# STUDIES OF THREE ROCK SAMPLES FROM BRAZIL

By

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## PREFACE

The present work concerns petrographical and sedimentpetrographical investigations of three rock samples from Brazil, which were given to me by my teacher, Prof. Dr. C. W. Correns, from his collection.

Two of these rock samples (Chibinite and decomposed tinguaite) originate from the Serra de Poços 300 m. southeast of Pedra Balão by Poços de Caldas, the third rock sample (decomposed lava aglomeratica) originates from Laranjeiras by Poços de Caldas.

I wish to express my gratitude to my teacher, Prof. Dr. Correns for the permission of doing this work, and his zealous interest during its progress.

I sincerely thank Dr. P. Schneiderhöhn and Priv. Doz. Dr. O. Braitisch for valuable advice, Prof. Dr. S. Koritnig for the mineral comparison samples which were placed at my disposal, Prof. Dr. Wedepohl for proofreading of the manuscript, and Drs. I. Dreizler and W. Echle for practical hints and for proofreading of the original German manuscript.

### Abbreviations

a, b, c = the crystallographic axes.

x, y, z = the vibration directions of the fast, intermediate, and slow rays respectively.

△ = birefringence.

1 +, 1 — = uniaxial positive and negative respectively.

2 +, 2 — = biaxial positive and negative respectively.

l + = positive elongation (or length-slow).

l — = negative elongation (or length-fast).

// = cleavage.

## CHIBINITE

*Locality*: 300 m. southeast of Pedra Balão in the "serra de Poços" near poços de Caldas, Brazil.

## INTRODUCTION

Chibinite is an eudialyte-syenite, a type of elaeolite-syenites. (Elaeolite is the term for clouded nepheline, in which the alkali component separated as a result of slow cooling, similar to antiperthites).

Chibinite was named by RAMSAY after the Russian name of the Umptek mountains (Chibina - Tundra) on the Kola peninsula in the White Sea, where a body of this elaeolite-syenites occurs, of 1600 square kilometres area and 900 - 1000 metres thickness.

In the following the typical characteristics of chibinites or more generally of eudialyte-syenites are summarized (after ROSENBUSCH (27)):

1) Eudialyte or eucolite as a characteristic constituent.

2) The mostly greenish colors of the rock.

3) The abundance of aegirine and arfvedsonite.

4) The frequency of otherwise rare minor constituents.

In Poços de Caldas, the chibinite is accompanied by lujaurite in the form of a crescentic outcrop at the northern border of the alkaline massive of Poços de Caldas (10).

According to TRÖGER ($^{31}$), the original chibinite of the Umptek mountains (Chibina - Tundra) consists of the following minerals:

| Mineral | wt. % |
|---|---|
| Microcline-perthite ($Or_{41} . Ab_{57} . An_{02}$) | 44 |
| Nepheline | 33 |
| Aegirine | |
| Arfvedsonite ± ainigmatite ] | 20 |
| Eudialyte ± lamprophyllite | |
| Titanite ] | 3 |

*Textures and microstructures*:

The rock is holocrystalline, phaneritic (megascopically crystalline), hypidiomorphic to coarse trachytoid (trachytoid is a term applied to those igneous rocks in which the feldspars have a parallel to subparallel arrangement).

## MINERALOGY

The rock consists of the following minerals arranged according to their abundance:

(*A*) Major constituents:

(1) *Alkali feldspar*: — (K, Na) [$Al\ Si_3\ O_8$]

In the hand-specimen the mineral shows a seagreen color (pale yellowish green), with a vitreous lustre, cleavage surface has a pearly lustre.

*Color in thin section*: — Colorless, turbid.

*Form*: — The crystals are euhedral to subhedral, megascopic. They have a parallel to subparallel arrangement. They contain many inclusions of fine needles of apatite and minute crystals of zircon, which are largely oriented parallel to the cleavage traces.

*Cleavage*: — Perfect parallel to (001),
good parallel to (010).

*Relief*: — Negative relief.

$$n_z = 1.521$$

$$n_x = 1.516$$

I have used a mixture of cedaroil (n = 1.510) and eugenol (n = 1.541).

*Birefringence*: — Low, the interference colors are gray and white of the first order. The mineral is biaxial negative, with a large axial angle (about 70°).

*Optical orientation*: — The extinction angle amounts in sections parallel (001) to about 15°, measured between the traces of the cleavage (010) and the vibration direction x.

According to the preceeding, it is assumed that the mineral is microcline, although it does not show the characteristic grating (quadrille) structure.

Investigating the microclines of the eudialyte-syenites of the Lujaur-Urt mountains on the Kola peninsula W. RAMSAY and V. HACKMAN also did not find twinning in every case.

(2) *Nepheline*: — $K\ Na_3\ [Al\ Si\ O_4]_4$

Nepheline shows elaeolite character.

*Color in thin section*: — Colorless to turbid, with inclusions.

*Form*: — Nepheline occurs in euhedral crystals, which show in basal sections (0001) a hexagonal outline and in prismatic sections a rectangular outline.

*Cleavage*: — // $(10\bar{1}0)$ distinct.
// (0001) imperfect.

*Relief*: — Very low; $n_{\text{nepheline}} = n_{\text{Canada balsam}}$ .
$n_{\text{nepheline}} > n_{\text{alkali feldspar}}$ .

*Birefringence*: — Weak, the interference colors are gray of the 1st. order. Basal sections show a uniaxial negative interference figure without rings.

*Optical orientation*: — Prismatic sections show parallel extinction. Basal sections are isotropic. The traces of the cleavage $(10\bar{1}0)$ lie parallel to x.

Nepheline is here and there altered to cancrinite and hydronephelite (a variety of natrolite). Both minerals are described under the heading "secondary minerals".

(3) *Sodalite*: — $Na_8[Cl_2/(Al\,Si\,O_4)_6]$.

*Color in thin section*: — Colorless, with dark spots.

*Form*: — subhedral crystals.

*Cleavage*: — More or less distinct.

*Relief*: — Negative relief.

$n_{\text{sodalite}} \ll n_{\text{Canada balsam}}$ and $n_{\text{nepheline}}$ .
$n_{\text{sodalite}} < n_{\text{alkali feldspar}}$ .

*Birefringence*: — The mineral is isotropic.

(4) *Aegirine*: — $Na\,Fe^{\cdot\cdot\cdot}\,[Si_2O_6]$.

In the hand-specimen the aegirine crystals are black, prismatic, up to 3.5 cm. in lenght, with well-developed finely striated crystal faces.

*Color in thin section*: — Green, strongly pleochroitic:

x = deep green.
y = yellowish green.
z = greenish yellow to olive green.

*Form*: — More or less euhedral to subhedral crystals, which occasionally envelop the crystals of alkali feldspars and nepheline.

*Cleavage*: — Perfect parallel to (110). The angle amounts to about 93°.

*Relief*: — High positive relief:

$$n_{\text{aegirine}} >> n_{\text{Canada balsam}} .$$

*Birefringence*: — Very strong. The interference colors are masked by the inherent color of the mineral. The mineral is biaxial positive with a rather large axial angle ($\backsim$ 70°). Dispersion: $v > r$.

Amphibole could not be detected.

(*B*) Constituents occuring in medium amounts

(5) *The isomorphous series*: *Eudialyte — mesodialyte — eucolite*: —

Eudialyte : $(Na, Ca, Fe)_6 \, Zr[(OH, Cl)/(Si_3O_9)_2]$.

Eucolite : Is a variety of eudialyte containing Nb.

Mesodialyte : Is an intermediate member between the two.

Eudialyte-eucolite — mixed crystals are the characteristic accessory minerals of the rock. In the hand-specimen the minerals of this series appear beautifully bright rose-red to carmosine raspberry-colored, and bright ocker — to chestnut brown.

*Streak*: Uncolored. *Lustre*: Vitreous, strongly shining on the cleavage faces.

*Color in thin section*: — Mostly colorless to very faint rose-colored, no pleochroism.

*Form*: — Anhedral crystals, columnar or tabular, also stout.

*Relief*: — Fairly high positive relief. $n_{\text{mesodialyte}} = 1.600$.

*Birefringence*: — Low to isotropic, varying even in the same grain. The interference colors are anomalous (Berlin blue to brownish gray). Most crystals show a zonal structure, which consists of zones of different birefringence and opposed optical character and anomalous axial angle from 0 — 30°. The 2 + varieties show dispersion $v > r$.

RAMSAY also observed this zonal structure in the Kola-eudialytes, and referred it to an isomorphous mixed-crystal - series between eudialyte 1 + and eucolite 1 —.

KOSTYLEWA(²⁰) investigated the chemical composition and the physical properties of the mineral series eudialyte-eucolite of the Chibina- and Lujaururt mountains (on the Kola peninsula). She explained the continuous variation in the properties of this group as due to complete isomorphism of the two end members eudialyte and eucolite. When the two components are nearly equal, the mineral is called mesodialyte.

For the final investigation of the mineral, I prepared an X-ray powder diagram. (The sample originates from different parts of the rock). For comparison, an X-ray diffraction diagram was made also for an eudialyte sample from the Chibina mountains, Russia, which Prof. Dr. Koritnig kindly placed at my disposal. The two diffraction patterns show a good agreement.

Table 1.: X-ray diffraction patterns of the eudialyte - eucolite - mixed crystals.

| N.° | $\Theta$ / Cu K$\alpha_1$ | d Å | I | N.° | $\Theta$ / Cu K$\alpha_1$ | d Å | I |
|---|---|---|---|---|---|---|---|
| 1 | 6.20 | 7.1320 | 30 | 24 | 15.365 | 2.9069 | 16 |
| 2 | 6.854 | 6.5542 | 56 | 25 | 15.648 | 2.8556 | 80 |
| 3 | 7.312 | 6.0519 | 16 | 26 | 16.290 | 2.7460 | 11 |
| 4 | 7.732 | 5.7250 | 42 | 27 | 16.498 | 2.7123 | 32 |
| 5 | 8.14 | 5.4399 | 13 | 28 | 16.698 | 2.6807 | 34 |
| 6 | 8.80 | 5.0348 | 21 | 29 | 16.876 | 2.6533 | 10 |
| 7 | 10.282 | 4.3153 | 78 | 30 | 17.22 | 2.6018 | 40 |
| 8 | 10.523 | 4.2175 | 14 | 31 | 17.42 | 2.5729 | 20 |
| 9 | 10.794 | 4.1129 | 40 | 32 | 17.67 | 2.5376 | 20 |
| 10 | 11.189 | 3.9694 | 25 | 33 | 17.86 | 2.5115 | 8 |
| 11 | 11.651 | 3.8141 | 20 | 34 | 18.83 | 2.3864 | 14 |
| 12 | 11.884 | 3.740 | 10 | 35 | 18.98 | 2.3683 | 16 |
| 13 | 12.02 | 3.6986 | 12 | 36 | 19.323 | 2.3277 | 8 |
| 14 | 12.321 | 3.6096 | 20 | 37 | 20.90 | 2.1591 | 30 |
| 15 | 12.49 | 3.5615 | 26 | 38 | 21.1 | 2.1396 | 16 |
| 16 | 12.569 | 3.5395 | 32 | 39 | 21.283 | 2.1220 | 12 |
| 17 | 13.069 | 3.4063 | 29 | 40 | 22.434 | 2.0184 | 9 |
| 18 | 13.342 | 3.3378 | 13 | 41 | 22.84 | 1.9844 | 12 |
| 19 | 13.837 | 3.2206 | 75 | 42 | 24.769 | 1.8374 | 19 |
| 20 | 14.072 | 3.1679 | 32 | 43 | 25.67 | 1.7781 | 22 |
| 21 | 14.687 | 3.038 | 38 | 44 | 25.844 | 1.7669 | 20 |
| 22 | 14.977 | 2.9804 | 100 | 45 | 28.583 | 1.6099 | 20 |
| 23 | 15.244 | 2.9294 | 16 | | | | |

In table 1. are given the $\Theta$ — values and the d — values of the examined sample. (Apparatus calibrated with quartz).

(6) *Lamprophyllite*: — $Na_3Sr_2Ti_3[(O, OH, F)/(SiO_4)_2]_2$.

In the hand-specimen the mineral is brown, its development is laminated to scaly, brittle.

*Lustre*: — Submetallic, pearly on the cleavage faces.

Its external resemblance to astrophyllite is so striking that it is difficult to distinguish the two minerals without exact testing.

*Color in thin section*: — Weak pleochroitic:

x = straw yellow.
y = pale yellow.
z = orange yellow.

*Form*: — Plates elongated parallel to c.

*Cleavage*: — Perfect parallel to (100).

*Relief*: — High positive relief. $n_x = 1.744$. (Astrophyllite shows lower refractive index.). As immersion liquid, I used a mixture of $\alpha$-monobromnaphthaline ($n = 1.71$) and methyl-eneiodide ($n = 1.746$).

*Birefringence*: — Sections // (001) (i. e. at right angles to the acute bisectrix) show weak birefringence ($n_y - n_x$). The interference colors are gray of the 1st. order. Such a birefringence would be too weak for the same section in the case of astrophyllite. Sections // (100) show maximum birefringence ($n_z - n_x$), the interference colors rise up to green of the 2nd. order.

The mineral is biaxial positive with a moderate axial angle (about 30-40°).

*Optical orientation*: — 1+ or —.

x // b.

y // a in sections (001); but in sections (010) y / *a* = 5°.

z // c in sections (100) ; but in sections (010) *z* / *a* = 5°.

(*C*) Secondary minerals:

(7) *Cancrinite*: — $(Na_2,Ca)_4[CO_3/(H_2O)_{0-3}/(AL\ Si\ O_4)_6]$.

Cancrinite is a characteristic mineral of nepheline syenites. It is probably a deuteric mineral (autometamorphic), an alteration product of nepheline and feldspars, since it replaces sporadically both minerals, but particularly the nepheline.

*Color in thin section*: — Colorless.

*Form*: — Anhedral crystals, tending to be elongated parallel to c (c // x).

*Cleavage*: — // $(10\bar{1}0)$ perfect.
// (0001) good.

*Relief*: — Negative relief; $n_{\text{cancrinite}} < n_{\text{nepheline}}$.

*Birefringence*: — The interference colors vary from pale yellow of the 1st. order to blue of the 2nd order. The mineral is uniaxial negative. Basal sections give a good interference figure with one or two rings.

*Optical orientation*: — 1—, (c // x).

(8) *Hydronephelite*: — (Var. of natrolite).

$H\,Na_2\,Al_3\,Si_3\,O_{12}\,.\,3\,H_2O$ [DANA and FORD(7), p. 657].

Hydronephelite is an alteration product of nepheline.

*Color in thin section*: — Colorless.

*Form*: — No crystal faces.

*Cleavage*: — Indistinct parallel to $(10\bar{1}0)$.

*Relief*: — Negative relief; $n_{\text{hydronephelite}} < n_{\text{nepheline}}$ .

*Birefringence*: —

$\triangle_{\text{nepheline}} < \triangle_{\text{hydronephelite}} < \triangle_{\text{cancrinite}}$ .

The interference colors show yellow, orange, and violet of the 1st. order. The mineral is uniaxial positive. (Natrolite is biaxial).

*Optical orientation*: — 1+

(9) *Pectolite*: — $Ca_2\,Na\,H\,[SiO_3]_3$

By means of a chemical analysis of pectolite from New Jersey GONYER established the following formula:

$$4CaO\,.\,Na_2O\,.\,6SiO_2\,.\,H_2O.$$

The mineral belongs to the wollastonite group.

Until 1935 it was assumed that pectolite was monoclinic. By means of the crystallographic measurements which PEACOCK(27) carried out on 15 pectolite crystals from Paterson and Union Hill (New Jersey), he was able to establish beyond a doubt, in agreement with the results of the X-ray investigations (WARREN and BISCOE, Zs. Krist. 80, 1931, 391; the same 1932 I., 369) that pectolite crystallizes in the triclinic system.

*Color in thin section*: — Colorless.

*Form*: — Lath-like elongated parallel to the b-axis, tabular parallel to (100).

*Cleavage*: — Perfect parallel to (100) and (001). The angle between the two sets of cleavage (100) and (001), measured in sections (010) amounts to about 85°. This angle is designated in the old literature data as the $\beta$ - angle (on account of the assumption that pectolite crystallizes in the monoclinic system).

*Relief*: — High positive relief; $n_{\text{pectolite}} < n_{\text{lamprophyllite}}$ .

*Birefringence*: — Strong, the interference colors rise up to red of the 3rd. order.

The mineral is biaxial positive with a fairly large axial angle.

*Optical orientation*: — Section (010) is at right angles to the acute bisectrix. The axial plane is nearly the bisector of the angle between the cleavage traces (100) and (001), as observed in sections (010). The mineral has a positive elongation.

$z / b$ in sections (100) = 0°.

$z / b$ in sections (001) = $\backsim 2°$.

In nepheline-syenites of the mountains Lujaur-Urt and Umptek of the Kola peninsula, pectolite occurs in large masses accompanied by sphene, astrophyllite, aegirine, biotite, natrolite, and rarely by grains of fluorite, galena, and sphalerite. As numerous analyses show, pectolite varies in its chemical composition (FERSMAN(11) ).

*(D)* Minor constituents:

(10) *Fersmannite*: — $2Na_2(O, F_2) . 4CaO . 4TiO_2 . 3SiO_2$.

or $4CaTiO_3 . 2Na_2Si(O, F_2)_3 . SiO_2$ (when we combine CaO with $TiO_2$ and $Na_2O$ with $SiO_2$).

Fersmannite was discovered in the Chibina mountains as a new mineral in aegirine-nepheline-feldspar - dykes which cut the nepheline-syenites. It has been found in the form of well-developed small crystals (up to 1 cm. diameter) associated with aegirine and feldspar. It was called fersmannite in honour of the leader of the expeditions to the Chibina mountains Prof. Dr. A. FERSMAN(11).

Fersmannite occurs very rarely in the rock. It is accompanied by lamprophyllite.

*Color in thin section*: — Brown, very similar to sphene.

*Form*: — Wedge-shaped, also tabular.

*Relief*: — Very high positive relief.

$$n_{\text{fersmannite}} >> n_{\text{lamprophyllite}} .$$

*Birefringence*: — Strong birefringence, but the high order interference colors are masked by the color of the mineral itself. Fersmannite is biaxial negative, with a small axial angle. (Sphene is positive).

(11) *Apatite – and zircon inclusions*: in the feldspars in the form of minute needles, crystals, and grains.

## DECOMPOSED TINGUAITE

*Locality*: — 300 m. southeast of Pedra Balão in the "Serra de Poços" near Poços de Caldas, Brazil.

## INTRODUTION

Tinguaitic rocks are dike rocks of the nepheline-syenite family, that is, they belong to the adherents of those deep seated plutonic rocks which resulted from the solidification of the foyaitic initial magmas.

The first representatives of these tinguaitic rocks were named after an occurrence in the "Serra de Tinguá" near Rio de Janeiro.

According to ROSENBUSCH(27), the tinguaitic rocks are characterized by their green color, which is mainly imparted by the aegirine, and in the weathered condition they are characterized by a thin, grayish white, earthy weathered rind.

Tinguaite is widely distributed in the "Serra de Poços" from which the investigated rock sample originates. It occurs there as an independent rock mass and as a marginal facies of the elaeolite-syenite and elaeolite-porphyry.

According to TRÖGER(31) the original rock of the Tinguá mountains consists of the following minerals:

| Mineral | wt. % |
|---|---|
| Sanidine, microcline perthite, anorthoclase | 46 ($Or_{65}$ $Ab_{35}$) |
| Nepheline | 32 |
| Aegirine ± biotite | 21 |
| Apatite | 1 |

## SEDIMENTPETROGRAPHICAL INVESTIGATION

I. *Description of the investigated rock sample*:

The investigated tinguaite is decomposed to a bright flesh-colored, extremely soft clay with a mild greasy feel.

II. *Preparation of the sample*:

The rock sample has been prepared for the grain-size analyses according to the normal-method of Oden, recommended by CORRENS and SCHOTT(6) in the following way :

5.04 gr. of the substance were first soaked in 0.01 n. $NH_4OH$ overnight, crushed with a hard brush pencil and disaggregated with the finger.

The suspension obtained in this way was then shaken in a polyethylene bottle for about 150 hours. Finally the grain-sizes $> 63.2\ \mu\phi$ were mechanically separated through wet sieving into the fractions:

$$63.2 - 200,\ 200 - 632,\ \text{and} > 632\ \mu\phi.$$

The rest (grain-sizes $< 63.2\ \mu\phi$) was fractionated by the sedimentation procedure in an Atterberg - cylinder in the following particle - size classes using 0.01 n. $NH_4OH$ as a dispersing agent:

$$63.2 - 20,\ 20 - 6.32,\ 6.32 - 2,\ \text{and} < 2\ \mu\phi.$$

In order to determine the percentage of the elutriated fractions, definite amounts of the respective suspensions were dried at 110°C and weighed.

Table 1. gives the grain-size distribution in weight percent related to total weight of a sample dried at 110°C, as well as the water loss of the whole sample at 110°C.

In fig. 1. the grain-size distribution is graphically represented as a histogram.

Table 1.: Particle — size distribution

| Fraction ($\Phi$ in $\mu$) | wt. % |
|---|---|
| < 2 | 50 |
| 2 — 6.3 | 28 |
| 6.3 — 20 | 14 |
| 20 — 63.2 | 4 |
| 63.2 — 200 | 3 |
| 200 — 632 | 0.8 |
| > 632 | 0.2 |
| Sum | 100% |
| $H_2O$ at 110°C | 2% |

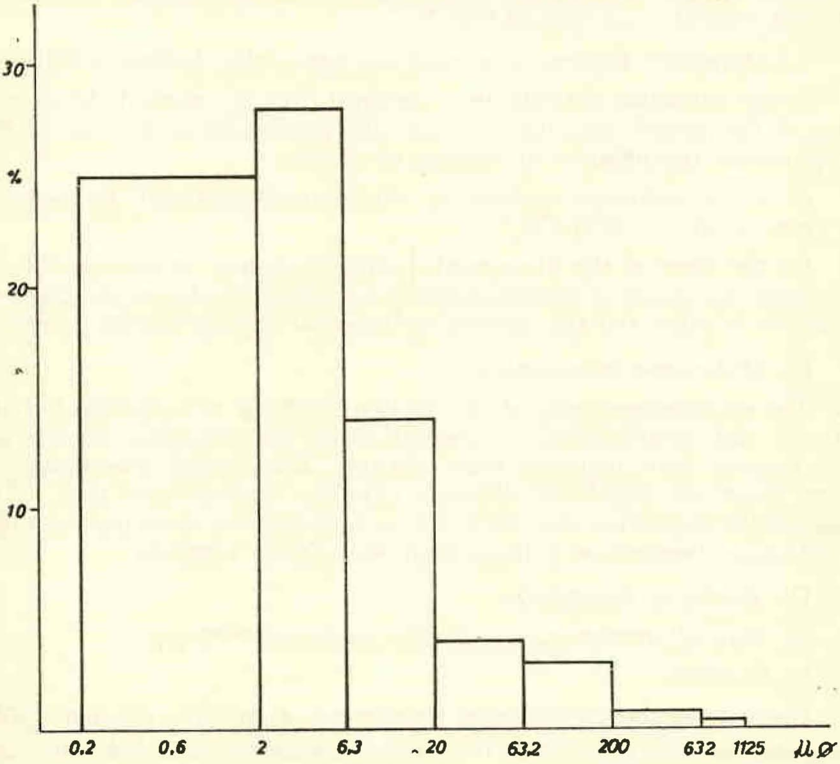

Fig. 1 — Grain-size distribution in weight percent related to total weight

III. *Methods of investigation*:

The mineral constituents of the individual fractions were identified by X-ray and/or microscopic investigations.

(1) X-ray investigation

The finest fractions ($< 20\ \mu\phi$) were investigated by X-rays.

a.) *Diffraction patterns of oriented aggregates*

Portions of the clay suspensions of the respective particle-size fractions less than 20 $\mu\phi$ containing from 20 to 25 mgr. clay substance were placed on glass slides of the type used for thin sections and allowed to dry at temperatures below 60°C. In this way the plate-like clay-minerals settle down oriented preferentially with (OOl) parallel to the surface of the slide. This specimen was then subjected to X-ray examination with a Phillips wide-range goniometer diffractometer (Müller Mikro 111 X-ray generator) using Ni–filtered Cu $K\alpha$–radiation at 36 kv and 14 ma. The diagrams obtained showed only OOl reflections which are most suitable for distinguishing the clay-minerals.

The quantitative estimations of the different mineral constituents based on relative intensities of certain basal reflections, were made after JOHNS, GRIM, and BRADLEY(17).

b.) *Diffraction patterns of oriented aggregates after heating to* 550°C.

X-ray diffraction patterns were obtained from an oriented clay-coated plate of the particle-size class $< 2\ \mu\phi$ after heating for an hour at 550°C, to determine the presence or absence of chlorite.

c.) *X-ray diffraction patterns of oriented aggregates with the Guinier-camera after v.* WOLFF(32):

On the basis of the film-recorded diffraction data, it was possible to determine the degree of crystallization of kaolinite, the di - or trioctahedral character of illite, and the possible occurence of chlorite besides kaolinite.

(2) Microscopic investigation

The constituting grains of the fraction $> 20\ \mu\phi$ were identified qualitatively and quantitatively in mounts under the polarizing microscope. The mounts were prepared with gelatine. For special determinations, other immersion liquids of different refractive indices were used. The quantitative evaluation was made for each fraction by counting from 500 to 900 mineral-grains on a mechanical stage (point counter).

IV. *Results of investigation*:

(1) Mineral components of the fine fractions $< 20\ \mu\phi$

1.) *Kaolinite*:

Kaolinite is the predominant constituent of the fine fractions. The diagnostic features for it were the basal interferences at 7.15 Å (001) and 3.57 Å (002). By interpretation of the X-ray diffraction data recorded by the Guinier-camera, the high degree of crystallization of the kaolinite could be proved on the basis of the following criteria [BRINDLEY(3)]:

(a) The group of lines between the interferences 4.45 Å (020) and 3.57 Å (002) [especially the line at 4.37 Å $(1\bar{1}0)$] is clearly defined. The line 4.17 Å $(11\bar{1})$ is an exception, since it cannot be resolved from 4.12 Å $(\bar{1}\bar{1}1)$, a phenomenon which for example LIPPMANN(22) also found in a well crystallized kaolinite of Schnaittenbach. (In the case of a typical fireclay mineral this group of lines fuses into a broad rather weak band).

(b) The triplet which corresponds to the lattice spacings 2.56 Å, 2.53 Å, and 2.49 Å is clearly resolved. (In the case of fireclay this triplet is replaced by a doublet).

(c) The intensity of the (060)-reflection with a spacing 1.48 Å is relatively high and is clearly resolved from the (060)-reflection of illite.

Since the 7.15 Å reflection can also belong to the chlorite plane (002), it was necessary to test for the possible existence of chlorite besides kaolinite. The absence of chlorite was proved on the basis of the following observations :

(1) The X-ray diffraction patterns of the sample heated to 550°C (see page 15) showed a total disappearance of the concerned line (7.15 Å), as well as of all other lines of kaolinite.

(2) The basal reflections (001) at 14 Å and (003) at 4.6 Å which are characteristic for chlorite and which are usually intense, are entirely absent in all the diagrams, also after heating at 550°C. [At such a temperature a partial dehydration of possibly present chlorite results, leading to an appreciable enhancement of the (001) reflection].

(3) The film-recorded diffraction patterns photographed with the Guinier-camera do not show at all the (060) line at 1.53 Å characteristic for trioctahedral chlorite.

(2) Illite:

Illite is far less abundant, but likewise common to all examined fractions. Its amount increases as the grain-size increases (see table 2). Illite was identified on the basis of the characteristic basal reflections (002) at 10 Å, (004) at 4.9 Å, and (006) at 3.33 Å, which remained unchanged after heating at 550°C in contrast to those of kaolinite. As the film-recorded reflections (020) and (060) (at 4.49 Å and 1.56 Å respectively) show, it is a dioctahedral (muscovite like) illite.

Table 2. shows the mineral-distribution in the individual fractions $< 20\ \mu\phi$, quantitatively estimated by comparison of the relative intensities of the 2nd. order reflection of chlorite at 3.5 Å directly with those of the 3rd. order reflection of illite at 3.3 Å (JOHNS, GRIM, and BRADLEY(17)).

Table 2.: Mineral-constituents of the fractions < 20 μΦ. (relative quantitative estimates expressed in percent).

| Mineral components | Fractions (in μψ) | | |
|---|---|---|---|
| | < 2 | 2 — 6.3 | 6.3 — 20 |
| Kaolinite | 85 | 80 | 75 |
| Illite | 15 | 20 | 25 |

(2) Mineral components of the fractions > 20 μφ

1.) *Clay - aggregates*:

In spite of the careful preparation of the sample, these aggregates occur in great amounts in the fractions examined microscopically. They are straw-yellow to brownish-yellow in the polarized light. The refractive index lies between 1.56 and 1.57. The mineral-constituents of these aggregates could not be identified microscopically, therefore they were powdered and examined qualitatively with X-rays. As the X-ray diffraction patterns showed, they consist of kaolinite and illite.

2.) *Red aggregates*:

These are bright reddish brown aggregates with a submetallic lustre. They occur in extremely small amounts. The refractive index is very high (> 1.746). An identification of the mineralogy of these aggregates was not possible because of their scarcity; however, they seem to be of a homogeneous mineral composition.

3.) *Iron oxide*:

Iron oxide occurs in varying amounts. It sometimes coats and impregnates in finest distribution the other mineral grains and clay-aggregates. It was identified as hematite on the basis of the X-ray diffraction patterns.

4.) *Feldspars*:

Feldspars occur in small amounts. The distinction between alkali feldspars and plagioclases was based on the difference in their refractive indices, using monochlorbenzol (n = 1.528) as the immersion medium. Some plagioclase-grains show a polysynthetic twinning. Among the alkali feldspars-grains, some show the characteristic quadrille structure of microcline.

Plagioclases are generally present in smaller amounts than alkali feldspars (see table 3.). In the fraction 63.2 — 200 μφ ,where the plagioclase percentage is higher than the alkali feldspar percentage, I have further attempted to subdivide the placioclases into plagioclases with $n < 1.541$ (albite) and placioclases with $n > 1.541$. Eugenol ($n = 1.541$) served as immersion medium.

The feldspars grains are colorless, but some grains are partly altered to sericite. They sometimes contain apatite- and other indeterminable mineral-inclusions.

5.) *Muscovite*:

Muscovite occurs in colorless scaly plates. Some of these plates contain irregularly arranged dark inclusions of iron ore. Between crossed nicols the plates show interference colors, which range from the gray of the 1st. order up to the red, blue, and green of the 2nd. order.

It cannot be decided with certainty whether chlorite laminae also occur besides muscovite laminae. The refractive index lies between 1.56 and 1.60.

6.) *Quartz*:

Quartz occurs in irregular grains. Its amount is minute and increases as the grain-size of the fractions increases (see table 3.). The quartz grains are generally colorless in polarized light, but some are colored due to the iron oxide. The optical properties are normal.

7.) *Apatite*:

Apatite was found as loose minute crystals only in the fraction 63.2 — 200 $\mu.\phi$.

Table 3. shows the mineral — distribution in the particular fractions $> 20$ $\mu\phi$, expressed as a percentage of the grain number.

Table 4. shows the mineral — content of the whole sample, calculated from the tables 1 to 3.

Table 3.: Mineral components of the fractions $> 20$ $\mu\Phi$ (in grain %)

| Mineral components | Fractions (in $\mu\Phi$) | | | |
|---|---|---|---|---|
| | 20 — 63.2 | 63.2 — 200 | 200 — 632 | > 632* |
| Clay aggregates | 95 | 60 | 12 | |
| Red aggregates | 1 | 0.7 | 1 | |
| Iron oxide | 2 | 23 | 63 | |
| Alkali feldspar | 1 | 4 | 19 | |
| Plagioclase | — | 6 ($Ab_I$) | 1 | |
| Muscovite | 0.5 | 4 | 1 | |
| Quartz | 0.5 | 2 | 3 | |
| Apatite | — | 1 | — | |

Table 4: Percentage of the individual minerals in the different fractions related to the total weight of the sample

| Mineral constituents | Fractions (μΦ) | | | | | | | Percentage of the individual minerals in the whole sample |
|---|---|---|---|---|---|---|---|---|
| | <2 | 2–6.3 | 6.3–20 | 20–63.2 | 63.2–200 | 200–632 | >632* | |
| Kaolinite | 42 | 22 | 11 | — | — | — | | 75 |
| Illite | 8 | 6 | 3 | — | — | — | | 17 |
| Clay aggregates | — | — | — | 3.8 | 2 | 0.1 | | 6 |
| Red aggregates | — | — | — | <0.1 | <<0.1 | <<0.1 | | <0.1 |
| Iron oxide | — | — | — | <0.1 | 0.6 | 0.4 | | 1 |
| Alkali feldspars | — | — | — | <0.1 | 0.1 | 0.2 | | 0.3 |
| Plagioclases | — | — | — | — | 0.2 | <<0.1 | | 0.2 |
| Muscovite | — | — | — | <0.1 | 0.1 | <<0.1 | | 0.2 |
| Quartz | — | — | — | <<0.1 | <0.1 | <0.1 | | 0.1 |
| Apatite | — | — | — | — | <<0.1 | — | | <<0.1<br>+ 0.2(>632) |
| Wt.% of the individual fractions | 50 | 28 | 14 | 4 | 3 | 0.8 | 0.2 | 100% |

* No quantitative data available, as the fraction consists of 16 grains only (alkali feldspar and opaque substance).

## LAVA AGLOMERATICA (DECOMPOSED)

*Locality*: — Laranjeiras, near Poços de Caldas, Brazil.

### INTRODUCTION

The term "agglomerate" was employed by Sir Charles Lyell for those accumulations of angular rock-fragments which are thrown up by volcanic eruptions. These rock-fragments consist partly of lava that had previously solidified in the vent or during the flight through the air, and partly of fragments of the country rock.

Description of the investigated rock sample:

The rock became a soft clay as a result of the decomposition processes. It consists macroscopically of white idiomorphic phenocrysts up to 6 mm. in length, which are thought to be originally augite and of steelgray ore grains (up to ∽1 mm $\phi$) in a very fine grained, earthy, brick-red matrix. In this brick-red matrix one also can observe dark reddish brown spots. The measurable surface of the white phenocrysts amounts to about 25% of the whole rock.

Methods of investigation

(a) *Microscopic investigation*

In order to obtain thin sections of the friable rock for microscopic examination, it was impregnated with methyl metacrylate "lucite" under a vacuum of 0.1 Torr.

Apart from the opaque ore grains, the rock is so fine grained that it appears isotropic between crossed nicols; hence a mineral identification by means of the polarizing microscope was not possible. However, one can observe the following phenomena in the polarized light:

1.) The idiomorphic, white phenocrysts with two distinct sets of cleavage which are at right angles to each other.

2.) the envelopment of the irregularly rounded, opaque ore grains by a thin weathered film, and

3.) the random distribution of reddish brown, fine ore particles, locally accumulated as spots.

(b) *X-ray investigation*

Basal reflection diagrams of oriented aggregates were made from the white phenocrysts and the matrix, according to the technique explained in the study of the decomposed tinguaite (see page 14). Powder diagrams were made from the (mechanically isolated) solid ore particles as well as from the dark reddish brown parts of the ground mass.

Results of investigation

(1) *The white phenocrysts*:

The following interferences of basal reflections indicate the occurence of metahalloysite according to BRINDLEY and ROBINSON:

| (hkl) | d Å |
|---|---|
| 001 | 7.59 (too high for kaolinite and fireclay) |
| 11 02 | 4.44 |
| 002 | 3.55 |

The (001) line is broad and very unsharp, when compared with the corresponding one of kaolinite. This is an indication for the greater randomness in the lattice of metahalloysite.

(2) *Opaque phenocrysts*:

From the powder diffraction patterns, it could be shown that both the solid steelgray ore particles and the dark reddish brown fine-grained spots consist of hematite exclusively.

(3) *The matrix*:

The X-ray diagrams of the ground mass similarly show basal reflections of metahalloysite as an essential constituent of the matrix and of hematite (finely distributed in the matrix).

## REFERENCES

1. AMER. GEOL. INST., *Glossary of geology and related sciences*, Washington (1957).
2. AMER. SOC. for TESTING MATERIALS (ASTM), *Index to the x-ray powder file*, (1960).
3. BRINDLEY, C. W., *X-ray identification and crystal structures of clay minerals*, London (1951).
4. CISSARZ, A., and JONES, W. R., *German-English geological Terminology*, (1931).
5. CORRENS, C. W., *Einführung in die Mineralogie*, Heidelberg (1949).
6. CORRENS, C. W. und SCHOTT, W., *Vergleichende Untersuchungen über Schlämm - und Aufbereitungsverfahren von Tonen Kolloid — Z.* 61, 68 — 80, (1932).
7. DANA, E. S. and FORD, W. E., *Dana's textbook of mineralogy*, 4. edit., 19. printing, (1958).
8. DREIZLER, I., *Untersuchungen an Sedimentgesteinen der westlichen Kontaktzone des Okergranites (Harz)*, Heidelb. Beitr. Mineral. u. Petrogr. 7, 439-468, (1960).
9. ECHLE, W., *Mineralogische Untersuchungen an Sedimenten des Steinmergelkeupers und der roten Wand aus der Umgebung von Göttingen*, Heidelb. Beitr. mineral. u. Petrogr. 8, 28 - 59, (1961).
10. ELLERT, R., *Contribuição â geologia do maciço alcalino de Poços de Caldas*, Univ. de São Paulo, Fac. de Filosofia, Ciências e Letras, Bol. 237, Geol. 18, 5-63, (1959).
11. FERSMAN, A. E., *Minerals of the Kola - peninsula*, Amer. Mineral., vol. XI, 289-299, (1926).
12. HEINRICH, E. W. M., *Mikroscopic Petrography*, (1956).
13. HINTZE, C., *Handbuch der Mineralogie, I. Band* (herausgegeben von G. LINCK) (1938).
14. HINTZE, C., *Handbuch der Mineralogie, II. Band* (1897).
15. HINTZE, C., *Hanbuch der Mineralogie. II. Band* (zusammengestellt u. herausgegeben von K. F. CHUDOBA) (1960).
16. JASMUND, K., *Die silikatischen Tonminerale*, 2 erweit. Aufl. (1955).
17. JOHNS, W. D., GRIM, R. E. and BRADLEY, W. F., *Quantitative estimations of clay minerals by diffraction methods*, Jour. Sed. Petrology 24, 242-251, (1954).
18. KHARWAL, A. D., *Über den Mineralbestand des Göttinger Lias*, Heidelb. Beitr. Mineral. u. Petrogr. 7, 45-62, (1959).
19. KERR, P. F., *Optical Mineralogy*, 3. edit., (1959).

20. KOSTYLEWA, E., *Isomorphe Reihe Eudialyt–Eukolit aus den Chibina- und Luiawrurt- Tundren (Halbinsel Kola)*, (Trav. Mus. Min. Acad. Sci. URSS. 3, 1929, 169-222. Russisch) Neues Jahrbuch Mineral. Geol. u. Paläont., (1931) 363-366.

21. LABOUNTZOW, A., *La fersmannite - un nouveau mineral des Monts Chibines*, (C. R. de l'Ac. d. Sc. de l'URSS. 1929. A. 297-301. Russisch). Neues Jahrbuch Mineral. Geol. u. Paläont., (1930) I, 125-126.

22. LIPPMANN, F., *Mineralogische Untersuchungen an einigen niederhessischen Tertiärtonen*, Heidelb. Beitr. Mineral. u. Petrogr. 3, 219-252, (1952).

23. NIEMANN, H., *Untersuchungen am grauen Salzton der Grube*: Königshall–Hinderburg, Reyershausen bei Göttingen Heidelb. Beitr. Mineral. u. Petrog. 7, 137-165, (1960).

24. PEACOCK, M. A., *On pectolite* (*Zs. Krist.* 90*A*. 1935, 97-111). Neues Jahrbuch Mineral. Geol. u. Paläont. (1935) I, 469-470.

25. PETTIJOHN, F. J., *Sedimentary rocks*, 2. edition, (1956).

26. REPORTORIUM zum neuen Jahrbuch u. Zentralblatt Mineral. Geol. u. Paläont. (1930-1935), II (Sachverzeichnis).

27. ROSENBUSCH-WÜLFING, *Mikroskopische Physiographie der Mineralien und Gesteine.*, II. 1, (1907).

28. SCHNEIDERHÖHN, P., *Untersuchungen zur Siebanalyse von Sanden und zur Darstellung ihrer Ergebnisse*, Neues Jahrbuch Mineral., 141-202 (1953).

29. STRUNZ, H., *Mineralgische Tabellen*, 3. Aufl., Leipzig (1957).

30. TRÖGER, W. E., *Optische Bestimmung der Gesteinsbildenden Minerale*, Teil 1, Stuttgart (1959).

31. TRÖGER, W. E., *Spezielle Petrographie der Eruptivgesteine*, Berlin (1935).

32. v. WOLFF, T. F., *Beschreibung einer leicht iustierbaren Guinier–Kamera für alle Winkeleinstellungen*, Heidelb. Beitr. Mineral. u. Petrogr. 4, 243-254, (1954).

33. WINCHELL, A. N. and WINCHELL, H., *Elements of optical mineralogy*, part II, 4. edition, (1951).

34. WINCHELL, A. N., *Elements of optical mineralogy*, part. III, 2. edition, 2. printing, (1939).

35. ZWAAN, P. C., *On the determination of pyroxenes by x-ray powder diagrams*, Leidse geol. Mededelingen, XIX, 167-276, (1954).

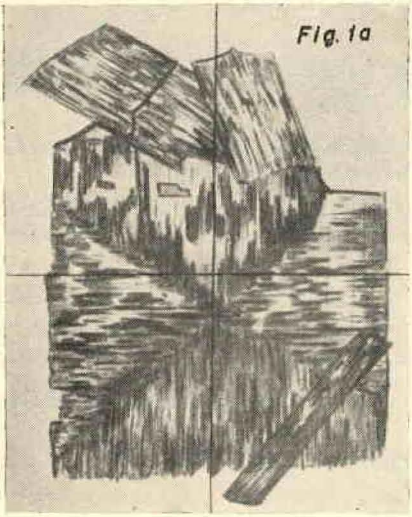

Fig. 1a — Alkali feldspar. Section ⊥ optic axis (X nicols).

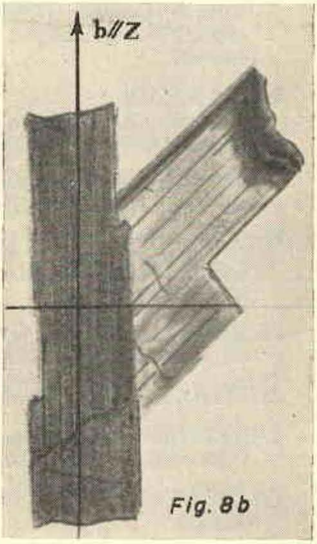

Fig. 8b — Pectolite Section // (100) # (001) perfect. (X nicols).

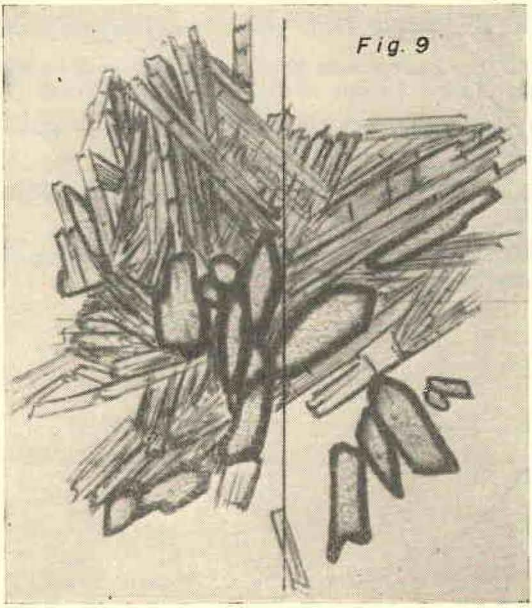

Fig. 9 — Fersmannite (brown) associated with lamprophyllite (pol. light).

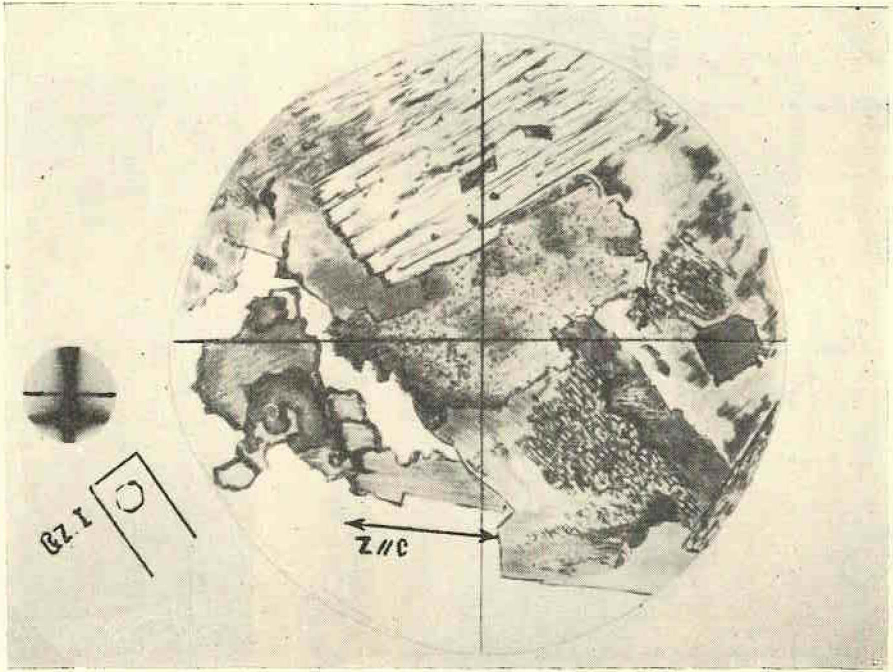

Fig. 7 — Hydronephelite, 1(+), 1(+). An alteration product of nepheline. (n hydronephelite<n nepheline) (X nicols).

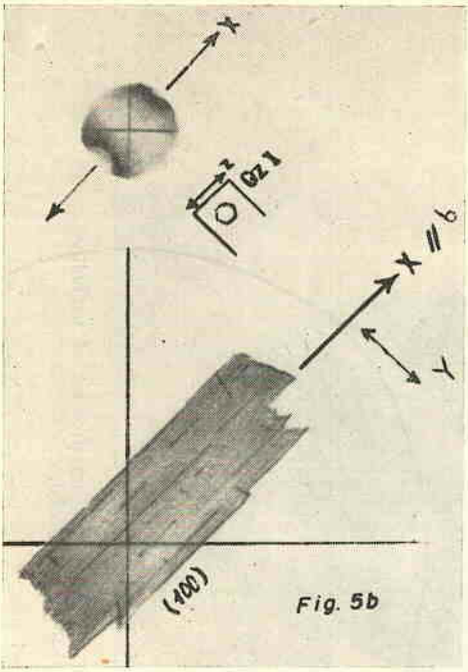

Fig. 5b

Fig. 5b — Lamprophillite, 2+ Section // (001) ⊥ acute bisectrix showing weak birefringence (X nicols).

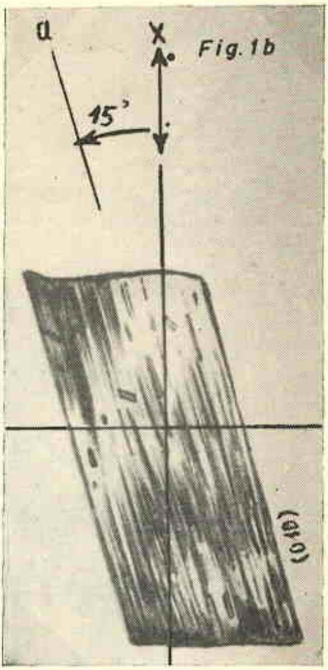

Fig. 1b

Fig. 1b — Alkali feldspar Section // (001) (X nicols)

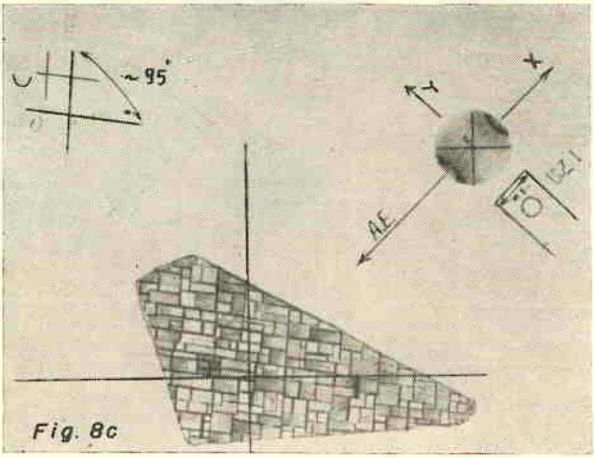

Fig. 8c

Fig. 8c — Pectolite, 2 + Section // (010) (⊥ acute bisetrix).#(100) perfect.#(001) perfect. (△ n'y — n'x = weak) (X nicols).

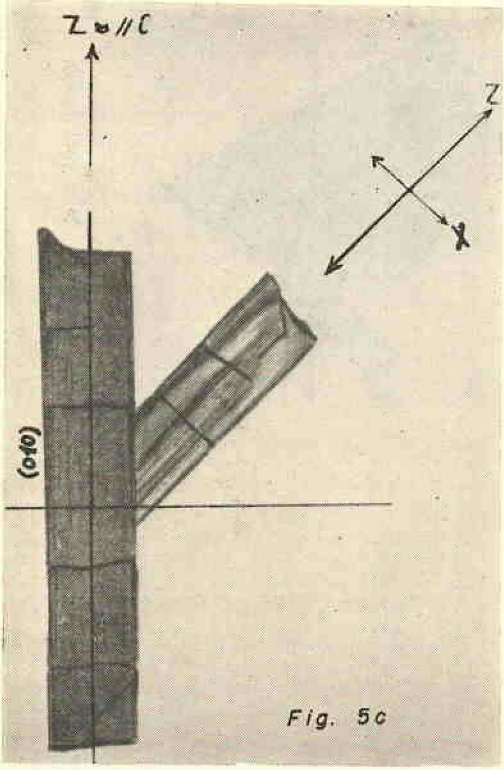

Fig. 5c — Lamprophillite. Section / / (100)
(X nicols).

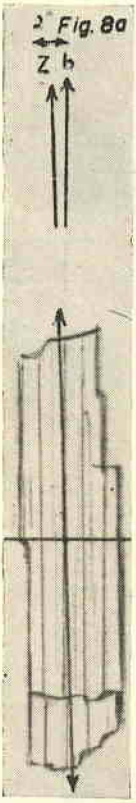

Fig. 8a — Pectolite (colorless in polarized light). Section (001). // (100) perfect.

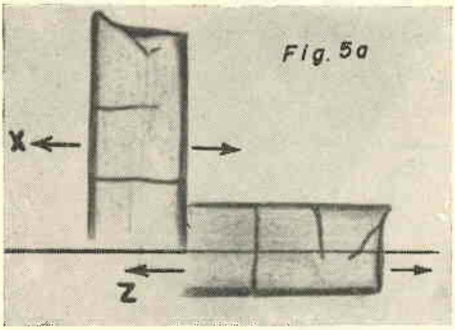

Fig. 5a — Lamprophyllite. Pleochroism: z = orange yellow. X = straw yellow (pol.-light).

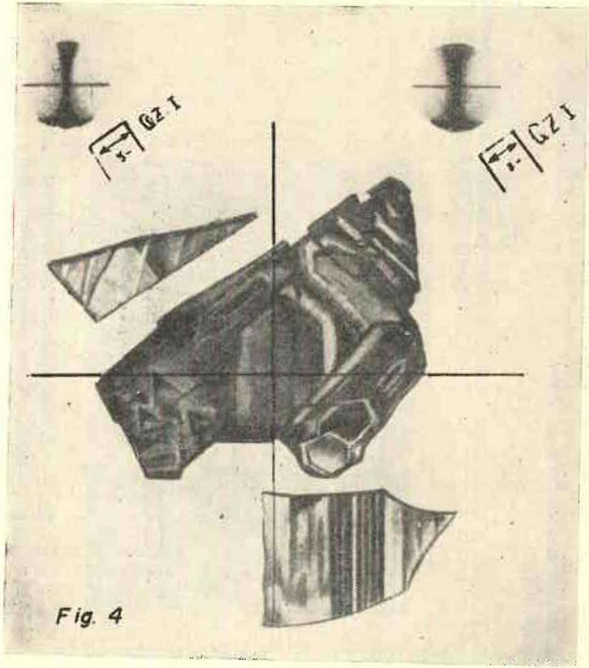

Fig. 4

Fig. 4 — The isomorphous series: — Eudialyte, 1 + with anomalous brownish gray interference color. Mesodialyte, isotropic. Eucolite, 1 — with anomalous Berlinblue interference color (X nicols).

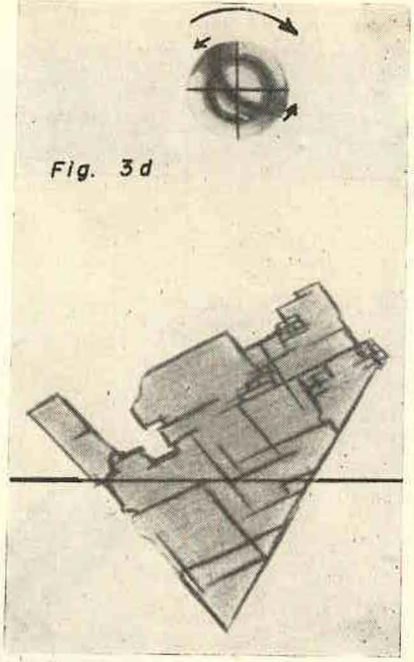

Fig. 3d

Fig. 3d — Aegirina. Section ⊥ optic axis. Dispersion: V > r (pol.-light).

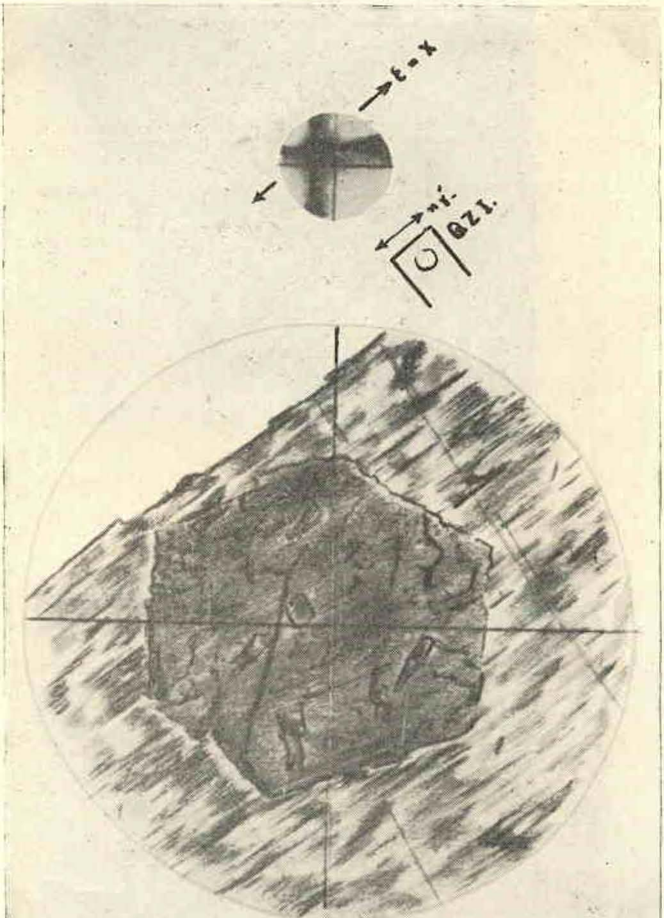

Fig. 2 — Nepheline, 1(—·) Section // (0001) (L optic axis) showing a hexagonal outline. (X nicols).

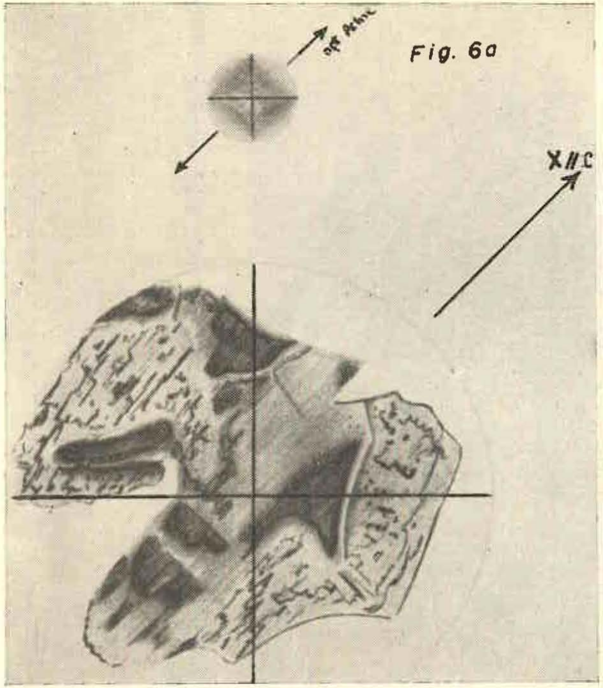

Fig. 6a — Cancrinite, e (—). Section // optic axis. #(1010) perfect. #(1000) good. (X nicols).

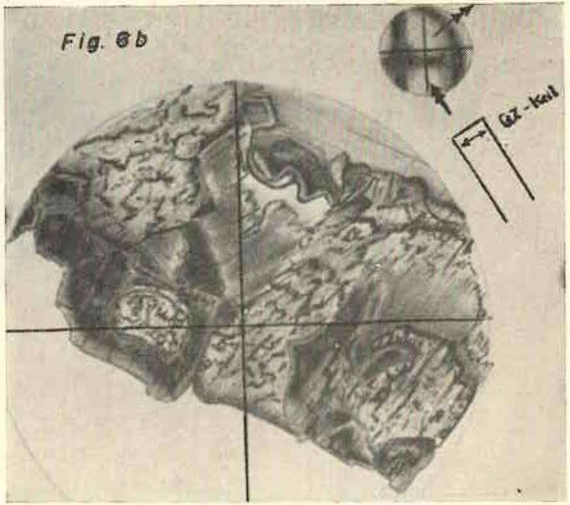

Fig. 6b — Cancrinite, 1(—). An alteration product of nepheline. (n cancrinite n nepheline) (X nicols).

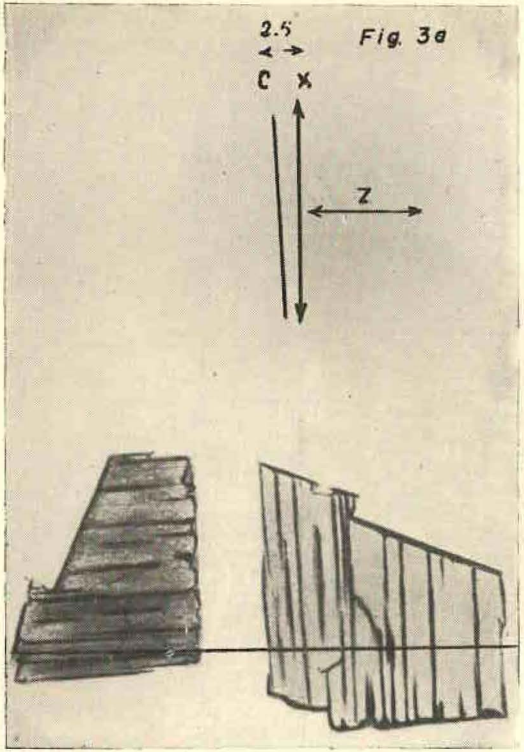

Fig. 3a — Aegirine Section // (010). Pleochroism: x = green. z = greenish yellow. (pol. light).

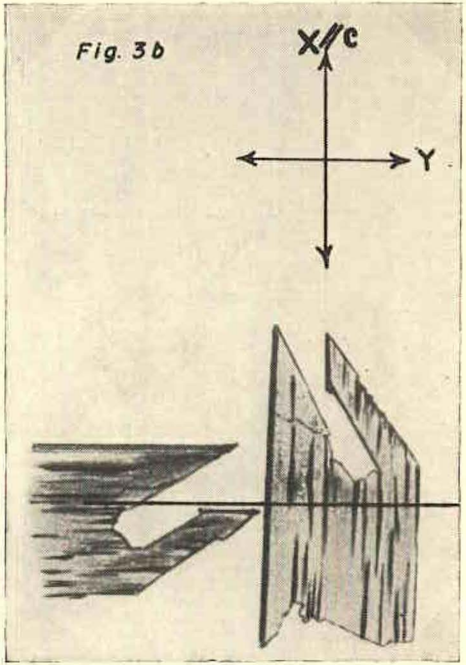

Fig. 3 b — Aegirine Section // (100), (⊥ obtuse bisectrix). Pleochroism: x = green. y = yellowish green. (pol. light).

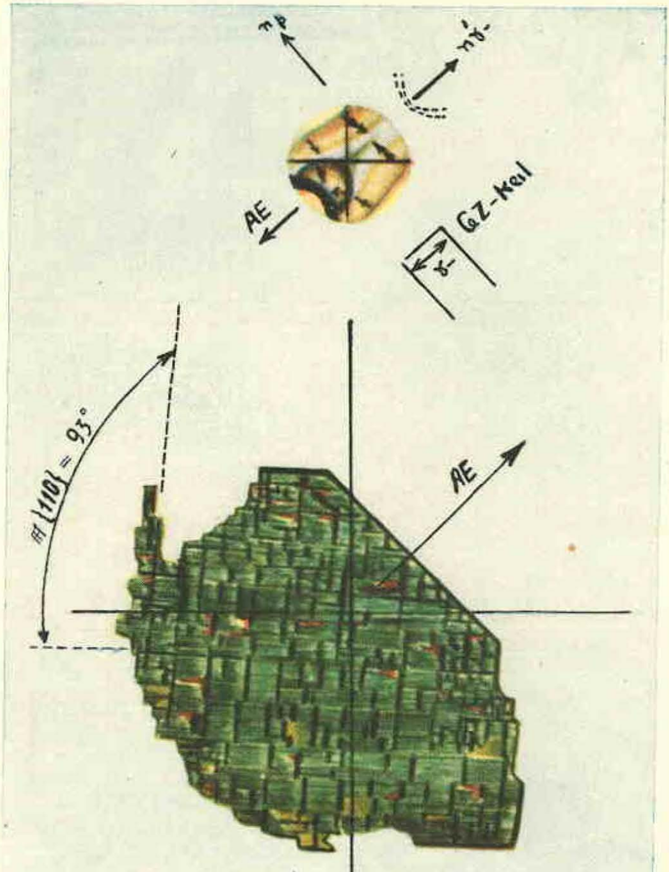

Fig. 3c — Aegirina, 2(—). Section // (001). (X nicols).