THE PARAGENESIS OF DUMORTIERITE

Will Kyselka

THE PARAGENESIS OF DUMORTIERITE

By Will Kyselka

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology at the University of Michigan, 1948

CONTENTS

THE PARAGENESIS OF DUMORTIERITE

PURPOSE

The mineral dumortierite was first recognized in 1880. During the succeeding years the discovery of other deposits of dumortierite throughout the world led to the publication of many articles describing the mineral, its properties and associates. A few of the papers have presented a description of the origin of dumortierite in the particular area concerned, but no studies have been made of its general paragenesis.

The purpose of this paper is to determine the paragenesis of dumortierite.by an examination and integration of the separate findings of the various investigators in this field.

HISTORY

The history of dumortierite begins on the 13th of November 1879, for it was on that day that Gonnard, while on a geological excursion southwest of Lyons, France, chanced to see a beautiful blue fibrous mineral adhering to a vein of feldspar in one of the gneissic blocks used in repairing the road near Beaunan. As he thought the mineral to be kyanite, he paid little attention to it and made no attempt to collect any more of the material or to trace its source. A short time later he submitted the specimen to Bertrand for determination. Bertrand was impressed with the remarkable pleochroic character of the mineral and, upon discovering that neither the optical angles nor other optical properties agreed with those previously described, declared the mineral to be a new species in a brief note published in 1880. This is the first article published on dumortierite. Encouraged with having found something new, Gonnard returned to the original locality the following year to trace the source of the mineral which he found to be a pegmatite dike. He collected more of the material, studied the geology of the region, and published his findings in 1881 in which he named the mineral in honor of Eugene Dumortier, an eminent French paleontologist. Gonnard's paper was accompanied by Damour's in which he presented a chemical analysis and proposed a formula for the new mineral.

Dumortierite was first noted in the United States at Harlem, New York. The intense blue color of the mineral attracted the attention of collectors who, lacking petrographic microscopes, called it the blue variety of tourmaline, indicolite. Webster's catalog of minerals published in 1824 records it as such, and it was so called until Riggs had occasion to examine a specimen in 1887. The presence of boric acid in the analysis of the material suggested to him that it might be a rare variety of tourmaline. He concluded that "this so-called indicolite is not such is certain, that it is a new boro-silicate is highly probable." Diller (1889) made a hasty examination of the material and concluded that it was not tourmaline, but it was E. S. Dana (1889) who compared it with the French material and identified it as dumortierite. According to Chamberlain it was noticed as early as 1865 at Kip Bay and near the upper end of Riverside Park in white oligoclase.

In 1902, Schaller summarized the then-known localities and occurrences of dumortierite, presenting a chemical analysis and proposing a formula for the mineral. Descriptions of new deposits appeared occasionally in the literature during the succeeding years, but the mineral elicited little more than academic interest. It was not until dumortierite became of economic importance in 1925 in the manufacture of porcelain for spark plugs that intensive study was made of the mineral. A detailed study of the commercial deposits of dumortierite at Oreana, Nevada, was published in 1928 by the Mackay School of Mines, together with a summary of the work which had been done on the mineral up to that time. Since the discovery of other materials more suitable for the manufacture of spark plug porcelain, dumortierite has been relegated to its former position - that of scientific interest.

ECONOMIC IMPORTANCE OF DUMORTIERITE

The dumortierite mined in the world's only commercial deposit at Oreana, Nevada, was used in the manufacture of porcelain for spark plugs. It proved to be superior to andalusite as a refractory material because of its higher aluminum content; dumortierite was subsequently abandoned in favor of a mineral of even greater aluminum content - bauxite.

Dumortierite has several important advantages over andalusite, kyanite, and sillimanite as a refractory material:

1) It burns to a practically pure white product.

2) It increases the toughness of porcelain.

3) It increases the electrical resistivity of porcelain.

4) It allows a greater temperature range in burning than does andalusite.

5) It has a high fusion point, and porcelain made from a mixture of dumortierite and andalusite has a very low coefficient of expansion.

The Champion Porcelain Company of Detroit, owners of the Oreana deposit, found that (Mackay Bulletin, p. 41) bricks made exclusively of dumortierite swell, and those made of andalusite exclusively sag, so that a proper mixture of the two yields a brick of the right quality.

Schaller (1916) suggested that dumortierite-bearing rock might be used for ornamental stone if large enough pieces were available. Both Schaller (1916) and Knopf (1924) suggest a possible use of dumortierite as a gem material. The quartz associated with dumortierite in Nevada often contains minute hair-like fibers of dumortierite which give the quartz a beautiful rose color and make it of gem quality.

DESCRIPTION

Physical Properties

General

Orthorhombic, 0.8897 : 1 : 0.6871. Crystals rare but often vertically striated on the prism faces due to repeated pseudohexagonal twinning according to the laws obeyed by cordierite and aragonite. Streak, nearly white or bluish white. Luster, vitreous and silky to dull. Diaphaneity, transparent to transluscent on thin edges or in crystals but opaque in massive material. Cleavage, macropinacoidal good, prismatic and basal imperfect. Fracture, rough. Hardness 7.

Color

The color of dumortierite is usually some kind of blue variously described as blue-violet, Prussian blue, azure, cobalt-blue, lilac, sodalite-blue, and ultramarine. Weathered surfaces may be nearly black. Less common colors are the lavender of California, the rose of Nevada, and the green of Val Donbastone and of Brazil.

The cause of the color of dumortierite has been a subject of much speculation. Damour (1881) thaught that it was due, perhaps, to the presence of titanium. Schaller (1905) finding the presence of titanium in the lavender dumortierite of California but not in the blue of Washington, suggested that the blue dumortierite contains no titanium replacing aluminum, whereas the red does. Lacroix (1922 a.), however, found titanium in both the rose and the lilac dumortierite of Madagascar, but whether the titanium occurred as rutile or as partial replacement of the aluminum is not certain from his analysis. Fairbanks (1926) noted that an appreciable quantity of either TiO_2 or Ti_2O_3 in minerals is usually accompanied by an increase in the refractive indices, and as a result the various colors of dumortierite can be explained by the presence of this element. But Peck (1926) found practically no difference between the indices of refraction of pink dumortierite and those of lavender and light blue, thus ruling out the suggestion that Fairbanks made of a relationship between titanium content, color, and refractive index. Free rutile, Peck pointed out, usually occurs as inclusions in dumortierite because the mineral has absorbed its full amount of titanium, and hence it probably forms part of the molecule of both pink and blue varieties. This conclusion is further supported by Peck's discovery of veinlets which are blue near the walls and pink at the center. A similar gradation was found by Jones (Mackay Bulletin, p. 23) in the Nevada dumortierite. Walker (1922) observed that the centers of some crystals of dumortierite had a different pleochroism from that of their exteriors. Peck suggested that the state of oxidation of the titanium may influence the color of dumortierite, and that in blue varieties it may be present as Ti''' replacing part of the aluminum, whereas in the pink variety it may be oxidized to Ti'''', replacing a part of the silica. He further pointed out that the color effects of iron, manganese, and small quantities of other elements should not be overlooked.

Structure

Dumortierite occurs as fibrous radiating masses at Ashby, Ontario; New York; Colorado; Arizona; and on the Antarctic continent. It occurs as rosettes and sunbursts in Riverside County, California and in New Mexico. The Washington dumortierite occurs in small spherules which, when broken, show radiating fibrous structure. A similar structure is reported at Luna, New Mexico. Very often dumortierite is found as disseminated grains such as in Bohemia, Arizona, and England. Kerr and Jenney (1935) found dumortierite occurring in three generations at Oreana, Nevada, which gave rise to three structural types: coarse euhedral crystals, matted masses, and fibrous veins or isolated crystals.

Specific Gravity

Schaller (1905) lists the following specific gravities for dumortierite:

3.36
3.265
3.22
3.319
3.226-3.43
3.211-3.302

The average specific gravity is 3.292. Variations in the recorded specific gravities are due largely to variations in the purity of the material.

Optical Properties

General

Interference figure, biaxial. Optic sign, negative. Birefringence (gamma minus alpha) = 0.010 to 0.027. Dispersion strong but indeterminate. 2V, 30-40°. Pleochroism, strong: alpha, blue to red; beta, colorless to red and yellow; gamma, colorless. Elongation parallel to c. Inclusions of rutile and titanite are common, and Diller and Whitfield (1889) have observed liquid inclusions and long tabular cavities in dumortierite.

Index of Refraction

The indices of refraction of dumortierite as determined by various investigators are listed in the accompanying table. The refractive index of the alpha ray varies, neglecting the two abnormal readings of 1.650 and 1.688, from 1.659 to 1.678;

TABLE OF THE INDEX OF REFRACTION
OF DUMORTIERITE

Investigator	Locality	Alpha	Beta	Gamma
Aubel (1931)	Tanganyika	1.675	1.685	1.690
Fairbanks (1926)	Nevada	1.677_{Li}	-	-
Larsen (1921)	California	1.670_{Na}	1.691_{Na}	1.692_{Na}
Linck (1899)	Switzerland	1.678_{Na}	1.686_{Na}	1.689_{Na}
Michel-Levy & Lacroix (1888)	Norway	1.650	1.712	1.728
Nemec (1935)	Moravia	1.688	-	1.689
Peck (1926)	Nevada (pink)	1.677_{Na}	1.685_{Na}	1.690_{Na}
Peck (1926)	Nevada (lavender)	1.675_{Na}	1.685_{Na}	1.690_{Na}
Peck (1926)	Nevada (light blue)	1.675_{Na}	1.685_{Na}	1.692_{Na}
Walker (1922)	Canada	1.659_{Na}	1.684_{Na}	1.686_{Na}
Wolff (1930)	California	1.668	1.687	1.688

beta from 1.684 to 1.691 (neglecting the abnormal reading 1.712); and gamma from 1.686 to 1.692 (neglecting the abnormal reading of 1.728). The wide variation in values of the alpha index suggests a possible correlation between the chemical composition of dumortierite and its index of refraction. It was hoped that sufficient data would be available for a study of this nature, but it was found that all but three of the investigators who submitted chemical analyses failed to include a determination of the index of refraction for that material. As a result of such meager information the attempted correlation had to be abandoned.

Chemical Properties

Pyrognostics

Dumortierite is infusible before the blowpipe, but loses its color becoming white. Yields a blue color on heating with cobalt nitrate. Renders a salt of phosphorous bead slightly bluish and opaline. Insoluble in acid and resistant to weathering, hence it is found among detrital products. When intimately mixed with potassium bisulphate and calcium fluoride and introduced into a flame the green color of boron may be obtained, but this is a very delicate test. An improved method of testing for minute amounts of boron has been described by Lacroix and Gramont (1921).

Bowen and Wyckoff (1926) studied the effect of heating dumortierite and found that little effect is produced in the mineral at a temperature of 800°C other than a loss of the deep-blue color. At 950°C it becomes slightly turbid. At 1200°C its index of refraction is lowered slightly, the elongation becomes positive and the product shows the X-ray spectrum lines characteristic of mullite. It completely breaks down to mullite ($3Al_2O_3 \cdot 2SiO_2$) after two hours at 1400°C, and probably silica and boric oxide. After 4½ hours at 1500°C, the boric oxide and water are completely expelled and sintering begins. At 1550°C, liquid first appears as a result of the melting of the eutectic between mullite and silica.

Formula

Eighteen chemical analyses of dumortierite have been made by eleven analysts, and no two analysts quite agree on the composition of the mineral. The causes of the disagreement of the chemical composition of dumortierite as suggested by Grawe (1928) are:

1 The small amount of material available for analysis.

2 Difficulty of obtaining material of requisite purity.

3 Difficulties inherent in methods of analysis.

4 Failure on the part of some analysts to detect all the constituents present.

5 Probability of vicarious replacement of aluminum by boron, hydrogen, iron, and titanium

Damour, failing to detect the presence of boron in his analysis of dumortierite, assigned it the formula $4Al_2O_3 \cdot 3SiO_2$. Other formulae have since been proposed and at the present time the two considered best are Schaller's (1905), $8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$, and Todd's (Walker, 1922) $8Al_2O_3 \cdot B_2O_3 \cdot 7SiO_2 \cdot H_2O$. These differ by only one molecule of SiO_2. Lebedev (1945), in offering an explanation for the weathering of tourmaline, axinite, and dumortierite, proposed the graphic formula $H_2B_2Al_4Si_4O_{18} \cdot 2Al_2SiO_5 \cdot 4Al_2O_3$ for dumortierite which shows the nucleus built up of two kaolinite nuclei. The composition, however, is identical with that of Schaller's.

OCCURRENCE

In the years following its discovery, dumortierite has been observed in localities of world-wide distribution.

North America

Several deposits of dumortierite have been found in the United States, but only one in Mexico and one in Canada.

United States

The only deposit of dumortierite in the eastern part of the United States is in New York, but many localities west of the Mississippi River are known in the states of Arizona, California, Colorado, New Mexico, Nevada, and Washington.

New York

Deep blue acicular crystals of dumortierite associated with oligoclase and quartz are found in a pegmatite vein extending from 4th Avenue and 123rd Street to Madison Avenue at 116th Street in the city of New York. At 171st Street and Fort Washington Avenue dumortierite is found in several pockets in a vein of coarse pegmatite in a mica schist. The vein, the body of which is a granular gray quartz, orthoclase, and muscovite, is about three feet wide and the pockets extend for about eighty feet. The dumortierite is found chiefly as inclusions in orthoclase, and a few inclusions have been noted in muscovite. In Harlem, according to Diller (1889), dumortierite occurs in a pegmatoid portion of a biotite gneiss. Fibers of dumortierite are scattered through quartz which is associated with orthoclase, plagioclase and tourmaline. Other minerals present are muscovite, xenotime, monazite, zircon, torbernite (?), autunite (?), apatite, garnet, and andalusite.

Arizona

Dumortierite in boulders of granular quartz from Clip, Arizona, was described by Diller and Whitfield in 1889. Lath-shaped prisms of dumortierite are included in quartz together with several large blades of muscovite, magnètite, and a little apatite and rutile. The principal mineral constituents are dumortierite and quartz, but small amounts of kyanite, magnetite, limonite, and muscovite are present. Feldspar, however, is absent.

Wilson (1929) recorded an occurrence of dumortierite near Quartzite, Arizona, in a vein cutting chlorite and quartz-sericite schists. The dumortierite occurs as fibers and small prisms, both disseminated and in veinlets. Associated minerals are quartz, kyanite, andalusite, sillimanite, pyrophyllite, muscovite, hematite, magnetite, rutile, leucoxene, pyrite, limonite, sapphirine (?), and some undetermined species. The andalusite, kyanite, and sillimanite show alteration to pyrophyllite instead of to muscovite. In regard to the origin Wilson states:

> "...a chlorite schist suggests derivation from igneous rocks, but a quartz-sericite schist leaves the origin questionable. Probably granitic magma invaded schists at considerable depth and permeated favorable portions of them with hot, pegmatitic emanations that were high in silica and alumina but contained also some boron, iron, and titanium. The distribution of the resultant minerals, which appear to have replaced metasomatically the schist, indicates these emanations to have been very fluid and possibly under great pressure."

A locality in the Patagonia Mining District 12 miles northeast of Nogales was reported by Dean G. M. Butler in a personal communication to Director Fulton of the Mackay School of Mines (Grawe, 1928).

California

Ford (1902) mentioned the occurrence of dumortierite in a quartz dike thirty to forty feet wide cutting a biotite-granite a few miles east of Dehesa, San Diego County, California. The upper part of this dike, according to Schaller (1905), the is a fine-grained, whitish schistose quartz containing sillimanite, a little muscovite, but no dumortierite. As the middle is approached the dike loses its schistose structure and toward the bottom becomes coarse in texture. The lower part of the dike exhibits no schistose structure, and presents a very coarse and mottled appearance due to dark bunches of dumortierite on a white quartz background. Dumortierite and quartz are the main constituents of the rock. Muscovite, sillimanite, magnetite, titanite, rutile, apatite, zircon, and undetermined inclusions make up the remainder. Schaller believes the dike to have been formed in two stages. During the first, the upper part of the dike was more or less completely formed and was solidified to a great extent. It was subsequently pushed upward by an intrusion of magma, comprising the second stage, and emplaced in its present position. Because the upper part of the dike was solidified, the boron-bearing gases of the seonnd intrusion had little effect upon changing its character, and as a result the presence of dumortierite is confined to the lower portion of the dike. The great pressure of the second intrustion apparently had two effects: one was to cause schistose structures to appear in the upper part of the dike, and the other was to cause the formation of sillimanite instead of andalusite.

According to Professor E.W. Heinrich (personal communication) dumortierite also occurs in a pegmatite near Alpine, close to the Dehesa locality. The body of the pegmatite, which is several feet thick, contains quartz, potash feldspar, black tourmaline, muscovite, and dumortierite. Much of the dumortierite is concentrated in a one- to two-foot band near the center of the dike.

MacMurphy (1930) recorded the occurrence of dumortierite in Riverside County scattered through a granodiorite country rock, the chief constituents of which are orthoclase, oligoclase, quartz, and biotite. Quartz generally forms a coarse-grained mosaic with dumortierite which is apparently widespread in the region, and titanite, magnetite, and apatite occur as accessory minerals. Dumortierite rosettes are commonly altered to sericite. Some tourmaline, zircon, corundum, and either cassiterite or rutile is also present.

Dumortierite as float was found by Wolff (1930) in Imperial County in a region of sills, volcanics, and faults.

Colorado

The only account of dumortierite in Colorado is that published by Findlay (1907). He found the mineral in an acid dike forty to eighty feet wide cutting epidote schist. The dike contains abundant rutilated quartz, feldspar, and muscovite. Present to a lesser extent are corundum and sillimanite, and a few crystals of hematite are sometimes seen. The blue dumortierite is in part made up of bundles of radiating needles, microscopic in size. The dike appears to be a molten rock injection and not formed by heated waters. The minerals in the pegmatite are essentially those in the nearby granite rock. The excess Al_2O_3 crystallized as corundum.

New Mexico

Two dumortierite localities are known in the state of New Mexico. One, near Luna (Schaller, 1916; Northrop, 1942), contains dumortierite in a ledge several feet wide in a partly sericitized quartz rock. The dumortierite is in the form of spherules, blue in color, and is found in seams a quarter of an inch wide. Smaller amounts of colorless spherulites of mica are associated with the dumortierite.

The other locality (Northrop, 1942) is in the Petaca district, Rio Arriba County. Here radiating clusters or sunbursts of dumortierite up to three inches across are found in a gray vein in the west slope of La Madera Mountain. The mineral has a dark bluish-lavender tint.

Nevada

Occurrences of dumortierite have been reported in three Nevada counties: Pershing, Washoe, and Nye. It was in the Rochester Mining District of Pershing County that dumortierite was found in quantites large enough and of sufficient quality to warrant commercial production. The mineral is pink in color and was mistaken for rubellite by Jones (1913) in a hasty examination of the sericite schists of the district. Knopf (1924) called attention to the mistake in a paper he published describing the geology of the ore deposits of the Rochester District.

The greater part of the rocks exposed in the Rochester District are Triassic lavas, chiefly trachytes and keratophyres, intruded by irregular areas of aplite and dikes of granite porphyry. In some areas the trachyte has been considerably altered and replaced by quartz, sericite, andalusite, and dumortierite. The dumortierite occurs as lavender to pink splotches in the schist, but more commonly as a network of quartz-dumortierite veins. Intergrowths of mica and dumortierite are common. Andalusite is associated with dumortierite and quartz in such an intimate way that very often it can be distinguished from quartz only with the aid of a microscope. Knopf (1924) suggested that boron-bearing gases which permeated the closely spaced network of fractures was responsible for the development of the boron. Jones (1928) attributed the formation of dumortierite to both pneumatolytic and hydrothermal action, and Kerr and Jenney (1935) to a hydrothermal stage only. Dumortierite, and andalusite are present in considerable concentrations, together with minor amounts of titanite, rutile, leucoxene, zircon, magnetite, pyrite, limonite, tourmaline, biotite, and vein carbonate.

Dumortierite occurs in segregations in granite associated with quartz and muscovite at the southern end of the Granite Range in Washoe County. (Grawe, 1928, p. 10).

Round Mountain (Grawe, 1928, p. 11), Nye County, contains sodalite-blue dumortierite as a quartz replacement within a granite mass.

Washington

Ford (1902) reported the occurrence of small spherulites of blue dumortierite in a fine-grained mass of quartz, muscovite, and andalusite in Skamnia County. The occurrence of spherulites is similar to that of Luna, New Mexico. Pyrite is abundant and leucoxene is found surrounding grains of magnetite.

Canada

Blue dumortierite, associated with quartz, microcline, kyanite, muscovite, and tourmaline, occurs in a pegmatite vein cutting through a gneiss near Bancroft, Ontario.(Walker 1922). Slender prisms of dumortierite which lie on the cleavage plane of mica show some degree of orientation. Dumortierite is also included in quartz, microcline, and coats joints in the pegmatite itself.

Mexico

Wittich and Kratzert (1921) studied the dumortierite of the Sierra de Guadalcazar inthe State of San Luis Potosi. They found the dumortierite associated with topaz in quartz boulders, and assumed the source to be pegmatite veins cutting a laccolith northwest of Guadalcazar. The dumortierite is dark ultramarine blue and fibrous, associated with quartz, muscovite and topaz.

South America

The known occurrences of dumortierite on the South

American continent are restricted to the countries of Argentina and Brazil.

Argentina

Dumortierite occurs as an accessory mineral in granite at Potrero, Province of Catamarca, Argentina according to Romberg (1893).

Brazil

Two occurrences of dumortierite are reported by Rimann (1914) near Rio de Janeiro. One is at Ipanema on the south slope of the Morro de Cantagallo where six pegmatite dikes, four of which contain dumortierite, cut a cordierite-sillimanite gneiss. The other one is in the suburb of Copacabana where beautiful blue prismatic crystals of dumortierite associated with andalusite occur where two pegmatite dikes intrude a garnet-cordierite gneiss. At Diamentina, Riacho das Varras, Candonga, and Cachorra de Paraima, Ferraz and Rocatti (1927) found dumortierite in the diamond-bearing sands.

Europe

The occurrence of dumortierite has been reported in England, France, Bohemia, Austria, Germany, Switzerland, Russia, and Norway.

England

Mackie (1925) recorded the occurrence of dumortierite in gneiss, pegmatite, and granite from four localities in Aberdeenshire and Banffshire, Scotland, and in the granite of

Cornwall, England. Fibrous aggregates of dumortierite occur in several three- to four-inch pegmatite veins cutting through schist, and are associated with monazite, pleochroic andalusite, pink and green garnet, anatase, brookite, brown and bluish tourmaline, apatite and iron ores. It is found in gneiss and foliated granite at Portsoy. The occurrence of dumortierite in the Cornish granite is associated, as in the pegmatite veins, with pleochroic andalusite, tourmaline, monazite, and also colorless and purple fluorite.

Groves (1928) studied the occurrence of dumortierite in the sediments from scattered localities in England. He obtained a single grain of dumortierite from the concentrates of the Blackheath Beds of Shirley, Surrey; another from the Bagshot Beds of Bournemouth associated with blue tourmaline. Other localities he lists are the Bridgport sands, Dorset, the upper greensand of Lulworth Cove, Dorset, and a single striated grain from the Bagshot Beds midway between Winborne and Ringwood, Dorset. He pointed out that most of the dumortierite that has been found in English sediments is of a "Stephens Ink" blue color. In all cases the greatest care is necessary in the diagnosis to prevent any possible confusion with blue tourmaline. Groves also mentions dumortierite in the granite of Land's End, Cornwall. Brammall (1928) found a few fragments of dumortierite in the detritals at Dartmoor, and in granite near its contact with slate. Hayward (1932) noted dumortierite in the Lower Greensand of the Dorking-Leith Hill district.

France

Dumortierite is found at several places in the vicinity of Lyons (Rhone) where it occurs in a pegmatite gneiss. At Beaunan (Gonnard, 1881) it is found as slender blue fibers in the midst of veinlets or lenses of feldspar and pegmatite which cuts the gneissic country rock. The mineral, disseminated as small fibers throughout a white pegmatite at Brignais (Gonnard, 1888), is associated with large black crystals of tourmaline, garnet, muscovite, and cordierite, the latter being largely altered to mica. Pseudomorphs of mica after dumortierite are common.

Bohemia

Rosler (1902) observed dumortierite in the kaolinized products of decay of a muscovite-biotite granite at Imligan, near Chodeau; at Schobrowitz, near Karlsbad; and at Oberbris, near Pilsin. At Putimov, near Pelhrimov, Kratochvil (1921) found dumortierite and andalusite as small prisms and grains in aplite dikes penetrating granite and gneiss. Two deposits of dumortierite have been found in Moravia, one of which has been described by Kosicky (1926) as occurring with sillimanite in small veinlets of pegmatite traversing a sillimanite-biotite gneiss at Vymyslice, near Moravsky, Krumlov; and the other as occurring as prismatic crystals with chlorapatite and andalusite aggregates in a pegmatite at Dolni and Horni Bory near Velke Mezirici (Nemec, 1935). Kratochvil (1929) described a deposit at Kank, near Kutna Hora in which the dumortierite occurs in aplitic injections in migmatitic gneiss.

Austria

Minute blue specks in scapolite from Schwanberg, Styria were identified as dumortierite by Meixner (1940).

Germany

Websky (1885) found dumortierite in a pegmatite dike with corundum in the Riesengebirge of German Silesia, at Wolfshau, west of Schmiedeberg. A similar occurrence has been observed by Hlawatsch (1911) in the gneiss near Weitenegg. Laubman and Steinmetz (1920) reported dumortierite in a pegmatite dike with sillimanite, staurolite (?), tourmaline, and rutile near Marchaney, Oberpfälzer, Bavaria.

Switzerland

An occurrence of dumortierite in a quartz-rich muscovite pegmatite from the southern margin of the Bergeller Massif of the Swiss Alps was reported by Hugi and Hirichi (1925). Linck (1899) had previously described a similar occurrence in the pegmatite of the lower Val Donbastone in upper Veltlin. Pegmatite intrusions in gneiss and schist are common occurrences in the southern part of Ticino, according to Taddei (1940). The minerals which have been recorded in them include tourmaline, beryl, garnet, scapolite, torberite, perperite, vivianite, graftonite, fuchsite, orthite, columbite, tapiolite, and dumortierite.

Russia

Dumortierite occurs as a microscopic constituent in pegmatite, together with black, blue, and pink tourmaline, garnet, and cordierite which cuts basic rocks that are intercalated between garnet-mica-gneissin the Ouvildy Lake district of the Russian Urals, according to Kuznetzov (1923). Various mineral replacements occur at the contacts. In a study of the alkaline rocks of the southern part of the Kyshtym district, Ural, Kuznetzov (19) discovered that the nepheline-syenites, alkali-syenites, miaskites, and granite-gneisses were intercalated with bands of amphibolite, quartz, and garnet-gneiss, and all were cut by pegmatites and aplites. It is in these dikes that dumortierite, associated with blue, gray, and rose tourmaline, cordierite, and beryl, is found. The Central Balkhash region contains bodies of quartzite formed by hydrometamorphism and penumatolytic metamorphism of granodiorite-porphyry in which, according to Astashenko (1940) a variety of minerals is found, among which are andalusite, corundum, diaspore, alunite, molybdenite, zunyite, chalcopyrite, and dumortierite.

Norway

Inclusions of minute fibers of dumortierite in the cordierite gneiss of southern Norway associated with cordierite and sillimanite have been described by Michel-Levy and Lacroix (1888) from the vicinity of Bamle, Tvedestrand, Kragero, and Arendal.

Africa

Tanganyika

Aubel (1931) reported the occurrence of dumortierite, prussian-blue in color, in quartzose nodules associated with pegmatites near the massif of Sombwe, near Ubwari.

Southwest Africa

A specimen of cobalt-blue dumortierite from the Erongo Mountains of Southwest Africa was described by Silberstein (1933).

Madagascar

Dumortierite is disseminated in quartzite which is accompanied by other quartzites containing lazulite at Anfoka, near Soavina, according to Lacroix (1922a), and in view of all the other occurrences, Grawe (1928) suggests that the quartzite may be veins of granular replacement quartz.

Antarctica

King George Land, Adelie Land, and Queen Mary Land

Mawson (1940) observed dumortierite in morainal boulders at Cape Denison on the Antarctic Continent. The boulders had been derived from pegmatites and were composed of coarse microcline, much quartz, some sillimanite, and feldspar.

A quartz boulder in the same location was seen to contain apatite, biotite, magnetite, quartz, feldspar, zircon, magnetite, and sillimanite. Dumortierite occurs as faint blue patches in the clear quartz.

ORIGIN

Dumortierite appears to result from the reaction of high temperature magmatic waters or vapors, rich in aluminum and boron, upon various types of country rock. In a few occurrences, however, dumortierite is scattered throughout the country rock and not confined to clearly-defined late veins. The host rocks for the disseminated grains are granites and metamorphics; coarsely crystalline dumortierite is found only in pegmatite veins.

Granite Rocks

The accounts of the occurrence of dumortierite in granite are few and those that have been published are somewhat inadequate for a study of the paragenesis of the mineral.

Two dumortierite-bearing granites contain andalusite, quartz, mica, and tourmaline associated with the dumortierite; and in addition fluorite and monazite are found in one and corundum in the other. The presence of these atypical granitic and typical pegmatitic minerals suggests that the environment in which they were formed was far removed from that of a true granite and bordered on that required for pegmatite formation. Tourmaline in granite indicates, as a rule, the action of solutions or vapors during a late stage in the rock consolidation or after its crystallization. The presence of andalusite indicates abnormal aluminum content, and corundum may form under excessively high aluminum concentrations. However, the possibility that these represent merely a suite of unusual accessory minerals cannot be denied. Microscopical evidence would be desirable.

Pegmatitic and Aplitic Dikes

Dumortierite occurs most commonly in pegmatite and aplite dikes as the result of pneumatolytic and hydrothermal activity. Quartz is an invariable associate and muscovite is usually present either as a primary mineral or as an alteration product. In most cases some other aluminum mineral accompanies dumortierite, such as andalusite, corundum, kyanite, pyrophyllite, sillimanite, or topaz, apparantly as the result of excessive aluminum. The common boron-bearing associate is tourmaline. Feldspar occurs with dumortierite in many localities but is notably absent in others, especially those on the North American continent. Sulfides are not commonly found with dumortierite but in a few cases pyrite accompanies it. Whether titanite or rutile occurs depends upon the amount of titanium that dumortierite contains in solid solution.

Investigators are not entirely agreed upon the mode of origin of the deposits they studied. For example, three studies have been made of the dumortierite deposit at Oreana, Nevada, and as many opinions have been expressed regarding its origin. Knopf (1924) concluded that the deposit was pneumatolytic in origin; Jones (1928) suggested that it was both pneumatolytic and hydrothermal; and Kerr and Jenney (1935) concluded that it was of hydrothermal origin only. All are in agreement, however, that the dumortierite is late and is the result of heated fluids charged in aluminum, boron, and silica invading the tuffaceous country rocks and reacting with them.

Metamorphic Rocks

The occurrence of dumortierite in metamorphic rocks has been reported in a few instances but here, too, the available data leave much to be desired in working out the paragenesis of the mineral. It has been found in foliated granite, and as minute fibers in cordierite gneiss. However, two possible origins of dumortierite in metamorphic rocks are suggested by the examination of the data: one, that the dumortierite was present in the rocks prior to metamorphism and suffered no appreciable change due to the dynamic processes, and the other that solutions or vapors present during metamorphism were responsible for the formation of dumortierite through reaction and replacement.

The first speculation is substantiated to some extent by the results of the experiments of Bowen and Wycoff (1926) who found that temperatures up to 800° C. have little effect upon dumortierite other than to cause it to lose its blue color, and that at temperatures even as high as 950° C., only a slight change takes place. The temperatures of dynamic metamorphism probably do not equal, much less exceed this value, but the effect of high pressures on the decomposition point should not be overlooked. Probably directed pressure alone is insufficient to form dumortierite as a recrystallization product under regional metamorphic conditions. If the particular area were near a contact, then the heat from an igneous body might be sufficient to produce dumortierite, provided that boron were available or provided in some manner to the country rock. The only common mineral from which boron might be derived is tourmaline.

The conclusion is advanced, therefore, that dumortierite in metamorphic rocks must have been present prior to diastrophism and not changed in the process, or to have been introduced in part by the action of volatiles from nearby igneous masses.

BIBLIOGRAPHY

Astashenko, K. I.,(1940) Secondary quartzites of the central Balkhash region; Compt. Rend. (Doklady), Acad. Sci. USSR, vol. 27, pp. 477-480. (Reviewed in Min. Abs. vol 9, 1944-46).

Aubel, Rene Van (1931) Sur quelques mineraux du Congo Belge (prehnite, dumortierite, danburite); Ann. Soc. Geol. Belgique, Publ. Congo Belge, vol. 53, pp. c77-c79. (Reviewed in Min. Abs. vol 4, 1929-31).

Bertrand, Emile (1880) Sur un mineral bleu de Chaponost, pres Lyon; Bull. Soc. Min. de France, vol. 3, pp. 171-172.

Bertrand, Emile (1881) De l'application du microscope a L'etude de la mineralogie; Bull. Soc. Min. de France, vol. 4, p. 9.

Bowen, N.L., and Wyckoff, R.W.G. (1926) A petrographic and X-ray study of the thermal dissociation of dumortierite; Journ. Wash. Acad. Sci, vol. 16, pp. 178-189.

Brammall, Alfred (1928) Dartmoor detritals; a study in provènance; Proc. Geol. Assoc. London, vol. 39, pp. 27-48.

Chamberlain, B.B. (1888) The minerals of New York County, including a list complete to date; New York Acad. Sci. Trans, vol. 7, p. 230.

Clarke, F.W. (1924) The data of geochemistry; U.S.Geol Survey Bull. 770, p. 416.

Damour, A.,(1881) Analyse de la dumortierite; Bull. Soc Min. de France, vol. 4, p. 6.

Dana, E.S. (1889) Review of Riggs' "The so-calledHarlem indicolite"; Zeit. Kryst. vol. 15, p. 127.

Dana, E.S., and Ford, (1922) Textbook of Mineralogy; John Wiley and Sons, Inc., N.Y.

Diller, J.S. and Whitfield, J.E. (1889) Dumortierite from Harlem, N.Y., and Clip, Arizona; Am. Jour. Sci., 3rd ser., vol 37, pp. 216-219. Also U.S. Geol. Survey Bull. 64, pp. 31-33, 1890.

Fairbanks, E.E. (1926) Dumortierite from Nevada; Am. Min. vol 11, pp. 93-96. Correction p. 135.

Ferraz, Jorge Palmire de Araujo, and Rocatti, M. Alessandro (1927) Notes sur la mineralogie du Bresil; Bull. Soc. Min. de France, vol 50, p. 34.

Findlay, G.I. (1907) On an occurrence of corundum and dumortierite in pegmatite in Colorado; Journ. Geol. vol 15, pp. 479-484.

Ford, W.E. (1902) On the chemical composition of dumortierite; Am. Jour. Sci. (4th ser), vol 14, p. 426-430. Also Zeit. Kryst. vol. 37, pp. 417-421, 1903.

Gonnard, Ferdinand (1881) Note sur l'existence d'une espece minerale nouvelle, la dumortierite, dans le gneiss de Beaunan au-dessus des anciens aqueducs galloromains de la vallee de l'Iseron (Rhone); Bull Soc. Min. de France, vol 4, pp. 2-5.

Gonnard, Ferdinand (1888) Sur un nouveau gisement de dumortierite a Brignais (Rhone); Bull. Soc. Min. de France, vol. 11, pp. 264-265.

Gonnard, Ferdinand (1892) Sur un nouveau gisement de dumortierite dans le Rhone; Bull Soc. Min. de France, vol 15, p. 230.

Grawe, O.R. (1928) The Mineralogy of dumortierite; Nevada Univ. Bull, vol. 22, no. 2. (Mackay School of Mines Bulletin on Dumortierite), pp. 7-22, 30-31.

Groves, A.W. (1928) The identification of dumortierite as grains; dumortierite in Cornish granite; Min. Mag. vol. 21, p. 489.

Hayward, H.A. (1932) Proc. Geol. Assoc. of England, vol 43, p. 1.

Hlawatsch. D. (1911) Dumortierite von Weitenegg; Min. pet. Mitt. (Tschermak's, Wien), vol 30, pp. 140-141.

Hugi, E., and Hirschi, H. (1925) Dumortieritvorkommen aus den sudlichen Schweitzer Alpen; Schweiz. Min. Petr. Mitt., vol 5, pp. 251-252. (Reviewed in Neues Jahrb. Min., vol 2a, pp. 333-334, 1926).

Jeremine, E. (1945) Sur un nouveau gisement de dumortierite dans les colonies Francaises (Guinee). Bull. Soc. Min. de France, vol 68, no. 7.

Jones, J.C. (1913) Geology of Rochester, Nevada; Mining and Sci. Press, vol 106, pp 737-738.

Jones, J.C. (1928) The geology of the deposit of dumortierite in Humboldt, Queen Canyon, Pershing County, Nevada. Nev. Univ. Bull., vol 22, no. 2 (Mackay School of Mines Bull on Dumortierite) pp. 23-26.

Just, Evan (1937) Geology and economic features of the pegmatites of Taos and Rio Arriba Counties, N.Mexico. N.M. Sch. Mines, State Bur. Mines & Min. Res, Bull. 13, 73 pp.

Kerr, Paul F. and Jenney, Phillip (1935) The dumortierite-andalusite mineralization at Oreana, Nevada; Econ. Geol, vol 30, p. 287-300.

Knopf, Adolph (1924) Geology and ore deposits of the Rochester District, Nevada; U.S. Geol. Survey Bull 762, pp. 18-19.

Kratochvil, Josef (1921) Mineraly Pelhrimvoska (Minerals from near Pelhrimov) Casopis Musea Ceskeho (Jour. Bohemian Mus.) Praha, vol 95, pp. 112-118. (Reviewed in Min. Abs. vol 2, p. 118, 1923-1925).

Kratochvil, Josef (1929) (Contributions to the mining history and to the mineralogical topography of Bohemia); Vestnik Statniho Geol. Ustavu Ceskoslovenske Republiky, vol 5, pp. 95-101. (Reviewed in Mins.Abs., vol 5, 1932-1934, p. 86.

Kuznetzov, E.A. (1923) The rocks of the Ouvildy Lake, Ural Mountains; (Trans. inst. Econ. Min. Petrogr,, 'Lithogaea'), Moscow, no. 2.

Kuznetzov, E. A. (19) Alkaline rocks of the southern part of Kyshtym District, Ural; Sci. Techn. Dept. Supreme Council of National Economy, no. 371.

Lacroix, Alfred,(1889) Contribucions a l'etude des gneiss a pyroxene et des roches a wernerite; Bull. Soc. Min. de France, vol 12, pp. 219-221.

Lacroix, Alfred (1922a) Mineralogie de Madagascar, vol 1, pp. 401-403. Augustin Challamel, Rue Jacob 17, Paris.

Lacroix, Alfred, and de Gramont, A (1922) Sur la recherche spectrale du bore et sur sa presence dans quelques silico-aluminates naturels; Bull. Soc. Min. de France vol 44, pp. 67-77.

Larsen, E.S. (1921) The microscopic determination of the non-opaque minerals; U.S. Geol Survey Bull. 679, p. 70.

Laubman, H., and Steinmetz, H. (1920) Phosphat fuhrende Pegmatite des Oberpfalzer und Bagerischen Waldes; Zeit. Kryst. vol 55, 523-586.

Lawson, Andrew C. (1904) The orbicular gabbro at Dehesa, San Diego,Co., Calif.; Bull. Dept. Geol. Univ. Cal. vol 3, pp. 383-396.

Lebedev, V.I. (1945) Chemical formulae of tourmaline, axinite, and dumortierite; Compt. Rend. (Doklady), Acad. Sci. URSS, vol 47, pp. 635-639. (Reviewed in Min. Abs. vol 9, 1944-1946).

Linck, G. (1899) Die pegmatite des oberen Veltlin; Zeit. Naturwiss. (Jena) vol 33, pp. 345-360.

MacMurphy, F. (1930) Dumortierite from Riverside County, California; Am. Min. 1930, vol 15, pp. 79-80.

Mackie, William (1925) Dumortierite in British Rocks; Trans Edinburgh Geol. Soc., vol 11, p. 352.

Mawson, Douglas (1940) Record of minerals of King George Land, Adelie Land and Queen Mary Land. Australasian Antarctic Expedition 1911-1914, Ser A, 1940, vol 4 (Geology), pt. 12., pp. 369-403.

Meixner, Heinz (1940) Einige neu Mineralfunde (dumortierit, skapolith) aus dem Koralpengebiete, Steiermark B2w, Karnten. Zentralbl. (Min. Abs review. A. 1940, pp. 19).

Michel-Levy, A, and Lacroix, A. (1888) Refringence et birefringence de quelques mineraux des roches; Compt. Rend., vol 106, p. 777.

Michel-Levy, A., and Lacroix, Alfred (1888) Sur un nouveau gisement de dumortierite; Compt. Rend, vol 106, pp. 1546-1548.

Niggli, P., and Faesy, K., (1921) Silicates; Zeit. Kryst., vol 56, p. 338.

Nemec, Frnatisek (1935) Nove nalezy nerostne od dumortierite a H. Boru u Vel. Mezirici (Zap Morava). (Newly found minerals from Dolni and Horni Bory near Velke Mezirici, Veda Prirodni, Praha, vol 16. pp. 287-289. (Reviewed in Min. Abs, vol 6, 1935-1937, p. 357).

Northrop, Stuart A. (1942) Minerals of New Mexico; Univ. of N.M. Bull., Geol. Series, Vol 6, no 1, July 1942., p. 131

Peck, Albert B. (1926) Dumortierite as a commercial mineral; Am. Min., vol 11, pp. 96-101.

Riggs, R.B. (1887) The so-called Harlem indicolite; Am.Jour. Sci. (3rd Ser.) vol 34, p. 406.

Rimann, Eberhard (1914) Uber ein neues Vorkommen von Dumortierite; Centralbl. Mineralogie, pp. 615-620.

Romberg, J., Petrographische Untersuchungen an argentinischen Graniten; Neues Jhrb. Beilage Band 8, p. 340, 1893.

Rosicky, Vojt (1926) Mineralogicke Zpravy z Moravy (Mineralogic communications on Moravia); Casopis Moravskeho Musea Zemskeho, (Bull. Moravian Museum), vol 22, pp. 138-158, (Reviewed in Min. Abs, vol 3, p. 123, 1936. Neues Jhrb. Min., p. 337, 1926. Revue de Geologie, VIII., annee fascicule, 1927).

Rosler, H. (1902) Uber hussakit (xenotim) und andre seltene gesteinbildene Mineralien; Zeit. Kryst., vol 36, p. 262.

Schaller, Waldemar T. (1905) Dumortierite from New York City, U.S. Geol. Survey Bull 262, pp. 91-120. Also Am. Jour. Sci, (ser 4) vol 19, pp. 211-224, 1905).

Schaller, Waldemar T. (1916) Gems and precious stones; U.S. Geol Survey Min. Resources 1916, pt. 2. p. 893, 1919.

Schrader, F.C. (1914) The Rochester Mining District, Nevada; U.S. Geol Survey Bull 580, pp. 325-372.

Silberstein, G. (1933) Ein Blauer sudwestafrikanischer Schmuckstein; Zeit. Prakt. Geol., vol 41, p. 53. (Reviewed in Min. Abs. 1935-1937, p. 9 vol 6).

Taddei, C. (1940) Pegmatiti della Svizzera Italiana e minerali in esse contenuti; Schweiz. Min. Petr. Mitt, vol 20, pp. 247-252. (Reviewed in Min. Abs., vol 8, 1941-1943, p. 163).

Vernadsky, W. (1890) Sur la reproduction de la sillimanite; Bull. Soc. Min. de France, vol 13, p. 258.

Walker, T.L. (1922) Dumortierite from Ashby Twp, Addington Co., Ontario; Univ. Toronto Studies, Geol. Ser. 1922, no. 14, pp. 80-83.

Websky, A (1885) A note, Sitzungsb. der niederr, Gesell. (Bonn) vol 42, p. 202.

Webster, M.H. (1824) Catalogue of the minerals which have been discovered in the State of New York arranged under the heads of the respective counties and towns in which they are found, 32 pp., Albany, N.Y., 1824.

Whitlock, Herbert Percy (1903) List of N.Y. mineral localities; N.Y. St. Mus. Bull 70:108.

Wilson, Eldred D. (1929) An occurrence of dumortierite near Quartzite, Arizona. Am. Min. vol 14, pp. 373-381.

Wittich, Ernesto, and Kratzert, I. (1921) Contribuciones a la mineralogia mexicana; Soc. Cient. "Antonio Alzate" Memorias, vol 39 (1920-1921), pp. 651-655. (Reviewed in Min. Abs. vol 1, p. 371).

Wittich, Ernesto, and Kratzert, I., (1921) Uber ein neües Vorkommen von Dumortierite im Granit bei Guadalcazar, Nordmexico; Centralb. Mineralogie, pp. 648-650, 1921.

Wolff, John E. (1930) Dumortierite from Imperial County, California; Am. Min. vol 15, pp. 188-193.

Anonymous, Notes on Canadian minerals; Univ. of Toronto Studies, Geol. Ser. no. 12, p. 69, 1921.

MINERAL ASSOCIATES OF DUMORTIERITE

Locality	Reference	Host Rock	Country Rock	Quartz	Muscovite	Tourmaline	Orthoclase	Andalusite	Magnetite	Apatite	Rutile	Zircon	Sillimanite	Biotite	Kyanite	Pyrite	Corundum	Garnet	Plagioclase	Topaz	Pyrophyllite	Titanite	Others
Granite																							
Argentina, Portrero Catamarca	Romberg (1893)	Granite	Granite	x	x	x		x									x						
United States																							
Nevada, Granite R.	Grawe (1928)	Granite	Granite	x	x						x									x		x	x
Calif., Riverside Co.	MacMurphy	Granite	Granodiorite	x	x	x	x		x	x	x			x			?					x	x
Aplite & Pegmatite																							
Antarctica	Mawson (1940)	Pegmatite	Muscov schist	x	x								x						x				
Bavaria	Laubman & Steinmetz (1920)	Pegmatite		x		x					x		x										x
Bohemia,																							
Kank	Kratochvil (1929)	Aplite	Gneiss	x	x		x																
Pelhrimov	Kratochvil (1921)	Aplite	Gr. gneiss	x				x															x
Brazil, Copacabana	Rimann (1914)	Pegmatite	Cord. gneiss	x	x	x	x	x		x	x	x		x		x		x	x	x			x
Ipanema	Rimann (1914)	Pegmatite	Cord. gneiss	x	x		x	x	x		x	x	x					x					x
Canada, Ashby Twp.	Walker (1922)	Pegmatite	–	x	x	x	x								x								
England, Cornwall	Mackie (1925)	Pegmatite	Granite	x	x		x	x		x								x					x
France, Rhone	Gonnard (1881)	Pegmatite	Cord. gneiss	x		x	x			x	x		x	x				x			x		x
Germany, Wolfshau	Websky (1885) Lacroix (1922)	Pegmatite	–	x	x		x										x						x
Madagascar	~~Quartsi~~	Quartzite	Quartzite	x																			x
Mexico, Guadalacazar	Wittich & Kratzert (1921)	Pegmatite	Granite	x	x	x			x											x			x

Locality	Reference	Host Rock	Country Rock	Quartz	Muscovite	Tourmaline	Orthoclase	Andalusite	Magnetite	Apatite	Rutile	Zircon	Sillimanite	Biotite	Kyanite	Pyrite	Corundum	Garnet	Plagioclase	Topaz	Pyrophyllite	Titanite	Others
Moravia, Vymyslice	Rosicky (1926)	Pegmatite	Granite gneiss	x			x						?										
Russia, Balkhash	Astashenko (1940)	Pegmatite	Granodiorite	x				x									x						
Ouvildy Lake	Kuznetzov (1923)	Pegmatite	Basic igneous rock	x		x												x					x
Ural	Kuznetzov (19)	Pegmatite	Akaline rock	x	x		x											x					x
Switzerland																							
Bergeller massif	Hugi & Hirichi (1925)	Pegmatite	Granite	x	x	x				x				x					x				
Ticino	Taddei (1940)	Pegmatite	Gneiss & schist	x	x	x	x																
Veltlin	Linck (1899)	Pegmatite	–	x	x	x				x				x					x				x
Tanganyika	Aubel (1931)	Pegmatite	Quartz nodules	x	x		x																x
United States																							
Arizona, Clip	Diller & Whitfield (1902) Ford (1902) Schaller (1905)	Quartz	–	x	x				x	x	x				x								
Patagonia	Jones (1928)	Quartz	–	x	x				x						x								
Quartzite	Wilson (1929)	Pegmatite	Schist	x	x			x	x		x		x		x	x					x		x
California, Picacho	Jones (1928)	Quartz	–	x	x				x													?	x
Imperial Co.	Jones (1928)	–	–	x	x										x						x		x
Riverside Co.	Jones (1928)	Quartz	–	x	x																		x
San Diego Co.	Ford (1902) Schaller (1905) Heinrich	Pegmatite	–	x	x	x				x	?	x	x			x	x			x		?	x
Colorado, Canyon City	Findlay (1907)	Pegmatite	Epidote Schist	x	x	x	x				x	x	x				x						
Nevada, Humbolt Queen County	Jones (1928) Fairbanks (1926) Peck (1926)	Quartz	Sericite Schist	x	x	x		x	x		x			x		x				x			x
Lincoln Hill	Knopf (1924)	Quartz	Sericite Schist	x	x			x				x											
Oreana	Kerr & Jenney (1935)	Pegmatite	–	x		x	x	x		x	x	x		x		x						x	x
Round Mountain	Jones (1928)	Quartz	Granite	x	x																		
New Mexico	Schaller (1916)	Quartz	–	x	x																		
New York	Schaller (1905)	Pegmatite	Mica schist	x	x	x	x	x		x		x			x		x		x				x
Washington, Skamia Co.	Ford (1902) Schaller (1905)	Pegmatite	–	x	x			x	x	x						x							x
<u>Metamorphic</u>																							
Norway, Tvedestrand	Michel-Levy & Lacroix	–	Cordierite gneiss	x	x	x			x	x	x	x	x	x					x				x
Portsoy, Aberdeen	Mackie (1925)	–	Granite gneiss	x	x																		
				40	32	17	15	12	10	12	13	8	9	8	6	6	7		6	3	3	3	

ANALYSES OF DUMORTIERITE

Locality	Reference	Sp.G.	SiO_2	Al_2O_3	Fe_2O_3	FeO	Ti_2O_3	TiO_2	B_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	MnO	Ig. Loss	Total
Argentina, Portrero	Romberg (1893)	3.255	35.01	51.49	1.04	-	0 -	1.08	2.51	0.28	0.54	0.96	3.62			3.02	99.55
Canada, Ontario	Walker (1922)	3.309	30.46	60.80	1.08	-	0.08	-	5.37	-	0.77	-	-	-	0.11	1.32	99.99
France, Beaunan	Damour (1881)	3.36	29.85	66.02	1.01	-	-	-	-	-	0.45	-	-	-	-	2.25	99.58
Madagascar, Anfoka	Lacroix (1922)	-	30.34	61.24	0.71	0.29	0.59	-	5.00	0.36	0.18	0.18	0.05	-	-	1.29	100.23
Switzerland, Veltlin	Linck (1899)	3.22	36.81	57.27	-	-	-	-	?	1.66	1.38	-	-			1.31	98.43
UNITED STATES																	
Arizona, Clip	Ford (1902)	3.319	29.86	63.56	0.23	-	-	-	5.26	-	-	-	-	-	-	1.41	100.32
	Whitfield (1899)	-	27.99	64.49	-	-	-	-	4.94	-	Tr	-	-	0.20	-	1.72	99.34
	Whitfield (1899)	-	31.52	63.66	-	-	-	-	2.62	Tr	0.52	0.37	0.11	-	-	1.34	100.14
California	Ford (1902)	3.226	30.58	61.83	0.36	-	-	-	5.93	-	-	-	-	-	-	2.14	100.84
	Schaller (1905)	-	28.68	63.31	0.23	-	1.45	-	5.37	-	-	-	-	-	-	1.53	100.56
Nevada	Peck (1926)	-	37.05	55.01	-	-	-	0.63	4.65	All others 2.66					Loss Free basis		
	Davis (1928)	2.99	40.83	47.67	0.14	-	0.65	-	3.15	0	0.13	0.22	0.76	-	-	6.56	100.11
	Davis (1928)	3.26	37.10	53.63	0.16	-	0.72	-	4.80	0	0.15	0.22	0.35	-	-	2.82	99.95
	Davis (1928)	3.23	33.24	57.42	0.18	-	0.75	-	5.40	0	0.11	0.24	0.34	-	-	2.42	100.10
New York, Harlem	Ford (1902)	3.211	31.24	61.26	0.10	-	-	-	6.14	-	-	-	-	-	-	2.09	100.83
	Riggs (1887)	-	34.82	55.30	-	-	-	-	4.07	-	0.57	1.72	1.04	-	-	2.96	100.52
	Whitfield (1899)	-	31.44	68.91	-	-	-	-	Tr	-	-	-	-	-	-	-	100.35
Washington	Schaller (1905)	-	28.51	59.75	2.48	-	-	0.95	5.54	0.68	-	-	-	-	-	2.12	100.03

UNIVERSITY OF MICHIGAN
3 9015 00326 6205

KYSELKA