

Comments on 'No K/T boundary at Anjar, Gujarat, India: Evidence from magnetic susceptibility and carbon isotopes'

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Based on magnetic susceptibility and $\delta^{13}\text{C}_{\text{org}}$ data Hansen *et al* (2001) have argued that K/T boundary does not exist in Anjar intertrappean sediment section in the Deccan trap province. The K/T boundary is commonly identified by the disappearance of Cretaceous index fossil (e.g., *Micula prinsii*), in association with geochemical and geochronological markers. The geochemical and mineralogical signatures include Ir anomaly, shocked quartz, Ni-rich spinels, micro-diamonds, fullerenes, amino acids and more recently identification of nano-size phases of iron has been added to this list for identification of extinction horizons. At Anjar, the presence of iridium enrichment in three ferruginous bands of intertrappean sediments (Bhandari *et al* 1995, 1996), association of fullerenes (Parthasarthy *et al* 2000) and nano-size iron phases in these bands (Bhandari *et al* 2000) strongly suggest the existence of the K/T boundary horizon. Besides these well established criteria, the age of intertrappean sediments is well constrained, both by the ^{39}Ar - ^{40}Ar ages of the overlying and underlying flows (Venkatesan *et al* 1996) and the palaeomagnetic stratigraphy, which suggest their deposition during 29R (Shukla *et al* 2001a).

The dissimilar nature of magnetic susceptibility profile in Anjar compared to other K/T sections such as El Kef section, Tunisia, and the absence of the negative shift in $\delta^{13}\text{C}_{\text{org}}$ profile in Anjar has

been advocated as reasons for the absence of K/T boundary by Hansen *et al* (2001). Unfortunately, both of these signatures are not unique characteristics of the K/T boundary. Variation in magnetic susceptibility (χ) has been used as indicator of KTB by the authors without providing any physical basis for the same. In view of the fact that variation in χ can be caused by a variety of factors such as soil formation, presence of authigenic magnetite/goethite, fly and volcanic ash deposits, it is essential to suggest the causative mechanism for the enhancement of χ at the KTB. The early work on the K/T sections from Petriccio, Italy and in DSDP sites by Worm and Banerjee (1987) using magnetic susceptibility data, suggests a magnetic anomaly at K/T boundary due to the presence of black magnetic microspherules which are believed to be of impact melt origin. However, their affect can hardly be seen in shale deposit which themselves have magnetic materials.

Anjar intertrappean sediments are lacustrine deposits formed during semi-arid conditions proximal to fluctuating coastline (Khadkikar *et al* 1999). These sediments also have volcanogenic clay minerals derived from the weathering of nearby flows. The Deccan flows, with abundant magnetic minerals, e.g., titanomagnetite, can supply these minerals to the intertrappeans, and thereby influence the magnetic susceptibility of the sediments and

therefore, their profiles may have no relevance to KTB.

The negative shift in $\delta^{13}\text{C}_{\text{org}}$ profile associated with K/T transition and attributed to forest fire, may not coincide exactly with the extinction horizon as the preservation of carbon bearing sediments involve many geochemical processes. Indeed, Hansen *et al* (1996) have mentioned that $\delta^{13}\text{C}_{\text{org}}$ profile exhibits some delay with respect to the exact extinction horizon in the typical K/T section at El Kef, Tunisia. At Anjar, the authors do not find a negative shift in $\delta^{13}\text{C}_{\text{org}}$, which could be due to the absence of C3 plants during the KTB event. The palaeoenvironmental reconstruction attempted by Khadkikar *et al* (1999), suggested the prevalence of semi-arid to 'mock aridity' type of climate condition at Anjar. Thus, it is expected that under such climate, the stress loving plant community would thrive which will have less negative $\delta^{13}\text{C}_{\text{org}}$ (plants having C-4 type photosynthesis pathway).

Bhandari *et al* (1993) reported absence of iridium anomaly from Deccan flows (Ir concentration ≤ 0.027 ppb) and intertrappeans at various locations, e.g., Takali, Chui hill, Padwar, Bargi Canal and Jirabad (Ir concentration range from 0.008 to 0.12 ppb) with the sole exception of Anjar (Bhandari *et al* 1995). Rocchia *et al* (1988) have also reported absence of iridium enhancement in both the flows and intertrappean sediments at several locations in the Deccan Province. Although all the characteristic palaeontological or geochemical evidences are absent, the authors find a susceptibility change and $\delta^{13}\text{C}_{\text{org}}$ excursion pattern at Chui hill and attributed them to K/T boundary.

The authors further argue that there is causal relationship between the iridium enrichment and associated clay layers, which could be rhyolitic bentonites. The flows in the Anjar area are alkali basalts having affinity to Ocean Island Basalts such as Réunion basalts (Shukla *et al* 2001a) and are not rhyolitic. The iridium contribution from these flows (Ir concentration range between 2 and 178 ppt) is not sufficient for the observed iridium anomaly (Shukla *et al* 2001b). Considering the ages of underlying flows (65.1 ± 0.5 Ma) and overlying flows (65.4 ± 0.6 Ma) together with palaeomagnetic stratigraphy Shukla *et al* (2001a) suggest the deposition of iridium around KTB event.

The assertion of the authors that no K/T boundary exists at Anjar is also influenced by report of the presence of dinosaur fossils above the upper iridium rich layer (Bajpai and Prasad 2000). Fragmentary nature of fossil pieces and eggs of dinosaurs above the upper iridium layer may indicate their presence in secondary context as no big bones have been found. The lithostratig-

raphy of the Anjar lake sediments (Shukla *et al* 1997) has been reconstructed by partially overlapping sedimentary horizons along the hill slope in the absence of any marker bed and therefore such a stratigraphic correlation is fraught with uncertainty. However, one spectacular sedimentary structure viz., the lenticular cherty limestone horizon above the upper most iridium layer suggests that during the deposition of iridium in the shale horizon environment was initially calm and became turbulent after this event. The lenticular bedding requires current or wave action, preferably in a tidal environment. The possibility of local reworking of fossils from the preexisting fossil beds or from the surrounding area without any significant modification cannot be ruled out. Therefore, drawing any conclusion that there is no KTB at Anjar, without a detailed supporting sedimentological analysis of the basin sediments, is erroneous. The similarity in the ages of overlying and underlying flows within errors indicate that the time available for deposition of about 6m of sediments could be too short (< 1 Ma) for the development of Palaeocene fossils. We would like to emphasize that the three independent geochemical markers like iridium, fullerenes and nano-size particles together with geochronological constraints support the preservation of impact records of KTB at Anjar.

In summary, we would like to point out that one cannot ignore the presence of iridium anomaly, fullerenes and associated nano-meter size particles in Anjar while interpreting the magnetic susceptibility profile and $\delta^{13}\text{C}_{\text{org}}$ data. The conclusion that there is no K/T boundary at Anjar based on magnetic susceptibility and $\delta^{13}\text{C}_{\text{org}}$ criteria developed by Hansen *et al* (2001) ignore the overwhelming geochemical and geochronological evidences and appear erroneous. Independent work of enhanced iridium and the geochronological and palaeomagnetic framework obtained by the French group (Courtillot *et al* 2000) amply prove the presence of KTB at Anjar. In our opinion, the paper by Hansen *et al* should have been titled "K/T boundary at Anjar: No evidence from magnetic susceptibility and $\delta^{13}\text{C}_{\text{org}}$ excursion pattern" rather than the other way around.

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