Water production from lunar samples and simulants

Conference or Workshop Item

Water Production from Lunar Samples and Simulants

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1. Introduction

- **Water** is a critical resource needed to support future crewed space exploration.
- **In situ experiments** are required to analyse and harvest water on the Moon.
- ProSPA is an analytical module for in situ regolith analysis on-board the Luna-27 mission [1].
- ProSPA will search for volatiles and also perform **an ISRU demonstration**.
- **Reduction of lunar minerals** is planned to be performed on the lunar surface using ProSPA

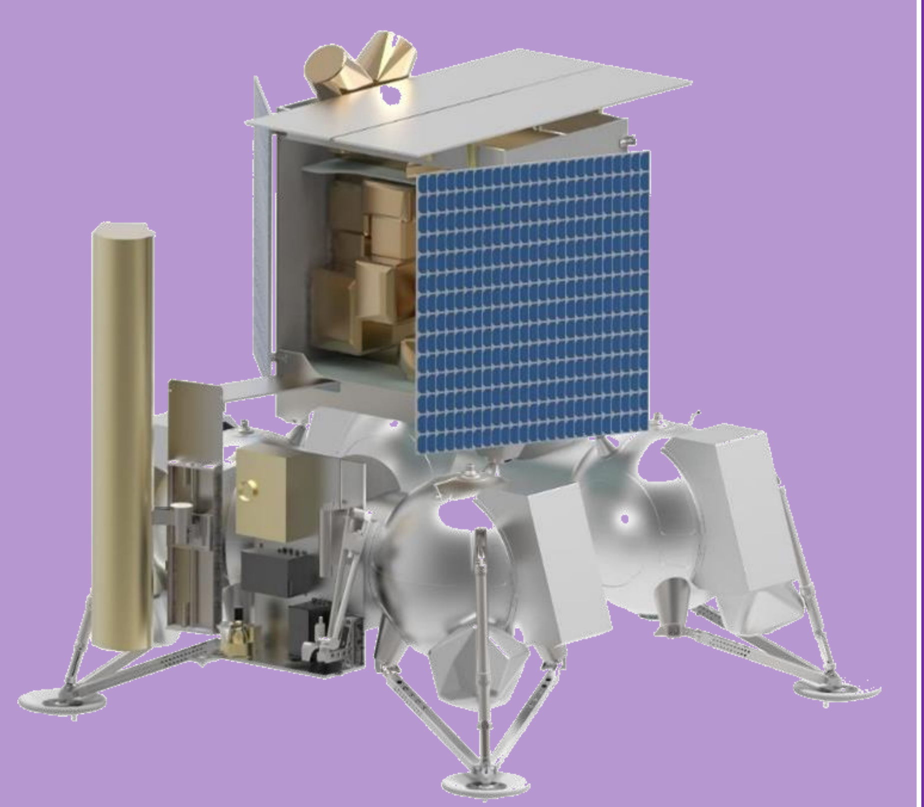

Fig 1 Luna-27 Lander.

In this work, lunar simulants and samples are reduced in a ProSPA breadboard model [2.3]. The results will help determine the feasibility of ProSPA producing water on the lunar surface.

2. Method

- Water can be produced from hydrogen reduction of **FeO-bearing minerals**.
- ProSPA is **not optimized** for this technique and the reaction must take place in a static (non-flowing) system (Fig. 2).
- **Ilmenite** is used as an 'ideal' lunar mineral for initial testing [2,3].

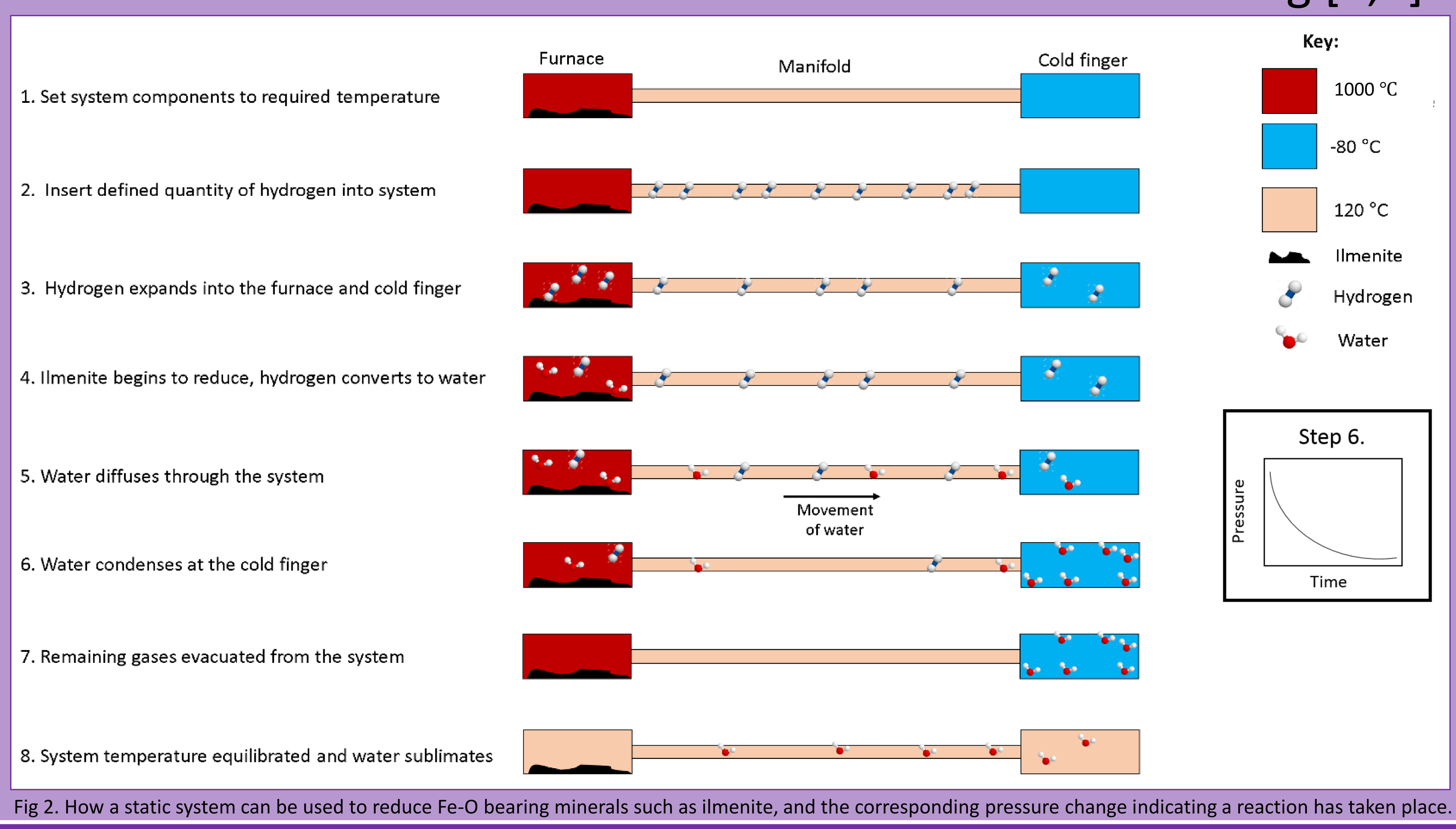

Fig 2. How a static system can be used to reduce Fe-O bearing minerals such as ilmenite, and the corresponding pressure change indicating a reaction has taken place.

3. Lunar Simulant

- NU-LHT-2M, a highland simulant with ~1.05 wt.% ilmenite [4]. Later sieved to remove <38 μm fraction.
- Pressure drop suggests reduction has occurred.
- Ilmenite grains show evidence of reduction along with small amounts of pyroxene and plagioclase.
- Yields of 0.29±0.04 wt.% O_2, compared to 3.43±0.14 wt.% O_2 for pure ilmenite.

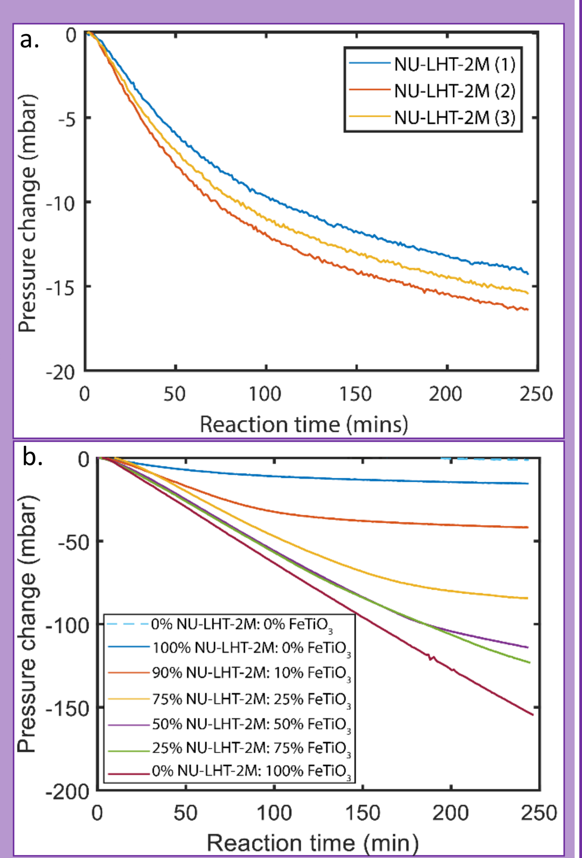

Fig. 3 Reduction pressures for a) NU-LHT-2M, and b) NU-LHT-2M doped with ilmenite ($FeTiO_3$)

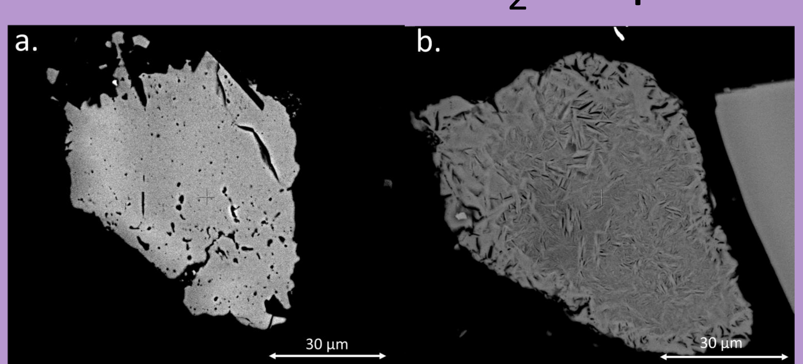

Fig. 4 BSE images of NU-LHT-2M grains before reduction. a) ilmenite, and b) plagioclase

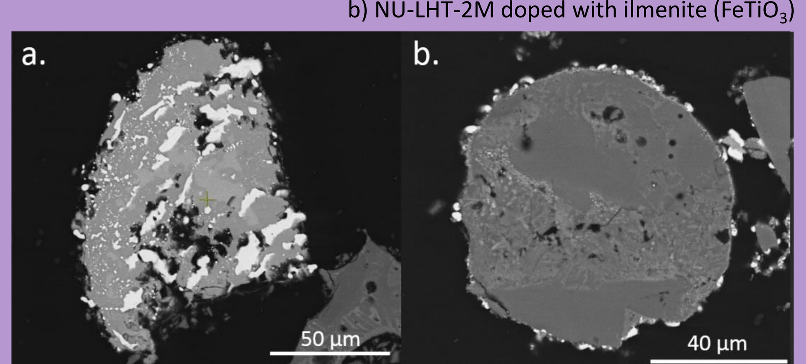

Fig. 5 BSE images of NU-LHT-2M grains after reduction. a) ilmenite, and b) plagioclase

4. Lunar Meteorite

- NWA12592, a feldspathic fragmental lunar regolith breccia [5].
- Manually crushed and sieved, with fines <38 μm removed
- Some samples treated with EATG [6,7] to remove secondary oxides from weathering.
- Some reduction recorded (0.07±0.02 wt.% O_2), no significant difference with EATG.
- Melt material and relatively large grain sizes could be limiting yields.

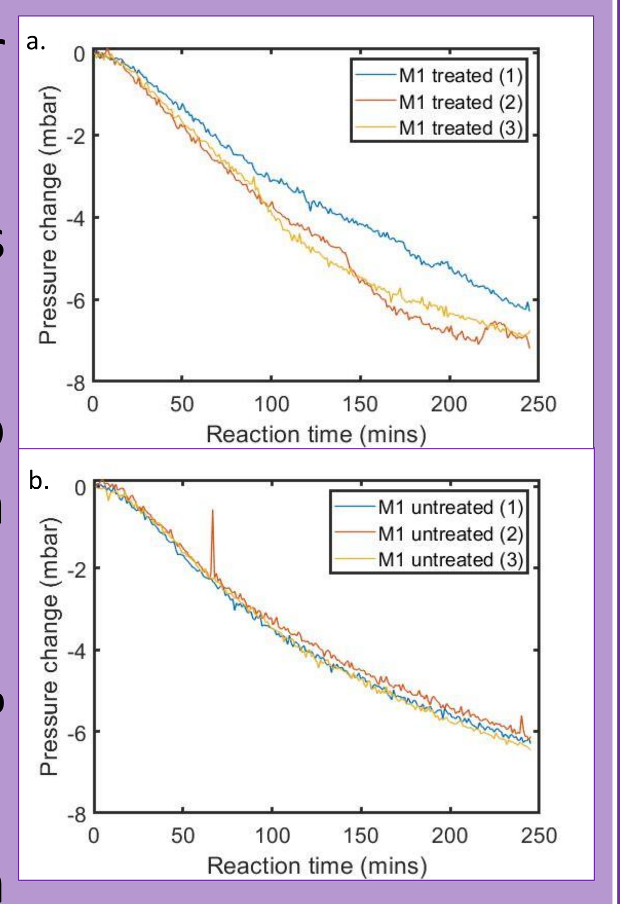

Fig. 6 Reduction pressures for a) EATG treated NWA12592, and b) un-treated NWA12592.

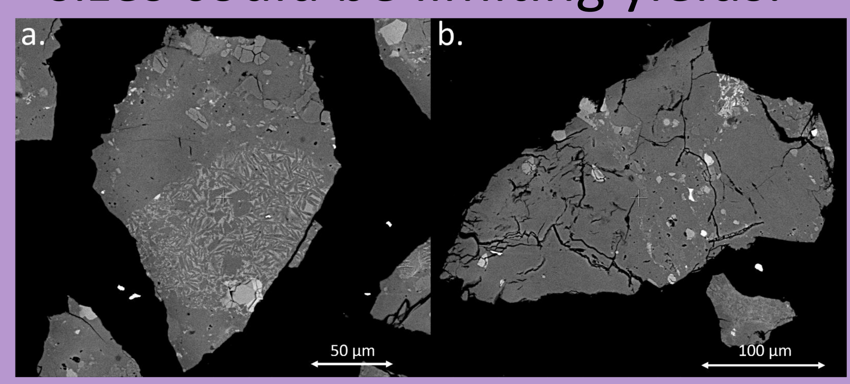

Fig. 7 BSE images of grains of NWA12592 before reduction.

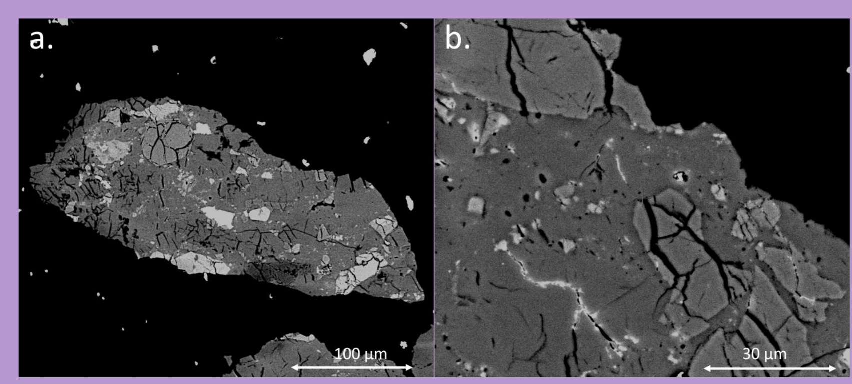

Fig. 8 BSE images of grains of NWA12592 after reduction.

5. Apollo Samples

- 10084 mare soil, <1 mm sieved fraction of Apollo 11 bulk soil [8]. Later sieved to remove <38 μm fraction. Relatively rich in FeO (1-3 vol.% ilmenite) [9].
- Significant reaction observed, with yields of 0.94±0.03 wt.% O_2.
- Different mineralogies show reduction.

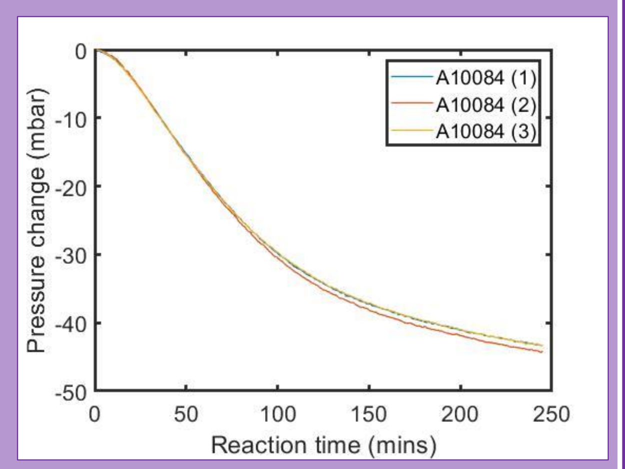

Fig. 9 Reduction pressures for 10084.

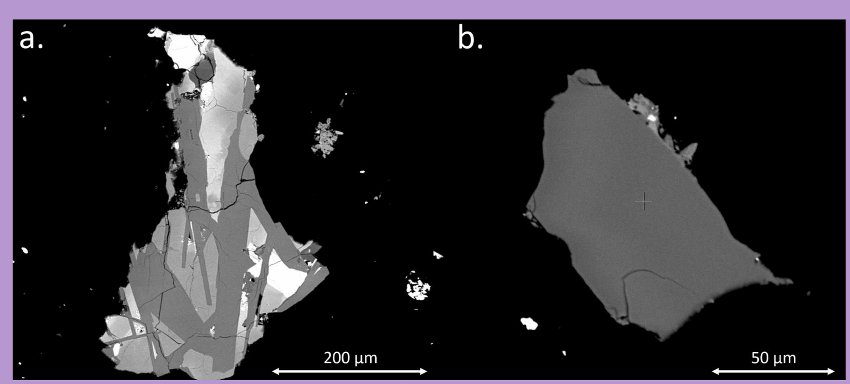

Fig. 10 BSE images of grains of 10084 before reduction.

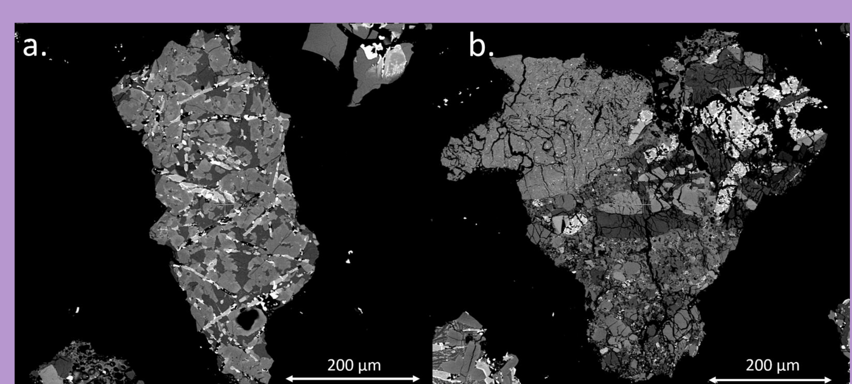

Fig. 11 BSE images of grains of 10084 after reduction.

- 60500 highland soil, unsieved fraction of Apollo 16 bulk sample. Later sieved to remove <38 μm fraction. Relatively poor in FeO (trace ilmenite) [10].
- Some reaction observed, with yields of 0.18±0.02 wt.% O_2.
- Mostly pyroxene reducing.

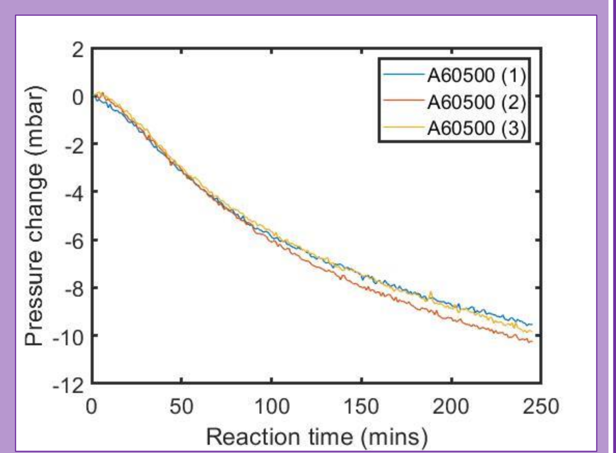

Fig. 12 Reduction pressures for 60500.

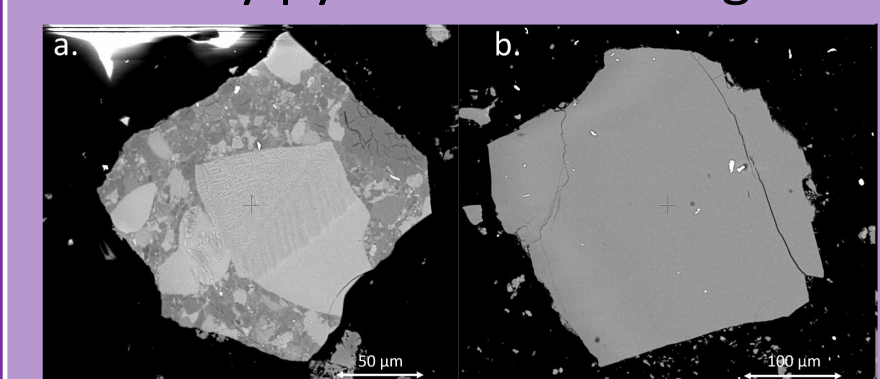

Fig. 13 BSE images of grains of 60500 before reduction.

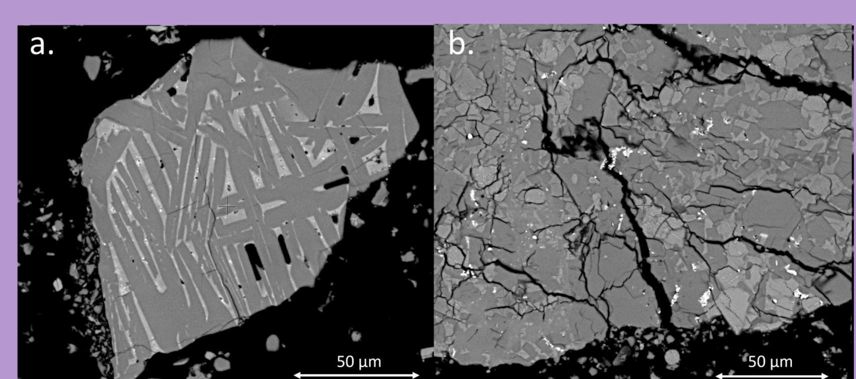

Fig. 14 BSE images of grains of 60500 after reduction.

1. Conclusions

- Lunar simulants and samples can reduce in a ProSPA-like system.
- Highland samples give lower yields, but still measurable.
- Could this be the 1st ever production of water on the lunar surface?

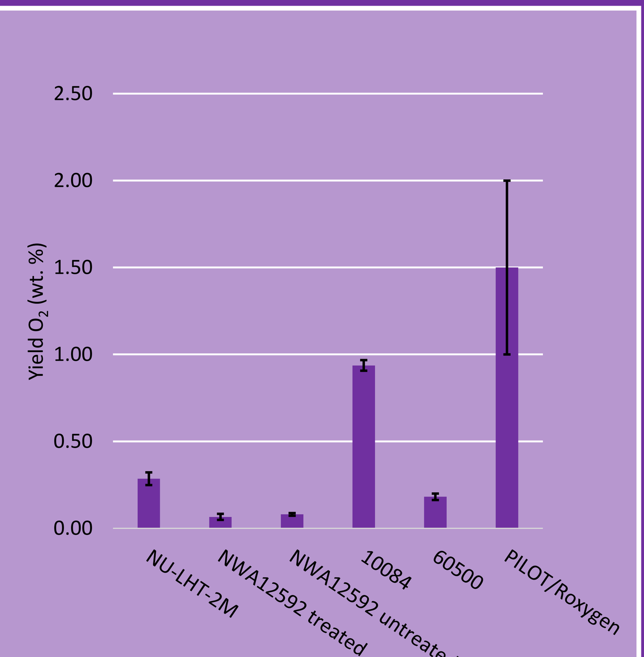

Fig. 15 Comparative yields from samples reduced in this work w.r.t. PILOT/Roxygen hydrogen reduction reactors [11].

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References: [1] Barber et al. (2018) *LPSC XLIX*, #2172. [2] Sargeant et al. (2019) *PSS*, 104759 (in press). [3] Sargeant et al. (2019) *PSS*, 104751 (in press). [4] Stoeser et al. (2010) NASA/TM-2010-216438. [5] Hayden et al. (2019) The Met. Bull. #108 in *Meteoritics & Planet. Sci.* (In Prep). [6] Cornish & Doyle (1984) *Palaeontology*, **27**(2) 421-424. [7] Greenwood et al. (2012) Geoch. et Cosmo. Acta, **94** 146-163. [8] Meyer (2009) *Lunar Sample Compendium*, 10084. [9] Kong et al. (2013) *Icarus*, **226** 891-897. [10] Meyer (2010) *Lunar Sample Compendium*, 60500 and 65510. [11] Sanders & Larson (2012) *J. Aero. Eng.*, **26** 5-17.