**Supplementary Materials**

The procedures for sediment sampling to geochemical analysis, piston core description and the experimental conditions of the equipment are detailed below:

**1. Supplemental material for the Methods section**

**1.1. Sampling**

Two sediment cores, named PC31 and PC51, were obtained with a 6.0 m long PC device during the MR11 oceanographic mission and were used in this study. The PCs were collected in the upper slope of Rio Grande Cone around 215 km from the coast. They were retrieved at water depths of 1155 and 538 m, respectively**.** Immediately upon core recovery onto the ship’s deck, the PVC liner containing the sediments was removed from the outer iron tube and cut into 100 cm sections. Each section of the liner was then split lengthwise into a working half for sampling and an archive half for onboard core descriptions and storage.

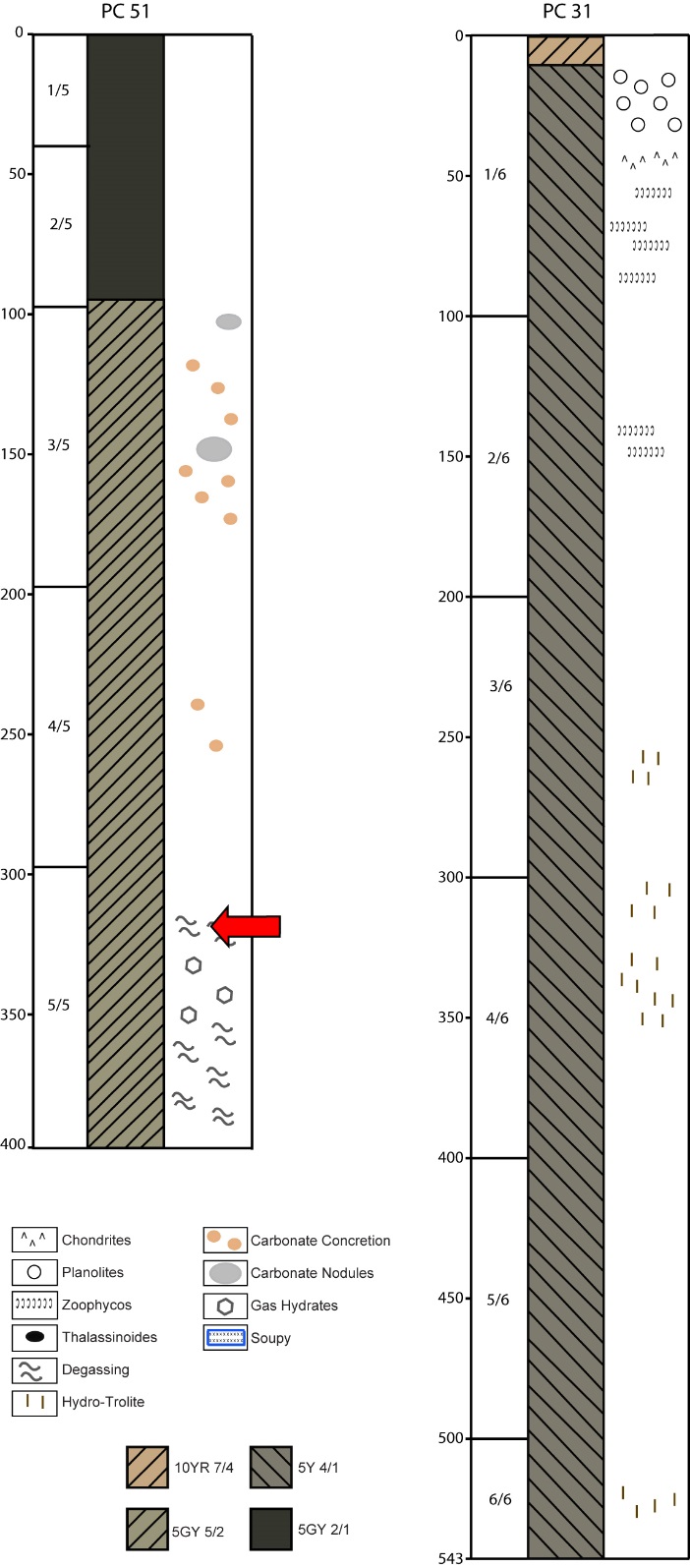
The sediments were sampled from the working half at regular intervals of 30 cm (three per core section) for geochemical analysis (TOC, TN, TS, stable isotope and radiocarbon analysis for bulk organic sediments). Samples for paleontological analysis were collected immediately below the geochemical samples. Sediment samples for mud gas analysis (C1–C5 hydrocarbons) were obtained from the top of each section (one per section). These samples were collected from the freshly exposed tops of the core sections using a spatula and were immediately placed into IsoJars. The sediment samples filled one third of the IsoJars, while another third was filled with distilled water, leaving the top third with air (headspace). Five drops of diluted Zephiran Chloride bactericide were added to the IsoJars in order to reduce microbial activity. The IsoJars were kept refrigerated at 4 °C (Rodrigues et al. 2017). For sulfate analysis of the interstitial water, the sediment samples of the working half were collected at regular intervals of 30 cm (three per core section) and pieces of 10 to 20 cm were squeezed onboard using titanium hydraulic Manheim squeezers. Interstitial water samples were collected in 50 ml syringes attached to the base of each squeezer. Approximately, 40 mL was transferred to plastic bottles and stored at 4 °C for further analyses onshore (Manheim et al. 1994).

**1.2. Piston core descriptions**

The two representative piston cores selected for this study (PC51 and PC31) were described as follows:

PC-51 cores (3.97 m long/535 m water depth) consisted of a dark green-gray mud with concretions and carbonate nodules between 100 and 180 cmbsf. At the interval from 185 to 270 cmbsf authigenic carbonate nodules were present. Between 315 and 397 cmbsf degassing structures were described and gas hydrates were found at the interval 345–365 cmbsf.

PC-31 cores (5.43 m long/1156 m water depth) consisted of a grayish orange mud in the top10 cmbsf, changing to a light olive gray (10–543cmbsf). Planolites and chondrites (10–50 cmbsf) and Zoophycos ichnofossils (50–90 and 140–150 cmbsf) and hidrotroilite (250–270, 300–350 and 510–525 cmbsf) were found. Core sections showing degassing features in muddy sediments from PC51 and PC31are depicted in Figure S1.

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**Figure S1.** Main sedimentary features identified in the studied piston cores. Core units are divided based on 100 cm sections. According to the Geological Color Chart, 10YR 7/4 is grayish orange; 5GY 2/1 is greenish black; SGY 5/2 is dusky yellow green and 5Y 4/1 is olive gray.

**1.3. Total organic carbon, total nitrogen and total sulfur**

The samples were analyzed for TOC and TN in a LECO elemental analyzer, model TRUSPEC (USA), equipped with an infrared detector for carbon analysis and conductivity detector for nitrogen analysis. An oxygen atmosphere (99.9999% pure) was used at 950 °C in the combustion step. The flow rate of oxygen was 10 L min–1 and all products obtained by combustion were carried by helium (99.99% pure). Approximately 100 mg of sediment samples were encapsulated within sheets of tin. The encapsulated samples were placed in an autosampler with capacity for 30 samples. Before analysis, the samples were heated to 60 °C for 24 h, powdered and inserted into Falcon tubes. A solution of 3.2 mol L–1 HCl was added to the Falcon tubes, which were then heated in a water bath at 60 °C to remove carbonate minerals. Acidified samples were dried and washed with Milli-Q water after acid evaporation. After the washing step, the Falcon tubes were heated to 60 °C for 24 h.

The samples for TS were analyzed in a LECO elemental analyzer model SC632. Approximately 100 mg of sediment samples were introduced into the equipment. Along with the standard and samples, about 500 mg of the LECO COM-CAT was used to ensure total combustion of the material. All samples were analyzed in triplicate. Reference materials from marine sediments (PACS-2, MESS-2 and GBW 07313) were used for validation of results.

**1.4. Stable carbon isotope analysis of bulk sediment**

Stable carbon isotope ratios (13C/12C) were determined using a gas chromatograph (Thermo Fisher Scientific, GC IsoLink, Germany) coupled to an isotope ratio monitoring mass spectrometer (Thermo Scientific DELTAV Plus, Germany) via a Conflo IV interface (Thermo Fisher Scientific, Germany). The gas chromatograph contained a 30 m × 0.32 mm fused silica column Carboxen Plot 1006 (Supelco) and was operated at a heating ramp of 70 °C to 150 °C over 10 min. All 13C/12C values are reported relative to a reference CO2 of known carbon isotopic composition (δ13C= −32.82 ± 0.25‰) which was introduced directly into the ion source in three pulses at the beginning of each run. The reference gas was calibrated against the Vienna Pee Dee Belemnite (VPDB) standard. Each measurement was performed in at least triplicate. The isotopic data are reported using the delta notation with δ13C variations relative to the international VPDB standard:

δ13C = (Rsample/Rstandard − 1) \* 1000

Where R is the measured 13C/12C isotopic ratio in the sample and the standard, and differences in the ratio between standard and sample are reported in parts per thousand or per mil (‰).

**1.5. Radiocarbon dating of bulk sediment**

The sediment samples from PC31 and PC51 were analyzed by AMS at the Radiocarbon Laboratory of the Fluminense Federal University (LAC-UFF). All samples were acidified with HCl to remove carbonates. After adding pre-combusted CuO (50–100 mg) and Ag wire (5 mg), dry samples were placed in quartz tubes, sealed under vacuum and combusted at 900 °C for 3 h in a muffle oven. The gas was purified using dry-ice/ethanol traps in a graphitization line (Macario et al.2015*)*. The CO2 subsamples for 14C analysis were converted to graphite targets using the zinc/titanium hydride method with iron catalyst (Xu et al. 2007). Individual torch-sealed tubes were heated at 520 °C for 7 h in a muffle oven (Macario et al. 2015) and graphitized samples were pressed in aluminum cathodes to be measured in a NEC 250kV Single Stage Accelerator System (SSAMS).

The isotopic fractionation was corrected by measuring the δ13C on-line in the accelerator (Linares et al. 2015). Background was measured using processed graphite, which yielded average 14C/13C ratios of 6 × 10−13. Results are expressed in conventional radiocarbon ages, percent modern carbon (pMC) and Δ14C according to the definitions in Stuiver and Polach 1977.

**1.6. Sulfate concentrations in the interstitial water**

Sulfate concentrations in the interstitial waters were determined using a Dionex (model ICS 5000) ion chromatograph consisting of a pump (ICS-5000 DP-5) and a conductivity detector. The analytical column was an IonPac AS 19 hydroxide-selective anion-exchange column (2 × 250 mm) with supermacroporous resin. An anion self-regeneration suppressor ASRS 300 2 mm was used to reduce the conductivity of the mobile phase. Samples were diluted using 18 MΩ water and the standards also were prepared from pure reagents and 18 MΩ water. Standard solutions were measured repeatedly in order to estimate the accuracy and external precision of the measurements.

**1.7. Gas analysis**

A gas chromatograph equipped with a capillary column, VP-Plot Alumina/KCl, 30 m × 0.53 mm, film 10.0 μm was used to determine C1–C5 hydrocarbon concentrations in the sediments. The GC-14A was configured with a 0.5 mL injection, split 1:7, and a flame ionization detector (FID) for gas detection. Run conditions for the column were 75 °C; ramping at 30 °C min–1 to 170 °C, and holding for 10 min. Helium was used as the carrier gas at a constant volume of 5 mL min–1. The injector temperature was 190 °C and the FID temperature was held at 200 °C.

**2. References of supplemental material**

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| **3. Figures and table of supplemental material** | | | |
| **A** | **B** | **C** | **D** |
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| **E** | **F** | **G** | **H** |
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| **Figure S2.** Concentrations of total organic carbon, total nitrogen, methane and sulfate, TOC:TN and TS:TOC atomic ratios, percent of modern carbon (14C) in sediments and δ13C-org from PC31 sample. | | | |

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| **A** | | **B** | | **C** | **D** | |
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| **E** | **F** | | **G** | | | **H** |
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| **Figure S3.** Concentrations of total organic carbon, total nitrogen, methane and sulfate, TOC:TN and TS:TOC atomic ratios, percent of modern carbon (14C) in sediments and δ13C-org from PC51 samples. | | | | | | |

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| **Table 1.** Results of sediment analysis. | | | | | | | | | | | | | | |  |
| **LAB Code** | **Depth (cmbsf)** | **TC**  **(% m/m)** | **IC**  **(% m/m)** | **TOC**  **(% m/m)** | **TN**  **(% m/m)** | **TS**  **(% m/m)** | **TOC:TN** | **TS:TOC** | **13C-org**  **(‰)** | **pMC** | **14C age**  **(BP)** | **Δ14C (‰)** | **Biostratigraphic**  **Depth (cm)** | **Epoch** | |
| **PC51** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |
| 150348 | 12.5 | 1.57 | 1.12 | 0.44 | 0.06 | 0.03 | 8.23 | 0.03 | -22.81 | 8.93 | 19400 ± 90 | -911 | 10 | 10Ka-Recent\* | |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 50 | 10Ka-Recent\* | |
| 150349 | 112.5 | 1.51 | 0.97 | 0.54 | 0.09 | 0.38 | 7.21 | 0.26 | -22.63 | 8.73 | 19580 ± 80 | -913 | 107 | 15ka-10ka \*\* | |
| - | - | - | - | - | - | - | - | - | - | - | - | - | 159.5 | 15ka-10ka \*\* | |
| 150350 | 212.5 | 1.87 | 1.41 | 0.46 | 0.07 | 0.55 | 8.18 | 0.45 | -22.91 | 8.17 | 20120 ± 90 | -919 | 207 | 15ka-10ka \*\* | |
| 150351 | 260 | 1.75 | 1.30 | 0.45 | 0.07 | 1.16 | 7.49 | 0.96 | -22.92 | 7.42 | 20890 ± 100 | -926 | - | - | |
| 150352 | 287.5 | 1.06 | 0.45 | 0.61 | 0.10 | 1.75 | 7.12 | 1.08 | -23.08 | 4.46 | 24730 ± 130 | -954 | - | - | |
| 150353 | 312.5 | 1.28 | 0.97 | 0.31 | 0.06 | 1.15 | 5.91 | 1.39 | -22.84 | 2.67 | 29110 ± 160 | -974 | 307 | 42ka-15ka\*\*\* | |
| 150354 | 360 | 0.94 | 0.32 | 0.62 | 0.11 | 1.05 | 6.74 | 0.63 | -25.31 | 4.11 | 25640 ± 130 | -959 | - | - | |
| - | 362.5 | 0.99 | 0.45 | 0.54 | 0.11 | 1.00 | 5.79 | 0.70 | nd | nd | nd | nd | - | - | |
| - | 387.5 | 1.13 | 0.63 | 0.51 | 0.11 | 0.70 | 5.17 | 0.51 | -25.27 | nd | nd | nd | - | - | |
| 150356 | 412.5 | 0.91 | 0.37 | 0.54 | 0.11 | 0.52 | 5.54 | 0.36 | -24.27 | 3.22 | 27610 ± 160 | -968 | - | - | |
| **PC31** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |
| 150037 | 8 | 0.50 | 0.04 | 0.46 | 0.06 | 0.11 | 9.63 | 0.09 | -18.59 | 11.00 | 17730 ± 90 | -891 | 6 | 15ka-10ka \*\* | |
| 150186 | 56 | 0.80 | 0.19 | 0.61 | 0.08 | 0.04 | 9.36 | 0.03 | -21.79 | 16.81 | 14320 ± 70 | -833 | 58 | 15ka-10ka \*\* | |
| 150109 | 108 | 0.70 | 0.11 | 0.58 | 0.07 | 0.08 | 9.48 | 0.05 | -20.96 | 5.90 | 22730 ± 240 | -941 | 106 | 15ka-10ka \*\* | |
| 150189 | 182 | 0.49 | 0.02 | 0.47 | 0.06 | 0.04 | 8.96 | 0.03 | -19.68 | 18.66 | 13490 ± 60 | -815 | 160 | 15ka-10ka \*\* | |
| 150190 | 208 | 0.59 | 0.01 | 0.58 | 0.08 | 0.12 | 8.51 | 0.07 | -19.79 | 19.07 | 13310 ± 70 | -811 | - | - | |
| 150191 | 258 | 0.57 | 0.04 | 0.53 | 0.08 | 0.04 | 7.35 | 0.03 | -20.59 | 2.06 | 31170 ± 190 | -980 | - | - | |
| 150192 | 282 | 0.57 | 0.04 | 0.53 | 0.06 | 0.13 | 10.19 | 0.09 | -21.20 | 2.72 | 28930 ± 190 | -973 | 260 | 15ka-10ka \*\* | |
| 150110 | 308 | 0.60 | 0.09 | 0.51 | 0.08 | 0.05 | 7.57 | 0.03 | -20.89 | 5.18 | 23780 ± 270 | -949 | 306 | 15ka-10ka \*\* | |
| 150193 | 358 | 0.56 | 0.03 | 0.52 | 0.09 | 0.00 | 6.96 | 0.00 | -21.72 | 3.07 | 27990 ± 140 | -970 | 360 | 42ka-15ka\*\*\* | |
| 150194 | 382 | 0.58 | 0.05 | 0.53 | 0.07 | 0.05 | 8.55 | 0.03 | -20.45 | 2.83 | 28650 ± 200 | -972 | - | - | |
| 150346 | 408 | 0.60 | 0.10 | 0.50 | 0.07 | 0.00 | 7.84 | 0.00 | -20.20 | 2.84 | 28620 ± 160 | -972 | 406 | 42ka-15ka\*\*\* | |
| 150347 | 458 | 0.59 | 0.06 | 0.53 | 0.07 | 0.00 | 9.24 | 0.00 | -20.61 | 2.15 | 30830 ± 290 | -979 | 460 | 42ka-15ka\*\*\* | |
| 150038 | 482 | 0.57 | 0.06 | 0.51 | 0.07 | 0.17 | 8.79 | 0.13 | -19.82 | 4.40 | 25100 ± 150 | -956 | - | - | |
| 150195 | 528 | 0.64 | 0.11 | 0.53 | 0.08 | 0.00 | 7.94 | 0.00 | -21.42 | 3.87 | 26130 ± 150 | -962 | 531 | 42ka-15ka\*\*\* | |

\* Holocene (10Ka-Recent); \*\* Pleistocene (15ka-10ka); \*\*\* Pleistocene (42ka-15ka). ka = one thousand years; nd = not determined.