

EVIDENCE FOR THE PRESENCE OF WATER IN THE LUNAR INTERIOR FROM ELECTRICAL CONDUCTIVITY. J. Yi¹ and S. Karato¹, ¹Department of Geology and Geophysics, Yale University, 210 Whitney Avenue, New Haven, CT 06511, USA (jun.yi@yale.edu)

Introduction: Recent geochemical studies of some low-Ti glasses and lunar melt inclusions report high water content suggesting that the source regions of these materials (mantle) may contain a large amount of water [1, 2, 3]. However, these geochemical studies provide poor constraints on the water content of the mantle because one needs to assume the degree of melting and other complications regarding the processes by which these samples were transported to the surface. Geophysical observations, such as electrical conductivity, have better constraints on the distribution of water (hydrogen) because of high sensitivity to water content. In this presentation, we analyze electrical conductivity observations using the latest knowledge of physical and chemical properties of minerals to infer the water distribution in the deep lunar interior.

Although electrical conductivity is highly sensitive to water content, it also depends on other factors such as temperature, oxygen fugacity, Fe and Al content [4, 5]. Also some of the important elements such as H (hydrogen) and Al (aluminum) are partitioned among co-existing minerals, and the partition coefficients changes with thermodynamic conditions. For instance, for a given total content, the concentration of H and Al in some minerals (such as orthopyroxene) can change more than a factor of ~ 10 as a function of thermochemical conditions. Because H and Al (in orthopyroxene) have important effects on electrical conductivity, these details need to be included in evaluating the water content in the Moon from electrical conductivity.

For example, in previous studies on the temperature of the lunar interior from electrical conductivity, Al partitioning was not considered in any detail [6, 7]. In this presentation, we will estimate the water distribution in the Moon from electrical conductivity taking into account of these mineral physics details.

Mineralogical models of the lunar mantle: In our model, 60 vol% of olivine, 30 vol% of orthopyroxene and 10 vol% of garnet are the three main phases [8]. The hydrogen partition coefficient was calculated from the solubility of hydrogen in olivine and orthopyroxene [9, 10]. Both Hashin-Shtrikman average scheme and percolation theory have been adopted to obtain the electrical conductivity of multi-phase mixture, based on that for independent phase and volume fraction.

Al partitioning between orthopyroxene and co-existing garnet: Al has an important effect on the electrical conductivity of orthopyroxene [11, 12]. In two papers cited above, all Al was assumed to be in orthopyroxene. This assumption is incorrect in a realistic mineralogy where Al is also present in other minerals such as garnet. The ratio of Al content between two coexisting minerals (known as partition coefficient) has been determined for a few mineral pairs under the thermodynamic conditions relevant to the lunar mantle [13]. We use these experimental results to calculate Al content in orthopyroxene. As shown in Fig.1, most of Al is in garnet, and orthopyroxene contains only $\sim 1\%$ or less of Al_2O_3 . Consequently, the high conductivity in the lunar interior cannot be attributed to the Al effect.

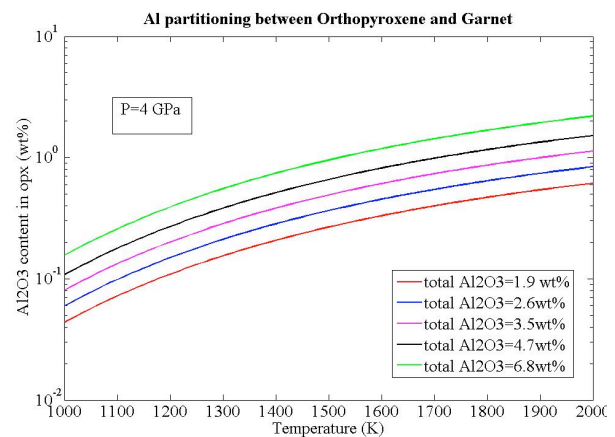


Fig 1. Concentration of Al_2O_3 in orthopyroxene, assuming the volume fraction of orthopyroxene and garnet is 30 vol% and 10 vol%, considering the Al-partitioning between orthopyroxene and garnet.

Conductivity model of olivine and orthopyroxene mixture considering the hydrogen partitioning:

The conductivity-depth profile is calculated with the simplified assumption of a uniform chemical composition as olivine and orthopyroxene mixture with the ratio of 2:1 based on our mineralogical model (the volume fraction of garnet is small and its direct effect on conductivity is ignored). Hydrogen partitioning between olivine and orthopyroxene is calculated as a function of temperature and total water content (Fig. 2). It can be seen that the hydrogen content in each mineral will be very different under different thermodynamic conditions.

Fig.3 shows the electrical conductivity of an olivine-orthopyroxene mixture as a function of total water content. The calculated conductivity of a mixture depends on the averaging scheme.

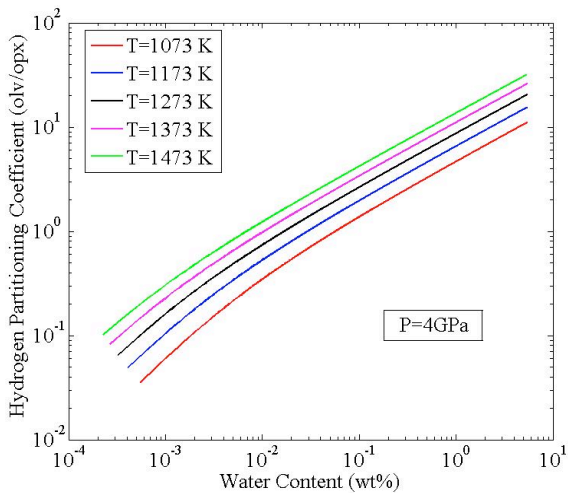


Fig.2 Hydrogen partitioning between orthopyroxene and olivine as a function of temperature, pressure and total water content.

Fig. 4 shows the temperature-depth profiles for a range of water content. If dry model is assumed, temperatures in the deep mantle exceeds (dry) solidus that is not consistent with other geophysical inferences [6, 14]. However, for water content of 0.01-0.001 wt%, we get reasonable temperature-depth profiles.

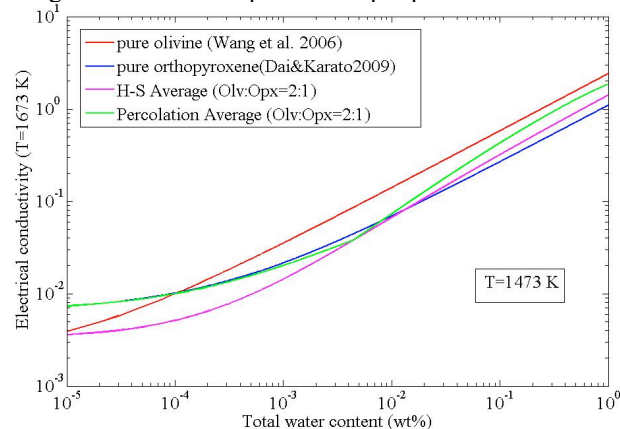


Fig 3. Electrical conductivity of olivine and orthopyroxene mixture (volume fraction ratio 2:1) at temperature of 1473K, pressure of 4GPa.

Summary and Conclusions: We present a model of electrical conductivity in the lunar mantle where the influence of partitioning of key elements (H and Al) is included. We show that Al content in orthopyroxene in this model is less than ~1 %, and in such a case, a dry model predicts deep mantle temperatures far exceeding

the dry solidus. In contrast, reasonable temperature-depth profiles are inferred if the water content of 0.01-0.001 wt% is assumed. These values of water content are consistent with some geochemical estimates [2, 3] and lunar evolution models [15].

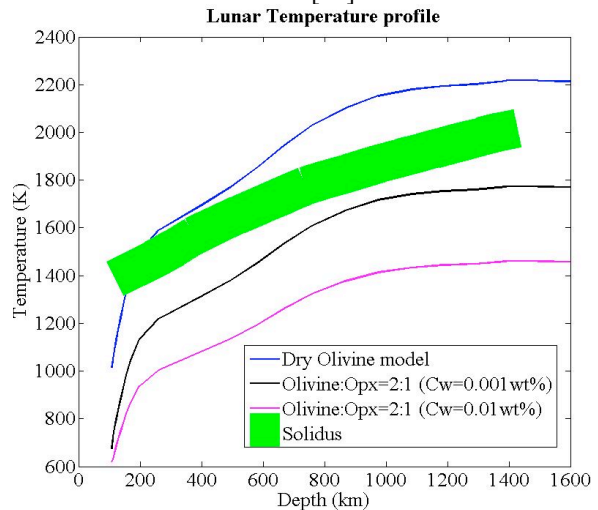


Fig.4 Lunar temperature profile inversed from Lunar conductivity (Hood et al. 1982) assuming different mineralogical models and water content).

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