Background Briefing:
Impact Air Blasts Produced by Near-Earth Asteroids

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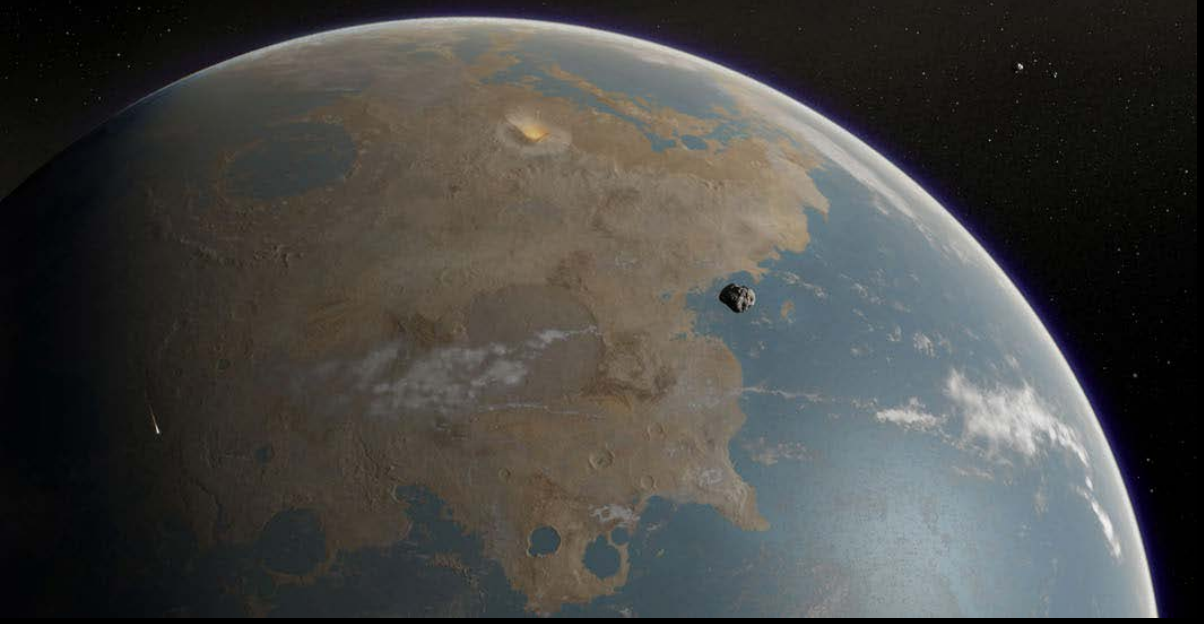
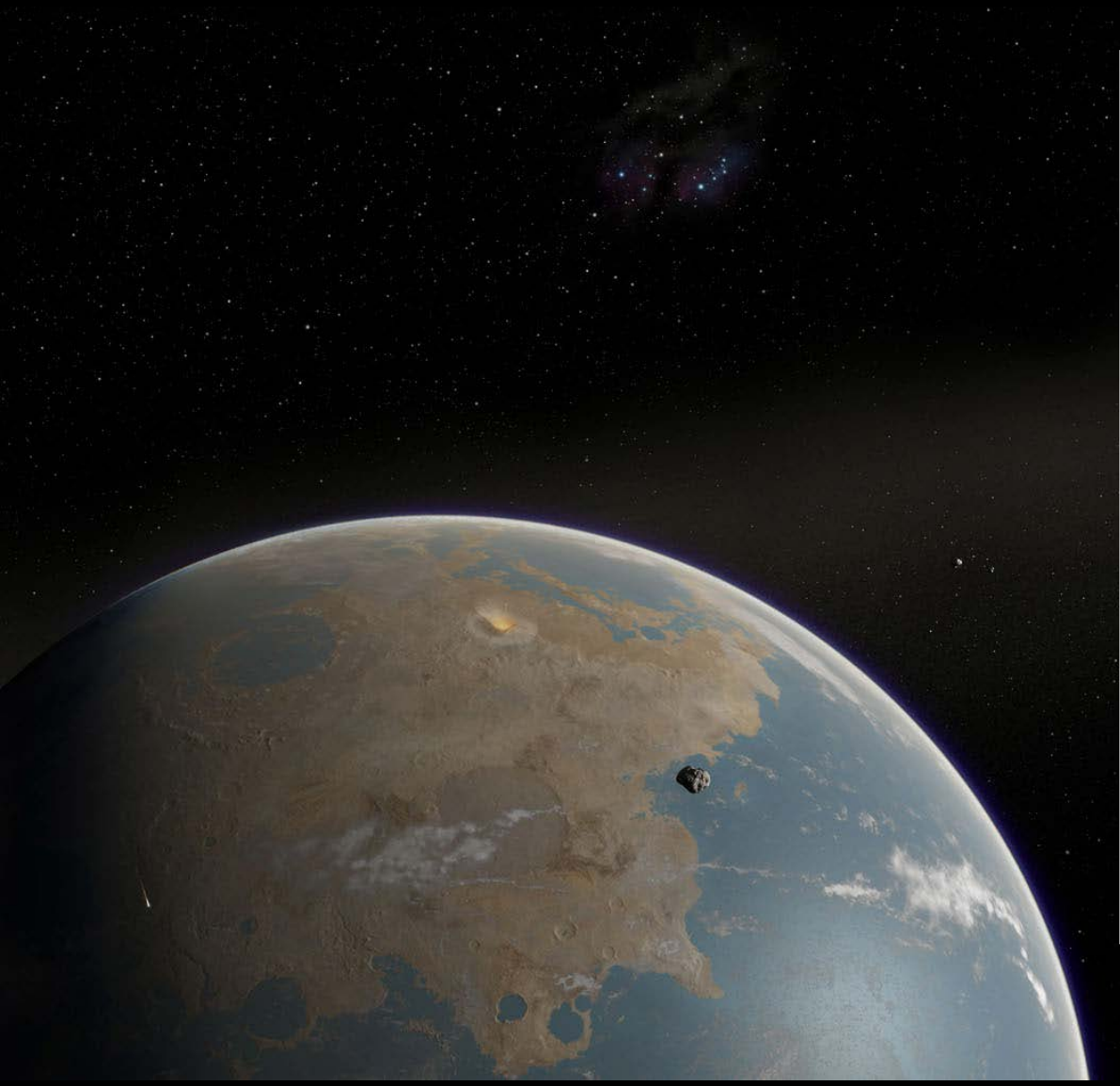


Detail from CLSE (Daniel D. Durda) image at
http://www.lpi.usra.edu/nlsi/training/illustrations/bombardment/

BRIEFING ABSTRACT



On Friday, 15 February 2013, a small asteroid penetrated Earth's atmosphere and catastrophically disrupted over Russia, injuring people and damaging buildings in the area around Chelyabinsk (55.2N, 61.4E). The injuries and damage were caused by shock waves and associated air blasts. I have received a lot of queries about these types of events and have collated some notes here to address them.

Detail from CLSE (Daniel D. Durda) image at
http://www.lpi.usra.edu/nlsi/training/illustrations/bombardment/

CURRENT ESTIMATES OF EVENT PROPERTIES

Based on information released by Peter Brown and/or attributed to NASA (as of 18 February 2013)

- Diameter of asteroid = 55 ft (17 m)
- Mass of asteroid = 10,000 tons
- Velocity of asteroid = 40,000 mph (17-18 km/s)
- Blast altitude = 15 to 20 km
- Equivalent energy of the explosive event = 500 kt of TNT

NOTE: Other sources have generated different estimates for the values above; these values are preliminary and may change significantly.

The event was roughly an order of magnitude more energetic than the Sikhote-Alin event of 1947 (~10 kt), but roughly an order of magnitude less energetic than the Tunguska event of 1908 (~2-20 MT).

Caveats: Estimates of past events (even historical events like Tunguska) come with lots of uncertainty.

That uncertainty underscores the need for modern, high-quality measurements of impact-generated air blast events.

CURRENT ESTIMATES OF EVENT PROPERTIES

Based on information reported from Russia
(as of 18 February 2013)

- A portion of the catastrophically fragmented asteroid survives
- The meteoritic material resembles ordinary chondrites – which are from a class of stony asteroids that contain a small amount of metal

Previously, the largest documented explosive fragmentation of an ordinary chondritic asteroid occurred over northwestern Arizona in the Gold Basin area. That event involved an ~8 meter diameter asteroid with the kinetic energy equivalent to 5 to 50 kt of TNT. Several thousand relics of the asteroid were found in the desert.

Gold Basin event

IMPACT VELOCITY

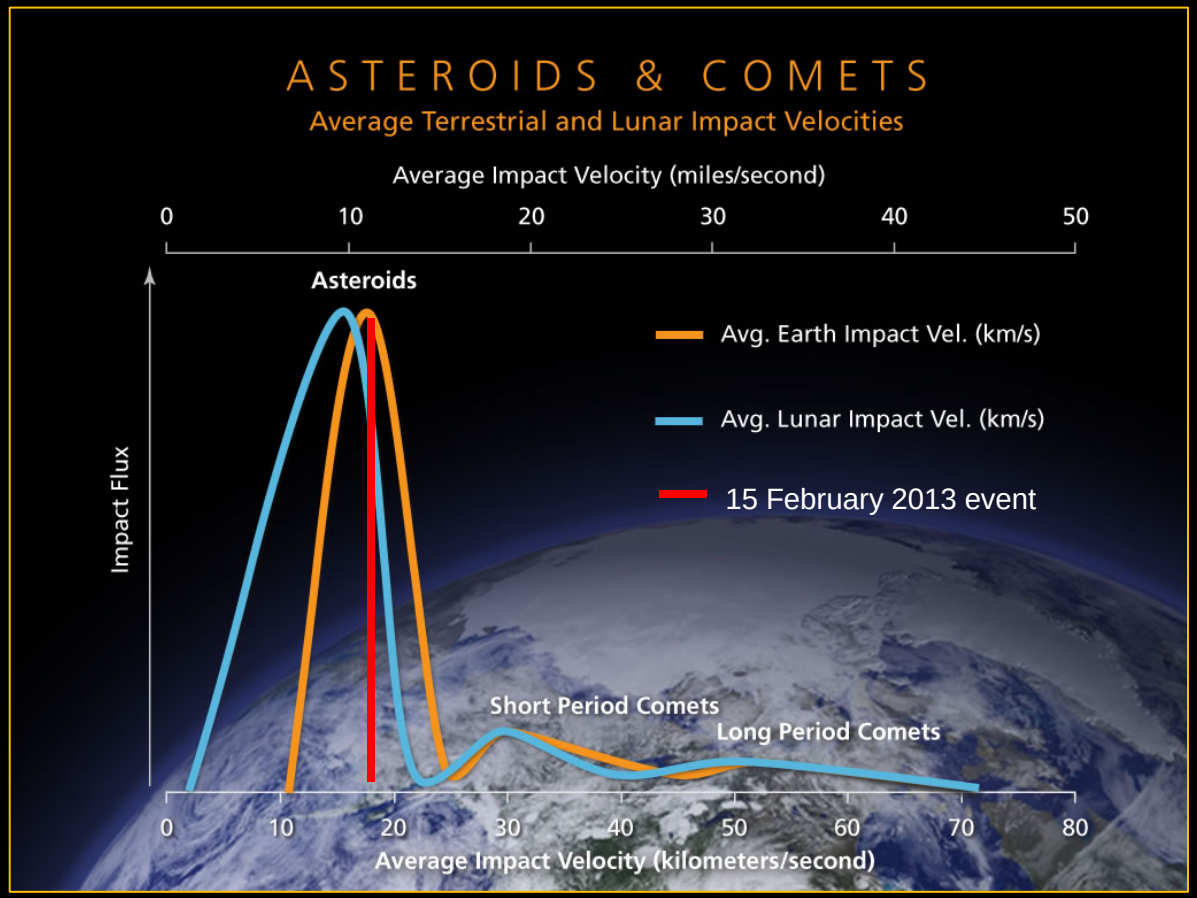


Illustration credit: CLSE (Shaner and Kring)

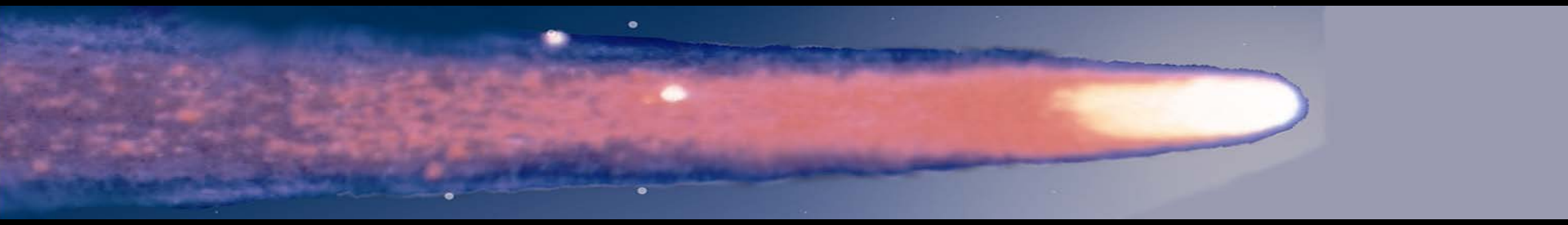
Typical asteroid velocity

Average impact velocities of asteroids hitting the Earth are about 18 km/s.

The object that hit Earth 15 February 2013 has an estimated velocity of 17-18 km/s, which is typical of an asteroid and much lower than that of typical comets.

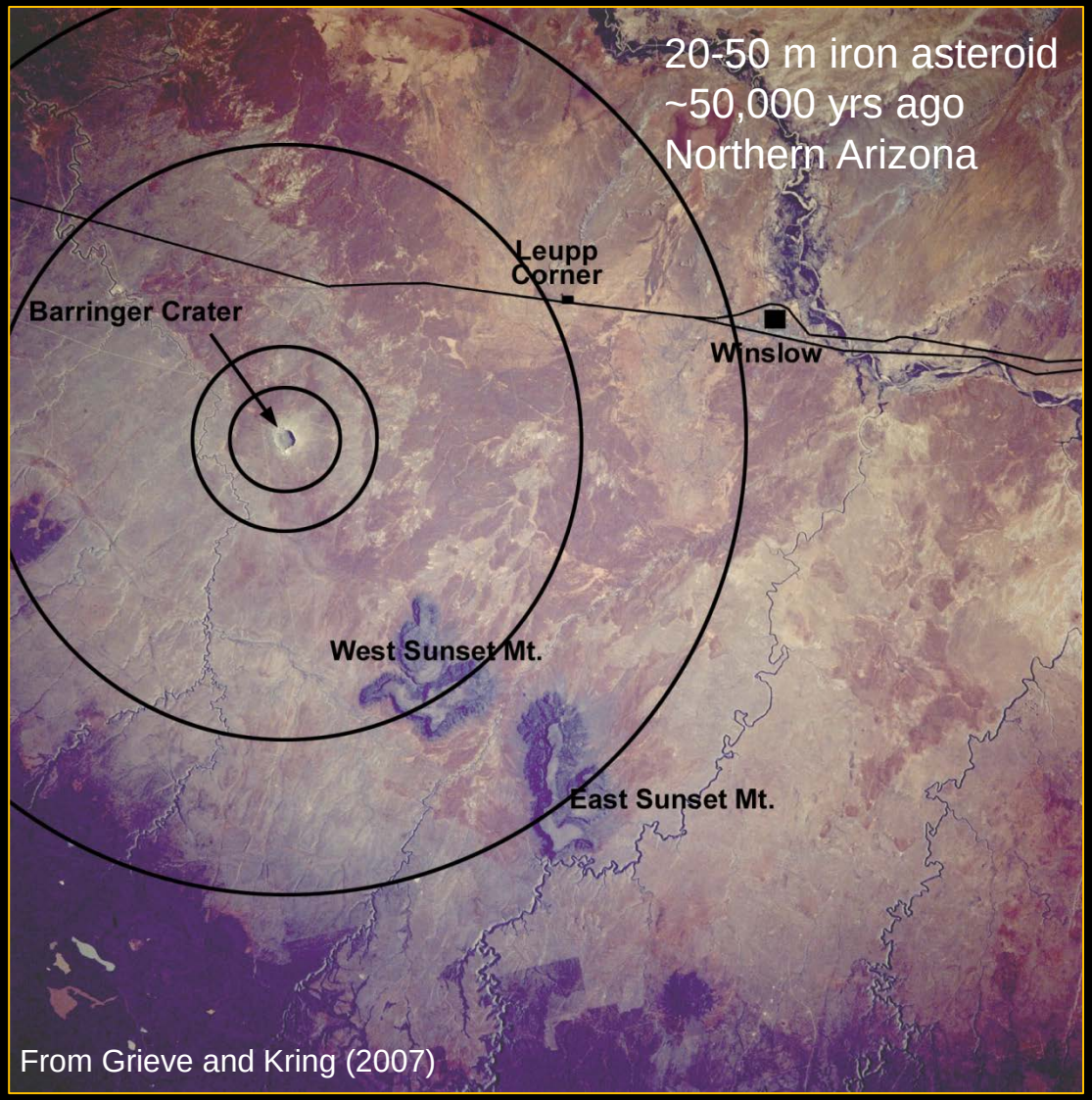
Thus, the velocity and the recovery of ordinary chondrites are consistent.

COMPONENTS OF IMPACT AIR BLASTS



- Shock waves are produced by objects moving faster than the speed of sound (i.e., Mach 1). Impacting NEA penetrate the atmosphere with a speed equal to or in excess of 11.2 km/s (≥25,000 mph or ≥ Mach 35), producing a ballistic shock wave.
- A second, explosive shock wave, is produced when the object catastrophically fragments in the atmosphere or hits the surface to produce an impact crater
- The shock waves are accompanied by high-velocity air blasts

CASE STUDY OF AN IMPACT AIR BLAST – BARRINGER (METEOR) CRATER



From Grieve and Kring (2007)

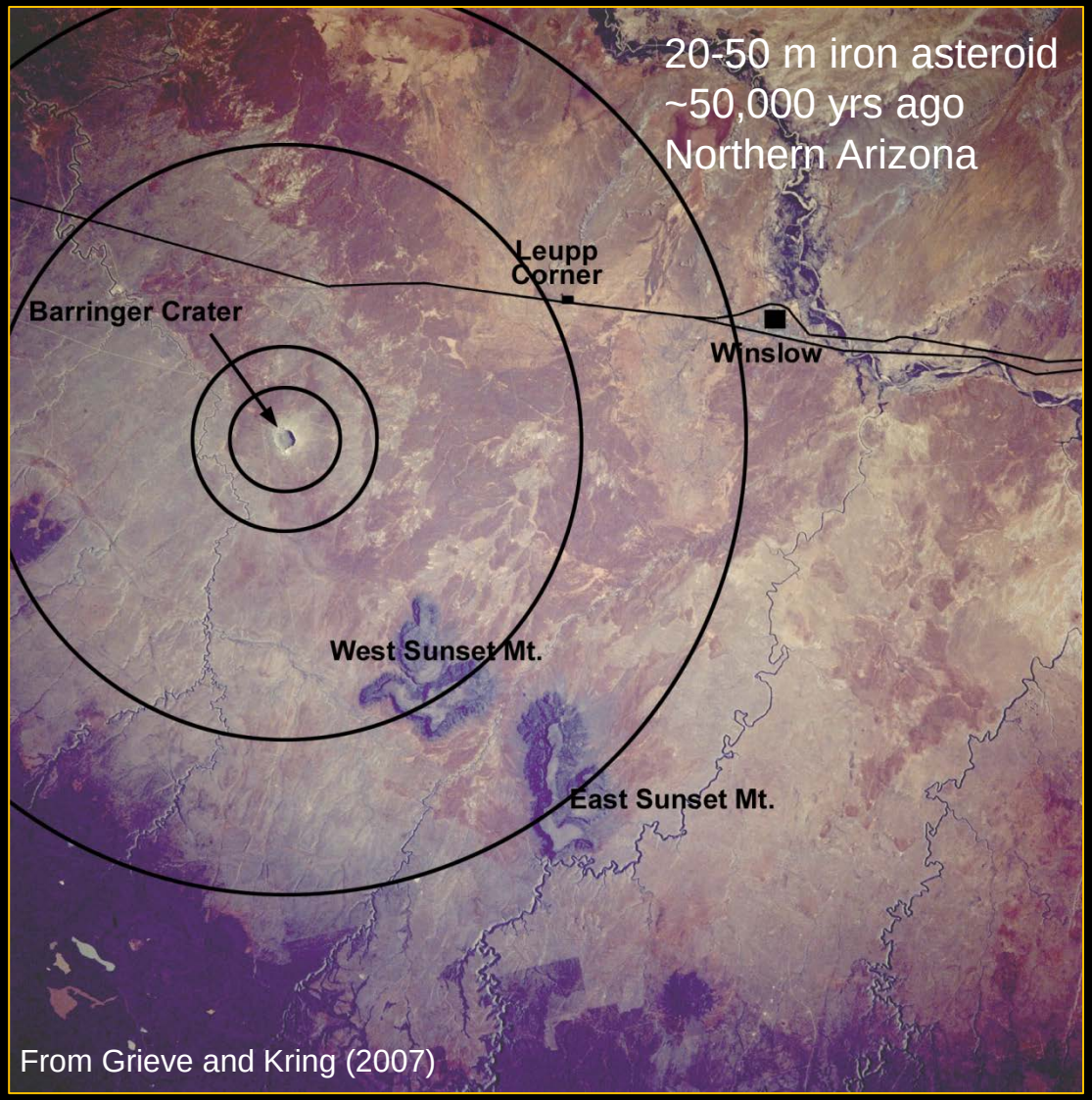
Small cratering events

In small events, the fireball, shock wave, and airblast are the major environmental effects.

The blast effect was immediately lethal for human-sized animals within the inner 6 km diameter circle.

Severe lung damage would occur within the next 10-12 km diameter circle due to the pressure pulse alone and animals would be severely injured and unlikely to survive.

CASE STUDY OF AN IMPACT AIR BLAST – BARRINGER (METEOR) CRATER



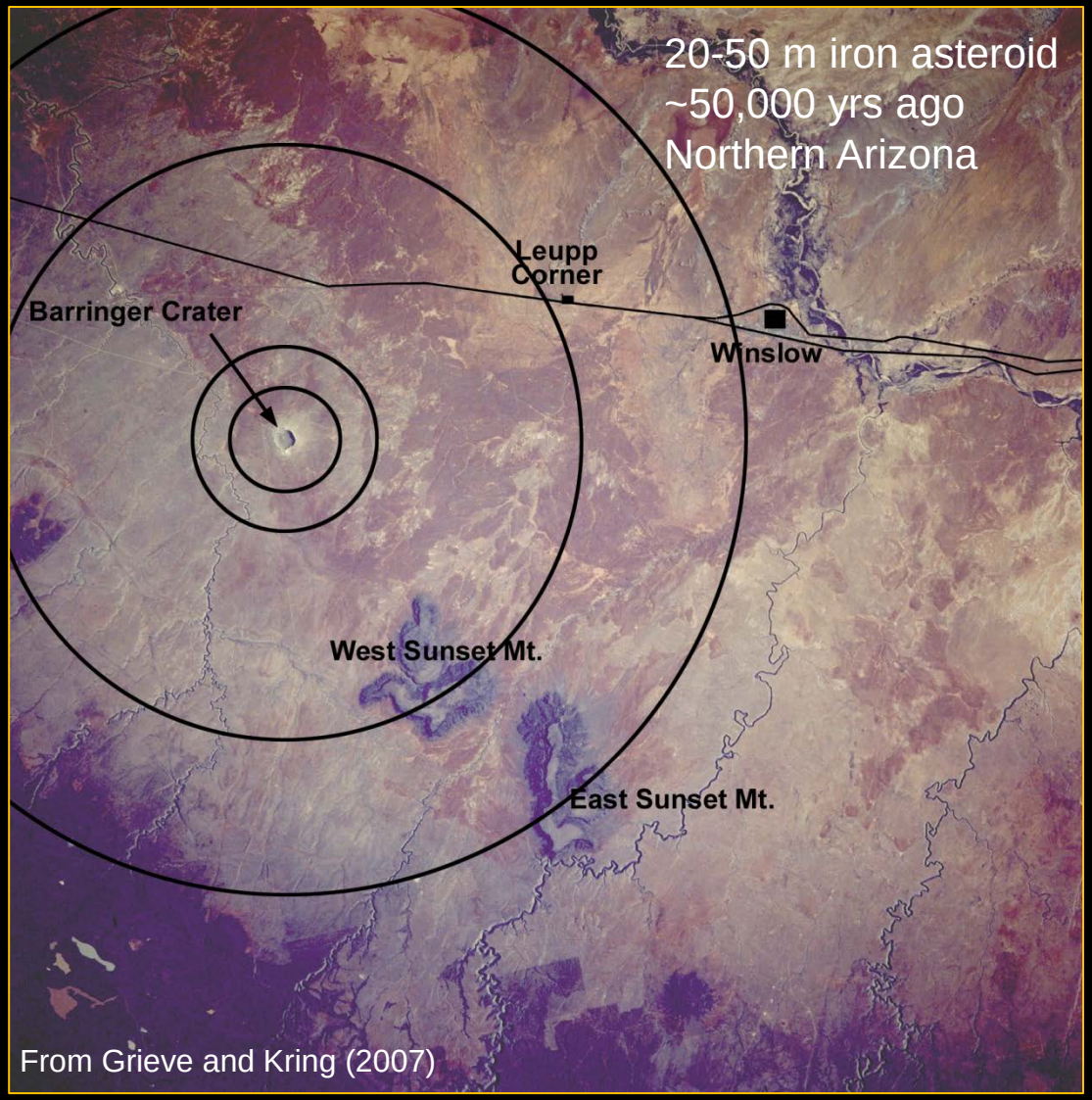
From Grieve and Kring (2007)

Small cratering events

Winds would exceed 1500 km/hr within the inner circle and still exceed 100 km/hr at radial distances of 25 km (3rd circle).

The outermost ~50 km circle represents the outer limit of severe to moderate damage to trees and human-structures of comparable strength.

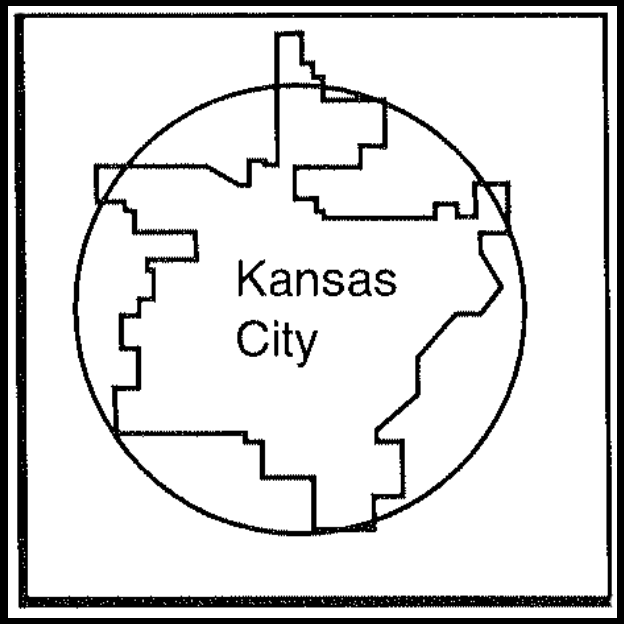
CASE STUDY OF AN IMPACT AIR BLAST – BARRINGER (METEOR) CRATER



From Grieve and Kring (2007)

Small cratering events

Such an event today could decimate the population of an urban area equivalent to the size of Kansas City, U.S.A. (population 425,000).



40 km circle corresponding to severe to moderate damage.

CASE STUDY OF AN IMPACT AIR BLAST – MANICOUAGAN

From Grieve and Kring (2007)

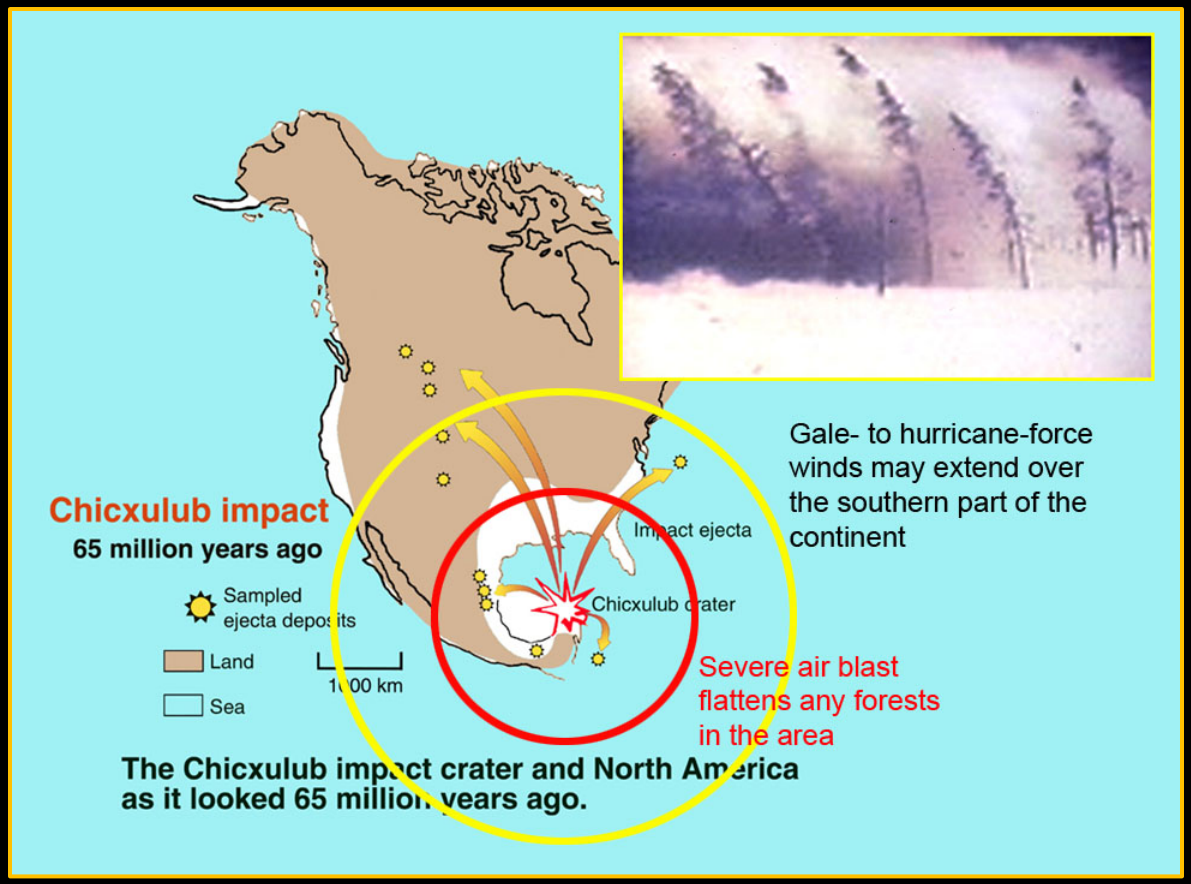
Manicouagan

Larger impact cratering events will produce air blasts that affect a larger area.

Manicouagan is a crater with a diameter of ~100 km.

That impact air blast affected a large fraction of Canada.

CASE STUDY OF AN IMPACT AIR BLAST – CHICXULUB CRATER



The Chicxulub impact crater and North America as it looked 65 million years ago.

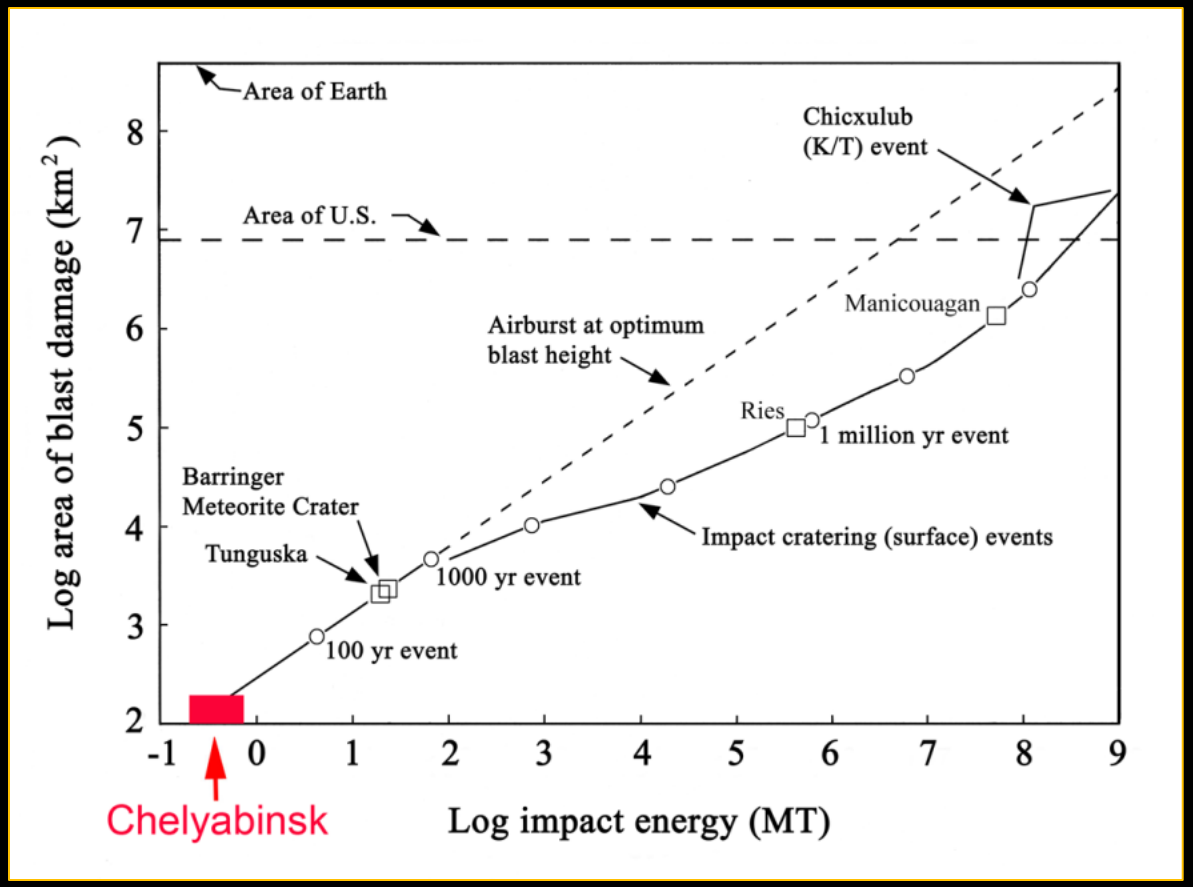
Dinosaur-killing event

At the extremely large end of the spectrum is the Chicxulub impact event that caused a mass extinction 65 million years ago.

The air blast produced by that impact event affected a large fraction of North America.

The airblast is only one of many environmental effects produced by this size of impact event.

IMPACT AIR BLASTS OF DIFFERENT SIZES



Modified after Figure 1.5 of Grieve and Kring (2007). Please see that paper or PPTx notes (below) for a description of the uncertainties associated with the data plotted in the diagram

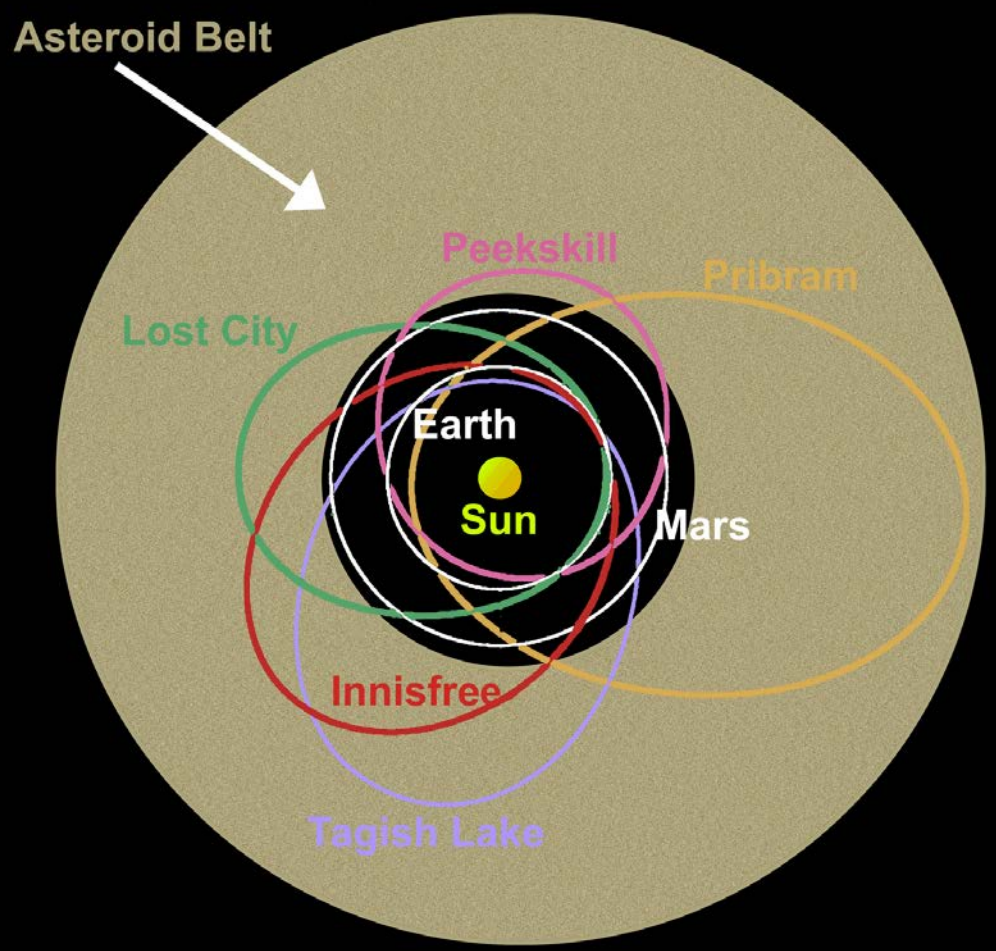
Impact air blasts

The Chelyabinsk event is at the extreme (small) end of the types of events that produce air blasts.

Less frequent, larger events can affect larger areas.

As the world's population grows and occupies a larger fraction of the Earth's surface, events like Chelyabinsk will potentially affect more people.

SOURCES OF NEAR-EARTH ASTEROIDS



Schuchardt & Kring/NASA Univ. Arizona Space Imagery Center

NEA source region

Near-Earth asteroids come from the main asteroid belt.

Their orbits, once nearly circular, have been perturbed by gravitational processes into elliptical orbits that cross the orbit of Earth.

The pre-impact orbits of previously fallen meteorites illustrate this point.

THE STRUCTURAL INTEGRITY OF NEAR-EARTH ASTEROIDS

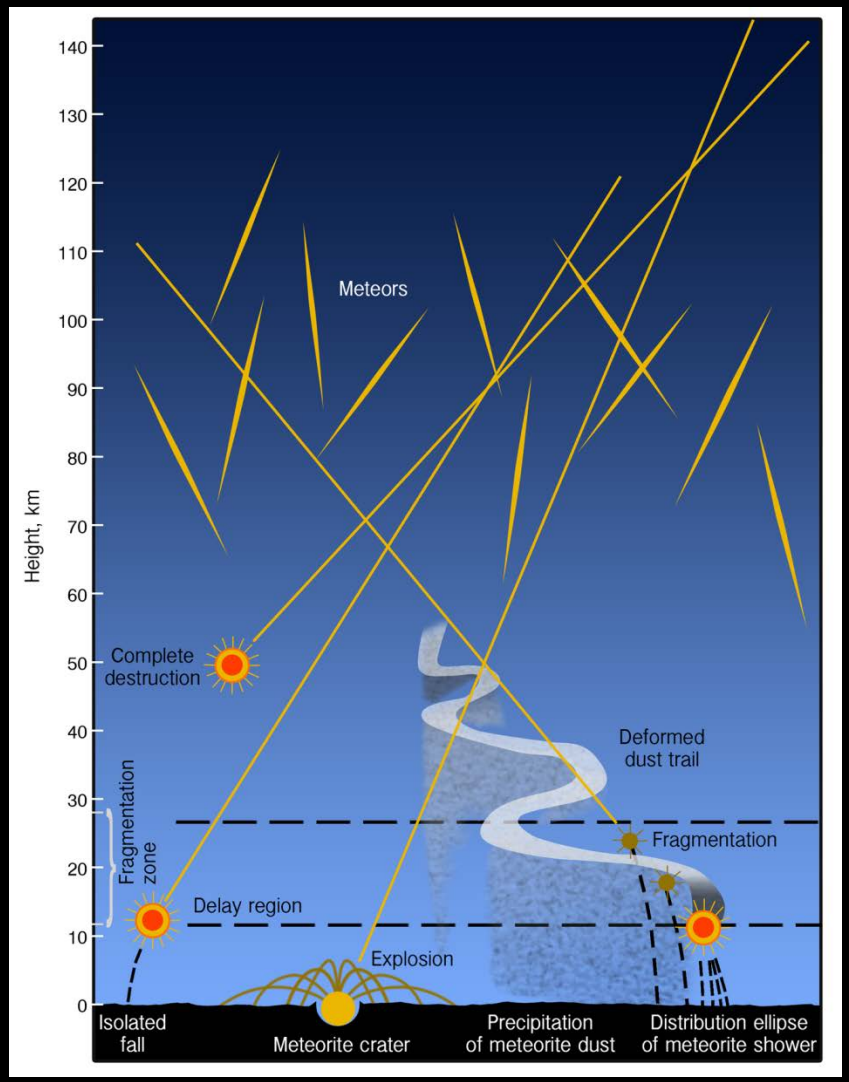
The measured compressive strengths of ordinary chondrites may not be the best measure of the structural integrity of near-Earth asteroids.

Instead, the strength of material may be limited to structural flaws (like fractures or material contrasts) rather than the strength of individual clasts within them.

The fall phenomena associated with meteorites support the idea that structural flaws limit the strength of near-Earth asteroid material. For example, fragmental breccias preferentially fall apart in Earth's atmosphere and produce meteorite showers.

IMPORTANT : The Chelyabinsk event, if documented well, can be used to determine the strength of the near-Earth asteroid, which is a fundamental parameter needed for impact mitigation strategies.

PENETRATING EARTH'S ATMOSPHERE



Meteoroids in Earth's atmosphere

The atmosphere is an effective filter of impacting debris

Intermediate-size objects that are not destroyed in the upper atmosphere can fragment, producing a shower of debris, or survive nearly intact, producing a single meteorite.

Multiple fragmentation events are possible.

Larger objects that are not significantly decelerated and reach the ground can produce hypervelocity impact craters.