PRELIMINARY ANALYSIS OF SIMEIO: A LOW Ni-Ir KAMACITE GRAIN OF UNUSUAL ORIGIN FROM COMET WILD2. M. Humayun[1], J. I. Goldstein[2], A. Mubarok[2], A. J. Westphal[3], Z. Gainsforth[3], S. R. Sutton[4], B. Lai[4], E. Silver[5] and R. M. Stroud[6], [1]Florida State University, Tallahassee, FL 32310, USA (humayun@magnet.fsu.edu), [2]University of Massachusetts, Amherst, MA, USA; [3]Space Sciences Laboratory, UC Berkeley, CA, USA; [4]Advanced Photon Source, Argonne National Laboratory, Chicago, IL, USA; [5]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA; [6]Naval Research Laboratory, Washington DC, USA.

Introduction: The mineralogy of Comet 81/P Wild 2 includes a diverse set of minerals with a broad range of compositions indicating an unequilibrated body. Individual mineral fragments including olivines, pyroxenes, and sulfides, and microchondrules and micro-CAIs have been observed [1, 2]. Kamacite is reported from a variety of tracks, but is usually too small (<5 µm) for laser ablation ICP-MS (LA-ICP-MS) analysis [1]. Simeio was a ~10 µm x 15 µm kamacite grain from Track 41, the largest metal particle yet recovered from Stardust tracks. Simeio has been previously investigated by SXRF and SXRD [3]. It is characterized by low-Ni (2.2 wt %), a nearly chondritic Co/Ni ratio [3]. Upper limits on Ga, Ge and As contents were previously reported [3].

To facilitate further analyses, Simeio was extracted from its aerogel keystone, mounted at UC Berkeley in EMBED 812 epoxy in an Al holder, then polished at UMass. Here, we report new results from an examination of its polished surface by optical microscopy, SEM and LA-ICP-MS.

Methodology: The SEM and EDS analyses were performed using a Zeiss Supra 55VP field emission gun SEM at Sandia National Labs in Albuquerque, NM. The variable pressure mode was used to alleviate the charge on the surface of the non-conducting material. The chamber pressure was adjusted to 29 Pa, and a 15 kV acceleration voltage was used with the 120 micron aperture and ~20 nA current. A Bruker quad SDD EDS detector was used with Bruker Esprit software to acquire EDS data.

The polished mount of Simeio was analyzed using an ESI New Wave™ UP193FX excimer LA-ICP-MS system at the Plasma Analytical Facility, FSU [4]. Masses for S, P, S, and 21 siderophile elements were collected in low resolution. The spot size was 20 µm, with 5-second dwell time at 50 Hz (250 laser shots), and 1.7 GW/cm^{2}power density. A spectron Ni Jet sampler cone and Ni-X skimmer cone were used which enhanced the Fe-Co-Ni signal by a factor of 10, and the Ir signal by a factor of 3, relative to normal cones. Higher molecular interferences resulted in higher backgrounds at the low mass elements but the technique was optimized for high mass elements since many of the lower mass elements had been determined by SXRF [3] or X-ray microcalorimeter. Prior to analyzing Simeio, metal grains ≤20 µm in diameter in the chondrites Semarkona LL3.0 (n=40) and Paris CM (n=16) were analyzed for comparison. Background was monitored after Simeio had been loaded and before and after laser ablation on Simeio for a total of an hour. Two analyses of the epoxy embedded aerogel around Simeio were also performed.

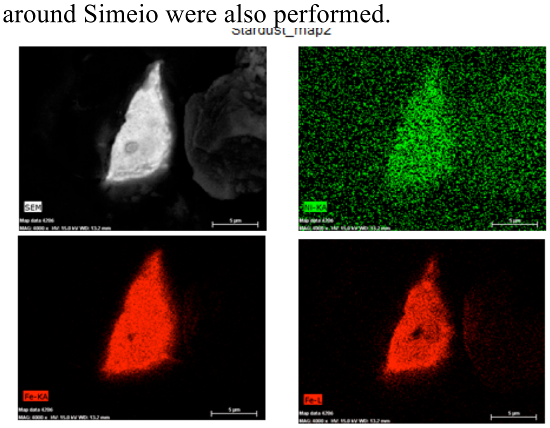

Fig. 1: a) BSE image; **b)** Ni Kα, **c)** Fe Kα, **d)** Fe L, maps of Simeio. Scale bar = 5 µm.

Results: The distribution of Fe and Ni in Simeio observed by EDS is fairly even in the metal (Fig. 1). A detailed analysis of the distribution of these two elements lacks the precision that we seek because of the small size of the polished particle and resolution of the X-ray source size. The small round area in the center of the particle (Fig. 1a) is just a contaminant on the surface of the specimen. The Ni content of Simeio, determined by standardless EDS, is ~2.1wt. %, similar to the SXRF value of 2.2±0.2 wt. %, a rather unusual Ni content in meteoritic metal [5].

The first observation to be made on the LA-ICP-MS results is that the signal from Simeio was ~50x weaker than expected from similar sized chondritic metal grains (Fig. 2). The Simeio grain failed to ablate completely. A plausible explanation is that it detached during laser ablation due to mechanical/electro-mechanical stresses. Strong signals from the surrounding matrix for Si, P, S, V, Cr, Cu, W, Pt and Au were detected, the origin of which is unclear. A blank on the epoxy was taken at two additional spots which showed less Si, but still showed strong signals for many of the other elements making an epoxy background correction unreliable. Further, the signal from Simeio was too weak to exceed the background at many elements

(As, Mo, Ru, Rh, Pd, Sn, Sb, Re). The $(Co/Ni)_{CI}$ ratio was measured in Simeio to be 1.33, close to the value determined by SXRF of 1.6 [3]. A subsequent determination at the APS resulted in a $(Co/Ni)_{CI}$ ratio of 2, and better abundances on Cu, Ga, Ge and As. The high Pt signal overwhelmed the Os background with ^{190}Pt interference. The Ir background was clean providing an upper limit of $(Ir/Ni)_{CI}$ of ~0.2, establishing that Simeio does not have a chondritic refractory siderophile element pattern. The abundance of Ga was corrected for epoxy background, and Ge yielded an upper limit higher than that obtained by SXRF.

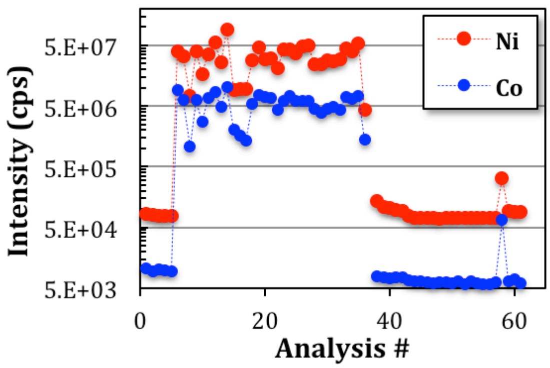

Fig. 2: ^{59}Co and ^{60}Ni intensities in Semarkona metal (LHS), Simeio (RHS, #58) and blanks by LA-ICP-MS.

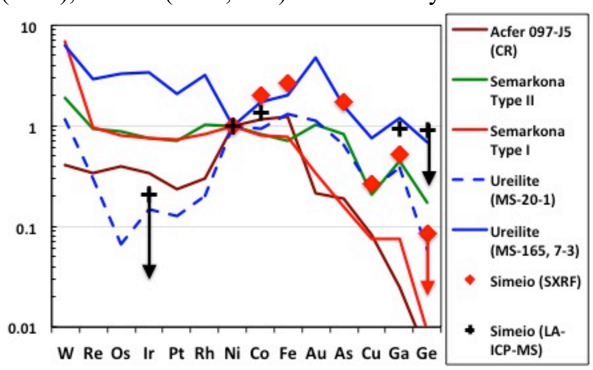

Fig. 3: CI-chondrite normalized abundances of siderophile elements in selected metal from chondrites, ureilites, and from Simeio. Upper limits only for Ir and Ge abundances are depicted by arrows.

Discussion: *Comparison with meteoritic metals:* Fig. 3 combines the APS and ALS SXRF results with the LA-ICP-MS determined for Co, Ni, Ga, Ge and Ir on Simeio. Selected analytical results are shown for comparison. An average for several metal grains from a Type II chondrule from the primitive ordinary chondrite, Semarkona LL3, has volatile element abundances comparable to Simeio, but lacks the low Ni content. A similar average from a Type I chondrule and from the CR chondrite Acfer 097 [4], are too low in As, Cu and Ga and too high in Ni to fit Simeio, although such metal often exhibits the low Ir seen in Simeio. The low Ni (~2 wt. %) is unusual in chondritic metal, but is not uncommon in ureilites, where it is formed by reduction of Fe from silicates. Ureilites have two kinds of metal [6-7]. A high Ir residual metal that is enriched in compatible siderophile elements (e.g. MS-165), and trapped metallic liquid depleted in compatible siderophiles (e.g. MS-20) [7]. In addition to matching the low Ni and Co contents, ureilite metal is similar in its volatile element abundances, although if the Ge content in Simeio is much lower than the detection limits obtained by SXRF, then even this discrepancy will be sufficient to rule out a ureilitic origin for Simeio.

Ureilites as the source of Simeio: Ureilites are an enigmatic group of unequilibrated achondrites, the exact origin of which remain debated [6-7]. Ureilites have been subjected to local-scale partial melting that has removed both metallic and silicate melts. Ureilites contain more carbon than even CI carbonaceous chondrites, a fact that is not understood. Oxygen isotopes link ureilites to carbonaceous chondrites [8], but Ti, Cr and Ni isotopes point to a closer affinity with other differentiated bodies [9]. The carbon in ureilites causes a reduction reaction producing Fe-metal and CO gas, possibly triggering explosive volcanism [6, 10]. Such volcanism may scatter metallic melts depleted in Ir in the inner solar system, followed by radial transport [11] and accretion to comets. Alternatively, ureilite-like processes may occur on carbon-rich bodies in the Kuiper Belt during impact melting, thus Simeio could have formed in such processes closer to the region where Wild 2 accreted. Urelitic processes on Wild 2 itself are generally inconsistent with the mineralogy of most Wild 2 materials, e.g., the absence of phyllosilicates or silicate minerals of ureilitic composition [1, 12]. Simeio was indeed an unusual particle and so an unusual origin may not be surprising. Future measurements of other metal particles should help decide whether such metal has chondritic or ureilitic affinity.

References:

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