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A brief petrographic study of graphite ore from the Moyale area, southern Ethiopia.

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REPORT

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A brief petrographic study of graphite ore from the Moyale area, southern Ethiopia.

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Summary:

This report describes the petrography of the graphite ore from the Moyale graphite deposit in southern Ethiopia. The method for the image-processing of thin sections is described. Eight thin sections were available and the average values of the following parameters are:

Area percent graphite = 7.9 %
Size of graphite grains = 0.0361 mm^2 (range 1.383-0.004 mm^2)
Length of longest axis of graphite grains = 0.407 mm (range 3.83-0.08mm)
Length of shortest axis of graphite grains = 0.155 mm (range 1.93-0.02mm)

This values must be regarded as maximum values and it is suggested that these measurements should be repeated with a larger number of thin sections before any beneficiation tests of the graphite ore are performed.

Keywords: Industrial minerals	Africa	Ethiopia
Graphite	Image-processing	

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INTRODUCTION

This report is based on a petrographical study of some thin sections collected by I Lindahl in May 1996. The area was visited by the author in November 1996 together with Said Mohammed and Wubie Reta. Reta was the responsible field geologist.

The Moyale graphite deposit is situated about 5-6 km east of the town Moyale at the border to Kenya in southernmost Ethiopia, 3°33'20" N and 39°00'13" E. The area has been investigated both by a regional mapping group and during the last years by industrial mineral geologists from EIGS.

The purpose of this report is to give a brief petrographic evaluation of the graphite ore and to use image processing to determine the mode and grain-size distribution of the graphite minerals from a set of selected thin sections. Geological and geophysical maps and earlier geological reports have not been available during the compilation of this report. Geologists from EIGS currently work with a compilation of the geological and chemical data from this deposit.

GEOLOGICAL SETTING

The area is partly covered, with 1 to 2 metres with overburden and is vegetated with small bushes and trees (Fig. 1 & 2).

The rocks in this study area comprise , quartz-mica schists, quartzites and graphite schists which are intruded by several generations of syntectonic granitic and pegmatitic veins and dykes. (Fig. 3.) The rocks have been deformed both before and after the granitic intrusions. The degree of metamorphism of the graphite bearing rock is equal to middle/upper greenschist facies.

The area with graphite mineralization is several km long and several hundred metres wide. In this area numerous smaller and larger lenses of graphite schist occur. These were located by detailed ground geophysical surveying followed by systematic trenching and sampling (Fig. 4 & 5).

The graphite ore

The graphite ore is a graphite bearing quartz-feldspar-mica schist, often strongly altered and kaolinitized. The graphite is are well crystallized and flaky and is oriented parallel to the foliation in the graphite schist. In hand specimen the graphite schist gives the impression of being of good quality and relatively coarse flake size.

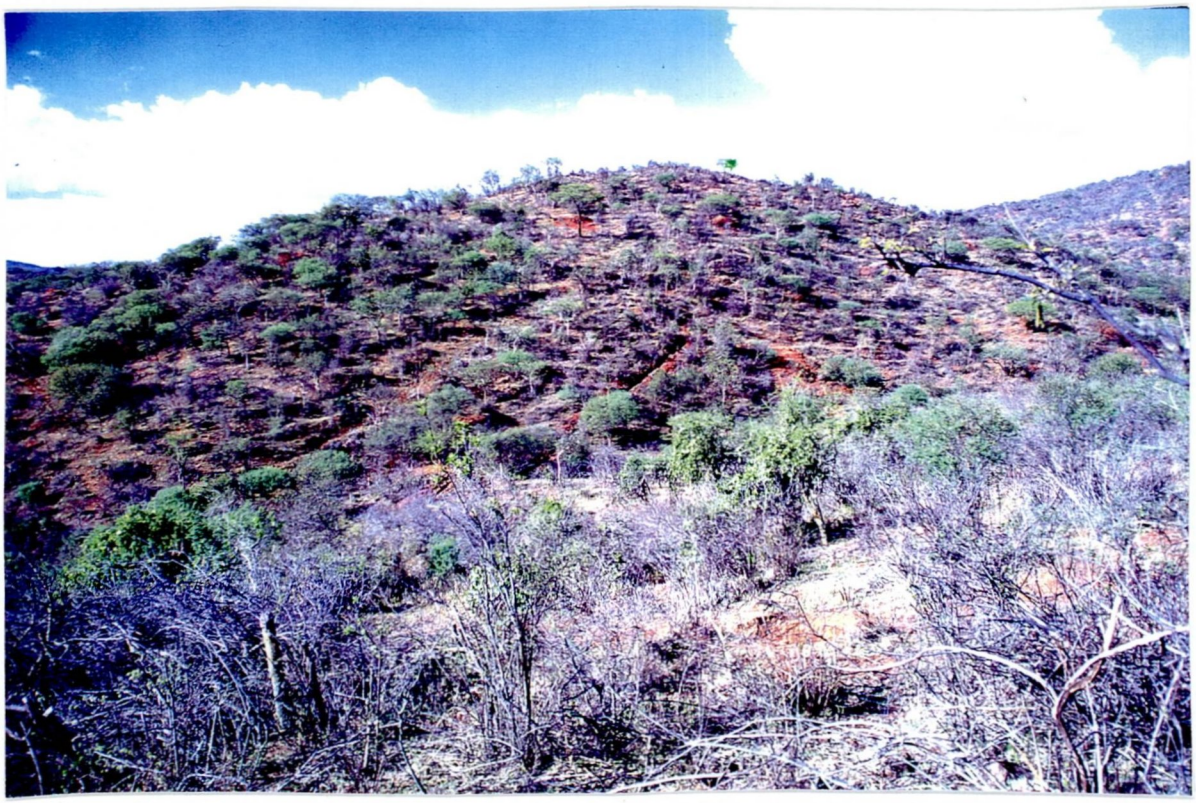

Figure 1 The landscape at the Moyale graphite area

Figure 2 The landscape at the Moyale graphite area

Figure 3 Amphibolite intruded by numerous granitic veins, country rock to the graphite schists

Figure 4 Trenching of the graphite-bearing schist

Figure 5 Trenching of the graphite-bearing schist

Image processing of thin sections

Eight different thin sections from the Moyale deposits where studied with the purpose of determining the volume percentage of graphite together with the grain size and morphological parameters of individual graphite grains (longest/shortest axis, max. and min. grain size).

First I will describe the process of acquisition, processing and calculation of digital thin section images, using one thin section as an example. Second I will discuss the results from all the studied thin sections.

The equipment used was the Kontron KS300 image processing software connected to a Olympus BM 60 microscope with a video camera. The process is as follows:

An image of a thin section is digitised with this equipment (Fig. 6). The colours in such an image are divided in such a way that black minerals are enhanced. The result is a binary image only in black and white where all the initially black minerals are shown white (Fig 7.). This image is then processed so that every object smaller than a selected boundary value are eliminated and black areas within larger white objects are filled. The result (Fig. 8) is an image where the white areas as correspond as close possible to the graphite grains in the initial image.

The program can then calculate the percentage of white in relation to black, which again approximates the percentage of graphite and a set of morphological parameters of each individual graphite grain. Several approximations are done during this process, however the results are far more accurate than would be possible by a manual measurement of the same parameters. Because the thin section was studied in transmitted light the area percentage and size of graphite are overestimated.

The calculations show that in this example the area percentage of graphite is 13.9 %. The calculated values of the longest and shortest axis and the area each individual graphite grain, that is every white object in Fig. 8, is given in Table 1 below. In this example the average size of the graphite grains is 66465 micron^2 . The average values of the longest and shortest mineral axes are 488.9 and 196.2 micron respectively. During sieving processes the shortest mineral axis will in general be regarded as the maximum size that passes through a sieve.

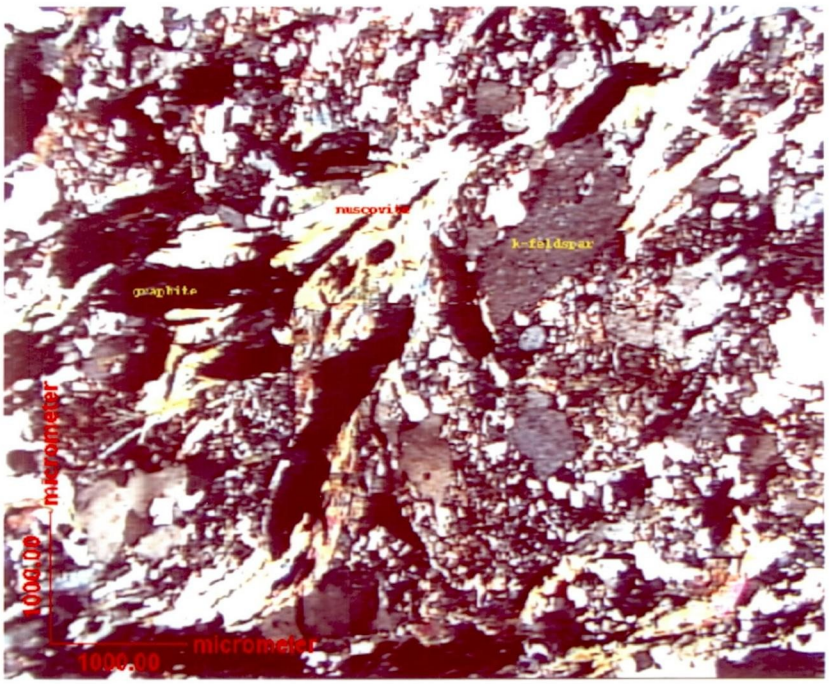

Figure 6 Picture of thin section used in example

Figure 7 Binary image, with opaque phases of fig 6 is shown in white

Figure 8 Processed binary image where small objects are eliminated

Table 1 Longest, shortest axis and area of individual graphite grains from fig. 8

FERETMIN (micron)	FERETMAX (micron)	AREA (micron^2)	
26.6	219.4	4480.8	
85.2	209.2	9932.4	
118.4	428.5	31813.6	
76.0	148.9	4704.8	
363.0	488.0	28453.0	
66.1	374.8	9484.3	
367.7	614.9	118367.6	
96.9	206.4	11202.0	
496.2	736.8	211194.6	
82.3	142.5	6945.2	
668.9	1108.4	214704.6	
168.8	258.7	26063.3	
415.9	843.6	158545.3	
84.3	524.3	18670.0	
67.2	181.8	5451.6	
176.7	247.8	11650.1	
62.0	337.7	8140.1	
101.7	525.5	22926.7	
246.3	396.7	35697.0	
44.9	184.4	4480.8	
141.1	252.0	24495.0	
65.7	156.6	4182.1	
61.8	135.1	5526.3	
1786.5	2391.1	1065233.3	
149.5	283.5	14189.2	
344.5	599.6	94918.1	
369.1	737.7	145924.4	
288.3	1096.3	160487.0	
363.8	617.2	116575.2	
70.1	152.7	4331.4	
246.7	570.8	28602.4	
62.0	248.7	5227.6	
87.0	167.4	5152.9	
165.6	284.0	16205.5	
61.7	206.4	6198.4	
84.1	192.5	6123.8	
101.3	153.2	4928.9	
141.3	232.4	11351.3	
97.4	168.9	3883.4	
113.9	174.4	7617.3	
42.2	207.9	4555.5	
548.3	2182.2	525223.3	
318.2	1109.3	108659.2	
357.2	464.1	77891.1	
108.9	183.1	8065.4	
44.3	221.0	6646.5	
167.8	515.1	44882.6	
81.1	159.6	8662.9	
74.5	154.4	5377.0	
60.4	206.4	5899.7	
216.6	531.2	34278.1	
45.2	217.1	4704.8	
42.2	309.9	9335.0	
78.9	190.8	6049.1	
79.7	271.3	10007.1	
79.7	246.2	10007.1	
378.8	945.2	170419.4	
62.0	142.1	5078.2	
62.0	152.9	4555.5	
79.7	170.7	4630.2	
106.4	273.0	14861.3	
374.6	998.1	130316.3	
336.3	3949.4	313132.6	
196.2	488.9	66465.1	Average value
1786.5	3949.4	1065233.3	Max value
26.6	135.1	3883.4	Min value

RESULTS

The process described above was repeated for all the 8 thin sections available in this study and the average and max./min values of the measured parameters were calculated. The results are given in Table 2. The average volume percentage of graphite was calculated to be 7.9 %

Table 2 Statistical data for selected morphological features of Moyale graphite

	AREA (micron^2)	AREA (mm^2)	PERIM (micron)	FERETMIN micron	FERETMAX (micron)	ELLIPSEA (micron)	ELLIPSEB (micron)
Average	36147.8	0.036	1471.9	155.8	407.0	172.4	57.8
Max	1382548.0	1.383	19290.7	1982.3	3836.5	1919.8	518.7
Min	3808.7	0.004	267.4	17.7	85.9	38.0	5.5

Explanation: Area = area of grains, PERIM = length of grain perimeter, FERETMIN = length of shortest axis of grain, FERETMAX = length of longest axis of grain, ELLIPSEA = length of longest axis of a theoretical ellipse surrounding the grain, ELLIPSEB = length of shortest axis of a theoretical ellipse surrounding the grain..

A plot of the shortest versus the longest axis of measured graphite grains is shown in Fig. 9

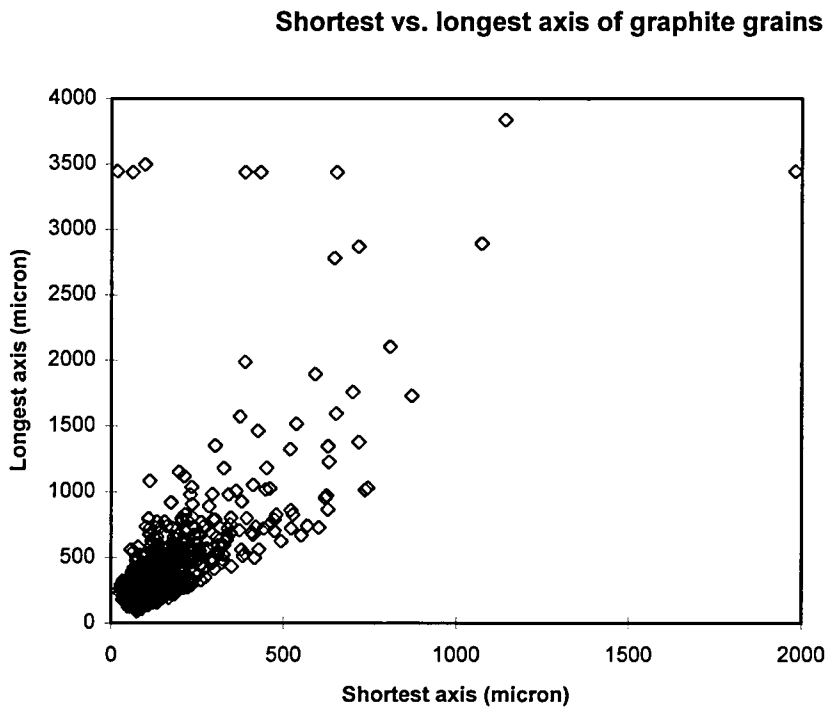

Figure 9 Plot of shortest versus longest axis in graphite grains

DISCUSSION AND CONCLUSIONS

The calculations presented above are representative of the Moyale graphite ore, only if the following assumptions and approximations are done:

1) The available thin sections are representative for the graphite ore both for the percentage of graphite in the rock and for the distribution of the graphite grains in the samples and thin sections.
2) The graphite is the dominant opaque mineral in the ore, this concur with the observations in the thin sections.
3) The digital processing of the images, for instance the eliminating and filling of small objects does not significantly change the percentage of graphite minerals with respect to the gangue minerals.

To use the above calculations to plan and design grinding and graphite beneficiation experiments, the values of grain size (area in table 2) should be regarded as maximum values, because the area of opaque minerals is overestimated when studied in transmitted light.. To what degree this would influence the present results is not known. However the present study can be repeated with a larger number of thin sections and thus be more representative.

Based on the available material, the following average parameters characterise the Moyale graphite ore:

- Average area percentage of graphite = 7.9 %
- Average size of graphite grains = 36147 micon^2
- Average length of longest axis of graphite grains = 407 micron
- Average length of shortest axis of graphite grains = 155 micron

This exercise should be repeated with a larger number of thin sections before any graphite beneficiation tests are done.

A total evaluation of the Moyale graphite deposits can be done when the geological and geophysical maps are compiled and chemical analyses of trench samples are available.