High pressure-temperature experiments to probe the interior of small rocky exoplanets

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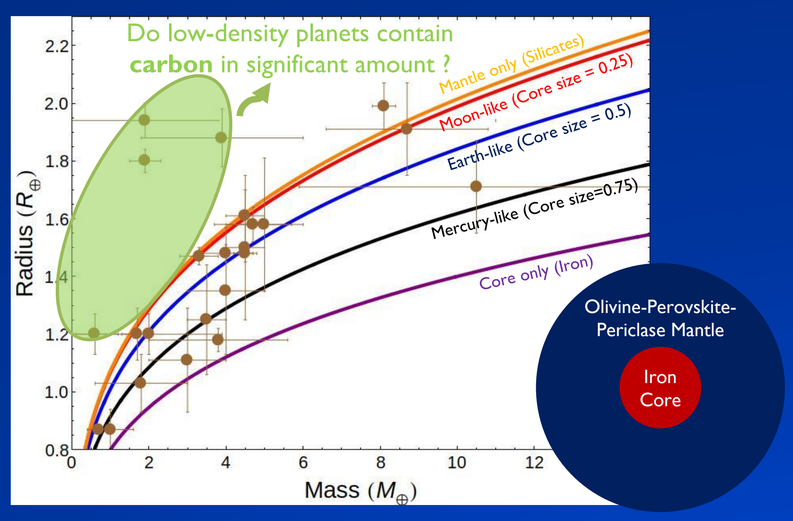
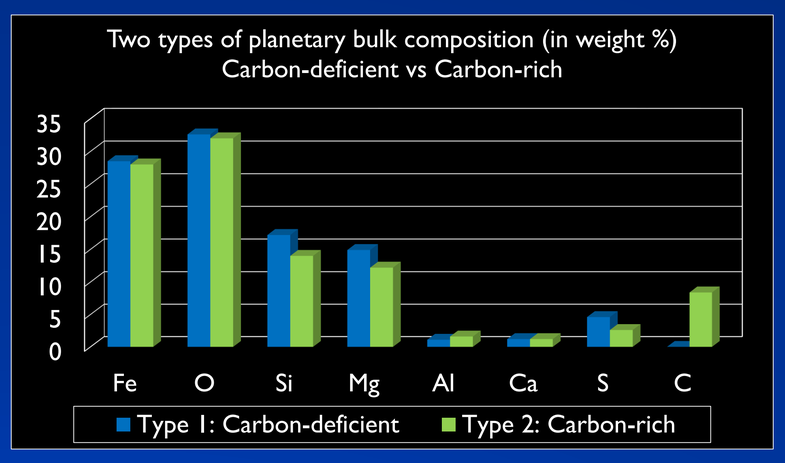
Carbon-rich rocky planets



Theoretical Mass-Radius relations, compared with observations, give clues about the existence of carbon-rich rocky exoplanets.

Bulk composition assumption



We aim to study the mineralogy of rocks of two types of planetary bulk composition: carbon-deficient (0 wt% C) representative of solar system planets and carbon-rich (8.4 wt% C) representative of exoplanets around the star HD19994. We prepare two sets of compositional mixtures as shown in the figure (derived from [1]).

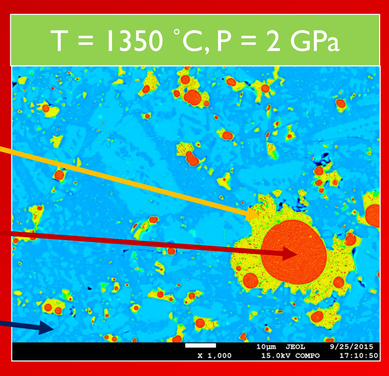
High-pressure setup

We perform high-pressure-temperature experiments (1-2 GPa, 1250-1550 °C) on a piston cylinder apparatus.

Experimental Results

(False-color images of experimental run products taken at the Netherlands National Electron Microprobe facility in Utrecht University)

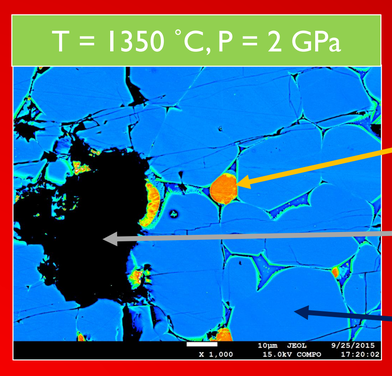
Type 1: Carbon-deficient



Similarities

1. Blue silicate-rich regions mainly contain olivine, $(Mg_xFe_{1-x})_2SiO_4$.
2. Yellow-red regions mainly contain iron and sulfur.

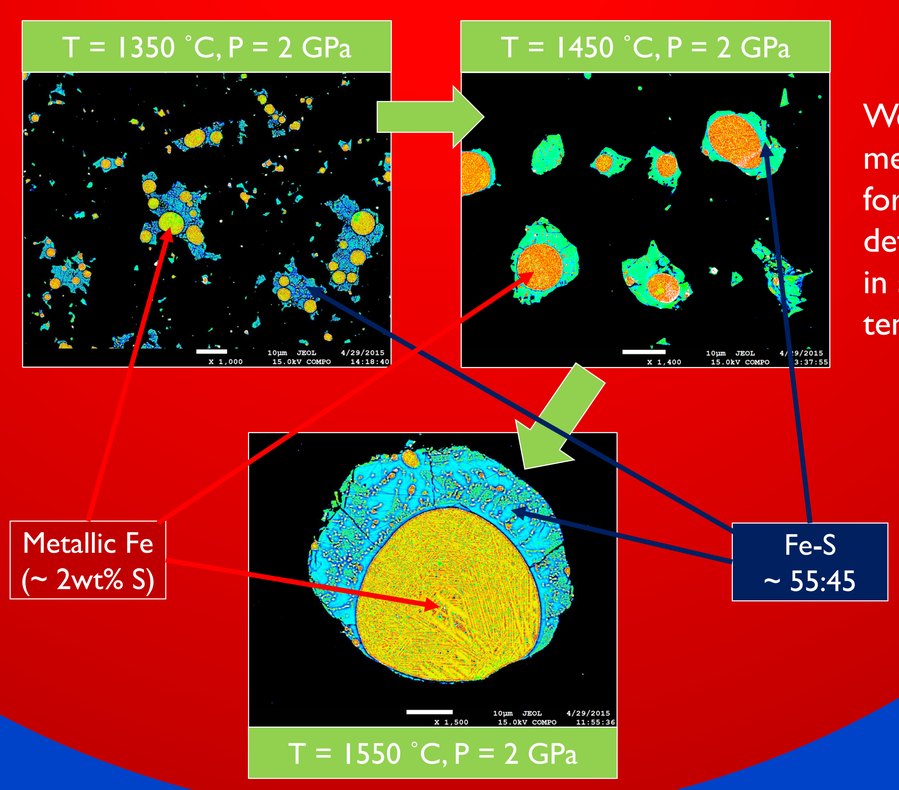
Type 2: Carbon-rich



Differences

1. Red regions in the *Type-1: carbon-deficient* image are metallic iron blebs surrounded by iron sulfide in yellow. In the *Type-2: carbon-rich* image, only iron sulfide is present and such metallic iron blebs are absent.
2. Black regions in the *Type-2: carbon-rich* image contain carbon in the form of graphite. Carbon does not form any carbide species like silicon carbide.

Growth of metallic blebs in carbon-deficient (Type-1) samples



We found that the metallic iron blebs formed in carbon-deficient samples grow in size with increasing temperature.

Conclusions

1. Carbon-rich planets might have rocks similar to Earth in their upper mantle (example, olivine).
2. Metallic iron blebs grow in size with temperature.
3. Presence of carbon in iron sulfide hampers the formation of metallic iron.
4. Carbon does not form any carbide species like silicon carbide, stays as graphite at least up to 2 GPa.
5. Since graphite transforms into diamond beyond 5 GPa, it seems possible for carbon-rich planets to have diamond layers in addition to graphite layers.

References

[1] Moriarty J. et al. (2014), ApJ, 787:81, AAS

[2] Madhusudhan N. et al. (2012), ApJ, 759:L40, AAS

Acknowledgements

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