

## Pantelleritic Obsidians from the Volcano Chabbi (Ethiopia)

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Received June 30, 1969

*Abstract.* Chabbi, a Quaternary volcano in the Ethiopian Rift, appears to be unique in having erupted only non-porphyrritic pantelleritic obsidians showing a very restricted range in composition. Petrogenetic schemes for deriving these lavas are discussed, and it is suggested that some degree of effective superheating, followed by failure of the magmas to crystallise because of their dryness (and hence high viscosity) can account at least for the absence of phenocrysts.

### Introduction

The volcano Chabbi (Lat.  $7^{\circ} 10' N$ , Long.  $38^{\circ} 27' E$ ) is one of a series of Quaternary peralkaline silicic centres lying within the Main Ethiopian Rift. This active volcano was not recognised as such until 1959 and the only account of the centre is by Mohr (1966), who showed Chabbi to be a shield-like mass of silicic obsidian flows. One of us (I.L.G.) visited Chabbi briefly during the summer of 1967 and made the additional field observations noted below while collecting a small suite of samples.

### Field Relations

The field relations and tectonic setting of Chabbi have been described by Mohr, who was correct in stressing the complexity of this centre. There are several separate vents (Fig. 1) each of which is fairly steep-sided, and which coalesce to give a dome-shape to the volcano. There is almost no dissection of Chabbi, and the total thickness of flows is not known. It is possible that the volcano is a basaltic shield veneered with rhyolite, but we consider this extremely unlikely. Judging from the relative states of erosion of the various vents and from the amounts of pumice cover, the volcanic activity can be estimated to have continued over several thousands of years.

Mohr (1966) drew attention to one very important facet of the geology, namely that all the flows examined and sampled in the field are non-porphyrritic obsidians. Although an extensive search was made, no porphyritic flows were found. Certainly the visible lavas from the Main, East, Northeast, North and Hot Cone centres of Mohr (1966) are all non-porphyrritic, while reconnaissance suggests that those from the West centre are similar. Pumice layers between the lavas, and rhyolite fragments in the pyroclastic units, also appear to be aphyric.

The non-porphyrritic character of the lavas is not typical of silicic peralkaline centres in the Ethiopian Rift. Fantale (Gibson, 1967) and the Gariboldi Pass complex (Cole, 1968), the only other two centres examined in any detail, are composed

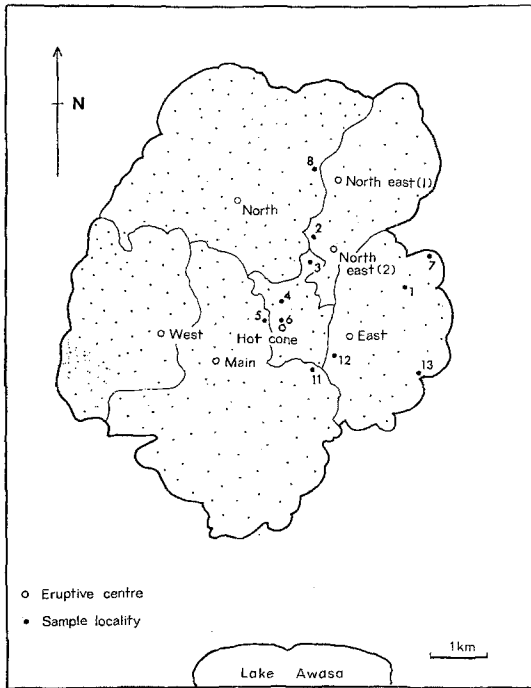


Fig. 1. Outline map of Chabbi volcano, after Mohr (1966). The area of Quaternary obsidians is shown stippled, and also indicated are the major eruptive centres and the sample localities

predominantly of porphyritic lavas and tuffs, with pure obsidians comprising probably less than 5% of the total effusive products. Reconnaissance suggests that other Rift centres are comparable to Fantale in this respect.

In view of this unusual characteristic of the Chabbi lavas, an attempt was made to assess whether the peculiar composition of the lavas had in any way influenced the character of the volcanism.

As stated by Mohr (1966), the vast majority of the products of this centre are normal silicic flows. These typically are 10–20 m thick, with steep, sharp flow-terminations, and rough uneven upper surfaces. These features indicate that the magma on eruption was viscous. It has recently been suggested (Schmincke and Swanson, 1967) that peralkaline lavas such as these might be unusually fluid on account of the high alkali and low alumina contents. We wish to stress that the field evidence from this centre indicates that the viscosity of these flows was, on eruption, similar to that of many calc-alkaline obsidians, such as those from central Iceland (Walker, 1965).

Associated with the obsidian lavas are intercalated beds of air-fall tuffs and agglomerates. No ash-flow tuffs have been identified with certainty. The units described by Mohr (1966, p. 12) as pyroclastic “flows” are more readily explained as normal viscous silicic flows veneered by airfall pumice.

There appears to be a relative scarcity of pumice deposits associated with the obsidians, and many eruptions had virtually no explosive phase. A similar situation exists at Fantale, and we suggest that this indicates low volatile contents of the magmas. The significance of this is discussed later.

Table. *Analyses of non-porphyrific pantelleritic obsidians from Chabbi volcano. Sample localities are shown in Fig. 1*

	1	2	3	4	5	6	7	8	11	12	13
SiO <sub>2</sub>	74.4	74.4 <sup>a</sup>	74.2	74.3	74.3	74.3	73.8	74.0	74.1	74.9	74.8
ZrO <sub>2</sub>	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.25
TiO <sub>2</sub>	0.35	0.27	0.27	0.26	0.27	0.27	0.26	0.27	0.29	0.27	0.28
Al <sub>2</sub> O <sub>3</sub>	9.42	9.41	9.40	9.35	9.44	9.48	9.54	9.46	9.62	9.46	9.69
Fe <sub>2</sub> O <sub>3</sub>	1.77	1.65	1.74	1.28	1.61	1.79	1.73	1.91	1.76	1.53	1.61
FeO	2.88	2.90	2.90	3.34	2.82	2.90	2.97	2.65	2.84	2.87	2.92
MnO	0.22	0.21	0.21	0.22	0.21	0.20	0.23	0.21	0.22	0.22	0.22
MgO	0.16	0.13	0.15	0.20	0.12	0.16	0.19	0.23	0.20	0.17	0.14
CaO	0.20	0.24	0.21	0.20	0.28	0.18	0.23	0.25	0.20	0.20	0.30
Na <sub>2</sub> O	5.33	5.49	5.23	5.66	5.29	5.52	5.62	5.42	5.53	5.49	5.53
K <sub>2</sub> O	4.29	4.39	4.26	4.44	4.39	4.48	4.43	4.41	4.37	4.47	4.38
H <sub>2</sub> O <sup>+</sup>	0.47	0.41	0.40	0.32	0.36	0.31	0.49	0.30	0.29	0.40	0.37
F	0.25	0.25	0.24	0.25	0.23	0.23	0.25	0.25	0.25	0.25	0.24
Cl	0.16	0.16	0.16	0.17	0.16	0.16	0.17	0.16	0.16	0.16	0.16
	100.05	100.16	99.62	100.24	99.73	100.23	100.16	99.77	100.07	100.63	100.89
O=F, Cl	0.15	0.15	0.14	0.15	0.14	0.14	0.15	0.15	0.15	0.15	0.14
Total	99.90	100.01	99.48	100.09	99.59	100.09	100.01	99.62	99.92	100.48	100.75
Q	34.3	34.1	34.1	33.9	34.4	33.5	32.9	33.3	33.1	34.5	33.7
Or	25.6	26.1	25.6	26.1	26.1	26.7	26.1	26.1	26.1	26.7	26.1
Ab	24.1	23.6	24.1	23.6	23.6	23.6	24.1	24.1	24.6	23.6	25.2
Ac	5.1	5.1	5.1	3.7	4.6	5.1	5.1	5.5	5.1	4.2	4.6
Ns	3.3	3.8	3.1	4.4	3.4	3.8	3.8	3.3	3.5	4.0	3.5
Hy	5.5	5.4	5.5	6.4	5.3	5.5	5.9	5.4	5.5	5.5	5.5
Il	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Z	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
CaF <sub>2</sub>	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4
Hl	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

<sup>a</sup> SiO<sub>2</sub> by difference. Samples all dried at 105° C. P<sub>2</sub>O<sub>5</sub> in all samples < 0.05%. Analysts: R. MacDonald and S. A. Malik (SiO<sub>2</sub>, F, Cl).

### Analytical Data

Eleven analyses of non-porphyrific, non-hydrated obsidians are given in the Table. Chemically the rocks are transitional between comendites and pantellerites (Noble, 1968), but using the arbitrary division between these groups established by Lacroix (1927) and adopted by Noble (1968) namely, 12.5% normative femic constituents, the Chabbi lavas are classified as pantellerites. The analysed specimens are thought to be representative of all the flows of the volcano, and it is therefore striking that these flows have virtually identical compositions.

### Origin of the Chabbi Lavas

Two features of the Chabbi flows are particularly interesting petrogenetically.

1. It is clear from the Table that the composition of the Chabbi obsidians, erupted probably over several thousands of years, has remained virtually constant.

2. There appears to be a complete lack of phenocryst minerals.

In conventional terms, these features are difficult to reconcile. Liquids formed by *fractional crystallisation* should contain and be in equilibrium with crystals, except in the case of complete crystal removal. This aphyric condition can normally be expected to persist over only a small temperature interval, unless the magmas become, and remain during ascent and eruption, either appreciably superheated or rapidly cooled below the stage of labile crystallisation. Porphyritic magmas might become aphyric by being rapidly moved to a lower pressure regime, with subsequent resorption of phenocrysts. Assuming that the liquids were brought quickly to the surface, they may have been erupted in an aphyric condition, since they will remain effectively superheated due to pressure release.

However, we consider it extremely unlikely that the fractional crystallisation of batches of basaltic magma over a longer period of time could have so accurately reproduced the same rhyolitic composition, and prefer to consider further alternatives.

A modification of this scheme is that a single superheated rhyolitic magma derived ultimately from basic magma was intruded into a sub-volcanic magma chamber and was able to exist for a long time without crystallising i.e. it passed from superheated to supercooled. Crystallisation was thus unable to destroy the uniformity of composition and the magma was available for periodic eruption at the surface. Alternatively intrusion of a porphyritic magma at its liquidus temperature, followed by pressure relief during tectonism, may have resulted in the whole mass being raised above the liquidus. In both cases, further crystallisation must have been delayed for a considerable period of time. We suggest that crystallisation in the Chabbi magmas was inhibited by their high viscosity, itself a function of their relatively anhydrous nature. It is known from experimental work on rhyolitic compositions that rates of crystallisation are exceedingly slow in dry systems, and several authors (Tuttle, 1952; Luth *et al.*, 1964; Nicholls and Carmichael, 1969; Bailey and Macdonald, 1969) have suggested that certain peralkaline rhyolites have evolved under dry conditions. These observations are consistent with the field evidence at Chabbi, where pyroclastic material is relatively scarce, and where, on eruption at least, the magmas were very viscous.

#### *Partial Melting of Basic Material*

Since the source material is likely to have remained constant, and provided that pressure-temperature conditions were not too variable, it is possible that partial fusion of a basic rock could have produced the series of Chabbi obsidians (cf. Bailey, 1964; Bailey and Schairer, 1966). Such magmas, however, cannot have been formed with appreciable superheat and would be expected to have crystallised during ascent to the surface. Again, crystallisation may have been inhibited by the high viscosities of the liquids. Alternatively, a rhyolite magma may have been held at depth (? in the mantle) and was kept above its liquidus temperature by the regional geothermal gradient. Such a body may have been tapped only during periods of tectonic disturbance.

#### *Complete Fusion of Peralkaline Granite*

This is a possible mechanism for producing homogeneous rhyolite magmas, if it is assumed that they were superheated and remained so. Blocks of microgranite

have been recorded in the flows and tuffs from the Fantale (Lacroix, 1930) and Gariboldi Pass volcanoes, but none has so far been found at Chabbi, even in the pyroclastic materials.

### *Liquid Immiscibility*

There may be some form of liquid immiscibility relationship between basalt and rhyolite at temperatures above the rhyolite liquidus, whereby the silicic liquids were separated from the basalt and brought to the surface in a superheated condition. In the case of Chabbi, where there are no basalts in the exposed volcanic pile, the possibility of the former co-existence of rhyolitic and basaltic magmas is questionable.

### Conclusions

We feel that some combination of superheating, derived either at the site of magma genesis, or by relatively rapid movement into the crustal environment, followed by supercooling due to dryness, can explain the lack of crystals in the Chabbi rocks. Whether their composition could have been so accurately reproduced by a recurrent process involving a "eutectic" composition, e.g. fractional crystallisation or partial fusion of basic material, or whether the lavas have been derived from a single magma batch, is not known.

In the nature of its products, Chabbi appears to be a unique volcano. When the tectonic setting and petrology of the other Quaternary Ethiopian volcanoes are better known, some further clues as to the evolution of Chabbi may be found.

*Acknowledgments.* We wish to thank S. A. Malik of the Geochemistry Unit, Department of Geology, University of Reading, for the determination of SiO<sub>2</sub>, F and Cl in the analysed specimens, and M. J. Saunders of the Grant Institute of Geology, University of Edinburgh for aid in determining the other elements. Drs. D. K. Bailey, K. G. Cox, P. G. Harris, B. G. Jamieson and B. G. J. Upton kindly read the manuscript and offered several useful suggestions for its improvement.

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