Forum

Basinward transport of Chicxulub ejecta by tsunami-induced backflow, La Popa basin, NE Mexico: Comment and Reply

COMMENT

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Lawton et al. (2005) describe valley-like deposits in the continental to shallow marine La Popa basin northwest of Monterrey, Mexico, and interpret these as the result of Chicxulub impact induced-tsunami backflow. They further speculate that the thick siliciclastic units, known from the deep paleocanyons of the continental slope to the south and southeast, can also be explained as tsunami backflow deposits. We find no evidence to support this notion in their paper or in more than 45 exposures we examined to the south. Below we comment on their tsunami backflow interpretation and the lack of evidence from Mexico to Texas.

Central to the tsunami idea is the wave run-up transport of deeper water sediment shoreward, followed by backflow transport of shallow water material from the coastal-deltaic complex basinward into the Gulf of Mexico. According to Lawton et al. (2005, p. 82), evidence for tsunami backflow should be found in the deeper water offshore by the presence of shallow water clasts, including the macrofossil assemblage described from the La Popa basin, and four paleocurrent measurements with the "primary flow direction in the valley-fill deposit basinward, generally to the south or southeast." We measured over 100 paleocurrent directions on ripples and flute casts in the deep paleocanyon deposits and all data range between N30–N200, with a mean direction of N117 (Keller et al., 2002). But since all paleocanyons necessarily flow basinward to the east-southeast, this merely marks the normal flow pattern and drainage from uplifted land areas located to the northwest and linked to the onset of the Laramide orogeny (Salvador, 1991). The La Popa incised valley fills mark the shallow part of the paleocanyons, which can be observed in deeper settings southeast of the Monterrey–Ciudad Victoria area. Such features are consistent with our observations of sedimentation via mass flows and turbidity currents in a paleochannel system and in no way indicate tsunami backflow.

We found no evidence of tsunami backflow in over 45 deep-water (>500 m) exposures with thick siliciclastic deposits to the south and southeast of Monterrey (Stinnesbeck et al., 1993; Adatte et al., 1996; Keller et al., 2003). In all of these exposures, a mixed assemblage of neritic and bathyal benthic foraminifera is found in one or two impact spherule layers at the base of the siliciclastic deposits (Alegret et al., 2001), which indicates reworking and transport from their initial deposition on the continental shelf, but no coastal macrofossils are present. The transport occurred a long time after the original spherule ejecta deposition and prior to the Cretaceous-Tertiary (K-T) boundary, as indicated by the presence of two impact spherule layers separated by a 15–20-cm-thick sandy limestone with J-shaped burrows infilled with spherules and truncated. The same burrows are found near the base in the overlying sandstone, and the upper unit of sand-silt-mudstone layers is also strongly burrowed (Keller et al., 1997; Ekdale and Stinnesbeck, 1998). This indicates repeated colonization of the ocean floor during deposition of the siliciclastic units, which rules out tsunami deposition within hours to days of the Chicxulub impact. Moreover, the original impact spherule layer was recently discovered in late Maastrichitan marls more than 5 m below the siliciclastic deposit and predating the K-T boundary by 300 k.y. (Keller et al., 2002, 2003). No tsunami backflow interpretation can be reconciled with these data.

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The very shallow La Popa basin is a poor choice to base an interpretation of tsunami-induced backflow, as high-energy regimes from currents and storm events create similar sedimentary structures. This is evident along the Brazos River, Texas, where water depth ranged from 50 to 100 m and scoured paleochannels are infilled with a basal conglomerate and sandy glauconite rich in Chicxulub impact ejecta, followed by multiple sandstones with burrowed surfaces (Yancey, 1996; Gale, 2005). High-resolution bio- and chemostratigraphies indicate that these deposits are of latest Maastrichtian age and coeval with the siliciclastic deposits of NE Mexico. The Brazos deposits were also originally interpreted as tsunami deposits, but were later determined to be 4–5 storm events, separated by significant time during which marine organisms colonized the ocean floor (Gale, 2005). This leaves the tsunami-backflow interpretation of the La Popa basin without supporting evidence in the surrounding region of either Texas or NE Mexico.

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REPLY

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Keller and Adatte raise four objections to the tsunami backflow hypothesis proposed by Lawton et al. (2005) for strata at the Cretaceous-Paleogene boundary in the La Popa basin. We summarize and address those objections in sequence below.

1. East-southeast flow directions recorded in sediment-gravity flow deposits at numerous deepwater Cretaceous/Paleogene sites along the western Gulf of Mexico record expected orientations of submarine canyons linking shelf and basinal settings; therefore, the La Popa backflow deposit is simply the upstream end of one of these canyons. This argument has no obvious bearing on the nature of the sediment-transport system that fed debris to the sediment-gravity flows. The shelf part of the sediment-bypass system must have been tied by some means to the system's deeper part and bathymetric features of the basin likely controlled the flow directions of the downdip sediment-gravity flows. However, submarine canyons probably did not extend all the way to the latest Cretaceous shoreface zone, as suggested by Keller and Adatte (2005); in the modern Gulf of Mexico, the submarine canyons terminate several tens of kilometers from the shoreline (Bryant et al., 1991). The deepwater end-Cretaceous sites of eastern Mexico actually lay in a foreland basin in which turbidity currents flowed along a foredeep from a prograding fluvial-deltaic system that lay to the west and northwest (Soegaard et al., 2003). The bathymetric profile of that basin remains poorly understood, but submarine canyons need not have been a component of the bathymetry.

2. Faunal and sedimentologic evidence in the deepwater deposits fails to tie the La Popa backwash deposits to the deepwater sites. Keller and Adatte (2005) cite the absence of coastal organisms from the deepwater sites as deleterious to the backflow hypothesis. This absence is indeed puzzling, but could be explained by downcurrrent loss of larger fragments or unfortunate outcrop availability. Plant debris and Turonian mudstone clasts described from some ejecta-bearing deepwater sites (e.g., Stinnesbeck et al., 1993; Schulte et al., 2003) must have come from terrestrial or coastal settings and partially breached Laramide folds, respectively, and abundant marl clasts universally attributed to the underlying Mendez Formation may in part represent the micrite clasts in the La Popa backflow deposit (Lawton et al., 2005). There are ample observational data to tie the deepwater sites to coastal ones.

3. The deepwater ejecta-bearing deposits constitute several horizons colonized by burrowers and thus cannot represent a single event. Indeed, we expect postbackflow sediment reworking to have occurred along the early Paleogene Gulf rim. Vigorous tsunami backflow had the potential to transport and store tremendous volumes of ejecta-bearing sediment on the shelf. This ejecta-rich debris would have been available for reworking by large-scale storm events (hurricanes), a mechanism invoked by Keller and Adatte (2005), and attendant transport to deeper water within a few thousand years of the impact.

4. The deposits we attributed to supercritical flow may represent conventional deposits of current- or wave-generated processes, which are conditions intrinsic to many channels, tidal creeks, and storms. Sedimentary structures must be considered in the context of their lateral and stratigraphic arrangement for proper interpretation (e.g., Van Wagoner et al., 1990), and a vast literature exists concerning recognition of wave-, tide-, and river-dominated depositional systems. In these systems, upper flow regime conditions are transient and invariably alternate with subcritical flow conditions recorded by diagnostic sedimentary structures. The La Popa backflow deposit, with its preponderance of turbulent supercritical flow indicators, coarse grain size, substantial thickness, and absolute absence of sedimentary structures created by subcritical flow, does not conform to typical facies models for fluvial or nearshore marine environments, nor typical incised valley fills. It is, in fact, an extraordinary deposit.

In conclusion, the La Popa basin is an auspicious locality, not a poor choice, for understanding mechanisms and deposits of tsunami-induced backflow. The La Popa backflow deposit provides potential insight into how huge volumes of sediment are reworked basinward following tsunami run-up; indeed, it may force us to reexamine some existing interpretations for the origin of coeval deepwater deposits flanking the Gulf of Mexico.

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