RYUGU-LIKE PHYLLOSILICATE CLAST FROM A GIANT CLUSTER IDP OF PROBABLE COMETARY ORIGIN: EVIDENCE FOR MATERIAL EXCHANGE BETWEEN ASTEROIDAL AND COMETARY REGIONS. D. J. Joswiak[1], D. E. Brownlee[1], A. N. Nguyen[2], T. M. Hahn[3], T. Nakamura[4], T. Morita[4], M. Kikuiri[4], K. Amano[4], E. Kagawa[4], H. Yurimoto[5], T. Noguchi[6], R. Okazaki[7], H. Yabuta[8], H. Naraoka[7], K. Sakamoto[9], S. Tachibana[9,10], S.-I. Watanabe[11], and Y. Tsuda[9], [1]University of Washington, Department of Astronomy, Seattle, WA 98115, [2]Astromaterials Research and Exploration Science, NASA JSC, Houston, TX 77058, [3]Jacobs JETSII contract, NASA JSC, Houston, TX 77058, [4]Tohoku University, Sendai 980-8578, Japan, [5]Hokkaido University, Sapporo 060-0810, Japan, [6]Kyoto University, Kyoto 606-8502, Japan, [7]Kyushu University, Fukuoka 812-8581, Japan, [8]Hiroshima University, Higashi-Hiroshima 739-8526, Japan, [9]ISAS/JAXA, Sagamihara 252-5210, Japan, [10]The University of Tokyo, Tokyo 113-0033, Japan, [11]Nagoya University, Nagoya 464-8601, Japan. Correspondence: (joswiak@astro.washington.edu)

Introduction: The presence of hydrous minerals in comets is currently an open question. They were commonly produced inside primitive meteorite parent bodies but apparently not inside the active comets that never contained liquid water. Despite examination of hundreds of particles returned from the Jupiter Family comet Wild 2 by the Stardust (SD) spacecraft, no phyllosilicates have yet been found [1-3]. Near IR spectra obtained by the Rosetta spacecraft of short-period comet 67P Churyumov-Gerasimenko (67P CG) similarly did not reveal the presence of phyllosilicate minerals [e.g. 4]. IR spectral features in ejecta from comet Temple 1 were interpreted as hydrated minerals [5] but this match is controversial.

Studies of a giant cluster interplanetary dust particle (IDP) have demonstrated that the IDP has a large number of chemical and physical properties consistent with its derivation from a comet including 1) its porous aggregate morphology similar to fragile aggregate particles imaged from comet 67P CG, 2) an unequilibrated mineral assemblage, 3) mineral isotopic compositions similar to like minerals in comet Wild 2 [6], 4) uncorrelated Fe-Mn ratios of olivines that mimic those from Wild 2 [7], 5) high presolar silicate abundance [8] and 6) Kool grains which are observed in comet Wild 2 but not in chondrites [3]. Our examination of 70+ >5 µm fragments from the IDP have shown that it is overwhelmingly composed of anhydrous silicates. We have observed, however, a 5 x 15 µm porous aggregate fragment (LT10), which contains a rare phyllosilicate clast encased in anhydrous mineral and rock fragments. We conducted detailed TEM and O isotopic analyses of this particle to constrain its origin.

Sample Prep and Analysis: Particle LT10 was hand-picked from the interior of a giant cluster IDP that was collected in the stratosphere. The giant cluster IDP is a large fragile, anhydrous chondritic porous particle consisting of thousands of petrologically unequilibrated grains, submicron to ~40 µm in size and is thought to have been ~350 µm in size which pancaked on the collector flag during collection in the stratosphere.

LT10 was washed in hexane and embedded in epoxy resin. Microtome slices (70 nm) were produced and placed on 10 nm C films on TEM grids. The sections were studied with a Tecnai TF20 STEM at the University of Washington by conventional TEM/EDX techniques including element mapping. The potted butt was additionally observed with a FESEM where BSE images were acquired. A TEM microtomed section of LT10 was analyzed for O isotopes using the NanoSIMS 50L at NASA Johnson Space Center with a focus on the phyllosilicate portion of the particle. Prior to analysis, the backside of the grid was coated with 10 nm of Au for stabilization. Microtome sections of Orgueil phyllosilicate-rich matrix served as the isotopic standard and was used to correct for instrumental mass fractionation. Unfortunately, the C-film prematurely failed during the analysis, resulting in large statistical errors. Future measurement of the phyllosilicate clast from the potted butt is anticipated.

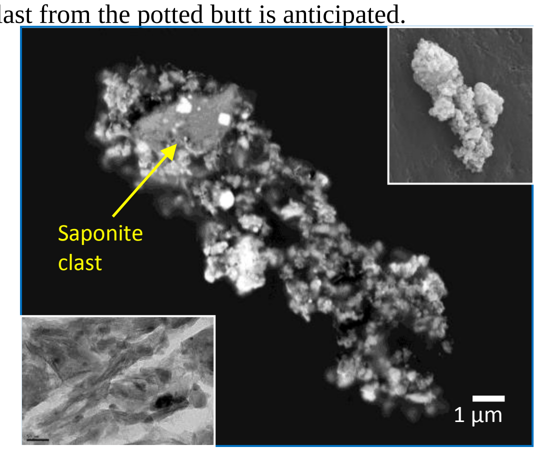

Fig. 1: Potted butt BSE image of porous aggregate particle LT10 from the giant cluster IDP showing phyllosilicate clast. Upper-right inset: SE image of whole particle. Lower-left inset: High-resolution TEM image of interior of saponite-rich phyllosilicate clast.

Results Particle LT10 is a fine-grained porous aggregate similar to common porous IDPs. It is dominated by anhydrous silicates including $Fo_{80,97}$ olivines, $En_{84}Wo_2$ pyroxene, LIME enstatite, Fe,Ni sulfides, a fassaite+spinel CAI, a Kool grain, Fe,Mg silicate glass and other phases (Fig. 1). Enclosed in the interior of the particle is a ~3 x 5 µm poorly crystalline phyllosilicate clast loosely adhering to adjacent phases. Compositional analyses (black circles, Fig. 2) and 1.3nm lattice fringes observed in a few areas of the clast (Fig. 1, inset) are consistent with Mg-rich saponite. We observed ~0.7nm fringes in one region suggesting a small amount of serpentine may also be present. Sulfides consist of anhedral to euhedral pyrrhotite and pentlandite. Carbonates and magnetite were not found. Slight Si enrichments of the saponite are likely due to retained Si oil from the collector flag or Si-rich material present in the phyllosilicate matrix itself.

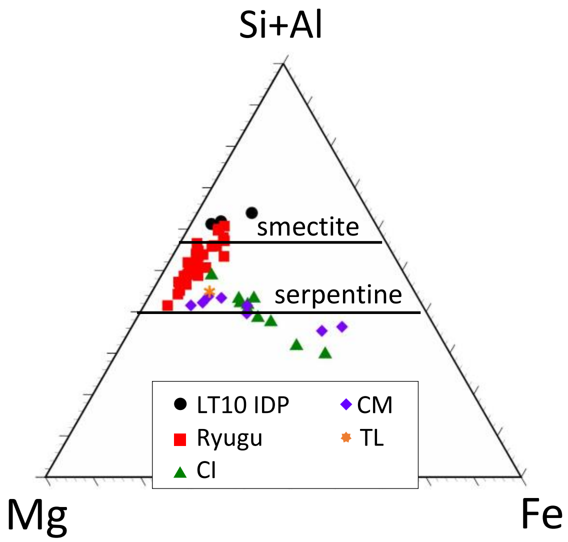

Fig. 2: Ternary diagram showing phyllosilicate compositions of LT10, asteroid Ryugu (C107) and CI, CM, and Tagish Lake chondrites [10-13].

Measured Al_2O_3 abundances in the LT10 clast are relatively high. Average values along with Al_2O_3 concentrations in Ryugu and the CI, CM and Tagish Lake (TL) chondrites are shown in Fig. 3

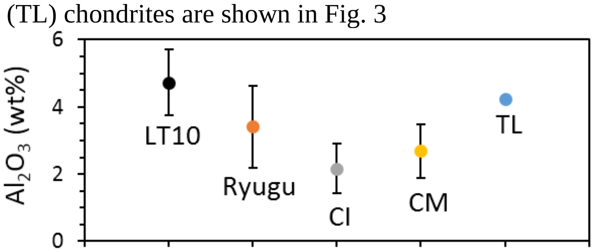

Fig. 3: Average Al_2O_3 values and 1σ SD of phyllosilicates in LT10, Ryugu (C107) and chondrites [10-13].

Oxygen isotopes collected on the LT10 phyllosilicate clast are ^{16}O-poor ($\delta^{17}O = 12 \pm 20$‰ and $\delta^{18}O = 16 \pm 9$‰; 1σ) and in an oxygen-3-isotope diagram fall closest to Ryugu, CI chondrites and Tagish Lake.

Discussion: The physical, chemical and isotopic properties of the clast in LT10 suggest that it is similar to Ryugu phyllosilicates. These include 1) high Mg# and similar Fe/(Fe+Mg) ratios, 2) dominance of smectite over serpentine, 3) high Al_2O_3 in the phyllosilicates and 4) preliminary ^{16}O-poor O isotope ratios. This clast probably formed inside a warm wet parent body and was then liberated and transported to an ice-rich nebular region where nearly all silicates were anhydrous. Its altered parent body could have formed in either the asteroid or comet formation regions.

Based on examination of returned samples and IR spectroscopic studies, phyllosilicates appear to be uncommon in samples of active comets, yet these minerals dominate carbonaceous asteroids. A reasonable interpretation is that ^{26}Al heating produced wet environments in asteroids that did not occur in bodies that became active comets. The consequences of this are that the rocky components in active comets are predominantly composed of preserved anhydrous nebular solids without abundant secondary minerals that form from aqueous processes.

A recent study, based on O isotopes of primary anhydrous minerals [9], has suggested that Ryugu and CI chondrite parent bodies accreted in proximity to comets in the outer solar system. If so, then this would enhance the opportunity for material exchange between asteroids and short-period comets. Because the phyllosilicate clast in the giant cluster IDP has mineralogical and chemical properties resembling Ryugu phyllosilicates, and because of its rarity and enclosure in a anhydrous aggregate of likely cometary origin, it is a potentially important tracer material. This clast is evidence that materials ejected from asteroids were accreted into comets as rare xenoliths.

Conclusions: A very rare phyllosilicate clast from the giant cluster IDP (which has a likely cometary origin) has properties that match phyllosilicates from samples from the asteroid Ryugu. This finding provides evidence that local material may have been exchanged between the asteroids and short-period comets. The incorporation of the LT10 clast into the giant cluster IDP parent body may be the first direct evidence that hydrated silicates are present in comets, but likely did not form in the comet itself.

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