Meteórite Impact Cratering on Earth: Geological and Biological Consequences

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Mercury Mariner 10
Venus – 32 km crater Aurelia
Venus – 30 km crater
Mars – crater in stream
Mars – 2.3 km crater with sediments?
Mathilde and Eros
Ida and Dactyl
Eros
Callisto
Ganymede crater chain
Dione
Mimas
Comet Borelly
Ries-crater (Germany)
24 km diameter, 14.6 Ma
Impact Craters on Earth (2005)
CRITERIA FOR IDENTIFICATION OF IMPACT STRUCTURES

A. Morphology
   Circular Outline
   Rim Structure
   Central Structure

B. Geophysics
   Gravity
   Magnetics
   Seismics

C. Mineralogy and Geochemistry
   Brecciation
   Shock Metamorphism
   Traces of Meteoritic Material
MONOMICT

FRAGMENTATION IN SITU

CATACLASTIC CRYSTALLINE ROCK

POLYMICT

MELT WITH FRAGMENTS

BRECCIA WITH GLASSY OR CRYSTALLINE MATRIX

FRAGMENTS WITH MELT

BRECCIA WITH CLASTIC MATRIX AND MELT PARTICLES (GLASSY OR CRYSTALLINE)

FRAGMENTS

BRECCIA WITH CLASTIC MATRIX
Meteoritic Components in Impactites:
Second possibility (apart from shock metamorphism) to confirm impact origin of a geological structure or of an ejecta deposit
Giant impact structures in 250 Ma

Manicoaugan  Puchezh-Katunki  Morokweng  Chesapeake
Chicxulub  Popigai

80-180 km

% extinction marine genera

(A. Montanari 2004)
More smaller impacts

(A. Montanari 2004)
K-T boundary at Frontale di Apiro, Italy
Woodside Creek, New Zealand
(Modified after Wolbach et al., 1990)

![Diagram showing relative depth and concentration of Ir and soot](image)
Chicxulub impact structure - KT boundary age
FIG. 2 Plot of $\varepsilon_{\text{Nd}}$ against $\varepsilon_{\text{Sr}}$ for samples of Haitain black glass (squares) and melt rock from the Chicxulub (circles) and Manson (triangles) impact structures at the time of impact 65 Myr ago. The $\varepsilon$ notation is defined in Table 1. Inset shows the details of the Haitian and Chicxulub data at an expanded scale. The mantle array follows a trend between the mid-ocean-ridge basalt (MORB) and ocean-island basalt (OIB) fields and is shown to emphasize the significant difference in the isotopic composition between mantle-derived volcanic rocks and the Haitian glass and Chicxulub melt rock.
Chicxulub – a 200 km diameter 65 Ma impact crater
Chicxulub Impact Structure, Mexico
ca. 200 km diameter
65 Ma; K-T boundary
# Yax-01 Stratigraphy
*(Dressler et al. 2003)*

<table>
<thead>
<tr>
<th>Tertiary</th>
<th>0.00 - 794.63</th>
<th>Massive, (cross-) laminated, soft sedimentary deformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impactites</td>
<td>794.63 - 894.94</td>
<td>Suevites, melt breccias</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>894.94 - 1510.97</td>
<td>Megablocks: Limestone, dolomite anhydrite (27.4%). Impact breccia and melt dykes + petroleum</td>
</tr>
</tbody>
</table>

- Evidence of a hydrothermal system at Chicxulub
  - extensive evidence of hydrothermal alteration in impactites
    - Zurcher et al. *(LPSC 34)*, Zurcher and Kring *(LPSC 34)*, Hecht et al. *(LPSC 34)*
  - evidence of post impact fluid and organic matter mobilization in megablocks
    - Wittman et al. *(LPSC 34)*, Lüders et al. *(LPSC 34)*
  - hydrocarbon-rich material in megablocks
    - pre-, post- or syn-impact?
    - source?

A. Jones 2004
Yax-1
Lithostratigraphy
Each blue dot below represents a cenote such as the one to the left.
Chicxulub Impact
65 Million Years Ago

- Paleoland
- Sea
- Submerged Continent
- Sampled Ejecta
During the Cretaceous the northern part of the Yucatán was covered by a shallow sea. At the time of impact, tsunamis would have radiated across the Gulf of Mexico basin, reaching heights of 50 to 100 m as they approached the coast of what is today Chiapas, Tamaulipas, Nuevo León, Texas, Louisiana, and Alabama.
<table>
<thead>
<tr>
<th>Agent of Environmental Change</th>
<th>Time Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fireball irradiance</td>
<td>Minutes</td>
</tr>
<tr>
<td>Thermal pulse from ejecta (fires)</td>
<td>Hour+</td>
</tr>
<tr>
<td>Winds (500 km/hr), giant waves</td>
<td>Hours</td>
</tr>
<tr>
<td>Dust veil (cold, darkness)</td>
<td>Months</td>
</tr>
<tr>
<td>Acid rain (nitric and sulphuric)</td>
<td>Year</td>
</tr>
<tr>
<td>Stratospheric aerosols (cold)</td>
<td>Decades</td>
</tr>
<tr>
<td>Ozone depletion (UV exposure)</td>
<td>Decades</td>
</tr>
<tr>
<td>( \text{H}_2\text{O} ) greenhouse effect</td>
<td>Decades</td>
</tr>
<tr>
<td>Poisons and mutagens</td>
<td>Years-millenia</td>
</tr>
<tr>
<td>( \text{CO}_2 ) greenhouse effect</td>
<td>Millenia</td>
</tr>
<tr>
<td>Impact-triggered volcanism</td>
<td>Millenia?</td>
</tr>
<tr>
<td>Disrupted climate</td>
<td>Million years</td>
</tr>
<tr>
<td>Layer</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Coal</td>
<td>Fern (Laevigatosporites)-dominated recovery flora; CO₂, H₂O induced</td>
</tr>
<tr>
<td>Laminated (carbonaceous) Shale</td>
<td>greenhouse warming dust settles</td>
</tr>
<tr>
<td>Satiny Claystone/Ejecta Layer</td>
<td>Fern (Cyathidites)-dominated surviving understory plants</td>
</tr>
<tr>
<td></td>
<td>time of semi-darkness, reduced temperatures, acid rain</td>
</tr>
<tr>
<td>Hackly Claystone/Ejecta Layer</td>
<td>Canopy killed</td>
</tr>
<tr>
<td>Coaly Shale, organic-rich mudstone</td>
<td>Pre-event Maastrichtian conditions; canopy of gymnosperms; understory</td>
</tr>
<tr>
<td></td>
<td>angiosperms, ferns</td>
</tr>
</tbody>
</table>

**Image Description:**
- The image shows a cross-section of geological layers with annotations indicating the duration and conditions of different periods.
- The layers are labeled with different geological terms and their associated geological and environmental conditions.
- The duration of events is marked with estimates, such as "about 10 years" or "up to 3 months."
"The picture's pretty bleak, gentlemen. ... The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut."
Alleged crater “Bedout” near Australia

Figure 2. Plots of $\delta^{13}$C (after Holser and Schönlaub, 1991; PDB—Peedee belemnite) and Ir abundance data (dashed parts of line after Holser et al., 1989) for Gartnerkofel (Austria) Permian-Triassic section. Lithostratigraphy is shown on left.
The critics say that they are driven by the lack of data backing up the original Becker papers. “They presented insufficient evidence of an impact crater or an age ascribed to it,” says Paul Renne, a geochronologist at the University of California, Berkeley, and a signatory to the same letter to Science. “The latest Science paper undermines their credibility,” says Renne, who argues that the data in the published paper do not support its conclusions. “A lot of researchers who were sceptical before are now sure Becker’s group are wrong.”
Permo-Triassic boundary:

- No shocked quartz
- Small Ir anomaly
- PGE ratios non-chondritic
- Os isotopes terrestrial
- No He-3
- No impact – evidence for extensive volcanic influence
So much for today's biology lesson on "intelligent design." Turning now to the subject of "intelligent geography..."
Comet P/Shoemaker-Levy 9 (1993e) • May 1994

Hubble Space Telescope • Wide Field Planetary Camera 2
What Happens When an Impact Takes Place?

Bolides (up to 5 MT)
• Great fireworks display, no damage

Tunguska-class (15 MT) impact
• Damage similar to large nuclear bomb (city-killer)
• Average interval for whole Earth: 100 yr.
• Minor risk relative to other natural disasters (earthquakes, etc.)

Larger local or regional catastrophes (e.g. 10,000 MT)
• Destroys area equivalent to small country
• Average interval for whole Earth: 100,000 yr.
• Moderate risk relative to other natural disasters

Global catastrophe (> 1 million MT)
• Global environmental damage, threatening civilization
• Average interval for whole Earth: 1 million years
• Major risk relative to other natural disasters
Fireball scorches plants and animals out to 10 km

Large animals killed or wounded by pressure pulse and air blast up to 24 km from impact

Hurricane force winds up to 40 km
END TIMES SHOCKER...

KILLER METEOR HEADS FOR U.S.

What you must do NOW to help save millions of lives

GOVT. & CHURCH LEADERS’ PLANS AND SPECIAL PRAYERS TO AVOID DISASTER
The end of the world
A brief history of an enduring belief

PLUS: The year in verse • The last personality cults • The greatest financial trades • Bhutan Powerful women in Africa • Christian monasteries • The Romans in China • German atonement Go • The world’s oldest companies • Cranberries • Press freedom in developing countries Graffiti • Mule-packing • Odessa • Academics and The Economist • A competition
"It's just an asteroid about to hit the earth. Don't worry about it."
In diesem Buch wird in allgemeiner verständlicher Form auf die sehr reale Gefahr hingewiesen, die von Einschlägen von Asteroiden oder Kometen ausgeht, und es werden die viel häufigeren Explosionen von kleineren Körpern in der Atmosphäre diskutiert. Außerdem werden die Struktur und die Entstehung von Meteoritenkratern erklärt, Kriterien für die Identifikation von Meteoritenkratern genannt, sowie Details einiger der momentan etwa 150 bekannten Impaktkrater auf der Erde beschrieben.