

Lecture 11 (10/18/2006)

Crystallography

Part 4:

Crystal Forms
Twinning

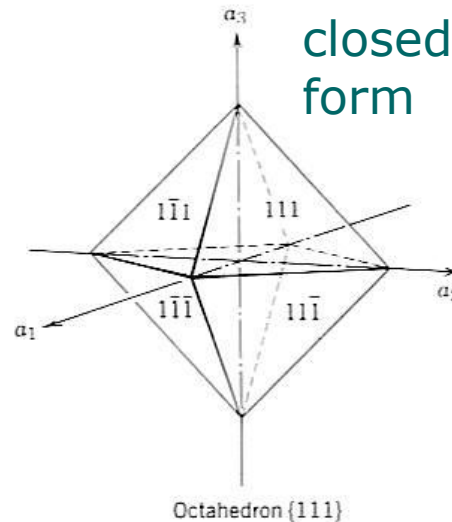
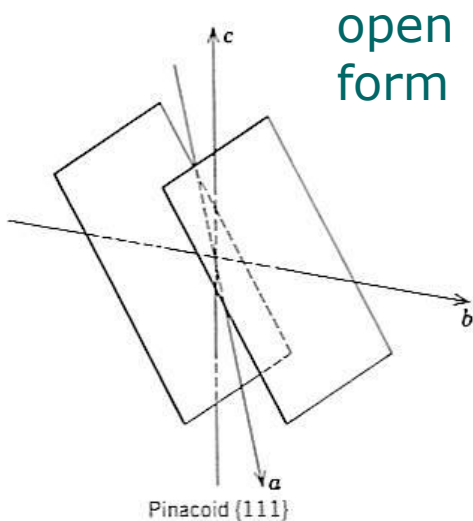
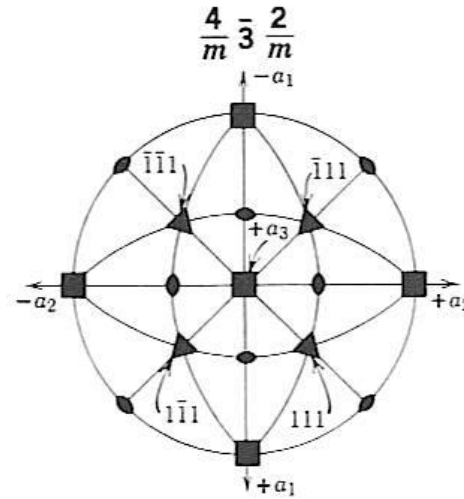
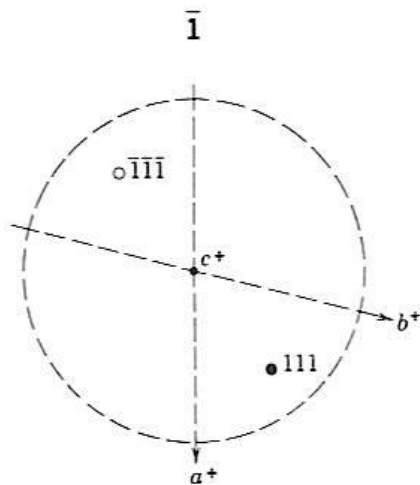
A stylized, dark teal silhouette of a mountain range is positioned in the bottom right corner of the slide, partially overlapping the text area.

Crystal Forms

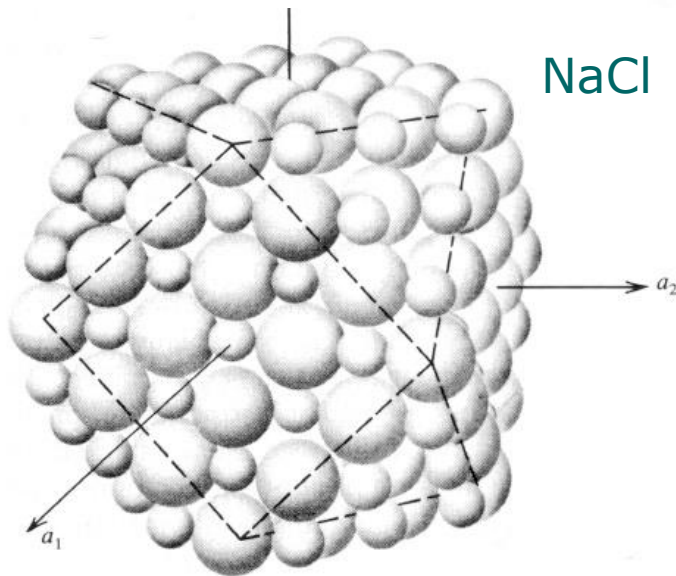
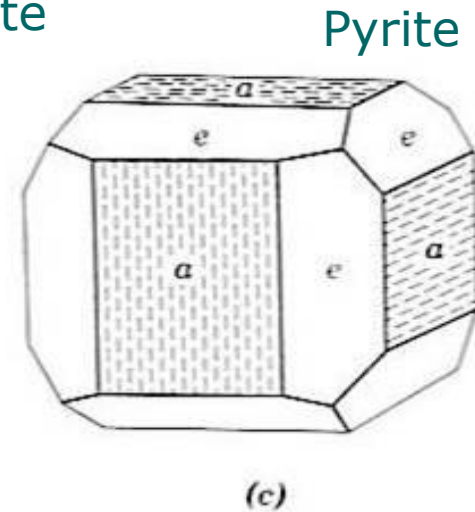
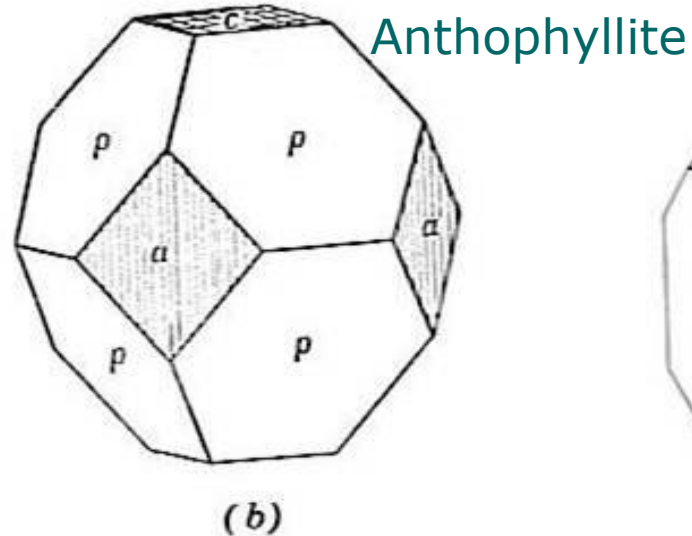
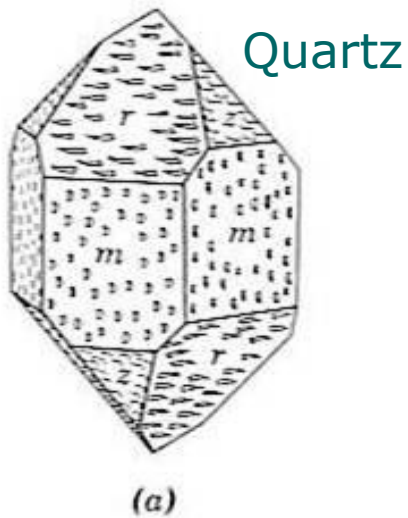
Habit: the general external shape of a crystal (e.g., prismatic, cubic, bladed...)

Form: refers to a group of faces which have the same relation to the elements of symmetry.

Crystals with higher degrees of symmetry tend to generate more form faces.



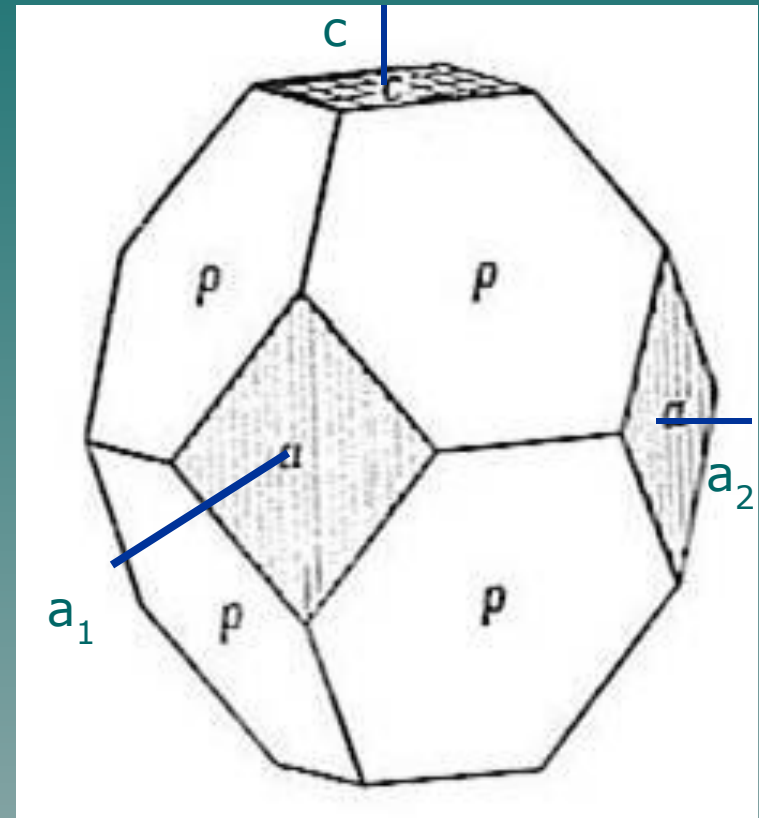
Unique Attributes of Crystal Forms



Faces of particular forms commonly share unique physical or chemical attributes

Form Indexes

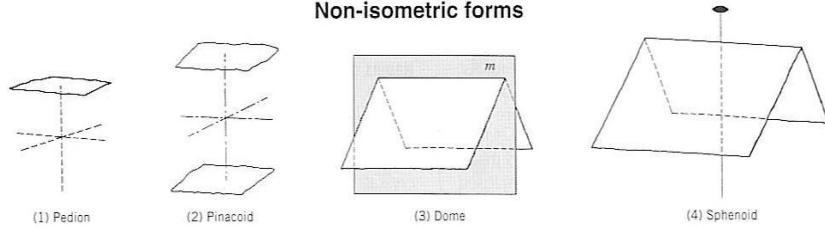
- ◆ defined by the Miller index (hkl) of the face in the positive quadrant
 - ◆ enclosed in brackets {hkl}
- a {100}, ρ {111}, c {001}



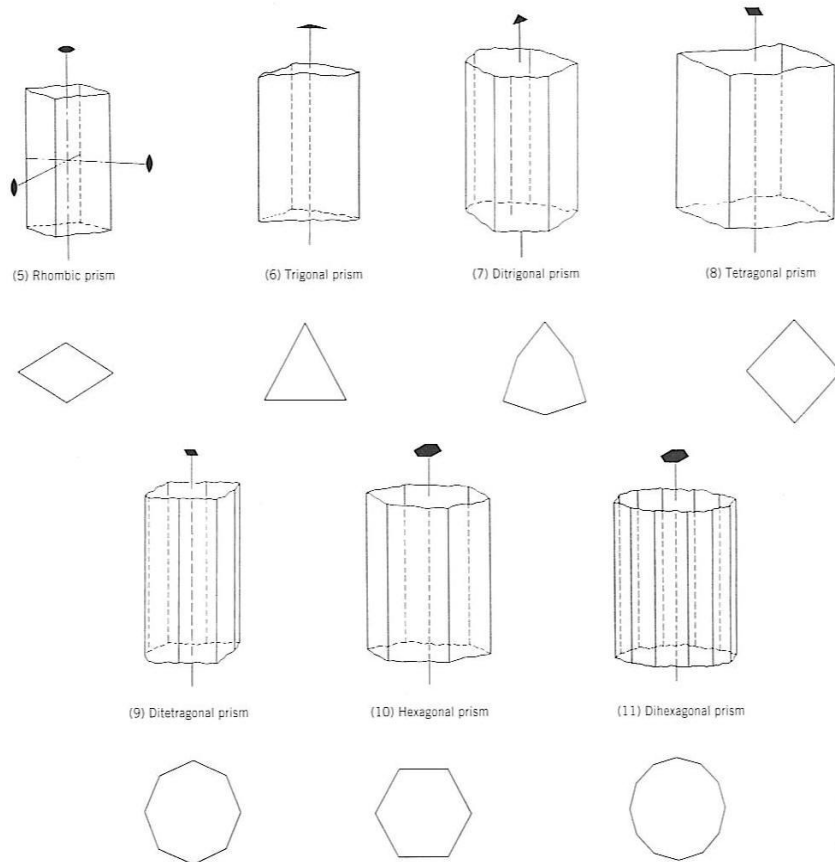
Tetragonal 4/m 2/m 2/m

Low Symmetry Forms

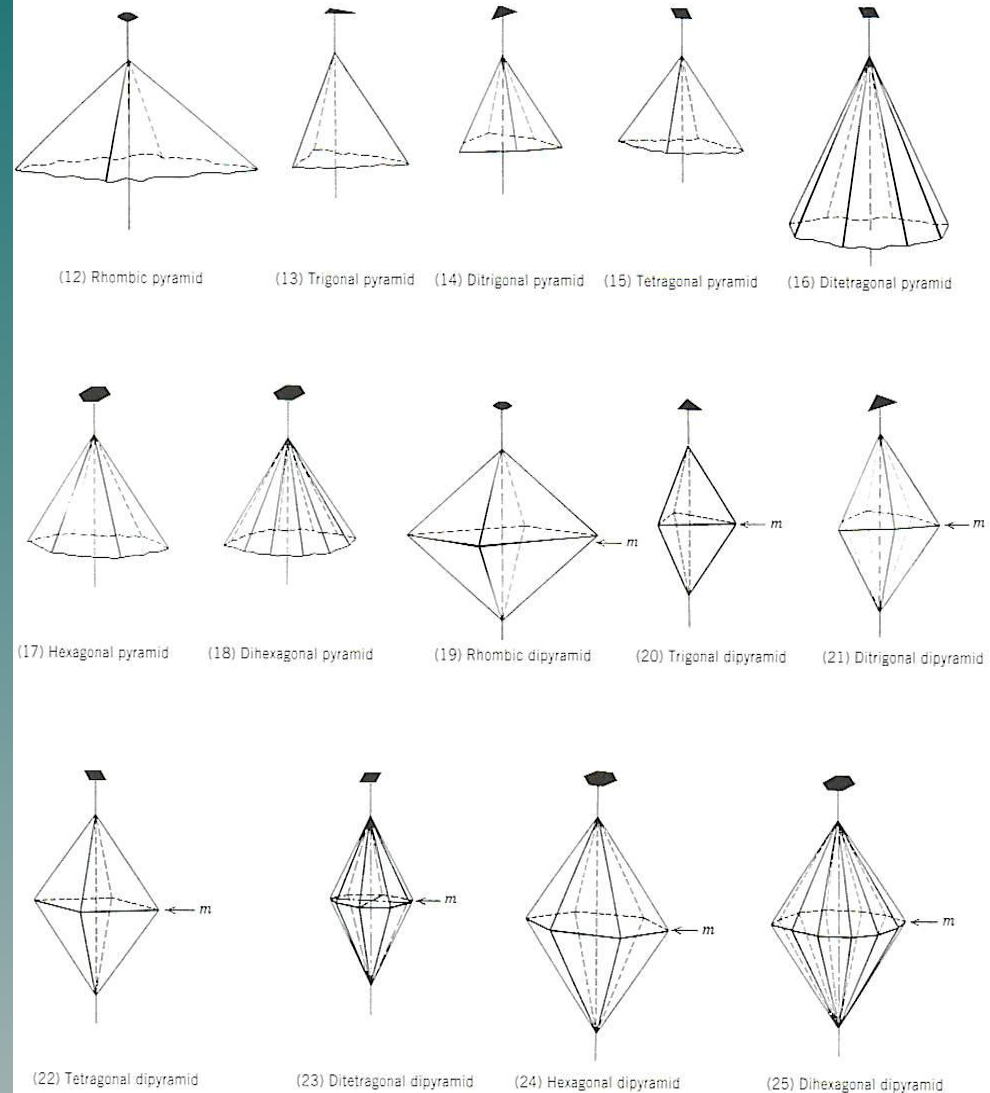
Non-isometric forms



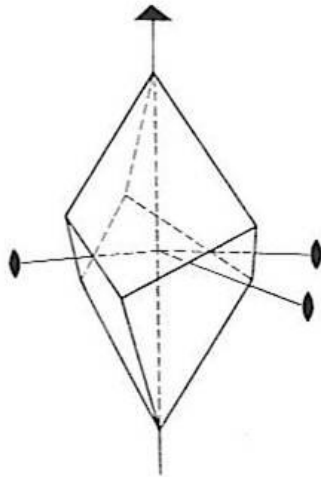
Prisms



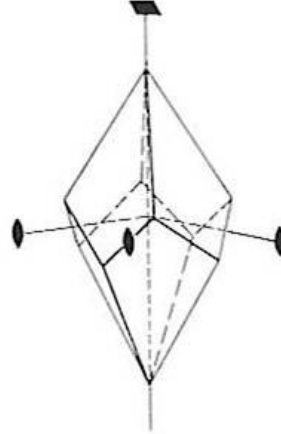
Pyramids and Dipyramids



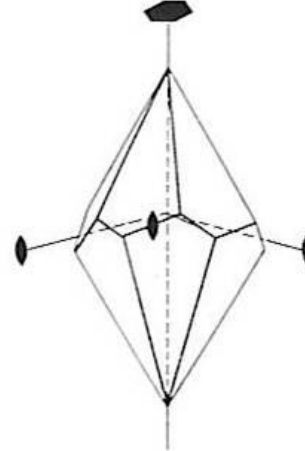
Trapezohedron, Scalehedron, Rhombhedron, Disphenoid



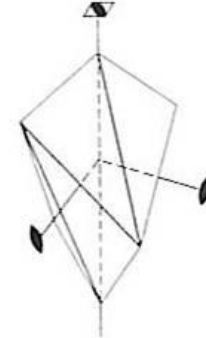
(26) Trigonal trapezohedron



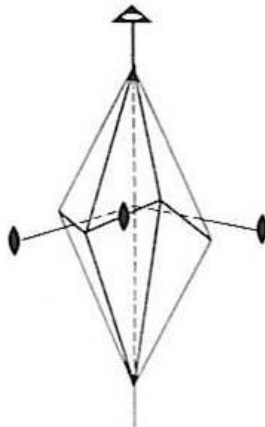
(27) Tetragonal trapezohedron



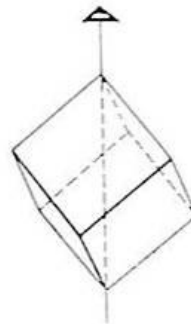
(28) Hexagonal trapezohedron



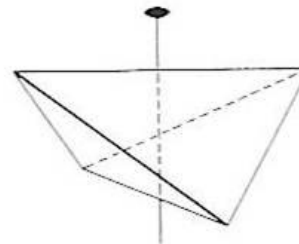
(29) Tetragonal scalenohedron



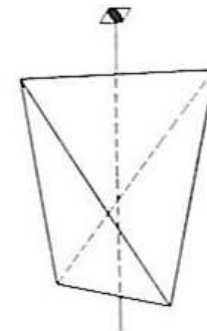
(30) Hexagonal scalenohedron



(31) Rhombohedron

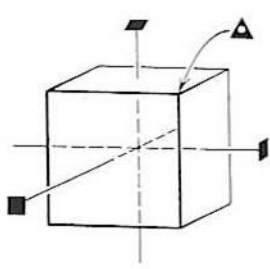


(32) Rhombic disphenoid

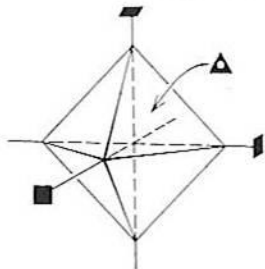


(33) Tetragonal disphenoid

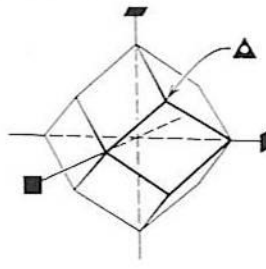
Isometric Forms



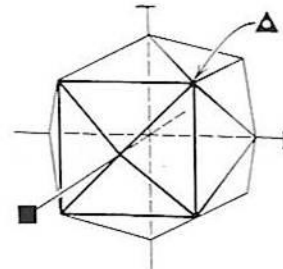
(34) Cube (hexahedron)



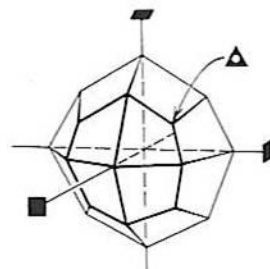
(35) Octahedron



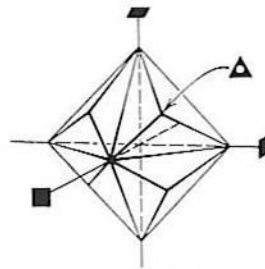
(36) Dodecahedron



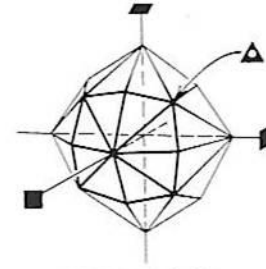
(37) Tetrahexahedron



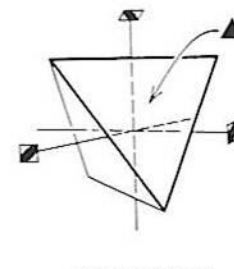
(38) Trapezohedron



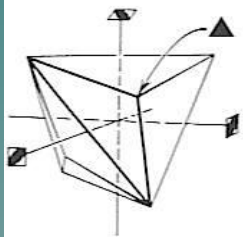
(39) Trisoctahedron



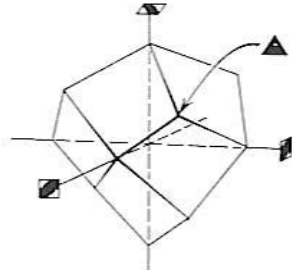
(40) Hexoctahedron



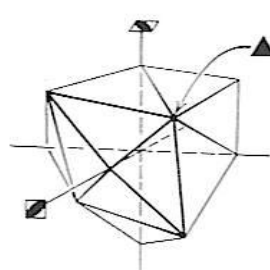
(41) Tetrahedron



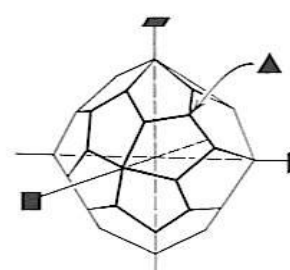
(42) Tristetrahedron



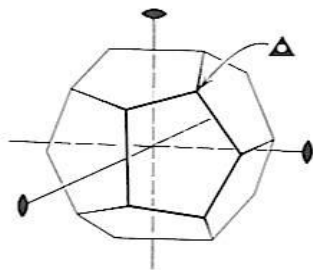
(43) Deltoid dodecahedron



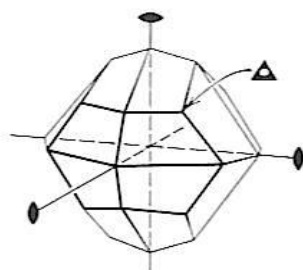
(44) Hextetrahedron



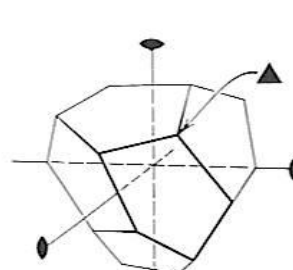
(45) Gyroid



(46) Pyritohedron



(47) Diploid



(48) Tetartoid



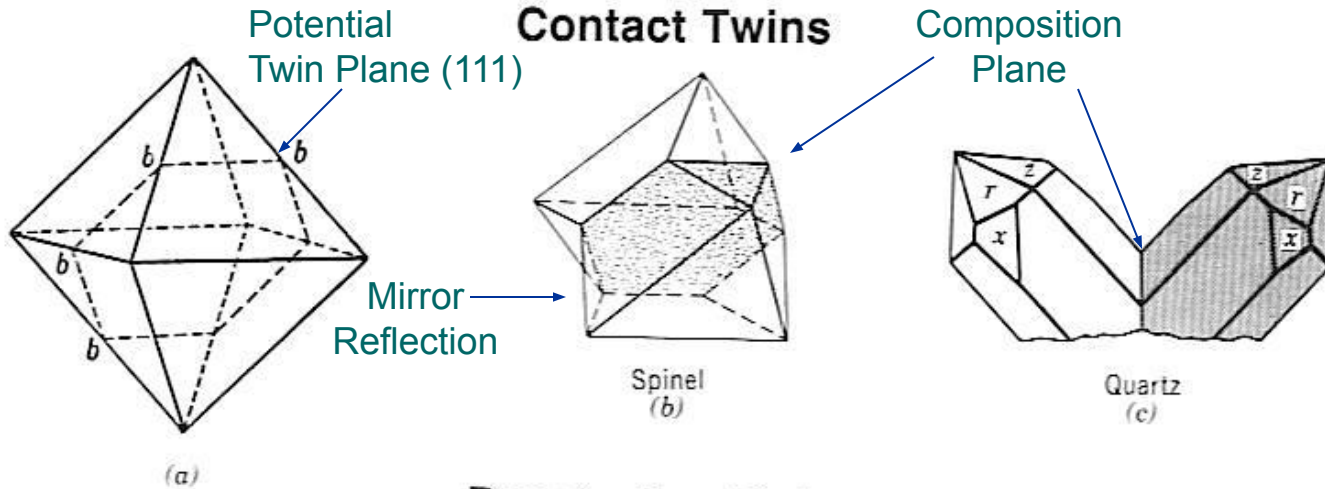
Twinning



- ◆ Symmetrical intergrowth of two or more crystals related to a symmetry operation (twin element) that is otherwise absent in a single crystal.
- ◆ Twin elements includes mirrors, rotation axes (usually 2-fold) and roto-inversion that usually do not align with symmetry elements in the crystal.
- ◆ Twin Laws define the twin element and its crystallographic orientation (twin planes are identified by its Miller index (hkl) , twin axes are defined by a zone symbol $[hkl]$).

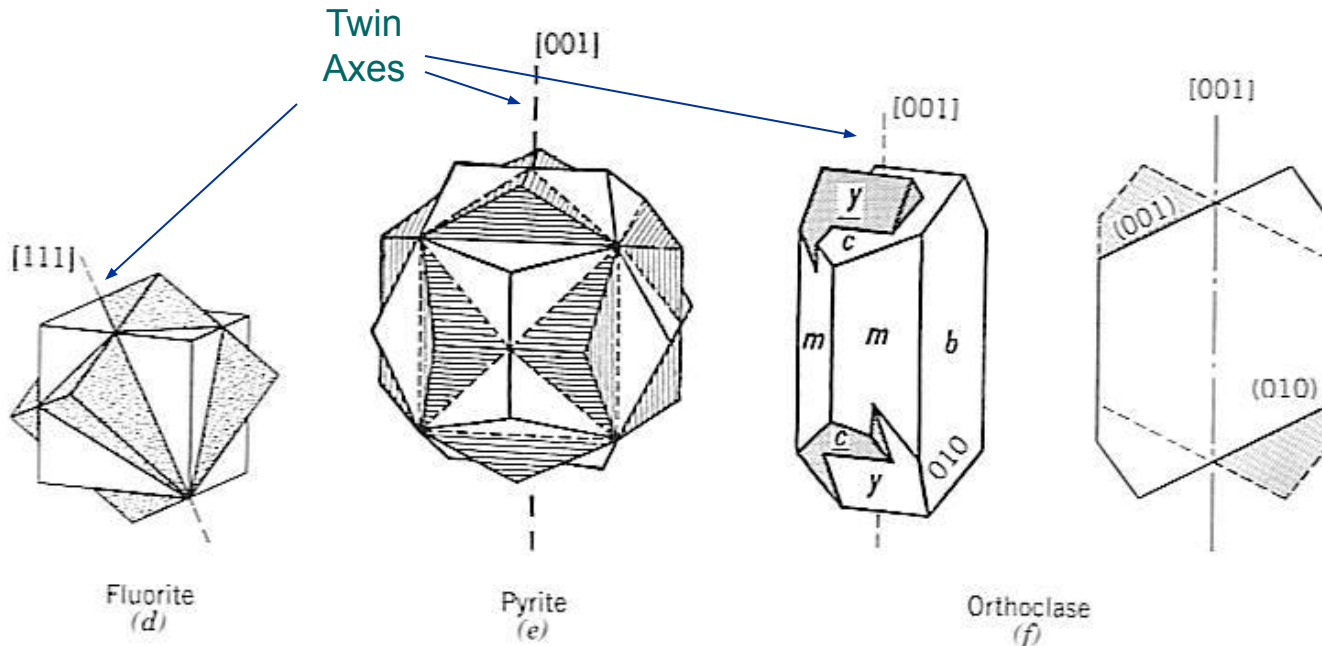
Twin Types

Contact Twins



Contact Twins
Composition planes correspond to twin planes (mirrors)

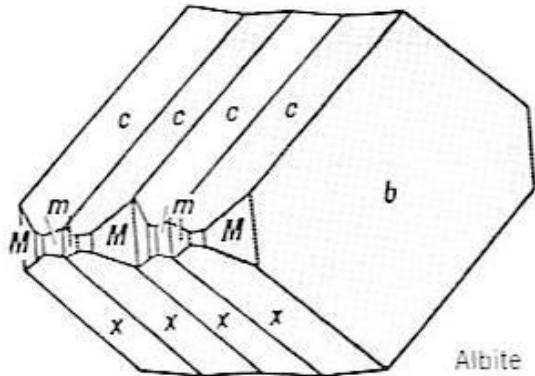
Penetration Twins



Penetration Twins
Composition planes are irregular; formed by rotational twin axis operation

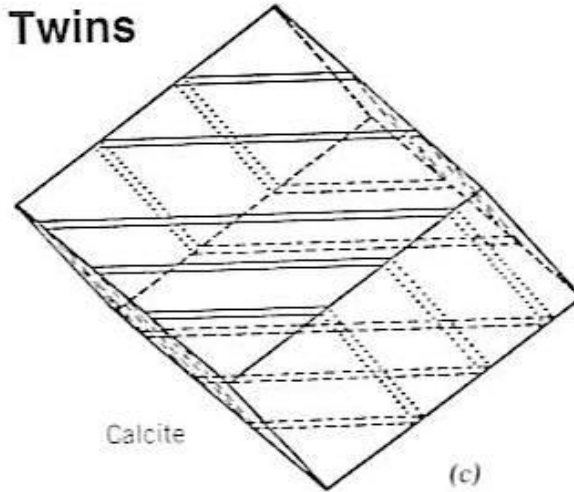
Multiple Twins

Polysynthetic Twins



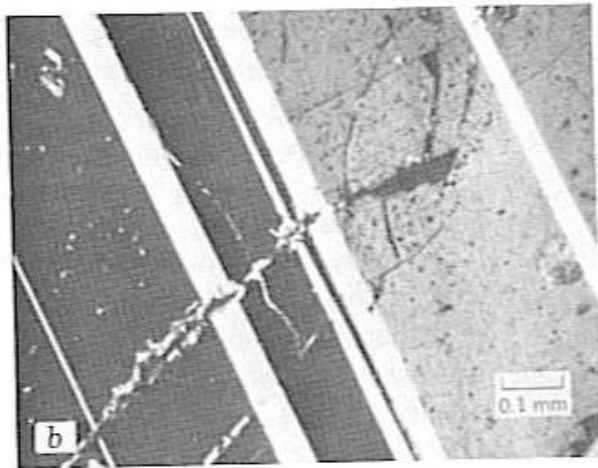
(a)

Albite

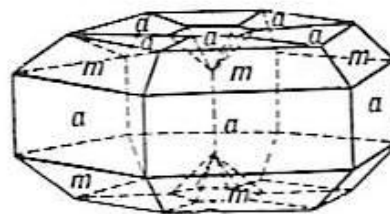


Calcite

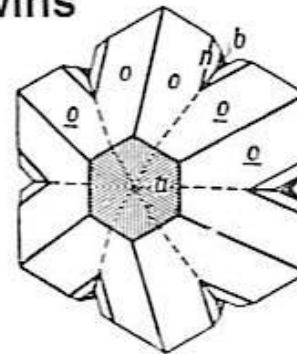
(c)



Cyclic Twins



Rutile
(d)



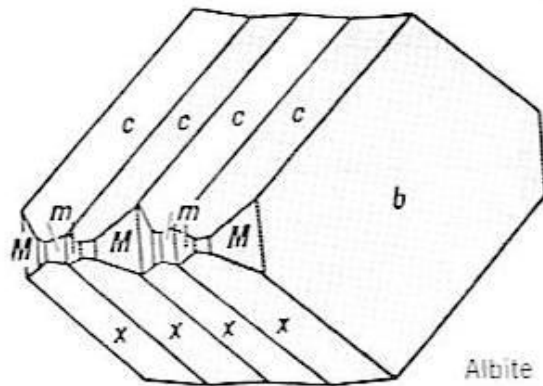
Chrysoberyl
(e)

Formed from 3 or more twinned crystals

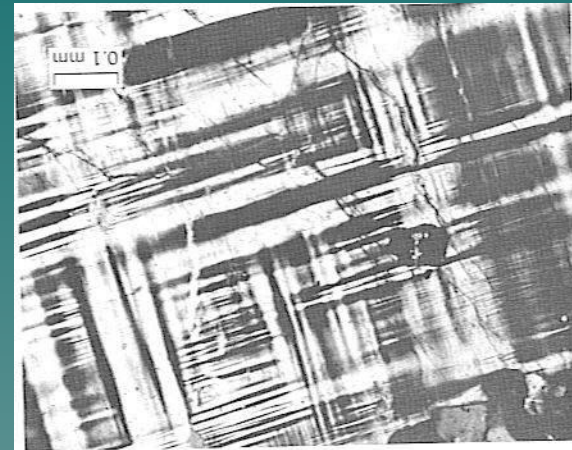
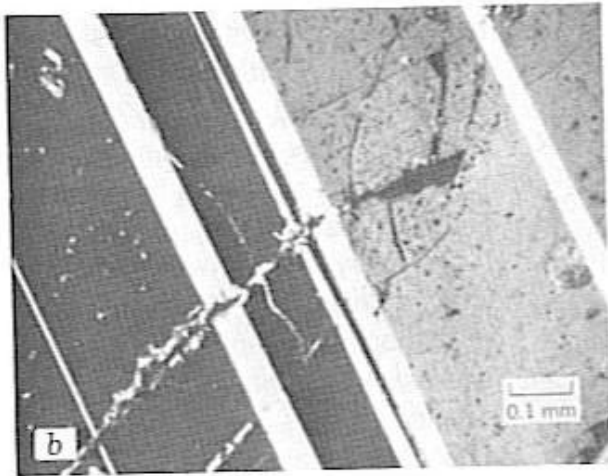
- Polysynthetic twins where composition planes are parallel

- Cyclic twins where composition planes are not parallel

Twin Laws in the Triclinic System



(a)



Albite combined with Pericline Law [010] twin axis results in "tartan twinning" in microcline (K-feldspar)

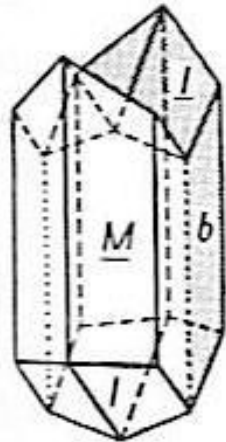
Albite Law
 $\{010\}$ twin plane

Twin Laws in the Monoclinic System



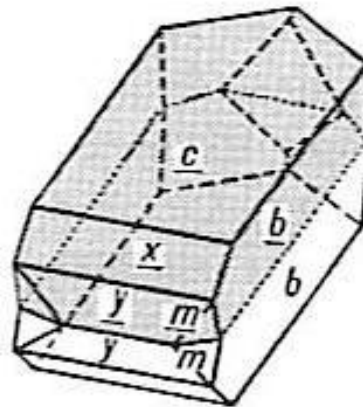
Monoclinic Twins

Note that twin planes do not align with mirror planes



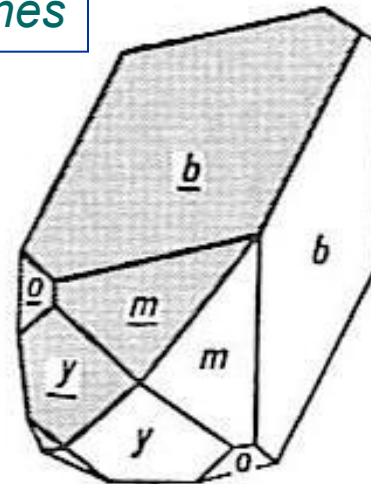
Gypsum.
Twin plane {100}.

Swallow-tail
twin



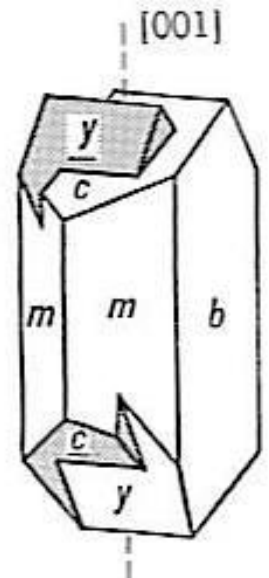
Twin plane {001}.

Manebach
twin



Twin plane {021}

Baveno
twin

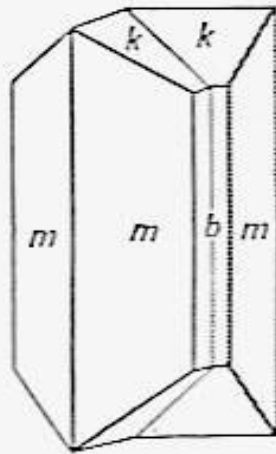


Twin axis [001].

Carlsbad
interpenetration
twin

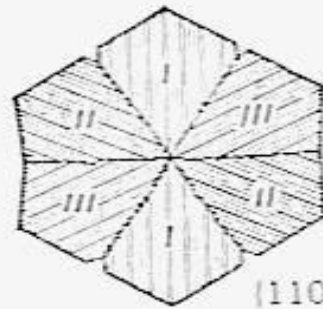
Orthoclase

Twin Laws in the Orthorhombic System



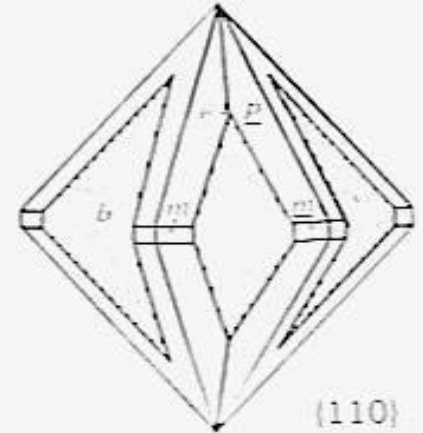
contact & cyclic
twinning

(110)



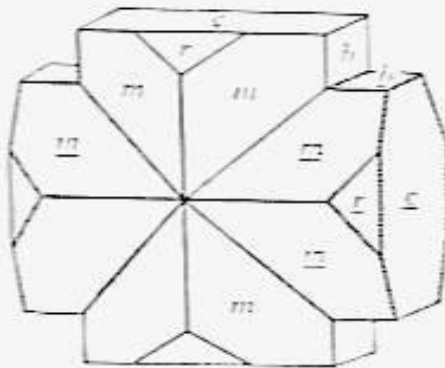
(110)

Aragonite
(a)

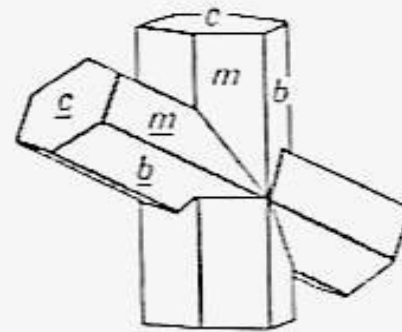


(110)

Cerussite
(b)



(031)



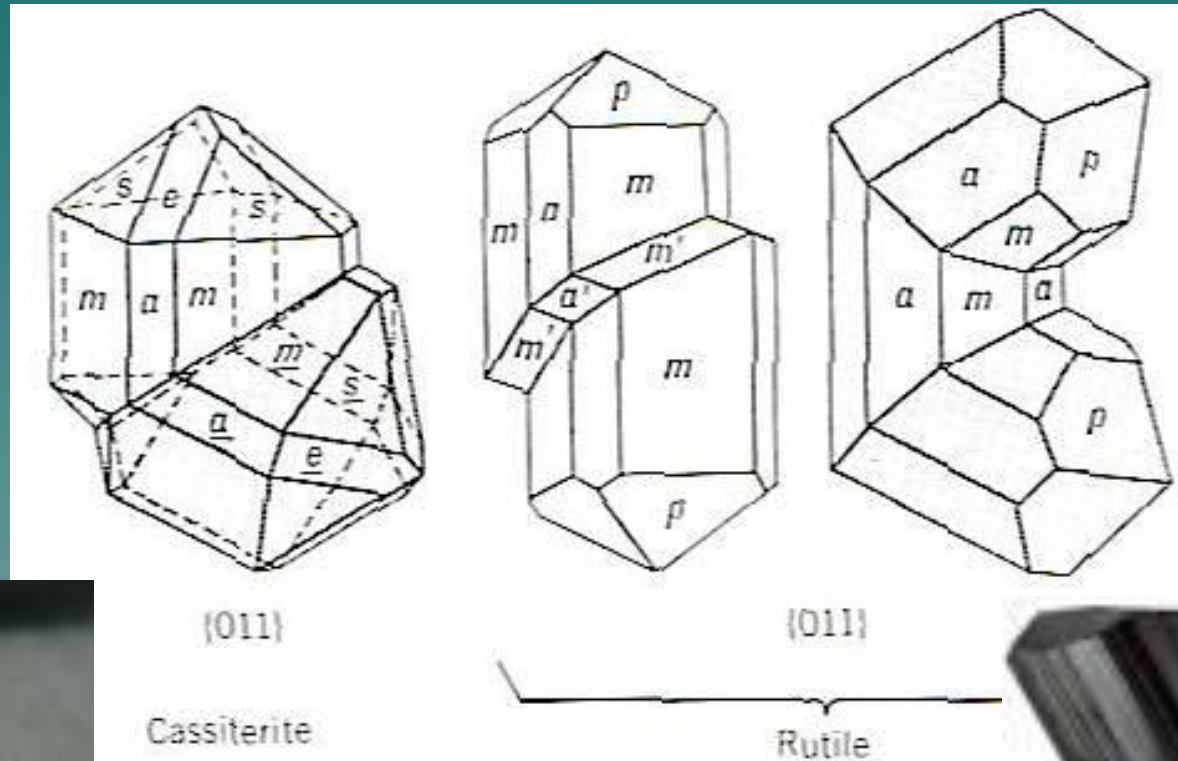
(231)

Staurolite
(pseudo-orthorhombic)
(c)



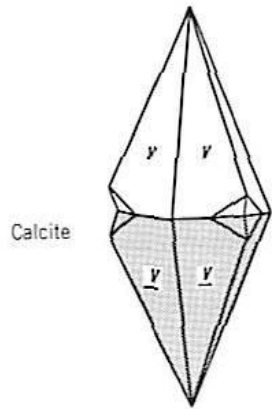
Contact or Penetrative??

Twin Laws in the Tetragonal System

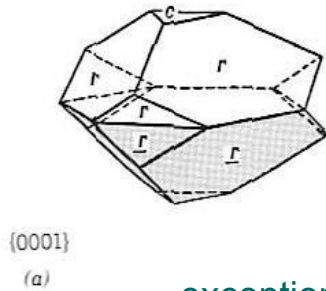


Twin Laws in the Hexagonal System

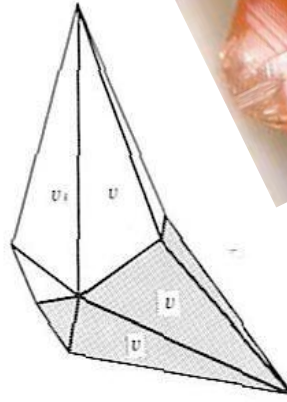
$\{01\bar{1}2\}$ is most common and may produce single contact or polysynthetic twins



Calcite

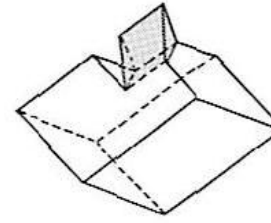


$\{0001\}$
(a)

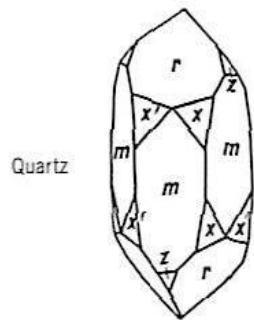


$\{01\bar{1}2\}$

(b)



$\{01\bar{1}2\}$

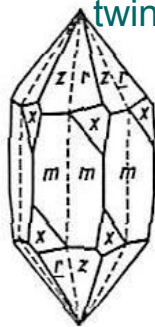


Quartz

$\{11\bar{2}0\}$

Brazil twin

(c)

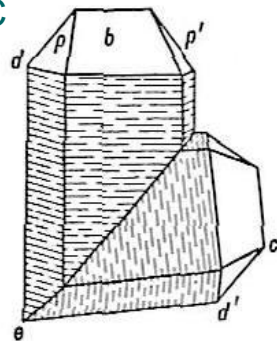


$[0001]$

Dauphiné twin

(d)

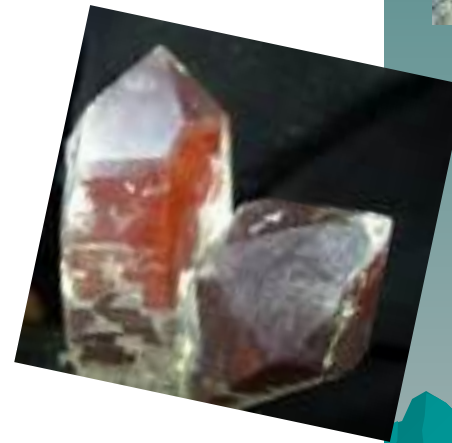
exception:
twin axis $\parallel C$



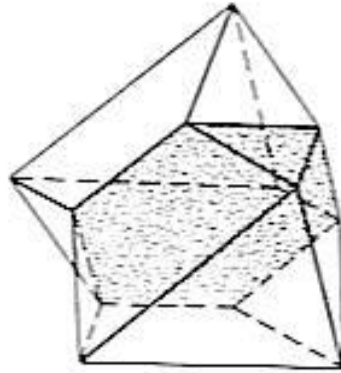
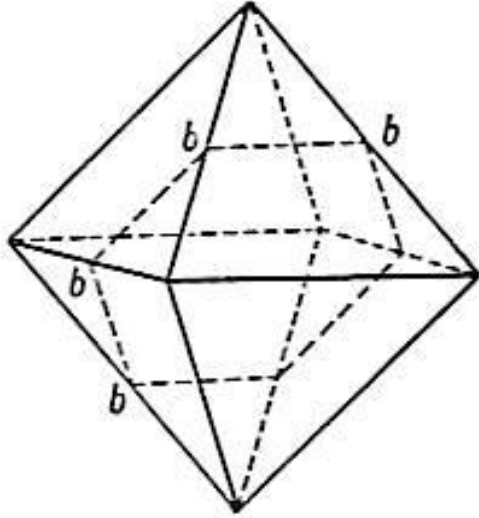
$\{11\bar{2}2\}$

Japan twin

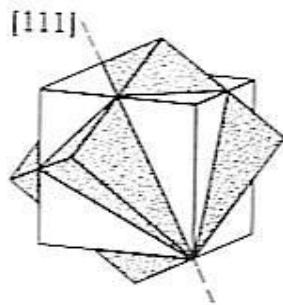
(e)



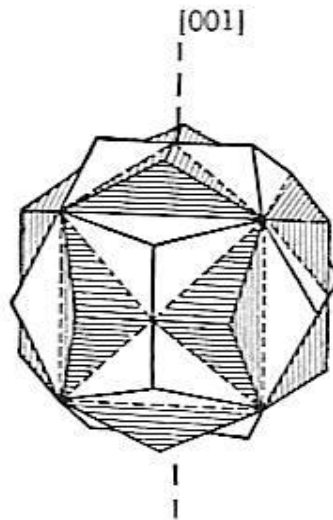
Twin Laws in the Isometric System



Spinel
(b)



Fluorite
(d)



Pyrite
(e)



Penetrative
twins with
twin axes
parallel to
rotational
axes

Next Lecture

No Lecture Next Week
Yeah!!!

