CHARACTERISTICS OF A NEW CARBONACEOUS CHONDRITE, METAL-RICH-LITHOLOGY FOUND IN THE CARBONACEOUS CHONDRITE BRECCIA AGUAS ZARCAS. I. Kerraouch[1,2], A. Bischoff[1], M. E. Zolensky[3], A. Pack[4], Markus Patzek[1], E. Wölfer[1], C. Burkhardt[1] **and M. Fries**[3].[1]Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm Str. 10, D-48149 Münster, Germany. ikerraou@uni-muenster.de, [2]Department of geology, University of Science and Technology Houari Boumediene (USTHB), Alger, Algeria, [3]NASA Johnson Space Center, Houston TX, USA, [4]Universität Göttingen, Geowissenschaftliches Zentrum, Goldschmidtstr. 1, D-37077 Göttingen, Germany.

Introduction: The Aguas Zarcas meteorite fell in Costa Rica on 23 April 2019 at 21:07 local time, with a total mass of about 27 kg. Hundreds of fusion-crusted stones ranging from 0.1 to 1868 g were recovered (The Meteoritical Bulletin).

The meteorite was classified as a CM chondrite, but some lithlogies show a different texture to that of CM. In this study, we investigated the petrography, mineralogy, chemistry, and isotopic composition of an unusual "Metal-rich-lithology" from this fresh fall.

Methods: Back-scattered electron imaging (BEI), elemental mapping, electron microprobe analysis (EMPA), and Ti isotope analysis were conducted at the Institut für Planetologie (IfP), University of Münster. Bulk oxygen isotopes were obtained using the IR-Laser … at the Universität Göttingen. Chondrule diameters were measured with two different methods: (a) light microscopy transmitted light (MTL), using a calibrated reticle and (b) using backscattered-electron images (BSE). The maximum length and the greatest width perpendicular to the long axis of each chondrule were measured and averaged, the size is the mean of the length and width. Chondrule abundances were also calculated.

Results: The main stone of our study (1.8cm x 1.2cm x 1cm) is quite dark, with visible chondrules, metal and olivine grains. The sample is a breccia. We have noted clasts of two main lithologies, (1). Metal-rich-lithology (84.15 vol%) and (2) brecciated CM-lithology (15.85 vol%) with clasts of at least three different petrologic subtypes.

Metal, sulfides, olivine, pyroxene, and carbonate represent major phases in the metal-rich lithology (Fig.1). Olivine and pyroxenes occur both in the chondrules and as clasts in the matrix as well, having similar compositions in both areas. The average compositions of olivine is Fa13.3±19.9 (n=120). Zoned olivine is abundant in the majority of chondrules. The mean compositions of low-Ca pyroxene and diopside are $Fs_{2.4\pm3.3}$ $En_{95.1\pm4.9}$ $Wo_{2.5\pm2.4}$. and $Fs_{1.9\pm1.5}$ $En_{60.8\pm6.1}$ $Wo_{37.3\pm6.0}$ successively. Phyllosilicates, both of matrix and rims have similar composition with the mean total of ~87.3 (±4.0 wt%).

Metal and sulfides represent 3 vol% in the whole sample. The metal (2.25 vol%) is kamacite and taenite, ranging from a few µm up to 550 µm and having circular shapes; others are sometimes irregular in shape but have well-rounded edges. Taenite occurs sometimes as exsolutions in the kamacite. Sulfides (0.75 vol%) are pyrrhotite and pentlandite. Pentlandite occurs as exsolutions in pyrrhotite. Some sulfides contain inclusions of metal grains. Very often, the metal-rich lithology contains metal and sulfide together with its preterrestrial alteration products.

The chondrules are round to slightly irregularly-shaped having rather thick, fine-grained, phyllosilicate-rich rims (up to 160 µm thick). Several chondrule types have been identified (PO, BO, POP, RP). Most of them contain a high abundance of metal and sulfide grains either inside and/or at their edges and are similar in texture to typical chondrules in CR2 chondrites. In addition the metal-rich-lithology also contains a very high abundance of altered chondrules with different textures and mineralogies.

Chondrules sizes vary from 14 to 800 µm. The different methods used for size determination of chondrules give almost the same average chondrule size and model abundance: A mean size of 186 µm by means of optical microscopy with an abundance of 29 vol%, and 149 µm by using BSE mosaic maps with 31.5 vol%.

Two types of Ca, Al-rich inclusions (CAIs) can be distinguished. The first has a rounded shape, are spinel-rich surrounded by an Al-rich diopside rim and another round CAIs is hibonite- rich. The second irregularly-shaped CAIs are larger (~500 µm), very complex, and unusual in mineralogy. On average they have a remarkably high abundance of calcite (~53 vol%). They are typically composed of calcite and spinel with some small perovskite grains (<2 to 10 µm). In some cases, minor fassaite was found enclosed within the spinel.

The CAIs are surrounded by an Al-rich diopside rim of variable thickness.

The O-isotope composition of the metal-rich-lithology falls below the terrestrial fractionation line (TFL) and far from the field of CM chondrites ($\delta^{18}O$=3.8; $\delta^{17}O$=2.7) (Fig.2). While the Ti isotope compositions are $\varepsilon^{46}Ti = 0.55 \pm 0.14$, $\varepsilon^{48}Ti = -0.03 \pm 0.04$ and $\varepsilon^{50}Ti = 2.55 \pm 0.24$ (n = 6; all uncertainties are 95% CI) (Fig.3) and agree within error with literature values for CR chondrites [1-2].

Discussion and conclusion: From the mineralogical study, silicates and phyllosilicates within the metal-rich-lithology show the same composition as the CM-chondrites [3], but texturally the sample shows some similarity with CRs (chondrules surrounded by metals) [4-5]. On the other hand, the chondrule size data are clearly different to those of the CM-chondrites (~270 µm) [5]. The data also show, that CM chondrites have a significantly lower chondrule abundance of approximately 20 vol% compared to the chondrule abundance within the metal-rich lithology (30 vol%). CR chondrite are even more different, with mean chondrules diameters ~700µm and 55 vol% for chondrule abundance [4].

However, based on the oxygen isotopes the stone is neither CM nor CR (Fig. 2). However, the Ti isotopes suggest a close relationship to the CR-chondrites (Fig. 3).

These characterizations lead to some important questions. (1) Based on previous data the fresh fall Aguas Zarcas is not a homogeneous CM2 chondrite as it has been classified (according to the Meteoritical Bulletin). (2) What is the nature of the Metal-rich-lithology stone, and what is its relationship with CR-chondrites? (3) Why is the calcite in the CAI so unusual?

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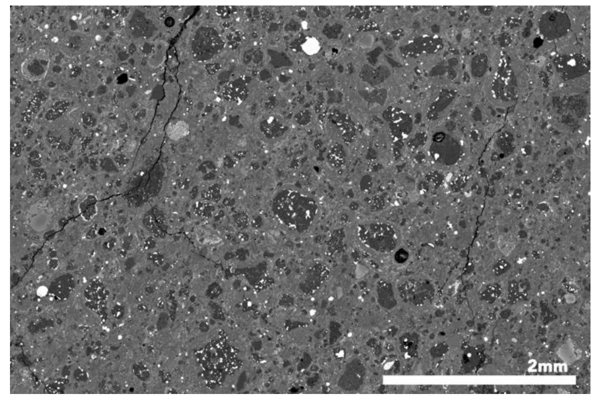

Fig. 1: BSE Image of the metal-rich lithology.

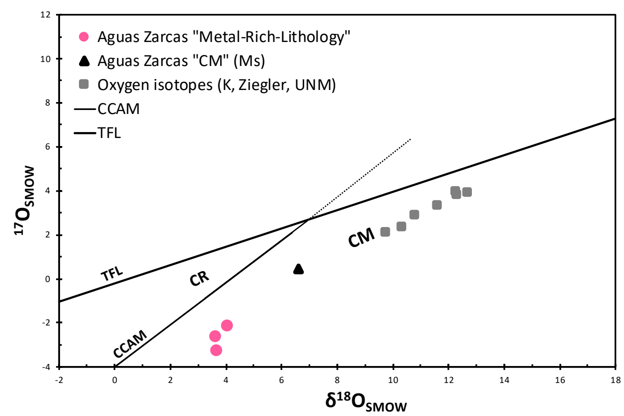

Fig. 2: Bulk oxygen isotopes of the metal-rich-lithology compared to CM lithologies found in Aguas Zarcas, from this study and from K. Ziegler (Meteorite Bulletin Database).

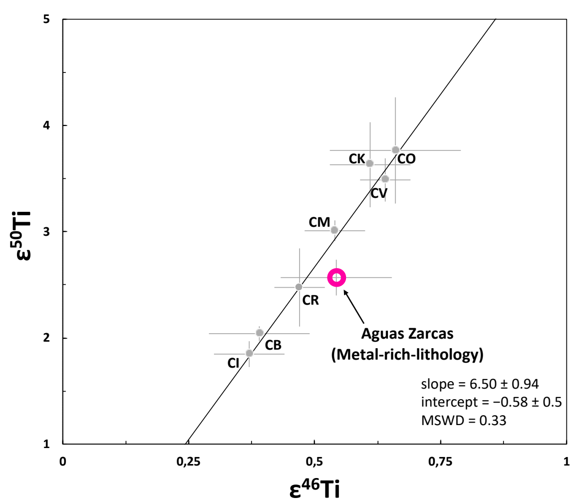

Fig. 3: ε50Ti vs. ε46Ti for the Metal-rich-lithology shows a possible relationship to CR-chondrite.