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# PETROGRAPHY OF THE SUFAYA DISTRICT IN NORTH-EAST SUDAN

*With 1 Textfigure*

The area of Sufaya, North-East Sudan, is in its greater part built up of reddish syenites and granites. They are penetrated by younger differentiates, aplites and lamprophyres and still much younger extrusive rocks, different kinds of trachytes and rhyolites. The extrusive rocks are accompanied by large quantities of tuffs. There also occur contact metamorphic marbles. Ore deposits of magnetite and martite are in connection with a latemagmatic intrusive phase and genetically probably contemporaneous with aplites and lamprophyres.

## INTRODUCTION

The area of Sufaya, province Kassala – NE Sudan – is situated in the big mountain chain which begins in Northern Egypt extending to Eritrea, where it enters in the old crystallinic schield of Central Africa. This mountain chain, about 150 km wide, runs approximately parallel to the western coast of the Red Sea. Sufaya, belonging to the great Nubian Desert, is situated somehow in the centre of that chain, about 220 km north-northwest of Port Sudan and almost 100 km from the Red Sea coast.

Field explorations were performed in three small areas (together about 10 $km^2$) completely separated from each other: Mafdeib, Aguissan and Ankura. These areas are of especial interest by their iron ore deposists.

Our work proceeded without having any special knowledge because no geological or petrographical data had existed in the Sufaya region. Two geological books about Africa (Behrend 1942/3, Krenkel 1938) do not mention the eruptive rocks of Sufaya.

The above-mentioned mountain chain is built up in its central part of metamorphic, high-grade crystallin schists penetrated by large mass of different igneous rocks. On its east side there are low-grade schists, and near the Red coast steep layers of pelitic and psamitic sediments are to be found.

The Sufaya region, a characteristic rocky desert, is very interesting as to its morphology. Several hundred metres high hills built up of igneous rocks protrude from the plain sand drifts mixed with smaller or larger rock fragments. This sand and rock fragments thank their origin to the intensive action of insolation and mechanical desintegration of igneous rocks. Owing to a very poor rainfall the atmospheric chemical decomposition of these rocks is reduced to a minimum.

The investigated rocks of the Sufaya district are divided into four groups:

1. Intrusive igneous rocks: syenites and granites.
2. Hypabyssal igneous rocks: aplites, pegmatites and lamprophyres (aschistes and diaschistes).
3. Extrusive rocks: trachytes, rhyolites and their tuffs.
4. Contact-metamorphic rocks: different kinds of marbles.

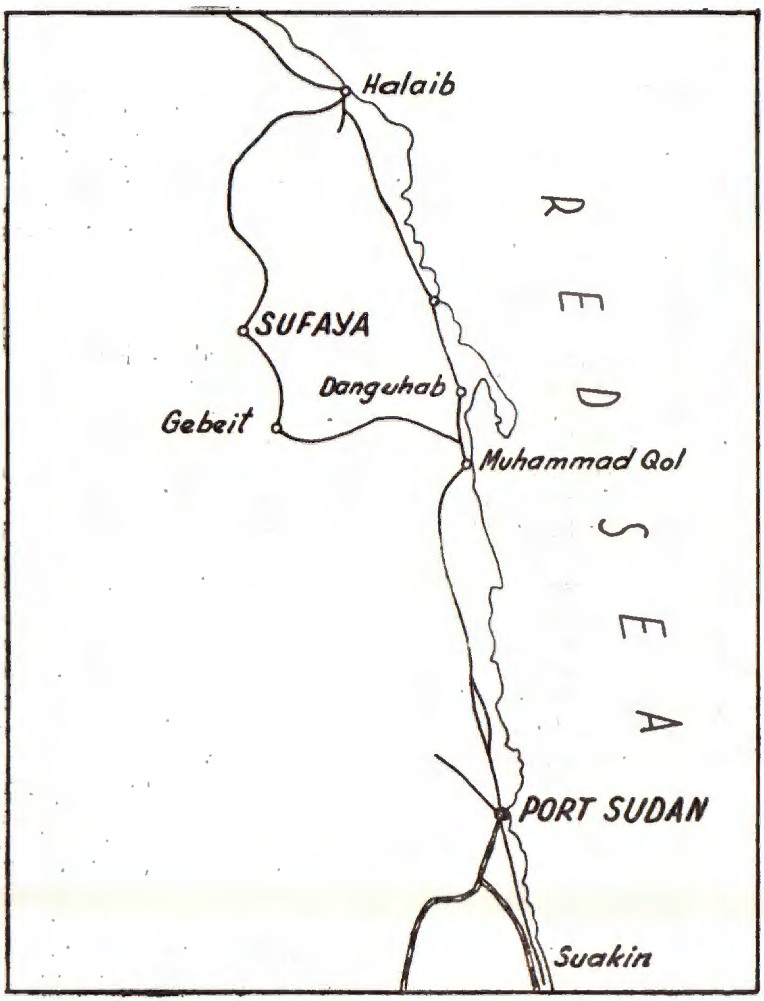


Fig. 1. Geographical situation of Sufaya
*Sl. 1. Geografski položaj Sufaye*

Within the mapped area the absence of sediments rendered it impossible for us to find any sign of the geological age of the intrusive rocks, or individual extrusive rocks, respectively. We can say, however, according to the existing indications, that syenites and granites are the oldest rocks here, which during the Cenozoic were several times penetrated by different extrusive rocks. Among the extrusives the dark and fine-grained trachytes are probably the oldest, and the red microcrystalline and porphyritic rhyolites are of relative younger extrusion.

The youngest intrusive differentiates are aplites, pegmatites and lamprophyres.

All these igneous rocks belong to the same magmatic province.

(Note: All the chemical analyses are made by M. Tajder with assistence of V. Marci and D. Sarvan).

## I. INTRUSIVE IGNEOUS ROCKS: SYENITES AND GRANITES

The terrain is built up predominantly of reddish syenites and granites. The size of the grains of these rocks is very variable; some of them display such coarse grains as to resemble pegmatites.

Megascopically noticeable differences appear also in their texture. The coarse-grained kinds are of allotriomorphic granular texture, which in the more fine-grained rocks become hypidiomorphic granular. Some rocks display a porphyroid texture with larger idiomorphic feldspars and with remaining smaller hypidiomorphic – in some places more or less idiomorphic – feldspars. In the fine-grained varieties from this texture developed the rare trachytoid granular texture. These two last textures pass into an interesting, almost panidiomorphic, texture.

These prevailingly reddish, differently hued rocks thank their colour to the reddish fedspars, which in turn become red due to the finely dispersed hematite. White syenites and granites were encountered on the Ankura Hill.

According to their mineral composition these are leucocratic rocks composed mainly of feldspars. The feldspars are in greater part alkaline: microcline, microcline-perthite and natron-orthoclase. Acid plagioclases occur in smaller quantities. The ratio between the acid plagioclase and the alkali feldspars varies in different places, so that some of these rocks approach the monzonite-adamellite series, thanks to a greater contents in plagioclase. It is very significant that feldspars are in their greater part kaolinized; therefore it is very difficult to make an exact determination of these minerals, and most often this is quite impossible.

In these rocks quartz occurs almost regularly. Usually it is not represented in large quantities, but in some specimens there is as much quartz as to make transitional types into granites. Melanocratic minerals occur but in very small amounts, and we can say that predominantly they do not occur at all. Hornblende is the most frequently encountered ferromagnesian mineral. Of accessory minerals there occur apatite, magnetite, titanite, ilmenite and hematite, and of secondary minerals kaolin and calcite.

Owing to their coarse-granular texture and very hot dry climate the rocks are rather crushable on the surface.

As an example we took for a detail study a syenite from Aguissan. The specimen of this rock was taken in the vicinity of the ore deposit. It belongs to the coarse-grained variety; its colour is reddish. Larger cleavages of reddish feldspars are noticeable megascopically. The dark hornblende grains are grouped together.

Under the microscope the rock displays an allotriomorphic granular texture. It is composed of feldspars and a small amount of amphibole. As accessory minerals there occur titanite, hematite, apatite, and as secondary mineral kaoline. Calcite and quarz are probably the primary minerals.

Feldspars are natron-orthoclase, microcline and microperthite, and less acid plagioclase (oligoclase). In alkali feldspars twins appear very rarely, and then only as Carlsbad twins. Microperthites can be distinguished thanks to the aboundant separated albite lamellaes. The oligoclase are characterized by thin polysynthetic twins. All the feldspars had undergone intensive kaolinization.

The chemical analysis shows the following composition:

| | |
|---|---|
| $SiO_2$ | 63,64 |
| $TiO_2$ | 0,75 |
| $Al_2O_3$ | 16,34 |
| $Fe_2O_3$ | 3,89 |
| FeO | 0,28 |
| MnO | 0,02 |
| MgO | 0,41 |
| CaO | 1,12 |
| $Na_2O$ | 7,20 |
| $K_2O$ | 4,27 |
| $P_2O_5$ | 0,35 |
| loss of ign. | 1,45 |
| $H_2O-$ | 1,10 |
| | 99,82 |

The CIPW Norm:

| | | | |
|---|---|---|---|
| Q | 4,2 | Q | 4,2 |
| or | 25,6 | | |
| ab | 61,8 | F | 88,5 |
| an | 1,1 | | |
| di | 0,7 | P | 1,4 |
| hy | 0,7 | | |
| il | 0,6 | | |
| tn | 1,0 | M | 6,3 |
| hm | 3,9 | | |
| ap | 0,8 | | |

Magmatic parameter: I.5.2.4

Niggli Values:

| | | | |
|---|---|---|---|
| si | 259 | | |
| al | 40,5 | k | 0,28 |
| fm | 15,5 | mg | 0,16 |
| c | 4,5 | | |
| alk | 39,5 | qz = | +1 |

Magma type: Nordmarkitic

Knowing the results of the microscopic studies, the norm can indicate the approximative mineral composition: about 90% feldspars (natron-orthoclase, microcline, microperthite, oligoclase), about 2% hornblende, and about 8% accessory minerals.

According to the mineral composition the rock belongs to the group of syenites, and owing to the higher contents in natrium it corresponds to sodaclase syenite and nordmarkite.

The textural varieties in these rocks, from those coarse-grained to porphyroid and to the trachytoid granular, point to the fact that these are rocks belonging to the marginal facies, closer to the surface, where during the crystallization a greater number of volatile components had accumulated. At lower temperatures these volatile components provoked an intensive kaolinization of feldspars.

## II. HYPABYSSAL IGNEOUS ROCKS

### *A. Aplites*

Within the area of the above-mentioned intrusives there exists a vein facies, i. e. rocks which occur as 1 m-thick veins or smaller masses. They are usually of saccharoidal texture, rarely porphyroid. Their mineral composition is alkali feldspars (like in syenites), quartz and biotite. It is beyond doubt that these aplites, granite-aplites are in fact a younger and therefore a more acid differenciate of the same intrusion.

### *B. Diorite-lamprophyres*

In the closest vicinity of the Mafdeib, Aguissan and Ankura ore deposits small masses of diorite-lamprophyres were found. A larger elongated body exists northwest of the Ankura ore deposit, extending almost parallel with the Ankura ore occurrence.

The colour of these rocks varies from grey to dark grey to black. The rocks are homogeneous, their structure is massive, apparently they are fresh, very hard and tough. Within the above-mentioned larger elongated body the gradual transition from those light coloured to the black types can be followed well, thanks to changes in the ratio between the colourless and coloured constituents. The variation in size of the mineral grains can also be noticed – their textures vary from the fine-grained to medium- and coarse-grained. As a particular appearance the dark aggregate occur as 1 m-thick veins in which the uralitized pyroxenes and hornblende reach even ten centimetres in size. These are the true holomelanocratic pegmatitic types.

All these quantitative mineral variations, the variations in size of the mineral constituents and variations in texture, point to the fact that in this relatively small body the physico-chemical conditions had been changing frequently at the time when the magma was in the phase of crystallization. This changes gave origin to the related, but according to their texture and ratio of constituents, different types of rocks. Such crystallization conditions and differences in rock types are usually encountered along the borders of larger magmatic (intrusive) rock complexes.

These are, accordingly, the hypabyssal or veiny types of rocks, in this case diaschistic, which developed undoubtedly during a posterior solidification of a larger magmatic intrusion.

The microscopicaly analysed specimens display a fine- to medium-grained hypidiomophic texture. The texture of some fine-grained specimens is almost subophitic, very similar to that of diabase. The plagioclase developed here as hypidiomorphic long lathes, partialy intersecting each other. The remaining interstices are filled with other mineral constituents, which here and there only developed in idiomorphic forms.

The main mineral constituents are plagioclase. The examination on universal stage showed that they belong to andesine or to a somewhat more acid labradorite. All of them are crystals with lath habit, the edges of which are very often corroded. The plagioclases occur as polysynthetic twins, often clearly with zonal structure, which, is the witness of sudden changes which took place during the crystallization. They display almost always as if they were caught by different processes of alterations, predominantly by the process of kaolinization. Therefore the plagioclases are turbid, full of very thin products of alterations, therefore rather unsuitable for precise microscopic studies.

In some specimens there occurs orthoclase, but in much smaller quantities, and also quartz. Both of them fill out the interstices among the plagioclase grains.

The next main constituent is green hornblende occurring in the form of larger or smaller, sometimes slightly elongated and sometimes irregularly shaped grains. These amphiboles occur partly as needle-like and radiolitic aggregates. Very rarely in the cores of such aggregates the relics of almost colourless monoclinic pyroxene can be found. We can conclude, therefore, that the aggregates of the uralitic amphibole developed as a deuteric product of the alteration of pyroxene into amphibole. The amphibole is sometimes altered, and the most frequently encountered product of metamorphosis is green chlorite. The amount of amphibole varies from 20 to 50% of the rock, sometimes even more.

Among the femic constituents here and there occurs biotite, but in small amounts.

As accessory minerals there occur allways magnetite (1–10%) and apatite. Secondary mineral are uralite, epidote, chlorite, kaolinite and calcite.

Besides the types just mentioned there are rocks containing large amphiboles within a granular ground mass. Such varieties of diorite-lamprophyres could be named porphyroid lamprophyres.

The chemical analysis of one diorite-lamprophyre is:

| | |
|---|---|
| $SiO_2$ | 52,53 |
| $TiO_2$ | 0,74 |
| $Al_2O_3$ | 16,96 |
| $Fe_2O_3$ | 6,04 |
| FeO | 3,21 |
| MnO | 0,03 |
| MgO | 5,16 |
| CaO | 6,20 |
| $Na_2O$ | 4,89 |
| $K_2O$ | 1,85 |
| $P_2O_5$ | 0,48 |
| $H_2O+$ | 2,51 |
| $H_2O-$ | 0,14 |
| | 100,44 |

CIPW Norm:

| | | | |
|---|---|---|---|
| or | 10,9 | | |
| ab | 41,4 | F | 71,1 |
| an | 18,8 | | |
| di | 7,0 | P | 13,4 |
| hy | 6,4 | | |
| ol | 2,3 | O | 2,3 |
| mt | 8,3 | | |
| hm | 0,2 | M | 10,0 |
| il | 1,5 | | |
| ap | 1,1 | A | 1,1 |

Niggli Values:

| | | | |
|---|---|---|---|
| si | 139 | | |
| al | 26,4 | k | 0,20 |
| fm | 40,2 | mg | 0,51 |
| c | 17,7 | | |
| alk | 15,7 | qz = —24 | |

Magma type: lamprodioritic to natron-gabbroidic

## III. EXTRUSIVE ROCKS AND TUFFS

Within the explored area there are many extrusive rocks and tuffs. These extrusive rocks can be – according to their habit and relative age – divided into three groups. The oldest and most frequently encountered extrusive rocks are the dark gray cryptocrystalline rocks without any phenocryst. They are accompanied by great amounts of tuffs resembling extrusives. These rocks are penetrated by veins of younger, dense, microcrystalline extrusive rocks containing sporadical phenocrysts. Their colour varies from brown to yellow. They are jointed with the extrusives, displaying a typical porphyritic texture and containing large phenocrysts.

The dark gray cryptocrystalline extrusive rocks penetrate the intrusive rocks. In some places they build up hillocks, and in other they occur as lenses or regularly shaped veins within the intrusive rocks.

Their texture varies from cryptocrystalline to microcrystalline. A high magnification under the microscope shows that they are built of leucocratic minerals, feldspars and a litlle quartz accompanied by greater or smaller amounts of biotite. Feldspar occurs in the form of small grains or thin lathes, and biotite occurs as small and thin plates. Of accessory minerals magnetite occurs in great amounts, thus contributing, next to the mentioned texture, to the dark colour of these rocks.

The dark grey extrusive rocks are accompanied by tuffaceous materials which megascopically resemble extrusives, so that often it is very difficult to distinguish them from each other.

Under the microscope the thin section displays a clastic texture, because it is built up of crystal fragments, predominantly feldspar crystals. Sometimes the tuffaceous material can be distinguished megascopically thanks to their macro-brecciated and clastic nature.

The chemical composition of such an extrusive from Aguissan:

| | | CIPW Norm: | | | |
|---|---|---|---|---|---|
| $SiO_2$ | 57,47 | | | | |
| $TiO_2$ | 0.24 | | | | |
| $Al_2O_3$ | 18,27 | Q | 8,9 | Q | 8,9 |
| $Fe_2O_3$ | 5,13 | or | 24,2 | | |
| FeO | 2,18 | ab | 32,0 | F | 61,1 |
| MnO | 0,01 | an | 4,9 | | |
| MgO | 5,91 | C | 5,8 | C | 5,8 |
| CaO | 1,17 | en | 14,7 | P | 14,7 |
| $Na_2O$ | 3,79 | mt | 6,4 | | |
| $K_2O$ | 4,10 | hm | 0,7 | M | 8,0 |
| $P_2O_5$ | 0,15 | il | 0,5 | | |
| $H_2O+$ | 1,52 | ap | 0,4 | | |
| $H_2O-$ | 0,11 | | | Magmatic parameter: | |
| | 100,05 | | | II.4.2.3 | |

Niggli Values:

| | | | | |
|---|---|---|---|---|
| si | 175 | | | |
| al | 33,0 | k | 0,42 | |
| fm | 44,0 | | | |
| c | 4,0 | mg | 0,60 | Magma type: |
| alk | 19,0 | qz = —1 | | si – kamperitic |

Since it is impossible to determine the mineral composition by means of the microscope, the rock can be classified only through chemical analyses and the obtained norms. The silica content points out that the rock is neutral. Owing to the low content of calcium and relatively high content of alkali, the rock trends towards the group of trachytes. The calculation results: 8,9% quartz, 24,2% orthoclase (sanidine) and 36% acid oligoclase with 13,5% an. If we take that potassium feldspar contains a high content of natrium, as is usually the case, the result would be more alkali feldspar and less plagioclase (now more basic than 13,5% an). In the first case the rock might belong to the group of trachyandesites (latite), and in the second case to the group of trachytes.

The brown and yellow microcrystalline extrusive rocks occur within the extrusive rocks and their tuffs as smaller weins. They thank their colour to the oxidized and limonitized accessory minerals. They are porous, and of a microcrystalline texture with feldspar lathes in the groundmass. They usually do not contain any phenocryst. Here also the leucocratic minerals prevail.

There follows the chemical analysis of a red-brown extrusive rock from Mafdeib:

| | |
|---|---|
| $SiO_2$ | 63,64 |
| $TiO_2$ | tr. |
| $Al_2O_3$ | 12,79 |
| $Fe_2O_3$ | 6,22 |
| FeO | 1,07 |
| MnO | 0,05 |
| MgO | 1,20 |
| CaO | 3,63 |
| $Na_2O$ | 0,36 |
| $K_2O$ | 4,64 |
| $P_2O_5$ | 0,12 |
| loss of ign. | 6,20 |
| $H_2O-$ | 0,27 |
| | 100,18 |

CIPW Norm:

| | | | |
|---|---|---|---|
| Q | 36,9 | Q | 36,9 |
| or | 29,3 | | |
| ab | 3,2 | F | 51,0 |
| an | 18,5 | | |
| C | 0,9 | C | 0,9 |
| en | 3,2 | P | 3,2 |
| mt | 3,9 | | |
| hm | 4,0 | M | 8,2 |
| ap | 0,3 | | |

Magmatic parameter: I.3.3.1

Niggli Values:

| | | | |
|---|---|---|---|
| si | 287 | k | 0,89 |
| al | 34,0 | | |
| fm | 34,0 | mg | 0,24 |
| c | 17,0 | qz | = +127 |
| alk | 15,0 | | |

Magma type: opdalitic

The loss of ignition is rather high: 6,20%. Next to water here appears the carbon dioxide, and these two components are represented cca. 50/50. The carbon dioxide and calcium give calcite. In spite of the fact that through microscopic study this mineral could not be determined, the rock when treated with HCl shows a strong reaction to carbonates.

According to the chemical composition this rock belongs to rhyolite.

The porphyritic rocks are grey or reddish, and of a more or less noticeable porphyritic texture. The phenocrysts reach up to 1 cm in size belonging always to feldspars which in their central part are fresh and along the borders red and turbid owing to alteration.

In some of these rocks the phenocrysts are plagioclase, and in others alkali feldspars. The plagioclase belong to the oligoclase, seldom acid andesines, while the alkali feldspar is sanidine. However, a determination showed that the internal reconstitution has already developed in sanidin, because the results testify to the existence of isomicrocline.

In these specimens also amphibole occurs as phenocrysts. Some of those phenocrysts are throughout altered into an aggregate of chlorite, limonite and calcite. In other specimens, in turn, amphiboles display partially a distinguishable bluish-violet colour with a corresponding pleochroism. Such a colour is usually met among alkaline amphiboles.

The groundmass is microcrystalline, composed of feldspars in the form of small lathes. It may be presumed that in the groundmass alkali feldspar – sanidin, isomicroclin respectively, are mostly represented. As accessory mineral there occurs magnetite in relatively rich quantities, and as secondary minerals there are chlorite, epidote, calcite, limonite and kaolin.

All the feldspars are highly kaolinized.

The chemical analysis of one such rock from Aguissan shows the following result:

| | | | | | |
|---|---|---|---|---|---|
| $SiO_2$ | 66,63 | | | CIPW Norm: | |
| $TiO_2$ | 0,34 | | | | |
| $Al_2O_3$ | 14,75 | Q | 15,6 | Q | 15,6 |
| $Fe_2O_3$ | 4,34 | or | 42,4 | | |
| FeO | 0,42 | ab | 31,0 | F | 76,0 |
| MnO | 0,06 | an | 2,6 | | |
| MgO | 0,39 | di | 1,7 | P | 1,9 |
| CaO | 1,15 | hy | 0,2 | | |
| $Na_2O$ | 3,67 | mt | 0,6 | | |
| $K_2O$ | 7,19 | hm | 3,9 | | |
| $P_2O_5$ | 0,16 | il | 0,6 | M | 5,4 |
| $H_2O+$ | 0,97 | ap | 0,3 | | |
| $H_2O-$ | 0,08 | | | | |
| | 100,15 | | | Magmatic parameter: I.4.1.3. | |

Niggli Values:

| | | | | |
|---|---|---|---|---|
| si | 297 | k | 0,55 | |
| al | 38,5 | | | |
| fm | 19,5 | mg | 0,14 | |
| c | 5,5 | qz = +51 | | Magma type: |
| alk | 36,5 | | | potassium nordmarkitic |

According to the mineral and chemical composition this rock belongs to rhyolites.

## IV. CONTACT MARBLES

In the area of Ancura almost parallel with the elongated zone of diorite-lamprophyres, larger carbonate rock bodies extend in the direction NO–SW. Megascopically, these are marbles, differing greatly from each other. They contain smaller or larger quantities of silicate minerals. These silicate minerals undoubtedly testify that these rocks are contact metamorphic marbles which took their origin from the contact metamorphosis of the carbonate sediments (limestones, dolomites or dolomitic limestones) under the influence of magmatic intrusion.

Their colour varies on a large scale: they occur as sugar-white rocks, as pale green, green, brown-grey, green-yellowish with dark strips, brown with green strips, dark-grey with white strips etc. Some of them are fine-grained, while others are medium- to coarse-grained rocks. Some of them close to coarse-grained calcite contain many long prismatic minerals. All these differences in colour and texture are the consequence of the difference in their mineral composition and the kind of the products of metamorphosis and weathering.

The main mineral constituent of the contact marbles is calcite. The differently sized grains are either completely irregular or of polygonal shape, so the rock has a beautiful mosaic-saccharoidal texture. Calcite is characterized by lamellar twinning.

The next mineral constituent which is also very significant in these contact marbles is olivine, i. e. forsterite. It occurs in the form of very small egg-shaped grains, but some grains of forsterite are bigger up to 1 cm in diameter. The grains are cracked which is particularly noticeable in the larger ones. When fresh, it is white. In some kinds of marbles olivine altered either partially or completely to serpentine minerals, chrysotile or antigorite, rarely to talc. These minerals are sometimes accompanied by magnetite occurring as a very fine powder. The serpentine minerals and talc are in thin sections almost colourless, but they nevertheless colour the marbles green in different hues.

The following important mineral constituent is amphibole, tremolite. Megascopically this mineral is pale green, and in thin section it appears colourless. Tremolite developed as long prismatic, asicular or fibrous crystals. Extinction angle is 17–20°.

Very rarely there occur marbles containing darker amphiboles, actinolite, then small isotropic brown-green spinel and magnetite.

Among the interesting and very rare texture the poikilitic texture is to be mentioned: the coarse calcite grains include numerous fine grains of forsterite, spinel and magnetite.

According to their mineral composition the following types of contact marbles were determined:

Contact marble with forsterite
" " " serpentine
" " " tremolite (even up to 50%)
" " " forsterite and tremolite
" " " forsterite, spinel and magnetite
" " " talc and serpentine

These contact marbles are sometimes accompanied by smaller masses and veins of brown-red ferromagnesium carbonate (iron rich breunnerite). However, the question about the origin of ferromagnesium carbonates remains open, i. e. did ferromagnesium carbonates develop simultaneously with marbles, or did iron get metasomatically in marbles from solutions in a hydrothermal phase of plutonic or volcanic magmatism?

Such a Fe-cabonate has the following chemical composition:

| | |
|---|---|
| MgO | 30,73 |
| FeO | 18,13 |
| CaO | 2,83 |
| loss of ign. | 45,59 |
| $SiO_2$ | 2,22 |
| $R_2O_3$ | 0,20 |
| $H_2O^-$ | 0,06 |
| | 99,76 |

Next to ferromagnesium carbonate here and there thin hematite veins can be found, as well as veins of coarse-grained calcite with large black amphibole, which could be connected with the pneumatolytic and hydrothermal phase of the magmatic action.

### *Petrography of the nearest area of Ore Deposits*

The Mafdeib ore deposit. The rocks of this area belong prevailingly to one special structural type of diorite which developed as a marginal facies or partially as a dike facies. This type is somewhat more basic and rich in ferromagnesian minerals. These are the diaschistic basic differentiates of a large syenite and granite intrusive complex. According to the genesis, texture and mineral composition these rocks can be classified among lamprophyres (spesartites and kersantites). Due to the tectonic pressure some rocks are brecciated, crushed or mylonitized and therefore exposed to considerable alteration.

Next the lamprophyres there are also the typical syenites.

In the ore aggregate there occur the same minerals which are found in fresh or altered diorite-lamprophyres.

The Agguissan ore deposit. The predominant rocks in that area are the leucocratic types of rocks: prevailingly granite-aplite and quartz-diorite-aplite, and more rarely alkali granite. Some of these rocks are in their greater part altered.

There are also numerous varieties. Mesocratic and melanocratic types containing larger quantities of femic minerals and resembling diorite-lamprophyres are rare. There exist transitional types between leucocratic aplitic rocks and those rich in femic minerals.

Extrusive rocks belonging to the clan of trachytes, trachyandesites and even rhyolites are not frequently encountered.

The Ankura ore deposit. The greater part od rocks of which the Ankura ore deposit is built up belongs to the fine-grained altered aplites, and to the basic diorite-lamprophyres. These last rocks rich in femic minerals (amphibole and biotite) contain great amounts of ore mineral i. e. magnetite. On other hand, in ore there appear those minerals which occur as the main constituents in the igneous rocks. However, it is very interesting that the ore often contains high concentrations of biotite, phlogopite respectively, actinolite, and in some places a lot of coarse-grained almost idiomorphic apatite. Also here there occur brecciated, crushed and altered rocks.

In conclusion we can say that the ore occurrences at Mafdeib, Agguissan and Ankura are in direct connection with the altered rocks, leucocratic granite-aplites and mesocratic diorite-lamprophyres. These rocks are undoubtedly the youngest hypabyssal differentiates of the intrusive syenite-granite complex, so that the origin of the ore occurrence could be attributed to that phase of the magmatic action. Such a conception of the genetic origin is supported by the fact that as gangue minerals only those minerals occur which are at the same time the mineral constituents of the mentioned igneous rocks, and by sporadically strong concentrations of phlogopite, actinolite and apatite, i. e. minerals which characterize a later pegmatitic and pneumatolytic phase of intrusive magmatism. Hence, from the genetical point of view the origin of the iron ore, magnetite and martite, could be contemporaneous with the origin of aplites and diorite-lamprophyres.

*Received 2th November, 1963.*

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## REFERENCES

Behrend (1942/43): Afrika, III/1–3. Berlin.

Krenkel (1938): Geologie Afrikas III. (Geologie der Erde). Berlin.

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## PETROGRAFSKA GRAĐA PODRUČJA SUFAYA U SI SUDANU

Područje Sufaye u SI Sudanu nalazi se u velikom planinskom lancu koji teče paralelno zapadnoj obali Crvenog mora oko 220 km sjeverno od Port Sudana i oko 100 km udaljeno od obale Crvenog mora. To je prava kamena pustinja i geografski spada u Nubijsku pustinju. U tom području istražena je petrološka građa tri odvojena lokaliteta Mafdeib, Aguissan i Ankura, ukupne površine oko 10 km². Veći dio zauzimaju crveni intruzivi, alkalni sijeniti i graniti. Oni su probijeni mlađim ašistnim i diašistnim diferencijatima osobito aplitima i dioritlamprofirima, te mnogo mlađim efuzivima različitih vrsta trahita i riolita. Uz efuzive vezane su veće mase tufova. Na sjeverozapadnom dijelu ankurskog lokaliteta javljaju se i kontaktni mramori. U sva tri spomenuta lokaliteta nalazimo i rudne pojave magnetita i martita koje su vezane na jednu kasnomagmatsku intruzivnu fazu odnosno vjerojatno sinhrone sa aplitima i lamprofirima.

Veoma je interesantna morfologija terena. Brda eruptiva uzdižu se do kojih par stotina metara iznad zaravnjenog nanosa pijeska sa većim ili manjim krhotinama stijena. Pijesak, krhotine, pa i cijeli poligonalni i oštrobridni blokovi nastali su ekstremno snažnim insolacijskim mehaničkim trošenjem eruptiva. Kemijsko trošenje u ovom području je zbog veoma rijetkih oborina posve reducirano. Promjene u stijenama koje su često znatne, rezultat su djelovanja znatnih količina volatila u kasnomagmatskoj hidrotermalnoj fazi.

Zbog nedostatka sedimenata u istraženom području nismo naišli ni na kakove elemente na osnovi kojih bi mogli zaključiti na geološku starost intruzija i efuzija. Ima međutim, doduše krajnje nesigurnih, indicija, koje bi govorile za krednu i postkrednu starost intruzija i efuzija.

Sijeniti i graniti imaju raznoliku strukturu: od alotriomorfno zrnaste preko hipidiomorfno zrnaste ili porfiroidske do trahitoidske sitnozrnaste, a katkada i do panidiomorfne zrnaste strukture. Sudeći po strukturama stijene bi većinom pripadale jednom rubnom facijesu intruzivnog magmatskog tijela. Sijeniti i graniti izgrađeni su od alkalijskih feldspata (natronortoklasa, mikroklina i mikroklinpertita), kiselih plagioklasa i kvarca. Alkalijski feldspati redovno preovlađuju, ali s obzirom na omjer vrsta feldspata ima i prelaza prema monzonit-adamelitskoj grupi stijena. S obzirom na količinu kvarca postoje prelazi od sijenita preko kvarcsijenita do granita. Feldspati su crvene boje od fino dispergiranog hematita i katkada u značajnoj mjeri kaolinizirani. Melanokratskih minerala je malo. Najčešća je hornblenda, katkada i alkalijska. Među ostalim akcesornim mineralima zanimljivo je prisustvo kalcita.

Analiza jednog sijenita nalazi se u engleskom tekstu ovoga rada.

Kao mlađi kiseliji diferencijat iste intruzije dolazi i žilni facijes, a p l i t i, tj. sijenitapliti i granitapliti, katkada i sijenit porfiri i granitporfiri. Apliti se od sijenita i granita razlikuju svojom saharoidalnom zrnastom strukturom i redovito relativno većom količinom kvarca.

U mlađe hipoabisalne diašistne diferencijate ove intruzije ubrajamo i bazičnije d i o r i t l a m p r o f i r e. Katkada grade i tijela dužine kojih par km i širine 100 do 200 m, dakle oblika grede. To su stijene tamne boje, sive, katkada i skoro crne. Obično su sitno do srednjezrnaste hipidiomorfne strukture, ali ima i varijeteta sa strukturom nalik na ofitsku. Veličina zrna i omjer salskih i femskih minerala koleba u dosta širokim granicama. U toj masi nađu se i žile debljine kojih 1 m, monomineralne, sastavljene samo od uralitiziranih piroksena ili hornblende sa dimenzijama zrna katkada i preko 10 cm. To su već pravi holomelanokratni pegmatitoidni tipovi, pirokseniti i hornblenditi.

Pretežni dio ovih lamprofira sastavljen je od plagioklasa andezina ili kiselog labradora i zelene hornblende. Posve podređeno dolaze ortoklas i kvarc, te biotit. Ponekad ima znatnih količina uralita. Od akcesornih minerala značajniji su naročito apatit i magnetit. Magnetita ima u nekim varijetetima i preko 10%. Analiza jednog lamprofira nalazi se u engleskom dijelu teksta.

Najmlađe stijene su svakako e f u z i v i. Sa njima dolaze i veće mase tufova. Efuzivi i neki tufovi se na terenu vrlo teško razlikuju.

S obzirom na habitus, sastav i relativnu starost možemo efuzive podijeliti u tri skupine:

a) Tamnosivi kriptokristalasti i mikrokristalasti efuzivi i njihovi tufovi su najrašireniji. Nemaju jasno izražene porfirske strukture. Dolaze kao pokrovi ili kao žile ili omanja tijela u intruzivima. Zbog veoma malih dimenzija mineralnih sastojaka mineralni sastav nije se dao tačnije odrediti. Sastavljeni su od feldspata, te manje kvarca i biotita. Zbog relativno veće količine magnetita imaju tamnu boju. Prema kemijskoj analizi i odgovarajućem normativnom sastavu mogu se ovi efuzivi svrstati u t r a h i t e. Analiza jednog takvog tamnog trahita nalazi se u engleskom tekstu.

b) Tamnosive efuzive i njihove tufove na mnogim mjestima probijaju u formi manjih žila smeđasti i žuti mikrokristalni efuzivi bez porfirske strukture. Boja im potiče od oksidiranih femskih minerala. Leukokratski su, sa istim mineralnim sastavom kao trahiti, ali sa većom količinom kvarca. Pripadaju grupi r i o l i t a. Kemijska analiza jednog žutog mikrokristalnog riolita nalazi se u engleskom dijelu teksta.

c) Treću grupu efuziva čine r i o l i t i sive i crvenkastih boja sa jasnom porfirskom strukturom. Utrusci, najčešće sanidin, imaju dimenzije i do 1 cm. Katkada sadrže i malo kiselih plagioklasa, rijetko i alkalnog amfibola. Analiza jednog porfirskog riolita nalazi se u engleskom tekstu.

Na više mjesta u području Sufaye, a naročito u području lokaliteta Ankura nalaze se veće mase kontaktno metamorfnih stijena. Osobito su zastupljeni kontaktni mramori, ali ima i drugih tipova, primjerice sa granatima i piroksenima.

Značajka k o n t a k t n i h m r a m o r a je da ih ima različitih boja i habitusa. To je uvjetovano različitim silikatnim mineralima i njihovim udjelom u sastavu stijene, različitom dimenzijom sastojaka, načinom njihovog rasporeda te vrstom i količinom sekundarnih minerala. Kontaktni su mramori poput šećera bijeli, zatim nježno zelenkasti, zeleni, sivi, smeđe sivi, zelenožuti, pa pjegavi, šareni i prutasti, od sitno do krupnozrnastih. Osim kalcita u mineralnom sastavu se nalaze forsterit, tremolit, spinel, magnetit, talk, hrizotil i antigorit. Prema navedenim kontaktnim mineralima zaključujemo da su ovi mramori nastali kontaktnom metamorfozom karbonatskih sedimenata, dolomita ili dolomitskih vapnenaca, djelovanjem jedne magmatske intruzije.

Uz mramore nalazimo ponegdje i manje mase i žile crvenosmeđeg feromagnezita (brojnerita). Uz feromagnezit nađe se negdje i hematita, kalcita, krupnih crnih amfibola i drugih minerala koji ukazuju na postojanje jedne pneumatolitske faze.

U petrografskoj građi neposredne okoline rudnih tijela zastupljeni su najviše ašistni i diašistni tipovi, dakle aplitski i lamprofirski diferencijat, ali podređeno ma i drugih stijena. Ove stijene su često jako izmijenjene, uz to zbog snažnih tektonskih pokreta obično zdrobljene, brečaste, mikrobrečaste pa i milonitizirane. Među nekim stijenama ima varijeteta i sa veoma mnogo magnetita. i do 30%, pa čine gotovo prelaz u rudu. Činjenica da su rudne pojave vezane na izmijenjene aplitske i lamprofirske stijene dopušta nam da određenije zaključimo i o genezi ruda željeza. Naime, navedene stijene su nesumnjivo zadnji hipoabisalni diferencijati intruzivnog sijenit-granitskog kompleksa, pa bi u tu magmatsku fazu mogli staviti i stvaranje rudišta. U prilog pretpostavke takove geneze govori i to što među mineralima »jalovine« u rudi nalazimo samo one minerale koji dolaze kao redovni sastojci navedenih stijena, a uz to i mjestimice značajne koncentracije flogopita, aktinolita, apatita i drugih minerala koji su karakteristični za jednu kasnomagmatsku, pegmatitsku i pneumatolitsku fazu intruzivnog magmatizma. Prema tome rudni minerali magnetit i martit mogli bi biti genetski sinhroni sa aplitima i lamprofirima.

*Primljeno 2. 11. 1963.*

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