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Anisotropism in Garnets

Arthur B. Merkle

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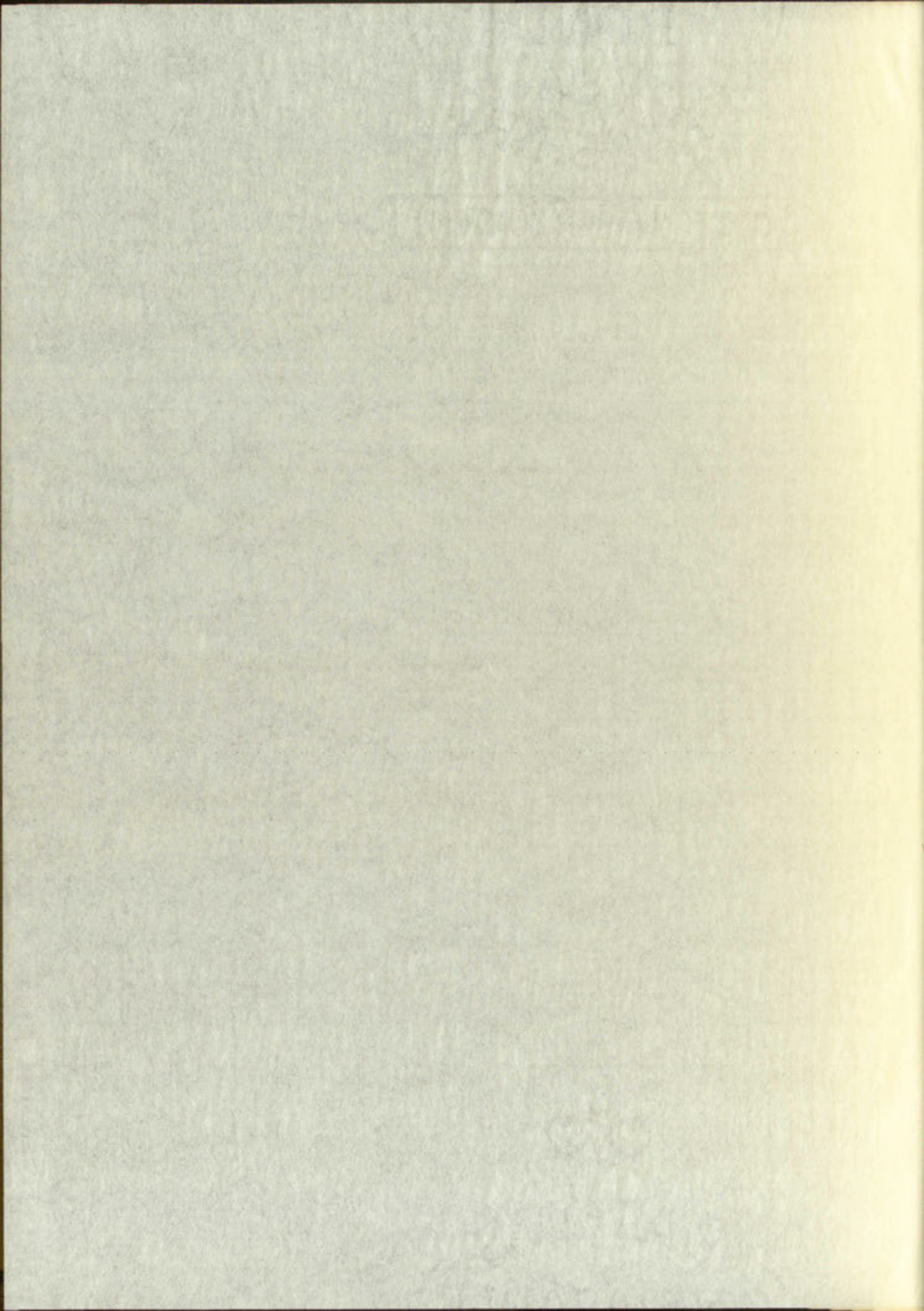
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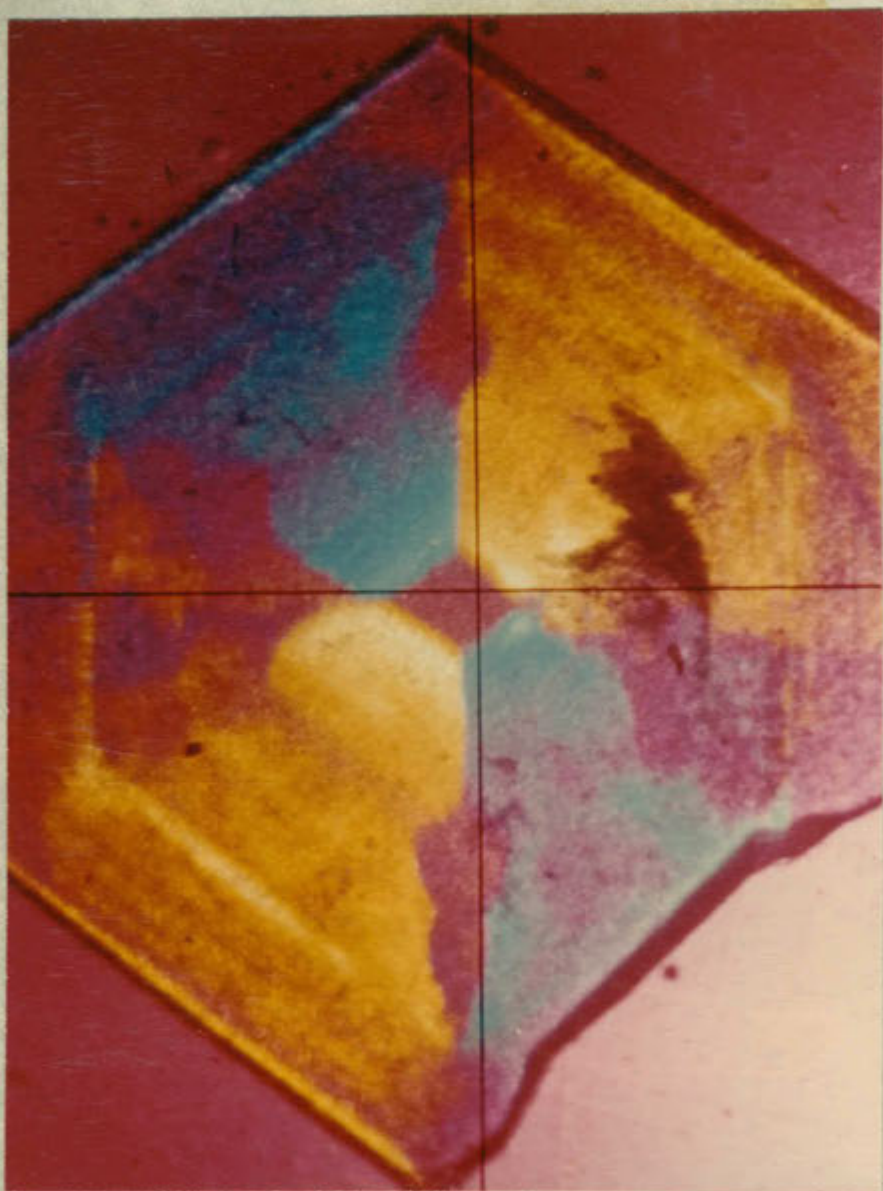
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Garnet VI. C. Anisotropic crystal, view parallel two-fold axis, before heating, X-nicols, first order red plate, 26X.

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ANISOTROPISM IN GARNETS



By

Arthur B. Merkle

A Thesis

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Geology

The University of New Mexico

1961



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ABSTRACT

Six anisotropic garnets are studied by optical, thermal, and X-ray diffraction methods in an attempt to determine the cause of anisotropism. The garnets are all ugrandites with compositions ranging from chromian grossularite to nearly pure andradite; the composition having been estimated from indices of refraction and unit cell dimensions. In all cases the birefringence is 0.004 or less. Both positive and negative uniaxial and biaxial figures are sometimes observed. Heating of the garnets at 900°C for periods of 96 to 264 hours reduced the anisotropism in five of the six garnets studied; this observation is in agreement with previously reported studies. Precession and powder X-ray diffraction photographs show no detectable change from unheated to heated samples. Precession photographs of several sectors of a single anisotropic garnet yield identical patterns with isometric $Ia\bar{3}d$ symmetry, suggesting that anisotropism is not caused by twinning. I feel the cause of anisotropism in garnets is due to a combination of strain and rate of crystal growth in the metamorphic environment. A technical garnet bibliography of over 300 papers, written from 1900 to 1960 is presented; papers on anisotropic garnets written before 1900 are also included.

ABSTRACT

Six anisotropic garnets are studied by optical, thermal, and X-ray diffraction methods to determine the cause of anisotropy. The garnets are all pyrope with compositions ranging from 100% pyrope to 100% almandine. The compositions have been estimated from indices of refraction and unit cell dimensions. In all cases the birefringence is 0.001 or less. Both positive and negative uniaxial and biaxial figures are sometimes observed. Heating of the garnets at 900°C for periods of 96 to 288 hours reduced the anisotropism in five of the six garnets studied. This observation is in agreement with results reported earlier. X-ray diffraction photographs show no detectable change in interaxial angles. X-ray diffraction photographs of several garnets show slight anisotropic garnet field (anorthite) patterns with characteristic left symmetry, suggesting that anisotropy is not caused by twinning. I feel the cause of anisotropy in garnets is due to a combination of strain and rate of crystal growth in the metamorphic environment. A detailed garnet morphology of over 500 garnets, with data from 1900 to 1960 is presented; papers on anisotropic garnets written before 1900 are also included.

INTRODUCTION

The Garnet Group

The term garnet is derived from the Latin granatus, meaning grainlike. This mineral crystallizes in the hexoctahedral class of the isometric system and forms a group of isomorphous silicates whose general formula is $R_3^{+2} R_2^{+3} (SiO_4)_3$. Winchell (1933, p. 174) has divided the garnet group into two species with the following names and compositions:

<u>Specie</u>	<u>Type</u>	<u>Composition</u>
Pyralspite	Pyrope	$Mg_3Al_2(SiO_4)_3$
	Almandite	$Fe_3Al_2(SiO_4)_3$
	Spessartite	$Mn_3Al_2(SiO_4)_3$
Ugrandite	Uvarovite	$Ca_3Cr_2(SiO_4)_3$
	Grossularite	$Ca_3Al_2(SiO_4)_3$
	Andradite	$Ca_3Fe_2(SiO_4)_3$

According to Dana (1932, p. 591-592) the two common habits of garnet are dodecahedral and trapezohedral. Their hardness ranges from 6.5 to 7.5; the specific gravity varies from 3.15 to 4.3.

Menzer (1928, p. 300-304) described the structure of garnet as follows: space group Ia3d; eight formulas to the unit cell.

TABLE I

The Garnet Group

The garnet group is defined here as the $Ca_{2-3}Mg_{1-2}Al_2Si_2O_{12}$ meaning crystalline. This mineral crystallizes in the hexoctahedral class of the rhombohedral system and forms a group of isomorphous silicates whose general formula is $R_2^{+2}R_2^{+3}(SiO_4)_2$. The R_2^{+2} and R_2^{+3} are divided into two species with the following names and compositions:

Species	Formula	Composition
Almandine	$Al_2Mg_2Si_2O_{12}$	Almandine
Pyrope	$CaMg_2Si_2O_{12}$	Pyrope
Uvularite	$CaMg_2Al_2Si_2O_{12}$	Uvularite
Spessartine	$CaMg_2Al_2Si_2O_{12}$	Spessartine
Andradite	$Ca_3Mg_3Si_3O_{12}$	Andradite

According to Dana (1937, p. 521-522) the garnet habits of garnet are octahedral and rhombohedral. The hardness ranges from 6.5 to 7.5; the specific gravity varies from 3.5 to 4.5. Jensen (1937, p. 380-381) mentioned the following of garnet as follows: "The garnet group is defined to the unit cell."

Lattice Parameters

<u>Ion</u>	<u>Position</u>	<u>Parameters</u>
R ⁺³	16	(0,0,0)
Si ⁺⁴	24	(1/4, 3/8, 0)
R ⁺²	24	(1/4, 1/8, 0)
O ⁻²	96	(x,y,z)

In aluminum garnets the oxygen parameters are, $x=0.04 \pm .01$, $y=0.055 \pm .01$, and $z=0.64 \pm .015$; in calcium-iron and calcium-chrome garnets the oxygen parameters are, $x=0.035 \pm .01$, $y=0.04 \pm .01$ and $z=0.655 \pm .015$.

Dana (1932, p. 591) describes the structure of garnet as follows, SiO₄ tetrahedra are independent of each other; R⁺³ atoms lie in the center of a group of six oxygen atoms, and R⁺² atoms in the center of a group of eight oxygen atoms.

Substitution in garnets may occur freely within each species, but is limited to about 20% between the two species.

Garnets are normally isotropic. Some, however, show optical anisotropism. Winchell (1933, p. 180) states anisotropism is usually restricted to ugrandite, but is sometimes seen in spessartite.

Lattice Parameters

Ion	Position	Parameters
R ²⁺	1a	(0,0,0)
Si ⁴⁺	2b	(0, 1/2, 1/2)
R ³⁺	2c	(1/2, 1/2, 0)
O ²⁻	9d	(x, y, z)

In aluminum garnets the oxygen parameters are, $x=0.01$, $y=0.02$, and $z=0.01$; in calcium-iron and calcium-chrome garnets the oxygen parameters are, $x=0.02$, $y=0.01$, and $z=0.01$.

Van (1952, p. 501) describes the structure of garnet as follows, SiO₄ tetrahedra are independent of each other; R²⁺ atoms lie in the center of a group of six oxygen atoms, and R³⁺ atoms in the center of a group of eight oxygen atoms.

Substitution in garnets may occur freely within each species, but is limited to about 20% between the two species.

Garnets are normally isotropic. Some, however, show optical anisotropy. Winchell (1952, p. 180) states anisotropy is usually restricted to ugrandite, but is sometimes seen in spessartite.

Purpose, Scope, and Method

The three main purposes of this thesis are:

1. The description of anisotropism in garnets.
2. A study of the effect of heat on anisotropic garnets.
3. A study of the cause of anisotropism in garnets.

Experimental work of three types, optical, thermal, and X-ray, was done between November 1959 and March 1961.

Anisotropic garnets from California, Canada, New Mexico, and Tasmania were studied. A literature search was made, and a selected bibliography of all technical garnet papers from 1900 to 1960 prepared; papers dated prior to 1900 were included only if they pertained directly to anisotropism in garnets.

Acknowledgments

The author wishes to express appreciation to Dr. Abraham Rosenzweig, of the University of New Mexico Geology Department, for suggesting the problem and guiding the research. The author wishes to thank Dr. V. C. Kelley, Dr. W. E. Elston, Mr. W. W. Pinch, and Mr. W. R. Seager for supplying garnet samples used in this study. The author also wishes to thank Dr. J. P. Fitzsimmons for translating Russian literature. Special thanks to the reference staff of the University of New Mexico library

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for obtaining numerous references via inter-library loan. I wish to express my appreciation for the research assistantship under a Sandia Corporation contract which provided me with financial support during my graduate study. The precession camera used in the X-ray studies was obtained through a Research Corporation grant.

Previous Work

Since anisotropism was first observed in garnets, many attempts have been made to define its cause. In these attempts two methods of study have been used, optical and X-ray diffraction. Previous studies indicate two main causes of garnet anisotropism:

1. Twinning of elements with a lower symmetry.
2. Stress and pressure caused by isomorphous substitution during formation of the garnet.

The following statements are those of the authors; their terminology is used in all cases.

The first optical study of anisotropic garnets was carried out by Mallard in 1876. His studies led him to believe anisotropism was caused by twinning of individuals with a lower symmetry.

Klein (1898) studied various garnets from Vilui, Siberia and decided they were composed of twinned monoclinic or triclinic individuals showing vicinal forms. He also found anisotropism was not dependent on composi-

for obtaining various responses via their sensory system.
I wish to express my appreciation for the assistance
provided me with financial support during the course of this
study. The present research was supported by the National
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References

1. Adams, J. P. (1965). The effects of sensory deprivation on
the development of the visual system. *Journal of Experimental Psychology*,
71, 1-10.

2. Hubel, D. H., & Wiesel, T. N. (1962). The receptive fields
of simple cells in the monkey striate cortex. *Journal of Neurophysiology*,
25, 996-1005.

3. Hubel, D. H., & Wiesel, T. N. (1968). The orientation
selectivity of cells in the monkey striate cortex. *Journal of Neurophysiology*,
31, 334-355.

4. Hubel, D. H., & Wiesel, T. N. (1977). The receptive
fields of simple cells in the monkey striate cortex. *Journal of Neurophysiology*,
41, 754-767.

5. Hubel, D. H., & Wiesel, T. N. (1978). The orientation
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41, 768-781.

The first optical study of the visual system was
conducted by Helmholtz in 1857. His studies led him to
believe that the visual system was composed of a series of
stages, each of which performed a specific function. This
view was supported by the work of other researchers, such as
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tion. Klein wrote further of a connection between "optical structure" and external form. Anisotropism is also affected by pressure differences and the relative size of atoms in the structure. Anisotropic garnet crystals are built up by overgrowths of twinned monoclinic or triclinic individuals in various orientations upon a small single crystal. This twinning produces an orthorhombic symmetry which is secondary and caused by either tensions due to isomorphous substitution or twin laminae. The external symmetries of the garnets vary with crystal growth and need not all be the same.

Kirganov (1941) said anisotropism in garnets is caused by the presence of intergrown twin laminae.

Corin (1943) stated anisotropic garnets are caused by leucite-type polysynthetic twinning.

Lehmann (1888) said anisotropic garnets are a "mechanical mixture" of two or more chemically different garnet types. The different thermal coefficients of expansion of these types cause stress within the crystal, that varies with crystallographic direction. Homogeneous crystals have similar coefficients of expansion in all directions, whereas in mixed crystals the coefficients of expansion vary with the crystallographic directions. This could be the cause of anisotropism in garnets.

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Brauns (1891) stated that optical observations show anisotropism in garnets caused by an isomorphous substitution of two or more chemically different garnet types. This substitution creates internal stress and tension causing anisotropism. The amount of anisotropism is varied by a variation of stress with crystallographic direction. This is analagous to phenomena seen in sylvite and flourite.

Rinne (1925) was the first person to study anisotropic garnets by the use of X-ray diffraction (the Laue and powder methods). His experiments showed anisotropic garnets are caused by variations in the electron paths due to a slight shifting of the atomic nucleus. This shifting was probably caused by stress and pressure due to twinning and isomorphous substitution within the crystal.

Starkov (1950) described three distinct types of optical anomalies in garnets:

1. Crystals consisting of concentric anisotropic zones, forming true hexagons with sectoral extinction (Starkov fig. 2, p. 284). More commonly the hexagonal figure is not displayed due to the fact that the crystals were cut in different orientations. The number of the birefringent zones and their

thickness are variable. All bands extinguish parallel to the 110 trace of the crystal. This extinction appears in six regular sectors corresponding to the faces of a hexagon.

2. Crystals are characterized by a system of bands in each sector, generally trending at an angle near 60° to the trace of the (110) face for the given sector and parallel to the trace of the (110) face in one of the adjoining sectors. These bands are uniform in width and situated in a triangle between the central core and the peripheral part of the crystal (Starkov fig. 4, p. 285).
3. Crystals with birefringent bands arranged perpendicular to the trace of the (110) face. These bands do not have sharp boundaries and are generally found near the edge of the crystal. In cross section, these bands form a "rectangular lattice with the concentric layers." /

Starkov felt these features were caused by isomorphous replacement of Fe^{+2} by Ca^{+2} . The difference in the ionic

/ The expression in quotation is a direct translation from the Russian. Starkov provides no illustration of this garnet type, and consequently the description of this anisotropism remains ambiguous.

thickness and volume. The
 crystallinity is the ratio of the
 crystalline volume to the total
 volume of a sample.

2. Crystals are characterized by a degree of order
 in each section, generally consisting of an
 angle near 60° to the normal of the (111)
 face for the given section and parallel to
 the normal of the (111) face in one of the
 adjoining sections. These faces are unique
 in which and situated in a regular pattern
 the crystal size and the crystal part of
 the crystal structure (Fig. 1, 2, 3).

3. Crystals with different faces arranged
 perpendicular to the axes of the (111) face.
 These three faces have sharp boundaries and
 are generally found near the edge of the
 crystal. In these sections, these faces have
 a characteristic shape with the corners
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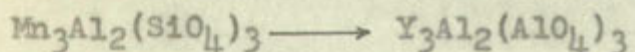
radii of these two ions will cause a distortion "of the electron shell surrounding ions of andradite" thus creating internal stress. Impurities in the crystallizing solution were systematically arranged in layered overgrowths. These also could cause anisotropism.

Merwin (in Wright, C. W., 1915, p. 108) performed the first thermal experiments with anisotropic garnets. He observed that they became isotropic when heated to 800° for a few hours.

Soloviev and Nikogosyan (1938) found that anisotropic garnets lost their birefringence within the temperature range 750°-850°C and a heating time of 72-168 hours.

Kozu (1940) observed that anisotropic zones in garnets decreased in intensity with increased temperature.

Yoder and Keith (1951) working with artificially prepared garnets, found a complete solid solution between spessartite and yttrogarnet



Yttrogarnet has been shown to be isometric. However, at 1970°C±50° a solid state transition occurs between yttrogarnet and yttroalumite. X-ray studies by Donnay show yttroalumite to be tetragonal with a primitive lattice.

Keith and Roy (1954) presented further evidence substantiating the experiments of Yoder and Keith.

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Yoder and Keith (1951) worked with synthetic
prepared garnets, found a complete solid solution between
spinel and pyrope.



Pyrope has been shown to be isotropic. However, at
1070°C a solid state transition occurs between

pyrope and pyrope. X-ray studies by Berman
show pyrope to be tetragonal with a primitive
lattice.

Keith and Roy (1951) presented further evidence sup-
porting the experiments of Yoder and Keith.

EXPERIMENTAL WORK

Procedures

The purpose of the experimental work of this thesis is three-fold:

1. Identification of the garnet type.
2. Relation of the crystallographic properties to anisotropism.
3. Relation of the thermal behavior to anisotropism.

The garnets studied in this thesis were unoriented garnet masses (garnets I, II, and III), small single crystals (garnets IV and V), and orientated thin sections of large single crystals (garnet VI).

All garnets were heated in an electric furnace, under oxidizing conditions and atmospheric pressure, to temperatures of 900°C for intervals ranging from 96 to 264 hours. The results of this work are presented in table 2.

The index of refraction of the garnets was determined by the immersion method on crushed fragments. Optic signs and figures were obtained with the polarizing microscope. The $2V$ was approximated by the curvature of the isogyres. In each garnet studied the birefringence is approximated as 0.004 or less. The universal stage was not used in any of the optical observations.

X-ray powder photographs were taken of garnets I, II, III, and IV; Buerger precession photographs were taken of

EXPERIMENTAL

Procedure

The purpose of the present study is to determine

is three-fold:

1. Identification of the garnet type.
2. Relation of the crystallographic properties

to microstructure.

3. Relation of the chemical behavior to microstructure.

The garnets studied in this thesis were prepared

garnet (garnets I, II, and III), and also garnet

(garnets IV and V), and synthesized in the laboratory of

single crystals (garnet VI).

All garnets were heated in an electric furnace, under

oxidizing conditions and atmosphere of oxygen. In garnets

series of 900°C for intervals ranging from 10 to 100 hours.

The results of this work are presented in Table I.

The index of refraction of the garnets was determined

by the immersion method in various liquids. The refractive

and density were measured with the polarizing microscope. The

IV was approximated by the difference of the densities. The

each garnet studied the optical density is approximated as

0.001 or less. The optical density was not used as a

of the optical characteristics.

X-ray powder diffraction measurements of garnets I, II, III,

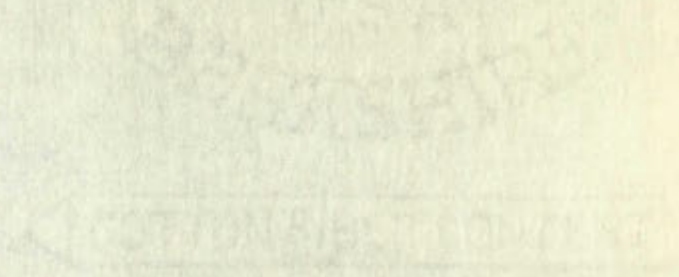
III, and IV showed garnet structure. The X-ray diffraction

garnets IV, V, and VI. Filtered molybdenum and copper radiations were used. The unit cell dimensions and the symmetry of these garnets were determined from the reflections present on these photographs. The unique space group $Ia\bar{3}d$ was selected because the systematic extinctions of this group impose conditions that are fulfilled by the garnets studied. That is, reflections of the type hkl are present only if $h+k+l$ is even; hhl reflections are present only when l is even; furthermore, for hhl , $2h+l$ is a multiple of four, and $hk0$ reflections are present only when both h and k are even.

The crystals of garnet VI were large enough to isolate various portions of the crystal in the X-ray beam, permitting an examination of the orientation of various crystal segments in order to detect twinning. In general, the procedure is as follows: the crystal is centered in the X-ray beam and lined up on a symmetry axis. A precession photograph is then taken. The crystal is then shifted, so the X-ray beam strikes the outer edge of a portion of the crystal. Another precession photograph is taken. This procedure is repeated at regular intervals around the crystal's edge. If detectable twinning is present it will be seen as a change in the orientation of the diffraction pattern. No detectable twinning was observed in garnet VI.

garnets IV, V, and VI. The only cell boundaries and the
radiation were noted. The cell boundaries and the
symmetry of these garnets was determined from the reflex-
ions present on these crystal faces. The origin of the
group IABD was determined because the systematic extinction
of this group implies conditions that are fulfilled. The
garnets studied. That is, reflections of the type hkl are
present only if h is even and k is odd. The only
only when l is even. Therefore, the cell is a
multiple of four, and the relationship is preserved
when both h and k are even.

The crystals of garnet VI were large enough to make
various portions of the crystal in the 1- μ beam, making
it an examination of the orientation of these crystals
appears in order to detect twinning. In general, the
procedure is as follows: the crystal is mounted in the
X-ray beam and tilted up to a steep angle. A photograph
photograph is then taken. The crystal is then tilted and
the X-ray beam strikes the other side of a portion of the
crystal. Another photograph is then taken. This
procedure is repeated at regular intervals around the
crystal edge. It is usually possible to measure at least
be seen as a change in the order of the diffraction
pattern. No acceptable patterns were observed in garnet VI.



Garnets seen in plates I. B, I. D, and II. C are not the same areas seen in plates I. A, I. C, and II. B; these areas are of adjacent thin sections in the rock sample.

Composition of the Garnets

The composition of the garnets studied has been determined from triangular diagrams plotted by Sriramadas (1957, p. 294-298). These diagrams relate unit cell dimension and index of refraction to composition. The compositions of these garnets are shown in table 1.

Anisotropism of the Garnets

Garnet I.

Location:

One and a quarter miles north of Darwin, near the Thompson Mine, Darwin mining district, Inyo County, California.

Megascopic description:

The garnet occurs as a yellowish-green mass in a tactite.

Optical properties:

The thin-section color of the garnets is light yellowish-gray. The masses are made up of zoned dodecahedra. Numerous inclusions are present. The crystals are composed of anisotropic and isotropic zones (Pl. I. A). Wavy

Table 1.--Garnet composition

Garnet number Location	Unit cell dimension	Index of refraction	Composition (after Sriramadas, 1957)
I Darwin, California	11.9Å ^o	1.830±.005	53% Andradite 34% Grossularite 16% Others
II Silverhill Mine, New Mexico	12.0Å ^o	1.865±.005	83% Andradite 12% Grossularite 5% Others
III Unknown	12.0Å ^o	1.870±.005	85% Andradite 7% Grossularite 8% Others
IV Iron King Mine, New Mexico	12.0Å ^o	1.880±.005	90% Andradite 2% Grossularite 8% Others
V Tasmania	12.0Å ^o	1.875±.005	88% Andradite 5% Grossularite 7% Others
VI Orford, Canada	11.8Å ^o	1.730±.005	90% Grossularite 10% Others (probably uvarovite in part)

Table 1. - (continued)

Location	Number of sites	Year	Number of sites
I Larvis, California	13,700	1,850,000	537
XI Silver Hill, Miss., Mex. Mexico	15,500	2,500,000	114
XII Unknown	15,000	1,800,000	102
IV Iron Mine, Miss. New Mexico	11,500	1,800,000	97
V Tombria	11,000	1,800,000	82
VI Orford, Canada	11,000	1,700,000	94

extinction is seen in some crystals. Faint uniaxial and biaxial figures are seen. The optic sign varies from (+) to (-). The optical anomalies resemble Starkov's type 1.

Garnet II.

Location:

Southeast of the Silver Hill mine, NW $\frac{1}{2}$ sec. 3, T. 25 S., R. 21 W., Hidalgo County, New Mexico.

Megascopic description:

The rock is a solid mass of green, brown, and red garnet. Some euhedral crystals are present. These crystals show zoning which can be distinguished by color differences.

Optical properties:

The thin-section color is a yellowish-green. The garnets are massive, anhedral, and cloudy with numerous inclusions. Wavy extinction is present. The optic sign and optic figure are not determinable. Anisotropism is present in the entire mass (Pl. I. C).

Garnet III.

Location:

Unknown.

Megascopic description:

Garnet crystals occur in a calcite mass with chalcopyrite, malachite, and magnetite. The garnet is green-brown and zoned.

extinction is seen in some crystals, and biaxial figures are seen. The optic sign varies from (-) to (+). The optical formula is $10V:10V:10V$ type I.

Garnet II.

Location:

Southeast of the Silver Hill mine, T. 22 S., R. 21 W., Hidalgo County, New Mexico. Mesoscopic description:

The rock is a solid mass of green, brown, and red garnet. Some euhedral crystals are present. The crystals show zoning which can be distinguished by color differences.

Optical properties:

The thin-section color is a yellowish-green. The garnets are massive, anhedral, and show sharp boundaries. Wavy extinction is present. The optic sign and optic figure cannot be determined. Garnet is present in the entire mass (Pl. I, C).

Garnet III.

Location:

Unknown.

Mesoscopic description:

Garnet crystals occur in a calcite matrix with quartz, epidote, malachite, and magnetite. The garnet is green, brown and zoned.

Optical properties:

Thin-section color of the garnets is greenish-brown. The garnet is massive with some euhedral crystals. Zoning present in the garnets parallels dodecahedral faces (Pl. II. A). Some wavy extinction is observed. These garnets are mostly isotropic; anisotropism is seen in zones of varied widths, which outline dodecahedral faces (Pl. II. B). The anisotropism resembles Starkov's type 1; uniaxial and biaxial figures are observed.

Garnet IV.

Location:

Iron King mine, Jarilla Mountains, sec. 34, T. 21 S., R. 8 E., Otero County, New Mexico.

Megascopic description:

Euhedral, yellowish-brown garnets occur in a granular marble with specular hematite. These garnets are zoned and are both dodecahedral and trapezohedral in habit.

Optical properties:

The crystal studied is a yellowish-brown dodecahedron 0.5 mm in size. The crystal is anisotropic and contains some inclusions. Anisotropism varies with crystallographic direction. Due to the small size of the crystal, optic figures and signs are not observed.

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Optical properties

This section covers the optical properties of the material. The crystal is biaxial with the optical axes in the plane of the crystal. The optical axes are nearly perpendicular to each other. The optical axes are nearly perpendicular to each other. The optical axes are nearly perpendicular to each other.

Figure IV

Location

From the above, the following conclusions can be drawn. The crystal is biaxial with the optical axes in the plane of the crystal. The optical axes are nearly perpendicular to each other.

Microscopic observations

Microscopic observations of the crystal show a characteristic pattern. The crystal is biaxial with the optical axes in the plane of the crystal. The optical axes are nearly perpendicular to each other.

Optical properties

The crystal shows a characteristic pattern. The crystal is biaxial with the optical axes in the plane of the crystal. The optical axes are nearly perpendicular to each other. The crystal shows a characteristic pattern. The crystal is biaxial with the optical axes in the plane of the crystal. The optical axes are nearly perpendicular to each other.

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Garnet V.

Location:

Tasmania (precise locality and mode of occurrence not known).

Megascopic description:

The crystals are greenish dodecahedrons. Their size ranges from 0.5 mm to 1.0 mm; the crystals are intergrown with some inclusions.

Optical properties:

The crystal studied is a greenish dodecahedron 0.7 mm in size. Anisotropism seen in the crystal varies with crystallographic direction. Because of the crystal size, optic figures and signs are not observed.

Garnet VI.

Location:

Orford, Sherbrooke County, Quebec, Canada.

Megascopic description:

Emerald green garnet crystals occur in a soft white talc.

Optical properties:

Three dodecahedral garnet crystals were studied. Their color in thin section is greenish; their size is about 3.5 mm. Three orientated thin sections were made.

Figure 1.

Location: ...
The crystal is located in the ...

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A. perpendicular to a three-fold axis; B. perpendicular to a four-fold axis; and C. perpendicular to a two-fold axis.

Crystal A. Anisotropism in this crystal is a combination of Starkov's type 1, and type 3 (Pl. III. A and B). Anisotropic zone boundaries are not sharp. The crystal shows biaxial negative optic figures. A $2V$ of 60° is estimated from the curvature of the isogyres.

Crystal B. This crystal is mainly isotropic with some small anisotropic bands (Pl. III. C and D). The anisotropism is similar to Starkov's type 1. Faint traces of similarly orientated biaxial (-) figures are observed.

Crystal C. Thin isotropic sections are observed. The central part of the crystal is biaxial (-); $2V$ is about 60° . Six triangular areas are arranged about the central portion. These sectors are uniaxial; their optic signs alternate (+) and (-). This crystal is shown on Plate IV. The anisotropism is a combination of Starkov's type 1 and type 3.

A. perpendicular to a three-axis axis; and B. perpendicular to a four-axis axis.

Crystal A. The orientation in this crystal is a combination of the two axes (95% III. A and III. B) and the boundaries are not clear. The axial distance of the crystal is 60° is estimated from the measurements of the frequency.

Crystal B. This crystal is similar to crystal A with some small surface defects. The orientation is similar to crystal type I. The axial distance of the crystal is estimated to be 60° from the measurements.

Crystal C. This crystal is similar to crystal B. The central part of the crystal is estimated to be about 60°. The axial distance is estimated to be about the central part. The axial distance is estimated to be about the central part. This crystal is similar to crystal A. The axial distance is estimated to be about the central part. The axial distance is estimated to be about the central part.

Symmetry of Anisotropic Garnets

Based on procedures stated in the beginning of the experimental work section, the symmetry of the six anisotropic garnets is found to be $Ia\bar{3}d$. There are no observable deviations from this. No detectable twinning is seen in garnets IV, V, and VI. X-ray patterns of garnets IV, V, and VI are in no way altered with heat.

Thermal Treatment and Results

The six garnets studied have been heated in an electric furnace, under oxidizing conditions and atmospheric pressure, to a temperature of 900°C for ~~held for~~ intervals ranging from 96 to 264 hours. Optical and X-ray properties remain constant after heating. Only the amount of anisotropism in the garnets is changed. Where possible to observe, as in garnet VI, the optics of the anisotropic zones are in no way altered with heat. X-ray patterns are also unaltered. Results of this treatment are shown in table 2.

CONCLUSIONS

Thermal treatment of five of the six garnet samples show either a reduction in or a destruction of the anisotropism of the garnets. In these five cases the samples were heated to 900°C for ~~intervals~~ intervals ranging from 96 to 264 hours. The sixth sample (garnet I)

Summary of experimental results
Based on procedures outlined in the preceding section
experimental work was carried out in the following manner
anisotropic behavior is found to be large. This is
observable deviations from the isotropic behavior
is seen in graphs IV, V, and VI. The anisotropic
graphs IV, V, and VI are in many respects similar to

Graphs I and II and III
The six graphs which have been plotted in the
electrical curves, under existing conditions, for
graphic pressure, for a constant temperature, and for
intervals ranging from 10 to 100 hours. The anisotropic
properties remain constant after a certain time interval
of anisotropy in the curves in Figure 1. It is
possible to observe, as in Figure 1, the anisotropic
anisotropic nature and to see a very slight anisotropic
patterns are also indicated. Details of this anisotropic
are shown in Table I.

CONCLUSIONS

The experimental results of the present work
show that a reduction in the anisotropy of the
anisotropy of the curves. In these curves the
angles were varied at 1000 hour intervals
ranging from 10 to 100 hours. The anisotropic curves

Table 2.--Results of thermal treatment of the garnets

Garnet number	Temperature attained	Hours held	Observed results
I. Darwin, California	900°C	226	Thin section color changed from light-yellow-gray to yellow-brown. Heat had no observable effect on anisotropism (Pl. I. B).
II. Silver Hill mine, New Mexico	900°C	226	Thin section color changed from yellowish-green to brown-yellow. Faint traces of anisotropism remain in the mass (Pl. I. D). Heat reduced the amount of anisotropism.
III. Unknown	900°C	264	Thin section color changed from greenish-brown to brown-yellow. Thin anisotropic zones remain (Pl. II. C). Amount of anisotropism was reduced with heat.
IV. Iron King mine, New Mexico	900°C	168	Thin section color changed from yellowish-brown to red-brown. The amount of anisotropism was greatly reduced.
V. Tasmania	900°C	96	Thin section color changed from greenish to yellowish-brown. Heating reduced the anisotropism present. However, it did not produce a completely isotropic crystal.
VI. Orford, Canada	900°C	168	Thin section color changed from greenish to brown-green. Zones remaining anisotropic became yellow-green. Anisotropism is reduced in amount in each crystal (Pls. III and IV).

was heated to 300°C. The change in the anisotropic nature of the crystals (class I, II, III) was observed generally with all previously prepared work.

Under photomicroscopy the crystals show a general tendency to elongate along the x-axis (c-axis) and the y-axis (b-axis). The elongation is observed in the crystals. These facts show anisotropy.

It is observed that in crystals of class I, II, III the internal structure of the crystals.

According to the nature of the crystals, solid isotropically prepared with respect to the properties of an anisotropic crystal is observed under certain conditions.

The crystals are prepared by the method of the present time. The crystals are prepared by the method of the present time.

The crystals are prepared by the method of the present time. The crystals are prepared by the method of the present time.

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destroy the anisotropic effect is probably in some way proportional to the amount of strain that the garnet has undergone during its formation.

With further study this could probably be developed into a tool to define the temperature and pressure of formation of a metamorphic deposit containing anisotropic garnets.

This "strain" hypothesis does not take into account the sharp boundaries and distinct crystallographically orientated zones of anisotropism in the garnets. A possible but unproven reason for these could be the rate of growth of the crystal. The faster the growth the more pronounced the anisotropic effect. These anisotropic zones are usually parallel to the outer faces of the crystal and would represent growth surfaces.

The anisotropic effect seen in garnets could be due to a combination of strain and growth rate of the crystal.

The absence of detectable twinning does not rule out the possibility that twinning is the cause of anisotropism in garnets. One needs to use other and better methods for determining the presence of twinning in garnets.

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The anisotropic effect seen in garnets could be due to a combination of strain and growth rate of the crystal. The absence of identical twinning does not rule out the possibility that twinning is the cause of anisotropy in garnets. One needs to use other and better methods for determining the presence of twinning in garnets.



A. Garnet I: Anisotropic crystals, before heating, X-nicols, 80X



B. Garnet I: Anisotropic crystals, after heating for 226 hours, X-nicols, 80X



C. Garnet II: Anisotropic mass, before heating, X-nicols, 26X



D. Garnet II: Anisotropic mass, after heating for 226 hours, X-nicols, 26X



A. Garnet III: Anisotropic crystals, before heating, plane polarized light, 26X



B. Garnet III: Anisotropic crystals, before heating, X-nicols, 26X

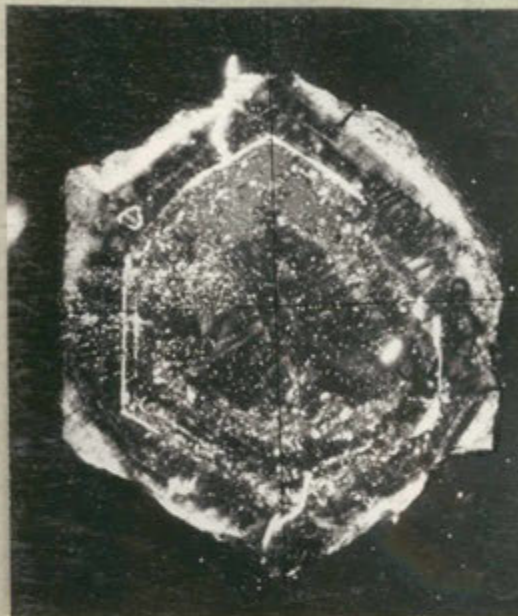


C. Garnet III: Anisotropic crystals, after heating for 264 hours, X-nicols, 26X

PLATE III



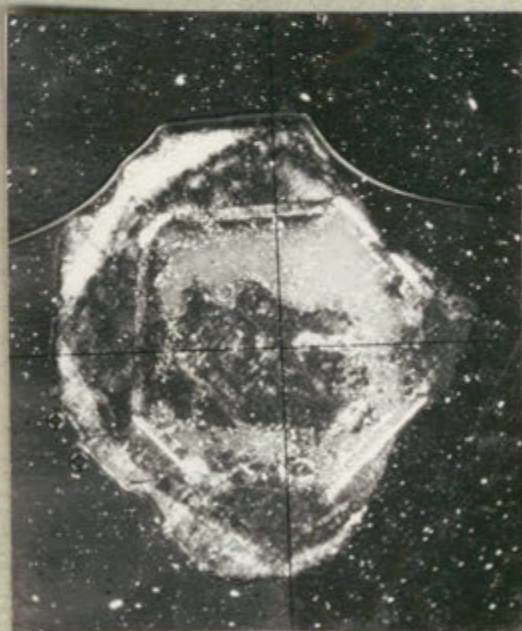
A. Garnet VI.A: Anisotropic crystal, view parallel three-fold axis, before heating, X-nicols, 26X



B. Garnet VI.A: Anisotropic crystal, view parallel three-fold axis, after heating for 168 hours, X-nicols, 28X

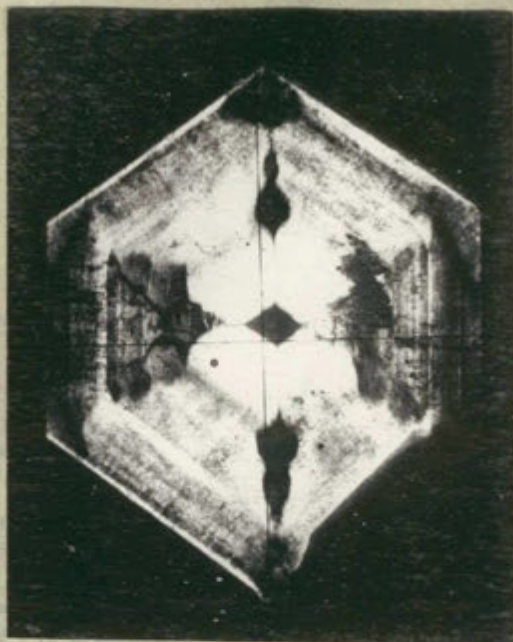


C. Garnet VI.B: Anisotropic crystal, view parallel four-fold axis, before heating, X-nicols, 26X



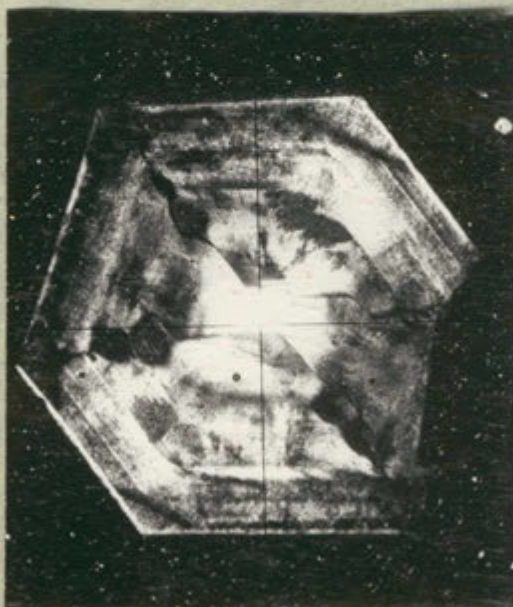
D. Garnet VI.B: Anisotropic crystal, view parallel four-fold axis, after heating for 168 hours, X-nicols, 28X





A. Garnet VI.C: Anisotropic crystal, view parallel two-fold axis, before heating, X-nicols, 26X

B. Garnet VI.C: Anisotropic crystal, view parallel two-fold axis, after heating for 1 1/4 hours, X-nicols, 28X



C. Garnet VI.C: Anisotropic crystal, view parallel two-fold axis, rotated 45° from A., before heating, X-nicols, 26X

D. Garnet VI.C: Anisotropic crystal, view parallel two-fold axis, rotated 45° from A., after heating for 1 1/4 hours, X-nicols, 28X

SELECTED BIBLIOGRAPHY

Where possible this bibliography follows the form set forth in Suggestions to Authors of the reports of the United States Geological Survey. Otherwise articles are given as found in the secondary references. The bibliography was compiled from the following sources:

1. Bibliography and Index of Geology Exclusive of North America.
2. Bibliography of North American Geology.
3. Chemical Abstracts.
4. Geologic Literature on North America.
5. Poggendorff's Biographisch-Literarisches Handwörterbuch.
6. Royal Society Catalogue of Scientific Papers.

Abrahams, S. C., and Geller, S. C., 1958, Refinement of the structure of a grossularite garnet: *Acta. Cryst.* v. 11, p. 437-441.

Agar, W. M., and Krieger, J. C., 1932, Garnet rocks near west Redding, Connecticut: *Am. Jour. Sci.*, v. 29, p. 68-80.

Alderman, A. R., 1935, Almandine from Botallack, Cornwall: *Mineralog. Mag.*, v. 24, p. 42-48.

Alessi, A. J., 1938, Chloride garnets of Michigan: *Mineralogist*, v. 6, p. 9-10.

Amaral, S. E., 1949, Nota sobre uma granada de Ouixadá, Ceara: *Mineração e Metal.*, v. 14, p. 78-79.

Andreatta, Cito, 1938, Giacimenti di granato almandine ai contatti del massiccio intrusivo di Cima d'Asta e loro paragenesi: *Studi Trentini Sci. Nat.*, v. 19, p. 105-130 (in Italian).

- Angel, Franz, and Schaidler, Ferdinand, 1950, Granat und Omphazit aus dem Eklogit des Gertrusk: *Carinthia* II, Jg. 139-140, p. 33-36 (in German).
- Asano, Goro, 1950, Garnets in banded iron areas, from Manchuria: *Jap. Assoc. Mineralogists*, v. 34, p. 179-187 (in Japanese).
- Asano, Goro, and Okada, S. C., 1940, Almandite from the Kung-Chang-Ling iron mine: *Manchukuo Geol. Inst.*, no. 98, p. 51-56 (in Japanese).
- Badalov, S. T., 1951, Vanadium-containing tourmaline and garnet: *Mem. Soc. Russe. Mineral.*, v. 80, p. 212-213 (in Russian).
- Bain, G. W., 1923, Almandite and its significance in the contact zones of the Grenville limestone: *Jour. Geology*, v. 31, p. 650-658.
- Balk, Robert, 1944, Comments on some eastern Adirondack (New York) problems: *Jour. Geology*, v. 52, no. 5, p. 289-318.
- Belkov, I. V., 1949, Srastanie granata s muskovitom: *Doklady Akad. Nauk. SSSR*, v. 64, no. 2, p. 241-243, (in Russian).
- Benedicks, Carl, 1907, Yttrium-bearing manganese garnet: *Bull. Geol. Inst. Univ. Upsala*, v. 7, p. 271-277.
- Ben-Saude, Alfredo, 1894, Beitrage zu einer Theorie der optischen Anomalien der regularen Kristalle: *Lisbon* (in German).
- Bertaut, Felix, and Forrat, Francis, 1957, Garnet parameters: *Acad. Sci. (Paris) Comptes rendus*, v. 244, p. 96-99 (in French).
- Betekhtin, A. G., 1946, On chrome garnets from the Nizhne-Tagilsk dunite Massif: *D. S. Beluandin Jubilee Vol. Acad. Sci. SSSR*, p. 68-73 (in Russian).
- Bianchi, A. P., 1923, Interesting crystals of andradite in the serpentine of the Passo della Rossa: *Atti. Acad. Lincei*, v. 32, p. 504-508.
- Billiet, V. P., and Vanderdriessche, A. D., 1937, Grenats de La région de Bastogne-Libramont: *Soc. Belge. Geol.*, v. 47, p. 222-224 (in French).

Angel, Franz, and Scharf, Ferdinand, 1950, *Geologie und
Gesteine aus dem Kibitz der Gegend: Gesteine II,
p. 139-140, p. 13-36 (in German).*

Amano, Goro, 1950, *Granite in contact with gneiss, from the
Kang-Chang-ling, Japan. Mineralogist, v. 25, p. 179-
187 (in Japanese).*

Amano, Goro, and Ueda, S. G., 1950, *Aluminates from the
Kang-Chang-ling from near Manchuria Geol. Inst.,
no. 98, p. 51-56 (in Japanese).*

Babalov, S. T., 1951, *Vanadium-containing tourmaline and
garnet. Mem. Soc. Russ. Mineral., v. 60, p. 215-
217 (in Russian).*

Bain, G. W., 1951, *Aluminates and the significance in the
contact zones of the Grenville Isthmus: Jour.
Geology, v. 51, p. 680-688.*

Balk, Robert, 1944, *Comments on some earlier Aluminates
(New York) problems: Jour. Geology, v. 52, no. 2,
p. 289-318.*

Belov, I. V., 1949, *Granite crystals a microcrystals
Doklady Akad. Nauk. SSSR, v. 61, no. 2, p. 211-213,
(in Russian).*

Benedict, Carl, 1907, *X-ray-bearing minerals
Bull. Geol. Inst. Univ. Quebec, v. 1, p. 271-277.*

Bergström, Alf, 1894, *Beitrag zu einer Theorie der
optischen Anomalien der regulären Kristalle. Abhandl.
(in German).*

Bertrand, Felix, and Forster, Francis, 1951, *Garnet paragonite
Acad. Sci. (Paris) Comptes rendus, v. 232, p. 92-93
(in French).*

Bethune, A. G., 1916, *On some garnets from the Wilson-
Tasler district, Maine: U. S. Geological Survey Vol.
Acad. Sci., p. 68-75 (in Russian).*

Bianchi, A. F., 1951, *Interesting crystals of andalusite in
the serpentine of the zone della Rocca. Atti. Acad.
Lincei, v. 32, p. 201-208.*

Blivet, V. P., and Verbeek, A. D., 1931, *Grenats
de la région de Bastogne-Luxembourg: Soc. Belge. Geol.,
v. 17, p. 223-224 (in French).*

- Bobrovnik, D. P., 1950, Garnets from coal seams of the Lemberg region: Mem. Soc. Russe. Mineral., v. 80, p. 127-139 (in Russian).
- Becke, H. E., 1914, The garnet group: Zeitschr. Krist., v. 53, p. 149-157 (in German).
- Borobév, V. P., 1897, The optical structure of garnet in the Eugene-Maximillian mine: Mem. Soc. Russe. Mineral. no. 1 (in Russian).
- Brammell, A. C., and Bracewell, S. P., 1936, Variability of garnet in granites: Mining Mag., v. 24, p. 254-265.
- Brauns, R. A., 1891, Die optischen Anomalien der Kristalle: Preisschr. Jablonowski Ges., Leipzig, 370 p. (in German).
- _____, 1907, Light effect of garnet, zircon, and sapphire: Neues Jahrb. Min. Geol., no. 1, p. 13-20 (in German).
- _____, (no date given), The chemical constitution of garnetiferous crystalline schists, cordierite rocks, and sanidinite from the Lake Laach Region: Neues Jahrb. Min. Geol., v. 34, p. 85-175 (in German).
- Bressler, C. T., 1950, Garnet deposits near Wrangell, Southeastern Alaska: U. S. Geol. Survey Bull. 963-C, p. 81-93.
- Briere, Y. A., 1920, An amphibolite with garnet, olivine, and hypersthene: Soc. Mineral. France Bull., v. 43, p. 300-303 (in French).
- Brindley, J. C., 1954, The garnetiferous beds of the Leinster granite aureole and their small scale structures: Sci. Proc. Roy. Dublin Soc., v. 26, p. 245-262.
- Brock, R. W., 1915, A British Columbia example of the contact metamorphism of a granite to a garnet: Roy. Soc. Can. Trans., v. 9, p. 175-180.
- Brown, I. A., 1929, A garnet-bearing dike near Mornya, New South Wales: Linnean Soc. N. S. Wales 54, pt. 3, p. 176-184.

- Bobrovnik, D. P., 1920, Garnets from coal seams of the
Leningrad region: *Mem. Soc. Russ. Mineral.*, v. 50,
p. 127-132 (in Russian).
- Becke, H. E., 1911, The garnet group: *Zeitschr. Krist.*,
v. 33, p. 119-127 (in German).
- Borobev, V. P., 1927, The optical structure of garnet in
the Muzone-Maximilian mine: *Mem. Soc. Russ. Mineral.*,
no. 1 (in Russian).
- Brammell, A. G., and Bracewell, S. P., 1936, Variability
of garnet in granites: *Mining Mag.*, v. 52, p. 224-225.
- Brauns, R. A., 1891, Die optischen Anomalien der Kristalle:
Zeitschr. Daptonomik Ges., Leipzig, 370 p. (in
German).
- 1907, Light effect of garnet, zircon, and sapphirine:
Neues Jahrb. Min. Geol., no. 1, p. 13-20 (in German).
- (no date given), The chemical constitution of
garnetiferous crystalline schists, cordierite rocks,
and sapphirine from the Lake Louise Region: *Neues
Jahrb. Min. Geol.*, v. 34, p. 62-172 (in German).
- Bressler, G. F., 1950, Garnet deposits near Wrangell,
southeastern Alaska: *U. S. Geol. Survey Bull.*, 963-G,
p. 81-93.
- Brice, Y. A., 1920, An amphibole with garnet, olivine,
and hypersthene: *Soc. Mineral. France Bull.*, v. 43,
p. 300-303 (in French).
- Brindley, J. G., 1921, The garnetiferous beds of the
Lainster granite aureole and their small scale
structure: *Soc. Roy. Dublin Soc.*, v. 25,
p. 212-222.
- Brock, R. W., 1915, A British Columbia example of the
contact metamorphism of a granite to a garnet: *Roy.
Soc. Can. Trans.*, v. 9, p. 175-180.
- Brown, I. A., 1929, A garnet-bearing dike near Moruya,
New South Wales: *Linnæan Soc. N. S. Wales J.*,
p. 176-181.

- Brun, Albert, 1930, Optical constants of almandite, sphalerite, and zircon: *Bull. Soc. Franc. Mineral.*, v. 53, p. 35-46 (in French).
- Buddington, A. F., 1950, Composition and genesis of pyroxene and garnet related to Adirondack anorthosite and anorthosite-marble contact zones: *Am. Mineralogist*, v. 35, nos. 9-10, p. 659-670.
- Buddington, A. F., and Whitcomb, Lawrence, 1941, Geology of the Willsboro quadrangle (New York): *N. Y. State Mus. Bull.* 325, 137 p.
- Buttgenbach, H. P., 1922, The garnets of Bastogne and Salm-Chateau: *Ann. Soc. Geol. Belg.* 45, p. 249-260 (in French).
- 1930, Crystals of gold, titanite, and garnet: *Acad. royale Belgique Bull. cl. sci.*, v. 16, p. 874-880.
- Carithers, L. W., and Guard, A. K., 1945, Geology and ore deposits of the Sultan Basin, Snohomish County, Washington: *Washington Div. Mines and Geology Bull.*, v. 36, 90 p.
- Carozzi, Enrico, 1926, A chromiferous spessartite from St. Barthelmy, Valle d'Aosta: *Atti Accad. Lincei*, (6) 3, p. 230-232 (in Italian).
- Carpanese, T., 1932, Garnet, vesuvianite, ilmenite, and titanite from Monte Roseo di Verra (Monte Rosa Group). *Atti Accad. Lincei* 15, p. 591-595 (in Italian).
- Charlu, T. G. K., 1951, A note on the development of large garnets in Sutherland migmatites: *Geol. Mag.* v. 88, no. 3, p. 185-191.
- Christophe-Michel-Levy, Mireille, 1956, Reproduction artificielle des grenats calciques; grossulaire et andradite: *Soc. Franc. Miner.*, B. t. 79, no. 1-3, p. 124-128 (in French).
- Coetzee, C. B., 1941, An anorthite-epidote-garnet hornfels from Namaqualand, South Africa: *Mineralog. Mag.* 26, p. 134-139.
- Colasso, Teresa, 1937, I minerali dei filoni pegmatitici di Olgiasca: *Soc. Ital., Sci. Nat. Milano, Atti* v. 76, f. 4, p. 403-418 (in Italian).

Brun, Albert, 1930, Optical constants of almandine, spinel, and garnet. Bull. Soc. Franc. Mineral., v. 53, p. 35-46 (in French).

Buddington, A. F., 1920, Composition and genesis of pyroxene and garnet related to almandine-spinel and anorthite-muscovite contact zones. Am. Mineralogist, v. 5, nos. 9-10, p. 653-670.

Buddington, A. F., and Whitcomb, Lawrence, 1911, Geology of the Wilkes quadrangle (New York): N. Y. State Mus. Bull. 137 p.

Büttgenbach, H. F., 1922, The garnets of Bostange and Salm-Garsum. Ann. Soc. Geol. Belg. 45, p. 249-260 (in French).

_____, 1930, Crystals of gold, titanite, and garnet. Ann. Royale Belgique Bull. of. vol. 16, p. 616-620.

Garthwaite, L. W., and Guard, A. K., 1912, Geology and ore deposits of the Siltan Basin, Snohomish County, Washington. Washington Div. Mines and Geology Bull. v. 36, 90 p.

Garzanti, Enrico, 1926, A omphacite-spinel zone. St. Bernhard, Valle d'Aosta. Atti Acad. Lincei, (6) 3, p. 230-232 (in Italian).

Garzanti, Enrico, 1927, Garnet, vesuvianite, titanite, and titanite from Monte Rosso di Vercelli (Monte Rosso Group). Atti Acad. Lincei 12, p. 291-292 (in Italian).

Garvin, T. G. K., 1921, A note on the development of large garnets in Sutherland Highlands. Geol. Mag. v. 58, no. 3, p. 182-191.

Christophe-Michel-Levy, Maxime, 1926, Reproduction artificielle des grenats calciques; grossulites et andradites. Soc. Franc. Mineral., 5, 77, no. 1-2, p. 121-122 (in French).

Cozzee, G. B., 1911, An anorthite-spinel-garnet zone. Lela from Hamaraland, South Africa. Mineralog. Mag. 26, p. 121-122.

Colusso, Teresa, 1927, I minerali del Lilloni gabbro. Di Ossigeno: Soc. Ital. Sci. Nat., Atti, v. 76, 1, p. 103-112 (in Italian).

- Colomba, Luigi, (no date), Iron chromium garnet from Praborna (S. Marcel): 1 st. Min. Univ. Torino. Atti Accad. Lincei, 19, II, p. 146-150 (in Italian).
- Conant, L. G., 1935, The New Hampshire garnet deposits: Econ. Geology, v. 30, no. 4, p. 387-399.
- Conforto, B. S., 1947, Origin of garnets and zirconia in magnetite sand: Ricerca sci., 17, p. 1609-1610.
- Connah, F. E., 1913, The garnet rocks of Chillagoe, Queensland: Queensland Roy. Soc. Proc., 22, p. 31-34.
- Corin, Francois, 1938, A propos des grenats de la region de la zone de paliseul: Soc. Belge Geologie, B. t. 48, f. 2, p. 451-473 (in French).
- , 1943, New observations concerning the anisotropy of the garnets of Ardenne: Ann. Soc. Belge Geologie, Bull. 66, p. 143-148 (in French).
- Cornu, F. J., 1906, Analysis of garnet from the granulite of Etmannsdorf, lower Austria: Min. Pet. Mitt., v. 25, p. 355-356.
- Corstorphine, G. S., (no date given), The occurrence in Kimberlite of garnet-pyroxene nodules carrying diamonds: Geol. Soc. South Africa Trans. and Proc., v. 10, p. 65-68.
- Dana, E. S., 1932, A textbook of mineralogy: New York, John Wiley and Sons, 851 p.
- De Beaupuis, F. S., 1922, Garnet from the island of Quessant: Soc. Mineral. France Bull., v. 45, p. 5-7 (in French).
- Donnay, J. D. H., and Faessler, Carl, 1941, Trisoctahedral garnet from the Black Lake Region, Quebec: Toronto Univ. Studies, Geol. Ser. 46, p. 19-24.
- Doughty, D. C., and White, E. A. D., 1960, Imperfections in yttrium iron garnet crystals: Acta Cryst., v. 13, pt. 10, p. 761-762.
- Dunn, J. A., 1932, Reaction minerals in a garnet-cordierite-gneiss from Mogok, Burma: India Geol. Survey Res., 65, p. 445-456.

Colombo, Luigi, (no date), Two specimens garnet from
 Piedmont (S. Italy): I. N. S. Univ. Torino.
 Acti Acad. Lincei, 19, II, p. 116-120 (in Italian).

Constant, L. C., 1935, The New Hampshire garnet hypothesis
 Econ. Geology, v. 30, no. 4, p. 327-337.

Conrath, B. S., 1917, Origin of garnets and clinopyroxene in
 magmatic sands: Science vol. 47, p. 1609-1610.

Conrad, F. E., 1913, The garnet rocks of Gulliver
 Queensland: Queensland Geol. Soc. Proc., 22, p. 31-34.

Cox, Wessels, 1938, A propos des garnets de la région
 de la zone de Palissot: Soc. Belge Géologie, 5, 2,
 p. 151-153 (in French).

1943, New observations concerning the kinship of
 the garnets of Andover: Am. Soc. Belge Géologie,
 Bull. 66, p. 113-118 (in French).

Cornu, F. J., 1908, Analyse of garnet from the granulite
 of Himmelsberg, lower Austria: Mitt. Geol. Inst.,
 v. 25, p. 355-356.

Corstorphine, G. S., (no date given), The occurrence of
 kinked garnet-pyroxene nodules during
 diagenesis: Geol. Soc. South Africa Trans. and Proc.,
 v. 10, p. 62-68.

Dana, E. S., 1935, A textbook of mineralogy: New York,
 John Wiley and Sons, 621 p.

De Beaulieu, F. S., 1922, Garnet from the island of
 Guernsey: Soc. Mineral. France Bull., v. 52, p. 2-7
 (in French).

Donnay, J. D. H., and Passer, Carl, 1911, Mineralogische
 garnet from the Black Lake region, Quebec: Toronto
 Univ. Studies, Geol. Ser. 46, p. 19-21.

Douglass, D. O., and White, E. A. D., 1960, Implications
 in pyroxene from garnet crystallites: Jour. Geol., v. 68,
 pt. 10, p. 761-762.

Dunn, V. A., 1932, Reaction minerals in a garnet-cordierite-
 quartz from Nagor, Bihar, India: Geol. Survey Ind.,
 p. 145-156.

- Durrell, Cordell, 1943, Geology of the Sierra Nevada northeast of Visalia, Tulare County, California: California Jour. Mines and Geology, v. 39, no. 2, p. 153-168.
- Eakle, A. S., 1917, Minerals associated with the crystalline limestone at Crestmore, Riverside County, California: Univ. Cal. Bull. Dept. Geol., v. 10, p. 327-360.
- Eckel, E. B., 1932, Garnet as an amygdale mineral: Am. Mineralogist, v. 17, no. 11, p. 522-529.
- Edwards, A. B., 1936, On the occurrence of almandine garnets in some Devonian igneous rocks of Victoria: Roy. Soc. Victoria, Pr. N. S., v. 49, pt. 1, p. 40-50.
- Eitel, W. C., 1921, The polynary miscibility of garnet minerals: Zeitschr. Krist. 56, p. 526-531 (in German).
- Endell, K. R., 1913, Garnet-amphibolite and eclogite from Tromso and Tromsdalind: Centr. Min. Geol., p. 129-133 (in German).
- Eskola, Pentti, 1921, The eclogites of Norway: Viden - skapssels kapets Skrifter 1, no. 8, p. 118.
- Fedorow, E. von, 1897, Der Granat von den Turjinsk'schen Gruben: Zeitschr. Krist., v. 27, p. 276-290 (in German).
- Fermor, L. L., 1934, Note on the manganese-lime series of garnets: India Geol. Survey Recs., v. 68, pt. 3, p. 337-343.
- _____ 1938, Garnets and their role in nature: Indian Assoc. Cultivation Sci., Special pub. no. 6, pi-iii, 1-105.
- _____ 1938, Khoharite, a new garnet, and the nomenclature of garnets: India Geol. Survey Recs. 73, p. 145-156.
- _____ 1952, A new chrome garnet: Geol. Mag. 89, p. 145-147.
- Fleischer, Michael, 1937, The relation between chemical composition and physical properties in the garnet group: Am. Mineralogist, v. 22, no. 6, p. 751-759.

1917, *Geology of the Sierra Nevada*
 northeast of Visalia, Tulare County, California;
 California Jour. Mines and Geology, v. 27, no. 2,
 p. 153-168.

1917, Minerals associated with the crystal-
 line limestones of Greatport, Riverside County,
 California; Univ. Cal. Publ. Geol., v. 10,
 p. 327-360.

1932, Garnet as anhydrous mineral; Am.
 Mineralogist, v. 17, no. 11, p. 522-528.

1936, On the occurrence of almandine
 garnet in some Devonian igneous rocks of Victoria;
 Roy. Soc. Victoria, Pt. W. 8., v. 49, pt. 1, p. 40-50.

1931, The polymorphic instability of garnet
 minerals; Zeitschr. Krist., v. 56, p. 286-291 (in German).

1913, Garnet-amphibole and calcite from
 Troms and Tromsdaalen; Centr. Min. Geol., p. 127-
 133 (in German).

1921, The calcites of Norway; Vidensk.
 Selskabs skrifter 1, no. 6, p. 118.

1897, Der Granit von den Turin'schen
 Alpen; Zeitschr. Krist., v. 27, p. 276-290 (in
 German).

1931, Note on the manganese-lime series of
 garnets; India Geol. Survey Rec., v. 68, pt. 3,
 p. 327-363.

1938, Garnets and their role in nature; Indian
 Assoc. Christian Sci., Special pub. no. 6, p. 111,
 1-102.

1938, Rhodarsite, a new garnet, and the nomenclature
 of garnets; India Geol. Survey Rec., 73, p. 125-126.

1922, A new chrome garnet; Geol. Mag., 89, p. 117-
 117.

1937, The relation between chemical
 composition and physical properties in the garnet
 group; Am. Mineralogist, v. 22, no. 6, p. 751-759.

- Folinsbee, R. E., 1941, The chemical composition of garnet associated with cordierite: *Am. Mineralogist*, v. 26, no. 1, p. 50-53.
- Ford, W. E., 1915, A study of the relations existing between the chemical, optical, and other physical properties of the members of the garnet group: *Am. Jour. Sci.*, v. 40, p. 33-49.
- Fowler-Billings, Katherine, and Page, L. R., 1942, The geology of the Cardigan and Rumney quadrangles, New Hampshire: Concord, New Hampshire plan. comm., 31 p.
- Fowler-Lunn, K. S., and Kingsley, Louise, 1937, Geology of the Cardigan quadrangle, New Hampshire: *Geol. Soc. America Bull.*, v. 48, no. 10, p. 1363-1386.
- Franco, R. R., 1945, Granada almandina em Pernambuco: *Mineração e Metal.*, v. 9, no. 53, p. 221-223.
- Frankel, J. J., 1959, Uvarovite garnet and South African jade from Transvaal: *Am. Mineralogist*, v. 44, nos. 5 & 6, p. 565-591.
- Frietsch, Rudyard, 1957, Determination of the composition of garnets without chemical analysis: *Geol. Fören. Stockholm, Förh.* v. 79, h. 1, no. 488, p. 43-51.
- Geller, S. C., and Miller, C. E., 1959, The synthesis of uvarovite: *Am. Mineralogist*, v. 44, nos. 3 & 4, p. 445-446.
- 1959, Substitution of Fe^{+3} for Al^{+3} in synthetic spessartite: *Am. Mineralogist*, v. 44, nos. 5 & 6, p. 665-667.
- 1959, Silicate garnet-yttrium-iron garnet solid solutions: *Am. Mineralogist*, v. 44, no. 11-12, p. 1115-1120.
- Gentile, A. L., and Roy, Rustum, 1960, Isomorphism and crystalline solubility in the garnet family: *Am. Mineralogist*, v. 45, nos. 5 & 6, p. 701-711.
- Glasser, F. P., 1959, On the stability and synthesis of uvarovite $Ca_3Cr_2Si_3O_{12}$: *Am. Mineralogist*, v. 44, no. 11-12, p. 1301-1303.

Folinsbee, R. E., 1947, The chemical composition of
 garnet associated with cordierite and clinopyroxene,
Geol. Soc. Lond., v. 56, no. 1, p. 20-23.

Ford, W. E., 1952, A study of the relations existing
 between the chemical, optical, and other physical
 properties of the members of the garnet group, *Am.
 Jour. Sci., v. 50, p. 31-47.*

Fowler-Billings, Katherine, and Page, L. R., 1943, The
 geology of the Gardner and Murray quadrangles,
 New Hampshire, *Geol. Surv. New Hampshire, p. 31 p.*

Fowler-John, K. S., and Kinsley, Lester, 1937, Geology
 of the Gardner quadrangle, New Hampshire, *Geol.
 Soc. America Bull., v. 48, no. 10, p. 153-158.*

Francis, R. H., 1945, Garnet almandine at Barre,
Mineralog. e Metall., v. 9, no. 53, p. 221-223.

Frankel, J. J., 1950, Uvarovite from the South African
 beds from Transvaal, *Am. Mineralogist, v. 35, no.
 5 & 6, p. 282-291.*

Frisvold, Robert, 1957, Determination of the composition
 of garnets without chemical analysis, *Geol. Soc.
 Stockholm, Fort. v. 79, n. 1, no. 482, p. 43-51.*

Gellax, R. O., and Miller, O. E., 1950, The synthesis of
 uvarovite, *Am. Mineralogist, v. 35, no. 3 & 4,
 p. 442-446.*

1959, Substitution of Fe^{2+} for Al^{3+} in synthetic
 uvarovite, *Am. Mineralogist, v. 44, no. 2 & 3,
 p. 662-667.*

1959, Silicate garnet-yttrium-iron garnet solid
 solutions, *Am. Mineralogist, v. 44, no. 11-12,
 p. 1112-1120.*

Gentile, A. J., and Fox, Hester, 1960, Isomorphism and
 crystalline solubility in the garnet family, *Am.
 Mineralogist, v. 45, no. 5 & 6, p. 701-711.*

Glasser, V. J., 1959, On the stability and synthesis of
 uvarovite, *Am. Mineralogist, v. 44, no. 11-12,
 p. 1101-1103.*

- Gliszczynski, S. V., 1940a, Garnet twins?: Zentr. Mineral., Geol. p. 252-253 (in German).
- Gnevushev, M. A., Kalinin, A. I., Mikheev, V. I., and Smirnov, G. I., 1956, Changes in the elementary cell dimensions of garnets as a function of their chemical composition: Zapiski Vsesoyuz. Mineral. Obshchestva 85, p. 472-490 (in Russian).
- Goodspeed, G. E., and Coombs, H. A., 1932, Quartz-diopside-garnet veinlets: Am. Mineralogist, 17, p. 554-560.
- Gossner, B. R., 1931, Composition of garnets of the garnet group: Neues Jahrb. Min., v. 64, p. 225-233 (in German).
- Gossner, B. R., and Ilg, E. C., 1932, Mineralogy of the Bavarian Forest and the chemical composition of the almandite-spessartite series and of cordierite: Centr. Mineral. Geol. p. 1-12 (in German).
- Gottfried, C. D., 1930, Minerals from the Adamello Mts. (Trentino): Chem. Erde., v. 5, p. 106-112 (in German).
- Green, J. N. F., 1915, The garnets and streaky rocks of the English Lake District: Mineral Mag., v. 17, p. 207-218.
- Gregory, H. E., 1916, Garnet deposits on the Navajo Reservation, Arizona and Utah: Econ. Geology, v. 11, p. 223-230.
- Grill, E. S., (no date given), Epidote and garnet from the Brosso Mine, Piemont: Atti. Accad. Lincei, v. 23, I, p. 535-538.
- Grubenmann, U. A., (no date given), The garnet-olivine rock of the Gorduno Valley and its accompanying rocks: Vierteljahresschrift Naturf. Ges. Zurich, v. 53, p. 1-28 (in German).
- Hall, A. L., 1925, On "Jade" (massive garnet) from the Bushveld in the Western Transvaal: Geol. Soc. South Africa Trans., v. 27, p. 39-55.
- Harker, R. I., 1954, Further data on the petrology of the pelitic hornfelses of the Charn Chuinneafinchbea Region, Ross-Shire, with special reference to the status of almandine: Geol. Mag. v. 91, no. 6, p. 445-462.

- Olaszowski, S. V., 1960, Garnet schists, *Geol. Mag.*, v. 77, p. 222-223 (in German).
- Goodspeed, G. E., and Gump, H. A., 1932, Garnet schists, *Am. Mineralogist*, v. 17, p. 234-250.
- Goerner, B. R., 1931, Composition of garnets of the garnet group, *Neues Jahrb. Min.*, v. 64, p. 228-233 (in German).
- Goerner, B. R., and Lig, E. G., 1932, Mineralogy of the Bavarian Forest and the chemical composition of the almandine-grossularite series and of cordierite, *Geol. Mineral. Geol.*, p. 1-12 (in German).
- Gottrich, G. D., 1930, Minerals from the Adirondic Mts. (Trenton), *Geol. Surv. v. 2*, p. 106-112 (in German).
- Green, J. W. F., 1912, The garnets and staurolite rocks of the English Lake District, *Mineralog. v. 17*, p. 207-218.
- Gregory, H. E., 1916, Garnet deposits on the Nevada Reserve, *Arizona and Utah: Econ. Geology*, v. 11, p. 223-230.
- Grill, E. S., (no date given), Epidote and garnet from the Brown Mine, Missouri, *Atl. Acad. Sci.*, v. 5, p. 222-228.
- Grubermann, U. A., (no date given), The garnet-olivine rock of the Gordon Valley and its accompanying rocks, *Veröffentlichungen des Geol. Landes v. 2*, p. 1-28 (in German).
- Hall, A. L., 1922, On "Jade" (massive garnet) from the Bushveld in the Western Transvaal, *Geol. Soc. South Africa Trans.*, v. 27, p. 20-22.
- Harker, R. I., 1921, Further data on the petrology of the pelitic hornfels of the Gurnee Gneiss, *Geol. Soc. London, Rose-Schist, with special reference to the status of almandine*, *Geol. Mag.*, v. 38, no. 6, p. 412-462.

- Hartmans, N. E., and de Jong, W. F., 1940, Determination of garnets: *Naturwetensch. Tijds.*, v. 22, p. 237-240 (in German).
- Hartshorne, N. H., and Stuart, A. R., 1950, Crystals and the polarizing microscope: London, Edward Arnold & Co., 549 p.
- Hasegawa, Shuzo, 1955, Corundum and andradite from Okita, Daito-Machi, Iwate prefecture: *Jap. Assoc. Mineralogists*, v. 39, no. 5, p. 194-203 (in Japanese).
- Heritsch, Franz, 1926-7, Chemistry of garnets: *Neues Jahrb. Min. Abt. A*, v. 55, p. 60-91 (in German).
- Heritsch, H. D., 1933, X-ray examination of garnet from the gorge of the Lieser near Spittal (Carinthia): *Zeitschr. Krist.*, v. 85, p. 392-403 (in German).
- Herriot, A. N., 1956, Notes on an occurrence of garnet in the felsite of Tinto, Lanarkshire: *Geol. Soc. Glasgow, Tr.* v. 22, pt. 1, p. 94-99.
- Hezner, Laura, 1914, Analysis of a garnet in asbestos from Binnental: *Centr. Min. Geol.*, p. 325 (in German).
- Hietanen, Anna, 1959, Kyanite-garnet gedritite near Orofino, Idaho: *Am. Mineralogist*, v. 44, nos. 5 & 6, p. 539-564.
- Himmel, Hans, 1938a, Ernita=garnet: *Zentr. Mineral., Geol.* p. 243-245 (in German).
- Houston, J. R., 1955, The garnet deposit near Wrangell, Alaska: *Rocks and Minerals*, v. 30, nos. 11 & 12, p. 563-569.
- Howard, J. W., 1933, Garnets: *Jour. Chem. Education*, v. 10, p. 713-716.
- Howie, R. A., and Subramaniam, A. P., 1957, The paragenesis of garnet in charnockite, enderbite and related granulites: *Mineralog. Mag.*, v. 31, no. 238, p. 565-585.
- Hummel, F. A., 1950, Synthesis of uvarovite: *Am. Mineralogist*, v. 35, nos. 3 & 4, p. 324-325.
- Icki, Y. A., 1942, Chemical analysis of garnet from Hahossu, Fushun Prefecture, Fengtien Province, Manchuria: *Mem. Geol. Inst. Manchoakuo*, v. 17, p. 98-100 (in Japanese).

Hartman, W. E., and de Jong, W. J., 1953, *Geology of the ...*
of ...
2:0 (in German).

Hartman, W. E., and Stewart, J. K., 1953, *Geology of the ...*
the ...
Co., ...

Hasegawa, Shozo, 1952, *Geology and structure of the ...*
Daito-Koshi, Iwate Prefecture, Japan, *Journal of ...*
v. 32, no. 2, p. 197-202 (in Japanese).

Hartshorn, Franz, 1926-7, *Geology of ...*
Tanzania, *Ann. A. S. G. S.*, ...

Hartshorn, H. D., 1933, *A new ...*
the ...
v. 32, no. 2, p. 197-202 (in Japanese).

Hartshorn, H. D., 1936, *Notes on an ...*
in the ...
v. 32, no. 2, p. 197-202 (in Japanese).

Hartshorn, H. D., 1937, *Notes on an ...*
in the ...
v. 32, no. 2, p. 197-202 (in Japanese).

Hartshorn, H. D., 1938, *Notes on an ...*
in the ...
v. 32, no. 2, p. 197-202 (in Japanese).

Hartshorn, H. D., 1939, *Notes on an ...*
in the ...
v. 32, no. 2, p. 197-202 (in Japanese).

Hartshorn, H. D., 1940, *Notes on an ...*
in the ...
v. 32, no. 2, p. 197-202 (in Japanese).

Howard, J. W., 1933, *Geology of ...*
v. 10, p. 113-116.

Howe, R. A., and ... 1937, *Geology of ...*
of ...
v. 10, p. 113-116.

Howe, R. A., 1937, *Geology of ...*
v. 10, p. 113-116.

Howe, R. A., 1938, *Geology of ...*
v. 10, p. 113-116.

- Ignatev, N. A., 1934, Amphibolites, garnet-gedritites and micaïtes from Shuertskii, Karelia: Trans. Inst. Petrog. Acad. Sci. SSSR, v. 6, p. 65-82 (in Russian).
- Ingerson, Earl, and Barksdale, J. D., 1943, Iridescent garnet from the Adelaide Mining District, Nevada: Am. Mineralogist, v. 28, no. 5, p. 303-312.
- Ito, T. D., 1935, Crystallographic studies on minerals: Beitr. Mineral. Japan, Neue Folge I, 259 p. (in Japanese).
- Jaffe, H. W., 1951, The role of yttrium and other minor elements in the garnet group: Am. Mineralogist, v. 36, nos. 1 & 2, p. 133-155.
- Jayaraman, N., 1937, Mineralogy and chemical composition of garnets from the schist complex of Nellore: Indian Acad. Sci. Proc., S, A, 148-160.
- Jeremejew, W., 1882, Doppelbrechung am Granat: Zeitschr. Krist., v. 1, p. 589 (in German).
- Jurkovic, Ivan, 1953, Garnet in skarn, Novo Brdo: Vestnik Zavod. Geol. Geofis. Ins. Serbia, v. 10, p. 125-134 (in Russian).
- Kalinin, P. V., 1955, Garnets from the pegmatite veins of Southern Transbaikalia: Trudy Moskov. Geol. Razvedochnogo Inst. Im. S. Ordzhonikidze, v. 28, p. 39-46 (in Russian).
- Keith, M. L., and Roy, Rustum, 1954, Structural relations among double oxides of trivalent elements: Am. Mineralogist, v. 39, nos. 1 & 2, p. 1-23.
- Keith, M. L., and Schairer, J. F., 1952, The stability field of sapphirine in the system $MgO-Al_2O_3-SiO_2$: Jour. Geology, v. 60, no. 2, p. 181-186.
- Kelley, V. C., 1938, Geology and ore deposits of the Darwin silver-lead mining district, Inyo County, California: California Journal of Mines and Geology, Report 34, of the State Mineralogist, p. 503-562.
- Keyes, C. B., (no date given), Garnet contact deposits of copper and the depth at which they are formed: Econ. Geology, v. 4, p. 365-372.

- Ignatiev, N. A., 1938, Amphiboles, garnet-gedrites and micas from Gusevskii, Karelian Trans. Inst. Geol. Acad. Sci. USSR, v. 6, p. 52-53 (in Russian).
- Ingrison, Carl, and Warkentin, J. D., 1943, Iridescent garnet from the Abitibi Mining District, Nevada. Am. Mineralogist, v. 28, no. 5, p. 303-312.
- Ito, T. G., 1935, Crystallographic studies on minerals. Beitr. Mineral. Japan, Neue Folge I, 229 p. (in Japanese).
- Jaffe, H. W., 1921, The role of yttrium and other minor elements in the garnet group. Am. Mineralogist, v. 6, nos. 1 & 2, p. 133-137.
- Jayaraman, N., 1937, Mineralogy and chemical composition of garnets from the schist complex of Wailor. Indian Acad. Sci. Proc., B, A, 115-160.
- Jermolow, W., 1883, Doppelbrechung an Granat. Zeitschr. Krist., v. 1, p. 289 (in German).
- Jurkovic, Ivan, 1923, Garnet in skarn, Novo Brdo. Vestnik Savod. Geol. Inst. Serbia, v. 10, p. 122-134 (in Russian).
- Kalinin, P. V., 1925, Garnets from the pegmatite veins of Southern Transbaikalia. Trudy Moskov. Geol. Nauchno-Issled. Inst. S. Ordzhonikidze, v. 26, p. 39-46 (in Russian).
- Keith, M. L., and Roy, Rastus, 1925, Structural relations among double oxides of trivalent elements. Am. Mineralogist, v. 10, nos. 1 & 2, p. 1-23.
- Keith, M. L., and Schaller, J. P., 1925, The stability field of asphurite in the system MgO-Al₂O₃-SiO₂. Jour. Geology, v. 33, no. 2, p. 181-186.
- Kelley, V. C., 1938, Geology and ore deposits of the Berlin silver-lead mining district, Inyo County, California. California Journal of Mines and Geology, Report 31, of the State Mineralogist, p. 203-262.
- Keyes, O. E., (no date given), Garnet contact deposits of copper and the depth at which they are formed. Econ. Geology, v. 4, p. 362-372.

- Kirganov, R. N., 1941, The garnets of the Palkin mineral deposits near Sverdlovsk: Soc. Russe Miner., Mem., v. 70, Iv. 1, p. 23-45 (in Russian).
- Klein, J. F. G., 1883, Optische Studien am Granat: Neues Jahrb. Min. 1, p. 87 (in German).
- _____ 1894, Optische Studien am Granat, Vesuvian, und Pennin: Berlin Akad. S. Ber., p. 49 (in German).
- _____ 1895, Beitrage zur Kenntnis des Granats in optischer Hinsicht: Neues. Jahrb. Min., p. 68 (in German).
- _____ 1898, Optische Anomalien des Granats und neuere Versuche sie zu erklaren: Berlin Akad. S. Ber., 16 p., (in German).
- Knorring, O. V., 1946, A manganese garnet enclosed in sphalerite from Kimito in southwestern Finland: Comptes Rendus Soc. Geol. Finlande, no. 138, p. 77-87.
- _____ 1951, A new occurrence of uvarovite from northern Kanelina in Finland: Mineralog. Mag., v. 29, no. 213, p. 594-601.
- Knorring, O. V., and Kennedy, W. O., 1958, The mineral paragenesis and metamorphic status of garnet-hornblende-pyroxene-scapolite gneiss from Ghana (Gold Coast): Mining Mag., v. 31, no. 241, p. 846-859.
- Kokta, Jar, and Nemeč, Fr., 1936, Granat ultrabazických hornin od Cernina: Veda Přírodní, r. 17, o. 6-8, p. 176-180 (in Czechoslovakian).
- Kolderup, N. H., and Rosenquist, I. T., 1952, Giant garnet crystals from Gjlanger, western Norway: Bergens Mus. Arb. 1950, Nat. Rekke no. 6, 11 p.
- Koning, L. P. G., 1947, On cassiterite and garnet from the Kaokoveld, S. W. Africa: Koninkl. Nederlandse Akad. Wetensch. Proc., v. 50, no. 10, p. 1343-1347.
- Kostov, Ivan, 1950, The morphology of garnets: Annuaire Univ. Sofia. Fac. Sci., v. 3, no. 46, p. 329-339.
- Kozu, Shukusuke, and Kwano, Y., and Yagi, K., 1941, Studies on garnet from Wadatoge (II); chemical properties: Japanese Assoc. Mineralogists, J.v. 25, no. 1, p. 1-12 (in Japanese).

Rizganov, R. N., 1961, The garnets of the Khibiny massifs
deposits near Sverdlovsk: Dokl. Akad. Nauk SSSR, v. 157,
p. 10, 11, p. 23-25 (in Russian).

Klein, J. P. G., 1967, Optische Studien an Granat, Bismut
Tantalat, Nr. 1, p. 27 (in German).

1966, Optische Studien an Granat, Bismut, und
Tantalat: Berlin Akad. S. Ber., p. 49 (in German).

1965, Beiträge zur Kenntnis der Granat- und Bismut-
Tantalat-Granate: Jahrb. Min., p. 65 (in German).

1968, Optische Anomalien des Granats und andere
Versuche an Granat: Berlin Akad. S. Ber.,
p. 16 (in German).

Knorring, O. V., 1966, A manganese garnet analyzed in
epherite from Finland in Southwestern Finland: Suomen
Geol. Soc. Geol. Finlanda, no. 137, p. 17-19.

1967, A new occurrence of uvarovite from Karelia
Karelia in Finland: Mineralog. Mag., v. 32, no. 233,
p. 291-292.

Knorring, O. V., and Kennedy, W. C., 1966, The chemical
paragenesis and metamorphic evolution of garnet-epherite-
pyroxene-apatite granulites from Ontario: Canadian
Mining Jour., v. 31, no. 211, p. 24-27.

Kokta, Jar, and Hames, Fr., 1970, Granulitische
Granite in Gerdalen, Veda (Finland), v. 17, p. 2-6,
p. 176-180 (in Czechoslovakian).

Koldberg, W. H., and Rosenqvist, I. T., 1955, Granit
crystals from Gällared, western Norway: Bergens Mus.
Ard. 1950, Ser. Berke no. 6, p. 11.

Konka, J. P., 1967, On catalytic and garnet from
the Karkovsk, S. W. district, Khabarovsk
Akad. Wetensch. Proc., v. 20, no. 10, p. 1317-1321.

Kostov, Ivan, 1956, The morphology of garnets: Annals
Univ. Sofia, Ser. Sci., v. 3, no. 4, p. 287-292.

Kozu, Shinzuke, and Kuno, Y., and Yagi, K., 1967,
Studies on garnet from Khabarovsk (U.S.S.R.): Mineralog.
properties: Japanese Assoc. Mineralogists, v. 26,
no. 1, p. 1-12 (in Japanese).

- Kozu, Shukusuke, and Kawano, Y., 1938, Spessartitic almandite from Nagakubo, Ishikawa: Japanese Assoc. Mineralogists ..., J. v. 20, no. 5, p. 210-223 (in Japanese).
- 1939, Chemical composition of garnet from Anamushi: Japanese Assoc. Mineralogists, J. v. 21, no. 2, p. 80-85, (in Japanese).
- Kozu, Shukusuke, and Ohmori, K., 1939, Change in the refractive index and the specific gravity of garnet influenced by the andradite molecule in it: Japanese Assoc. Mineralogists, J. v. 22, no. 1, p. 37-41 (in Japanese).
- 1942, Garnet from Nishidohira, Ibaragi Prefecture, (Japan): Japanese Assoc. Mineralogists, J. v. 28, no. 5, p. 225-243 (in Japanese).
- Kozu, Shukusuke, and others, 1940, Studies on garnet from Wandatoge (1); modes of occurrence and physical properties: Japanese Assoc. Mineralogists, J. v. 24, no. 5, p. 221-228 (in Japanese).
- 1940, The influence of temperature on the zonal structure of garnet: Japanese Assoc. Mineralogists, J. v. 23, no. 4, p. 178-188 (in Japanese).
- 1941, Studies of garnet from Kyuchorei, Manchoukuo, (II); chemical properties: Japanese Assoc. Mineralogists, J. v. 25, no. 2, p. 51-57 (in Japanese).
- Kozu, Shukusuke, and Takane, K. R., 1939, Cell constant of garnet from Anamushi: Japanese Assoc. Mineralogists, J. v. 21, no. 3, p. 123-125 (in Japanese).
- 1939, Cell constant of spessartite-almandite from Ishikama: Japanese Assoc. Mineralogists, J. v. 21, no. 1, p. 33-35 (in Japanese).
- Kozu, Shukusuke, and Takane, K. R., and Takeuti, T. V., 1939, Cell constants of andradite and of grossularite-andradite from Otaki: Japanese Assoc. Mineralogists, J. v. 21, no. 5, p. 239-244 (in Japanese).
- Kozu, Shukusuke, and Takeuti, T. V., and Kizaki, Y. S., 1942, Grossularite from Fusodo and Kyudodo, Heianhokudo, Korea: Japanese Assoc. Mineralogists, J. v. 28, no. 4, p. 136-148 (in Japanese).

- Koizumi, S., and Kawano, Y., 1938, Spessartite
mineralite from Nagano, Japan; Japanese Assoc.
Mineralogists, J. v. 20, no. 2, p. 213-223 (in
Japanese).
- 1939, Chemical composition of garnet from Amakusa;
Japanese Assoc. Mineralogists, J. v. 21, no. 2,
p. 80-82, (in Japanese).
- Koizumi, S., and Omori, K., 1939, Garnet in the
refractive index and the specific gravity of garnet
influenced by the andradite molecule in it; Japanese
Assoc. Mineralogists, J. v. 22, no. 1, p. 37-41 (in
Japanese).
- 1942, Garnet from Nishidaira, Ibaraki Prefecture,
Japan; Japanese Assoc. Mineralogists, J. v. 23,
no. 2, p. 222-223 (in Japanese).
- Koizumi, S., and others, 1940, Studies on garnet from
Wadato (I); modes of occurrence and physical
properties; Japanese Assoc. Mineralogists, J. v. 22,
no. 2, p. 221-228 (in Japanese).
- 1940, The influence of temperature on the total
structure of garnet; Japanese Assoc. Mineralogists,
J. v. 22, no. 2, p. 178-188 (in Japanese).
- 1941, Studies of garnet from Kyushu, Manchuria,
(II); chemical properties; Japanese Assoc. Mineralo-
gists, J. v. 22, no. 2, p. 21-27 (in Japanese).
- Koizumi, S., and Takano, K., 1939, Cell constants
of garnet from Amakusa; Japanese Assoc. Mineralo-
gists, J. v. 21, no. 2, p. 123-125 (in Japanese).
- 1939, Cell constants of spessartite-mineralite from
Ishikawa; Japanese Assoc. Mineralogists, J. v. 21,
no. 1, p. 33-35 (in Japanese).
- Koizumi, S., and Takano, K., and Takami, T., V.,
1939, Cell constants of andradite and of grossularite-
andradite from Otsu; Japanese Assoc. Mineralogists,
J. v. 21, no. 2, p. 239-241 (in Japanese).
- Koizumi, S., and Takami, T., V., and Kizaki, Y., S.,
1942, Grossularite from Furodo and Kyudoko,
Hokkaido, Korea; Japanese Assoc. Mineralogists,
J. v. 23, no. 1, p. 136-148 (in Japanese).

- Kozu, Shukusuke, and Takeuti, T. V., and Ohmori, K. R., 1940, A new method for obtaining the chemical composition of garnet by computation using the physical constants: Japanese Assoc. Mineralogists, J. v. 23, no. 5, p. 203-212 (in Japanese).
- 1940, Cell constants of dark green and dark red garnet crystals from Naganobori, Prefecture, Yamaguti: Japanese Assoc. Mineralogists, J. v. 23, no. 4, p. 155-164 (in Japanese).
- 1940, The relation between chemical composition and physical properties in the garnet crystals from Ishikawa, Anamushi, and Nakatsugawa: Japanese Assoc. Mineralogists, J. v. 23, no. 2, p. 51-65 (in Japanese).
- 1941, Garnets from the Kaso manganese mine: Japanese Assoc. Mineralogists, J. v. 26, no. 4, p. 151-171 (in Japanese).
- Kozu, Shukusuke, and Yagi, K. D., 1941, Chemical studies of garnet and its mother rock from Amataki: Japanese Assoc. Mineralogists, J. v. 26, no. 3, p. 101-121 (in Japanese).
- Krieger, M. H., 1937, Geology of the Thirteenth Lake Quadrangle: New York State Mus. Bull. 308, 124 p.
- Krishna Rao, J. S. R., 1953, Manganese garnets from Chipurupalle area, Vizagapatam district: Indian Acad. Sci., pr. Sec. A, v. 38, no. 1, p. 20-22.
- Lacroix, A. B., 1914, Garnets of the almandite-spessartite-pyrope groups from Madagascar: Soc. Mineral. France Bull., v. 37, p. 108-112.
- Ladco, R. B., 1922, Garnet: U. S. Bur. Mines Rept. Inv., no. 2347, 16 p.
- Lakshmi Narayana Rao, S. V., 1955, Garnets from the ortho- and para-gneisses of the Narsipatam area, Vizagapatam district: Geol. Min. & Met. Soc. India, Q. J. v. 27, no. 3, p. 139-141.
- Lavrenko, E. I., and Laz'ko, E. M., 1954, Garnets from Archean and Proterozoic sediments of the Aldan shield: Doklady Akad. Nauk SSSR, v. 99, p. 613-616 (in Russian).
- Veneto Soc. (Italian).

Kozu, Shinzuke, and Takami, S. Y., 1940, A new method for separating the composition of garnet by means of the physical constants. Japanese Assoc. Mineralogists, *J. v. 23*, no. 2, p. 122-128 (in Japanese).

1940, Cell constants of early garnet and their physical constants from Japan. Japanese Assoc. Mineralogists, *J. v. 23*, no. 2, p. 122-128 (in Japanese).

1940, The relation between chemical composition and physical properties in the garnet crystals from Ishikawa, Yamaguchi, and Nagasaki. Japanese Assoc. Mineralogists, *J. v. 23*, no. 2, p. 122-128 (in Japanese).

1941, Garnets from the Late Mesozoic of Japan. Japanese Assoc. Mineralogists, *J. v. 24*, no. 2, p. 122-128 (in Japanese).

Kozu, Shinzuke, and Yagi, K. D., 1941, Chemical studies of garnet and its relation to the Late Mesozoic of Japan. Japanese Assoc. Mineralogists, *J. v. 24*, no. 2, p. 122-128 (in Japanese).

Krieger, K. W., 1937, Garnet of the Triassic of the Gneiss: New York State Geol. Surv., *100*, 122 p.

Krivanac, J. S., 1937, Garnets from the Gneiss: *Chiriquita area, Virginia*. Geol. Surv., *100*, 122 p.

Lacroix, A. B., 1911, Garnets of the Gneiss: *pyrope group from Madagascar*. Geol. Surv., *100*, 122 p.

Lacroix, A. B., 1922, Garnet: *pyrope group*. Geol. Surv., *100*, 122 p.

Lacroix, A. B., 1925, Garnets from the *ortho-and para-gneisses of the Huronian area, Michigan district*. Geol. Surv., *100*, 122 p.

Lacroix, A. B., 1927, Garnets from the *ortho-and para-gneisses of the Huronian area, Michigan district*. Geol. Surv., *100*, 122 p.

Lacroix, A. B., and Lacroix, K. M., 1927, Garnets from the *ortho-and para-gneisses of the Huronian area, Michigan district*. Geol. Surv., *100*, 122 p.

Dokidokid, Wash 3288, *v. 23*, p. 122-128 (in Russian).

- Lee, D. E., 1958, An andradite-spessartite garnet from Pajsberg, Sweden: *Am. Mineralogist*, v. 43, nos. 3 & 4, p. 208-215.
- Lehmann, Otto, 1888-1889, Molekularphysik mit besonderer Berücksichtigung mikroskopischer Untersuchungen und Anleitung zu solchen, sowie einem Anhang über mikroskopischer Analyse: Leipzig, W. Engelmann (in German).
- Lester, J. G., 1939, Garnet segregations in granite gneiss of De Kalb, County, Ga.: *Jour. Geology*, v. 47, no. 8, p. 841-847.
- Levin, S. B., 1948, Petrology and genesis of Gore Mountain garnet, New York (abs.): *Geol. Soc. Am. Bull.*, v. 59, no. 12, pt. 2, p. 1335-1336.
- 1949, Garnet evidence in Adirondack petrogeny (N. Y.): *New York Acad. Sci. Trans.*, Ser. 2, v. 11, no. 5, p. 156-162.
- 1950, The physical analysis of polycrystalline garnet (abs.): *Am. Mineralogist*, v. 35, nos. 3-4, p. 285-286.
- 1950, Genesis of some Adirondack garnet deposits: *Geol. Soc. Am. Bull.*, v. 61, no. 6, p. 519-565.
- 1951, Origin of hornblende rims on Adirondack garnet (abs.): *Am. Mineralogist*, v. 36, nos. 3 & 4, p. 319.
- Lindgren, Waldemar, 1914, The origin of the "garnet zones" and associated ore deposits: *Econ. Geology*, v. 9, p. 283-292.
- Lindroth, G. T., 1919, The nature of the garnet in mid-Swedish ore-deposit contact-rock formations: *Geol. Fören Förh.*, v. 41, p. 64-87.
- 1945, Till Vigdad Kannedom om granateus natur i de Mellansvenska Skarnjarmalmerna: *Geol. Fören. Stockholm, Förh.*, v. 67, no. 3, p. 351-359.
- Lucchi, G. de, 1940, Studi geologico-petrografici sul massiccio dell' adamello; il giacimento di contatto di Q. 2591 del M. Faunas del Frefone: *R. Ist. Veneto Sci. Atti.*, v. 98, pt. 2, d. 1, p. 79-98 (in Italian).

Lee, D. E., 1956, An andradite-bearing garnet zone
 Fajardo, Sweden: *Am. Mineralogist*, v. 41, no. 3,
 p. 208-212.

Lehmann, Otto, 1888-1889, *Koformige, kolloidale
 Bausubstanz mikroscopischer Aufbereitung und
 Anfertigung zu isolieren, sowie einer andern
 mikroscopischer Analyse*: Leipzig, W. Engelmann (in
 German).

Leister, J. G., 1939, Garnet segregation in granitic gneiss
 of De Kalb County, Ga.: *Geol. Soc. Am. Bull.*, v. 51,
 p. 811-817.

Lavin, S. B., 1918, Petrology and genesis of some Montana
 garnets, New York (abs.): *Geol. Soc. Am. Bull.*,
 v. 29, no. 12, pt. 2, p. 1335-1336.

1919, Garnet evidence in Algonkian terranes
 (N. Y.): *New York Acad. Sci. Trans.*, v. 21,
 no. 2, p. 158-162.

1920, The physical analysis of polymineralic garnets
 (abs.): *Am. Mineralogist*, v. 5, no. 1, p. 202-
 206.

1920, Genesis of some Algonkian garnet deposits
Geol. Soc. Am. Bull., v. 51, no. 6, p. 819-825.

1921, Origin of hornblende rims on Algonkian garnets
 (abs.): *Am. Mineralogist*, v. 6, no. 3, p. 278-
 280.

Lindgren, Waldemar, 1911, The origin of the garnet zone
 and associated ore deposits: *Geol. Soc. Am. Bull.*,
 p. 287-292.

Lindroth, G. T., 1917, The nature of the garnet in
 Swedish ore-bearing contact-rock formations
Fören. Forh., v. 41, p. 62-67.

1918, *Die Veste Kannedon am Grönland* (in
 German): *Geol. Forh.*,
 Stockholm, Forh., v. 42, no. 2, p. 121-127.

Lucchi, G. de, 1940, Studi geologico-petrografici sul
 massiccio delle "abmalie" in glaciamento di contatto
 di G. 2591 del M. Yanna del Friuli: *Riv. Ital.
 Veneto Sci. Att.*, v. 38, pt. 2, p. 129-135 (in
 Italian).

- Macdonald, R. D., 1944, Regional metamorphism in the Kenogamisis River area (Ontario): *Jour. Geology*, v. 52, no. 6, p. 414-423.
- Machatschki, F. D., and Gartner, H. R., 1927a, Biotite-garnet amphibolite from the Koralps, Westeiermark: *Centr. Mineral. Geol.* p. 314-320 (in German).
- Machibu, Isamu, 1942, Garnet from Kyuchorei, Manchuria; III modes of occurrence: 1. 2. *J. Japanese Assoc. Mineralogists, Petrol., Econ. Geol.* v. 27, p. 1-27, p. 87-106 (in Japanese).
- Mackowsky, M. T., 1939, Über die chemisch-physikalischen Zusammenhänge in den Granatsystemen Grossular-Melanit and Melanit-Titanmelanit unter dem Einfluss des Eisens bzw. Titans: *Chemie d. Erde (Linck)* v. 12, no. 2, p. 123-157.
- , 1939, Einige Bemerkungen zu der Analyse eines Japanischen Granats: *Zentr. Miner. Abt. A*, no. 8, p. 251-253 (in German).
- Maier, Wilhelm, 1951, Gedrillte Asteriten im Rosenquarz und Granat: *Heidelberg Beitr. Miner. Petrog.*, v. 2, no. 5, p. 428-431 (in German).
- Mallard, E., 1876, Explication des phenomenes optiques anomaux que presentent un grand nombre de substances cristallisees: *Ann. d. Min.*, v. 7, no. 10 (in French).
- Marchenko, E. Ya., 1955, Zonal differentiation in Skarns from River Tibek (Khakass Autonomous Region): *Doklady Akad. Nauk. SSSR*, v. 104, p. 619-621.
- Mason, Brian, and Berggren, Thelma, 1942, A phosphate-bearing spessartite garnet from Wodgina, Western Australia: *Geol. Foren. Stockholm, Forh.* v. 63, h. 4, no. 427, p. 413-418.
- Matiba, I. S., 1940, Studies of garnet from Kyuchoeri Manchoukuo (I) Physical constants: *Japanese Assoc. Mineralogists, J.* v. 24, no. 6, p. 251-270 (in Japanese).
- , 1942, Studies of garnet from Kyuchorei, Manchuria (3); Modes of occurrence: *Japanese Assoc. Mineralogists, J.* v. 27, nos. 1 & 2, p. 1-27, 87-106 (in Japanese).

- McConnel, Duncan, 1933, Garnets from Sierra Tlayacae Morelos, Mexico: *Am. Mineralogist*, v. 18, p. 25-29.
- ____ 1942, Griphite, a hydro-phosphate garnetoid: *Am. Mineralogist*, v. 27, no. 6, p. 452-461.
- ____ 1943, Isomorphism and isotypism among silicates and phosphates: *Science*, v. 97, p. 98-99.
- ____ 1948, Garnets, their properties, occurrences and utilization (abs.): *Colorado-Wyoming Acad. Sci. Jour.*, v. 3, no. 5, p. 35.
- Meixner, Heinz, 1938, Kraubather Lagerstätten studien III; Uwarowit von Kraubath - eine Fehlbestimmung und Fundortsverwechselung und Zirkon von Kraubath: *Zentr. Miner. Abt. A*, no. 4, p. 115-120 (in German).
- ____ 1952, "Eklogit" - Granat von der Saualpe, Kärnten; eine Richtigstellung: *Neues Jarb. Miner., Monatshefte* no. 1, p. 1-13 (in German).
- Mende, Ilse, 1941, The lattice constants of magnesium aluminum garnet: *Zentr. Miner. Geol. A*, no. 6, p. 137-139 (in German).
- Menzer, G. R., 1926, The crystal structure of garnet: *Zeitschr. Krist.* 63, p. 157-158 (in German).
- ____ 1928, The crystal structure of garnet: *Zeitschr. Krist.* v. 69, p. 300-396 (in German). 542 25 237
- Michel-Levy, M. C., 1951, Reproduction artificielle de grenats ferro-manganesiferes; serie almandin-spessartine: *Acad. sci. (Paris) Comptes rendus*, v. 232, no. 21, p. 1953-1954 (in French).
- Mikheev, V. I., 1957, X-ray determination of minerals: *Kristallografiya*, v. 2, p. 466-469.
- Miller, W. J., 1912, The garnet deposits of Warren County, New York: *Econ. Geology*, v. 7, p. 493-501.
- ____ 1914, Geology of the North Creek quadrangle, Warren County, New York: *New York State Mus., Bull.* 170, 90 p.
- ____ 1938, Genesis of certain Adirondack garnet deposits: *Am. Mineralogist*, v. 23, no. 6, p. 399-408.

1938, Genesis of certain Algonkian granite plutons
 Am. Mineralogist, v. 23, no. 6, p. 399-408.

1938, Geology of the North Great Smoky Mountains
 Warren County, New York; New York State Mus.
 Bull. 170, 90 p.

1937, The granite deposits of Warren
 County, New York; Geology, v. 7, p. 487-491.

1937, K-ray determination of minerals;
 Kristallografiya, v. 2, p. 466-469.

1937, Reproduction of crystalline
 granitic ferro-magnesian rocks; Ann. Soc.
 Geol. Ind. (Paris) 1937-1938 (in French),
 v. 232, no. 21, p. 1923-1924.

1938, The crystal structure of garnet;
 Kristallografiya, v. 2, p. 390-396 (in German).

1936, The crystal structure of garnet;
 Zeitschr. Krist. 63, p. 127-128 (in German).

1936, The lattice constants of magnesian
 aluminum garnet; Zeitschr. Krist. 63, no. 6,
 p. 127-129 (in German).

1935, "Kifogit" - Garnet von der Kifogit, Kifogit;
 eine Kristallstruktur; Neues Jahrb. Mineral., Monatshefte
 1935, Mineral. Abt. A, no. 11, p. 112-113 (in German).

1935, Garnet from the Kifogit, Kifogit;
 Ueber die Kristallstruktur - eine Kristallstruktur und
 Kristallstruktur der Kifogit; Neues Jahrb. Mineral. Abt. A,
 1935, v. 3, no. 2, p. 32.

1935, Garnet, their properties, occurrence and
 utilization (in Russian); Colorado Mining Lab. Bul.
 1935, v. 2, no. 2, p. 1-10.

1935, Isomorphism and facies in some aluminous
 and phosphatic; Science, v. 81, p. 100-101.

1935, Garnet, a hydro-thermal mineral;
 Mineralogist, v. 27, no. 6, p. 152-161.

Morales, Mexico; Am. Mineralogist, v. 27, p. 152-161.

McDonnell, Dunsmuir, 1933, Garnet from the
 Dunsmuir, California; Am. Mineralogist, v. 18, p. 152-161.

- Milton, Charles, and Davidson, Norman, 1950, An occurrence of natrolite, andradite, and allanite in the Franklin Furnace quadrangle, New Jersey: *Am. Mineralogist*, v. 35, nos. 7 & 8, p. 500-507.
- Miyashiro, Akiho, 1953, Calcium-poor garnet in relation to metamorphism: *Geochim. et Cosmochim. Acta*, v. 4, no. 4, p. 179-208.
- M'lintock, W. F. P., 1916, Zeolites and associates: minerals from the Tertiary lavas around Ben More, Mull: *Roy. Soc. Edinburgh Trans.*, v. 51, pt. 1, p. 1-33.
- Morimoto, Ryohei, 1944, Mode of occurrence of garnet at Nijo Volcano; microscopic observation of garnet-bearing xenoliths: *Jour. Japanese Assoc. Mineralogists, Petrol., Econ. Geology*, v. 32, p. 231-238 (in Japanese).
- Mosebach, R. S., 1935, Über die Entstehung der Barytgänge im Jungerssen Granit des Spessarts bei Aschaffenburg: "*Senckenbergiana*," v. 17, p. 219-223 (in German).
- 1938, Petrographische *Studieren* im Kristall in dem Spessart, 5; Pegmatite und deren mineralien: *Senckenbergiana* (Senckenb. Naturf. Ges.), v. 20, no. 6, p. 443-462 (in German).
- 1953, Mineral-synthetic and petrologic-interpretation on the example of agate, chalcedony and garnets: *Chem. Erde*, v. 16, p. 123-134 (in German).
- Mountain, E. D., 1938, Tabular spessartine crystals in muscovite: *Mineralog. Mag.*, v. 25, no. 162, p. 125-134.
- Murdoch, Joseph, 1938, Some garnet crystals from California: *Jour. Geology*, v. 47, no. 2, p. 189-197.
- Narayanalyzer, L. A., 1921, Occurrence of garnetiferous sillimanite gneisses, scapolite gneisses, and the associated marble beds in the Coimbatore district: *Proc. 7th Indian Sci. Cong.*
- Neilson, J. W., 1958, Growth of magnetic garnet crystals: *Jour. App. Phys.* v. 29, no. 3, p. 390-391.

Milton, Charles, and Davidson, Norman, 1950, An occurrence of nepheline, andradite, and sillite in the Franklin Furnace quadrangle, New Jersey: *Am. Mineralogist*, v. 35, no. 7 & 8, p. 500-507.

Miyashiro, Akio, 1953, Calcium-poor garnet in relation to metamorphism: *Geochim. et Cosmochim. Acta*, v. 17, no. 1, p. 177-208.

W'inton, W. F. L., 1916, Eclogites and associated minerals from the Tertiary lavas around Ben More, Mull: *Roy. Soc. Edinburgh Trans.*, v. 31, pt. 1, p. 1-33.

Norimoto, Ryobu, 1944, Mode of occurrence of garnet at Mt. Volcano: microscopic observation of garnet-bearing xenoliths: *Jour. Japanese Assoc. Mineralogists, Petrol., Econ. Geology*, v. 32, p. 231-236 (in Japanese).

Mosbach, R. S., 1935, Über die Entstehung der Geysergänge im Jungeren Granit des Spessarts bei Aachalshausen: *"Senckenbergiana"*, v. 17, p. 219-223 (in German).

1936, Petrographische Notizen im Kristall in dem Spessart, 2: Pegmatite und deren Mineralien: *Senckenbergiana (Senckenb. Naturf. Ges.)*, v. 20, no. 6, p. 143-165 (in German).

1937, Mineral-syntectite and petrologic-interpretation on the example of agate, chalcedony and garnet: *Chem. Erde*, v. 16, p. 123-134 (in German).

Mountain, R. D., 1936, Tabular spessartine crystals in muscovite: *Mineralog. Mag.*, v. 52, no. 162, p. 125-134.

Ward, Joseph, 1936, Some garnet crystals from California: *Jour. Geology*, v. 44, no. 2, p. 189-197.

Karapınar, I. A., 1931, Occurrence of garnetiferous sillimanite gneisses, soapstone gneisses, and the associated marble beds in the Colaba district: *Proc. The Indian Soc. Geol.*

Kelton, S. W., 1928, Growth of magnetite garnet crystals: *Jour. App. Phys.*, v. 29, no. 3, p. 390-391.

Nikolov, N., 1936, Chemische-mineralogische Untersuchungen einiger Granate in Bulgarien: Sofia, Univ., Ann. 32, Fac. phys.-mat., Lv. 3, p. 51-66 (in Bulgarian, German Summ.).

Nishikawa, Shoji, 1917, Crystal structure of a garnet: Tokyo Math. Phys. Soc. Proc. (2), v. 9, p. 194-197 (in Japanese).

Novjacek, Radim, (no date given), Garnet from Marchendorf near Sobotin: Mineralog. Abstracts 4, p. 516-517.

_____, 1931, Über Granate der Pegmatite aus der Tschechoslowakei: Vestnick II. tr. Kral. Ces. Spol. Nauk. Sept., 1-55.

Ohmori, K. R., 1939, Mode of occurrence in garnet in the environs of Ishikawa: Japanese Assoc. Mineralogists, J. v. 21, no. 1, p. 18-25 (in Japanese).

_____, 1941, Studies of garnet from Suisyo-Yama in the Hida Mountains: Japanese Assoc. Mineralogists, J. v. 25, no. 6, p. 249-265 (in Japanese).

_____, 1942, Studies of garnets in the andesites forming the Volcano Nijosan: Japanese Assoc. Mineralogists, J. v. 27, nos. 1 & 2, p. 27-58, 69-87 (in Japanese).

Ohmori, K. R., and Hasegawa, S. A., and Yokoyama, K. R., 1956, Samarskite and garnet from Kasuya pegmatite mine in Ishikawa Town, Fukushima Prefecture: Japanese Assoc. Mineralogists, J. v. 40, no. 1, p. 1-4 (in Japanese).

Pabst, Adolf, 1931, The garnets in the glaucophane schists of California: Am. Mineralogist, v. 16, no. 8, p. 327-333.

_____, 1938, Garnets from vesicles in rhyolite near Ely, Nevada: Am. Mineralogist, v. 23, no. 2, p. 101-103.

_____, 1943, Large and small garnets from Fort Wrangell, Alaska: Am. Mineralogist, v. 28, no. 4, p. 233-245.

_____, 1955, Manganese content of garnets from the Franciscan schists (California): Am. Mineralogist, v. 40, nos. 9 & 10, p. 919-923.

Nikolov, H., 1936, Quarzite-mineralogische Untersuchungen
einiger Quarzite in Bulgarien; Sofia, Univ., Ann. 32.
Fac. Phys.-math., IV, 2, p. 21-66 (in Bulgarian,
German Summary).

Nishikawa, Shoji, 1917, Crystal structure of a garnet;
Tokyo Inst. Phys., Soc. Proc. 12, p. 192-197
(in Japanese).

Novjacek, Radim, (no date given), Garnet from Metchikof
near Sobotin; Mineralog. Abstracts 11, p. 216-217.

1921, Über Quarzite der Fokanische aus der Fokanische-
Kalkstein; Veselich II, 1. Teil, 2. Aufl., 2. Aufl., 1921.
Sept., 1-22.

Omori, K. H., 1939, Mode of occurrence in garnet in the
environs of Ishikawa; Japanese Assoc. Mineralogists,
J. v. 21, no. 1, p. 18-22 (in Japanese).

1941, Studies of garnet from Sulu-Lana in the
Hida Mountains; Japanese Assoc. Mineralogists, J. v.
22, no. 6, p. 219-222 (in Japanese).

1942, Studies of garnet in the andalusite forming
the Volcano Misono; Japanese Assoc. Mineralogists,
J. v. 27, nos. 1 & 2, p. 27-28, 29-31 (in Japanese).

Omori, K. H., and Hasegawa, S. A., and Yokoyama, K. H.,
1926, Garnetite and garnet from the Fokanische Quarzite
in Ishikawa Town, Fukushima Prefecture, Japan;
Assoc. Mineralogists, J. v. 18, no. 1, p. 1-8 (in
Japanese).

Peab, Adolf, 1931, The garnets in the glaucophane schists
of California; Am. Mineralogist, v. 16, no. 8,
p. 327-333.

1938, Garnet from vesicles in nephelite near Ely,
Nevada; Am. Mineralogist, v. 23, no. 5, p. 101-102.

1943, Large and small garnets from Fort Wadsworth,
Alaska; Am. Mineralogist, v. 28, no. 1, p. 233-235.

1922, Manganese content of garnets from the
Franciscan schists (California); Am. Mineralogist,
v. 10, nos. 2 & 10, p. 919-923.

- Parsons, A. L., 1935, Trisoctahedral garnet from west Thetford Mines, Province of Quebec: Toronto Univ. Studies Geol. Ser. 38, p. 33-36.
- Partridge, F. C., 1934, The identification of kimberlite and kimberlite minerals by spectroscopic and other methods: South Africa Geol. Soc. Trans., v. 37, p. 205-211.
- Pavlovic, Stojan, 1952, Andradite-grossularite of Trepca: Sbornik Radova Srpska Akad. Nauk., no. 23, no. 4, p. 1-6.
- Pearl, R. M., 1941, Spessartite in pegmatite at Mount Antero, Colorado: Am. Mineralogist, v. 26, no. 1, p. 54.
- Philipsborn, H. von., 1928, Relations between index of refraction, density and chemical composition in the garnet group: Abhandl. Math.-Phys. Klasse. Sachs. Akad. Wiss., v. 40, p. 1-42.
- Phillips, F. C., 1956, An introduction to crystallography: London, Longmans, Green and Co., 324 p.
- Pinto, A. C., 1945, Breves notas petrologicas referentes a regido de Angonia: Lisboa, Univ., Mus. e Lab. Miner. e Geol., B. s. 4, no. 13, p. 85-97 (in Portuguese, Fr. Summa.).
- Polar-Mantuani, L. A., and Klemen, R. D., 1940, Spessartite from the Pohorje Mountains (Yugoslavia): Zentr. Mineral., Geol., p. 112-127 (in German).
- Poldervaart, Arie, 1953, Metamorphism of basaltic rocks-a review: Geol. Soc. America Bull., v. 64, no. 3, p. 259-273.
- Povarennykh, A. S., 1952, Prehnite-garnet skarn from Chatkal'skii Rayon: Mem. Soc. Russe Mineral., v. 81, p. 55-58 (in Russian).
- Preclik, K., 1924, An almandite-cordierite hornfels of unknown origin: Centr. Mineral. Geol., p. 652-664 (in German).
- Radice, M. M., 1943, Una andesita granatifer a de Coquelen (Territorio del Rio Negro): La Plata Univ. Nat. Mus., notas t. 8, Geol. no. 25, p. 191-199.

Parsons, A. L., 1935, *Emplacement of the ...*
 Theobald Mines, Nevada, *Journal of*
Studies Geol. Soc. Am. 38, p. 1-12.

Partridge, F. G., 1931, *The ...*
 and kyanite minerals by ...
 methods; *South Africa Geol. Survey* ...
 p. 202-211.

Pavlovic, Stefan, 1952, *Amphibole ...*
 Spornik Narodna Školska Zbirka ...
 p. 1-6.

Pearl, S. M., 1941, *Spessartite in ...*
 Anvers, Colorado; *Am. Mineralogist*, ...
 p. 21.

Philippson, H. von., 1925, *Relation ...*
 refraction, density and ...
 garnet groups; *Abhandl. Bayer. Akad.* ...
 Akad. Wiss., v. 49, p. 1-11.

Phillips, P. C., 1956, *An introduction to ...*
 London, Chapman, Green and Co., Ltd.

Pinco, A. G., 1915, *Brava notes ...*
 região de Angaité; *Revista de*
 e Geol., S. S. B., no. 13, p. 25-31 (in Portuguese).

Polar-Pantani, L. A., and Elmer, R. S., 1930, *Notes*
 from the Polar Mountains (Greenland);
Mineral. Geol., p. 112-117 (in German).

Poldvanski, Aris, 1957, *Heterophane of ...*
 a review; *Geol. Soc. America Bull.*, ...
 p. 259-273.

Poverennyykh, A. S., 1952, *Prehnite ...*
 Cherkasskiy rayon; *Sov. Geol. Zh.* ...
 p. 22-28 (in Russian).

Prell, E., 1931, *An amphibole ...*
 unknown origin; *Central. Mineral. Geol.* ...
 (in German).

Radice, M. V., 1913, *Una ...*
 (Territorio del Rio Negro); *La*
 Mus., notes v. 8, Geol. no. 25, p. 1-17.

- Raisin, C. A., 1901, On altered rocks near Bastogne: Geol. Soc. London Quart. Jour., v. 57, p. 55-72.
- Rakusz, J., 1924, Studies on the garnet from Dobschau: Centr. Mineral. Geol., p. 353-356 (in German).
- Rao, B. R., 1945, Elastic constants of garnets: Indian Acad. Sci. Proc., v. 22, A, p. 194-198.
- Rast, Nicholas, and Sturt, B. A., 1957, Crystallographic and geologic factors in the growth of garnets from Central Perthshire: Nature, v. 179, no. 4554, p. 215.
- Reichert, Robert, 1935, Kristallographische Beobachtungen an einigen Tuffmineralien aus dem Borzsonyer-Gebirge: Foldtani Kozlony, v. 65, f. 10-12, p. 342-349 (in German).
- Renard, A. L., 1882, Les roches grenatiferes et amphiboliques de la Region de Bastogne: Bull. Mus. Roy. d'Hist., v. 1 (in French).
- Richard, L. M., 1911, Garnet deposits of Georgia: Mineral World, v. 34, p. 1135.
- Riedel, Josef, 1952, Neue Mineral- und Gesteinsfunde im Ostronggebiet: Austria Geol. Bundesanst. Verh., v. 3, p. 159-163 (in German).
- Rinne, F., 1925, Feinbauliche Erorterungen und Röntgenographische Erfahrungen uber optische Anomalien: Cbl. Min. A., p. 225-241 (in German).
- Rogers, A. F., and Kerr, P. F., 1942, Optical mineralogy: McGraw-Hill Book Company, Inc., New York and London.
- Rossetti, Vasco, 1946, Garnets of Orida: Rend. Seminar. Facolta. Sci. Univ. Cagliari, v. 16, p. 29-40.
- Roy, D. M., and Roy, Rustom, 1957, The system $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O VI}$: The grossularite- $3\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 6\text{H}_2\text{O}$ Join: Geol. Soc. Am. Bull. v. 68, p. 1788.
- Sanero, Edoardo, 1935, Sopra due granati delle miniere de Cogne in Val d' Aosta: Periodico Miner., v. 6, no. 3, p. 213-220.
- Satterly, Jack, 1943, Geology of the Dryden-Wabigoon area (Ontario): Ontario Dept. Mines Ann. Rpt. 1941, v. 50, pt. 2, iii, 67 p.

Rabin, C. A., 1961, On altered rocks and ...
 Geol. Soc. London, vol. 81, p. 1-12.

Rabin, J., 1958, Studies on the ...
 Geol. Mineral. Geol., p. 101-120 (in German).

Rao, S. R., 1955, Elastic constants of ...
 Acad. Sci. Proc., v. 21, A, p. 100-102.

Raaf, Nicholas, and Scott, B. A., 1957, Crystalline ...
 and geologic factors in the growth of ...
 Central Pennsylvania, v. 100, p. 1-12.

Reicher, Robert, 1955, Kristallinische ...
 an einigen ...
 Politische ... v. 55, 1-10-12, p. 101-110
 (German).

Renard, A. L., 1955, Les roches granitiques ...
 de la Région de ...
 v. 1 (in French).

Richard, L. M., 1911, Gypsum deposits of ...
 World, v. 35, p. 1232.

Riedel, Josef, 1952, Neue Mineral- und ...
 Geomorphologie, v. 1, p. 123-125 (in German).

Riney, F., 1955, Feldspathic ...
 graphische ...
 Geol. Min. A., p. 225-231 (in German).

Rogers, A. F., and Kerr, F. F., 1912, ...
 McGraw-Hill Book Company, Inc., New York and London.

Ross, Vaseo, 1915, Gypsum of ...
 Pacific Sci. Univ. California, v. 1, p. 123-130.

Roy, D. M., and Roy, Watson, 1957, The ...
 510-515 VI: The ...
 Geol. Soc. Am. Bull., v. 68, p. 1188.

Sano, Eusebio, 1955, Sobre ...
 de ...
 no. 3, p. 213-220.

Satterly, Jack, 1913, Geology of the ...
 (Ontario): Ontario Dept. ...
 v. 20, pt. 2, 11, 47 p.

- Satterly, Jack, 1943, Mineral occurrences in Pary Sound district (Ontario): Ontario Dept. Mines Ann. Rept., v. 51, pt. 2, 1942, iv, 86 p.
- 1943, Mineral occurrences in the Haliburton area (Ontario): Ontario Dept. Mines Ann. Rept., v. 52, pt. 2, iv, 106 p.
- Schaacke, Ingeburg, 1949, Geometry and optics of optically anomolous crystals illustrated by melilite and garnet: Neues Jahrb. Mineral., Geol., Abhandl. 80A, p. 145-162 (in German).
- Schairer, J. F., and Yagi, Kenzo, 1952, The system $\text{FeO-Al}_2\text{O}_3\text{-SiO}_2$: Am. Jour. Sci., Bowen Volume, pt. 2, p. 471-512.
- 1952, The stability relations of iron cordierite and almandine garnet (abs.): Am. Geophys. Union (Trans.), v. 33, p. 328.
- Schipani, Rosa, 1953, I granati delle rocce cristalline della Calabria: Not. Miner. Siciliana e Calabrese, f. 4, p. 5-13 (in Italian, Engl. Summ.).
- Schurmann, H. M. E., 1938, Granatführender Diorit aus der Sierra Nevada, Kalifornien: Neues Jahrb. Beilage, v. 74, Abt. A, no. 2, p. 225-250 (in German).
- Serdyuchenko, D. P., 1955, Grossularite and andradite from the Archean complex of the Aldan Plateau: Doklady Akad. Nauk. SSSR, v. 104, p. 775-778 (in Russian).
- Seridutschenko, D. V., 1933, Almandite from some deposits of N. Caucasus and the Ukraine: Mem. Soc. Russe. Min., v. 62, p. 97-101 (in Russian).
- Serra, Aurello, 1910, Remarkable garnet from Fluminimaggiore (Sardinia): Acad. Sci. tis. Mat. Napoli Tendus, p. 222-224.
- Shannon, E. V., and Gonyer, F. A., 1927, Almandite-spessartite garnet from Gwynns Falls, Baltimore: Washington Acad. Sci. Jour., v. 17, p. 534-536.
- Sharma, N. L., 1944, Garnet: Jour. Sci. & Indus. Res., Delhi, v. 2, no. 4, p. 238-244.
- Stockwell, C. E., 1927, An Almandite Garnet from the
Am. Mineralogist, v. 12, no. 4, p. 221-222.

Watters, Jack, 1953, Mineral occurrences in Perry Sound District (Ontario): Ontario Dept. Mines Ann. Rept., v. 51, pt. 2, 1953, iv, 86 p.

Watters, Jack, 1953, Mineral occurrences in the Haliburton area (Ontario): Ontario Dept. Mines Ann. Rept., v. 52, pt. 2, iv, 106 p.

Wobeser, Ingoburg, 1953, Geometry and optics of optically anomalous crystals illustrated by malinite and garnet: Neues Jahrb. Mineral., Geol., Abhandl., 80A, p. 155-165 (in German).

Wobeser, J. F., and Yagi, Kenzo, 1952, The system FeO-Al₂O₃-SiO₂: Am. Jour. Sci., Bowen Volume, pt. 2, p. 471-515.

Wobeser, J. F., 1952, The stability relations of iron cordierite and almandine garnet (abs.): Am. Geophys. Union (Trans.), v. 33, p. 358.

Wobeser, J. F., 1953, I granati della roccia cristallina della Calabria: Not. Miner. Sicilia e Calabria, t. 1, p. 2-13 (in Italian, Engl. Summ.).

Wobeser, J. F., 1953, Granatfärbung: Not. Miner. Sicilia e Calabria, v. 1, pt. 2, p. 225-250 (in German).

Wobeser, J. F., 1953, Grossularite and andradite from the Ansohn complex of the Alder Flatau: Doklady Akad. Nauk. SSSR, v. 104, p. 775-778 (in Russian).

Wobeser, J. F., 1953, Almandine from some deposits of R. Caucasus and the Ukraine: Not. Miner. Sicilia e Calabria, v. 1, pt. 2, p. 97-101 (in Russian).

Wobeser, J. F., 1953, Hematitische garnet from Flatau: Not. Miner. Sicilia e Calabria, v. 1, pt. 2, p. 225-231.

Wobeser, J. F., and Geyer, F. A., 1951, Almandine-grossularite garnet from Guyana Falls, Balaclava: Washington Acad. Sci. Jour., v. 17, p. 236-238.

Wobeser, J. F., 1951, Garnet: Jour. Sci. & Indust. Res., Delhi, v. 2, no. 1, p. 238-241.

- Shaub, B. M., 1949, Paragenesis of the garnet and associated minerals of the Barton Mine near North Creek, New York: *Am. Mineralogist*, v. 34, nos. 7 & 8, p. 573-582.
- Shavkova, N. N.m, 1947, O dvukh granatakh kolskogo poluos-trova: *Doklady Akad. Nauk. SSSR*, v. 58, no. 6, p. 1143-1146 (in Russian).
- Shilin, L. L., 1951, Garnets from the Shislim Mountains: *Trudy Mineralog. Muzeya, Akad. Nauk. SSSR*, no. 3, p. 146-149 (in Russian).
- Sirovich, G. D., Analyses of garnet of the Tavolato Gully: *Gazz. Chim. Ital.*, v. 43, I, p. 36-38.
- Skinner, B. J., 1956, Physical properties of end-members of the garnet group: *Am. Mineralogist*, v. 41, nos. 5 & 6, p. 428-436.
- Smith, F. G., 1952, Decrepitation characteristics of garnet: *Am. Mineralogist*, v. 37, nos. 5 & 6, p. 470-491.
- Solovev, S. P., and Nikogosyan, Kh. S., 1938, Abnormal garnets of the Tyrny-Auz (Northern Caucasus) Region and their transition to the isotropic state on heating: *Soc. Russe. Miner., Mem.*, v. 67, no. 4, p. 651-654 (in Russian).
- Sobolev, V. S., and Vartanova, N. S., and Shainyuk, A. I., 1951, Problems of garnet growth in sediments: *Zapiski Vsesoyuz. Mineral. Obschestva*, v. 80, p. 122-126 (in Russian).
- Sriramadas, A., 1957, Diagrams for the correlation of unit cell edges and refractive index with the chemical composition of garnets: *Am. Mineralogist*, v. 42, nos. 3 & 4, p. 294-298.
- Starkov, N. P., 1950, Optical anomalies in garnets from Gora. Saroba, Southern Ural: *Mem. Soc. Russe. Mineral.*, v. 79, p. 283-290 (in Russian).
- Stewart, F. H., 1950, Note on garnet crystals from Cairnie, Aberdeenshire: *Miner. Mag.*, v. 29, no. 210, p. 252-253.
- Stockwell, C. H., 1927, An X-ray study of the garnet group: *Am. Mineralogist*, v. 12, no. 9, p. 327-344.

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 Great, New York, in: *Journal of Petrology*, v. 8, p. 113-116 (in Russian).

Shaw, E. I., 1921, Garnets from the ...
 Great, New York, in: *Journal of Petrology*, v. 12, p. 116-119 (in Russian).

Strobel, G. B., Analysis of ...
 Great, New York, in: *Journal of Petrology*, v. 13, p. 10-12.

Skinner, B. J., 1926, Physical properties of ...
 of the garnet group, *Am. Mineralogist*, v. 11, p. 128-133.

Solich, P. G., 1922, Description of ...
 garnets, *Am. Mineralogist*, v. 7, p. 10-12.

Solovay, S. V., and Khorozov, M. S., 1921, Garnets of the ...
 and their transition to the ...
 heating, *Sov. Mineralogist*, v. 1, p. 621-624 (in Russian).

Solovay, V. S., and Verbov, B. S., 1921, Problems of garnet growth in ...
 Vsesoyuz. Mineral. Obozreteniye, v. 1, p. 112-113 (in Russian).

Spiridonov, A., 1927, Diagrams for the ...
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Starov, W. F., 1920, Optical ...
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Mineralogist, v. 19, p. 253-259 (in Russian).

Stewart, F. H., 1920, Note on garnet ...
 California, *American Mineralogist*, v. 5, p. 222-223.

Stowell, C. H., 1927, An X-ray study of the garnet group,
Am. Mineralogist, v. 12, no. 9, p. 327-331.

- Stose, G. W., and Glass, J. J., 1938, Garnet crystals in cavities in metamorphosed Triassic conglomerate in New York County, Pa: *Am. Mineralogist*, v. 23, no. 7, p. 430-435.
- Strekalova, L. A., 1914, Crystals of spessartite in the muscovite from the Montenaja Villa, Ural: *Acad. Sci. Petrograd Bull.*, p. 1329-1337 (in Russian).
- Strock, L. W., 1930, Spessartite from Avondale, Delaware County, Pennsylvania: *Am. Mineralogist*, v. 15, p. 40-41.
- Sugiyama, Ruiji, and others, 1943, Morphological study of minerals, part I: *Tokyo Sci. Mus.*, B. no. 10, 33 p., (in Japanese).
- Sumin, N. G., 1954, Some peculiarities of skarn minerals of iron-ore deposits: *Trudy Mineralog. Muzeya, Akad. Nauk. SSSR*, no. 6, p. 131-138 (in Russian).
- Swaminathan, V. S., 1928, Mode of occurrence and chemical composition of garnet from Nellore District, Madras: *15th, Indian Sci. Cong. Proc.*, p. 228.
- Takahashi, J. A., and Kitahara, J. J., 1951, Studies on garnet and augite placer deposits at Wa-Are, South Sakhalin: *Japanese Assoc. Mineralogists*, J. v. 34, nos. 5 & 6, p. 165-172, 199-204; v. 35, no. 1, p. 15-23 (in Japanese).
- Takenouti, T. B., 1937, Garnet from the Hitachi Mine: *Japanese Assoc. Mineralogists*, J. v. 17, no. 5, p. 239-248 (in Japanese).
- Takeuti, T. R., 1939, Refractive indices and specific gravities of garnet crystals found in Japan: *Japanese Assoc. Mineralogists*, J. v. 21, no. 5, p. 205-228; v. 22, no. 1, p. 1-25 (in Japanese).
- , 1941, Studies of garnets and of its country rock from Amataki: *Japanese Assoc. Mineralogists*, J. v. 26, no. 2, p. 51-78 (in Japanese).
- , 1942, Studies of minerals and rocks occurring in the Yagoshi Mine and its vicinity (6); Garnet: *Japanese Assoc. Mineralogists*, J. v. 27, no. 2, p. 106-114 (in Japanese).

Stose, G. W., and Glass, L. E., 1938, Garnet crystals in cavities in reworked felsic conglomerates in New York County, N. Y. Mineralogical Magazine, v. 23, no. 7, p. 430-432.

Strobel, L. A., 1911, Crystals of spinel in the muscovite from the Hotschka Villa, Ural, Russia. Sol. Petrogr. Bull., p. 1329-1332 (in Russian).

Strook, L. W., 1930, Spinelite from Nevada, Nevada County, Pennsylvania. Am. Mineralogist, v. 15, p. 40-41.

Sugiyama, R. H., and others, 1913, Morphological study of minerals, part I: Tokyo Sol. Min., v. 10, no. 11, p. 1-10 (in Japanese).

Suzuki, K. G., 1925, Some peculiarities of spinel crystals of iron-ore deposits: Tsuchi Kagaku, Matsuyama, Japan. Min. 2228, no. 6, p. 111-112 (in Russian).

Swaminathan, V. S., 1928, Mode of occurrence and chemical composition of garnet from Kallur District, Mysore. Indian Sol. Min., p. 221.

Takahashi, J. I., and Kishida, J. I., 1927, Studies on garnet and spinel in the Kurohara area, south Sakhalin: Japanese Assoc. Mineralogists, v. 7, no. 2 & 3, p. 125-128, 192-204, 21, no. 1, p. 1-10 (in Japanese).

Takemoto, T. E., 1937, Garnet from the Hotschka Mine: Japanese Assoc. Mineralogists, v. 7, no. 2, p. 239-246 (in Japanese).

Takemoto, T. E., 1939, Retrospective studies and specific gravities of garnet crystals found in Japan: Japanese Assoc. Mineralogists, v. 7, no. 2, p. 202-223; v. 22, no. 1, p. 1-25 (in Japanese).

1911, Studies of garnets and of the country rock from Amakusa: Japanese Assoc. Mineralogists, v. 7, no. 2, p. 21-28 (in Japanese).

1912, Studies of minerals and rocks occurring in the Yagohri Mine and the vicinity (6): Japanese Assoc. Mineralogists, v. 7, no. 2, p. 106-111 (in Japanese).

- Tauber, A. G., Banks, E. C., and Kedesdy, H. D., Synthesis of germanate garnets, *Acta. Cryst.*, v. II, p. 893-894.
- Thilo, Erich, 1941, Über die Isotypie zwischen Phosphaten der allgemeinen Zusammensetzung $(Me_1)_3 (Me_2)_2 (PO_4)_5$ und den Silikaten der Granatgruppe: *Naturwissenschaften*, Berlin, v. 29, no. 16, p. 239 (in German).
- Tilley, C. E., 1921, Precambrian para-gneisses of southern Eyre Peninsula, South Australia: *Geol. Mag.*, v. 58, p. 251-259, 305-312.
- 1926, Garnet in pelitic contact-zones: *Mineralog. Mag.*, v. 21, p. 47-50.
- 1926, Some mineralogical transformations in crystalline schists: *Mineralog. Mag.*, v. 21, p. 34-46.
- Tomba, A. M., 1952, I minerali del gruppo dell'Ortler; III, staurolite, granato e biotite di val peder: *Acad. Naz. Lincei, Atti, cl. Sci., Rend. S. 8*, v. 13, f. 1 & 2, p. 79-82.
- Trainer, J. N., 1945, Pseudomorphism and zonal growth of garnets from Garnet Hill, California: *Rocks and Minerals*, v. 20, no. 8, p. 359-363.
- 1948, Vicinal forms on garnets: *Rocks and Minerals*, v. 23, no. 2, p. 105-107.
- Tröger, E. S., 1959, Die Granat-Gruppe: Beziehungen zwischen Mineralchemismus und Gesteinsart: *Neues Jahrbuch für Mineralogie, Abhandlungen*, v. 93, no. 1, p. 1-44 (in German).
- Uhlig, J. C., 1910, The garnets in volcanic rocks and bombs of the lower Rhine district: *Bonn. Verh. Nat. Ver. preuss. Rhineland-Westfalens.*, v. 67, p. 307-403 (in German).
- Van der Lingen, J. S., 1929, Garnets: *South African Jour. Sci.*, v. 25, p. 10-15.
- Vermaas, F. H. S., 1952, Manganese-iron garnet from Otjosondu, Southwest Africa: *Am. Mineralogist*, v. 37, nos. 11 & 12, p. 1065.
- Vistelius, A. B., 1943, On the garnets from the region of the Lake Balkhash: *Soc. Russe. Miner., Mem.* v. 72, nos. 3 & 4, p. 167-173 (in Russian).

Fisher, A. G., Banno, H. C., and Kober, H. D., *Synthetic*
 of garnets, *Acta. Geol.*, v. 11, p. 193-224.
 Fisher, A. G., 1951, Über die typische wischen Proben
 der allgemeinen Zusammensetzung (Mg²⁺) (Mg²⁺)
 und den Effekten der Granatgruppe: *Abhandlungen*
 Berlin, v. 20, no. 10, p. 239 (in German).
 Fisher, A. G., 1951, Free-spinning garnets of southern
 Tyrol, *South Australian Geol. Mag.*, v. 20,
 p. 221-229, 302-312.
 1956, Garnet in pelitic contact-zones: *Mineralog.*
Mag., v. 21, p. 17-20.
 1956, Some mineralogical transformations in crystal-
 line schists: *Mineralog. Mag.*, v. 21, p. 31-46.
 Tompa, A. M., 1952, I minerali del gruppo dell'Orlov; III,
 staurolite, granato e distite di vari gradi: *Ann.*
Nat. Mus. Lincei, Atti. Cl. Sci., Rend. S. 8, v. 13, 1.
I & 2, p. 79-82.
 Trainer, J. N., 1952, Pseudomorphs and local growth of
 garnets from Garnet Hill, California: *Rock and*
Minerals, v. 20, no. 8, p. 329-353.
 1958, Mineral forms on garnets: *Rock and Minerals*,
 v. 23, no. 2, p. 102-107.
 Troger, K. S., 1959, Die Granat-Gruppe: *Beziehungen*
 zwischen Mineralchemie und Gesteinsart: *Beziehungen*
 zwischen Mineralogie, *Abhandlungen*, v. 23, no.
 1, p. 1-14 (in German).
 Uhlir, J. G., 1910, The garnets in volcanic rocks and
 bombs of the lower Rhine district: *Bonn. Verh.*
Nat. Ver. prov. Rheinland-Westfalen, v. 61,
 p. 207-403 (in German).
 Van der Linde, J. S., 1959, Garnets: *South African*
Jour. Geol., v. 3, p. 10-15.
 Verma, P. H. S., 1952, Manganese-iron garnet from Orissa,
 Southeast Africa: *Am. Mineralogist*, v. 37, no. 11,
 p. 1062.
 Vlasov, A. S., 1953, On the garnets from the region of
 the Lake Balkhash: *Sov. Russ. Miner.*, v. 12,
 nos. 3 & 4, p. 157-173 (in Russian).

- Vitaliano, C. J., 1944, Contact metamorphism at Rye Patch, Nevada: *Geol. Soc. Am. Bull.*, v. 55, no. 8, p. 921-950.
- Walcott, A. J., 1937, Asterism in garnet, spinel, quartz, and sapphire: *Field Mus. Nat. History Pub.* 397, *Geol. Ser.*, v. 7, no. 3, p. 39-57.
- _____ 1938, Asterism in garnet, spinel, quartz, and sapphire: *Mineralogist*, v. 6, no. 6, p. 3-4.
- _____ 1939, Asteriated garnet: *Mineralogist*, v. 7, no. 5, p. 191-192, 215-217.
- Weinschenk, E. S., 1896, Beiträge zur Systematisch der Granatgruppe: *Zeitsch. Krist. und Mineral.*, v. 25, p. 365 (in German).
- Wentorf, R. H., Jr., 1956, The formation of Gore Mountain (N. Y.) garnet and hornblende at high temperature and pressure: *Am. Jour. Sci.*, v. 254, no. 7, p. 413-419.
- Wiley, John, 1947, A further note on Purgatory Chasm, Massachusetts: *Rocks and Minerals*, v. 22, no. 3, p. 213.
- Wilson, L. G., 1956, Thermal expansion of a grossularite garnet: *Australian Jour. Phys.*, v. 9, p. 403-405.
- Winchell, A. N., 1924, Petrographic studies of limestone alterations at Bingham: *Am. Inst. Mining Metall. Engineers Trans.*, no. 1322-M, 16 p.
- _____ 1933, Elements of optical mineralogy, pt. II, Descriptions of minerals: New York, John Wiley and Sons, 459 p.
- Winchell, Horace, 1958, The composition and physical properties of garnet: *Am. Mineralogist*, v. 43, nos. 5 & 6, p. 595-599.
- Woodland, A. W., 1935, Spessartite in the Cambrian manganese ore of Merionethshire: *Geol. Mag.*, v. 72, p. 384.
- Wright, C. W., 1915, Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: *U. S. Geol. Survey Prof. Paper* 87, 110 p.

Wieland, G. J., 1914, Garnet metamorphism of the
 Pecos, New Mexico. Geol. Soc. Am. Bull., v. 25, p. 921-920.

Widom, A. J., 1937, Asbestos in garnet, orthopyroxene
 and sapphirine. Field Mus. Nat. History, Chicago, v. 30, p. 1-27.

Widom, A. J., 1938, Asbestos in garnet, orthopyroxene, and
 sapphirine. Mineralogist, v. 6, no. 1, p. 3-4.

Widom, A. J., 1939, Asbestos in garnet. Mineralogist, v. 7, no. 2,
 p. 191-192, 215-217.

Widom, A. J., 1939, Beiträge zur Systematik der
 Granatgruppen. Zeitsch. Krist. und Mineral., v. 55, p. 362 (in German).

Widom, A. J., 1950, The formation of some minerals
 (N. Y.) garnet and hornblende at high temperatures
 and pressures. Am. Jour. Sci., v. 48, no. 7, p. 413-419.

Widom, A. J., 1957, A further note on garnet. Geol.
 Massachusetts: Rocks and Minerals, v. 12, no. 3, p. 213.

Wilson, L. G., 1950, Thermal expansion of a garnet
 garnet. Australian Jour. Phys., v. 3, no. 1, p. 107-108.

Winnicki, A. W., 1921, Petrographic studies of the
 alterations at Piquette, Mich. Mining Geol. Engineers Trans., no. 1222-23, 16 p.

Winnicki, A. W., 1937, Elements of optical mineralogy, pt. II,
 Descriptions of minerals. New York, John Wiley and Sons, 459 p.

Winnicki, A. W., 1958, The composition and physical
 properties of garnet. Am. Mineralogist, v. 43, no. 5 & 6, p. 592-599.

Woodward, A. W., 1955, Spessartite in the Gneiss
 manganese ore of Madinatadin: Geol. Mag., v. 72, p. 381.

Wright, C. W., 1915, Geology and the deposits of copper
 Mountain and Kasaan Peninsula, Alaska. U. S. Geol. Survey Prof. Paper 87, 110 p.

- Wright, W. I., 1938, The composition and occurrence of garnets: *Am. Mineralogist*, v. 23, no. 7, p. 436-449.
- Yagi, K. S., 1944, Petro-chemical studies on rocks from New Guinea: I garnet-biotite-migmatite from Ranshiki River, Anggi Region: *Jour. Japanese Assoc. Mineralogists, petrol., -Econ. Geol.*, v. 32, p. 89-105 (in Japanese).
- Yedlin, L. N., 1947, Garnet at Roxbury and West Redding, Connecticut: *Rocks and Minerals*, v. 22, no. 9, p. 824-826.
- Yoder, H. S., Jr., 1950, Stability relations of grossularite: *Jour. Geology*, v. 58, no. 3, p. 221-253.
- 1955, Almandite garnet stability range (abs.): *Am. Mineralogist*, v. 40, nos. 3 & 4, p. 342.
- Yoder, H. S., Jr., and Keith, M. L., 1951, Complete substitution of aluminum for silicon- The system $3\text{MnO}, \text{Al}_2\text{O}_3, 3\text{SiO}_2\text{-Y}_2\text{O}_3, 5\text{Al}_2\text{O}_3$: *Am. Mineralogist*, v. 36, nos. 7 & 8, p. 519-533.
- Yoshimura, Toyotumi, 1936, On the garnet from Mitsuishi, Hitaka Province: *Japanese Assoc. Mineralogists ...*, J. v. 14, no. 6, p. 257-265; v. 15, no. 1, p. 26-40 (in Japanese).
- Zedlitz, Otto, 1933, Andradite rich in titanium: *Zentr. Min. Geol.*, 1933 A, p. 225-239 (in German).
- 1935, Titaniferous calcium-iron garnets: II: *Zentr. Mineral., Geol.* 1935 A, p. 68-78 (in German).
- Zombory, Laszlo, 1935, Daten zur chemischen Zusammensetzung der Granate von vaskö-Dognacska: (*Ung. Akad. Wiss.*), v. 52, p. 170-187 (in Hungarian).
- Zorkovsky, Belo, 1956, The chemical character of the garnet from the andesite of Vel'ky Saris: *Geol. Sbornik (Bratislava)*, v. 7, p. 321-331 (in Russian).

Wright, W. I., 1956, The composition and occurrence of
Garnets: *Am. Mineralogist*, v. 41, no. 7, p. 430-444.

Yagi, K. S., 1944, Petro-chemical studies on rocks from
New Guinea: I garnet-biotite-muscovite from Ranau
River, Arak Region: *Jour. Japanese Assoc. Mineralo-
gists*, v. 32, p. 89-102 (in
Japanese).

Yedlin, L. W., 1947, Garnet at Hoxbury and West Bedford,
Connecticut: *Rocks and Minerals*, v. 22, no. 2,
p. 82-88.

Yoder, H. S., Jr., 1950, Stability relations of grossularite:
Jour. Geology, v. 58, no. 3, p. 221-227.

_____, 1952, Almandine garnet stability zones (abs.): *Am.
Mineralogist*, v. 37, nos. 3 & 4, p. 315.

Yoder, H. S., Jr., and Lindsley, T. R., 1951, Complete
substitution of aluminum for silicon: The system
 $3\text{MgO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$: *Am. Mineralogist*,
v. 36, nos. 7 & 8, p. 219-223.

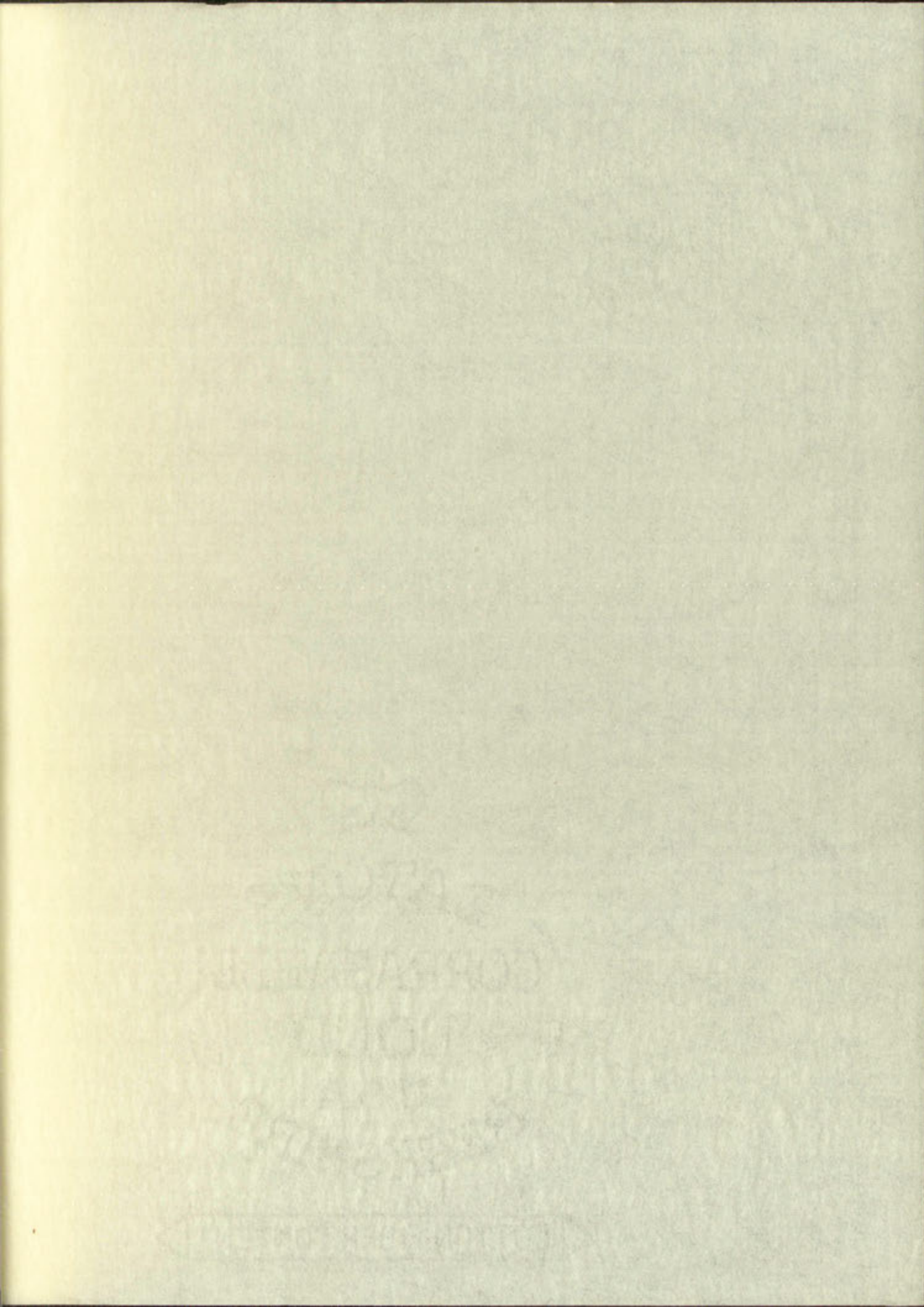
Yoshimura, Toyotomi, 1936, On the garnet from Hida-
land, Hida Province: *Japanese Assoc. Mineralogists* ...
J. v. 11, no. 6, p. 257-262; v. 12, no. 1, p. 25-40
(in Japanese).

Zedler, Otto, 1933, Andradite with titanite: *Monatsh.
Min. Geol.*, 1933 A, p. 222-232 (in German).

_____, 1935, Titaniferous calcium-iron garnets: III:
Monatsh. Mineral. Geol., 1935 A, p. 68-76 (in German).

Zobory, Laszlo, 1932, Daten zur chemischen Zusammensetzung
der Granate von Vasko-Dagraszka: (*Ung. Akad. Wiss.*)
v. 52, p. 170-187 (in Hungarian).

Zorkovskiy, Boris, 1956, The chemical character of the
garnet from the andesite of Vajk's series: *Geol.
Sbornik (Pravoslav)*, v. 7, p. 321-331 (in Russian).



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