The occurrence of nigerite, a new tin mineral in quartz-sillimanite-rocks from Nigeria.[1]

(With Plate VI.)

By R. Jacobson, M.Sc., F.G.S.

and J. S. Webb, A.R.S.M., B.Sc., F.G.S.

Geological Survey of Nigeria.

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I. Introduction.

A NEW tin mineral, which has been given the name 'nigerite', was discovered in June 1944 during an investigation of the tin-bearing pegmatites of Kabba Province, central Nigeria.[2] The chemical and physical properties of nigerite have been determined by F. A. Bannister, M. H. Hey, and H. P. Stadler, and their results will be published in the next number of this Magazine. Dr. Hey's analysis shows SnO_2 25·33, Al_2O_3 50·91, Fe_2O_3 11·90, ZnO 4·51 %, &c., and the unit-cell contents are given by the formula $(Zn,Mg,Fe'')(Sn,Zn)_2(Al,Fe''')_{12}O_{22}(OH)_2$.

Nigerite is found as a common constituent in certain quartz-sillimanite-rocks associated with the tin-bearing pegmatites. Although locally abundant, nigerite is more likely to remain of scientific rather than economic interest. The principal occurrences are located in the uninhabited bush east of the Egbe–Lafia road, in the north-west corner of Kabba Province, central Nigeria (text-fig. 1).

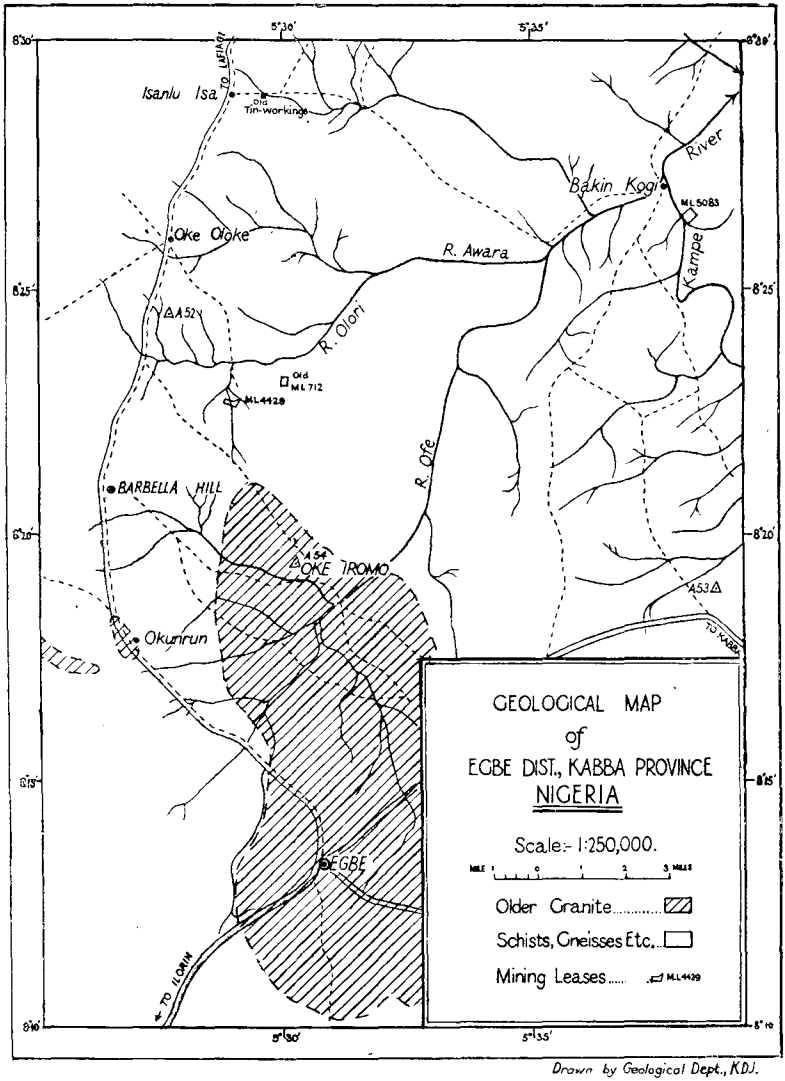
II. General geology.

The area under consideration is composed of pre-Cambrian schists, gneisses, and granite. Tin-bearing pegmatites, genetically related to the granite, are well developed especially along the eastern marginal zone of the granite. The quartz-sillimanite-rocks, wherein nigerite was found, occur in close association with these pegmatites.

(i) *Schists.*—The schists represent a series of altered sediments. They include mica-, quartz-, and quartz-mica-schists, also quartzites and

[1] Published with the permission of the Director of the Geological Survey of Nigeria.

[2] This mineral was first mentioned in the Nigerian Geological Survey Annual Report, 1944.



Drawn by Geological Dept., KDJ.

TEXT-FIG. 1. Simplified geological and locality map of the area in which the nigerite-bearing rocks occur.

quartz-sillimanite-schists. Garnetiferous granulites and massive amphibolites are well developed locally. The regional trend of the foliation of these rocks is N.–S.

(ii) *Gneisses.*—The gneisses consist of banded granite-gneiss and soft felspathic gneiss, grading imperceptibly into schist.

(iii) *Granite.*—The Egbe Granite, which occupies the south-central part of this area, is a member of a suite of 'Older Granites', with which the tin-bearing pegmatites are genetically related.[1] The rock is a porphyritic biotite-hornblende-granite, which in places is distinctly gneissose. Pegmatites are particularly well developed around the eastern margin, and the granite itself is traversed by numerous small pegmatite dikes. It is interesting to note that the Older Granites, of which the Egbe outcrop is a member, are older than the Younger Granites of north-central Nigeria, with which the main period of tin mineralization is related.

III. Pegmatites.

The detailed mineralogy and paragenesis of the pegmatites have recently been described by the authors.[1] The pegmatites may be divided into three groups, according to their mineralogical composition. They may be further subdivided into 'simple' and 'complex' varieties, depending upon the extent to which they had been affected by late-stage albitization. In addition to these three groups the pegmatite suite also includes quartz-tourmaline veins and quartz-sillimanite veins.

(*a*) *Microcline-quartz-pegmatites.*—The bulk of the pegmatites within the Older Granites are simple microcline-quartz types. They also occur in the schists and gneisses but they are not so numerous as the microcline-quartz-muscovite-pegmatites. The complex varieties sometimes contain cassiterite and columbite-tantalite.

(*b*) *Microcline-quartz-mica-pegmatites.*—The bulk of the economic deposits of cassiterite and columbite-tantalite occur in association with the albitized microcline-quartz-muscovite-pegmatites in the schists and gneisses. Microcline-quartz-*biotite*-pegmatites are well developed in the contact zone of the Egbe Granite. They are sometimes albitized to an appreciable degree but are invariably poorly mineralized.

(*c*) *Quartz-mica veins.*—These occur only in the schists and gneisses and are always smaller than the average felspathic pegmatite. They are composed of coarse muscovite and glassy quartz and sometimes contain

[1] R. Jacobson and J. S. Webb, The pegmatites of central Nigeria. Bull. Geol. Surv. Nigeria, 1946, no. 17.

cassiterite, columbite-tantalite, and other accessory minerals. The mica is orientated roughly perpendicular to the walls of the vein.

A quartz-mica marginal facies is commonly present on the walls of the microcline-quartz-muscovite-pegmatites, especially on the hanging-wall.

IV. Quartz-sillimanite-rocks containing nigerite.

Quartz-sillimanite-rocks containing nigerite have been found at the following localities:

(*a*) *M.L.*[1] *4429*: Three miles south-east of Oke Oloke, and about two miles from the contact of the Egbe Older Granite.

(i) A large quartz-sillimanite vein which has been worked for cassiterite.

(ii) A subordinate quartz-sillimanite facies associated with the quartz-mica margin of a large albitized microcline-quartz-muscovite-pegmatite 250 yards west-north-west of (*a*).

(iii) Several small quartz-sillimanite veins.

(*b*) *Old M.L. 712*: About two miles east of (*a* i). A large albitized microcline-quartz-muscovite-pegmatite with a well-developed quartz-sillimanite facies associated with the quartz-mica margin on the hanging-wall.

(*c*) *Old tin-workings three-quarters of a mile east of Isanlu Isa*: A large albitized microcline-quartz-muscovite-pegmatite which has been worked for cassiterite. The quartz-sillimanite-rock was found in the spoil heaps but was not noted in situ.

(*d*) *M.L. 5083*: South-east of Bakin Kogi. Several intensely albitized pegmatites have been worked for cassiterite on this lease. A few small pieces of the quartz-sillimanite-rock were found in the spoil heaps, but the rock was not seen in situ.

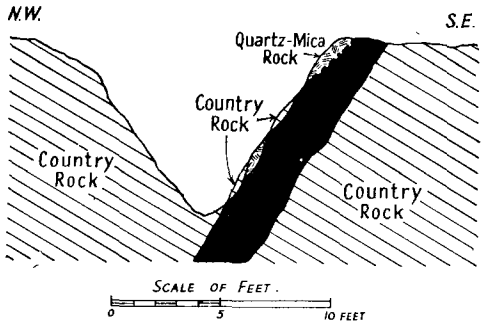
Of these, (*a* i) and (*b*) are by far the best and most interesting exposures. It is perhaps worth recording that a quartz-sillimanite vein containing andalusite, garnet, and chrysoberyl has been found recently near Hoss 200 miles to the north of the Egbe area.[2]

(*a*) *M.L. 4429*, (i) *Quartz-sillimanite vein.*—This vein (text-fig. 2) is 18–30 inches wide and outcrops over a distance of 200 feet; old tin-workings, however, indicate that it is probably at least 600 feet long. The vein strikes N. 50° E., dipping at an angle of 40–60° to the NW. Except for minor irregularities, the walls are smooth and the contact with the country-rock appears to be sharp, but weathering is too extensive for accurate observations or even to determine the precise nature of the country-rock. A most important feature is the development, in places, of a quartz-mica marginal facies which resembles closely the quartz-mica margins of some of the felspathic pegmatites and also the quartz-mica veins.

[1] M.L. is the abbreviation for 'Mining Lease'.

[2] R. Greenwood, Geology of the plateau tinfields. Interim Report Geol. Surv. Nigeria, 1945, no. 1.

The quartz-sillimanite-rock is extremely hard and tough. Quartz is abundant, and, in addition to the massive type common to these deposits, there is a very fine-grained sugary variety. Much sillimanite occurs as sheaf-like aggregates of fibrolite. Locally, andalusite, often pink in colour, becomes an abundant constituent. In addition to the normal white muscovite of the quartz-mica marginal facies, there is a very subordinate silvery-white mica distributed sparingly through the vein. Other accessory minerals include: (*a*) garnet, in segregations up



TEXT-FIG. 2. Diagrammatic section across a nigerite-bearing quartz-sillimanite vein (black). Note the discontinuous quartz-mica facies on the hanging-wall. (Locality: M.L. 4429, 3 miles north-east of Barbella Hill.)

to 4 inches in diameter, (*b*) dark brown cassiterite, and (*c*) the green spinel, gahnite. All these are scattered irregularly throughout the rock, but gahnite may be concentrated in narrow bands parallel with the walls of the vein. Nigerite, though unevenly distributed, is sometimes locally abundant and is often associated and intergrown with gahnite, often as a coating on the crystal faces. Generally it occurs as isolated brown hexagonal plates up to $\frac{3}{8}$ inch in diameter. Pale yellow tabular crystals of chrysoberyl are not uncommon.

M.L. 4429, (ii) *Quartz-sillimanite facies associated with the quartz-mica margin of an albitized felspathic pegmatite.*—A 6-feet wide microcline-quartz-muscovite-pegmatite outcrops about 250 yards WNW. of the vein mentioned above, trending in the same direction. The outcrop is about 300 feet long but extends some way to the SW. along the line of some old workings. A narrow band of quartz-sillimanite-rock, containing andalusite and a little nigerite, was observed associated with the quartz-mica marginal facies. This latter rock is well developed on the hanging-wall, and the quartz-sillimanite band appears to occur between the

quartz-mica zone and the country-rock. Spoil heaps in the old workings indicate that the quartz-sillimanite facies was also present in that part of the dike which was worked for cassiterite. The felspathic core of the pegmatite contains abundant fine-grained albite, with which the bulk of the cassiterite was probably associated—the normal association in these tin-bearing pegmatites (Jacobson and Webb, 1946, loc. cit.).

M.L. 4429, (iii).—Traces of nigerite were also found in several smaller quartz-sillimanite veins on this lease; these veins vary from 2 inches to 1 foot in width.

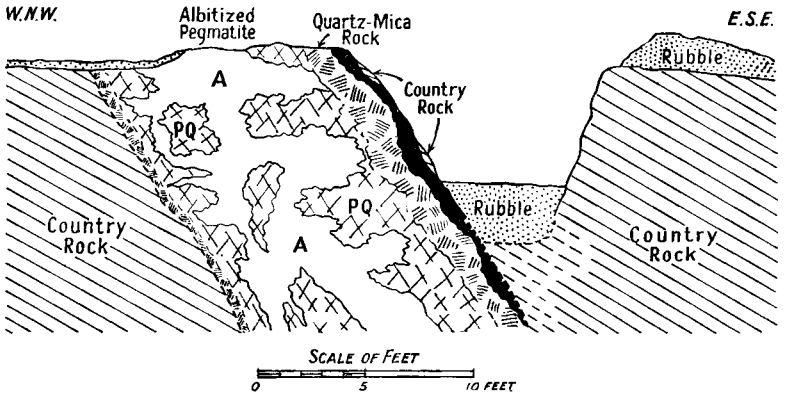
Other veins in the same locality include (*a*) quartz-mica veins, (*b*) quartz veins, and (*c*) a quartz vein carrying a little sillimanite and ilmenite. Stream concentrates in the vicinity contain a little gold.

(*b*) *Old M.L. 712.*—A large dike of albitized microcline-quartz-muscovite-pegmatite, which has been worked for cassiterite, outcrops on this lease. The dike is exposed for 600 feet along the strike, but prospecting trenches indicate that it continues for several hundred yards to the SSE., the strike direction being S. 23° E. The dip is variable, 30–60° to the ESE. As the foot-wall is not exposed, it was not possible to determine the width, which probably exceeds 10 feet. On the hanging-wall of this dike, there is a 16-inch quartz-mica margin which grades into a quartz-sillimanite facies. This latter zone varies from an inch or so to about one foot in width, and is not always present. The bulk of the nigerite occurs in this quartz-sillimanite band; a little nigerite and gahnite are also present in the quartz-mica margin near the quartz-sillimanite-rock. The relationship with the country-rock is not fully exposed (text-fig. 3), but it is probable that the quartz-sillimanite facies occurs on the contact.

The felspathic core of the pegmatite contains abundant fine-grained albite, microcline-perthite, quartz, and muscovite. Garnet, cassiterite, and other accessory minerals are also present. The quartz-sillimanite facies is similar to that described above. Again, nigerite is distributed irregularly and is sometimes associated and intergrown with gahnite and muscovite. Chrysoberyl is not uncommon. It is significant that nigerite and gahnite also occur sparingly in the quartz-mica facies.

(*c*) *Old tin-workings three-quarters of a mile east of Isanlu Isa.*—A few lumps of quartz-sillimanite-rock were observed in the spoil heaps around an albitized microcline-quartz-muscovite-pegmatite which has been worked for cassiterite. A little nigerite and chrysoberyl occur in the quartz-sillimanite facies. Garnet and cassiterite are also present.

(*d*) *M.L. 5083.*—Two albitized microcline-quartz-muscovite-pegmatites have been worked on this lease. A few small pieces of the quartz-sillimanite-rock were observed in the spoil heaps. A little nigerite is present.



TEXT-FIG. 3. Diagrammatic section across a complex dike on old M.L. 712, 4 miles north of Oke Iromo. Most of the dike is composed of coarse microcline-perthite-quartz-pegmatite (PQ) veined and replaced by later fine-grained albite-quartz-rock (A). A quartz-mica band is well developed on the hanging-wall in contact with the marginal facies, which is a nigerite-bearing quartz-sillimanite-rock (black).

V. MINERAL ASSOCIATIONS.

The following lists show the mineral associations in the nigerite-bearing rocks and also a connexion between them and the pegmatite suite:

I. Quartz-sillimanite-rock.	II. Quartz-mica-rock.	III. The common quartz-mica facies of the pegmatite suite.
Nigerite	**Nigerite**	**Quartz**
Quartz	**Quartz**	**Muscovite**
Sillimanite	Muscovite	Gahnite
Andalusite	Gahnite	Garnet
Gahnite	Garnet	Cassiterite
Garnet	Cassiterite	Columbite-tantalite
Chrysoberyl	Apatite	Beryl
Cassiterite		**Apatite**
Columbite-tantalite		Tourmaline
Silvery-white muscovite		
Apatite		

(*a*) *Nigerite.*

The new mineral nigerite occurs as shiny dark-brown, hexagonal plates up to $\frac{3}{8}$ inch in diameter. In the hand-specimen it has an

appearance similar to that of thin, well-formed biotite flakes, but it is extremely brittle. Nigerite is feebly magnetic.

Basal sections are rare in thin section and nigerite is usually seen as pale brownish-yellow laths with a high relief. The laths are frequently traversed by cracks which rarely continue into the adjacent minerals. There is also a definite, though feeble, basal cleavage or parting. Crystal form is usually well developed except where displacement or 'faulting' has been caused by a post-crystallization movement. No corrosion or replacement by other minerals has taken place. Occasionally one crystal cuts across another to form a cross (pl. VI, fig. 4). Faint, patchy pleochroism is sometimes visible, ϵ pale brownish-yellow, ω slightly darker brownish-yellow. Basal sections, which are generally hexagonal, give a positive uniaxial figure. The birefringence is low.

Inclusions are rare and appear to be mainly quartz, though they are too small to be positively identified. Nigerite crystals are frequently surrounded by a dense mat of fine sillimanite fibres (fibrolite). In one section it is found growing on the surface of gahnite crystals, and a wedge of nigerite has been seen penetrating the gahnite. An octahedron of the latter mineral completely covered by a coating of nigerite was collected from the same locality. This relationship is quite common. Muscovite has been noted intergrown with and penetrated by crystals of nigerite (pl. VI, fig. 5).

(*b*) *Associated minerals.*

Quartz is the most abundant constituent of the rock, and is present as an allotriomorphic mosaic of interlocking grains, which occasionally show evidence of strain. The grain-size varies considerably. It is colourless, but frequently appears to be milky owing to disseminated fine needles of sillimanite. Occasionally it encloses nigerite, cassiterite, chrysoberyl, &c. Quartz replaces andalusite extensively (pl. VI, fig. 6).

Sillimanite is present mainly as a mat of extremely fine fibres (fibrolite) which is brownish-grey in thin section (pl. VI, figs. 1 and 3). Occasionally it occurs as discrete crystals. It is commonly found around nigerite and cassiterite, and has also been noted surrounding garnet and residual pools of andalusite. As mentioned before, quartz is frequently riddled with needles of sillimanite, which may be arranged irregularly, in parallel orientation, or in radiating aggregates. Where quartz is replacing andalusite, any sillimanite present is confined to the quartz.

Andalusite originally crystallized as occasional segregations of large, pale-pink crystals; these have since been extensively replaced by quartz (pl. VI, fig. 6) and now occur as scattered, optically continuous relics. In

some specimens andalusite apparently composed the bulk of the rock before replacement. It is usually colourless in thin-section, though when pleochroism is visible it is colourless to pale-pink. The replacing quartz may contain associated wisps of white mica, and fibrolite sometimes surrounds residual pools of andalusite.

Muscovite, occurring as 'books' up to $\frac{1}{2}$ inch in diameter, is one of the major constituents in the nigerite-bearing quartz-mica-rocks. In sections from the quartz-sillimanite facies, however, it can only be found as subordinate interstitial wisps and flakes. In both cases it is always closely associated with quartz. Broadly speaking, sillimanite and muscovite show a tendency to be mutually exclusive in these rocks containing nigerite.

Gahnite is a characteristic constituent. It is invariably dark-green and occurs as irregular grains to perfect octahedra up to $\frac{1}{4}$ inch in diameter. Gahnite contains inclusions of quartz and is often coated and intergrown with nigerite.

Garnet forms segregations up to 4 inches across and individual euhedral crystals $\frac{1}{2}$ inch in diameter have been found. The garnet is red-brown in colour and is essentially free of inclusions. It is generally enclosed in quartz but may be surrounded by a zone of fibrolite. Decomposition has produced iron and manganese oxides, which fill cracks in the mineral and may also occur as a dendritic halo surrounding the crystal. The garnet is probably a spessartine-almandine, which is the characteristic garnet of the pegmatite suite.

Cassiterite occurs as irregular crystals and aggregates. As with most of the Nigerian pegmatite tinstone, it is zoned and intensely pleochroic in blood-red and brown; twinning is a common feature. Inclusions are plentiful and consist mainly of quartz and columbite-tantalite. Occasionally the textural relationship between cassiterite and quartz indicates replacement by quartz (pl. VI, fig. 2). Its relationship to nigerite is obscure: both are usually surrounded by fibrolite, but the cassiterite rarely shows good crystal form (pl. VI, fig. 3) and often contains inclusions, thereby differing considerably from nigerite in both respects.

Columbite-tantalite is present as small, black rods and grains (pl. VI, figs. 2 and 3). The tabular crystal form, as shown by a series of cross-sections, resembles the habit of the coarser columbite-tantalite found in the associated felspathic pegmatites and quartz-mica veins. Furthermore, some grains show deep red-brown, translucent edges possessing a high relief, and are pleochroic. Columbite-tantalite occurs enclosed in cassiterite and nigerite. It is most commonly concentrated in quartz

near cassiterite, often surrounded by fibrolite. In one slide, a crystal of columbite-tantalite was seen penetrating slightly into a euhedral crystal of chrysoberyl.

Chrysoberyl is present in the quartz-sillimanite-rocks as good platy crystals up to 1½ inches long (pl. VI, fig. 3). It is colourless to pale yellow, contains no inclusions and has not been affected by replacement. Chrysoberyl occurs enclosed in quartz and occasionally surrounded by a zone rich in sillimanite. A few crystals have been seen coated with nigerite.

Apatite is very subordinate, though widespread, and forms irregular pools of poorly shaped crystals in quartz.

IV. Paragenesis.

A detailed paragenesis for the constituents of the nigerite-bearing quartz-sillimanite-rocks has not been attempted in view of the restricted nature of the field exposures and the consequent inadequate number of critical specimens. The available material, however, has provided sufficient data to justify certain interesting conclusions. A study of the relationships between the various mineral constituents shows that:

(*a*) Andalusite was one of the earliest minerals and is replaced to a considerable degree by quartz.

(*b*) Sillimanite formed after andalusite. The occurrence of fibrolite around residual pools of andalusite indicates that at least some of the alumina for sillimanite may have been acquired at the expense of andalusite.

(*c*) Garnet, chrysoberyl, gahnite, columbite-tantalite, nigerite, and cassiterite, all started to crystallize before most of the sillimanite. It is possible also that they started to crystallize in the order given, but there was considerable overlap in most cases. The position of columbite-tantalite relative to cassiterite, nigerite, and sillimanite is established.

(*d*) Gahnite started to crystallize before nigerite, and nigerite continued to be deposited after gahnite had ceased to form, often as orientated overgrowths on the latter.

(*e*) Where muscovite is present in any quantity, sillimanite is either absent or subordinate. The concentration of potash in the solutions may have been one of the governing factors.

V. Conclusion.

The nature of the available field exposures is not conducive to a complete interpretation of the origin of these interesting nigerite-bearing

rocks. However, the field relationships and mineral assemblages prove the existence of a close connexion with the stanniferous pegmatite suite in Nigeria. It is probable that the nigerite-bearing rocks are the result of a peculiar and unusual phase of pegmatite development.

It is hoped that it will be possible to continue the investigation of these deposits with a view to obtaining further critical evidence concerning their genesis.

EXPLANATION OF PLATE VI.

Photomicrographs of nigerite in quartz-sillimanite-rocks from Nigeria.

Ordinary light. C cassiterite, Ch chrysoberyl, CT columbite-tantalite, F fibrolite, M muscovite, N nigerite, Q quartz. (Photomicrographs by J. A. Gee, Royal School of Mines, London.)

FIG. 1. A typical section showing crystals of nigerite surrounded by dense mats of fibrolite in clear quartz. The laths of nigerite are transverse sections of hexagonal, platy crystals. ×10.

FIG. 2. Nigerite, sillimanite, and quartz are seen surrounding a large crystal of dark-brown cassiterite, which is somewhat replaced by quartz. Small black rods and grains of columbite-tantalite are disseminated in the quartz surrounding the cassiterite, and a few grains can be seen enclosed in the latter. ×20.

FIG. 3. A segregation of fibrolite, nigerite, and cassiterite in clear quartz. Small grains of columbite-tantalite and a large crystal of chrysoberyl are included. ×10.

FIG. 4. A cruciform growth of two crystals of nigerite in fibrolite and clear quartz. Note the concentration of fibrolite around the nigerite. ×32.

FIG. 5. A large dark nigerite crystal penetrates a crystal of muscovite. Both minerals are replaced by a tongue of clear quartz. ×22.

FIG. 6. A single crystal of andalusite (high relief) partially replaced by a mosaic of clear quartz grains. The smudgy dark areas represent dense fibrolite, which is actually translucent but the negative was under-exposed to capture the quartz-andalusite relationship. ×11.