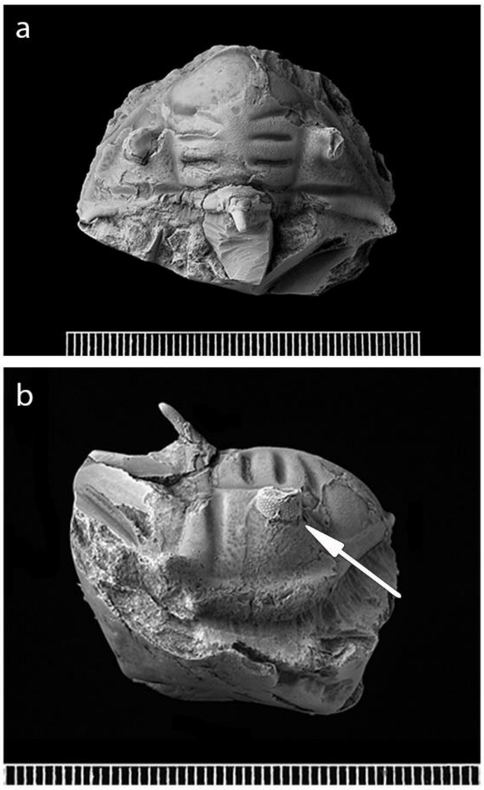

Figure 6

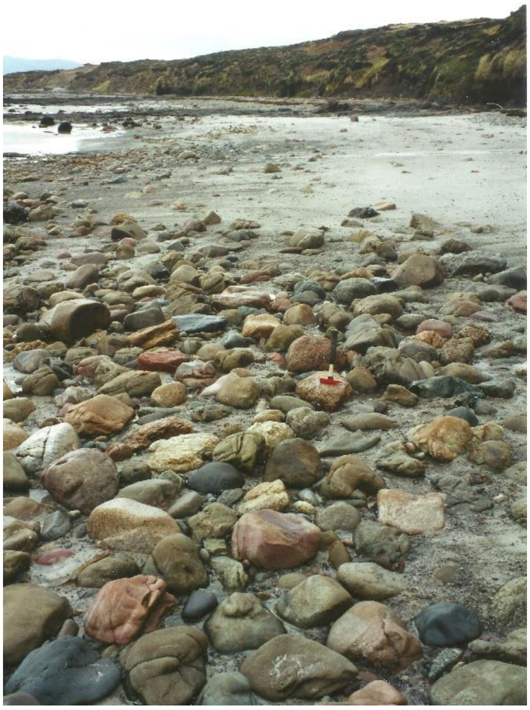

Figure 7

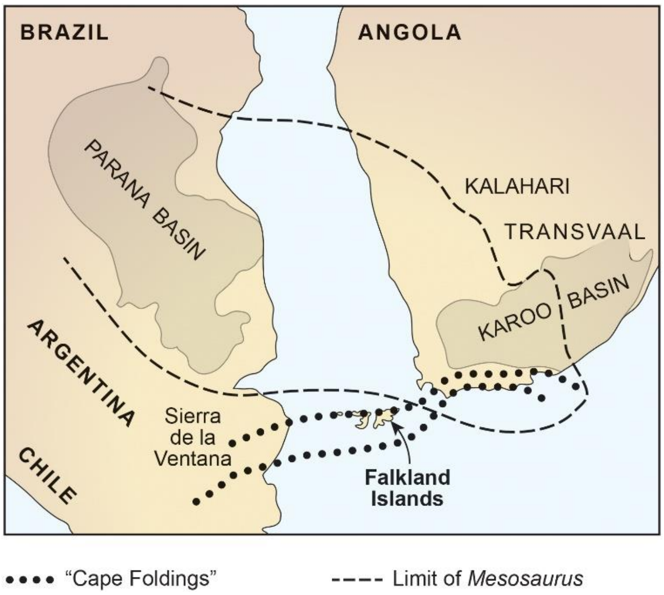
BRAZIL
ANGOLA
PARANA BASIN
KALAHARI
TRANSVAAL
KAROO BASIN
ARGENTINA
Sierra de la Ventana
CHILE
Falkland Islands
"Cape Foldings"
Limit of Mesosaurus

Figure 8

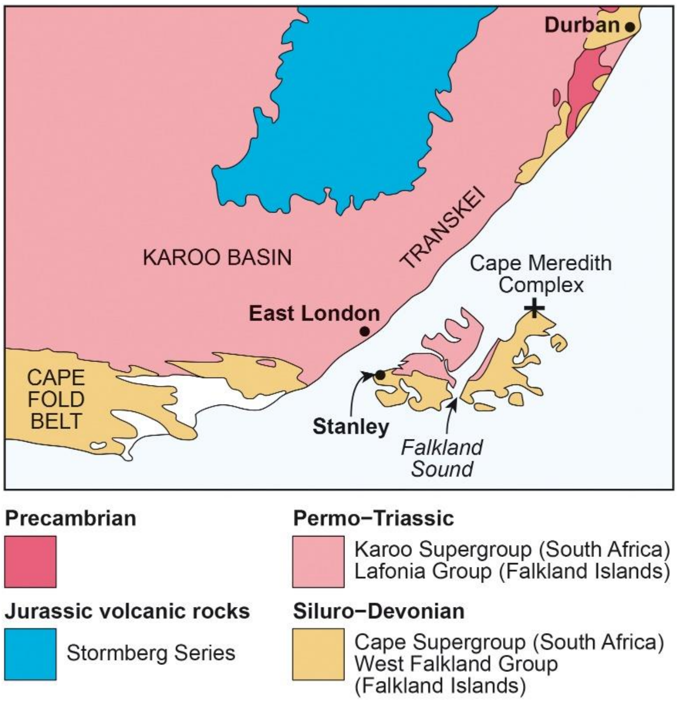
Durban
KAROO BASIN
TRANSKEI
East London
Cape Meredith Complex
CAPE FOLD BELT
Stanley
Falkland Sound
Precambrian
Permo–Triassic
Karoo Supergroup (South Africa)
Lafonia Group (Falkland Islands)
Jurassic volcanic rocks
Stormberg Series
Siluro–Devonian
Cape Supergroup (South Africa)
West Falkland Group
(Falkland Islands)

Figure 9