A CHEMICAL AND MINERALOGICAL STUDY OF THE FELDSPARS FROM THE MICA-PEGMATITES OF NELLORE, MADRAS

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Introduction

THE feldspars from the Nellore mica-pegmatites comprise different types varying in chemical composition and mineralogical properties.[1] The most abundant of these feldspars are (1) an albite-oligoclase containing about 10 per cent. of Na_2O along with 2 per cent. of K_2O and (2) an orthoclase containing 16 per cent. of K_2O and 0·5 per cent. of Na_2O. In addition to these two main types there are also found appreciable quantities of perthites the most conspicuous of them being a green orthoclase variety, and a flesh-red microcline feldspar. The green variety occurs with varying intensities of colour. Examination of such specimens revealed that their soda feldspar contents were variable and ranged from 22 to 30 per cent.

Of the feldspars noted above, those which occurred in considerable quantities were (1) albite-oligoclase, (2) white orthoclase, (3) flesh-red microcline and (4) green perthite-microperthite. The other feldspars, especially the cream-coloured variety and the microperthites are of limited occurrence and large lumps of these are seldom found.

The occurrence of mica in the pegmatite masses is a matter of great economic importance. It was noticed that workable deposits of mica were located only in such areas where there was a preponderance of the albite-oligoclase and orthoclase varieties and that in localities where the other varieties of feldspar preponderated the deposits were poorly developed.

Edmondson Spencer [2, 3, 4] has carried out an elaborate study of several varieties of potash-soda-feldspars, especially the perthitic ones, from various parts of the world. He has made detailed investigations on the moonstones (orthoclase-microperthites) and other related potash-soda-feldspars from Ceylon and various other localities and has discussed the relationship between their chemical and physical properties and also the effect of high temperatures upon them. He has analysed some specimens of microcline-microperthites and an albite from the mica-pegmatites of Kodarma, Bihar, and also a few specimens of microcline-microperthites from Patna State, Orissa. Finally, in his last paper, he has applied the results of his earlier investigations to some questions of petrogenesis and differentiation with particular reference to granite and granite pegmatites. Spencer's work, excepting that on the moonstones from Ceylon, is of a general character dealing with the chemistry of the microperthites in relation to their physical properties and origin.

While dealing with the composition of granite pegmatites Spencer[5] makes a remark on the Kodarma pegmatites. He says, " Quantitatively, the Kodarma pegmatites are predominantly potassic, the majority being of the ' simple' quartz-microcline-muscovite type. Where the soda feldspar is present in more than subordinate amounts, it occurs almost to the exclusion of the potash feldspar. There is nothing approaching the 40 : 60 potash : soda-feldspar ratio of Vogt's residual magma".

Recently Sharma[6] has published a detailed megascopic and microscopic study of the feldspars from the mica-pegmatites of Kodarma. But he has not given any chemical analysis of these feldspars. A perusal of the paper gives no idea of the proportions of soda and potash feldspars in the pegmatite mass, but it is apparent that potash feldspar predominates.

It is rather interesting to note that while the feldspars from the Kodarma pegmatites have received widespread attention those from the Nellore pegmatites have received very little attention. In spite of their large distribution these feldspars have not been studied systematically. Sometime back Biswas[7] published a paper discussing the probable origin of the mica-pegmatites of Nellore, but he made no detailed reference to the individual feldspars present therein. His reference to the feldspars is as follows: " The pegmatite magma constitutes a system of albite-orthoclase-muscovite-quartz-volatiles equilibrium. The prevalence of sodic plagioclase (andesine to albite) in pegmatite dykes of Nellore indicates a melt initially saturated with these compounds. The relation between the potash feldspar and these sodic plagioclases is a eutectic one with extensive zones of solid solutions on either side of the boundary curve."

The feldspars from the mica-pegamatites of Nellore form an interesting series and unlike those of Kodarma they are made up of a mixture of the soda and potash varieties in equal proportions. Sometimes the sodic variety preponderates over the potassic one and thus approaches the 40 : 60 potash : soda-feldspar ratio of Vogt's residual magma. Nowhere in the Nellore pegmatites is the soda feldspar found to occur to the complete exclusion of the potash feldspar. The sodic variety of the Nellore feldspar is an albite-oligoclase-muscovite-quartz-type, the potassic variety being an orthoclase-muscovite-quartz type. These feldspars also differ from those of the Kodarma pegmatites in that the main potassic variety is orthoclase instead of microcline. The present work was undertaken to study in detail the above characteristics of the feldspars from the Nellore pegmatites.

Megascopic and Microscopic Characters

The feldspars studied in this work can be classified under three main heads as follows: (*a*) Feldspars without perthitic intergrowths (*non-perthitic*), *viz.*, Albite-oligoclase, orthoclase and microcline; (*b*) Perthite-microperthites; and (*c*) Microperthites.

Non-perthitic Feldspars: (*a*) *Albite-Oligoclase.*—This feldspar is widely distributed and is almost always white with the characteristic twinning striations on (001) face. It comprises two or three different types with a slight variation in composition. Most of the samples examined were quite fresh and they showed only a slight alteration when examined under the microscope. Several specimens revealed the presence of scattered inclusions of muscovite scales. Some samples of this feldspar exhibit a parallel growth with clear glassy quartz, and some of them are characterised by a subdued play of colours. This phenomenon is visible only when the crystals are held in a particular angle to the incident light. Sections cut parallel to (001) show between crossed nicols the characteristic albite lamellar twinning. Extinction angle on (001) with reference to the trace of (010) cleavage is symmetrical, 2° 30′ and 3°. Extinction angle on (010) with reference to the trace of (001) cleavage is 16° and 15° 30′.

Two samples of the feldspar from two different areas, one from the Thallabedu Mica Mine and the other from the Shaw Mica Mine, were analysed and their compositions are given in Table II. A recalculation of the two analyses in terms of various feldspar molecules results in the following formulæ: (1) $Or_{12}Ab_{85}An_3$ and (2) $Or_9Ab_{87}An_4$.

(*b*) *White Orthoclase.*—This feldspar also occurs over a large area and is snow-white in colour. Though specimens from the surface show considerable alteration, the alteration is only very slight in samples from the fresh rock. Such alteration can be seen along cracks where there is a turbidity due to the formation of kaolin. Excepting for a few small grains of quartz as well as of minute scales of muscovite, this feldspar is very pure. It is closely associated with clear quartz and also with big books of muscovite mica. It presents clevages in two directions, *viz.*, parallel to (001) and (010), the former one being better developed than the latter. It shows no twinning and only in one case was a very faint incipient microcline twinning noticeable. Extinction angle on (001) with reference to (010) = 4° 30′. Extinction angle on (010) with reference to (001) = 6°.

A sample of this feldspar was subjected to chemical analysis (No. 3, Table II) and the composition calculated as feldspar molecules gives the following formula : $Or_{96\cdot7}Ab_3An_{0\cdot3}$. In addition to this specimen, two other specimens of orthoclase, one from Pallimitta Mica Mine and the other from Shaw Mine, were also analysed, but they were found to contain more soda and less potash than the specimen mentioned above. Microscopic examination of these two latter specimens showed the presence of thin veins of albite, thus confirming the results of chemical analysis. Very faint cross-hatching, not of the microcline but of the green perthite type, was also noticed in these two feldspars.

Swaminathan[8] examined several specimens of feldspars and has published the results of their chemical analysis. Although the specimens examined by him and by the author were from the same locality, the author has found serious variation in the chemical composition of the feldspars and he considers that Swaminathan's results require revision.

(*c*) *Flesh-red Microcline.*—Though hand specimens of this feldspar appear fresh, they reveal under the microscope an advanced state of alteration and turbidity. The kaolinization of this feldspar is more pronounced in (001) and (100) sections than in (010) sections. Isolated inclusions of albite which are not in optical continuity with the microcline host are found scattered without any definite orientation. No perthitic inclusions either of the films or veins type were noticeable. The cross-hatch is rather coarse (Microphotograph, Fig. 1, Pl. V). The cleavage parallel to (001) is alone well developed. Under high power this feldspar shows fine vesicles of ferruginous matter distributed unevenly throughout its body. Extinction angle on (001) with reference to the trace of (010) = 15° 20′. Extinction angle on (010) with reference to the trace of (001) = 5° 40′.

A sample of this feldspar was analysed and the results obtained were expressed in feldspar molecules. The formula was found to be $Or_{93\cdot9}Ab_{5\cdot6}An_{0\cdot5}$.

Perthite-Microperthites.—This group includes the following four types of feldspars :

(*a*) rich green orthoclase perthite
(*b*) pale-green orthoclase perthite
(*c*) pearl-white orthoclase perthite and
(*d*) flesh-red microcline perthite.

The last two of these four feldspars are only of very limited occurrence.

The Green Perthite-Microperthite.—This variety has been o
previously by Swamianthan and is described by him in his paper.
feldspar is not of restricted occurrence, as in addition to the localiti
tioned by Swaminathan, it is also often met with in many of the tes
Saidapuram, where search was made for good muscovite mica. It
found in the waste heaps from a few abandoned mica pits.

This feldspar is unique in character and offers many interestin
for study. The potash member of this feldspar appears to be an ort
and is green in colour. It shows the presence of very fine cross-l
on (001) face, but sections or cleavage flakes parallel to tl
give almost straight extinction with reference to the trace of (010) c
The coarse albite lamellæ or 'veins' extend regularly in a directio
parallel to (100). The veins vary in size and shape. In sections cut
to (001) they range in width from 0·2 mm. to 1·2 mm. while on (010)
the range is from 0·5 mm. to 1·2 mm. The (010) sections show
alternate bands of albite and potash feldspar along a direction whic
an angle of about 70° with the trace of the basal cleavage. Th
however, is found to be variable. In addition to these wide perthiti
one can also notice microperthitic lamellæ of albite, which owing
higher birefringence than the surrounding potash feldspar could be
between cross nicols under the microscope. With (001) sections thes
perthitic bands of albite lie almost parallel to the wide albite ban
parallel to the edge *ac* and normal to the trace of (010). In additi
could see in the (001) sections, very minute microperthitic bands c
much smaller than those mentioned already. When seen through
nicols they appear as very faint and narrow lighted areas. These
lie also in a direction parallel to the general run of perthitic bands
few cases they are also found lying in a perpendicular direction.

In all the perthitic feldspars analysed, it was found that the
bands, whether of the 'vein' type or the 'film' type, were almos
longer in sections cut parallel to (001) than in sections cut parallel
The thickness of these films is less in (010) sections than in (001)
The length of the coarse perthitic lamellæ varies from 1″ to 3″
sections and from ·5″ to 2″ in (010) sections. In (010) sections
feldspars, the perthitic and microperthitic structures are more reg
uniform than in (001) sections. Under low magnification, extincti
for (010) with reference to (001) cleavage is found to be about 7°.
high magnification, however, there is considerable separation of the n
thitic lamellæ of albite, which permits accurate measurement of th
tion angles of the two feldspars. The extinction angle of the potash

is about 5° and that for the soda feldspar of the microperthites about 20°. Under high magnification, the microperthitic structure is better defined on (010) sections than on (001) sections. In (010) sections the films (microperthitic lamellæ) are packed very closely. They appear to be shorter and thinner than those found on (001) sections (Microphotographs, Figs. 2, 3, 4 and 5, Pl. V). Multiple albite twinning is seldom observed in the microperthitic lamellæ.

The 'primary' or 'vein' perthite is very common in these green perthites and their lamellæ exhibit in almost all cases on basal sections the characteristic albite multiple twinning. Because of the very fine cross-hatching exhibited by the potash member of these feldspars and the fact that the 'vein' type of perthitic bands which are commonly met with only in microclines are present in these feldspars also, these have so far been wrongly considered to be microcline perthites.

The presence of cross-hatching in the potash member of this feldspar is interesting, because it exhibits the optical properties of an orthoclase and not microcline. (001) Cleavage flakes of this feldspar show almost straight extinction with reference to the trace of (010) cleavage while microcline would give an extinction angle of 15° 30′. Secondly, sections cut parallel to (010) show almost symmetrical interference figures in convergent polarized light. The obtuse bisectrix which is the direction of slow vibration is almost normal to (010) and parallel to the crystallographic axis *b*, while in microcline the obtuse bisectrix would make an angle of 15° 30′ with the normal to (010). Calculation of the optic axial angle from the refractive indices (Table I) gives about 50° while for microcline it is 83°. These observations show that the green potash feldspar is not microcline, but a feldspar of the orthoclase type.

The soda feldspar occurring as perthitic bands is white and so appears prominently on the green background of potash feldspar. The perthitic structure is easily seen with the naked eye, because the perthitic bands or 'veins' are rather coarse and have a thickness of about 1 mm. The microperthitic structure, however, is so fine and composed of such extremely thin elongated bands of albite oriented almost parallel to the coarse albite bands that a high magnification is necessary for their examination. On (001) sections, the coarse 'primary' or 'vein' perthitic bands show occasionally along their width the pinching-in and swelling out effect which is commonly observed in the albite bands of perthite.

(001) *Cleavage Flakes.* Extinction with reference to the trace (010) is straight for the potash member, at times reaching 1° to 1° 30′. Extinction for the albite-oligoclase bands is symmetrical and the angle of extinction is

4°. The extinction angle shown by the microperthitic lamellæ of albite is difficult to measure, but it is less than 3°. Cloudy patches mixed with fine granular matter are observed under high power in the body of the potash feldspar. The cloudy turbid patches which do not appear to be due to kaolinization, show a very faint birefringence. The feldspar is hidden from view in those places where these turbid patches occur. The plagioclase feldspar is free from these cloudy patches. The cross-hatching in the potash feldspar is very fine and uniform under low power and the lines of the cross-hatching are very closely packed. But under high power this cross-hatching is found to be made up of very fine alternating dark and white lines which present a fibrous structure (Microphotograph, Fig. 1, Pl. VI). The spacing of these lines is not uniform and they traverse alternating, longitudinal and horizontal zones of dark and bright areas (Microphotograph, Fig. 2, Pl. VI). These alternating bands of dark and light areas run parallel to the direction of general run of the perthitic lamellæ and also perpendicular to this direction. This effect is due to the close and regular packing of the dark fibrous bundles of the cross-hatching, which enclose bright areas in which these fibrous bundles are more widely spaced. Thus this type of longitudinal and horizontal bright and dark zones results in a 'mat'-like structure and the resulting cross-hatching looks as if it is made up of alternating bright and dark squares (Microphotograph Fig. 3, Pl. VI). The alternating bright and dark bands running parallel to the direction of the perthitic and microperthitic lamellæ are developed more prominently than those running perpendicular to this direction. The contacts between the coarse albite bands and the potash feldspar are always slightly irregular and form a serrated border which becomes noticeable only when the section is examined between crossed nicols. There is invariably present in the potash member at its junction with the soda member a thin zone which does not generally show an uniform extinction, nor is it extinguished simultaneously with either of the feldspars. The extinction angle of this zone of feldspar is about 10° with reference to the trace of (010) cleavage.

(010) *Cleavage Flakes.*—Extinction of the potash member with reference to the trace of (001) cleavage is oblique and the extinction angle for the bright green and pearl-white feldspars is 5° 20′ while for the pale green feldspar it is slightly more, *viz.*, 6°. Short, sinuous and spindle-shaped microperthitic lamellæ are found in abundance parallel to the usual perthitic plane and form an angle of 70° 30′ with the trace of basal cleavage. The extinction angle of these microperthitic lamellæ is slightly more than that of the coarse perthitic bands and it is 20° with reference to the basal cleavage. The extinction angle of the coarse perthitic bands of albite is 19°. These sections give a

biaxial symmetrical interference figure for the potash member when examined between crossed nicols in convergent polarized light.

Sections perpendicular to (010) *and almost parallel to* (100).—In these sections the traces of the basal cleavage and the (010) cleavage cut each other at 90°. When examined between crossed nicols in convergent polarized light these sections give a biaxial interference figure which is almost symmetrical.

An examination of the two sections (010) and (100) shows that the optic axial plane is perpendicular to (010) and only slightly inclined to the basal plane. The Bx_o, which is the direction of slow vibration, is almost normal to (010) and parallel to the crystallographic axis *b*. The Bx_a, which is the direction of fast vibration, makes an angle of $+ 5° 20'$ with the crystallographic axis *a*.

Size and Distribution of the Perthitic and Microperthitic Lamellæ.—The bands of albite in these feldspars can be classified into two main groups :—(i) The coarse perthitic bands or 'veins' which vary from 0·2 mm. to 1·2 mm. in thickness and from 20 mm. to 80 mm. in length.

(ii) (*a*) Fine microperthitic lamellæ 'films' varying from 0·001 mm. to 0·005 mm. in thickness and from 0·05 mm. to 0·5 mm. in length. These lamellæ form the main feature of the microperthites and they can be compared to the 'strings' mentioned by Alling[10] in his recent paper on plutonic perthites.

(*b*) Very fine lamellæ, not so abundant as those of the previous type. They can be compared with the 'stringlets' of Alling.[10] Unlike the 'strings' and 'stringlets' of the plutonic perthites examined by Alling the zones of these microperthitic lamellæ not only overlap but also intergrade. They are not distinct in size and distribution. The transition from one type to the other is very gradual and imperceptible. For the sake of convenience, however, these microperthitic lamellæ are subdivided into two classes according to Alling to indicate their approximate size.

Curves showing the size of perthitic and microperthitic lamellæ as well as their distribution in (001) and (010) sections of the green feldspar are given in Figs. 1–4,

Fig. 1 PERTHITIC BANDS (VEINS).

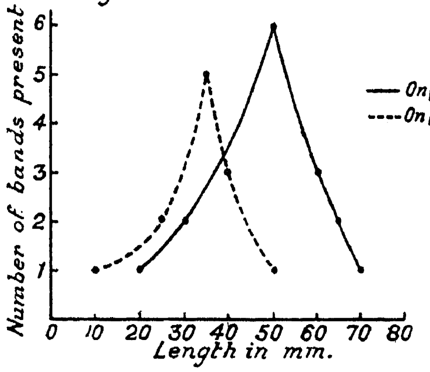


Fig. 2 PERTHITIC BANDS (VEINS).

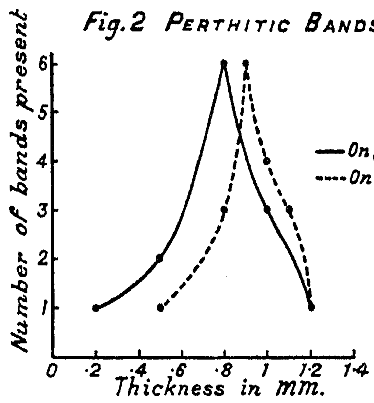


Fig. 3 MICRO-PERTHITIC BANDS (FILMS)

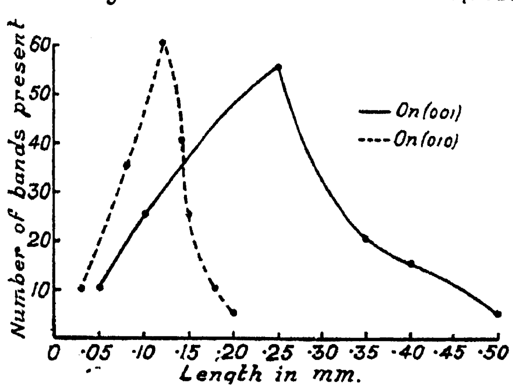
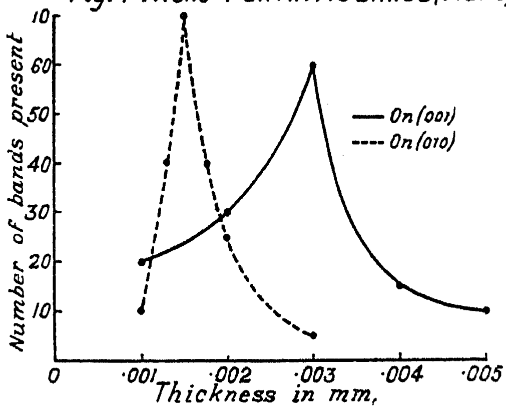


Fig. 4 MICRO-PERTHITIC BANDS (FILMS).



The Pearl -White Perthite-Microperthite.—Despite the lack of colour this variety resembles in all other properties the green perthite. It is similar to the green perthite which has been deprived of its colour by heat treatment. This feldspar exhibits schiller phenomenon to a marked degree.

Flesh-red Microcline Perthite.—This feldspar has only a very limited distribution and occurs as small isolated patches within the flesh-red microcline belt. The potash member, which is a typical microcline, has coarse cross-hatching on (001). It resembles more or less the flesh-red microcline described already. Only one set of cleavages parallel to (001) alone is well developed. This feldspar is considerably altered.

Microperthites.—These are seldom found in large lumps and are observed only in the mica dumps but not in the pegmatite dykes. A detailed examination of these feldspars was not undertaken due to want of sufficient material. But chemical analyses of small specimens were carried out to ascertain their relation to the major feldspars of the pegmatite. Microscopic examination reveals that they resemble the microperthitic portion of the perthite-microperthites, but they differ in the distribution and size of the microperthitic lamellæ. The microperthitic lamellæ, which are larger in size and more numerous than those in the green perthites, are closely packed together, These microperthites can be classified into four groups according to their colour : (i) Green microperthite, (ii) Pale-green microperthite, (iii) Cream coloured to white microperthite, and (iv) Flesh-red microcline microperthite. The optical properties of the first three groups resemble closely those of the microperthitic portion of the green perthite. The extinction angle on (001) with reference to the trace of (010) varies from 0° to 2° and on (010) with reference to the trace of (001) it varies from 6° to 7°. Due to the close packing of the microperthitic lamellæ it is difficult to measure accurately the extinction angles. The flesh-red microcline microperthite shows an extinction angle of about 15° on (001) and about 6° 30′ on (010).

Specific Gravities and Refractive Indices.—Specific gravities, refractive indices, optic axial angles and birefringence (calculated from the refractive indices), and the extinction angles of the various samples are given in Table I.

TABLE I

Specimen	Sp. Gr.	Refractive indices			Calculated optic axial angles (2V.)	Birefringence (γ–α)	Extinction angles	
		α	β	γ			On (001)	On (010)
1	2·6158	1·5256	1·5297	1·5358	78·9°	·0102	2° 30′	16°
2	2·6209	1·5254	1·5292	1·5357	73·2°	·0103	3°	15° 30′
3	2·5608	1·5188	1·5250	1·5266	58°	·0078	4° 30′	6°
4	2·5655	1·5207	1·5251	1·5278	78·5°	·0071	15° 20′	5° 40′
5	2·5765	..	..	..	..	..	..	..
6	2·5668	1·5198	1·5242	1·5250	49°	·0052	0°–1° 30′	5° 20′
7	Not determd.	..	..	..	..	..	4°	19°
8	2·5781	*1·5199	1·5244	1·5253	52·2°	·0054	0°–1°30′	5° 20′
9	2·5809	..	..	..	..	..	..	..
10	2·5704	1·5200	1·5243	1·5256	60°	·0056	0°–2°	6°
11	2·5836	*1·5210	1·5255	1·5283	70·5°	·0073	15°	5° 30′
12	2·5722	1·5197	1·5236	1·5247	55·2°	·0050	0°–1′	6° 30′
13	2·5730	1·5202	1·5246	1·5255	48·2°	·0053	0°–1° 45′	6° 54′
14	2·5742	1·5205	1·5247	1·5261	64°	·0056	1°20′	6° 49′
15	2·5691	1·5214	1·5243	1·5277	85·1°	·0063	13° 52′	6° 32′

* Determination of refractive indices, etc., were made for the *Or* microperthitic portion only.

The determination of refractive indices was made with an Abbe refractometer using thin polished slices cut parallel to the principal planes of the indicatrix. The good development of the (010) face, which forms one such plane, facilitates easy working of this method. Further, this method was found to be better suited for the determination of refractive indices of these feldspars than the well-known immersion method. The correction is only about ± ·0002. But this method has only a limited application as it requires initial fixing up of the principal planes of the indicatrix and as such unsuited for the determination of the refractive indices of irregular grains.

The specific gravities of the powdered samples were determined by the specific gravity bottle method as recommended by Tutton.[11]

Specimens taken for examination.—

Nonperthitic	1.	White albite-oligoclase ..	from Thallabedu
	2.	White albite-oligoclase ..	from Shaw Mine
	3.	White orthoclase ..	from Thallabedu
	4.	Flesh-red microcline ..	from Pallimitta
Perthite-microperthites	5.	Green perthite ..	from L. N. Mine
	6.	Green portion (potash feldspar) of No. 5	,,
	7.	White portion (albite) of No. 5	,,
	8.	Pearl-white perthite ..	from Thallabedu
	9.	Pale-green perthite ..	from L. N. Mine
	10.	Green portion (potash feldspar) of No. 9.	,,
	11.	Flesh-red microcline perthite ..	from Pallimitta
Microperthites	12.	Green microperthite ..	from L. N. Mine
	13.	Pale-green microperthite ..	,,
	14.	Cream coloured to white microperthite	from Pallimitta
	15.	Flesh-red microcline microperthite	,,

Preparation of Specimens for Chemical Analysis.—To separate prior to chemical examination the perthitic and microperthitic constituents of the specimens of feldspar, the following method proved helpful. Since the two constituents were present in layers of appreciable thickness and were also well separated, a simple process of careful grinding was sufficient to yield thin plates of each constituent uncontaminated with the other. The thin plates thus obtained were examined microscopically prior to their chemical analysis.

Method of Analysis.—Samples which had been examined and found to be free from surface impurities were crushed to fine powder, in an agate mortar.

A weighed quantity of the material (0·5 gm.) was fused with pure anhydrous sodium carbonate in a platinum crucible. The cooled melt was taken in dilute hydrochloric acid, and silica, alumina, calcium and magnesium were determined as usual. Iron was estimated colorimetrically by the well-known potassium thiocyanate method. For the estimation of alkalies a separate portion of the material was analysed by the Lawrence Smith method and the alkalies were weighed as chlorides. From these mixed chlorides potassium was determined by the cobaltinitrite method as modified by Wasselicef and Matwejeb[12] and perfected by Sunawala and Krishnaswami.[13] The amount of sodium chloride was obtained by difference and the corresponding Na_2O calculated.

TABLE II

Chemical Composition Per cent.

Specimen	SiO_2	Al_2O_3	Fe_2O_3*	MgO	CaO	Na_2O	K_2O	Loss on ignition	Total
1	67·19	20·20	0·08	Nil	0·61	9·85	2·10	0·16	100·19
2	67·25	20·35	0·05	Nil	0·72	10·15	1·59	0·14	100·25
3	64·27	18·70	0·07	0·02	0·05	0·36	16·05	0·20	99·72
4	64·32	18·95	0·31	0·02	0·09	0·64	15·49	0·30	100·12
5	65·15	19·19	0·22	0·01	0·14	2·50	13·02	0·20	100·43
6	64·71	18·42	0·28	0·02	0·05	1·12	15·05	0·22	99·87
7	66·99	20·28	0·12	Nil	0·60	9·55	2·45	0·14	100·13
8	64·89	19·15	0·09	0·01	0·16	2·44	13·10	0·18	100·02
9	65·47	19·31	0·15	0·02	0·17	3·51	11·52	0·20	100·35
10	64·85	19·00	0·22	0·02	0·07	1·84	13·99	0·21	100·20
11	65·34	19·10	0·34	0·01	0·10	3·03	12·23	0·33	100·48
12	64·83	18·82	0·27	0·02	0·08	1·70	14·09	0·16	99·97
13	65·08	18·95	0·14	0·01	0·10	1·95	13·83	0·22	100·28
14	64·82	19·01	0·10	0·02	0·13	2·12	13·52	0·21	99·93
15	64·71	18·85	0·31	0·01	0·08	1·56	14·36	0·30	100·18

* Total iron expressed as Fe_2O_3.

TABLE III

Percentage Mineral Composition of the Specimens

(*Calculated from Table II*)

Per cent.

	Feldspars				Other constituents				
	Potash feld-spar	Soda feld-spar	Anorthite	Total feld-spar	Excess SiO_2	Excess Al_2O_3	Fe_2O_3	MgO	Loss (H_2O)
1	12·23	83·32	3·12	98·67	0·68	0·59	0·08	..	0·16
2	9·40	85·94	3·67	99·01	0·51	0·55	0·05	..	0·14
3	94·80	2·93	0·28	98·01	0·75	0·60	0·07	0·02	0·20
4	91·63	5·45	0·50	97·58	1·03	0·87	0·31	0·02	0·30
5	76·84	20·96	0·78	98·58	0·66	0·71	0·22	0·01	0·20
6	88·68	9·53	0·28	98·49	0·62	0·15	0·28	0·02	0·22
7	14·74	80·70	3·06	98·50	0·69	0·74	0·12	..	0·14
8	77·28	20·85	0·88	99·01	0·28	0·60	0·09	0·01	0·18
9	67·94	29·44	0·93	98·31	0·81	0·73	0·15	0·02	0·20
10	82·73	15·60	0·38	98·71	0·38	0·61	0·22	0·02	0·21
11	71·89	25·45	0·56	97·90	1·06	0·72	0·34	0·01	0·33
12	83·34	14·15	0·45	97·94	0·95	0·58	0·27	0·02	0·16
13	81·35	16·50	0·56	98·41	0·83	0·58	0·14	0·01	0·22
14	79·62	17·92	0·73	98·27	0·64	0·73	0·10	0·02	0·21
15	84·84	13·20	0·45	98·49	0·51	0·52	0·31	0·01	0·30

TABLE IV

The Quantities of the Feldspar Members Recalculated to a total of 100

Samples	$K_2O \cdot Al_2O_3 \cdot 6\,SiO_2$ *Or*	$Na_2O \cdot Al_2O_3 \cdot 6\,SiO_2$ *Ab*	$CaO \cdot Al_2O_3 \cdot 2\,SiO_2$ *An*	(*Ab* + *An*)
1	12·40	84·44	3·16	87·60
2	9·49	86·80	3·71	90·51
3	96·72	2·99	0·29	3·28
4	93·90	5·58	0·52	6·10
5	77·95	21·26	0·79	22·05
6	90·04	9·68	0·28	9·96
7	14·97	81·93	3·10	85·03
8	78·05	21·06	0·89	21·95
9	69·11	29·95	0·94	30·89
10	83·81	15·80	0·39	16·19
11	73·43	26·00	0·57	26·57
12	85·09	14·45	0·46	14·91
13	82·67	16·77	0·56	17·33
14	81·02	18·24	0·74	18·98
15	86·14	13·40	0·46	13·86

TABLE V

Quantities of the Two Feldspar Members as Calculated from Micrometric Measurements

Samples	*Or* mixed crystal by weight	*Ab* mixed crystal by weight	*Ab* by weight as microperthitic lamellæ in the *Or* mixed crystal
5	80·64	19·36	3·12
8	79·28	20·72	3·21
9	77·75	22·25	3·25
11	79·48	20·52	4·21
12	89·75	10·25	9·87
13	87·43	12·57	12·31
14	87·02	12·98	12·60
15	90·87	9·13	8·76

In Table VI (*a*) are given the micrometric measurements of specimens **5** and 9 (the green and pale-green perthite microperthites) and in Table VI (*b*) are given the mineral composition of these two feldspars with those of the Or and Ab mixcrystal components of specimen **5** and Or component of specimen 9, as calculated from their respective chemical composition. Results in Table VI (*c*) were derived by direct calculation from Tables VI (*a*) and VI (*b*). It was assumed, during this calculation, that the microperthitic albite is of the same chemical composition as that of the vein albite.

TABLE VI

Distribution of the Three Feldspar Members (Or, Ab and An) in Feldspars 5 and 9

Results obtained from the various methods	Feldspar member and its distribution	Specimens 5	6	7	9	10
(*a*) Calculated from micrometric measurements	*Or* mixcrystal by weight	80·64	..	..	77·75	..
	Ab mixcrystal by weight	19·36	..	..	22·25	..
	Ab mixcrystal in *Or* mixcrystal as films	3·12	..	..	3·25	..
(*b*) Calculated from chemical composition	Potash feldspar *Or* ..	77·95	90·04	14·97	69·11	83·81
	Soda feldspar *Ab* ..	21·26	9·68	81·93	29·95	15·80
	Anorthite *An* ..	0·79	0·28	3·10	0·94	0·39
	(*Ab* + *An*) ..	22·05	9·96	85·03	30·89	16·19

(*c*)		Specimen No. 5 — Calculated from analysis No. 5 — With the help of analysis 6	Specimen No. 5 — Calculated from analysis No. 5 — With the help of analysis 7	Specimen No. 9 — Calculated from analysis No. 9 with the help of analysis 10
Calculated from both (*a*) & (*b*) above	(i) *Or* in *Or* mixcrystal	75·41	75·52	67·89
	(ii) *Or* in *Ab* mixcrystal	2·54	2·43	1·22
(The quantities given here represent the percentage amount in the total specimen)	(iii) (*Ab* + *An*) in *Or* mixcrystal	8·40	8·75	12·80
	(iv) *Ab* in *Or* mixcrystal	8·11	8·44	12·49
	(v) *An* in *Or* mixcrystal	0·24	0·29	0·31
	(vi) *Ab* as solid solution in *Or*	4·99	5·32	9·55
	(vii) *An* in *Ab* of the *Or* mixcrystal	0·29	0·31	0·31
	(viii) (*Ab* + *An*) in *Ab* mixcrystal	13·65	13·30	18·09
	(ix) *Ab* in *Ab* mixcrystal	13·10	12·80	17·46
	(x) *An* in *Ab* mixcrystal	0·55	0·50	0·63

Discussion

Table IV shows that the albite-oligoclase feldspar (Nos. 1 and 2) contains 84·44–86·80 per cent. of soda feldspar and about 3 per cent. of anorthite. The orthoclase feldspar (No. 3) from Thallabedu mica mine holds about 97 per cent. of potash feldspar, the rest being soda feldspar whereas the flesh-red microcline (No. 4) from Pallimitta holds a slightly larger quantity of soda feldspar. In the perthite-microperthites (Nos. 5, 8, 9 and 11) the amount of potash feldspar varies from 69 per cent. to 78 per cent., soda feldspar from 21 to 30 per cent. and anorthite from 0·57 to 0·94 per cent. In the microperthites the percentage of potash feldspar ranges from 81 to 86 per cent., soda feldspar from 13 to 18 per cent. and anorthite from 0·46 to 0·74 per cent.

It can be seen from Table VI (*c*) that in the orthoclase mixed crystal (green portion) of the green perthite microperthite (No. 5), the amount of potash feldspar *Or* actually present is only about 75·5 per cent. of the total feldspars whereas the chemical analysis of the specimen 5 reveals the presence of nearly 78 per cent. of this constituent. It can therefore be deduced that about 2·5 per cent. of *Or* is present in the perthitic lamellæ of albite in a state of solid solution. This orthoclase mixed crystal also contains about 8 per cent. of soda feldspar partly (about 5 per cent.) in solid solution and partly (about 3 per cent.) as microperthitic lamellæ of albite. An examination of the pale-green perthite-microperthite (specimen 9) gives similar results excepting that this feldspar contains a larger percentage of soda.

It can be seen from Table VI (*c*) that in the albite mixed crystal (the coarse perthitic lamellæ or 'veins') of the green feldspar (specimen 5) the amount of soda feldspar *Ab* actually present is about 13 per cent. whereas chemical analysis of specimen 5 indicates the presence of this constituent to the extent of 21 per cent. These results show that 8 per cent. of soda feldspar is present in the *Or* mixed crystal. The amount of anorthite present in specimen 5 is very low being only 0·79 per cent. of which 0·5 per cent. occurs in the soda feldspar of the 'veins' (*Ab* mixed crystal), and the rest occurs in the *Or* mixed crystal, most probably along with the soda feldspar present therein.

The above points indicate that in these perthitic feldspars mutual solubility exists between the potash and soda members on the one hand, and the soda member and anorthite on the other, whereas the potash member and anorthite appear to be immiscible. It can be deduced therefore that the small amount of anorthite present in the *Or* mixed crystal is due to the presence of albite which can hold it in solution. This view is supported by the fact that the ratio of *Ab* to *An* is almost the same both in the *Or* mixed, crystal and in the *Ab* mixed crystal. It also follows from this view that the pure potash member should be free from anorthite.

Heat-treatment.—Almost all the coloured feldspars, excepting the flesh-red and cream coloured ones, lose their colour on heating them even at 300° C. The rich green perthite loses its colour on heating and is changed into a pearl-white feldspar. The cloudy patches seen in thin sections of the green feldspar disappear on heating and are converted into opaque granular material. Heating the specimens of the various perthitic feldspars at a temperature of about 800° C. and subsequent slow cooling to the room temperature does not produce any change in the perthitic structure or in the cross-hatching of the potash member. But on continued heating in the vicinity of 1000° C. and cooling suddenly, the following changes become noticeable. Some of the microperthitic lamellæ disappear almost completely and are replaced by areas which show a slightly higher birefringence than the surrounding potash member. The coarse perthitic bands, however, retain their original characters on heating, but the contact zones between them and the orthoclase host appears slightly widened. The zone is no longer sharp but develops into a somewhat ill-defined area which is not extinguished simultaneously with either of the feldspar members. The extinction angle for this zone on (001) face with reference to the trace of (010) is about 10°. Under similar conditions of heat treatment the cross-hatching of the potash feldspar tends to fade out. The extinction angles of the soda and potash feldspars were not altered by heating, but that of the potash member on (010) section showed a slight increase.

The Relationship between Iron Content and Colour.—Though a glance at the composition of these feldspars does not give us any clue as to the exact role of iron, a closer study reveals that iron plays an important part in the colouration of these feldspars. The increase in the quantity of iron with the increase of colour is easily noticed, but the colour itself may differ. The flesh-red feldspars which contain the maximum amount of iron owe their colour to the potash feldspar (microcline) which contains numerous minute specks of ferruginous vesicles. These vesicles are distributed throughout the mass of the potash feldspar and are abundant especially near its contacts with the albite present in the microcline perthites. These vesicles are rarely present in the albite lamellæ. The colour of these flesh-red feldspars is not destroyed by heat. The ferruginous vesicles occur largely in isolated areas and because of this the colour is never uniform throughout. Even in the case of the cream coloured feldspar the colour is probably due to vesicles of ferruginous matter, although no proof of it could be obtained microscopically. The very pale yellowish pink-colour of this feldspar is not destroyed by heat but persists like that of flesh-red feldspar even at high temperatures.

The green colour of the perthites and microperthites is completely destroyed by heat. The loss of colour is brought about even at a very low temperature, *viz.*, 300° C. and this loss of colour does not result in any noticeable change in the structure of the feldspar. But analyses carried out before and after heating show that almost all the iron present originally in the ferrous state is oxidised during heating.

The green colour of these feldspars is caused by a green turbidity probably due to a ferrous compound in a fine state of division as cloudy patches within the body of the feldspar. These special areas of turbidity were absent in the heated specimens. However, thick specimens of this mineral lose their general transparency on heating and become translucent and sometimes opaque acquiring a pearl-white colour. This is perhaps due to the development of numerous cracks within the feldspar. But such development of cracks in the body of the feldspar cannot explain loss of the original green colour, because small fragments which developed no cracks showed similar loss of green colour on heating. Thin sections of the heated specimens are perfectly clear except for the isolated patches of a granular opaque material in places originally occupied by the cloudy patches. The cloudy patches which are present in thin sections of the feldspar before heating render the whole field somewhat hazy but heating the specimen to 300° C. removes this turbidity (Microphotographs, Figs. 4 and 5, Pl. VI) and the sections show clearly all the minute details.

Though almost all the perthites examined exhibit schiller, the colour shown by them are not true schiller colours but due to a metallic impurity such as iron. The iron is present in the ferrous state in the green feldspar and as a ferric compound (probably as hematite or limonite) in the flesh-red feldspars. Although it appears that the schiller exhibited by these feldspars is due to their microperthitic structure, no relationship could be deduced between the nature of the microperthite structure and the colour of the specimens. Specimens with a poor development of the microperthitic structure exhibited feeble schiller effect and those with regular development of the microperthitic structure exhibited the effect strongly.

Origin of the Green Perthite-Microperthite.—Biswas[7] has discussed the origin of the Nellore mica-bearing pegmatites in a generalised manner. He has not, however, considered in detail the origin of the individual feldspar members of the pegmatite. It is generally considered that the two major feldspar members, *viz.*, orthoclase (including microcline) and albite-oligoclase, are the direct products of crystallisation of the potash-rich and soda-rich portions respectively of the residual pegmatite magma. The origin of the perthites cannot however be explained by the above simple view. To discuss the origin of these perthites, especially the green variety, it is necessary to consider their close association with minerals such as samarskite and beryl. The concentration of such minerals found in the close vicinity of these feldspars suggests that these feldspars crystallised during the last stages of consolidation of the potash-rich portion of the pegmatite magma.

The perthitic bands, *viz.*, the veins and films, appear to have formed simultaneously with their potash feldspar host and bear an eutectic relation to it because:

(i) The $(Ab + An)$ content of the coarse perthitic bands is uniform, *viz.*, 19 per cent. of the total feldspar.

(ii) Though the change from the 'film' to the 'vein' type is not gradual, several perthitic bands having intermediate sizes are often present.

(iii) Small lense-shaped blebs of albite are found scattered in the potash feldspar and these have a similar optical oritentation as that of the albite present in the 'veins'.

(iv) The contact zones of the *Or* with *Ab* are similar on either side of the vein.

(v) The abundance and size of the 'films' in the potash feldspar are the same near the veins as in regions further away.

(vi) The 'vein' as well as the 'film' perthite are in optical continuity with their orthoclase host.

Summary

The various feldspars from the mica-pegmatites of Nellore have been examined microscopically and chemically. They could be grouped under three main heads according to their composition and microscopic characters, *viz.*, (1) feldspars without any perthitic intergrowths, or non-perthitic variety, (2) perthite-microperthites and (3) micro-perthites.

These feldspars do not show on heating any appreciable alteration, excepting that in the green variety the colour is completely lost. The colour of the green feldspar can be attributed to the presence of a greenish turbidity due to a ferrous compound which gets oxidised on heating and loss of colour occurs.

The soda and potash members of the green perthites were separated by an easy method and they were examined chemically. The results of analysis

were utilised to calculate the composition of the perthite as regards the various feldspar members present therein. This procedure also yielded data regarding the mutual solubility of the various feldspar components present. It could be deduced that such mutual solubility exists, though to a limited extent, between the potash and soda feldspar on the one hand and between soda feldspar and anorthite on the other. Potash feldspar and anorthite, however, seem to be immiscible. It can be noticed that the soda member is more soluble in the potash member than *vice versa*.

It is shown that the colour of these feldspars is not schiller colour but due to an iron compound. The schiller exhibited by these feldspars appears to be due to their microperthitic structure.

The perthitic feldspars appear to have formed during the later stages of consolidation of the pegmatite magma. The 'vein' and the 'film' types of perthitic lamellæ seem to have originated simultaneously with their potash feldspar host.

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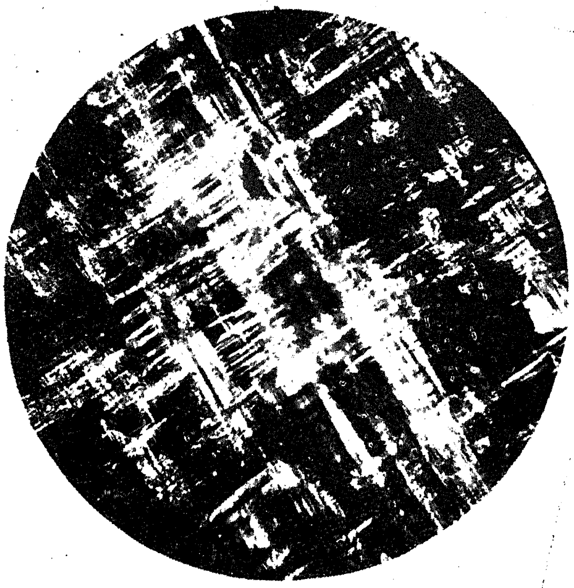


Fig. 1

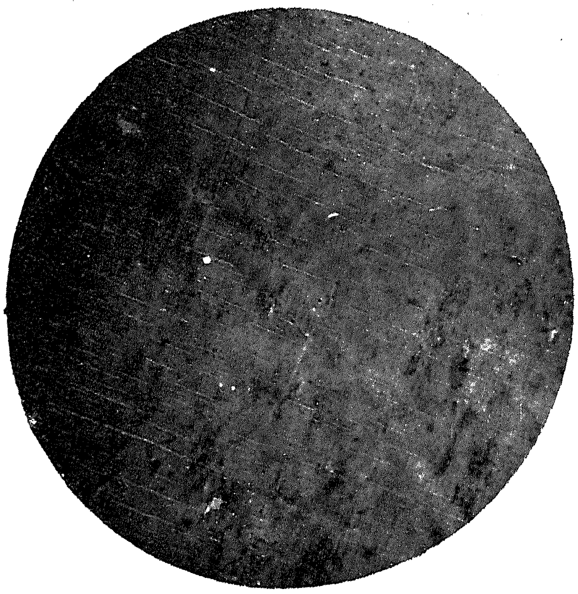
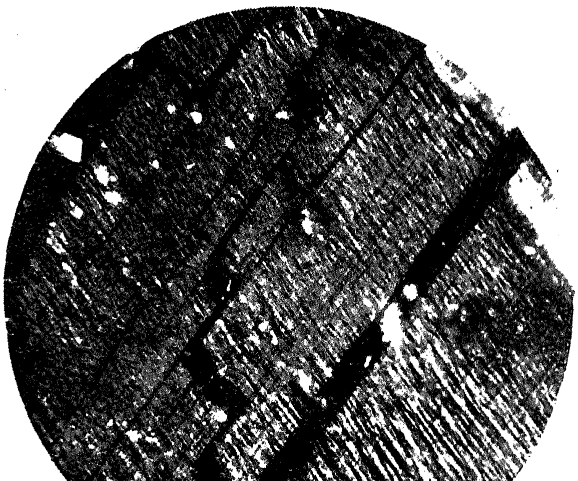


Fig. 2

Fig. 3



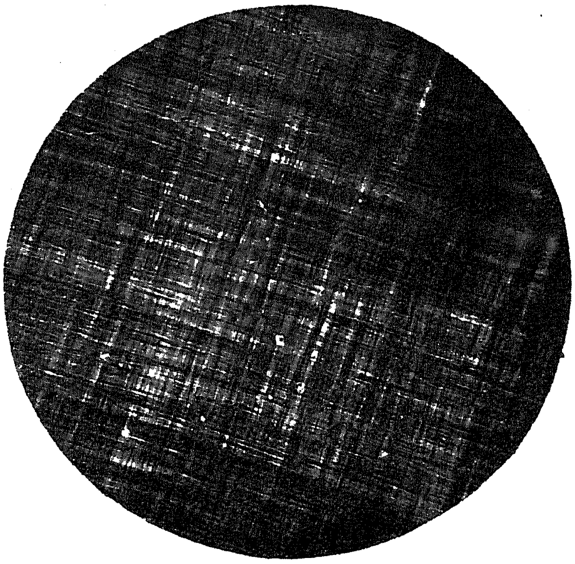


FIG. 1

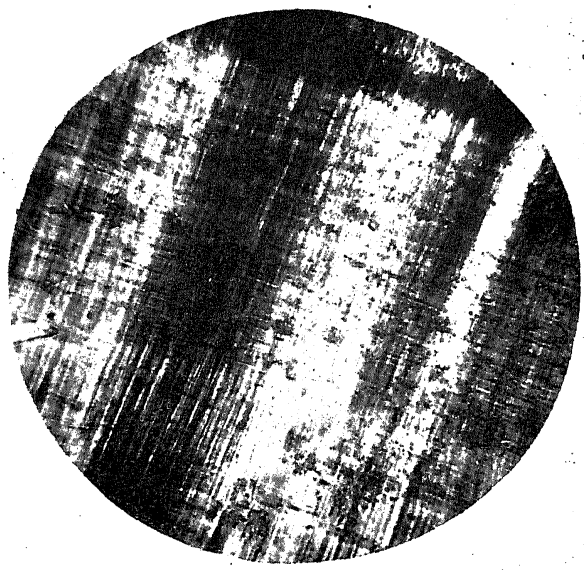


FIG. 2

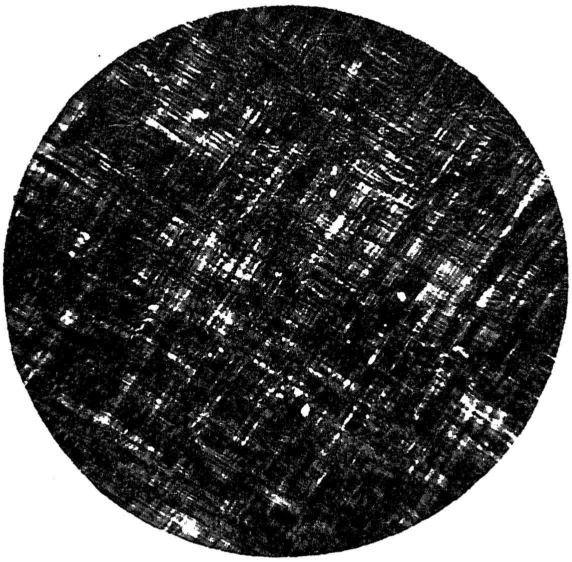


FIG. 3

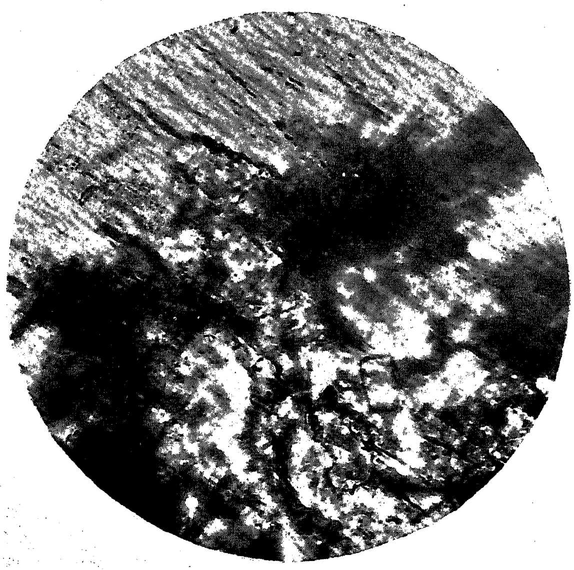


FIG. 4

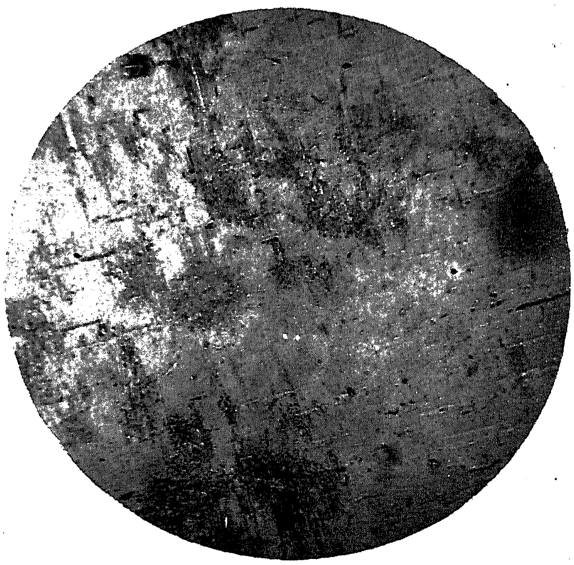


FIG. 5