MAJOR, MINOR AND TRACE ELEMENTS IN SOME GLASSES FROM THE NWA 1664 HOWARDITE. G. Kurat[1], M. E. Varela[2], E. Zinner[3], T. Maruoka[3] and F. Brandstätter[1], [1]Naturhistorisches Museum, Postfach 417, A-1014, Vienna, Austria (gero.kurat@univie.ac.at), [2]CONICET - UNS, Dpto. de Geologia, San Juan 670, 8000, B. Blanca, Argentina, [3]Laboratory for Space Sciences, Physics Department, Washington University, St. Louis, MO 63130, USA.

Introduction: The new howardite NWA 1664, 6.31 kg, is a polymict breccia consisting mainly of mineral fragments and lithic clasts (diogenitic and eucritic) embedded in a fine-grained clastic matrix. This rock has abundant glass fragments (up to 2 cm), glass spherules (up to 1 cm) and chondrule-like objects. Most of the glass fragments are devitrified to variable degrees, some have vitrophyric textures and some are fully hyaline. Here we present the results of a major and trace element analyses of these glass fragments. Our preliminary results allow us to speculate that the howardite glasses and those present in angrites (D'Orbigny) and eucrites (Cachari) share similar formational processes and have similar origins.

Methods and Results: Major chemical compositions of glasses were obtained using an ARL-SEMQ microprobe and an analytical scanning electron microscope JEOL 6400, (NHM, Vienna). Trace element analyses of glasses and pyroxenes were made with the Cameca IMS 3F ion microprobe at Washington University, St. Louis. Major and trace element analyses were performed on four glass fragments (A1af, A1b, A1d and A4a) and one glass sphere (A1as, Fig. 1). The glass fragment A1af, 1.5 mm in size, is totally devitrified. The sphere A1as, 700 ìm in diameter, has feathery pyroxenes growing from the surface at one side and schlieren outlining counter-flowing convection cells. Both objects contain round bubbles up to 50 µm in diameter. Glass fragments A1b and A1d are small objects (400 and 200 ìm, respectively) of partly devitrified glass. Fragment A4a consists of partly devitrified glass (400 ìm in size) in contact with a 400 ìm long pyroxene (Fs_{47} Wo_{18} En_{35}, Fig. 2). The glass has inclusions of one silica (~95 wt% SiO_2) and four plagioclase (An_{90} – An_{95}) clasts.

The major element composition of all glasses is variable. Each object has its own chemical composition that varies within mostly narrow limits. Only few elements have correlated abundances within and between individual objects: FeO and MnO are positively correlated and straddle the FeO/MnO ~ 36 ratio line. CaO and Al_2O_3 contents follow more or less closely the chondritic CaO/Al_2O_3 ratio line. Also, the Na_2O content is roughly correlated with the CaO content straddling a line which intercepts the x-axis at about 4 wt% CaO. Within objects variation of chemical composition follows several correlations such as Cr_2O_3 and FeO (A1af only), Cr_2O_3 and CaO anticorrelation (A1af only), Al_2O_3 and FeO anticorrelation (A1af, A1as, A1d and A4a), Cr_2O_3 and MnO anticorrelation (A1as and A1b) and K_2O and Na_2O anticorrelation (A1as, A1b, A1d and A4a). Chemical variability within a given object is usually small (e.g., ± 0.1 wt% for minor and ± 1 wt% for major elements), except for object A1a, which is highly heterogeneous (CaO: 5 – 12 wt%, K_2O: 0.15 – 1.25 wt%, FeO: 16 – 28.9 wt%). The ranges of the chemical composition of all objects is as follows: SiO_2 (43.4 – 50.4 wt%), TiO_2 (0.52 – 0.83 wt%), Cr_2O_3 (0.26 – 0.65 wt%), Al_2O_3 (9.6 – 14 wt%), FeO (16 – 28.9 wt%), MgO (5.4 – 13.3 wt%), CaO (5 – 12 wt%), Na_2O (0.07 – 0.28 wt%) and K_2O (0.06 – 1.26 wt%).

Trace element contents of all glasses are very similar and show a flat refractory element abundance pattern at about 10 x CI (Fig. 3). Distinct negative deviations from this pattern are exhibited by Ti, Sc, Ca and occasionally also Eu. Moderately volatile elements Sr and Ba can be depleted or enriched and B, V, Cr, Mn and Fe are all depleted with respect to the refractory elements. Cobalt is strongly depleted (0.02 - 0.1 x CI) and Li is commonly enriched (~70 x CI) with respect to the refractory lithophile elements.

Discussion: Howardites are polymict brecciated achondrites consisting mainly of fine- to coarse-grained basaltic fragments, melt rocks, minerals, meteorite clasts and a variety of glass fragments [1,2]. In terms of major components, howardites are intermediate members of a continuous sequence of polymict breccias, including polymict and monomict eucrites to polymict and monomict diogenites [3,4]. The brecciated texture has been attribute to impact processes on an achondrite parent body [5]. Brown glass fragments can be relatively abundant (15 - 20 %) in some howardites like Bununu, Malvern and Kapoeta [6]. The average major element chemical compositions of these glasses are similar to their respective bulk compositions. Exceptions to this are the glass-rich howardites Monticello [7] and Yamato Y7308 [8 ,9] that show also siliceous glasses. Based mainly on the bulk compositions, glasses from Bununu, Malvern and Kapoeta howardites are consider to be the result of impact melting of average surface material on a single parent body, with the siliceous glasses of Monticello and Y7308 representing melting of differentiated lithologies such as fayalitic granites [9]. Thus, all glass fragments in howardites are widely believed to have an impact origin.

The NWA 1664 glass fragments range in composition from the Mg-rich Bununu group into the Fe-rich eucrite group. This chemical variation can occur on a micrometer scale, as is observed in fragment A1af. While the spherule A1as is Mg-rich (12.1 wt% MgO, 17.9 wt% FeO), the glass fragment associated with it is Fe-rich (6.6 wt% MgO, 19.8 wt% FeO). The most characteristic features of NWA 1664 glasses are their chemical heterogeneity in major and minor element abundances and their very high K contents. These elements paint a chaotic picture for the formation of the glass objects. We have no idea yet as to what these features mean.

In contrast to the major elements, refractory lithophile trace element abundances in the glass objects are unfractionated and 10 x CI abundances. They obviously signal a common homogeneous source that had chondritic relative abundances of these elements. The occasional high contents of Ba, Sr and Li and slightly fractionated REE pattern with $La_N > Lu_N$ (La_N, Lu_N: normalized abundance) disturb this harmony but could be of terrestrial origin (e.g., glass G1b1, Fig. 3).

NWA 1664 trace element abundances in glasses are similar to those of bulk eucrite Juvinas and of glasses from the eucrite Cachari and the angrite D'Orbigny (Fig. 4). Recent data on D'Orbigny showed that the bulk composition alone does not seem to provide enough of an argument to favor of an impact origin. D'Orbigny glasses have the same composition as the bulk rock but formation of glasses by shock has to be excluded as D'Orbigny has no shock features and its glasses are as ancient as the rock itself [10]. Similarly, NWA 1664 glass objects match the composition of bulk howardites but shock features are missing in the rock. The variable compositions of the glass objects and their different behavior with respect to the distribution of different elements indicate individual formation and processing. The uniform refractory trace element contents indicate derivation from a common chondritic source. This NWA 1664 glass objects share this feature with glasses from other achondrites (Fig. 4) and with glass inclusions in olivines and of glass matrices of chondrules from carbonaceous chondrites [11,12]. These can not be coincidences, these objects must have a common source, a source with chondritic refractory elemental abundances.

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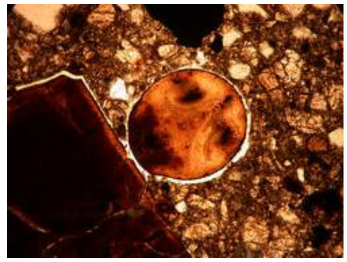

Figure 1 Transmitted light image of glass fragment A1af (left) and glass sphere A1as. Note the schlieren outlining counter-flowing convection cells.

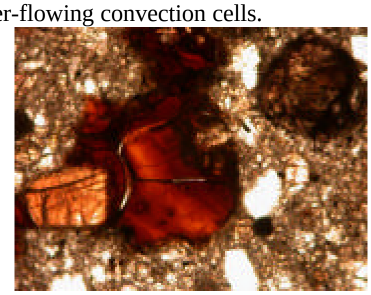

Figure 2 Transmitted light image of glass fragment A4a. Note the intimate association of pyroxene (left) and glass.

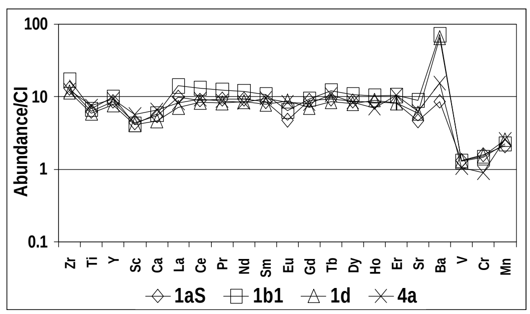

Figure 3 Normalized trace element abundance in four glass fragments of the NWA 1664 howardite.

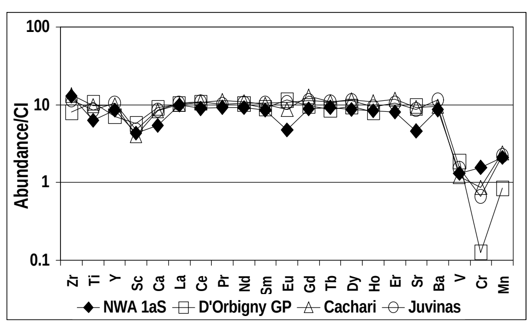

Figure 4 Normalized trace element abundance in glass A1as (center of the spherule) of NWA 1664, in the bulk eucrite Juvinas and in glasses from the eucrite Cachari and the angrite D'Orbigny.