DOCUMENTING ANTARCTIC ALTERATION OF EUCRITES. D. W. Mittlefehldt[1] , A. A. Turner[2,3] and L. Le[2], [1]Astromaterials Research Office, NASA Johnson Space Center, Houston, TX, USA (david.w.mittlefehldt@nasa.gov), [2]GCS-Jacobs JETS-NASA Johnson Space Center, Houston, TX, USA, [3]Dept. of Geology, University of Nevada, Las Vegas, Las Vegas, NV, USA.

Introduction: When meteorites were discovered in Antarctica, it was anticipated that terrestrial alteration would be at a minimum because of their deep-freeze storage where chemical reaction rates would be low. However, early compositional and petrologic studies established the presence of terrestrial alteration phases (e.g., [1, 2]). These were especially prevalent in chondrites because metal and troilite are most susceptible to terrestrial alteration [3]. Howardites, eucrites and diogenites (HEDs) are less prone to alteration because they have low abundances of metal and troilite. Nevertheless, investigations of HED meteorites document a wide array of mineralogical, compositional and isotopic effects of terrestrial alteration (e.g., [4-8]).

Studies of the mineralogical effects of alteration [4] were done with old scanning electron microscope (SEM) technology which could only image small regions at a time. The micro-context of alteration phases was revealed, but larger-scale context was difficult to establish. Here we demonstrate the utility of whole-thin-section X-ray mapping of eucrites by modern SEMs to document large-scale distributions of alteration materials which serve to evaluate sample freshness, highlight regions for detail study, and facilitate testing a hypothesis for alteration of eucrites [8].

Samples and Methods: We have studied eucrites from the Allan Hills, Elephant Moraine, Lewis Cliff and Grosvenor Mountains icefields. Here we focus on Stannern-group eucrite LEW 88010. Image grids of backscattered electrons (BSE) and X-ray intensities for major and minor elements were collected using a JEOL 7600F FEG SEM at magnifications of 100× to 150× to cover entire sample areas. Individual images were mosaicked into whole-section X-ray maps and BSE image. Six individual X-ray mosaics were assigned colors and combined to produce images that facilitate mineralogical identification. Different element choices allow for highlighting different mineralogical assemblages. Regions of interest were imaged at higher resolution to document textures.

Results: The curved top and right side of the LEW 88010,18 (Fig. 1a) is an exterior surface of the meteorite, indicated by vesicular fusion crust. The 3D shape of the exterior surface relative to the plane of the thin section is unknown. Magmatic phases are pigeonite, augite, plagioclase, silica, ilmenite, Ca-phosphate and troilite. Near the fusion crust are patches and veins of a $CaSO_4$ alteration phase, probably gypsum [4] (Fig. 1b).

Gypsum partially fills vesicles in the fusion crust (Fig. 1b) demonstrating that it was formed after atmospheric passage. Gypsum occupies cracks with connections to the exterior surface mostly within ~500 µm of the base of the fusion crust, but up to ~840 µm away (arrow, Fig. 1a).

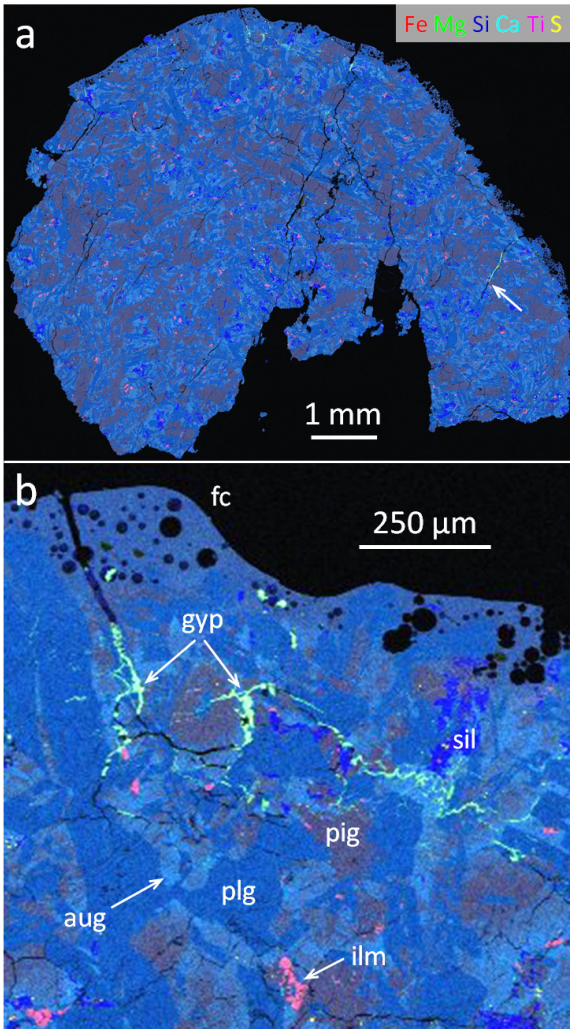

Figure 1. a. Elemental mosaic of LEW 88010,18. b. Detail of near-surface area showing $CaSO_4$ (presumed to be gypsum) in veins and in vesicles in the fusion crust. Abbreviations: aug – augite; fc – fusion crust; gyp – gypsum; ilm – ilmenite; pig – pigeonite; plg – plagioclase; sil – silica.

Textures of gypsum within vesicles, and cross-cutting plagioclase and pigeonite (Fig. 2) show no evidence of interaction between gypsum and its substrate.

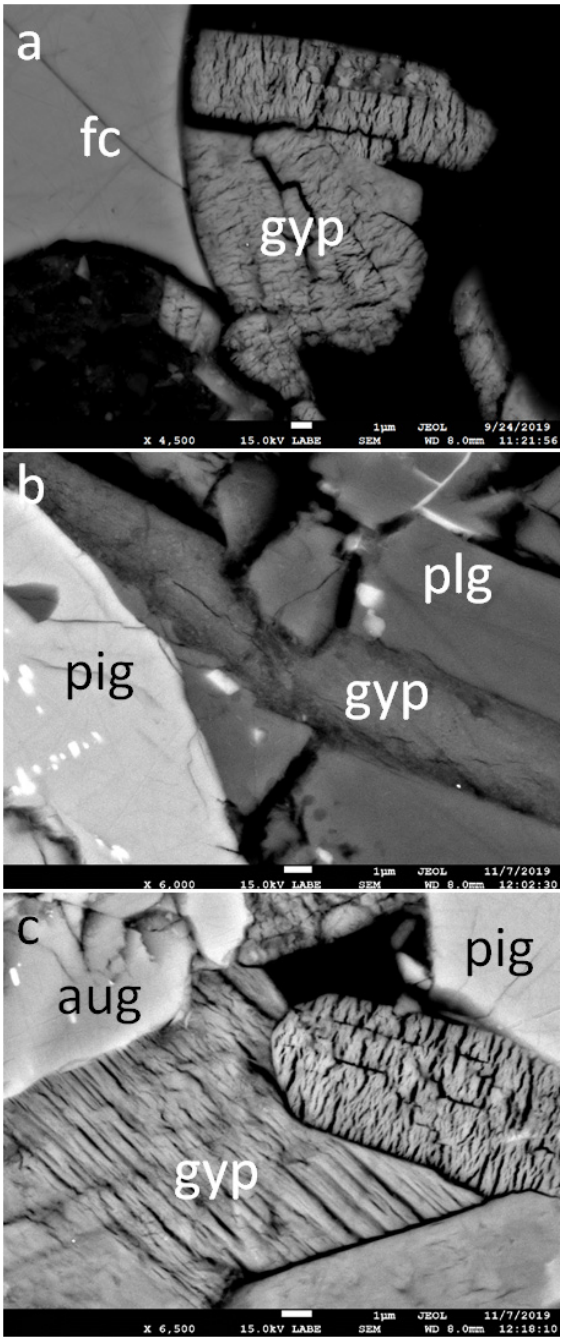

Figure 2. Details of $CaSO_4$ (gyp) in: a. vesicles in the fusion crust (fc); b. cutting plagioclase (plg) and pigeonite (pig); and c. cutting pigeonite and augite (aug).

Discussion: We have highlighted gypsum because of the hypothesis [8] that melt waters in cracks in Antarctic eucrites promote oxidation of FeS to form sulfuric acid solutions which attack rare-earth-element (REE)-rich phosphates. Iron is largely fixed at the site of alteration as iron oxides/hydroxides ("rust") (cf., [2]). The solutions mobilize P, S, Ca and REE. This results in anomalous REE patterns for different splits of individual eucrites [8]. Gypsum precipitates are expected byproducts. We found no textural evidence for interaction between gypsum and its substrates in any section examined (Fig. 2), indicating that this phase is not a product of in situ alteration. The textures are consistent with precipitation of gypsum from brines that minimally interacted with the host. Gypsum is present as partial fillings of vesicles in fusion crust and in many cracks with openings to the exterior (Figs. 1a, b, 2a), suggesting preferential precipitation at the sites of brine evaporation.

Troilite is an accessory phase in LEW 88010 and mostly occurs as few-micron-sized grains especially concentrated in mesostasis regions that also contain Ca-phosphate. Troilite is typically unaltered in our thin section, but a few small regions of "rust" are present. Numerous grains of Ca-phosphate are present. These observations tend to negate the alteration hypothesis [8]. However, a key aspect of the hypothesis is that REE are mobilized on the scale (several mm) of individual samples. Thus, concentrations of gypsum can be distant from sites of troilite-Ca-phosphate alteration. Examination of several sections of an individual eucrites is needed to fully test the alteration hypothesis.

The elemental maps can serve to guide in situ measurements, such as laser ablation inductively-coupled-plasma mass spectrometry, to determine anomalous trace element signatures resulting from alteration and further constrain Antarctic alteration processes.

Key Findings: Elemental X-ray mapping by SEM or electron microprobe provides a relatively rapid method to document terrestrial alteration effects in meteorites that can be used to evaluate the potential for chemical/isotopic contamination, and to identify specific regions for detailed study of alteration processes.

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