SHORT-TERM COALIFICATION: A NEW IMPACT-RELATED PROCESS?

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Introduction: Coalification defines the process in which vegetable matter like wood and peat becomes converted into coal of increasingly higher rank with anthracite, and in some cases graphite, as the final product. Heat, pressure and time are the important factors driving coalification that in geology leads to the formation of coal deposits. Simulation of natural coalification has been performed in the laboratory, and industrial coalification from biomass within hours is known as hydrothermal carbonization. Observations from known and proposed impact events suggest that natural short-term coalification up to the highest rank can possibly take place when vegetable matter is exposed to high shock pressures and temperatures.

Observations: Since a couple of years, the Holocene Chiemgau impact event is considered to have produced a large meteorite crater strewn field in southeast Bavaria, Germany [1, 2]. The roughly 60 km x 30 km elliptically shaped strewn field comprises more than 80 craters including as largest structures the 600 m-diameter Lake Tüttensee crater and, from Sonar soundings, a probable 900 m x 400 m rimmed doublet crater at the bottom of Lake Chiemsee. The impact is documented by abundant impact melt rocks and various glasses, shock-metamorphic effects, geophysical anomalies and ejecta deposits, and substantiated by the abundant occurrence of metallic, glass and carbon spherules, accretionary lapilli, and of strange matter in the form of iron silicides like gupeiite and xifengite, and various carbides like, e.g., moissanite SiC [2]. The occurrence of nanodiamonds has been reported in [3]. From dating archeological objects the impact must have happened more than 2500 years BP in the Bronze Age/Celtic era [4].

From the beginning of investigating the impact area, partly very peculiar carbonaceous material has abundantly been found in the Chiemgau strewn field. The most common occurrence is charcoal more or less regularly intermixed in impact breccias. A second class of carbonaceous matter comprises dense black glassy fragments up to the size of a few centimeters. Between charcoal and glass-like carbon, a broad variety of carbonaceous fragments is observed that obviously reflects intermediates in a series from charcoal to glass-like carbon. We observe a kind of monomictic charcoal breccia composed of finely grinded and firmly caked charcoal particles, crumbly however hard, partially glass-like carbonaceous matter with a few intermixed charcoal particles, pieces that combine merging charcoal and glass-like carbon, stratified and very tough glassy carbon reminding of primary wood fiber, and, on a millimeter scale, alternately stratified and glass-like carbon. Charcoal has regularly preserved the typical cellular structure only but is no longer flammable. Frequently, the glass-like carbon has become strongly vesicular thus resembling a true carbon glass. Pieces of writable, graphite-like substance with magnetic properties add to the spectrum of exotic carbonaceous matter, as well as a slightly magnetic fragment of glass-like carbon interspersed with tiny reddish spheroidal aggregates. Under the SEM, the aggregates partly reminding of algae structures proved to contain magnetite, but the most intriguing observation were diatom skeletons sticking in the glass-like carbon (Fig. 1).

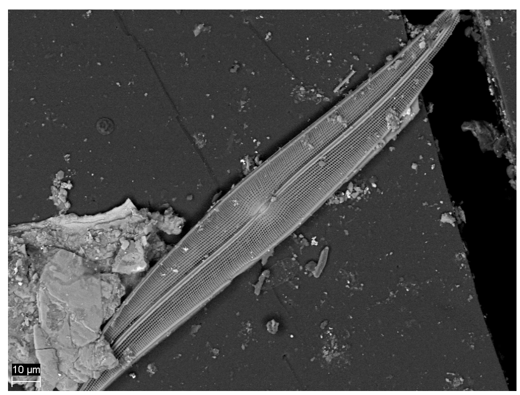

Figure 1. SEM image of a diatom skeleton in glass-like carbon suggesting impact coalification from Lake Chiemsee peat.

A preliminary EDX analysis of a glass-like carbon fragment reveals mostly carbon, a high amount of oxygen (up to 25 wt. %), small amounts of Al, Si and Ca, and traces of Na, Mg, S, Cl, K and Fe. Raman spectra of the sample (Fig. 2) show greatly disordered elemental carbon mostly in an amorphous state. Similar Raman spectra of disordered carbon are known from, e.g., Allende carbonaceous chondrite, carbon matter from the Sudbury impact structure and artificially shocked graphite [5] .

Discussion: The observations of the various carbonaceous finds strongly suggest they belong to a certain process of coalification beginning with vegetation mostly in the form of wood, passing the stage of charcoal, and ending with the glass-like carbon. Even higher stages of coalification may be documented by the above-mentioned graphite-like sample and the nanodiamonds found in carbon spherules for which an extraterrestrial origin or a formation in an impact process is discussed [3].

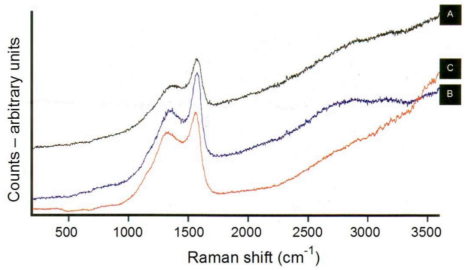

Figure 2. Raman spectra of a glass-like carbon sample from the Chiemgau impact area showing greatly disordered elemental carbon mostly in an amorphous state.

The glass-like carbon fragment with aggregates resembling algae structures and diatom skeletons suggests that also organic matter from an aqueous environment may have undergone the postulated short-term coalification process, and we point to the fact that post-glacial bogs and peat formation are common in the Lake Chiemsee region.

Summarizing the observations, the find of carbon matter in various modifications up to highest stages of an obvious coalification in young, Holocene geologic environs excludes any long-term processes known from coal deposit formation. Glass-like carbon has been shown to evolving from cellulose by thermal decomposition at 3,200°C [6], but the question remains how such a process could have run in nature. High pressure and strong heat acting in nature in a short time may be provided by explosive volcanism, giant landslides and meteorite impact. In the present case, it doesn't need much imagination to reasonably explain the exotic carbon matter to have originated from the Chiemgau Holocene impact event. From computer simulations [M. Rappenglück, pers. comm.] a roughly 1,000 m sized impactor is suggested to have been a low-density disintegrated, loosely bound asteroid or a disintegrated comet to account for the extensive strewn field. The incoming cosmic projectile must have encountered a densely arborous landscape also hosting large areas of bogs and peat deposits. This giant reservoir of organic matter exposed to impact shock and explosion could have been the source for the observed coalification, although the most part of the vegetation probably simply burned. For the time being it is largely unresolved what happened in detail. The glass-like carbon with its intriguing Raman spectrum, the pieces having graphite properties, and possibly the formation of nanodiamonds may speak in favor of an immediate shock transformation from organic matter to high-rank carbon. This is substantiated by charcoal fragments in direct contact with dense glass-like carbon. In shocked rocks, the coexistence of strongly shocked minerals and minerals largely unaffected is a common observation and may be explained by the strongly nonlinear process of shock propagation. This may apply also to the observation that algae aggregates and diatom skeletons could have survived the formation of the glass-like carbon.

Related observations. Comparable finds have only recently been reported in context with the postulated and heavily disputed giant Younger Dryas impact in North America 12,900 BP [7]. Like copies of the Chiemgau finds, the authors present glass-like carbon and a piece of pine wood grading into glass-like carbon. The peculiar transition is explained by impact shock wave passage having only affected one side of a tree.

In the Rubielos de la Cérida structure as part of the large Mid-Tertiary Azuara impact event, charcoal in close coexistence with glass-like, partly vesicular carbon has been described to contribute to an impact microbreccia [8, 9]. Microprobe element scans show the black glass-like particles to be composed of carbon and oxygen as the only major components. X-ray powder diffractograms display a typical amorphous glass "hump". Like with the Chiemgau pieces, particles in the microbreccia show charcoal immediately grading into the glass-like carbon. The role of remarkable contents of oxygen detected in the carbon particles both from the Chiemgau and Rubielos de la Cérida samples is still unclear. The possibility of the oxygen trapped in fullerene-like structures may be considered. Fullerenes are reported to occur also in glass-like carbon from the Younger Dryas proposed impact.

Conclusion: While in impact research shock metamorphism is in general attributed to rocks and minerals, the observations of glass-like carbon and possibly carbon glass in direct contact with organic matter suggest a new type of shock effect in nature.

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