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The age of the alkaline rhyolites of the Central Eastern Ethiopian Plateau and of the edge of the Rift

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Geochimica. — *The age of the alkaline rhyolites of the Central Eastern Ethiopian Plateau and of the edge of the Rift.* Nota di MASSIMO NICOLETTI e CLAUDIO PETRUCCIANI, presentata (*) dal Corrisp. M. FORNASERI.

RIASSUNTO. — Nell'altopiano etiopico centro-orientale e nelle scarpate che da questo scendono nella fossa dancala e nel Main Ethiopian Rift affiorano estensivamente rioliti alcaline e trachirioliti. Le età K–Ar ottenute da una cinquantina di campioni hanno permesso di stabilire che tali rioliti appartengono a due cicli vulcanici distinti.

Il ciclo più antico, oggetto di questo lavoro, rappresentato dalle « rioliti di Alagi », si è iniziato 32 M.A. [1] fa ed è finito circa 20 M.A. fa. Il secondo, rappresentato dalle « rioliti di Balci » si è iniziato circa 10 M.A. fa ed è continuato fino a tempi molto recenti.

INTRODUCTION

In central Ethiopia (see in fig. 1 a geographic sketch of the region considered), vulcanites from the tertiary age between the Eocene and the present are extensively outcropping. A subdivision of the vulcanites recently proposed by B. Zanettin, E. Justin-Visentin distinguishes, from the bottom upwards, the following formations: Ashangi basalts, Aibà basalts, Alagi basalts and rhyolites, Termaber basalts.

In the Southern sector, which comprises the Main Ethiopian Rift, the Balci rhyolites associated with basalts are superimposed on these formations.

It appears from the geologic and petrographic investigations that these acid formations range from trachyrhyolitic to alkaline ryolitic lithotypes. An extensive dating program by the K–Ar method has been undertaken on the acid rocks with a view to determining the precise chronological sequence of the effusive events. From the results obtained so far it can be said that the rhyolites of this region of Ethiopia are attributable to two volcanic cycles sharply separated from a chronological viewpoint. The first, constituted by the " Alagi rhyolites ", is comprised between 32 and 20 M.Y.; the second, by the " Balci rhyolites ", between 10 M.Y. and recent times. The investigations concerning the group of later vulcanites are still in progress and will be discussed in a future paper.

Hereby only the data relating to the former cycle will be discussed. The " Alagi rhyolites " outcrop in a vast portion of the Central-Eastern Ethiopian Plateau, from North to South, from the Amba Alagi area (from which they get their name) at about 13° through Addis Ababa at about 9°, forming a belt roughly 450 km long by one hundred km wide located towards the Eastern edges of the Plateau and also in part extending along the escarpment.

(*) Nella seduta del 26 novembre 1973.

(1) M.Y. = million years.

The thickness of these vulcanites varies and is the greatest along the Plateau's edges, locally as thick as about 1,000 meters. This forms a tremendous mass of acid vulcanites, certainly among the world's largest.

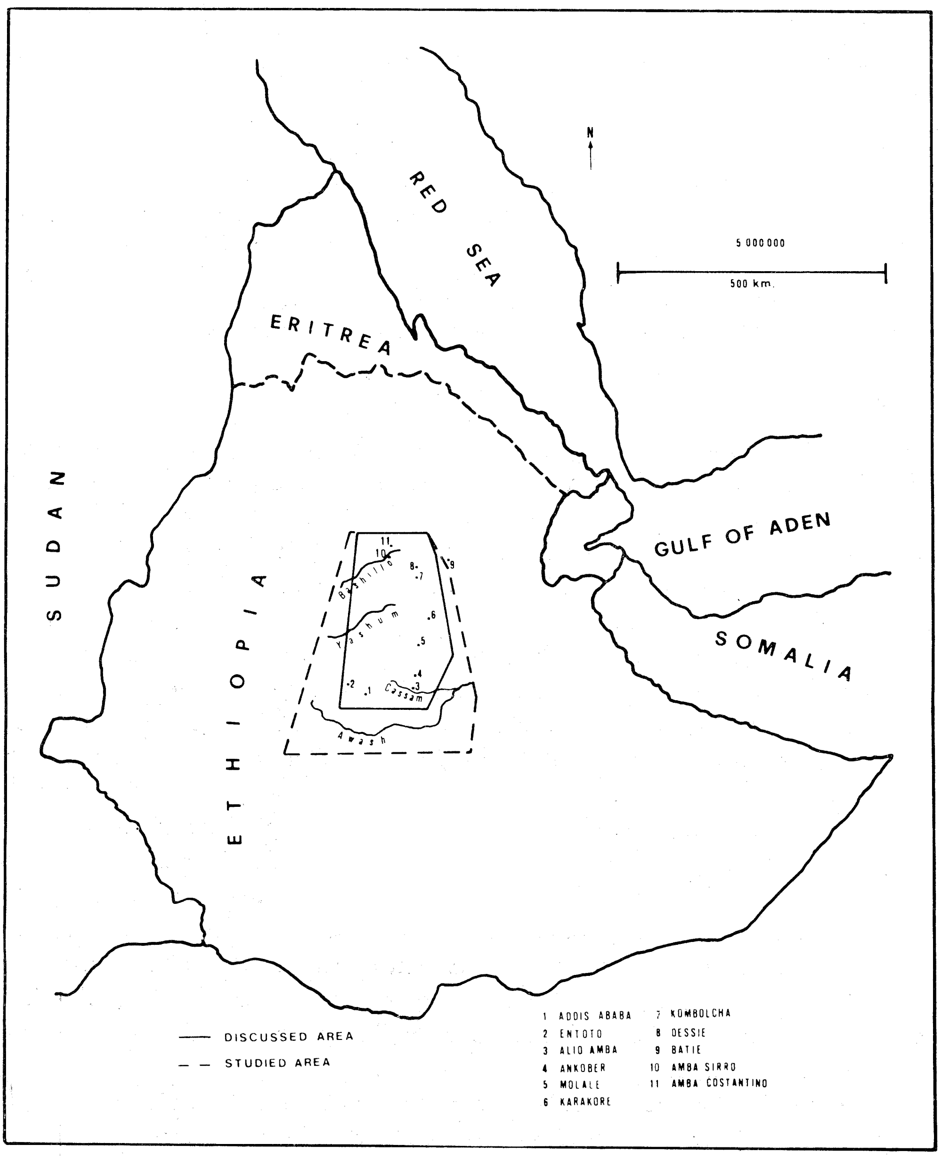

Fig. 1. – Geographic sketch of the region considered.

The geologic data relating to this region, are reported from the work of B. Zanettin, E. Justin-Visentin (1972–1973), A. Gregnanin, E. Piccirillo and E. Abebaw (1973–1972).

The samples studied were supplied to us by the same authors.

EXPERIMENTAL METHODS

The materials analysed were in some cases total rocks; for the most part, anorthoclase concentrates separated from the mother rock by conventional enrichment methods. Argon was extracted and purified by means of a line derived from the early model by J. K. Evernden and G. H. Curtis (1965) and later modified by M. Nicoletti and made much faster in operation.

In particular, the unnecessary transfert operation was dispensed with and the gases released by the molten mineral were allowed to react simultaneously on the getters: Ti—Zr at 500° C, Cu—CuO—Al at 900° C, artificial zeolites and silica gel at 0° C.

When the pressure in the system has dropped to a constant value around or lower than 10^{-3} mmHg, the getters, except the artificial zeolites which remain at 0° C through the entire operation, are cooled down, first slowly then rapidly to the temperature of — 80° C and the residual gases are collected on activated charcoal cooled to — 190° C.

Argon isotopic analyses were made with an A.E.I. MS_{10} mass spectrometer set up, adjusted and adapted to this kind of measurement by M. Nicoletti. This instrument has proved highly versatile in terms of measurement reproducibility, of the almost non-existent fractioning factor (after finding the proper repeller tension conditions), of speed of analysis, of off times between analyses extremely short as compared to other spectrometers, and finally of the almost non-existent " memory effect " even after a great many analyses.

Potassium was determined by a flame spectrophotometer, Optica Mod. CF_4. Duplicate age measurements on P_{207} standard muscovite have yielded a value of 80.2 ± 2. M.Y., in good agreement with the proposed 81.1 ± 1 M.Y.

THE SAMPLES EXAMINED

In some cases the provenance of the samples is clearly defined. This happens as a rule for the plateau areas where the local series are exposed throughout their extent. Under other circumstances, above all in the escarpment area, the location of the samples within the respective series is not precisely defined because of the lack of suitable sections.

As predictable, the samples from the basal part of the Alagi formation are those which have shown the oldest ages. Sample Et_{69}–45, which represents one of the first ignimibritic levels of the Amba Costantino series, has shown an age of 32 M.Y.; Sample Et_{72}–460 (Yashum Valley), representing a limited discontinuous level, the only one present in the local Alagi series, which here appears almost totally basic, turned out to be slightly older: 32.9 M.Y. Roughly of the same age is also a rhyolite collected from the upper levels of the series which outcrops above the town of Kombolcha (Sample Et_{73}–29; $t = 32.0$ M.Y.) (2).

The upper levels in the series present in the Amba Costantino area (sample: Et_{69}–27) and in the nearby Amba Sirro (Sample: Et_{72}–493) have shown ages of respectively 28.1 and 29.1 M.Y. (3). It appears from the results reported that the acid series outcropping in the area from the Nile through the Bashillo watershed and up to Kombolcha, did effuse in a relatively short period of time between 32 and 28 M.Y.

TABLE I

	Region	Sample	Mineral	^{40}Ar rad cc.S.T.P./g	% ^{40}Ar rad	% K	$t \pm \varepsilon$ (M.Y.)
North Plateau Nile Borona	Amba Costantino Kombolcha	Et_{69}–45	AN.	4.7403 10^{-6}	56.63	3.68	32.0±1
		Et_{72}–460	AN.	4.6388 10^{-6}	73.78	3.50	32.9±0.6
		Et_{73}–29	AN.	3.4401 10^{-6}	93.01	2.53	32.0±0.6
		Et_{72}–103	W.R.	3.8440 10^{-6}	46.08	3.72	27.7±1.25
		Et_{69}–27	AN.	1.7316 10^{-6}	74.21	1.53	28.1±0.9
	Amba Sirro	Et_{72}–493	AN.	3.0534 10^{-6}	83.94	2.60	29.1±0.6
South Plateau	Molale	Et_{73}–682	AN.	3.821 10^{-6}	61.40	3.77	25.4±0.5
		Et_{73}–675	W.R.	3.9050 10^{-6}	65.03	4.02	24.0±0.4
		Et_{73}–692	AN.	3.6172 10^{-6}	62.94	3.99	22.5±0.4
		Et_{73}–690	W.R.	3.3180 10^{-6}	65.51	4.03	21.1±0.4
Plateau Escarpment Boundary	Karakore	Et_{72}–25	A.N.	3.6523 10^{-6}	75.17	4.75	19.1±0.4
	Entoto	Et_{72}–13a	SAN.	8.8084 10^{-6}	81.63	9.94	22.0±0.4
	Scarpata Alio Amba	Et_{71}–100	AN.	4.0609 10^{-6}	90.06	4.18	24.1±0.4
	Cassam	Et_{72}–39	AN.	2.5905 10^{-6}	69.81	2.76	23.3±0.4
		Et_{73}–6	AN.	3.2501 10^{-6}	72.52	4.47	18.5±0.3

AN. = Anorthoclase. W.R. = Whole Rock. SAN. = Sanidine.

(2) We have also dated a sample representative of the lower levels, collected on the road to Batie (Sample Et_{72}—107), which has shown an age of 27.7 M.Y., slightly lower and seemingly conflicting with the values obtained for the overlying levels. It should be pointed out, however, that while the other data were obtained on anorthoclase, the latter relates to a rock *in toto* which, as is known, yields age values lower than those of minerals.

(3) These dates are in good agreement with those determined by Leeds Isotopes on an Amba Alagi rhyolite, showing an age of 27.8 M.Y.

Another important series from the Plateau, of the thickness of about 1,000 m, the greatest so far found in the area, is that of Molale, located near the Danakil escarpment. Four samples collected at elevations between 2,460 and 3,370 (m.a.s.l.) were considered, and namely Et_{73}–682, Et_{73}–675, Et_{73}–692, Et_{73}–690; the results obtained were respectively 25.4, 24.0, 22.5 and 21.1 M.Y.

The sample collected at the lowest point, Et_{73}–682, does not represent the base of the ignimbritic series, but is located above the massive layer of the first basalt flow typical of the area. The data reported show that in this area the upper terms of the series have an age definitely younger than the

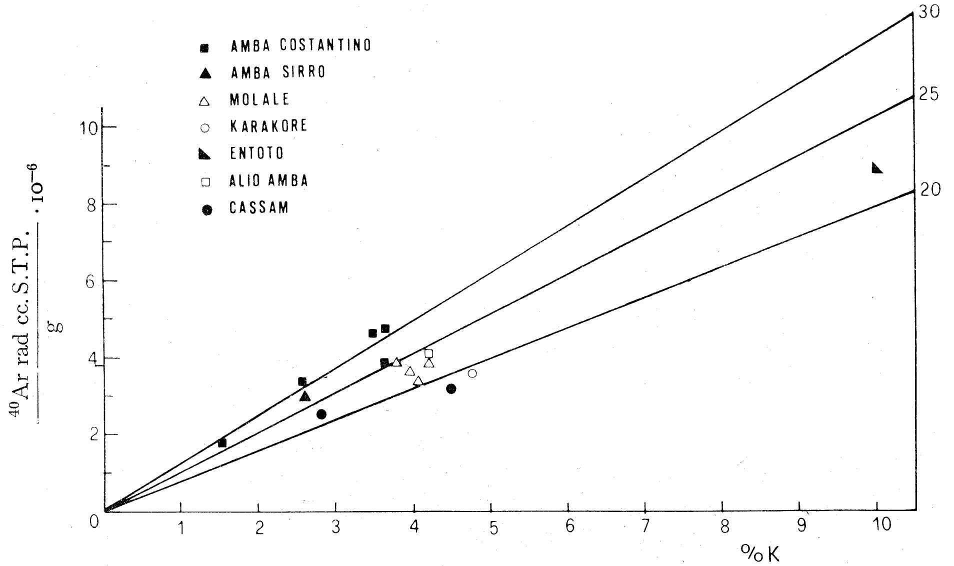

Fig. 2. – Distribution of experimental results in the isochronal diagram:

$$\frac{^{40}\text{Ar rad cc. S.T.P.}}{\text{g}} \cdot 10^{-6} \div \% \text{K}.$$

corresponding terms exposed in the area to the North discussed above, but at the present stage of our knowledge it cannot be established whether the beginning of the acid volcanism is contemporary with that of the areas described above.

Large masses of highly vitreous acid lavas outcrop at the plateau-escarpment boundary: they seem to represent the conclusive event in the Alagi acid volcanic cycle. The age determinations on these materials substantially confirm this viewpoint: the rhyolite collected near Karakore (sample Et_{72}–25) shows an age of 19.1 M.Y. and that collected near Entotto, immediately N of Addis–Ababa (sample Et_{72}–13a) an age of 22.0 M.Y.

As stated before, the rhyolites outcropping along the Danakil escarpment are not clearly definable from a stratigraphic viewpoint.

An ignimbrite collected near the Olio–Amba along the track linking Ankober with the Danakil lowlands (sample Et_{71}–100) has shown an age of 24.1 M.Y. Other samples outcropping in the Cassam ravine (sample Et_{72}–39 and Et_{73}–6) have shown ages of 23.3 M.Y. and 18.5 M.Y. in fairly good agreement with the value of 20 M.Y. obtained by I.L. Gibson *et al.* (1971) for an acid level outcropping on the opposite side of the Cassam at higher elevations than those studied by us.

These results rule out the hypotheses of certain authors, such as P.A. Mohr (1967, 1968), who believed the rhyolites outcropping from the escarpment to be from the Pliocenic age.

The experimental result obtained are shown in Table I, and in fig. 2.

Conclusions

The results obtained so far make it possible to clearly determine the existence of two different acid volcanic cycles, separated in time. The older cycle, whose products outcrop, at least in the territory considered here, only on the Ethiopian plateau and the adjoining Danakil escarpment, extends between 32 and 20 M.Y.

The younger cycle, for which numerous data are already in our hands, now appears to fall between 10 M.Y. and recent times.

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Roma, Centro Studi per la Geochimica Applicata alla Stratigrafia recente del Consiglio Nazionale delle Ricerche, June 1973.

References

Curtis G. H. and Evenden J. K. (1965) – K–Ar *dating of late cenozoic in East Africa and Italy*, «Current Antropology», *6*, 343–385.

Gibson I. L. and Rex D. C., Dakin F. (1971) – *Age of the Ethiopian flood basalt succession*, «Nat. Phys. Sc.», *234*, 880–883.

Gregnanin A. Piccirillo E. M. and Abebaw E. (1973) – *The subdivision of volcanic series in the Ethiopian Plateau: New Geological interpretation of the Dessie–Kombolcha area.* «Boll. Soc. Geol. It.» (in press).

Gregnanin A. and Piccirillo E. M. (1973) – *Some remarks on the volcanic series and structure of the Central Ethiopian Plateau*, «Boll. Soc. Geol. It.» (in press).

Mohr P. A. (1967) – *The Ethiopian Rift System*, «Bull. Geophys. Obs.», *11*, 1–65.

Mohr P. A. (1968) – *The Cenozoic volcanic succession in Ethiopia*, «Bull. Volc.», *32*, 5–14.

Zanettin B. and Justin–Visentin E. (1972) – *Serie di vulcaniti etiopiche*. Nota I: *La serie dell'altopiano etiopico centro–orientale*, «Boll. Soc. Geol. It.», *92*, 313–327.

Zanettin B. and Justin–Visentin E. (1973) – *Serie di vulcaniti etiopiche*. Nota II: *La serie della scarpata dell'altopiano etiopico centro orientale*, «Boll. Soc. Geol. It.» (in press).