Geology 284 - Mineralogy, Fall 2005
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Symmetry

External Shape of Crystals reflects Internal Structure

External Shape is best described by Symmetry

Symmetry

- Repetitive arrangement of features (faces, corners and edges) of a crystal around imaginary lines, points or planes
- Reflects internal ordering and repetition of atoms in the mineral structure

Cubic Shape of Halite reflects its cubic internal structure

Reflection across a Mirror Plane

Exists if two halves of an image or figure are identical

Mammals have Bi-lateral Symmetry (a mirror plane)

Rotational Symmetry

- Rotation of x degrees with respect to a line called the rotation axis leaves the image or shape unchanged

Rotational Symmetry

- If an object looks the same after rotation of $360^o/n$, that object is said to have n-fold rotational symmetry or an n-fold axis
- Called n-fold, because it takes n rotations to return to its original position
- Only certain angles ("-folds") of rotational symmetry are possible in minerals

Rotational Symmetry in Minerals

Name	Short-hand	Angle	Symbol
1-fold	1	360^o	
2-fold	2	180^o	
3-fold	3	120^o	
4-fold	4	90^o	
6-fold	6	60^o	

Only these five types of rotational axes are possible in minerals!

5-fold, 7-fold and other symmetries are not possible in crystals, because you can't fill space with 5-sided objects

6-fold rotation illustrated

Rotational Symmetry of 3-dimensional Objects

6-fold Rotational Axis of Beryl Crystal

To test for rotational symmetry

- Hold a wooden block or crystal with your index finger and thumb on two opposite corners, opposite faces or opposite edges
- Rotate the block or crystal 60^o, 90^o, 120^o, 180^o, and check to see if it looks the same
- Grasp it in other orientations to check for additional rotation axes

All symmetry elements must intersect at the center of the crystal!

Many Crystal shapes have several (or many) Rotation Axes that cross at the center

Inversion or a Center of Symmetry – symbolized by 1 with a bar over it "1-bar"

For every point or face on one side of the center of symmetry,

there is similar point or face at an equal distance on the opposite side of the center

Inversion Centers in Crystals

Rotoinversion: combined rotation and inversion

4-bar - 90^o rotation followed by inversion through the center

4-bar - shapes have two faces or sets of faces on the top and two faces or sets of faces on the bottom, offset by 90^o

Rotoinversion: combined rotation and inversion

3-bar - 120^o rotation followed by inversion through the center

3-bar - shapes have three faces or sets of faces on the top and three faces or sets of faces on the bottom, offset by 60^o

see rhombohedron

"Dogtooth Spar" also has 3-bar symmetry

3-bar axis in Rhodochrosite Rhombohedron

Types of symmetry possible in Minerals

- 1, 2, 3, 4, 6 "proper rotations"
- m mirror planes
- 1-bar center of symmetry
- 4-bar rotoinversion
- 3-bar rotoinversion

These symmetries can be combined in 32 different ways to describe crystal shapes and structures

Minerals are Grouped into Six Crystal Systems based on Symmetry (see handout)

Crystal System	Characteristic (or minimum) Symmetry
Isometric (Cubic) System	four 3 or 3-bar
Hexagonal System	one 6, 6-bar, 3 or 3-bar
Tetragonal System	one 4 or 4-bar
Orthorhombic System	three 2 and/or m
Monoclinic System	one 2 and/or m
Triclinic System	1 or 1-bar

Isometric System

- Four 3 or 3-bar (corner-corner of reference cube)
- All isometric shapes also have three perpendicular 4, 4-bar or 2 axes
- These are the crystallographic axes a_1, a_2, a_3; all equal length
- Isometric forms are equidimensional
- Highest symmetry system

The Cube and Octahedron are simple, common Isometric Forms

Isometric Minerals: Fluorite (CaF_2)

Isometric Minerals: Garnet $(Ca,Fe,Mg,Mn)_3Al_2Si_3O_{12}$

Halite

Isometric Minerals: Pyrite

The Six Crystal Systems (see handout)

Crystallographic Axes

- Reference axes
- Conventional ways to hold and refer to faces on crystals
- Different convention for each system

Crystallographic Axes:
Isometric System

Crystallographic Axes:
Tetragonal System

Tetragonal Examples

Crystallographic Axes:
Orthorhombic System

Crystallographic Axes:
Monoclinic System

Crystallographic Axes:
Triclinic System

Crystallographic Axes:
Hexagonal System

Hexagonal Examples

The Six Crystal Systems – Axial Relationships (see handout)