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Early Quaternary global terrestrial impact of a whole comet in the Australasian tektite field, newest apparent evidences discovery from Thailand and East Asia

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Abstract: Further to our current research in layered and splashed tektites, and numerous impact multiple craters in Ubon; our 1997 new discovery evidences in Khorat, both in northeast Thailand, includes the wide continental burns, mass extinction of trees, ancient elephants, other mammals; and the thick catastrophic loess. All of these were linked to an extraordinary global disaster in a catastrophic event in Thailand and East Asia. These evidences were belonged to and superimposed on the known Australasian tektites strewn field that covers $^{1}/_{10}$ of the Earth's surface. The age of the event must be correlated with the radiometric dating of tektites by Laser-fusion $^{40}Ar/^{39}Ar$ methods and gave ages between 0.770 ± 0.020 Ma, which was most consistent with an early Quaternary and is possibly correlated with a glacial stage at O-isotope stage 20.2, and magnetic stage ~NN20.

In Northeast Thailand several locations in sands pumping pits, 20 km east of Khorat, were deep enough to > 12 m to reveal abundant or numerous irregular piles of the whole or partly burnt, partly or wholly petrified trees, logs, huge trunks or woods pushed and pulled down abruptly on the basement by tremendous force. A few ancient tree genera can be identified. Nearby complete ancient elephants teeth and bones of *Zygolophodon (Sinomastodon)* sp. and *Stegolophodon (Eostegodon)* sp. of a Pleistocene age are found buried above the bottom of the pits.

These evidences could suggest an event for an enormous terrestrial impact of a big comet, judged by the abundant distribution of layered tektites relative to craters, and a considerable size and large numbers of multiple craters in the 800 x 1,140 km center between Hainan Island-Cambodia, with Ubon at a western edge. Microtektites and microspirules were found in the catastroloess both in Khorat and central China indicating a corresponding age. Depletion of water in Australasian tektites and high ^{10}Be in Chinese catastroloess suggests both were temporally originated in a dry cool glacial stage of the Pleistocene glacial period.

It was evidently the Australasian tektites field was caused by a global impact of a comet. The cometary impact theory that formulated the catastrophic disaster, named here the Buntharik Event, is suggested from this consequence in northeast Thailand and East Asia. There were 2 episodes in the destruction after impact and formed tektites in the field, and prolonged episode forming even greater and the first known catastroloess field, superimposed the former. It was also the only first apparently known evidences of a destruction of a comet impact.

INTRODUCTION

New apparent evidences of the most disastrous catastrophic event will be given after the contending views of tektites. The currently discovery is the numerous possible multi-impact craters in the extra large center by Wasson and his team in 1994 (Fig. 1), and new discovery of continental wide bursts, and forest fire burns; the mass extinction of animals and plants; and the one introduced here as the catastroloess, with thickness > 12 m to 50 m of catastrophic earth-sands burial characteristic, globally widespread from the sources. It covers one-third of global surface (Bunopas *et al.*, 1998), comparing with tektites in the same field cover one-tenth of the Earth's surface (Glass and Pizzutto, 1994). It has been known before by most scientists as a normal "loess", but no one has imagined before as it was one of the most significant geological terrestrially record on earth. No body aware of its major direct connection associating with tektites in this extravagant catastrophic event. Eventually, we all in East Asia are settling on this catastrophic loess, one way or another, even on top of the ranges to bottom of the valleys or the bottom of the seas.

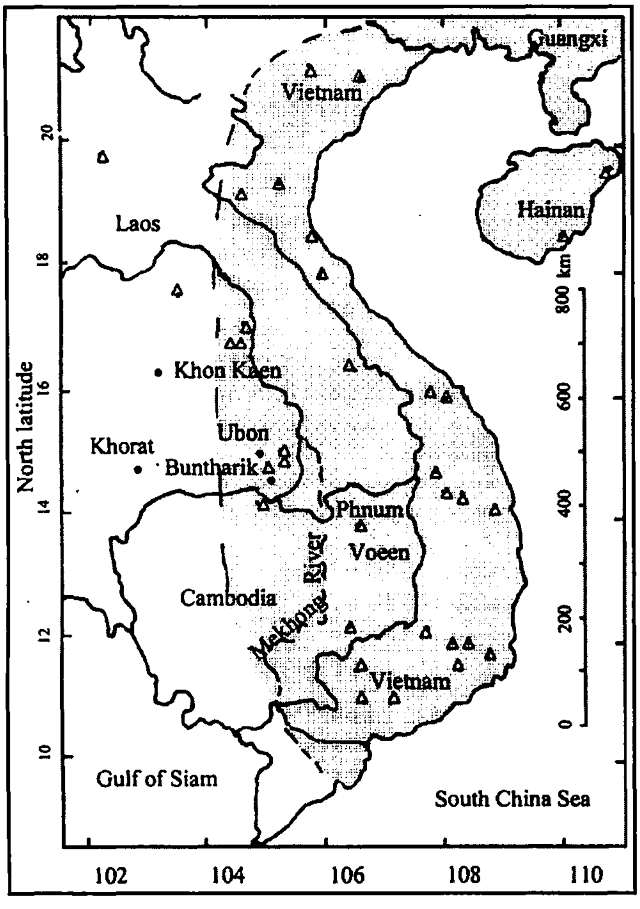

Figure 1. Location map of Southeast and East Asia (Hainan). Triangles shows the provenance of Southeast Asian layered tektites or Muong Nong tektites (modified from Wasson, 1991 with data also, from Izokh and An 1988).

The Australasian tektites strewn field, the best known tektites field on earth consists two kinds of tektites in Thailand. The layered tektites (Barnes and Pitakpaivan, 1962; Barnes, 1971; Wasson, 1991) or stratified tektites (Bunopas *et al.*, 1997) with distinctive banding and relics of incomplete melted parent materials and were solidified on the ground shortly after the impact and they were distributed with in or close to the craters in the center, and the splashed tektites (Wasson, 1991) or formed tektites (Bunopas *et al.*, 1997) are found in various forms and shapes that were distributed away from the craters in the center in Thailand and East Asia. They are commonly small in size, less than 0.3–0.5 kg, but the layered tektites in or near the Hainan-Indochina-Thailand impact center (Fig. 1) can be up to exceptional sizes around 12.8 kg (Barnes, 1971) or even 24 kg (Wasson, 1991). Special aero-ablated forms common in Australia were the small broken solid pieces trajectory through lower space and fall down at sites more than 3,000 km from source to as far as Tasmania. Both varieties of tektites consist (Table 1) of more than 70% SiO_2, 12% Al_2O_3, 5% Fe_2O_3 + FeO, and the rest being TiO_2, MnO, CaO, Na_2O, K_2O to make the total up to 99.9% (Glass, 1990; Glass and Koeberl, 1989; Wasson, 1991). Mineral inclusions ranging from 20–150 micron of zircon, chromite, rutile and quartz plus corundum (Glass and Barlow, 1979). All the inclusions showed evidence of various degrees of shock metamorphism. They indicated gases trapped in similar to the atmospheric or a little lighter (Hennecke *et al.*, 1975). Temperature range for various possible and observed thermal reaction in Muong Nong tektite-type indochinites was from 1,000 to 2,000°C under normal atmospheric condition (Glass and Barlow, 1979). Various methods of radiometric dating of tektite covered one-third of the Earth's surfaces from this field are between 0.709–0.770 ± 0.020 Ma (Zahringer, 1963; Gentner *et al.*, 1967; 1969; Blum *et al.*, 1992; Izett and Obradovich, 1992), or a Lower Quaternary age (Bunopas *et al.*, 1997; Bunopas *et al.*, 1998).

The global sheet of the catastroloess or the catastrophic loess is > 12 m in Thailand (Bunopas *et al.*, 1997) Asia and less in Australia and much less in New Zealand, was misinterpreted, and was already known to be widespread in these regions as an ordinary "loess" for many centuries. This atmospheric earth-sands buried numerous fossil trees and large numbers of fossil mammals found in the lower part in the sandpits in northeast Thailand. This sands are correlated with the famous Chinese style loess or the Chinese yellow earth in Xi-an in central and north China (Wang *et al.*,

Table 1. Chemical analyses of Australasian tektites.

Wt %	Muong Nong Type (2)		Indochinites (52)		Billitonites (14)		Philippinites (21)		Australites (32)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
SiO_2	72.97	72.44–73.50	73.68	70.58–81.36	71.32	68.30–76.40	70.87	68.90–72.10	73.06	68.91–79.51
TiO_2	0.75	0.74–0.76	0.82	0.47–1.03	0.78	tr–1.10	0.83	0.63–1.04	0.68	0.08–0.90
Al_2O_3	12.97	12.59–13.34	12.47	8.87–14.39	12.04	9.86–13.50	13.48	12.08–15.23	12.23	9.36–15.42
Fe_2O_3	0.35	0.29–0.41	0.32	0.03–0.82	0.77	0.06–2.25	0.79	0.50–2.03	0.60	0.23–1.48
FeO	4.16	4.03–4.20	4.52	2.81–5.63	5.10	3.17–6.81	4.30	3.03–5.32	4.14	3.11–5.30
MnO	0.10	0.09–0.10	0.11	0.06–0.32	0.14	0.08–0.32	0.09	0.08–0.16	0.12	tr–2.42
MgO	1.97	1.93–2.00	2.05	1.11–2.93	3.18	2.38–4.96	2.67	2.23–3.65	2.04	1.35–2.49
CaO	2.16	2.16–2.16	2.17	1.00–3.48	2.95	2.22–3.92	3.14	2.50–3.97	3.38	1.48–5.10
Na_2O	1.60	1.58–1.61	1.42	0.90–2.00	1.55	0.77–2.46	1.41	1.18–1.76	1.27	0.91–1.84
K_2O	2.47	2.45–2.48	2.39	1.84–3.16	2.19	1.57–2.76	2.31	1.69–2.56	2.20	1.25–2.56
Total	99.50		99.95		100.02		99.89		99.72	

* Data from Barnes and Pitakpaivan (1962) and Barnes (1963).

1985; Heins *et al.*, 1991; Li *et al.*, 1991; Han *et al.*, 1997). The catastroloess field covers 1/3 (Bunopas *et al.*, 1999) while the well known Australasian tektites strewn field covers 1/10 of the Earth's surface (Glass, 1990), besides the former is readily apparent visually and less contending.

The first known extinction of ancient floras in northeast Thailand included *Diptereocarioxylon* sp.; *Dipterocarpoxylon* sp.; *Terminalioxylon* sp. and common gymnospermes *Araucarioxylon* sp., and the first fossil palm found in Southeast Asia, *Palmoxylon* sp. of affiliate Tertiary or early Quaternary. Identifiable ancient elephants teeth and bones of *Zygolophodon (Sinomastodon)* sp. and *Stegolophodon (Eostegodon)* sp. of a Pleistocene age are found amongst crocodile teeth and bones, some other mammal's bones. This extraterrestrial catastrophe, named here the "Buntharik Event", had caused the occurrence of Lower Quaternary tektites and the global continental fire, burning forest, thick atmospheric loess-sandy debris accumulation, which also admixed to those local vital normal conditions in mountainous valleys, smoothen the physiogeography of most valleys and flood plains in Thailand.

The knowledge from 1997 discovery might also paves ways to the understanding of what had happened with the dinosaurs in the North American Continent, in K-T boundary, 65 Ma ago. We found that present synthesis supported the comet theory that terrestrially collided with the earth, with dating on tektites was 0.770 ± 0.020 Ma (Izett and Obradovich, 1992) and created the unbelievable disaster in the most hazardous Buntharik Event, the late global event of this kind. Only microtektites and glass microspirules were studied from offshore of Haiti (Izett *et al.*, 1991; Sigurdsson *et al.*, 1991) for the K-T event. The analogous of the two events was the large mass extinction of lives suggesting both were most likely the duplicate events though much smaller impactor suggested by restricted iridium of the younger Buntharik Event in the DSDP sedimentary cores (Schmidt *et al.*, 1993).

We will review the issues surrounding the impact event, as well as the production of catastroloess. Similarly, the composition, age, and especially the contending views on the origins of tektites in this paper. This paper discuss the consequence of the 1997 discovery evidences, that made the cometary impact theory in the Australasian tektites strewn field.

TEKTITES

Tektites generally appear to be opaque black; however as mentioned by Glass (1990), some tektites transparent brown or green are found in the globe less than 50 Ma old and are richest in Thailand and Indochina. Tektites found at any levels at present apart from above the basement or at lower level in the covering sands can only reflects a reposition, since or during the catastrophe, later mixing with vital natural condition until finally settled down to normal, and much later long reworking geological processes until the present day.

Contending views of tektites

Although most investigators believe that tektites are impact-produced glasses, their origin is still controversial (e.g., O'Keefe, 1976; Wasson, 1991). During the 1970's and 80's, the idea of extraterrestrial origin for the Australasian tektite belt was very popular (Izokh and An, 1988). It was indicated by the dimensions of the belt itself, the lack of impact craters, an absence of known impactites, and little indication of concentric zonation relative to possible terrestrial source and ballistic considerations (O'Keefe, 1976).

It is widely accepted today that the tektite shower over Australia and Southeast Asia occurred about 0.6–0.7 Ma (O'Keefe, 1976). Australian geologists have however disputed this date, and point out that tektites lie *in situ* in a stratigraphically very young series of deposits whose ^{14}C age is 5–10 Ka. This 'age paradox' of tektites has long been problematic and was confirmed in the Vietnam study by Izokh and An (1983). In their opinion, the age paradox is a strong point in favour of the extraterrestrial origin model for tektites. They contended that tektite showers occurred when there were collisions of extraterrestrial objects **above** the globe. The many ages of these events are reflected in the different carbon isotope dates given for tektites, as well as explaining the position of tektites in varying levels of loess and yellow sands. Izokh and An (1988) did not distinguish between types of tektites, since they regarded all as formed by extraterrestrial collision.

Extraterrestrial tektite origin has not been refuted until the present; and the current consensus is that tektites are the result of one or more impacts of large bodies with Earth. This argument is developed later in this paper.

Similarly, the **number** of associated impact craters is a hotly contested topic. Two models for the origin of Australasian tektites compete in recent research.

Ford (1988) used satellite imagery to define an elliptical depression 10 km x 6 km in Phnum Voeene, northeast Cambodia, a formation claimed to be caused by the impact of an extraterrestrial object. Ford (1988) suggested that melted Mesozoic sandstone yielded tektites in place, with those ejected into the atmosphere producing a concentric arrangement of different types of tektites. Layered tektites occurred proximally; discs and dumbbells over mainland Southeast Asia; discs and spheres over Indonesia and the Philippines; and aero-ablated forms distally over Australia as far as Tasmania. This single-crater hypothesis has been endorsed by Blum *et al.* (1992), Koeberl (1992) and Schnetzler (1992). Based on the study of trace elements in Muong Nong-type tektites from Indochina, Koeberl (1992) interpreted a single, slightly heterogeneous source, rather than different source regions.

However, Wasson (1991) noted that large layered tektites (with thickness of 2–3 cm and masses up to 24 kg), found throughout east-northeast Thailand and other Indochinese regions, implied a multicrater centre with minimum dimensions of 800 x 1,124 km, extending from Hainan Island (Yuan, 1981; Futrell and Wasson, 1993) to southern Vietnam (Izokh an An, 1988) and Cambodia. This represents a major centre containing numerous impact craters with a collective size thousands of times larger than that estimated by Ford (1988). Wasson did not overlook the possibility of a fragmented extraterrestrial object or a large comet as being responsible for forming such an extra large cratering centre. The largest impacts ejected the microtektites and some splashed form tektites above the atmosphere, while numerous smaller impacts produced a nearly continuous sheet of impact melt across much of Southeast Asia (Wasson, 1991; Wasson and Heins, 1993; Wasson *et al.*, 1995).

There is compelling evidence indicating that layered tektites formed as sheets or pools of melt. From a lens-shaped mass of tektites excavated near Phang Daeng, it was concluded that layered tektites represented 'puddles' of melted soil resultant from the impact of a large 'diffused body' and the consequent fireball (Barnes and Pitakpaivan, 1962). Because there are difficulties with the impact transport of melt at distances > 600 km, tektite distribution across a field > 1,140 km in length is inconsistent with their formation in a single crater. Layered tektites should therefore be deposited within a few crater radii of their parent crater, and many craters are required to account for their distribution across a field > 1,140 km long. Confirmation of this model may be obtained by the discovery of predicted km-size craters or by demonstrating that extensive and widely separated regions yield only layered tektites, and were thus covered with continuous melted sheets ejected from independent craters.

Tektites expedition in Thailand and Southeast Asia

Since the first collection of Barnes and Pitakpaivan (1962) from the Department of Mineral Resources in 1960 at Phang Daeng near now Mukdahan, more collection was done with reports, but not until Ramsey Ford of the University of Tasmania, Australia (Ford, 1988) and the senior writer made two half months on route surveys to investigate the nature and distribution of tektites (Ford, 1988; Bunopas, 1990, 1992). After the investigation Ford proposed the mechanism that the tektites could be involved in the trajectory from Cambodia to as far as Tasmania and known as the australite (Ford, 1988). Ford's australite resembles a small layered tektite in our terminology here.

Contributions made by Wasson and colleagues from Institute of Geophysics and Planetary physics of the University of California, Los Angeles and the Department of Mineral Resources in Thailand (Wasson, 1987, 1989, 1991; Wasson and Heins, 1993; McHone *et al.*, 1994; Fiske, Puttaphiban and Wasson, 1996; Bunopas *et al.*, 1997, 1998) had have lighted up the interest of wider groups of local scientists at home and aboard. This was new findings occurred in late 1997.

In Indochina countries, since the activity in Laos of LaCroix (1935) there was no further movement. In Vietnam, Fontaine (1966) made an independent noted of some medium Muong Nong tektites near Ho Chi Minh City with little further discussion. Twenty years later until Izokh and An (1988) studied tektites in Vietnam and mentioned that they were similar in composition in body and shape with the Australo-Asiatic belt extended as a narrow 11,000 km from Tasmania to Vietnam. Izokh and An stressed that all of these facts indicate the belt was the single event — a grandiose tektite shower. They believed an extraterrestrial impact of tektites fell to the earth.

Ford (1988) proposed one single crater in Phnum Voeene, in northeast Cambodia. While Wasson (1991) on the other hand favors multicrater of origin of tektites. He notes layered tektites having thickness of 2–3 cm and masses up to 24 kg are found throughout east Northeast Thailand and the Indochina countries shown to have a minimum dimension of multicrater of 800 x 1,124 km from Cambodia to Hainan Island (Fig. 1).

There were a few publications referring to Cambodia tektites including Hildebrand *et al.* (1994); Hartung *et al.* (1994); Hartung (1990); Hartung and Rivolo (1979); Ford (1988). In China, Yuan (1981); Xu *et al.* (1989); and Futrell and Wasson (1993) reported the occurrence of layered tektite weighing 10.8 kg from Wenchang, Hainan Island, south China.

Scattered tektites in the neighbouring countries of Thailand were recorded in west Malaysia, Indonesia and Myanmar? (Sia, 1978; Lam, 1983; Stauffer, 1983; Gangadharam *et al.*, 1978). These areas are regarded by us as possibly outside the multimpact cratering area of Wasson (1991) or multicrater center in this paper.

The Australasian strewn field tektites and the 3 older fields

Tektites generally appear to be opaque black, however as mentioned by Glass (1990), some tektites are transparent brown or green.

Tektites are found scattered over large areas of the Earth's surface called strewn fields (Fig. 2). The tektites from a given strewn field are believed to be the result of a single event or tektite shower. Tektites from each strewn field are characterized by their composition and age. The youngest strewn field, the Australasian, has an age of 0.7 Ma (Zahringer, 1963). Tektites belonging to the Australasian strewn field are found in Australia, Indonesia (Borneo, Java and Belitung Island), Malaysia, Indochina (Vietnam, Cambodia and Laos), Thailand, southern China and the Philippines. Some authors believe that the Australasian tektites (australites) are 0.83 Ma old (Storzer *et al.*, 1984), whereas others believe they fell < 20,000 years ago (Chalmers *et al.*, 1976). Microtektites belonging to the Australasian strewn field have been found in deep-sea sediments from the Indian Ocean, western Pacific Ocean, and the Philippine Sea (Glass *et al.*, 1979). They have a stratigraphic and formation age of ~ 0.7 Ma (Gentner *et al.*, 1970). Age dating on the Australian tektites by laser fusion $^{40}Ar/^{39}Ar$ was 0.770 ± 0.020 Ma (Izett and Obradovich, 1992). There was no evidence of a 0.8–0.9 Ma old for micro-australite layer in deep-sea cores as stressed by Glass (1976).

The Ivory Coast tektites have radiometric ages of ~ 1 Ma. Tektites from this strewn field are rare; however, Ivory Coast microtektites have been found in the eastern equatorial Atlantic Ocean.

Tektites found in Czechoslovakia, called moldavites, are 14.7 Ma old (Gentner *et al.*, 1967). These tektites are distinguished by their transparent nature and green color.

The oldest strewn field is the North American, which has an age of ~ 34 Ma old (Zahringer, 1963). Tektites belonging to this strewn field have been found in Texas (bediasites) and Georgia (georgianites). A single specimen was found at Martha's Vineyard and one possible came from Cuba (Garlick *et al.*, 1971). Microtektites belonging to the North American strewn field have been found in the Gulf of Mexico, Caribbian Sea, Barbadoss, and on the continental slope off New Jersey (Glass and Zwart, 1979; Sabfillippo *et al.*, 1985; Keller *et al.*, 1987; Thein, 1987).

Based on the number (mass) of microtektites per unit area at each site, Glass *et al.* (1979) calculated that there are approximately 100 million, 20 million and 1,000 million tones in the Australasian, Ivory Coast and North American strewn fields, respectively. No microtektites are found from the Czechoslovakian field.

There is now also evidence of Australasian microtektites recovery from China Cenozoic loess (Heins *et al.*, 1991; Li *et al.*, 1991) and in the catastroloess at Korat in Thailand (Burrett, per comm.). Microtektite-like bodies, some with glasses preserved in their interiors, have been found in sediments associated with the Cretaceous-Tertiary (K-T) and a few other impact event (e.g., Izett *et al.*, 1991; Sigurdsson *et al.*, 1991).

Other glasses that have been linked with tektites includes Darwin glasses, irghizites and Libyan desert glass. Darwin glass in Tasmania may be associated with a small nearby crater (Fudali and Ford, 1979). Irghizites are found in the Zhamanshin impact structure in southern Siberia. They have compositions and ages similar to the Australasian tektites, but many are composite form consisting of numerous droplets welded together. Libya desert glass refers to silica-rich glass bodies found in Egypt desert (Week *et al.*, 1984). They have sometimes been liked with tektites, but they do not have the typical splash shapes and they are composed primarily of silica (> 97%). This glasses have gage of ~ 28 Ma (Storzer and Wagner, 1971).

Glass (1990) made his conclusions on tektites that they are generally small, rounded glass objects that superficially resemble obsidian. They occurred in four widely separated regions of the Earth's surface called strewn fields which range in age from 0.7–34 Ma Compositionally they resemble terrestrial sedimentary deposits. The presence of lechatelierite, coesite, baddeleyite and shocked relict crystal that the tektites were formed by an impact event. However unlike the Cretaceous-Tertiary (K-T) boundary layer, the microtektite layers are not associated with mass extinction or iridium anomalies. The absence of mass extinctions associated with the tektite events may simply reflect the smaller size of tektite events in comparison with the K-T boundary event. The lack of an iridium anomaly, however, is perplexing (Glass, 1990). Nevertheless, later it was known that iridium anomaly associated with the Australasian tektite-producing impact from masses regarded as the impactor of the Australasian tektites was limited due to at least three order of magnitude smaller than that impactor at the end of Cretaceous (Schmidt *et al.*, 1993).

However, the discovery of 2 genera of Mastodont and Stegodon in Thailand (Bunopas *et al.*, 1998) may add to the knowledge of the mass extinctions of these ancient elephants, with some extinct ancient trees in the Australasian tektites field.

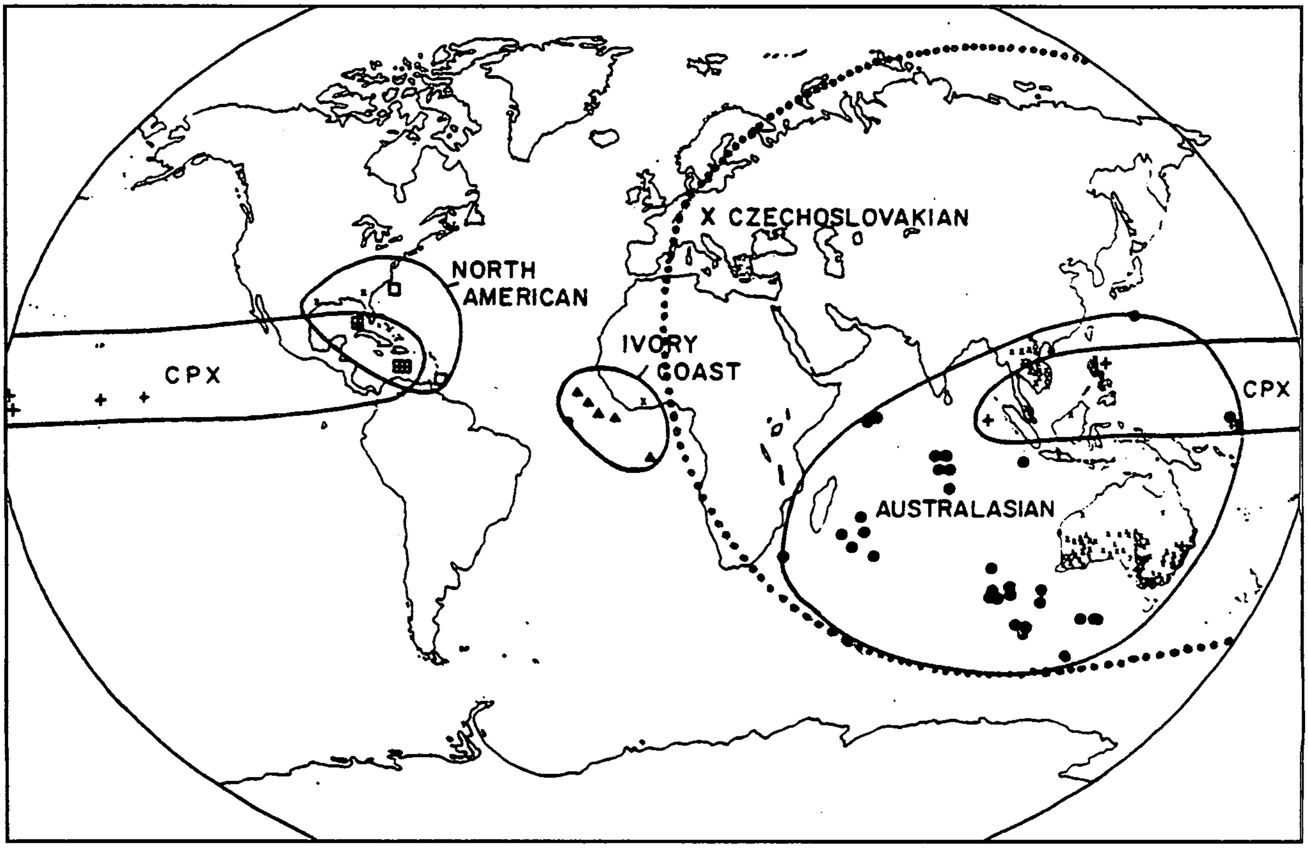

Figure 2. Map showing the Australasian, Ivory Coast, Czechoslovakian and North American tektite strewn fields. Also shown is the clinopyroxene-bearing (Cpx) spherule-layer strewn field (Glass, 1985). Locations of tektite occurrences on land are in indicated by X. Core sites where Australasian, Ivory Coast, and North American microtektites have been indicated by dots, solid triangles and open squares, respectively, Sites where Cpx-bearing spherules have been found are indicated by plus signs, Sites where North American microtektites and Cpx spherules have been found are indicated by square with a plus sign inside (from Glass, 1990). Dotted line added is probably a minimum extension of the newly discovered Quaternary catastroloess field (see text).

IMPACT MODEL OF TEKTITES ORIGIN

It is commonly accepted, as noted by Wasson and Heins (1993), that tektites formed by the impact melting of continental sediments base on the close similarities of elemental abundance patterns (Taylor and McLennan, 1979; Koeberl, 1986; 1992; Wasson, 1991) and isotopic ratio (Shaw and Wasserburg, 1982; Blum *et al.*, 1992). Primarily because two of the four strewn fields appear to be linked to known impact craters, most recent discussions of tektites formation include the assumption that they are produced in craters having diameters at least as large as that of Botsumtwi (10.5 km). It is clear that a large amount of energy must be deposited in one place in order to launch tektites and microtektites though the atmosphere; tektitic melt having mm-size or large dimensions that remains in the troposphere or stratosphere will fall out within 10s of km of the production site. Melosh (1989) states that the minimum energy requirements for an atmospheric blowout event correspond to the production of a 3-km crater.

Two classes of model for the origin of Australian tektites have been discussed in recent papers (Wasson, 1991):

1. the traditional single-crater hypothesis has been endorsed by Blum *et al.* (1992), Koeberl (1992) and Schnetzler (1992). On the trace elements study of high- and low-refractive index of Muong Nong-type tektites from Indochina Glass and Koeberl (1989) interpreted these results to indicate a single, slightly heterogeneous source for the Muong Nong-type tektites, rather than different source regions. Ford (1988) also reported to have a 80-km source crater in Phnum Voeene, northeast Cambodia;
2. in contrast, Wasson (1991) argued that the properties of layered tektites require formation in a multitude of craters scattered across Southeast Asia. The fireball radius corresponds approximately to a few crater radii (Melosh, 1989). Because large layered tektites are found in a region ~1,140 km long, Wasson inferred that the Australasian tektites originated in a multitude of km-size craters throughout a region extending from Hainan Island to Cambodia (Fig. 1).

Much of the basis for multiple crater or single crater models of tektites formation, Fiske *et al.*, 1996 noted in his report of the excavation of layered tektites in Buntharik, Thailand, has come from paleomagnetic and chemical studies (Chapman and Scheiber, 1969; de Gasparis *et al.*, 1975; Shaw and Wasserburg, 1982; Wasson, 1991; Koeberl, 1992, 1993, 1994; Schnetzler, 1992; Blum *et al.*, 1992; Matsuda *et al.*, 1993; Wasson and Heins, 1993).

The magnetic reversals suggested multiple impact craters model (Chapman and Scheiber, 1969; de Gasparis *et al.*, 1975; Shaw and Wasserburg, 1982; Burns, 1989; Schneider *et al.*, 1992) and, multiple craters (Wasson, 1991) indicate a diffused object (Barnes, 1964; Blum *et al.*, 1992) or a fragmented object (Wasson, 1991; Wasson and Heines, 1993) or a comet (Bunopas *et al.*, 1998) impact. The very similar suggestive time of origin with the last reversals of magnetic field is also noted.

Multiple impact crater in the 800 x 1,140 km impact center from Hainan, Vietnam, Northeast Thailand and Cambodia

The search for impact center which normally contains variable size of layered tektites in Thailand, and much wider areas in the Indochina were studied initially from space imageries in 1994. A group of suspected impact craters, with diameters range form 5 to 10 km in south of Ubon Ratchathani were investigated. One in Buntharik appeared to have three quarter of their remaining three km diameter circular raised ridges below 25 to below 50 m above the ground, all were subdued within the scarcely exposed Cretaceous sandstone and shale terrain, out of the salt, under the widespread covers of Quaternary Catastroloessic sands. Shock indications in quartz grains from a weathered sandstone basement in Buntharik were identified by Clive Burrett from the group.

Mineral inclusions in Muong Nong-type tektites indochinites all showed evidence of various degrees of shock metamorphism (e.g. fracturing, droplet formation, X-ray asterism). The mineral assemblage indicate a sedimentary source material. Thus it appears that the Muong Nong-type tektites indochinites were formed by shock melting of a well sorted, silt-size, sedimentary material (Glass and Barlow, 1979).

The largest possible impact crater is more than 80 km across with two third of its northern part observed from a blown up imagery are nicely preserved in the correlated terrain of Phanum Voeene in northeast Cambodia. This was the crater discovered by Ford (1988).

A multiple impact origin for the Australasian tektites was documented by intensive laboratory works and fields observation of Wasson (1991). High-precision neutron-activation studies of Southeast Asia tektites confirm their close compositional relationship to well-mixed continental sediment. In confirmation of early study, concentrations of volatile metals, Zn, Ga, As and Sb are 2–4 times lower in splashed-form tektites than in layered (or Muong Nong-type) tektites. The Th/U ratio is higher in splash-form than in layered

Table 2. Major element X-ray fluorescence analyses of layered tektites from Huai Sai, Ubon Ratchathani, northeast Thailand (in wt %) (from Fiske *et al.*, 1996).

Oxide	T-257A	T-261B	T-262A	T263W	Average	Koeberl, 1992*	Schnetzler, 1992†	Wasson, 1991§
SiO_2	79.66	79.96	78.86	78.49	79.54 ± 0.06	78.93 ± 1.50	76.25 ± 3.05	
TiO_2	0.61	0.60	0.61	0.62	0.61 ± 0.01	0.63 ± 0.05	0.68 ± 0.10	
Al_2O_3	9.14	8.95	9.25	9.49	9.2 ± 0.2	10.19 ± 0.98	11.10 ± 1.53	
Fe_2O_3‡	3.79	3.71	3.80	3.96	3.82 ± 0.09			
MnO	0.09	0.09	0.09	0.09	0.09 ± 0	0.08 ± 0.01		0.07 ± 0.01
MgO	1.53	1.48	1.51	1.58	1.52 ± 0.04	1.43 ± 0.13	1.67 ± 0.34	
CaO	1.48	1.43	1.47	1.55	1.48 ± 0.04	1.21 ± 0.15	1.63 ± 0.52	1.90 ± 0.65
Na_2O	1.52	1.48	1.55	1.54	1.52 ± 0.03	0.92 ± 0.09	1.40 ± 0.19	1.36 ± 0.22
K_2O	2.28	2.25	2.28	2.30	2.28 ± 0.02	2.42 ± 0.10	2.47 ± 0.19	2.42 ± 0.65
P_2O_5	0.09	0.09	0.09	0.09	0.09 ± 0			
Total	100.19	100.04	100.51	99.71	100.11			

* 19 samples analyzed by microprobe for major elements.
† 75 analyses compiled by Schnetzler, 1992, including data of Koeberl, 1992; shows 1σ range of composition.
§ 16 samples analyzed by neutron activation; samples from northeast Thailand only.
‡ Samples are fully oxidized during preparation of the fused disk.

tektites; this implied loss of about 30% of the initially U from the splashed-form tektites. Volatile contents of layered tektites are similar to those in continental sediments indicating minor or negligible loss during formation. Remarkably coherent relationship between Cr and Co and an associated Ni-Co correlation indicate the variable presence of a minor ultramafic component having an atypically low Cr/Co ratio.

Layered tektites having thickness of 3–20 cm and mass up to 24 kg are found throughout a region now show to have minimum dimensions of 800 x 1,140 km (Wasson, 1991, Fig. 1). There is compelling evidence indicating that the layered tektites formed as sheets or pool of melt. Because there are severe difficulties with the impact transport of melt > 600 km, their distribution across a field > 1,140 km in length is inconsistent with their formation in a single crater; maintenance of the melt in a liquid state required that it remained in the fireball until it neared the ground. Thus layered tektites should deposited with a few crater radii of their parent crater, and many craters are required to account for their distribution across a field > 1,140 km long. Confirmation of this model can be obtained discovering the predicted km-size craters or by demonstrating that extensive and widely separated regions yield only layered tektites, and were thus covered with continuous melted sheets ejected from independent craters.

It is not possible to create a crater field 1,200 km long as a result of a meteoroid disintegrating in the Earth's atmosphere. The largest strewn field for the meteorite is about 100 km long (for Campo del Cielo — Cassidy *et al.*, 1965). Speculations about multiple impacts was further made by Wasson (1991) for the 800 x 1,140 km field that could not disregarded a comet with a vertical possible impact. The dimension was incompatible with a single source model. Rather the Australasian tektites were produced by the impact of a fragmented object. The largest impact or impacts ejected the microtektites and some splashed formed tektites above the atmosphere while numerous smaller impacts produced a nearly continuous sheet of impact melt across much of Southeast Asia (Wasson, 1991; Wasson and Heins, 1993). Fiske *et al.* (1996) have analyzed (Table 2 and Table 3), shape, composition and spatial distribution of 6 kg of layered tektite fragments excavated from a 3 m x 3 m area near Ban Huai Sai, north of Amphoe Buntharik in Ubon, northeast Thailand. Their analysis suggests that these fragments represent a single homogeneous mass that underwent fragmentation far in the past and has undergone little disturbance since its distribution. They have also studied the stratigraphic occurrence of layered tektites exposed *in situ* near Ban Huai Om. Tektites were found along a disconformable paleo-erosion covered by recent aeolian sand, called here partly reworked catastroloess, similar to other occurrences throughout Southeast Asia. This stratigraphic relationship provides little chronostratigraphic information and, thus, does not support a stratigraphic "age paradox" for Australasian tektites. The present-day surface density of layers tektites in this area is 2 to 20 g/m^2 (Fiske *et al.*, 1996).

Table 3. Trace element X-ray fluorescence analyses of layered tektites from Huai Sai, Ubon Ratchathani and comparison to previous studies of layered tektites from Thailand (data in ppm) (from Fiske *et al.*, 1996).

Element	T-257A	T-261B	T-262A	T263W	Average	Koeberl, 1992*	Wasson, 1991†
Nb	16.3	16.2	16.4	16.7	16.4 ± 0.2		
Zr	369.8	359.7	368.3	376.0	368 ± 6	280 ± 101	305 ± 36
Y	26.1	26.0	25.9	26.7	26.2 ± 0.3		
Sr	119.6	116.7	116.0	118.8	118 ± 1.5	136 ± 48	134 ± 25
U	2.2	2.0	2.1	2.9	2.3 ± 0.4	2.5 ± 0.4	2.6 ± 0.3
Rb	99.3	98.1	97.1	98.3	98.2 ± 0.8	110 ± 11	116 ± 15
Th	12.7	11.9	12.7	13.5	12.7 ± 0.6		15 ± 2
Pb	20.0	18.0	19.4	18.0	19 ± 0.9	6.8 ± 1.5	
Ga	11.2	11.3	11.3	11.4	11.3 ± 0.1	24 ± 6	13 ± 2.5
Zn	55.4	53.9	54.6	55.7	54.9 ± 0.7	67 ± 10	50 ± 14
Cu	12.8	12.5	13.1	13.5	13.0 ± 0.4	14 ± 4	
Ni	26.5	27.8	25.2	27.8	27 ± 1	49 ± 17	49 ± 35
V	58.8	60.1	61.2	60.3	60 ± 1	72.3 ± 15.7	
Ce	95.7	103.5	104.8	91.8	99 ± 5	60.7 ± 4.0	79 ± 9
Ba	367.2	350.6	345.0	373.1	359 ± 12	341 ± 57	396 ± 30
La	26.3	28.7	32	35.6	31 ± 4	28.2 ± 2.0	41 ± 4

* 19 samples analyzed by neutron activation.
† 16 samples analyzed by neutron activation; samples from northeast Thailand only.

Parent material or source crater of Australasian tektites and climate during the terrestrial impact

Some Precambrian and Paleozoic granites were, among 11 observation pitting areas beside the more common lateritic gravel beds and Mesozoic sandstones, seen at the bases of the pits in Vietnam (Izokh and An, 1988) indicating source materials. A possible origin of tektites by soil fusion at impact sites was noted by Schwarcz (1962).

Original rocks from the basement before they were molten must be Jurassic-Cretaceous continental sandstones, from the Jurassic-Cretaceous continental redbeds Khorat Group, and with very thin decomposed sandy soil in the region, which is confirmed by our latest field investigation and geology of the area in Thailand (Bunopas *et al.*, 1997). Blum *et al.* (1992) stated that "Nd and Sr isotope data provide evidence that all the Australasian tektites were derived from single sedimentary formation age close to 170 Ma" and "are most explained with a single impact event". These were melted on land by the impact source and add nothing to them judged by chemical analyses, rare earth minerals, mineral fluid inclusions and trace elements (Schwarcz, 1962; Glass, 1970; 1972; Muller and Genter, 1973; Glass and Barlow, 1979; Glass and Koeberl, 1989; McLennan, 1989), but a possible offshore impact site has been also given (Schnetzler *et al.*, 1988), and Hartung (1990) questioned the Tanle Sap for a site also.

Water depletion of tektites (Vickery and Browning, 1991) and also ^{10}Be in Chinese loess might indicate a dry cold, in a glacial stage and with the recommended age it could be an isotope stage 20.2 (Wasson and Heins, 1993), or a Lower Quaternary paleomagnetic stage (~MM 20). These tektites were dated around 0.750 ± 0.20 Ma (Izett and Obradovich, 1992) before present time, and were belonged to the Australasian strewn-field, probably the late tektite fields known in our geological history.

In order to have enough tektites distributed in the Australasian tektites strewn field Wasson and Heins (1993) mentioned that they needed only a thickness for > 10 m of "loess" as parent source in the 800 x 1,200 km area from Cambodia-Hainan Island. Unfortunately, it is inconsistent with their idea because the fact that the loess they needed, which is now known as catastroloess, was generated after the impact and immediately after tektites were generated. Thus it was not possible to find such a source of sediment loess in the 800 x 1,200 km area as proposed except the Jurassic-Cretaceous continental sandstone. There is only one significant loess in south China, or Indochina target area, the Australasian tektites field "loess". In Figure 1 of Wasson (1991), the rare-earth-element pattern in layered tektites through followed the pattern of similar REE pattern in the Luachuan loess but was consistently well separated. This might suggest the different sources of both materials. Field evidence confirms late coming of "loess" in sections in Buntharik (Fiske *et al.*, 1996), in Vietnam (Izokh and An, 1988) and were now apparently found above tektites layer in Ubon Ratchathani and Sri Saket (Bunopas *et al.*, 1997; 1998). Late settling of "loess" is confirmed by the discovery of microtektites and glass microspirules in China "loess" (Heins *et al.*, 1991; Li *et al.*, 1991) suggested that the time of origin of both were temporal. Microtektites are also found in Thai catastroloess at Ban Som, Tha Chang, Khorat in early 1999 by Burrett exploration team.

Layer tektites formed as pools or sheets of melt

The descriptor "layered" derives from the presence of subparallel layers demarked by color and/or bubble contents (Barnes and Pitakpaivan, 1962). In most layered tektites the layers are subplanar, but folds are present in some. In rare cases faults cut across the layered structure (Futrell and Watson, 1993). The long axis of elliptical bubbles trend to be parallel to the layered planes, and vitrous silica grains are often elongated in the plane leading to a "shimmery appearing linear structure" (Barnes and Pitakpaivan, 1962). The layering was explained by small amount of differential (probably down slope) flow in a pool or sheet melt (Barnes and Pitakpaivan, 1962). Key supporting evidence is provided by the magnetic remanence study of de Gasparis *et al.* (1975). The inclinations of the measured paleofields are inclined by about 20° relative to the layering, roughly the same as the present-day inclination of the field in Southeast Asia; since the inclination similar 750 ka ago, this observation strongly supports the inclination that the layering was produced by processes occurring after the melt was deposited on the Earth's surface.

The arguments that the layering could have developed during ejection of melt from the crater or during its subsequent flight. If it was present during the moment of ejection, the pre-existing regular layering would have destroyed or distorted. If the layering was produced in flight, the same objections apply. It is doubtful that large (> 24 kg) melt globs could have solidified in flight. The observed directions of magnetic remanence (mentioned above) would be inconsistent with such a scenario. It seems irrefutable that, stressed by Wasson (1991), the layered tektites formed as pools or sheets melt.

THAILAND NEW DESTRUCTIVE DISCOVERY

New 1997 discovery of the evidences apart from the current well known common tektites, near the end of September (Bunopas *et al.*, 1998), are the continental fires; the mass extinction from an early identification of trees and mammals and a reptile; and the presence of the global sheet of > 10 m thick over Thailand and East Asia, known here in a new term as the "catastroloess". In places this "catastrophic loess" was misinterpreted as "wind blown sands", "semi-arid climate sands", " aeolian sands", "climatic controlled sands" and etc., and was already known to be widespread in the Australasian region as ordinary "loess" in north Thailand for some years since 1983 (Vella *et al.*, 1983; Sibrava, 1993).

300 km west of the edge of the impact center in Ubon Ratchathani, in several locations from 20 km and 100 km, respectively, in Tha Chang and Chum Phuang in east of Khorat or Nakhon Ratchasima in Northeast Thailand, many commercial sands pumping pits investigated since 1996, were deep enough to more than 12 m to reveal numerous irregular piles of the whole or partly burnt (Fig. 3), partly or wholly petrified trees, logs, huge trunks or woods above the basement. Almost all are angiospermes, dicotyledones genera including *Diptereocarioxylon* sp.; *Dipterocarpoxylon* sp.; *Terminalioxylon* sp. and many others and common gymnospermes *Araucarioxylon* sp. and the first fossil palm found in Southeast Asia, Palmoxylon sp. of affiliate Tertiary or early Quaternary.

Nearby two newest sand pits in Tha Chang (now Amphoe Chalerm Phrakiat), identifiable ancient elephant teeth (Fig. 4) and bones of Zygolophodon *(Sinomastodon)* sp. previously recorded from lignite bearing shales at Mae Moh mine in Lampang, north Thailand (Koenigswald, 1959) and Stegolophodon (Eostegodon) sp. of a Pleistocene age are found amongst crocodile teeth and bones, some other mammal's bones and those burnt trees mentioned above, above the black muddy earth at bottom of the sands pits (Fig. 5a and 5b).

Samples from Figure 4 from Figure 5a have been kept for further research and are in the custody of Sangad Bunopas and Chiyan Hinthong of the DMR. Beautiful ancient tusks, unfortunately fragmented during excavation are entrusted to the town of Chalerm Prakiat. Some beautiful ancient tusks from the pits in Figure 5b had been lodged at Rajapat Institute in Khorat.

Global explosive megablasts, continental fires, extreme high heat phenomena

Chemical and mineral inclusion data of these tektites indicate a sandy sedimentary origin, sandstone parent material, melted considerably much more above 2,000°C from the impact of a groups of liquid fireballs or comets. Temperature range for various possible and observed thermal reaction in Muong Nong tektite-type indochinites

Figure 3. Partly burnt trees and unburnt trees, two in many piles of trees at the base of the catastroloess at Tha Chang, 16 km east Khorat. Both were unearthed to surface.

Figure 4. Teeth of ancient elephants, *Zygolophodon (Sinomastodon)* sp. and *Stegolophodon (Eostegodon)* sp., locality as above.

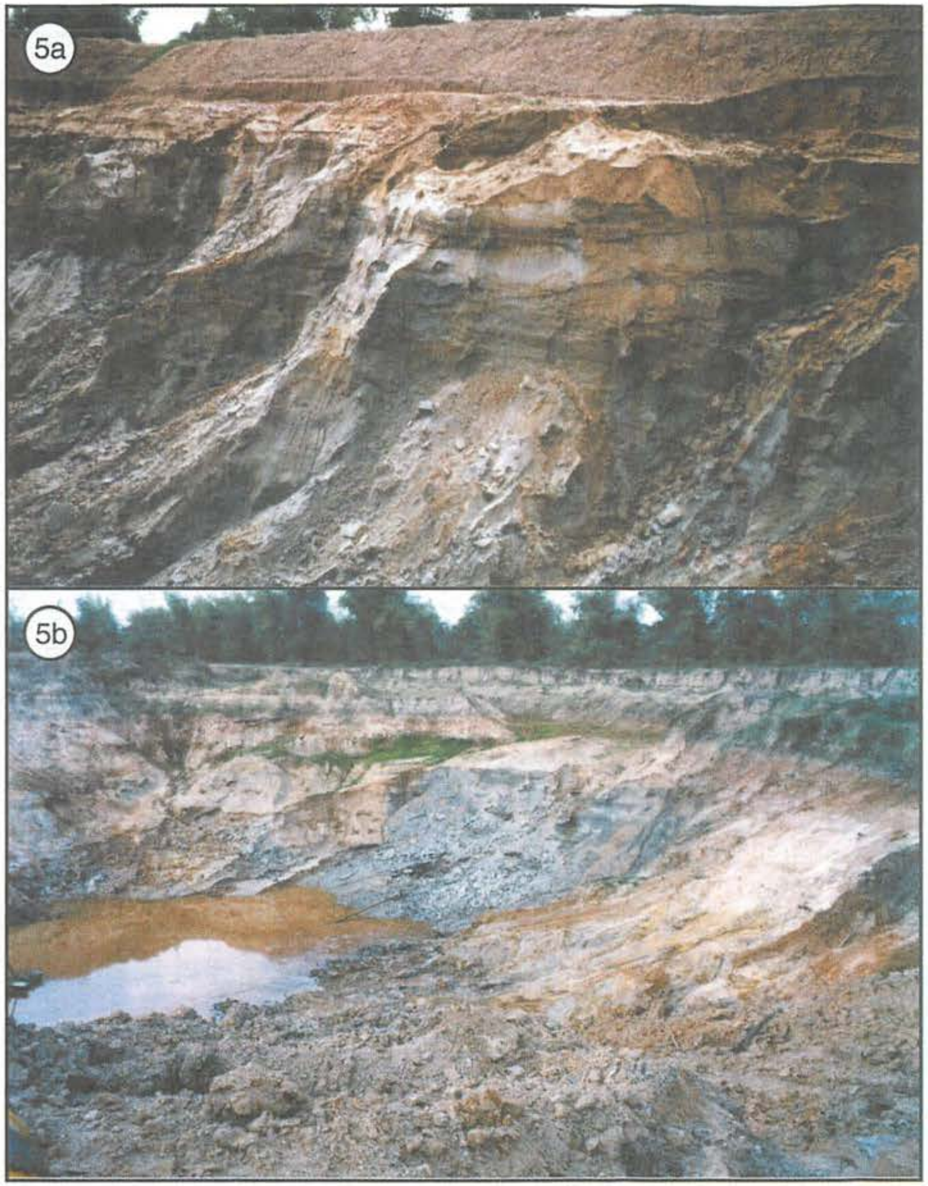

Figure 5. Inside a sandpit at Tha Chang, Khorat, northeast Thailand (5a), showing 8 m of vertical layering of the catastroloess in the lower part the lower, and 4 m of the recent river floodplain reworking at the upper part (5b), east Tha Chang is similar but was 50 m deep, containing microtektites and burnt trees are abundant in places.

was from 1,000 to 2,000°C under normal atmospheric condition (Glass and Barlow, 1979). Muong Nong tektites represent the impactites where, the parent material was immediately melted and rapidly solidified, following by explosions in the reaction like several massive gigantic nuclear bombs, blasting of solidified layers and the injection of fragments of molten glass which spinning in the atmosphere far from the collision sites (Thailandites), or even into the Earth's orbit and solidified before retouching the ground, some with the trajectory to as far as Tasmania (Australite), 3,000 km apart (Ford, 1988). Radiometric dating by K/Ar ages and other methods of tektites from this field are between 0.709–0.770 ± 0.020 Ma (Zahringer, 1963; Gentner *et al.*, 1967; 1969; Blum *et al.*, 1992; Izett and Obradovich, 1992), or a Lower Quaternary age indicate also the age of the catastrophe.

In northeast Thailand, loess are settling on the lateritic sands and gravels, mentioned also by Fiske *et al.* (1996) with tektites at surface contact of loess and the lateritic sands. Izokh and An (1988) reported most locations in 11 pitting areas, from Ho Chi Minh City in southern areas to Hanoi in northern Vietnam, the occurrences of charcoal and woods at the bottom parts of Vietnamese loess. Loess in this sense should be corrected as catastrophic loess or catastroloess.

Sharply broken without root and broken and cutting top and without branches indicated they were abruptly pulled and pushed down by a tremendous force to the ground. Numerous occurrences of burnt trees (Fig. 3), burnt trunk, burnt wood fragments and charcoals from most commercial sand pits in the lower parts of the catastroloess in wide areas in, east and northeast of Khorat, or Nakorn Ratchasima indicated very severe forest fires. The very severe explosive blasting in the very wide areas during the event, 300 km from the edge of impact center. Similar woods and wood fragments, frequently burnt, are found also at Srisaket, near Ubon Ratchathani which thought to be at the western margin of the impact center. The burnt woods though not plentiful outside Khorat were also reported in all parts of Thailand indicating the presence of the widespread burnt are regional wide. Most of the burnt woods are in parts petrified and were covered in the lower part of the catastroloess.

Mass extinction of animals and plants

East of Khorat or Nakhon Ratchasima at Tha Chang identifiable ancient elephant teeth and bones of *Zygolophodon (Sinomastodon)* sp. previously recorded from a Miocene Mae Moh lignite mine in Lampang in northern Thailand; and *Stegolophodon (Eostegodon)* sp. (Fig. 4) of a Pleistocene age are found amongst crocodile teeth and bones, some other mammal bones and those burning trees mentioned above the black muddy earth bottom of the sands pits. Fossil ancient elephants were preliminary identified by Japanese professor at Kobe University in late 1997.

Vozenin-Serra of Paris University P. and M. Curie, Paleobotanique et Paleoecologie, Paris, in late 1998 kindly identified some fossil woods from nearby sandpits at east of Khorat at Tha Chang to consist of *Terminalioxylon* sp., *Dipterocarpoxylon* sp., *Araucarioxylon* sp. and *Palmoxylon* sp., fossil palm wood first found in Southeast Asia.

Vozenin-Serra previously investigated specimens from the same region 10 years ago when the communication was restricted (Vozenin-Serra and Prive-Gill, 1989). The presence of Araucariacae in Southeastern Asia at a relatively recent epoch was remarked. A comparison with other fossil woods localities reveals close floristic resemblance with Myanmar, Western Bengal and Kachchh. Their specimens at Tha Chang (now Amphoe Chalerm Prakiat) were dislocated to higher position in the sands to above ground geologically or by human for a long time after they were buried by thick sheet of sands as found at many commercial sandpits nearby today.

The catastroloess — also known as atmospheric yellow earth sands, catastrophic loess or atmospheric loess

These catastrophic sands has proved to be a distinctive single blanket, though mixing with the local prevailing normal geological active condition near base, covered all of Thailand, Laos, Vietnam and is outstanding thicker, close to 130 m around Xi-an, Yellow River in north China (Wang *et al.*, 1985; Han *et al.*, 1997). Catastroloess outcrops are exposed throughout Thailand in some scenic places at Hod in south Chiangmai, at Nanoi in Nan (Fig. 7), and at Phrae, all in north Thailand, at Lom Sak (Fig. 6) in central Thailand and at Suan Phuang, Ratchaburi, in southwest central Thailand, all with average thickness of 3–60 m. They are usually covered by thick fine to medium gravels or large stream cobbles at high elevation at Hod. This indicates the uplifting of the mountainous areas was rather late in the Quaternary.

In north Thailand its 30 m thick catastroloess shows remarkable gully and rills erosional surfaces at Na Noi, Nan (Fig. 7). This sort of scenic spots are famous at Chiangmai and Phae. It extends south to Ratburi at Suan Phueng (Fig. 8). Thinner catastroloess extends further south to Malaysia, Indonesia or possibly to as far as Australia and New Zealand, and east to the Philippines, and

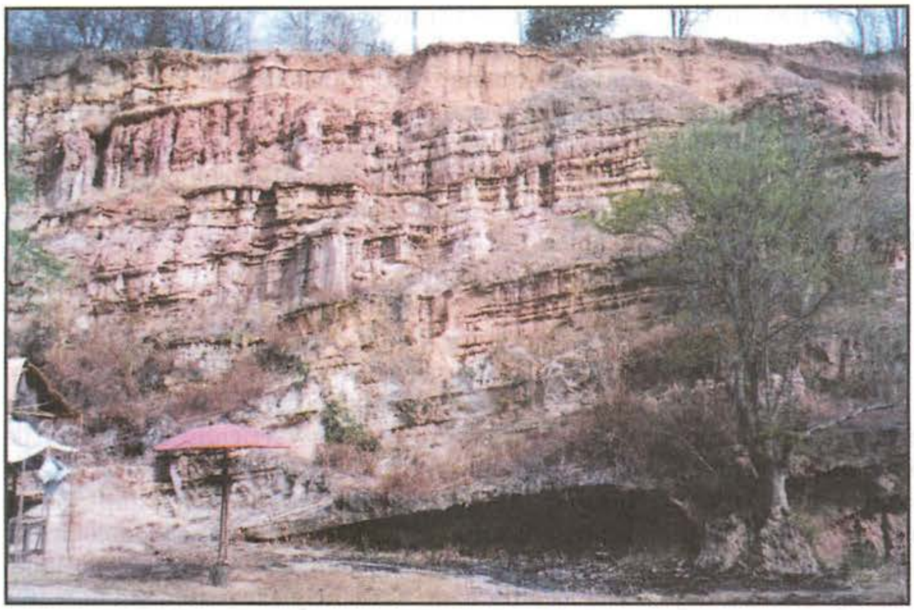

Figure 6. Slightly tilted 50 m thick of lower part of the catastoloess and thick interbedding of local thin gravels at 16 km on highways west of Lom Sak, north central Thailand.

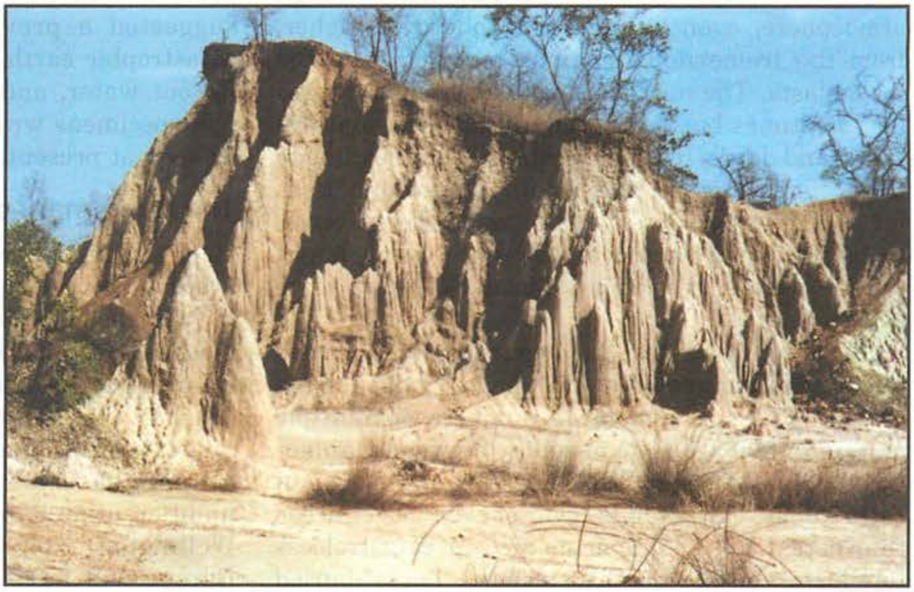

Figure 7. Catastroloess typically widely exposed showing typical gullies or rill affect erosion at "Hom Chom", Nanoi in Nan, northern Thailand.

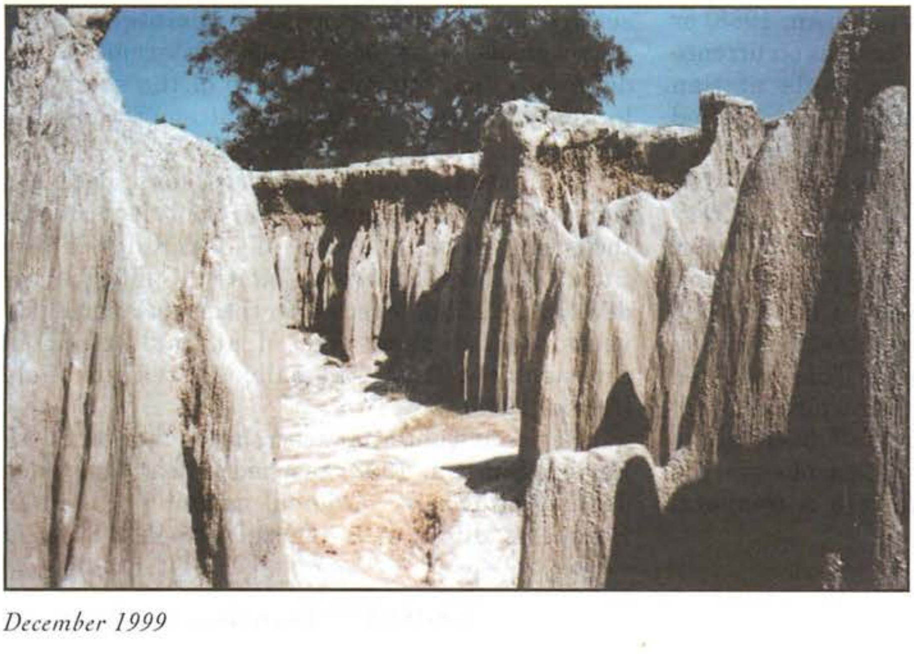

Figure 8. Ratburi, Suan Phueng, gently tilted beds of catastroloess and finely interbedded local gravels, showing common rill marked erosion. The top part is also the same horizon of catastroloess.

possibly and beyond to Korea and Japan in the Western Pacific rim, and to Myanmar, and further beyond West Asia on the west. The floors of the Gulf of Thailand were filled with this catastroloess-sands seen during a time of low sea water 18,000 years ago (Fig. 9, Blaine Cecil, 1988).

Depletion of water in Australasian tektites (Vickery and Browning, 1991; Gilchrist *et al.*, 1969) and high ^{10}Be in Chinese "loess" (Shen *et al.*, 1992), or to be precise catastroloess, originated in a glacial age temporal to tektites.

Long periods of many Plio-Pleistocene glaciations from the prominent uplifting of Tibet Highlands and high mountain chains in Europe must have gathered enormous mass and widespread sands or the yellow earth debris during these many dry cold periods in many glacial stages. With repeated gusty storms and enormous suction from the impact center of the event, the debris in a dry cold glacial stage could be sucked up high to a high atmosphere, even to the stratosphere or higher, from the tremendous suctions required from the megablasts. The suctions must have been prolonged for sometimes but later gradually ceased, massive sands and debris in the atmosphere soon settling to the grounds through north China, Indochina, to as far as the impact sites and beyond. The process, understood that was occurred as one event, might take hundreds or even a thousand of years to be back to normal.

This could suggest the event for an enormous terrestrial impact of a big comet, judged by a considerable size and large numbers of multiple craters in 800 x 1,140 km center between Hainan-Cambodia (Wasson, 1991). The spreading of catastrophic earth sands cover of even larger areas than of tektites (1/3 comparing to 1/10, of catastroloess to tektites) on the Earth's surface. "Loess" buried tektites in Thailand (Fiske *et al.*, 1996; Bunopas *et al.*, 1997) and in Vietnam (Izokh and An, 1988) or Hainan Island (Xu *et al.*, 1985). Previous occurrence of "loess" horizon on terrace gravels at San Kamphaeng, in northern Thailand was suggested by Vella *et al.* (1983) nearly two decade ago.

Microtektites and associated noble glass were studied from north China loess (Heins *et al.*, 1991). Li *et al.* (1991) also reported the discovery of microtektites and glass microsperules and implications in north China loess. Clive Burrett also reported his discovery of microtektites at Ban Som, Tha Chang, Khorat, Thailand. This explained that microtektites and glass microspirules were caught up in the atmosphere and fall down late to settle down within the massive catastroloess. The existing of both materials indicate a temporal event.

Original Chinese catastroloess has medium sand, silt and clay size range similar to Thailand catastroloess. Abnormally high CaO, and significantly low SiO_2 in the loess (Table 4) suggested an exotic sources to Thailand, which was one of the impact area with the chemical minerals content of sandy sediments similar to tektites (Tables 1–3, 5).

A remarkable discordance between early Quaternary, catastrophic earth-sands and a Neogene lake beds (Fig. 10) with abundant excellently preserved Pliocene fishes at west Lom Sak, in upper central Thailand. The atmospheric earth-sands were rapidly vertically overfilled the lake, through water at the topmost lake to the bottom of the lake bed. The discordant plane represent an excellent time plane, chronologically of a Pliocene-Pleistocene boundary in Thailand. The locality is at a recently excavated small water pond at Ban Bo Pla, west Lom Sak. The area suggested a previous natural lake before the catastrophic earth-sands or catastroloess came to fill out water, and trapped upper Tertiary living fish specimens wrapped them and fossilized them as seen at present.

The Quaternary catastroloess field

In Figure 2 we traced an extension of an arbitrary boundary of this Quaternary catastroloess for catastroloess field (using Glass, 1990 map) to most eastern Africa and Europe, but must be rather thinned out westwards so did in north Russia and Alaska. This can only done by remote sensing by quick terrain study through commercial video-graphic media. Paul Vella collected some undifferentiated loess from Wairarapa in north of Wellington, New Zealand in the south Pacific. Europe will have a mixed up stratigraphy of a normal geologic sequences of loess and catastrophic sequences of catastroloess. Microtektites or microspirules may be a useful criterion for the differentiation, but must aware of the secondary loess of the latter. There is no attempt to discuss the matter.

The Quaternary catastroloess did not significantly reach the American Continents during the event. From the record of 1,095 ft drilled core from Tuelelake, Siskiyou Country, California, for developing a climate record for the past three million years, do not show sign of an intervening of catastroloess from Australasian tektites field (Adam, 1988).

Regional Quaternary correlation in the ESCAP Region (Sibrava, 1993) reached a dead end when dealing with loess. Original meaning of loess in Europe is differ with the catastrophic loess in

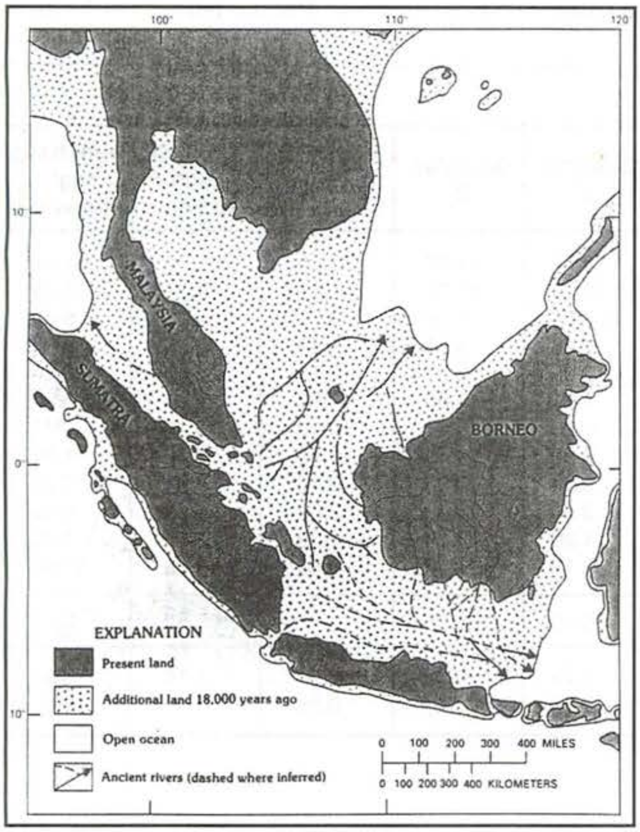

Figure 9. Land area of the continental shelf that was exposed approximately 18,000 years ago during a time of lower sea level (from Blaine Cecil, 1988).

Table 4. Average % of chemical minerals and grain size average in mm from 0.005–0.25 of Chinese loess (data from Wang and Sasajima, 1985).

Average % of chemical minerals of:	
SiO_2	39.34–63.54
Fe_2O_3	2.39–7.34
TiO_2	0.25–0.90
Na_2O	1.28–2.32
MnO	< 0.35
Al_2O_3	7.83–14.79
FeO	0.46–2.46
CaO	4.83–20.44
K_2O	1.24–2.60
MgO	< 9.26
Grain size average in mm 0.005–0.25:	
0.005–0.01	< 20%
0.01–0.05	> 50%
0.05–0.25	< 25%

Figure 10. A remarkable discordance between the lower Pleistocene catastroloess (upper) and Neogene (Pliocene) lake bed (lower) with abundant well preserved Pliocene fishes. Pliocene-Pleistocene boundary locality at a recently excavated small water pond, while men at right were searching some remnant of beautiful fish fossils foreground search for fossil fish, west of Lom Sak. Specialist claimed these were Miocene fishes species according to their record, this became a paleontological conflict quite common in conventional record.

Table 5. Major element contents of tektites in the mainland Qiongzhou-Leizhou areas, Hainan Island, south China (after Yuan, 1981).

	Tektites							Basalts	
	Longlouxi	Wenchang High School	Tanniu	Diluzai	Qionghai I	Qionghai II	Average	Wenchang High School	Wenchang High School
SiO_2	75.25	72.85	74.59	73.80	73.54	73.07	73.85	48.39	53.91
Al_2O_3	11.52	11.97	11.79	12.26	11.32	11.33	11.69	13.37	15.78
Fe_2O_3	0.50	0.40	0.49	0.59	0.89	0.90	0.63	5.25	5.40
FeO	5.43	6.46	5.38	5.01	4.78	5.31	5.40	7.23	5.29
CaO	2.00	2.20	2.03	2.14	2.03	2.25	2.11	8.40	8.86
MgO	1.44	1.93	1.50	1.54	1.61	1.85	1.64	9.75	5.13
MnO	0.11	0.11	0.11	0.08	0.09	0.12	0.10	0.16	0.14
TiO_2	0.73	0.74	0.78	0.78	0.80	0.88	0.78	2.30	1.91
P_2O_5	0.11	0.12	0.08	0.12	0.34	0.28	0.18	0.64	0.29
K_2O	2.20	2.40	2.40	2.40	3.30	2.90	2.60	1.70	0.60
Na_2O	1.30	1.50	1.50	1.50	1.20	1.36	1.39	3.40	3.30
Total Fe	6.53	7.57	6.468	6.18	6.19	6.79	6.60	13.28	11.07
Total	100.59	100.68	100.65	100.25	99.90	100.25	–	108.59	100.61
MgO/CaO	0.72	0.97	0.78	0.72	0.79	0.82	0.80	1.16	0.58
Na_2O/K_2O	0.59	0.63	0.63	0.763	0.39	0.47	0.56	2	5.5

* Concentration in % except total Fe, MgO/CaO and Na_2O/K_2O

Thailand, China or East Asia. The great different is the thickness and the areal distribution where the earlier was confined to lateral transported geologically, while the later was mainly vertically atmospheric suspended then laid down in a global catastrophic event. With a careful treatment the catastroloess will serve as a good key horizon for the Quaternary correlation.

In ancient geologically active areas, tilted lower part of the catastroloess and thick interbedding of local thin gravels at 16 km on highways east of Lom Sak, north central Thailand (Fig. 6). Thin local small gravels interbedded with the much thicker exotic catastrophic atmospheric sand beds of > 50 m thick.

In Thailand as well as Indochina catastroloess has remarkably affected common Quaternary areal landforms and geology in Southeast Asia. Geomorphological transformation in both active and less active areas was a major effect of catastroloess. All over Southeast and East Asia, landscapes were transformed by the catastroloess at a speed that exceeded normal geological processes by many orders of magnitude. Mountain summits, intermountain valleys, river valleys, and flood plains all underwent rapid change as they were filled, smoothed, flattened, or swallowed up by over 10 m of catastroloess. These processes admixed with local geological processes and led to thinning or thickening of the catastroloess as it mixed with lower Pleistocene beds such as those consisting of small local pebbles. Examples of these admixtures are locally exposed at Lomsak (Fig. 6), Na Noi (Fig. 7), and Phrae (all north Thailand), at Ratburi (8) (central Thailand) and at Na Thavee (south Thailand). In most areas the middle and upper parts of the catastroloess exhibited no structure because of secondary wash-out and reworking in later time. Geomorphologically, they show the maturity of typical terrains. Catastroloess forms normal coastlines, beaches, and constitute the seabed in the Gulf of Thailand (Fig. 9). 18,000 years ago at the time of the last marine regression, catastroloess constituted a continental sand bridge to northern Australia (Blaine Cecil, 1988). On top of mountain ranges granite boulders that were surrounded by these catastroloess assumed an appearance that mimicked real granite exfoliation weathering. This phenomenon is especially conspicuous in the famous Doi Inthanon Ranges west of Chiangmai.

Another effect of the catastroloess was to shift the course of rivers such as the Mun and Chi, in Thailand. The Mekong River was moved eastwards from the Grand Lake in Cambodia towards southern Laos and northeast Cambodia. The Grand Lake (Tonle Sap) itself became overfilled and deserted. Hartung (1990) suggested a tektite source crater in the Tonle Sap, but this is considered unlikely. Economic implication of catastroloess is impressive for living instant for present mankind and other habitats. We may assume that catastroloess/yellow earth-sands are the origin of fertile soils throughout the region and across the continent. If so, cultivation can be extended to the base of mountains, as well as on alpine plains. These soils are perfectly suited to the cultivation of rice, oil-palm, and rubber; as well as to various forms of light cropping and evergreen tree cultivation.

Sands suitable for construction and road works are available from many source areas in Thailand. Material is obtained from the plains flanking the Chao Praya or other rivers, from 'ancient sands' on the central plain, and from lowlands around most cities. The sand works and pits in Khorat are good examples of catastroloess currently being developed.

Sand horizons have implications for deep piling and tunnelling in Bangkok. It is estimated that there is 10 to > 30 m of catastroloess underlying ~10 m of young black mud in the bed of the Chao Phraya River. These sands are the result of repeated accumulation of catastroloess derived upstream, with their ever-increasing weight causing subsidence on a seasonal and an annual basis.

These sands may ultimately prove a resource critical in the building industry, and development of catastroloess deposits may replace precious minerals as a source of income in a number of Asian countries. All lowland and floodplain areas should contain at least some thickness of catastroloess and/or the secondary enriched equivalent sands. Offshore deposits are also worth consideration, given that the floors of the Gulf of Thailand are filled with this type of sand (Blaine Cecil, 1988).

DISCOVERY ENSEMBLE OF COMET IMPACT THEORY

Comet impact theory terrestrially (Angier *et al.*, 1985), inconsistent with the extraterrestrially (Izokh and An, 1988) was repeatedly emphasized by some authors (cited in ref.) but none find sufficient evidences around the world to support it before in the world.

At this moment, we can report the discovery of our apparent 5 evidences in Thailand. We like to stress that the theory suggested by the matter is strongly supported by these 5 categories of evidences. The comet impact in the Australasian tektites strewn field, in Thailand all apparent evidences are found with high confidence in northeast Thailand (Bunopas *et al.*, 1997, 1998) as the followings:

i. Global distribution of layer tektites, splashed tektites and/or ablated form tektites and layered tektites currently found.
ii. Impact crater(s) and impact center, in the 800 x 1, 200 km impact center with its western edge at Buntharik in Northeast Thailand currently presented by Wasson (1991) and Wasson *et al.* (1995), and is supported here.
iii. Continental forest fires during and after the impacts of the extraterrestrial object.
iv. The mass extinction of ancient floras and faunas.
v. The presence of thick catastroloess. This can be proved as a sheet of vertical settling of the atmospheric yellow earth sands of almost 10 m to over 50 m in thickness covering all over the Australasian. Thick covering of the catastroloess that caused more severe extinction of lives comparable to the other agents. This was a greatest global massacre, and added to the early Pleistocene a significant mass extinction.

All these evidences support a cometary theory with all presented syntheses discovered in Thailand. Without 5 apparent evidences in the event the cometary impact theory is not applicable true.

The comprehensive cometary impact theory then suggested, from evidences in Thailand, that the catastrophe by a large comet impact with great tremendous shocks and quakes, and massive explosions sending huge global fireworks and showers of tektites to the sky and continental forest fires everywhere. Later falls of steady dried rains of earth-sands from debris and dust accumulated during a glacial period sucked up to a high atmosphere even gradually settling thick global catastroloess for thousands of years. The catastroloess long covered most lives to death leading to the global mass extinction. The analogous of the disaster would probably be in the field of all nuclear bombs on earth.

We are puzzled that, there is thin catastroloess ½ m to 2 m only, often with concretionary lateritic, pisolitic sands in areas near Buntharik on the west edge of the huge multicrater (see above), and is exceeding underwent laterization than other nearby areas in the northeast. Probably there was a sign of heaviest torrential rains during the event than anywhere else out and away from the center. This is probably similar to the whole of Vietnam known from many test pits by Izokh and An (1988).

Enormous explosions of exceeding a few hundred km high into the sky of the Jupiter were live-showed from the space satellite video that captured the explosive impacts of a few end members of the Shoemaker Comet that passed too close to the Jupiter's gravitational field in late 1995 and was seemed to be only a minor case of an impact. This was a sight and sound live display we could have live pretested from any scientific theory.

THE ANALOGOUS WITH THE K–T EVENT

The knowledge from this discovery paves ways to the understanding that the K-T loess buried alive the dinosaurs in Mongolian Yellow Red Mountain in the Gobi Desert and similarly in the dinosaur National Monument in Utah and at Black Hill Park in South Dakota in the North American Continent, 65 Ma ago and became very significant mass extinction. We found that our synthesis supported the comet theory that terrestrially collided with the earth, where in a later time ancient elephants including mastodons and stegodons, and others were buried alive by late Pleistocene hazardous Buntharik Event (Bunopas *et al.*, 1998), and created one of the great global disaster of mass extinction.

Catastroloesses of both ages, the K-T catastroloess and the Pleistocene catastroloess, at the sites, show amazing similarities of gully or rill erosion typical features of loess but are greatly differs in degrees of compactions. Both faunas were similar perfectly preserved in these structureless loesses; also showing similar mass of evenly grain size distribution throughout, but of only different ages. The duplicated catastrophe were in accordance with the newly formulated, comprehensive cometary impact theory by Bunopas *et al.* (1999). Both dinosaurs and ancient elephants were killed by different comets in similar manner, died, or buried alive and became the mass extinction in places. Loesses in these sense are nominated the name, catastroloess for both ages by the authors for the last two years of these catastrophic loesses.

Significantly high CaO and low SiO_2 contents of Chinese loess is much different from the surroundings and of tektites (Tables 1–3, 5) indicating the exotic sources of Chinese loess (Table 4) to Thailand and Asia as mentioned above. Chinese Pleistocene loess has medium sand, silt and clay size range (Wang and Sasajima, 1985).

In brief, the 1997 discovery evidences comprising tektites; multicraters; burnt trees or petrified trees and petrified burnt trees; mass extinction of faunas and floras and the catastroloess formed a principle sequence in the cometary impact theory of both in the Lower Pleistocene Buntharik Event (0.77 Ma) and most likely the analogous in the K-T boundary event (65 Ma) with similar evidences (Izett and Dalymple, 1991; Sigurdsson *et al.*, 1991) and loess burying other fossils and dinosaurs at Alberta Dinosaur Park (Angier, 1985).

We conclude that the analogous of catastroloess killed ancient elephants in the Quaternary and last dinosaurs in the K-T boundary. The difference was only in time, and from different and size of comet, and different but consistent catastroloess, from the same cometary impact theory (Bunopas *et al.*, 1999). Similar mass extinction of buried alive of ancient elephants (mastodons and stegodons) and dinosaurs, in different times and places.

Besides, analogous with the K-T event was the significant mass extinction of dinosaurs and the younger mastodons here by burial under the similar catastroloess of both ages in Gobi Desert and the North American Continent. The Quaternary Buntharik Event that killed mastodons is a good duplicate of the K-T Boundary Event by a similar cometary impact, of a big comet, but smaller than the latter seen from the destructive evidences.

CONCLUSION

We propose the Buntharik Event, the name derived from a town south of Ubon Ratchathani where most evidences mentioned can be examined in a few hours, had caused the occurrence of Lower Quaternary tektites and the global continental fire, burning forest, mass extinction, thick catastrophic loess-sandy debris accumulation. The catastroloess admixed to those local vital normal conditions in mountainous valleys; smoothen to the current physiography of all valley and flood plain areas; and caused the extinction of many older plants and animals.

In lowlands or floodplain areas or paddy fields everywhere in Thailand contain some thickness of catastroloess or/and the secondary enriched equivalent sands of several metres. This is applied also to the floors of the Gulf of Thailand that were filled with this sands (Fig. 8, Blaine Cecil, 1988).

Catastroloess was not the surface windblown sands in arid region deposition, but can be virtually real only at the topmost few meters reworking by some geological processes repeatedly, and by the Recent yearly flooding and denudation since they were originally formed.

Tektites found at any levels at present apart from above the basement or at lower level in the covering sands can only reflects a reposition, since or during the catastrophe, later mixing with vital natural condition until finally settled down to normal, and much later long reworking geological processes until the present day.

The knowledge from this discovery of the 0.75 Ma, Buntharik Event might also paves ways to the understanding of what had happened with the dinosaurs in the North American Continent, 65 Ma ago. The impactor in the Buntharik Event though much smaller than that impactor at the end of Cretaceous, and restricted iridium anomaly in DSDP cores (Schmidt *et al.*, 1993), but had already involved some mass extinction of ancient elephants on land in an early Pleistocene in Asia.

We discovered 3 destructive evidences in Thailand apart from 2 more expanding knowledge about layered tektites and made known for the multiple crater of the impact of a comet to form the Australasian tektites strewn field. These were 5 criterions for the cometary impact of the Australasian tektites field. Above all, most of our works were pay off on the discovery of the Quaternary catastroloess and the Quaternary catastroloess field from the second episode of the same single impact. This may yield many implications to Malaysian and Thailand geology and internationally.

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