h24 Chicxulub bolide crater < pronounced *chicks-HU-loob*, Kyte's rock >

A tsunami at least 50-100 meters high appeared along the Texas coast.
—Joanne (Jody) Bourgeois.[1]

At the outset there was a search for the smoking gun; a very large impact crater of exactly the same age as the iridium-rich E-K clay. Compared astronomical and 40Ar/39Ar ages of tephras in marine deposits in Morocco, used to calibrate the age of Fish Canyon (Colorado tuff) sanidine (FCs) standard, has resulted in a mutually consistent age of ~65.95 Ma for the E-K boundary.[2] Of 170 appropriately large impact craters and structures on Earth already known, none had the right age.

Impact craters are not preserved on Earth for long as topographic features. Convincing evidence that an ancient circular structure is due to a meteorite impact is shock-metamorphosed quartz (***Figure h24.1***) grains in the country rock or in the associated ejecta. Otherwise, all the features could be, arguably, volcanic and most before the 1980s were referred to as cryptovolcanos. (No more, but Carolyn Shoemaker recalls: "That took a while to work out.")[3] At first, sentiment was for explaining the iridium anomaly as due to volcanism or to special conditions of sedimentation.

Volcanism can release ash with higher than background concentrations of iridium. Extremely slow deep-ocean sedimentation rates can result in sediments with elevated amounts of iridium. But anomalous iridium E-K boundary sites around the world soon came to number more than 100 in otherwise unremarkable sediments.[4] The impact hypothesis with each became more reasonable.

Any existing E-K impactor scar should be findable where rocks older than Cenozoic crop out or wherever the satellite-imaged oceanic topography is not deeply buried by terrigenous sediments. Such areas total to about 80% of Earth's surface. Seafloor lost by subduction since the Cretaceous equals about 30% of Earth's surface. At the beginning of the search, that the impact crater could be found had, at least, a chance of 8 to 5. Also, a strewn field of tektites (small glassy droplets produced when country rock immediately adjacent to the vaporized impact site is melted and ejected as droplets that quickly chill) should be findable. Tektite-glass can be radiometrically dated. Analogous, and found in the E-K boundary clay, are diagenetically altered microcrystalline spherules of basaltic composition in northern Italy [5] and at Deep Sea Drill Project site 465 in the central Pacific.[6]

In Texas, the end-Cretaceous succession includes a sand layer of variable thickness (up to 100 cm) that occupies unconnected swales eroded into end-Cretaceous chalk sediments. Fossils in the sand are earliest Cenozoic. The few survivor micro-planktonic species present in the sand layer, as described by Richard Olsson in 1993, are opportunistic and dwindle upward while new species diversified rapidly.[7] The shutdown of the latest Cretaceous (Maastrichtian Stage) shelf environment and the evident erosion of top of the chalk by shelf crossing tsunamis, is consistent with a sudden event such as a bolide which caused the extinction of many photosynthetic plankton. In concert, bivalved mollusks were dealt a heavy blow. David Jablonski and David M. Raup (1995) have found statistically that, for the survival of a genera, neither body size nor habitat was a factor but those that were spread across many continents fared better than those with smaller geographic ranges.[8]

Thick, and spectacular, tsunamis deposits of E-K boundary age are located in Cuba and Haiti. In Cuba, the tsunamis formation is 450 meters thick and contains blocks up to 2 meters in diameter. So, a Caribbean location for the impact crater could be inferred. And, debate as to the origin of the iridium anomaly was soon to cease: In Haiti, the terminal sediment layer of the Cretaceous contains, mixed together the iridium anomaly and irrefutable evidence for a bolide: abundant shock-metamorphosed quartz grains, and tektites. Also, Luann Becker in 2000 found fullerenes in the iridium-rich clay layer with noble gas isotope ratios as in carbonaceous-chondrite bolide fallout.[9]

The crater may have been located. In 1978, geophysicist Glen Penfield, during a routine survey for oil off the north coast of the Yucatan Peninsula, noted a large, semicircular, magnetic anomaly 120 kilometers in diameter. Available onshore gravity surveys showed that the associated structure continues beneath the peninsula.[10] Apparently, beneath a cover of Cenozoic limestones, a large impact crater lies buried. This significant find was made available in 1981. The impact crater has been given the name Chicxulub which is that of the nearby town and the locality (trivia: Chicxulub means, in translation from the dialect, "the tail of the devil").

In 1999, excavations in southeastern Missouri clay pit near Artiola exposed three layers of sediment, each about a half-meter thick. Top down, using Carl E. Campbell's description, these are:

> A dead zone that contains virtually no fossils. This is a thick bed of absorbent montmorillonite clay (that miners scoop up and sell as Kitty Litter) eroded from the ancient Appalachians. It is interpreted as recording a time following end-Permian worldwide mass extinctions.
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> A jumbled mix of broken limestone and fossils that range in size from microscopic plankton- to hand-size shells, abundant crumb-size microtektites and, so far, one a 6-centimeter tooth and a vertebra that probably came from a large marine reptile, *Mosasaur hoffmani*. This is interpreted as evidence of tsunami, which swept northward into the bay covering what's now Missouri, and which was generated by a comet (or asteroid) impactor into the shallow ocean just north of Mexico's Yucatan Peninsula, 65 million years ago.
>
> A layer that contains traces of seafloor burrows and large numbers of phosphate nodules that include the fossils of ammonites (extinct relatives of today's chambered nautilus).[11]

But is this the whole story? The clay layer that marks the E-K boundary in terrestrial successions at other sites throughout western North America occurs as a couplet: the upper layer about 1 centimeter and the lower layer about 2-3 centimeters in thickness. The upper layer could be lateral scatter from nearby sites as ejecta fell back unevenly. However, it might be ejecta from a smaller (32 kilometers in diameter) impact crater, near Manson, Iowa, which has the right age. If so, the impact was a double one.

And is the Chicxulub Crater truly the smoking gun of the end-Cretaceous impact or is it a "zombie," a theory that after the rot has more than set in, lumbers on, the walking un-dead? Gerta Keller has proven to her and many others' satisfaction by noting at El Penon and other localities in Mexico that *below* the end-Cretaceous extinction boundary separated by 4-9 m of normal sedimentation (with burrows formed by colonizing ocean floor creatures and deposited at about 2-3 cm per thousand years) is the Chicxulub-tectite event, which thereby dates 300,000 years too old![12] ❑

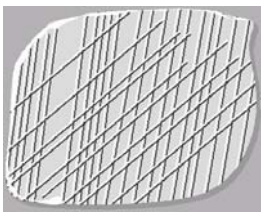

Figure ***h****24.1* Sketch of a quartz grain with telltale lamellae that show it was formerly a high-pressure SiO_2 polymorph—the first lab-made was coesite (monoclinic, density 2.93 g/cm^3) by Loring L. Coes Jr. in 1953[13] and then stishovite (tetragonal, density 4.35 g/cm^3) by S. M. Stishov and S. V. Popova in 1954.[14]

Meteor (*sic*: -ite) Crater—officially named (D. M.) Barringer Crater—east of Flagstaff, Arizona, has features that G. K. Gilbert (1843-1918), first chief geologist of the USGS. interpreted as indicative of volcanic explosion. However, in the 1960s, **Eugene (Gene) Merle Shoemaker** (1928-1997) noted that the cratered strata is overturned in the rim debris (Coon butte). This inversion is like that produced by a shallow-below-ground atomic bomb explosion or, by inference, by a meteorite large enough to have exploded on impact. This "bolide" explanation found corroboration when Shoemaker and Edward Ching-Te Chao discovered that fused-appearing crater derived Coconino quartz sandstone grains are natural coesite.[15]