NOBLE GASES FROM IN SITU AND WHOLE ROCK ANALYSES OF MAIN-GROUP PALLASITE SERICHO.
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Introduction: The formation of the pallasites has been investigated in detail [e.g. 1 and references therein] and yet still remains controversial. The pallasite Sericho was identified in Kenya in 2017 [2]. It is a main-group pallasite with a similar texture as the Brenham pallasite. It contains about 70% olivine, 29% metal, troilite, schreibersite and trace chromite [2].

Here, we present first isotopic and elemental noble gas data on Sericho bulk material and in situ analyses. Primordially trapped noble gases can provide information about the early history of a meteorite's parent body. In Brenham, e.g., solar wind (SW) derived Ne and possibly Xe were found [3]. These could have been trapped in the solar nebula or in the early regolith of the parent body [3]. An observation of SW noble gases in Sericho would confirm their detection in Brenham. Additionally, we estimated cosmic-ray exposure ages as a contribution to the pallasite data inventory [e.g. 4].

Material and Methods: Samples were taken from two Sericho fragments of ~ 2.5 cm diameter. *Ser1* and *Ser2* are full slices (~2.5 mm thick) of these two fragments, whereas *SerP* consists of 12.5 g sawing powder from both *Ser1* and *Ser2*. We analyzed two powder aliquots (*SerA* 80.55±0.02 mg, *SerB* 74.93±0.02 mg). The polished slices were analyzed in situ by UV laser ablation before being crushed for preparation of major mineral separates (olivine, Fe,Ni metal, troilite and hematite, 2-9 mg).

Noble gases were extracted from *SerA* and *SerB* by heating to 1700°C in a crucible. Gas from the mineral separates was extracted by heating with a Nd:YAG IR laser (1064 nm) with a beam diameter of 50 to 250 µm. All gases He-Xe were analyzed with an in-house-built sector field noble gas mass spectrometer [5]. From the polished slices, the gas was extracted by in situ UV laser ablation (213 nm) [6] and He and Ne were measured with a high sensitivity mass spectrometer equipped with a molecular-drag pump [7]. The UV laser was run at 10-20 J/cm^2 for 1-3 min. to ablate spots of ~ 2-10 µm x 0.1-0.4 mm^2. Additionally, two aliquots of *SerP* were analyzed for major element composition with a Thermo Scientific Element XR ICP-MS.

Results and Discussion: The major mineral phases were identified with EDS analyses on the SEM. Olivine grains have diameters of 2-5 mm and are in a matrix of Fe-Ni metal with interstitial troilite (Fig. 1). The metal has transformed to hematite at the outer border of the original meteorite fragment.

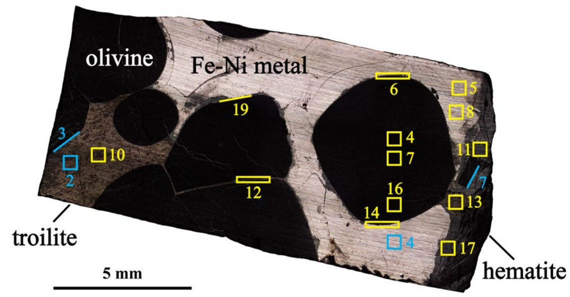

Fig. 1: *Ser1* reflected light microscope picture with marked mineral phases and laser spots and lines, in search for trapped He and Ne.

Sawing powder. (Table 1) Neon and ^{3}He are abundant (blank contributions <0.2 % for all isotopes) and entirely cosmogenic, whereas there is also some likely radiogenic ^{4}He. The ^{36}Ar/^{38}Ar (blank corrections ~7 % and ~1 % for ^{36}Ar and ^{38}Ar, respectively) is only slightly above the cosmogenic ratio. Together with the low ^{40}Ar/^{36}Ar, it suggests the presence of only very minor trapped ^{36}Ar and ^{38}Ar and excludes the presence of significant atmospheric ^{36}Ar. Likewise Kr and Xe concentrations are very low (blank corrections 12-33 %). Their isotope ratios are hence error-prone but mostly consistent with atmospheric Kr and Xe.

Table 1 Noble gas concentrations and isotopic ratios at STP and cosmic-ray exposure ages for SerP (Sericho bulk powder).

aliquot	^{20}Ne 10^{-8} cm^3/g	^{20}Ne/^{22}Ne	^{21}Ne/^{22}Ne	^{84}Kr 10^{-10} cm^3/g
SerA	16.58±0.21	0.8666±0.0046	1.0110±0.0069	0.91±0.11
SerB	16.96±0.20	0.8753±0.0037	1.0115±0.0040	0.51±0.12

aliquot	^{4}He 10^{-8} cm^3/g	^{3}He/^{4}He x 10^4	^{36}Ar 10^{-8} cm^3/g	^{36}Ar/^{38}Ar	^{40}Ar/^{36}Ar
SerA	673.5±5.6	1081±11	1.439±0.033	0.762±0.016	60.2±6.2
SerB	454.3±4.6	1612±19	1.335±0.034	0.695±0.017	35.3±6.9

aliquot	^{78}Kr	^{80}Kr	^{82}Kr ^{84}Kr≡100	^{83}Kr	^{86}Kr
SerA	0.77±0.12	4.36±0.73	21.0±3.6	21.4±3.6	31.6±5.3
SerB	0.85±0.25	4.6±1.4	22.3±7.0	19.9±6.5	32±10

aliquot	^{132}Xe 10^{-10} cm^3/g	^{124}Xe	^{126}Xe ^{132}Xe≡100	^{128}Xe
SerA	0.271±0.019	0.361±0.063	0.462±0.057	7.98±0.71
SerB	0.221±0.020	0.524±0.092	0.472±0.072	7.63±0.91

aliquot	^{129}Xe	^{130}Xe	^{131}Xe ^{132}Xe≡100	^{134}Xe	^{136}Xe
SerA	101.2±9.4	15.6±1.5	80.7±7.9	37.4±3.7	32.9±3.3
SerB	103±12	15.1±1.8	83±11	37.0±4.8	31.9±4.4

In situ UV laser ablation. Helium and Ne were examined by in situ ablation of single mineral grains and grain boundaries in order to search for trapped SW suggested to be carried in or on Brenham olivine [3]. The Ne isotopic compositions in *Ser1* and *Ser2* overlap (Fig.

2), suggesting that both fragments originate from close to each other within the meteoroid.

The measured average $^3He/^4He$ is 0.1138±0.0066 for olivine, 0.225±0.013 for metal, 0.1377±0.0044 for troilite and 0.1320±0.0062 for olivine-metal boundaries, similar to the bulk data. The $^{20}Ne/^{22}Ne$ ranges from ~0.6 to ~1.1 and $^{21}Ne/^{22}Ne$ from ~0.8 to ~1 (Fig. 2). The average $^{21}Ne/^{22}Ne$ is 1.005±0.014 for olivine, 0.770±0.069 for metal, 0.824±0.016 for troilite and 0.986±0.021 for olivine-metal boundaries. Neon and ^3He in all measured mineral phases are therefore purely cosmogenic. Due to extremely low extracted gas amounts (^{21}Ne max. 2.9 x 10^{-14} cm^3), Ne was mostly not detected in metal.

The models by Leya and Masarik [8] predict cosmogenic production rates in dependence of the pre-atmospheric radius and the depth within a meteoroid. To date, no such models exist for pallasites. Since ordinary chondrites (OC) have a more similar bulk chemical composition to pallasites, the OC model [8] is used here for a rough estimation: The mass and mineralogy of Sericho [2] confine its pre-atmospheric radius to a minimum of 50 cm. Contrary to most OCs, the shielding ratio $^{21}Ne/^{22}Ne$ of *SerP* is >1 (Table 1), which is due to its low Si and high Fe content. The OC model is therefore capable of considering pallasitic compositions for big meteoroids. Using the average major element composition of *SerP*, the OC model [8] defines the possible depth ranges for different radii for the given $^{21}Ne/^{22}Ne$ shielding ratio. These depth ranges (max. depth 120 cm) in meteoroids of 50 to 500 cm radius were used to predict $^{21}Ne/^{22}Ne$ ratios for troilite and olivine, by applying the chemical composition of troilite and olivine, respectively, to the model. The predicted $^{21}Ne/^{22}Ne$ ratios are ~0.93-0.96 for troilite and ~1.02-1.03 for olivine (Fig. 2). The higher values for olivine compared to troilite are caused by the higher ^{21}Ne production in Mg and Si than Fe and S. The discrepancy between the OC model prediction and our results shows that the model is not readily applicable to a pallasite. However, it predicts a higher $^{21}Ne/^{22}Ne$ for olivine than for troilite, in agreement with our results. These can therefore be explained with the chemistry-dependent cosmogenic production rate.

Neon in the olivine-metal boundary is dominated by cosmogenic Ne from olivine and no other trapped component was present. Thus, unlike Brenham [3], no SW derived Ne could be found at olivine-metal grain boundaries or in any other mineral phase or bulk sample of Sericho. If any noble gases had been trapped in the solar nebula or in the early regolith of the parent body, they must have diffused out of the rock during differentiation in the parent body. This is consistent with the lack of abundant trapped Ar, Kr and Xe.

CRE age. Since Sericho has a large radius, it is hard to define its cosmic-ray exposure (CRE) age. An estimation was done with the OC model [8], using the average major element composition of *SerP*, $^{21}Ne/^{22}Ne$ as shielding ratio and a maximum depth of 120 cm. The model yields possible depth ranges for different radii. The resulting average ^{21}Ne and ^{38}Ar ages of roughly 160 Ma and 130 Ma, respectively, lie within the range observed for other pallasites [4] The ^3He age (~100 Ma) is significantly lower and indicates atmospheric He loss.

Conclusion: Our study revealed: (i) no trapped noble gases are present in Sericho in contrast to Brenham [3], (ii) we are able to detect the differences in cosmogenic Ne in distinct mineral phases by UV laser ablation (typically ~5 µg ablated) induced by the chemical differences of olivine, metal and troilite and (iii) we estimated the CRE age of Sericho to be ~130-160 Ma, consistent with many main-group pallasites [4].

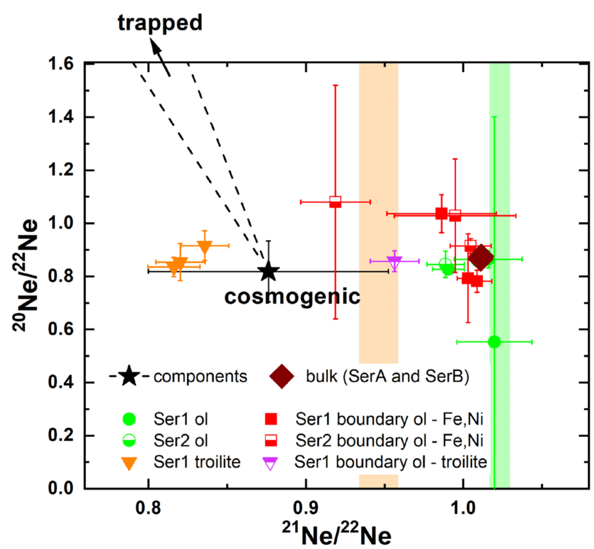

Fig. 2 Ne isotopic compositions of Sericho minerals released by in situ laser ablation and of Sericho bulk samples. The shaded areas mark the predicted ranges for troilite and olivine (ol).

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References: [1] Donohue P. H. et al. (2018) GCA, 222, 305-318. [2] Gattacceca, J. et al. (2018) Meteoritics & Planet. Sci., The Meteoritical Bulletin, No. 106. [3] Mathew K. J. and Begemann F. (1997) JGR, 102, 11015-11026. [4] Herzog G. F. et al. (2015) Meteoritics & Planet. Sci., 50, 86-111. [5] Riebe, M. E. I. et al. (2017) Meteoritics & Planet. Sci., 52, 2353-2374. [6] Heber V. S. et al. (2009) GCA, 73, 7414-7432. [7] Baur H. (1999) EOS, Transactions, AGU, 80, 46, 1118. [8] Leya I. and Masarik J. (2009) Meteoritics & Planet. Sci., 44, 1061-1086.