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ABSTRACT

During January 1967, 28 sites were occupied in the Eastern Rift in Kenya with three high-frequency, high-gain, portable seismographs. The microearthquakes recorded seem to be confined primarily to the center of the rift. They are directly related spatially to faults, some of which first formed in the early Tertiary, to a geothermal area, and to a recently dormant volcano. This study gives a clearer picture of the relation of seismic activity to rifting than is possible with the larger earthquakes routinely located by the world-wide seismic stations.

INTRODUCTION

Microearthquakes considered in this study are earthquakes as small as magnitude −2. Felt earthquakes are generally larger than magnitude 3 on the logarithmic Richter scale. Because microearthquakes occur in large numbers, significant data can normally be collected in a day or two (Oliver and others, 1966; Ward and others, 1969). Zones of activity can be identified quickly and the instruments moved closer. In this way current seismicity can be located to within a few kilometers. Epicenters of larger earthquakes located with the standard seismic instrumentation may be in error by tens of kilometers. The purpose of this study was to locate and study the microearthquakes in an intracratonic rift valley, the Eastern, or Gregory, Rift of Kenya. The good spatial resolution of the experimental method allows us to conclude that most of the seismic activity is associated with the younger network of so-called grid faults in the rift valley itself and to a lesser extent with the older faults that form the major escarpments of the valley. Furthermore, we can relate some events directly to volcanoes and geothermal areas.

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FIELD PROGRAM

During January 1967, 28 sites were occupied with high-gain, high-frequency, highly portable backpack seismographs. The details of the instruments and recording procedures used are described by Ward and others (1969). Figure 1 shows the location of these sites and the average number of microearthquakes per day with recorded amplitudes greater than or equal to 2 mm at 30-dB attenuation and within 20 km of the site. Events of this size are approximately of magnitude −0.7 (Ward and others, 1969). Numerous smaller events were recorded at some sites; while they are not included in Figure 1, they are tabulated in Table 1. The number of events per day was found to be generally characteristic of a site within a factor of 3 over a period of a few months (Ward and others, 1969). The number may fluctuate by a greater amount from year to year, however.

HISTORIC SEISMICITY

Figure 2 summarizes the historic seismicity through 1967 as compiled from Gutenberg and Richter (1954), Sykes and Landisman (1964), the 1953 through June 1964 bulletins of the Lwiro seismic station operated by the Institut pour la Recherche Scientifique en Afrique Centrale (IRSAC), and the preliminary epicenters of the U.S. Coast and Geodetic Survey. The best located epicenters in this figure may be 10 to 20 km in error. Depths are poorly known, but all events appear to be shallow (<70 km).

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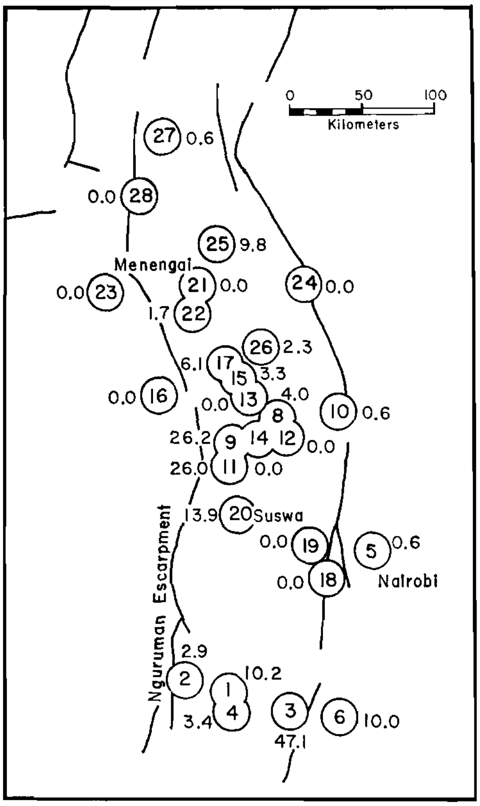

Figure 1. Map of the major scarps in the Eastern Rift of Kenya showing the location of the 28 recording sites occupied in this study. Decimal numbers represent the average number of events per day greater than 2 mm at 30-dB attenuation and within 20 km of the site.

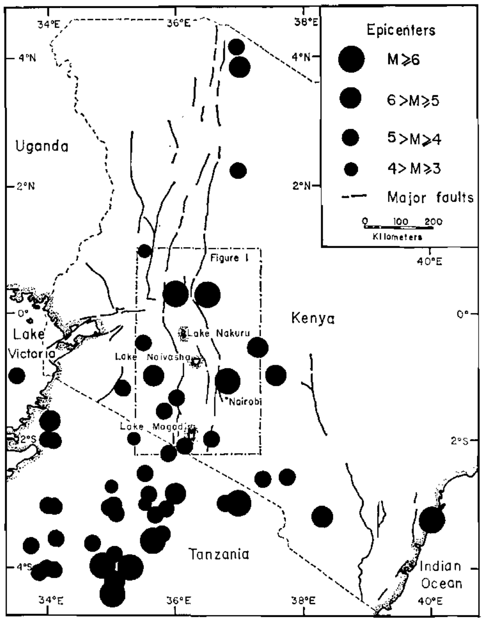

Figure 2. Map of the historic seismicity of Kenya from sources described in the text. The rectangle in the center shows the location of Figure 1. Earthquakes of greater magnitude are plotted with larger circles.

There is a general decrease in seismic activity northward from the Tanzania border. Many of the smaller events were located only by the IRSAC network in the Republic of Congo. Hence the northward decrease of activity may be due in part to the greater distance from the seismic stations. The same decrease, however, is reflected in the microearthquake data (Fig. 1). The larger earthquakes are not confined to the rift but scatter about it. Sykes and Landisman (1964) and De Bremaecker (1959) have demonstrated that this scatter is real and is not completely caused by poor epicentral locations. Sutton and Berg (1958) were able to relate certain larger earthquakes to faulting in the Western Rift by intensity studies. De Bremaecker (1959) concluded that most of the earthquakes in the Western Rift were on the faults bordering the rift. In the Eastern Rift, however, there is no clear clustering of the large events near faults, volcanoes, or other geologic features. The microearthquakes in our study are more numerous in the center of the valley. They seem confined primarily to the rift. Nevertheless, not enough sites were occupied outside of the rift to clearly define this trend.

DISCUSSION OF DATA

Faulting

The largest number of microearthquakes, 47.1 events per day, were recorded at site 3 at the base of a 30-m scarp on the eastern side of the rift valley near the southern border of Kenya. The events generally had an S-P time of less than 0.2 second and were therefore within 2 km of the instrument. The faults here are in Pliocene to Pleistocene lava flows and are typical of the so-called grid faults cutting the floor of the rift valley. These faults strike predominantly north-south but in many areas are cut obliquely by minor faults. They are thought to have formed in the lower middle Pleistocene (Matheson, 1966; Baker, 1958). There is evidence of rejuvenation of these faults in the upper Pleistocene Olorgesaile Lake Beds, 40 km to the north-northwest. The most recent

TABLE 1. RECORDING SITES OCCUPIED WITH A PORTABLE SEISMOGRAPH IN KENYA LISTING THE NUMBERS OF MICROEARTHQUAKES RECORDED AND THE LOCATION, GAIN, AND LENGTH OF TIME OF RECORDING

Station	Events per day amp ≧ 2 mm @30dB S − P ≤ 2.5	S − P > 2.5	Events recorded	Hours of noise-free recording	Attenuation	Lat	Long E.
1	10.2	2.7	58	54.33	30	1.88 S.	36.29
2	2.9	3.2	46	66.45	24	1.81 S.	36.07
3	47.1	4.9	192	45.41	30	1.91 S.	36.50
4	3.4	0.0	11	11.62	30	1.89 S.	36.30
5	0.6	1.2	3	40.43	42	1.27 S.	36.80
6	10.0	2.9	18	33.58	48	1.93 S.	36.69
7	..	..	3	0.0	48	1.85 S.	36.78
8	4.0	0.0	4	23.77	48	0.77 S.	36.40
9	26.2	7.1	15	10.10	36	0.87 S.	36.25
10	0.6	0.6	2	34.71	42	0.72 S.	36.64
11	26.0	3.7	60	45.28	36	0.88 S.	36.25
12	0.0	0.0	0	11.60	42	0.78 S.	36.41
13	0.0	1.3	1	18.21	48	0.63 S.	36.27
14	0.0	0.0	0	12.43	42	0.83 S.	36.34
15	3.3	2.0	9	35.31	36	0.61 S.	36.26
16	0.0	0.6	4	42.69	36	0.67 S.	35.93
17	6.1	1.6	6	15.73	36	0.55 S.	36.19
18	0.0	0.7	3	34.85	36	1.38 S.	36.63
19	0.0	0.0	0	23.85	36	1.25 S.	36.55
20	13.9	1.4	24	36.28	36	1.14 S.	36.27
21	0.0	0.0	0	8.55	48	0.23 S.	36.08
22	1.7	0.7	73	70.46	18	0.35 S.	36.06
23	0.0	0.0	2	13.12	36	0.26 S.	35.72
24	0.0	0.0	0	44.41	36	0.22 S.	36.50
25	9.8	0.0	5	7.36	42	0.05 S.	36.15
26	2.3	0.0	3	12.65	36	0.46 S.	36.35
27	0.6	1.1	6	42.03	30	0.35 N.	35.93
28	0.0	1.8	7	26.97	36	0.13 N.	35.85

earthquake in Figure 2 from the region of this survey was a magnitude 4.5 event in 1962 near site 3.

Significant numbers of microearthquakes near the scarps of grid faults were found at five other sites: (1) within 4 km of site 25, 35 km northeast of Nakuru, (2) less than 3 km from site 22 on the western shore of Lake Nakuru, (3) near site 26, 30 km east of the Nakuru, (4) within a few kilometers of sites 1 and 4 on fault blocks near the eastern shore of Lake Magadi, (5) within 3 km of site 17 northwest of Lake Naivasha. Thompson and Dodson (1963) cite geologic evidence near this last site for the most recent faulting, latest Pleistocene, in the whole Naivasha region.

At site 2 near the base of the Nguruman escarpment, which forms the western wall of the rift valley, and at site 6 near the eastern edge of the valley, several events per day within a few kilometers were recorded. According to Baker (1958), motion on the Nguruman fault began with about 1000 m of throw in the middle to lower Tertiary. There is some evidence of later movement at the end of the Tertiary or early Pleistocene. Less vertical motion has occurred on the eastern border faults, which were formed later in the Tertiary (Matheson, 1966).

Activity was very low at sites 10, 18, 24, and 28 on the border faults and sites 5, 16, and 23 near the border faults. The only sites with much activity on or near border faults were in the southern part of the survey area where the over-all activity was high anyway. Sites 19 and 27 on grid faults also had little activity. Thus microearthquake activity was found near many but not all faults in this region. The grid faults were more active than the border faults. One might reasonably expect that the areas of seismic activity would shift in time. Similar microearthquake surveys run regularly should allow one to map these changes. Rejuvenated or continuing motion does seem to be taking place even on faults first formed in the early Tertiary.

Geothermal Activity

The second-highest seismic activity, 26.2 events per day, was recorded at sites 9 and 11 near the numerous steam jets south of Lake Naivasha. While this area was the one place in the region covered by this paper considered to have steam of commercial value, attempts at development failed. A temperature of 177° C was suddenly reached in a drill hole at 936-m depth (Thompson and Dodson, 1963). Sites 1 and 4, near the hot springs at Magadi and near grid faults, show modest activity, as does site 15 near steam jets north of Lake Naivasha. In Iceland, microearthquakes were found to be related to some major thermal areas (Ward and others, 1969). These areas were more active than the jets in Kenya, however. They had subsurface temperatures on the order of 230° C and pressures up to 17 bars. This is undoubtedly related to the far greater precipitation in Iceland. As in Iceland, not all geothermal areas had microearthquakes at the time of the survey. Fracturing related to the microearthquakes might increase the rock permeability and thus promote water circulation and allow the steam and hot water to reach the surface. Thermal vents have been observed to open up along faults formed during some earthquakes in Iceland.

Volcanoes

The third most active microearthquake area was near site 20 on the western flank of Suswa, which last erupted about a century ago (McCall and Bristow, 1965). The highest microearthquake activity in Iceland was similarly found to be associated with a recently dormant volcano (Ward and others, 1969). This survey shows that Suswa is not extinct. No activity was recorded near Menengai Caldera (site 21), which also has not been active for a century or so (McCall, 1957). Activity at site 8 may be related to the old crater on the eastern shore of Lake Naivasha, but this should be viewed with caution. It also could be related to the fact that the level of Lake Naivasha has steadily declined 15 m since 1895.

CONCLUSIONS

The most important conclusions of this work are:

(1) High-gain portable seismographs moved every few days can be used effectively to explore the relation of seismicity to geologic features.

(2) The grid faults seem more active than the border faults of the rift valley.

(3) The volcano Suswa is not extinct.

(4) Microearthquakes are found near some steam jets and hot springs.

(5) Microearthquakes recorded near many faults, some of which formed in the early Tertiary, show that these fractures are presently active.

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