APPENDIX II

STABLE ISOTOPE DATA FROM BRAZOS RIVER KTB SECTIONS

From Keller, this volume,
Keller et al., this volume,
Abravovich et al., this volume

Oxygen and carbon isotope analyses were conducted on most Brazos River KTB sequences. In some sections, analyses were performed on well-preserved specimens of the benthic foraminifer *Lenticulina* spp. in the size fraction 150–250 μm with little or no sediment infilling chambers. For other sections, bulk rock or the fine fraction (38–63 mm) washed residue was analyzed. The latter consists mainly of small planktic foraminifera and nannofossils and provides a good measure of near-surface water conditions. The planktic foraminifer *Heterohelix globulosa* was previously analyzed for the KT3 section and published in Barrera and Keller (1990) and hereby also for Mullinax-3. In Mullinax-1 δ^{13}Corg was also analyzed along with PGEs. For some sections, various other benthic species (*Anomalina acuta*) and Cretaceous planktic (*Pseudoguembelina costulata*) and Danian species (*Guembelitria cretacea*) were also analyzed.

Stable isotope analysis was performed using a fully automated carbonate preparation system (GasBanch II) connected on-line to an isotope-ratio mass spectrometer (Delta Advantage, Thermo Finnigan, Bremen, Germany). Isotope-ratio values are reported relative to NBS-19 with $\delta^{13}C = 1.95‰$ (V-PDB). Precision, assessed on the basis of repeated measurements of the carbonate standard, was generally better than 0.06‰ for each analytical batch. The locations of the Brazos River KTB sequences are shown in Figure 1 of Appendix I.

Brazos River outcrops (2007)

BRAZOS-1

Table 1. Brazos-1 section, stable d^{13}C and d^{18}O isotope data from washed residues fine fraction (38–63 µm) and *Lenticulina* spp. (> 180 µm). See Keller et al. (this volume; Fig. 7) for the litholog and Figure 2 in Appendix I. The various lithologies of the sandstone complex (A–H, sample notations from Hansen et al., 1987) were also analyzed. Samples A–H correspond to samples 1–7 in the Brazos litholog (See Fig. 2 in Appendix I). The highly variable isotope values reflect both diagenesis and heterogenous deposition of the various layers in the sandstone complex.

BRAZOS Well KT1

Table 2. Brazos KT1 well, stable d^{13}C and d^{18}O isotope data from *Lenticulina* spp. (> 180 µm) (> 180 µm) and selected samples for *Heterohelix globulosa* and *Guembelitria cretacea*. See Keller et al. (this volume; Fig. 8) for litholog.

Brazos Well Mullinax-1

The Mullinax-1 well was drilled at the same GPS location as well KT3 (see Keller et al. this volume for discussion). Stable isotope analyses were performed on the benthic foraminifer *Lenticulina* spp., the planktic foraminifer *Pseudoguembelina costulata* and bulk rock, as well as δ^{13}Corg. The data for samples 1–87 is illustrated in Figure 1 along with PGE data (Table 3). Data for the Maastrichtian zones CF1-CF3 are illustrated in Figure 3 (Abramovich et al., this volume) (see Table 4). The PGE data is discussed in Gertsch et al. (this volume).

The δ^{13}C and δ^{18}O records of benthic foraminifera show consistent Maastrichtian trends above and below the sandstone complex with reworked Chicxulub impact spherules. They gradually decrease across the KTB mass extinction with Danian values beginning about 90 cm above the top of the sandstone complex (see Keller et al., 2007, this volume). Ir, Ru, and Pd concentrations are highest just above the sandstone complex and appear to be condensed and remobilized (see Gertsch et al., this volume). PGE data are published in Gertsch et al. (this volume).

Figure 1. Stable isotope and PGE data from Brazos core Mullinax-1. See Gertsch et al. this volume for discussion of PGE data.

Table 3. Mullinax-1 well, stable d^{13}C and d^{18}O isotope data of bulk rock and *Lenticulina* spp. (see Keller et al. this volume Figures 2 and 9 for litholog and biostratigraphy).

Table 4. Mullinax-1 well, stable d^{13}C and d^{18}O isotope data of *Lenticulina* spp. and Pseudoguembelina costulata, Maastrichtian samples 81–147 (see Keller et al. this volume and Abramovich et al.; this volume Fig. 3).

COTTONMOUTH CREEK SECTIONS

The Cottonmouth Creek is a tributary to the Brazos River and located about 2 km south of Highway 413 across the Brazos River (Fig. 1; Appendix I). Outcrops analyzed along this creek include CMA and CMW, which are two sections 10 m apart and for this study have been combined as CMAW. Well KT3 was drilled near the CMAW sections in the 1980s (Hansen et al., 1987; Keller, 1989). The CMW section is located directly beneath and to the side of the waterfall. Sections CMB and CMC are sections about 30 m and 50 m down creek from CMAW that span the sandstone complex and the interval above it (mostly Danian). The CM1 section of Hansen et al. (1987) and Keller (1989) is equivalent to CMB-CMC. The CM4 sections of this study and of Hansen et al. (1987) and Keller (1989) are the same outcrop vicinity (Fig. 1). See Keller et al., this volume for discussion of the sections.

Figure 2. Cottonmouth Creek waterfall outcrops CMAW and CMB are correlated based on the top of the sandstone complex, biostratigraphic and stable isotope data. Note the sample notations in CMAW begin with negative numbers below the yellow clay that consists of altered impact glass spherules (cheto smectite).

Cottonmouth Creek Waterfall CMAW-CMB

The two Cottonmouth Creek waterfall sections CMA and CMW located 10 m apart are here combined as CMAW. CMB located about 50 m down creek are the best outcrops for the KTB transition (see Adatte et al., this volume, Keller et al., this volume). CMAW and CMB form a composite sequence across the KTB. Consequently, much effort was invested in geochemical data analyses including stable isotopes of bulk rock, planktic and benthic foraminifera and dCorg (Table 5). Parts of this dataset are published in Keller et al. (2007, 2009) and Keller et al., this volume.

Foraminiferal Isotope Data (CMAW-CMB Sections)

The $\delta^{18}O/\delta^{13}C$ based on the benthic species *Lenticulina* and the planktic species *Heterohelix globulosa* from the CMAW-CMB composite section show light $\delta^{18}O$ and heavy $\delta^{13}C$ values for *H. globulosa* (Fig. 3). *Lenticulina* show the opposite trend, though there is a large scatter in the data points. There are insufficient data points for the benthic species *Cibicidoides.* The scatter is partly due to sediment infilling of foraminiferal chambers in some specimens but the main scatter is due to the varying environmental conditions across the KTB transition with heavier $\delta^{13}C$ values in the Maastrichtian and lighter values in the early Danian, as seen in Figure 4.

Figure 3. $\delta^{18}O/\delta^{13}C$ plot of benthic and planktic species from the CMAW-CMB sections.

Cottonmouth Creek stable isotope data are summarized in Figure 4 and earlier discussed benthic foraminifera in Keller et al. (2007) and Keller et al. (this volume). Additional data are presented here for planktic foraminifera and δCorg. Notable in this dataset is the $\delta^{13}C$ shift at the KTB well above the top of the sandstone complex, which demonstrates that this clastic deposit with its reworked impact spherules was deposited prior to the KTB mass extinction. Also notable is the short $\delta^{13}C$ excursion associated with the yellow clay layer below the sandstone complex. This yellow clay layer consists of altered impact glass (cheto smectite, see Keller et al., 2007; Adatte et al., this volume) and appears to represent the primary Chicxulub impact signal.

Figure 4. Stable isotope data (bulk rock, planktic and benthic foraminifera and Corg) of the Cottonmouth Creek CMAW-CMB sections. Note the major negative excursion at 62 cm marks the yellow clay layer that consists of altered impact glass (cheto smectite).

Cottonmouth Creek Well KT3

Well KT3 has been variously labeled Brazos core (Keller, 1989), Brazos 1 and well KT3 (see Keller et al., this volume). Data on KT3 were first published in Keller (1989) and Barrera and Keller (l990). For background information see Keller et al., this volume. Data Tables 7 and 8 document the Maastrichtian-Danian interval. Figure 5 shows the plotted isotope data across the KTB transition samples 200–289.

Figure 5. Stable isotope data across the KTB transition in Cottonmouth Creek well KT3 samples 200–289. Note the gradual negative shift in d13C across the KTB in both

benthics and the Cretaceous species H. globulosa. The latter demonstrates that this species survived the KTB mass extinction for some time into the early Danian.

Table 7. Stable isotope data from *Lenticulina* spp. and *H. globulosa* from Cottonmouth Creek well KT3. Lenticulina spp. were run on a group of about 30 specimens, but single species analysis was also done on the upper part (Danian) of the section. Most notable is the is the gradual decrease in d13C values across the KTB into the Danian in the planktic foraminifer *H. globulosa*, which demonstrates that this species survived the mass extinction at least for some time into the P. eugubina zone Pla (see also Barrera and Keller, 1990; Keller et al. this volume).

Table 8. Stable isotope data from *Lenticulina* spp. and *H. globulosa* from Cottonmouth Creek well KT3 samples 10–209.

DARTING MINNOW CREEK

Wells Mullinax-2 and 3

Mullinax-2 and 3 were drilled as overlapping cores on a meadow above Darting Minnow Creek at a distance of about 150–200 m from the waterfall. This is the shallowest depositional environment encountered in the Brazos area. Paleodeposition occurred at middle neritic depth during the late Maastrichtian and shallowed to inner neritic depth with the sea level fall at the time of the sandstone complex deposition in CF1. In Mullinax-2 and 3 a thick root zone indicates subaerial exposure. The KTB is marked by erosion above the rootzone (see Keller et al., this volume) for the KTB faunal turnover, Abramovich et al. (this volume) for the Maastrichtian record, and Adatte et al. (this volume) for the sedimentary environment. A great effort was invested in stable isotope analyses of bulk rock and well-preserved planktic (*Heterohelix globulosa, Pseudoguembelina costulata*) and benthic foraminifera (*Lenticulina* spp.) (Tables 9–11). These data are illustrated in Figure 6.

Figure 6. Summary of stable isotope data from Mullinax-3. Note that stable isotope data from the root zone interval is based on the dark gray claystones and the foraminifera therein, which are found between the roots and gypsum crystals.

The shallow depositional environment that is evident in the root zone interval of well Mullinax-3 below the KT boundary is also reflected by the stable isotope data of planktic and benthic foraminifera (Fig. 12). $\delta^{13}C$ values for the benthic *Lenticulina* spp. and planktic *Heterohelix globulosa* and *Pseudoguembelina costulata* are largely overlapping with minimal surface-to-deep gradient, as would be expected in very shallow water environments. A minor though distinct surface-to-deep gradient is apparent in the $\delta^{18}O$ values that likely reflect salinity effects and possibly warmer surface waters. There are two major isotope excursions. One is near the base of zone CF1 and stratigraphically corresponds to a similar excursion in CMAW associated with the yellow clay that represents the primary Chicxulub impact spherule ejecta layer now altered to cheto smectite (Fig. 4; see also Adatte et al., this volume; Keller et al., 2007, this volume). The second excursion is across the KTB and begins in the root zone interval where $\delta^{13}C$ and $\delta^{18}O$ values dramatically decrease by 3 permil in planktic foraminifera and to a lesser extent in benthic foraminifera. This negative $d^{13}C$ shift partly represents the productivity drop across the KTB, but may be amplified by the shallow water conditions and multiple emersions (e.g., salinity effects and paleosoil formation). Note that the KTB is above the root zone, which indicates that the latter is equivalent to the sea level fall that resulted in the sandstone complex in zone CF1 below the KT boundary. A hiatus marks the KT boundary with subzone P1a(1) and the uppermost Maastrichtian part of zone CF1 missing. Recovery in subzone P1a(2) reflects the global trend. The negative shift near the top of the analyzed interval coincides with another hiatus.