REVIEW OF THE AUSTRALASIAN TEKTITE SOURCE CRATER LOCATION AND CANDIDATE STRUCTURE IN THE SONG HONG-YINGGEHAI BASIN, GULF OF TONKIN. A. Whymark[1], [1]Consultant Wellsite Geologist (aubrey@tektites.co.uk).

Introduction: The Australasian tektite strewn field is the youngest of the major strewn fields. Tektites fell over 16-18 percent of the Earth's surface. The distal ejecta has a strongly down-range distribution pattern, indicative of an oblique impact from the north-northwest. The estimated size of the source crater is ~40 km diameter, based on a calculated ejecta layer thickness from microtektite concentrations [1]. Evidence is reviewed, a general source crater location suggested and a strong candidate structure identified.

Observations: The evidence is briefly reviewed:

1) Microtektite distribution. Microtektite regression patterns, [2] and [3] being the most recent, indicate a source location in the Indochinese area *sensu lato*. The possibility that the pattern is regressed too far back to the northwest is considered due to lack of microtektite data in the Eurasian continental region.

2) Macro-tektite and layered impact glass distribution. Very similar proximal splashform tektite morphologies and Muong Nong-type layered impact glasses are found in north-eastern Thailand, central-southern Laos and Vietnam, to the west, and on Hainan Island and the Leizhou Peninsula, to the east. The east-west equidistant centre of the bilaterally symmetrical distribution pattern is in the Gulf of Tonkin; not the Indochinese Peninsula, which lacks tektites to the west. The dominance of Muong Nong-type layered impact glass in Savannakhet, Laos, and surrounding areas [4] is explained as the only landward extension of a major (butterfly) ray. The westerly butterfly ray and most of the main down-range ray ('scraping' the south east of Vietnam) fell in the South China Sea.

3) Crater ray system. Although somewhat subjective, crater rays can be used to point to the source crater. Proximal rays are poorly defined; however, distinct rays are observed both in the Philippines and in Australia. These rays are suggestive of a crater in the Gulf of Tonkin, although the margin of error allows for a position anywhere from the eastern part of the Indochinese Peninsula to Hainan Island [5].

4) Rb-Sr considerations. It was determined that the last major Rb/Sr enrichment event occurred at ~170 Ma [6], interpreted as probably being coincident with the time of deposition of the source rock sediments. This interpretation limits the search area for the Australasian tektite source crater to middle Jurassic terrain. The whole rock composition of tektites is, however, far from ideal for this dating method.

In selecting a rock for Rb-Sr dating one is looking for a slowly deposited, fully marine fine grained shale (mainly illite) [7]. Australasian tektites formed from a mixture of sandstones and shales [8][9]. These sediments were most likely very rapidly deposited deltaic to shallow marine sediments.

It is suggested that the middle Jurassic age may represent an averaged age of sediments that have recently been reincorporated into a new depositional cycle, i.e. the Rb-Sr clock was not reset. It would be enlightening to test 'whole rock' deltaic sediments and cored sediments in the Gulf of Tonkin to determine Rb-Sr age vs. age of deposition.

5) ^{10}Be concentrations. The older/deeper buried the source material is, the lower the ^{10}Be concentration. Tektite ^{10}Be iso-concentration maps can be drawn up. These indicate the source crater is on the eastern side of the Indochinese Peninsula or in the Gulf of Tonkin, centred on 17° N, 107°E [10].

Absolute concentrations of ^{10}Be (half life of 1.36 Ma) in tektites are too high for a middle Jurassic source rock alone. ^{10}Be concentrations in australites are 1.35-2.04 x 10^8 atom g^{-1} (typically 1.5 x 10^8 atom g^{-1}). In indochinite splashform tektites and Muong Nong-type layered impact glasses ^{10}Be concentrations are 0.50-1.35 x 10^8 atom g^{-1} (typically 0.75-0.89 x 10^8 atom g^{-1}) [11][12][13]. By a process of elimination, it was concluded that the ^{10}Be was derived from the target material [11]. Tektites derived from depth should contain little or no ^{10}Be unless derived from sediments deposited within the last few million years [11]. In order to see the observed concentrations of ^{10}Be in tektites derived primarily from a middle Jurassic source rock, thorough mixing with soils/sediments within the zone of meteoric water percolation and/or recent surficial fluvial deposits must be implied [6]. Thorough mixing is less probable in the last formed, deepest excavated, Muong Nong-type layered impact glasses. A more satisfactory explanation is that the target rock is a thick column of rapidly deposited Plio-Pleistocene sediment with high sedimentation rates of at least 0.02 cm/yr^{-1} [11].

6) Absence of crater. Much smaller tropical craters of comparable age, such as Bosumtwi Crater (10.5 km Ø, 1.07 Ma [14]) and Lonar Crater (1.8 km Ø, 0.656 ±0.081 Ma [15]) form very evident lakes. The implication is that the Australasian tektite source crater must have either been very significantly eroded or buried. The former is highly improbable given the ±0.788 Ma age [16][17], whereas the latter is highly plausible if the crater were located in the Song Hong-Yinggehai (SHY) Basin. The depo-centre of the SHY Basin has accumulated 17 km of sediment since the middle Eocene [18], or on average 0.035 cm/yr^{-1}. This is 275 m in the last 0.788 Ma, probably an extremely conservative estimate given that peak sedimentation rates are recorded in the Plio-Pleistocene [19].

Discussion: The Gulf of Tonkin is very consistent with microtektite regression patterns; macro-tektite distribution and morphology; best-fit crater ray system pattern; ^{10}Be iso-concentration patterns, the SHY Basin has a very high sedimentation rate which will both rapidly bury a crater and explain the high ^{10}Be content of Australasian tektites. Furthermore, a Gulf of Tonkin impact into very rapidly deposited deltaic and shallow marine sandstones, siltstones and shales provides the perfect tektite source material and gives explanation as to why a potentially misleading (averaged previous cycle) Rb-Sr age may be obtained.

Having identified the probable target region, a search for the Australasian tektite source crater in the SHY Basin was conducted. Publically available bathymetric and gravity data did not reveal any possible structures. A review of papers studying shale diapir-like structures in the SHY Basin appeared to reveal a semi-circular arrangement for these features (Fig. 1, left) [20][18][21]. The established explanation for these recently formed shale diapir-like structures is that they have a north-south alignment and are caused by en échelon-type faulting in the Song Hong-Yinggehai pull-apart basin [21]. If one instead assumes a ring arrangement, the central semi-circular ring was around ±40 km in diameter. Slight variability in the geographic positions of shale diapir-like structures was noted between publications. These shale diapir-like structures are of significant economic value as hydrocarbon traps.

Having reviewed low resolution free-air gravity data in [22], high resolution free-air gravity data was kindly provided by GETECH (Fig. 1). This revealed a 43 (±3) km diameter circular feature centered on 17°45'20"N, 107°50'30"E. This feature appeared to tie in with the aforementioned semi-circular arrangement of shale diapir-like structures. A total of two semi-circular and two outer partial, basin-restricted, 'rings' are noted, on which shale diapir-like structures occur. These 'rings' extend ~90 km from the proposed point of impact. The possibility that these 'rings' are compressional ridges surrounding the crater, due to impact in soft sediment is considered. The apparently off-circular arrangement of outer 'rings' might be explained by the basin geometry and by the oblique angle of impact. In [19], after Gong and Li (1997, 2004), a question mark exists on Late Miocene and Pliocene sediment isopachs maps atop this circular feature, leading to a question of whether this area is 'chaotic' on seismic data. If this is an impact crater, the largest SHY Basin collapsed shale diapir (CN-61) [21] would lie on the down-range rim.

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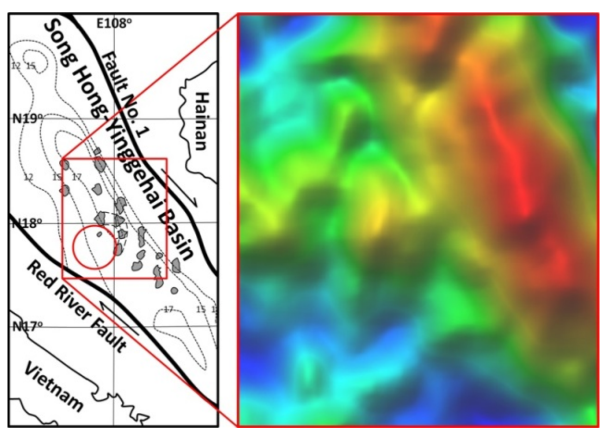

Fig. 1: Left: Shale diapir-like structures (shaded) in the Gulf of Tonkin after [18][20][21][23], note that precise positioning is not independently verified. Dashed lines equal sediment isopachs (km). Right: A 43 (±3) km diameter circular feature noted on GETECH free-air gravity in the bottom-left quadrant.