PHYLLOSILICATE MINERALS IN CARBONACEOUS CHONDRITE MATRIX CLASTS IN THE NILPENA POLYMICT UREILITE: EVIDENCE FOR A C1-LIKE CHONDRITE-UREILITE CONNECTION Adrian J. Brearley[1] and Marty Prinz[2], [1]Institute of Meteoritics, Dept. of Geology, University of New Mexico, Albuquerque, New Mexico 87131, USA. [2]Department of Mineral Sciences, American Museum of Natural History, New York, NY 10024, USA.

Polymict ureilite breccias have recently been recognized as an important group of ureilites whose petrological characteristics differ in significant ways from monomict ureilites [1]. At present three meteorites, North Haig, Nilpena and EET 83309, belong to this group. All three contain a variety of mineral and lithic clasts as well as the dominant coarse-grained component which is mineralogically and compositionally consistent with monomict ureilites. Of special interest among these clasts are black, fine-grained inclusions which petrologically are consistent with carbonaceous chondrite matrix of some sort [2]. The presence of such materials within polymict ureilites is of importance because it suggests a link between ureilites and carbonaceous chondrites. This possibility is supported by oxygen isotope data [3] which show that ureilites have a wide range of oxygen isotopic compositions which fall along a ^{16}O mixing line defined by the components in Allende and other C3 meteorites. A large (3mm) black carbonaceous chondrite matrix clast from Nilpena lies on this mixing line and has a unique oxygen isotopic composition unlike that of any known carbonaceous chondrite matrix material. It lies on the extension of the Allende mixing line and extends the carbonaceous chondrite line by 6°/₀₀ beyond all the previously analysed samples. It is important to establish the exact mineralogic nature of this clast in order to determine its relationship to other carbonaceous chondrite matrices. This clast is similar to other matrix clasts in Nilpena and in other polymict ureilites and is taken to be representative of all of them.

We have studied ultramicrotomed sections of the fine-grained clast by transmission electron microscopy (TEM). Additional information on the coarser grained (>1μm) phases in the clast and its bulk chemistry has been obtained by electron microprobe [2]. The results of the microprobe studies have shown that the clast contains Fe-rich olivine, magnetite and pentlandite with minor amounts of Mn-bearing ilmenite, chloroapatite and an unusual Fe-Mn-Mg carbonate. The TEM studies have shown that the mineralogy of the fine-grained (<1μm) fraction of the clast is very different from that of the coarser-grained component. This fraction is found to be dominated by phyllosilicate phases with accessory pentlandite, troilite and magnetite; no olivine or pyroxene have been found. The phyllosilicate minerals tend to have a platy morphology and are exceptionally fine-grained, with grain sizes from <10nm up to 300nm. The sulfides and oxides tend to be larger and range from 100nm up to 500nm in size and are distributed throughout the clasts. No very fine-grained sulfides, disseminated or intergrown with the phyllosilicate phases, have been observed.

High resolution electron microscopy and electron diffraction analysis of the fine-grained phyllosilicate component show that it consists largely of a phase with a c-repeat of ~7Å, which appears to be consistent with a serpentine group mineral. This conclusion is supported by compositional data obtained by analytical electron microscopy (see below). The serpentine exhibits a limited range of morphologies, occurring typically as platy crystals 20-60nm wide and 100-300nm in length. Occasional kinked or slightly curved crystals are also present, but are rather rare, and no rolled or highly curved serpentine morphologies, such as those found in CM carbonaceous chondrites [4,5,6,7], have been observed. The serpentine crystals are highly ordered in most cases, and only rarely show evidence of interlayering or phenomena such as layer terminations. Where coherent interlayers are present they are exclusively single layers of a phase with a basal d-spacing of 14Å. This phase may be a chlorite of some type, but data presented below suggest that it is more likely to be a smectite. This 14Å phase is present as platy crystals with a grain size similar to that of the serpentine. Characteristically, single grains actually consist of two or more subgrains which are separated by low angle sub-grain

PHYLLOSILICATE MINERALS IN CARBONACEOUS MATRIX CLASTS IN NILPENA.
Brearley, A.J. and Prinz, M.

boundaries. It is found to undergo an electron beam induced transformation to an amorphous phase much more rapidly than serpentine. Stacking disorder is much more common in the 14Å phase than in serpentine and basal (001) planes are frequently undulose or wavy in character. This phase frequently contains coherent interlayers of phases with basal d-spacings of 7Å and 9Å, probably serpentine and talc respectively. The crystals of serpentine and the 14Å phase are set in amorphous matrix which contains ultrafine crystallites of layer lattice phases which have basal periodicities of between 10 and 14Å. These crystallites appear to be "embryonic" phyllosilicates, are usually three or less layer units in thickness and are invariably less than 10nm in length. Similar crystallites with very short range order are also an important component of the matrices of CM carbonaceous chondrites [6].

Analytical electron microscopy of the matrix phases has confirmed the HRTEM and electron diffraction identification of serpentine in the matrix clast. Because the majority of grains are smaller than the electron beam diameter (<100nm), few endmember analyses of serpentine have been obtained. Nevertheless it has been possible to ascertain that the serpentines have relatively constant Fe/(Fe+Mg) ratios of ~0.29 and contain 3-4wt% Al_2O_3 (normalised to 100wt%). Analyses of the 14Å phase all contain significantly more Si and lower $\sum$Mg+Fe contents than serpentine and also appear to contain some Na. These compositions are most consistent with an Mg-rich, Fe-bearing smectite-type clay, probably saponite. Saponite has also been reported recently in the Orgueil C1 carbonaceous chondrite by Tomeoka and Buseck [8] and was also found to have variable basal spacings between 10 and 15Å. The rest of the analytical data for the phyllosilicates, plotted in a (Si+Al)-Fe-Mg ternary atom percent diagram, all lie on, or close to, a mixing line from the Si+Al apex to a serpentine with Fe/(Fe+Mg) = 0.29. At least some of this spread in data can be attributed to the presence of coherent interlayers of other phases, especially serpentine, within the saponite. However, a number of analyses from the amorphous matrix contain significantly more Si than can be satisfactorily explained by saponite, suggesting that an amorphous silica phase may be its chief component.

The mineralogy of the clast suggests that it has very close affinities to CI1 chondrites and may, in fact, be a CI1, although its oxygen isotopic composition is somewhat different from that of other CI1s. The absence of tochilinite and Fe-rich serpentine (cronstedtite) in the clast is strong evidence that the clast is not related to CM carbonaceous chondrites. In addition the phyllosilicates are generally much finer grained than those found in CM chondrite matrices [4,5,6]. Although phyllosilicates have been reported in both CV3 and CO3 carbonaceous chondrites, they are only very poorly developed [9,10]. There are several mineralogical similarities between the Nilpena clast and the CI1's that have been studied by TEM techniques to date. For example, Orgueil contains both Mg-serpentine and saponite [8,11] and serpentine and smectite-type clays also occur in Alais [12]. Magnetite, which has been observed in Alais, also occurs in the Nilpena clast. Unlike, Orgueil, however, the clast does not contain abundant finely dispersed ferrihydrite [8]. This phase has been found to contain significant quantities of S and Ni which, in the Nilpena clast, are contained in crystals of troilite and pentlandite.

The occurrence of such C1-like clasts within Nilpena and other polymict ureilites suggests that such material may have been the precursor, or a portion of the precursor, of ureilites. This idea is supported by the oxygen isotopic composition of the clast and whole rock [3]. It may be that CI1 chondrites have a wider compositional range than previously recognized, or the clast is representative of a new type of carbonaceous material parental to ureilites. The possibility that the inclusions are foreign must also be considered, but is deemed unlikely.

References 1) Prinz, M. et al (1987) Lunar Planet. Sci. XVIII, 802-803. 2) Prinz, M. et al (1987) Meteoritics 22, 482-483. 3) Clayton, R.N. and Mayeda, T.K. (1988) GCA 52, 1313-1318. 4) McKee, T.R. amd Moore, C.B. (1979) Proc. Lunar Planet. Sci. Conf. 10, 839-852. 5) Mackinnon, I.D.R. (1980) Proc. Lunar Planet. Sci. Conf. 11, 839-852. 6) Barber, D.J. (1981) GCA 45, 945-970. 7) Tomeoka, K and Buseck, P.R. (1985) GCA 49, 2149-2163. 8) Tomeoka, K and Buseck, P.R. (1988) GCA 52, 1627-1640. 9) Tomeoka, K and Buseck, P.R. (1986) Meteoritics 21, 526. 10) Keller, L and Buseck P.R. (1988) Lunar Planet. Sci. XIX, 595-596. 11) Bass, M.N. (1971) GCA 35, 139-147. 12) Mackinnon, I.D.R. and Kaser, S.A. (1988) Lunar Planet. Sci. XIX, 709-710.