MINEROLOGY OF SPHERULES AT THE CRETACEOUS-PALEOGENE IMPACT BOUNDARY IN SOUTH CAROLINA: IMPLICATIONS FOR PLUME PROCESSES AND BOLIDE IDENTIFICATION.

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Introduction: A 10 cm section of clay capped by a 7 cm-thick spherule bed (Fig. 1) at the contact between uppermost Maastrichtian and lower Paleogene sediments exposed near Gaston, South Carolina preserves a record of the terminal Cretaceous-Paleogene impact approximately 1500 km NNW of the Chicxulub crater. Iridium and platinum concentrations (Fig. 1), measured using an Agilent Technologies 7500 quadrupole ICP-MS, suggest that the boundary sequence here may be especially rich in an extraterrestrial component. The original matrix of the spherules (Fig. 2) largely has been replaced by hydrous phosphates of the woodhouseite-svanbergite-goyazite series. However, relict grains of shocked quartz and silicate glass have been identified. Additionally, the spherules contain fragments of iron-nickel and nickel metal and a population of somewhat unusual vanadium, nickel, and/or carbon-bearing Ti-Fe oxides. Given the possibility that the metal fragments might be derived from the Chicxulub bolide, we have tried to eliminate every possibility that they are contamination from sample preparation or other sources. Thus far, we remained convinced that the metal is indigenous to the spherules. But the Ti-Fe oxides unequivocally are native to the samples. Consequently, they are an attractive target to determine what their compositions may indicate about the nature of the impacting asteroid and/or the conditions in the vapor plume.

Ti-Fe Oxide Chemistry: We have investigated the composition of the Ti-Fe oxides using quantitative and semi-quantitative wavelength dispersive spectrometry (WDS) and semi-quantitative energy dispersive spectrometry (EDS) using a JEOL 8600 electron microprobe. During previous reconnaissance, we noted that many of the grains exhibit textures similar to decomposing oxides in a melt matrix (Fig. 3A). But the grains presently are surrounded by phosphates suggesting that those phases may have replaced an original melt matrix. We also noted that the grains often contained fine veins of carbon (graphite?). We initially assumed that the Ti-Fe oxides were ilmenite, but our analytical results are more consistent with Mg-poor armalcolite or ferropseudobrookite with a stoichiometry close to $(Fe_{0.7}, Mn_{0.3})Ti_2O_5$, with detectable concentrations of Mg, Al, Cr, and occasionally Ni. This result is important because it supports the hypothesis that the spherule matrix originally was a hot melt. Although members of the armalcolite-pseudobrookite solid-solution series do exist in some endogenic rocks, they more commonly are formed in environments characterized by very high temperatures and rapid quench [2]. If ilmenite-titanomagnetite was reduced at high temperatures in the presence of a carbonate-rich melt (as one might expect from the Chicxulub impact), that may also explain the veins of carbon. They could have formed in a manner similar to the intergrowth of titanomagnetite and graphite observed in carbonatite magmas [3].

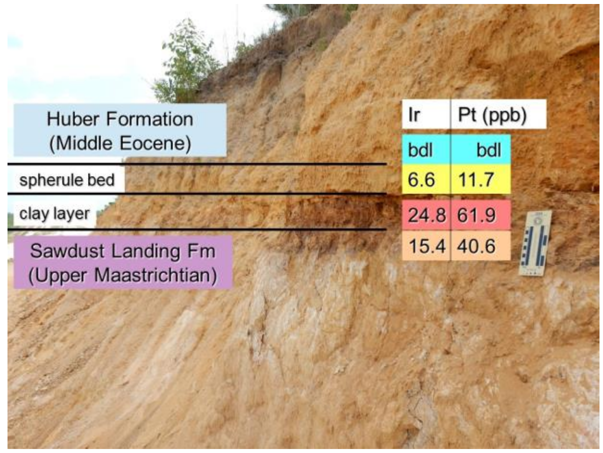

Figure 1. Photograph of the Cretaceous- Paleogene boundary exposed in the upper Coastal Plain of South Carolina. The sequence consists of an approximately seven centimeter-thick spherule bed overlying a ten centimeter-thick dark clay. Iridium and platinum concentrations are listed (bdl=below detection limit).

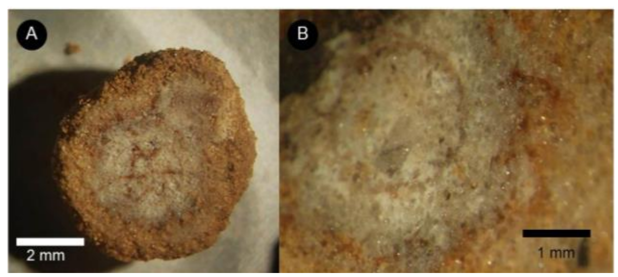

Figure 2. Photographs of goyazite spherules found above the boundary clay.

This conclusion suggests that our data may place significant constraints on the vapor plume environment at this distance from the crater. We are less confident that any of the grains preserve undisturbed remains of the impactor.

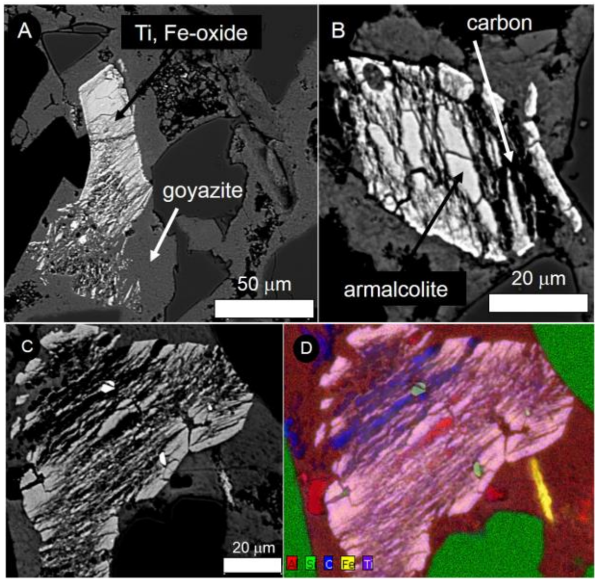

Figure 3. Backscattered-electron micrographs of Ti-Fe oxide grains in goyazite spherules from the Cretaceous-Paleogene boundary, South Carolina. A) The grain exhibits textures typical of thermal decomposition. B & C) Some grains, with Mg-poor armalcolite compositions, contain veins of carbon. D) An X-ray element composition map illustrates the distribution of carbon (blue), aluminum (red), silicon (green), iron (yellow), and titanium (violet).

References: [1] Harris R.S. et al. (2015) *LPS*, *46*, 2969. [2] El Goresy A. and Chao E.C.T. (1976) *Earth Planet. Sci. Lett.*, *30*, 200-208. [3] Kogarko L. N. and Ryabchikov I. D. (2013) *Petrologiya*, *21*, No. 4, 350–371.