which can be absorbed if the inversion takes place well below the final burning temperature. If this were not true and the change took place near the final temperature, a decidedly weaker porcelain might result.

Incidentally, during this inversion the andalusite does not outwardly break down and lose its original form, so that good artificial pseudomorphs of this mixture of $3Al_2O_3 \cdot 2SiO_2$ and glass after andalusite are readily obtained by simply heating for a sufficiently long period above the inversion temperature. This can not be done with cyanite because the expansion at the inversion point is so great that the cyanite breaks down into a chalky, friable mass.

The writer here wishes to acknowledge his sincere thanks to Dr. J. A. Jeffery, President, and Mr. F. H. Riddle, Research Director of the Champion Procelain Company, whose interest and co-operation have made this note possible.

AN UNUSUAL OCCURRENCE OF CYANITE

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In the Reed-Wekusko Map-Area in Northern Manitoba a series of sediments has been mapped by Dr. F. J. Alcock of the Geological Survey of Canada as the Wekusko series, which he describes as follows:

> The Wekusko series consists of gneisses and mica schists most of which are believed to be of sedimentary origin. The paragneisses are finely banded rocks locally showing distinct bedding and crossbedding and with conglomeratic horizons. They vary from light gray to dark gray in colour. They consist of quartz, feldspar, biotite and usually garnet. The mica schists vary considerably depending on the kind of secondary silicates developed in them: garnet, staurolite, and garnet-staurolite types are the common varieties and in one locality a cyanite-bearing schist is associated with the other types. Five distinct areas of these rocks occur in the Reed-Wekusko sheet. . . . Immediately east of the outlet of Anderson lake a ridge approximately 1500 feet long and from 100 to 200 feet wide extends in a northeast direction. The ridge is bordered on the west by low, swampy land facing Anderson lake and on the east by a stretch of muskeg 150 feet wide, to the east of which runs a ridge of red granite-gneiss. The ridge of schist is well exposed throughout: it has been heavily glaciated and shows big grooves and furrows, one of which is 8 feet in width and 6 feet in depth. Like the paragneiss many varieties are met with and all gradations from the garnet gneiss to micaceous schists containing abundant staurolite crystals are encountered. The commonest variety is a biotite schist containing both staurolite and garnet. Towards the northeast end of the ridge a garnetiferous mica schist is developed in which garnet rhombic dodecahedrons, varying in size up to 2½ inches in diameter in places, comprise most of the rock.

The series consists of staurolite, cyanite and garnet schists striking north 35 degrees east and dipping at an angle of 70 degrees to the northwest away from the adjacent granite-gneiss. The dominant rock variety is a green chlorite schist containing crystals of cyanite, staurolite, and garnet. Certain bands show large fans of white and reddish cyanite standing out prominently on the weathered glaciated surface. Bands in which staurolite crystals are predominant are also common, the staurolite crystals reaching in places a length of 2½ inches. Two bands averaging 3 feet in width are of a light coloured schist made up of quartz, muscovite, biotite, and small crystals of staurolite.

The staurolite and cyanite crystals for the most part lie in rows which seem to represent original bedding planes. The bands are commonly wavy suggesting drag folding on a small scale in the beds, a feature which is emphasized in places by narrow crenulated bands of quartz."[1]

The staurolite-garnet-cyanite phase of this sedimentary series is of special interest, both on account of the unusual colour of the cyanite, and of the exceptional occurrence of the mineral in a series where elsewhere in the same series staurolite and garnet occur not infrequently in close relationship. The series, which is interbedded with basic and acid lava flows of early Pre-cambrian age, has suffered intense dynamic metamorphism during the movement which accompanied the intrusion of the granites, which are now exposed in various parts of the field. As a result of this movement have been formed the minerals which characterize the series—quartz, biotite, muscovite, chlorite, staurolite and garnet. The latter two minerals are found in bands in the schist far removed from contact with the granite, and are apparently genetically connected with the chemical composition of the sediments as well as with the degree of metamorphism to which the sediments were subjected. On the north shore of Snow lake, for example, immediately northwest of the old Anderson cabin, a well defined staurolite schist is exposed some 5 miles distant from the nearest granite outcrop. The staurolite bands clearly represent old bedding planes, striking 323 degrees, and dipping 40 degrees northeastwards while the strike of the schist is 23 degrees, and the dip 70 degrees eastwards. The staurolite bands alternate with a fine grained, pepper and salt mica schist, in which considerable garnet has been developed. Small bands of quartz run with the bedding planes, and have been crenulated by the shearing. The shearing has also affected the orientation of the staurolite crystals, which are arranged with their vertical axes in the main in the shearing planes,

[1] The Reed-Wekusko Map-Area. F. J. Alcock. **Mem. 119.** *Geol. Surv. Can.*, 21-22, (1920).

though the banding is parallel to the planes of sedimentation. Typical of the occurrence of staurolite is the tailing off of the crystals into lenses of quartz, which owing to intergrowth with fine plates of muscovite in parallel arrangement, resemble somewhat groups of fibrolite crystals. The constant association of quartz with staurolite would suggest that a certain transference of quartz from the siliceous bands took place during the shearing process, and that the staurolite crystallized in a siliceous bath. There is evidence also that staurolite crystallized late in the period of mineral rearrangement, as the flakes of muscovite and biotite are frequently bent round the crystals of staurolite as though by force of crystal growth of the staurolite. Quite commonly also the garnets, which are in this locality small, are arranged on the margin of the staurolite crystals, in a position which indicates that they were formed before the growth of the staurolite crystals had been completed.

The Snow lake occurrence may be taken as representative of the staurolite-garnet development in the Wekusko series, though somewhat exceptional in the clearness with which the bedding planes are defined. No clue was found in the field as to special temperature or pressure conditions which might give rise to the development of staurolite and garnet where elsewhere in the series mica schist, mica-hornblende schist and chlorite schist, with invariant quartz and occasional feldspar, occur as the dominant rock types. In a region of widespread plutonic action it is not possible to assume that contact metamorphism from the roof of a batholith, near the surface but not exposed, may not have played the principal part in the formation of staurolite and garnet: but the elongation of the mineral bands along bedding planes points to the chemical composition of certain beds as the controlling factor in the mineral expression.

A very interesting case of metamorphism is that referred to by Alcock (*vide supra*) from the east end of Anderson lake, west of a granite contact. This is the only known occurrence of cyanite in the Wekusko series, and apparently the only recorded occurrence of a reddish cyanite. The locality is interesting as well on account of the exceptional development of garnets which rival in size and beauty the best garnet occurrences of this continent. The following is the rock gradation southeastwards (towards the granite) across the strike, which varies from 20 degrees to 50 degrees east of north:

(1) Compact mica schist, light coloured, with abundant quartz.
(2) Cyanite schist, the cyanite appearing in reddish rosette-like aggregates and in white tufts on the weathered surface.
(3) Staurolite schist, with numerous tufts of white cyanite.
(4) Chlorite schist with large garnets—a wide zone.
(5) (Across a muskeg) Pepper and salt biotite schist grading eastward into contact rock, in which considerable epidote has been developed. Beyond this lies the granite.

The cyanite appears in clusters and tufts, seldom in isolated crystals. It invariably shows a reddish tint, except where the mineral has weathered white. No blue crystals were found. The cyanite band No. (2) in the above description, to the naked eye seemingly free from staurolite, is the narrowest band in the series, with a maximum width of 6 feet. In band No. (3), in which staurolite accompanies the cyanite, the crystals of staurolite are not so well developed as in the Snow lake occurrence, while the tufted cyanite runs in lines across the strike of the schist, as though in lines either of original bedding or of secondary shear.

The microscopic examination reveals the following facts:

(a) While the staurolite appears on field examination to be restricted to band No. 3, it is in reality present in all the bands from No. 1 to No. 5 It persists from the immediate vicinity of the granite into the normal dynamically metamorphosed sediments.

(b) Both garnet and cyanite are restricted in range, garnet near the contact, and cyanite further removed. Staurolite accompanies both minerals.

(c) Biotite has suffered more complete change to chlorite in the near vicinity of the granite than at a greater distance, very complete, for instance, in bands No. 4 and No. 5, not at all in No. 1.

(d) The variety of minerals is very limited: quartz, biotite, chlorite, staurolite, cyanite, garnet, a little muscovite. Feldspar is very rare.

(e) Quartz has crystallized in part before garnet, staurolite and cyanite, and occurs very abundantly as inclusions in these minerals. The crystallization of quartz was not completed until after these minerals had ceased to grow. Staurolite crystallized somewhat earlier than garnet, whose period of crystallization began before the completion of growth of the staurolite crystals, and ended before biotite ceased to crystallize. The relationship of staurolite to cyanite in this connection was not determined.

(f) The structure is that defined by Grubenmann as crystalloblastic. There is a definite parallelism in the arrangement of the minerals, but no indication of strain. Owing to concurrent crystallization with quartz, the staurolite, cyanite and garnet show no well defined crystal outlines: they appear rather as skeletons and filaments intergrown with granular quartz. The outlines of the quartz crystals, on the other hand, are well defined. Where staurolite or cyanite reach large size, the structure is more definitely porphyroblastic.

(g) The cyanite crystals are in thin section colorless, or show slightly reddish tint, with very faint pleochroism. The cleavage (100) is pronounced, usually in the direction of crystal elongation and in the plane of schistosity of the rock. There is an interesting exception in band No. 3, where the cleavage lines swing from the plane of schistosity to an angle of 43 degrees with that plane. (See Fig. 1.) This is a rather remarkable illustration of the effect

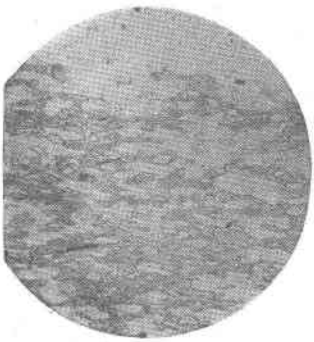

FIG. 1. Cyanite with cleavage lines oblique to schistosity. (Plane polarized light)

FIG. 2. As in Fig. 1. (Between crossed nicols)

of movement through pressure, during the period of crystallization, in overcoming the natural tendency of the crystal to grow in the direction of its *c* axis. A close study of the microphotograph will reveal the fact that there is even in this case, in places, an elongation along the cleavage lines, but broken by the very definite bands of quartz crystals in the direction of movement. On the (010) face, the angle of extinction varies from 3 to 7 degrees, measured from the (100) cleavage trace. In sections on the (100) face, the extinction angle is 30 degrees with the fair cleavage trace of (010). An irregular basal cleavage is also noted.

Staurolite shows the characteristic pleochroism from straw yellow to brownish red, is even more completely pitted with quartz inclusions than is the cyanite, and is intergrown with quartz and shreds of muscovite. In cross section imperfect traces of the (010) cleavage are noted. As in the case of cyanite, the elongation in the plane of schistosity is not invariably along the *c* axis of the crystal. In both cases, apparently, the initial growth of the crystals took place irrespective of stress planes, and the position of crystal axes remained unchanged as growth proceeded. One might suggest that staurolite and cyanite, two aluminous silicates, grew originally along planes of sedimentation, and that later or more pronounced stress movements influenced the direction of extension of crystal growth, but left the orientation unaffected.

The garnet is pink in transmitted light, full of well formed quartz crystals, and definitely later than the earliest stage of staurolite crystallization, and earlier than biotite, between which and the garnet some resorption has taken place. In thin section the garnet appears as skeletal crystals, with little suggestion of the very perfect dodecahedral outlines which are characteristic of the large crystals of the garnet zone.

GENETIC RELATIONSHIPS. In a contact zone garnet, staurolite and cyanite have developed in a quartz-mica schist, which forms part of a sedimentary series where elsewhere garnet and staurolite, unaccompanied by cyanite, occur in bands far removed from surface contacts. The absence of sericite and of feldspars points to a low content in alkalies; the abundance of quartz and the aluminous silicates, to a high silica-alumina content. The typical gneiss of the sedimentary series has the following analysis,[2]

SiO_2	63.84%
Al_2O_3	20.34
Fe_2O_3	3.34
Fe O	3.98
Mg O	2.20
Ca O	0.64
Na_2O	0.95
K_2O	2.42
H_2O	1.05
TiO_2	0.80
	99.56

The conditions favorable for the formation of cyanite would appear to be (a) excess of alumina and low content in alkalies and

[2] F. J. Alcock, *loc. cit.*, p. 22.

alkaline earths, and (b) high temperature conditions, though not so high as would necessitate the crystallization of the silicate of alumina as sillimanite. In general, staurolite is a high pressure mineral,[3] with pressure as a factor of greater significance than temperature, while garnet may form under a greater range of pressure and temperature conditions than either of the other two minerals. In contrast to garnet and staurolite, the stability of cyanite would appear to be here conditioned by proximity to igneous intrusion; for it is improbable that no sediments occur elsewhere in the series with similar high-alumina, high-silica, low-alkali content to that single band in which cyanite has been developed. The complete absence of sillimanite in a band of this composition would seem to be conclusive evidence that the temperature of formation of the metamorphic minerals was less than that which conditions the 'deep zone' of Grubenmann. The mineralization of the whole sedimentary series suggests rather a gradation from 'upper zone' temperatures, where not directly affected by igneous intrusion, to the 'middle zone' conditions where the intrusion of igneous batholiths raised the temperature of crystallization in the vicinity of the igneous bodies.

THE ORIGIN OF A NITER DEPOSIT NEAR DUBOIS, IDAHO[1]

Harold T. Stearns, *U. S. Geological Survey*

In the fall of 1922, while the writer was mapping the geology of the lava plain near Dubois, Idaho, his attention was called by Mr. Murray McWhorter to a deposit of a white crystalline salt in a cave in sec. 22, T. 11 N., R. 36 E. This salt was found to be practically pure potassium nitrate.

The niter sputters when ignited on charcoal, and under the microscope it is optically biaxial with a very small angle. The crystals vary in size, the maximum being about 1 millimeter in diameter. Analysis of a sample of the niter by Earl V. Shannon[2] gave the following results:

[3] F. Becke, *Fortschr. d. Min. Kryst. u. Petr.*, **5**, 223, (1916).

[1] Published by permission of The Director, United States Geological Survey.

[2] Shannon, E. V., Nat. Museum, Washington, D. C.