1 **Introduction to Environmental Geology, 5e**
Chapter 12
Impact of Extraterrestrial Objects

2 **summary in haiku form**
come from outer space
they're extraterrestrial
making "astroblemes"

3 **Case History: The Tunguska Event**
- On June 30, 1908, blue-white fireball exploded over Tunguska River Valley
- The blasting force equivalent of 10 megatons of TNT, 10 H-bombs
- 2,000 km^2 of forest to be flattened and burned
- At least 1,000,000 km^2 heard the explosion
- Estimated size of the asteroid 20 to 50 m in diameter
- Loss of lives in millions if it had occurred in major cities
- Narrowly missed a similar hit in 2004 *(and 2013!)* and could happen again

4 **Case History: The Tunguska Event**
Figure 12.1

5 **Earth's Place in Space**
- Only planet in the solar system is believed to host life
- Planet filled with and modified by life
- Periodic drama caused by continued impact of material from outer space: Asteroids, meteoroids, and comets
- Meteoroids and asteroids from the asteroid belt between the orbits of Mars and Jupiter, whereas comets from the Kuiper belt or Oort Cloud

6 **Asteroids**
- Size: Ranging from 10 m (32 ft) to 1000 km (621 mi)
- Composed of rocky or metallic material, or rock–metal mixtures
- Most of them in asteroid belt between Mars and Jupiter
- Some off of their orbits and entering Earth's orbit due to collision of asteroids

7 **Meteoroids**
- Origin: Small, fragmented space particles from disintegration of asteroids
- Size: Ranging from dust-size to a few meters
- Meteor: Burning meteoroids due to frictional heat from their entrance to Earth's atmosphere
- Meteor shower: A large number of meteors

8 **Comets**
- Origin: Originated from the Oort Cloud, deep in the solar system, about 50,000 times the distance between Earth and the Sun
- Size: Ranging from a few meters to a few hundred kilometers

- Composition: A rocky core and surrounded by ice and covered by carbon-rich dust
-
- Orbit: Intersects Earth's orbit sometimes

9 **Solar System**

Figure 12.3

10 **Early Evolution of Earth**

- Bombarded by meteoroids, asteroids, or comets (MACs)
-
- The formation and makeup of Earth contributed by the impact of the MACs
-
- Earth's evolution greatly affected by the impacts—both destruction and construction effects

11 **Aerial Bursts and Impacts**

- MACs traveling at high speed 26,000 to 156,000 mile/hr
-
- Undergo remarkable changes when entering Earth's atmosphere: aerial burst or collide with Earth
-
- Aerial bursts: As the meteoroid entered in the atmosphere at about 85 kilometers (53 miles) above Earth's surface, became a meteor, emit light, and disintegrated in the air
-
- Cause direct impacts on collision with Earth

12 **Aerial Bursts and Impacts**

Figure 12.5

13 **Impact Craters (1)**

- The most direct and obvious evidence of extraterrestrial impacts
-
- 50,000-year-old Barringer Crater in Arizona: The most famous meteor crater in the United States
-
- 1.2 km (.75 mi) in diameter and 590 ft in depth, bowl-shaped depression with upraised ejection rim (850 ft)
-
- Resulted from the impact of a small asteroid, 25 to 100 m in diameter

14 **Impact Craters (2)**

Figure 12.6a

15 **Impact Craters (3)**

- Craters involved with extremely high temperature, velocity, and pressure; different from craters from other terrestrial geologic processes
-
- Shocking metamorphism: Forming high-pressure modified minerals such as quartz or materials of mixing partial melting rocks and impacting objects
-
- Other associated processes: Vaporization, melting, and ejection of materials

16 **Impact Craters (4)**

Happened before and likely to happen again

- Barringer Crater and others on Earth
- Remotely studied craters on the Moon and Mars
- Impact on Jupiter
  - Comet Shoemaker-Levy 9 orbited Jupiter and became 21 fragments
  - In 1994, the family of fragmented "string of pearls" entered Jupiter's atmosphere and exploded

- Energy released: Greater than that of the entire stockpile of nuclear weapons on Earth

17 **Impact Craters (5)**

Figure 12.10

18 **Mass Extinction (1)**

- Massive and sudden loss of plants and animals relative to the number of new species being added
-
- Several hypotheses suggested: Rapid climate change, plate tectonics, extremely large volcanic events, and impacts of extraterrestrial objects
-
- Six major mass extinctions during the last 540 million years: Near the end of Ordovician (443 mya), Devonian (350 mya), Permian (245 mya), Cretaceous (K-T boundary), Eocene (35 mya), and near the end of Pleistocene (2 mya to present)

19 **Mass Extinction (2)**

- Earliest: ~ 443 mya, near end of the Ordovician period, extinction of 100 families and associated species, related to global cooling
-
- Second: 350 mya, near the end of Devonian, death of 70 percent of all marine invertebrates, probably related to climate change and global cooling
-
- Third: 245 mya, the end of Permian
  - 95 percent of all marine species
  - Possibly caused by more than a single catastrophe
  - Likely spanned for a 7 million-year period

20 **Mass Extinction (3)**

Fourth: around the K-T boundary, 65 mya

- Abundant evidence to suggest that it was caused by the impact of a giant asteroid (diameter of 10 km) in the vicinity of the Yucatan Peninsula
- Extinction of about 70 percent of all genera, such as dominant species of dinosaurs
- The K-T boundary was a very thin layer of clay, Fossils found in rocks below the clay were not in rocks above the clay
- Setting stage for the evolution of mammals, including humans

21 **Mass Extinction (4)**

- Fifth: Mass extinction
  - Near the end of Eocene, 35 mya
  - Likely resulted from cooling and glaciation
  -
- Sixth: Near the end of Pleistocene to present
  - Ongoing mass extinction of mammals, reptiles, amphibians, birds, fish, and plants
  - Overhunting by Stone Age men may have been a partial cause of this event
  - Extraterrestrial impact 12,900 years ago

22 **Extraterrestrial Impact 12,900 years ago?**

- North America was ecologically different 13,000 years ago
- Populated by Pleistocene megafauna that included mammoths, dire wolves, American lions, short-face bears, giant ground sloths, camels, and horses
- Paleo Americans, especially the Clovis culture
- The possible causes of the extinction of the megafauna and the termination of the Clovis culture: Extraterrestrial (cosmic) impact 12,900 years ago
- More physical evidence related to the possible impact to be discovered

23 **K-T Boundary Mass Extinction (1)**

- 65 million years ago, a comet or asteroid with a diameter of about 10 km (6.2 mi) impacted

Earth in the vicinity of what is now the Yucatan Peninsula

- Concentration of a platinum metal called iridium in the thin clay layer that represented the K-T boundary in Italy
- Many fossils found in rocks below the clay were not in rocks above the clay layer

24 **K-T Boundary Mass Extinction (2)**

- A buried impact crater with a diameter of approximately 180 km (110 mi) at the Yucatan Peninsula is discovered in 1991
- Impact triggered global fire: Vaporization of the limestone bedrock, which contained some sulfur, produced sulfuric acid in the atmosphere; additional acids were added as a result of burning nitrogen in the atmosphere
- Following the impact, a long period of acid rainfall. The dust in the atmosphere circled Earth, there was essentially no sunlight reaching the lower atmosphere, the food chain virtually stopped functioning

25 **K-T Boundary Mass Extinction (3)**

Figure12.12

26 **Environmental Risk of the Impact (1)**

- Depending upon both the probabilities and the consequences of the impacts
- Catastrophic impact risks: Aerial blasts or direct ground impact
- Impact area: Regional or global scale, mass extinction
- Smaller event about every 1,000 yrs, and larger event occur every 40 to 100 million years or so

27 **Environmental Risk of the Impact (2)**

Figure 12.13

28 **Minimizing the Impact Hazard (1)**

- Identify all potentially hazardous near-Earth objects (NEOs)
- Categorize the comets and asteroids crossing Earth's orbits
- Spacewatch program, developed in 1981, about to expand its observation to the entire solar system
- NEAT (near-Earth asteroid tracking) system, support by NASA, focusing on the size and distribution of NEOs

29 **Minimizing the Impact Hazard (2)**

- Around 135,000 Earth-crossing asteroids with a diameter of 100 m or less
- About 20 million NEOs, 4 percent with the ability to penetrate and excavate a crater; another
  40 percent to penetrate the atmosphere and post a threat
- Designing an approach to divert large objects away
- Designing a plan for early evacuation for smaller impact events, if precise location can be predicted

30 **Critical Thinking Topics**

- Do you think building a space colony is a feasible solution to the impact of MACs? Why or why not?

-
- Will new technology be available to shield us from potential major aerial bursts or direct impact? If yes, how?
-
- Should we have an equal emphasis on the environment threats at the Earth's surface and the potential threats from the space? Explain

All figures for Chapter 12

The End !!!