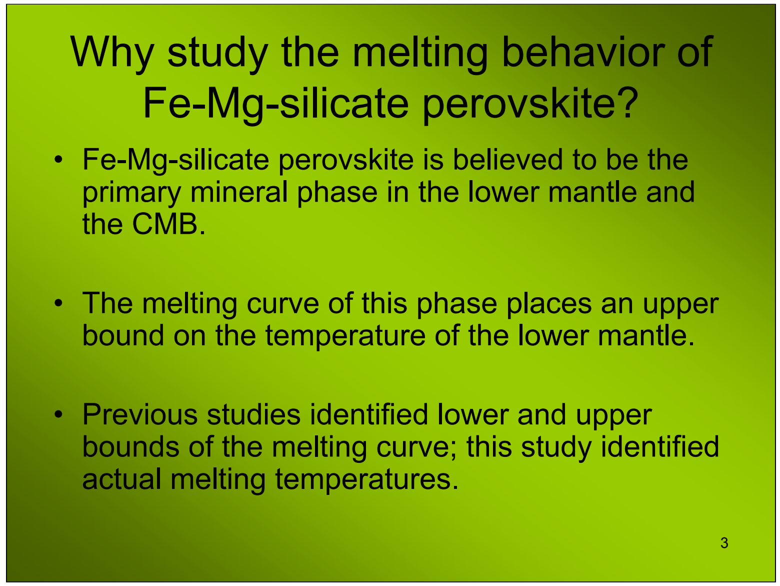
Melting of Iron-Magnesium-Silicate Perovskite

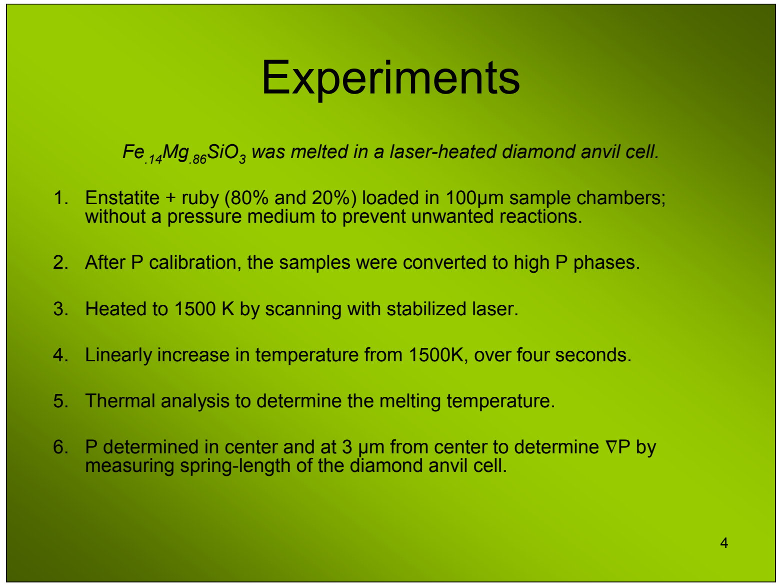
Sweeney and Heinz (1993), GRL 20, 855-858

Introduction

1. Purpose of study
2. Experimental method
3. Results of the experiments
4. Implications for the lower mantle and CMB
5. Conclusions



1. From 670 km down to CMB
2. Implications for style of solid-state convection in the lower mantle
3. Implications for chemical evolution of the mantle



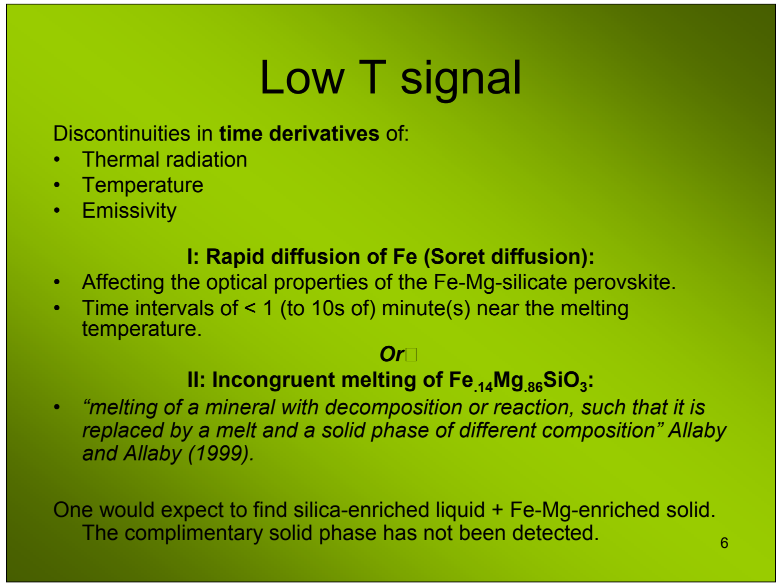
1. -
2. relaxation of samples and volume changes due to phase transitions decreased peak pressures by <10 percent. This decrease was compensated by thermal pressure at laser-heated spots. Results will show that the melting behavior is virtually independent of P
3. Up to 1500K to avoid Soret diffusion and melting.

High T signal

Discontinuities in:
- Thermal radiation
- Temperature
- Emissivity
- Laser power

Melting:
- Sudden increase in brightness at center of heated spot.
- Optically transparent (ppl) & isotropic (xpl) center of heated spot (≈5μm) after quenching and decompression (→ GLASS!).

(uncorrected) Melting temperature = temperature immediately prior to the higher temperature signal.



Soret diffusion: Heinz and Jeanloz (1987) found 10s of minutes, this study <1 min.

Able to keep system at temp near melting for much longer time, without run-away occurring. Run-away = melt absorbs more laser power than the solid. Small heating spot -> large temperature gradients, rapid diffusion.

Soret diffusion = thermal diffusion: lighter components migrate toward the hotter end. In order to establish an equal distribution of internal energy.

Incongruent melting: volume of melt is small compared to volume probed by x-ray analysis, equally small volume of complementary phase could be missed among the strong and numerous diffractions of the perovskite phase!

Alternative interpretation for high T signal…

Discontinuities in:

- Thermal radiation
- Temperature
- Emissivity
- Laser power

I: Melting:

- Sudden increase in brightness at center of heated spot
- Optically transparent (ppl) & isotropic (xpl) center of heated spot (≈5μm) after quenching and decompression (→ GLASS!)

Or

II: Liquidus of Fe-Mg-silicate perovskite

(uncorrected) Melting temperature = temperature immediately prior to the higher temperature signal.

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Results

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- Melting curve slope is slightly negative, but virtually P independent.
- High T (±100K) and Low T (±85K) signals converge at higher pressures: ΔT=300K at 30 GPa and 140K at 94 GPa.
- Scatter is possibly due to chemical heterogeneities.

Comparison with previous studies

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- "Temperatures can be compared among experiments with different spot sizes if the radial temperature profiles have the same functional form".
- **Heinz and Jeanloz (1987) to 60 GPa**
- Bassett et al. (1988) to 70 GPa
- **Knittle and Jeanloz (1989) to 97 GPa**
- **This study: 30-94 GPa**

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Basset et al used different sample geometry and heating function.

H+J (1987) same slope within error for melting curve, H+J may have overcorrected measured temperatures for temp fluctuations over time caused by laser-power fluctuations.

K+J (1989) found significant pos slope for melting curve above 60 GPa.

900-1100 degrees lower at 95 GPa.

High P versus Low P experiments

- Low P: integrated thermal radiation increased rapidly → destabilization of temperature control system.
- High P: integrated thermal radiation shows a small but sharp decrease → temperature control system maintained stability

Change in properties of either the melt or the solid near 60 GPa?
Knittle and Jeanloz (1989):

0-25 GPa: liquid undergoes a continuous transition from 4- to 6-fold coordination of Si, but Si is still predominantly octahedrally coordinated.

>60 GPa: Si coordination has uniformly approached 6, the melt becomes less compressible: structural changes no longer contribute to compression → $\Delta V > 0$. "The melting curve of $(Mg,Fe)SiO_3$ perovskite is close to that of Fe."

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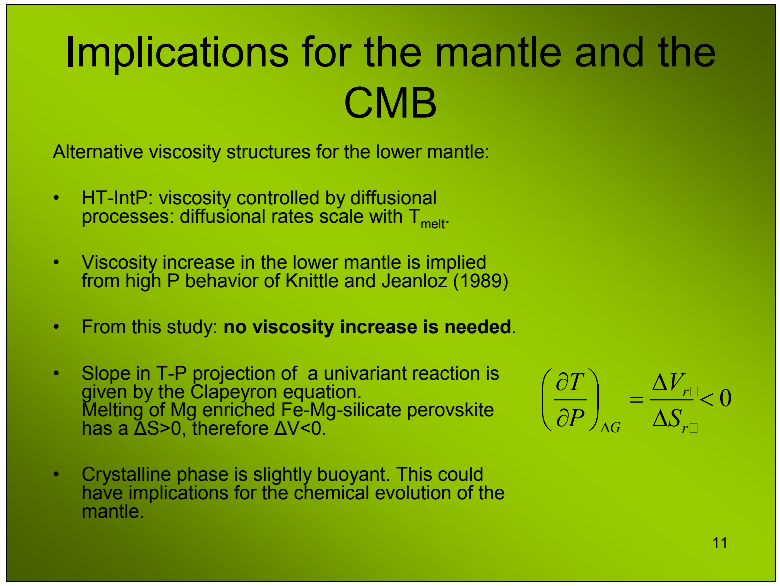
High P experiments up to 900-1100 K higher temperatures than this study



Diffusional process controlled viscosity: weertman creep??

e.g. Neutrally buoyant perovskite in a chondritic melt, then chemical differentiation of the mantle could not be explained by perovskite crystal fractionation. And melting of mantle would not be precluded by minor element partitioning between the liquid and perovskite since the nearly equal densities would lead to homogeneous mixing by vigorous convection.

Conclusions

- The low temperature signal has been interpreted as rapid diffusion of Fe.
- The high temperature signal has been interpreted as melting of the Fe-Mg-silicate perovskite
- The melting curve appears to be virtually independent of P.
- The new melting curve is several hundred degrees below previous estimates.
- New upper bound for temperature of lower mantle.
- No viscosity increase in the lower mantle is implied from this study.