THE COSMIC CLOCK, THE CYCLE OF TERRESTRIAL MASS EXTINCTIONS. J. A. Marusek, *IMPACT*, (RR 6, Box 442, Bloomfield, IN 47424 e-mail: tunga@custom.net or james.marusek@navy.mil)

Introduction: Over the past 500 million years, great terrestrial cataclysms forced global mass extinctions. A detailed study of postulated extinction mechanisms has lead to insight on both timing and cause. Two primary mechanisms, Oort cloud comet impacts and nearby supernova events, are believed responsible. A dual cycle of extinctions is observed and well ordered in geological time. Both mechanisms are synchronized to the passage of the solar system through the spiral arms of the Milky Way galaxy.

Extinction Mechanism – Deep Impacts: The theory that a 10- to 15-kilometer diameter asteroid/ comet impacted Mexico 65 million years ago bringing the Cretaceous period, the age of the dinosaurs, to an abrupt end has been generally accepted. The destructive force from an asteroid or comet impact has been likened to a comparably-sized nuclear explosion without the radioactive fallout effects. When analyzed in this manner, an impact mortality study showed the resulting damage is too localized to adequately explain the global nature of the end-Cretaceous extinction. This size impact would release ~100 million megatons TNT equivalent energy and produce only a regional zone of devastation (blast wave 3-psi peak overpressure) within 3,800 kilometers from the impact point. Several postulated effects, such as global firestorm, ejecta debris-induced impact winter, and mega-tsunami with deep landmass penetration are not supported [1].

These unexpected results led to a reevaluation of the impact hypothesis. The estimate of impactor size was derived from equations comparing impactor crater size to that of a comparable nuclear <u>surface</u> burst. But if the impactor was larger, such as a long period comet (LPC), it would have sufficient energy to penetrate the Earth's crust (especially an ocean impact where the crust is thin) and this assumption would begin to fall apart. Deep impacts produce smaller craters because most of the energy is released within the interior of the planet. The impact energy can be thought of as the sum of the energy released at the surface and the energy released deep within the Earth's mantle. The surface component can be approximated to the blast and thermal radiation effects from a comparably-sized nuclear explosion. The effects of the impact energy released in the mantle are obscure and are only observable in massive flood basalt eruptions, the creation of a deep magma hot spot, kimberlite pipes and interior structure anomalies, such as magnetic pole reversals.

This analysis was expanded to the end-Permian extinction, which shared distinct similarities with the end-Cretaceous. In both extinctions, massive volcanic flood basalt eruptions took place and a significant drawdown of oxygen levels in the atmosphere and oceans occurred. From this study, a hypothesis took shape describing a cluster of comet impacts over a short geological timeframe (5-8 million years) as the cause of the end-Permian extinction. Several impacts were of sufficient size to rupture through the Earth's crust, producing deep impact effects. The impacts focused shock destruction on the opposite side of the Earth creating fractures at continent/ocean seams. The resulting Emeishan & Siberian Traps generated prolonged periods of surface flood basalt eruptions inducing extensive acid rainfall. Acidification targeted evolutionary weaknesses within marine and terrestrial life forms, culminating in a massive die-off at the end of the Permian Period [2].

In summary, one mechanism capable of producing a global extinction event is deep impact from a LPC. It is theorized these massive, high velocity comets can drive through the Earth's crust and deep into the Earth's interior producing episodes of massive flood basalt eruptions on the other side of the globe.

Extinction Mechanism – Supernovae: Galactic cosmic rays (GCR) are high-energy charged particles that originate outside our solar system. GCR flux has been linked to climate variability [3]. GCRs interact with the Earth's atmosphere through nuclear collisions producing a cascade of protons, neutrons & muons, which can penetrate through the stratosphere and troposphere [4]. Ionization in the lower atmosphere (below 35 km) is almost exclusively produced by GCRs, except for the lowest 1 km over land where radioactive gases are the main cause of ionization [5, 6, 7]. Minor variations in GCR signal is amplified into significant climate forcing through ion-induced cloud condensation nuclei (CCN) production. Ions created by GCRs rapidly interact with molecules in the atmosphere and convert to complex cluster ions (aerosols) acting as CCN at typical atmospheric supersaturations of a few percent [8]. Experiments with charged raindrops have shown that they are 10-100 times more efficient in capturing aerosols than uncharged drops [9]. Clouds are of considerable importance for the Earth's radiation budget. Low optically thick clouds increase albedo, which drives global cooling. A 1% increase in GCR flux is responsible for a ~0.14^{o}K drop in global temperature [10]. Increased GCR flux increases low clouds (especially over the tropics), increases planetary albedo, decreases global temperature and increases the strength of the stratospheric polar vortex [11].

The spiral arms are a catalyst for new short-lived

Table 1. Terrestrial Cataclysms

Predicted Extinction Event Time (My BP)	**Actual Extinction Timing** [1] (My BP)	**Extinction Agent**	**Extinction Boundary**	**Observed Deep Impact Effect: Flood Basalt Eruptions** **[Impact Crater]**	**Observed Supernova Effect: Ice Ages Epochs**
0	~ 0.01	Supernovae	End-Pleistocene[2]		Pleistocene Great Ice Age
65	65	Deep Impact	End-Cretaceous	Deccan Traps [Chixculub Crater]	
145	145	Supernovae	End-Jurassic		Jurassic/Cretaceous Ice House Period [3]
210	213	Deep Impact	End-Triassic	Newark Supergroup/Central Atlantic Magmatic Province (CAMP) [Manicouagan Crater]	
290	286	Supernovae	End Carboniferous		Carboniferous/Permian Great Ice Age [3]
355	360	Deep Impact	End-Devonian	Late Devonian Hot Fields of Baltica & Siberia [Siljan & Woodleigh Craters]	
435	440	Supernovae	End- Ordovician		Ordovician/Silurian Great Ice Age [3]
500	505	Deep Impact	End-Botomian	Antrim Plateau Volcanics (Australia)	

1. Reference: "The Geologic Time Scale", U.S. Geological Survey at http:geology.er.usgs.gov/paleo/geotime.shtml
2. Massive extinctions occurred at the end of the Pleistocene. Most of these are associated with the larger megafauna. The following disappeared from America, Europe and Australia: All herbivores > 1000 kg, 75% of herbivores 100-1000 kg, 41% of herbivores 5-100 kg, < 2% of herbivores < 5 kg.
3. According to Fabeur et al., the midpoint of the "ice house" periods occurred at 144 My before present (BP), 293 My BP and 440 My BP [13].

spectral type O or B star creation. GCRs are produced when a star exhausts its nuclear fuel and explodes into a supernova. It is theorized that nearby supernovae can inject bursts of GCRs towards Earth which expands low cloud cover, reduces global temperatures, and forces Earth into an ice age epoch (IAE).

Extinction Clock: By studying the location and kinematics of the Galactic spiral arm structure, Leitch & Vasisht provided evidence linking the arm crossing to deep impact mass extinctions. During arm crossing, tidal and collisional encounters with gas and dust clouds perturbed the Oort cloud injecting comets into the inner solar system [12]. This extinction pattern is timed to the ~145 million years (My) cycle of spiral arm crossing.

Shaviv provided evidence of another extinction agent, one caused by nearby supernovae, which are manifested as ice age epochs [10]. This cycle is also synchronized to spiral arm crossings, which triggers star formation, but lags behind by ~ 65 My accounting for the life cycle of O & B stars, solar system orbital dynamics and galactic magnetic field effects.

This dual cycle of mass extinctions (one from deep impacts and the other from supernovae) is defined in Table 1. The predicted 65My/80My extinction cycle is shown and matches very well with actual extinction timing and extinction agent effects.

The end-Permian, the largest terrestrial extinction, is outside this well-defined cycle. The cause appears related to deep impacts from a massive inrush of LPCs as evidenced by the Emeishen & Siberian Traps [2]. One possible explanation of this extinction is the interaction of the Milky Way galaxy with the Large Megellanic Cloud (LMC). A prominent peak in star formation rates within both the Milky Way and the LMC occurred ~ 300 My ago. This peak correlates with the perigalacticon passage of the LMC [10]. Tidal forces during the perigalacticon may have caused a large disruption of the Oort cloud driving the extinction.

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