

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

### COMMENT

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Valley-fill deposits in the continental to shallow marine La Popa basin to the northwest of Monterrey, Mexico, are interpreted by Lawton et al. (2005) as the result of Chicxulub impact-induced tsunami backflow. There is little if any support for this notion in their paper and it contradicts their earlier publication on the same outcrops (Lawton et al., 2001).

As evidence of the tsunami run-up in the La Popa basin, Lawton et al. (2005) cite deeper water elements in a mostly shallow water assemblage (e.g., echinoderms, bryozoans, corals, gastropods, oysters, ammonites, and some unidentified foraminifera). Among this assemblage, only the ammonites could possibly be interpreted as open marine faunal elements, but according to Lawton et al. (2001), the only ammonite present in the Delgado Sandstone Member of the Potrerillos Formation is *Sphenodiscus pleurisepta* (Conrad). This characteristic early to late Maastrichtian species is, however, explicitly found in extremely shallow water, where it is often associated with oyster accumulations (e.g., Ifrim et al., 2004).

In their 2001 publication, Lawton et al. described the sedimentary structures of the La Popa basin as consistent with incised valley deposits, an interpretation we agree with. The incised valleys cut erosively into the Delgado Sandstone Member, which is of Maastrichtian age. Above the erosional surface, the upper mudstone member is considered to be of Paleogene age (Lawton et al., 2001). The base of this unit is formed by a fining-upward conglomeratic to mudstone sequence of variable thickness, which Lawton et al. (2005) now interpret as “tsunami-generated backwash.” Lawton et al. (2001, p. 231) state that in the area of the El Papalote and El Gordo diapirs, the “fossil evidence suggests that as much as five million years—from latest Maastrichtian to middle Paleocene—are missing at the unconformity.” Although the age of the valley fills is clearly not well constrained in the absence of microfossils, Lawton et al. (2005) nevertheless conclude that it is of Cretaceous-Tertiary (K-T) age. The only evidence for a near-K-T age of these deposits are reworked ejecta of the Chicxulub impact (Lawton et al., 2005). These ejecta are easily redeposited into younger sediments. In eastern and southern Mexico, Guatemala, Belize, and Haiti, for instance, Chicxulub impact spherules are commonly reworked into sediments of Danian age (e.g., Keller et al., 2003). The La Popa spherules are also reworked, with the age of the sediments unknown.

Both Vega et al. (1999, p. 108) and Lawton et al. (2001, p. 232) point out that *Cimomia haltomi* (Aldrich), a Paleocene nautiloid, is present in clasts in the conglomerate forming the base of the upper mudstone member, which they now interpret as tsunami deposit (Lawton et al., 2005). Clearly, the presence of Paleocene nautiloids, which evolved hundreds of thousands of years after the K-T boundary, marks the conglomerate as post-K-T in age and unrelated to the Chicxulub impact.

Mixing of fossils of different shallow water facies is a characteristic feature of incised valley fills that always mark “a major sequence

boundary” described by Lawton et al. (2001) for the contact between the Delgado Sandstone and upper mudstone member. We follow their interpretation and Soegaard et al. (2003), that the valley infill is a transgression conglomerate at the base of the transgressive systems tract.

The mixing of lithologies in the incised valley fill is related to uplift and erosion of the El Papalote and El Gordo diapirs, rather than to any tsunami-induced backflow. Tectonic uplift had important influence on the sediment deposition in the La Popa basin (Lawton et al., 2001). Shallow water carbonate lentils, including oolitic limestone and bioclastic grainstone, developed in the area above and close to the diapirs, while siliciclastic deposition prevailed between these bathymetric highs (e.g., Lawton et al., 2001). Thus, it is no surprise to find a mixture of shallow water carbonate and siliciclastic clasts in valley-like depressions near the margin of an active diapir, overlying a sequence 1 boundary, which exposed and caused erosion of a shallow water deltaic complex.

The data presented by Lawton et al. (2005) thus fits perfectly well into the sequence stratigraphic context outlined for the La Popa basin by Lawton et al. (2001), Soegaard et al. (2003), and others. Curiously, Lawton et al. (2005) base their extraordinary interpretation of tsunami-induced backflow deposits solely on the observation of “rare bedsets,” which “dip counter to the south-directed flow,” and which they interpret as collapsed antidunes indicating supercritical flow regimes (Lawton et al., 2005, p. 82). However, antidunes and supercritical flow regimes also occur in channels, tidal creeks, storm deposits on the upper shoreface, and turbidity currents and thus also fit a sequence stratigraphic interpretation.

Lawton et al. (2005) presented a self-fulfilling scenario in which they excluded any data that does not fit their hypothesis and omitted any discussion between competitive interpretations. We agree with Carl Sagan who noted that extraordinary claims need extraordinary evidence. Lawton et al. (2005) have failed to present convincing evidence for their extraordinary claim of tsunami-induced backwash.

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## REPLY

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Stinnesbeck et al. address some important uncertainties about the sedimentologic and sequence stratigraphic origins of the tsunami deposit in the La Popa basin. We welcome the opportunity to expand upon these aspects of the deposit.

Stinnesbeck et al. mistakenly understood us to argue for tsunami run-up on the basis of “deeper water elements in a mostly shallow-water assemblage.” In fact, we argue the opposite: The gastropods, oysters, bryozoans, foraminifera, and even ammonites represent a shallow marine to coastal faunal assemblage mixed and dragged to deeper water by the return flow. Micrite and calcareous siltstone fill the gastropods and are present as intraclasts, which are locally armored by ejecta grains. These lithic types are not known elsewhere in the uppermost Cretaceous basin stratigraphy (e.g., Aschoff, 2003); they were likely derived from coastal environments such as estuaries and salt marshes that lay beyond the basin. The mixed shallow marine to coastal fauna lying offshore of its original habitat is a key argument for the polarity of the flow. We regret if this point was not clear in the paper.

As noted by Stinnesbeck et al., the precise age of the valley-fill deposit is imperfectly constrained. The ammonite, *Sphenodiscus pleurisepta*, is present up to and in the valley-fill deposit. Five km to the south, the Paleocene nautiloid, *Cimomia haltomi*, is present in what is probably a transgressive lag at the base of the overlying upper mudstone member of the Potrerillos Formation (Vega et al., 1989; Lawton et al., 2001). Micrite fill of ammonites in the valley fill indicates that they are reworked. Thus, the valley-fill deposit lies at or near the stratigraphic Cretaceous-Paleogene boundary. Our interpretation of a Cretaceous-Paleogene unconformity (Lawton et al., 2001) predated recognition of both Chicxulub-derived ejecta in the valley-fill deposit (Aschoff et al., 2001) and obvious differences in the sedimentology of the valley fill and near-diapir debris flow deposits, present only within 1 km of the El Papalote diapir (Rowan et al., 2003). On the basis of biostratigraphy alone, one may conclude that the valley-fill deposit does not precisely record the Mesozoic-Cenozoic boundary, and therefore might not be coeval with an end-Cretaceous impact. However, stratigraphic restriction of the ejecta to a single level incised into Upper Cretaceous strata, intimate association of ejecta and weakly lithified intraclasts indicated by ejecta armoring, and a mixed fauna with fill resembling the intraclasts combine to indicate that ejecta arrival and the large erosive event were nearly simultaneous impact-related phenomena.

A general lack of diapir-derived detritus in the valley-fill deposit makes the diapiric-source hypothesis offered by Stinnesbeck et al. (2005)

untenable. The nearby El Papalote diapir was a unique source for mafic metaigneous clasts present in nearby Upper Cretaceous through Paleogene strata (Garrison and McMillan, 1999; Giles and Lawton, 2002). Although locally abundant in strata flanking the diapir (Lawton et al., 2001; Giles and Lawton, 2002; Rowan et al., 2003), metaigneous clasts are extremely rare in the valley fill. Moreover, red algal detritus derived from diapir-flank bioherms (e.g., Hunnicutt, 1998) is a common component of strata near the diapirs, but is rare in the valley fill. Although some debris was eroded from the diapir by the back flow, and a small amount of that material resides in the valley fill, the tsunami deposit had a fundamentally different provenance than the strata derived from the diapirs.

The sequence stratigraphic position of the valley-fill deposit is critical to understanding its origin. A basinwide reappraisal of the Delgado Sandstone Member of the Potrerillos Formation (Aschoff, 2003) revealed that the ejecta-bearing beds do not represent a conventional valley fill overlying a sequence boundary. Rather, the valley fill lies within a retrogradational parasequence set in the upper part of the Delgado Member and overlying upper mudstone member, and therefore occupies a transgressive systems tract. The tsunami deposits thus punctuate the sequence stratigraphy of the basin, occupying a stratigraphic position not predicted by base-level models, an observation that emphasizes their allogenic event origin.

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