MINERALOGY OF DARK CLASTS IN CR CHONDrites, EUCRites AND HOWARDITES; M.E. Zolensky1, M.K. Weisberg2, P.C. Buchanan3, M. Prinz2, A. Reid3 and R.A. Barrett4; 1SN2, NASA Johnson Space Center, Houston, TX 77058; 2American Museum of Natural History, New York, NY 10024; 3Geosciences, University of Houston, Houston, TX 77204; 4Lockheed ESCO, 2400 NASA Rd. 1, Houston, TX 77058.

INTRODUCTION: "Dark clasts" are encountered in many meteorites, and are generally described as "CM-like"; this belief has promulgated the idea that CM parent bodies were (are?) in widely divergent orbits, encountering many other types of meteorite parent bodies. We have embarked upon an examination of dark clasts from a variety of meteorites, initially the CR chondrites Al Rais, El Djouf 001 and Renazzo, the Bholghati and EET 87513 howardites, and the LEW 85300 polymict eucrite. We have already reported some results for the latter meteorite [1], here we report results from the other meteorites.

CLASTS IN CR CHONDrites: Dark clasts occur in all CR chondrites, making up 26 vol.% of Al Rais, 1% of El Djouf 001 and 7.5% of Renazzo. These are the same objects referred to as dark inclusions by Weisberg et al. [2]. In general, these materials are assemblages of submillimeter-sized chondrule-like objects and aggregates within opaque fine-grained matrix. The chondrules consist of olivine (Fo88,99), orthopyroxene (En85,99) and Fe-Ni metal or magnetite. Some chondrules contain phyllosilicates that are compositionally similar to those in the larger (mm-sized) chondrules in the rest of the meteorite. Matrices of the dark clasts contain submicrometer-sized silicates, magnetite framboids and placquettes, carbonates and sulfides. Some clasts are surrounded by sulfide-rich rims; most do not have a sharp contact with the host meteorite.

Analytical electron microscopic examination of the matrix of these clasts reveals that it consists predominantly of intergrown serpentine and saponite, occasionally coherently intergrown as observed in Orgueil [3]. Most of the phyllosilicates are flaky and fine grained (up to ~60 nm); coarser-grained (up to ~400 nm) plates and cylinders of serpentine are also present. For serpentine, Mg/Fe atomic ratios vary from 1 to 7; individual, reliable saponite analyses were not obtained. The most abundant anhydrous phases are pyrrhotite, pentlandite, magnetite, olivine (~Fo90), enstatite (~En89) and diopside. Minor phases identified include spinel, glass, and carbonaceous spheres (~200 nm diameter). The matrices of Renazzo and Al Rais are mineralogically similar to those of these clasts, although they are not as phyllosilicate rich. In addition, bulk major element and oxygen isotopic compositions of dark clasts appear to be similar to those of the CR host matrix [2].

Matrices of the dark clasts in Al Rais are more phyllosilicate-rich than those of the dark clasts in Renazzo or El Djouf 001. This result is consistent with the observation that most components (chondrules, refractory-rich inclusions, dark inclusions, etc.) in Al Rais appear to be more hydrated than those in Renazzo and El Djouf 001.

CLAST IN THE EET 87513 HOWARDITE: The EET 87513 dark clast contains submillimeter-sized lithic chondrules and abundant sulfides. Chondrules contain olivines (Fo69-89) and pyroxenes (En90-98 Wo1-5) (Buchanan and Reid, in preparation). The matrix consists predominantly of flaky and platy serpentine (Mg/Fe = ~1.15), with a maximum grain size of ~350 nm. The 7 A basal lattice fringes of this serpentine are corrugated, with abundant edge dislocations. This morphology can be produced by heating to temperatures less than approximately 400°C, and has been observed in some hydrous, chondritic interplanetary dust particles [4]. The most abundant anhydrous phases in the clast matrix are pyrrhotite, pentlandite, enstatite (~En87), olivine (Fo90-100) and diopside. Also encountered is flaky saponite (intergrown with serpentine), chromite, tochilinite, tochilinite-serpentine, and carbonaceous spheres.
MINERALOGY OF DARK CLASTS: Zolensky M.E. et al.

CLASTS IN THE BHOLOGHTI HOWARDITE: Reid et al. [5,6] have reported on dark clasts from Bholghati. On the basis of textures and bulk composition, one of these clasts resembles CI chondrites; the remaining clasts resemble CM chondrites. The CI-like clast contains a few olivine grains (5-40 μm diameter, Fo₉₀) The matrix of the clast consists dominantly of flaky saponite (2 nm maximum grain size), pyrrhotite, pentlandite, magnetite (framboidal) and minor chromite. We find no serpentine to be present, in contrast to typical CIs.

The CM-like clasts contain submillimeter-sized chondrule-like objects along with individual grains of olivine, pyroxene, glass, Fe-Ni metal and sulfides. These chondrule-like objects fall into two groups, often intimately associated within the same clast. The first group generally contains olivine with the composition Fo₉₀; occasionally they are composed of iron-poor pyroxene (En₉₁.₈ko₈₁₆). The second group contains zoned olivines ranging in composition from Fo₉₀ (cores) to Fo₅₁ (rims).

The matrix of the clasts examined were found to consist predominantly of anhydrous ferromagnesian silicates structurally intermediate between serpentine and enstatite (of the type produced by heating of serpentine beyond ~400°C [7]), olivine, saponite flakes, enstatite (En₉₀.₁₉₆), pyrrhotite and pentlandite. Serpentine and tochilinite, common constituents of CM chondrites, were not located in the Bholghati clasts.

CLASTS IN THE LEW 85300 EUCRITE: Kozul and Hewins [8] and Zolensky [9] have reported the mineralogy of dark clasts within LEW 85300. These clasts contain submillimeter sized chondrule-like objects, with olivine (Fo₅₁), pyroxene, glass, Fe-Ni metal and sulfides. The dark matrix consists predominantly of olivine (Fo₅₀-₆₉; but probably contaminated by terrestrial rust), pyroxene and augite. Less common are saponite flakes, pyrrhotite, pentlandite and Fe-Ni metal.

DISCUSSION: Although most of the clasts superficially appear to resemble CM chondrites, upon closer examination only the clast from EET 87513 is similar to CMs. All of the clasts contain varying amounts of saponite, indicative of high water/rock ratios during alteration [10]. At first sight, these results appear to lend no support to the contention that CM fragments are the most abundant foreign materials in meteorites. However, saponite is also more stable against heating than is serpentine (~700°C upper stability limit for saponite vs 500°C for serpentine) or tochilinite. It is therefore possible that serpentine (+ tochilinite) was originally present in more of these clasts, but has been transformed by heating. This scenario is most likely for the Bholghati clasts, containing abundant "intermediate" anhydrous ferromagnesian silicates. For those clasts which contain serpentine, it is safe to conclude that clast temperatures did not exceed 400-500°C while situated in the host.

The matrix of most of the dark clasts described here bear an intriguing resemblance to hydrated interplanetary dust particles (IDPs) [4]. Both materials consist predominantly of saponite, olivine, pyroxene, oxides, and sulfides (with exceptions). It is certainly possible that at least some of these IDPs could share parent bodies with the far larger dark clasts.

The higher abundance of phyllosilicates in the matrices of dark clasts in CR chondrites, compared to the host CR matrix, suggests that the dark clasts were hydrated prior to their incorporation into the host chondrite. The phyllosilicate-rich nature of dark clasts in Al Rais, compared to those in the other CR chondrites, suggests that Al Rais may be from a "wetter" (characterized by a higher water/rock ratio) region of the CR parent body.