

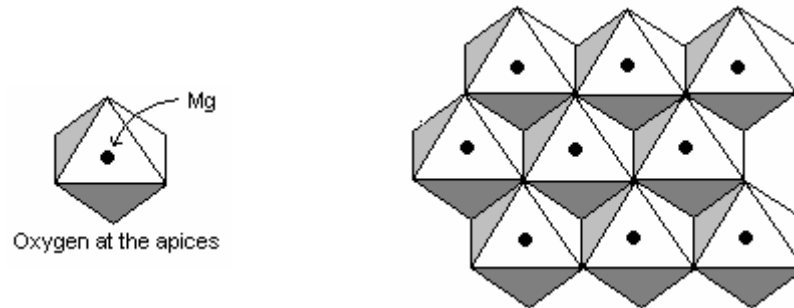
## Lecture 10: Mantle Minerals

### Lower Mantle

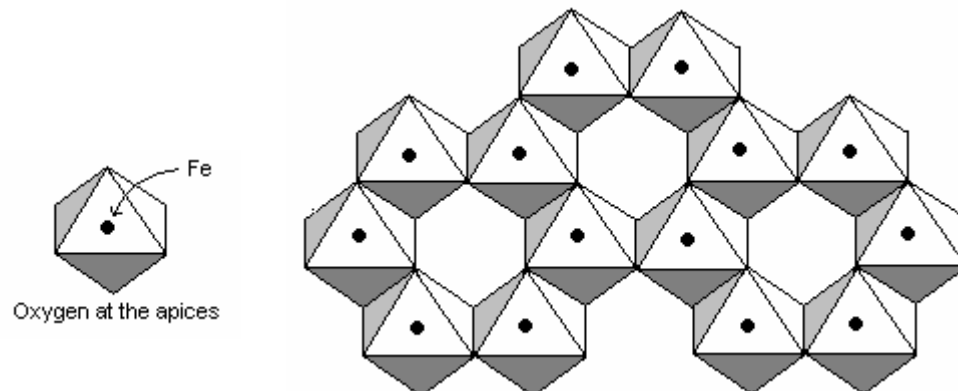
The lower mantle extends from about 700 km to the core at about 2900 km and represents nearly forty-nine percent of Earth's mass. Analysis of seismic waves and stony meteorites indicates that it mostly contains compounds of oxygen with magnesium and silicon, although some iron is also present. Because magnesium is slightly more abundant than silicon in the lower mantle, early researches suggested that it was made up of periclase (MgO) and stishovite (SiO<sub>2</sub>), the high-pressure form of silica found in meteorite craters.

#### *Structures of Periclase and Stishovite*

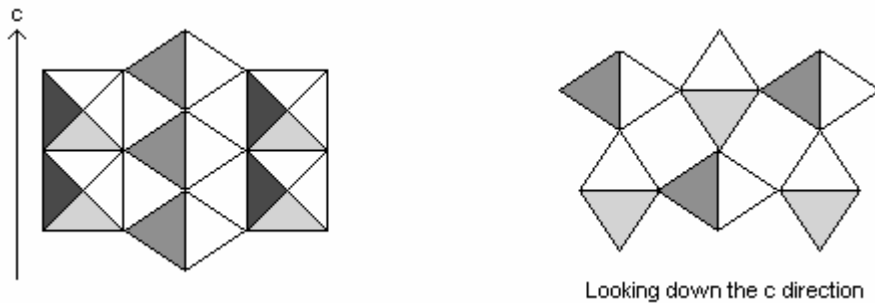
Periclase is an isometric mineral that has a CCP structure just like halite. Magnesium is in six-fold coordination, so that each magnesium atom is surrounded by an octahedron of oxygen atoms. The oxygen octahedra share both edges and apices, creating trioctahedral sheets shown below.



Before looking at the structure of stishovite, this is a good place to look at a few iron oxides because their structures are based on the structure of periclase. The structure of wustite (FeO), for example, is identical to the structure of periclase and contains the same trioctahedral sheets. The structure of hematite (Fe<sub>2</sub>O<sub>3</sub>) is similar to the structure of periclase, but one third of the octahedra are vacancies as shown below. The structure consists of dioctahedral sheets.



Like periclase, wüstite, and hematite, stishovite has six-fold coordination in which each atom of silicon is surrounded by six atoms of oxygen. It does not, however, have the same structure. Stishovite is isostructural with rutile ( $\text{TiO}_2$ ), as shown below.

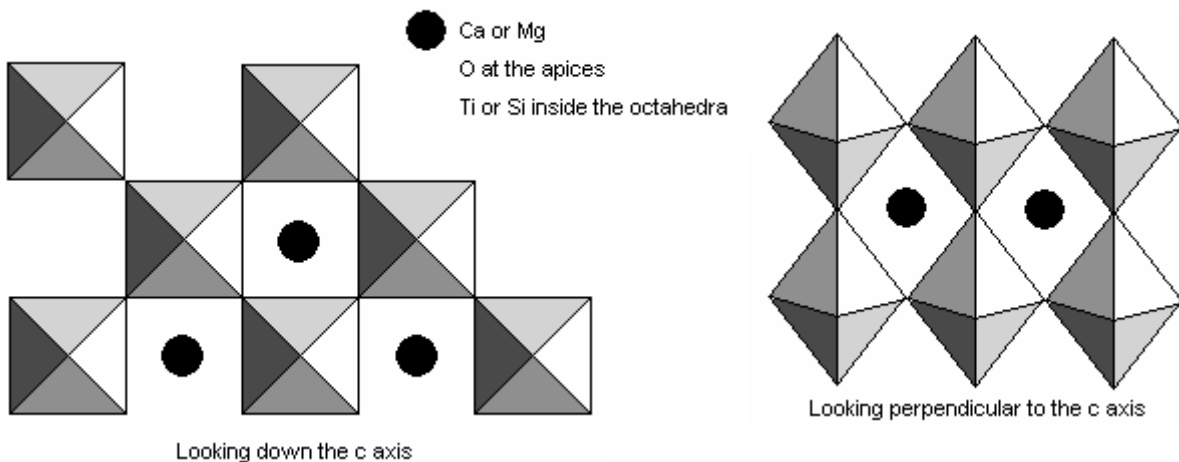


### New Ideas about the Lower Mantle

During the late 1980s, new experiments in high-pressure mineralogy suggested that the lower mantle might be a mixture of periclase and  $\text{MgSiO}_3$ . At pressures in the lower mantle,  $\text{MgSiO}_3$  would have the same structure as perovskite ( $\text{CaTiO}_3$ ). Note that although  $\text{MgSiO}_3$  in the perovskite structure may be the most abundant mineral in the planet, it is not yet a mineral because it has never been found!

#### Perovskite Structure

In perovskite, titanium atoms occupy octahedral sites that only share corners. Large calcium atoms fill the twelve-fold cubo-octahedral void.



### Transition Zone and the Upper Mantle

The transition zone and upper mantle contain about eighteen percent of the Earth's mass. Seismology data and research of high temperature and pressure minerals indicate that these regions consist mostly of  $\text{Mg}_2\text{SiO}_4$  and  $\text{MgSiO}_3$  minerals. The dominant mineral has the stoichiometry of  $\text{Mg}_2\text{SiO}_4$  and several polymorphs. Polymorphs are minerals with the same composition but different structures.

The  $\text{Mg}_2\text{SiO}_4$  polymorphs include ringwoodite, wadsleyite, and olivine. In each polymorph, silicon is in tetrahedral coordination with oxygen and magnesium is in octahedral coordination with oxygen. The polymorphs differ in the way these polyhedra are arranged.

The highest-pressure polymorph of  $\text{Mg}_2\text{SiO}_4$  occurs at the base of the transition zone and is called ringwoodite or  $\gamma\text{-Mg}_2\text{SiO}_4$ . It is isostructural with spinel ( $\text{MgAl}_2\text{O}_4$ ). In the middle of the transition zone at about 520km, ringwoodite changes to wadsleyite or  $\beta\text{-Mg}_2\text{SiO}_4$ . Wadsleyite can hold a lot of water—up to about three percent by weight. If it is saturated, the mantle may hold a volume of water equal to about twenty oceans! The last  $\text{Mg}_2\text{SiO}_4$  polymorph is olivine, occurring at the top of the transition zone. The structure of olivine, in addition to those of ringwoodite and wadsleyite, is difficult to visualize, but 3D pictures available online help a lot.

