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BARTHOLOMEW SULIVAN'S GEOLOGICAL OBSERVATIONS IN THE FALKLAND ISLANDS (1838 TO 1845) AS COMMUNICATED TO CHARLES DARWIN

by

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When in 1846 Charles Darwin published the first account of the geology of the Falkland Islands, he made clear at the beginning that "My examination was confined to the eastern island; but I have received through the kindness of Captain Sulivan and Mr Kent, numerous specimens from the western island, together with copious notes, sufficient to show the almost perfect uniformity of the whole group." A modern geological map (e.g. Aldiss and Edwards 1999) shows the oldest Falkland Islands rocks to be the *ca* 1000 million years old, granite and gneiss of the Proterozoic **Cape Meredith Complex**, which has a very small outcrop on the southernmost point of West Falkland. This 'basement' complex is unconformably overlain by the **West Falkland Group**, a thick succession of marine, near-shore clastic strata ranging in age from Silurian to Carboniferous: a fossiliferous unit in the middle of the group (Fox Bay Formation) can be dated at about 400 million years old. The West Falkland Group underlies most of West Falkland and the northern part of East Falkland. In the southern part of East Falkland a younger succession of strata, the **Lafonia Group**, has at its base a Permo-Carboniferous glacigenic unit (Fitzroy Tillite Formation) formed about 300 million years ago, which passes upwards into a thick succession of Permian lacustrine strata. The metamorphic and sedimentary rocks are cut by a multitude of Jurassic and Cretaceous dolerite dykes ranging in age between about 180 and 120 million years. The regolith covering the bedrock was largely produced during the last 2 million years or so, by a variety of weathering and periglacial processes, with an extensive peat cover developed over approximately the last 17 000 years.

Darwin's association with Sulivan and Kent started with the famous voyage of HMS *Beagle* (1831-1836), on which ship Bartholomew Sulivan was a lieutenant and William Kent was the assistant surgeon. In his geological notes, written-up whilst still aboard the *Beagle*, Darwin acknowledged a suite of specimens procured for him from West Falkland by Kent early in 1834. However, in the case of Sulivan, who became a life-long friend of Darwin, a wealth of important geological observations and specimens were acquired much later, during Sulivan's subsequent surveying voyages to the Falklands in command of HMS *Arrow* (1838-39) and HMS *Philomel* (1842-1845). This is made clear by a careful reading of Darwin's scientific paper in

parallel with the surviving letters written by Sulivan to Darwin during those later voyages. It is also clear from the letters that Sulivan observed and described many geological features that were not recognised by Darwin as being of importance, and which have only been 'rediscovered' in relatively recent times. The letters in question have recently been made available online as part of the Darwin Correspondence Project Database (http://www.darwinproject.ac.uk: see letters 429, 675, 730, 886 and 13847). Some may be incomplete and they do not represent the entire correspondence since Darwin's replies have not survived and it is not certain that all of Sulivan's letters have done so. Apart from their geological content, the extant letters contain much zoological data, with Sulivan responding to requests from Darwin for details of the feral horses, cattle and rabbits and much more besides. There is also general naval and family gossip and descriptions of contemporary events in South America. Whilst the importance of Sulivan's zoological observations to Darwin's developing ideas on natural selection has been noted by several of Darwin's biographers (e.g. Armstrong 1992), Sulivans's prescient geological observations have been generally overlooked.

A short biography of Sulivan by Andrew David is available in *The Dictionary of Falklands Biographies* (Tatham, 2008). A more extensive account based on Sulivan's letters home was prepared by his son, Henry Norton Sulivan, and published in 1896, but unfortunately it focuses almost exclusively on Naval matters and pays scant attention to the Falklands. Something of Sulivan's character is revealed by a comment in a letter written by Darwin to his sister Catherine, from HMS *Beagle* at Valparaiso and dated 29 July 1834. In it, Darwin bemoans the fact that Lieutenant Wickham had left the ship since "He is far the most conversible being on board, I do not mean talks the most, for in that respect Sulivan quite bears away the palm."

In his 1846 paper Darwin made use of his own '*Beagle*' observations of the geological structure around East Falkland but also drew extensively on information sent by Sulivan from HMS *Arrow*, also relating to East Falkland. Subsequent information on West Falkland sent by Sulivan from HMS *Philomel* was given only passing mention by Darwin in a footnote to the 1846 paper. Presumably that account was already well advanced by the time Sulivan's letters were received. The footnote reads: "Captain Sulivan seems to have found on the western island subordinate beds of a conglomerate or coarse grauwacke[1]. On this island there appear also to be traces of tertiary and boulder formations, corresponding with those of Tierra del Fuego. Captain Sulivan observed on the western island numerous basaltic dykes."

Geological Structure

Sulivan's letter 429 was written from HMS *Arrow* and is dated 20 October 1838. It is clear from his comments that Sulivan had been attempting to visit specific localities in the area around Berkeley Sound for which Darwin had requested information

supplementary to that collected during the Beagle expedition. In addition, Sulivan described how he had set out to construct cross-sections of the geological structures seen in the hills that he traversed: "I have begun to make a little section of every range I cross, and I will try to colour a chart at each place I go to" – he was endeavouring to make the first geological map of the islands. The fruits of this labour, dated variously between November 1838 and April 1839, were consolidated into a single document identified in the database as letter 13847 and described there as 'possibly incomplete'. Numerous sketches of geological structures are included and three of them were utilised by Darwin in his 1846 paper. The difference in style between Darwin's cross sections from his Beagle visits, and those drawn by Sulivan is instructive. Darwin's drawings are simplified and diagrammatic, omitting minor complications to better illustrate the fundamental issues, whereas Sulivan attempts to record every last detail and nuance of the rock structure. One of the sketches used by Darwin (Figure 1 in the 1846 paper) usefully demonstrates the acuteness of Sulivan's observations. In this drawing of folded strata 'in a cliff on the southern coast' (of East Falkland, most probably in the vicinity of Fitzroy) Sulivan has carefully recorded the precise relationships of bedding and cleavage (Figure 1). A present-day geologist would interpret this in terms of the refraction across different lithological layers of an axial-planar cleavage, but in the mid-19th century such relationships were largely unappreciated. In his paper Darwin notes: "I have never myself seen an instance of this structure, and I believe it is a new and interesting case."

Towards the end of the '*Arrow'* survey, Sulivan had realised that the geological structure became markedly simpler in the southern part of East Falkland, and in his first letter to Darwin from HMS *Philomel* (Letter 675, written from Montevideo at the end of the survey season and dated 10 May 1843) he confirms that the whole of Lafonia is underlain by relatively flat-lying strata, in contrast to the folded and cleaved rocks seen farther north. Otherwise, the observations made during the '*Philomel'* surveys relate to West Falkland. There, Sulivan noted the unusual NNE-SSW trend of the Coast Ridge, contrasting it to the east-west trend of the more northerly West Falkland upland ranges, and the less well-defined arrangement of hills in the south of that island. These trends reflect the fundamentally different geological structures of East and West Falkland but their importance was not appreciated by Darwin.

Stone runs

Soon after arriving in Berkeley Sound aboard HMS *Arrow* (on 15 October 1838) Sulivan had trekked south to the 'great valley of fragments' described by Darwin in his *Journal of Researches* (1839) – the largest of the Falkland Islands stone runs it is now known as 'Princes Street'. In letter 429 Sulivan wrote: "I sat on a rock overlooking the Fragments for some time and tried to form Theories … but they all

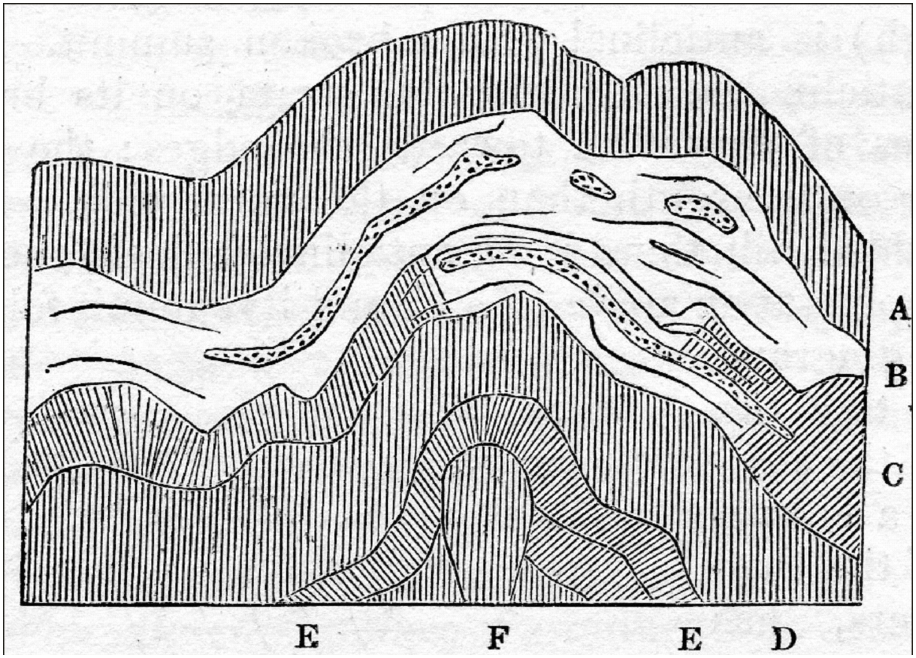

Figure 1. A sketch by Sulivan of folded and cleaved strata, probably in the vicinity of Fitzroy, East Falkland, as utilised by Darwin in his 1846 paper on the geology of the Falkland Islands. Darwin's explanation reads as follows, presumably following Sulivan's original notes:
A, D, F. Beds of clay-slate, with cleavage-laminae perpendicular to the horizon.
E and part of C. Similar beds, with the cleavage at right angles to every flexure.
B and parts of C. Beds of imperfect, non-laminated clay-slate, with intercalated seams of sandstone represented by the dotted parts.
F. Nucleus or core of clay-slate formed by the lateral crushing of the strata, about two feet high and one foot broad.
These nuclei occur in almost all the folds.

ended in smoke." Nevertheless, he did note the slightly rounded edges of many blocks, the relationship of the stone runs to the neighbouring quartzite cliffs and appears to have been the first to register the striped appearance of some stone runs, with strips occupied by quartzite boulders alternating with vegetated strips (Figure 2).

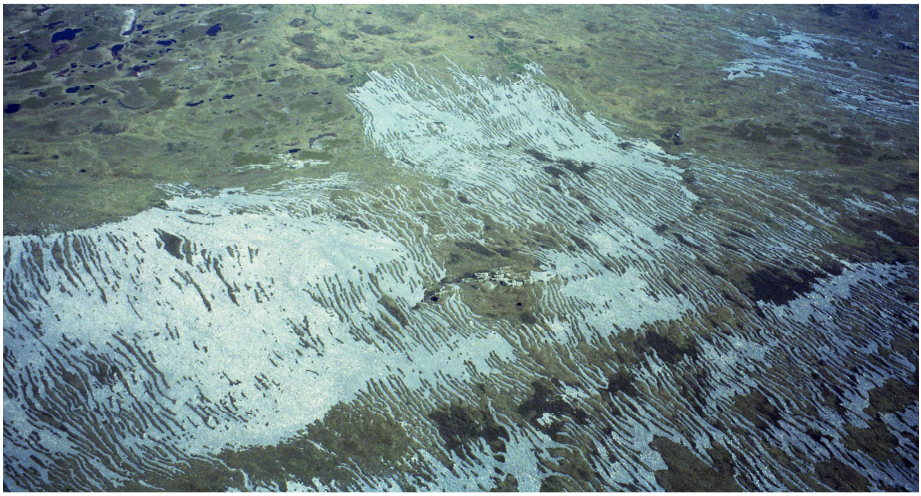

Figure 2. An aerial view of stone runs near Mount Challenger, East Falkland, showing the characteristic linear stripes produced by periglacial sorting that were apparently first noted by Sulivan, who likened them to "the waves of the sea beach". This view is about 300 m wide.

It has always been something of a puzzle that despite his interest in the stone runs Darwin made no mention of the spectacular striped patterns developed in many places. Sulivan compared their regularity to the 'waves of the sea beach' and in his letter to Darwin, which included a rough sketch, he added ' … now I daresay you know all this but as I do not recollect it in your description I mention it …". In subsequent letters from the '*Philomel'* surveys Sulivan commented on the distribution and character of stone runs in West Falkland.

Glacial cirques

On both East and West Falkland, Sulivan climbed many of the highest peaks to establish triangulation stations for his survey. In letter 675 he describes climbing to the highest point on West Falkland, which he names as Mt Beaufort but which is now known as Mt Adam, and expresses astonishment at features found there and at another nearby peak, either the subsidiary summit to the north-north-east (Mt Donald) or perhaps Shingly Mountain to the south-east (Figure 3a). Sulivan inserted a sketch map of the feature at the summit of 'Mount Beaufort' into the letter (Figure 3b) and described it as follows; the quotation is taken verbatim from letter 675:
"The most remarkable thing is that the summits of the two highest mountains are both semicircular resembling the half of a Crater and both are open to the NE. Mount Beaufort is very remarkable … The Summit for nearly half a mile along the edge of

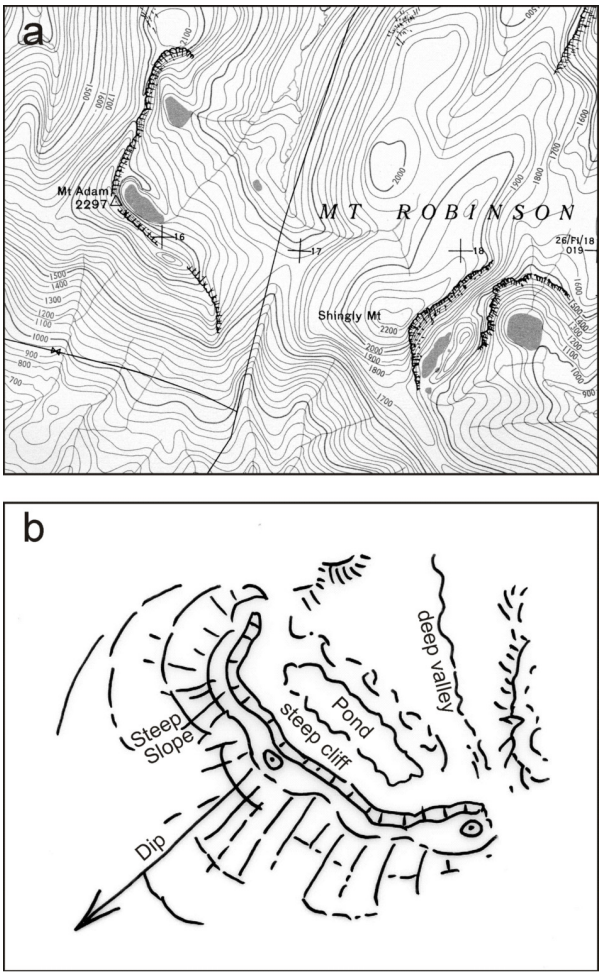

Figure 3. Sulivan's sketch of the glacial cirque on Mount Adam, West Falkland compared with the features shown on a modern topographic map.
a. The glacial cirques on Mount Adam and Shingly Mountain, West Falkland, as represented on DOS 453 (Series H791), Falkland Islands 1:50 000 Sheet 10, 1961; the area shown measures 6 km by 4.5 km, heights in feet.
b. A copy of Sulivan's sketch map showing the glacial cirque on Mount Adam. 'Dip' probably refers to the topographical dip slope rather than to the dip of the strata, which in the Mt Adam area are mostly inclined gently towards the north-east

the Cliff is nearly level the Cliff has fallen away till it has deposited a slope of fragments very steep reaching to within 10 feet of the summit, and about 200 feet down forming one Edge of a small deep lake outside of which is a mound very little higher than the water. This mound seems to have been a large mass of the Cliff which has fallen outwards leaving a hollow inside which hollow forms the lake."
Sulivan has described, perfectly, a glacially-eroded cirque now occupied by a small lake dammed by a terminal moraine ridge.

Darwin would probably have received this description in the British summer of 1843. In the previous year he had revisited sites in North Wales to examine them in the light of ideas of glaciation then gaining scientific credence, so was certainly interested in the subject and familiar with the debate then current. Unfortunately, at that time, cirques were not regarded as having a definitively glacial origin, and Darwin failed to make the connection with Sulivan's description. Instead, the Falklands examples were forgotten and only rediscovered in the early 1970s (Clapperton 1971). Thereafter, about 35 glacial cirques were soon identified from the highest parts of both East and West Falkland (Greenway 1972).

The Fitzroy Tillite Formation

An unappreciated glacial origin was also inherent in Sulivan's descriptions of unusual conglomeratic lithologies from both East and West Falkland. He first mentions having seen a 'porphyritic sandstone' around Port Fitzroy in letter 675 written from HMS *Philomel*, but the sighting appears to have been made towards the end of his earlier survey work on HMS *Arrow*. Aboard the *Philomel*, Sulivan had put into Port Sussex (on the west coast of East Falkland) and noted the same rock type. The term 'porphyritic' would normally be applied to a fine-grained igneous rock containing a scattering of large, isolated crystals, but here Sulivan uses the term to describe a sedimentary sandstone containing isolated pebbles of quartzite and granite. Later in letter 675 he describes a similar rock from the south side of Byron Sound, West Falkland, as follows; again the quotation is taken verbatim from letter 675:
"… it is nearly a hard clay, the colour yellow in one part & blue in another, yet every where 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[2] 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 now well-known cliff section exposing the Fitzroy Tillite Formation at Hill Cove on the north coast of West Falkland (Figure 4). Sulivan continues:

“This formation has some resemblance to that at the head of Port Fitz Roy containing granite and other Pebbles and which extends along the Flank of Mount Wickham Range to the Westward, but I do not think it is exactly the same. The Pebbles are larger the rock less compact and the variety of rocks much greater.”

Figure 4. Boulders of granite and quartzite weathering out of the Fitzroy Tillite Formation in a sea cliff near Hill Cove, West Falkland, exactly as described by Sulivan

Once again, Sulivan’s observations are spot on, and the differences that he notes between East and West Falkland are fundamental to modern interpretations of this unit. His comment that the deposit contains ‘rocks not found in the Islands’ is also important since it demonstrates that he was not just content to describe the geology, but was also thinking about the processes by which it may have developed. Even though he was unaware of the existence of the Cape Meredith Complex (it was not discovered until 1902, by the Swedish geologist J Gunnar Andersson) he was quite right in his supposition, and it is now believed that the Fitzroy Tillite Formation contains glacially transported boulders from as far afield as what are now the Transantarctic Mountains (Stone and Thomson 2005).

But what did Darwin make of it? In the footnote to his 1846 paper he rather hedges his bets, referring both to 'conglomerate' and to 'boulder formations'. It would appear however that at first he misunderstood the description since Sulivan returns to the subject in a later letter (No 730, dated between 13 January and 12 February 1845) wherein he attempts to correct errors in a reply from Darwin which has not survived. Sulivan writes: "You say it is the 'Ice formation', and suppose it to be on the South side of the Islands. It is quite the contrary."

Darwin's interpretation is given away by his use of 'ice formation'. From his Beagle observations around Patagonia, and subsequent trips to Scotland and Wales, Darwin had concluded that erratic boulders were carried onto shorelines at times of higher relative sea level, by icebergs and drifting floes (e.g. Darwin 1842). From that point of view it was natural that he should suppose the Falklands deposit to be on the south coast, where Antarctic ice might be expected to arrive. The apparent softness of the rock described by Sulivan from the Hill Cove section would also have misled Darwin into assuming that it was of relatively recent origin.

Paradoxically, Darwin's 'ice formation' interpretation was closer to the truth than Sulivan might have thought. The Fitzroy Tillite Formation is now known to be a glacigenic deposit laid down during an ice age approximately 300 million years ago. At the time all of the southern continents were joined into the enormous landmass known as Gondwana, and traces of the glaciation are preserved in all of them: for example the Dwyka Tillite in South Africa, the Crashsite Conglomerate in the Ellsworth Mountains, Antarctica, and the Sauce Grande Formation in Argentina, South America. The Falklands example, as so accurately described by Sulivan, was not rediscovered and correctly associated with this glacial episode until the early 20th century (Halle 1912). It was another fifty years before the differences that Sulivan had noted between East and West Falkland were rediscovered and interpreted in terms of different glacial environments; a terrestrial ice sheet in the west, glaciomarine deposition in the east (Frakes and Crowell 1967).

Falkland Pebbles

Agate pebbles are a well-known and much-collected attribute of some northern beaches, particularly in West Falkland. Pebble Island almost certainly derived its name from them, and was so called as early as the late 1760s. Sulivan was well aware of them and wrote in letter 675 that he intended to send Darwin a selection, but it is not clear whether or not he did. He records that in the coves at the head of White Rock Bay, in the north-east of West Falkland, the pebbles were much more numerous than on the Pebble Island beaches but more importantly goes on to describe their mode of occurrence, as follows, verbatim:
"They are contained in a shallow bed of earthy marl (I cannot describe it better) which has covered the other Formations in the hollows to a depth of from 3 to 6 feet,

and is in some places itself covered by earthy soil to an equal depth - as the bed containing the pebbles is worn away they line the beach at its foot and are washed up by the sea to the highest mark of the Tide: in one place this bed rests on a bed of peat about three feet thick which has filled the valley previous to the Pebble bed being deposited."
To illustrate this account Sulivan includes a cross-section showing the relationships of the various beds (Figure 5).

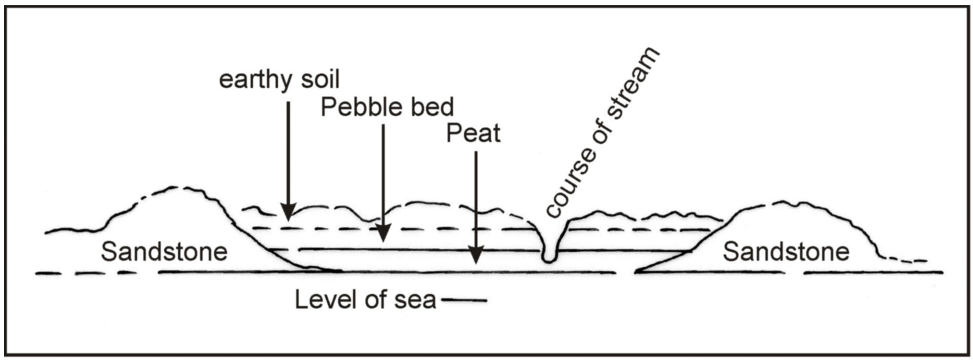

Figure 5. A copy of Sulivan's sketch showing the 'Pebble bed', a layer of 'earthy marl' containing agate pebbles resting on peat in White Rock Bay, West Falkland.

Though the origin of the pebbles has been much-debated (e.g. Aldiss and Edwards 1999) I do not think that Sulivan's description has been taken into consideration, and as far as I am aware no detailed studies have been made of the White Rock Bay locality. The most popular current hypothesis is that the agate pebbles (which would most probably have formed in cavities in volcanic lava) have been eroded and washed ashore from a source beneath the sea to the north. Sulivan's account of the White Rock Bay occurrence would seem to complicate rather than clarify such a process, demonstrating as it does that the accumulation of the pebbles has been going on for a considerable time. His final comment was "where do the Pebbles come from!!?" We still can't answer that question with certainty.

Fossils

Sulivan's "official" palaeontological memorial is *Schellwienella sulivani*, a species of brachiopod discovered in Darwin's '*Beagle'* collection from Port Louis and so-named, presumably at Darwin's suggestion, by Morris and Sharpe (1846) in their description of his fossils. For an illustration, see Falkland Island Journal 9(2) for

2008, page16, where the species is labelled according to its original allocation to the genus *Orthis*.

Whilst in White Rock Bay examining 'Falkland pebbles', Sulivan had also discovered a rock containing fossils but he thought it unusual, describing in letter 675 "… a sandstone more resembling that of Berkeley Sound and in it are fossil worms …" and noting later " … but I do not recollect ever seeing any worms in that." The Berkeley Sound sandstone was that forming what is now known as the Fox Bay Formation, about 400 million years old, and the source of Darwin's '*Beagle'* fossil collection. The Fox Bay Formation is also seen in the vicinity of White Rock Bay, where Sulivan's 'fossil worms' might just possibly have been articulated sections of crinoid stems (Figure 6).

Figure 6. Fossilised sections of articulated crinoid stems, a possible explanation for Sulivan's description of fossil 'worms'. This example is from Pebble Island, West Falkland. The 2-pence coin is 2.5 cm in diameter.

Although he would have been familiar with disarticulated and dispersed crinoid remains from his time with Darwin in Berkeley Sound, Sulivan may not have seen long, articulated sections before. Nevertheless, it is perhaps more likely that the 'worms' were trace fossils, the preserved burrows and trails of marine animals rather than the remains of the animals themselves. Meandering trails are common on some bedding surfaces in the Fox Bay Formation and some certainly have a worm-like appearance (Figure 7). Sulivan notes that the 'worms' are accompanied by a few of the familiar shells that "… appear to me to resemble those in the Berkeley Sound sandstone". Though Sulivan sent specimens back to Darwin they cannot be identified

in the latter's extant collection. If the association with trace fossils is valid, although Sulivan's identification of 'worms' may not have been strictly correct he was closer to the truth than the majority of contemporary geologists, who commonly regarded trace fossils as the impressions of fucoid seaweeds, rather than the work of marine animals.

Figure 7. Trace fossils (the feeding trails of marine invertebrates), another possible explanation for Sulivan's description of fossil 'worms'. This example is from Fox Bay, West Falkland. The 2-pence coin is 2.5 cm in diameter.

Letter 730 also notes the discovery of fossils at another West Falkland site, Burnt Harbour on the south coast of Saunders Island. These shells, Sulivan thought, were familiar forms though he noted later (Letter 886, written from Montevideo on 4 July 1845) that their location was "… further to the Westward than any I had before found." Two specimens were apparently sent back to Darwin and one of them (Figure 8) can be readily identified in the NHM's 'Darwin Collection' from Sulivan's description: "They are only the casts of shells but are very numerous being 15 in number on one bit of stone about 15 square inches". Any remaining doubt is dispelled by a small sketch of one of the shells (now known as *Australocoelia*

palmata) included in the letter 730, and by the locality name scratched on the back of the specimen, presumably by Sulivan (Figure 9).

Figure 8. Specimens of the brachiopod Australocoelia palmata collected by Sulivan on Saunders Island, West Falkland, and subsequently incorporated into Darwin's fossil collection which is now held by The Natural History Museum, London. The 2-pence coin is 2.5 cm in diameter.

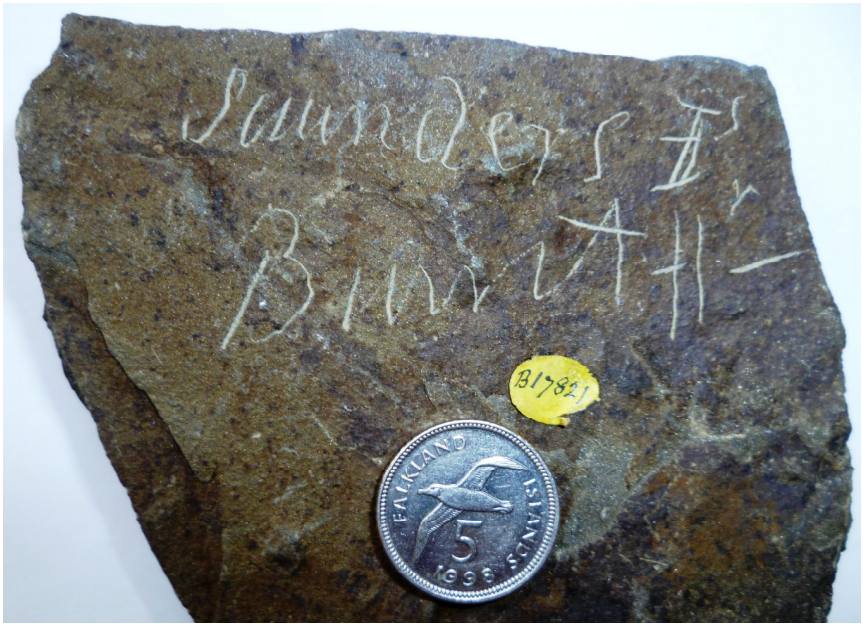

Figure 9. The inscription " Saunders I^s Burnt H^r " scratched on the back of the specimen shown in Figure 8, presumably by Sulivan. The 5-pence coin is 1.8 cm in diameter.

One other aspect of Sulivan's palaeontological observations in the Falklands is noteworthy. Around what is now Port Philomel he describes "… an extensive sandstone formation different from all the others …" by virtue of being " … more compact … and of a dark Colour but generally a dirty Yellow, having black lines apparently of some vegetable origin in it …". This unit is now defined as the Port Philomel Formation; it succeeds the Fox Bay Formation and is characterised by the presence of fragmentary plant remains (Aldiss and Edwards, 1999). Sulivan would have been unaware of the fact that he was describing plant fossils amongst the oldest then known – and Darwin didn't make the connection either.

A fascinating aside in letter 730 is Sulivan's account of an opportunistic trip, during a spell of fine weather, across to the coast of Patagonia taking soundings of water depth. He took HMS *Philomel* into the Rio Gallegos estuary to take on fresh water and whilst there discovered vertebrate bones and teeth in the cliffs, filled 'six casks' with the fossils and arranged for their dispatch back to Britain. These proved of great

scientific importance as precursors to the extinct megafauna famously discovered farther north by Darwin during the '*Beagle*' expedition. Sulivan's fossils were studied and described by Richard Owen, the top comparative anatomist of his day and founder of London's Natural History Museum, but sadly Sulivan's role in the discovery was soon forgotten, as recounted by Brinkman (2003).

Intrusive dykes

Arguably, the single most important contribution made by Sulivan to the full appreciation of Falkland Islands geology was his discovery of the intrusive dyke swarms of West Falkland. This was a completely new aspect, hardly done justice by the footnote to Darwin's 1846 paper noting that "Captain Sulivan observed on the western island numerous basaltic dykes". It has previously been supposed that Sulivan reported the presence of dykes to Darwin during the '*Beagle*' expedition (Aldiss and Edwards 1999; Greenway 1972), but the correspondence discussed here makes it clear that the discovery was made later, during the surveys by HMS *Philomel*.

All of the dyke descriptions come in letter 730, the first mention with specific reference to dykes cutting the quartzose sandstones of New Island and Weddell Island (though Sulivan refers to Weddell by its original name of Swan Island). However, Sulivan notes that he had been observing the features more widely for some time, but had only recently become convinced as to their origin. He describes "Numerous dykes running perpendicular in a North and South direction" but also included in the letter a sketch showing a dyke cutting obliquely across horizontal strata in the cliffs of a small island. Later in the letter he comments " … there are hundreds of these dykes running miles in length … and some are twenty feet wide, and all sizes from that down to two inches." However, with only Darwin's vague footnote as a published guide, the full extent of the West Falkland dyke swarm remained unappreciated and did not become apparent until more detailed geological investigations in the early to middle 20th century: Greenway (1972) conservatively records between three hundred and four hundred, mostly in West Falkland. The ages of the dykes are now known to range between about 180 and 120 million years (Stone et al. 2008).

The acuteness of Sulivan's observations is once again demonstrated by the detail that he recorded. For example, he describes the effects of thermal metamorphism adjacent to the dykes as follows: "one reason that made me doubtful before about the dykes being Igneous was, that the rock on each side was so little altered (tho for some inches it was decidedly so, and where the vein had fallen out the two sides or walls of the crevice stuck up in this manner – [*and here Sulivan inserts simple sketches to illustrate his description*] – and were very much harder than the rest of the sandstone but only for two or three inches)". This description can be precisely matched by

modern observations, as can his description of the weathering style characteristic of the dykes that tends to reduce them to spreads of loose, spherical blocks (Figure 10). As Sulivan described it, one twenty-foot wide dyke "… was composed of numerous concentric masses which … looked exactly like a pile of shot … so small and regular were the balls."

Figure 10. Rounded blocks of dolerite produced by spheroidal weathering of a dyke at Port Sussex, East Falkland; a widespread phenomenon first recognised by Sulivan. The blocks in the foreground, above high water, have been preferentially colonised by yellow and white lichens.

Coal

It was perhaps inevitable that during his survey voyages Sulivan would have been caught-up in one of the recurring wild-goose-chases after reported coal discoveries. In letter 675 he writes with exasperation that the Governor (Lieutenant Richard Moody) had sent back to Britain some specimens of coal purportedly found on West Falkland, and that it had been confirmed as of good quality by an eminent and

reliable authority. As a result, Sulivan complains that he had received orders from the Admiralty to "examine and report on the beds of coal". After some speculation about the residue left after peat has been burnt, Sulivan goes on to suggest that the Governor might have been maliciously deceived by "coal out of the vessels hold", or perhaps by accidentally spilt, imported fuel. He does however ask Darwin to check the details of the specimens sent to Britain; the only time, I think, when Sulivan asked Darwin for assistance – and there is no conclusive record that Darwin obliged!

Some final thoughts on Sulivan's contribution

The breadth and accuracy of Sulivan's geological observations are truly remarkable. The recipient of those observations, Charles Darwin, made use of some of the information in his 1846 paper 'On the Geology of the Falkland Islands', but he simply did not appreciate the importance of much of it. This does not reflect badly on Darwin, who was merely operating within the scientific confines of his time. We can only be grateful that Darwin preserved the letters received from Sulivan so that retrospective credit can be given. Any regret must arise from the limited use made of the letters before the democratisation of Darwin's archive via the internet. Scholars viewing the material from Darwin's side had noted the use he made of Sulivan's zoological observations from the Falklands in developing ideas of evolution and natural selection; to appreciate Sulivans's geological capabilities it was necessary to view the material from a different perspective. But better late than never, and to Sulivan's many acknowledged achievements can now be added his pioneering contribution to comprehensive geological studies in the Falkland Islands.

Curiously, the sketches of geological features that Sulivan inserted into his letters, and his comments about them, may throw light on another of his supposed talents. Though Robert Fitzroy described Sulivan as "not a neat draftsman" (Sulivan, 1896, page 49), three competent water-colour paintings of Falklands scenes held by the National Botanic Gardens, Dublin, were thought probably the work of Sulivan in an assessment by Moore and Scannell (1986). However, the drawings included in his letters, though perfectly adequate for the purpose, do not indicate any great artistic talent on Sulivan's part, and several comments in his letters suggest ironic reference to an acknowledged lack of artistic ability. So, for example, in letter 429, he writes "I will try & explain this by a splendid section" – which proves to be a simple 2-dimensional line drawing. Again, letter 730 includes some rudimentary sketches of fossils which Sulivan describes as "giving you specimens of my talent for drawing". In these examples the underlining is Sulivan's own emphasis. He did work with water colours, sending Darwin a cross section of the Rio Gallegos cliffs in that medium, but it is only a simple two-dimensional sketch with a colour wash added. From this evidence it would seem unlikely that he produced the Dublin water-colour paintings.

In conclusion, it might be claimed that Sulivan's geological interest actually saved his life. In letter 675 he recounts an incident on an island ('Eagle Island', Speedwell Island in modern terms) where feral pigs were present:
"I had rather a formidable encounter with one large boar, & had to thank my being a little bit of a geologist for my victory for … after putting my two dogs to flight he made at me and tho I put a ball through him and a charge of small shot in his face he still came at me till just as he got within two feet and was jumping over a bunch of tussac I recollected my Geological hammer in my belt and got it out in time to strike him so fairly on the Forehead that he fell dead."

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Notes
1. A type of gritty sandstone, the German grauwacke now Anglicised to greywacke.
2. The correct spellings are gneiss and syenite.

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Glossary of terms used

axial planar cleavage … a fissility imposed on a rock during deformation that forms symmetrically within a fold, parallel to the plane that contains the fold axis and bisects the angle between the fold limbs.

dyke … a thin sheet of igneous rock cutting steeply across the host bedrock having been injected in a hot, molten state; its margins are commonly chilled against its cooler host, whilst the adjacent bedrock may be altered by the heat of the dyke (see thermal metamorphism, below).

glacigenic … describing a sediment deposited by glacial processes in general.

glaciomarine … describing a sediment deposited beneath ice that is floating on the sea but has a terrestrial origin, and so contains much rock debris that melts out of the ice and falls to the sea bed.

lacustrine … describing processes active in a lake, or the sediment deposited therein.

periglacial … conditions developed in a frigid environment either marginal to, or in the absence of, glaciers or ice sheets; these conditions commonly involve permafrost.

regolith … the accumulation of unconsolidated rock debris, gravel, sand, clay and soil that covers bedrock.

terminal moraine … the ridge of rock debris (see till, below) that accumulates at the front of a glacier as the advancing ice melts.

Tertiary (or *tertiary* as used by Sulivan) … the relatively recent interval of Earth history from about 65 million years ago to about 2.6 million years go; now more commonly referred to as Cenozoic.

thermal metamorphism … the alteration of a rock by heat.

tillite … the rock type produced by the lithification of *till*, the general term for glacially-deposited, rubbly sediment comprising a range of rock debris held in a matrix of sandy clay.

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