GEOS 3310 Lecture Notes: Extraterrestrial Objects

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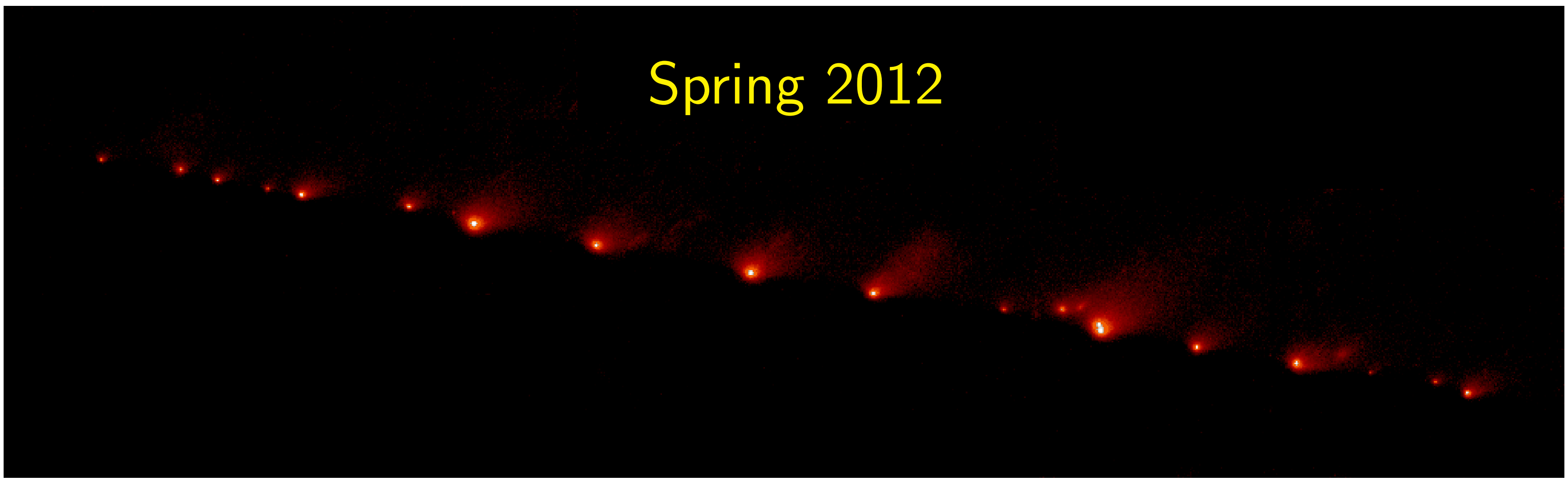

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Terrestrial Impacts

Identified Historical Impacts

Impacts are relatively rare, so few have been identified in human history:

1490 Shanxi Province, 10,000 people were said to have been killed by a hail of "falling stones"

1908 Tunguska, Siberia, Russia

- airburst 5-10 km above surface
- downed some 80 million trees over 2,000 square kilometers (830 sq mi)
- 10 MT equivalent yield, no recorded deaths

Prehistoric Impacts

Generally much larger (more readily preserved)

50KA Meteor (Barringer) Crater, near Grand Canyon, AZ. Object 50 m diameter, equivalent yield 2.5 MT, 2km diameter crater

65MA Chicxulub crater, Yucatan, Mexico. 10 km object, 180 km crater, 100 million MT yield, helped or caused dinosaur extinction. Identifiable today by ring of sinkholes .

214MA Manicougan Impact (and reservoir), Quebec, Canada

Meteor Crater

Figure 1: Meteor (Barringer) Crater, Arizona, southeast of the Grand Canyon. Crater is 1,200m in diameter, 170 m deep. Image from USGS .

Chicxulub Impact

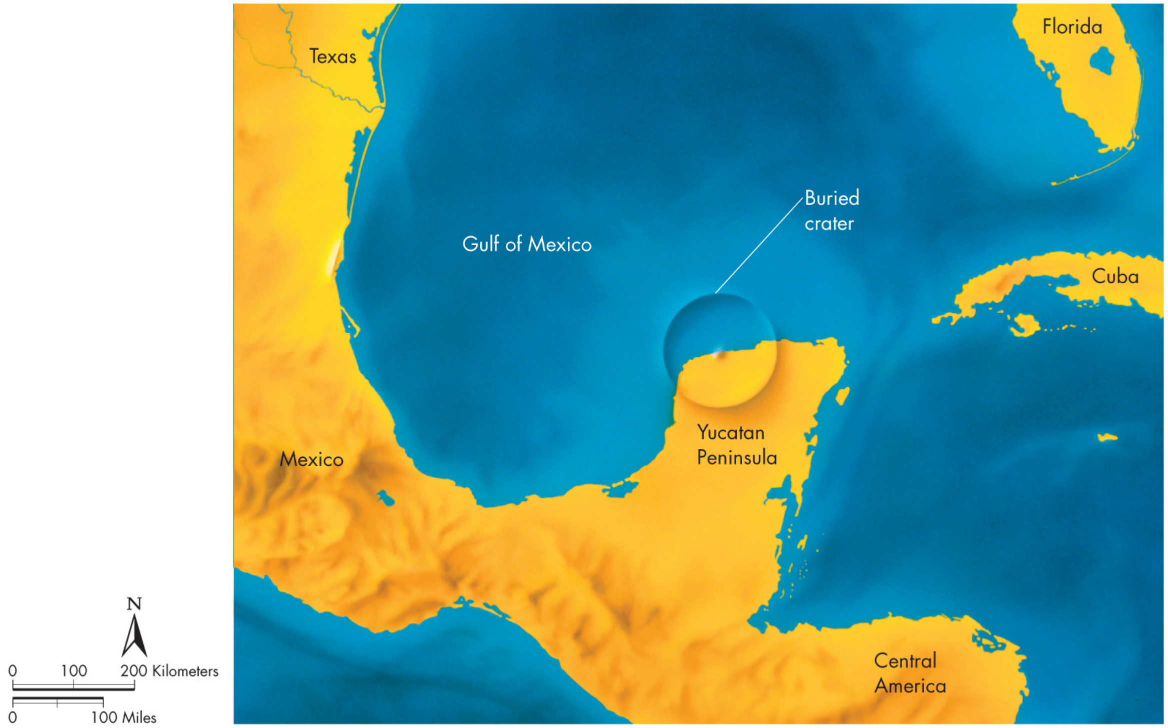

Figure 2: Chicxulub (buried) impact crater, Yucatan Mexico. Impact occurred 65 million years ago, and is strongly implicated in the extinction of the dinosaurs. 180 km in diameter. Keller [Fig. 12.11, 2011].

Manicougan Astrobleme

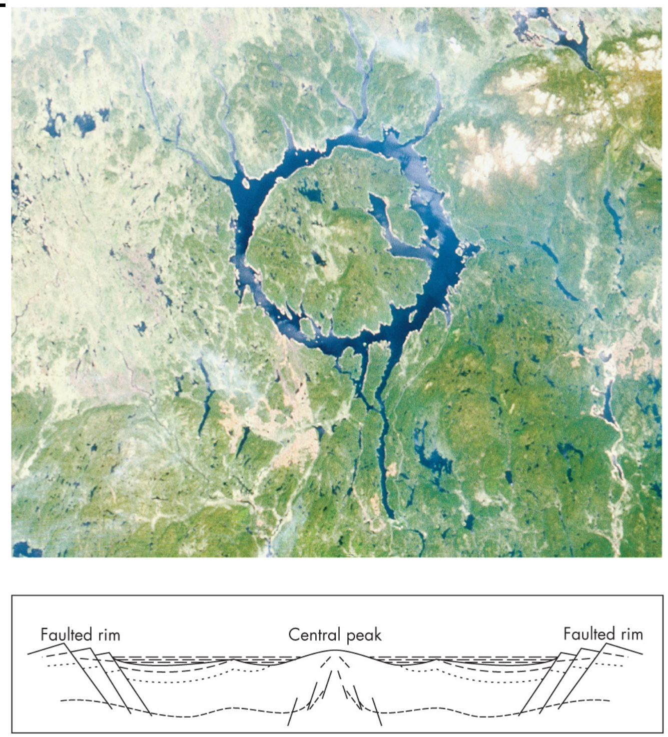

Figure 3: Manicougan eroded crater (astrobleme), Quebec, Canada. About 214 million years old, original rim (eroded) was probably 100 km in diameter. Similar scale as Chicxulub,Keller [Fig. 12.9, 2011].

Shoemaker-Levy

- a *comet* that entered Jupiter orbit, and came close enough to break into pieces in 1992 (see titlepage image)
- Gene Shoemaker , NASA's leading meteor/crater expert discovered it (with others) in 1993
- the pieces collided with Jupiter in July 1994
  - impacts generated large fireballs about the size of earth (see also Wikipedia)
  - impact scars persisted for months

Impact Risk

Risk Estimates

Risk of death from meteorite impact is extremely small, since risk of impact decreases dramatically with increasing object size (see also Fig. 4):

Object Size	**Impact Frequency**	**Equvalent Yield**	**Crater Size**	**Estmiated Casualties**
10 km	100 MY	$1x10^9$ KT	200 km	mass extinction (e.g. Dinosaurs)
1 km	2-4 MY		20 km	millions
50 m	1000 yr		1 km	$5x10^5$–$1.5x10^9$
10 m	1 yr	15 KT	N/A	$\ll 1$
1-10 m	38/yr	-	-	0

N.B. Hiroshima atomic bomb had 13KT yield

Size and Frequency

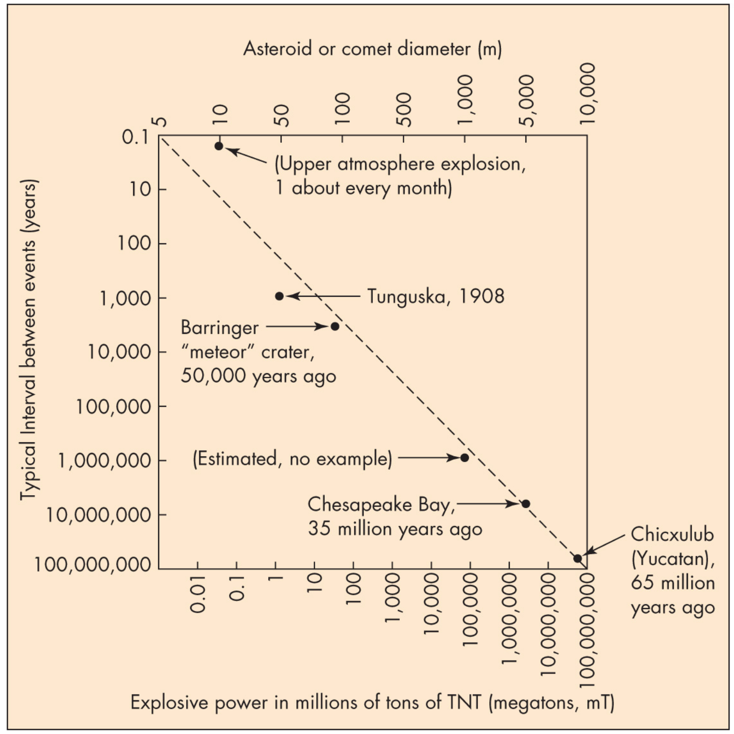

Figure 4: Extraterrestrial object size, impact frequency and energy release. Hiroshima atomic bomb was 15 Kt; after [Fig. 12.13, Keller, 2011].

Important Definitions

- larger, but sub-planetary bodies in the solar system generally referred to as *asteroids*

- distant, partly icy bodies orbiting the Sun are *comets*, which develop a tail or halo as they approach the Sun

- much smaller bodies referred to as *meteoroids*

- when these enter Earth's atmosphere, they are commonly referred to as shooting stars, and scientifically as *meteorites* (see mnemonic song)

- Jupiter serves an important role in sweeping up many potential meteorites in the solar system (Jupiter has the largest gravitational field of the planets)

Earth-Meteoroid Interactions

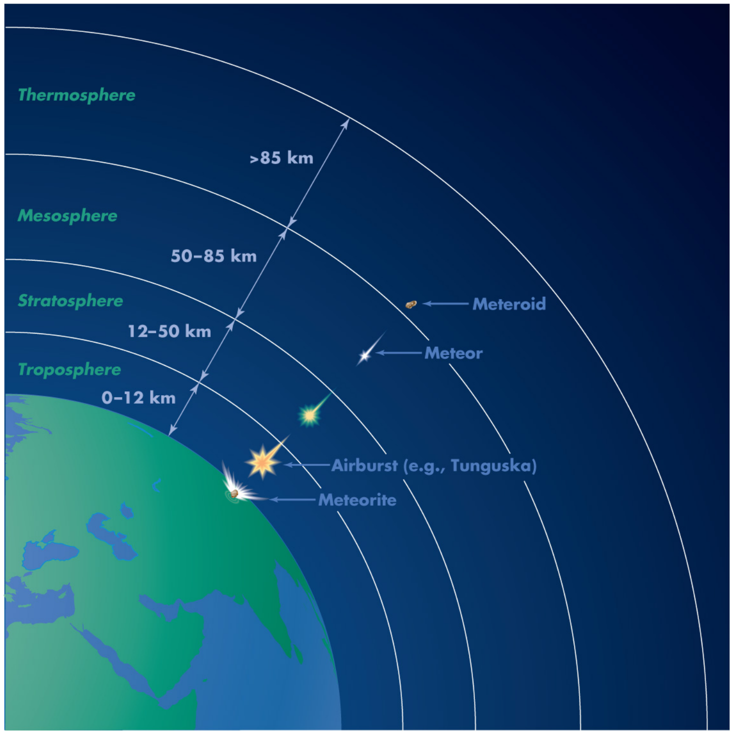

Figure 5: Meteoride interaction with earth and its atmosphere. Most burn up or pass harmlessly through the atmosphere. After [Fig. 12.5, Keller, 2011].

“Managing” the Hazard

- NASA maintains a Near-Earth Object (NAO) tracking program

- results of this indicate one potentially hazardous object,
  - 4 impact opportunities 2048-2057
  - now revised to 1:400,000 chance of collision
  - upon discovery had a projected 0.0340% chance of Earth impact, or 1 in 2,940 chance
  - most likely to strike unihabited area and go unnoticed, except by missile defense systems [Brown et al., 2002] (i.e. approximately 1:10^{14} chance you’ll be standing where it hits)

  - compare to 1 in 280,000 chance of being struck by lightning in your lifetime, and 1 in 15,890,700 chance of winning the Texas lottery, and 1 in 100 of dying in an automobile accident

- most other natural hazards pose a vastly greater personal risk than meteorite impact [Chapman and Morrison, 1994, Borden and Cutter, 2008]

- first space tracking of a meteorite that hit Earth happened in 2008

- only two documented cases of humans hit by meteorites, no injury in either case

Other Resources

Useful Links

This is intended to be an ever-evolving list of useful links on the general topic of this note set.

- Popular articles and scientific papers:
  - Science magazine articles on risk and possible response Milani [20030620], Reimold [20030620]
  - analysis of satellite early-warning network unidentified atmospheric explosions [Brown et al., 2002]
  - National Geographic

- good videos of meteors
  - Johnstown, PA
  - Denver, CO (space junk?)

- Northern Rockies, 1972 , object 4-30 m
- Austin, TX 2009

- Wikipedia pages on
  - Terrestrial Impact Events ,
  - Shoemaker-Levy comet impact on Jupiter
  - Meteor (Barringer) Crater, AZ
  - Sedan Crater, NV test of nuclear excavation potential

- Annual meteor showers (Earth passes through ancient comet trails):

  Perseid late August
  Leonid mid-November, 2009 predicted to be good
  Online Estimator NASA has a nice meteor flux estimator to help guide your viewing

Bibliography

Kevin A. Borden and Susan L. Cutter. Spatial patterns of natural hazards mortality in the United States. *International Journal Of Health Geographics*, 7, DEC 17 2008. ISSN 1476-072X. doi: 10.1186/1476-072X-7-64. URL http://www.ij-healthgeographics.com/content/7/1/64.

P. Brown, R. E. Spalding, D. O. ReVelle, E. Tagliaferri, and S. P. Worden. The flux of small near-earth objects colliding with the earth. *Nature*, 420(6913):p294 –, 11 2002. ISSN 00280836. URL http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=8540653&site=ehost-live.

Clark R. Chapman and David Morrison. Impacts on the earth by asteroids and comets: Assessing the hazard. *Nature*, 367(6458):p33 –, 1994. ISSN 00280836. URL http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=9403292186&site=ehost-live. Contains great relative risk table, comparing to auto accident, etc.

E. A. Keller. *Introduction to Environmental Geology*. Prentice Hall, 5th edition, 2011. ISBN 9780321727510. URL http://www.pearsonhighered.com/educator/product/Introduction-to-Environmental-Geology-5E/9780321727510.page.

Andrea Milani. Extraterrestrial material–virtual or real hazards? *Science*, 300(5627):p1882 –, 20030620. ISSN 00368075. URL http://search.ebscohost.com/login.aspx?direct=true&db=syh&AN=10174824&site=ehost-live.

Wolf U. Reimold. Impact cratering comes of age. *Science*, 300(5627):p1889 –, 20030620. ISSN 00368075. URL http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=10174829&site=ehost-live.