The 1972 Eruption of Kartala Volcano, Grande Comore

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Abstract

A summit eruption of Kartala commenced on September 8th, 1972 and finished on October 5th, 1972. In the course of this eruption, approximately 5×10^6 m^3 of alkali olivine basalt was erupted from a N-S fissure system within and adjacent to the caldera. Aa flows were partly ponded within the caldera, almost filling the 1918 Choungou Chagnoumeni crater pit, and partly spilled NW down the flanks of the volcano. The lavas are of uniform composition, almost identical to those erupted in 1965 and closely resembling the majority of flows erupted during the last 115 years. One-atmosphere melting experiments support petrographic and chemical evidence that the lavas are cotectic, with coprecipitation of olivine, augite and plagioclase. The lavas were erupted at, or close to, their liquidus temperature, determined at approximately 1170° C. Whereas eruptions of Kartala in the nineteenth century were distributed widely along a fissure system approximately 45 km long by 7 km wide, the eruptions since 1918 have been confined to the vicinity of the summit caldera.

Introduction

This paper presents a brief account of the summit eruption that occurred on Kartala during September and October 1972. The eruption is discussed in the light of other recent investigations of the geology of Grande Comore.

Grande Comore is the westermost and largest (approx. 60 × 20 km) of the four islands comprising the Comores Archipelago at the

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northern end of the Mozambique channel (DE ST. OURS, 1958; ESSON *et al.*, 1968). The island consists of two large basaltic shield volcanoes in a juvenile and undissected state. Of these La Grille volcano, which forms the northern part of the island, is a dormant volcano composed of basanitic to nephelinitic lavas (STRONG, 1972), on which no activity has been recorded during the past 120 years.

Kartala, the larger of the two volcanoes, lies at 11° 45' S and 41° 03' E and attains a height of 2361 m. It is a relatively steep sided shield with a maximum gradient of 24° on its upper slopes. Up to 1900 m altitude it is densely covered with tropical rain-forest while the topmost 400 m are colonised by *Philippia comorensis* scrub. The volcano is surmounted by a large caldera complex (ca. 4 × 3 km) resulting from the intersection and coalescence of several subcircular collapse structures, individually not exceeding 1.5 km across (BATTISTINI, 1967; STRONG and JACQUOT, 1970). Kartala differs morphologically from La Grille in supporting far fewer parasitic ash-cones on its flanks than the latter.

Kartala has erupted alkali olivine basalts in the past which are distinctly less silica-undersaturated than those of La Grille. Some are strongly porphyritic oceanites or ankaramites carrying large phenocrysts of olivine and augite, only rarely accompanied by plagioclase phenocrysts (STRONG, 1972).

Historic Activity

Kartala has erupted frequently since records commenced with the French colonisation of the island some 120 years ago. Eruptions occurred in 1857, 1858, 1859, 1860, 1862, 1872, 1880, 1904 and 1918. Further small eruptions within the confines of the caldera took place in 1948, 1952 and 1965 (DE ST. OURS, 1958; BATTISTINI, 1967).

Whereas the average height of the outer walls of the caldera complex is around 100 m, the lowest portion of the rim is found on the northern side of the caldera at Porte d'Itsandra, a locality where lava overflowed from the caldera onto the flanks in prehistoric times and again in 1860.

Early in the twentieth century a conspicuous pit-crater, Choungou Chahalé, existed in the central part of the caldera. According to LACROIX (1938) this, in 1905, measured some 500 m across and was approximately 100 m deep. In August 1918, following a small eruption

of lava from an 80 m fissure on the north flanks of Kartala at 1980 m altitude, violent explosive activity occurred within the caldera. An expedition some two months later discovered the Choungou Chahalé pit to have been greatly enlarged to its present dimensions of 1300 × 800 m with a maximum depth of 300 m. Furthermore, a new circular collapse pit, Choungou Chagnoumeni, came into existence with the 1918 eruption. This new pit lay some 400 m NW of the lip of Choungou Chahalé, about midway between the latter and an incipient collapse structure some 250 m diameter which lies 300 m south of Porte D'Itsandra. The new (Chagnoumeni) pit also had a diameter of c. 250 m and was vertical sided with a depth of 30 m.

In April 1948 a Strombolian-type eruption was reported from Choungou Chagnoumeni in which blocks were hurled over one hundred metres high. Again, in February 1952, a small Strombolian-type eruption occurred in the Chagnoumeni pit. In a revival of activity in mid-July 1965, a small basaltic flow of aa type was emitted from a short NNE-SSW fissure linking Choungou Chahalé and Choungou Chagnoumeni and a portion of this flow descended into the Chahalé pit-crater.

Kartala remained dormant for a further seven years until the occurrence of the latest summit eruption.

Eruption of 1972

During this eruption, which commenced on the afternoon of September 8th, 1972 and terminated on October 5th, lava was emitted from four fissures within the caldera and possibly from one external to it. All phases of the eruption have been described as Strombolian.

Eruption was vigorous on September 8th and 9th and after a few days of diminished activity, eruption again reached a maximum of intensity during the 13th, 14th and 15th of September. During the initial two days a flow of aa lava was emitted along approximately 600 m of an old fissure zone (F_1) extending N-S from near the Choungou Chagnoumeni crater-pit to Le Porte d'Itsandra. The lava eruption occurred with fountaining along the line of the fissure. Much of the lava erupted during the first days flowed NNW out of the caldera through Le Porte d'Itsandra and extended approx. 2 km down to the 2000 m contour. The thickness of this flow is generally less than 5 m.

A cinder-cone built up near the southern end of the F_1 fissure immediately north of Choungou Chagnoumeni. By September 12th this cone had built up to some 20 m in height (Fig. 1).

F_2, the southernmost eruptive site is a short fissure zone a few metres west of Choungou Chalalé. Between F_2 and Choungou Chalalé a zone of fissuring several metres long developed and was marked by fumarolic activity.

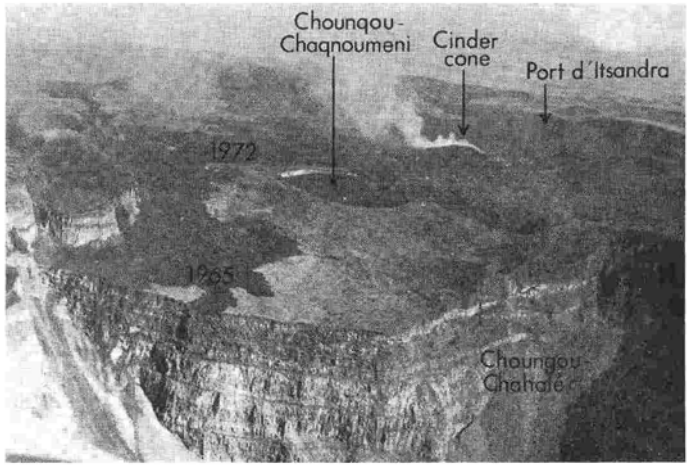

FIG. 1 - Aerial view towards the N.W. across Choungou-Chahalé. The main N.S. fissure zone extends obliquely across the picture from Porte D'Itsandra and can just be discerned on the 1965 lava flow.

F_3 is a short fissure zone lying within the caldera immediately NW of Choungou Chagnoumeni and was the site of a small cinder-cone which grew on September 8th and 9th.

F_4 was an active fissure to the S of F_3 and represents an extrapolation of the same plane of weakness. Some of the lava erupting from F_4 coalesced with that issuing from F_1. Some partially overran the 1965 lavas and some spilled ESE into the Choungou Chahalé pit. Sulphur deposits developed around fumaroles along F_4.

From the 9th to the 13th activity became confined to the scoria cone growing at the southern end of F_1, with small quantities of the lava cascading into the Choungou Chagnoumeni pit. During September 13th-15th, in a resurgence of activity, explosions within the caldera more violent than those accompanying the first two days of the eruption, could be heard in the town of Moroni. Blocky lava flowed north-

westward from the vicinity of Porte D'Itsandra partly overrunning the lava of September 8th-9th, attaining a length of between 4 and 5 km, to terminate at an altitude of approximately 1500 m. This flow was initially reported to have been emitted from a short fissure, F_5 (Fig. 2), external to the caldera. However, it is possible that it was merely

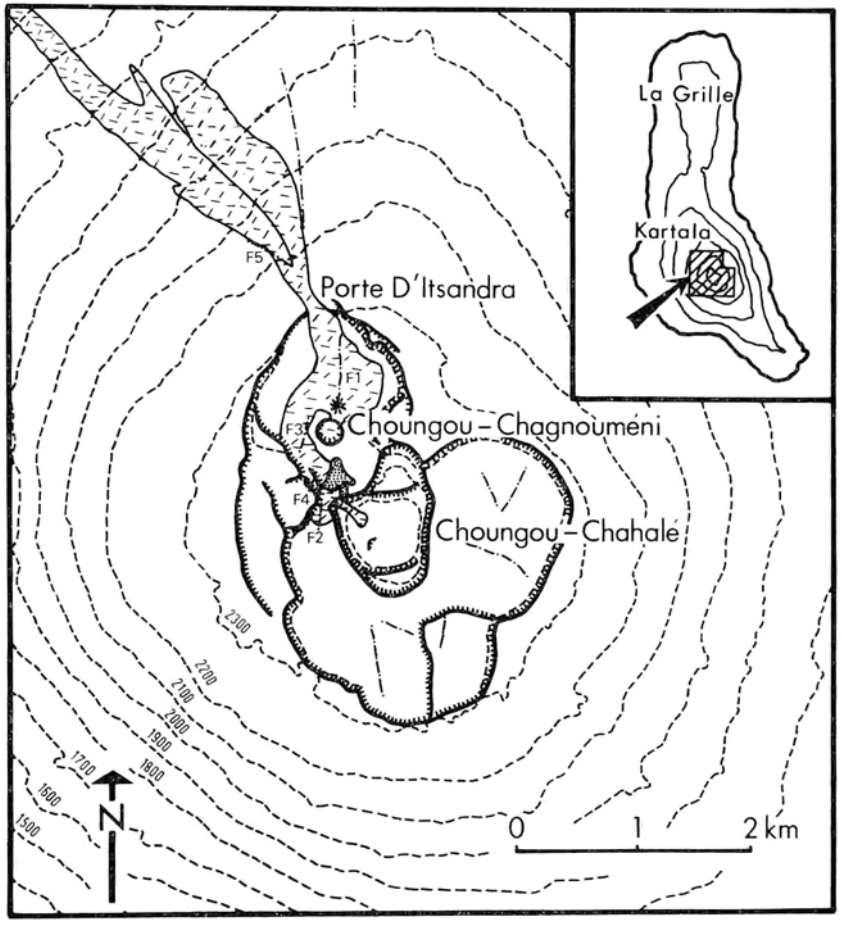

FIG. 2 - Map of the caldera showing extent of the 1965 lavas (stippled) and 1972 (dash ornament). Contours in metres.

fed from a lava-tunnel within the earlier flow unit. The thickness of this flow at its front ranges from 1-8 m; an eye-witness described it as advancing at the speed of a bull-dozer. Bush-fires were initiated in the vicinity of this flow.

After September 15th lava continued to erupt from F_1, particularly from the main cinder-cone which ultimately grew to some 40 m in height. A small lava-lake was maintained in the crater of this cone throughout the eruption, from which intermittent fountaining took place. Lava from the cone flowed southwards into Choungou Chagnoumeni, largely filling it in the process. The pit is now filled to within 5-7 m of the rim on its southern side. The viscous, highly scoriaceous lava within it does not form a lava-lake with a horizontal surface but inclines northwards towards the cone from which it was supplied.

The 1972 lavas consist of rough, scoriaceous and a slabby-surfaced aa. The new flows cover an area of approximately 2.5 km^2. Assuming an average thickness of c. 2 m this represents an extrusion of some 5×10^6 m^3 of lava (compared to c. 0.15×10^6 m^3 in 1965).

A thin veneer of basaltic tephra was observed over much of the caldera and the uppermost flanks of the volcano. In places, this was only distinguishable with difficulty from earlier tephra (from the 1965 event?) on which the beginnings of lichen growth were sometimes apparent.

Products of the 1972 and 1965 Eruptions

Examination of lava and tephra samples erupted in 1972 indicates essential homogeneity of the eruption products. Two samples, representative of (a) lava erupted from F_1 and (b) new tephra within the caldera were selected for analysis.

72-GC-24 is a sample from the surface of a slaggy-topped aa flow, some 250 m SW of Choungou Chagnoumeni. It is highly vesicular basalt, seen in thin-section to consist of microlites, less than 0.5 mm long, of olivine, augite and plagioclase, in a pale brown and almost opaque glassy matrix. The crystals are inferred to have grown during quenching and no indication of intratelluric phenocrysts was recorded. Reconnaissance probe-analysis of the minerals shows molecular compositions of (a) olivine, Fo_{76} (b) augite, $Ca_{48}\,Mg_{38}\,Fe_{14}$ and (c) plagioclase An_{80}.

72-GC-22 was sampled from tephra within the caldera on the lip of an escarpment 750 m WSW of Choungou Chagnoumeni where it formed a thin coating a few centimetres deep over older materials. It consists of frothy irregular particles 3 cm across. In thin-section it is seen to consist of a pale brown glass containing quench microlites

TABLE 1 - Chemical analyses of basalts erupted in 1972 and 1965.

	1	2	3	4
SiO_2	47.29	47.28	47.38	47.96
TiO_2	2.76	2.84	2.73	2.52
Al_2O_3	14.78	14.76	14.56	14.37
Fe_2O_3	2.16	2.34	1.75	2.22
FeO	10.31	9.92	10.36	9.66
MnO	0.192	0.187	0.182	0.18
MgO	5.93	5.84	6.18	6.33
CaO	11.62	11.63	11.77	12.00
Na_2O	3.22	3.26	3.22	3.05
K_2O	1.26	1.28	1.26	1.30
P_2O_5	0.40	0.39	0.39	0.45
H_2O	0.10	0.38	0.11	0.25
CO_2	0.20	0.20	0.20	—
TOTAL	99.92	99.89	100.11	100.70
		C.I.P.W. NORMS		
or	7.45	7.58	7.46	7.68
ab	18.86	19.17	18.01	19.45
an	22.17	21.91	21.59	21.66
ne	4.55	4.60	5.03	3.43
di	27.10	27.43	28.30	28.62
ol	10.55	9.57	10.94	10.09
mt	3.13	3.40	2.54	3.22
il	5.24	5.41	5.19	4.78
ap	0.95	0.93	0.93	1.06
		TRACE ELEMENTS		
Ba	450	450	470	422
Zr	165	200	150	198
Y	35	30	35	—
Sr	490	485	510	475
Rb	35	35	35	33
Zn	105	125	105	106
V	280	280	260	—
Ni	82	63	71	—

1. 72-GC-22 Basaltic scoria 1972.
2. 72-GC-24 Basalt lava 1972.
3. 72-GC-23 Basalt lava 1965.
4. GC-123 Basalt lava 1965.

Data for column 4 from D. F. STRONG, 1971. Major element analyses for 1, 2 and 3 by M. Saunders. Trace-element analyses for 1, 2 and by G. R. Angell.

of olivine augite and plagioclase. Probe data indicate compositions as follows: (a) olivine, Fo_{71}, (b) augite, $Ca_{46}\,Mg_{40}\,Fe_{13}$ and (c) plagioclase An_{83}.

A new sample (72-GC-23) was collected from the surface of the small 1965 aa flow, erupted a long a southerly continuation of the F_1 fissure, between the Choungou Chahalé and Choungou Chagnoumeni crater-pits. This too is a highly vesicular rock composed of abundant quench-crystals of olivine, augite and plagioclase in a finely-granular matrix opaque with Fe-Ti oxide grains. This 1965 lava however does contain some sparse micro-phenocrysts of olivine and augite (c. 1.0 mm). Compositions of the groundmass minerals obtained on the microprobe were Fo_{76}, $Ca_{47}\,Mg_{42}\,Fe_{11}$ and An_{82}. A new analysis of the rock, together with an analysis from the same flow presented by STRONG (1972), is given in Table 1.

The compositions of the 1965 and 1972 products are almost identical. However, the observation of sparse microphenocrysts of augite and olivine in the 1965 lava, suggests that the slightly higher values for MgO in the 1965 lava analyses may reflect a small but real difference between the magmatic compositions.

STRONG (1972 noted that the most magnesian aphyric lava on Kartala contained approximately 7 % MgO and proposed that the more picritic Kartala lavas were due to accumulation of augite and olivine. More differentiated lavas containing less than 6 % MgO are seemingly scarce on Kartala and none are known with less than 5 %. The lavas erupted in 1972 may perhaps represent residual liquid retained within Kartala after the 1965 event, which has undergone a very slight further fractionation during the intervening seven years.

Melting Studies at 1 Atmosphere

Experiments were conducted on the three analysed samples from the 1972 and 1965 eruptions, using Ag/Pd and Mo capsules (Table 2).

The majority of experimental runs were made at the fO_2 of the Ni-NiO equilibrium (N) and the remainder at the Fe-FeO equilibrium (W). The results, taken in conjunction with the chemical and petrographic data suggest:

(a) that in both eruptions, magmas were extruded at (1965), or slightly above (1972), their liquidus temperatures and that the latter were close to 1170° C. Since the fO_2 at the Ni-NiO equilibrium at 1200° C

TABLE 2.

Temp. °C	*Time (hrs)*	*Buffer*	*Capsule*	*Result*
(a)	*72-GC-22*			
1208	17	N	$Ag_{40}Pd_{60}$	All glass
1176	16	N	$Ag_{40}Pd_{60}$	All glass
1163	17	N	$Ag_{40}Pd_{60}$	Estimated 70-80 % glass. Plag. augite and (?) olivine.
1151	21	W	Mo	Estimated 70-80 % glass. Plag. olivine and (?) augite.
1066	17	N	$Ag_{70}Pd_{30}$	Plag. augite and olivine. Estimated 20 % of finely crystalline quench products.
(b)	*72-GC-23*			
1208	17	N	$Ag_{40}Pd_{60}$	All glass
1176	16	N	$Ag_{40}Pd_{60}$	All glass
1163	17	N	$Ag_{40}Pd_{60}$	Estimated 80-90 % glass. Plag. olivine and augite.
1151	21	W	Mo	Estimated 80 % glass. Relatively abundant olivine, lesser plag. and augite.
1066	17	N	$Ag_{70}Pd_{30}$	Plag. augite and olivine. Estimated 20-30 % of fine granular quench crystals.
(c)	*72-GC-24*			
1200	17.25	N	$Ag_{40}Pd_{60}$	All glass
1176	16	N	$Ag_{40}Pd_{60}$	All glass
1163	17	N	$Ag_{40}Pd_{60}$	Estimated 70-80 % glass. Plag. cpx and (?) olivine.
1142	4	W	Mo	Estimated 50 % glass. Plag. augite and olivine.
1123	16	W	Mo	
1066	17	N	$Ag_{70}Pd_{30}$	Plag. augite and olivine. Estimated 30-40 % of fine granular quench crystals.

is $10^{-7.17}$ (HUEBNER, 1971), while the corresponding value for Fe-FeO is 10^{-12}, Ni-NiO is likely to offer a closer reflection of the fO_2 actually obtaining in the Kartala magmas, in view of the fO_2 determinations made on natural basalts by FUDALI (1965) and SATO and WRIGHT (1966).

(b) that the magmas represent near-cotectic compositions at which clinopyroxene, plagiocase and olivine coexist with liquid at, or close to, the atmospheric liquidus.

STRONG's (1972) data indicate that such cotectic characteristics were probably acquired as a consequence of extended augite-olivine fractionation at relatively low pressures (< 10 kb) and that these compositions lie at the low-Mg terminations of olivine-augite « control-lines ».

Discussion of Historic Activity on Kartala

The historic eruptions of this volcano are distributed along a zone of rifting 6-8 km broad, extending NNW-SSE across the island for

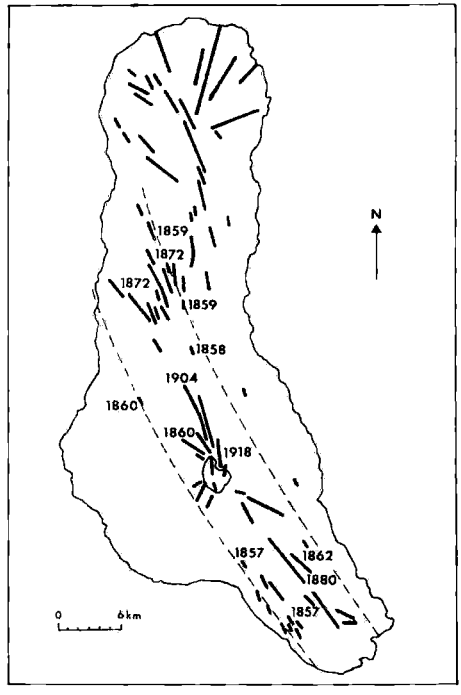

FIG. 3 - Sketch map of fissure systems on Grande Comore, indicating locations of historic eruptions within the active zone of Kartala (dashed lines).

some 45 km (Fig. 3). Since 1918 however, eruptions have become much more localised and have occurred near the summit of Kartala, within or very close to, the caldera.

The nephelinite/basanite eruptions of La Grille appear to be associated with a less productive fissure zone sub-parallel to, and NE of, the Kartala fissure zone.

The lavas erupted from the Kartala fissure zone over the last 115 years have, with few exceptions, remained remarkably constant in composition. This point can be illustrated with reference to the Mg and K contents, taken from analyses presented by STRONG (1971).

TABLE 3.

Date	*MgO*	K_2O	*Comments*
1857	6.65	1.35	
»	6.47	1.40	
»	6.49	1.38	
1858	6.66	1.28	Early phase of eruption
»	5.50	1.39	Later phase of eruption
1859	6.65	1.32	
»	6.60	1.22	
1860	11.22	0.83	Flank eruption
»	9.16	0.95	
»	5.49	1.39	Summit eruption
1862	7.83	1.04	
1872	6.66	1.44	
»	6.69	1.12	
1880	14.82	0.78	
1904	6.12	1.34	
1918	5.75	1.47	
1965	6.33	1.30	
»	6.18	1.26	
1972	5.93	1.26	
»	5.84	1.28	

In 1857-59 the lavas emitted contained approximately 6.5 % MgO although a late pulse of the 1858 flow was unusually fractionated, with MgO reduced to 5.50 %. The unusual presence of small plagioclase phenocrysts in this pulse suggests the likelihood of a small degree of fractionation of all three principal silicate phases.

In 1860 an almost identical, relatively highly fractionated lava was erupted at the summit while ankaramitic lava, enriched in (presumably) cumulus olivine and augite was emitted at lower levels on the western flank.

Strongly porphyritic lava erupted in 1880 from the rift zone in the southern part of the island but, since that date, all Kartala lavas have been residual in type. The latest eruption accordingly produced

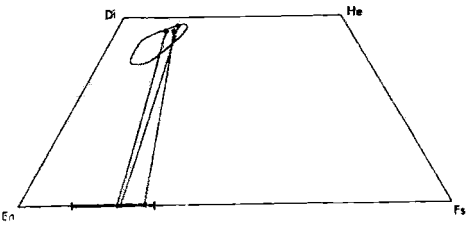

FIG. 4 - Compositions of clinopyroxenes and olivines in the 1965 and 1972 lavas. Stippled area indicates compositional field of Kartala pyroxenes (STRONG, 1971). Thick bar on Mg-Fe join indicates compositional range of olivines in Kartala lavas (STRONG, 1971).

an entirely predictable lava type and there has been no consistent chemical trend displayed by the Kartala lavas during the last century.

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