MATRIX MINERALOGY OF THE BALI CV3 CARBONACEOUS CHONDRITE. Lindsay P. Keller[1] and Kathie L. Thomas[2], [1]SN14, NASA Johnson Space Center, Houston, TX 77058 and [2]Lockheed, 2400 NASA RD. 1, Houston, TX 77058.

Introduction. C3 carbonaceous chondrites were originally thought to have escaped the effects of aqueous alteration that have modified the mineralogy of the CI and CM chondrites. However, recent transmission electron microscope (TEM) studies have shown that hydrated silicates are locally well-developed in some C3 falls [1-3]. In this report, evidence for extensive aqueous alteration under oxidizing conditions is described from a TEM study of the Bali CV3 chondrite. These results have implications for alteration processes and parent body environments.

Bali is a fall (1907, Central African Republic) and belongs to the oxidized subgroup of the CV3 chondrites [4]. A preliminary petrographic and mineralogical study of Bali was reported by Hoinkes and Kurat [5], who noted that many of the chondrules and inclusions were partly altered to hydrous silicates and that metal blebs had been replaced by fine-grained oxide-sulfide intergrowths.

Experimental. Fragments of Bali were obtained from the Naturhistorisches Museum in Vienna. These consisted of chips from the exterior of the meteorite with intact fusion crust as well as samples from the interior. The techniques used to prepare thin sections and TEM specimens are described elsewhere [1, 3]. A probe mount of Bali (Smithsonian sample USNM-4839-1) was also studied.

Results. Thin sections of Bali show a pronounced foliation defined by flattened chondrules and inclusions (aspect ratios ≤ 2). The fabric of Bali resembles Leoville (CV3) [6]. The alteration products in Bali are not homogeneously distributed (also noted by G. Kurat, pers. comm.). In heavily altered areas, it is difficult to pick out individual grains in chondrules; large grains in chondrules and inclusions have been "fractured" into a mosaic of small (<10 μm) crystals. Many of the chondrules and inclusions are surrounded by ~100 μm wide rim of fine-grained olivine (Fa 30 to 35). Aggregates of magnetite are abundant in Bali matrix and increase in grain size and abundance in the heavily altered regions (up to 50 μm in dia.) relative to less altered areas (<10 μm). Fe-S aggregates in matrix have been partly oxidized with local redistribution of Fe as haloes around the objects.

Matrix olivines show a wide compositional range (Fa10 to Fa70), but >90% of olivine grains fall in the range of Fa15 to Fa50. The olivines contain numerous planar defects that parallel the (100) planes. High resolution TEM images show that considerable strain is associated with the planar defects. Selected area electron diffraction (SAED) patterns of the [010] zone axis for matrix olivines show diffuse streaking along a*. In addition to the streaking, weak reflections with a spacing consistent with the unit cell of magnetite occur in one SAED pattern. The planar zones are <2 nm wide and are found in both low- and high-Fe olivines.

Phyllosilicates are abundant in the regions between olivine grains in matrix. They also replace olivine along the planar defects such that (001) planes of olivine and saponite are parallel. The phyllosilicates show 1-nm basal spacings in high resolution images and have compositions consistent with saponite (a Mg-rich trioctahedral smectite). There is a positive correlation between saponite grain size and the size of interstices between olivine grains.

Magnetite is ubiquitous in Bali matrix and contains <1 wt. % each of MgO, TiO_2, and Cr_2O_3). Minor minerals in matrix include low-Ca and high-Ca pyroxenes, fine-grained chromite, and isolated grains of Ca-phosphate.

One inclusion was studied in detail in the TEM; it has been extensively altered and consists largely of high-Ca pyroxene, Mg-rich olivine, nepheline, Fe-bearing spinel, and phyllosilicates. The inclusion is surrounded by a rim of Fe-rich olivine (Fa30 to Fa35). The phyllosilicates are dominated by saponite, but sparse lath-shaped grains of Na-K mica also occur. The mica grains are up to 200-nm long, ~20-nm wide, and are intimately intergrown with saponite.

Discussion. Bali has undergone pervasive aqueous alteration that has resulted in the formation of abundant saponite and magnetite from anhydrous silicates (mostly olivine). In some of the heavily altered regions of Bali, alteration products comprise 25 to 50 % of matrix. The textures indicate that the magnetite lamellae in matrix olivines formed prior to aqueous alteration. While it is clear that olivine provided most of the Mg and Si for saponite formation, the source of Al and Na is currently unknown. We have not observed any aluminous phases other than saponite in matrix. Aluminous phases such as feldspars, feldspathoids, and glass are known to occur in the matrices of other CV3 chondrites [7] and so we assume that they were originally present in Bali but have been subsequently altered. By analogy to terrestrial occurrences, the assemblage saponite + magnetite indicates alteration at low temperatures in an oxidizing environment.

The planar defects in Bali matrix olivines are distinctive and have been reported from only one other meteorite, the Mokoia CV3 chondrite by Tomeoka and Buseck [2]; they suggested that the planar defects in Mokoia consist of thin lamella of Fe-oxide/hydroxide that formed at elevated temperatures under oxidizing conditions. They also showed that phyllosilicates formed preferentially in these disrupted zones. We observe the same features in Bali matrix, and further, the diffraction data suggest that at least some of the planar defects are magnetite in an epitaxial relationship with olivine. There is also evidence that some of the fine-grained olivine in matrix was derived from larger grains by parting along (100) planes (i.e., parallel to the planar defects).

The alteration assemblage in Bali matrix consists of saponite coexisting with magnetite. This assemblage, plus the occurrence of planar defects in matrix olivine suggests that similar alteration processes were operating on the parent bodies of Bali and Mokoia. The olivines in Bali matrix have unequilibrated compositions, so that Bali must have escaped the thermal metamorphism that has homogenized matrix olivine compositions in Allende.

Conclusions. Olivine and pyroxenes in chondrules, inclusions, and matrix in Bali have been altered to a mixture of saponite and magnetite at low temperatures and in an oxidizing environment. The similarities in alteration assemblages and olivine microstructures suggest similar alteration conditions for Bali and Mokoia. Bali probably was not heated appreciably after accretion, because olivines in matrix are unequilibrated. Three CV3 falls (Mokoia, Kaba, and Bali) are now known to contain significant amounts of phyllosilicates. All three chondrites contain saponite coexisting with Fe-rich phases, (Fe oxide in Bali and Mokoia, Fe-Ni sulfides in Kaba). The effects of alteration in CV3 chondrites are largely similar, the main difference between individual members is related to redox conditions, which affects the mineralogy of the coexisting Fe-rich phases.

References. [1] Keller, L. P. and Buseck, P. R. (1990) *GCA* 54, 1155. [2] Tomeoka, K. and Buseck, P. R. (1990) *GCA* 54, 1745. [3] Keller, L. P. and Buseck, P. R. (1990) *GCA* 54, 2113. [4] McSween, H. Y. (1977) *GCA* 41, 1777. [5] Hoinkes, G. and Kurat, G. (1975) *Meteoritics* 10, 416. [6] Cain et al. (1986) *EPSL* 77, 165. [7] Peck, J. A. (1984) *XV LPSC*, 635.