SILICATE INCLUSIONS IN THE KODAIKANAL IIE IRON METEORITE. Kurat G.1; Varela M. E.2 and Zinner E.3 1Institut für Geologische Wissenschaften, Universität Wien, Althanstrasse 14, A-1090 Vienna, Austria, gero.kurat@univie.ac.at, 2CONICET, UNS Dpto Geologia, San Juan 670, 8000 B. Blanca, Argentina, 3Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO 63130, USA.

Introduction: Silicate inclusions in iron meteorites display an astonishing chemical and mineralogical variety, ranging from chondritic to highly fractionated, silica- and alkali-rich assemblages [e.g., 1]. In spite of this, their origin is commonly considered to be a simple one: mixing of silicates, fractionated or unfracti- onated, with metal [1-4]. The latter had to be liquid in order to accommodate the former in a pore-free way which all models accomplish by assuming shock-melting.

II-E iron meteorites are particularly interesting because they contain an exotic zoo of silicate inclusions, including some chemically strongly fractionated ones [e.g., 1, 5-9]. They also pose a formidable conundrum: young silicates are enclosed by very old metal [e.g., 4, 10-13]. This and many other incompatibilities between models and reality forced the formulation of an alternative genetic model for irons [14]. Here we present preliminary findings in our study of Kodaikanal silicate inclusions.

Results: The Kodaikanal sample containing the three silicate inclusions studied (GI-1, GI-2 and GI-3, Fig. 1) belongs to the 4 mm thick slide (H988, NHM Vienna) shown in [15] and comes from the left lower corner.

Inclusion GI-1 is round and consists exclusively of glass, decorated by small schreibersite crystals (see detail of BSE image in Fig 1). Inclusions GI-2 and GI-3 are multiphase inclusions consisting of glass, clinopyroxene (cpx) and low-Ca pyroxene (from here on opx) with minor chromite, apatite and whitlockite. Inclusion GI-2 (~ 9 mm in size) has pyroxenes - ranging in size from 500 to more than 2000 µm - located in the center. The anhedral cpxs are mantled by opxs forming euhedral to subhedral skeletal crystals. Chromite is mainly associated with the opx. Needle-like crystals of apatite and whitlockite are restricted to one area near the surface.

The mineralogy of GI-3 is similar to that of GI-2, however, as GI-3 is only a small part of a bigger inclusion we have decided to perform trace element analyses in inclusions GI-1 and GI-2 only. The major element chemical compositions of the main phases in both inclusions are given in the Table.

Glass in GI-1 (Ko-glass1) is enriched in the heavy REE over the light REE and has distinct negative Eu and Yb abundance anomalies (Fig.2). The glass has high contents of Nb (200 x CI), Be, B (~110 x CI) and Rb (>200 x CI) and low contents of Cr (~0.015 x CI) and Co (0.006 x CI). In inclusion GI-2, glasses in contact with pyroxenes (Ko-glass3) show similar patterns, different from that in glass adjacent to apatite (Ko-glass5). All three glasses have fractionated LREE and slightly fractionated HREE, with Ko-glass3 having REE contents close to chondritic abundances and Ko-glass5 around 0.3 x CI.

The two GI-2 glasses have a positive Eu anomaly and similar
considering that opx overgrows cpx, the Mg exchange between silicates and the environment which is probably due to incomplete metasomatic Fe-

drite cpx. Low-Ca pyroxene and cpx are not in equilibrium with respect to the Fe-Mg distribution, a feature widespread among iron and other meteorites, 

chemical composition similar to opx from H chondrites, however, with TiO₂, Al₂O₃ and Cr₂O₃ contents somewhat high, up to about twice that of H chondrite pyroxenes. The cpx in inclusion Gl-2 has a composition comparable to cpx of ordinary chondrites – similar to L chondrite cpx - but has no similarity with H chondrite cpx. Low-Ca pyroxene and cpx are not in equilibrium with respect to the Fe-Mg distribution, a feature widespread among iron and other meteorites, which is probably due to incomplete metasomatic Fe-Mg exchange between silicates and the environment [e.g., 19]. Considering that opx overgrows cpx, the shift in Fe/Mg ratio is in the wrong direction from an igneous point of view.

From their morphology, the two pyroxenes in Gl-2 appear to have grown from a liquid (skeletal crystals) but that liquid could not have had the chemical composition the co-existing glass now has. The pyroxenes are obviously far out of equilibrium with the glassy mesostasis.REE abundances of a melt in equilibrium with cpx and opx in the inclusion Gl-2 would need to be about 40 x CI (except, Eu 10 x CI) and 20 x CI (except, La 100 x CI), respectively. That is very different from what we observe in the glass in context with the pyroxenes in this inclusion (REE around 1 x CI). Similar disequilibria have been described for silicate inclusions of Miles and Weeke-roo Station and prompted the proposal that the feldspathic glass could have formed by re-melting of pre-existing feldspar + pyroxene [7] or feldspar + pyroxene + tridymite [8]. Although some match of the REE patterns with those of the glasses can be obtained by these mixtures, two important features cannot be matched: First, the highly fractionated Na₂O/K₂O ratio of the glasses (around 1) is clearly impossible to achieve by melting of albite feldspar from H chondrites and needs a fractionation mechanism that involves non-silicates. Something like the sulfide fractionation process [20] suggested for widespread Na-K fractionation observed in LL chondrites must have been at work. Second, many glasses and also pyroxenes have a negative Yb abundance anomaly [e.g., 8, 9] which cannot be explained by either shock or partial melting. This anomaly is also present in our sample and is accompanied by a negative Eu anomaly in glassy inclusion Gl-1 (as it is also in pyroxenes in Colomera [9]). In addition, the LREE are depleted with respect to HREE (as they are in a similar manner in pyroxenes of Colomera [9]). This pattern clearly resembles that of an ultra-refractory component [e.g., 21-23] and suggests that condensation could have played a role. If this is correct, then also the alkali fractionation could have a nebular origin – similar to that of chondrules and other chondritic constituents [e.g., 19, 20].

**Conclusions:** Phases in glass-bearing multiphase silicate inclusions in the Kodaikanal IIE iron are chemically far out of equilibrium and strongly fractionated, as previously observed in several IIE irons. Our data suggest that nebular condensation and sub-solidus nebular processing are responsible for this situation. Surprisingly, the REE abundance pattern in glassy inclusion Gl-1 suggests that ultra-refractory condensates could have been involved in the formation of silicate inclusions in IIE irons. We take this as yet another hint for a nebular origin of meteoritic irons [e.g., 14].

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