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Research Paper

An Analysis of Paleomagnetism of the Ngong Basalts of Kenya

W.C. Kirui[1], J.P. Patel[2]
[1]*Department of Physics, Masinde Muliro University of Science and Technology, P.O. Box 190- 50100, Kakamega, Kenya*
[2]*Department of Physics, University Of Nairobi, Kenya Science Campus, P.O. Box 30197-00100, Nairobi, Kenya*

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ABSTRACT: *This paper presents results of paleomagnetic study of the ngong basalts, volcanic rocks of lower tertiary age, dated 5.3 my, from Kenya. Specimens of the ngong basalts , from six sites were sampled and treated in alternating field up to 100mT, stable primary components of the natural remanence isolated and various magnetic parameters analyzed. The cleaned mean directions have been classified as intermediate for all the sites . The mean intermediate direction and corresponding pole position of the ngong basalts is calculated at declination D=84.5^0, inclination I=0.8 ^{0} (α_{95}= 23.8 ^{0}) and longitude 125.0 ^{0} E, latitude 0.93 ^{0} N (A_{95}=16.2 ^{0}). These results may, together with others, assist in developing a magnetostratigraphic correlation of Nairobi area rocks.*

1.1 Introduction

The geology of the east African rift system as a whole has been summarized by Baker et al. (1972) and the sequences and geochronology of the Kenya rift system discussed in Baker et al. (1971). The Kenya rift volcanic erupted nearly continuously from early Miocene to holocene times producing mainly nephelinites, alkali basalts and phonolites in the Miocene period. Pliocene activity was trachytic, nephelinitic to basaltic in most parts of the Kenyan rift system.

The formations of which the country surrounding Nairobi area is built for the quaternary and tertiary include limuru trachytes, Nairobi phonolites, ngong basalts, tuffs and agglomerates, mbagathi phonolitic trachytes, Nairobi trachytes and kerichwa valley trachytes.

Ngong basalts are presumed to cover about 130 km^2 constituting ngong hills and adjacent foothills.

1.2 sampling

For this study, the ngong basalts were sampled along the south-westerly Nairobi-magadi road, mostly at road cuttings around Kiserian township at latitude 1° 25'S, longitude 36°42' E in Kenya.

A total of six sites were obtained from the formation yielding a total of 20 oriented block samples. Sites 8-11 were sampled from the western edge of the ngong hills with site 8 being at the bottom progressively to site 11 at the top. The perpendicular height between sites 8 and 11 was about 100m with sites 9, 10 along the adjoining slanting edge of an incline of about 30^0. The rest of the sites 6and 7 were sampled on the eastern side of the hills. The blocks were first dislodged from their parent position with a sledgehammer, and then carefully replaced in their original position noting their orientation angles. The collection and orientation of the block samples was done as described by Collinson et al. (1964). Each individual block sample was oriented in situ using a compass and an inclinometer, recording the dip and strike of the formation. The bearing, latitude and longitude were also noted for every sample. The maximum error in strike, dip and position angles is less than 2% of a degree while in the bearing measurements; it is up to 1^o.

[1]*Department Of Physics, Masinde Muliro University Of Science And Technology, Kakamega, Kenya*

1.3 Measurements

The block samples collected in the field were taken to the laboratory and re-oriented in the same position as in situ and cores of diameter 2.5cm drilled out. The cores were then cut into sizeable specimens of length about 2.5cm, which were then used in magnetic analysis of the remanence. Each specimen had its natural remanence measured at zero field and at each demagnetization step. Cleaning of the specimens was done utilizing the alternating field (a.f.) demagnetizing equipment. All rock specimens were demagnetized and at each demagnetization step, their remanence was measured using a spinner magnetometer (Forster,1966). The optimum cleaning field of a site was pre-determined using site pilot specimens.

The pilot specimens for each site were demagnetized up to 100 mT or until the optimum cleaning field was attained, in steps of 5mT using the alternating field demagnetization equipment. At each step of demagnetization the natural remanence was measured on the spinner magnetometer. The demagnetization vector plots and the stability curves were then computed. The optimum field intensity, the field necessary to clean the secondary magnetism of the rocks of a given site was then deduced from the plots. The choice of the optimum field from the stability index curves is as explained by Briden (1972), the stability index (S.I) is defined for successive equal increments of alternating fields of 5mT. During the successive demagnetization, the field at which the stability index (S.I.) is maximum is chosen as the most suitable cleaning field. All site specimens were then demagnetized with a field 10 mT below and above this chosen field. The field which then gave the smallest α_{95} (radius of cone of confidence) is selected finally as the true site cleaning field. All further samples of the site were cleaned and their magnetism measured at this field. In some sites, a single field suitable for all site specimens could not be found. Most of the specimens then required full step by step demagnetization before an end point could be identified. In addition, it was necessary to discard a number of specimens which behaved erratically either by not giving a distinct grouped end direction on the stereo nets, decay curves, or stability index curves. In such cases, the specimens were subjected to Watson's (1956) test for randomness at 5% significant level before discarding.

1.4 Results and discussion

A total of 20 samples of the Ngong basalts were collected from six sites, sites 6 - 11. The site mean directions before and after a.f. demagnetization are given in Table 4.

At least one specimen from each site was fully demagnetized in steps of 5 mT in order to determine the site cleaning fields. The optimum field deduced from the stability index (SI) curves in Fig. 4(a) varies between 20 to 35 mT. All the S1 curves show high stability of the natural remanence which initially rises from about 0.5 to 0.9 within their mean destructive fields (Mdfs) of between 20 - 40 mT. This phenomena is also exhibited in Fig. 4(b) of plot of directional changes of the pilot specimens where apart from the initial large variations at fields up to 20 mT, a noticeable grouping of the directions is evident. This indicates that most secondary components of magnetism has been cleaned.

The inference of high stability of the natural remanence of the ngong basalts from Fig. 4 (a) is also exhibited by the intensity demagnetization curves in Fig 4(c).

TABLE 4 – NGONG BASALTS

ST.	N	Before a.f. Cleaning R	D	I	K	α_{95}	After a.f. Cleaning R	D	I	K	α_{95}	Hc	Pole Position Long.	Lat.	δm	δp	A_{95}	PLT
6	3	2.81	248.0	20.7	4.1	70.5	2.96	83.6	1.64	40.9	18.4	35	125.7	2.4	18.4	9.2	-	I
7	3	2.82	244.1	-7.4	10.9	39.2	2.89	74.2	-21.6	13.4	35.2	35	137.9	15.8	37.5	18.3	-	I
8	2	1.997	344.5	-10.3	332.5	13.7	1.99	82.9	21.6	115.9	23.4	25	115.4	14.7	29.2	15.3	-	I
9	4	1.86	217.9	67.2	1.4	104.0	3.75	74.8	20.4	11.9	27.8	25	136.8	-12.4	29.8	15.5	-	I
10	5	4.29	184.2	-18.3	5.6	35.8	4.51	100.9	-18.2	6.1	28.7	30	115.3	6.7	24.7	13.0	-	I
11	3	2.97	285.3	7.0	59.5	16.1	2.86	112.3	14.6	36.8	20.6	20	118.2	-38.3	21.1	10.8	-	I
						Mean	4.8	84.5	0.8	11.31	23.8		125.0	0.88			16.2	

(Symbols same as in table 3).

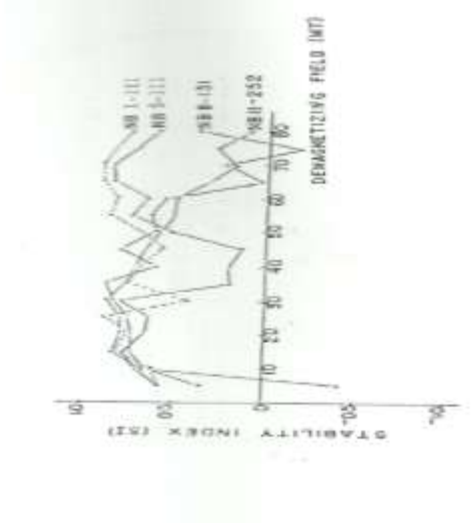


FIG. 4b: STABILITY INDEX CURVES FOR PILOT SPECIMENS OF NGONG BASALTS.

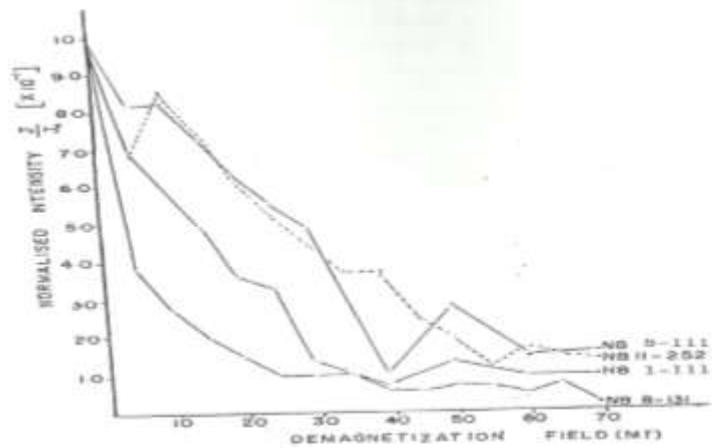


FIG. 4C: NORMALISED DEMAGNETIZATION CURVES FOR PILOT SPECIMENS OF NGONG BASALTS.

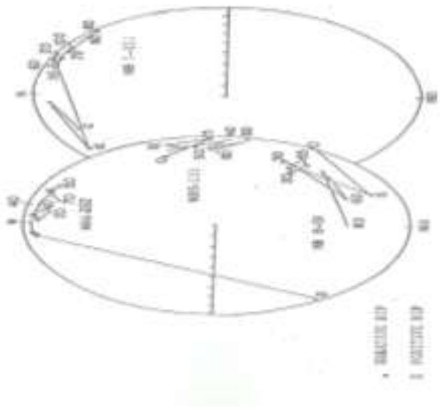
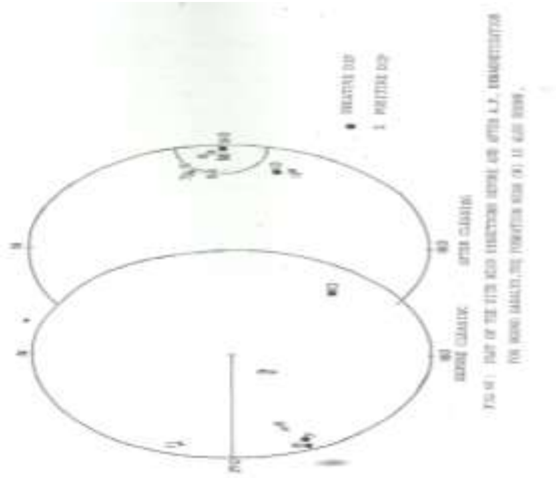


FIG 4d: PLOT OF DIRECTIONAL CHANGES OF PILOT SPECIMENS FROM NGONG BASALTS

These demagnetization curves show varied characteristics for the specimens with NB1- 511 and NB 11- 252 having a much higher mean destructive fields than specimens NB 1-111 and NB 8 - 131. This large variation in the mean destructive fields indicate that the specimens of the Ngong basalts have a wide range of coercivities, the highest illustrated by the intensity decay curve representing NB 11 - 252 in Fig. 4(c).
The site mean remanent directions before and after a.f. demagnetization given in Table 4, are plotted on the equal area stereo nets in Fig. 4(d).The directions are distributed randomly before a.f. cleaning while a noticeable

clustering of mean sample directions is apparent after a.f. cleaning. Significant increase in values of K, the estimate of Fisher's (1953) precision parameter with corresponding reduction of α_{95}, the radius of circle of confidence of 95% level of significance is evidence of adequate cleaning of secondary components of magnetizations using a.f. technique.

The cleaned directions have all been subjected to Watson's (1956) test for randomness at 95% probability and none has been excluded from the final analysis on this criteria. The cleaned directions have accordingly been classified as intermediate according to Dagley et al. (1967). No normal or reversed direction has been observed from the sampled sites of the Ngong basalts.



These results are similar to those obtained for the Kirikiti basalts (Patel, 1977) dated 5.1 my by Baker (1958) where normal and intermediate polarities were observed. While sampling, it was noted that the basalts occur in massive thickness over the Ngong hills and the surrounding areas. Sampling for sites 6, 7 was done on the eastern side of the hills while sites 8 - 11 were sampled on the western side of the Ngong hills with site 8 at the bottom rising to site 11 at the top of the hill. From this observation, the significant but scattered cleaned mean directions of the sites of the Ngong basalts can be assumed to represent different flows which must have been extruded at different times.

The directions and circles of confidences of sites 10 and 11 overlap and the F-ratio test at 5% level of significance show that they are insignificantly different suggesting the two results are the same. Similar conclusion is obtained in regard to sites 8 and 9. All the remaining sites are significantly different.

An overall mean direction, declination D=84.5° inclination 1=0.8 ° (α_{95} = 23.8 °) has been calculated from the directions of the six sites (cf. Table 4). The paleomagnetic pole is calculated by two methods. A single pole with an oval of confidence is obtained at 126.2 E, 5.5° N (δm=23.8°, δp=11.9 °) from the mean of the site directions. The other pole with a circle of confidence is obtained at 125.0° E, 0.93° N (A_{95} = 16.2 °) from the average of site poles listed in Table 4. The mean paleomagnetic pole, computed from the site poles was preferred since the number of sites exceeds two and were geographically widespread.

These results are believed to represent a good estimate of the mean field direction and paleomagnetic pole for the sampled parts of the Ngong basalts because of the improvement in grouping of both' sample and site directions after the alternating field cleaning. Sampling was carried out over a large area, thus averaging out possible errors due to secular variations.

II. CONCLUSION

This rock formation from the Ngong hills contains an alkaline series ranging from nephelinites, basanites to basic and phonolitic tephrites. Sampling was done on the eastern side (sites 6, 7) and on the sloping edge of western side of the hills which possibly consist of multiple flows. The flows could not be distinctly identified in the field. However, magnetically, they divide into five groups of sites 6-11, each having intermediate but distinct direction.

Ngong basalts have been dated at 5.3 my. From the distribution of sites it is evident that the youngest of the sampled flows represented by site 11 has a direction of greatest declination which progressively reduces to that of site 7 suspected to be the oldest of the flows. This implies that the field transition during eruption of ngong basalts was from normal to reversed, and that since all the directions are intermediate and probably represent successive fows, then they must have been extruded during the same transitory event most probably during transition of the field from normal polarity between 5.69 my to 5.43 my to the reversed polarity between5.43- 4.87 my according to Heirtzer et.al. (1968) Polarity scale.

The mean paleomagnetic pole for the ngong basalts is computed at 125.0° E, 0.93° N (A_{95} = 16.2 °) for its intermediate directions . These intermediate directional flows of the ngong basalts , may be tentatively, correlated to one of the middle flows of the kirikiti basalts (Patel, 1977).

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[13]. Word on the authors:
[14]. W.C. Kirui, is currently a Physics lecturer at Masinde Muliro university of Science and technology, formerly served in the same position in Maseno university. He has an interest in geophysics. This paper is an excerpt of his M.sc. thesis at the University of Nairobi.
[15]. Prof J.P. Patel, Is a renown professor of physics who has taught for a long time at the university of Nairobi's department of physics. Professor Patel has published extensively in Paleomagnetism and is an established authority in Geophysics for over three decades.