THE EJECTA BLANKET OF THE CHICXULUB IMPACT CRATER, PETROGRAPHIC AND CHEMICAL STUDIES OF THE K-P SECTION OF EL GUAYAL AND OF THE UNAM BOREHOLES.

T. Salge[1], [1]Museum für Naturkunde, 10099 Berlin, Germany, tobias.salge@rz.hu-berlin.de.

Introduction: Impactites from the Chicxulub impact crater (D~180 km, ~65 Ma) on the Yucatán peninsula, Mexico, were studied petrographically (polarisation, scanning electron and cathodoluminescence microscopy) and chemically (XRF, TXRF, PGE, EMPA) to investigate the compositional evolution of ejecta during transit through the atmosphere. The impact target comprised a ~3 km thick carbonate-anhydrite-dominated sedimentary sequence on top of a crystalline silicate basement. Samples from three different sites were studied, including five samples from the UNAM-5 as well as three samples from the UNAM-7 boreholes near the outer crater rim, and 42 bulk rocks samples, individual particles and accretionary lapilli from the K-P site of El Guayal (~520 km SW of the crater centre).

Stratigraphy: At UNAM-5, a 172 m thick suevitic breccia was encountered between 332.0 and 504.0 m depths [1]. At UNAM-7, the sequence of impactites consists of a suevitic breccia (222.2 to 348.4 m) on top of a polymict silicate melt-poor breccia. The latter is intercalated with evaporite megablocks representing an analogue to the Bunte Breccia of the Nördlinger Ries crater [2]. At El Guayal, an impact-related sequence was emplaced between Upper Cretaceous limestones and earliest Palaeocene marls [3,4]. It consists of (1) a basal, ~40 m thick, monomict carbonate megabreccia, (2) followed by an ~10 m thick suevitic unit, where an upper ~2.3 m subunit contains at its basis abundant accretionary lapilli, and (3) on top, a several cm thick clay layer. In the clay layer of El Guayal, the presence of Chicxulub impact ejecta (e.g. carbonate melt spheroids) together with the PGE-enriched impactor component links the K-P boundary with the Chicxulub impact.

Results: The cooling history of the impact ejecta is recorded by the texture of the non-luminescent carbonate melts. In the polymict silicate melt-poor breccia of UNAM-7-381.4 m, polygonal to interlobate carbonate melts were deposited mainly in liquid state, whereas at El Guayal spherulitic carbonate melts were rapidly quenched. The cogenetic association of carbonate melts with variably textured calcite crystals displays temperature variations during transport through the atmosphere. The carbonates in the polymict silicate melt-poor breccia of UNAM-7 show complete melting and/or recrystallisation. An anhydrite core of a (clay altered) silicate melt particle contains a crystallisation sequence (Fig. 1). The larger columnar crystals display degassing vesicles, which are missing in the smaller interlobate crystals, indicating partial decomposition and coherent melting of anhydrite at T~1465°C. These observations indicate pronounced thermal alteration and transport in the ejecta curtain with higher temperatures than estimated for the Bunte Breccia from the Nördlinger Ries [5]. At El Guayal, larger variations of thermal alteration are recorded by recrystallisation of the rim of solid calcite particles and quenched carbonate melt particles. Intermixing of hot silicate melt with (fossil-bearing) calcite resulted in annealing of the different components. Degassing voids associated with microcrystalline calcite crystals in silicate melt indicate a complex annealing reaction including calcite recrystallisation and decomposition at T~680–900°C.

In the polymict silicate melt-poor breccia of UNAM-7, calcite decomposition and subsequent back-reaction is indicated by degassing vesicles associated with incorporation of microcrystalline calcite into plastically deformed anhydrite particles. In the overlying suevitic breccia, silicate melt particles were deposited in molten state as indicated by reaction rims against matrix. Alteration due to reaction with seawater caused enrichment in Br, Cl, Sr and SO_3 in the silicate melts. These observations suggest that the calcite matrix at UNAM-7 formed by an exothermic reaction of decomposed calcite and anhydrite (CaO) with water and subsequent back-reaction with CO_2. This reaction and impact melts provided the thermal energy for the crystallisation of euhedral anhydrite from sulphate-rich fluids at T>350°C in the matrix and also within degassing voids of carbonate melts.

The accretionary lapilli of El Guayal contain mainly <150 µm sized shocked and molten particles and were formed during a late stage of plume evolution in a turbulent, steam condensing environment. Multiple laminations, each with decreasing grain size, document recurring heat increase.

Conclusions: Based on the observations of the proximal UNAM boreholes, the distal K-P site of El Guayal and observations on the southern Yucatán peninsula [6,7], the following five stages can be distinguished for the deposition and alteration of the Chicxulub ejecta blanket: (1) Impact-induced seismic activity resulted in the collapse of the Yucatán platform and proximal deposition of local material near the shelf region. In the high-pressure zone between impactor and sedimentary target, jetting accelerated

decomposition products (CaO, CO_2, SO_x) in the atmosphere. A hot vapour flow was initiated by target water explosively vaporised and a prolonged energy release during fast-back-reaction of CaO with CO_2 to calcite. (2) Carbonate melts from intermediate target lithologies were excavated with anhydrite megablocks and initiated a lateral extending ejecta curtain (Fig. 2, upper image). Thereby, the exothermic back-reaction to calcite induced transport at elevated temperatures. Additional steam generation changed an initially ballistic transport to a flow-like transport in a similar process as proposed by [8]. (3) After some 10s of minutes, the turbulent expanding ejecta plume partially collapsed separating the falling suevite from impactor material that had been lifted into the stratosphere (Fig. 2, lower image). Combination of hot silicate melt with carbonates initiated a gas-driven basal flow (T~550–1100°C). In an upper, moderately tempered (T~100°C), turbulent ash cloud steam condensed and accretion of ash-sized material arriving from the basal flow formed accretionary lapilli. (4) The impactor component was deposited with the finest ejecta in the K-P clay of El Guayal presumably over weeks to years. (5) The prolonged transport of ejecta in the hot ejecta plume induced the alteration processes observed in the ejecta deposits.

It can be concluded that a certain amount of CO_2 has back-reacted to calcite, whereas SO_x gases were completely liberated into the atmosphere. These observations including the abundant presence of carbonate melts support that the amount of CO_2 released to the atmosphere during the Chicxulub impact was overestimated previously [9,10].

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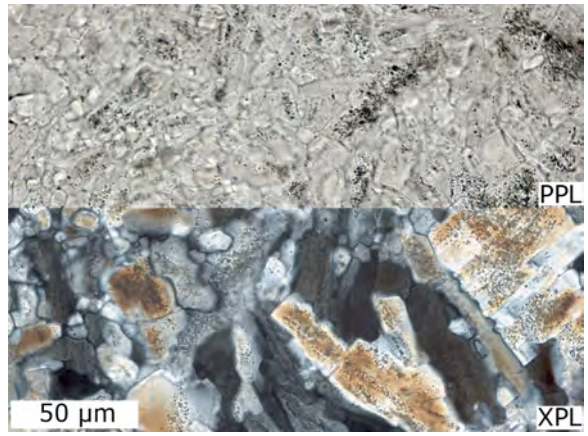

Fig. 1 Micrograph of a crystallisation sequence at an anhydrite core in a silicate melt particle of UNAM-7-381.40 m. Note the abundant degassing vesicles in large columnar crystals which are missing at smaller interlobate crystals. XPL: cross polarised light; PPL: plane polarised light.

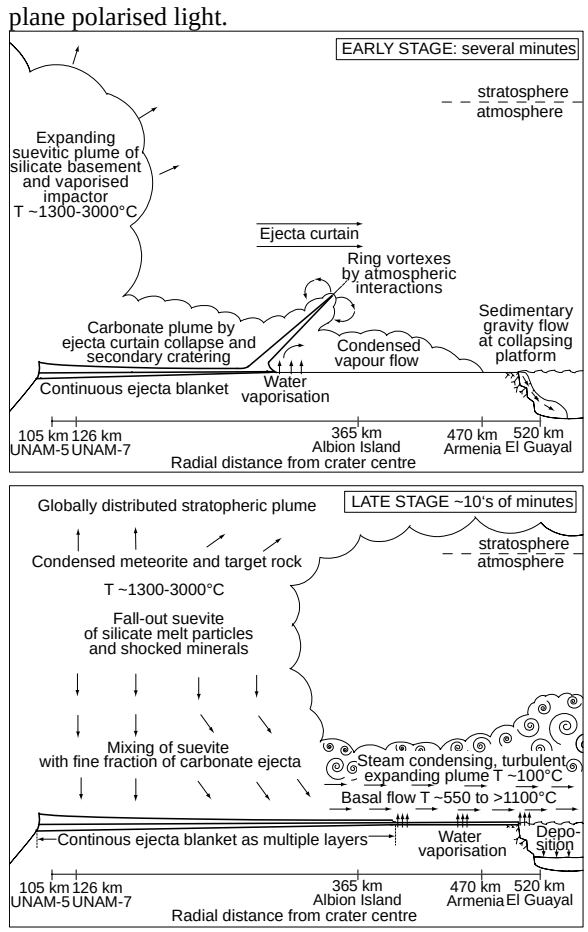

Fig. 2 Model of Chicxulub ejecta plume behaviour at an early stage and during late stage. A final crater diameter of ~200 km is assumed and crater modification processes are not shown. Not to vertical scale.