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SOMMAIRE

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VISITS TO ECUADOR AND THE GALAPAGOS BY MEMBERS OF THE EXECUTIVE COUNCIL

by

T.E. BARLOW,
Secretary-General.

One of the difficulties experienced by the Foundation in carrying out its aims for the Station and ensuring that there is always full understanding between the Government of Ecuador and ourselves, is that of communicating across the enormous distances which separate Quito and the Station from the majority of Council members. Furthermore, Council members have many demands on their time, so that occasions for visiting Ecuador are rare, and opportunities to reach the Islands even less common. It is fortunate therefore that in the last eighteen months three members of Council have been able to visit Quito on behalf of the Foundation, and two of them were able to spend several weeks at the Station.

The President, Professor J. Dorst, spent part of August and September 1967 in the Galapagos, and later visited Quito where he met members of the Government.

Professor J.-P. Harroy visited Quito in March 1968 and took part in important discussions with Ministers and permanent officials about the future of the Islands.

The Secretary-General, Captain Sir Thomas Barlow, went to the Station for three weeks in September and October 1968, and then visited Quito.

Formation of a Committee for Galapagos Islands Affairs

Professor Harroy's visit coincided with the inception of a Committee formed under the auspices of the Minister for Foreign Affairs, and consisting of all those bodies who are concerned with developments in the Galapagos. The President is Doctor Luis Ayora (President of the Commision de Valores), and amongst its distinguished members is Sr. Cristobal Bonifaz, member of the Foundation's Executive Council.

At the meeting of the Committee which Professor Harroy attended three important items were discussed :

a) The serious threat to the status of the Islands as a National Park and to the survival of their wildlife, which is posed by the continuing uncertainty concerning the limits of the areas which are to be defined as Reserves.

b) Arising from this the Committee considered that there was an urgent need to send officials to the Islands to establish legal boundaries.

c) Also arising from the situation emerged the desirability of ensuring closer relations between the Foundation and people in Ecuador.

Between the visits of Professor Harroy and the Secretary-General, Dr. Velasco Ibarra was elected President of the Republic, the Government which he formed had taken office, and the Secretary-General was accordingly able to meet the new Ministers who are now responsible for the affairs of the Galapagos.

The Secretary-General was invited to a meeting of the Committee for Galapagos Affairs on 18th October and was handed there a formal resolution which the Committee had passed recommending to the Government that a Commission of two cartographers and a lawyer should be sent to the Islands immediately to carry out the work of surveying the boundaries of the Reserve areas on the four inhabited islands and to examine the claims of settlers whose lands appear to have extended beyond the provisional boundaries proposed by the Station.

The Committee has also recommended to the Government a basis for an administrative structure to ensure that the regulations for the acquisition of land on the borders of the Reserves are strictly observed in future.

During the Secretary-General's stay at the Station a big step in this direction was taken by the appointment of two officials from the Department of Inginiero Sr. Pablo Rosero, Director General de Bosques, to work on the Islands on conservation problems.

Publication of the results of researches

Discussion between the Secretary-General, Sr. Cristobal Bonifaz, the Director of the Station and the President of the Casa de Cultura in Quito, indicate that there is an urgent need to communicate more widely in Ecuador and elsewhere in South America the results of the work carried out at the Station. The Station depends for its existence on sympathetic understanding in the Islands and in Ecuador of its purposes and activities. It has therefore been approved by the Executive Council that all scientists working from the Station shall be requested to prepare, as part of the customary report on their results, a brief summary in Spanish which the Director of the Station will cause to be given proper circulation amongst educational and scientific institutions in Ecuador. The Executive Council considered that this was a reasonable request to make of visiting scientists and that it was preferable to ask them to supervise their own translations rather than prepare it at the Station and risk misinterpretation of the author's intentions.

Educational Programme in the Islands

Recent visitors to the Station will have noticed the emphasis which education is receiving there. Regular classes are given for schoolchildren in natural history, and courses in conservation are provided for teachers and students from the mainland. This trend will be increased, and it is very gratifying that the Minister of Education in Quito has appointed Sr. Saltos, Supervisor of Education in Santa Cruz, as official adviser on education matters to the Station. This will stimulate the growth of activities in this respect and lead to greater appreciation of the scientific importance of the Islands.

The Scientific Programme of the Station

The Executive Council of the Foundation has felt the need for giving a lead to scientists on the pattern of research work which it is desirable to carry out in the long term at the Station. Accordingly a Scientific Programme has been drawn up which will serve to indicate fruitful lines of research and where the Station sees the priorities to lie in terms of habitat conservation. This programme will be circulated widely and will be included in a forthcoming issue of Noticias.

The expansion of facilities at the Station

Coupled with this programme is the Foundation's desire to improve certain of the Station's facilities. The new dining hall has proved a great success. Next it is necessary to improve the cabin accommodation. This is already being done as funds and material become available.

More important, however, is the need to provide better quarters for the educational side of the Station's work. It is proposed to build a separate lecture hall and museum so that work in the laboratory will not be disrupted by classes of instruction and by visitors seeking the museum. If funds are available it is hoped to start work on this scheme shortly.

POR SEGUNDA VEZ SE EFECTUA CURSO DE CIENCIAS NATURALES EN LAS ISLAS GALAPAGOS

por

Lucio SALTOS GOMEZ
Supervisor de Educación.

Satisfactorios resultados pudieron apreciarse al finalizar el Segundo Curso de Historia Natural aplicada a la conservación de la Flora y Fauna del Archipiélago de Colón, al que asistieron unos 35 profesores primarios de los que laboran en las diferentes escuelas de las Islas.

Es bien conocido por el mundo entero, la importancia que las Galápagos tienen para la ciencia, así como una probable fuente fructífera industria turística, que hasta el momento se halla inexplotada o mal concebida. Las Islas guardan en su seno especies de animales o plantas y sus raros descendientes que hace mucho tiempo desaparecieron de la faz de la tierra o risquezas geológicas de gran interés dentro del campo científico. Justamente conservar esta riqueza científica es la meta de los cursos de Ciencias Naturales que vienen organizandose bajo los auspicios de la Estación Biológica Charles Darwin y la colaboración de la Supervisión de Educación del Archipiélago, a fin de interesar al profesorado, para por su intermedio llegar a las Comunidades, de manera especial a las generaciones crecientes, haciendo conciencia de éstas la importancia de que merece guardar celosamente este tesoro para el conocimiento de las nuevas generaciones; para plantearles los problemas típicos de la conservación y buscar las soluciones más convenientes a éstos, con la cooperación de la Comunidad toda así preparada.

En los diez días de duración del curso, se recogió abundante información de las plantas y animales de las Galápagos, se investigaron y conocieron los factores geológicos y ecológicos que influyeron para la supervivencia de éstos, se observó abundante material concreto, se observaron algunas películas y vistas fijas relativas a los tópicos antes enunciados y se intercambiaron experiencias.

Al término del Curso, en sencilla ceremonia de clausura, el profesorado manifestó su agradecimiento a la Estación y su decisión de tomar a cargo la labor de conservación en las Comunidades donde laboran.

Puerto Ayora, 24 de octubre de 1.968.

UNO DE LOS ASPECTOS DE LAS EXHIBICIONES EN EL LABORATORIO PRINCIPAL DE LA ESTACION DE INVESTIGACION BIOLOGICA CHARLES DARWIN DE LAS GALAPAGOS, EN LA REALIZACION DEL CURSO DE CIENCIAS NATURALES. PROFESORES OBSERVANDO LA CLASIFICACION DEL REINO ANIMAL CON ESPECIMENES VIVOS.

Foto Tj. de Vries.

TO COORDINATE CONSERVATION EDUCATION IN THE GALAPAGOS ISLAND

Senor Lucia SALTOS GOMEZ has been appointed by the Ecuadorian Ministry of Education to organize and coordinate conservation education in the Galapagos Islands. The appointment was made in August by Dr. Ciceron Robles Velasquez, Minister of Education and President of the Unesco National Commission of Ecuador.

For four years Sr. Saltos, as Supervisor of Education, has worked in close association with the Charles Darwin Research Station to develop education programmes to promote an understanding of conservation needs and principles amongst the islands' communities. This new post will enable him to extend the teaching of conservation biology in the schools of the Archipelago, to develop programmes for adult education, exhibitions and training courses for future guides of the National Park.

ROGER PERRY.

BEAGLE III

by

T.E. BARLOW,
Secretary-General.

We reported in December 1967 (Noticias No.9/10) that we had plans in hand for a new research vessel to replace Beagle II. The point that most people associated with the Foundation will want to know, is her name, and it is a pleasure to record that she will be called Beagle III.

The new vessel has already been laid down and she will be ready to sail for the Islands in the early summer of 1969. It has not been a simple matter to decide on her design and construction, or where she was to be built. After our experience with the wooden hull of Beagle II, it seemed that the choice of material should lie between steel and fibre glass, or a variation of this - teak with a nylon or fibre glass skin. We felt that we must plan for a life of 20 - 25 years, and we could not be certain how fibre glass would last, nor how it would stand local conditions for this length of time. Steel, we were sure would last, and is definitely stronger - though heavier and of course liable to corrosion. The cost of a fibre glass hull would perhaps be slightly more, but there was little to choose. Technical knowledge about repairs to fibre glass hulls has made much progress but we were not convinced that it would be such a practicable possibility to carry out repairs on the islands - if they proved necessary - and this would be an important factor in deciding whether to use fibre glass or not. Eventually it was decided to stick to proven experience and build of steel.

While this examination of materials was going on we were also exploring Boatyards in many countries to discover one that would build a vessel to our special requirements, at a price which we could afford. We chose a firm in Kent (England) called John Perry (Marine) Limited. This is a small but experienced firm and its Director has shown a great interest in the vessel. He will build her for a specially toughened steel called Corten. The hull will be coated outside with a protective rubber coating (Limpetite) designed to prevent corrosion. This substance is well proved by twenty years' marine experience to give excellent anti-corrosive protection. It bonds perfectly on to the steel and is hard enough to withstand considerable impact from accidental blows or knocks.

The interior of the hull will be sprayed with a polyurethane foam to provide insulation and stop sweating.

So much for the basic construction; now to give some details of her size and her interior lay-out. She will be 65 feet (20 m.) in overall length, with a beam of 16½ feet (5 m.), and will draw 5'8" (1.7 m.).

She will therefore be able to navigate comfortably in all waters where she will need to go and she can be drawn up on the sloping stretch of beach near the Station for maintenance and cleaning.

She will have two Gardner diesel engines to give her a maximum speed of about 11 knots, with a range of 3000 miles. We deliberated for a long time whether to give her the same sailing capacity as the old Beagle, but came to the conclusion that with more reliable engines this was not necessary and would mean sacrificing other desirable features. She will therefore just have a pair of steaying sails.

There will be a capacious saloon on the upper deck for meals and relaxation (if any of our visitors have time for it), and at the forward end will be the wheelhouse, charttable, radio and galley. Above the saloon will be an open bridge and steering position. There should be plenty of space on the upper deck to carry a dinghy and still leave room for other activities.

Down below are four double cabins for passengers, each with a desk, a small laboratory space and cabins for the Captain and crew.

We hope that travel on Beagle III will be much more comfortable than it was in her predecessor, and also faster. There will be such luxuries as fresh water, because she will have a self-contained water making plant, and enough generating plant to have electric light wherever it is needed. There will also be enough to run one refrigerator for the cook and another for the laboratory, so that there should be space for food and for the material which the expeditions collect, without competition.

Finally, we must say something of how we are able to afford this splendid vessel, and must first and foremost acknowledge our immense debt of gratitude to Mrs. Vincent Astor, whose husband Commodore Vincent Astor visited the Galapagos in his yacht Nourmshal in 1930 as leader of an expedition to collect flora and fauna. When Commodore Astor's widow heard of the fate of Beagle II, and of the Foundation's need for a replacement, she informed Dr. Hal Coolidge that she would support the project. The Astor Foundation has contributed a great part of the cost and Mrs. Astor has personally added to the gift. Without her generosity and understanding and the efficient assistance of the U.S. National Appeal of the World Wildlife Fund, we would not have been able to embark on the project.

A further magnificent contribution came to us as a result of the gracious patronage of Her Majesty Queen Elizabeth II to the showing of Anglia Television's film of the Islands, "The Enchanted Isles", and of the immense interest which H.R.H. Prince Philip has always taken in the conservation of Galapagos wildlife. (See Noticias No. 9/10). The receipts from the "première" of this film were handed to the World Wildlife Fund (British National Appeal) by Prince Philip as a contribution to the cost.

Beagle III will complete building at the end of April, and should

therefore be ready to start her voyage to the Galapagos in the early summer. If all goes well she should reach Santa Cruz two months later, where she can be certain of an enthusiastic welcome.

VOLCANIC ACTIVITY ON ISLA FERNANDINA

by

R. PERRY,
Director of the Charles Darwin Research Station
at Bahia Academy, Islas Galapagos.

At 1500 hours local time on 21 May lava began to flow briefly from a vent on the southeastern slope between Punta Mangle and the summit of Fernandina. The initial stages of the eruption were witnessed by Dr. R.T. Peterson, member of the Advisory Scientific Committee of the C.D.F., and by Sr. M. Castro from the cruiseship ms "Navarino" at anchor off Punta Espinosa. This event was of short duration, for no evidence of activity could be seen from the coast when the area was again visited on 4 June.

Subsequently, a major event, involving the lowering of the floor of the central caldera, occurred on 11 June.

At 1700 hours local time on 11 June an explosion in the west of the Archipelago was followed by a giant mushroom-shaped cloud rising high in the sky. The shock of the explosion was felt at Puerto Ayora on Santa Cruz, at Puerto Villamil on Isabela, and on Floreana; and heard at San Cristobal. By 1745 hours a number of further explosions had occurred and the eruption cloud extended to Santa Cruz; the diameter of this cloud from the CDRS was recorded as apex 140°, base 11°. A fall-out of grey volcanic ash spread over a wide area and reached as far as Puerto Villamil, some 90 kms. to the southeast. Flashes as from electrical discharges occurred over the area of the eruption during the night.

Throughout the following days seismological records at the CDRS showed persistent activity with an average of approximately 200 shocks every 24 hours, with the maximum amount of events being observed on 19 June. Between 1400 and 1500 hours GMT on 22 June a decreasing tendency of activity was noticed, shocks becoming less and less frequent. By 8 July seismic activity had all but ceased.

During an ascent to the rim of the caldera made by a team from the CDRS on 19 June, persistent tremors were felt. The frequency and violence of these tremors was such that, at a point on the main outer slope of the volcano (685 m. alt.), between 1730 and 2330 hours local time, 56 were counted, each lasting from 2 to 6 seconds, and of these 14 were sufficient to cause rock-falls from cones on nearby slopes. Loose material dislodged by tremors from the inner slopes of these cones caused periodic dust-clouds that appeared as isolated eruptive areas on the external slopes of the volcano. The tremors grew and subsided, rather than being felt as abrupt shocks, giving the impression almost as if the whole island were balanced on a jellylike mass. It was found that these movements had caused, and were continuing to cause, the collapse of areas of the inner walls of the caldera; rock-falls occurring at frequent intervals and giving rise

to dust-clouds that filled the crater and overflowed in the direction of prevailing winds. Large areas of the edge of the caldera had fallen into the crater and the existing borders were found, in the part visited on the east, to be heavily fissured. Trees and vegetation on inner slopes had been dislodged by the tremors and subsequent rock-falls. Because of the clouds of dust, it was not possible to see the floor of the crater. The most active was judged to be the southeastern area of the caldera and a large platform, lining this part of the crater wall, about midway between the floor and the rim, was believed to have been the site of greatest activity.

No evidence was found, 19-20 June, to indicate that lava was flowing. No flows were noticed from the sea; no light was visible over the mountain at night; nor was any excessive heat felt from the rim of the caldera. Seawater temperature records taken were considered as normal for the period of the year :

Punta Espinosa, Fernandina :	18 June 1968 - 18.2°C
North coast of Fernandina :	19 June 1968 - 19.3°C
Punta Vincente Roca, northern Isabela :	21 June 1968 - 20.3°C.

Sulphur fumes, however, were noticed on the ascent, and may have originated from an active solfatara area reported in February of this year (1968) as increasing on the western inner slope of the caldera.

Members of an expedition led by Dr. T. Simkin, Smithsonian Institution, and including Dr. R.I. Bowman, Dr. K. Howard, U.S. Geological Survey and Dr. P. Colinvaux, Ohio State University, travelled to the Galapagos Islands on 3 July to study the collapse and its effects on the island ecosystem. Their initial report, after a flight over Fernandina on 4 July, indicated that the southern part of the caldera floor had been lowered and a large lake still to be present. "Despite the collapse of several cubic kilometers of material, the only indication of associated igneous activity in the caldera was a small new cone on the slumped northwest floor". Observations, subsequently confirmed by a ground survey, showed that the caldera floor in the south had been lowered by some 300 meters.

Because of the dangers of continuing rock-falls neither of these parties, that of the CDRS or of the Smithsonian Institution, were able to enter the crater. It is, needless to say, evident that dramatic disturbances must have occurred to biotic communities within the caldera, not the least of which would have been due to the movement of the lake from the position it previously occupied over the northern and western parts to the lowered southern part of the crater floor. During the time of the last visit inside the caldera by a team from the CDRS, in February and accompanied by Mr. Eric Shipton of the Royal Geographical Society of London, the lake was estimated to cover an area of some 120-140 hectares. It formed in effect a complex of islands and inlets due to the unevenness of the crater floor, was bordered in many places with reeds (Cyperus ligularis and C. anderssonii) and supported almost certainly the largest population in the archipelago of the Galapagos

pintail (Anas bahamensis galapagoensis). A count of these ducks on 19 February indicated their numbering in the order of 2,000 birds (1,929 adults were counted). Large numbers of young must have been in the crater at the time of the eruption. In addition, other aquatic birds, including the Black-necked stilt (Himantopus mexicanus), were found in the crater. Some fuller assessment of the effects of the June eruption should be possible, probably towards the end of the year or early in 1969, when a descent can again be made to the floor of the caldera.

A preliminary account of the event, with associated data received from seismic and infrasonic detection stations in North and South America, appears as a report Fernandina Caldera Collapse (Event No. 9-68) of the Center for Short-Lived Phenomena of the Smithsonian Institution.

THE 1968 COLLAPSE OF FERNANDINA CALDERA, GALAPAGOS ISLANDS

by

Tom SIMKIN
Smithsonian Institution
Washington, D.C. 20560

and

Keith A. HOWARD
U.S. Geological Survey
Menlo Park, California 94025

INTRODUCTION

The June 1968 activity of Fernandina volcano in the Galápagos Islands was monitored by distant infrasonic detectors and seismographs, and observed from different parts of the archipelago. Reports collected and distributed by the Smithsonian Center for Short Lived Phenomena (SCSLP) indicated unusually intense atmospheric and seismic disturbances, and a party from the Charles Darwin Research Station that climbed the volcano at the height of seismic activity on June 19 reported the caldera was collapsing. As a result of these reports a study team including ourselves and biologists Robert I. Bowman and Paul A. Colinvaux was organized and dispatched, and field observations were made in early July.

Acknowledgment is gratefully expressed to the numerous eyewitnesses in the Galápagos who have liberally given their time and patience to our questioning, and to the many others who gave valuable help to our study. The U.S. Air Force supplied excellent photographic and logistic support, and the amateur radio work of Forrest Nelson and Virgil Bowers provided vital communications assistance. For their companionship as well as their observations and assistance we particularly thank Robert I. Bowman, Sharon Simkin, the Angermeyers of Academy Bay, and the members of the Darwin Station.

SETTING

Fernandina Island (also called Narborough) is a large basaltic shield volcano on the western edge of the submarine Galápagos platform (fig.1), which rises more than 3,000 m above the surrounding deep sea floor (Shumway and Chase, 1963). At its summit, nearly 1500 m above sea level, is a deep caldera 4 by 6 ½ km across. Five other shields of similar size and shape, each with a large summit caldera, coalesce to make up Isabela Island (also called Albemarle) just to the east (Banfield

and others, 1956). Fernandina has a gently sloping base and a steep central portion (slopes to 34°), which then flattens out nearing the rim of the caldera. Williams and McBirney (1968) have likened its shape to that of an overturned soup plate and have attributed this form to distension from ring-dike injections whose surface expressions are several concentric rows of spatter and scoria cones surrounding the caldera (fig.2).

The elliptical caldera of Fernandina is elongate toward the northwest-southeast. Before the 1968 activity it was 800 m deep and had a flat floor 2.2 by 3.9 km across, marked near its center by a slightly eroded tuff cone nearly 200 m high (figs.2 and 4, upper). A shallow lake occupied the northwest end of the floor. Prominent terraces 1/2 km wide occurring half way down the walls at both ends of the ellipse are former floor levels. A series of slumped benches a few tens of meters wide were present inside the rim on all sides (fig.2).

Remarkably little information exists on the rocks of Fernandina, as pointed out by Richards (1962). Petrologic reconnaissance (McBirney and Aoki, 1966; McBirney and Williams, unpub. data) suggests that the rocks are mainly tholeiitic basalts like the rocks of the Isabela shields. An age of less than a million years was shown for flows sampled in a paleomagnetic study (Cox and Dalrymple, 1966).

HISTORIC ACTIVITY

The Galápagos Archipelago is one of the most volcanically active regions in the world (McBirney and Williams, 1968), and in his catalog review of Galápagos volcanoes, Richards (1962) terms Fernandina the most active in the archipelago. The record of eruption in historic times is probably far from complete because the island is uninhabited, seldom visited, and its view from settlements is blocked by the heights of Isabela Island.

Richards' review (1962) shows that Fernandina was frequently active from 1813 to 1825. After an eruption in 1846, no eruptions are known until 1927 and again in 1937. There were eruptions in 1958, possibly in 1959, and in 1961.

All eruptions for which descriptions are available have included lava flows, and most have also included normal explosions. Air photographs (fig.2) show that many recent flows have issued from spatter cones in rows concentric around the caldera rim, and some from cones lower on the flanks of the volcano. In 1957 or 1958 lava flowed down the southwest wall and over the floor of the caldera. This activity evaporated the lake that had covered the floor (fig.2), but rainfall gradually renewed the lake so that it covered the northwest end of the floor in early 1968.

An earthquake of magnitude 7.2 apparently originated at Fernandina in April, 1962 (Sheepmaker and Egred, 1966). According to summit visitors

of recent years, fumaroles have been active in the west wall, the east edge of the floor, and on the southwest rim of the caldera.

Activity on the volcanoes of neighboring Isabela Island has commonly preceeded by several years eruptions on Fernandina; no such apparent correlation can be made with historic volcanism in other parts of the archipelago. Two eruptions, both on Isabela Island, have been reported in the archipelago since the completion of Richards' catalog of 1962. One was on Wolf volcano in 1963 and the other on Sierra Negra in 1963-1964 (McBirney and Williams, unpub. rept.).

1968 EVENTS

The first observed activity of 1968 was the eruption of a small lava flow just north of the site of the 1961 eruption, at an elevation of about 700 m on the east flank of Fernandina. This activity began at 1500[1] on May 21, covered an estimated 10 km^2, and was declining at 2300 when the observers' ship left the area[2]. No further activity was observed before June 11 despite visual searches of the east side of the island on May 25 and June 4.

The activity on June 11 began at 1018 with an earthquake that was recorded at Quito, Ecuador. At approximately 1100 a large white vapor cloud was observed from Academy Bay, 140 km east of Fernandina (fig.1). The cloud was described as columnar, developing into a mushroom shape upon reaching its full height (probably greater than 20 km) some 15 to 30 minutes after it was first sighted. It showed well-defined margins, and its stem finally rose so that clear sky could be seen beneath it from Academy Bay. However, a report from the fishing boat San José situated at Urvina Bay, only 35 km west of Fernandina caldera (fig.1), suggests that eruption clouds remained low in the sky over the volcano, becoming darker as the afternoon wore on. No sounds were heard to accompany these events. At about 1600, a dark ash cloud appeared that was visible from Academy Bay. The underside of this cloud was pink according to the crew of the San José, and observers at Academy Bay emphasized that it was darker and had markedly more diffuse boundaries than the morning cloud. The cloud grew rapidly from a mushroom shape to that shown in Figure 3[3], which spread at an altitude of approximately 20 km. In a picture taken by a TIROS satellite at 1630 it appears as a circular cloud 50 km in diameter and centered over Fernandina; no other clouds were present within 150 km. The eastern edge of the cloud had reached Academy Bay by 1800 and yet the shape of the cloud base was the same as that shown in Fig.3, suggesting continuous feeding by the volcano during this period and horizontal speeds of approximately 1 1/2 km/min.

Acoustic events began with a loud deep boom originating at 1708 on June 11. This lasted perhaps as long as a second and was likened to a sonic boom or nearby dynamite blast by listeners 220 km to the east, at Wreck Bay (fig.1). It was followed in 5 to 8 seconds by a lesser blast, and then for the next 2 hours smaller explosions that sounded at Academy Bay like distant bombing were heard at intervals of generally 1 to 5

minutes. The initial blast registered on a barograph at Wreck Bay, and the whole series of atmospheric disturbances were recorded by infrasonic (long wave-length atmospheric sound wave) stations throughout the western hemisphere. Two hours of strong disturbances corresponding to the sounds heard in the Galápagos were recorded at the ESSA station at Boulder, Colorado; weak signals preceeded them for 3 1/2 hours and followed them for at least 1 3/4 and probably as many as 8 1/2 hours afterward (V.H. Goerke, personal communication, 1968). Goerke described the blasts as "stupendous" and comparable to the largest of man-made explosions.

Flashes from extraordinarily thick bolts of lightning over the volcano became visible from Santa Cruz Island after sunset, about 1900. A crew member of the San José in Urvina Bay noted that although the flashes appeared to be electrical discharges they did not interfere with radio reception. Light flashes resembling distant fireworks or lightning behind clouds were visible from Wreck Bay at about 30-second intervals, not all in the same spot but separated by an angular distance corresponding roughly to the width of Fernandina Island. The light flashes were no longer visible from Academy Bay or Wreck Bay at 2300.

In addition to lightning, flashes of red, green, and violet light were reported by the boat San José in Urvina Bay. An observer at Academy Bay noticed an orange glow lasting a few seconds late in the evening. And several kilometers to the north, at an elevation of 200-250 meters on Santa Cruz, observers saw the lightning plus many transient red "fingers of fire" which they likened to acetylene torches. Fountaining of lava or hot glowing gas thus may have been a part of the June 11 activity.

Ash fell in Urvina Bay late on June 11. It darkened the San José and turned the sea murky. Fallout began at Villamil, 85 km to the southeast, about 2400 and continued for 20 hours, leaving 25 grams per square meter. Because of the fall the men of the San José found it difficult to breathe, and many of the inhabitants of Villamil reported sore throats.

An earthquake was felt throughout the islands at 1720 (intensity of 3 to 4 on the modified Mercalli scale at Academy Bay), shortly after the loud explosion. Five earthquakes per day from Fernandina were registered in Quito from June 12 to 14. Seismic activity then increased to a maximum on June 18 and 19, when approximately 200 events per day were recorded on a seismograph at Academy Bay. Fifty-six tremors were counted during a 6-hour period June 19 by a Darwin Station party on the flank of the volcano. Seismic activity then decreased so that by June 24 only a few events occurred per day. On July 10-12, while we were on the upper flank and rim of the volcano, we felt an average of three significant and six minor tremors per day. Most seismic events reported by the USCGS for the Fernandina activity had magnitudes between 4 and 5, but 17 events of magnitude 5.0 to 5.4 were recorded between June 13 and 21. The maximum number of seismic events reported by the USCGS was on June 19 (55 events > magnitude 4.0), but the peak activity of large events was on June 15, when in addition to many smaller events, there was one of magnitude 5.4 and three others of 5.1 and 5.2.

There are indications that volcanic activity occurred on southern Isabela Island as well as on Fernandina. On June 12 gray smoke was seen by the crew of the San José at 20 to 40 places on Isabela from northeast of Sierra Negra caldera to Cerro Azul (fig.1), a distance of 35 km. No glow or lava was seen[4]. While the possibility remains that these were man-made fires (such as were observed June 18 on the flank of Cerro Azul by the Darwin Station party), the descriptions by the San José crew indicate active volcanic vents.

On June 19 a party of five led by Roger Perry of the Charles Darwin Research Station ascended the volcano. An account by L.C. Saltos appeared in El Commercio of Quito on July 3, p. 1 and was translated as SCSLP event report number 24. They felt many earthquakes, and during their brief stay at the caldera rim (1330 to 1430) the caldera was completely obscured by dust from constant rock avalanches down the walls. They noticed a sulfurous smell at an elevation of about 1,000 m on their ascent of the north flank, but detected no evidence of lava flows.

At 0830 on June 21 an Ecuadorian Air Force plane piloted by Captain F.E. Sevilla flew over the caldera. A dust cloud extended over the caldera to an altitude of 3,000 m, but the flight took place during a lull in the seismic activity and in the morning, when avalanche activity was at a minimum, and the caldera floor was clearly visible through the dust. By that time the lake had been shifted to the southeast end of the caldera by major collapse of the floor. No sign of fresh lava was to be seen, but a small puff of white vapor was present over the northwest floor, and dust rose from avalanches on the walls. Much the same situation prevailed at noon on July 4 when the caldera was photographed by our group from a USAF plane (figs.5 and 6), and no further changes were apparent by July 10-13, when we were on the rim of the caldera.

CALDERA COLLAPSE

The main visible result of the activity was collapse of the caldera floor, the southeast part of which dropped over 300 m. The volume of collapse was 1-2 km^3 which, among the rare historic collapses, places this event midway between the 1955 enlargement of Kilauea caldera (0.2 km^3 Macdonald, 1965) and the 1883 collapse of Krakatoa (18 km^3 - Verbeek, cited in Williams, 1941, p.256). The caldera floor was tilted down to the southeast, while the northwest end remained hinged (fig.4). The lake which had been at the northwest end moved down to the southeast end, and its surface now stands approximately 300 m below the former level of the floor. The main collapse took place along an elliptical fault essentially coincident with the former outline of the floor. The boundary fault was thus the same as that along which the last major (prehistoric) collapse had occurred which isolated the wide terraces at each end of the elliptical caldera from the rest of the floor.

The collapse of the main floor of the caldera was, with the exception of a small downdropped block on the west side, remarkably coherent. The central cone on the floor remained intact and shows no sign of fracturing.

Numerous transverse fractures formed in the northern third of the floor, but the central third, between the fractured area and the lake, is smooth, gently sloping, and apparently unbroken. The floor now sags in the middle, as shown by the curvature of the northern lakeshore. Such a basining effect in calderas is sometimes used to suggest an inward dip of the bounding faults (Kingsley, 1931; MacDonald, 1965; Williams and McBirney, 1968).

A broadly elliptical area of 1/2 km^2, elongated east-west and crossing the main collapse on the west side of the floor, dropped as an independent block (fig.5). The part of this block that was formerly in the wall of the caldera dropped an estimated 120 m, while the remaining third extending out into the floor dropped an estimated 50 to 150 m more than the adjacent main floor. Several ponds up to 100 m across remained on the block in July, suggesting that part of the lake was trapped by subsidence of this block before the major collapse shifted the lake to the other end of the caldera. One-third of the area of the small block had been the site of previous collapse independent of the main floor, as before 1968 it occupied a cirque-like indentation in the wall whose floor was 100 m above the main caldera floor.

The small collapsed block is the site of vigorous fumarolic activity. Ten to twenty fumaroles could be seen on July mornings, but only one was visible on the warmer afternoons when the vapor did not condense as readily. The area had previously been the site of sulfurous fumaroles, and visitors in February 1968 noticed an apparent increase in fumarolic activity as evidenced by dying trees in the vicinity. Most of the present fumaroles issue from talus along fault scarps near the center and along the west and north edges of the block, but the most prominent one and the only one that produces visible vapor in the heat of the day issues from a new low-rimmed explosion crater 50 m across and near the center of the block (fig.5). We surmise that the crater was formed during the explosive events of June 11.

The walls of the caldera are now oversteepened and are constantly avalanching (fig.6 and 7), but very little of the rim has yet slid into the caldera. New fractures are present on the rim 1/2 km back from the edge of the caldera, and they increase in size and number approaching the edge, yet new vertical displacements are generally less than 1 m and are mostly nil. In places near the edge, however, the ground has been so severely jolted that large clods of sod have been thrown up and underlying blocks of rock weighing several kilograms have been bounced into the air.

Avalanches on the walls are loose rockfalls averaging about 2 minutes in duration. They are much more common in the afternoon than in the morning, evidently because warming causes thermal expansion and evaporation of capillary water binding the rocks. During our stay at the rim, visibility in the caldera was best in the early morning and rockfalls could be heard only about three-quarters of the time, but by noon rockfalls were continuous and later in the afternoon it was often impossible to see across the caldera because of rockfall dust. Earth tremors felt on the rim were followed within a few seconds by the roar of increased avalanche activity. A pall of brown dust rose above the caldera each

afternoon and extended several tens of kilometers to leeward (fig.6), contributing to the ash that partly veneers vegetation on the island.

ASH

The source of the ash blown into the air on June 11 is uncertain. The ash consists mainly of lithic fragments, but broken crystals and glass are present in the finer fractions. The small crater in the fumarole block is probably inadequate as a source vent, and though the caldera lake may hide another possible source, it is also likely that some of the material was blown into the air from the floor and walls by jolting and air currents created by floor collapse. In this respect, however, it should be noted that no seismic disturbance accompanied the initial appearance of the darker, afternoon cloud, and that the airwave activity for this period as recorded when it reached the ESSA Colorado infrasonic station showed only minor disturbances such as had preceeded it by over 2 hours. The median grain size of new ash on the north rim of the caldera is 2 mm, and lapilli of dense basalt up to 1 1/2 cm (weighing nearly 2 g) are present. Small lithic lapilli are found on the north flank to a distance of 2 1/2 km from the caldera. No pumice was found.

The total quantity of ash and dust produced is estimated to be between 10^7 and 10^9 kg. Lapilli ash collected from a flat rock surface on the rim 1/4 km back from the northeast edge of the caldera in July indicates a fall there of 1.2 kg/m^2. Fine ash that fell on Villamil, 85 km to the southeast, was collected immediately after the fall by Juacinto Gordillo from freshly-laundered clothing that had been laid out to dry; it records a fall of 0.025 kg/m^2. The distribution of ash around the north and east coasts of Fernandina in July indicated a greater fall to the south, towards Villamil. In the caldera new dust or ash is quite thick. A black lava flow on the northwestern terrace is now completely covered, and its buried margins are subdued (fig.4), indicating a burial of probably a meter or more. Gullies cut in the floor as the lake shifted from one end to the other appear to be cut in a thickness of several meters of ash or dust resting on the 1937-1958 lava flow. The estimated total ash and dust, however, if expressed in volume equivalent of magma, is several orders of magnitude less than the volume of collapse.

Some previous eruptions from Galápagos calderas have produced far more pyroclastic ejecta than the 1968 activity of Fernandina. A layered tuff unit on the rim of Fernandina contains blocks weighing several kilograms and attests to major pyroclastic activity in the past. This tuff is buried by some of the dark barren flows on the flanks of the volcano, but can be recognized on older flows to the north shore of the island, and provides the soil in which much of the island's vegetation grows. On Cerro Azul volcano (fig.1), ash covers the upper slopes (Banfield and others, 1956) and is apparent on air photographs as a thick mantle. Such deposits show that some eruptions, possibly associated with caldera collapse, blast out considerable ash.

SPECULATIONS ON CAUSE OF COLLAPSE

The caldera collapsed into a chamber at depth by withdrawal of magma, but the present location of the magma is unknown. The coherence of the caldera floor during collapse suggests that a great thickness collapsed as a unit and that the underlying chamber into which it dropped lies at considerable depth. The small fumarolic collapsed block is inferred to have dropped into a relatively high cupola.

The scarcity of identified erupted products accompanying the collapse of 1-2 km^3 leads to a substantial "room problem". The only erupted materials known - the lava of May 21 and the ash of June 11 - make up a volume at least an order of magnitude less than the collapse. If there was lava fountaining on June 11, as suggested by some eyewitness accounts, it might have taken place around the boundary fault where its products would now be buried by talus. The absence, however, of any visible fresh lava on the caldera floor precludes a collapse origin by massive engulfment or isostatic sinking. Significant flank activity could have taken place unobserved, particularly on the southern and western slopes of the volcano. A program of post-collapse aerial photography now underway may allow us to detect additional extrusions.

Intrusions - another possible location of the displaced magma - are less easily detected. The volume of Fernandina Island is small enough that nearsurface instrusions of 1-2 km^3 might alter the shoreline or perhaps cause surface fracturing. The shoreline, however, shows no indications of vertical movement and surface fracturing is limited to 1/2 km from the caldera, but these observations clearly do not eliminate the possibility of some new near-surface intrusions. Additional possibilities, similarly difficult to evaluate, are that room for the collapse was made either by copious submarine flows or else withdrawal of magma to great depths. In this latter regard it is intriguing to speculate on the reported concurrent eruptions on Isabela Island. If venting really did occur on Isabela, it was probably related to the Fernandina activity and implies a huge magmatic plumbing system with intervolcano connections deep beneath the sea.

NOTES

1/ All times given are local times which are 6 hours behind Greenwich Mean Time.

2/ Observations by Miguel Castro, who was present as a guide on the Lindblad tour vessel Navarino, and had also witnessed the 1961 eruption of Fernandina.

3/ Fig.3, the cloud photograph, was reversed left to right in printing.

A sequence of photographs figured by Jaggar (1947, p.483) records development of a cumulus cloud from vertical fume columns above Mauna Loa in 1916, and similar cumulus formation has been reported over Kilauea by MacDonald (1955) and Cadle & Frank (1968).

4/ Perry's group on June 19 noted that large quakes frequently triggered brief rockfalls on the cinder cones that flank Fernandina volcano - these falls produced low "puffs" of dust from the cones that could be mistaken for volcanic activity by distant observers not experiencing the tremors. However, this explanation cannot fit the Isabela "smoke" observations because the smoke was described as high and continuous for approximately 10-minute periods.

5/ The biological effect of the June activity on Fernandina is being described by Robert I. Bowman.

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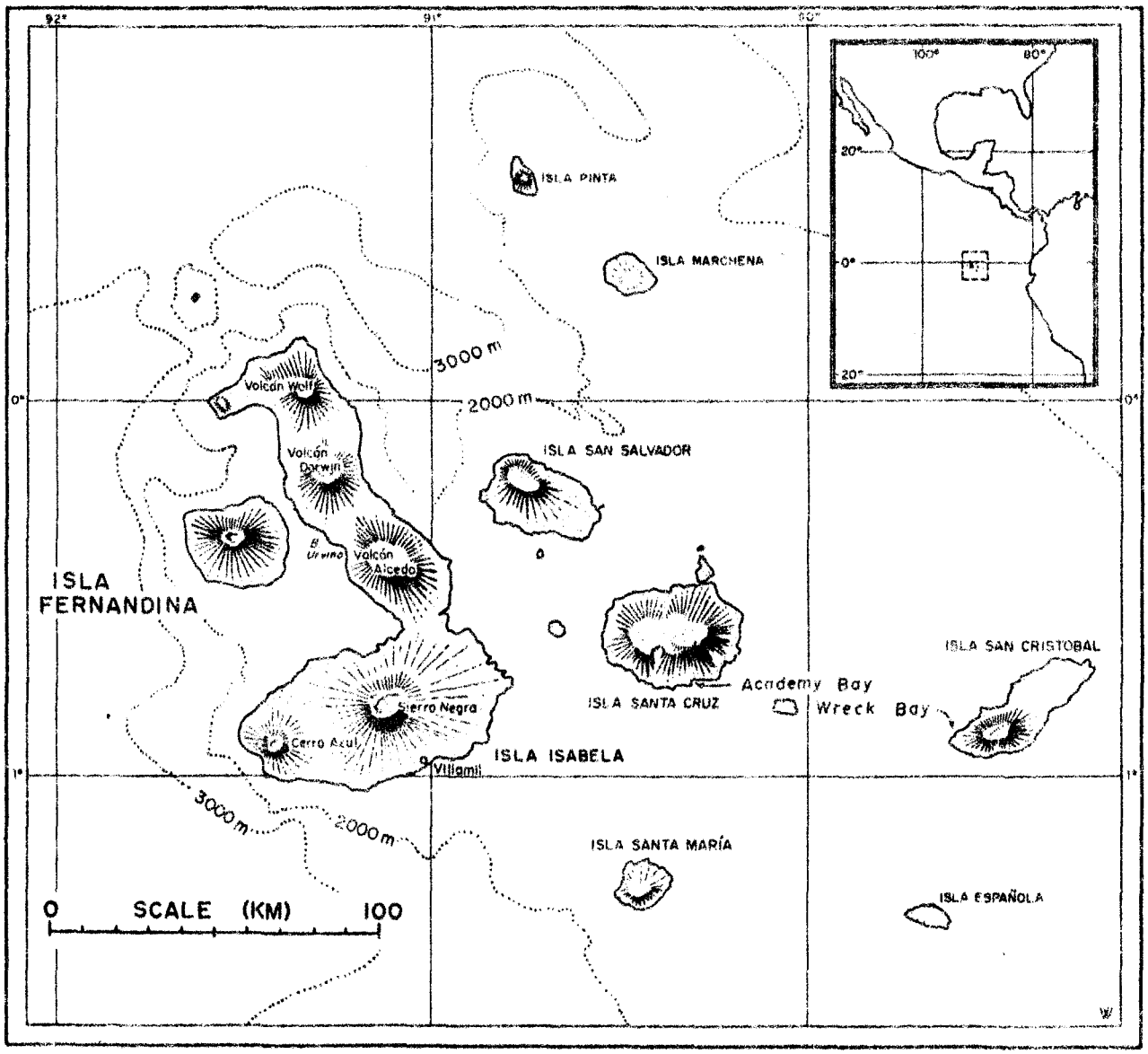

Figure 1. Location map of Galapagos archipelago adapted from American Geographic Society map. Two smaller islands roughly 200 km north of Fernandina are not shown.

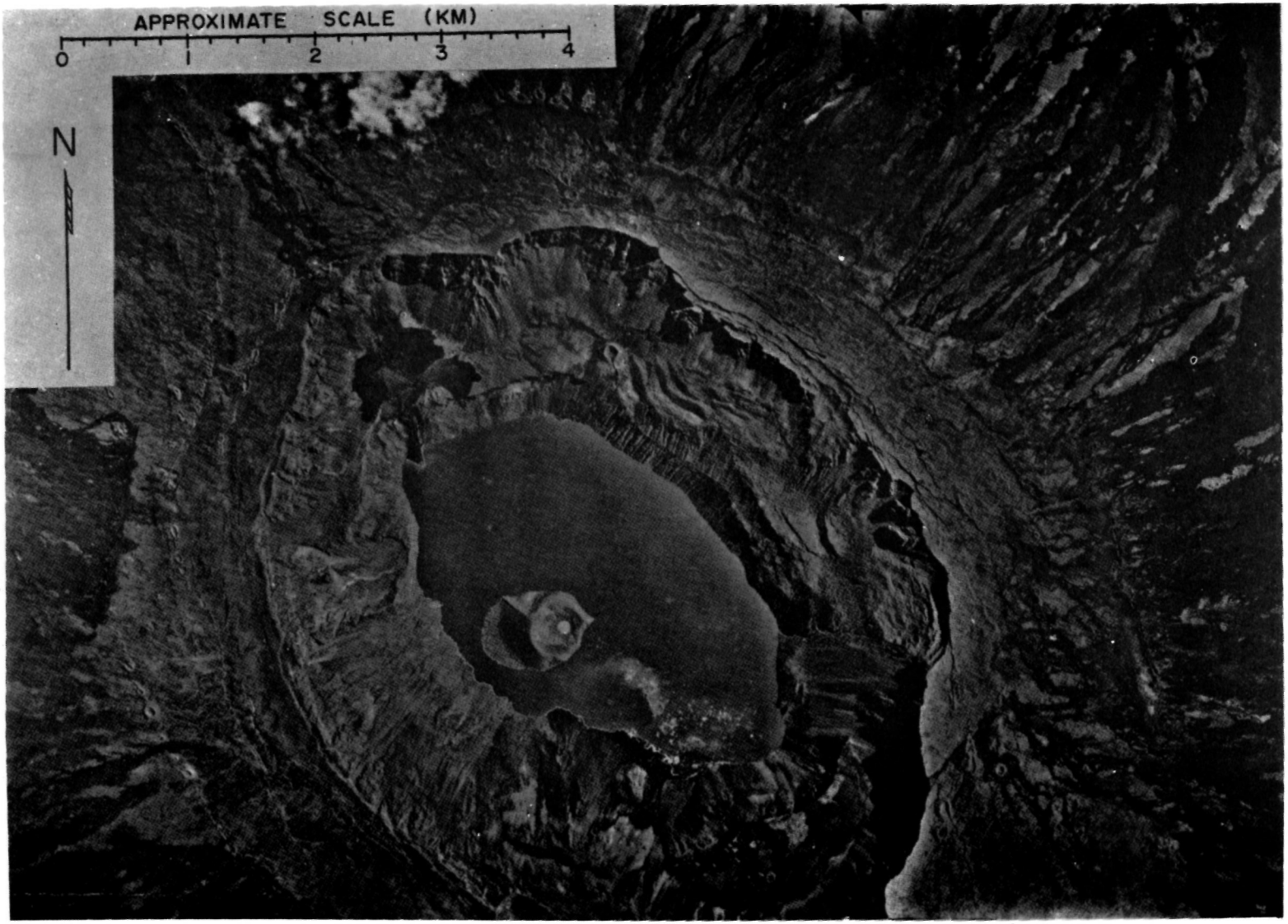

Figure 2. Air photo mosaic of Fernandina caldera before 1968 collapse. Photographs taken by U.S. Air Force in May, 1947.

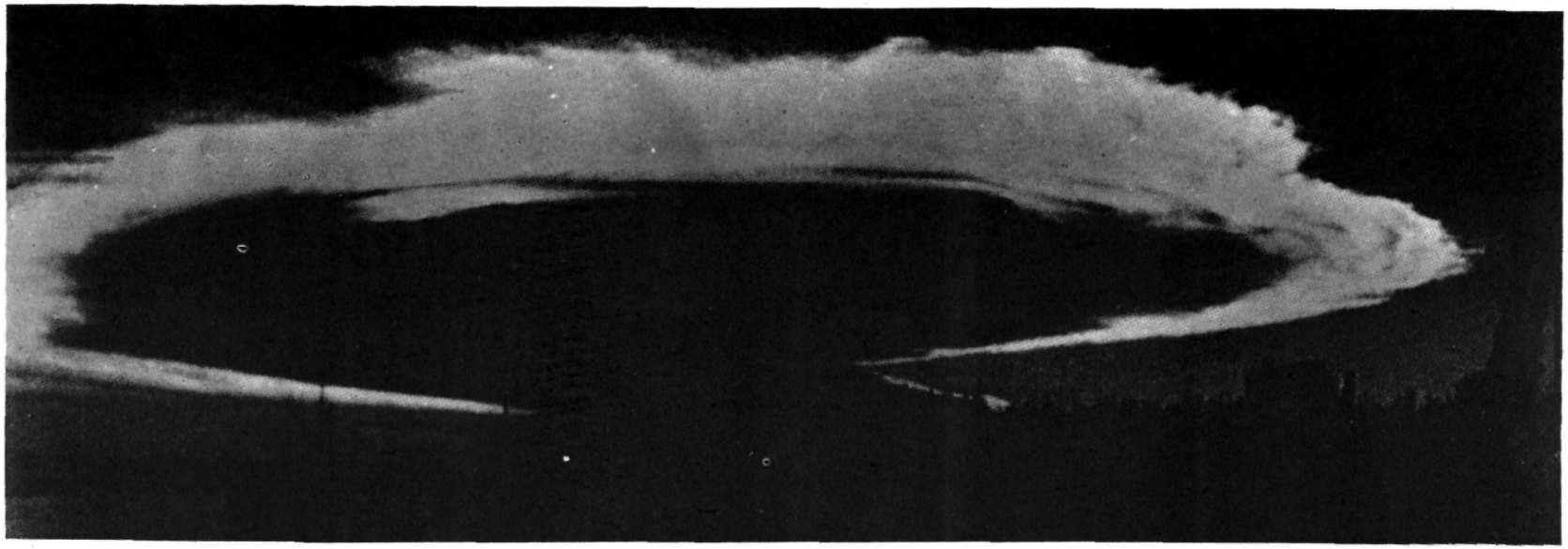

Figure 3. Volcanic cloud from Academy Bay backlighted by late afternoon sun at approximately 1710 on June 11, 1968. Diameter of cloud is estimated to be 175 km at the time of this photograph. Cloud was shown by TIROS satellite at 1630 to be circular, 50 km in diameter, and centered over Fernandina. Photo by Miss Jan Harte.

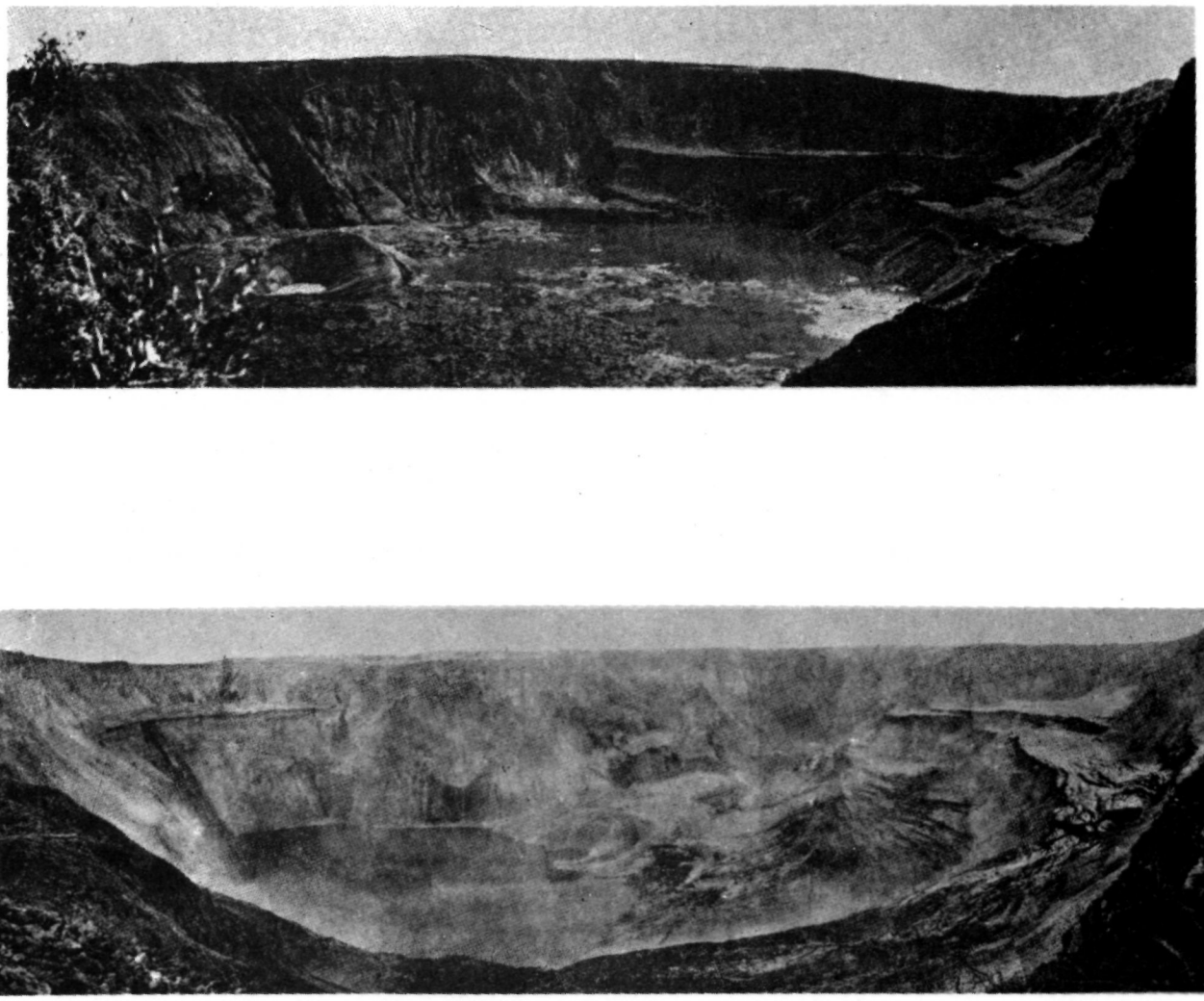

Figure 4. Upper panorama was taken prior to 1968 collapse (by P. Colinvaux in August, 1966) and the lower one shortly after the collapse (by T. Simkin on July 12, 1968). Both are from the east rim of Fernandina Caldera, but Colinvaux's position was slightly south of Simkin's. The scale of both panorama is nearly identical.

NOTE: Printer unfortunately reduced lower photo by approximately 1/3 and scales are no longer equal

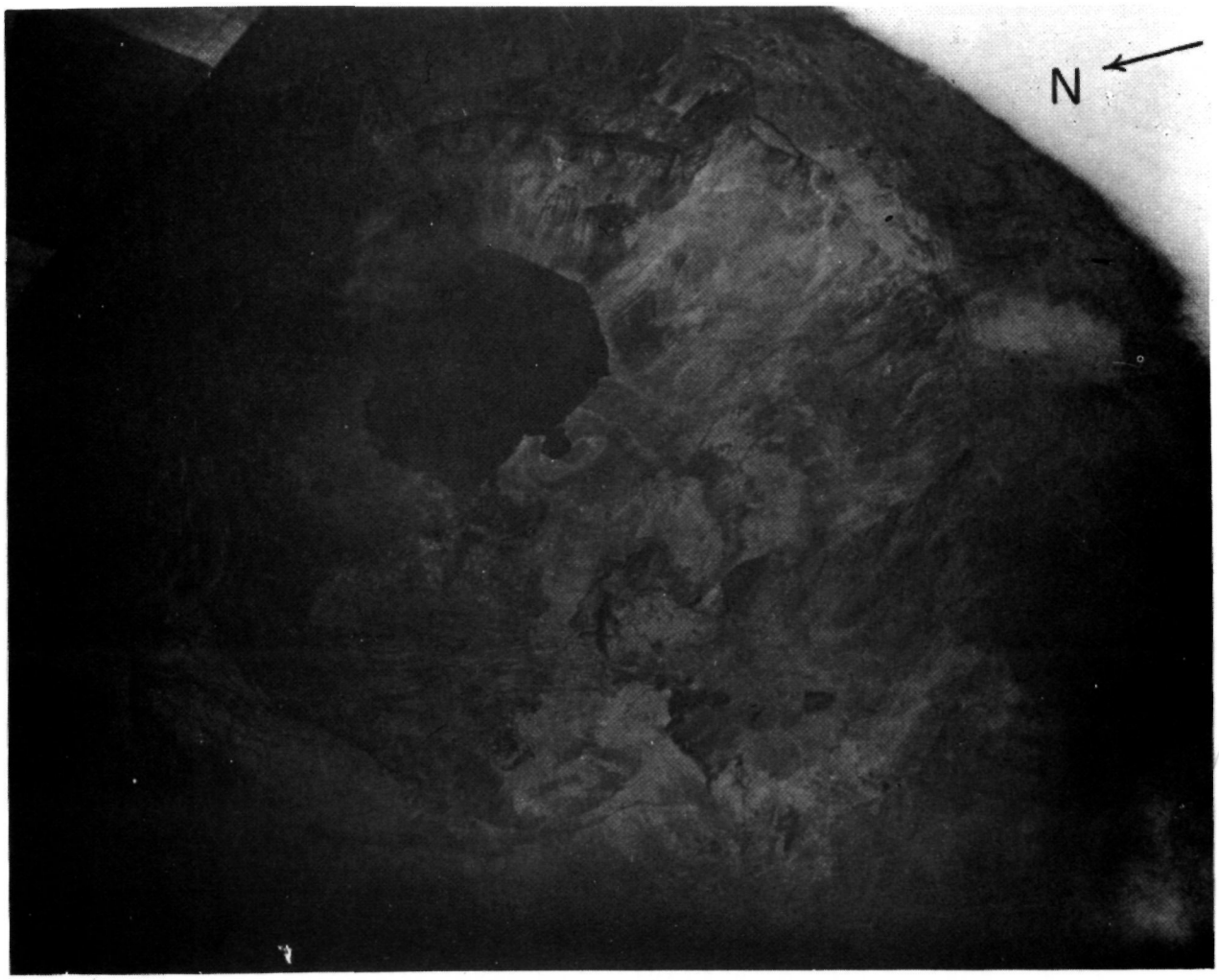

Figure 5. Air photo of Fernandina summit taken July 4, 1968. Small collapse block in right foreground is the site of a new crater and numerous fumaroles. Photo by G. Pierson, USAF.

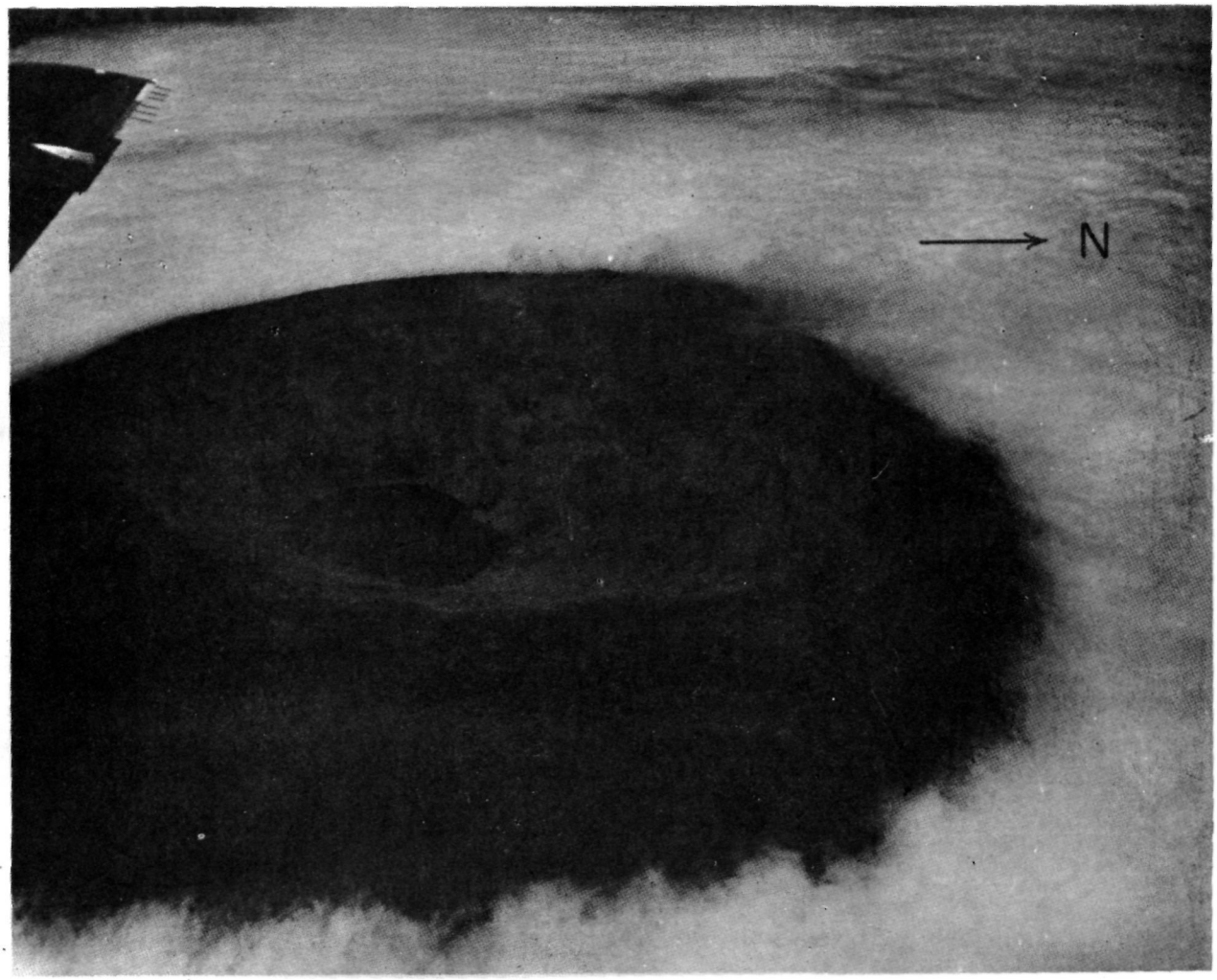

Figure 6. Air photo also taken by G. Pierson on July 4, 1968. Note rock avalanche on far side (southwest) of caldera and dust moving out to the northwest.

Figure 7. Rock avalanches on the northwest wall of the caldera at 1700, July 11, 1968. Photo by T. Simkin.

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ESTUDIOS CIENTIFICOS EN LAS ISLAS GALAPAGOS

A partir de su iniciación en diciembre de 1959, la Fundación Charles Darwin para las Islas Galápagos ha dado apoyo e impulso a los estudios científicos en el Archipiélago de Colón. La Estación Biológica Charles Darwin, construida y administrada por la Fundación y oficialmente inaugurada el 21 de enero de 1964, provée actualmente en Santa Cruz un centro para investigaciones a científicos de diversas nacionalidades. A lo largo de los años los científicos del Ecuador, Bélgica, Canada, Finlandia, Francia, Alemania Occidental, Gran Bretaña, Holanda, Japón, Suecia, Suiza y Los Estados Unidos, han recibido la hospitalidad y asistencia del personal residente en la Estación.

Los estudios científicos han sido conducidos dentro de una gran diversidad de campos; campos que incluyen tanto el aspecto físico como el medio ambiente biológico, contribuyendo cada uno de ellos al progreso en nuestro conocimiento de la estructura y origen de estas islas y de su notable flora y fauna. Los resultados de tan originales investigaciones científicas en el Archipiélago, forman una serie numerada de contribuciones de la Fundación Charles Darwin. Por supuesto, éstas no están restringidas a un órgano en particular, en cuyo caso son inevitablemente publicadas en la lengua particular del científico concernido en el trabajo. Para los primeros días de 1968, unas 70 de estas Contribuciones han sido publicadas y la siguiente es una revisión de los principales estudios científicos y de los resultados que ellos describen.

A continuación del autor o autores se da el título de los trabajos en el idioma en el cual fue publicado; el nombre de la publicación con el número de la página; el año de la publicación; y, el número de la Contribución (FCD No.) de la Fundación Charles Darwin.

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Es editada otra serie de Informes Científicos y de Conservación por la Estación Biológica Charles Darwin y distribuida a través de la Dirección General de Bosques. Por el mes de diciembre de 1968 quince habián sido editados.

FUNDACION CHARLES DARWIN PARA LAS ISLAS GALAPAGOS

CHARLES DARWIN FOUNDATION FOR THE GALAPAGOS ISLANDS

FONDATION CHARLES DARWIN POUR LES GALAPAGOS

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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.