Galapagos Archipelago

Though a main reason for a holiday in the Galapagos Islands is the unique opportunity to see the wildlife at close hand, there is much to interest geologists, for the islands are among the world's most active volcanic areas. Of the many recent eruptions, the latest was in the Sierra Negra caldera on Isabella Island in October 2005. Moreover, the location in the trade winds and in an area of major oceanic current mixing has lead to a climate with moist highlands but arid lowlands. Erosion is slow in the latter, and the lavas, tephras and volcanic structures are all well preserved (Fig. 1).

The Galapagos lie on the equator, about 1000 km west of Ecuador, as an archipelago of thirteen large islands and six smaller islands together with many small islets, all formed by basaltic volcanism. Each island appears to be a single volcano except Isabella, which consists of an arcuate chain formed by merging of six volcanoes. The archipelago stands on the Nazca plate, just south of the Galapagos spreading centre that separates the Cocos and Nazca plates, and the islands rise from a broad shallow platform near the crest of the East Pacific Rise.

The archipelago is thought to have originated by passage of the Nazca plate, ESE over a hotspot known as the Galapagos mantle plume. Thus, the oldest island, Espanola, which is volcanically extinct, lies to SSE and beyond that is a chain of seamounts, forming the Carnegie Ridge, extending towards South America. A second seamount chain, the Cocos Ridge, extends NE from the Galapagos spreading centre on the Cocos plate and was produced about 5M years ago, when the spreading centre was situated over the mantle plume. Since then the spreading centre has migrated northwards leaving the plume beneath the Nazca plate. The youngest islands and most volcanically active are Isabella and Fernandina in the NW of the archipelago, which now lie directly above the hotspot. The islands do not form a single or dual line of volcanoes, but (as noted by Darwin, 1860) are oriented in two alignments ENE and NNW. These appear to have no relationship either to absolute plate motion (easterly), or to plate divergence (southerly). Their orientation has been ascribed to subjacent lithospheric fractures (McBirney & Williams, 1969).

Volcanism

Galapagos volcanoes are basaltic shield volcanoes, and two different morphologies are seen. In the east, smaller volcanoes with gentler slopes are akin to those of Hawaii occur and likened to upturned saucers. In the west the shields are unusual in having gentle lower slopes that steepen above to slopes of ~30º, before flattening at the summit, to create the profile of an upturned soup bowl (Fig. 2).

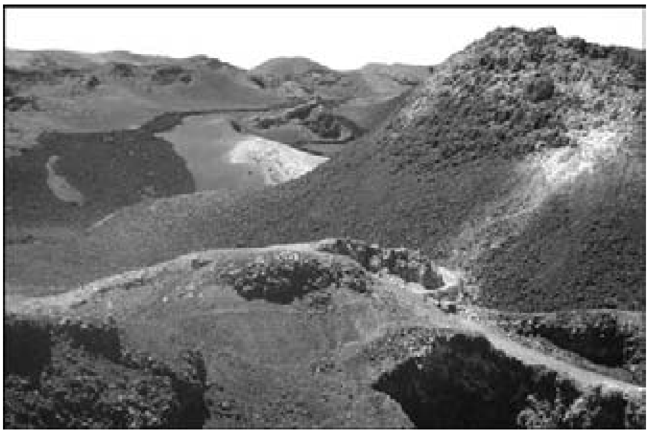

***Figure 1**. A dark flow of fresh lava amid a landscape dominated by parasitic volcanic cones of tephra and spatter on Isabella Island.*

The cause of this non-uniform profile may be the presence of intrusive sills, ring dykes or cone sheets that support the steeper flanks at high levels. Alternatively, the profile may be created by an abundance of vents along concentric fissures that are circumferential to the flat summits, while fewer radial fissures are the only vent sites on the lower flanks and aprons. An arresting feature of the Fernandina volcano is the swarm of arcuate fissures around the caldera, and no other volcano in the world shows this feature so vividly (McBirney & Williams, 1969).

The contrast in volcano profiles may relate to differences in lithospheric strength and thickness beneath the western and eastern islands, as a fracture zone at 91ºW separates oceanic lithosphere of different ages. West of the fracture zone, the lithosphere is older, colder and thicker, better able to support the load of a large volcano than younger lithosphere to the east (White, 1997).

The western volcanoes are characterised by large deep summit calderas due to collapse of the subjacent magma chamber. That on Sierra Negra is about 10 km in maximum diameter. The collapse of a caldera appears to be episodic, and a partial collapse on Fernandina in 1968, when the floor dropped by over 300m, is recorded by McBirney and Williams (1969).

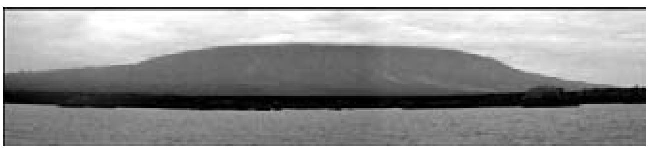

***Figure 2**. The shield volcano on Fernandina Island, with the inverted-soup-bowl profile characteristic of the western volcanoes. Local cloud cover is due to temperature inversion that creates the garua mist at high levels.*

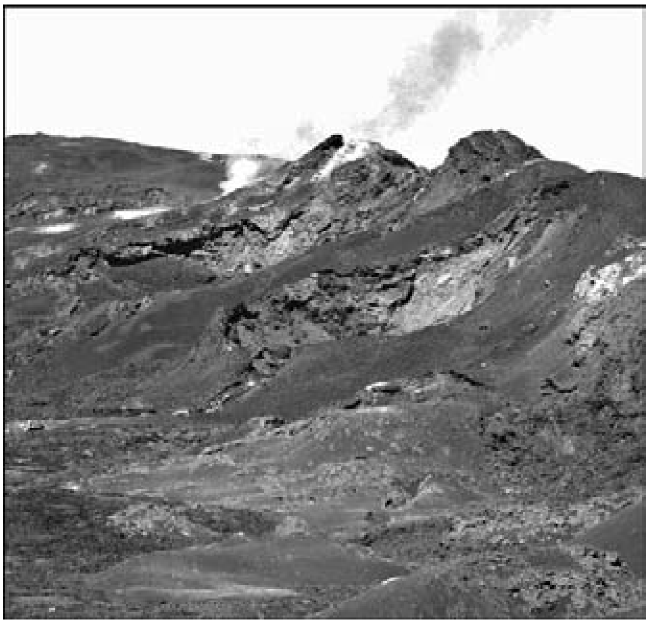

Figure 3. Active fumaroles on the caldera rim of Sierra Negra. (Photo: Ron James)

Sierra Negra, Isabella Island

This volcano erupted for several days in October 2005, producing lava flows into the caldera and also down the northeast slopes. On our visit, about one month later, the lava flows had ceased but fumaroles on the caldera rim were still active (Fig. 3) and vegetation on the caldera floor had been burnt off. Fresh lava flows covered the northeast sector of the caldera floor, and some appeared to have originated at vents along circumference fissures near the caldera rim (Fig. 4). Myriads of fine filaments of fragile golden Pele's hair were scattered over the surrounding landscape downwind of these recently active vents.

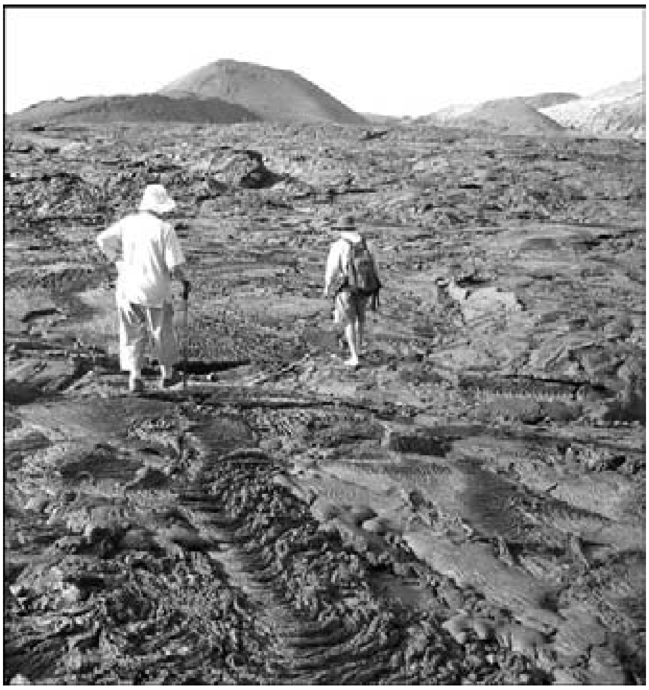

Figure 5. Lava flows and tephra cones at Sullivan Bay.

Sullivan Bay, Santiago Island

The southeast end of Santiago Island is a barren waste of black lavas, dotted with spatter and driblet cones. Two large buff-coloured palagonite tuff cones dominate the landscape at the bay (Fig. 5) and have arisen from phreato-magmatic eruptions of basaltic lava through water-saturated rocks (McBirney & Williams, 1969). The lava flows are generally smooth, either flat or gently undulating, and including spectacular examples of pahoehoe (Fig. 6).

Flank eruptions were recorded here in 1897, and were pre-dated by active lavas recorded by FitzRoy, predate these. Yet a striking feature is that the delicate surface features of the lavas are still preserved and appear to have undergone little erosion.

Figure 4. The Sierra Negra caldera with recent lava flows down its wall and across its floor. (Photo: Ron James)

Darwin (1860) was struck by the numerous tuff cones on the Islands, and San Cristobal reminded him of the Midlands: *one night I slept on shore on part of the island where black truncated cones were extraordinarily numerous: from one small eminence I counted sixty of them, all surmounted by craters more or less perfect. The greater number consisted merely of a ring of red scoriae or slags cemented together and their height above the plain of lava was not more than from fifty to one hundred feet: none had been very lately active. The entire surface of this part of the island seems to have been permeated, like a sieve, by the subterranean vapours: here and there the lava whilst soft has been blown into great bubbles; and in other parts, the tops of caverns similarly formed have fallen in leaving circular pits with steep sides. From the regular form of the many craters, they gave to the country an artificial appearance, which vividly reminded of those parts of Staffordshire where the great iron foundries are most numerou*s.

***Figure 6**. Intestinal pahoehoe basalt at Sullivan Bay.*

Climate

The islands are isolated and surrounded by hundreds of kilometres of open ocean, and the climate is largely determined by the ocean currents and the trade winds. The islands' climate is therefore surprisingly comfortable, as Darwin commented: *Considering that these islands are placed directly under the equator, the climate is far from being excessively hot; this seems chiefly caused by the singularly low temperature of the surrounding water, brought here by the great southern Polar current.*

In fact the Galapagos are situated at a meeting point of several major ocean currents: the Humboldt Current sweeping north from the Antarctic, the warm Panama Current from the north and the cold equatorial counter-current. The intensities of the currents vary cyclically as the trade winds that blow them weaken and strengthen, giving rise to two distinct seasons. For most of the year the islands are cooled by the Humbold Current, which is energised by the Southeast Trades. On reaching the Galapagos platform the cold waters of the deep current surface to cool the overlying air immediately above, and thus produce a temperature inversion in the atmospheric column. The column contains much evaporated moisture, and when the inverted layer is intercepted by the high volcanic mountains it is condensed as a high level mist known as the *garua*. The cool season lasts from May to December, producing moist damp highlands but arid dry lowlands and low lying islands. Erosion of volcanic tephra at these low levels is reduced and surface features of great age persist in apparently fresh forms.

References

Darwin, C., 1860. *Journal of Researches into the Geology and Natural History of the Various Countries visited by H.M.S. Beagle under the Command of Captain FitzRoy, R.N., 1832-36*. Third Edition. Reprinted 2004 as: "The Voyage of H.M.S. Beagle". Folio Society: London.

McBirney, A.R. & Williams, H., 1969. Geology and petrology of the Galapagos Islands. *Geol. Soc. America Memoir* 118.

White, W.M., 1997. A brief introduction to the geology of the Galapagos.http://www.geo.cornell.edu/geology/GalapagosWWW/GalapagosGeology.html

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