Fe_2Si (HAPKEITE) FROM THE SUBSOIL IN THE ALPINE FORLAND (SOUTHEAST GERMANY): IS IT ASSOCIATED WITH AN IMPACT?

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Abstract

Mm- to cm-sized metallic particles in the subsoil of the Alpine Foreland are composed mainly of iron silicides Fe_3Si, mineral gupeiite, and Fe_5Si_3, mineral xifengite. Contribution of the iron silicide Fe_2Si, mineral hapkeite, and of more peculiar mineral components, last but not least the find situations, are speaking in favor of a meteoritic origin of the iron silicide pieces and suggests a relation to the Holocene large Chiemgau impact event.

Introduction

-- Iron silicides have been playing a major role in the discovery and discussion of the Holocene large Chiemgau meteorite impact event [1-15].
-- They were detected by local history researchers in the Alpine Foreland (Southeast Germany, Fig. 1) in the subsoil down to the substratum.
-- The iron silicides proved to be Fe3Si, mineral gupeiite, and Fe5Si3, mineral xifengite. The iron silicides regularly occurred near rimmed craters.
-- Early conclusion: Both the strange matter and the craters could perhaps be related with a meteorite impact in historical time, especially with regard to strongly restricted terrestrial formation of gupeiite and xifengite and their occurrences in cosmogenic globular particles from the Yanshan area in China [16].

Fig. 1. Location map for the finds of the iron silicides.

– An industrial origin was considered because the iron silicides had been produced in the local industry as a completely unknown byproduct.
– An industrial production could largely be excluded because of many find situations absolutely incompatible with anthropogenic support.
– Here, we report on completely new analyses of these iron silicide particles from different locations, their in part complex internal and external structures and their obviously complex formation history, using various SEM and TEM techniques. They show the industrial hypothesis can be ruled out with a high degree of probability, and they suggest a cosmic, extraterrestrial origin.

The material

-- The mass of iron silicides so far sampled in the region totals about 2 kg.
-- The size of the particles ranges between the order of a millimeter and few centimeters. The largest piece is 6 cm long and has a mass of 162 g.
-- Some of the particles exhibit a spherical or ellipsoidal shape, but often a convex smooth front combines with a flat irregularly shaped rear side (Fig. 2 F, G).
-- The surfaces show metallic luster and lack practically any corrosion.
-- In many cases, a regmaglyptic surface resembling ablation features of meteorites is striking (Fig. 2 E, F).
-- Frequently, sparkling crystals can be seen with the naked eye to stick out from the metallic matrix (Fig. 2 G, Fig. 3).

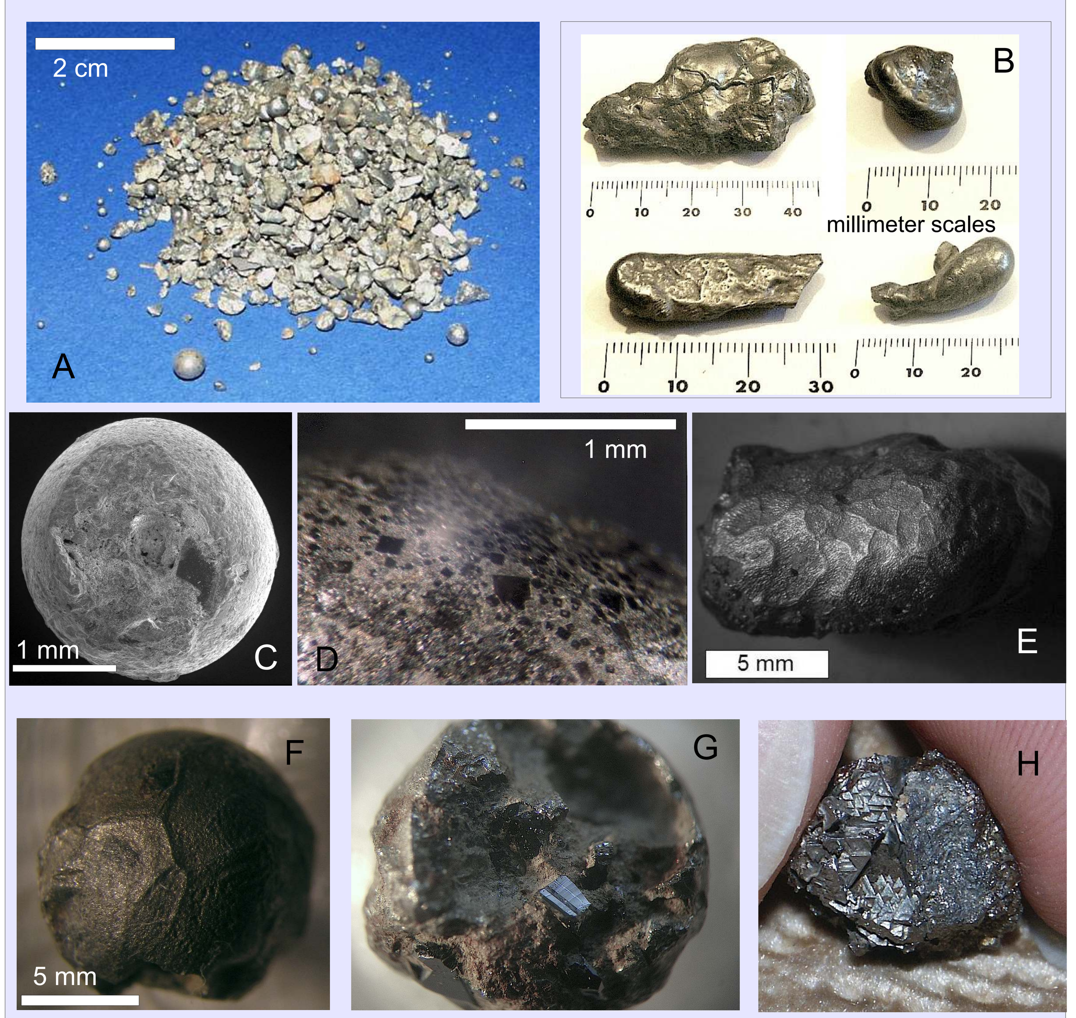

Fig. 2. The iron silicide matter from the Chiemgau region. A: small-sized metallic particles - angular and spherical. B: "Splash" form of iron silicide particles. C: SEM image of iron silicide perfect spherule. D: cubiform crystals paving the surface of an iron silicide particle. E, F: regmaglyptic surface of iron silicide particles. G: rear side of the particle in F. H: pyramidal shape of iron silicide particle.

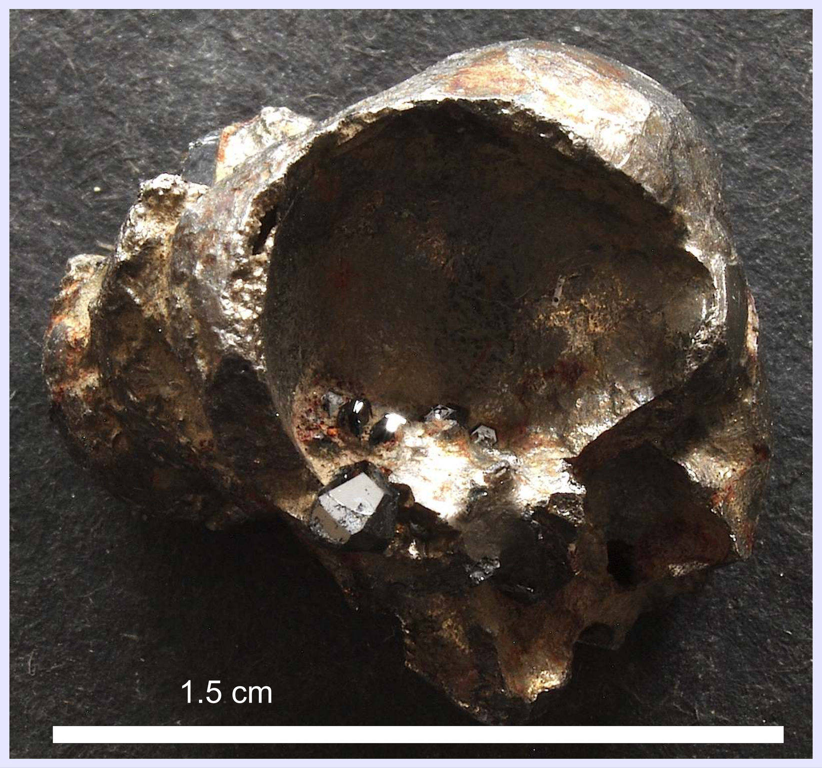

Fig. 3. Iron silicide particle with sparkling silicon carbide (moissanite) larger crystals sticking out from the metallic matrix.

Analytical SEM, TEM and EBSD: External and internal structure

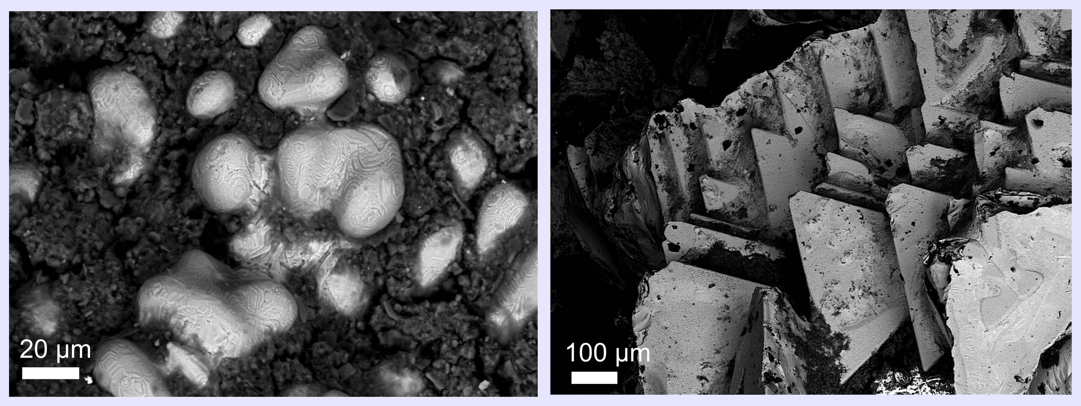

Fig. 4. Amoebae-like and pyramidal-shaped (possibly hexagonal xifengite) iron silicide in widely unstructured iron silicide.

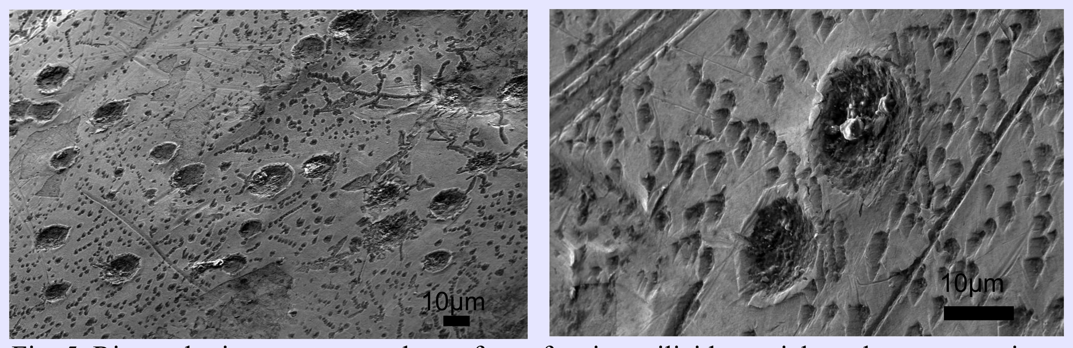

Fig. 5. Rimmed micro-craters on the surface of an iron silicide particle and two craters in more detail. The many angular pits could be imprints of zircon crystals now removed (see Fig. 6).

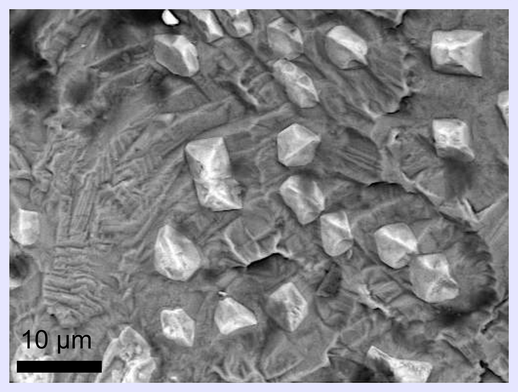

Fig. 6. Zircon crystals in iron silicide matrix. The white tips on the crystals have been shown to be uranium.

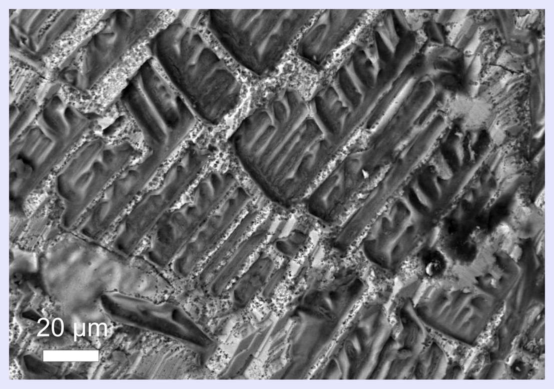

Fig. 7. Zirconium (zircon or/and baddeleyite) possible exsolution lamellae in iron silicide.

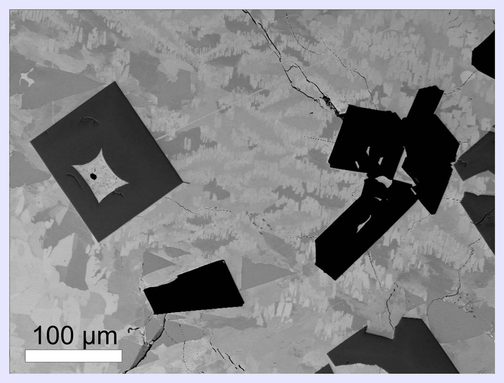

Fig. 8. Typical texture of many iron silicide particles: titanium carbide (dark gray) and silicon carbide (moissanite, black) crystals in a matrix of intergrowth of various iron silicide minerals (gupeiite, xifengite, hapkeite, fersilicite, ferdisilicite).

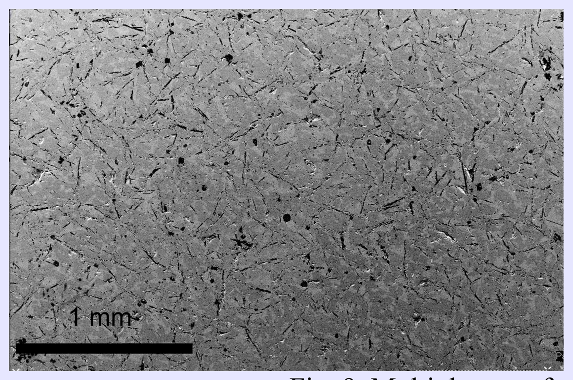

Fig. 9. Multiple sets of subparallel, mostly open fractures in iron silicide matrix.

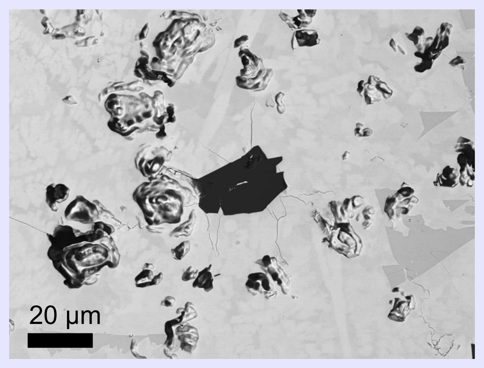

Fig. 10. Peculiar ornate structures in the iron silicide matrix lacking a conclusive explanation. Possibly spotty melting of the matrix.

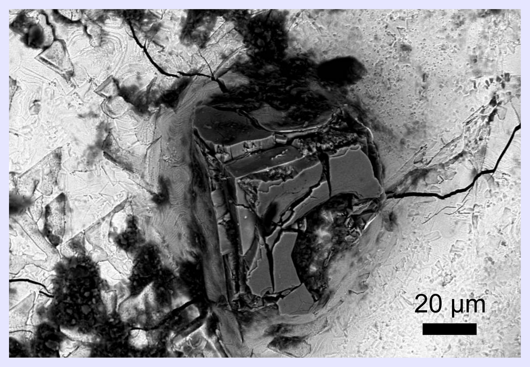

Fig. 11. Strongly fractured titanium carbide crystal in iron silicide matrix. Note the open, tensile fractures pointing to dynamic spallation fracturing.

Uranium

Among the more than 30 chemical elements (including, e.g., the REE cerium, neodymium and yttrium, but few nickel) so far established in the iron silicide samples, uranium has attracted special attention. It is in general found associated with zirconium (Fig. 12, Fig. 6) or without zirconium (Fig.13), and frequently together with cerium/neodymium. Interestingly, only in one case uranium has been shown to coexist with thorium, however in Th traces only (Fig. 13). Except for a faint signal of polonium no other decay products were analyzed. Not any lead was seen in the uranium spectra, and all other measured spectra (totaling some hundred) proved to be free of lead, too.

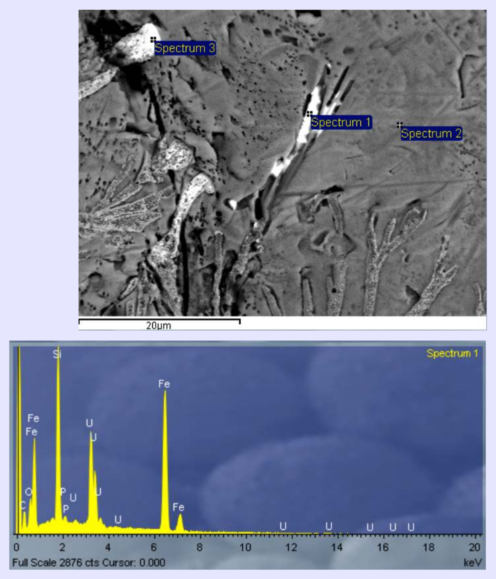

Fig. 12. Iron silicide with significant uranium peak in spectrum 1. Spectrum 2 shows uranium and mostly zirconium (similar to Fig. 5), spectrum 3 more or less pure iron silicide.

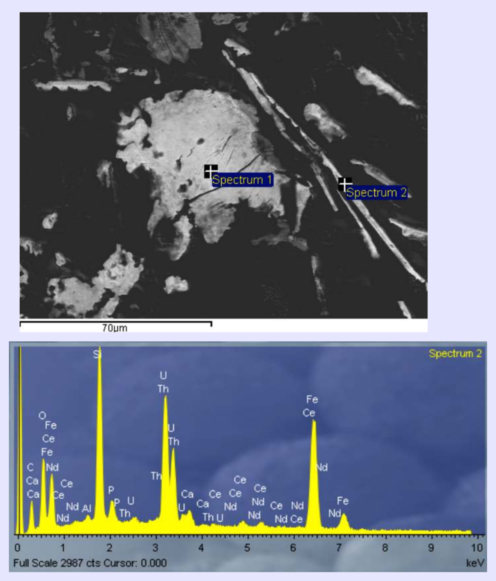

Fig. 13. Iron silicide with significant uranium peak in spectra 1and 2. REE cerium and neodymium contribute to the spectra, but thorium shows as a trace only - the only spectra where Th was measured at all.

CAIs

Recent analyses [17] show that the iron silicides from the Chiemgau impact strewn field contain peculiar CAIs in the form of the monoclinic high-temperature (>1,500°C), low-pressure dimorph of $CaAl_2O_4$, mineral krotite, and the orthorhombic $Ca_2Al_2O_5$ dicalcium dialuminate high pressure phase with the brownmillerite-type structure. For the iron silicide particles the intimate CAI coexistence of the high-temperature/low-pressure $CaAl_2O_4$ krotite and the high-pressure $Ca_2Al_2O_5$ phase imply a complex formation history.

Hapkeite

While the iron silicides gupeiite and xifengite as well as the common TiC had already been microprobe-analyzed in the very beginning of the investigation of the iron silicides from the Chiemgau area, only much more sophisticated procedures using SEM, TEM and EBSD were able to reveal the incredibly complex nature of the peculiar matter. From these investigations the existence of the iron silicide Fe_2Si, mineral hapkeite became evident. In Fig. 14 hapkeite shows intergrown with gupeiite and xifengite to form the iron silicide matrix that is hosting a titanium carbide (TiC) crystal. In Fig. 15 the Fe_2Si phase is also clearly documented and in part appears like the yolk of fried eggs within a so far unidentified calcium silicate phase, possibly a wollastonite polymorph. In the literature two hapkeite polymorphs, a cubic and a trigonal modification, have been reported, and here the trigonal polymorph (S.G. P3*m*1, No. 164 [18 ,19]) has been established.

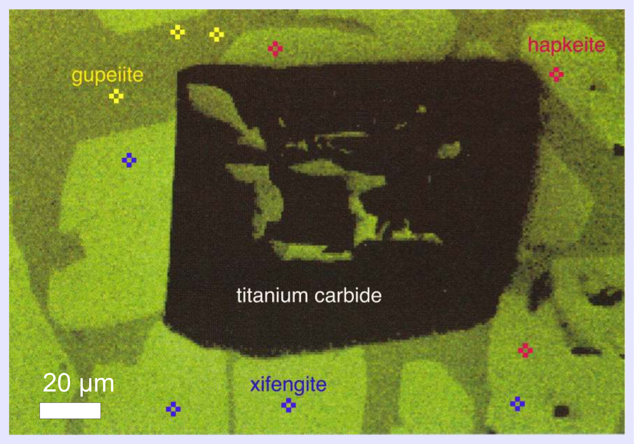

Fig. 14. Titanium crystal in the matrix of intergrowth of gupeiite, hapkeite and xifengite iron silicides.

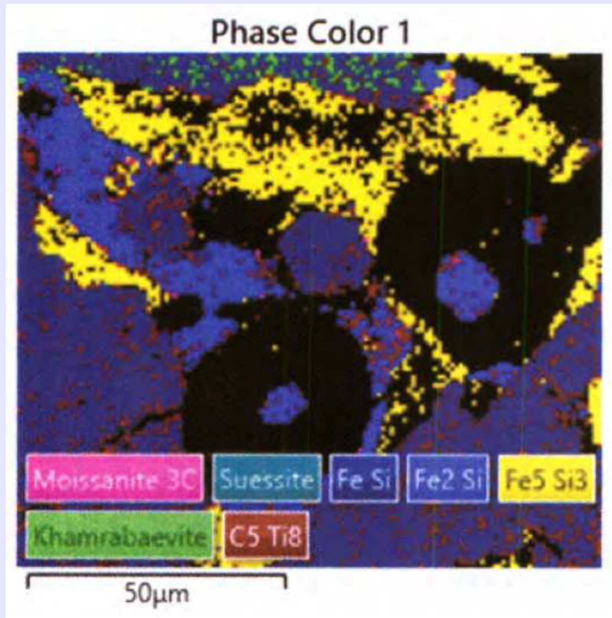

Fig. 15. Phase diagram for moissanite and titanium carbide phases in iron silicide (fersilicite, hapkeite, xifengite) matrix. Suessite is represented by only few counts. The black areas seem to be a calcium silicate near to wollastonite-1T without matching it and possibly being one of the several $CaSiO_3$ polymorphs.

Discussion and relations

The Chiemgau impact and meteorite crater strewn field

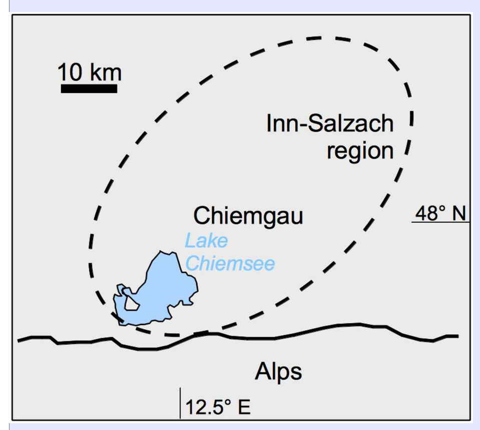

Fig. 16. Location map of the Chiemgau impact elliptically shaped strewn field (see Fig. 1).

-- The Chiemgau strewn field [3, and references therein] dated to the Bronze Age/Celtic era comprises more than 80 mostly rimmed craters scattered in a region of about 60 km length and ca. 30 km width in the very South-East of Germany (Fig. 16, Fig. 1).
-- The crater diameters range between a few meters and a few hundred meters, among them Lake Tüttensee, the hitherto established largest crater of the strewn field with a rim-to-rim diameter of about 600 m and an extensive ejecta blanket.
-- Geologically, the craters occur in Pleistocene moraine and fluvio-glacial sediments.

-- The impact is substantiated by [3, and references therein]:

- heavy deformations of the Quaternary cobbles and boulders in and around the craters
- abundant fused rock material (impact melt rocks and various glasses) occur
- shock-metamorphic effects (planar deformation features, PDFs, diaplectic glass)
- geophysical anomalies
- abundant occurrence of metallic, glass and carbon spherules, accretionary lapilli
- high-pressure/high-temperature carbon allotropes [7, 13].

-- The impactor is suggested to have been a roughly 1,000 m sized low-density disintegrated, loosely bound asteroid or a disintegrated comet in order to account for the extensive strewn field.

The Chiemgau impact and the iron silicides

There is strong evidence that the iron silicides are linked to the Chiemgau meteorite impact event:

-- Many find situations in the Chiemgau area are practically excluding any anthropogenic deposition.
-- There is an obvious extraterrestrial relation of most other gupeiite and xifengite iron silicide occurrences on earth.
-- There is a problematic formation of gupeiite and xifengite in a geologic oxygen-free environment.
- Tiny iron silicide particles are frequently incorporated in accretionary lapilli from the Chiemgau strewn field (Fig. 17).
-- Iron silicide particles are interspersing highly porous carbonate recrystallization relics of probably carbonate impact melt (Fig. 17).
-- "Splash" forms and regmaglyptic surfaces (Fig. 2) point to aerodynamic processes.

Fig. 17. Accretionary lapillo with a core of an iron silicide fragment (upper), and iron silicide particles (small arrows) interspersed in a probable recrystallization product of impact carbonate melt (lower). Width of images c. 8 mm and 7 cm.

-- There is evidence of one or more shock events the iron silicides underwent:

- Moissanite crystals in part show multiple sets of closely spaced planar features (Fig. 18) reminding of shock-produced planar deformation features (PDFs) known from various minerals.

Fig. 18. Multiple sets of planar features in a moissanite crystal - possibly a shock effect. Field width 80 µm.

- The peculiar occurrence of uranium without its decay products (Fig. 11) may be interpreted as the result of a shock event that could have led to complete resetting of the U-Pb isotopic system as is observed e.g., in some tektites [20] and in zircons from the Chicxulub K-T impact event [21].
- Ubiquitous open fractures traversing the iron silicide particles in irregular patterns (Fig. 10) and as multiple sets of subparallel open fissures (Fig. 9) are implying tensile character of the deformations and may easily be explained by impact shock spallation.
- The occurrence of the many micrometer-sized rimmed craters on the surface of an iron silicide particle (Fig. 3) may point to a highly energetic cosmic bombardment, and the supposed open imprints of lost zircon crystals (Fig. 3) could possibly be witness of a shock collision in space.
- The impact of tiny zircons into a plastic or even liquid matter and the obvious sudden freezing of the expansion waves of the disturbance (Fig. 6) point to abrupt change of the material's properties.

The Chiemgau impact and the iron silicides, cont.

Opponents and critics of the Chiemgau impact *per se* don't grow tired of pointing to an industrial byproduct of the iron silicides [22]. They ignore:
-- Iron silicides occur in the most reduced meteorites.
-- Cubic moissanite and titanium carbide exist in some meteorites and have been verified in cosmic dust.
-- On earth, the hapkeite, Fe_2Si iron silicide (in its cubic form) is known from the Dhofar 280 lunar fragmental breccia meteorite [23] and has been reported for magnetic spherules in Hungary that are ascribed to cosmic dust or meteorite impact [24]. A grain similar in composition to hapkeite occurs in the FRO 90228 ureilite [25], and Fe_2Si, together with TiC and supernova material, was established in the Orgueil meteorite [26].

Conclusions

From our analyses and within the specific context, the early supposition the strange metallic matter found in the Alpine Foreland might have a cosmic origin appears to be confirmed, and a relation to the Holocene meteorite impact strewn field in the region under discussion related with the so-called Chiemgau impact event [5] is strongly supported.

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