THE CRETACEOUS-TERTIARY BOUNDARY IMPACT EJECTA AT BLAKE NOSE (ODP LEG 171B) AS RECORD OF THE CHICXULUB IMPACT. F. Martinez-Ruiz[1]; M. Ortega-Huertas[2]; I. Palomo[2] and J. Smit[3], [1]Instituto Andaluz de Ciencias de la Tierra (CSIC-UGR). Facultad de Ciencias. Campus Fuentenueva. 18002 Granada, Spain, e-mail:fmruiz@goliat.ugr.es; [2]Departamento de Mineralogia y Petrologia. Facultad de Ciencias. campus Fuentenueva. 18002 Granada, Spain, e-mail: mortega@goliat.ugr.es; [2]Department of Sedimentary Geology, Vrije Universiteit, 1081HV Amsterdam, Netherlands, e-mail: smit@geo.vu.nl.

Introduction: The ODP Leg 171B recovered an excellent Cretaceous-Tertiary (K/T) boundary interval in ODP Site 1049. This site is located on the eastern margin of Blake Nose (NW Atlantic) at a present depth of 2671 m below sea level. The K/T boundary sediments were recovered from three adjacent holes: 1049A (30°08.5436'N, 76°06.7312'W), 1049B (30°08.5423'N, 76°06.7264'W) and 1049C (30°08.5370'N, 76°06.7271'W). A single 17-, 7- and 9-cm thick bed of green spherules, capped by a red layer, is respectively marking the K/T boundary at the three holes. This bed occurs at the biostratigraphic boundary between the Cretaceous and the Paleocene. It sharply overlies slumped uppermost-Cretaceous foraminiferal-nannofossil ooze and is overlain by Tertiary clay-rich ooze with planktonic foraminiferal assemblages indicative of Early Danian Foraminiferal Zone P-alpha [1]. The variable thickness of the spherule bed at the three holes drilled suggests reworking of the ejecta material down slope. The green spherules are nonetheless a record of the Chicxulub impact-generated material.

Samples and methods: The spherule bed and sediments above and below were taken in continuous sampling every 2 cm. Spherules were hand-picked under a stereomicroscope. Bulk samples and representative hand-picked spherules were subjected to mineralogical and geochemical analyses using X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) for mineralogical analyses. Quantitative microanalyses of clay minerals were obtained by transmission electron microscopy in scanning TEM mode only from edge particles using a 70 Å diameter beam and 200x1000 Å scanning area and a short counting time to avoid alkali loss [2]. Atomic Absorption (AA) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) were used for geochemical analyses.

Results: The spherule bed at Blake Nose consists of a coarse and poorly cemented unit. Mineralogical analyses reveal it is mostly composed of clays and minor proportions of carbonates, mainly derived from the presence of Cretaceous clasts within the spherule bed. Other minerals also present in lower proportions are quartz, zeolites and minor amounts of rutile, biotite and some lithic fragments. Clays are mostly smectites since spherules are diagenetically altered to smectite. Sediments above and below the spherule bed are mostly composed of calcite, clays and minor amounts of quartz. Clay mineral assemblages in Cretaceous and Tertiary sediments are mostly composed of smectite and lower proportions of illite and kaolinite. The contact of the spherule bed with sediments above and below is very sharp. The contact surface of the Cretaceous sediments contains some spherical impressions that seem to be bubbles or deformations by deposition of spherules in soft sediments. Cretaceous sediments are slump-folded, however, the overlying stratigraphy is undisturbed. Deformation of Cretaceous sediments is a general feature at proximal ejecta sites. Deformation and large-scale slope failures were related to the seismic energy input from Chicxulub impact [3].

SEM observations revealed that the morphologies of the Blake Nose spherules are tektite-like and they mainly correspond to perfect spheres (Fig. 1) and lesser proportions of oval spherules. Size usually ranges from 100 µm to 1000 µm. Some hollow spherules and spherical voids are filled with smaller spherules that may represent diagenetic infills of original bubbles. The surface of the spherules is nodular, smooth or rough and color is dark-green pale-yellow or light-green. The XRD scans on oriented samples revealed that spherules are mainly composed of smectite, and TEM microanalyses revealed that the smectite corresponds to a dioctahedral type. Some compositional variations were observed between dark green spherules and pale yellow spherules. Dark green spherules are richer in Fe and pale yellow ones are richer in Ca. TEM microanalyses on pale yellow spherules also revealed that they contain a very rich-Ca matrix altering to smectite, and some calcite crystals are observed in this matrix.

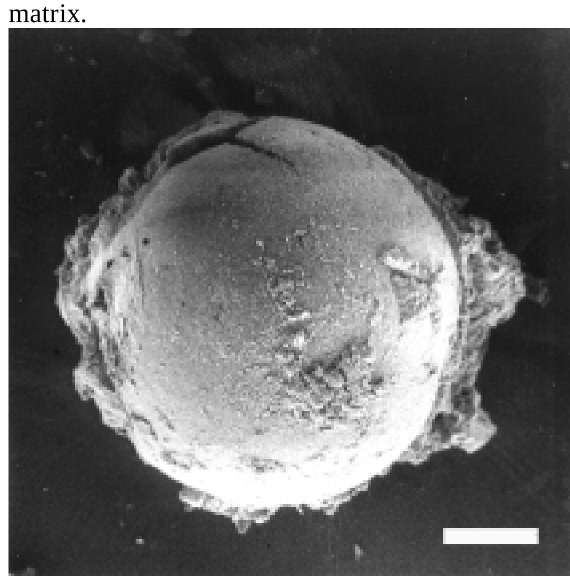

Figure 1. SEM photograph showing one example of smectite spherules from Blake Nose (ODP Leg 171B). Scale bar = 200 µm.

This suggests that Ca-rich material could have been the precursor. Such observations on dark-green spherules revealed instead very high silica areas that do not correspond to a real smectite composition, suggesting Si-rich glass could have been the precursor in this type of spherules and that smectite directly replaced the original precursor [4].

The data from chemical analyses performed on samples from the K/T boundary interval at Blake Nose revealed that the boundary bed is depleted in Ca, as can be expected from the decrease in biogenic calcite. Fe and Mn profiles from the K/T boundary interval are mainly governed by diagenetic remobilization. The top of the spherule bed (the red layer) is marked by a significant Fe increase, and Mn also increase just above the red layer, while lower Fe and Mn concentrations are present within the spherule bed, these peaks indicate diagenetic remobilization of both elements. The Ir concentration is very low at Blake Nose [5] reaching the highest concentration above the spherule bed. Regarding other possible extraterrestrial elements, Cr, Co and Ni also present low concentrations at Blake Nose [6]. Cr decreases considerably in the spherule bed, which points to the absence of a significant extraterrestrial Cr contribution. Although Co and Ni concentrations are not as high as in distal sections, both elements are enriched in the upper part of the spherule bed, suggesting a possible extraterrestrial contamination. Nevertheless, no clear evidence for significant extraterrestrial contribution is observed at Blake Nose, suggesting that the spherule bed material mainly originated from the alteration of target rock derived-material. REE C1-normalized patterns also suggest that spherule bed material derive from upper crustal rocks.

Discussion and conclusion: The K/T material from Blake Nose derives from the fallout of the material generated by the Chicxulub impact. The spherules from Blake Nose are similar to spherules from different locations on the North America Atlantic margin, such as Bass River [7] and DSDP 603B [8], and all of them represent the same diagenetically altered impact ejecta. Spherules from the El Mimbral and La Lajilla sections in Mexico are also similar but often contain a preserved impact glass core [9, 10]. In Haiti, exposures of the ejecta deposits also reveal spherules are not completely altered, consisting of impact glasses and glass spherules. Two types of glass have been recognized at Haitian sections: black andesitic glass and honey color CaO-rich glass [11, 12]. At Blake Nose, the original material has been altered to smectite, however, compositional differences in the analyzed spherules suggest that they may derive from different precursor glass types. Mineralogical and geochemical evidence indicate that the smectites derive from the alteration of Si-rich and Ca-rich materials. In fact, the precursor of the Blake Nose spherules could have been compositionally similar to those impact glasses reported at Haitian sections. The geochemical composition of the boundary bed support that the impact-generated material mainly derived from melted target rocks. As occurs for tektites or impact-generated material derived from the inner ejecta, Ir and other extraterrestrial elements show lower concentrations than at distal locations. Only Ni and Co have higher concentrations within the upper part of the spherule bed, however, these concentrations are not high enough to support significant extraterrestrial contribution. On the other hand, original concentrations have been severely modified after deposition. Low Eh conditions led to trace-element remobilization. Fe and Mn mobilized, diffusing upward and precipitating upon encountering the oxygenated pore waters required for their precipitation. As different oxygen conditions are required for precipitation of these elements, they became decoupled showing peaks at different depths. Major chemical changes also accompanied the diagenetic alteration of glass to smectite. REE, and possibly other associated elements, where significantly depleted during this alteration. Eh and alteration of glass are therefore the main factor controlling the geochemical profiles across the K/T boundary at Blake.

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