

## DARWIN IN GALÁPAGOS: HIS FOOTSTEPS THROUGH THE ARCHIPELAGO

by

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### INTRODUCTION

Charles Darwin visited Galápagos for five weeks, from 15 September to 20 October, in 1835. This is a small fraction of the total of 248 weeks he spent on the voyage of the HMS *Beagle* (27 December 1831 to 2 October 1836), yet his experiences in Galápagos were of disproportionate importance in the development of his scientific thinking. As he wrote in his autobiography,<sup>1</sup> he was deeply influenced by his discovery of the similarity of Galápagos plants and animals to those on mainland South America, and especially ‘by the manner in which they differ slightly on each island in the group’. But while in Galápagos, Darwin was primarily a geologist.<sup>2,3</sup> He repeatedly attempted to explain the geomorphology he observed in terms of processes he could only infer: uplift, the direction of lava flows, their terrestrial or subaqueous origin and the eroding effects of seas. He also developed a theory of magmatic differentiation from looking at crystals embedded in the volcanic rock.<sup>4</sup>

Where was Darwin in Galápagos and what did he see? Much has been written about him on his visit to the islands,<sup>5–7</sup> but there is still confusion about exactly where Darwin set foot upon the four islands he visited: Chatham (San Cristóbal), Charles (Floreana), Albemarle (Isabela) and James (Santiago). Only one study has attempted to elucidate his whereabouts,<sup>8</sup> but it lacked information from the most revealing manuscripts<sup>9,10</sup> and so was incomplete and incorrect on points of detail. We attempted to answer these questions by first conducting an extensive search in bibliographic material for relevant information,<sup>11,12</sup> and then by retracing his steps as best as we could from 19 October to 14 December 1996,<sup>13</sup> that is at approximately the same time of year and season (dry) as Darwin’s visit.<sup>14</sup> Here we describe the route he took, several of his key geological observations, and changes that have taken place to the fauna and flora since his visit 165 years ago. By visiting the places he visited we were able to appreciate what caught Darwin’s attention, and why. The geological features seen and noted by Darwin are still extant today. The living world is in sad contrast, for it is no longer possible to see several components of the fauna and flora he observed.<sup>15,16</sup> Thus the information presented here is of potential value to scholars wishing to revisit his sites for historical or for scientific purposes (figure 1; see table 1 for GPS readings).

Table 1. Locations of sites as determined by GPS readings

island	name of site	south	west
Chatham	Cerro Tijeretas	0°53'26.7"	89°36'29.0"
Chatham	Fresh Water Bay, Honda Pond	0°51'29.0"	89°37'36.7"
Chatham	Dalrymple, 200 ft offshore	0°49'30.4"	89°31'25.3"
Chatham	Puerto Grande Beach	0°45'31.1"	89°27'29.4"
Chatham	Cerro Brujo, 50 ft below highest rim	0°45'39.2"	89°27'25.0"
Chatham	Cerro Brujo rim, near mouth	0°56'33.9"	89°29'25.6"
Chatham	High Crater, 1 mile in Craterized District	0°45'12.7"	89°25'19.9"
Chatham	beach at south edge of Craterized District	0°44'51.6"	89°26'22.5"
Chatham	landing site of Sulloway; tourist marker	0°43'19.0"	89°23'30.9"
Chatham	Cerro Brujo, group of seven dykes	0°45'43.0"	89°27'53.3"
Chatham	Pan de Azucar landing beach	0°41'53.5"	89°21'45.4"
Chatham	Pan de Azucar beach, where gully starts	0°42'11.4"	89°21'42.9"
Chatham	Pan de Azucar, 100 ft from summit	0°43'27.2"	89°21'11.9"
Charles	Black Beach	1°16'38.1"	90°29'17.6"
Charles	road to highlands near Black Beach	1°16'42.9"	90°28'40.8"
Charles	trail junction to Cerro Pajas	1°18'07.4"	90°27'09.6"
Charles	Cerro Pajas summit	1°17'43.5"	90°27'26.8"
Charles	behind south end of Post Office Beach	1°14'25.8"	90°26'57.3"
Charles	spring at base of hill	1°18'51.7"	90°27'17.8"
Charles	spring and pirate caves	1°18'57.6"	90°27'12.3"
Charles	spring at Cruz Farm	1°17'08.3"	90°28'12.4"
Charles	double cliff, facing Cerro Ballena	1°15'22.4"	90°29'18.0"
Charles	Champion	1°14'07.0"	90°23'08.0"
Albamarle	north Beagle Crater rim; Darwin's descent	0°16'19.0"	91°21'06.3"
Albamarle	Beagle Lake shore; Darwin's descent	0°16'29.8"	91°21'04.3"
Albamarle	freshwater ravine mouth by sea	0°16'27.6"	91°21'59.3"
Albamarle	Punta Cristóbal	0°52'55.1"	91°30'37.4"
Albamarle	cement dock at Caleta Iguana	0°58'48.0"	91°26'45.4"
Albamarle	Isla Tortuga summit, at climb point	1°00'44.8"	90°52'15.8"
James	Buccaneer Cove, camp	0°10'07.3"	90°49'28.9"
James	Buccaneer Cove, mid north beach	0°10'05.2"	90°49'28.8"
James	Buccaneer Cove, mid south beach	0°10'15.8"	90°49'36.5"
James	Buccaneer Cove, Pinnacle	0°10'07.7"	90°49'33.7"
James	Cerro Cowan, west side climb point	0°11'04.9"	90°49'51.9"
James	freshwater trickle	0°10'53.9"	90°50'12.1"
James	red hill in lava flow	0°13'51.7"	90°50'43.2"
James	vegetation in front of brown lava aa flow	0°14'09.4"	90°50'03.1"
James	northeast rim of salt crater lake	0°14'26.4"	90°49'59.4"
James	south shore of salt crater lake	0°14'32.6"	90°50'09.7"
James	northwest rim of Salina Escondida	0°16'26.6"	90°50'30.6"
James	southernmost pebble beach on lava flow	0°14'09.0"	90°50'54.9"
James	Buccaneer Cove, tip of promontory	0°09'57.1"	90°49'37.8"
James	tortoise pools	0°13'55.1"	90°47'01.2"
James	above Jaboncillos	0°12'43.0"	90°47'00.3"
James	Jaboncillos; trees and pottery area	0°12'24.8"	90°47'06.2"
James	Jaboncillos; bowl area near Scalesia fence	0°12'46.3"	90°46'56.2"
James	near top of island	0°13'06.2"	90°46'29.9"
James	Caseta at Central	0°14'29.1"	90°45'04.4"

CHATHAM (SAN CRISTOBAL)

*Cliff at NW end of Chatham (Cerro Tijeretas)*

At 4.15 pm on 16 September 1835 the *Beagle* anchored off the northwestern end of Chatham (Dalrymple Rock N57W, Kicker Rock N30E)<sup>17</sup> and Darwin landed for an hour. We now know that his first venture on to Galápagos soil was at Cerro Tijeretas, the present visitor site of the Galápagos National Park just northeast of Puerto Baquerizo Moreno. FitzRoy mentioned climbing a little hill here.<sup>18</sup> In his geological notes<sup>19</sup> [758] Darwin described a cliff, in which:

at a height of several ft above high water mark a breccia of huge fragments of vesicular & compact Basalt were united by a hard calcareous sandstone. In this were fragments of recent shells.

He extracted limpets (specimen 3290) and plates of chiton from the rock. From his work in South America, Darwin was particularly interested in uplifts and the ‘Cliff’ was notable in that he regarded it as ‘proof of elevation to a small degree within recent times’.<sup>20</sup> [758] Otherwise Darwin was not impressed by his first visit on shore comparing the country ‘to what we might imagine the cultivated parts of the Infernal regions to be’.<sup>21</sup>

Cerro Tijeretas is the only place in the vicinity of the *Beagle*’s anchorage with a cliff that has the calcareous rock referred to by Darwin. Here there are large reddish rock conglomerates containing several species of shells on the southwestern side of the cove at Cerro Tijeretas. The present National Park trail that leads down to the shore at Cerro Tijeretas ends near where Darwin landed.

*SW end of Stephen’s Bay (Puerto Grande)*

On 17 September the *Beagle* weighed anchor at 8.35 am and moved to Stephen’s Bay where it anchored at 11 am (Kicker Rock N10E, Finger Peak N45E).<sup>22</sup> Darwin went on shore in the afternoon to collect specimens but he wrote very little about where he landed. Here ‘the country was smoother and I believe the lava subaqueous, having flowed into shoal sea’.<sup>23</sup> [758] Puerto Grande is the closest landing site to the *Beagle*’s anchorage and fits Darwin’s brief characterization of the place.

While Darwin was on shore, Captain FitzRoy took a boat across Stephen’s Bay to Finger Hill (now known as Cerro Brujo) and spent the night there. We are convinced that Darwin did not join FitzRoy. Darwin was keenly interested in geology and if he had gone to Finger Hill he would surely have spent his time examining the unique geology of the crater. Instead, for that day, he wrote in the *Beagle* Diary ‘When on shore I proceeded to botanize ...’.<sup>24</sup>

On this day, Darwin saw his first marine iguanas (*Amblyrhynchus cristatus*). In the *Beagle* Diary he wrote:<sup>25</sup>

The black Lava rocks on the beach are frequented by large (2–3 ft) most disgusting, clumsy Lizards. They are as black as the porous rocks over which they crawl & seek their prey from the Sea—Somebody calls them ‘imps of darkness’.<sup>26,27</sup>

Today, due to predation by feral mammals (cats, dogs and rats) marine iguanas have all but disappeared along the coast of Chatham.<sup>28</sup>

Another animal Darwin mentioned seeing on 17 September, and which can no longer be found on Chatham, is the Galápagos hawk. It was so tame and approachable he was able to push one off a branch with his gun.<sup>29</sup> Tamelessness was also a feature of the Galápagos dove (*Zenaida galapagoensis*);<sup>30</sup> Midshipman King caught a dove in his hat.<sup>31</sup> Today doves are scarce on Chatham. Mockingbirds (*Nesomimus melanotis*) were also tame and common and, though not abundant on the island today, are still relatively unwary of humans. Darwin collected three of the four species of mockingbirds; he did not see the Hood (Española) Island species (*Nesomimus macdonaldi*). He noted that each island he visited had only one exclusive variety of mockingbird.<sup>32-34</sup> This was important to him later in developing his theory of evolution when he appreciated the significance of geographical isolation.

#### *Terrapin Road (Bahía Tortuga de Agua Dulce)*

On 18 September the *Beagle* lifted anchor at 8 am and came to a new anchorage at Terrapin Road at noon (Mt Pitt N76E, Kicker Rocks S50W).<sup>35</sup> Darwin landed here and climbed his first Galápagos tuff crater, which is now called Pan de Azucar. Darwin considered the tuff craters to be ‘the most striking feature in the geology of this Archipelago’.<sup>36</sup> As Simkin points out, ‘It was Darwin who first recognized how these tuff craters formed from the interaction of lava with water’.<sup>37</sup>

At Terrapin Road Darwin described ‘a level district of Basalt & Greystone, smoothed over & the interstices filled up by Calcareous Tufa’.<sup>38[749]</sup> In a shallow stream bed leading from Bahía Tortuga de Agua Dulce inland to Pan de Azucar, we found these flat slabs of lava covered in part with a white calcareous cement, which was studded with shell fragments. Darwin walked inland to ‘the broken remains of a low but broad<sup>39</sup> [sic] crater’.<sup>40</sup> He described the site as ‘some small hills in parts detached, in others joined to a central mass’.<sup>41[749]</sup> He ascended the tuff cone, measured the angles of strata, described the colour and texture of the tuff, and correctly estimated the height to be about 800 feet.

Darwin first mentions Galápagos tortoises (*Geochelone elephantopus*) on this day, recording that the *Beagle*’s ‘hunting party brought back 15 Tortoises: most of them very heavy and large’.<sup>42</sup> We found no tortoises at this site, only some old scats at the base of Pan de Azucar. However, tortoises can still be found a couple of miles to the northeast at a National Park visitors’ site called the Galapaguera.

#### *Fresh Water Bay (Bahía de Agua Dulce)*

The following day the *Beagle* lifted anchor at 9 am and sailed around the northeastern extremity of Chatham, reaching Freshwater Bay on the southern coast at 1.30 pm on 20 September. It stayed at Fresh Water Bay until 3 pm. We searched for evidence in the literature suggesting that Darwin went ashore, but found no such indication. In the *Beagle Diary*<sup>43</sup> he wrote: ‘At one point there were little rills of water, & one small cascade.—The valleys in the neighbourhead<sup>44</sup> [sic] were coloured a somewhat brighter green’. FitzRoy wrote in much more detail about this place: ‘I think it of very great importance, since there is no other natural Watering place [during the dry season] for

any number of Ships among the Islands'.<sup>45</sup> Some of the crew landed to determine the feasibility of collecting fresh water and found it to be a very difficult landing. The *Beagle* returned to this place on 11 October while Darwin was camping on James and spent two days taking on water for the ship.<sup>46</sup>

We found three cascades of water and two streams. We landed at La Honda, the largest stream that forms a freshwater pool behind a pebble beach. We had to swim ashore as we were unable to land by boat due to heavy swells. Nonetheless this little cove is the most accessible water source, and from FitzRoy's description<sup>47</sup> it is clearly the place where his men obtained water.

The *Beagle* left Fresh Water Bay and anchored in Stephen's Bay that same evening at 6.20 pm on 20 September. This was the same anchorage they had used on 17 September. Here the *Beagle* crew caught their first Galápagos turtles, most likely the Pacific Green turtle (*Chelonia mydas agassisi*) which is by far the most common species.<sup>48</sup> The *Beagle* stayed in Stephen's Bay until 22 September.

#### *Finger Hill and the 'Craterized District'*

According to the Field Notebooks,<sup>49</sup> on Monday 21 September Darwin and his servant Syms Covington were taken by boat '6 miles from the ship' to an area of many volcanic cones (Darwin called it a 'Craterized District'<sup>50[757]</sup>). On the way they passed Finger Hill. Darwin examined it up close from the boat. We know this because he described breaking a fragment off one of the broad dikes in the side of the hill.<sup>51[752]</sup> We thoroughly examined Finger Hill and found that there are ten dikes, they are on the sea side of the volcano, and they can only be observed and reached by boat. Darwin also mentioned Kicker Rock, describing its 'most singular form—a flat topped mass is surrounded by absolutely perpendicular cliffs.... On one side is an equally abrupt spire.—Rock height is 400 ft'.<sup>52[753]</sup>

Darwin depicted the Craterized District as:

a strange black district, bare of all vegetation & studded over with small Craters, so as to resemble those parts of Staffordshire & Shropshire where Iron Foundries are most common.<sup>53[754]</sup>

He also referred to this region as the 'Phlegrean fields'.<sup>54[731],55-57</sup> This is clearly the stretch of craters on the northwestern side of Chatham, but it is a vast area. Where exactly did Darwin land and explore?

Darwin and his servant landed at the Craterized District on 21 September and slept on a sand beach that night.<sup>58</sup> There are several small sand beaches along the length of the Craterized District. Darwin described two lava flows: one destitute of vegetation, rough and like 'a sea petrified in its most tempestuous moments',<sup>59[755],60</sup> and the other smoother and 'partially clothed with a stunted vegetation'.<sup>61[755]</sup> Darwin most likely landed and slept on the little beach that borders the southern edge of the Craterized District. This would have placed him at a convenient spot to examine both lava flows, and today at least it is the easiest beach to land at, the others having many submerged rocks at low tide. We know that he did not land at the far northern end of the Craterized District because of its great distance from the *Beagle*'s anchorage (11.25 miles).

Darwin described in great detail the craters in both lava flows,<sup>62[755–757]</sup> noting that their diameters ranged from 30 to 150 yards, that they were elevated from 50 to 100 feet above the surrounding country, that they were generally within one-third of a mile of each other and some were within 30 yards from rim to rim. He also described circular pits about the size of the smaller craters, from 30 to 60 feet deep, and gutters from 2 to 4 feet deep running from the base of the craters. In the *Beagle Diary*<sup>63</sup> he wrote ‘From one point of view I counted 60 of these truncated hillocks...’.

From these descriptions we know that Darwin must have ventured deep into the flow to make his measurements, and to where the craters and pits are dense. This area is much closer to the southern edge than the northern edge of the flow. Furthermore, there is a sketch<sup>64[752]</sup> of a volcanic tuff cone that can only be Finger Hill, viewed from inland. The perspective of the sketch shows that it was not made close to the hill but rather from deep within the Craterized District. He depicted the vegetated lava flow mentioned above as having flowed from the interior of the island around the base of Finger Hill.<sup>65[752]</sup> This is indeed how it appears from the Craterized District. However, the flow does not reach to the base of Finger Hill but only to within *ca.* 300 metres of the volcanic cone. Darwin believed that Finger Hill was once an island and that lava from Chatham flowed around its base thus connecting it to Chatham.

Darwin saw two tortoises on the vegetated lava flow,<sup>66</sup> and recorded that one of the tortoises was eating a prickly pear.<sup>67</sup> Presumably he was referring to *Opuntia* cactus. We found no tortoises or *Opuntia* on either side of the Craterized District, although they both exist elsewhere on the island. The *Opuntia* may have been destroyed by goats introduced after Darwin’s visit; there is no evidence of any introduced animals being on Chatham when Darwin was there. We found copious amounts of goat droppings throughout the area, on both lava flows, and frequently heard and saw feral goats. Reference to *Opuntia* cactus is significant for another reason. Darwin collected two, perhaps four, specimens of the now extinct large form of the large ground finch *Geospiza magnirostris* somewhere on this island.<sup>68</sup> According to Sulloway,<sup>69</sup> after he had left the archipelago Darwin apparently remembered seeing these birds for the first time on Chatham. The vegetated lava flow may have been the locality where these finches were encountered because they would probably have depended on the especially large seeds of *Opuntia megasperma* (and *Cordia lutea*) for food in the dry season.<sup>70</sup>

It is also interesting to note that while Darwin says one of the lava flows was destitute of vegetation, we did find candelabra cactus (*Jasminocereus thouarsii* var. *thouarsii*) scattered throughout the craterized flow, exclusively on the precipitous sides of the chimney cones and in the circular pits. We also found a Galápagos tomato plant (*Lycopersicon cheesmanii*) and a cutleaf daisy (*Lecocarpus*), both in flower, in a pit in the centre of the district. Darwin collected both of these plants.

Darwin collected a rice rat (*Oryzomys galapagoensis*) on Chatham.<sup>71,72</sup> The species is now extinct on this island. Rice rats were not collected on any other island, but an introduced rat (*Rattus rattus*) was found on James.

Darwin and Covington returned on board the *Beagle* on the evening of 22 September. The *Beagle* lifted anchor at 6.30 am on 23 September and set sail for Charles.

CHARLES (FLOREANA)

At 5.20 pm on the 24 September the *Beagle* anchored at what was then and still is called Post Office Bay. It stayed there until 3 pm on 26 September, then moved to Black Beach (Saddle Pt S11.10W, Round Hill S73E)<sup>73</sup> at 5 pm, where it stayed until 8.05 am on 28 September. Charles was the only inhabited island in Galápagos in Darwin's day. There was a settlement on the island consisting of about 200 political prisoners. Captain FitzRoy described it as 'an oasis in the Desert'.<sup>74</sup> There were many introduced crops growing in the highlands: sweet potato, sugar cane, Indian corn, yucca [cassava], pumpkin, plantain, Quito orange, castor oil plants, melon and bananas. Some of the plants collected by Darwin were later described by the botanist Joseph Dalton Hooker as being introduced.<sup>75</sup> FitzRoy took 'on board live pigs and a quantity of vegetables' from this settlement, and collected a small quantity of water from the highlands, which he conveyed down the hill in bamboo pipes.<sup>76</sup> Although the water was good, the supply was 'quite precarious in 1835'.<sup>77</sup>

Darwin was struck by the 'extreme tameness' of the land birds.<sup>78</sup> He talked about a boy 'Sitting by the side of a Well, with a long stick in his hand, as the doves came to drink he killed as many as he wanted & in half an hour collected them together & carried them to the house'.<sup>79</sup> We saw only one dove on Charles. The scarcity of doves today has been linked to the presence of feral cats.

Mr Nicholas Lawson, acting governor of the settlement, hiked down from the highlands and then accompanied Darwin and FitzRoy on the morning of 25 September back up to the settlement. However, instead of climbing directly to the settlement from Post Office Bay they took a boat to Black Beach and hiked from there along a 'good path'.<sup>80</sup>

We followed the 'old road' to Asilo de Paz, near where the settlement used to be. The 'old road' is now an overgrown path but would have been the trail that Darwin and FitzRoy used. At Asilo de Paz are 'several springs & small pools',<sup>81</sup> including the 'Governors Dripstone', which FitzRoy referred to in the Narrative.<sup>82</sup> Upon reaching the cultivated area they were struck by the lushness of the place: 'the body is cooled by the fine Southerly trade wind & the eye refreshed by a plain green as England in the Spring time'.<sup>83</sup> They returned to the *Beagle* that evening and the next day explored Post Office Bay.

Darwin found the island covered with vegetation and wrote that there appeared to be no recent lava flows. Charles had little interest to him geologically and he wrote scantily about the island.<sup>84</sup> Nonetheless, on 27 September Darwin climbed to the summit, which FitzRoy called Round Hill and which is now known as Cerro Pajas:

The highest hill is 1800 ft, its summit is formed out of the remains of a Crater, this escarpment consists of red glossy scoria, united together. -From this point I counted in different parts of the Island ... from 39-40 hills, in the summit of all of which there is a more or less perfectly circular depression.<sup>85[747]</sup>

In following in Darwin's footsteps we hiked to the summit of Cerro Pajas. Darwin wrote that the hill was 'covered in its upper parts with coarse grass and shrubs'.<sup>86</sup> Unfortunately the coarse grass today has been replaced with an introduced *Lantana camara* with vicious thorns. The other shrub, also with vicious thorns but a native plant

that Darwin probably saw, is *Zanthoxylum fagara*. There are relatively few of these trees now and none is very large. Formerly the island most likely supported a forest of such trees, occupied by the now extinct sharp-beaked ground finch (*Geospiza difficilis*, originally named *G. nebulosa*<sup>87</sup>). The *Beagle* collection of finches contains two specimens.<sup>88</sup> Today Cerro Pajas supplies the nesting grounds of a species of dark-rumped (Hawaiian) petrel (*Pterodroma phaeopygia*). Darwin made no mention of this bird; however, he was not there during its breeding season.

The Charles tortoise (*Geochelone nigra elephantopus*) is now extinct but in Darwin's day there were still tortoises on Charles. Even then their numbers were diminishing rapidly, and Darwin does not mention seeing any:

Of course the numbers have been much reduced; not many years since the Ship's company of a Frigate brought down to the Beach in one day more than 200, -where the settlement now is, around the Springs, they formerly swarmed. -Mr. Lawson thinks there is yet left sufficient for 20 years: he has however sent a party to James Island to salt (there is a salt mine there) the meat....<sup>89</sup>

Shells were to be seen lying around the settlement, some used as flower pots.<sup>90</sup>

While in the islands Darwin wrote 'Mr. Lawson states he can on seeing a Tortoise pronounce with certainty from which island it has been brought'.<sup>91</sup> Later on in the voyage Darwin began to recognize this as being important evidence, together with the fact that different species of mockingbird are restricted to different islands, for evolutionary divergence in geographical isolation.<sup>92</sup> Darwin also noted differences in the flora of the different islands:

For instance the berry-bearing tree, called Guayavita [*Psidium galapageium*], which is common on James Island, certainly is not found on Charles Island, though appearing equally well fitted for it.<sup>93</sup>

### *The 'double cliff'*

Other than Cerro Pajas, Darwin described only one geological feature on Charles. He wrote that the shore of Charles contained evidence of uplift because of the presence of large round boulders above the high tide mark. We think that he examined this coast from the boat as he was travelling between Post Office Bay and Black Beach:

On the north side of the Island, I noticed in many places a beach of large rounded Rocks, which appeared to me decidedly to be quite beyond the reach of the Surf at the present level. -In one spot, there was a low double cliff, & on the top of the [sic] both a bank of such pebbles. [small sketch] Perhaps this raised beach may be, where highest, 15 ft above the line of any present action.<sup>94[748]</sup>

Later in his volume on *Volcanic Islands* Darwin discounted his explanation of an uplift when he was informed by eyewitnesses that 'the rounded boulders, now lying on its summit, are merely the remnant of those which had been rolled up during storms, to their present height'.<sup>95</sup> To find this 'double cliff' we walked along the coast from Black Beach north towards Post Office Bay, and also searched for it by boat. We found the double cliff approximately half a mile north of Black Beach. As Darwin described it, the shore consists of large pebbles and boulders, some of which appear to be above the high tide mark.

CHAMPION

Darwin did not visit the satellite islands around Charles, nevertheless he wrote:

Mr. Chaffers inform all the small Islands around Charles have all Craters. - Champion Isd is a much weathered Crater, partially composed of Sandstone, containing marine shells.<sup>96[732]</sup>

He mentions that ‘Mr. Chaffers ... brought me from Champion Is a fossil shell: which he extracted from Volcanic Sandstone at the height of 400–500 ft’.<sup>97[748],98</sup> He then conjectures:

Has this been a horizontal upheaval. - Everything shows that in place of these Islands being formed by pile of poured out matter, there has been upheaval extending over these different Isd.<sup>99[732-733]</sup>

Later, however, Darwin wrote that ‘Proofs of the rising of the land are scanty and imperfect’.<sup>100</sup>

Champion is biologically interesting because it has populations of mockingbirds and snakes once abundant on Charles but now rare or extinct, and thus represents a remnant of what Charles once was. Mockingbirds were present on Charles during Darwin’s visit, but became extinct on Charles at the end of the last century.<sup>101</sup> The status of the Galápagos snake (*Philodryas biserialis*) is unclear but it is rare if present at all. FitzRoy wrote that several snakes were caught on Charles.<sup>102</sup> Champion, unlike Charles, has no introduced mammals.

On 28 September, at 8.05 am, the *Beagle* weighed anchor and set sail for Albemarle.

BRATTLE (TORTUGA)

On 28 September the *Beagle* sailed past Brattle (Tortuga). Darwin did not land here but he described the island’s perfect crescent shape.<sup>103[760,788-789]</sup> Brattle was important to Darwin in that it represented the perfect example of a phenomenon that he and the officers of the *Beagle* involved in the survey of the islands had been observing frequently in Galápagos; that many sandstone (tuff) islands and island tuff cones were eroded on the southern side.

He listed 28 instances of this phenomenon, and could find no exception to the rule.<sup>104[788-789]</sup> He noted 12 islands that ‘form separate islets, and now exist as mere crescents quite open to the south, with occasionally a few points of rock marking their former circumference’, Brattle being the largest and most perfect.<sup>105</sup> The other islands were three of the Crossman’s, Cowley, Gardner, Champion and Enderby near Charles Island, two small islets near Indefatigable, an islet near James (possibly Albany) and a small islet described by Lieutenant Sullivan as containing a salt lake which ‘has a part of the southern side of the circular ridge not higher than 20 ft, whilst the remainder is perhaps 300 ft above the level of the Sea’.<sup>106[789]</sup> This last islet is clearly one of the Bainbridge Rocks off the southeastern coast of James. Darwin also listed 16 tuff

craters, which had the side facing the south much lower than the other parts of the rim. He explains the phenomenon of the cones being broken down on one side as follows:

Throughout the islands of the archipelago, both the sea, from the tradewind & the long swell of the Great Ocean constantly unite their unwearied forces against Southern shores.<sup>107/790]</sup>

The prevailing winds also give rise to a higher build-up on the leeward rim, as Darwin noted on his visit to Ascension Island.<sup>108</sup>

#### ALBEMARLE (ISABELA)

##### *Point Christopher (Punta Cristóbal)*

On 29 September the *Beagle* rounded the southern end of Albemarle, anchoring from 1 pm to 3 pm, at Iguana Cove (Caleta Iguana).<sup>109</sup> A whale boat was lowered to survey Elizabeth Bay and the western shore of Narborough (Fernandina) Island,<sup>110</sup> but we could find no evidence suggesting that Darwin landed. FitzRoy noted the large numbers of ‘hideous iguanas ... were quite startling!’<sup>111</sup> Continuing round the southwestern end of Albemarle, the *Beagle* passed an area similar to the Craterized District of Chatham. This is clearly the area around Point Christopher. Darwin wrote:

Passed a point studded over with little truncated cones ... the Craters were very perfect & generally red-coloured within. - The whole had even a more work-shop appearance than that described at Chatham Island.<sup>112</sup>

Darwin was probably eager to explore this area on foot but ‘A calm prevented us from anchoring for the night’ and he did not land.<sup>113</sup>

While sailing northwards along the west coast of Albemarle, Darwin was impressed by the island’s immense volcanoes, which he conjectured to ‘be surmounted by enormous Craters, from which bare & black streams of Lava can be traced down their sides’.<sup>114[759]</sup> Both Darwin and FitzRoy observed an active fumarole on Albemarle. Darwin wrote ‘...in 2d mound from the south, there was steam issuing from Crater high up’.<sup>115[744–745]</sup> He referred to this mound, now known as Sierra Negra, as Volcano Hill.<sup>116[759]</sup> Darwin did not have the opportunity to climb and examine any of the volcanoes on Albemarle. In a letter to Lyell in 1857,<sup>117</sup> he wrote ‘I always regretted that I was not able to examine the great craters on Albemarle Isd, one of the Galapagos’.

##### *Banks (Tagus) Cove*

The *Beagle* passed the American Whaler *Science* in the morning of 30 September and at 6.18 that evening she arrived at Banks Cove.<sup>118</sup> Darwin explored Beagle Crater on 1 October. Although he only spent one day there he devoted over a third (36 pages) of his geological notes on Galápagos<sup>119</sup> to descriptions of Beagle and Tagus Craters. Darwin did not give Beagle Crater a name but its identity is clear from his description. Furthermore, he drew a fairly detailed sketch of both craters and the intervening land.<sup>120[745]</sup>



crater.<sup>123[734]</sup> There are actually six islands but four of them are very small and two appear to be joined together. They have never been named and so we have named them after crew members on the *Beagle* who helped Darwin with making collections in Galápagos (see figure 2).

At Beagle Crater Darwin made two other salient geological observations. The first was a prevalence of ‘a pisolitic structure: the balls [ranging] from size of shot to small bullets, formed of thin concentric layers of the finer particles of the sandstone (margin note 3250).<sup>124[761]</sup> These pisolitic balls were also known as rapilli<sup>125</sup> and are today called accretionary lapilli. We found a profusion of them on the northern rim of the crater. The second feature was an abundance of furrows or ‘longitudinal doons

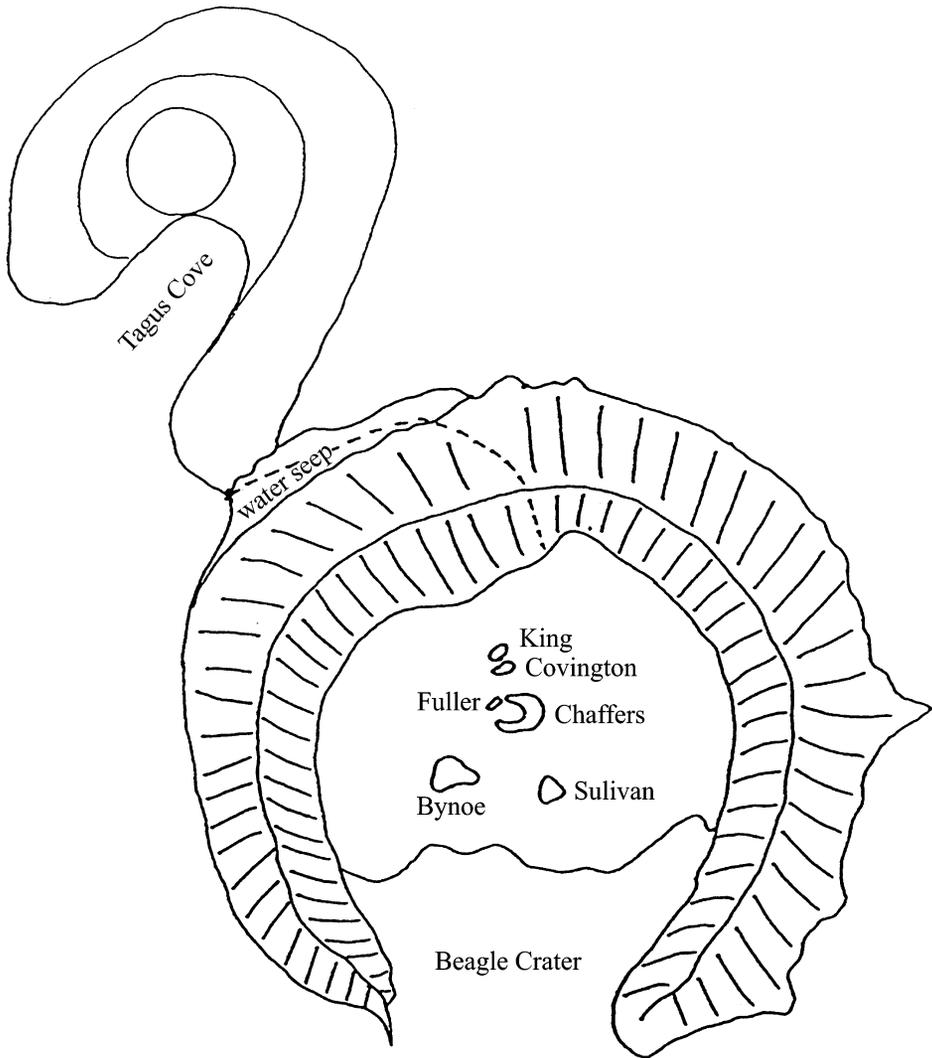


Figure 2. New names for islands in Beagle Crater, Albemarle (Isabela) Island. The map is drawn from aerial photographs in the archives of the Charles Darwin Research Station, Galápagos.

[dunes]<sup>126[762]</sup> on the external slope of Beagle Crater. He was much struck by them and in a letter to Lyell in 1850 wrote:

...I think you overlook the cream of my case of tuff-strata at Galápagos, viz that the beds form narrow streams, hollow within from the setting of the outside crust, & therefore no one c<sup>d</sup> here suppose that we had once **horizontal strata** uplifted....<sup>127</sup>

The furrows were 'from 8 to 20 or 40 feet wide, are separated from each other by shallow gullies'.<sup>128[762]</sup> He likened the dunes to the roofs of plastered vaulted passages, cracked into plates.<sup>129</sup> At the rim these dunes sometimes were hollow tunnels and on the north-western lip of the crater they opened into hoods.<sup>130[763]</sup>

Darwin described Banks Cove, although he did not examine it as thoroughly as Beagle Crater. He depicted the cove as being larger than Beagle Crater and in a much more demolished state, with sides 'weathered by the sea into bold cliffs'.<sup>131[766]</sup> He also briefly mentioned another crater with a salt lake at its bottom within the outer ring of Banks Cove; this lake is now known as Darwin Lake. Darwin believed that Beagle Crater was formed above water whereas Banks Cove was probably formed by a marine eruption.<sup>132[745]</sup>

The importance of Beagle Crater and Banks Cove to Darwin lay in their uniqueness:

I have particularly described these Craters because I do not recollect having read of an exactly parallel case - nor indeed of a large Crater entirely composed of Volcanic Sandstone under any circumstances.<sup>133[767]</sup>

The last feature to be described for this area were the lava flows between Beagle Crater and Banks Cove.<sup>134</sup> These flows emanate from what is now called Darwin Volcano. Darwin observed that 'One enormous stream, many miles broad<sup>135</sup> [sic], almost entirely destitute of vegetation (I believe I must except 2 or 3 plants of a Cactus) interfolds behind & between the Sandstone Craters'.<sup>136[768]</sup> He poetically compares this stream with the lava flow of the Craterized District on Chatham Island:

The outline of the field of Lava as compared to the Basaltic one of Chatham Is<sup>d</sup> is much smoother - there is not that appearance of huge frozen billows, or nearly so many fissures of contraction. On the contrary the surface itself is excessively rough. I should compare the one to the ocean, the other to a lake violently agitated by a storm.<sup>137[768],138</sup>

He also mentions another more recent and blacker lava flow which crosses the former flow and 'which has flowed from a minute & perfect Crater high up on sides of mountain'.<sup>139[769]</sup> From Beagle Crater this lava flow is easily observed and identified, and the surface resembles the circular pattern of a roughly ploughed field.

As for animal life, Darwin<sup>140</sup> wrote that the rocks abounded with large marine iguanas. He also saw his first land iguanas (*Conolophus subcristatus*) on the slopes of the craters:

We here have another large Reptile in great numbers - it is a great Lizard, from 10-15 lb in weight & 2-4 ft in length, is in structure closely allied to those imps of darkness<sup>141</sup> which frequent the sea-shore. - This one inhabits burrows to which it hurries when frightened with quick & clumsy gait. They have a ridge & spines along the back; are colored an orange yellow, with the hinder part of back brick red. - They are hideous animals but are considered good food: This day forty were collected.<sup>142</sup>

It would not be possible to collect 40 today. During the expedition we found no land iguanas. However, on a return visit during the wet season we found three on the northern base of the outer slope of Beagle Crater. We also found six tortoises on the return visit. Darwin did not mention finding tortoises here and perhaps they are absent during the dry season. Finches abound at Banks Cove and we found several small ground finches drinking water from seeps in the rock at the water source, as did Darwin.<sup>143-145</sup> However, unlike Darwin, who saw many doves in the area, we only saw two. Doves, which nest on the ground, have probably succumbed to predation by cats, which were introduced after Darwin's visit. Goats are another addition to the island since Darwin's time. In the two days that we were at Beagle Crater and Banks Cove we saw two dozen goats and found their droppings as well as cat scats everywhere.

The *Beagle* left Banks Cove on 2 October at 10 am, rounded the north of Albemarle on 3 October and reached Buccaneer Cove on James Island on the morning of 8 October.

#### JAMES (SANTIAGO)

##### *Buccaneer Cove*

The *Beagle* arrived at Buccaneer Cove<sup>146</sup> on 8 October at 11.20 am. Darwin landed with Covington, the surgeon Bynoe and his assistant Fuller,<sup>147</sup> and the *Beagle* left at 5.30 pm for Chatham to take on water. The men camped in the valley behind Buccaneer Cove. They had difficulty in finding a spot to pitch their tent because of the numerous land iguana burrows.<sup>148</sup> To Darwin, the iguanas had a stupid appearance when they slept with their eyes shut or walked slowly, pausing to shake their heads up and down. He noted<sup>149</sup> that they ate much cactus and 'run away like dogs from one another with pieces'. A finch was observed picking from the same piece, often alighting on the back of an iguana.<sup>150</sup> Other animals noted were the hawk and mockingbird<sup>151</sup> and these can still be seen today. The land iguana, however, has since become extinct on James.

On arriving at Buccaneer Cove they met a party of men, sent from Charles by Mr Lawson to salt fish and tortoise meat.<sup>152</sup> Before lifting anchor, FitzRoy gave these men a 50 lb bag of biscuit, which was received as if it were gold, since they had been living off nothing but tortoise meat.<sup>153</sup> Darwin and his companions employed these men to bring water to them from the 'miserable little Spring of Water'<sup>154</sup> at the foot of the ravine that appears to split Cerro Cowan in half. FitzRoy estimated a yield of about 10 gallons of water an hour from this spring.<sup>155</sup> When we visited the site on 6 November, we managed to collect one litre in half an hour (less than half a gallon in an hour).

Sometime before 13 October the surf broke over the water source and spoiled the pool of fresh water.<sup>156</sup> Fortunately, an American whaler gave them three casks of water.<sup>157</sup> We, too, noted how the surf at high tide contaminated the pool of freshwater.

Darwin described the geology of Buccaneer Cove in much detail, paying particular attention to the 'promontory',<sup>158[770]</sup> which defines the northern side of Buccaneer Cove. A geological formation composed of layers of basalt and scoria stood at the base

of the promontory on the beach, a structure that he found 'rather curious'.<sup>159[718]</sup> He measured the streams of lava, described their colour and crystal composition,<sup>160,161</sup> and drew a sketch of the formation.<sup>162</sup> We located this formation on the northern end of Buccaneer Cove on the beach near the base of the promontory. Although Darwin never named the formation, we have called it 'Darwin's Layer Cake'.

Another aspect of the promontory of interest to Darwin was the core or 'bosom' of an eroded crater.<sup>163[720]</sup> This is a mass of a 'quite compact, greenish or blackish grey Trachyte, with few Cryst of glassy feldspar'<sup>164[720-721]</sup> located in the lower centre of the promontory. In the lower surface of this formation Darwin found similar rock 'but containing larger and more abundant crystals of glassy Feldspar'.<sup>165[721]</sup> This important observation was key in developing his ideas on how different types of material could be extruded from the same vents.<sup>166</sup> Darwin also wrote about there being 'grand dykes'<sup>167[773]</sup> and how they formed 'lofty & singular pinnacles'.<sup>168[772]</sup> These black dikes can be found on the southern side of the promontory.

Finally, Darwin described the mass of land on the south side of the cove which is now called Cerro Cowan. He noted that this hill was the

highest (850 ft) in the neighbourhead [sic]; is surmounted by remains of a large Crater. The whole is composed of Volcanic Sandstone, full of fragments of lava, which abound to such a degree, that some layers are composed of them. - The outside is worn into high & steep cliffs; which are continued deeply beneath the sea.<sup>169[778]</sup>

From the appearance of the unique layers of rock which composed the formation he reasoned that they were of 'subaqueous origin'.<sup>170[778]</sup>

### *Highlands*

Darwin and his companions made two excursions into the highlands, on 9 and 12 October. Their walk was long and at what Darwin estimated to be an elevation of 2000 feet where 'the country begins to show a green color' they came across 'a couple of hovels' where the tortoise hunters lived.<sup>171</sup> At such an elevation the Guayavita tree is and was common (Duncan Porter, personal communication). Darwin wrote that the berries were a principal food of both tortoises and land iguanas. He resided for two days at the hovels, during which time he lived on fried tortoise meat. He ventured a further two miles and an additional 1000 feet in elevation to some springs. Here he found tortoises to 'swarm in the neighbourhead'<sup>172</sup> [sic] of the Springs'.<sup>173</sup> The average size of an adult tortoise was almost a yard long and too heavy to lift off the ground but it could easily carry him.<sup>174</sup> He noted that they would lie submerged in the springs and drink great mouthfuls of water ('about 10 gulps in a minute'<sup>175</sup>). Broad paths made by the tortoises extended for miles from the springs.<sup>176</sup> Darwin calculated that they walked at the rate of 30 yards in five minutes. At the time of his visit tortoises were laying their eggs in sandy soil or in hollows in the rocky ground.<sup>177</sup> Unlike turtles, he observed, tortoises cannot be placed on their backs to secure them because they are able to right themselves.

Pools of water and tortoises can be found today in an area called Central in the highlands. However, we think it more likely that he was at another area called Jaboncillos, which is closer to the summit.

While Jaboncillos is now barren and dry due to devastation by introduced goats,

when Darwin was there Jaboncillos was probably lush and green, covered with *Scalesia*,<sup>178</sup> *Zanthoxylum fagara* and ferns. Darwin wrote:

During the greater part of each day clouds hang over the highest land: the vapor condensed by the trees drips down like rain. Hence we have a brightly green and damp Vegetation & muddy soil.<sup>179</sup>

Jaboncillos is near the summit of James, the clouds do hang over this area during the day and the few remaining *Zanthoxylum fagara* trees at Jaboncillos continually drip with moisture collected from the clouds. Jaboncillos is 800 metres high (2624 feet), which is close to the elevation that Darwin estimated the springs to be (3000 feet). In contrast, Central is only 600 metres high (1968 feet).

Another reason for believing that Darwin was at Jaboncillos is the fact that his description of a crater best fits the one we found there:

...there is a large & perfect Crater, circular, sides very precipitous and bottom well wooded. In the vicinity nothing, but Trachytic lava is found: the channels, by which the lava has flowed over the rim are yet visible. —The walls of the Crater are chiefly composed of bright red & very glossy scoria, united together.<sup>180 [770]</sup>

Darwin made a comparison of rock specimens<sup>181</sup> from different elevations on James and found:

The Trachytic lavas in the lower parts of the Isd are very cellular & the imbedded Crystals of glassy Feldspar very large & abundant: [whereas] - in the higher central part, the rock generally is more compact, the base blackish grey with scarcely any Crystals, & or they are abundant & small, the base itself being Crystalline.<sup>182 [770]</sup>

Close to the summit of James, Darwin encountered a number of rails which he also called water hens. We saw this bird, which is now known as the Galápagos Rail or Galápagos Crake<sup>183,184</sup> (*Laterallus spilonotus*) and like Darwin we heard it ‘uttering loud & peculiar Crys’.<sup>185</sup> Interestingly Darwin stated that there were no tree ferns on James.<sup>186</sup> There are tree ferns but not at Jaboncillos.

### *The salina*

On 11 October Darwin and his companions were taken by the head of the tortoise hunters (the ‘Mayór-domo’) in a boat down the coast to a salina. This salina is now referred to as the Salt Mine by the Galápagos National Park Service. The ‘Mayór-domo’ landed Darwin and his men on the lava flow in James Bay or ‘Puerto Grande’ as Darwin called it.<sup>187 [779]</sup> Where exactly he landed on the lava flow is unknown, but it was at one of the several spots where there are large grey boulders full of olivine crystals. Darwin described these boulders as being a few feet above the present level of tides, and was impressed with how they abounded with olivine.<sup>188 [780]</sup>

To reach the salina Darwin crossed the bare lava flow, then ‘utterly destitute of vegetation’,<sup>189 [779–780]</sup> but today sparsely covered by several plant species, most commonly the lava cactus (*Brachycereus nesioticus*). Darwin used evocative language to describe the pahoehoe lava flow:

The surface is smoother than in the Basalt of Chatham Is<sup>d</sup>, yet here there are great waves & fissures. The superficies itself has formed singular ringed & twisted forms, which resemble cables, folds in thick drapery and rugged bark.<sup>190 [780]</sup>

Within the surface of the flow: ‘The sides of the little Fissures which have acted as Fumaroles are yet white’,<sup>191[780]</sup> and these fissures are still visible today. A more recent, darker stream of lava had crossed the greater flow but due to the size of the trees growing in its margin, Darwin reasoned that it was very old.<sup>192[780]</sup> He noted that:

A Terrapin was caught some years since with its Shell appearing to have been burnt years before. The inhabitants believe this the effect of Volcanic fire. I rather accidental fire in wood.<sup>193[723]</sup>

Darwin was impressed by the picturesque appearance of the salina:

At the bottom of this Crater is a Lake, which is only 3 or 4 inches deep & lies on layers of pure & beautifully Crystallized Salt. The Lake is quite circular & fringed with bright green succulent plants; the sides of Crater are steep & wooded; so that the whole has rather a pretty appearance.<sup>194</sup>

The salt was collected from the central parts of the lake because the edge was soft and muddy.<sup>195[783]</sup> Darwin questioned whether the salt was ‘a Volcanic exhalation’ rather than evaporated seawater which had percolated into the crater.<sup>196[783]</sup> Today there is only a thin layer of impure muddy salt and it is no longer quarried. *Opuntia* trees (*Opuntia galapageia*), once present in the neighbourhood and recorded by Darwin in a sketch,<sup>197</sup> are now scarce, owing to damage by feral animals.

There was one other tuff crater that Darwin considered worthy of description on James. FitzRoy called this crater Sugar Loaf (Pan de Azucar).<sup>198</sup> Darwin examined the outer slopes and was struck by the ‘perfect smoothness’ of the layers of tuff.<sup>199[784]</sup> He likened the lower slope to an immense and cracked plastered floor.<sup>200</sup> Lieutenant Sullivan, one of the officers of the *Beagle*, gave Darwin a description of the interior.<sup>201[783]</sup>

Darwin briefly mentioned a third crater: ‘At the distance of 2–3 miles there is another hill of similar appearance, in the Crater of which there is said to be another Salina’.<sup>202[783]</sup> We found this crater immediately to the south of Sugar Loaf. We climbed it and discovered a tiny salina in the bottom, as Darwin had been informed. Since we can find no name for this crater we have named it ‘Salina Escondida’, as it has remained hidden until now. In the *Beagle* collections are the stomach contents of a flamingo. Although the specimen was not labelled, Darwin notes that flamingos were found in the salinas.<sup>203</sup> We also found flamingos in both of the salinas.

### *Buccaneer Cove again*

From 12–16 October, Darwin and his companions were busy collecting specimens.<sup>204</sup> On 12 October Darwin paid another visit to the hovels and spent the night there, as mentioned earlier. Darwin spent 14 October wandering about bird collecting, and observing the land iguanas.<sup>205</sup> At Buccaneer Cove Darwin measured air and sand temperatures remarking on how high they were:

During the last two days, the Thermometer within the Tents has stood for some hours at 93°. —In the open air, in the wind & sun, only 85°. —The sand was intensely hot, the Thermometer placed in a brown kind immediately rose to 137, & how much higher it would have done I do not know: for it was not graduated above this. - The black Sand felt far hotter, so that in thick boots it was very disagreeable to pass over it.<sup>206</sup>

We measured similar temperatures.<sup>207</sup>

On 17 October, at 3.50 pm, Darwin and his companions were back on board the *Beagle*.

#### SURVEYS AND DEPARTURE<sup>208</sup>

On 8 October, the day Darwin landed on James, Lieutenant Sullivan and a party of men returned from surveying the central islands, having left the *Beagle* on 16 September.<sup>209</sup> While Darwin was on James, the *Beagle* sailed towards Chatham around the north of James and Indefatigable (Santa Cruz). At 11 am on 11 October it anchored at Fresh Water Bay on Chatham,<sup>210</sup> where the crew took on fresh water, wood and 30 tortoises on that afternoon and the next day.<sup>211</sup> Today tortoises are no longer found on this part of the island. They unmoored at 6 am on 13 October and headed towards Hood (Española) Island. On their way they surveyed Macgowen Reef. On the morning of 14 October they anchored on the north side of Hood. They then sailed off towards Charles, anchoring on the west coast at 9 pm. Here they saw an American whaler at anchor. At 5.30 the next morning they headed to Post Office Bay, anchoring at 11 am. There they stayed until 3 pm on 16 October. Although FitzRoy wrote about the post office barrel at Post Office Bay, he said it was no longer used and that letters were left at the settlement. Their next stop was at Black Beach to take on wood, potatoes and pigs. They also picked up mail from a schooner that had just arrived from Guayaquil. On the ship were cattle for the settlement. The *Beagle*, after leaving Charles, navigated up the east coast of Albemarle and at 2.30 pm on 17 October sent a boat to James Island to collect Darwin and his companions.

FitzRoy<sup>212</sup> stressed the danger of getting lost on islands like James. On the day they picked up Darwin from Buccaneer Cove a search was being conducted for a man missing from the American whaling ship that had supplied Darwin with fresh water less than a week earlier.<sup>213</sup> On 18 October the *Beagle* cruised up the northeastern coast of Albemarle. On 19 October they picked up Chaffers, who had been surveying the islands of Tower, Bindloe and Abingdon.<sup>214</sup> Chaffers had collected rock specimens for Darwin from these islands including fossil shells from Bindloe:<sup>215</sup> ‘There is a steep Crater also of Volcanic Sandstone; out of which Mr Chaffers procured 3 species of shells, & saw many fragments of an Oyster (3292),’<sup>216[785]</sup> At sunset on 20 October, after surveying Wenman (Wolf) and Culpepper (Darwin) Islands, they sailed out of Galápagos waters, headed for Tahiti.

#### ACKNOWLEDGEMENTS

We owe a debt of gratitude to many people who helped us in the bibliographic and field aspects of this study, especially to Richard Keynes for generously allowing us to transcribe Charles Darwin’s geological notes on Galápagos. We thank Adam Perkins and Godfrey Waller at the Department of Manuscripts and University Archives of Cambridge University Library, Ken Atherton at the United Kingdom Hydrographic

Office in Taunton, and staff at the Public Record Office in Kew for permission to examine bibliographic material. In Galápagos, we thank Eliecer Cruz, Diego Bonilla and staff of the Galápagos National Parks Service, as well as the staff of the Charles Darwin Research Station for support, encouragement and permission to follow the route Darwin took, and for transport on several occasions.

#### NOTES

- 1 N. Barlow (ed.), *The autobiography of Charles Darwin, 1809–1882* (Collins, London, 1958).
- 2 Pearson (see note 3) has shown that while in Galápagos Darwin wrote ‘a total of 109 manuscript pages on volcanic observations (in addition to field notes), and only 37 on zoology’.
- 3 P.N. Pearson, ‘Charles Darwin on the origin and diversity of igneous rocks’, *Earth Sciences Hist.* **15**, 49–67 (1996).
- 4 *Op. cit.*, note 3.
- 5 J. Browne, *Charles Darwin. Voyaging* (Princeton University Press, Princeton, NJ, USA, 1995).
- 6 F.J. Sulloway, ‘Darwin and the Galápagos’, *Biol. J. Linn. Soc.* **21**, 29–59 (1984).
- 7 A. Desmond and J.R. Moore, *Darwin* (Michael Joseph, London, 1992).
- 8 *Op. cit.*, note 6.
- 9 Cambridge University Library, Manuscripts Department, DAR 37.2. (folio numbers are indicated in square brackets).
- 10 R. FitzRoy, *Log of the Voyage of the Beagle 1831–1836* (Admiralty 53/236 Part 2. Public Record Office, Kew) (unpublished manuscript, 1831–1836). We have included in the text FitzRoy’s bearings of land formations taken at anchor where the localities of those anchorages are in any way ambiguous (see note 13).
- 11 Darwin’s original manuscripts are kept in the Darwin Archive of Cambridge University Library. We examined and obtained photocopies of his geological notes (note 9) and field notebooks (see note 145) on Galápagos. We obtained a copy of Darwin’s zoological diary, section on Galápagos, from Professor Richard Keynes who was in the process of transcribing it for publication. We found Darwin’s 90 pages of geological notes (note 9) particularly revealing in that they contained sketches and descriptions of unique geological formations that he examined. They have never been transcribed before. Although there is a published transcription of Darwin’s Field Notebooks edited by Nora Barlow (see note 12), it is focused on the biology of the islands and we found that the original notes contained information on the geology of Galápagos that was not included in the published version. At the Hydrographic Office in Taunton we examined and made copies of the Admiralty charts of Galápagos made by Captain FitzRoy. At the Public Record Office in Kew we obtained a copy of the section in Captain FitzRoy’s log of HMS *Beagle* (note 10) that pertained to Galápagos. Finally we scrutinized both Darwin’s and FitzRoy’s published accounts of Galápagos for more information regarding his whereabouts and descriptions of the natural history he observed.
- 12 N. Barlow (ed.), *Charles Darwin and the voyage of the Beagle* (Pilot Press, London, 1945).
- 13 In Galápagos we attempted to match descriptions in the literature with identifiable locations and geological features. In the section in Captain FitzRoy’s log of HMS *Beagle* (note 10) that pertained to Galápagos, FitzRoy took compass bearings of key land formations when at anchor. For example, when the *Beagle* was anchored at Black Beach on Charles Island he wrote in his *Log* (note 10) that Saddle Pt was S11.10W and Round Hill (Cerro Pajas) was S73E. Using these bearings, adjusted for the change of degrees in the Earth’s polarity

- between 1835 and 1996, we were able to approximate the *Beagle*'s anchorage using a Global Positioning System (GPS) and compass. We took a boat to the various positions where we calculated the *Beagle* to have anchored, determined probable landing sites using Darwin's descriptions of land formations, and looked for the geological formations Darwin described. GPS observations were made at all these landing sites and geological formations. We made comparative natural history observations and assessed similarities and differences in the fauna and flora between Darwin's time and today.
- 14 One of us (P.R.G.) did not participate in the footstep retracing but has visited at other times all four islands and most of the sites visited by Darwin.
- 15 Darwin wrote (see note 16) 'We may infer... what havoc the introduction of any new beast of prey must cause in a country, before the instincts of the indigenous inhabitants have become adapted to the stranger's craft of power'. Havoc there has been, as much from herbivores as carnivores. Eleven species of mammals have now been introduced to Galápagos (H.N. Hoeck, 'Introduced fauna', in *Key environments. Galápagos* (ed. R. Perry), pp. 233–245 (Pergamon, Oxford, 1984)), and some of them, especially goats and black rats, have been responsible for extinctions of certain finch and mockingbird populations since Darwin's visit (P.R. Grant, *Ecology and evolution of Darwin's finches*, 2nd edn (Princeton University Press, Princeton, NJ, USA, 1999)).
- 16 C. Darwin, *Journal of Researches into the Natural History and Geology of the Countries visited during the Voyage of H.M.S. Beagle round the World*, 2nd edn (John Murray, London, 1845).
- 17 *Op. cit.*, note 10.
- 18 Captain Robert FitzRoy, *Narrative of the Surveying Voyage of His Majesty's Ships Adventure and Beagle between the years 1826–1836 describing their examination and the southern shore of South America and Beagle's Circumnavigation of the globe—in three volumes*, vol. II. (Henry Colburn, London, 1839).
- 19 *Op. cit.*, note 9 [758].
- 20 *Ibid.*
- 21 R.D. Keynes (ed.), *Charles Darwin's Beagle Diary* (Cambridge University Press, 1988).
- 22 *Op. cit.*, note 10.
- 23 *Op. cit.*, note 9 [758].
- 24 *Op. cit.*, note 21.
- 25 *Ibid.*
- 26 Darwin most likely took 'imps of darkness' from Byron (see note 18). A copy of his journal was on the *Beagle*.
- 27 G.A. Byron, 7th Baron, *Voyage of H.M.S. Blonde to the Sandwich Islands, in the years 1824–25*. (London, 1826).
- 28 While in Galápagos, Darwin and the *Beagle* crew conducted two experiments with marine iguanas (see note 32). A seaman tied a weight to one and sank it. When an hour later they drew up the line the iguana was still alive. Darwin noted that when frightened an iguana would not swim out to sea but would run away over the rocks. He repeatedly threw an iguana into the water and observed that it always swam back to the land. He surmised that its predators were marine rather than terrestrial.
- 29 *Op. cit.*, note 21.
- 30 *Op. cit.*, notes 12, 21. Also note 33.
- 31 *Op. cit.*, note 21.
- 32 C. Darwin, *Journal of Researches into the Geology and Natural History of the Various Countries Visited by H.M.S. Beagle* (Henry Colburn, London, 1839).
- 33 R.D. Keynes (ed.), *Charles Darwin's Diary of Observations on Zoology of the Places Visited during the Voyage in 4 volumes* (unpublished manuscript).
- 34 N. Barlow (ed.), *Bull. Brit. Mus. (Nat. Hist.) Historical Ser.* **2**, 201–278 (1963).
- 35 *Op. cit.*, note 10.

- 36 C. Darwin, *Geological Observations on the Volcanic Islands Visited during the Voyage of H.M.S. Beagle*. Part 2 of *The Geology of the Voyage of the Beagle* (Smith, Elder & Co., London, 1844).
- 37 T. Simkin, 'Geology of Galapagos Islands', in *Key environments. Galápagos* (ed. R. Perry), pp. 15–41 (Pergamon, Oxford, 1984).
- 38 *Op. cit.*, note 9 [749].
- 39 Misspellings like these have helped scholars to date Darwin's early writings: F.J. Sulloway, 'Further remarks on Darwin's spelling habits and the dating of *Beagle* voyage manuscripts', *J. Hist. Biol.* **16**, 361–390 (1983).
- 40 *Op. cit.*, note 21.
- 41 *Op. cit.*, note 9 [749].
- 42 *Op. cit.*, note 21.
- 43 *Ibid.*
- 44 *Op. cit.*, note 39.
- 45 Captain Robert FitzRoy, 'Remarks on Galápagos Islands, the NE Coast of Tierra del Fuego, and Magellan Strait—HMS *Beagle* 1835'. (A list of documents sent to the Hydrographer of the Admiralty 16 September 1846 and 14 April 1845. Sailing directions and nautical remarks referring to the coasts of South America, and the Galápagos Islands, intended to be incorporated with the directions and remarks published by the Admiralty on the authority of Captain Phillip Parker King.)
- 46 *Op. cit.*, note 18.
- 47 *Ibid.*, *op. cit.*, note 45.
- 48 *Op. cit.*, note 18.
- 49 *Op. cit.*, note 12.
- 50 *Op. cit.*, note 9 [757].
- 51 *Op. cit.*, note 9 [752].
- 52 *Op. cit.*, note 9 [753].
- 53 *Op. cit.*, note 9 [754].
- 54 *Op. cit.*, note 9 [731].
- 55 Darwin may have borrowed here from Lyell who refers to a plain in the Val del Bove as 'more uneven than the surface of the most tempestuous sea' (see note 56).
- 56 C. Lyell, *Principles of Geology*, 3 vols (London, 1830–33). Darwin had a copy on the *Beagle*.
- 57 The 'Phlegrean fields' was most likely taken from Lyell, *op. cit.*, note 56: 'Instead of inferring, from analogy, that the ancient Vesuvius was always at rest when the craters of the Phlegrean fields were burning—that each cone rose in succession—and that many years, and often centuries of repose intervened between each eruption—geologists seem to have conjectured that the whole group sprung up from the ground at once'.
- 58 *Op. cit.*, note 21. See also note 98.
- 59 *Op. cit.*, note 9 [755].
- 60 *Op. cit.*, note 55.
- 61 *Op. cit.*, note 9 [755].
- 62 *Op. cit.*, note 9 [755–757].
- 63 *Op. cit.*, note 21.
- 64 *Op. cit.*, note 9 [752].
- 65 *Ibid.*
- 66 *Op. cit.*, note 21.
- 67 *Op. cit.*, note 12.
- 68 F.J. Sulloway, 'The *Beagle* collections of Darwin's Finches (Geospizinae)', *Bull. Brit. Mus. (Nat. Hist.)*, *Zool. ser.* **43**, 49–94 (1982). There is a lack of certainty in just how many specimens Darwin collected on Chatham (and Charles and James). Other specimens were collected on this island by FitzRoy, Fuller and Covington, some of them presumably at

- another locality. As many specimens of *Geospiza magnirostris* were collected on Chatham (and Charles) as any other species, yet the populations of these extremely large finches became extinct after the *Beagle* visit, for reasons unknown.
- 69 Sulloway, *op. cit.*, note 4, p. 49.
- 70 B.R. Grant and P.R. Grant, 'Niche shifts and competition in Darwin's finches: *Geospiza cinirostris* and congeners', *Evolution* **36**, 637–657 (1982).
- 71 Darwin noted that 'at least 10 species found near the cultivated ground at Charles Island, have been imported', *op. cit.*, note 16.
- 72 C. Darwin (ed.), *The Zoology of the Voyage of H.M.S. Beagle Under the Command of Captain FitzRoy. Part 2. Mammalia. By George Robert Waterhouse. Part 3. Birds. By John Gould. Part 4. Fish. By Leonard Jenyns. Part 5. Reptiles. By Thomas Bell. 3 or 5 volumes.* (Smith, Elder & Co., London, 1838–43).
- 73 *Op. cit.*, note 10.
- 74 *Op. cit.*, note 18.
- 75 *Op. cit.*, note 71.
- 76 *Op. cit.*, note 18.
- 77 *Op. cit.*, note 45.
- 78 *Op. cit.*, note 16.
- 79 *Op. cit.*, note 21.
- 80 *Op. cit.*, note 18.
- 81 *Op. cit.*, note 21.
- 82 *Op. cit.*, note 18.
- 83 *Op. cit.*, note 21.
- 84 *Op. cit.*, note 9.
- 85 *Op. cit.*, note 9 [747].
- 86 *Op. cit.*, note 21.
- 87 *Op. cit.*, notes 6 and 68.
- 88 A third and final specimen was collected in 1852 by Dr Kinberg on a Swedish expedition: C.J. Sundevall, 'On birds from the Galapagos Islands', *Proc. Sci. Meetings Zool. Soc. Lond.*, pp. 124–130 (1871). That the species was once common is indicated by fossils of at least six individuals: D. Steadman, 'Holocene vertebrate fossils from Isla Floreana, Galápagos', *Smiths. Contr. Zool.* **413**, 1–103 (1986). The large form of *Geospiza magnirostris*, now extinct (see note 68), was apparently the most abundant finch species on the island according to the fossil evidence (229 individuals).
- 89 *Op. cit.*, note 21.
- 90 *Op. cit.*, note 18.
- 91 *Op. cit.*, note 33.
- 92 In his Ornithological Notes, *op. cit.*, note 34, Darwin states 'When I recollect, the fact that the form of the body, shape of scales & general size, the Spaniards can at once pronounce, from which Island any Tortoise may have been brought. When I see these Islands in sight of each other, & possessed of but a scanty stock of animals, tenanted by these birds, but slightly differing in structure & filling the same place in Nature, I must suspect they are only varieties.... If there is the slightest foundation for these remarks the zoology of Archipelagoes—will be well worth examining; for such facts undermine the stability of Species'.
- 93 *Op. cit.*, note 32.
- 94 *Op. cit.*, note 9 [748].
- 95 *Op. cit.*, note 36.
- 96 *Op. cit.*, note 9 [732].
- 97 *Ibid.*

- 98 In *Volcanic Islands*, *op. cit.*, note 36, Darwin writes that ‘One of the officers gave me some fragments of shells, which he found embedded several hundred feet above the sea, in the tuff of two craters, distant from each other’. These specimens are regarded as the first palaeontological record from the Galápagos Islands: see Jere H. Lipps and C.S. Hickman, ‘History of Galapagos geology: Darwin’s lost Galapagos fossils’, *Geol. Soc. Am., Prog. with Abstracts*, v. 22 (1990). Although Darwin does not specify the name of the officer or the location of the craters in *Volcanic Islands*, *op. cit.*, note 36, it is clear from Darwin’s geological notes (*op. cit.*, note 9) that the officer in question was the master of the *Beagle*, Edward Main Chaffers, and that one of the two craters was Champion island [732, 748], the other being one on Bindloe (Marchena) Island [718, 784–785].
- 99 *Op. cit.*, note 9 [732–733].
- 100 *Op. cit.*, note 36.
- 101 R.L. Curry, ‘Whatever happened to the Floreana Mockingbird?’, *Noticias de Galápagos* 43, 13–15 (1986). Had this most distinctive species disappeared before 1835, Darwin would have had much less reason to add mockingbirds to the tortoises as evidence for the geographical replacement of similar species.
- 102 *Op. cit.*, note 18.
- 103 *Op. cit.*, note 9 [760, 788–789].
- 104 *Op. cit.*, note 9 [788–789].
- 105 *Op. cit.*, note 36.
- 106 *Op. cit.*, note 9 [789].
- 107 *Op. cit.*, note 9 [790].
- 108 In *Volcanic Islands*, *op. cit.*, note 36, Darwin describes the cones at Ascension: ‘The greater number of them had their truncated summits cut off obliquely, and they all sloped towards the S.E., whence the trade-wind blows. This structure no doubt has been caused, by the ejected fragments and ashes being always blown, during eruptions, in greater quantity towards one side, than towards the other.’ And in the Galápagos ‘this same power might here, also, aid in making the windward and exposed sides of some of the craters, originally the lowest’.
- 109 *Op. cit.*, note 10.
- 110 *Op. cit.*, note 18.
- 111 *Ibid.*
- 112 *Op. cit.*, note 21.
- 113 *Ibid.*
- 114 *Op. cit.*, note 9 [759].
- 115 *Op. cit.*, note 9 [744–745].
- 116 *Op. cit.*, note 9 [759].
- 117 *The correspondence of Charles Darwin*, vol. 6, 1856–1857 (Cambridge University Press, 1990).
- 118 *Op. cit.*, notes 10 and 18.
- 119 *Op. cit.*, note 9.
- 120 *Op. cit.*, note 9 [745].
- 121 *Op. cit.*, note 21.
- 122 *Ibid.*
- 123 *Op. cit.*, note 9 [734].
- 124 *Op. cit.*, note 9 [761].
- 125 P.H. Barret, P.J. Gautrey, S. Herbert, D. Kohn and S. Smith (eds), *Charles Darwin’s Notebooks, 1836–1844* (Cambridge: British Museum (Natural History)/Cambridge University Press, 1987).
- 126 *Op. cit.*, note 9 [762].
- 127 *The correspondence of Charles Darwin*, vol. 4, 1847–1850 (Cambridge University Press, 1988).
- 128 *Op. cit.*, note 9 [762].

- 129 *Op. cit.*, note 9.
- 130 *Op. cit.*, note 9 [763].
- 131 *Op. cit.*, note 9 [766].
- 132 *Op. cit.*, note 9 [745].
- 133 *Op. cit.*, note 9 [763].
- 134 *Op. cit.*, note 9.
- 135 *Op. cit.*, note 39.
- 136 *Op. cit.*, note 9 [768].
- 137 *Ibid.*
- 138 Darwin may have borrowed from Byron, *op. cit.*, note 27: 'As far as the eye could reach we saw nothing but rough fields of lava, that seemed to have hardened while the force of the wind had been rippling its liquid surface. In some places we could fancy the fiery sea had been only gently agitated; in others, it seemed as if it had been swept into huge waves'.
- 139 *Op. cit.*, note 9 [769].
- 140 *Op. cit.*, note 32.
- 141 *Op. cit.*, note 26.
- 142 *Op. cit.*, note 21.
- 143 *Ibid.*
- 144 This is only one of only two references to finches made by Darwin in the *Diary*, *op. cit.*, note 21, and field notebooks (see note 145).
- 145 C. Darwin, Down House Notebook 1.17 (field notebooks 1831–36).
- 146 Darwin called it 'Freshwater Cove of the Buccaneers' in the *Diary*, *op. cit.*, note 21, and 'Fresh-water Bay' in *Volcanic Islands*, *op. cit.*, note 36. We refer to it as Buccaneer Cove, as it is now called, to avoid confusion with Fresh Water Bay on Chatham Island.
- 147 It is unclear whether four or five people left the *Beagle* to camp on James. According to Darwin 'Myself, Mr. Bynoe & three men were landed...', *op. cit.*, note 21. FitzRoy says Darwin 'was landed, accompanied by Mr. Bynoe, besides his servant and H. Fuller...', *op. cit.*, note 18.
- 148 *Op. cit.*, note 21.
- 149 *Op. cit.*, note 12.
- 150 *Op. cit.*, note 144.
- 151 *Op. cit.*, note 33.
- 152 *Op. cit.*, note 21.
- 153 *Op. cit.*, note 18.
- 154 *Op. cit.*, note 21.
- 155 *Op. cit.*, note 45.
- 156 *Op. cit.*, notes 12 and 21.
- 157 *Op. cit.*, note 21.
- 158 *Op. cit.*, note 9 [770].
- 159 *Op. cit.*, note 9 [718].
- 160 It has been established by McBirney and Williams (see note 161), and Pearson, *op. cit.*, note 3, that Darwin's observations on crystals embedded in rock on James helped him to develop and substantiate the theory of magmatic differentiation through gravity settling.
- 161 A.R. McBirney and H. Williams, 'Geology and petrology of the Galápagos Islands', *Geol. Soc. Am. Memoir*, **118** (1969).
- 162 *Op. cit.*, notes 9 and 36.
- 163 *Op. cit.*, note 9 [720].
- 164 *Op. cit.*, note 9 [720–721].
- 165 *Op. cit.*, note 9 [721].
- 166 *Op. cit.*, note 160.
- 167 *Op. cit.*, note 9 [773].
- 168 *Op. cit.*, note 9 [772].

- 169 *Op. cit.*, note 9 [778].  
170 *Ibid.*  
171 *Op. cit.*, note 21.  
172 *Op. cit.*, note 39.  
173 *Op. cit.*, note 21.  
174 *Ibid.*  
175 *Op. cit.*, note 145.  
176 *Ibid.*  
177 *Op. cit.*, note 32.  
178 At Jaboncillos, the only *Scalesia* trees are growing in fenced enclosures. Goat destruction of *Scalesia* is probably the main reason why *Camarhynchus psittacula* (large tree finch) is now apparently very scarce, whereas in Darwin's day it must have been fairly common, as there are as many specimens from James in the *Beagle* collection (5) as there are of any other finch species (five each for *Geospiza scandens* and *G. fuliginosa*). Of the seven finch species collected by members of the *Beagle* on this island it is the only one we did not see in retracing Darwin's visit and on two other visits to the highlands.  
179 *Op. cit.*, note 21.  
180 *Op. cit.*, note 9 [770].  
181 Dr Sandra Herbert has pointed out to us that an expedition (see note 161) to Galápagos in 1964 was unable to find a representative of one of these specimens (No. 3268) on James. We believe that Darwin most likely collected this specimen from the vicinity of the crater at Jaboncillos in the highlands of James and this needs to be verified.  
182 *Op. cit.*, notes 9 [770] and 160.  
183 Darwin also mentions finding this bird on Charles, *op. cit.*, note 33. According to Castro (see note 184), *Laterallus spilonotus* has not been reported from Charles since 1983. However, since her publication, there have been sightings of this bird on Charles reported to the Charles Darwin Research Station.  
184 I. Castro and A. Phillips, *A guide to the birds of the Galápagos Islands* (Princeton University Press, Princeton, NJ, USA, 1996).  
185 *Op. cit.*, note 33.  
186 *Op. cit.*, note 21.  
187 *Op. cit.*, note 9 [779].  
188 *Op. cit.*, note 9 [780].  
189 *Op. cit.*, note 9 [779–780].  
190 *Op. cit.*, note 9 [780].  
191 *Ibid.*  
192 *Ibid.*  
193 *Op. cit.*, note 9 [723].  
194 *Op. cit.*, note 21.  
195 *Op. cit.*, note 9 [783].  
196 *Ibid.*  
197 *Op. cit.*, note 21.  
198 *Op. cit.*, note 10.  
199 *Op. cit.*, note 9 [784].  
200 *Op. cit.*, note 9.  
201 *Op. cit.*, note 9 [783].  
202 *Ibid.*  
203 *Op. cit.*, note 33.  
204 The number of finch specimens assembled by the four *Beagle* collectors—Darwin, FitzRoy, Covington and Fuller—was fairly uniform at one to five per species per island (Chatham, Charles and James) (see note 68). Darwin's own collecting appears to have been consistent with the others' in this regard. This suggests that finches were collected systematically for

variety and not in ignorance of the different types. In fact the only ones missing altogether from the collection that might have been collected in view of the itineraries of the collectors were species that are largely restricted to medium or high elevations; *Camarhynchus pauper* and possibly *C. parvulus* and *C. psittacula* from Charles, and *Cactospiza pallida* on James. Darwin's own collection was the most diverse, comprising all nine of the currently recognized species that were collected. It is possible, however, that some were given to him by Syms Covington, his personal assistant; and uncertainties about the localities must be stressed (see note 68).

205 *Op. cit.*, note 145.

206 *Op. cit.*, note 21.

207 We also measured similar sand and air temperatures, and similar sea temperatures. From 99 measurements in the weather journal kept on board the *Beagle*, the mean temperature of the sea in Galápagos was 68°F. These measurements were taken daily at 8 am, noon and 8 pm, from 16 September to 20 October when the *Beagle* was either at anchor or moving from island to island. The lowest temperature measured was 58.5°F, at the southwest extremity of Albemarle Island. We took 15 sea temperature measurements at Darwin's landing sites and anchorages and they ranged from 63 to 72.5°F, with a mean of 69.3.

208 *Op. cit.*, notes 10 and 18.

209 Lieutenant Sullivan surveyed Sullivan Bay (named after him by Captain FitzRoy) on James Island. The coastline in FitzRoy's map agrees with today's coastline. This brings into question the age of the lava flow that surrounds the 'kipukas' or isolated hills in Sullivan Bay. It is generally thought that the lava flow is only 100 years old, dating from 1897 when a flank eruption was observed on the southern side of James by members of a scientific expedition led by Charles Miller Harris; see A.F. Richards, *Archipelago de Colon [Archipiélago de Colón], Isla San Felix and Islas Juan Fernández. Catalog of Active Volcanoes of the World 14*. 50 pp. (IAVCEI, Rome, 1962). However, FitzRoy's charts suggest that the lava flow that forms the coastline is over 165 years old and the more recent eruption, while it may have caused lava to flow over the earlier flow, did not change the shape of the coastline.

210 *Op. cit.*, note 10.

211 *Op. cit.*, notes 10 and 18.

212 *Op. cit.*, notes 18 and 45.

213 *Op. cit.*, note 18.

214 Out of a total of five specimens of *Geospiza scandens* from James two are large enough to have been thought referable to the distinctive form of this species on Bindloe (Marchena; also Abingdon = Pinta), and to have arrived as 'stragglers' (see note 6). The proportion is extraordinarily high in view of the distance from Bindloe (ca. 40 km) and the exceptionally low (current) population of the species on that island. Another possibility is that they were collected by someone in the cactus just behind the beach on Abingdon when the *Beagle* picked up Chaffers from his surveying boat: the last opportunity to collect terrestrial bird specimens before leaving Galápagos.

215 *Op. cit.*, note 98.

216 *Op. cit.*, note 9 [785].