A GIANT TSUNAMI DEPOSIT AT CRETACEOUS-TERTIARY BOUNDARY IN CUBA. R. Tada[1], H. Takayama[1], T. Matsui[1], M. Iturralde Vinent[2], E. Tajika[1], T. Oji[1], S. Kiyokawa[3], D. Garcia[4], H. Okada[5], K. Toyoda[6], T. Hasagawa[7], [1] Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan, [2] Museo Nacional de Historia Natural, Obispo no. 61, Plaza de Armas, La Habana 10 100, Cuba, [3] National Science Museum, Department of Geology, 3-23-1 Hyakuninn-cho, Shinjuku-ku, Tokyo 169-0073, Japan, [4] Instituto de Geologia y Paleontologia Via Blanca y Linea del Ferrocarril San Miguel del Padron, La Habana 11 000, Cuba, [5] Department of Earth and Planetary Sciences, Hokkaido University, N10 W8, Sapporo 060-0810, Japan, [6] Graduate School of Environmental Earth Science, Hokkaido University, N17 W8, Sapporo 060-0810, Japan, [7] Department of Earth Sciences, Faculty of Science, Kanazawa University, Kakuma-machi, Kanazawa 920-1192, Japan.

Introduction: A giant tsunami is one of the probable consequences of the impact, and possible tsunami deposits have been reported at the K/T boundary (KTB) from around the margins of the Gulf of Mexico [1, 2]. However, their origin is still controversial, and an alternate impact shock-induced megaturbidite origin has been advocated [3]. One of the arguments against a tsunami origin is the lack of "homogenite", a thick, normal graded, structureless deposit formed by tsunami in deep sea environment [4, 5].

Cretaceous to early Tertiary deposits were widely distributed on Cuba and the presence of a giant KTB event deposit was proposed based on presence of upper Maastrichtian coarse clastic rocks with thickness in excess of 400 m [6]. However, no convincing evidence is found on its relation to the impact, and its depositional mechanism has not been investigated in detail.

Geological Setting: Cuba is formed by several different terranes including the Cretaceous Cuban Arc and Southern Terranes detached from the southeastern margin of Yucatan Peninsula, which were accreted to the southern margin of Bahamas platform during the early Tertiary [7]. At the time of KTB impact, the Cretaceous Cuban Arc was probably located approximately 500 km to the south of its present position [8], and a deep oceanic basin existed between the Bahamas platform and the Cretaceous Cuban Arc. The Peñalver Formation was deposited on the northern slope of the Cretaceous Cuban Arc. The formation disconformably overlies the Campanian to uppermost Maastrichtian Via Blanca Formation whose depositional paleodepth is estimated at 600 to 2000 m [9]. The formation is conformably overlain by the Danian to Thanetian formations [7].

Lithology of the Peñalver Formation: The Peñalver Formation is divided into two lithological units. The lower unit overlies the Via Blanca Formation with an irregular erosional surface and consists of 25 m thick granular bioclastic calcirudite with large intraclasts from the Via Blanca Formation. The bioclastic calcirudite is poorly-sorted, homogeneous with grain-supported fabric, and dominantly composed of fragments of shallow water macrofossils as well as shallow water limestone probably derived from the carbonate platform on the Cretaceous Cuban Arc. Size grading is not obvious throughout the unit.

The upper unit is more than 155 m thick and is subdivided into subunits A and B in ascending order. Subunit A is composed of a coarse- to fine-grained, normally graded calcarenite with frequent intercalations of thin conglomerate layers in its lower part. A few large mudstone intraclasts also occur in the lower part. The middle part is massive with abundant large-scale water-escape structures, whereas the upper part is faintly thick-bedded with very rare water-escape structures. Fragments of shallow-water macrofossils drastically decrease in the basal part, and they are absent in the middle and upper parts. The middle and upper parts are characterized by significant increase in planktonic foraminifers, decrease in benthic foraminifers, and dominance of serpentine fragments (within non-calcareous fraction). The grain composition of subunit A is distinctly different from the lower unit, suggesting that the source of the two units are different. Bioturbation is absent throughout subunit A. Subunit B is composed of massive, homogeneous calcilutite without bioturbation. The calcilutite is composed of coarse silt grains including planktonic foraminiferal skeletons and fine silt- to clay-size calcareous matrix with nannofossils. The abundance of serpentine fragments decreases drastically in this subunit.

The upper unit shows a single normal size-grading with upward increase in sorting. More importantly, the grain size distribution shows a rapid upward decrease in the coarsest grain-size components and a consequent increase in skewness. This is known as coarse-tail grading suggestive of settling from a dense sediment cloud [10].

Relation with the K/T Boundary Impact: Macro- and microfossil assemblages in the Peñalver Formation are examined to constrain the timing of deposition, confirm reworking, and specify the source of the reworked materials. The lower unit contains only shallow water macrofossils derived from carbonate platform of the Cretaceous Cuban Arc. The upper unit, on the other hand, contains abundant microfossils. Various species of planktonic foraminifers and nannofossils with different diagnostic ages are found from the upper unit, whereas no Tertiary species are found. Dominance and the assemblage of Campanian to late Maastrichtian species suggest that the upper unit is mostly composed of the materials reworked from the underlying Via Blanca Formation. The occurrence of the nannofossil *Micula prinsii* within a large intraclast in the lower unit suggests that the age of the Peñalver Formation is younger than the latest Maastrichtian (<65.4 Ma), whereas the absence of Tertiary microfossils throughout the formation suggests the age older than the earliest Danian (> 65.0 Ma). Thus, the age of the Peñalver Formation is tightly constrained between 65.4 and 65.0 Ma.

Examination of thin sections revealed that altered vesicular glass of up to 2 mm in diameter, now replaced by heulandite, smectite and calcite, are present in small amount in the lower unit. Their concentration is highest near the bottom of the unit, decreases upward, and disappears near the top of the unit. These vesicular glass grains are similar in texture and size to those described from probable KTB deposits in Belize [11]. Glass spherule is almost absent.

We also examined >60 µm acid-insoluble residue, and found small amount of shocked quartz from the upper unit but it is absent in the lower unit. Concentration of shocked quartz in the Peñalver Formation is very low because of dilution by resuspended sediments. However, the flux of >60 µm shocked quartz to the Peñalver Formation amounts to 15000~20000 grains/cm^2, which is slightly larger than the flux estimated at Beloc [12]. The combination of its tight stratigraphic age constraint, and presence of altered vesicular glass and shocked quartz strongly suggest the KTB impact origin of the Peñalver Formation.

Depositional Mechanisms: Significant basal erosion, granule-size poorly-sorted grains with grain-supported fabric, homogeneous lithology without size grading, common occurrence of large intraclasts, and abundant bioclasts from shallow platform together suggest a grain flow origin of the lower unit. The probable source for these sediments is the carbonate platform on the Cretaceous Cuban Arc. On the other hand, single normal coarse-tail grading, abundant water escape structures, and the lack of sedimentary structures indicative of current influence in the calcarenite of the upper unit suggest rapid deposition from dense sediment suspension [10]. Finer grain sizes, homogeneous appearance without bioturbation, and mixed microfossil assemblages probably reworked from the underlying Via Blanca Formation within the calcilutite of the upper unit suggest late stage deposition from the suspension. These characteristics of the upper unit are consistent with those of homogenite[5]. Thus, the upper unit is interpreted as a giant homogenite [13]. Thin conglomerate layers intercalated in the basal part of the upper unit, whose characteristics are similar to those of a storm-wave induced deposits [14], could represent down-slope transported materials eroded by repeated tsunamis that hit the carbonate platform on the Cretaceous Cuban Arc.

Discussion and Summary: It is demonstrated that the Peñalver Formation is the KTB deposit formed by grain flow and subsequent tsunamis. It is possible that the grain flow was triggered either by the impact-generated seismic wave or by the tsunami wave generated by the impact. Alternatively, the tsunami could have been induced by the grain flow. However, the distinctly different grain composition between the lower and upper units suggests different source. Namely, shallow platform of the Cretaceous Cuban Arc for the grain flow and deeper slope sediments for the homogenite. This may further suggests that homogenite of the upper unit does not have genetic relation with the grain flow deposit of the lower unit. If true, it is most likely that the grain flow was triggered by the impact-generated seismic wave within a few minutes after the impact, whereas the homogenite was formed by the subsequent tsunamis generated by the KTB impact and reached the site after the grain flow deposit was emplaced.

References: [1] Bourgeoris, J. et al. (1988) *Science*, *241*, 567-570. [2] Smit, J. et al. (1992) *Geology*, *20*, 99-103. [3] Smit, J. et al. (1996) *GSA Spec. Pap., 307*, 151-182. [4] Bohor, B.F. (1996) *GSA Spec. Pap., 307*, 183-195. [5] Kastens, K.A. and Cita, M.B. (1981) *GSA Bull.,92*, 845-857. [6] Pszczolkowski, A. (1986) *Bull. Pol. Acad. Sci., Earth Sci., 34*, 81-93. [7] Bralower, T.J. and Iturralde-Vinent, M.A. (1997) *Palaios*, *12*, 133-150. [8] Rosencrantz, E. (1990) *Tectonics*, *9*, 1037-1059. [9] Brönnimann, P. and Rigassi, D. (1963) *Eclogae Geol. Helv.*, *56*, 193-480. [10] Allen, J.R.L. (1982) *Sedimentary Structures, Their Character and Physical Basis, vol. II*. Amsterdam, Elsevier, 643 p. [11] Ocampo, A.C. et al. (1996) *GSA Spec. Pap.*, 307, 75-88. [12] Leroux, H. et al. (1995) *EPSL*, *131*, 255-268. [13] Takayama, H. et al. (2000) *Sed. Geol.*, (in press). [14] Einsele, G. and Seilacher, A. (1991) *in* Einsele, G. et al. eds., *Cycles and Events in Stratigraphy, Berlin, Springer-Verlag,* 377-382.