AQUEOUS ALTERATION IN THE CM2 AGUAS ZARCAS METEORITE. L. J. Hicks and J. C. Bridges, School of Physics and Astronomy, University of Leicester, LE1 7RH, UK (ljh47@leicester.ac.uk).

Introduction: The Aguas Zarcas meteorite is a recent confirmed fall meteorite, over Alajuela in Costa Rica on 23 April 2019, and is classified as a CM2 carbonaceous chondrite [1]. CM2 chondrites typically feature an abundance of serpentine [2] and early powder XRD analyses of Aguas Zarcas confirm the dominant presence of these phyllosilicate clay minerals [1]. This is evidence of aqueous alteration occurring within the meteorite and preserves a record of the parent body processes and evolution. A new meteorite fall such as Aguas Zarcas is ideal for investigating the parent body aqueous alteration processes due to a lack of terrestrial weathering affecting the sample.

Samples and Methods: A polished thin section was prepared from a 2.9 g specimen of the Aguas Zarcas meteorite, which had been collected within 5 days after the fall.

Initial observations of the thin section and EDX measured using a FEI Sirion 200 FEG-SEM, and lift-out sections extracted using a FEI Quanta 200 3D dual-beam FIB-SEM at the University of Leicester Advanced Microscopy Facility. Lift-out sections measure approximately 15×5 μm and thinned to ~100 nm. Transmission electron microscope (TEM) analyses were performed using a JEOL 2100+ TEM at the University of Nottingham, with Bright-Field (BF) imaging and dark-field STEM imaging.

Results: The Aguas Zarcas thin section reveals a complex CM2 mineralogy, featuring olivine (Fo_{57-99}) and pyroxene ($En_{94-99}Fs_{1-3}$) grains both within chondrules and throughout the matrix, along with FeNi sulphides, and an abundance of phyllosilicate clays, but only a minor presence of Fe metal constituents.

A FIB lift-out section was extracted from phyllosilicate clays found within a mostly pyroxene ($En_{99}Fs_{1}$) chondrule that featured a rim of altered FeNi sulphide (see Figure 1A). Figure 1B shows the phyllosilicates to have mineralogical variations, either chemically or structurally.

BF-TEM images reveal these variations to be structural differences in the crystalline clays (see Figure 2), where crystalline phyllosilicates surround partially crystalline regions. High-resolution (HR) TEM images reveal lattice fringe spacings present in both regions, with a platy structure in the more crystalline region (Figure 3A), and the partially crystalline region featuring curved crystal structures (Figure 3B). The platy lattice spacing measured an average 7.39 Å (standard deviation of 0.07 Å), and the curved lattice spacings averaged 7.42 Å (standard deviation 0.16 Å).

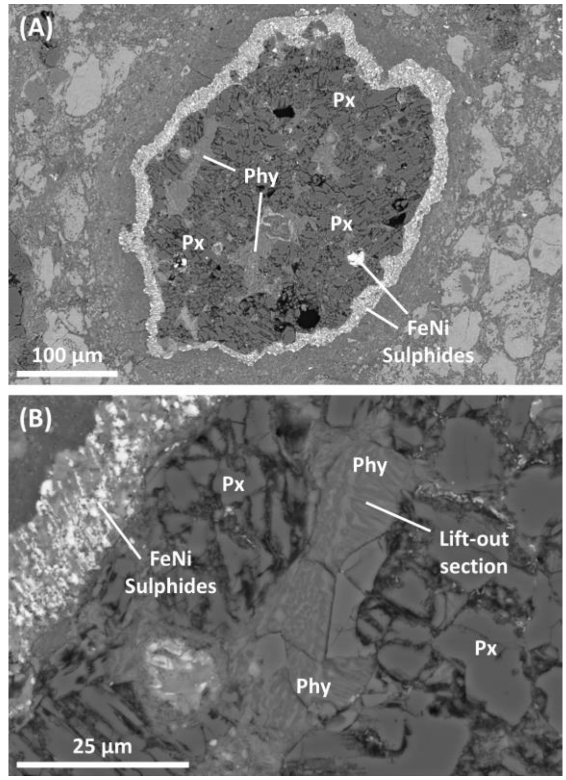

Figure 1. (A) FEG-SEM back-scattered-electron image of chondrule featuring pyroxene (Px) with phyllosilicates (Phy) and FeNi sulphides. (B) Higher magnification image of the phyllosilicates from which a FIB lift-out section was extracted.

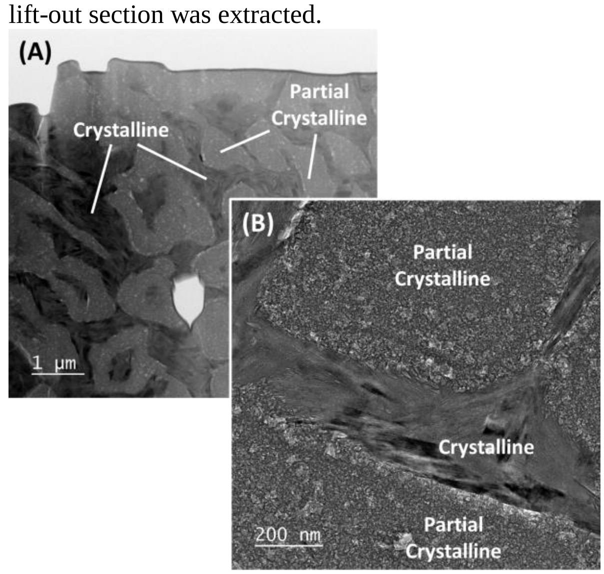

Figure 2. BF-TEM images of Aguas Zarcas lift-out section, showing crystalline phyllosilicates surrounding partially crystalline phyllosilicates. (A) BF-STEM image. (B) 20 kX magnification.

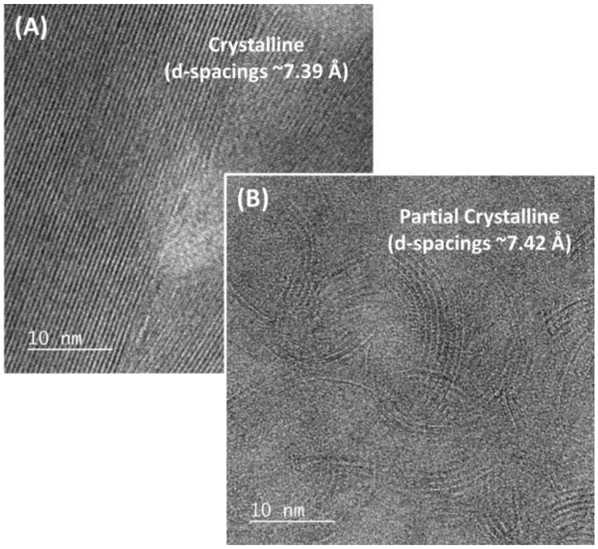

Figure 3. HR-TEM images of phyllosilicates. (A) 500 kX magnification of platy crystalline phyllosilicates showing average lattice fringe spacings averaging ~7.39 Å. (B) 500 kX magnification of curved partially crystalline phyllosilicates, showing lattice fringe spacings averaging ~7.42 Å.

Chemical compositions, as shown in Table 1, reveal only minor variations between the platy crystalline and the curved partially crystalline clays.

Table 1. STEM-EDX chemical composition of serpentine phyllosilicates.

	Serpentine phyllosilicates			
	Crystalline	Partial crystalline	Orgueil* (Average)	Murchison* (Bulk)
Na_2O	0.4	-	-	-
MgO	23.2	26.0	20.9	14.0
Al_2O_3	6.2	4.2	2.2	3.3
SiO_2	40.6	37.6	31.9	22.3
SO_3	1.9	-	6.6	8.53
CaO	0.2	-	-	-
Cr_2O_3	0.8	-	-	-
FeO	26.7	32.3	24.4	33.4
NiO	-	-	1.76	2.05
Total	100.0	100.0	-	-

* Microprobe results for chondrule phyllosilicates referenced in [3]

Discussion: The TEM results from this investigation have shown the CM2 Aguas Zarcas to be mostly consistent with other CM2 meteorite phyllosilicate morphologies. Meteorites such as Murchison include large crystalline Fe-rich serpentine minerals with Mg-rich chrysotile-like group members [4]. Lattice spacings of ~7.0-7.4 Å have been measured in Murchison, similar to those measured in Aguas Zarcas, as well as chrysotile-like minerals with curved lattice structures and spacings measuring ~7.4 Å [4]. TEM observations of the CM2 meteorite QUE 93005,16 also revealed platy and curved serpentine with d-spacings measuring ~7.2 Å and ~7.6 Å respectively [5].

In order to obtain a detailed understanding of the alteration processes and constrain the history of the Aguas Zarcas meteorite parent body, further investigations are required of the phyllosilicates throughout the matrix and other chondrules. Additional techniques such as Fe-K XANES will also be sought to investigate changes in iron oxidation state across the various clay features and other signs of alteration.

References: [1] *Met. Bull.* (2019). [2] Hutchison R. (2004) *Meteorites: A petrologic, chemical and isotopic synthesis*. [3] Calvin W. M. and King T. V. V. (1997) *Meteorit. Planet. Sci.*, 32, 693-701. [4] Barber D. J. (1981) *Geochim. Cosmochim. Ac.*, 45, 945-970. [5] Velbel M. A. and Palmer E. E. (2011) *Clay. Clay. Miner.*, 59, 416-432.