Signs of a devastating asteroid impact in Indochina 800,000 years ago

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Published as "Source of the Australasian Tektites?" in *Meteorite*, February 2001
http://www.meteor.co.nz/

Introduction

One of the hurdles to increased public awareness about the hazard from asteroid and comet impacts is the scarcity of hard evidence of recent major impacts. A report in the March 2000 issue of Science therefore caught my attention. An archaeological excavation in South China, near the town of Bose found stone tools in sediments containing Australasian tektites (Yamei et al 2000). The researchers also found evidence of an episode of woody plant burning, widespread forest destruction and exposure of "cobble outcrops" when soil was scoured away. They suggested that this destruction was initiated by the event that generated the tektites - namely a major impact in Indochina (Vietnam, Laos, Thailand and Cambodia). This is still speculative (and controversial) but if, proven, would add an important piece to the jigsaw puzzle that should eventually reveal the source of the Australasian tektites. It could help determine the magnitude of the explosive event.

This article records my attempts to find out more about the Australasian tektite event and some speculation on the global consequences of the event.

Australasian tektites

Most tektites are glass beads or balls that are produced by ejection of material fused by large asteroid or comet impacts. For years scientists have been investigating the 'Australasian Tektite Strewn Field' that stretches from China to Australia, as well as large parts of the eastern Indian Ocean. Evidence points to an impact some 800,000 years ago in Indochina (Schmidt et al 1993, Hartung and Koeberl 1994, Schnetzler and Mchone 1996, Howard et al 2000, Glass 1999). However, the source crater is proving very elusive.

Working on the geographic variation in tektite concentration Glass and Pizzuto (1994) estimated the diameter of the impact crater to be between 32 and 114 kilometres. They made no assertions about the impactor's characteristics. If it was a stony asteroid travelling at a speed of 22km/s then its diameter would be between 2 and 5 km (see Appendix). Earlier estimates using iridium concentrations suggested a crater diameter less than 20km (Schmidt, Zhou and Wasson1993) but the later estimates are probably more reliable.

Map of Indochina showing locations mentioned in this article.

It seems remarkable that such a large "fresh" crater has not been found but a comparison of known impact craters with the expected cratering rate suggests that many ancient craters have not been found (Lewis 1999). It is possible that the Indochinese crater has been totally eroded away or covered by deep sediments - perhaps in the Mekong delta. However, political/military sensitivities in the area have reportedly hampered geological expeditions.

Hartung and Koberl (1994) studied a region in northern Cambodia near the Tonle Sap lake (also known as Tonle Sab). They raised the possibility that the 100 km by 35 km lake could be associated with the crater. They presented arguments for and against the hypothesis and concluded "many aspects of the Tonle Sap lake and basin are consistent with the hypotheses that it is the source crater...but further research is needed".

Schnetzler and Mchone (1996) studied several regions in Laos, looking for the source of the tektites. They concluded "none showed obvious evidence of extraterrestrial impact [crater]".

Howard et al (2000) studied sites in NE Thailand near the town of Khorat, looking for environmental effects of a major impact. They found petrified trees with trunks up to 2 metres in diameter "shattered, branchless, snapped, uprooted and burnt to the core" together with evidence of catastrophic floods. They report that the study location is "about 400km west of the area where layered tektites are most abundant, this area is believed by many to be close to the impact centre".

Povenmire, Liu and Xianlin (1999) report on several new finds of Australasian tektites near the Bose region in China. Combined with unconfirmed references to tektites some 1000km further north in Ganzu Province, they suggest that the total area of the Earth's surface covered by this strewn field may be in excess of 30%. "The Australasian event must have been much larger than previously supposed. This leads us back to a very basic question and that is, where is the 100km crater?"

Dass and Glass (1999) examined mineral inclusions in Muong-Nong type Australasian tektites and reported that the preliminary data were consistent with a source crater in southern Laos or adjacent area. Subsequently Glass (1999 and 2000) reported on further investigations of zircons in the tektites. He noted that additional studies were needed to define the southern geographical limit of shock metamorphism within the tektites and therefore the location of the source crater (based on other strewn fields, Glass assumes that shock metamorphism in tektites *increases* with distance from the source crater).

Regional environmental effects of an impact

Considerable research has been done in recent years into the environmental consequences of major impacts (Toon et al 1997). Most of this work has involved computer modelling. Although data from major impact events is gradually becoming available (for example - studies of the Chicxulub cratering event and the impact of Comet Shoemaker-Levy 9 with Jupiter) the modelling should still be regarded as somewhat speculative.

The appendix summarises the potential environmental effects of impacts by large asteroids and comets. Estimates of damage are given for 1, 2, 5 and 10 km stony asteroids (caution: at this stage there is no reason to assume the Indochinese impactor was a stony asteroid. Also it may have had an unusually shallow trajectory).

Implications of the Bose destruction

Assuming the impact site for the Indochinese impact event was in the vicinity of northern Cambodia then Bose is about 1200 km to the north. An impact by a stony asteroid at least 5 km in diameter would therefore be required to produced the observed forest destruction at Bose. This is based on the estimate that such an impact would produce a blast wave (1 psi overpressure) sufficient to knock down trees 1100 km from the impact. It is stressed that further research is needed to precisely date the impact event and the forest destruction at Bose and to link the events in order to substantiate this suggestion.

An impact this size would produce a transient crater 40 km across that would slump to form a ringed structure 100 km across. This is in agreement with Glass and Pizzuto's estimate, based on tektite distribution.

The suggestion that Bose forests were ignited by ballistic debris (in effect, radiant heat from millions of meteors - Toon 1997) supports this hypothesis. Such an effect would cover a radius of 5000 km for a 5km asteroid impact but is limited to about 600 km in the case of a 2 km asteroid. Note, however, that this region is subject to frequent devastating forest fires so a link to the impact event may be tenuous. An alternative to ignition from ballastic debris effects is the possibility that the impactor followed a very shallow trajectory that would have subjected a strip of land to intense radiant heat prior to impact (Lewis 1999).

Regional extinctions of plant and animal life could be expected but this is a region that could be expected to quickly recover through regeneration and migration.

A modern day analogy

Putting the speculative Indochina impact event in perspective, if the impact site had been San Fransisco then:

- the crater would have been as big as San Fransisco Bay,
- the giant Redwoods in Sequoia National Park, some 400 km to the east, would have been shattered and burnt (equivalent to the region studied by Howard et al).
- 1200 km further north in Washington State the Mt St Helens region would have seen destruction equivalent to the volcanic explosion in 1980 (distance comparable to the Bose region).

Global environmental effects of the impact

If a 5km diameter stony asteroid did strike Indochina 800,000 years ago then dust, soot and sulfur oxides would have spread around the globe within days and turned day into night. Freezing conditions would have occurred, in even tropical locations. It would have been months, possibly years, before photosynthesis could start again. Adding to the woes of surviving life, the ozone layer would have been destroyed so, once the skies cleared, UV radiation would become a deadly hazard. Moderate greenhouse heating may have occurred once the skies cleared. Irrespective of greenhouse heating, weather patterns would have been severely disrupted for years leading to extreme droughts and floods.

Despite the severe effects on life resulting from the environmental extremes it seems that there would be little long-lasting evidence of this event around the globe. Depending on the composition of the impactor and the characteristics of the impact, a layer of iridium and other indicators of an impact should show up in ice cores, ocean sediments, lake sediments and fossil coral reefs (Schmidt 1993). A possible problem is that this is a very difficult period to date, being beyond the range of many dating techniques but not old enough for others (Dr Peter Haines, University of Tasmania - personal correspondence). The tektite event has been variously dated at between 770,000 and 800,000 years ago. In a recent publication Lee and Wei (2000) used two deep sea cores to derive an age of 793,000 years. They also estimate a crater diameter between 90 and 116km.

The very severe cold spell was probably too short to show up in paleoclimate records (and might have been countered by a brief period of greenhouse warming). Data recently presented by Rutherford and D'Hondt (2000) in relation to glacial cycles over the past 3 million years do not appear to show any pronounced temperature fluctuations 800,000 years ago. D'Hondt cautioned that although the shift to 100,000 year glacial cycles is widely said to have occurred about 700 to 800 thousand years ago it actually began about 1.5 million years ago (personal correspondence).

Similarly, there do not appear to be any signs of the presumed destruction of surface life due to the temporary loss of the ozone layer.

If such an impact occurred today it could result in hundreds of millions, perhaps billions, of deaths, mostly through the collapse of agriculture and subsequent starvation (Paine 1999 and Garshnek 2000, Steel 2000). 800,000 years ago our ancestors, Homo Erectus, were roaming Africa and Southern Asia. Those who survived the direct blast and firestorm effects of the impact would have had to endure extremely harsh global conditions for several years. A species that could control and use fire would have been at a major advantage during those dark, cold months.

This impact may have been a very close call for the survival of mankind.

Acknowledgements

Thank you to the following people for providing advice and comments: Andrew Glikson, Charles Schnetzler, Steven D'Hondt, Alan Harris, David Morrison, Jay Melosh and Peter Haines.

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Appendix - Environmental Effects of Impacts

There are many environmental effects from the impact of a large asteroid or comet with the Earth. These effects depend mainly on:

- the characteristics of the asteroid or comet (size, speed, mass, material composition and strength, trajectory)
- the characteristics of the impact site (land, ice or ocean, latitude, types of rocks) and
- the prevailing climatic conditions (stage of ice age, association with other impacts, season).

There is, therefore, no such thing as a "typical" impact. Subject to this caution, and the speculative nature of many of the estimates, the following table sets out, in approximate chronological order, the expected environmental effects of a large stony asteroid with a speed of 22 kilometres per second striking land in the middle latitudes. This table is adapted from Steel, 1995 and Toon et al 1997.

Estimates of Environmental Effects of Major Asteroid Impacts

Environmental Effects	**Asteroid Diameter**			
	1 km	**2 km**	**5 km**	**10 km**
Kinetic Energy (millions of megatons of TNT)	0.1	1	10	100
Average impact interval	200,000 yrs	500,000 yrs	10 million yrs	100 million yrs
Crater Diameter - rim to rim [transient - slumps within minutes]	24 km [11 km]	46 km [20 km]	100 km [40 km]	200 km [70 km]
Radius for ignition from fireball radiation (within seconds)	150 km	250 km	600 km (but see ballistic ejecta)	1800 km (but see ballistic ejecta)
Blast radius for 4psi o'pressure (500km/h winds, buildings destroyed) and [1 psi o'pressure - trees knocked over] (hours)	130 km [300 km]	180 km [400 km]	470 km [1100 km]	1800 km [4000 km]
Area for firestorm ignition due to radiation from ballistic reentry of ejecta (within hours)	Local	Local (600 km radius)	Regional (5000 km radius)	Global
Earthquakes, hurricanes and tsunami (hours to months)	Regional	Regional	Global	Global
Dark skies and cooling from dust, soot and, possibly, oxides of sulfur.	Regional freezing for weeks. Moderate global effects for weeks (equivalent to Tambora volcanic explosion).	Skies darker than darkest cloud cover. Global drop of 8C for weeks then moderate global effects for months (no summer).	Severe global effects, day becomes night for months.	Very severe global effects. Day becomes night for months. Freezing conditions away from coastlines.

Environmental Effects	Asteroid Diameter			
	1 km	2 km	5 km	10 km
Acid Rain, pyrotoxins (poisons from fires) and heavy metals.	Regional for months	Regional for months	Global for months	Global for years
Ozone destruction (hazard from UV radiation)	Partial global destruction for years	Severe global destruction for years	Total global destruction for years	Total global destruction for decades
Global Greenhouse heating from water and CO_2	Negligible	Minor for years	Moderate for decades	Major for centuries
Global iridium layer (nanograms per square cm) - a signature of the impact.	0.4	2	8	80
Plant growth and extinctions.	Plant growth disrupted for months. Some global crop failures.	Plant growth disrupted for years. Some regional extinctions. Global crops failures.	Photosynthesis stops for months. Decades for plants to recover. Major regional extinctions.	Disruption for hundreds of years. Global mass extinctions

Notes:

1. Many of the values are very approximate and may vary by an order of magnitude.

2. Crater diameters were derived from the LPL Crater Calculator (http://www.lpl.arizona.edu/tekton/crater.html), using dense rock impactor and target surface and a 45 degree impact angle. Two diameters are given, the transient crater formed at the instant of the explosion and the rim-to-rim crater that forms after the transient crater collapses, the ground slumps (usually in concentric rings - see Melosh 1997) and the "rim" spreads further out. The transient crater is important for calculating environmental effects since it is associated with ejected material. The rim-to-rim crater is the one that geologists should be looking for.

3. Fireball ignition radius and ballistic ejecta ignition radius from Toon Figure 16. For shallow trajectories the pre-impact radiant heat from ablation of the asteroid may also be a source of ignition (Lewis 1999).

4. 4 psi Blast radius from Toon Figure 5. 1 psi blast radius based on 4 psi radius times 2.3 (average resulting from a simulation using Lewis's software). There is considerable uncertainty about blast wave effects, which are scaled up from nuclear explosion data. Melosh cautions that, with large impacts, the depth of the atmosphere will have a limiting effect on blast wave magnitude (personal correspondence).

5. Global iridium from Gersonde. Note that there will be greater concentrations of iridium near the impact site, particularly with the smaller impacts.

6. Another indirect consequence of impacts may be the release of huge quantities of methane (a potent Greenhouse gas) from undersea deposits of methane hydrates.

For updates to this table see http://www4.tpg.com.au/users/horsts/climate.htm