University of Anbar

Collage of Science

Department of Geology

Minerals / 1st stage.

Tectosilicates (Framework Silicate) & Bowen's Reaction Series

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TECTOSILICATES (FRAMEWORK SILICATE) & BOWEN'S REACTION SERIES

LECTURE NINE

TECTOSILICATES (FRAMWORKSILICATE)

Tectosilicates ($[Al_xSi_yO_{2(x+y)}]^{x-}$) structure is composed of interconnected tetrahedrons going outward in all directions forming an intricate framework. All the oxygens are shared with other tetrahedrons in this subclass. In the near-pure state of only silicon and oxygen, the prime mineral is quartz (SiO2). Aluminum ion can easily substitute for the silicon ion in the tetrahedrons. In other subclasses, this occurs to a limited extent but in the tectosilicates it is a major basis of the varying structures. While the
tetrahedron is nearly the same with an aluminum at its center, the charge is now a negative five (-5) instead of the normal negative four (-4). Since the charge in a crystal must be balanced, additional cations are needed in the structure and this is the main reason for the great variations within this subclass

THE MOST IMPORTANT PETROGENIC MINERALS FROM THE GROUP TECTOSILICATES

FELDSPAR GROUP	
ALKALINE FELDSPARS	
Orthoclase $KAlSi_3O_8$ Medium-temperature monoclinic K–feldspar	Sanidine $(K,Na)AlSi_3O_8$ High-temperature monoclinic K–Na feldspar
Microcline $KAlSi_3O_8$ Low-temperature trilinic K–feldspar	Anorthoclase $(Na,K)AlSi_3O_8$ High-temperature triclinic Na–K feldspar
PLAGIOCLASE ***Isomorphic series of Albite (Ab) - Anorthite (An)***	
Acid or Na–Plagioclase	Neutral or Na/Ca–Plagioclase
Albite $NaAlSi_3O_8$ (Ab) 0–10% an component Oligoclase 10–30% an component	Andesine 30–50% an component

BASE OR CAePLAGIOCLASE	
Labrador 50e70% an component	Bytownite 70e90% an component
Anorthite $CaAl_2Si_2O_8$ 90e100% an component	
FELDSPATHOIDES GROUP	
Nepheline $KNa_3Al_4Si_4O_{16}$	Leucite $KAlSi_2O_6$
ZEOLITE GROUP	
Fibrous zeolite	Cubic zeolites
Natrolite $Na_2Al_2Si_3O_{10}\$2H_2O$	Analcime $NaAlSi_2O_6\$2H_2O$ Phillipsite contains isomorphic admixtures K, Na, Ca, and $6H_2O$
SLIP ZEOLITES	
Laumonitite $CaAl_2Si_4O_{12}\$4.5H_2O$	Heulandite contains isomorphic admixtures K, Ba, Na, Sr, Ca and $12H_2O$
Clinoptilolite contains isomorphic admixtures K, Ba, Na, Sr, Ca, Mg, Fe^{2+} and $12H_2O$	

FELDSPAR GROUP

- Feldspar group is petrogenic most important assemblage of silicate minerals, as it covers almost 58% of the Earth's crust. The proportion of feldspar is extremely high in igneous, sedimentary and metamorphic rocks. The chemical compositions of feldspar group represent the aluminosilicates of potassium (Or-component), sodium (Ab-component) and calcium (An-component). It often forms isomorphic mixture of sodium and calcium components, i.e. plagioclase . Potassium and sodium component form isomorphic mixture only in igneous rocks that crystallize at high temperatures and the product is known as alkali feldspar.

ALKALI FELDSPARS

1. The alkali feldspars include monoclinic feldspars (orthoclase and sanidine) and triclinic feldspars (microcline and anorthoclase).
2. The hardness is from 6 to 6.5 and the relative density of 2.55-2.63. The color is usually white, and sometimes changes from pale pink to reddish due to admixtures of iron (especially microcline).

PLAGIOCLASE FELDSPAR SERIES

- Plagioclases are triclinic feldspars that form a complete isomorphic compounds which are the final members of the Na-plagioclase albite NaAlSi3O8 (Ab)and Ca-plagioclase anorthite CaAl2Si2O8(An)

Plagioclase Minerals and Their Compositions		
Mineral	% $NaAlSi_3O_8$ (%Ab)	% $CaAl_2Si_2O_8$ (%An)
Albite	100e90	0e10
Oligoclase	90e70	10e30
Andesine	70e50	30e50
Labradorite	50e30	50e70
Bytownite	30e10	70e90
Anorthite	10e0	90e100

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GROUP FELDSPATHOIDS

- The feldspathoids are a group of tectosilicates and alkali alum-silicate minerals which resemble feldspar, but have a different structure and much poor in silica content and alkali-rich elements like sodium, potassium and lithium. Feldspathoids occur in rare and unusual types of igneous rocks. The main minerals of the feldspathoids group are nepheline and leucite

ZEOLITES GROUP

- The zeolites includes hydrated alumosilicates of alkali (Na and K) and earth-alkaline (Ca, Ba, and Sr) elements. The group is represented by large number of minerals of different chemical composition, but with similar properties. The basic feature of their chemical composition is the water content, which is in adsorption and poorly connected to the grid (zeolite water). Such water zeolites are losing when heated, but water is easily readmitted in its lattice. Zeolite crystallizes in different morphological forms, in different crystal systems: cubic, orthorhombic monoclinic and hexagonal. All, however, have very similar properties: usually colorless or gray due to impurities, the relative density of 2.1-2.4 and weakly resistant to chemical weathering

Physical Properties of Olivine

Chemical Classification	Silicate
Color	Usually olive green, but can be yellow-green to bright green; iron-rich specimens are brownish green to brown
Streak	Colorless
Luster	Vitreous
Diaphaneity	Transparent to translucent
Cleavage	Poor cleavage, brittle with conchoidal fracture
Mohs Hardness	6.5 to 7
Specific Gravity	3.2 to 4.4
Diagnostic Properties	Green color, vitreous luster, conchoidal fracture, granular texture
Chemical Composition	Typically $(Mg, Fe)_2SiO_4$. Ca, Mn, and Ni rarely occupy the Mg and Fe positions.
Crystal System	Orthorhombic
Uses	Gemstones, a declining use in bricks and refractory sand

Physical Properties of Epidote

Chemical Classification	*Silicate*
Color	*Usually yellowish green to pistachio green, sometimes brownish green to black*
Streak	*Colorless*
Luster	*Vitreous to resinous*
Diaphaneity	*Transparent to translucent to nearly opaque*
Cleavage	*Perfect in one direction, imperfect*
Mohs Hardness	*6 to 7*
Specific Gravity	*3.3 to 3.5*
Diagnostic Properties	*Color, cleavage, specific gravity*
Chemical Composition	$Ca_2(Al_2,Fe)(SiO_4)(Si_2O_7)O(OH)$
Crystal System	*Monoclinic*
Uses	*Semiprecious gem*

Chemical Classification	*Silicate (Garnet mineral)*
Color	*Typically red, but can be orange, green, yellow, purple, black, or brown. Blue garnets are extremely rare.*
Streak	*Colorless*
Luster	*Vitreous*
Diaphaneity	*Transparent to translucent*
Cleavage	*None*
Mohs Hardness	*6.5 to 7.5*
Specific Gravity	*3.5 to 4.3*
Diagnostic Properties	*Hardness, specific gravity, isometric crystal habit, lack of cleavage*
Chemical Composition	*General formula: $X_3Y_2(SiO_4)_3$*
Crystal System	*Isometric*

Pyrope: $Mg_3Al_2(SiO_4)_3$
Almandine: $Fe_3Al_2(SiO_4)_3$
Spessartine: $Mn_3Al_2(SiO_4)_3$
Grossular: $Ca_3Al_2(SiO_4)_3$
Andradite: $Ca_3Fe_2(SiO_4)_3$
Uvarovite: $Ca_3Cr_2(SiO_4)_3$

Physical Properties of Augite

Chemical Classification	A single chain inosilicate
Color	Dark green, black, brown
Streak	White to gray to very pale green. Augite is often brittle, breaking into splintery fragments on the streak plate. These can be observed with a hand lens. Rubbing the debris with a finger produces a gritty feel with a fine white powder beneath.
Luster	Vitreous on cleavage and crystal faces. Dull on other surfaces.
Diaphaneity	Usually translucent to opaque. Rarely transparent.
Cleavage	Prismatic in two directions that intersect at slightly less than 90 degrees.
Mohs Hardness	5.5 to 6
Specific Gravity	3.2 to 3.6
Diagnostic Properties	Two cleavage directions intersecting at slightly less than 90 degrees. Green to black color. Specific gravity.
Chemical Composition	A complex silicate. $(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$
Crystal System	Monoclinic
Uses	No significant commercial use.

Physical Properties of Hornblende

Chemical Classification	*Silicate*
Color	*Usually black, dark green, dark brown*
Streak	*White, colorless - (brittle, often leaves cleavage debris behind instead of a streak)*
Luster	*Vitreous*
Diaphaneity	*Translucent to nearly opaque*
Cleavage	*Two directions intersecting at 124 and 56 degrees*
Mohs Hardness	*5 to 6*
Specific Gravity	*2.9 to 3.5 (varies depending upon composition)*
Diagnostic Properties	*Cleavage, color, elongate habit*
Chemical Composition	$(Ca,Na)_{2-3}(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH,F)_2$
Crystal System	*Monoclinic*
Uses	*Very little industrial use*

Microcline physical properties

Chemical Formula: *KAlSi3O8*

Color: *White, cream, light yellow, light brown, reddish-brown, pink, light blue, blue-green, green,*

Streak: *White*

Hardness: *6*

Crystal System: *Triclinic*

Transparency: *Translucent to opaque*

Specific Gravity: *2.5 - 2.6*

Luster: *Vitreous*

Fracture: *Conchoidal to uneven*

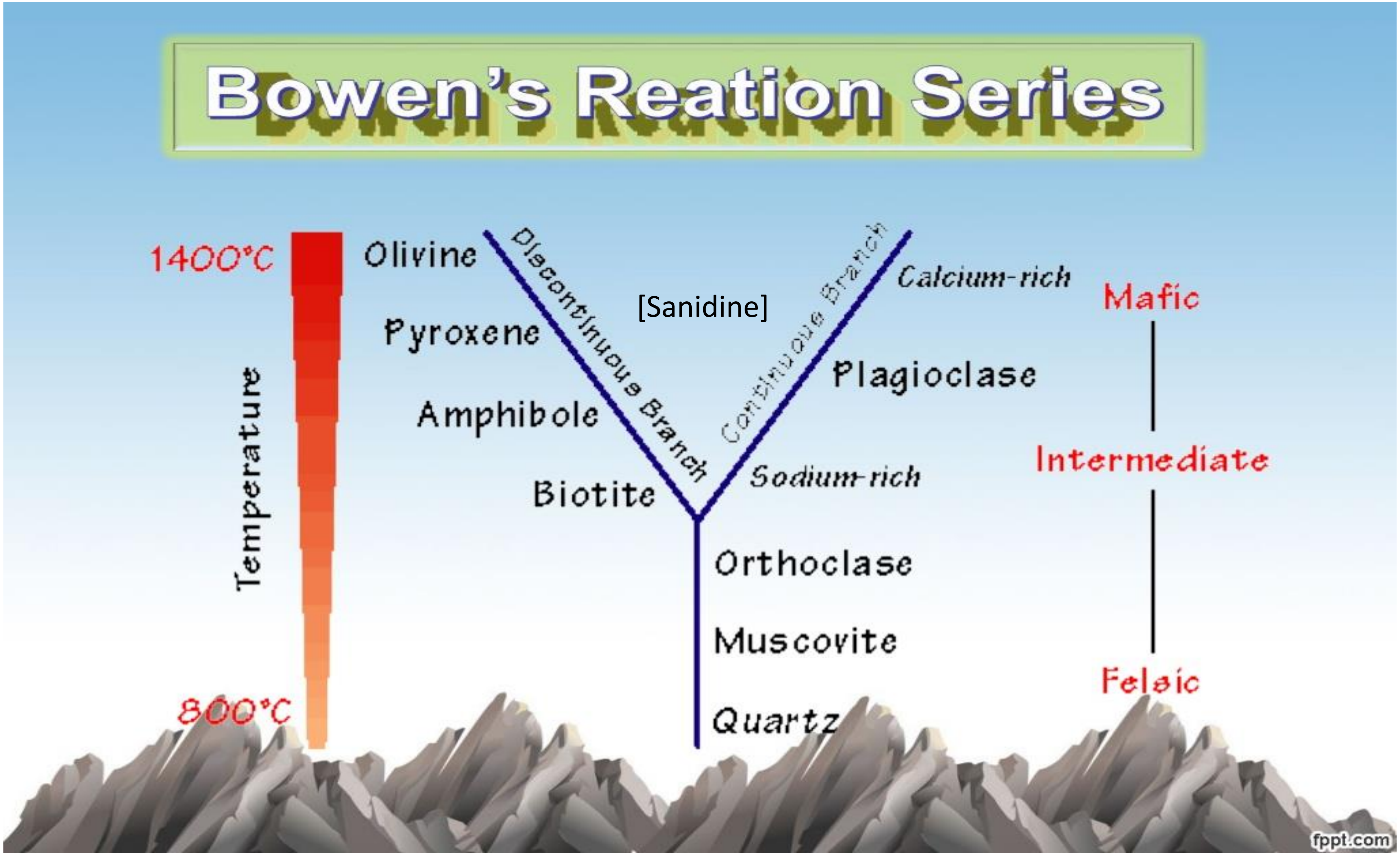
Tenacity: *Brittle*

Physical properties of anorthite

- ***Color:*** *White, grayish, reddish*
- ***Formula:*** $CaAl_2Si_2O_8$
- ***Crystal system:*** *Triclinic*
- ***Cleavage:*** *Perfect*
- ***Fracture:*** *Uneven to Conchoidal*
- ***Tenacity:*** *Brittle*
- ***Hardness:*** *6*
- ***Luster:*** *Vitreous*
- ***Diaphaneity:*** *Transparent to translucent*
- ***Specific gravity:*** *2.72–2.75*

Bowen's Reaction Series

- Back in the early 1900's, N. L. Bowen and others at the Geophysical Laboratories in Washington D.C. began experimental studies into the order of crystallization of the common silicate minerals from a magma. The idealized progression which they determined is still accepted as the general model for the evolution of magmas during the cooling process. As with everything else in geology, there are exceptions to this rule, but for the most part it works. Bowen's reaction series is a means of ranking common igneous silicate minerals by the temperature at which they crystallize. Minerals at the top have a relatively high crystallization temperature, which means that they will be the first minerals to crystallize from a magma that is cooling. IF they are chemically compatible with the magma as it continues to cool, they will grow larger by addition of external layers of additional material. [They then can potentially become the phenocrysts in a porphyritic igneous texture.] If they are chemically incompatible, they will react with the melt and recrystallize into new minerals. What determines this chemical compatibility is in large part the silica content of the melt.



Bowen's Reation Series
1400°C
800°C
Temperature
Olivine
Pyroxene
Amphibole
Biotite
Discontinuous Branch
Continuous Branch
[Sanidine]
Calcium-rich
Plagioclase
Sodium-rich
Orthoclase
Muscovite
Quartz
Mafic
Intermediate
Felsic
fppt.com

- Minerals on the left part of the "Y" of the diagram are what are called ferromagnesian minerals, because they contain iron (Latin: ferrum) and magnesium in their composition. This part of the series is referred to as the discontinuous series, since these minerals, if chemically incompatible with the melt as it cools, will usually completely react to form totally new minerals: an olivine crystallizing in a melt relatively high in silica (e.g., 60%) will completely recrystallize into pyroxene, and that pyroxene may in part or completely recrystallize into hornblende. Because they contain water (as OH - hydroxyl radicals) in their structures, hornblende and biotite in volcanic rocks are almost always phenocrysts that actually crystallized underground before the magma was erupted; they cannot form from crystallization of lava at the surface.

- The minerals on the right arm of the "Y" are the plagioclase feldspars, which form a continuous series from 100% Ca-plagioclase (anorthite) with the highest melting point, to 100% Na-plagioclase (albite) with the lowest melting point. The first crystals forming may only partially re-react with the melt, but without destroying the basic feldspar crystal structure. Very often, large plagioclase crystals in an igneous rock will have cores that are more calciumrich than the outer layers, and sometimes this layering (called zonation) can be clearly seen under the microscope, or even with the naked eye for particularly large crystals. In general, melts higher in silica are higher in sodium (Na) and lower in calcium (Ca).

- The lower portion of Bowen's Reaction Series is dictated more by chemistry than is the upper part. Biotite, orthoclase feldspar and muscovite are the only minerals here that contain large amounts of potassium; of these three, only biotite is found in volcanic rocks. Orthoclase is a mineral found in plutonic rocks, those that crystallize entirely underground. Its hightemperature (1000°C melting point) volcanic equivalent - with the same formula but a different crystal structure - is the mineral sanidine, which is common in high-silica volcanic rocks. Minerals near the bottom of the series also have much higher silica contents than the minerals at the top (e.g., pure olivine is about 38% SiO_2, while pure sanidine is 65% SiO_2). It is this increase in silica content that lowers the melting point; note that quartz, at the bottom of the series, is 100% SiO_2 and has the lowest melting point (about 700°C).

- As a result, rocks that crystallize from mafic melts (45-55% silica) will tend to be made up of minerals that are high in Bowen's reaction series - such as olivine, pyroxene and Ca-rich plagioclase feldspar, and will crystallize at higher temperatures than more silica-rich melts. Rocks from felsic melts (>65-70% silica) will be composed mostly of minerals from the bottom of the series - hornblende and/or biotite, Na-rich plagioclase, sanidine and possibly quartz. Rocks from intermediate magmas will contain minerals from the middle of the sequence. Worth noting is that these are the major minerals that will appear in the rocks; there will be numerous accessory minerals present that are not in Bowen's reaction series; these are present in small quantities only in most cases, but can be very informative about fine details of the magma origins, history and properties. Finding minerals in a volcanoc rock that shouldn't be there can also be extremely informative about the magma history, since there has to be a reason for their existence! Low-silica minerals (e.g., calcium-rich plagioclase, olivine, pyroxene) tend to be dark in color - dark gray for the plagioclase, dark green to black for olivine and pyroxene. As a result, low-silica volcanic rocks are commonly dark in color - dark gray to black. In general, the higher the silica content, the lighter the color of the rocks

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