CHEMISTRY AND PETROLOGY OF LOW-NICKEL STRATOSPHERIC PARTICLES: A NEW CLASS OF INTERPLANETARY DUST PARTICLES or NOT?

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Stratospheric particles collected just above the tropopause contain (i) anhydrous and hydrated chondritic interplanetary dust particles [IDPs] that are solid debris of undifferentiated Solar System bodies [1,2] and (ii) natural terrestrial particles [3]. Recently, I received stratospheric particles that were selected as probable extraterrestrial material on the basis of their morphology and colour alone rather than bulk chemical composition. Using identical selection criteria, other particles were allocated to investigators who observed that these particles include non-chondritic, low-Ni particles with trace element abundances consistent with an origin on a differentiated Solar System body, e.g. Earth, the moon, Mars or the eucrite parent body [4,5]. Lacking detailed petrological data, the origin of low-Ni particles is not yet established. Their energy dispersive spectra [EDS] exhibit distinct K and Ti peaks whereas these particles are enriched in Zn and Br [4,5] and Al enrichment is observed in at least one particle [6]. Limited mineralogical data are available for low-Ni particle U2001B6 that contains euhedral calcium alumino silicate grains and a variety of unidentified silicates with "percent levels of Fe and occasionally K" [6]. I have performed a detailed chemical and petrological analysis of three low-Ni, particles that were selected as probable extraterrestrial material in an attempt to establish a source for this newly-emerging group of stratospheric particles.

EXPERIMENTAL. Stratospheric particles L2001-18, L2001-20 and L2002*C2 were prepared for serial-ultramicrotome thin sectioning. Several sections (~100 nm thick) of each particle were analysed using a JEOL 2000FX analytical electron microscope [AEM] equipped with a TN 5500 EDS for *in situ* microanalysis of elements Z>10 using a 15-20 nm size probe. Bulk compositions were obtained by randomly probing thin sections using a probe size larger than the average grain size. The reduced EDS data have a rel. error of <~5% due to counting statistics and the determination of instrument k-factors.

RESULTS. Particles L2001-20 and L2001-18 are ellipsoidal and 28 μm x 11 μm and 14.5 μm x 7.4 μm in size, resp; L2002*C2 is subspherical and 22.5 μm x 17 μm in size. The particles are vesicular and have an irregular surface. In particles L2001-20 and L2002*C2 abundant single crystals, ranging from 0.15 μm x 0.15 μm up to 4.3 μm x 2.2 μm in size, are embedded in a dense matrix. In L2001-18 these crystals are rare and small (up to 0.57 μm x 0.4 μm in size). The matrix of the particles contains patches of subhedral layer silicate grains and areas of poorly-crystalline layer silicate microcrystallites in an amorphous groundmass. The relative proportion of these two matrix types is variably between particles, e.g. the matrix of L2001-18 is mostly layer silicate microcrystallites in an amorphous groundmass.

CHEMISTRY. All three particles show distinctly non-chondritic, CI/Si-normalised, major element abundances [TABLE 1]. The SiO_2 and Al_2O_3 distributions are quite uniform throughout each particle but other major elements show distinctly heterogeneous distributions, in part due to silicate grains embedded in the matrix [TABLE 2]. For example, FeO varies from 4.9-23.0 wt%, MgO from 0.0-14.6 wt%, CaO from 0.0-10.5 wt%, K_2O from 0.0-7.6 wt%. Sulfur in L2002*C2 varies from 0 to 8.8 wt% SO_3 locally. L2002*C2 shows local Zn-enrichment and local enrichment of Na_2O and P_2O_5 occur in L2001-20. The average MgO/FeO ratios in the particles [FIGURE 1], as well as their SiO_2, CaO, and K_2O contents, are distinctly different from CI and CM carbonaceous chondrite matrix [7] but within the range of terrestrial basalts and ash and pumice glass of the El Chichon and St Helens volcanos.

MINERALOGY. In L2001-20 single crystals in the matrix include (i) tridymite, (ii) SiO_2-Al_2O_3 crystals with compositions on the SiO_2-mullite join (Al_2O_3= 4.9 -18.8 wt%), (iii) anorthite, (iv) SiO_2-Al_2O_3-CaO crystals with compositions on the mullite-anorthite and mullite-tridymite cotectic lines, (v) subcalcic augite, (vi) hornblende, (vii) apatite, (viii) sphene and (ix) brookite. The same crystals occur in L2002*C2 plus non-stoichiometric (?) alkali-feldspar [SiO_2=74; Al_2O_3=19; K_2O=7(wt%)], ilmenite and Mg-bearing calcite. Only pure silica and plagioclase crystals were identified in L2001-18.

All three particles have areas of high sulfur content yet no S-bearing minerals were identified. There is some evidence that ultrafine S-bearing minerals are dissiminated in the layer silicate matrix. Also, some areas in the poorly-crystalline matrix of L2002*C2 contain iron and sulfur in relative proportions consistent with pyrrhotite [Fe/S (at%) = 0.8].

DISCUSSION. The distinctly non-chondritic bulk composions of three stratospheric particles are similar to compositions of terrestrial basaltic and associated volcanic rocks. The relative major element abundances in these particles are comparable with those of leached, high SiO_2 and Al_2O_3, ash particles from the St Helens volcano [8]. The vesicular texture and embedded crystals are typical of volcanic ash particles. The types and compositions of crystals embedded in the matrix are identical to microphenocrysts in ash particles from the El Chichon and St. Helens volcanos [8-11]. Layer silicates in the matrix of these stratospheric particles, as well as poorly-crystalline areas in this matrix due to devitrification of allophane (amorphous alumino-silicate complexes), are similar to these features in ash particles from the St. Helens volcano [8].

CONCLUSION. Three stratospheric particles L2001-18, L2001-20 and L2002*C2 have chemical and mineralogical properties in common with previously reported [4-6] low-Ni particles that have an origin on differentiated Solar System bodies. Detailed AEM analyses of these three particles unambiguously proves a terrestrial volcanic origin. If these three particles belong to the group of low-Ni particles, I conclude that this group of stratospheric particles consists of volcanic ash particles associated with explosive terrestrial volcanism rather than represent a new type of IDPs. The common presence of layer silicates dismisses the possibility of a lunar, martian or differentiated-asteroidal origin for non-chondritic, low-Ni, stratospheric particles.

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TABLE 1: CI(ref.7)/Si normalised major element abundances in three stratospheric dust particles.

	Mg	Al	Ca	Fe	K	S	Ti
L2002*C2	0.03	0.85	0.33	0.11	1.2	0.04	0.6
L2001-18	0.13	2.30	0.14	0.22	1.4	0.04	nd.
L2001-20	1.66	2.05	0.12	0.18	1.2	0.01	nd.

TABLE 2: Bulk major element compositions for three stratospheric dust particles.

	L2001-18	L2001-20	L2002*C2
SiO_2	56.5	60.3	60.15
Al_2O_3	22.5	21.6	19.3
MgO	5.5	5.4	2.3
FeO	12.9	11.0	10.5
MnO	nd	tr	tr
CaO	0.5	0.5	2.8
K_2O	0.9	0.8	1.7
TiO_2	nd	tr	0.3
SO_3	1.2	0.4	3.0

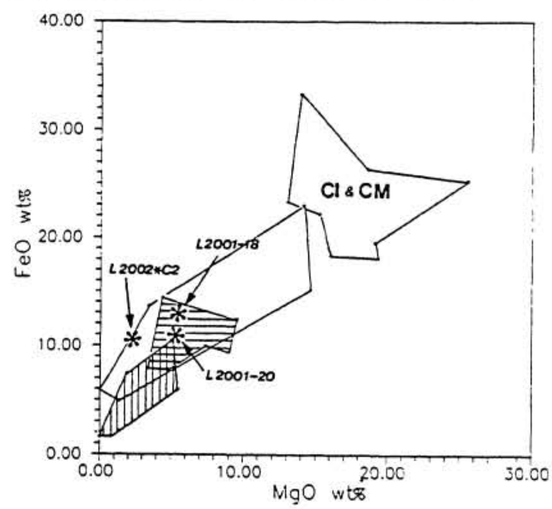

FIGURE 1: MgO vs FeO (wt%) concentrations for stratospheric particles L2001-18, L2001-20 and L2002*C2 compared to CI/CM matrix compositions (ref.7), terrestrial basalts [Carmichael et al.(1974) Igneous Petrology, McGraw-Hill Book Co] (horiz. hatching) and ash from the El Chichon and St Helens volcanos [various references] (vertical hatching). The unmarked field shows the chemical heteterogeneity of stratospheric particle L2001-20.