Ægirine and Riebeckite Anorthoclase Rocks related to the "Grorudite-Tinguaite" series, from the neighbourhood of Adowa and Axum, Abyssinia. [Plate III.]

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Introduction.
Description of Profiles.
Description of the Rock-specimens:—
The Grorudites:
The Paisanite.
The Sölvsbergites.
The Tinguaites.
The Trachyte and Pitchstone.
The Dolerites and Basalts.
Conclusions, and comparison with other African rocks.

In 1869 the late Dr. Sadebeck[1] gave a brief description of a collection of rocks, accompanied by a map and profiles, made by Dr. W. Schimper in the neighbourhood of Adowa and Axum, Abyssinia.

In the British Museum is a very similar collection, which was purchased from Dr. Schimper about the same time. As some of these rocks showed points of resemblance to the riebeckite-trachytes of Senafé, recently described by the author,[2] a somewhat more detailed petrographical examination of the specimens than Dr. Sadebeck was able to afford them appeared to promise something of interest.

The main result of that examination has been to show that the hills in this district of Abyssinia, with a few exceptions where dolerites occur, consist largely of ægirine- (or riebeckite) felspar rocks (with or without quartz or nepheline), which are closely related to the *grorudite-tinguaite* series of the Christiania District described by Brögger.[3]

The Museum collection is accompanied by profiles on which the

[1] *Zeits. Ges. f. Erdkunde*, IV, 1869, pp. 347–52.
[2] *Min. Mag.* 1899, XII, 92.
[3] Brögger, *Eruptivgesteine des Kristianiagebietes*, I.

locality of each rock is marked by a number corresponding to that on the specimen. These profiles are similar to those which are figured in Sadebeck's paper, but are reproduced here in slightly different form in order to illustrate the text, and also to correct certain inaccuracies in the nomenclature of some of the rocks, into which Dr. Sadebeck was led owing, apparently, to the want of a microscopic examination of his specimens.

The small diagrammatic sketch map (fig. IX) is a rough reproduction of the one made by Dr. Schimper, and shows the two main lines of country from which the specimens were collected, viz. *B A*, north to south, from the banks of the R. Mărăb to Amba Semajata; and *K L*, west to east, from Amba Gollo to Amba Hedscha.

DESCRIPTION OF THE PROFILES (pp. 258-9).

Profile I.—B-A, north to south, from the banks of the River Mărăb (*B*), 4,000 ft. to Amba Semajata (*A*), 9,800 ft.

The granite (1) on the banks of the Mărăb is a pale pink medium-grained rock, the felspar of which consists principally of microcline; biotite is present only in small amount. This rock is succeeded along the Hamedo Plain by biotite-gneiss (2 *a*, 3 and 4), micaceous phyllites (2 *b*), and hornblendic schists (2 *e*). Phyllite (2 and 11), with here and there a deep red ferruginous breccia (laterite, 5), claystone (10), and in Gadema Keflahit coarse sandstone (9), is the prevailing rock below the level of 7,000 ft. from the District of Schahagăne to Amba Semajata. Where the level of the country rises above 7,400 ft. in the mountains, Amba Subhat (8,600 ft.), Amba Bató (7,400 ft.), Gossoso (7,900 ft.), and Amba Semajata (9,800 ft.), the phyllites are broken through, with marked tilting of the strata, by ægirine-felspar rocks (6, 12, 13, 14 respectively, the "younger granites" of Sadebeck), which I have referred to the "grorudite" and "sölvsbergite" of Brögger, since they present the characters of intrusive hypabyssal rocks rather than those of lava flows.

Profile II.—C-D, across the Hamedo Plain, cutting Profile I at Keren.

This profile shows only dark biotite-gneiss (3 and 4), hornblende schist and phyllite (2).

Profile III.—E-F, parallel to I, in Schahagăne and Achsa Districts, from Abuna Alif (6,500 ft.) to Amba Bachele (6,300 ft.).

The rocks 7 and 8, of which, according to Schimper, these hills consist, are ægirine-felspar (anorthoclase) rocks, which I have referred to

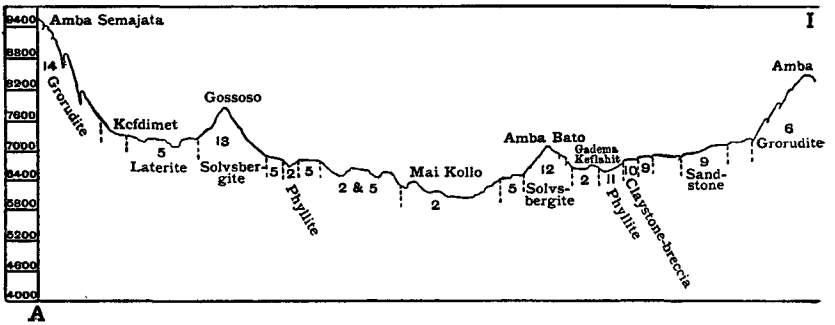
the "sölvsbergite" of Brögger. Between the two hills occur phyllites (Urthonschiefer) covered with pebbles of rocks 7 and 8 and of laterite. Sadebeck refers to a hornblende-bearing gneiss in this profile, and to porphyry raising the schists at Amba Bachele, but states that Schimper gives no porphyry on Abuna Alif. The sölvsbergite (7), with its rather platy structure, due to the arrangement of the felspars, appears to have been mistaken for a gneiss.

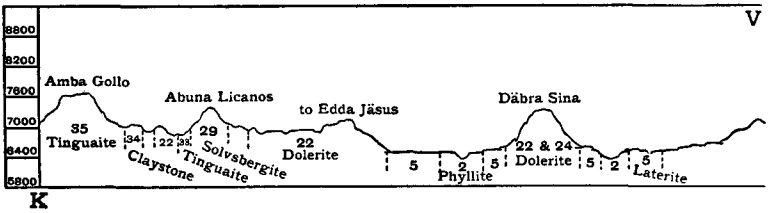
Profile IV.—G-H, across Mt. Scholoda, N. of Adowa.

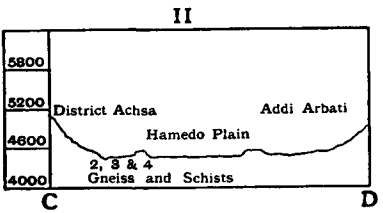
Mt. Scholoda consists of a quartz-anorthoclase-riebeckite rock similar to the "Paisanite" of Osann from Texas and to the Mynydd Mawr rock of North Wales. This rock (51-54) has been intruded through purplish phyllites (46-50). Near the contact the "paisanite" is very compact, and shows no phenocrysts of quartz and felspar. Near Adowa, at the foot of the mountain, the phyllites pass into gray roofing clay-slate (45).

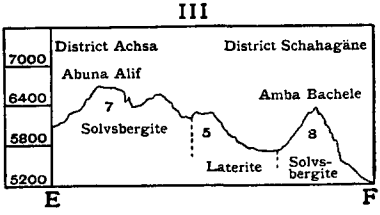
Profile V.—L-K, east to west, from Amba Hedscha to Amba Gollo, cutting Profile I in Amba Subhat.

A rock (15) from the uppermost part of Amba Hedscha (9,400 ft.) shows porphyritic anorthoclase, and presents rather the characters of a flow than of an intrusive rock. It is very similar to the riebeckite-trachyte of Kishyat near Senafe (see *Min. Mag.* 1899, XII, 94), but the iron silicate has been wholly altered to ferrite. The slopes of Amba Hedscha (20), as well as the slopes (18) and top (19) of Arbaatu Ensesa (8,500 ft.) are composed of an ægirine-felspar rock allied to "sölvsbergite." Sadebeck only refers here to hornblende-bearing schists. Between Arbaatu Ensesa and Amba Herres the country is marked by Schimper as not examined. Amba Herres consists of basalt (17). At Magdalai also occurs dark green compact basalt (16) with iron pyrites. Beyond Magdalai, where the level drops to 6,200 ft., the schists (2) again make their appearance. On the slopes of Amba Subhat is the laterite (5); at Ganef with the laterite is also a coarse-grained ophitic dolerite (22). At the foot of Amba Berrach, where the level sinks below 7,000 ft., schists (2) are again seen. From Amba Berrach (7,400 ft.) are specimens of both grorudite (23) like the rock (14) from Amba Semajata, and also of the more basic sölvsbergite. Then follow schists (2) with laterite, where the level again falls to 6,300 ft. From Däbra Sina (7,400 ft.) comes ophitic dolerite (24 and 22) like that of Ganef. Beyond Däbra Sina occur laterite and once more the schists (2), where the level sinks to 6,300 ft. At the point marked "to Edda Jasus"


I
Amba Semajata
Grorudite
Kefdimet
Gossoso
Laterite
Solvsbergite
Phyllite
Mai Kollo
Amba Bato
Gadema Kefishit
Solvsbergite
Phyllite
Claystone-breccia
Sandstone
Amba
Grorudite
A


V
Amba Gollo
Abuna Licanos
to Edda Jäsus
Däbra Sina
Tinguaite
Claystone
Tinguaite
Solvsbergite
Dolerite
Phyllite
Dolerite
Laterite
K


II
District Achsa
Addi Arbati
Hamedo Plain
Gneiss and Schists
C
D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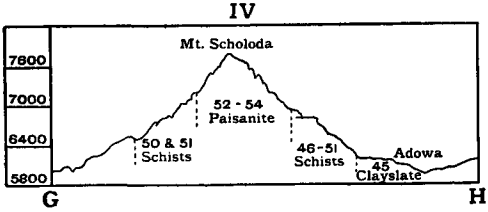
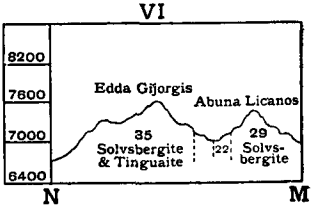
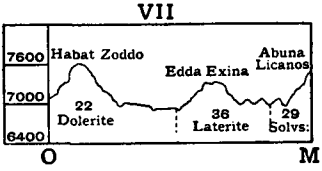
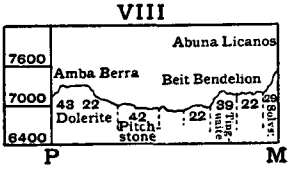
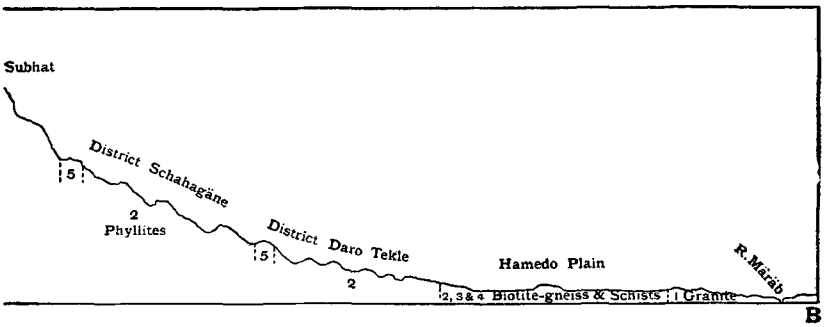
District Achsa
District Schahagäne
Abuna Alif
Amba Bachele
Solvsbergite
Laterite
Solvsbergite
E
F

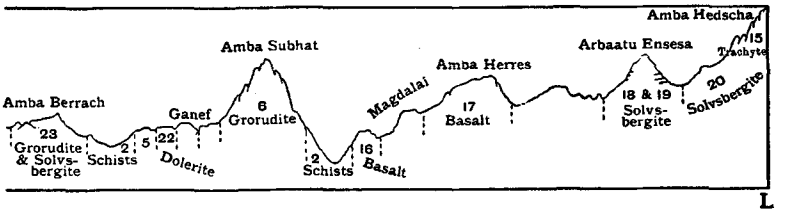

IV
Mt. Scholoda
Paisanite
Schists
Schists
Adowa
Clayslate
G
H


VI
Edda Gïjorgis
Abuna Licanos
Solvsbergite & Tinguaite
Solvsbergite
N
M

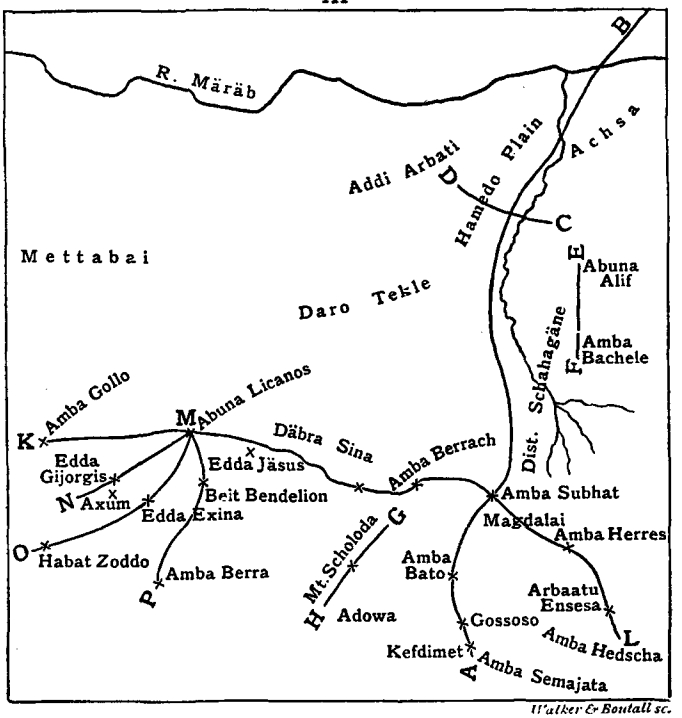

VII
Habat Zoddo
Abuna Licanos
Edda Exina
Dolerite
Laterite
Solvs:
O
M


VIII
Abuna Licanos
Amba Berra
Beit Bendelion
Dolerite
Pitchstone
P
M


Subhat
District Schahagäne
5
2
Phyllites
District Daro Tekle
5
2
Hamedo Plain
R. Märäb
2, 3 & 4 Biotite-gneiss & Schists
1 Granite
B


Amba Berrach
23
Grorudite & Solvsbergite
2
Schists
5
22
Dolerite
Ganef
Amba Subhat
6
Grorudite
2
Schists
Magdalai
16
Basalt
Amba Herres
17
Basalt
Arbaatu Ensesa
18 & 19
Solvsbergite
Amba Hedscha
15
Trachyte
20
Solvsbergite
L

IX


B
R. Märäb
Addi Arbati
D
Hamedo Plain
Achsa
C
Mettabai
Daro Tekle
E
Abuna Alif
Amba Bachele
F
Dist. Schahagäne
K
Amba Gollo
M
Abuna Licanos
Däbra Sina
Amba Berrach
Edda Gijorgis
Edda Jäsus
N
Axum
Beit Bendelion
Edda Exina
O
Habat Zoddo
P
Amba Berra
Mt. Scholoda
G
H
Adowa
Amba Subhat
Magdalai
Amba Herres
Amba Bato
Arbaatu Ensesa
Gossoso
L
Amba Hedscha
Kefdimet
A
Amba Semajata
Walker & Boutall sc.

dolerite (22) occurs again, and continues almost up to Abuna Licanos. At the foot of this hill is a dense glassy basalt (26). Abuna Licanos consists of an ægirine-felspar rock (29), sölvsbergite. Between Abuna Licanos and Amba Gollo occur alternately dolerites (22) and rocks (32, 33) containing both riebeckite and ægirine, with porphyritic nephelines, which I have referred to "tinguaites." Amba Gollo consists of tinguaite (35).

Throughout this profile schists (2) are only marked as occurring in four places, where the level sinks below 6,800 ft. Sadebeck refers the rock from Abuna Licanos to gneiss, but mentions that one would have expected an eruptive rock.

The three remaining profiles proceed from Abuna Licanos.

Profile VI.—M-N, Abuna Licanos to Edda Gijorgis. Edda Gijorgis consists of an ægirine-anorthoclase rock (sölvsbergite, 35*b*); an ægirine-felspar-nepheline rock also occurs (tinguaite, 35*c*). Between Edda Gijorgis and Abuna Licanos dolerite (22) is met with.

Profile VII.—M-O, Abuna Licanos to Habat Zoddo.

Habat Zoddo (7,500 ft.) consists of dolerite (22). Between this and Abuna Licanos are marked ferruginous breccias (laterite 5), but rock (37), which from its number should be near Edda Exina although it is not marked on Schimper's profile, is a grorudite like that of Semajata.

Profile VIII.—M-P, Abuna Licanos to Amba Berra.

Amba Berra consists of ophitic olivine-dolerite (43 and 22). At the foot occurs a perlitic pitchstone, with porphyritic felspar and green augite, probably intrusive in the dolerite. Between Amba Berra and Abuna Licanos is mainly dolerite (22) and laterite, but at Biet Bendelion occurs a tinguaite almost identical in character with that from the top of Amba Gollo.

DESCRIPTION OF THE ROCK-SPECIMENS.

I. The Grorudites: Paisanite.

The rocks here referred to grorudite occur on Amba Subhat (6), Amba Semajata (14), Amba Berrach (23), Edda Exina (37), and Kedane Meheret.

The closely-related paisanite (52-54) constitutes Mt. Scholoda, near Adowa.

These rocks are referred to grorudite because they have the characters of hypabyssal rocks, and contain a soda-iron-silicate (ægirine), a potash-soda

felspar and quartz. The amount of the ægirine, however, is generally less than in the typical grorudites of Brögger, so that the rocks are rather leucocratic in character, and in some cases may perhaps be referred to the *lindöites* of the same author.[1] In mode of occurrence too, according to the profiles, they differ from the grorudites of the Christiania region, for instead of forming dykes they appear to constitute hummocky-shaped hills, which may be in the nature of laccolites intruded into the phyllites and subsequently exposed by denudation. In colour they are mostly pale pink or brown instead of green, but this is due to the fact that the ægirine is partly, and in some cases wholly, decomposed into ferrite.

They fall under two main types—(1) *Amba Subhat type*, corresponding to the Grusletten type of Brögger; and (2) *Amba Berrach and Semajata type*, corresponding to the Kallerud type of Brögger.

(1) *Amba Subhat type.*

One specimen (6*a*) is a very fine-grained compact pale pink rock, showing no porphyritic crystals, but seen with the lens to be speckled with minute black points (ægirine). Another specimen (6 *b*) has the ægirine arranged in dark green bands, with clearer bands between, so that it presents very much the appearance of a fine-grained gneiss.

These rocks consist of small irregular prismatic ægirines in a base of rectangular felspars, with interspaces filled with clear granular quartz and minute grains of ægirine partly decomposed into ferrite (Fig. 1, Pl. 3).

The prismatic *ægirines* show pleochroism from grass-green (vibration along the length) to brownish yellow (vibration across the length). Most of them give nearly straight extinction, but one showing signs of a cleavage had an extinction angle of about 5°. Compensation with the quartz wedge took place along the length (a axis of indicatrix nearly coincident with crystallographic axis *c*). Of the *felspars*, one or two larger crystals occurred porphyritically. These showed fine twin striations, with symmetrical extinctions in one case as high as 15°. The rectangular felspars of the groundmass are kaolinised; many of the smaller ones are in Carlsbad twins; most of them give a peculiar undulose extinction as if divided into sectors, so that in one part of the rotation between crossed nicols the appearance is that of an hour-glass structure (4 sectors), and in another that of a black cross (8 sectors)—

[1] The "ægirine-granite" from Miask, described by Pirsson (*Am. J. Sci.* IX, 1900, p. 199), though of coarser grain, is a closely related rock.

See Fig. 1, Pl. 3.[1] To judge from the chemical composition of the rock these felspars must be referred to anorthoclase. The *quartz* only occurs in the groundmass. The structure is panidiomorphic, with no trace of flow-structure.

A quantitative analysis of this rock gave the following result (I). For comparison under II is given the analysis of a grorudite from Varingskollen, Christiania.[2]

		I.		II.
SiO_2	= ...	73·46	... ...	74·35
Al_2O_3	= ...	12·47	... ...	8·73
Fe_2O_3	= ...	3·64	... ...	5·84
FeO				1·00
CaO	= ...	0·32	... ...	0·45
MnO	= ...	traces	... ...	0·22
MgO				0·07
Na_2O	= ...	5·63	... ...	4·51
K_2O	= ...	4·03	... ...	3·96
Loss on ignition	=	0·44	... ...	0·25
		99·99		99·38

Sp. gr. ... 2·58

A specimen from the hill Kedane Meheret, west of Gossoso, is of a grey, almost colourless rock, which under the microscope presents very similar characters to those of the rocks of Mt. Subhat, with the exception that it contains no porphyritic ægirines. There is a little opacite and ferrite, however, which may represent altered ægirine, and one or two minute green grains in the base are probably of the same mineral. The felspars present the same peculiar extinction in sectors, and granular quartz fills the interspaces. This rock may perhaps be referred to the *quartz-lindöites* of Brögger (*l. c.* p. 133).

(2) *Amba Berrach type.*

Rock (23) from Amba Berrach is pale brown and thickly speckled with small milk-white felspars, giving rectangular and diamond-shaped outlines. It is coarser grained than the Mt. Subhat specimens. Under the microscope idiomorphic rectangular felspars are seen to occupy

[1] This extinction in sectors is precisely similar to that observed by Gränzer in the orthoclase-like mineral occurring in druses in leucite-tephrite from the Eulenberg (*Min Mith.* XI, 1889–90, p. 277, Taf V, figs. 4 and 5). A redetermination of the alkalies in this mineral would be desirable. It may possibly be anorthoclase.

[2] Brögger, *Eruptivgesteine des Kristianiagebietes*, I, p. 48.

almost the whole space. Between them is quartz, with short needles of ægirine surrounding the felspars (Fig. 2, Pl. 3). The *felspars* are mostly in Carlsbad twins, and show the same peculiar extinctions as in the case of the Subhat specimens. In many of them (*e.g.* the one on the left of the figure) the hour-glass structure is visible in ordinary light, owing to the fact that one half of the crystal has suffered kaolinisation more than the other. Between crossed nicols the kaolinised sectors show the very fine twin striations characteristic of anorthoclase, while the other two sectors extinguish uniformly. The pale green ægirine needles have th same optical characters as the ægirine of the Subhat specimens.

A pale pink rock (14) from Amba Semajata has the appearance of a very fine-grained granite. The rectangular and square-shaped sections of felspar show the same kind of extinction in sectors as in the preceding, but are in less amount. The interspaces contain mostly lath-shaped felspars, showing some approach to flow structure. Quartz is only sparingly present; opacite and ferrite in grains and patches probably represent altered ægirine. This rock is less acid than those of Mt. Subhat, and shows some approach to the sölvsbergites. In chemical composition, however, it is near to the quartz-lindöites of Brögger.

The result of a partial quantitative analysis of the rock from Amba Semajata is as follows (I). Under II is given for comparison the analysis of grorudite from Kallerud, and under III that of quartz-lindöite from Frön.

		I.		II.		III.
SiO_2	=	68·96	...	71·35	...	69·00
Al_2O_3	=	15·17	...	12·21	...	13·95
Fe_2O_3(+FeO)	=	3·10	...	5·67	...	3·94
CaO	=	0·71	...	—	...	—
MnO, MgO	=	traces	...	—	...	—
Alkalies, &c.	=	(12·06)	...	11·06	...	12·66
		100·00				

A very pale brown almost colourless rock (37) from Edda Exina is very similar to the rock from Amba Semajata, but the rectangular and square felspars are to a large extent replaced by longer lath-shaped felspars.

Paisanite.

The paisanite of Mt. Scholoda is a compact, cream-coloured rock, showing numerous small (up to 2 mm. square) porphyritic crystals of

clear quartz and felspar and blueish-black riebeckite. On the weathered surface the crystals of felspar and quartz stand out in high relief.

Under the microscope, porphyritic idiomorphic quartz and felspar crystals are seen to occur in a fine-grained allotriomorphic granular base of quartz and irregular felspars, in parts showing micro-pegmatitic structure (Fig. 3, Pl. 3.)

The porphyritic *felspars* show somewhat rounded outlines, and occur for the most part in groups of two or three individuals: they show lines of parting strongly marked by kaolinisation. No twin striations were observed, but the extinction was mottled and undulose. In cleavage flakes the extinction on *c* was $0°-2°$, and on *b* (showing bisectrix nearly normal) $9°-10°$. The porphyritic felspars are therefore most probably anorthoclase. The *felspars* of the base show most minute twin striations, and are also to be referred to anorthoclase.

The *quartz* phenocrysts are mostly rounded and embayed by the groundmass, but some well-defined hexagonal sections, showing positive uniaxial figures, also occur: they contain negative crystals and liquid inclusions with bubbles.

The *riebeckite* is in characteristic moss-like patches, interspersed between the quartz and felspar of the base, and also along the margins of the porphyritic felspars and quartz: it also occurs in larger grains included in the porphyritic felspars. The pleochroism is a=deep indigo blue, b=deep blue, c=pale brown, as determined in fragments, included in felspars, which showed cleavages. One or two minute grains of ægirine were observed in the slide.

Near the contact with the phyllite the rock becomes very compact, and is almost free from phenocrysts.

A quantitative analysis of the paisanite gave

SiO_2 ...	=	76·01
Al_2O_3 ...	=	11·96
Fe_2O_3 ...	=	2·06
FeO ...		
CaO ...	=	0·26
MnO ...	=	traces
MgO ...		
Na_2O ...	=	4·46
K_2O ...	=	4·73
Loss on ignition	=	0·28
		99·76

Sp. gr. ... 2·58

II. The Sölvsbergites.

The rocks here referred to sölvsbergite are ægirine-anorthoclase rocks containing either no quartz at all or only a small amount. They occupy as regards basicity an intermediate position between the grorudites containing quartz and the tinguaites containing nepheline. They are for the most part characterised by a trachytic flow structure as opposed to the panidiomorphic structure of the more acid grorudites, the felspars of the groundmass being long lath-shaped instead of short rectangular.[1] They are generally not markedly porphyritic. Owing to the platy arrangement of the felspars the rocks show a peculiar surface shimmer, and are often fissile. In all the above characters they closely resemble the sölvsbergites of the Christiania region described by Brögger.

These rocks occur at Edda Gijorgis (35 c), Amba Bachele (8), Abuna Licanos (29), Abuna Alif (7), Arbaatu Ensesa (18 and 19), Amba Bato (12), Gossoso (13), and Amba Berrach (23).[2]

They may be divided into two groups, viz.—

(1) *The Edda Gijorgis type*, to which also belong the rocks from Amba Bachele and Abuna Licanos.

(2) *Abuna Alif type*, to which belong the rest.

(1) *Edda Gijorgis type.*

This type is somewhat coarser grained than the other, and shows a sub-porphyritic structure with two generations of felspar.

The rock from Edda Gijorgis, which is the material used in the construction of the Obelisks at Axum, is a cream-coloured rock, speckled with greenish black patches of ægirine and small (about 1 mm. square) glassy felspars.

Under the microscope (Fig. 4, Pl. 3) the only minerals observed are felspar and ægirine, with a little opacite. The *felspar* is in two generations, both in large amount. The larger felspars show rectangular sections, and are mostly Carlsbad twins. They consist of anorthoclase, and present precisely the same characters as the porphyritic felspars of the

[1] Brögger remarks in connection with grorudite and sölvsbergite that it is probable that the short rectangular form of the felspars of the groundmass is connected with more acid composition, and the long lath-shaped form with a less amount of silica. (*l. c.* p. 48.)

[2] The ægirine-riebeckite-anorthoclase rock from Akub Teriki, Senafé, described by the author in a previous paper (*Min. Mag.* XII, 95) should without doubt be also referred to the sölvsbergites.

paisanite just described, with the same peculiar mottled undulose extinction and well-marked transverse lines of parting. The interspaces between these larger crystals is filled with long lath-shaped felspars of the second generation, showing well-marked flow structure. The *ægirine* occurs in fairly large amount in ragged patches, interpenetrated by the felspar laths. In sections showing a nearly rectangular cleavage, with an optic axis just off the field, the pleochroism was from brownish-yellow to grass-green. In a section showing only one cleavage with nearly straight extinction, and compensating with the quartz wedge along the length, the pleochroism was from brownish-yellow to grass-green with a trace of blue. The pleochroism therefore is—

$\mathfrak{a}$ = grass-green, with bluish tinge.
$\mathfrak{b}$ = grass-green.
$\mathfrak{c}$ = brownish-yellow.

A quantitative analysis of this rock gave the following result (I). For comparison, in II is given the analysis of sölvsbergite from the Lougenthal, Christiania.

		I.		II.
SiO_2	=	63·74	...	62·70
TiO_2	=	trace	...	0·92
Al_2O_3	=	17·86	...	16·40
Fe_2O_3	=	4·27	...	3·34
FeO	=	0·30	...	2·35
MnO	=	0·19	...	trace
CaO	=	0·83	...	0·95
MgO	=	0·10	...	0·79
Na_2O	=	7·23	...	7·13
K_2O	=	5·19	...	5·25
Loss on ignition	=	0·83	...	0·70
		100·54		100·53

One specimen (8 *b*) from Amba Bachele presents almost precisely the same characters as those of the Edda Gijorgis rock. It is a cream-coloured rock with a greenish tinge, due to specks of ægirine, and has a marked fissile character. Under the microscope it shows rectangular sections of anorthoclase, with interspaces filled with long lath-shaped felspars and ægirine in small irregular patches. The ægirine is in smaller patches, and the felspars of first generation are somewhat smaller and more lath-shaped than in the preceding rock.

A second specimen (8 *a*) from Amba Bachele, however, has a rather different structure, more akin to that of the grorudites.

This is a pale gray, somewhat cavernous rock, showing to the lens small porphyritic white felspars and black specks of ægirine. Under the microscope it is seen to consist of rectangular anorthoclases, similar to those in the preceding rock, and short prismatic crystals of ægirine, with the interspaces filled with an altered unindividualised felsitic-looking base instead of the long lath-shaped felspars of the preceding rock.

Rock (29), from Abuna Licanos, is a cream-coloured rock consisting of tabular felspars with black specks of ægirine and brown patches of an altered mineral. Under the microscope it is seen to be rather more coarse-grained and less porphyritic than the rock from Edda Gijorgis. The felspars of the first generation present the same characters, but are larger, as are also those of the second generation, which are rectangular rather than long lath-shaped. The ægirine is in rather more definite prismatic crystals.

(2) *Abuna Alif type.*

The rock (7) from Abuna Alif is, like the preceding, of a pale cream colour, with small black specks of ægirine, but is more compact and finer grained. It has a scaly appearance, and is markedly fissile, owing to the tabular arrangement of the felspars. It consists of a felt of lath-shaped felspars with trachytic flow structure, and ægirine in irregular prismatic fragments, interspersed between the felspar laths. Some granular epidote is present, due to the decomposition of the felspars.

From Arbaatu Ensesa there are two specimens.

One (18) is a deep reddish brown compact platy rock with greasy lustre, which under the microscope shows a similar structure to that of the preceding, except that the felspar mesh is finer-grained and the ægirine is in smaller amount: there is, however, much opacite and ferrite which gives the colour to the rock, and is the result probably of the decomposition of ægirine.

The other specimen (19) from Arbaatu Ensesa is coarser-grained and more like the Abuna Alif rock. It is, however, much decomposed, and no unaltered ægirine is seen in the section. This is also the case with the specimens from Amba Berrach (21), Gossoso (13), Amba Bató (12), and Amba Hedscha (20).

III. The Tinguaites.

These rocks contain, besides felspar and ægirine, also nepheline, and in some cases a certain amount of riebeckite accompanying the ægirine.

They occur between Abuna Licanos and Amba Gollo, at the top of Amba Gollo (35), and at Biet Bendelion (39) between Abuna Licanos and Amba Berra, and also on Edda Gijorgis (35*b*).

Though characterised by the same mineral constituents, they present different varieties of structure.

(1) *Tinguaite* between Abuna Licanos and Amba Gollo.

This is a rock with a peculiar mottled appearance, due to green patches of ægirine in a spotted colourless to pink groundmass.

Under the microscope are seen (Fig. 6, Pl. 3) ragged ophitic patches of ægirine, with a little moss-like riebeckite in a base of minute felspar microliths, showing marked flow structure. Scattered through the base, not standing out very prominently as porphyritic crystals, but looking as though they had separated almost at the same time as the felspar microliths, are numerous fairly large rectangular and hexagonal sections of nepheline, often congregated into groups surrounded by the ægyrine patches which radiate out from them. These nephelines are crowded with felspar microliths, like those of the base, arranged in a circular way in a sort of whirl.

(2) *Tinguaite* from top of Amba Gollo, and from Biet Bendelion.

The rock (35) from the top of Amba Gollo shows a clear white ground, through which are disseminated round patches consisting of a central brown part of altered nepheline, surrounded by dark green ægirine. Under the microscope the constituents are seen (Fig. 5, Pl. 3) to be the same as in the preceding, but the structure of the base is allotriomorphic granular instead of trachytic. The nepheline also occurs only in large irregular porphyritic crystals, surrounded by patches of grass-green ægirine with long projecting rays. The riebeckite is in larger amount in ophitic patches and moss-like aggregates, often showing, however, regular prismatic outlines with pleochroism *a* (along the length), deep indigo blue; *c* (across the length), pale brownish yellow; and with straight extinction and compensation with quartz wedge along the length.

The base showed only here and there lath-shaped felspar microliths, with flow structure, but consisted apparently mainly of interlocking felspars, showing no twin lamellæ : nepheline probably is also present.

The rock (39) from Biet Endelion showed almost precisely the same characters, except that the large nephelines were wholly decomposed.

(3) *Tinguaite* from Edda Gijorgis.

This rock (35 *b*) was of a different character to the preceding tinguaites.

It is a greenish grey rock, with greasy lustre like a phonolite, and

shows to the naked eye no porphyritic crystals of nepheline or patches of ægirine, but only minute black specks of the latter mineral.

Under the microscope small, rather pale green to yellow ægirines, in short prisms, are seen very uniformly distributed in a base of irregular interlocking felspars and much clear nepheline in small rectangular sections, some of them with inclusions of minute felspar microliths as in the tinguaite (1). In parts of this slide the felspars are lath-shaped, and show well-marked trachytic flow-structure with the nephelines wedged in between the laths. Some epidote is present. One or two larger porphyritic felspars much corroded also occur.

A quantitative analysis of this rock gave the following result (I). Under II, for comparison, is given the analysis of a tinguaite from Hedrum :—

		I.		II.
SiO_2	... = ...	57·81	...	56·58
Al_2O_3	... = ...	18·74	...	19·89
Fe_2O_3	... = ...	5·76	...	3·18
FeO	... = ...	0·42	...	0·56
MnO	... = ...	traces	...	0·47
CaO	... = ...	1·28	...	1·10
MgO	... = ...	traces	...	0·13
Na_2O	... = ...	9·35	...	10·72
K_2O	... = ...	4·52	...	5·43
Loss on ignition	= ...	1·50	...	1·77
Sp. gr. ...	... 2·64	99·38		99·83

The so-called nepheline-tephrite, from the valley of the Jamma, in Schoa, described by Michel Levy (C.R. CII, 1886, p. 451) appears to be a tinguaite, with characters very similar to those of the above rocks. It occurs in thick dykes in Jurassic rocks, and consists of nepheline and small microliths of felspar which Michel Levy refers to oligoclase, one or two porphyritic orthoclases and a green pleochroic "amphibole" (ægirine ?) in patches visible to the naked eye with long radiations.

Phonolites from Mt. Kenya and also from Teneriffe and Gran Canaria show close resemblances to the above tinguaites in containing ragged ægirine patches surrounding nepheline phenocrysts.

Some of the so-called "nepheline-syenite" (tinguaite) dykes in Pocos de Caldas, Brazil, described by J. Machado (*Min. Mitth.* IX, 1888, p. 337), present very similar characters to the tinguaite (3), *e.g.* the one represented in Fig. 6, Pl. V, and Figs. 3 and 4, Pl. VI (*loc. cit.*), the

pleochroic grass-green "augite," with its low angle of extinction, being most probably ægirine.

IV. The Trachyte and Pitchstone.

Trachyte (15), from the top of Amba Hedscha (9,200 feet).

This is a pale purplish trachytic-looking rock, showing small phenocrysts of anorthoclase. It is very similar in character to the riebeckite-anorthoclase-trachyte from Mt. Kishyat, described by the author (*Min. Mag.* 1899, XII, 94).

Under the microscope phenocrysts of anorthoclase, showing the characteristic fine twin striations, occur in groups in a trachytic base of small felspar laths, with flow structure. There is much opacite, which might very well represent altered riebeckite, as in the rock from Kishyat.

Pitchstone (42), from foot of Amba Berra.

This rock shows in a thin section a pale-brown perlitic glass crowded with minute felspar microliths (with a low power only visible between crossed nicols). It contains a few small phenocrysts of felspar, and one or two long prisms of pale-green augite, with extinction which in the two or three sections examined did not exceed 17°, and with pleochroism along the length, pale yellow green, and across the length yellow.

A quantitative analysis gave the following result (I). In II is given the composition of the anhydrous rock after deducting the loss on ignition, in order to show what relation it bears to the grorudites.

		I.		II.
SiO_2	=	67·03	...	71·13
Al_2O_3	=	14·25	...	15·12
Fe_2O_3	=	1·96	...	2·08
FeO	=	1·70	...	1·81
MnO	=	trace	...	—
CaO	=	1·05	...	1·12
MgO	=	trace	...	—
K_2O	=	3·90	...	4·13
Na_2O	=	3·85	...	4·08
Loss on ignition	=	5·73	...	—
		99·47		99·47

Sp. gr. ... 2·376

V. The Dolerites and Basalts.

The *dolerites* occur at Dăbra Sina, Ganef, and the top of Amba Berra. The rock (24) from the top of Dăbra Sina is a coarse-grained aggregate of purple titaniferous augite, and much clear unaltered olivine, with long prismatic felspars, and magnetite in grains and long rods. There is a slight approach to ophitic structure.

The dolerite from Ganef is similar, but here the ophitic structure is more pronounced: olivine is in large amount, but in smaller grains: some of the felspars show undulose extinction, and are probably less basic than the others.

The rock (43) from the top of Amba Berra is similar, but somewhat finer grained.

The *basalts* occur at Amba Herres (17), Magdalai (16), and also between Edda Jasus and Abuna Licanos (26). The first two have apparently the characters of old rocks, and the last of a glassy more recent lava.

The rock (17) from Amba Herres is non-porphyritic, and shows in section a fine-grained aggregate of felspar laths, augite and magnetite: in the section is seen a large irregular foreign quartz fragment, surrounded by the usual zone of alteration of pale green augite needles.

The rock (16) from Magdalai is also non-porphyritic. It is very fine-grained, and shows felspar laths and large magnetite grains, with augite converted into viridite: some calcite and epidote are also present.

The basalt (26) from near Edda Jasus is of a different character. It consists of sharply defined, small lath-shaped felspars, and some altered olivines in a dense glassy base.

CONCLUSIONS AND COMPARISON WITH ROCKS FROM OTHER PARTS OF AFRICA.

These rocks of Abyssinia, just as their counterparts in the Christiania Grorudite-Tinguaite District, offer a striking example of a "rock series" as defined by Brögger. Thus they belong to a number of types which, as regards mineral and chemical composition, possess certain relations in common, while in other respects they exhibit a continuous change of composition from one end of the series to the other. They are referred to the grorudite, sölvsbergite, tinguaite series, since they are hypabyssal rocks, characterised (1) mineralogically, by a potash-soda felspar (anorthoclase), a soda-iron silicate (ægirine and riebeckite[1]), with, in the more acid

[1] Brögger's cataphorite was not observed in these Abyssinian rocks.

members quartz, and in the more basic nepheline; and (2) chemically, by their low percentage of lime and magnesia, and their high contents of alkalies with soda in excess of potash.

According to Dr. Schimper's profiles they have been intruded through the phyllites and schists belonging to the basement rocks of Abyssinia (the metamorphic group of Blanford), and now form hummocky-shaped hills. This certainly appears to be the case with the paisanite of Mt. Scholoda, of which many specimens were collected on both sides of the mountain. In the case however of some of the other rocks, further observations in the field may possibly show that they do not constitute the main bulk of a mountain, as shown in the profiles, but occur as dykes traversing other rocks.

The magma from which they were differentiated must have been one rich in soda, and was in all probability a nepheline-syenite. The mineral character of the granite of the Mărab, which is the only coarse-grained plutonic rock in Dr. Schimper's collection, is not suggestive of its being the source of these rocks.

With regard to their geological age nothing definite can be said. The rocks, however, are mineralogically and chemically closely related to volcanic rocks in other parts of Africa which are referred to the Tertiary period. The resemblance between the above tinguaites and the phonolites of Mt. Kenya and of Teneriffe and Gran Canaria has already been remarked upon (p. 269). Anorthoclase is the prevailing felspar in the rocks both of Kenya and Kilimandjaro, and Rosiwal[1] has described phonolitic and trachytic rocks containing the same felspar in the S. of Abyssinia (Schoa).

This line of soda-rich volcanic rocks can be traced further south into Madagascar, where eruptions have taken place as in Abyssinia through the crystalline schists which form the basement rocks of the island. Amongst some rock specimens brought back by Dr. Forsyth Major from Sirabe, Madagascar, are trachytes presenting very similar characters to the riebeckite-trachytes of Senafe, and to the trachyte from Amba Hedscha (p. 270), in which the iron silicate, however, has been altered to opacite. Trachytes from Madagascar, in the Museum of Practical Geology, Jermyn Street, which, through the kindness of Mr. Teall, I have had the opportunity of examining, also contain porphyritic felspars showing the minute twin striations characteristic of anorthoclase.

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[1] *Beitr. Geol. Kennt d. Öst. Afrika*, 74 and 81, 1891.

The prevalence of volcanic rocks, rich in soda, would almost seem to be a characteristic feature of the African continent and its adjacent islands.[1]

EXPLANATION OF PLATE 3.

Microsections of rocks from Abyssinia.

Fig. 1.—Grorudite from Amba Subhat.

Grass-green ægirine and rectangular felspars in a quartz base containing minute grains of ægirine. Some of the felspars are represented as seen between crossed nicols, and show the extinction in sectors.
Magnification, 70 diam. ¼ inch objective.

Fig. 2.—Grorudite from Amba Berrach.

Rectangular felspars showing hour-glass extinction and fringed with minute needles of ægirine in a quartz base.
Magnification, 30 diam. ½ inch objective.

Fig. 3.—Paisanite from Mt. Scholoda.

Phenocrysts of anorthoclase and quartz (top of figure) with moss-like riebeckite in a granular quartz-felspar base.
Magnification, 10 diam. 1½ inch objective.

Fig. 4.—Sölvsbergite from Edda Gijorgis.

Phenocrysts of anorthoclase in a trachytic base of felspar laths and ragged grass-green ægirine.
Magnification, 17 diam. 1 inch objective.

Fig. 5.—Tinguaite from Amba Gollo.

In the centre is a large irregular phenocryst of nepheline surrounded by ægirine which radiates out from it. Above and below is more radiating ægyrine, and to the right and left moss-like riebeckite.
Magnification, 10 diam. 1½ inch objective.

Fig. 6.—Tinguaite from between Abuna Licanos and Amba Gollo.

Ragged patches of ægirine and hexagonal and rectangular sections of nepheline with a little riebeckite (centre of figure) in a base of minute felspar microliths showing flow structure.
Magnification, 10 diam. 1½ inch objective.

[1] Lacroix (*Comptes Rendus*, CXXVIII, 1467) has recently described rhyolites from Somali-land containing ægirine and riebeckite.

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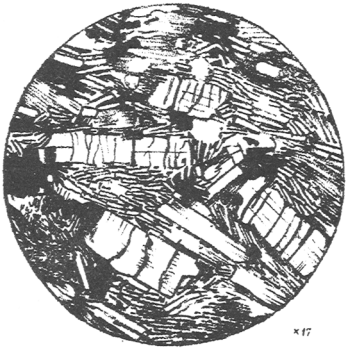

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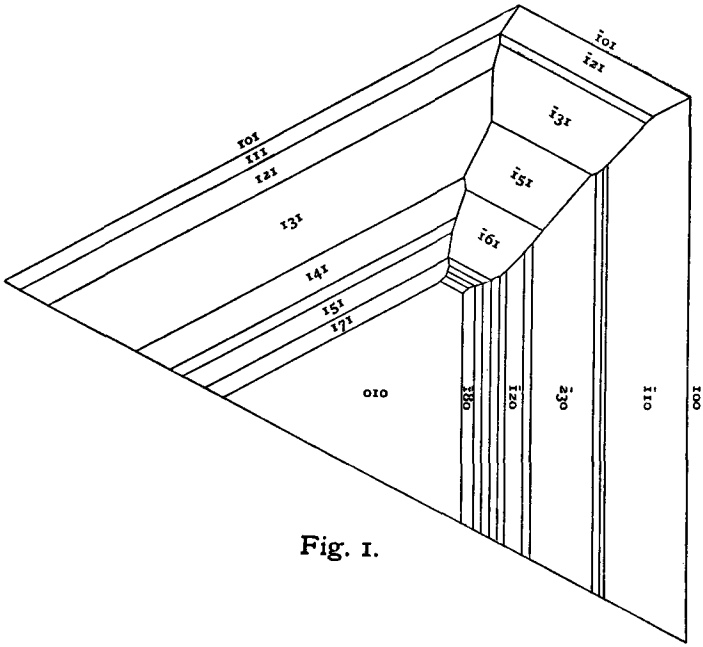
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Fig. 1.

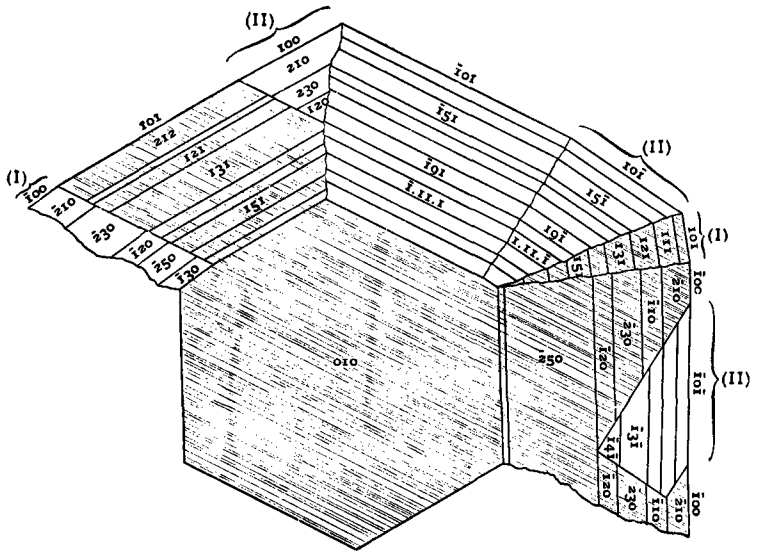
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Fig. 2.