SEM and TEM analyses of minerals xifengite, gupeiite, Fe_2Si (hapkeite?), titanium carbide (TiC) and cubic moissanite (SiC) from the subsoil in the Alpine Foreland: Are they cosmochemical? M. Hiltl[1], F. Bauer[2], K. Ernstson[3], W. Mayer[4], A. Neumair[4], and M.A. Rappenglück[4] [1]Carl Zeiss Nano Technology Systems GmbH, Oberkochen, Germany (mhiltl@online.de), [2]Oxford Instruments GmbH NanoScience, Wiesbaden, Germany (frank.bauer@oxinst.com), [3]University of Würzburg, Germany (kernstson@ernstson.de), [4]Institute for Interdisciplinary Studies, Gilching, Germany (info@mayer-chiemgau.de, agneumair@arcor.de, mr@infis.org)

Introduction: In the early 2000s when a group of local history researchers was licenced to practice metal detector probing for archeological objects they repeatedly encountered millimeter to centimeter-sized particles in the subsoil down to the substratum that proved to be iron silicides Fe_3Si, mineral gupeiite, and Fe_5Si_3, mineral xifengite, completely unknown in the rural districts of the Alpine Foreland. They suggested a possible meteoritic origin, and a few papers [1, 2, 3] seized on that idea, especially with regard to strongly restricted terrestrial formation of gupeiite and xifengite and their occurrences in cosmic globular particles from the Yanshan area in China [4]. However, an industrial origin of the ferrosilicides was rapidly brought up for discussion [5]. Later papers [6, 7, 8] again focused on an extraterrestrial origin of the ferrosilicides, but the industrial aspect remained essential. Here, we report on a completely new analysis of these iron silicide particles from different locations using various SEM, TEM and HISM techniques strengthening a cosmic origin.

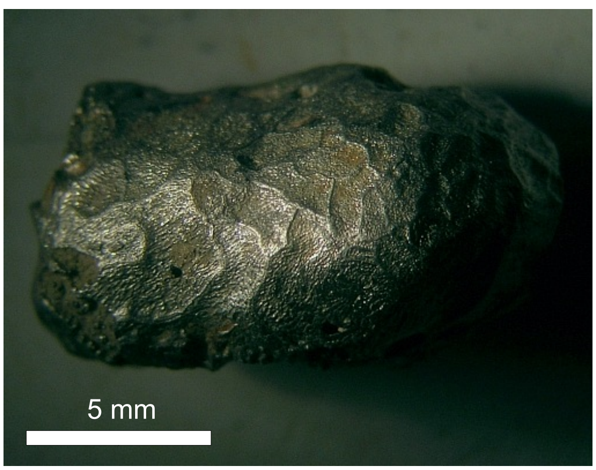

Fig. 1. Typical example of the investigated iron silicide particles. Note the slightly regmaglyptic surface of the particle.

Observations: The iron silicide finds cover a limited area of roughly 3,000 km^2, and until now they have yielded a mass of about 3 kg. Most of the iron silicide particles so far studied were recovered near the town of Marktl (48°15.2' N; 12°50.6'E) from the subsoil and its transition to the substratum being Quaternary sand and gravel. A concentration of individual finds was recorded over an area a few kilometers broad. The size of the particles ranges between the order of a millimeter and a few centimeters. The surfaces show metallic luster and lack practically any corrosion. In many cases, a regmaglyptic surface resembling ablation features of meteorites is striking (Fig. 1). Frequently, sparkling crystals can be seen with the naked eye to stick out from the metallic matrix (Fig. 2).

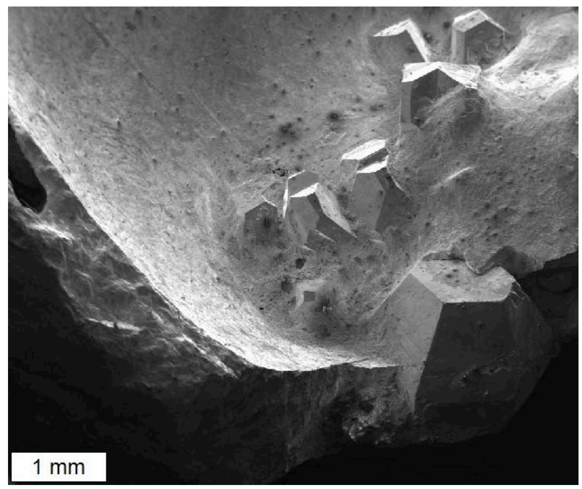

Fig. 2. SEM image of moissanite (SiC) crystals outgrowing from the iron silicide matrix.

SEM and TEM yield a stoichiometrically heterogeneous iron silicide matrix in intimate however largely well-ordered accretion composed of Fe_3Si (gupeiite), Fe_5Si_3 (xifengite), Fe_2Si (hapkeite?), FeSi, $FeSi_2$, and others, hosting extremely pure crystals of moissanite (SiC) (Fig. 2) and titanium carbide (TiC) (Fig. 3), and a broad variety of other elemental constituents (e.g., uranium, zirconium). An earlier electron microprobe analysis of a gupeiite particle showed clear affinity to meteoritic suessite from the North Haig and NWA 1241 ureilite meteorites corresponding with their low suessite nickel contents [9]. Electron backscatter diffraction and TEM lattice constant analyses show the moissanite to be the cubic modification. In part, the minerals exhibit strong mechanical overprint like deformation lamellae and open tensile fractures, and the particles' surface may be littered with rimmed 10-20 µm-diameter (impact?) craters (Fig. 4).

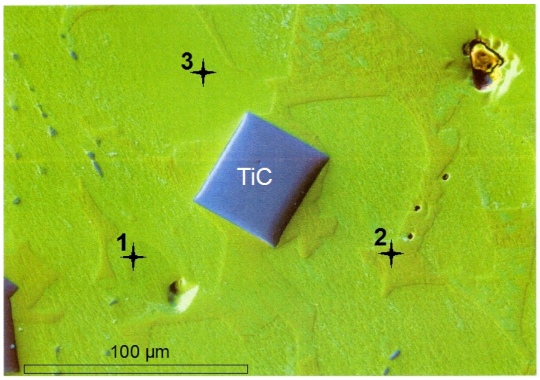

Fig. 3. Titanium carbide (TiC) crystal in a matrix of iron silicides; 1: FeSi, 2: Fe_3Si (gupeiite), 3: Fe_5Si_3 (xifengite).

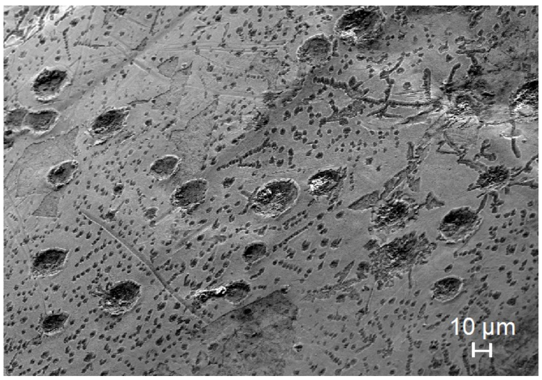

Fig. 4. Surface of an iron silicide particle that exhibits rimmed craters suggesting impacts from micrometer-sized projectiles.

Discussion: Minerals xifengite and gupeiite can form only under strongly reducing conditions explaining why they are extremely rare in nature on earth. Iron silicides have been analyzed in fulgurite glass from lightning into the ground [10, 11], but for the most part of so far a dozen gupeiite and xifengite occurences a context with an extraterrestrial origin has been established. With regard to shape and composition, most similar to the iron silicides under discussion are particles found in Southern Urals, Russia, up to 1 m deep in Pleistocene sediments that were studied as a possible new class of meteorites [12]. From N and noble gas analyses compared with properties of known meteorites, the authors favor a terrestrial formation from a however completely unknown process.

The latter holds true also for the iron silicides presented here, if we take a terrestrial origin into consideration. Excluding lightning to have produced a mass of at least 3 kg distributed over 3,000 km^2 however without leaving fulgurites, the strongly reducing conditions required for formation provide basic difficulties. An origin from industry has most intensively been discussed and investigated, and a factory has been spotted that has produced the extremely rare iron silicide minerals gupeiite and xifengite in a hitherto completely unknown byproduct [9]. The industrial/anthropogenic component, however, is basically incompatible with find situations like, e.g., in many hundred years old forests, in peat mires and in alp regions at more than 1,000 m altitude. Moreover, gupeiite and xifengite particles were detected below a medieval hoard of coins and below ground work of a medieval castle.

Therefore, since a geogenic and anthropogenic formation can largely be excluded, an extraterrestrial origin comes to the fore. Iron silicides occur in the most reduced meteorites (ureilites [13], enstatite chondrites [14], achondrites [15]). On earth, the Fe_2Si iron silicide is known only from the Dhofar 280 lunar fragmental breccia meteorite where it has given the mineral name hapkeite [16]. The cubic moissanite and the titanium carbide exist in some meteorites and have been verified in cosmic dust. Deformation lamellae and abundant open, tensile (spallation?) fractures in the iron silicides may point to shock load. The regmaglyptic surface of several iron silicide particles (Fig. 1) reminds of comparable and well-known features on meteorites, and the microcraters (Fig. 4) may possibly give evidence of micrometeorite impacts similar to lunar microcraters.

Conclusions: From these observations and analyses, the early supposition of the local history researchers the strange metallic matter might have a cosmic origin seems to be strengthened if not confirmed, all the more meanwhile a large Holocene meteorite impact strewn field in the region under discussion related with the so-called Chiemgau impact event has got clear contours [17].

References: [1] Raeymaekers, B. and Schryvers, D. (2004) *Paneth-Kolloquium Nördlingen*. [2] Hoffmann, V. et al. (2004) *Paneth-Kolloquium Nördlingen*. [3] Fehr, K.T. et al. (2002) *Status report*. [4] Yu Zuxiang (1986) *American Mineralogist*, 71, 228 (abstract). [5] Fehr, K.T. et al., *Der Aufschluß*, 55, 297-303. [6] Schryvers, D. and Raeymakers, B. (2005) *Proceedings EMC 2004,* Vol. II, 859-860. [7] Rappenglück, M. et al. (2005) *European J. of Mineralogy,* 17, Bh 1, 108. [8] Rösler, W. et al. (2005) *Meteoritics & Planet. Sci.*, 40, p. A129. [9] *http://www.chiemgau-impact.com/neu_min.html.*. [10] Parnell, J. et al. (2008) *LPS XXXIX*, Abstract #1286. [11] Essene E.J. and Fisher D.C. (1986) *Science*, 234, 189-193. [12] Basu, S. et al. (2000) *Meteoritics & Planet. Sci.*, 35, p. A22. [13] Keil K. et al. (1982) *Am. Mineral.*, 67, 126-131 [14] Lin Y. & El Goresy A. (2002) *Meteoritics Planet. Sci.*, 37, 677-599. [15] McCoy T.J. et al. (1999) *Meteoritics Planet. Sci.*, 34, 735-746. [16] Anand, M. et al. (2003) *LPS XXXIV*, Abstract #1818. [17] Ernstson, K. et al. (2010) *J. Siberian Fed. University, Engineering & Technologies,* 1, 72-103.