NEW IMPACT EVOLUTION MODEL MODEL OF FORMATION PROCESS AT THE END OF THE CRETACEOUS PERIOD. Y. Miura, S. Fukuyama, H. Kobayashi, and A. Gucsik, Department of Chemistry and Earth Sciences, Faculty of Science, Yamaguchi University, Yoshida, Yamaguchi 753-8512, Japan (dfb30@po.cc.yamaguchi-u.ac.jp).

Introduction: From Alvarez et al. (1980) [1] report, main origin of Cretaceous-Tertiary (K/T) geological boundary on the Earth is considered to be formed by iron meteorite with ~10 km in size hit to the Earth. Main reason of iron meteorite hit on K/T boundary is anomalous amount of Ir content, many shocked materials of shocked quartz, tektites, microtektites, stishovite, Ni-rich spinels and platinum-group elements (PGE) found at the K/T boundaries in the world by many researchers [1,2]. But they cannot find definite impact crater on the continental lands. But buried large impact crater was found Chicxulub impact crater, Yucatan Peninsula, Mexico, as origin of meteorite hit on the K/T boundary [2]. Such anomalous distributions and peaks of shocked materials and spherules before and after the K/T boundaries are difficult to explain only by a single impact so well [3,4,5,6]. The main purpose of this study is to elucidate new impact model of the K/T boundary [7].

Anomalous Data Around the K/T Geological Boundary: There are anomalous data before and after the K/T boundary which cannot explain only one simple imapct as asteroid with 10 km in size as follows [1–9]:

(1) Ir anomaly. The largest amount of Ir concentration is within the K/T boundary clay. But small spikes of high Ir amounts before just K/T boundary are reported, whereas some reports reveal that there are five peaks of high Ir amounts before and after the K/T boundary where one highest peak is within the K/T boundary clay.

(2) Shocked quartz. Anomalous shocked quartz can be found before and after the K/T boundary. The largest amount of shocked quartz can be found within the K/T boundary. Small spikes of shocked quartz amount before the K/T boundary are obtained on amount of shocked quartz. Density of shocked quartz is also changing before and within the K/T boundary.

(3) Impact crater. There are various impact craters before and after the K/T boundary:

(a) Quarkziz crater. Algeria (<70 Ma; c~3.5 km in diameter)

(b) Chukcha crater. Russia (<70 Ma; ~6 km)

(c) Tin Bider crater. Algeria (<70 Ma; ~6 km)

(d) Chicxulub crater. Yucatan, Mexico (64.98 Ma; ~170 km in diameter)

(e) Eagle Butte crater. Alberta, Canada (<65 Ma; ~10 km)

(f) Upheaval Dome crater. Utah, USA (<65 Ma; ~10 km)

(g) Beyenchime-Salaatin crater. Russia (<65 Ma; ~8 km)

Impact Varieties: The following varieties of spherules are significant data of detailed process of impact at the K/T boundary [7,9]:

(1) Spherules found a northern hemisphere are increased gradually before the K/T boundary (ca. 5 Ma). This means that the ring orbit withi minor fragments is mainly located on the northern hemisphere to make small impact craters before the K/T boundary.

(2) Gradual increase of spherules after the K/T boundary at southern hemisphere was found at the lowermost Paleocene (Danian) which is considered to be formed by Tsunami movement from Yucatan, Mexico [8]. This detailed process of impact materials can be also interpreted as different effects by many crashed fragment at K/T event (Table 1). These impact craters can be well explained by many impact projectiles from the different small objects.

(4) Spherules. Spherules gradually increase amount before the K/T boundary [8]. Anomalous amounts of spherules can be found within the K/T boundary clay. Composition of spherule rejected by the impacts mainly Fe-Si system as metallic and glassy spherules [3,8,9].

(5) Calcite. Physical properties (cell volume, density and ESR defect signals) of calcite minerals are changed before, within and after K/T boundary clay [3,7].

Impacts of Ring Fragments Around the Earth: Based on the above-mentioned anomalous impact data of Ir anomaly, shocked quartz and calcite, spherules and impact craters, the following new model of impacts is proposed [7] (Table 1):

(1) Single Fe-rich asteroid of ~10 to 15 km in size are close to the Earth before ca. 70 Ma. Progressive iron meteoroids by different projectiles from the asteroid belt are difficult to postulate as the crash fragmented comet Shoemaker-Levy 9 on the Jupiter.

(2) The asteroid breaks into many crash fragments, mainly by head-on collision crossing the Earth orbit around the Sun, and together with gravity of the Earth.

(3) There fragments which consist of several small masses with several hundred meters in size and large mass with ~8 to 10 km in size. The Fe-rich meteoroid is considered to be broken to many pieces from edge of the large body because it can explain many small impact craters before the K/T boundary. If there are big impacts on the ocean the similar event of the just K/T boundary should be founded. Total fragments of crash reveal ring formation around the Earth at the end of the Cretaceous period.

(4) Lighter fragments of crashed fragments hit to the Earth to make impact craters within ~6 km size on the lands and sea before the K/T boundary. This can be found as impact craters, density change of shocked quartz and calcite, Ir amounts and spherules at the end of the Cretaceous period.

(5) Largest fragment with ~8 to 10 km in size finally hits to shallow water of present Yucatan Peninsula, Mexico, to produce large K/T event which looks like single impact of asteroid. Large impact on the ocean makes pro-

gressive activities on the Earth including mass extinction after impact.

(6) Spherules of direct impact ejecta found before the K/T event are increased against just K/T boundary from final big collision.

Comparison with P/T Boundary: Spherules are found also at Permian Triassic (P/T) boundary at many localities including Hungary [9]. Multi-step impacts model from terrestrial ring at the K/T event [7] cannot be applied to the P/T boundary, whereas single shapr impact to deep sea ocean can be applied to explain anomalus spherules and terrestrial activity.

Conclusions: The following results can be summarized as follows:

(1) From the previous anomalous impact data of Ir and PGE anomalies, shocked quartz, spherules and Ni-rich minerals, progressive impacts are started before the K/T boundary.

(2) Small impacts by ring fragment from single large asteroid rotated around the Earth was started ca. 5 million years before just K/T boundary (65 million years ago). Progressive small impacts with small fragments are found after K/T boundary.

(3) These multiple impacts are explained by terrestrial rings fragments from one large asteroid.

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References: [1] Alvarez W. L. et al. (1980 *Sci. Am, 263*, 78–84. [2] Hildebrand, A. R. et al. (1991) *Geology, 19*, 867–871. [3] Miura Y. et al. (1985) *ESR Dating and Dosimetry (Japan), 1*, 469–476. [4] Miura Y. (1989) *Meteoritics, 24*, 305; *25*, 387. [5] Miura Y. (1991) *Shock Waves, 1*, 35–41. [6] Miura Y. et al. (1992) *Meteoritics, 27*, 261. [7] Miura Y. et al. (1997) *Proc. ISAS LPS (Sagimihara, Japan), 30* (in press). [8] Albertao G. A. et al. (1994) *Terra Nova, 6(4)*, 366–375. [9] Detre C. et al. (1997) *LPSC XXVIII*, 297–298.

TABLE 1. Proposed impact model at the K/T event [7].

Age (Ma)	Event	Evidence
(1) < ca. 70	Fe-rich asteroid (single)	Fe-rich impact materials
(2) < ca. 70	Breaking to fragments	Many impact craters before K/T boundary
		Impact materials before K/T boundary
(3) 65	Large mass hit to Mexico	Chicxulub buried crater
(4) < ca. 65	Small fragments to hit	Small impact craters after K/T boundary