34·3, copper oxide 45·2, water 20·5 = 100, the water being double that of dioptase.

Composition varies much through impuities; free silica, also alumina, black oxide of copper, oxide of iron (or limonite) and oxide of manganese may be present; the color consequently varies from bluish green to brown and black.

Pyr., etc.—In the closed tube blackens and yields water. B.B. decrepitates, colors the flame emerald-green, but is infusible. With the fluxes gives the reactions for copper. With soda and charcoal a globule of metallic copper. Decomposed by acids without gelatinization.

Obs—Accompanies other copper ores, occurring especially in the upper part of veins. Found in copper mines in Cornwall; Hungary; Siberia; Saxony; South Australia; Chili, etc.

In the U. S., similarly at the Schuyler's mines, New Jersey; at Morgantown, Pa.; at the Clifton mines, Graham Co., Arizona; Emma mine, Utah.

Chrysocolla is from *χρυσος, gold,* and *κόλλα, glue,* and was the name of a material used in soldering gold. The name is often applied now to borax, which is so employed.

CHLOROPAL.

Compact massive, with an opal-like appearance; earthy.

H. = 2·5–4·5. G. = 1·727–1·870, earthy varieties, the second a conchoidal specimen; 2·105, Ceylon, Thomson. Color greenish yellow and pistachio-green. Opaque to subtranslucent. Fragile. Fracture conchoidal and splintery to earthy. Feebly adhering to the tongue, and meager to the touch.

Var.—*Chloropal* has the above-mentioned characters, and was named from the Hungarian mineral occurring at Unghwar.

Nontronite is pale straw-yellow or canary-yellow, and greenish, with an unctuous feel; flattens and grows lumpy under the pestle, and is polished by friction; from Nontron, Dept. of Dordogne, France. *Pinguite* is siskin- and oil-green, extremely soft, like new-made soap, with a slightly resinous luster, not adhering to the tongue; from Wolkenstein in Saxony. *Graminite* has a grass-green color (whence the name), and occurs at Menzenberg, in the Siebengebirge, in thin fibrous seams, or as delicate lamellæ.

Comp.—A hydrated silicate of ferric iron, perhaps with the general formula $H_6Fe_2(SiO_4)_3 + 2H_2O$ or $Fe_2O_3.3SiO_2.5H_2O$ = Silica 41·9, iron sesquioxide 37·2, water 20·9 = 100. Alumina is present in some varieties.

The water and silica both vary much. The Hungarian chloropal occurs mixed with opal, and graduates into it, and this accounts for the high silica of some of its analyses.

Obs.—Localities mentioned above. *Chloropal* occurs also at Meenser Steinberg near Göttingen; *pinguite* at Sternberg, Moravia. On Lehigh Mt., Pa., south of Allentown, occurs in connection with iron deposits.

HŒFERITE. An iron silicate near chloropal. Color green. From Křitz, Bohemia.

Hisingerite. A hydrated ferric silicate, of uncertain composition. Amorphous, compact. Fracture conchoidal. H. = 3. G. = 2·5–3·0. Luster greasy. Color black to brownish black. Streak yellowish brown. From Riddarhyttan, Tunaberg, Sweden; Långban, etc., Norway.

The following are hydrous manganese silicates.

Bementite. Approximately $2MnSiO_3.H_2O$. In soft radiated masses resembling pyrophyllite. G. = 2·981. Color pale grayish yellow. From the zinc mines of Franklin Furnace, N. J.

Caryopilite. Approximately $4MnO.3SiO_2.3H_2O$. In stalactitic and reniform shapes. G. = 2·83–2·91. Color brown. From the Harstig mine near Pajsberg, Sweden.

Neotocite. A hydrated silicate of manganese and iron, of doubtful composition, usually derived from the alteration of rhodonite. Amorphous Color black to dark brown and liver-brown.

TITANO-SILICATES, TITANATES.

This section includes the common calcium titano-silicate, Titanite; also a number of silicates which contain titanium, but whose relations are not altogether clear; further the titanate, Perovskite, and niobo-titanate, Dysanalyte, which is intermediate between Perovskite and the species Pyrochlore, Microlite, Koppite of the following chapter.

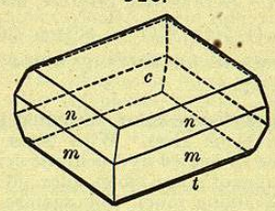
In general the part played by titanium in the many silicates in which it enters is more or less uncertain. It is probably in most cases, as shown in the preceding pages, to be taken as replacing the silicon; in others, however, it seems to play the part of a basic element; in schorlomite (p. 419) it may enter in both relations.

TITANITE. Sphene.

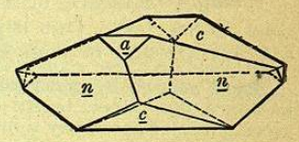
Monoclinic. Axes $\breve{a} : \dot{b} : \dot{c} = 0·7547 : 1 : 0·8543$; $\beta = 60° 17'$.

mm''',	110 ∧ $1\bar{1}0$ =	66° 29′.
cx,	001 ∧ $10\bar{2}$ =	21° 0′.
ss',	021 ∧ $0\bar{2}1$ =	112° 3′.
nn',	111 ∧ $1\bar{1}1$ =	43° 49′.
ll',	$\bar{1}12$ ∧ $\bar{1}\bar{1}2$ =	46° 7½′.
cn,	001 ∧ 111 =	38° 16′.
cm,	001 ∧ 110 =	65° 30′.
cl,	001 ∧ $\bar{1}12$ =	40° 34′.

916.

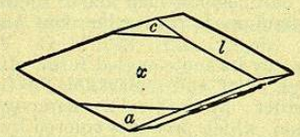


918.

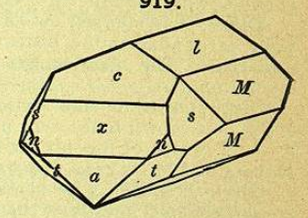


Twins: tw. pl. *a* rather common, both contact-twins and cruciform penetration-twins. Crystals very varied in habit; often wedge-shaped and flattened ∥ *c*; also prismatic. Sometimes massive, compact; rarely lamellar.

917.

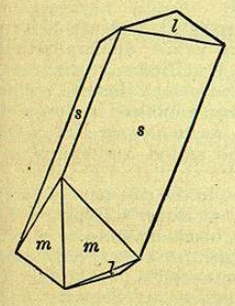


919.

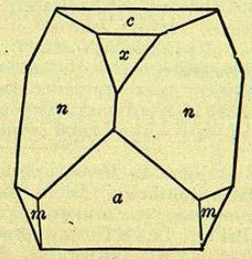


Cleavage: *m* rather distinct; *a*, *l* ($\bar{1}12$) imperfect; in greenovite, *n* (111) easy, *t* ($\bar{1}11$) less so (Dx.). Parting often easy ∥ *η* (221) due to twinning

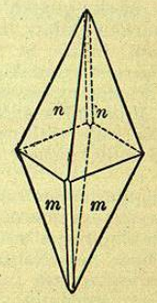
920.



921.



922.



923.

lamellæ. H. = 5–5·5. G. = 3·4–3·56; 3·541 Chester, Pirsson. Luster adamantine to resinous. Color brown, gray, yellow, green, rose-red and black. Streak white, slightly reddish in greenovite. Transparent to opaque.

Pleochroism in general rather feeble, but distinct in deep-colored kinds: c, red with tinge of yellow; b, yellow, often greenish; a, nearly colorless. Optically +. Ax. pl. ‖ b. Bx nearly ⊥ x (102), i.e., Bx ∧ $c = +51°$. Dispersion $\rho > v$ very large, and hence the peculiarity of the axial interference-figure in white light. Axial angles variable. $2E_r = 50°$ to $90°$. $\beta_y = 1{\cdot}894$. Birefringence high, $\gamma - \alpha = 0{\cdot}121$.

Var.—*Ordinary.* (*a*) *Titanite;* brown to black, the original being thus colored, also opaque or subtranslucent. (*b*) *Sphene* (named from $\sigma\phi\acute{\eta}\nu$, *a wedge*); of light shades, as yellow, greenish, etc., and often translucent; the original was yellow. *Ligurite* is an apple-green sphene. *Spinthere* (or Semeline) a greenish kind. *Lederite* is brown, opaque, or subtranslucent, of the form in Fig. 916.

Titanomorphite is a white mostly granular alteration-product of rutile and ilmenite, not uncommon in certain crystalline rocks; here also belongs most leucoxene (see p. 337).

Manganesian; Greenovite. Red or rose-colored, owing to the presence of a little manganese; from St. Marcel.

Containing yttrium or cerium. Here belong grothite, alshedite, eucolite-titanite.

Comp.—$CaTiSiO_5$ or $CaO.TiO_2.SiO_2$ = Silica 30·6, titanium dioxide 40·8, lime 28·6 = 100. Iron is present in varying amounts, sometimes manganese and also yttrium in some kinds.

Pyr., etc.—B.B. some varieties change color, becoming yellow, and fuse at 3 with intumescence, to a yellow, brown or black glass. With borax they afford a clear yellowish-green glass. Imperfectly soluble in heated hydrochloric acid; and if the solution be concentrated along with tin, it becomes of a fine violet color. With salt of phosphorus in R.F. gives a violet bead; varieties containing much iron require to be treated with the flux on charcoal with metallic tin. Completely decomposed by sulphuric and hydrofluoric acids.

Diff.—Characterized by its oblique crystallization, a wedge-shaped form common; by resinous (or adamantine) luster; hardness less than that of staurolite and greater than that of sphalerite. The reaction for titanium is distinctive, but less so in varieties containing much iron.

Distinguished in thin sections by its acute-angled form, often lozenge-shaped; its generally pale brown tone; very high relief and remarkable birefringence, causing the section to show white of the higher order; by its biaxial character (showing many lemniscate curves); and by its great dispersion, which produces colored hyperbolas.

Obs.—Titanite, as an accessory component, is widespread as a rock-forming mineral, though confined mostly to the acidic feldspathic igneous rocks; it is much more common in the plutonic granular types than in the volcanic forms. Thus it is found in the more basic hornblende granites, syenites, and diorites, and is especially common and characteristic in the nephelite-syenites. It occurs also in the metamorphic rocks and especially in the schists, gneisses, etc., rich in magnesia and iron and in certain granular limestones. It is also found in beds of iron ore; commonly associated minerals are pyroxene, amphibole, chlorite, scapolite, zircon, apatite, etc. In cavities in gneiss and granite, it often accompanies adularia, smoky quartz, apatite, chlorite, etc.

Occurs at various points in the Grisons, Switzerland, associated with feldspar and chlorite; Tavetsch; in the St. Gothard region; Zermatt in the Valais; Maderanerthal in Uri; also elsewhere in the Alps; in Dauphiné (*sphinthère*); at Ala, Piedmont (*ligurite*); at St. Marcel, in Piedmont; at Schwarzenstein and Rothenkopf in the Zillerthal, Pfitsch, Tyrol; Zöptau, Moravia; near Tavistock; near Tremadoc, in North Wales; in titanic iron at Arendal, in Norway; with magnetite at Nordmark, Sweden; Achmatovsk, Ural. Occasionally found among volcanic rocks, as at Lake Laach (*semeline*) and at Andernach on the Rhine.

In *Maine*, in fine crystals at Sandford. In *Mass.*, in gneiss, in the east part of Lee; at Bolton with pyroxene and scapolite in limestone. In *N. York*, at Roger's Rock on Lake George, abundant in small brown crystals; at Gouverneur, in black crystals in granular limestone; in Diana near Natural Bridge, Lewis Co., in large dark brown crystals, among which is the variety *lederite;* at Rossie, Fine, Pitcairn, St. Lawrence Co.; in Orange Co., in limestone; near Edenville, in light brown crystals in limestone; at Brewster, at the Tilly Foster iron mine. In *N. Jersey*, at Franklin Furnace, honey-yellow. In *Penn.*, Bucks Co., three miles west of Attleboro', associated with wollastonite and graphite. In *N. Carolina*, at Statesville, Iredell Co., yellowish white with sunstone; also Buncombe Co., Alexander Co., and other points.

Occurs in *Canada*, at Grenville, Argenteuil Co.; also Buckingham, Templeton, Wakefield, Hull, Ottawa Co.; at N. Burgess, honey-yellow; near Eganville, Renfrew Co., Ontario, in very large dark brown crystals with apatite, amphibole, zircon.

Keilhauite. A titano-silicate of calcium, aluminium, ferric iron, and the yttrium metals. Crystals near titanite in habit and angles. H. = 6·5. G. = 3·52–3·77. Color brownish black. From near Arendal, Norway.

Guarinite. $CaTiSiO_5$, as for titanite. In minute thin tables, flattened ‖ b (010), nearly tetragonal in form. H. = 6. G. = 3·487. Color sulphur-yellow, honey-yellow. Found in a grayish trachyte on Monte Somma.

Tscheffkinite. A titano-silicate of the cerium metals, iron, etc., but an alteration-product, more or less heterogeneous, and the composition of the original mineral is very uncertain. Massive, amorphous. H. = 5–5·5. G. = 4·508–4·549. Color velvet-black. From the Ilmen mountains in the Ural. Also from S. India, probably Kanjamalai Hill, Salem distr. An isolated mass weighing 20 lbs. has been found on Hat Creek, near Massie's Mills, Nelson Co, Virginia; also found, south of this point, in Bedford Co.

Astrophyllite. Probably $\overset{I}{R}_4\overset{II}{R}_4Ti(SiO_4)_4$ with $\overset{I}{R}$ = H, Na, K, and $\overset{II}{R}$ = Fe, Mn chiefly, including also Fe_2O_3. In elongated crystals; also in thin strips or blades; sometimes in stellate groups. Cleavage: b perfect like mica, but laminæ brittle. H. = 3. G. = 3·3–3·4. Luster submetallic, pearly. Color bronze-yellow to gold-yellow.

Occurs on the small islands in the Langesund fiord, near Brevik, Norway, in elæolite-syenite, embedded in feldspar, with catapleiite, ægirite, black mica, etc. Similarly at Kangerdluarsuk, Greenland. Also with arfvedsonite and zircon at St. Peter's Dome, Pike's Peak, El Paso Co., Colo.

Johnstrupite. A silicate of the cerium metals, calcium and sodium chiefly, with titanium and fluorine. In prismatic crystals. G. = 3·29. From near Barkevik, Norway.

Mosandrite. Near johnstrupite in form and composition and from the same region.

Rinkite, also near johnstrupite, is from Greenland.

Neptunite. A titano-silicate of iron (manganese) and the alkali metals. In prismatic monoclinic crystals. H. = 5–6. G. = 3·23. Color black. Southern Greenland.

PEROVSKITE. Perofskite.

Isometric or pseudo-isometric. Crystals in general (Ural, Zermatt) cubic in habit and often highly modified, but the faces often irregularly distributed. Cubic faces striated parallel to the edges and apparently penetration-twins, as if of pyritohedral individuals. Also in reniform masses showing small cubes.

Cleavage: cubic, rather perfect. Fracture uneven to subconchoidal. Brittle. H. = 5·5. G. = 4·017–4·039 Zermatt. Luster adamantine to metallic-adamantine. Color pale yellow, honey-yellow, orange-yellow, reddish brown, grayish black. Streak colorless, grayish. Transparent to opaque. Usually exhibits anomalous double refraction.

Geometrically considered, perovskite conforms to the isometric system; optically, however, it is uniformly biaxial and usually positive. The molecular structure (also as developed by etching, Baumhauer) seems to correspond to orthorhombic symmetry. Cf. Art. 411.

Comp.—Calcium titanate, $CaTiO_3$ = Titanium dioxide 58·9, lime 41·1 = 100. Iron is present in small amount replacing the calcium.

Pyr., etc.—In the forceps and on charcoal infusible. With salt of phosphorus in O.F. dissolves easily, giving a greenish bead while hot, which becomes colorless on cooling; in R.F. the bead changes to grayish green, and on cooling assumes a violet-blue color. Entirely decomposed by boiling sulphuric acid.

Obs.—Occurs in small crystals, associated with chlorite, and magnetic iron in chlorite slate, at Achmatovsk, near Zlatoust, in the Ural; at Schelingen in the Kaiserstuhl, in granular limestone; in the valley of Zermatt, near the Findelen glacier; at Wildkreuzjoch, between Pfitsch and Pfunders in Tyrol. Sometimes noted in microscopic octahedral crystals as a rock constituent; thus in nephelite- and melilite-basalts; also in serpentine (altered peridotite) at Syracuse, N. Y.

Knopite. Near perovskite but contains cerium. In black isometric crystals. From Alnö, Sweden.

Dysanalyte. A titano-niobate of calcium and iron. In cubic crystals. From the granular limestone of Vogtsburg, Kaiserstuhlgebirge, Baden. Has previously been called perovskite, but is in fact intermediate between the titanate, perovskite, and the niobates, pyrochlore and koppite.

A related mineral, which has also long passed as perovskite, occurs with magnetite, brookite, rutile, etc., at Magnet Cove, Arkansas. It is in octahedrons or cubo-octahedrons, black or brownish black in color and submetallic in luster.

See also the allied titanate, bixbyite, mentioned on p. 343.

Geikielite. Magnesium titanate, $MgTiO_3$. Massive, as rolled pebbles. H. = 6. G. = 4. Color bluish or brownish black. From Ceylon.

Oxygen Salts.

3. NIOBATES, TANTALATES.

The Niobates (Columbates) and Tantalates are chiefly salts of metaniobic and metatantalic acid, RNb_2O_6 and RTa_2O_6; also in part Pyroniobates, $R_4Nb_2O_7$, etc. Titanium is prominent in a number of the species, which are hence intermediate between the niobates and titanates. Niobium and tantalum also enter into the composition of a few rare silicates, as wöhlerite, låvenite, etc.

The following groups may be mentioned:

The isometric PYROCHLORE GROUP, including pyrochlore, microlite, etc
The tetragonal FERGUSONITE GROUP, including fergusonite and sipylite
The orthorhombic COLUMBITE GROUP, including columbite and tantalite
Also the orthorhombic SAMARSKITE GROUP, including yttrotantalite, samarskite, and ånnerodite.

The species belonging in this class are for the most part rare, and are hence but briefly described.

PYROCHLORE.

Isometric. Commonly in octahedrons; also in grains.

Cleavage: octahedral, sometimes distinct. Fracture conchoidal. Brittle. H. = 5–5·5. G. = 4·2–4·36. Luster vitreous or resinous, the latter on fracture surfaces. Color brown, dark reddish or blackish brown. Streak light brown, yellowish brown. Subtranslucent to opaque.

Comp.—Chiefly a niobate of the cerium metals, calcium and other bases, with also titanium, thorium, fluorine. Probably essentially a metaniobate with a titanate, $RNb_2O_6.R(Ti,Th)O_3$; fluorine is also present.

The following are analyses by Rammelsberg:

	G.	Nb_2O_5	TiO_2	ThO_2	Ce_2O_3	CaO	FeO	MgO	NaO_2	F
Miask	4·359	$\frac{3}{5}$ 53·19	10·47	7·56	7·00	14·21	1·84	0·22	5·01	—
Fredriksvärn	4·228	47·13	13·52	—	7·30	15·94	10·03	0·19	3·12	2·90

[ign. 1·39 = 101·52

Obs.—Occurs in elæolite-syenite at Fredriksvärn and Laurvik, Norway; on the island Lövö, opposite Brevik, and at several points in the Langesund fiord; near Miask in the Ural. Named from *πῦρ, fire*, and *χλωρός, green*, because B.B. it becomes yellowish green.

Koppite. Essentially a pyroniobate of cerium, calcium, etc., near pyrochlore In minute brown dodecahedrons. G. = 4·45–4·56. From Schelingen, Kaiserstuhl, embedded in limestone.

Hatchettolite. A tantalo-niobate of uranium, near pyrochlore. In octahedrons with *a* (100) and *m* (311). G. = 4·77–4·90. Color yellowish brown. Occurs with samarskite, at the mica mines of Mitchell Co., North Carolina.

Microlite. Essentially a calcium pyrotantalate, $Ca_2Ta_2O_7$, but containing also niobium, fluorine and a variety of bases in small amount. Isometric. Habit octahedral; crystals often very small and highly modified (Fig. 109, p. 40). H. = 5 5. G. = 5·485–5·562; 6·13 Virginia. Color pale yellow to brown, rarely hyacinth-red. From Chesterfield, Mass., in albite; Branchville, Conn.; Utö, Sweden. Also in fine crystals up to 1 in. in diameter at the mica mines at Amelia Court-House, Amelia Co., Va.