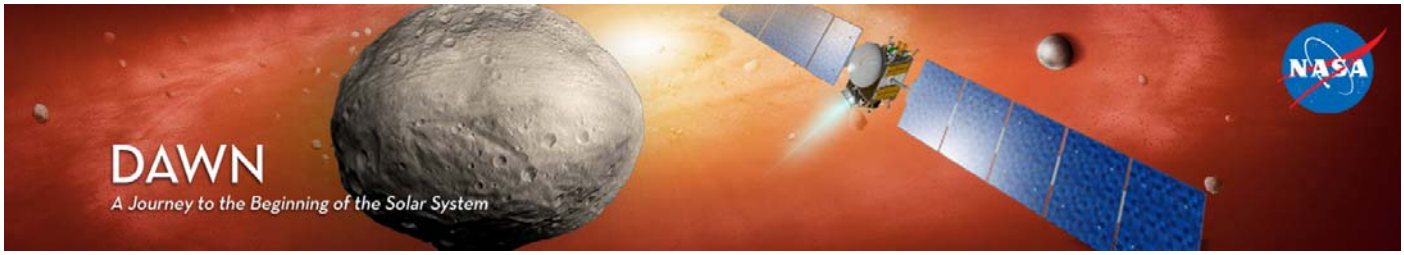


Mineral: Augite

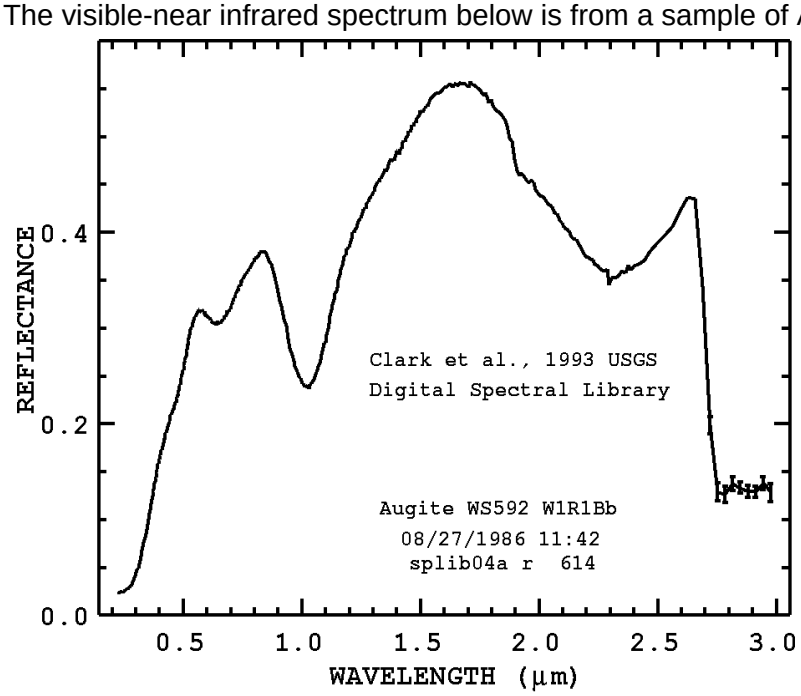
Augite is an important rock-forming ferromagnesian mineral in many igneous rocks and is also found in some hydrothermal metamorphic rocks. Augite is a high-calcium species in an important solid solution series of the pyroxene group having a general formula of (Na,Ca)(Mg,Fe,Al, Ti), $(Si,Al)_2O_6$. In this series, iron and magnesium ions can freely substitute between each other. Augite is the intermediate member of the series. Trace elements that may be associated with Augite include Mn, K, Ce, Yb, and Dy.

Mineral specimens of augite are usually dark green to black. Iron-free varieties may be colorless or white. Densities range from 3.25 to 3.55 g/cm^3, depending on the iron content.

The table below shows the chemical composition of a typical augite specimen.

Chemical Element	Percent composition (% wt)
Silicon (Si)	22.87
Titanium (Ti)	0.83
Aluminum (Al)	4.46
Iron (Fe)	6.68
Manganese (Mn)	0.16
Calcium (Ca)	12.05
Sodium (Na)	1.17
Potassium (K)	.001
Oxygen (O)	51.77

The visible-near infrared spectrum below is from a sample of Augite.



Mineral: Biotite

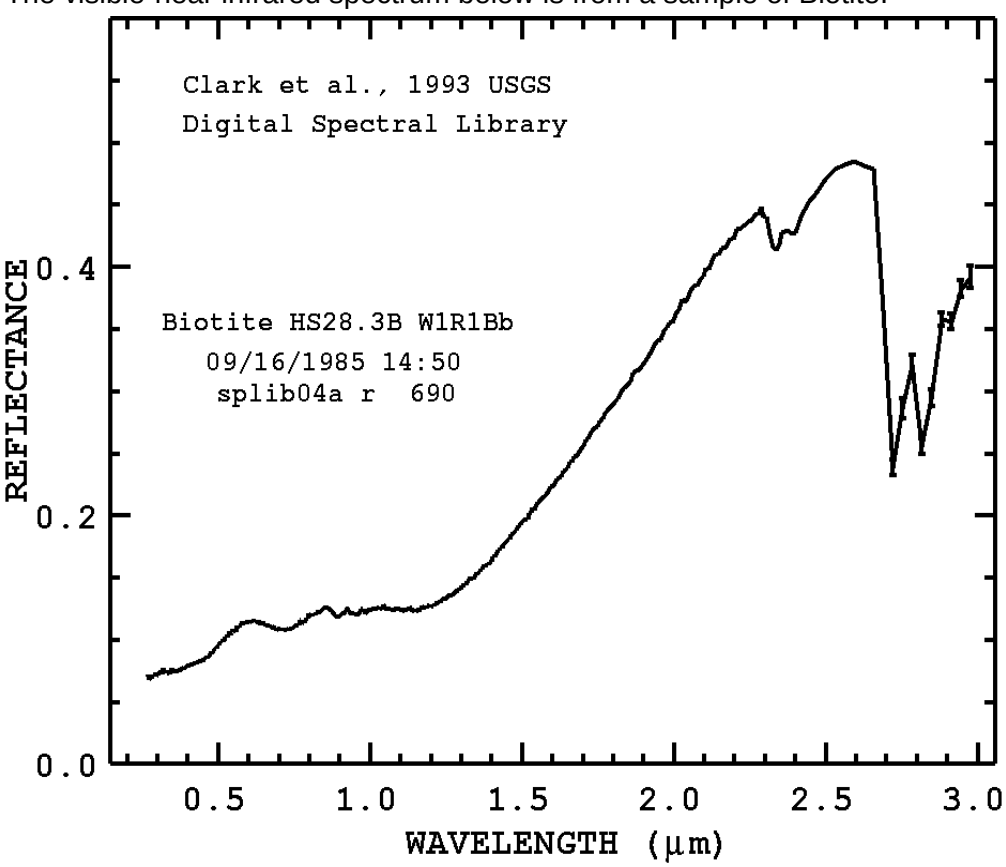
Biotite is a sheet silicate with the approximate chemical formula $K(Mg, Fe)_3AlSi_3O_{10}(F, OH)_2$. It has a flaky, shiny appearance, because iron, magnesium, aluminum, silicon, oxygen, and hydrogen form sheets that are weakly bond together by potassium ions. Biotite is found in a wide variety of igneous and metamorphic rocks.

The density of Biotite ranges from 2.7–3.1 g/cm³, depending upon the iron content, with an average of 3.09 g/cm³. It appears greenish to brown or black, and even yellow when weathered.

The table below shows the chemical composition of a biotite having an empirical formula of $KMg_{2.5}Fe^{2+}_{0.5}AlSi_3O_{10}(OH)_{1.75}F_{0.25}$ and a molecular weight = 433.53 g.

Chemical Element	Percent composition (% wt)
Silicon (Si)	19.44
Magnesium (Mg)	14.02
Aluminum (Al)	6.22
Iron (Fe)	6.44
Potassium (K)	9.02
Oxygen (O)	43.36
Hydrogen (H)	0.41
Fluorine (F)	1.10

The visible-near infrared spectrum below is from a sample of Biotite.



Mineral: Calcite

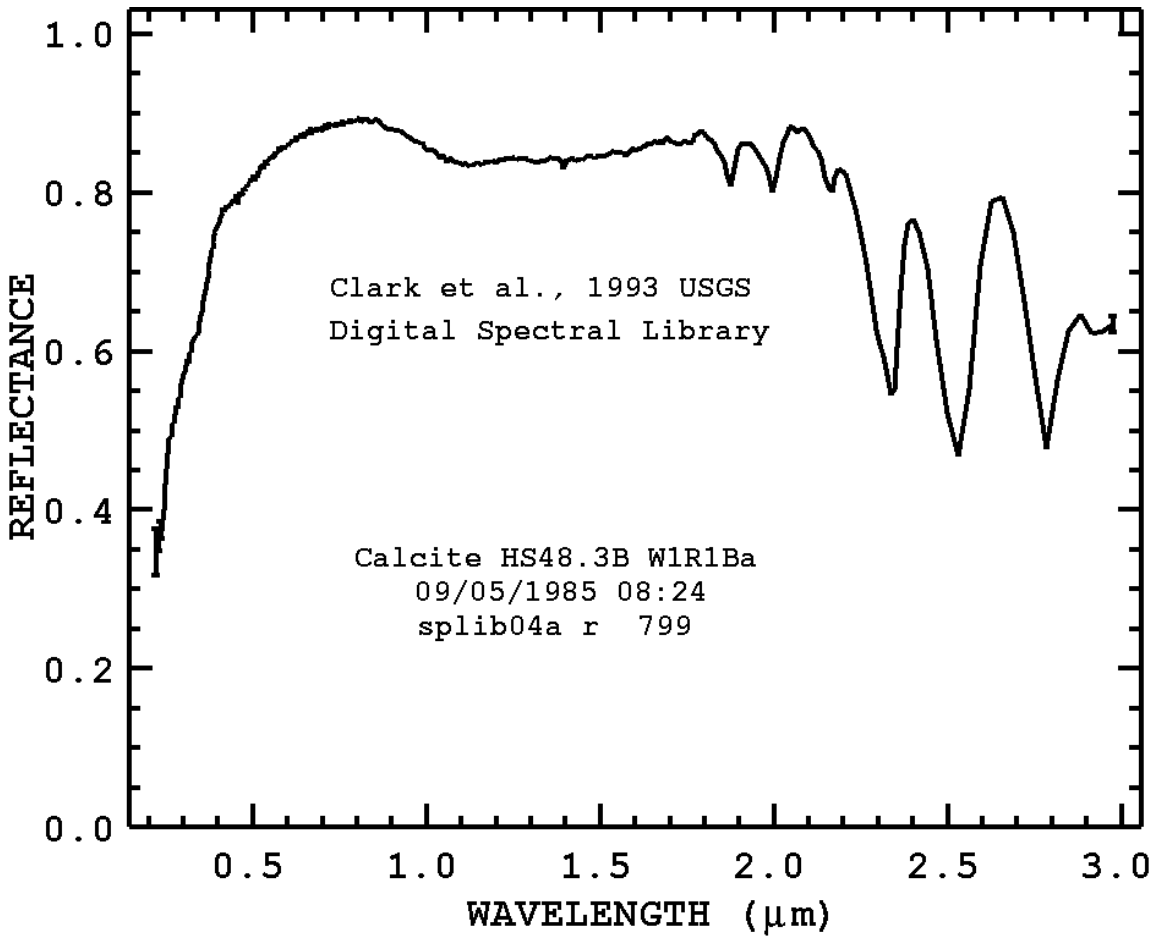
Calcite is a very common, stable form of calcium carbonate. It is an important rock-forming mineral in sedimentary, igneous, and metamorphic rocks. It may be pure $CaCO_3$ or it may contain other metals, such as Fe, Mg, and/or Mn that substitute for Ca.

Calcite is colorless, white, pink, yellow, or brown and has a density of 2.71 g/cm^3.

The table below shows the chemical composition of a chromite having an empirical formula of $CaCO_3$ and a molecular weight = 100.09 g.

Chemical Element	Percent composition (% wt)
Calcium (Ca)	40.04
Carbon (C)	12.00
Oxygen (O)	47.96

The visible-near infrared spectrum below is from a sample of Calcite.



Mineral: Chromite

Chromite is an oxide mineral belonging to the spinel group, an important group of oxide minerals with similar crystalline structures. Their general chemical formula may be written as $(X)(Y)_2O_4$, in which X and Y represent various metals. Usually magnesium is present in chromite substituting for the iron (II); iron (III) and aluminum commonly substitute for chromium in variable amounts. Other trace elements can include Mn, Ti, Ni, and Mg.

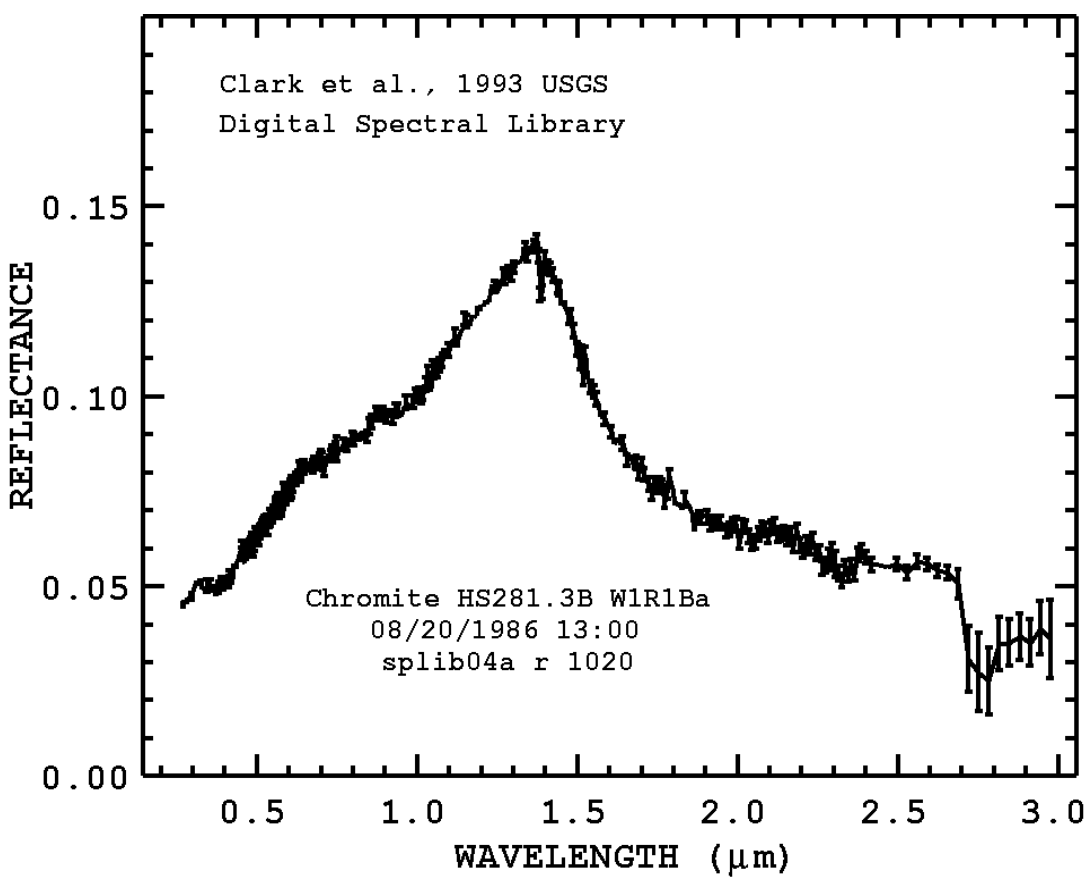
Chromite forms in deep ultra-mafic magmas and is one of the first minerals to crystallize. Because of its density, it falls to the bottom and is concentrated there.

The density of Chromite ranges from 4.5 – 5.09, with an average = 4.79 g/cm³, depending upon the iron content. It ranges in color from brown to black.

The table below shows the chemical composition of a chromite having an empirical formula of $Fe^{2+}Cr_2O_4$ and a molecular weight = 223.84 g.

Chemical Element	Percent composition (% wt)
Iron (Fe)	24.95
Chromium (Cr)	46.46
Oxygen (O)	28.59

The visible-near infrared spectrum below is from a sample of Chromite.



Mineral: Enstatite

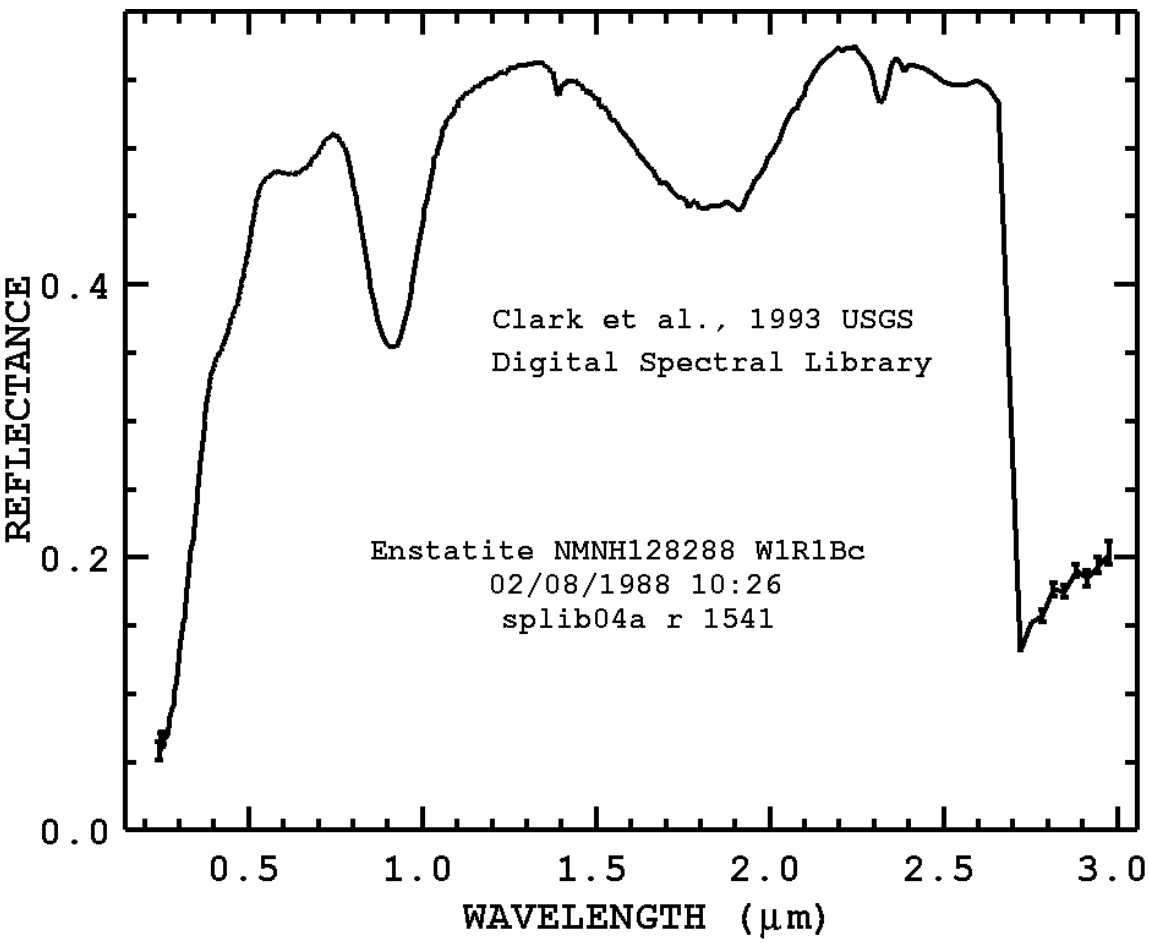
Enstatite is a member of a solid-solution series of orthopyroxenes that extends from enstatite, a magnesium silicate $Mg_2Si_2O_6$, to orthoferrosilite, and iron (II) silicate $Fe_2Si_2O_6$. Almost all the orthopyroxenes in this series contain trace elements of Ca, Mn, $Fe3^+$, Ti , Al, Cr, and Ni.

Enstatite is found in igneous environments and in magmatic mafic rocks. It is often greyish green to greyish white, greenish brown, or yellowish. Its density varies from 3.1-3.4 g/cm³.

The table below shows the chemical composition of enstatite having an empirical formula of $Mg_2Si_2O_6$ and a molecular weight = 200.78 g.

Chemical Element	Percent composition (% wt)
Silicon	27.98
Magnesium	24.21
Oxygen (O)	47.81

The visible-near infrared spectrum below is from a sample of Enstatite



Mineral: Fluorapatite

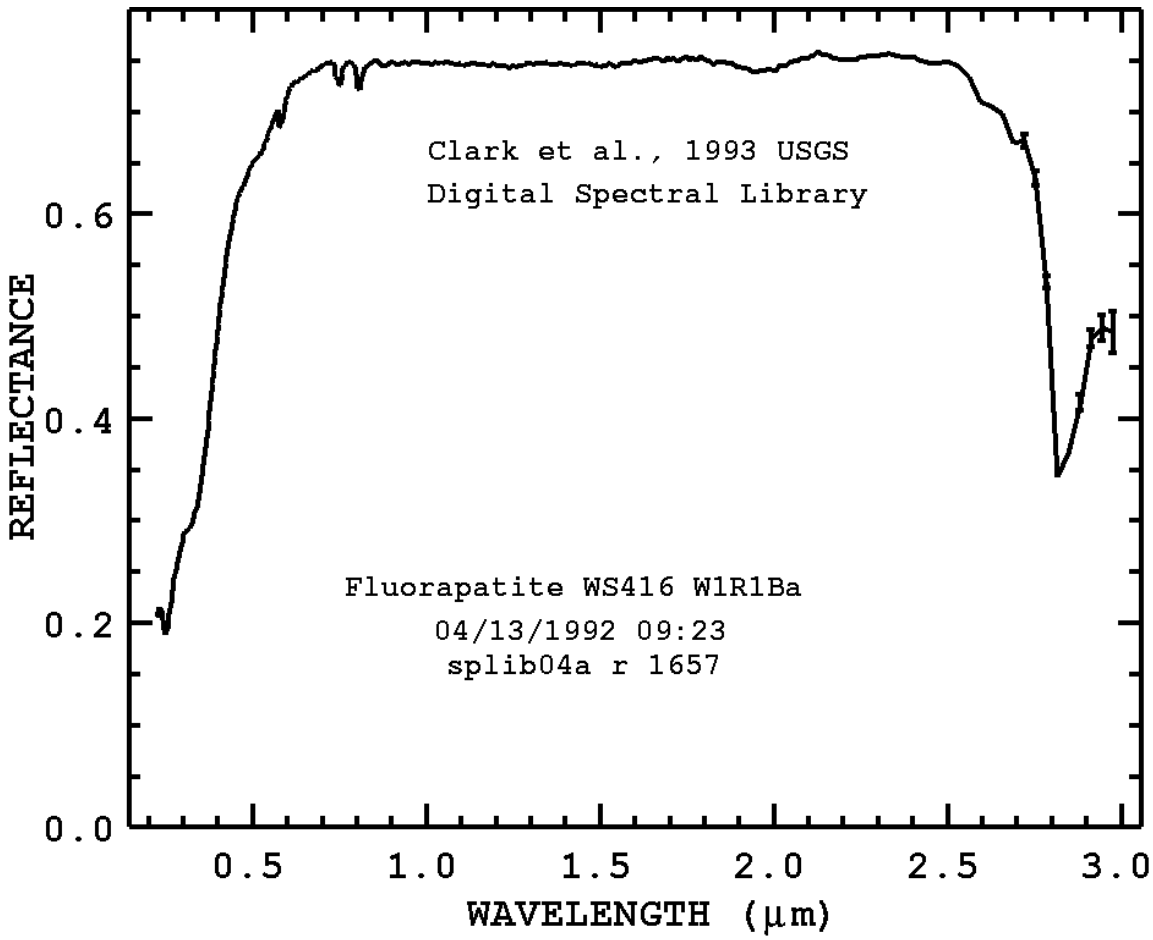
Fluorapatite is a calcium phosphate fluorine mineral of the apatite group. It occurs in many igneous rocks, in magnetite deposits, and metamorphic rocks. Trace elements may include Mn and Cl.

Fluorapatite can be greenish-yellow, bluish green, grayish green, blue, brown, or violet. Its density varies from 3.17 to 3.23 g/cm^3.

The table below shows the chemical composition of fluorapatite having an empirical formula of $Ca_5(PO_4)_3F$ and a molecular weight = 504.30 g.

Chemical Element	Percent composition (% wt)
Calcium	39.74
Phosphorus	18.43
Oxygen (O)	47.81
Fluorine	3.77

The visible-near infrared spectrum below is from a sample of Fluorapatite.



Mineral: Hypersthene

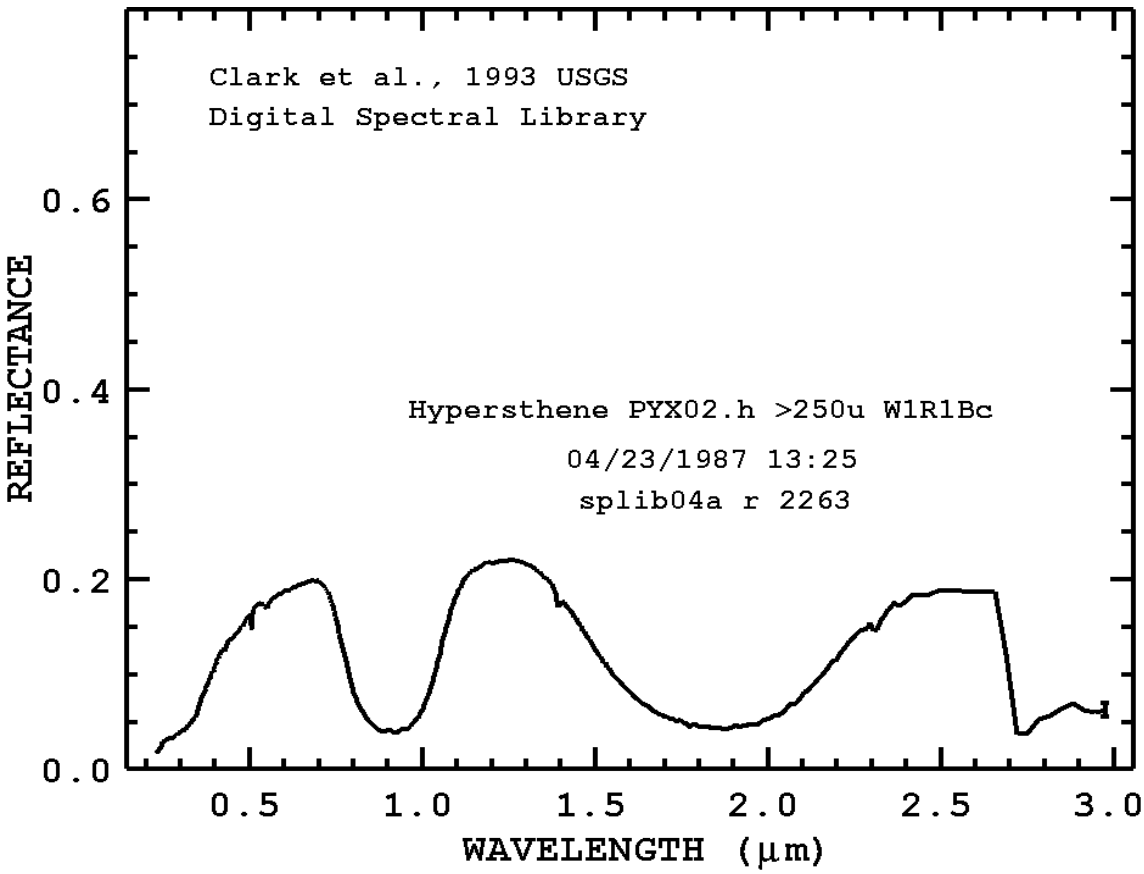
Hypersthene is a member of a solid-solution series of orthopyroxenes that extends from enstatite, $Mg_2Si_2O_6$, to orthoferrosilite, $Fe_2Si_2O_6$. Hypersthene contains an almost 1:1 ratio of magnesium to iron. Almost all the orthopyroxenes in this series contain trace elements of Ca, Mn, $Fe3^+$, Ti, Al, Cr, and Ni.

Hypersthene is found in igneous environments. It is gray to bronzy-brown, weathering to greenish-gray to greenish-brown. Its density range is from 3.2-3.9 g/cm³, with an average of 3.55 g/cm³.

The table below shows the chemical composition of Hypersthene having a chemical formula of $(MgFe^{2+})_2Si_2O_6$ and a molecular weight = 232.32 g.

Chemical Element	Percent composition (% wt)
Iron (Fe)	24.04
Magnesium (Mg)	10.46
Silicon (Si)	24.18
Oxygen (O)	41.32

The visible-near infrared spectrum below is from a sample of Hypersthene.



Mineral: Olivine

The Olivine series of neosilicates have isolated SiO_4^{-4} groups in their structure. The series is formed by continuous solid solution of two components: Mg_2SiO_4 and Fe_2SiO_4.

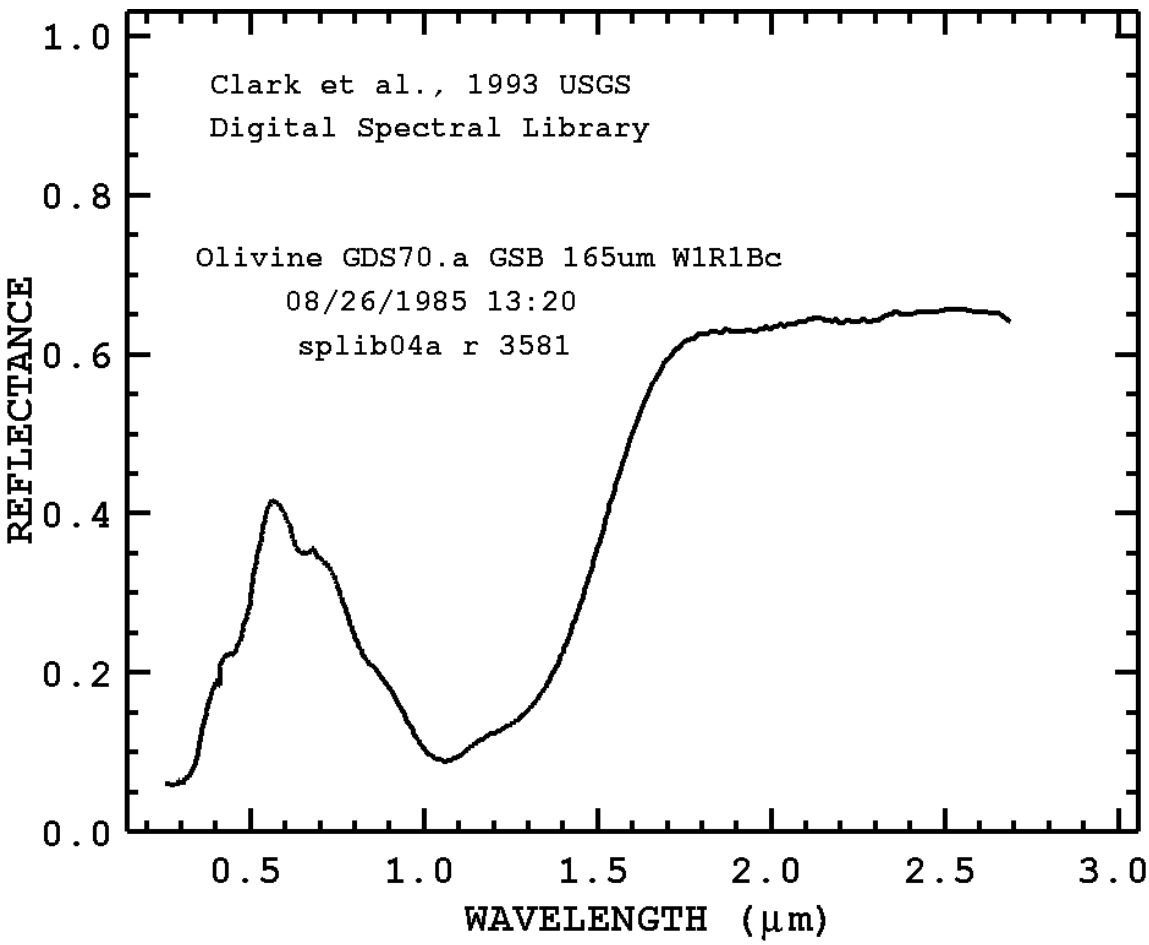
Olivine is found in ultramafic igneous rocks and marbles that formed from metamorphosed impure limestones. Trace elements include Ni, Co, Mn, and Ca.

Mineral specimens of olivine have a sugary texture and feel like sandpaper. They are a light, almost emerald green color. Common olivine has a density of 3.3 to 3.4 g/cm^3.

The table below shows the chemical composition of Olivine having a chemical formula of $Mg_{1.6}Fe^{2+}_{0.4}(SiO_4)$and a molecular weight = 153.31 g.

Chemical Element	Percent composition (% wt)
Iron (Fe)	14.57
Magnesium (Mg)	25.37
Silicon (Si)	18.32
Oxygen (O)	41.74

The visible-near infrared spectrum below is from a sample of Olivine.



Mineral: Pigeonite

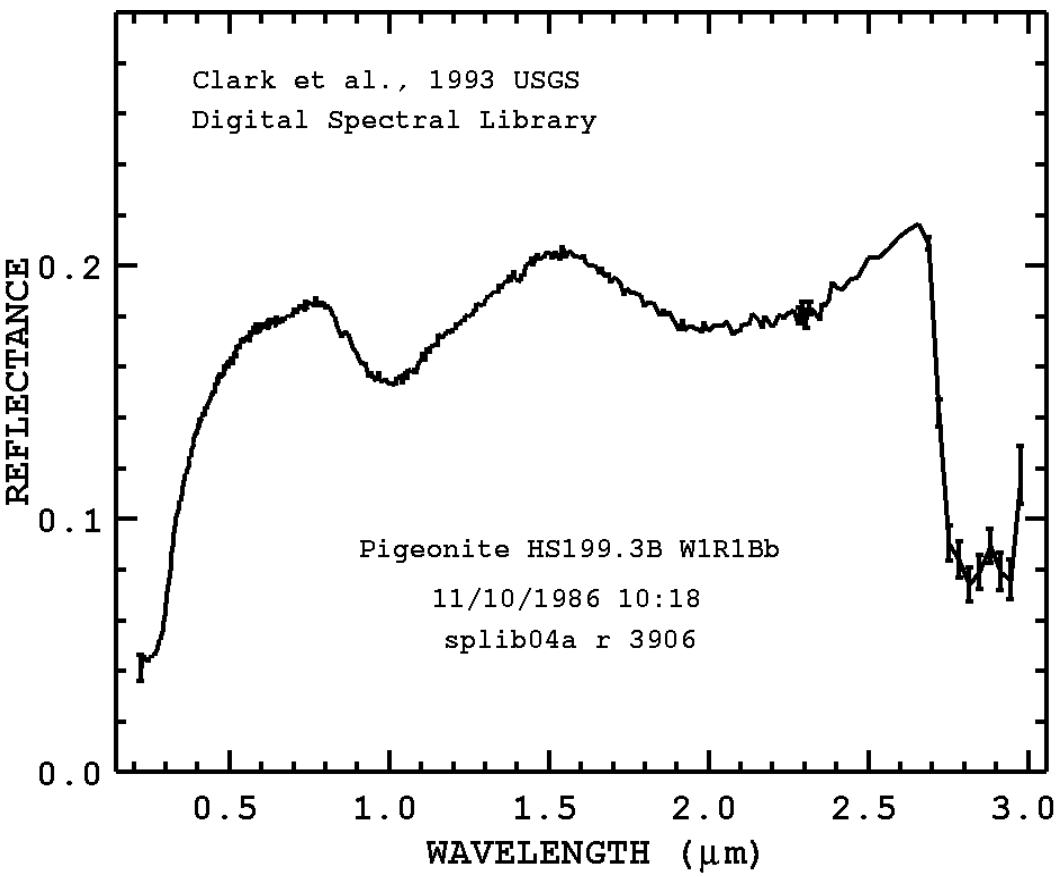
Pigeonite is an iron magnesium silicate mineral in the pyroxene family that occurs only in quickly chilled siliceous volcanic rocks, such as those formed from lava and near-surface igneous rocks.

Pigeonite can be brown, greenish or purple brown, or black in color depending on the iron concentration and has a density range of 3.3 to 3.75 g/cm^3. Trace elements that may be found in pigeonite include Al, Cr, Na, Mn, and Ti

The table below shows the chemical composition of Pigeonite having a chemical formula of $Mg_{1.35}Fe^{2+}_{0.55}Ca_{0.1}Si_2O_6$ and a molecular weight = 219.70 g.

Chemical Element	Percent composition (% wt)
Iron (Fe)	13.98
Magnesium (Mg)	14.93
Silicon (Si)	25.57
Oxygen (O)	43.69
Calcium	1.82

The visible-near infrared spectrum below from a sample of Pigeonite.



Mineral: Plagioclase

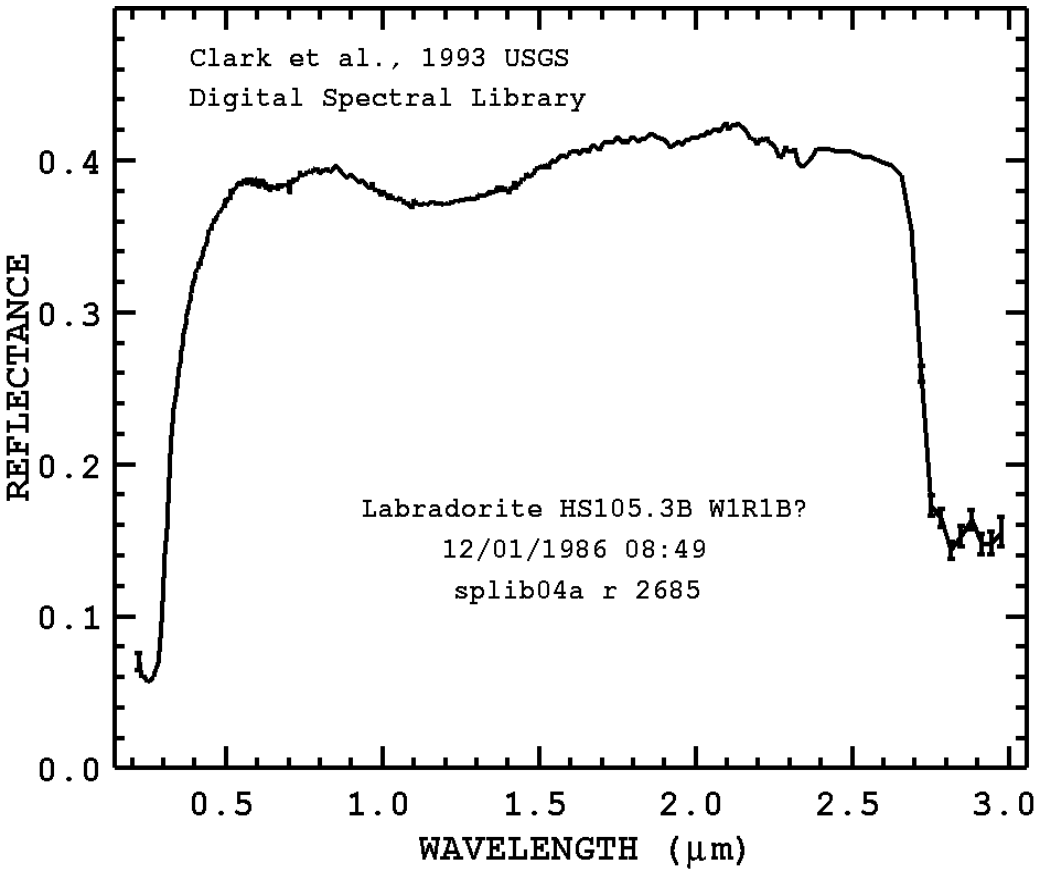
Plagioclase is an aluminum-containing silicate group name for feldspars that contain sodium and calcium. The general chemical formula for the group can be expressed as $(Na,Ca)(Si,Al)_4O_8$. These widespread minerals are found in nearly all igneous rocks, in many metamorphic rocks and some sediments. Plagioclase can be formed throughout the process of magma crystallization in what is called the continuous reaction series.

Trace elements, such as Sr, Pb Ba, Fe, Eu, Be, Ti, P, Li, Pb, B and halogens may also be incorporated during this time.

The colors of this series of mineral usually varies from white to pale blue to gray, while the density ranges from 2.62 to 2.76 g/cm^3. The table below shows the chemical composition of a typical plagioclase $Na_{0.5}Ca_{0.5}Si_3AlO_8$, having a molecular weight = 270.77 g).

Chemical Element	Percent composition (% wt)
Sodium (Na)	4.25
Calcium (Ca)	7.40
Aluminum (Al)	9.96
Silicon (Si)	31.12
Oxygen (O)	47.27

The visible-near infrared spectrum below is from Labradorite, one of the plagioclase species that contains almost equal concentrations of calcium and sodium ions.

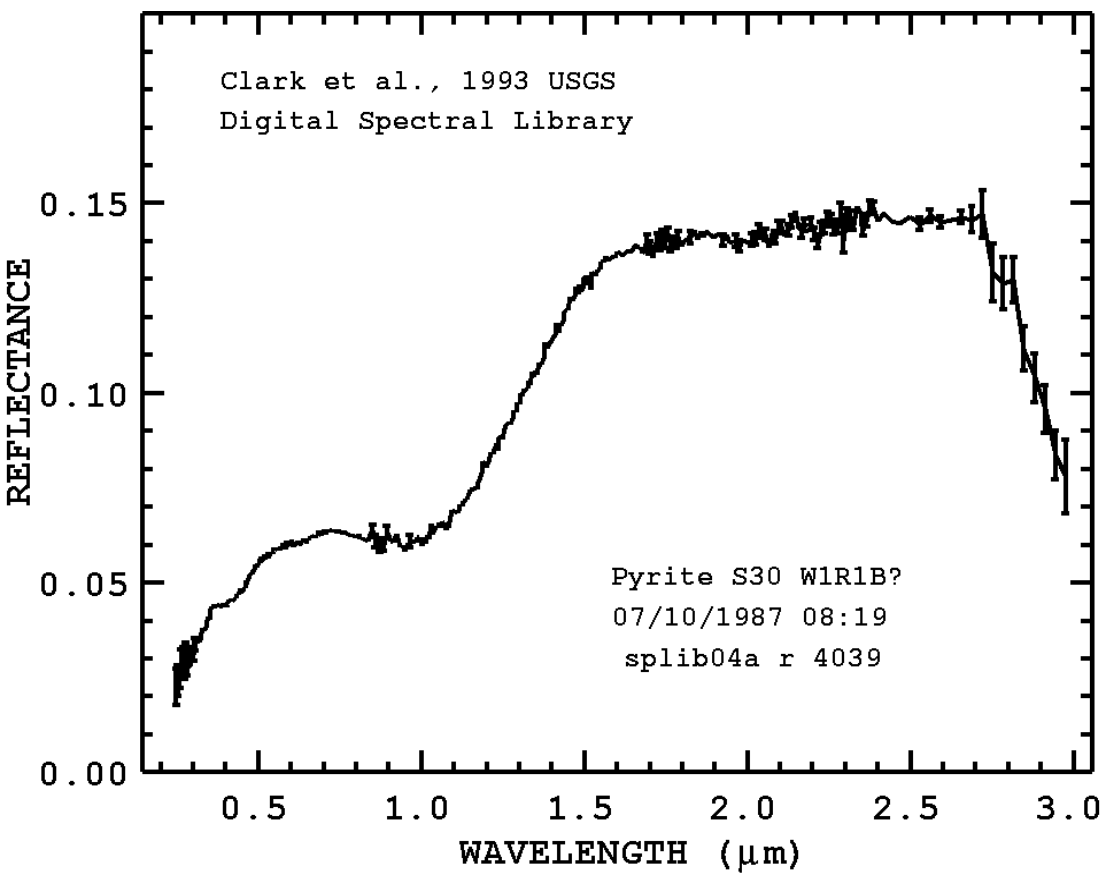


Mineral: Pyrite

Pyrite, iron sulfide, is one of the most common of all minerals. The mineral is the product of igneous, metamorphic and aqueous processes, so it occurs in sedimentary, magmatic and metamorphic rocks. Pyrite weathers readily to limonite.

Pyrite sometimes containing small amounts of cobalt, nickel, silver, and trace amounts of gold.

Pyrite is usually a pale brass yellow, but when it weathers, it is sometimes has a brown or rusty tarnish. Its density ranges from 5.00 to 5.02 g/cm^3. The table below shows the chemical composition of pyrite, FeS_2, having a molecular weight = 119.98 g).

Chemical Element	Percent composition (% wt)
Iron (Fe)	46.55
Sulfur (S)	53.45

Below is the visible-near infrared spectrum of Pyrite.