DISCUSSION

The sandstone layers occurring at the K/T boundary around the Gulf of Mexico are a complex deposit, size graded overall, with a distinct sequence of lithologies. We interpret this sequence to be the result of tsunami-wave activity initiated by the Chicxulub impact event on northern Yucatan. The K/T sandstone can be divided into four subunits, each one representing a different phase in the impact-tsunami scenario. We first discuss the tsunami-wave hypothesis, then alternatives given by other authors.

The basal Unit I invariably contains spherules and droplets, 0.5 to 10 mm in size, that we interpret as remains of molten ejecta—impact glass or (micro) tektites—because at Mimbral and Beloc some spherules contain a relict core of impact glass (Smit et al., 1992b). The tektites are invariably altered, but the same basic morphology is found in all K/T localities, including Beloc, and therefore can be easily recognized in the field and under a microscope. More than 99% of the tektites contain abundant bubble cavities, which are diagenetically infilled with clay minerals, or calcite. The bubble-cavity infillings may weather out, leading to interpretation as separate spherules, and the illusion of "accretionary lapilli," whereas they are actually bubble-cavity infillings enclosed in a spherule of clay minerals (Lyons and Officer, 1992). We also interpret the abundant rounded limestone fragments as ejecta, because invariably they are associated with the tektites and are highly similar in different places, whereas other detritus differs in composition from place to place, depending on the local source area. The ejecta are not primary deposits but are reworked into scours or channels gauged in the seafloor and mixed with local components, because the deposits are invariably cross-bedded.

Locally, we believe there is evidence for strong seismic activity, at least preceding the arrival of the first tsunami waves. At Moscow Landing, the ejecta deposits are associated with faults and soft-sediment deformation. The faults were active just before the deposition of the ejecta, because these deposits occur only near the faults and slumped areas. At Moscow Landing, La Lajilla, and El Peñon, material with ejecta is injected into fault planes below the K/T sandstone unit, indicating continued faulting during deposition of the K/T sandstone unit. At Bochil and in Guatamala (Hildebrand et al., 1994) the K/T sandstone complex is preceded by thick mass-flow conglomerates, probably triggered by seismic activity and moving downslope just before the arrival of the first tsunami waves, possibly before the arrival of the first ejecta. At Rancho Nuevo, Los Ramones, La Lajilla, and Mimbral, the Unit I and II channels are deeply loaded into the soft Mendez marls. Seismites—single, thick mass-flows of turbidites triggered by an earthquake—have some of the same characteristics as the K/T sandstone complex (Kleverlaan, 1989). It is reported that the seafloor has been deformed as a direct result of the earthquake and the loading by the seismite.

Unit II usually displays a set of well-sorted lenticular sandstones, with a wide variety of sedimentary structures indicating currents that change direction several times up-section, often by 180°. The material of Unit II is a mixture of locally derived material and material from nearshore areas (plant debris, terrigenous grains, shallow-water foraminifers) and differs from place to place, although some of the Unit I ejecta still occur at the base of some layers. The sedimentary structures—strong parallel lamination, climbing ripples, water-escape structures—show that these sandstones were deposited rapidly by strong currents varying in strength and direction. In none of the localities investigated by us did we observe that the lenticular sandstone layers are interrupted by layers of normal hemipelagic deposition, or layers with burrows, that would represent long periods of time between deposition of the individual sandstone layers.

We interpret the repeated change in current directions to be a result of deposition by up-surge and back-surge of several large tsunami waves, best observed in the La Lajilla section. In some localities (Beloc, Coxquihui), Unit II does not occur. Since the bulk of the material is derived from nearshore material (shallow-water bioclasts, coarse terrigenous grains, and plant debris) and winnowed foraminifers, we infer that these localities are either too far from the shore or are at a water depth below tsunami wave-base.

Unit III is essentially a continuation of Unit II, but represents the phase in which tsunami waves decrease in strength to such extent that fine sediment is able to settle in between ripple layers of fine sand deposited during wave surges. These mud-drapes are the first sediments to be enriched in iridium. Clearly, the deposition of iridium-rich phases is decoupled from the deposition of the coarse ejecta. Assuming a one-impact scenario, we infer that the iridium carrier particles are much finer grained and settle much more slowly than the coarse ejecta. Burrows occur in and at the top of the last sandstone ripples. Rare chondrites also occur on the surface of some of the lower sand ripples and the silt in between but not inside those lower sand ripples. Because the burrow-fabric is tiered, we conclude that the top surface was colonized after, not during, deposition of the sand ripples.

Unit IV represents the phase when currents induced by tsunami-waves are no longer capable of transporting fine sand at the seafloor, and silt and clay are able to settle on the seafloor. Regarding the large amount of winnowed foraminifers in the K/T sandstone unit, it is expected that most of the fine sediment has been washed out and remained suspended in the water-column during passage of the tsunami-waves. The mudstone interval is size graded, and we therefore infer that this graded interval represents an interval of days to weeks after the initiating tsunami event. The burrows present in this interval (which is not bioturbated) are difficult to interpret. These burrows could be due to a colonizing episode of weeks to months but could also be due to organisms trying to burrow back again in the seafloor sediment after being "uprooted" by the tsunami currents.

The K/T sandstone complex as a whole forms one contin-