Introduction to Mineral Crystallography

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New York City

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In 1916 Victor Goldschmidt published the nine volume *Atlas der Krystallformen*. It was a compilation of crystal diagrams from many books and references. Here is one of the 22 pages from the Atlas containing diamond crystal drawings.
Preface

About 20 years ago Vivien Gornitz taught a series of study groups about mineralogy to the New York Mineralogical Club, held at the American Museum of Natural History in New York City. The notes she used at the time were eventually developed into a book (*An Introduction to Minerals*, 1998) in which the second chapter focused on the basics of crystallography.

As the United Nations declared 2014 to be The International Year of Crystallography, Vivien was asked to provide a special lecture about mineral crystallography. With this in mind, she completely revised, rewrote and re-illustrated that chapter and transformed it into this new booklet.

Although this was used as an accompanying handout for that lecture, it functions fully as an independent educational publication.

The members of the New York Mineralogical Club thank Vivien for creating this interesting and timely special publication.

Mitch Portnoy  
*President & Bulletin Editor, New York Mineralogical Club*  
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Centerfold: International Year of Crystallography 2014

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**Prelude: What is a Mineral?**

A mineral is a homogeneous solid that occurs in nature and that has a specific, but not always fixed, chemical composition and a repetitive atomic arrangement. It can be formed by either geological or biological processes.

**Occurs in nature.** Materials with the same composition as minerals, but produced in the laboratory are, strictly speaking, not true minerals, but rather “synthetic” or “lab-grown” compounds.

**Homogeneous solid.** Consisting of a uniform material or phase. Not a mixture of different minerals, as in a rock. Homogeneity may depend on the scale, or magnification. An apparently homogeneous mineral on a visible scale may be inhomogeneous under higher magnification. E.g., blebs or streaks of albite in microcline.

**Specific, but not always fixed, chemical composition.** Normally, atoms are present in specific proportions. E.g., in quartz, or silica, SiO$_2$, the proportions of Si to O by weight are always 1:2. However, in many minerals, atoms or ions may replace each other within certain limits, based on atomic size and electrical charge. The size of the substituting atoms (or ions) cannot vary too much (otherwise, they simply wouldn’t fit into the crystal lattice). Also, electrical neutrality must be maintained. For example, in the alkali feldspars, some sodium ($\text{Na}^+$) can replace potassium ($\text{K}^+$) in microcline, without affecting the other ions present, since $\text{Na}^+$ and $\text{K}^+$ ions carry the same charge ($\text{K}_2\text{NaAlSi}_3\text{O}_8$). However in the plagioclase feldspar series, $1 \text{Ca}^{++}$ plus 2 $\text{Al}^{++}$ and 2 $\text{Si}^{++}$ in anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$) replace 1 $\text{Na}^+$ plus 1 $\text{Al}^{++}$ and 3 $\text{Si}^{++}$ in albite ($\text{NaAlSi}_3\text{O}_8$).

**Repetitive atomic arrangement.** This is characteristic of all crystalline solids. A crystal is a solid bounded by flat, planar surfaces (called faces) that are related to each other by symmetry (explained elsewhere in the text). This external symmetry reflects an internal symmetry of the atomic structure. Crystalline, on the other hand, implies a repeating pattern of atoms, ion, or molecules in a three-dimensional array or lattice. Apparently solid materials that lack such an ordered atomic structure are either glasses (e.g., obsidian, a volcanic glass), or mineraloids, such as opal (which although in precious opal shows a repetitive structure of tiny spheres on a microscopic level), is not ordered on the atomic scale. These spheres are tiny “marbles” of silica, not individual atoms or ions.

Minerals can form as a result of biological, as well as geological, processes. Examples of biominerals include the calcite or aragonite of mollusk shells and corals; aragonite in pearls; hydroxyapatite in bones, teeth, and ivory; some opal derived from diatom shells. Other common minerals often indirectly associated with biological activity include pyrite, sulfur, gypsum, and magnetite, among others.

1974 USA 10c Mineral Heritage Stamps, block of 4 in the shape of a diamond. The stamps picture petrified wood, tourmaline, amethyst, and rhodochrosite.
Introduction to Mineral Crystallography

Minerals often occur as regular, geometric solids known as *crystals*. The regularity and symmetry of crystals on the visible scale are a direct expression of a three-dimensional, ordered arrangement of the constituent atoms or molecules. Crystallography is the science that deals with the study of crystals and crystalline solids: what controls their external shapes and how they grow, and also how the atoms or molecules are arranged in space. While crystallography originated as a part of mineralogy, it now encompasses all forms of solid matter, including metals, lab-created chemical compounds, and important biomolecules (e.g., proteins, DNA).

1. Basic Definitions

*Crystal*: A solid bounded by smooth, flat planar surfaces, called *faces* (Fig 1).

Figure 1. Examples of crystals and crystal forms.

(a) Quartz  
\[ m = \text{hexagonal prism} \]
\[ r, z = \text{rhombohedrons} \]

(b) Apophyllite  
\[ p = \text{tetragonal pyramid} \]
\[ a = \text{tetragonal prism} \]
\[ c = \text{pinacoid} \]

(c) Pyrite  
\[ a = \text{cube} \]
\[ e = \text{pyritohedron} \]

*Crystalline*: A solid material in which the constituent atoms, ions, or molecules are arranged in an ordered pattern which repeats indefinitely in three dimensions. The external symmetry of the crystal visible to the naked eye (e.g., Fig. 2a, anhydrite) reflects its internal atomic symmetry (Fig. 2b).

Figure 2. Comparison of an anhydrite and its internal arrangement of atoms.

(a) Anhydrite crystal  
(b) Anhydrite — atomic structure

*Crystal Form*: A set of planar crystal faces related to each other by symmetry (discussed below). Several common examples are illustrated in Figures 1 and 2.
How can one distinguish between a natural crystal face and a cleavage surface, especially in crystals with good cleavage, for example, with rhombohedrons of calcite, octahedrons of fluorite or diamond, and prisms of pyroxene? One clue is the luster. A freshly-cleaved surface is shinier, and observation with a hand lens will show breaks or steps parallel to the cleavage direction. In contrast, a natural crystal face may show growth features, such as etch pits, hillocks (or raised areas), and striations.

Crystal Habit: The assemblage of forms that are typically present in a crystal constitutes its habit. Thus in Figure 1a, quartz crystals are typically hexagonal prisms (m) modified by two rhombohedrons (r, z). Apophyllite (Fig. 1b) combines a tetragonal prism (a) with a tetragonal pyramid (p), capped by two pinacoids. Pyrite (Fig. 1c) shows the cube (a) modified by a pyritohedron (e). Other characteristic habits include octahedron for diamond, cube for fluorite, hexagonal prism for beryl, dodecahedron for garnet, etc. Note that while crystals may grow distorted, the angles between equivalent faces remain constant. This is known as Steno's law of interfacial angles, after the discoverer (Fig. 3).

Figure 3. Some crystal habits — ideal and distorted: (a) Cube. (b) Octahedron. (c) Dodecahedron.

2. Symmetry
Symmetry refers to the repetition of a point or design motif by some geometrical operation. These operations include:

1) rotation around an axis
2) reflection across a mirror plane,
3) inversion through a center (equivalent to a center of symmetry), and
4) rotation combined with inversion.

Symmetry can be found in a wide variety of objects, including crystals (Fig. 4). Familiar examples are the bilateral (two-sided symmetry) of vertebrates, including human beings, five-fold symmetry of starfish, six-fold symmetry of snowflakes; also the two-dimensional repeating patterns of wallpaper, textiles or brick walls. In crystals, however, the requirement of filling three-dimensional space on an atomic level eliminates 5-fold, 7-fold, etc., types of symmetry (e.g., to use a two-dimensional analogy, try tiling a floor with regular pentagons, without leaving gaps; Fig. 5).

Figure 4. Examples of symmetry.
(a) Rotational Symmetry

3-fold rotation in tourmaline
4-fold rotation in a Native American basket
6-fold rotation in beryl
However, as it turns out, such tiling is possible, if combined with other shapes such as a five-pointed star, a narrow rhomb, or a “boat”—a shape approximating 3/5 of a star. The resulting patterns are known as Penrose tilings, after the British physicist Sir Roger Penrose, who studied their properties in the 1970s. These tiling patterns appear in Islamic art and their three-dimensional counterparts have been found in certain synthetic metal alloys and in a rare, recently discovered mineral from Russia, icosahedrite, Al₆₅Cu₃₅Fe₁₃. Such once “forbidden” crystals are called quasicrystals. Quasicrystals represent a new form of solid matter that falls in between the true periodicity of crystals and the irregular, disorderly arrangement of atoms in glass.

Figure 5. (a) Arrangement of pentagons with 5-fold symmetry axes, perpendicular to the page, leaving gaps between them. (b) Arrangement of hexagons with 6-fold axes, perpendicular to the page, forming a perfect fit, as in honeycombs.

Figure 6. Penrose tiling filling 2-D space; an analog of a 3-D quasicrystal.
3. Symmetry Operations

1) Rotation around an axis. Rotational symmetry refers to the number of times a crystal element can repeat around an axis through a full circle (360°), bringing it to an equivalent position (Fig. 4a).

- \( \Lambda_1 \): 1-fold symmetry (once in a 360° rotation)
- \( \Lambda_2 \): 2-fold symmetry (twice in a 360° rotation)
- \( \Lambda_3 \): 3-fold symmetry (three times in a 360° rotation)
- \( \Lambda_4 \): 4-fold symmetry (four times in a 360° rotation)
- \( \Lambda_6 \): 6-fold symmetry (six times in a 360° rotation)

2) Reflection across a mirror plane (m). The mirror plane divides the crystal into two equivalent halves that are related to each other as mirror images (e.g., like left and right hands; Fig. 4b).

3) Inversion through a center (I). Equivalent points are related to each other by passing a line from the point on the surface through the center to the equivalent point on the opposite side (Fig. 4c).

4) Rotation combined with inversion.
   - 1 Equivalent to inversion through a center (3).
   - 2 Equivalent to a mirror reflection (2).
   - 3 Equivalent to a 3-fold rotation combined with a center of symmetry (1 and 3).
   - 4 This combination of a 4-fold rotation with an inversion through a center has no other equivalent. It is unique.
   - 6 Equivalent to a 3-fold rotation combined with a mirror plane perpendicular to the rotational axis (1 and 2).

Figure 7. Symmetry elements associated with the three minerals in Fig. 1.

(a) Quartz
Hexagonal
32

(b) Apophyllite
Tetragonal
4/m2/m2/m

(c) Pyrite
Cubic
2/m3

Figure 8. Actual crystals of the three minerals shown in Fig. 1 and Fig. 7.

(a) Quartz
(b) Apophyllite
(c) Pyrite (pyritohedron)
Crystallography 2014

international year of crystallography

Crystallography matters!

International Year of Crystallography 2014
4. Crystal Systems
These are reference systems defined by a set of three (or four) axes in three-dimensions (Fig. 9). Each crystal system has a unique combination of axial lengths and angles separating them. In most cases, these reference axes are selected to coincide with rotational symmetry axes or to be perpendicular to mirror planes. They are also usually taken parallel to the intersection edges of the most common or prominent crystal faces. There are six crystal systems (although some texts divide the hexagonal system into two separate ones, namely the hexagonal and the trigonal (or rhombohedral) systems. The six crystal systems are:
1. **Cubic (or Isometric)**. All three axes are equal in length \( a_1 = a_2 = a_3 \) and mutually perpendicular.
2. **Tetragonal**. Two of the three axes are equal in length \( a_1 = a_2 \neq a_3 \). All three axes are mutually perpendicular.
3. **Hexagonal**. Three axes are equal in length and 120° apart \( a_1 = a_2 = a_3 \). The fourth axis, \( c \), is unequal in length to the other three, but is perpendicular to the plane in which they lie.
4. **Orthorhombic**. All three axes are unequal in length \( a \neq b \neq c \), but are mutually perpendicular.
5. **Monoclinic**. All three axes are unequal in length \( a \neq b \neq c \). The \( b \)-axis is perpendicular to the plane containing the \( a \) and \( c \) axes.
6. **Triclinic**. All three axes are unequal in length \( a \neq b \neq c \), and none of the angles between them is 90°.

Figure 9. The six crystal systems.
5. Crystal Classes (Point Groups)

Crystals can be further subdivided on the basis of a common set of symmetry elements into 32 crystal classes, distributed among the six crystal systems.

Table 1 lists the 32 crystal classes according to their crystal system and symmetry operations. The symbols summarize the symmetry operations. For example, under “Symmetry Elements”, $2A_2$ means 2 rotational axes of twofold symmetry, $3m$ means 3 mirror planes, $I$ is an axis of inversion, and so on. The notations under “Crystal Class” summarize the symmetry elements. For example, in the isometric system, the symmetry elements of the hexoctahedral class (with the highest symmetry) are: $4/m$ $3 2/m$. The 4 represents the three 4-fold rotational axes of the cube, along the 3 cube directions. The $/m$ means that there is a mirror plane perpendicular to the 4-fold axis—hence a total of three mirror planes perpendicular to the cube axes, 3 refers to 3-fold axes along cube diagonals (of which there are 4), the bar over the 3 means a combination of the 3-fold rotation axes with a center of symmetry, 2 refers to a set of 6 2-fold axes between cube edges, and the last $/m$ equals 6 mirror planes perpendicular to these. For other crystal systems, the highest symmetry axis is listed first, followed by other symmetry axes and mirror planes.

A careful examination of surface features on crystal faces, such as growth striations, natural or corrosion pits, or variations of luster, reveals the true symmetry of the crystal, which may be lower than that suggested by the actual habit. For example, pyrite often shows striations on its cube faces oriented parallel to the three cube directions. The real symmetry of pyrite is therefore lower than that of a complete cube; it is that of the diploidal class, with symmetry elements $2/m$ (Fig. 1c and Fig. 6c; Table 1). Similarly, an apparent octahedron of sphalerite shows four shiny and four striated or pitted faces consisting of two interpenetrating tetrahedra (Figure 10). This places the true symmetry of sphalerite into the hextetrahedral class, i.e., $4 3m$, with 3 fourfold axes combined with a center, 4 threefold axes and 6 mirror planes (Table 1).

Table 1. The 32 crystal classes and their symmetry operations.

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<tr>
<th>Crystal System</th>
<th>Crystal Class</th>
<th>Symmetry Elements</th>
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Cubic (Isometric)

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(1A_1 = 1A_1 + I)
6. Unit Cell
The unit cell is the smallest volume enclosing a group of atoms, ions, or molecules that when extended repeatedly in three dimensions produces the macroscopic (eye visible) crystal. It is the basic repeat unit (Fig. 11). The edges of the unit cell are taken to coincide with the crystallographic axes, which in most cases are also symmetry axes (see above).

Figure 11.

(a) The orthorhombic unit cell of sulfur. (b) The tetragonal unit cell of scheelite (CaWO₄).

7. Axial Ratios
In all of the crystal systems other than the isometric, the crystallographic axes differ in length. The axial ratios are the ratios of the lengths of the edges of the unit cells, which lie parallel to the crystallographic axes. For example, the orthorhombic mineral sulfur (Fig. 11a) has unit cell dimensions a = 10.47Å, b = 12.87Å, and c = 24.49Å (where 1Å = one hundred millionth of a centimeter). Taking the length along the b axis as 1, the ratios between the lengths of the a and c axes relative to b are (10.47/12.87) = 0.813, and (24.49/12.87) = 1.903, respectively. The axial ratios are then 0.813:1:1.903, in the sequence a:b:c. The tetragonal mineral scheelite (Fig. 11b) has unit cell lengths a₁ = a₂ = 5.25Å and c = 11.40Å. Its axial ratios are therefore 1:1:2.17.

8. Miller Indices
Miller Indices are the reciprocals of the relative distances at which the crystal faces intersect the crystallographic axes. For example, in Fig. 11a, the front face of the sulfur crystal intersects the a axis at a length of 1 unit distance, parallel to both the b and c axes. Thus the intercepts of this plane with the crystal axes are 1,∞,∞, respectively. The rhombic pyramid face (shaded) in Fig. 12 intersects the a, b, and c axes at unit lengths 1, 1, and 1 respectively, but the less steeply inclined rhombic pyramid intersects the crystallographic axes at 2 (a), 2 (b), and 2/3 (c). Dividing the latter by the common factor of 2 results in the proportions 1 (a), 1 (b), and 1/3 (c). Note that these represent relative lengths. Since it is cumbersome to deal with infinity and fractions, the fractions are first cleared and the reciprocals are obtained by inverting the numbers. These become the Miller Indices. The Miller Indices for the sulfur crystal (Fig. 11a) are the 100 (front face), 010 (right side face), and 001 (top face). The Miller Indices for the shaded pyramid face (Fig. 12) become 111, and for the less inclined pyramid are 113. The general symbol for Miller Indices for a crystal face is (hkl), where the h, k, and l represent the reciprocals of the intercepts along the a, b, and c axes respectively. The general symbol for a crystal form is {hkl}. Examples of Miller Indices for crystal forms on three common minerals are shown in Figures 13 and 14a, b.

Figure 12. Sulfur crystal — two dipyramids.
Figure 13. Pyrite crystal showing a cube modified by an octahedron and dodecahedron.
Figure 14.

(a) Orthorhombic crystal of topaz, showing prisms and dipyramid.

(b) Monoclinic crystal of orthoclase, showing prisms and pinacoids.

9. Crystal Lattices

The crystal lattice is the three-dimensional periodic array resulting from the repetition of a basic unit (i.e. the unit cell) in three directions in space. Crystal lattices contain the same symmetry elements of the 32 crystal classes (Table 1, also known as point groups), which refer to macroscopic crystals. However, there are two additional symmetry operations in 3-D lattices. These are:

1. Screw axis. This combines a rotation with translation along the rotational axis. Two, three, four, and six-fold screw axes can exist. For example, a 4 screw axis indicates a 90° rotation each 1/4 of the unit length along the axis. Both left and right hand screw axes are possible (Fig. 15a).

2. Glide plane. This combines reflection across a plane with translation. The design motif is translated forward one-half the repeat distance parallel to the mirror plane before being reflected (Fig. 15b).

M.C. Escher (1898 -1972) was a Dutch artist and draftsman, whose periodic artwork beautifully illustrate symmetry operations in two dimensions. Two examples of his artwork are shown in Figs. 16a, b.
10. Bravais Lattices

There are 14 distinct types of unit cell which possess the symmetry properties of the 32 crystal classes (or point groups) discussed earlier. When these unit cells are repeated indefinitely in space, they generate the points or nodes of a crystal lattice. The 14 lattices are called the Bravais Lattices (Fig. 17).

When the 14 Bravais lattices are combined with the symmetry operations belonging to the 32 crystal classes, and the additional symmetry operations of three-dimensional lattices (i.e., the screw axis and glide plane), this results in 230 unique patterns known as the 230 space groups. These space groups are the three-dimensional analogs of the 32 point groups.

Figure 17. The 14 Bravais lattices.
11. Polymorphism

Minerals with the same chemical composition that exist in more than one crystal structure, depending on different physical conditions of temperature and pressure, are known as polymorphs. Familiar examples include graphite and diamond (both C), calcite and aragonite (CaCO₃), and pyrite and marcasite (FeS₂). One polymorph is usually less stable than the other under normal surface terrestrial conditions. For example, diamond, aragonite, and marcasite are less stable at the Earth’s surface (i.e., metastable), and given enough time will invert to the more stable form. (However, the chemical bonds in diamond are so strong that for all practical purposes it will persist indefinitely).

Diamond and Graphite

A more strikingly divergent pair of polymorphs can scarcely be imagined! Both diamond and graphite are chemically identical – made of the element carbon. But there the similarity ends. Diamond is the hardest known substance; graphite one of the softest. Diamond had a highly brilliant luster (i.e. adamantine); graphite has a dull, submetallic, greasy luster. Diamond is a perfect heat conductor; graphite is not. The reason for this disparity lies in the crystal structure of the two minerals. In diamond, each carbon atom is tightly bonded to four other carbon atoms at the corners of a tetrahedron (Fig. A). Diamond also displays perfect octahedral (111) cleavage. In graphite, each carbon atom is linked to three others forming hexagonal sheets, much like a honeycomb or bathroom tiles (Fig. B). The sheets are stacked one on top of the other, like pages in a book, but they are connected to each other by much weaker bonds. Thus, graphite has perfect basal (0001) cleavage. The ability of carbon sheets to glide past each other makes graphite an excellent lubricant. This example dramatically illustrates the close connection between the atomic structure of minerals and their macroscopic physical properties.

12. Isostructuralism

There are minerals that differ in chemical composition but share the same crystal structures. These are known as isostructural minerals. Examples include (1) halite (NaCl), sylvite (KCl), chlorargyrite (AgCl), and galena (PbS); (2) the orthorhombic carbonates aragonite (CaCO₃), strontianite (SrCO₃), cerussite (PbCO₃), and witherite (BaCO₃).

Figure 18. Crystal structure of halite.
13. The Internal Structure of Minerals

Modern mineralogy began in 1914, when the Bragg father and son team (Fig. 19) used x-ray diffraction for the first time to investigate the internal arrangement of sodium and chlorine atoms in halite (Fig. 18). Within the last few decades, highly sophisticated instruments now probe extremely minute portions of a crystal to detect subtle variations in chemical composition, study tiny inclusions, and even “see” individual atoms in the crystal. An x-ray-diffraction instrument aboard the Curiosity rover on Mars is the first to probe the mineral make-up of another planet (but that is another story, for another day).

Diffraction is the optical phenomenon whereby light is deflected through a narrow slit or past the edge of an opaque object. One part of the light beam interferes with another, causing light waves to be either in or out of phase with each other. A common example of a diffraction grating is a series of finely engraved parallel lines on a metal plate, producing rainbow-like colors. In precious opal, the vivid play-of-color stems from the diffraction of light from multiple layers of tiny silica spheres of uniform size, stacked in a three-dimensional ordered array, just like the atoms in a crystal 1. The spheres in opal generally range from 0.15 to 0.30 micrometers in diameter (1 micrometer = 1,000th of a millimeter, or 1/1,000,000th of a meter), somewhat smaller than the wavelengths of visible light (0.4 to 0.7 micrometers). Smaller spheres (e.g., ~0.13 micrometers) diffract shorter wavelengths of visible light (purple, blue), whereas larger spheres (diameters of >0.25 to 0.35 micrometers) diffract red—the longest wavelengths of light. As light penetrates into opal, rays are reflected back from the different layers, either amplifying or dampening the light intensities (i.e., causing constructive or destructive interference). The layers of regularly-spaced spheres essentially act as a three-dimensional diffraction grating.

\[ n\lambda = 2d \sin \theta \]

where \( n = 1, 2, 3, 4, \ldots \), integer numbers
\( \lambda \) = the wavelength of incoming x-rays
\( d \) = distance between atomic planes in the crystal (interplanar spacings)
and \( \theta \) = the angle between the incoming and “reflected” x-rays and the atomic plane.

In ordinary opal or potch, the spheres are of varying sizes, or stacked irregularly—hence, the absence of play-of-color.

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1 In ordinary opal or potch, the spheres are of varying sizes, or stacked irregularly—hence, the absence of play-of-color.
This simple equation forms the basis of modern crystallography. Since x-rays from a given source have a specific wavelength, the term $n \lambda$ remains constant. Thus, as the crystal is rotated, the angle the x-ray beam makes with the different atomic planes will vary. Since the spacing, $d$, between atomic planes in the crystal does not change, the only variable is the angle, $\theta$, between atomic planes and the x-ray beam. “Reflections”—actually diffraction maxima—occur only for those angles, $\theta$, that satisfy the Bragg equation. X-ray diffraction is now widely used to identify minerals and to establish their atomic structure. It is also widely used in metallurgy, ceramics, and molecular biology.

In the classic Laue method, a stationary single crystal is exposed to a beam of x-rays in front of a plate of photographic film. The array of spots on the film represent diffraction from specific atomic planes, revealing the symmetry of the crystal in the direction of the beam (for example, if oriented in a cube direction, a crystal of halite or fluorite will display the 4-fold symmetry characteristic of the isometric system. The angle the spots form with the x-ray beam allows the interplanar distances to be calculated and the intensities of the spots are related to the atomic density of the corresponding planes. A powdered sample, placed in a flat cylindrical apparatus containing a narrow film strip, will display a series of curved lines. Measurement of the $\theta$ angles and the relative intensities of the lines yields an x-ray spectrum characteristic of that particular mineral. Major components of a mixture can also be identified in this manner. Other, more sophisticated refinements of these basic methods are routinely employed to examine the internal structure of crystals.

Figure 21. Examples of common crystal structures.
About the New York Mineralogical Club, Inc.

On September 21, 1886, in the home of Professor Daniel S. Martin at 236 West 4th Street, the New York Mineralogical Club was formed through the efforts of George F. Kunz, B.B. Chamberlin and Professor Martin. Monthly meetings followed at the homes of members, with hosts presiding. George F. Kunz was elected Secretary.

At the sixth meeting in March 1887, the name “New York Mineralogical Club” was officially adopted. A constitution and bylaws were approved at the eighth meeting. Since no president was required by this constitution, none was elected until April 1895 when George F. Kunz became the club’s first president, an office he held for many years. At the end of the club’s first year, it had a membership of forty-six, including several notable mineralogists.

The Club, whose original mission was to keep alive an interest in only NYC minerals, is now dedicated to increasing interest in the science of mineralogy through the collecting, describing and displaying of local, national and international minerals and associated gemstones

The club’s fine collection of more than 700 mineral specimens from New York City is housed at the American Museum of Natural History. The collection includes specimens of beryl, chrysoberyl, garnet, tourmaline, stilbite and xenotime, together with various other species. Many of these specimens were found during the construction of New York City’s subway system or in the bedrock underlying the foundations of New York’s famous skyscrapers. About twenty of the finest specimens are now on extended loan to the New York State Museum in Albany and on public view for the first time in decades.

During the 125 years the club has been in existence a number of honorary members have been appointed in recognition of the contributions in the field of minerals and mineralogy. They include: Joseph Arons*, Sir William Henry Bragg*, Russ Buckingham*, Lawrence H. Conklin, Marie Sklodowska Curie*, Edward S. Dana*, Clifford Frondel*, Victor Goldschmidt*, Richard Hauck, Carl Krotki*, Alfred Lacroix*, Charles Palache*, Frederick Pough*, Waldemar T. Schaller*, Leonard J. Spencer* and Herbert P. Whitlock*. (*Deceased)

Dozens of minerals and varieties have been named in honor of club members over the years. The most recent is that of nikischerite, named after Anthony (Tony) Nikischer, a lifetime honorary member of the NYMC.

Starting in the early part of the 20th Century, the Club has published significant booklets on a variety of topics. The most famous is probably James G. Manchester’s Minerals of New York City and Its Environs (1931). In recent years the Club has published four gem and mineral almanacs, two guidebooks to mineralogy as well as several others. Most have received regional or national awards.

A digital, scanned version of the rare “Manchester” was recently created on a CD-ROM in honor of the Club’s 125th Anniversary and made available to a wider public.

The decades of the 1960s, ’70s, and ’80s within the Club reflected the changes, polarity and tumult that the United States experienced at the same time. It was a time of elitism and feminism, great formality and casualness, friendship and strife, discovery and pettiness. Even as the Club celebrated its 100th Anniversary in 1986 to great acclaim (recorded in the esteemed New York Times, for example), with its annual banquet invitations printed by Tiffany’s and with its second female president at the helm, the Club was, in fact, near moribund. It was characterized by low participation, wholesale defections of entire internal segments (e.g., lapidary, gemology) and even vitriolic member resignations.

Due to the selfless efforts of Will Heierman during the late ’80s and early ’90s, the Club found a new life and is once again thriving and stable. He was ahead of his time. His emphasis on inclusiveness and diversity (in terms of both membership and activities) remain in effect to this day.

The New York Mineralogical Club remains one of the most active and esteemed clubs of its type in the United States.

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About the Author

Vivien Gornitz grew up in Queens and New York City, but spent a few formative years in Switzerland, where exposure to the Alpine scenery stimulated a life-long interest in geology and mineralogy. She studied chemistry at Barnard College, and mineralogy/geology at Columbia University under Profs. Paul F. Kerr and Ralph J. Holmes, both former Club members. While current research is focused on sea level rise and coastal impacts of climate change, she still retains a keen interest in minerals, gems and planetary exploration.