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THE VISIT OF HIS ROYAL HIGHNESS THE DUKE OF EDINBURGH TO THE GALAPAGOS

7 - 12 February 1971.

by

M.P. HARRIS.

As is well known after his commentary to the film 'The Enchanted Isles' and his book 'Wildlife Crisis', Prince Philip was very impressed with the Galapagos during his previous visit in November 1964, so it was perhaps not surprising that it was decided to revisit the islands as part of a tour of the South Pacific in early 1971 aboard H.M. Yacht 'Britannia'. During the Galapagos part of this cruise His Royal Highness was joined by H.R.H. Princess Alexandra and the Hon. Angus Ogilvy, Earl Mountbatten, Lord and Lady Brabourne and Sir Solly Zuckerman.

Dr Peter Kramer, Director of the C.D.R.S., Sr. Juan Black, official of the National Parks Service, and I were honoured in also being invited to join the party for the visit to the islands.

We rendezvoused with the 'Britannia' off Darwin Bay, Tower at 10.00 on 7 February, and stepped, slightly disrevelled and unshaven after a night's voyage on the fishing boat 'Narcisa de Jesús', aboard to be taken without more ado to meet His Royal Highness and the other members of the party. The whole day was spent at Tower and included a visit to the storm petrel colony via the path up the cliff which has been known as 'Prince Philip's Steps' since the previous visit.

Overnight the 'Britannia', under the command of Rear Admiral R.J. Trowbridge, moved anchorage to Pta. Tortuga (western Isabela) where the morning was spent looking at penguins and cormorants and in a vain search for a Mangrove Finch, though one was heard singing. However, there was some consolation in the form of a Killdeer (an American migrant wading bird) - the first record for the Galapagos. After lunch the party went to Pta. Espinosa by rubber boat and, as so often happens in small boat crossings of Canal Bolivar, everyone got soaked. At least this time it was due to aerial acrobatics of some curious dolphins. Our excursion allowed the crew of the 'Britannia' an afternoon at Tortuga and for the Ward Room to prepare for a barbecue that evening. Sufficient to say that rarely can there have been such a luxurious campfire on the islands, and rarely can such care have gone into removal of the traces afterwards. Some other yachts might be advised to follow this example of the British Navy.

The whole of 9 February was spent on Fernándina; the morning at Pta. Espinosa and the afternoon at Cape Hammond. To field workers used to long voyages in small boats there is something rather nice about starting lunch at Espinosa and going ashore at Cape Hammond after a short siesta.

The following day also showed the advantage of speed. Villamil received the party in the morning and we were welcomed and shown around by the Station's representative Sr.J. Gordillo and the National Park Warden A. Tupiza. As well as a good selection of migratory birds we were lucky enough to have some outstanding views of flamingos at the viallage salt lagoon. Yet another example of how tame birds will become if not molested. The afternoon was spent in the small boats around Champion fratrernizing with the sealions. Late evening saw the Britannia anchored off Academy Bay in company with the Ecuadorian Naval Vessel '25 de Julio', and 'Blue Rover', a British supply ship which was to accompany the 'Britannia' across the South Pacific.

On 11th February Prince Philip was officially welcomed to the islands by the Ecuadorian Minister of Defence, Sr. Jorge Acosta Velasco, and the party (accompanied now by H.M. Ambassador to Ecuador, Mr. Peter Mennell and his wife) drove from the village jetty to the Charles Darwin Research Station to see the tortoise rearing projects and the other facilities. An informal lunch was given in the village by the Minister of Defence, and this was followed by the presentation of much radio equipment, tents and other camping equipment to the Galapagos National Park Service, footballs to the Islands' schools and some building materials to the College at Academy Bay, some nice and useful reminders of the visit. In the evening His Royal Highness gave an official dinner on the 'Britannia' in honour of the Minister of Defence.

Both Dr. Kramer and Sr. Black took their leave at Academy Bay and I accompanied the vessel to Baltra and was put ashore with the Hon. Angus Ogilvy, Sir Solly Zuckerman and Mr. and Mrs. Mennell. The 'Britannia' then visited Hood before sailing for Easter Island.

In all appearances the visit was a great success and a nice compromise between informal enjoyment and formal support for the efforts of the National Park Service and the CDRS to protect the islands for posterity.

GEOLOGIC INVESTIGATIONS IN THE GALAPAGOS ISLANDS DURING THE SUMMER OF 1970

by

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During July and August of 1970 a group of 12 geologists carried out field studies in the Galapagos Islands. Different geological specialties were represented within the group and, after applying these to our common interest of Fernandina and its recent caldera collapse, we separated to cover different parts of the archipelago. Dr. Bert Nordlie and three graduate students from the University of Arizona (Terry Gerlach, John Delaney and Wayne Colony) studied volcanic gases and waters. Dr. James Case, with graduate students Jerry Barnes and Steve Ryland from the University of Missouri made geophysical observations. Dr. Willie Kinoshita of the U.S. Geological Survey (USGS) established precise level benchmarks to monitor tilting of Fernandina. And Dr. Keith Howard, also of the USGS, Dr. Bruce Nolf, Central Oregon College, and myself pursued general geologic studies of the development of Galapagos volcanoes.

Meeting on Fernandina in early July, we took four separate routes to the caldera rim in order to gain maximum information on the 1968 ash deposits. The USGS group, with Mrs Howard and Sr. Calapucha (Darwin Station), went up the north coast route, Dr. and Mrs Nolf climbed from the NW (Cape Douglas), and the Arizona group climbed from the SW (Cape Hammond). My wife and I climbed from the central west coast and found what must be the easiest route to the top of Fernandina. The 1968 ash eruption concentrated ashfall west and northwest of the volcano, and these substantial deposits have now been reworked by rain and compacted to form an easy path through and over the formidable blocky lava flows that guard Fernandina's summit. Landing on the west coast is difficult, however, because of the heavy Pacific swells and lack of protected coves. The University of Missouri group successfully landed there in mid August, but at least two more recent attempts have failed.

Studies by Simkin and Nolf of the ash deposits confirm the western block (see Simkin and Howard, 1970) as the vent source for the major 1968 eruption. A unit of rubble (containing blocks up to two meters in diameter) is localized around this vent area and reaches a maximum thickness of 4 meters on the western rim some 600 meters above the vent. Beyond the edge of this rubble unit small trees were blown down in directions generally radial to the vent source, indicating the action of a "base surge", or dense radially-directed ash cloud that has only recently been recognized as accompanying volcanic eruptions (Moore, 1967). The Fernandina eruption is unusual in that this base surge must have operated at an elevation 600 meters above the vent. Ash deposits cover the rubble unit to depths of 70 cm (and more where redistributed) providing a smooth

flat surface over much of the west and southwest smmit bench - a striking contrast to the combination of young lava flows and lush vegetation on this rim prior to the eruption. In bringing water from one side of the caldera to the other, Sr. Calapucha accomplished the remarkable feat of walking around the full caldera rim and down to the north coast camp in one long day.

We entered the caldera from the low point on the northwest rim, but shaking during the 1968 collapse has made parts of this steep slope unstable and ropes were required at one point near the top. A faster and better route appears to be that used by Darwin Station personnel (from the north end of a slightly lowered terrace on the rim above the west end of the northwest bench). Continuing rock avalanches preclude climbing routes down most walls of the caldera.

Seismic activity, although minor, still continues at the caldera two years after its collapse. During our three days in the caldera, three separate tremors were felt, but they were felt only by seated persons. One of these events appears on the Darwin Station seismogram and is estimated (John Filson, personal communication) to be in the 1-2 magnitude range.

Using an inflated life raft, Simkin and Nolf made a rough hydrographic survey of the new lake, finding that the floor slopes gently from the northwest to a maximum depth of approximately 80 meters near the southeast end. In addition, we studied the ash deposits and the vent area of the western block. Nordlie's group investigated the new fumaroles on the western block (and on the caldera's southwest rim), but were unable to collect gas samples.

Both ducks and stilts have returned to the lake and we observed several iguanas on the subsided floor. Vegetation on this floor, however, seems restricted to rerooted brush in the large debris avalanche that swept from the southwest wall out onto the floor and up the side of the central tuff cone. Land iguanas, curiously, seemed to be thriving in burrows on the western caldera rim where their nearest vegetation was either four meters below them (through the rubble unit) or several kilometers distant across barren ash deposits. On the north and east caldera rim, where ashfall was light, vegetation has recovered well and travel through the thick brush on this part of the summit bench is difficult. Rather than cut brush when moving around this part of the rim, it is now easier to drop down to the upper row of circumferential volcanic vents (4,000 ft contour and 3 1/2 to 4 km from grid center in Figure 1) and walk along the cinders immediately upslope from the vents.

Water samples from the new lake show that it contains approximately 3000 ppm sulfate and 1400 ppm each of Na and Mg. The sulfate has predictable effects on the alimentary system of those drinking the lake water, but, more significantly, the Mg consumed in 3-4 liters of lake water reaches the maximum daily tolerance to an acute load (Abbott

Labs, 1968) and this source further points out (p.20) that "excess magnesium acts as a sedative and extreme excesses may cause cardiac arrest". We all felt very tired during the period of time that we were drinking the lake water and this may have been partially caused by the water itself - with its high magnesium content, vile taste, and diarrhetic effects - as well as the more obvious causes of unaccustoned heat and exertions. In any case, future visitors to the lake are advised to avoid drinking the lake water if possible.

Probably the lightest alternative to carrying fresh water into the caldera, and one that is applicable elsewhere in the Galapagos, is the solar survival still described by Jackson and van Bevel (1965). In this still a sheet of light plastic is stretched over a hemispherical hole in the ground and a small stone placed in the center of the plastic to form a cone. Solar energy evaporates water in the soil which condenses on the underside of the plastic and runs down the cone to drop into a container placed in the center of the hole. We gathered 2-3 liters per day from the one lakeshore still that was made with the recommended "Tedlar" plastic, but our other stills, made with plastic of inferior wettability, formed water drops that fell immediately rather than run down the cone and into the container. During our nine days on the volcano's interior, the sun was behind cloud for a total of approximately three minutes. We all cheered.

The Arizona and USGS groups descended directly to the north coast base camp (015°/10 km on Fig.1) while the Nolfs and Simkins walked around the southwest caldera rim and descended the east flank of the volcano to the mangrove area at 085°/18 km (Fig.1). This latter route is an unhappy blend of thick brush on the upper slopes and blocky aa lava on the (seemingly interminable) lower slopes, but we were attempting (unsuccessfully) to locate and sample the new vents of the 1968 flank eruption.

At the risk of sounding like worried mothers, we would urge prospective climbers not to underestimate distances on Fernandina or difficulties of traveling over blocky lava flows. We found that we needed between 3 and 4 liters of water per person per day. Communications between separated groups on a volcano of that size can be vitally important and two small "walkie-talkie" radios were exceedingly valuable on our trip, but we regretted not having a radio for each group. If radios are not available, separated groups should agree on some basic signals to indicate position and distress, and these signals should take into account the difficulty of seeing across a caldera 5-6 km in diameter.

Dr. Kinoshita, ably assisted by Sr. Calapucha, successfully established "dry" tilt stations on all sides of Fernandina. Each station consists of three permanent bench marks forming an equilateral triangle approximately 60 meters on a side. The relative elevations of these three marks are leveled to first order accuracy and future releveling will detect both direction and magnitude of any tilting that has taken

place between levelings. This technique has been used successfully on Hawaii (Fiske and Kinoshita, 1969) and elsewhere to monitor the substantial inflation, or "breathing", recognized in active volcanoes. Knowledge of inflation behavior is valuable in efforts to understand (and, ultimately, to predict) volcanic activity.

After leaving Fernandina, the Arizona group studied the Alcedo geyser area, sampling and analysing both gas and water from the two lakes and fumarole areas. Those who have complained of urinary problems after drinking Alcedo water will be interested to know that a pH of 1.0 was measured in one lake. The Howards later spent a week and a half at the geyser and noted that the level of the geyser pool dropped 2 cm/day throughout their stay (K. Howard personal communication). The pool has since dried up completely (C. MacFarland, personal communication) making the collection of samples and data by the Arizona group particularly fortunate.

The Arizona group then moved to the south end of Isla Isabela where they obtained good gas samples and examined rates of both sulfur deposition and rock alteration at the Sierra Negra solfatara (Azufre). On leaving Azufre, the group divided for a month of geologic mapping of the 1963 Volcan Chico vent area (Delaney, Gerlach, and Colony) and Cerro Azul caldera (Nordlie). These areas had been unmapped topographically, but topo sheets of both have now been prepared as a part of this program. The group received excellent logistic support from Sr. Gordillo, Darwin Station representative on Isabela, and wardens Tupiza and Cartejena. During a support trip one-third of the way down Azul's southeast slope, Gordillo and Tupiza discovered wreckage of one of the two USAF P-39 fighters that crashed during observation of the April 1943 summit eruption of Azul.

The Howards' geologic mapping of Alcedo showed that although most of the volcano is basalt, there have been several eruptions of glassy, silica-rich rocks - obsidian and pumice. These differentiated rocks, together with the volcano's shape and its infrequency of recent eruptions, suggests that Alcedo is in an advanced stage of caldera evolution compared to the other volcanoes of Isabela and Fernandina (K.A. Howard, written communication, 1971). Howard also reached the floor of Volcan Wolf's caldera and visited several other island localities before returning home at the end of August.

After Fernandina, the Simkins and Nolfs spent 9 days mapping the Cape Berkeley volcano on northwest Isabela. The western half of this large volcano has been down-faulted to expose a natural cross-section of its interior. This valuable internal view of the volcano shows circumferential feeder dikes and structure consistent with the suggestion (Simkin, 1970 and in press) that the Galapagos volcanoes owe their uncommon shape to growth from arcuate feeder dikes (roughly vertical sheets within older rock) arranged in a broad circle many kilometers in diameter (as in ancient ring complexes) rather than the central feeder pipes that produce the more familiar conical volcanoes.

No land iguanas were seen on the Berkeley volcano although their apparent tracks were not rare. Feral cats, on the other hand, were seen at all three base camps and their tracks were common. Evidence of damage by introduced species was even more obvious at our next stop, Isla Marchena. Here we found goat tracks and stripped vegetation in every vegetated area (light areas in Fig.2) on our traverse from the southwest to northeast of this island that had, on last report, been free of goats. A party of Wardens from the Darwin Station has since gone to Marchena and exterminated 55 goats, but they estimate that a larger number remain. Introduced by fishermen to provide a ready supply of fresh meat, goats swiftly multiply and devestate the indigenous vegetation.

Our short reconnaissance of Marchena produced clear evidence that the summit is in fact a large caldera now largely filled with recent lava flows. A violently explosive eruption has mantled the outer slopes with rubble and ash (which offers a foothold for vegetation) and has been largely covered, in turn, by younger lava flows. Large tuff rings and cones in the caldera interior testify to a former lake or abundant groundwater. Active fumaroles were observed at 248°/3.2 km, 230°/3.1 km, and 025°/3.0 km (the island's summit). Circumferential feeders (see p.8) are well developed at a radius of 3 km from the center.

Marchena was also a rendezvous with Dr. Case's geophysics group from the University of Missouri. Their precise measurements of gravity and magnetic field allow recognition of anomalous areas and, by locating areas of unusually light or heavy, magnetic or non-magnetic, rock, they give valuable information on the structure and properties of underlying rock not visible at the surface. During their 20 days in the Galapagos, the Missouri group completed traverses of Marchena and Fernandina, partial traverses of Berkeley and Floreana, and many individual shore stations throughout the western part of the archipelago. These shore stations will be particularly valuable in providing firm gravity control to strengthen marine gravity studies in this important part of the eastern equatorial Pacific. Upon completion of their Fernandina traverse, the Missouri group was met at Punta Espinoza by the Golden Cachelot and transported to the east side of Isabela - we are all grateful to David Balfour, Cachelot personnel, and Lindblad Travel for their generous cooperation with our research.

Upon leaving Marchena, Nolfs and Sinkins traversed southern Isabela, landing at Iguana Cove on the West, climbing Cerro Azul for two days work (with Nordlie) around and in that caldera, and then across the Sierra Negra caldera where we worked on the remarkable sinuous ridge for a day before continuing down to Villamil. While descending S. Negra, we spent a night at Corazon Verde, the fine new Darwin Foundation Field Station at Santo Tomas. This neat building was constructed by Sr. Gordillo and wardens Cartejena and Tupiza. Its position - at 350 m elevation, in the crop-growing center, and roughly halfway between Villamil and Sierra Negra caldera - makes it a convenient, as well as pleasant scientific field station. On the way to Villamil, we passed construction of a new road that is intended to link Santa Tomas with Villamil within a year.

We thank the Darwin Station for its logistic support of our field work, the above-named individuals for their help on the volcanoes, and the personnel of the Bronzewing and Cristo Rey for their excellent charter service. Publications resulting from this field work will be listed in future issues of Noticias de Galapagos, and we hope that this summary of our expedition will be useful to those interested in Galapagos volcanoes.

REFERENCES

Abbott Labs, 1968, Fluids and Electrolytes, some practical guides to clinical use.

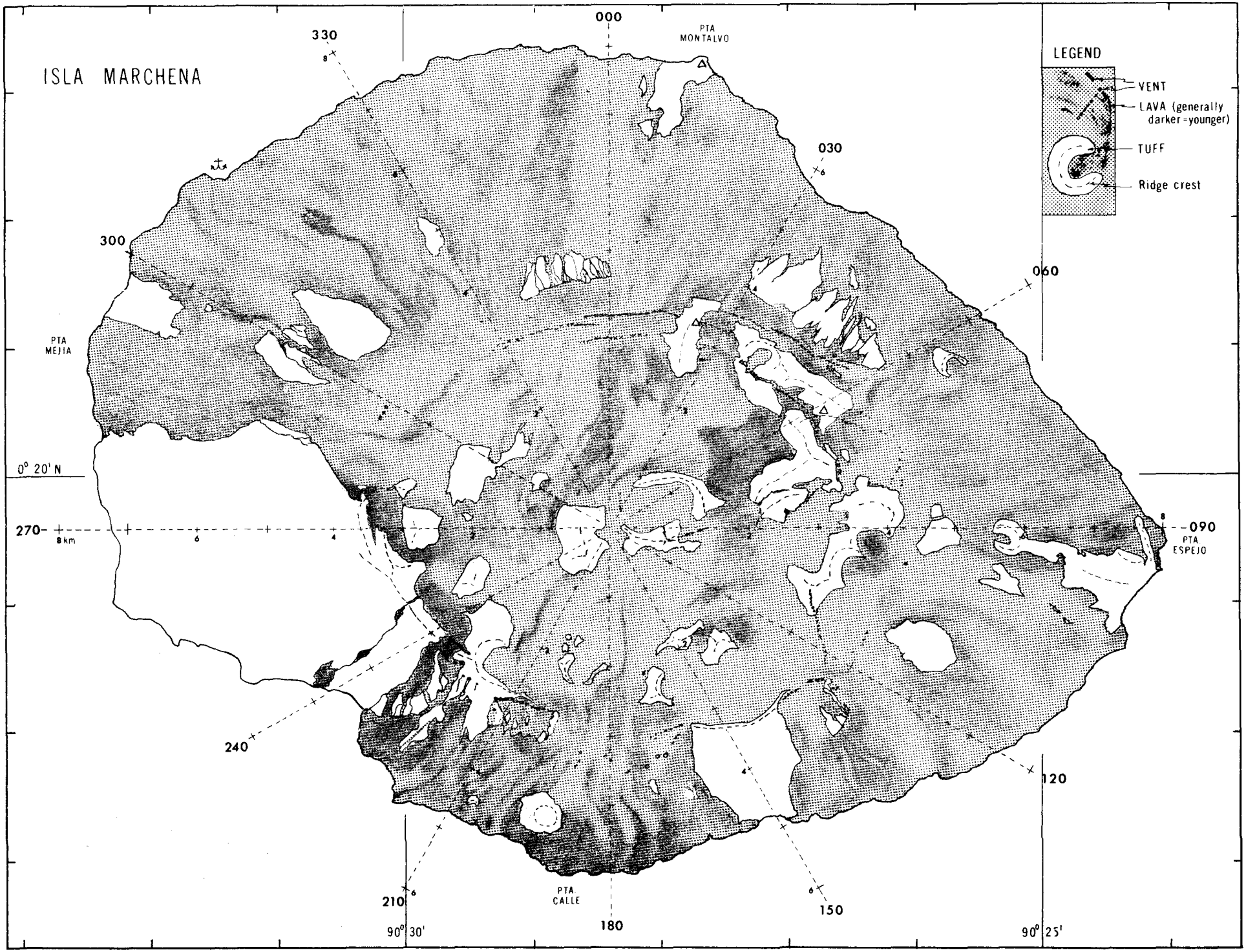
Fiske, R.S. and Kinoshita, 1969, Inflation of Kilauea Volcano prior to its 1967-1968 eruption, Science, v.165, pp.341-349.

Jackson, R.D., and van Bavel, C.H.M., 1965, Solar distillation of water from soil and plant materials : a simple desert survival technique, Science, v.149, pp.1377-1379.

Moore, J.G., 1967, Base surge in recent volcanic eruptions, Bull. Volcanologique, v.30, pp.338-363.

Simkin, T., and Howard, K.A., 1970, Caldera collapse in the Galapagos Islands, 1968, Science, v.169, pp.429-437.

Simkin, T., 1970, Origin of some flat-topped volcanoes and guyots, program of annual meetings of Geological Society of America, 1970, p.685.


ISLA MARCHENA
LEGEND
VENT
LAVA (generally darker = younger)
TUFF
Ridge crest
000
030
060
090
120
150
180
210
240
270
300
330
PTA MONTALVO
PTA MEJIA
PTA ESPEJO
PTA CALLE
0° 20' N
90° 30'
90° 25'
8 km

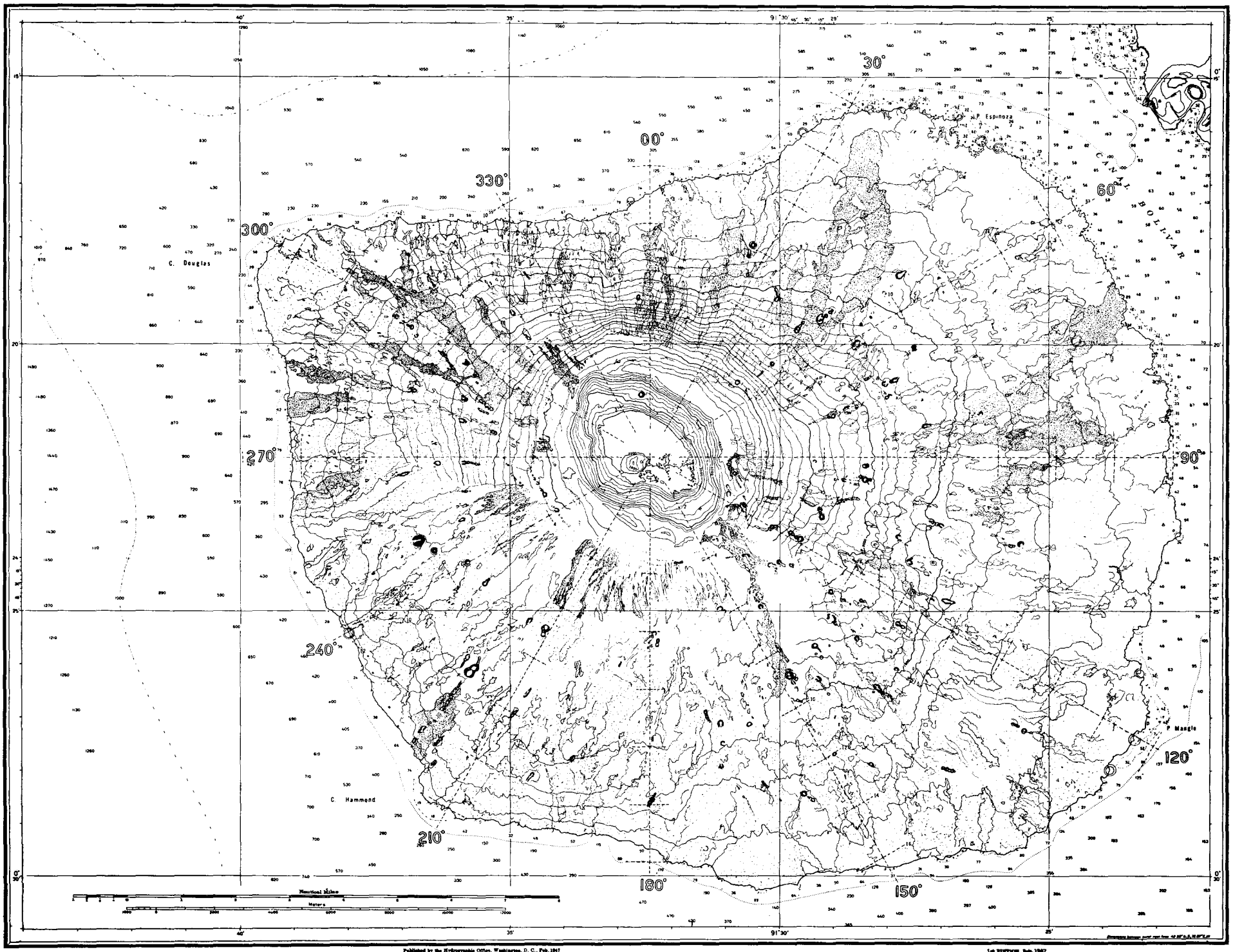


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ILLUSTRATION CAPTIONS

Fig.1 - Preliminary geologic map of Isla Fernandina. Open and closed dark circles represent volcanic vents, dark stipple represents darker (younger) lava flows, light stipple represents flows of intermediate age, and clear areas are oldest, largely vegetated, flows. Topographic base is from U.S. Navy Hydrographic Office Chart 5931 and radial grid is superimposed to enable convenient reference to specific points or features (e.g. the prominent volcanic vent at 250°/8.3 km or the radial vents at 220°).

Fig.2 - Preliminary geologic map of Isla Marchena. Symbols shown on legend and radial grid similar to that used in Fig.1.

MARINE GEOLOGICAL OBSERVATIONS NEAR THE GALAPAGOS ISLANDS

by

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Introduction

The U.S. Naval Oceanographic Office has recently completed two reconnaissance surveys of the western Galapagos Ridge. This east-west wedge-shaped ridge (Figure 1) upon which the Galapagos Islands sit was recently recognized to be an axis of sea-floor spreading--a branch of the Mid-Oceanic Ridge--by Herron and Heirtzler (1967) and Raff (1968). The Mid-Oceanic Ridge is an ever-widening crack, constantly filled by accretion of mantle derivatives along its crestal zone (Morgan, 1968; Vogt, et al., 1969). Data from the first cruise has been presented by Deffeyes, et al., 1971. The second cruise which took place in February and March 1971 is now in the process of data reduction; results will be reported in due course.

During this survey, soundings were collected with an Ocean Sonics Recorder (OSR) precision recorder, the total magnetic field with a Varian magnetometer, and seismic reflection data with a 30,000 joule Teledyne sparker system with a Raytheon PSR. Navigation was by ITT satellite SRN 9 and was augmented by celestial fixes and land bearings. Of special interest during the cruise is a series of four traverses run to embark and disembark an Ecuadorian observer, Captain Raul Canizares Robles, on the island of Baltra.

Results

The most striking characteristic of the western approaches to the island group is the lack of sediment cover along the base of the insular platform (Figure, Profiles 1 and 2). In both profiles, an opaque, hard reflector is present which appears to be the oceanic basement, i.e., pillow basalt. In profile 2, the sediment cover wedges to the east, ruling out burial by recent submarine lava flows. It is impossible to say if this is a case of non-deposition or erosion by bottom currents. Deep ocean currents are a common phenomena (Schneider, et al., 1967); and Heezen, et al., 1966, have suggested the Gulf Stream may occasionally scour the sea floor at depths of 4000 meters. In this area, the prime candidate would be the Cromwell Current, also known as the Pacific Equatorial Undercurrent, which flows eastward along the equator beneath the westward flowing Pacific South Equatorial Current. Velocities of 100 cm/sec at a depth of 75 meters between 92° and 94°W to the west of the islands

have been reported by Christensen (1971). His measurements fall to ± 30 cm/sec at 150 meters; however evidence shown in Christensen's profiles indicates bottom velocities in the order of 15-20 cm/sec at depths of 3500 meters. If the Cromwell Current is responsible for this lack of sediment, it indicates that it must extend to the sea floor at least on occasion.

A second possibility is that cold bottom waters from the Antarctic flowing northward through the Nazca Basin are eroding the sea floor. The erosion or non-deposition along the western margin of the Galapagos Platform might occur as these bottom waters are forced to the west around the Galapagos Platform and the Carnegie Ridge (Figure 1).

East of the islands, the Cromwell Current was found by Christensen (1971) to be weaker and diffuse which is in accordance with the observed sediment cover of profiles 3 and 4 (Figure 2). Profile 3 is of interest in that sediment is lacking drom 1-2.3 seconds in depth, whereas profiles 1 and 2 show a thin sediment cover at these depths. Also, existence of strong bottom currents on the platform is evidenced by areas of no sediment and the moating around topographic highs. This moating continues past burial of the peak in one instance suggesting a tenacity of bottom morphological features to resist leveling and to control bottom current flows. Profile 4 crosses several box-shaped depressions of the sea floor which, although they lack levees, appear to be submarine canyons. An alternative explanation would be grabens in the sediments with the underlying basement apparently unaffected. At the right end of profile 4, a new seamount was discovered. Its flat top suggests it may at one time have been emergent; however, Simkin (1971) has noted that Galapagos volcanoes tend to be formed by rows of circumferential vents which eventually by filling of the caldera would result in a flat-topped volcano.

The sediment cover near the Galapagos Islands is about 500 meters thick and is seen to contain a large number of opaque layers which are probably volcanic debris. Such material could have been carried seaward by turbidity flows from the island group, and some reflectors may be ash falls from any of the numerous volcanic events during the geologic history of these islands (Simkin and Howard, 1970).

The authors cannot resist a few speculative statements on the complex tectonic pattern of the eastern equatorial Pacific of which the Galapagos Islands occupy a prominent position. Morgan (1971) and Wilson (1963 and 1965) suggested the Galapagos Islands are the locus of a mantle "hot spot".

A "hot spot" as defined by Morgan (1970) is a narrow plume (pipe) of mantle material rising and then spreading out radially in the asthenosphere. As an oceanic plate moves over the upwelling, the continuous outpouring of basalt produces a linear aseismic ridge on the sea floor. It appears that ascending mantle material now localized under Fernandina and Isabella has in past time formed the entire Galapagos Platform and may indeed be responsible for both the Cocos and Carnegie Ridges (Figure 1). Mantle material is added to both the Nazca Plate, upon

which it is carried eastward with time by the plate motion, and to the Cocos plate, which carries it northward to form the Cocos Ridge. The mantle material which is swept to the northeast is probably presently leaking from the mantle plume along the weakened crust in the vicinity of the Galapagos Fracture Zone and the Galapagos Ridge crest. The Galapagos volcanics are apparently of Pleistocene age (Herron and Heirtzler, 1967). The suggestion that the entire platform is of this young age implies an enormous emplacement of material in geologically a very short time: note the central saddle in the Carnegie Ridge.

An alternative suggestion is that an ancestral Carnegie Ridge was bisected by the original Galapagos Ridge which moved the northern half northward to form the Cocos Ridge (Heath, et al., 1971).

Malpelo Ridge (Figure 1) does not readily fit either hypothesis; however, it is quite possible that it once was included in the northeastward moving Cocos Plate and quite recently shifted to the Nazca Plate with a westward migration of the Panama Fracture Zone. This would explain its parallelism to the Cocos Ridge. Morgan (1971) has suggested that there may be a differentiation process by which the deep mantle material is separated and the lighter fractionate rises "but is trapped by the asthenosphere-lithosphere interface (not a sharp boundary but a gradual transition in rigidity)." The pocket could migrate with the moving plates, supplying the "outlet" volcano(s) during the traverse and producing a Malpelo Ridge. It should be noted that Malpelo Ridge is near the Panama Fracture Zone (a highly seismically active feature). The lithosphere beneath this fracture zone must be relatively weak; nearby volcanism could be a side effect.

In summary, the western Galapagos Islands seem to be situated directly over a great upwelling of mantle material which, as it is poured out to form islands, has been carried away from its point of origin by motion of the Nazca and Cocos Plates (Johnson and Lowrie, 1971).

References

Christensen, N. 1971 - Observations of the Cromwell Current near the Galapagos Islands. Deep-Sea Research, Vol. 18, 27-33.

Deffeyes, K.S., Hey, R., Johnson, G.L., and Lowrie, A. 1971 - Plate Tectonics near the Galapagos Triple Junction. Trans. Amer. Geophys. Union, Vol. 52, 235.

Heath, G.R., van Andel, Tj.H., Bennett, R.H., Bukry, D., Charleston, S., Cronan, D.S., Dinkelman, M., Kaneps, A., Rodolfo, K.S., and Yeats, R.S. 1971 - Preliminary Results of JOIDES Deep Sea Drilling Project Leg 16 in the Eastern Equatorial Pacific. Trans. Amer. Geophys. Union, Vol. 52, 244.

Heezen, B.C., Hollister, C.D., and Ruddiman, W.F. 1966 - Shaping of the continental use by deep geotrophic contour currents. Science, 152, 502-508.

Herron, E.M., and Heirtzler, J.R. 1967 - Sea Floor Spreading near the Galapagos. Science, 158, 775-779.

Johnson, G.L., and Lowrie, A. 1971 - Cocos and Carnegie Ridges result of the Galapagos "hot spot" ?, Nature, London, in press.

Morgan, W.J. 1968 - Rises, trenches, great faults and crustal blocks. J. Geophys. Res., 73, 1959-1982.

Morgan, W.J. 1971 - Island chains, aseismic ridges and hot spots. Trans. Amer. Geophys. Union, Vol. 52, 371.

Raff, A.D. 1968 - Sea Floor Spreading - Another Rift. J. Geophys. Res., 73, 3699-3705.

Schneider, E.D., Fox, P.J., Hollister, C.D., Needham, H.D., and Heezen, B.C. 1967 - Furhter evidence of contour currents in the western North Atlantic. Earth and Planet. Sci. Letters, 2, 351-359.

Sinkin, T. 1971 - Origin of some Flat-Topped Volcanoes and Guyots. Geol. Soc. of Amer. Memoir in honor of H.H. Hess, in press.

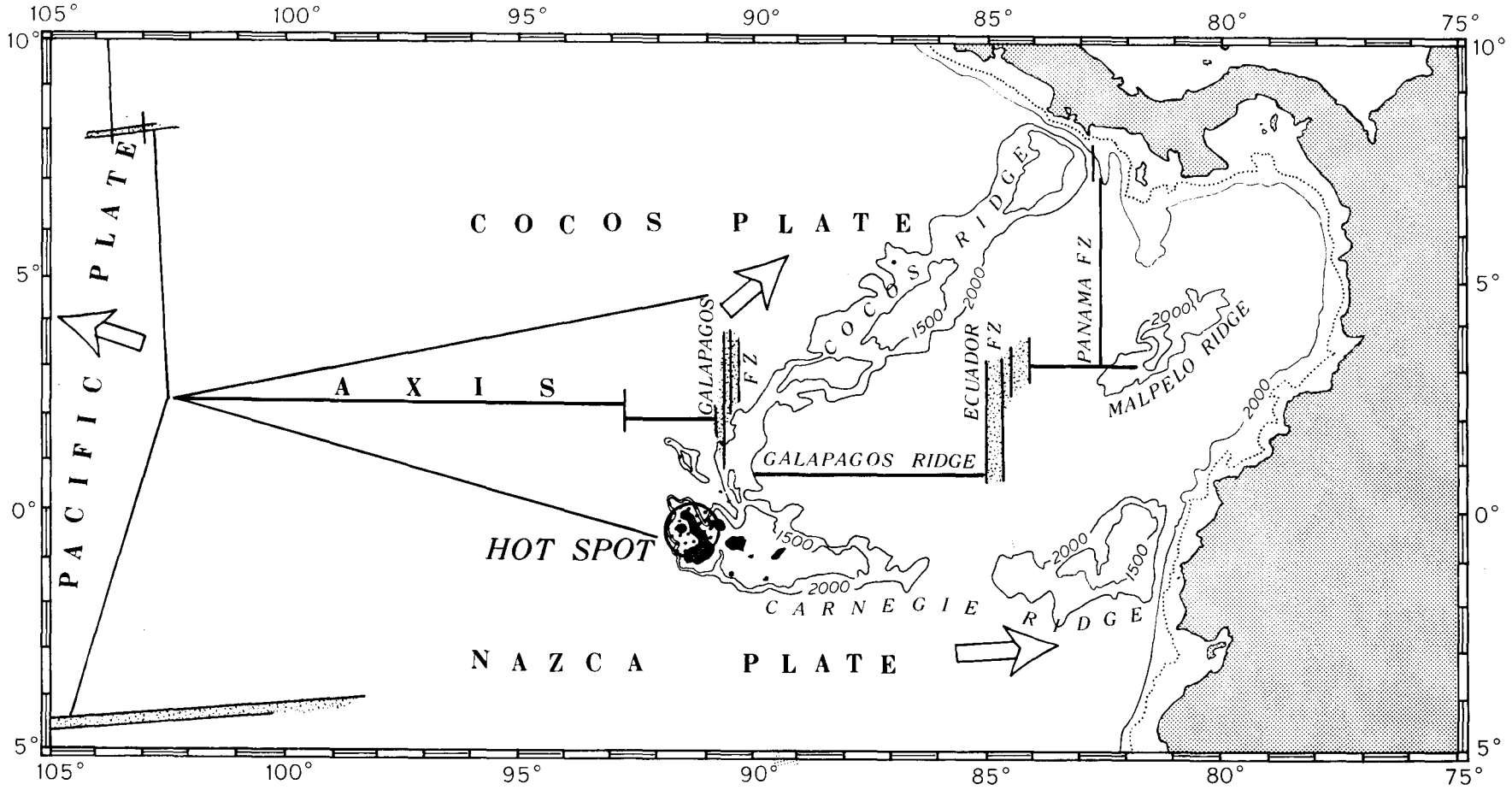
Sinkin, T., and Howard, K.A. 1970 - Caldera Collapse in the Galapagos Islands, 1968. Science, 169, 429-437.

van ANDEL, T., Heath, G.R., Malfait, B.T., and Henrichs, D.F. 1971 - Tectonics of the Panama Basin, Eastern Equatorial Pacific. Bull. Geol. Soc. Amer., Vol. 82, in press.

Vogt, P.R., Schneider, E.D., and Johnson, G.L. 1969 - The crust and upper mantle beneath the sea in the earth's crust and upper mantle. P.J. Hart ed., Geophys. Monograph 13, Amer. Geophys. Union, Wash. D.C., 556-617.

Wilson, J.T. 1963 - Continental Drift. Scientific Amer., V. 208, 86-100.

Wilson, J.T. 1965 - Evidence from ocean islands suggesting movement in the earth. Phil. Trans. Roy. Soc. (London) 258 (Symposium on Continental Drift) 145-165.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COCOS PLATE
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AXIS
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HOT SPOT
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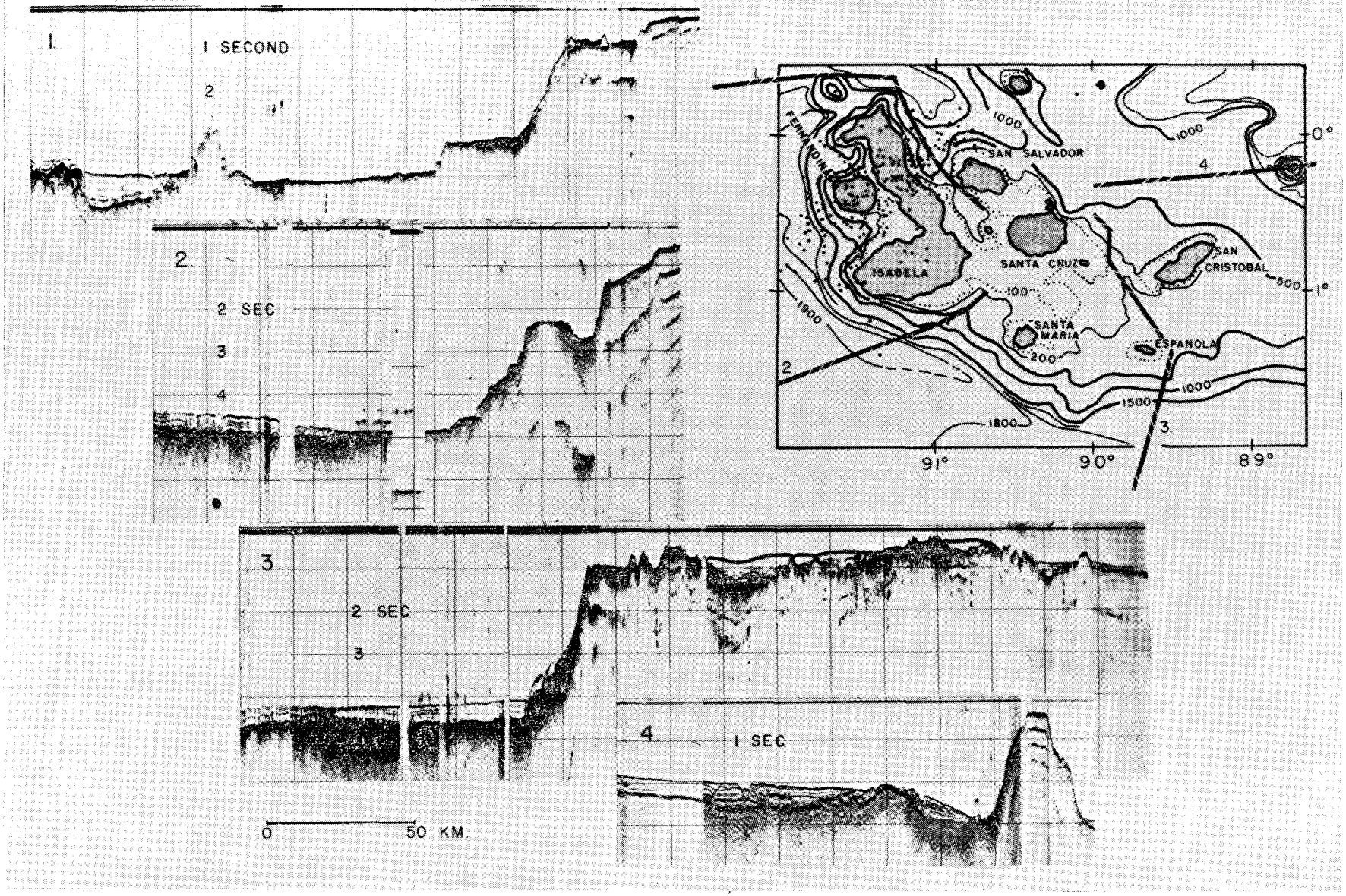
1
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SANTA MARIA
ESPANOLA
1000
1000
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1900
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1500
1000
1800
500
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91°
90°
89°

Figures

Figure 1. Major submarine features of the eastern equatorial Pacific. Dotted line is the 200 fathom isobath. Contours based on bathymetric chart presented by van Andel, et al., 1971, and various NAVOCEANO data.

Figure 2. Four seismic reflection lines across portions of the Galapagos platform. Small dots are earthquake epicenters, courtesy of ESSA, Rockville, Maryland. One second of travel time equals approximately one kilometer.

GALAPAGOS EARTHQUAKE SWARM

(copy of report submitted to Smithsonian Center for Short Lived Phenomena, May 4, 1971)

The National Ocean Survey (of NOAA, formerly Coast & Geodetic Survey) has located 3 recent earthquakes within 10 km of Isla Fernandina, the site of massive caldera collapse in 1968. The first, 1544Z April 9 and 4.5 m_b, was apparently felt by the sole resident of Isla Santiago, 75 km E of Fernandina. Two large events, 1719Z April 17 (5.4 m_b) and 1741Z April 18 (5.7 m_b), were felt by Edward McIntosh of the Golden Cachelot who was on the NE coast of Fernandina at the time of the April 18 quake. McIntosh reports that 6 to 8 puffs of white smoke, as distinct from reddish dust clouds caused by the earthquake, issued briefly from a group of cinder cones on the lower NE flank of the volcano. The seismograph 140 km from the caldera has registered many tremors beginning April 5th or 6th, and Rolf Sievers notes that the seismograms look very similar to those obtained during the 1968 collapse. Dr. John Filson (MIT) reports that the large Area Seismic Array (LASA) in Montana has located 21 events in the Galapagos starting April 9 and continuing. It seems likely that subsidence of Fernandina's caldera block has been renewed. The largest event on April 18, provisionally 5.7 m_b (and m_s) and located at 0.3° S 91.7° W, exceeds the largest event of the 1968 collapse (5.4 m_b) and all other reported Galapagos quakes since 1955. Seismic energy released already approaches that of the 1968 collapse, the largest known since Katmai (Alaska) in 1912.

Sources : (1) C. Von Hake, NOS-NOAA, Rockville, Md, 20852
(2) E. McIntosh, Lindblad Travel, 133 E. 55th St, New York, N.Y. 10022
(3) R. Sievers, Darwin Research Station, Isla Santa Cruz, Galapagos
(4) J. Filson, Mass, Inst. Tech. Cambridge, Mass. 02173

Reporting source : Tom Simkin, Smithsonian Institution, Washington, D.C. 20560

GALAPAGOS EARTHQUAKE SWARM

(7 July 1971)

Type of event : Geophysical

Date of occurence : April 5, 1971 to June 1971

Location of event : Fernandina, Galapagos Islands

Reporting source : Educational Expeditions International Research Team, Galapagos Islands

Source contact : Dr. Tom Simkin, Smithsonian Institution, Washington D.C.

"The earthquake swarm reported earlier (Event No. 42-71) continued into early June but recent inspection of volcano Fernandina, the general center of earthquake locations, shows that the caldera has not resumed the collapse begun in 1968. The caldera remains essentially the same and aerial reconnaisance shows that the nearby calderas Wolf and Darwin (Isla Isabela) are likewise unchanged. We note zones of strong recent fracturing on Northwest Fernandina and a group from the University of Oregon is reporting microseismic data from an array at this area."

THE BIOCHEMICAL DIVERSITY OF THE DARWIN'S FINCHES.

(Edinburgh University Galapagos Islands Expedition 1968)

The Darwin's Finches of the Galapagos Islands are one of the most intensively studied groups of animals, in particular with regard to their evolution. They illustrate adaptive radiation in an excellent way and have attracted many zoologists, notably Lack and Bowman recently, since Darwin appreciated their value in the study of evolution.

The group shows an amazing diversity of morphology, particularly in structures affecting their food and feeding behaviour and hence their ecology. In other respects; plumage, and other specific recognition characters, and in many structures not greatly affecting their feeding they are remarkably conservative. Clearly, when the many opportunities of the Galapagos environment presented themselves to the first finches, there was rapid diversification of some characters suiting different populations to different ways of life. It would be interesting to see how the group may have evolved biochemically, as it might be expected that different proteins and particularly enzyme structures and properties may prove optimal in the different niches occupied by the different species.

The extent of protein polymorphism has only recently been appreciated, initially in human haemoglobin and since in a wide range of animals and plants. Consistent interspecific differences of egg-white proteins, blood serum albumens, haemoglobins and other proteins have been shown in birds. Among finches, for example, the canary (Carduelis serinus) and the goldfinch (Carduelis carduelis) are different in the electrophoretic mobilities of their albumens and other proteins.

One of the projects on the 1968 Edinburgh University Expedition to the Galapagos Islands was to investigate the biochemical diversity of the finches.

They were caught in mist nets, and blood was taken by cardiac puncture after anaesthetising the birds with chloroform. Every effort was made to keep the birds alive and the majority were later released. The blood was then stored in a liquid nitrogen container, but due to the malfunction of the container some of the samples were lost. We did however manage to bring back 77 samples to Edinburgh (5 Geospiza magnirostris, 31 G. fortis, 17 G.fuliginosa and 1 Camarhynchus parvulus). Proteins were separated using starch gel electrophoresis and the gels were stained for general proteins, aromatic esterases and lactate dehydrogenase. Several other specific enzyme tests were carried out but none were satisfactorily detected.

Haemoglobins and albumens showed the same mobility in alle the samples and the other general proteins, probably mainly gamma globulins, were identical with the exception of the C.parvulus sample which showed

a small difference. Esterases, however, were highly variable with 8 different gel patterns shown, each with from 6 to 8 bands visible. Different patterns were not shown consistently between the various species, but most patterns occurred in several species. G.scandens was the most variable with 7 different patterns shown in 23 individuals, and G.fortis least variable with 28 out of 31 individuals showing the same pattern. G.fuliginosa showed 4 patterns from 17 individuals, one of which was identical to the pattern shown by the single C.parvulus sample.

Lactate dehydrogenase was also polymorphic with up to 4 bands present. All the bands were represented in samples from all 4 Geospiza species, and the pattern shown by the C.parvulus sample was the same as one shown by the other species.

What then can be said about the biochemical diversity of the Darwin's Finches ?

As might perhaps have been expected the proteins whose functions are rather more basic, the albumens and haemoglobins have not undergone any change. The enzymes however, whose functions are more specific are more variable. It is significant that this variability is expressed as a polymorphism throughout the genus rather than as specific patterns. This may indicate that the different genes producing the different enzymes were present before the adaptive radiation of Geospiza or that occasional interbreeding between the species has allowed them to spread throughout the genus. If the pattern of enzyme diversity of this group can be related tentatively to their ecology then perhaps it can be said that there is considerable overlap between the species and also that there is a possibility of ecological heterogeneity within a species. Few previous attempts have been made to relate biochemical diversity to ecological diversity.

It is becoming more popular not to consider a species as just a distinct ecological entity but to appreciate that genetically separate populations are capable of occupying a wide variety of subniches if presented with a heterogeneous environment. In addition these subniches may be partially occupied by closely related species.

It is highly relevant to consider the Darwin's Finches is this light as : several species of the same genus occur in the same area, (e.g. 4 of Geospiza in the arid zone of Indefatigable), each species is best suited to differing optima, chiefly seed size and hardness and yet show considerable overlap in choice of food, as well as a wide range of foods taken by each species. In addition there is practically no competition from other species outwith the genus. It is therefore possible to fit the data from the blood serum proteins into the general picture of what has happened and is at present happening to the genus Geospiza on the Galapagos Islands.

Hugh A. Ford - David T. Parkin
Patricia Parkin - Alastair W. Ewing
Edward McIntosh.

NEWS FROM THE CHARLES DARWIN RESEARCH STATION, GALAPAGOS

Scientific and Conservation Report - December 1970

The Organization of the National Park Service

A list of recommendations and plans on the organization and administration of the National Park Service and on research geared to conservation was submitted in October 1970 to the Director General of the Forestry Service through the UNDP-Office in Ecuador. The organization of the National Park Service was discussed in more detail with the leading officials of the Forestry Service, members of the Charles Darwin Foundation Executive Committee and the Director General of IUCN during their visit to the Islands on 4 to 8 December.

Some of the main conclusions of these discussions were :

i. The Forestry Service will appoint four, i.e. two additional, National Park Officials. A set of instructions will define their duties and status.

ii. The Forestry Service will apply for funds for housing, boats and equipment of the National Park Service.

iii. The National Park Service will in collaboration with the CDRS apply for funds for conservation programmes.

iv. The CDF and the CDRS will as previously organize and carry out conservational research in the islands.

v. The CDRS will as previously support the work of the National Park Service by advising on the planning and execution of conservation programmes.

vi. Until the Forestry Service will have organized within the next years the National Park Service completely the CDRS will as previously give its support by employing wardens that work under the supervision of the Park Officials and by putting at the Services disposal an office, transportation and equipment.

Tortoise Rearing Programme

i. G. e. ephippium. Twenty of the tortoises hatched at the Station in 1965 were returned to Pinzon on 10 December. They readily started feeding and were not attacked during the first four days. Nine animals of this age-group are kept at the Station for comparison of growth rate and mortality.
Thirty-nine eggs from eight nests were brought in October to the Station for hatching. More nests were found in December, but the eggs were left in these in order to investigate hatching under natural conditions (C. MacFarland).

ii. G. e. darwini. In the course of the protection programme on Santiago (see below) 120 eggs and 17 young recently hatched from protected

nests were brought to the Station for hatching and raising.

iii. G.e. chathamensis. The breeding group at the Station has laid 26 eggs in the months of July to November.

iv. G.e. hoodensis. The breeding group at the Station has laid 44 eggs in the months of July to November.

v. G.e. porteri. The breeding group at the Station has laid 19 eggs in the months of July to October.

Conservation Programmes

i. From August to December an extensive protection programme was undertaken on Santiago by one Park Official and two wardens. The main objectives were the discovery, exploration and protection of the tortoise breeding areas and the gathering of data on their biology and population size, composition and movements.
Previously unknown tortoise breeding areas were discovered. Some were effectively protected. In the course of this work 1400 pigs were killed.
195 new tortoises were marked, bringing the total to 349.
Also valuable contributions to the knowledge of the flora and insect fauna of the island were made.
A comprehensive report is prepared by the National Park Service.
This programme was supported by the donation of Mr.H.E. Hawkes.

ii. A party of ten hunters visited the Island of Marchena from 14 to 25 November to attempt to exterminate the recently introduced goats. The total population was estimated to consist of 80 to 100 individuals; 55 were shot. It is believed that introductions were attempted several times during the last decade.
This programme is supported by the donation of Mr. H.E. Hawkes.

iii. A party of three hunters visited the Island of Santa Fe (Barrington) from 29 November to 5 December. They killed 117 goats and estimated that about 60 were left on this island.
This programme is supported by the Frankfurter Zoologische Gesellschaft.

iv. Currently experiments are carried through in order to find methods to apply anticoagulants in rat control on Pinzon without affecting the native wildlife.
This programme is supported by the Frankfurter Zoologische Gesellschaft.

Isla Pinta

Pinta was visited in September and November by Mr. D. Weber and Mr. Tj. de Vries. They were struck by the terrible destruction that introduced goats have brought about on this island.
By 1968 the population had reached 3-5000 individuals and had already destroyed most of the low vegetation in the arid and transitional zones.

Now goats were common all over the island, invading even the humid zone to the top. Previously this area had dense undergrowth and was quite impenetrable, now it is completely cleared, leaving only higher bushes and trees. At least 45 to 250 plants endemic to Galapagos occur on Pinta and are thus seriously threatened. Four permanent quadrants were installed in the arid and humid zones to follow up further vegetational changes. There were no signs of surviving tortoises. The endemic rail (Lateralus spilonotis) was not heard. Finches were generally rare; G. magnitrostris and P. crassirostris were relatively common.

Isla San Cristobal

The north eastern parts of San Cristobal were visited in September. Fourty-three new tortoises were marked, bringing the total to 154. All animals encountered were adult males and females of breeding age. It is estimated that in this one area of several square kilometers the population consists of approximately 250 to 300 individuals.

Fire Out-Break on Alcedo (Isabela)

On 26 October several persons situated at James Bay, Santiago, aboard the R/V "Alpha Helix" sighted what was first considered a sign of volcanic activity on Volcan Alcedo, central Isabela : A smoke column rising about 800 to 1000 feet above the southern rim of the crater. During a visit to Alcedo on 10 to 15 November Mr. MacFarland and Mr. Maxwell noted that the source was a fire of undetermined origin which had at this time burned about six to ten hectares of the eastern interior slope of the crater. The fire was spreading. Reports have been made to the Smithsonian Institution.

Fumarole activity on Santa Fe (Barrington)

In the beginning of November fumarole activity has been observed at two localities in the northern part of Santa Fe. No sulfur fumes were noticed. A report was sent to Dr. Simkin, Smithsonian Institution (Tj. de Vries).

Ornithological Notes

i. The Flamingoes on southern Isabela had a successful breeding season this year (July to September). At least 40 young were raised at the Poza del Cementerio near Villamil (J.Gordillo).

ii. Six nests with two eggs each of the Lava-Gull (Larus-fuliginosus) were found on Genovesa in mid September (H.Grossmann).

iii. In September a census of approximately two-thirds of the total range of the Flightless Cormorant (Nannopterum harrisi) showed 663 nests which had been used in 1970 (M.P.Harris).

iv. During 1970 the Island of Espanola (Hood) was fequently visited by Dr. Harris for studies on the Waved Albatross (Diomedea irrorata). About ten thousand pairs bred in 1970, three times the estimates of previous years.

During these visits the Dark-billed Cuckoo (Coccyzus melacoryphus) and the Vermilion Flycatcher (Pyrocephalus sp.) were recorded the first time from this island. Also Purple Martins (Progne subis) were seen monthly from June to December; one female was dead in December. Furthermore the second Galapagos record was made for the Common Nighthawk (Chrodeilles minor) on 12 December.

Notes on Whales

On 18 November a 45 feet long adult female Baleen Whale (Balaenoptera sp.) was washed ashore 1 km east of the CDRS. A report was made to Dr. Philip Hershkovitz, Chigaco Nat. Hist. Mus. (C.MacFarland).
Two weeks later another dead whale, about 60 feet long, was reported from Punta Rocafuerte, south-eastern Santa Cruz.
During the last months unusual numbers of both Sperm and Baleen Whales have been observed around Fernandina and northern Isabela (M.P.Harris).

FUNDACION CHARLES DARWIN PARA LAS ISLAS GALAPAGOS

CHARLES DARWIN FOUNDATION FOR THE GALAPAGOS ISLANDS

FONDATION CHARLES DARWIN POUR LES GALAPAGOS

Créée sous les auspices de l'Organisation des Nations Unies pour l'Education, la Science et la Culture (UNESCO)

1, rue Ducale, 1000 BRUXELLES, Belgique

Buts et objectifs de la Fondation Charles Darwin pour les Galapagos (Art. 2 des Statuts, Bruxelles, 23 juillet 1959)

L'Association est chargée de l'organisation et de la gestion de la Station de recherches "Charles Darwin", dont le gouvernement de la République de l'Ecuador a autorisé l'établissement dans l'archipel des Galapagos à l'occasion du centenaire de l'énoncé de la doctrine de l'évolution (1858-1958).

L'Association propose aux autorités compétentes toutes mesures propres à assurer, dans l'archipel des Galapagos et dans les mers qui l'entourent, la conservation du sol, de la flore et de la faune, et la sauvegarde de la vie sauvage et de son milieu naturel. Elle arrête le programme de recherches de la Station biologique et la charge de toutes études scientifiques en rapport avec les objets ci-dessus.

Elle recueille et gère les fonds destinés au fonctionnement de la Station et à la promotion des recherches qui y ont leur base.

L'Association veille à la diffusion, par tous moyens appropriés, du résultat des travaux de la Station et de toutes informations scientifiques relatives aux réserves naturelles.