F. MACHADO

Mechanism of Fogo volcano Cape Verde Islands

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MECHANISM OF FOGO VOLCANO, CAPE VERDE ISLANDS

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SYNOPSIS

A brief description of this active volcano is presented. The mountain is a large cone with a summit caldera and many parasitic vents. The lavas are highly undersaturated nephelinic rocks and were spread over a basement of metamorphic limestone. Absence of significant differentiation in the lavas, and response of the activity to long-period Earth tides are two remarkable characteristics of the volcano. A shallow magma chamber is suspected, probably analogous to the underground cauldron subsidence of some ancient Scottish volcanoes.

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MECANISMO DO VULCÃO DA ILHA DO FOGO (CABO VERDE)

RESUMO

Apresenta-se uma breve descrição do vulcão da ilha do Fogo (Cabo Verde), o qual é constituído por um enorme cone com uma caldeira central e muitas chaminés adventícias. As lavas são rochas ultrabásicas, ricas de nefelina, e cobriram um soco de calcário metamórfico. A ausência quase total de diferenciação e o *contrôle* pela maré terrestre (de longo período) são duas importantes características deste vulcão activo. Admite-se que possa existir uma câmara magmática pouco profunda, análoga aos afundimentos subterrâneos de alguns antigos vulcões da Escócia.

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MÉCANISME DU VOLCAN DE L'ILE DE FOGO (CAP-VERT)

RÉSUMÉ

On présente une description sommaire du volcan de l'île de Fogo (Cap-Vert). Le grand cône volcanique a une caldeira centrale et de nombreuses cheminées adventives. Les laves néphéliniques, très pauvres en silice, ont couvert un socle de calcaire métamorphique. L'absence presque totale de différenciation et la réponse de l'activité aux marées terrestres (de longue période) sont deux importantes caractéristiques de ce volcan actif. On soupçonne l'existence d'une chambre magmatique peu profonde, peut-être semblable aux effondrements souterrains des anciens volcans écossais.

Mechanism of Fogo volcano, Cape Verde Islands (*)

F. MACHADO

1. INTRODUCTION

Fogo is the only active volcano among the Cape Verde Islands. It is located, together with the other islands of the group, on the West-African continental slope, at a latitude of about 15° North.

The islands were discovered by the Portuguese sailing ships in the 15th century and the first settlement was established at the end of that same century.

Fogo is a roughly circular volcanic cone with an area of about 180 sq. miles. In the middle, it exhibits a large crescent-shaped caldera, 5 miles in diameter, which has a huge central cone inside. The rim reaches an altitude of 9000 ft, whereas the central cone is 9300 ft high. The bottom of the caldera is at about 5200 ft a. s. l., so that the scarp has a maximum height close to 4000 ft.

The volcano has a composite constitution. The lava flows are of basaltic habit, most of them being silica-poor nephelinitic rocks. The total amount of pyroclastic material is relatively small but some tuff layers may be due to explosive activity at the central vent, and there are a number of parasitic cinder cones.

On the west side of the island there are small exposures of an old basement of metamorphic limestone, possibly of pre-Tertiary age. Prof. Assunção (personal communication), who is studying the Cape Verde rocks, assumes that assimilation of such limestones may have been responsible for the highly undersaturated character of the lavas.

(*) This is a slightly revised copy of the paper presented at the Colloquium on Atlantic Volcanoes, held at the Geological Society of London, on May 19th, 1965.

2. VOLCANIC ACTIVITY IN HISTORICAL TIMES

When the first settlers came to the Island of Fogo, about the year 1500, there was probably some volcanic activity at the central vent, and it seems that the volcano was continuously active until the middle of the 18th century. Usually there were only slight summit explosions of strombolian type, but occasionally some flank eruptions produced lava flows. At night the explosions were luminous, and an old chronicle tells that the volcano acted as a light house for navigation.

This continuous activity ceased abruptly about the year 1760, and since then only the following short flank eruptions (cf. Fig. 1) were recorded:

Several lava flows in 1785;
Small flows in 1799, 1847, 1852, and 1857;
Several flows in 1951.

All these effusive eruptions occurred at parasitic vents opening on the bottom of the caldera, at the base of the central cone. The 1951 eruption lasted for two months (Ribeiro, 1954); the others were still shorter, some having a duration of only one or two weeks.

3. FORMATION OF THE CALDERA

The volume of the central depression of this volcano was estimated at 6 cu. miles. If the depression was produced by some large volcanic explosion, a corresponding amount of loose material would be found on the slopes of the mountain.

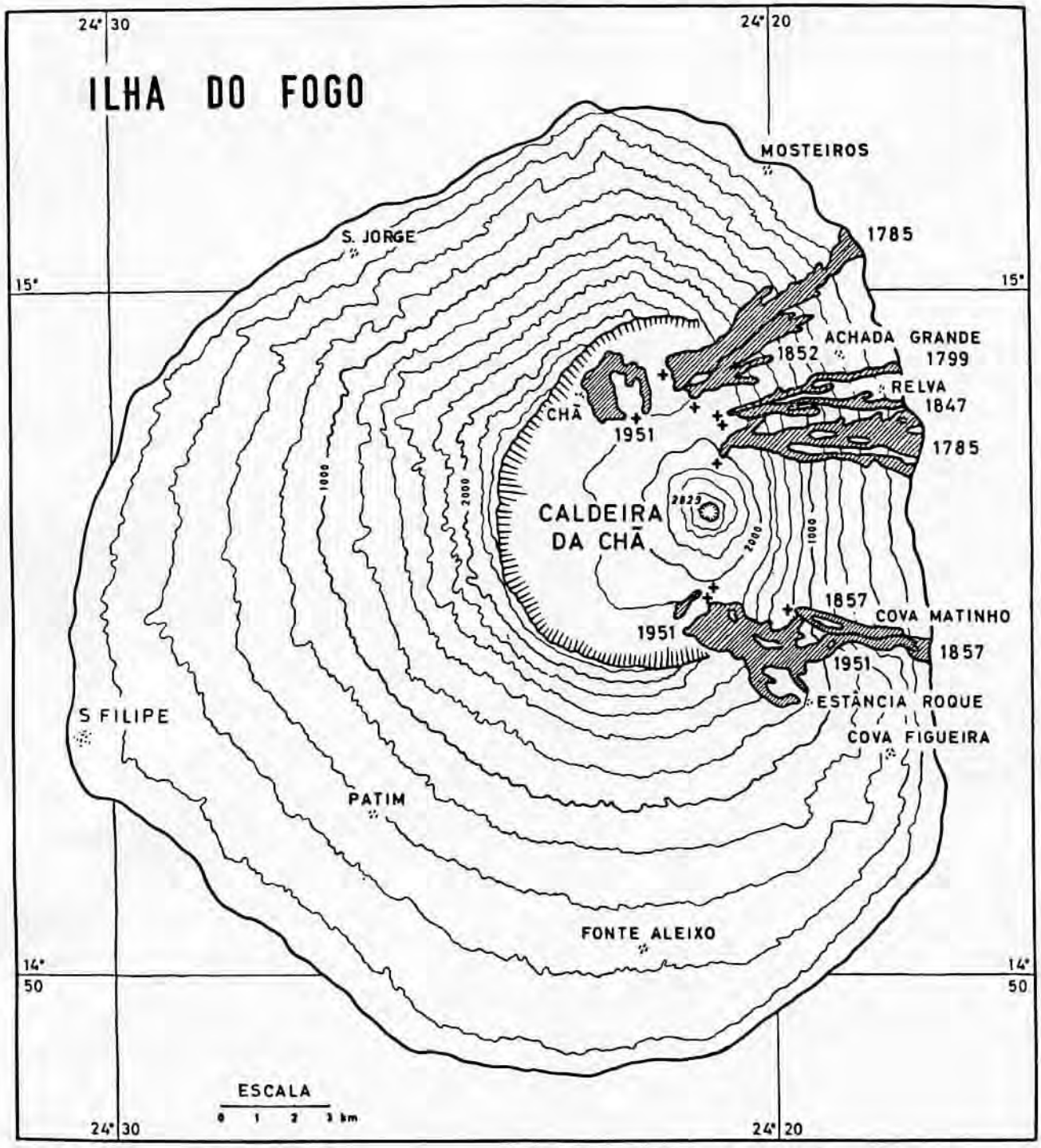

Fig. 1 — Map of Fogo volcano (the shaded areas are recent lava flows)

In fact there is very little loose material; the total volume is considerably below 1 cu. mile. In consequence, we must ascribe the caldera, not to explosion, but to the subsidence of a large cylindrical block into an underlying magma chamber. The caldera scarp represents then a circular fault.

In many calderas the subsidence is preceded by the emission of acid pumice (Williams, 1941). This is not the case of the Fogo volcano where there is no evidence of any explosive drainage of the magma chamber. The subsidence was probably due to a simple isostatic adjustment of the central part of the large cone.

If within a magma chamber there is some layering due to gravitative differentiation, the descent of the base of the central vent will imply a change in the composition of the correspond-

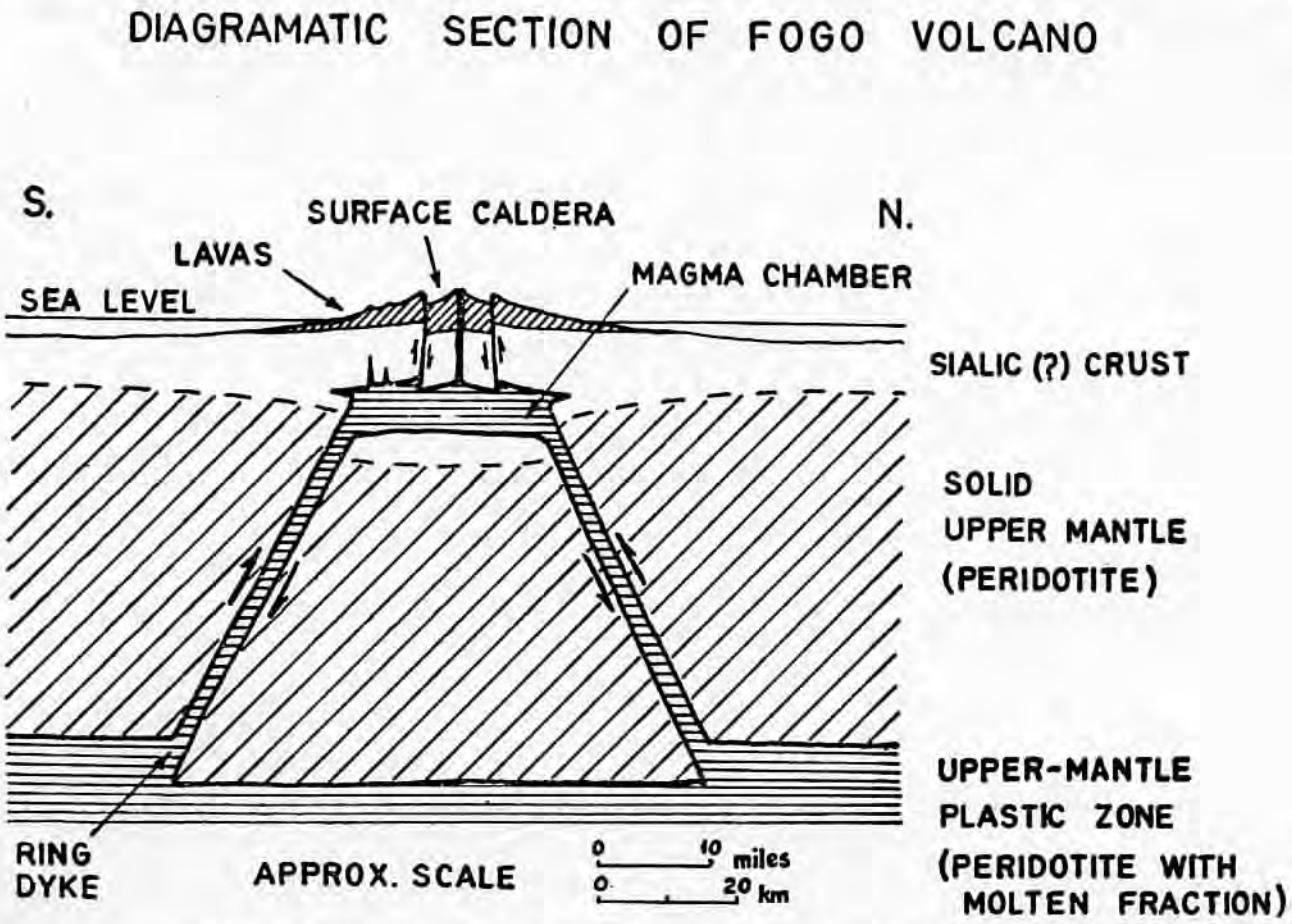

Fig. 2 — Section showing the hypothetical formation of the caldera and of the magma chamber

ing lavas. Here again Fogo is an exception; the old lavas have been classified as nephelinites, and those of the eruptions after the formation of the caldera are limburgites (Assunção, 1954). But the chemical composition is practically the same, the only difference being the presence of crystallized nepheline in the former lavas, whereas in the latter this mineral is included in the glassy base.

In fact, there is some occasional differentiation, and the lavas constitute, according to the German terminology, a «strong» Atlantic series with the following types:

Nephelinites,
Tephrites,
Phonolites.

The more acid types are, however, extremely rare; they probably represent only some very localized differentiation.

4. DEPTH OF THE MAGMA CHAMBER

It appears that most volcanoes have relatively shallow magma chambers. In the Azores, where the calderas have diameters of about 1 to 4 miles (Machado, 1959), the depth of the magma chambers is probably not more than 3 miles (Machado, 1954). It seems then that the diameter of the calderas and the depth of the magma chambers have the same order of magnitude.

If this holds for the Cape Verde Islands, it may be expected that the Fogo magma chamber is at a depth of about 5 miles.

5. FEEDING OF THE MAGMA CHAMBER

Additional evidence is provided by the Earth tides. Most of the Fogo eruptions occur at the minima of the Earth tide component with a period of 18.6 years. This points to the presence of some isolated shallow chamber, whose tidal

compression would force the magma upward (Machado, 1965).

On the other hand, the absence of differentiation suggests some almost permanent refeeding of the magma chamber (which, then, would not be isolated).

The two apparently conflicting facts may be reconciled if we assume that these magma chambers are formed by underground cauldron subsidence of the type postulated by Dr. Richey (1935) for some of the Tertiary Scottish volcanoes, and also that these underground reservoirs are fed through ring fractures where penetrates the plastic substratum probably formed of a mush of olivine crystals with an interstitial molten basaltic magma, as suggested by Prof. Wager (1958).

With release of pressure, this mush will exude, at its upper levels, a basaltic magma capable of feeding the volcanic eruptions. In this way, we may have a permanent supply of magma, and, at the same time, the plastic material which fills the ring dyke can resist the relatively rapid impulses of the Earth tide, as if the magma chamber was isolated from the deep plastic zone of the upper mantle.

It is interesting to note that the behaviour of Fogo volcano can be reasonably understood by assuming ring structures on two different scales: — first the large underground cauldron subsidence which formed a shallow magma chamber; and then the surface caldera which sank within that chamber (Fig. 2). The diameter of the caldera is 5 miles, whereas the diameter of the magma chamber, judging from the presence of peripheral vents, is probably 20 miles or more.

Finally, it must be emphasized that the Earth tide acts as a mere trigger-force and that some other direct cause of the eruptions has still to be sought.

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