RAY ADIE AND HIS 1952 PROPOSAL THAT THE FALKLAND ISLANDS HAD ROTATED. HOW HAS IT FARED?

by

Phil Stone and Dave McCarthy

Seventy years ago, a young South African geologist, Raymond John Adie, was putting together an outrageous interpretation of the Falkland Islands' geological history. Adie was newly arrived in England after three years working in the Antarctic with the embryonic Falkland Islands Dependencies Survey (FIDS) but on his way north he had spent time in the Falkland Islands and had taken the opportunity to travel around and look at the geology. When his ideas were published (Adie 1952) they introduced the startling suggestion – for the time – that the Falkland Islands had nothing to do with South American geology but were instead the eastern extension of South Africa's Cape Fold Belt and Karoo Basin, displaced by continental drift - and rotated by 180° in the process. But this was 1952 and continental drift was mostly rejected as an absurd impossibility. So, what led Adie to his radical proposal, and how has it fared since?

A brief biography of Ray Adie is included in the *Dictionary of Falklands Biography* (Tatham 2008). He was born in Pietermaritzburg in 1925, studied geology at the University of Natal and in 1946 travelled to Britain to join FIDS, sailing south later that same year to the Hope Bay base at the northern end of the Antarctic Peninsula. After spending the 1947 austral winter at Hope Bay, Adie, along with three companions from Hope Bay, undertook an epic dog-sledge journey south to the Stonington Island base (Figure 1) where Adie linked-up with Vivian Fuchs. Together they made extensive dog-sledge explorations farther south along the Antarctic Peninsula, the start of a long-term collaboration in the leadership of FIDS and its successor the British Antarctic Survey (BAS) (Fuchs 1982). Adie (Figure 2) would have been expecting to leave Stonington Island in 1949, but ice conditions prevented relief of the base and he was forced to spend a third winter in the Antarctic.

Relief of the Stonington Island base was finally effected in February 1950 with Adie and his colleagues taken north to the Falkland Islands. Adie had first seen Stanley on Christmas Eve 1946, on his way south, and described it as "one of the quaintest little Victorian towns I have ever seen … gaily painted red, green and orange roofs of the wooden houses, with their neat white walls, and prim gardens" (Adie 1951). In 1950 he was to spend over three months in the Falklands, breaking his journey north to make geological observations there. Nominally, this was at the request of Governor Clifford, who was anxious to have potential sources of agricultural lime examined; Adie made the most of the opportunity and travelled widely across both East and West Falkland.

Fig 1. The FIDS Hope Bay party after their arrival at the Stonington Island base, 4 January 1948. Left to right: Ray Adie, Mac Choyce, Frank Elliott, John Francis. BAS image AD6/19/2/E512/7. Photograph by John Eliot Tonkin.

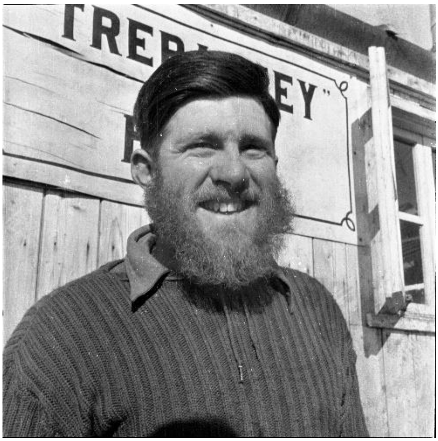

Fig. 2. Ray Adie at the Stonington Island FIDS base, 15 January 1949. BAS image AD6/19/2/E1315/11. Photograph by David G. Dalgliesh.

Falkland Islands pioneers

Adie would have been aware of the somewhat anomalous reputation of Falklands geology. Darwin (1846) had been delighted, but surprised, to find fossils at Port Louis, and not long after, Sharpe and Salter (1856) were equally surprised to discover the same fauna in rocks of equivalent age in South Africa. All of these fossils, of Devonian age and about 400 million years old, formed part of what became known as the widespread 'Malvinokaffric' fauna[1]. This was extended into South America by Clarke (1913) although, once again, Clarke was struck by the unexpected similarity between the Falklands fossils and those of South Africa, rather than the geographically closer South America. During his journeying around the Falklands Adie collected fossils at a number of locations (Figure 3) and with his South African background immediately recognised the association. His collection is preserved in the Sedgwick Museum, Cambridge University, and in his manuscript notes accompanying the specimens he simply uses the appropriate South African stratigraphical terms, hence his Falkland IslandS fossils are assigned to the Bokkeveld Series (Stone & Rushton 2012).

Fig. 3. A fossil brachiopod, Schellwienella sulivani *(part and counterpart) with scattered crinoid columnals, collected by Ray Adie near Chartres, West Falkland, and now held by the Sedgwick Museum, University of Cambridge. BGS image P104222.*

Other aspects of Falklands geology had also invited comparisons with South Africa. In the early years of the 20^{th} century two Swedish expeditions had visited the Falkland Islands: the Swedish South Polar Expedition (1901–1903) and the Swedish Magellanic Expedition (1907–1909). Reporting after these expeditions, Andersson (1907) and Halle (1911) recorded, *inter alia*, the discovery of a fossil *Glossopteris* flora in Lafonia (southern East Falkland), a Permian palaeoflora found widely across the Southern Hemisphere continents (Figure 4), and a glacigenic tillite unit (now the Fitzroy Tillite Formation) that Halle correctly correlated with the Upper Carboniferous to Lower Permian Dwyka tillites of South Africa. At around the same time, the continental drift controversy had been ignited by Alfred Wegener in a series of publications from 1912 onwards and he seized on Halle's correlations in the 3^{rd} and 4^{th} editions of his book *Die Ehtstehung der Kontinente und Ozeane* (Wegener 1922 & 1929).

Fig. 4. Fossil Glossopteris *leaves from South Africa. Identical fossils can be found throughout Lafonia, East Falkland. BGS image P573764.*

Although Halle (1911) had included an outline geological map of the Falklands in his report, the first attempt at comprehensive geological mapping was by Baker (1924), ‘Government Geologist’ from 1920 to 1922 and principally concerned with mineral prospecting. In that respect he was unsuccessful, but his work laid the foundations for the modern interpretation of Falklands geology, and he notably utilised Wegener’s ideas of continental drift to explain the geological similarities that he recognised with South Africa. However, in most other parts of the world the continental drift hypothesis was less favourably received, with outright rejection commonplace (e.g. Oreskes 1999). The South Atlantic region was perhaps the only part of the world where a geological consensus favoured drift, or the Displacement Hypothesis as it was then known (Stone 2015). One notable champion was the eminent South African geologist Alexander Du Toit, who was the first to suggest a physical removal of the Falkland Islands to a position that he thought more compatible with their relationship to the regional geology (Figure 5). These proposals (Du Toit 1927 & 1937) moved the Falklands north and placed them between the western Cape Province of South Africa and the Sierra de la Ventana region of Argentina where similar successions of rocks had been recognised (Keidal 1916).

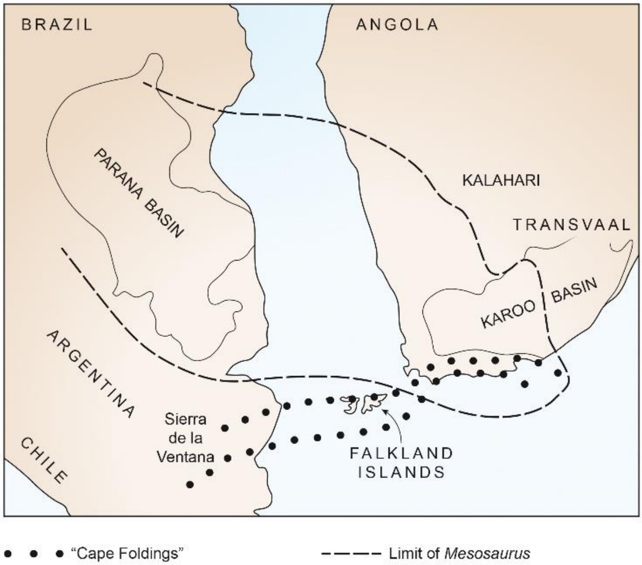

Fig. 5. The position proposed for the Falkland Islands by Alexander Du Toit in his 1977 reconstruction of the Gondwana supercontinent. Mesosaurus is a distinctive terrestrial vertebrate fossil. Image © BGS (UKRI).

The circumstances of Adie's inspiration

Du Toit's ideas failed to make much headway against the prevailing view of oceans as fixed and permanent features of the Earth's surface, and the assumption that there was no conceivable mechanism for the movement of continents. Du Toit died in 1948, but the cause of continental drift was then taken forward by Lester King, professor of geology at the University of Natal, with a paper carrying the unequivocal title *Necessity for Continental Drift*. Therein, King (1953) reinforced Du Toit's trans-Atlantic correlations but also highlighted the geological associations from the east side of Africa into the Antarctic, continents that had been only tentatively juxtaposed by Du Toit in his 1937 reconstruction of Gondwana, the name given to the 'supercontinent' comprising all of the present-day continents prior to their fragmentation and dispersal from about 180 million years ago – a process still in progress.

But for the South Atlantic the most significant aspects of King's 1953 paper appeared in a footnote and in an associated appendix. The footnote (King 1953, p. 2169) expressed his delight at the results achieved in South America and the Falkland Islands by two of his students, D. L. Niddrie[2] and R. J. Adie. In the preceding text King noted that "[t]he evidence of the writer's own students from South Africa who have worked in the Falkland Islands and in South America is that they were perfectly at home in the various formations (see Appendix), which to them were similar in type, in sequence, and in fossils." The Appendix to which King referred was written by Niddrie (1953) and described the geology of the Falkland Islands, stressing the South African correlations and applying South African stratigraphical terminology – Table Mountain, Bokkeveld, Witteberg, Dwyka, Ecca, Karoo – to the Falklands succession. The footnote also recorded that "R. J. Adie is publishing his opinions separately".

What Adie (1952) published separately was the remarkable description of the Falkland Islands as the eastern extension of the Cape Fold Belt and Karoo Basin (Figure 6), which had broken away during the fragmentation of Gondwana. Adie placed the Falklands to the east of South Africa and 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 tillite beds, 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". But this was 1952 and continental drift was mostly still thought of as fringe eccentricity.

Adie's 1952 paper does not seem to have made much impact and no scientific discussion of it was subsequently published. Its likely reception can be gauged by that afforded to a presentation at the 1950 meeting of the British Association for the Advancement of Science (BAAS) by one of Adie's FIDS colleagues, John Joyce. Joyce (a Captain in the Royal Engineers) spent the 1946 austral winter at the Stonington Island FIDS base on the Antarctic Peninsula, and then returned to work on his results at Imperial College, London. The 1950 BAAS meeting, held that year in Birmingham, was a wide-ranging affair, but it included a one-day symposium to discuss "The Theory of Continental Drift"; six speakers covered aspects of biogeography and geology. Joyce (1951) presented a reconstruction of Gondwana (Figure 7) in which he attempted to locate the origins of the Scotia Arc, but he also slid the Falkland Islands north by about 5 degrees of latitude so that in his reconstruction they lay to the SE of South Africa in terms of present-day geography. He had passed through Stanley when travelling to and from the Antarctic Peninsula and had been able to carry out some research work on the Falklands stone runs (impressively large, periglacial boulder fields), so would have been familiar with the islands' overall geological character.

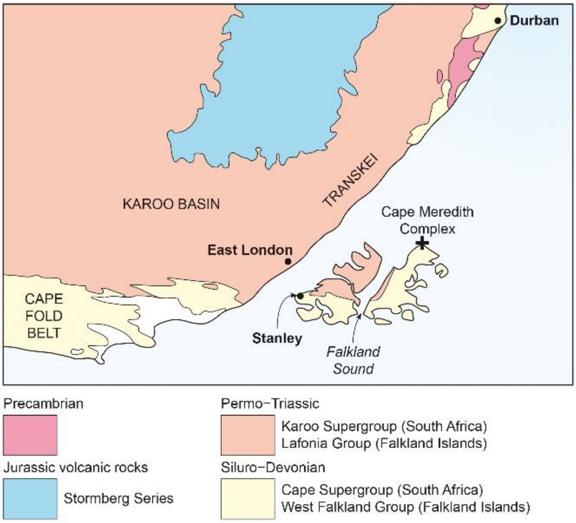

Fig. 6. The position proposed for the Falkland Islands by Ray Adie in his 1952 paper in The Geological Magazine. *Note the 180° rotation of the islands (Adie 1952). Image © BGS (UKRI).*

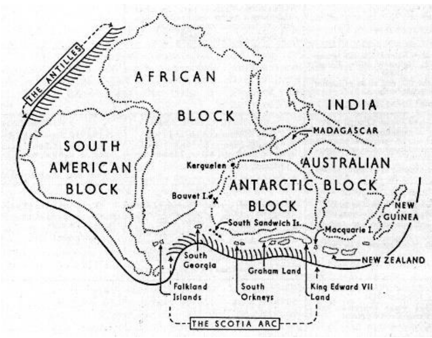

Fig. 7. The reconstruction of southern Gondwana proposed by John Joyce in his presentation to the 1950 meeting of the British Association for the Advancement of Science (Joyce 1951). Reproduced by permission of The British Science Association.

Unfortunately for Joyce, another speaker on the BAAS programme was the doyen of British geophysicists, Professor Harold Jeffreys, who was implacably opposed to the concept of continental drift. His contribution (Jeffreys 1951) was a rather patronising and world-weary dismissal of the continental drift hypothesis since, in his view, any conceivable mechanism must conflict with the basic physical properties of solids and liquids that “[w]e have all learnt at school” (1951, p 79); he bemoaned the fact that “[t]his is the fourth time that I have taken part in a public discussion of this theory” (p 80), implying that the time had come to call a halt to speculation. Perhaps to Jeffrey’s relief, neither Joyce nor Adie indulged in any further heretical speculation regarding the Falkland Islands, instead focussing on their Antarctic work. Nevertheless, the two veterans of the FIDS Stonington Island base would surely have met and discussed their ideas when Adie got back to Britain late in 1950 – Adie was based in Cambridge whereas Joyce was in London. If Adie’s Falkland Islands observations influenced Joyce’s Gondwana reconstruction it was fortunate, since Du Toit’s positioning of the islands between South Africa and South America was singled out for severe criticism at the BAAS meeting. Alternatively, it is possible that Joyce’s reconstruction catalysed Adie’s Falkland Islands interpretation.

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 Angel Borrello (1963). Borrello’s account (in Spanish) was based largely on the work of Baker (1924) but stressed correlations with the mainland of Argentina in preference to the South African connection. Borrello followed Harrington (1962) in regarding the Falkland Islands (*Las Malvinas*) as part of a fixed continental promontory extending from South America, with the metamorphic rocks of the Deseado Massif in Argentina extending eastward to underlie the archipelago. Borrello made additional correlations between the younger sedimentary rocks of the Falklands and possible equivalents around Deseado and in the Patagonian Precordillera of Argentina’s Chubut region. So began a controversy that continues today.

Continental drift becomes plate tectonics

Later in the 1960s the overarching controversial idea, continental drift, finally came of age as the plate tectonics revolution swept through geology – or at least all those parts of geology that had ignored the South Atlantic (Stone 2015). Plate tectonics provided a mechanism and rationale for the movement of continents. It might have been expected that Adie’s rotational model for the African origins of the Falkland Islands would have been revitalised; strangely, that did not happen. In 1956, after a spell in industry, Adie had re-joined FIDS as Chief Geologist and led a team based at Birmingham University. Also in 1956, in October and November, a comprehensive aerial photography campaign was completed in the Falkland Islands by Hunting Aerosurveys Ltd, as a basis for the preparation of a topographical map series (29 sheets) for the archipelago at a scale of 1: 50,000. The availability of the aerial photographs also provided an opportunity to improve the geological map; Baker’s

(1924) geological map was at a relatively small scale, lacked an accurate topographical base, and was only available as a fold-out figure within an obscure report. Nevertheless, it remained the definitive representation of Falkland Islands geology until the publication by the British Antarctic Survey, on behalf of the Falkland Islands Government, of a photogeological interpretation by Mary Greenway (1972), who worked with Adie's team at Birmingham University.[3]

Greenway's map and accompanying report was influenced and edited by Adie, who also contributed an appendix discussing the economic aspects of the geology. Given Adie's involvement and supervisory role it might be expected that Greenway's report would have supported his South African correlation of Falklands geology; rotation of the Falklands would not have been regarded as fanciful in the new era of plate tectonics. Instead, Greenway supported the South American connections of the Falklands to the Deseado area of Argentina, presumably with the approval – or at least the acquiescence – of Adie. So, by 1972, he would appear to have lost confidence in his earlier interpretation of Falklands geology, which in the language of the 1970s would have involved a rotated microplate.[4]

Through the late 1970s a number of Argentinian geologists worked in the Falkland Islands but for the most part focussed on the detail of the local geology, with their results published in the Argentine literature. Their tacit agreement with the regional correlation to Deseado and beyond can be assumed, but an exception to that consensus is suggested by Cingolani & Varela (1976). This important contribution provided the first radiometric date for the metamorphic rocks at Cape Meredith, West Falkland (*c*. 1100 Ma), and for the dolerite dykes that cut them (*c*. 190 Ma). Cingolani & Varela drew attention to the correspondence of these ages to those derived from the "Natal-Namaqualand" metamorphic rocks and the extensive Karoo dyke swarm, South Africa.

Argentinian involvement in Falkland Islands geological fieldwork ended abruptly in 1982. Thereafter, with renewed interest in the region and improved transport and logistical links, a number of projects were initiated applying increasingly sophisticated techniques to the problems of Falklands geology. One of the first reopened the question of microplate rotation. This was a study of the palaeomagnetic signature preserved in the dolerite dykes of West Falkland; as they had cooled and solidified, the alignment of iron-rich minerals had locked-in a trace of the prevailing magnetic field. As first reported by Mitchell *et al*. (1986) the results implied a substantial rotation of the dykes and their host rocks since their intrusion. These initial findings were confirmed by a more detailed study (Taylor & Shaw 1989), whilst the coeval origin of the Falklands dykes and the compositionally similar Karoo swarms of South Africa was confirmed by radiometric dates obtained by Mussett & Taylor (1994) from West Falkland. Further detailed study of the Falkland Islands dykes (Mitchell *et al*. 1999) showed that whilst some were indeed of Karoo type, others had more in common with dykes of the same age in East Antarctica, the so-called Ferrar swarm.[5] All of this tended to support a reconstruction of Gondwana in which the Falkland Islands were rotated back to lie close between the Eastern Cape of South Africa and the Dronning Maud Land region of East Antarctica; essentially this was the Adie model.

One other crucial piece of palaeomagnetic work remains frustratingly unpublished. There were sufficient limitations in the original dyke results to allow sceptics to dismiss their rotational implications. The scientists involved were convinced that their results were indeed valid, but additional work was clearly required to make the rotational interpretation unequivocal. Accordingly, a new palaeomagnetic project was planned, this time utilising the sedimentary rocks rather than the dykes, a change that would have eliminated some of the challenges to the original investigations. In 1993 and 1994, working with the British Antarctic Survey, Laurence Thistlewood collected more samples for palaeomagnetic analysis (Figure 8). His initial findings supported rotation and were presented at a major scientific conference but only a brief abstract was subsequently published (Thistlewood & Randall 1998). The full study was subsequently prepared for formal publication but, despite at least one favourable review that recommended publication with only minor adjustments needed, it was inexplicably abandoned. That this should have been allowed to happen was a scientific misfortune; a regrettable lost opportunity.

Fig. 8. One of the sampling sites at Port Sussex, East Falkland, used by Laurence Thistlewood in his 1993–94 palaeomagnetic survey. The results were rumoured to support rotation but frustratingly have never been published. Photograph by Phil Stone.

Nevertheless, other work in the 1990s did provide additional support for Adie's proposal. Curtis & 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. There were also detailed assessments of the geometrical process by which the Falklands microplate might rotate (e.g. Marshall 1994; Storey *et al*. 1999; Johnston 2000). It became clear that as much as 60° of rotation relative to South Africa, would be the result of the opening of the Atlantic Ocean. That reduced the amount requiring an independent tectonic explanation.

Into the 21st century

The 20th century closed with publication of a new geological map of the Falkland Islands accompanied by a comprehensive description of the geology (Aldiss & Edwards 1999). This provided a foundation for a range of subsequent studies, many of which were relevant to the rotational arguments; reviews of this most recent phase of work have been provided by Stone (2016a & b). Results derived from onshore geology have tended to strengthen the associations with South Africa and support rotation. Important examples are the close, detailed correlations drawn between parts of the Falklands succession and the coeval strata in the Cape Fold Belt and Karoo Basin of South Africa (e.g. Trewin *et al*. 2002; Hunter & Lomas 2003), and the comparison of the asymmetric aeromagnetic anomalies produced by the early Jurassic dykes and a subsequently discovered suite of early Cretaceous dykes (Stone *et al*. 2009). The results of the latter investigation were thought to be most compatible with the intrusion of the older dykes before, and the younger ones after, a rotation of their common host rocks. Hole *et al*. (2016) extended the detailed compositional correlation of the older, Jurassic dykes with those of the coeval Karoo and Ferrar swarms, all intruded at the initiation of the break-up of the Gondwana supercontinent. Increasingly sophisticated models were developed to explain how that break-up might have happened with consequential rotation of the Falklands microplate and its one-time neighbour, the Antarctic Ellsworth Mountains for which a comparable history of rotation was established (e.g. Martin 2007).

One of the principal lines of evidence utilised by Adie (1952) was the direction of ice-flow during deposition of the glacigenic Fitzroy Tillite Formation, and this unit has continued to be of significance in the rotation debate. Adie had cited the results of Baker (1924) who had deduced a flow from north to south – when rotated this matched the results obtained from Natal. But a subsequent detailed study by Frakes & Crowell (1967) disputed Baker’s observations and instead, from the overall depositional relationships, proposed ice flow from west to east with a source for the ice in South America; no microplate rotation or movement was required. Nevertheless, the strong similarity of the Fitzroy Tillite to the diamictites of the Dwyka Group of South Africa was re-emphasised by a succession of subsequent investigations. A distinctive fossil fauna in erratic limestone clasts from the Fitzroy Tillite (Stone *et al*. 2012) matched that long-known from the Dwyka diamictites and indicated a source in the Transantarctic Mountains of East Antarctica; soon after, discoveries in Argentina complicated the picture (González *et al*. 2013). Other detrital components also appeared to reinforce the South African association. Craddock *et al*. (2019) showed that the age profile of the zircon grain population was the same in both the Fitzroy and the Dwyka units and linked the abundance of garnet grains in the diamictites of both areas to an Antarctic source. The pink beach sands of the Falklands (Figure 9) are testament to the concentration of garnet in the Fitzroy Tillite Formation.

Fig. 9. Patches of pink sand on the beach at Hill Cove, West Falkland. The colour arises from relatively heavy, red garnet grains being eroded from the adjacent cliffs of Fitzroy Tillite Formation rocks and then concentrated on the beach by the action of wind and waves. Photograph by Phil Stone.

Of course, not all results from the Falklands were supportive of the South African connection and microplate rotation. Ramos *et al*. (2017) presented age and composition data for detrital zircons from West Falkland Group quartzites in support of a source for them in South America. They thought the case for a South African connection to be much less compelling and reiterated the lack of evidence for any significant structural break in the crust between the Falklands and South America. The cautionary response to that objection must be that absence of evidence is not evidence of absence. Ramos and his colleagues also reviewed the huge expansion in work on the geology of the three major offshore sedimentary basins surrounding the Falkland Islands, and updated the exercise a little later (Ramos *et al*. 2019), concluding that they provided no evidence for rotation. An even broader approach was adopted by Eagles & Eisermann (2020) who proposed a wholesale reinterpretation of South Atlantic tectonics in which the Falkland Islands were assigned a South American origin and their independent tectonic rotation was rejected.

Phil Richards of the British Geological Survey had led initial interpretations of the offshore geophysical datasets from the Falkland Islands and concluded that whilst there was no evidence to support rotation of a Falklands microplate (Richards *et al*. 1996), it may have occurred prior to the formation of the offshore basins (Richards & Fannin 1997). However, these assessments were based on 2D seismic reflection data and had no well control for the age of any of the offshore structures observed. They beg the question: what would sufficient evidence for plate rotation in the offshore datasets look like? Richards *et al*. (1996) had stated that they would expect to see evidence of both extension and compression in areas immediately surrounding the Falklands micro-plate, but such features were not evident in the data available to them at the time.

Up to this point the development of the North Falkland Basin had largely been associated with the opening of the South Atlantic (Richards *et al*. 1996), a process which began early in the Cretaceous Period, around 138 million years ago (e.g. Perez-Diaz & Eagles 2014). As further data was collected, particularly biostratigraphic information from hydrocarbon exploration wells in the sedimentary sequences deposited offshore, it allowed age correlation of basin-development and demonstrated that there were multiple phases of basin development or rifting (Richards & Hillier 2000). The earliest age thus established for the syn-rift sequences from the North Falkland Basin (that is, those deposited during active tectonic extension) is Middle Jurassic, very similar to the age of formation of the Outeniqua basin, offshore South Africa. This correlation had also arisen in a study by Ken Thomson (1998) that compared the structures observed in both the North Falkland and the Outeniqua basins. Thomson concluded that these structures were remarkably similar to each other and that the older structures in the North Falkland Basin could originally have been an extension of the Outeniqua Basin – if the North Falkland Basin had subsequently rotated by 180°.

Despite continued collection of offshore data from the sedimentary basins surrounding the Falkland Islands, there was little attempt to evaluate the new information with respect to possible rotation, which continued to be thought doubtful by most of the offshore community. However, a recent study led by Roxana Stanca did re-evaluate the older structures observed in the North Falkland Basin and concluded that the 180° rotation favoured originally by Adie (1952) and more recently by Thomson (1998) was an over-estimate, and that 140° may be more appropriate (Stanca *et al*. 2019). Although this might seem a trivial adjustment, it is actually quite significant (Figure 10). By reducing the amount of rotation required to satisfactorily reconstruct the Falklands back into an original position adjacent to South Africa, the change counters two of the principal problems identified by opponents of the rotation model: firstly, 180° of rotation exceeds that required by palaeomagnetic modelling; secondly, 180° would require an anomalously fast rate of plate rotation. By reducing the amount of rotation required Stanca *et al*. obtained a closer match to the palaeomagnetic data and restricted the rate of rotation to less than about 8° per million years, a much more credible figure than previous estimates.

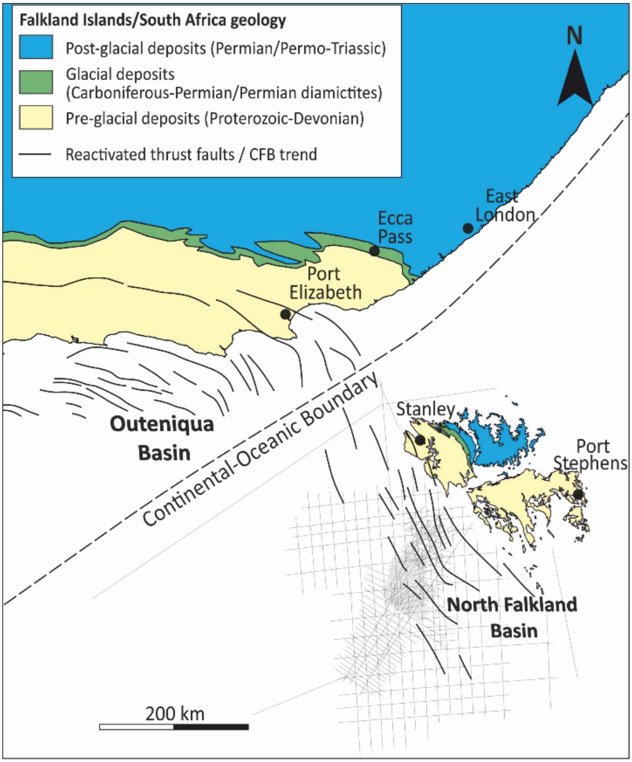

Fig. 10. Revised position of the Falkland Islands microplate at c. 180 Ma after Stanca et al. (2019). The structural trend or grain of the southern part of the North Falkland Basin and the correlated structures across South Africa and the Cape Fold Belt (CFB) are indicated with the black lines. Note the modified position of the Falkland Islands relative to Adie's original proposal (Figure 6). Image © BGS (UKRI).

But what about direct evidence for rotation? As outlined above, earlier investigators had argued that rotation of the microplate would result in both extension and compression surrounding the microplate, with the area most likely to illustrate evidence of compression, the result of continental collision, lying immediately to the west of the Falklands microplate, between South America and the Falkland Islands. To date there is no confirmatory evidence in the sparse data available from this offshore area. The reasoning behind its requirement is partly correct but assumes that the microplate rotated as a single entity, whereas modern tectonic research suggests that plates typically accommodate significant amounts of deformation internally, in what is known as intraplate deformation. In a yet-to-be-published study Stanca and her colleagues have identified a number of NE–SW trending, structures or fracture zones traversing the microplate offshore – one manifests ‘onshore’ as the Falkland Sound Fault – which could have accommodated significant amounts of rotation.

The geometry of this style of plate deformation has been compared to books falling over on a bookshelf, with significant rotation accommodated by slipping movements between each book in response to compression and lateral movement between the constraining shelves. The process was termed ‘bookshelf tectonism’ by its early proponents (e.g. Mandl 1987). Applying this model to the Falklands would see East Falkland and West Falkland as individually rotated ‘books’, with a third ‘book’ further to the west and represented by the Jason Islands. The necessary boundary faults (the ‘shelves’ constraining the ‘books’) are well established features at the northern and southern margins of the Falkland Plateau. Between them, intraplate deformation of ‘bookshelf’ type could go some way to explaining why, despite rotation, no direct evidence of compression was observed west of the Falklands in the earlier studies: investigations continue.

Résumé

The anomalous geology of the Falkland Islands, relative to the archipelago’s geographical position, was recognised at an early stage in the scientific exploration of the South Atlantic region. The apparent geological connections with South Africa were stressed by the early pioneers of continental drift, Alfred Wegener and Alexander du Toit, and it was his South African background that enabled Ray Adie to recognise the detailed correlation and to propose, in 1952, that the Falklands had originated as the rotated extension of eastern South Africa; with the advent of plate tectonics this became the Falklands microplate. Despite 70 years of controversy, debate and detailed investigations, the status of the Falklands microplate remains elusively equivocal.

Once published, Adie’s idea was largely ignored for the next 30 years, and by the early 1970s he seems to have retreated from the concept himself. But the first palaeomagnetic study of West Falkland dykes, published in 1986, supported rotation and reinvigorated Adie’s interpretation. Thereafter, through the remaining years of the 20th century, a wide range of geological studies produced compelling correlations with South Africa and brought the idea of a rotated microplate to the fore. Of course, there have always been dissenters, and the 21st century saw a growing challenge from those who saw the Falklands as a fixed, continental extension of the Argentine mainland and proposed alternative correlatives there for some of the Falklands’ geological features. In addition, the still-growing database arising from offshore hydrocarbon exploration seemed at first to preclude microplate rotation, but some of the latest interpretations were not only more favourable to Adie, but also identified structures that could accommodate the rotational deformation.

With all of these conflicting lines of evidence and opinion in play, it seems certain that the geology of the Falkland Islands will remain controversial for some time to come. Adie died in 2006 and would most probably have been greatly surprised by the resurgence, and current popularity, of his prescient idea.

Acknowledgements

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Notes

Note 1.
The term 'Malvinokaffric' was introduced by German palaeontologists in the early 1940s and has been widely used since then. Its racist connotations are now recognised and 'Malvinoxhosan' is preferred (Penn-Clarke & Harper 2020).

Note 2.
Niddrie (1953) records that he was "appointed Naval Meteorological Officer, Falkland Islands, after a term of duty at Simonstown Naval Base (Cape Province)." He acknowledges "several valuable discussions with Du Toit" prior to his departure which must therefore have preceded or closely followed Du Toit's death on 25 February 1948. He was probably in the Falkland Islands a little ahead of Adie's return early in 1950. Niddrie's South American experience was in Uruguay, presumably whilst travelling to Stanley.

Note 3.
Mary Greenway (now Mary Orchard) wrote an autobiographical entry for the *Dictionary of Falklands Biography* (Tatham 2008).

Note 4.
A *Falklands* microplate has been widely named in the scientific literature although Argentinian authors, naturally, prefer *Malvinas* microplate – but either way they deny it exists. Perhaps in a spirit of compromise, Ben-Avraham *et al*. (1993) introduced the term *Lafonia* microplate; this sometimes becomes *Lafonian* (e.g. Dalziel *et al*. 2013). All of these names refer to the same thing: a small fragment of continental crust carrying the Falkland Islands. The microplate's boundaries, and its relationship to the rest of the Falklands Plateau, remain topics for investigation and debate.

Note 5.
There are several different Falklands dyke swarms of Early Jurassic age, with most of the component dykes seen on West Falkland. The most reliable radiometric ages fall in the range of about 178 to 184 Ma. Karoo magmatism peaked at about 183 Ma, Ferrar magmatism at about 180 Ma. Relevant data is summarised by Stone (2016a). In the Falkland Islands there is also a younger, Early Cretaceous dyke swarm, with the most reliable radiometric ages falling in the range 131-138 Ma (Richards *et al*. 2013). The Jurassic dykes were intruded during the initial break-up of Gondwana, the Cretaceous dykes during the subsequent opening of the Atlantic Ocean.

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