Kaiho, K., et al., 2020, Pulsed volcanic combustion events coincident with the end-Permian terrestrial disturbance and the following global crisis: Geology, v. 49, https://doi.org/10.1130/G48022.1

Pulsed volcanic combustion events coincident with the end-Permian terrestrial disturbance and the following global crisis

**Kunio Kaiho1\*, Md. Aftabuzzaman1, David S. Jones2, and Li Tian3**

*1* *Department of Earth Science, Tohoku University, 6-3 Aramaki-aza aoba, Aoba-ku, Sendai 980-8578, Japan*

*2* *Amherst College Geology Department, 11 Barrett Hill Road, Amherst, Massachusetts 01002, USA*

*3 State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Wuhan 430074, China*

**METHODS**

*Biomarker analyses*

A 80–100 g of each sample was powdered following the removal of any apparent surface contamination. The powdered samples were extracted, concentrated, and separated into three fractions base on the methods developed by Kaiho et al. (2016b). The aliphatic hydrocarbon fractions (F1a) were analyzed using gas chromatography–mass spectrometry (GC-MS). The organic compounds were identified using the Agilent 7890B GC interfaced to an Agilent 7000 triple quadrupole mass spectrometer operated with ionizing-electron energy of 70 eV and scanned from m/z 50 to 600 with a scan time of 0.34 s. We used a fused silica HP-5MS capillary column (length: 30 m, internal diameter: 0.25 mm, film thickness: 0.25μm) with helium as the carrier gas. Samples were injected at 50°C and the temperature were held constant for 1.0 min. Then the temperature was raised to 120°C at a rate of 30°C/min, to 310°C at a rate of 5°C/min, and finally held constant for 20 min. Methods for Meishan and Bulla samples were written in Kaiho et al. (2016a).

*Mercury analyses*

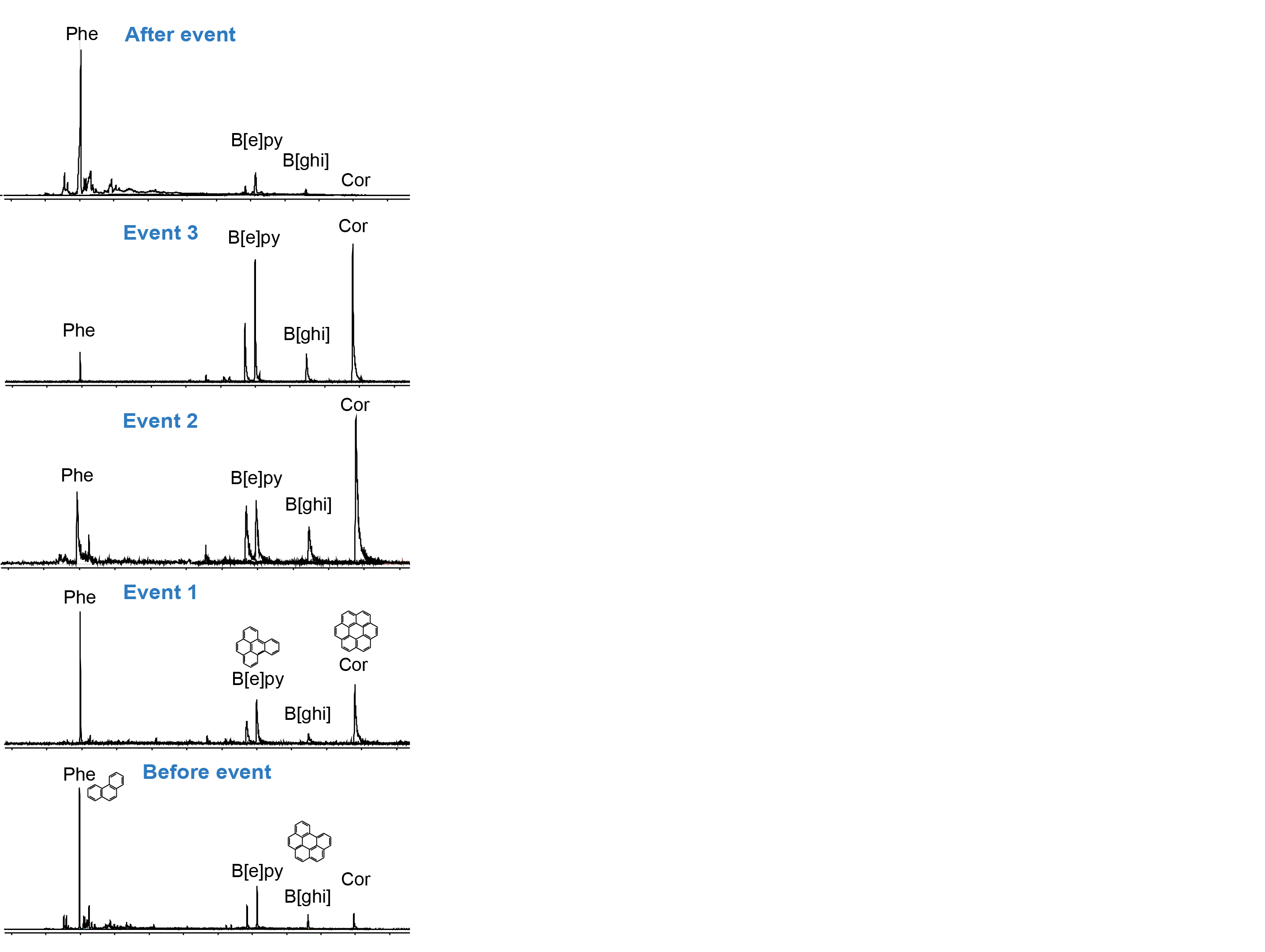
Whole rock powders were measured for mercury concentration using a Teledyne Leeman Labs Hydra IIC mercury analyzer. An autosampler introduced sample boats to an oven for thermal decomposition. Hg was collected on a gold filament and then released in a pulse by heating the filament. Mercury concentration was determined by atomic absorption spectroscopy. Relative standard deviation was <10%.

*Total organic carbon*

For total organic carbon (TOC), powdered samples (3 g, same powder samples as the biomarkers) were decarbonated in 6 N HCl at 70 °C for 24 h in 50 cc containers. Acid-treated samples were washed a few times with ultrapure water for neutralization using a centrifuge. Washing were stopped before floating samples in the water to avoid loss of samples, because powders float after neutralization. There are no floating materials like coal in the water in those samples studied. The dried residual carbonate-free powder samples (concentrated) were packed into a tin capsule and introduced to a Flush 2000 elemental analyzer (Thermo Fisher Scientific). Carbon content was corrected according to the weight loss engendered by the acid treatment. Relative standard deviation of TOC was <2% of measured values.

*Stable carbon isotopes*

We conducted stable isotope analyses of bulk powder obtained from limestone, marlstone, and mudstone samples taken from the Liangfengya section, using the Thermo Fisher DeltaV Advantage mass spectrometer coupled with the Thermo Quest Kiel-III automated carbonate device. The δ13Ccarb and δ18O values were calibrated to the NBS-19 international standard relative to Vienna Peedee Belemnite (VPDB). The external precisions (1σ) of the carbon isotope and oxygen isotope analyses, based on replicate measurements of a laboratory references ample (JCt-1) were ±0.03‰ and ±0.05‰, respectively. The carbon stable isotope ratios were expressed using the following equation: δ13C (‰) = (Rsample/Rstandard − 1) ×1000, where R sample is the 13C/12C of the sample and R standard is the 13C/12C of the standard, Pee Dee Belemnite (PDB). We analyzed the total organic carbon (TOC) content and the stable carbon isotope ratios of the TOC using the EA-DeltaV Advantage mass spectrometer connected to a Flush 2000 elemental analyzer (Thermo Fisher Scientific). The relative standard deviation was <2% of the average of the measured values. We expressed the stable carbon isotope ratios per mil, relative to VPDB international standards. The standard deviation was ±0.05‰.

****

**Figure DR 1. GC-MS chromatograms showing PAHs studied for samples in the before events (LFY14+0.2), combustion event 1 to 3 (LFY16, LFY19 (0–2), sample LFY20), and after events (LFY24+0.3) at the Liangfengya section. Each graph is summed ion chromatogram of m/z 178+252+276+300.**

**Table DR 1. Geochemical data in the Liangfengya section, South China craton**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | Hg/ |  | TOC | Residue |  |  | Cor/ | (C27n+C29n+C31n) | |  | C31 |  |
|  | Height | 13Ccarb | 18Ocarb | Hg | TOC | TOC | before | rate | (e+ghi+cor) | Cor/ | (e+ghi+Cor) | /(C17n+C19n+ | Volcanic | Biotic | Hopane | Rc |
| Sample | (cm) | (‰） | (‰） | (ppb) | (ppb/%) | (%) | collection | by HCl | /Phe | Phe | Coronene | C21n+C27n+ | event | event | 22S/ | (MPR) |
|  |  |  |  |  |  |  | (%) | in rock |  |  | index | C29n+C31n) |  |  | (22S+22R) |  |
| LFY 26+0.2 | 114 | -0.93 | -6.67 | 4.10 | 35.8 | 0.115 | 0.56 | 0.20 | 0.50 | 0.05 | 0.10 | 0.61 |  |  | 0.59 | 1.02 |
| LFY 25-0.1 | 102 | -1.21 | -6.99 | 5.28 | 45.0 | 0.117 | 0.70 | 0.17 | 0.46 | 0.03 | 0.07 | 0.05 |  |  |  | 1.08 |
| LFY 25-0.3 | 96 | -0.92 | -9.32 | 4.28 | 46.6 | 0.092 | 0.21 | 0.43 | 0.33 | 0.04 | 0.12 | 0.12 |  |  |  | 1.13 |
| LFY 25-0.5 | 90 | -1.11 | -7.77 | 5.28 | 63.8 | 0.083 | 0.26 | 0.32 | 0.34 | 0.02 | 0.05 | 0.06 |  |  |  | 1.03 |
| LFY 24+0.4 | 82 | -0.71 | -10.13 | 10.96 | 128.0 | 0.086 | 0.27 | 0.32 | 0.47 | 0.04 | 0.08 | 0.06 |  |  |  | 1.06 |
| LFY 24+0.3 | 77 | -0.98 | -9.71 | 42.79 | 43.4 | 0.985 | 1.27 | 0.78 | 0.53 | 0.02 | 0.04 | – |  |  |  | – |
| LFY 24+0.2 | 74 | -1.06 | -10.98 | 8.18 | 62.2 | 0.132 | 0.26 | 0.51 | 0.38 | 0.05 | 0.12 | 0.09 |  |  |  | 1.09 |
| LFY 24+0.1 | 71 | -0.72 | -10.58 | 3.36 | 42.7 | 0.079 | 0.22 | 0.36 | 0.38 | 0.04 | 0.10 | 0.08 |  |  |  | 1.07 |
| LFY 23+0.5 | 64 | -0.71 | -10.41 | 5.48 | 53.3 | 0.103 | 0.20 | 0.53 | 0.44 | 0.05 | 0.11 | 0.07 |  |  |  | 1.09 |
| LFY 23+0.3 | 57 | -0.76 | -10.10 | 7.86 | 98.8 | 0.080 | 0.14 | 0.56 | 0.52 | 0.06 | 0.11 | 0.02 |  |  |  | 1.11 |
| LFY 23+0.2 | 54 | -0.65 | -10.68 | 5.33 | 65.8 | 0.081 | 0.18 | 0.44 | 0.51 | 0.06 | 0.11 | 0.07 |  |  |  | 1.06 |
| LFY 23+0.1 | 49 | -0.37 | -10.02 | 2.14 | 37.0 | 0.058 | 0.21 | 0.27 | 0.50 | 0.10 | 0.20 | 0.27 |  |  |  | 1.09 |
| LFY 22 | 44 | -0.49 | -9.43 | 5.17 | 71.7 | 0.072 | 0.10 | 0.71 | 0.73 | 0.11 | 0.16 | 0.04 |  |  |  | 1.11 |
| LFY – 21 C (12-15) | 40 | -0.36 | -7.42 | 1.22 | 25.3 | 0.048 | 0.16 | 0.30 | 1.05 | 0.18 | 0.17 | 0.10 |  |  |  | 1.09 |
| LFY – 21 C (9-12) | 37 | -0.18 | -7.11 | 14.99 | 459.0 | 0.033 | 0.16 | 0.21 | 0.62 | 0.17 | 0.27 | 0.00 |  |  |  | 1.27 |
| LFY – 21 C (6-9) | 34 | -0.08 | -7.14 | 2.19 | 75.8 | 0.029 | 0.18 | 0.16 | 1.13 | 0.40 | 0.36 | 0.00 |  |  | 0.60 | 1.21 |
| LFY – 21 C (3-6) | 31 | -0.14 | -7.43 | 2.07 | 46.7 | 0.044 | 0.12 | 0.36 | 2.02 | 1.00 | 0.49 | 0.00 |  |  | 0.62 | 1.10 |
| LFY – 21 C (0-3) | 28 | 0.01 | -8.07 | 1.72 | 46.0 | 0.037 | 0.08 | 0.46 | 1.88 | 0.89 | 0.47 | 0.00 |  |  | 0.58 | 1.17 |
| LFY 21 b | 23 | -0.26 | -10.60 | 1.84 | 82.7 | 0.022 | 0.19 | 0.12 | – | – | – | 0.00 |  |  |  | 1.22 |
| LFY – 21 a (10-13) | 18 | 0.41 | -7.83 | 4.70 | 86.7 | 0.054 | 0.11 | 0.49 | 0.74 | 0.30 | 0.40 | 0.06 |  |  |  | 1.23 |
| LFY – 21 a (7-10) | 15 | 0.57 | -7.64 | 2.14 | 28.2 | 0.076 | 0.18 | 0.42 | 2.19 | 1.06 | 0.48 | 0.00 |  |  |  | 1.13 |
| LFY – 21 a (4-7) | 11 | 0.38 | -7.80 | 1.49 | 13.6 | 0.110 | 0.24 | 0.45 | 1.73 | 0.90 | 0.52 | 0.00 |  |  |  | 1.22 |
| LFY – 21 a (0-4) | 7 | 0.40 | -7.48 | 3.71 | 79.2 | 0.047 | 0.12 | 0.38 | 1.71 | 1.10 | 0.64 | 0.00 | 2 |  |  | 1.12 |
| LFY 20 | 2 | 0.25 | -10.08 | 12.24 | 282.7 | 0.043 | 0.12 | 0.36 | 22.63 | 12.93 | 0.57 | 0.05 | 2 |  | 0.60 | 0.91 |
| LFY – 19 (4-6) | -2 | -0.04 | -7.37 | 5.40 | 107.4 | 0.050 | 0.30 | 0.17 | 1.47 | 1.02 | 0.69 | 0.00 | 2 |  |  | 1.14 |
| LFY – 19 (2-4) | -4 | -0.12 | -7.17 | 8.98 | 321.3 | 0.028 | 0.25 | 0.11 | 3.19 | 2.23 | 0.70 | 0.00 | 2 |  |  | 1.38 |
| LFY – 19 (0-2) | -6 | -0.12 | -7.17 | 4.23 | 197.0 | 0.021 | 0.13 | 0.16 | 4.21 | 2.93 | 0.70 | 0.00 | 2 | EPE |  | 1.26 |
| LFY 18 | -8 | 0.01 | -9.65 | 24.30 | 153.4 | 0.158 | 0.29 | 0.55 | 3.05 | 2.06 | 0.68 | 0.30 | 2 |  |  | 1.36 |
| LFY – 17 (16.5-18.5) | -10 | 0.04 | -7.58 | 0.41 | 10.1 | 0.040 | 0.22 | 0.19 | 0.27 | 0.27 | 0.71 | 0.00 |  |  |  | 1.24 |
| LFY – 17 (14.5-16.5) | -12 | -0.55 | -7.22 | 1.19 | 37.1 | 0.032 | 0.20 | 0.16 | 0.46 | 0.29 | 0.63 | 0.00 |  |  |  | 1.12 |
| LFY – 17 (12.5-14.5) | -14 | -0.55 | -7.15 | 0.42 | 23.6 | 0.018 | 0.22 | 0.08 | – | – | – | 0.00 |  |  |  | 1.28 |
| LFY – 17 (10.5-12.5) | -16 | -0.73 | -7.03 | 0.50 | 27.3 | 0.018 | 0.19 | 0.09 | – | – | – | 0.00 |  |  |  | 0.86 |
| LFY – 17 (8.5-10.5) | -18 | -0.20 | -6.92 | 0.50 | 22.5 | 0.022 | 0.20 | 0.11 | 0.53 | 0.35 | 0.66 | 0.00 |  |  |  | 1.33 |
| LFY – 17 (6.5-8.5) | -20 | -0.24 | -7.02 | 0.88 | 31.0 | 0.028 | 0.20 | 0.14 | – | – | – | 0.00 |  |  |  | 0.88 |
| LFY – 17 (4.5-6.5) | -22 | 0.23 | -6.47 | 0.87 | 21.0 | 0.041 | 0.19 | 0.22 | 0.95 | 0.71 | 0.75 | 0.00 | 1 |  |  | 1.18 |
| LFY – 17 (2.5-4.5) | -24 | 0.24 | -7.09 | 1.00 | 25.4 | 0.039 | 0.20 | 0.20 | 1.19 | 0.93 | 0.79 | 0.00 | 1 |  |  | 0.87 |
| LFY – 17 (0-2.5) | -26 | -0.40 | -7.09 | 0.48 | 21.2 | 0.023 | 0.15 | 0.16 | – | – | – | 0.00 |  |  | 0.60 | 1.30 |
| LFY 16(Carbonate) | -29 | 0.58 | -7.79 | 4.15 | 63.6 | 0.065 | 0.33 | 0.20 | 2.49 | 1.50 | 0.60 | 0.14 | 1 | EPPE | 0.65 | 1.09 |
| LFY 16(Clay) | -34 | 0.53 | -8.79 | 29.35 | 520.9 | 0.056 | 0.11 | 0.53 | 3.30 | 1.91 | 0.58 | 0.26 | 1 |  |  | 0.98 |
| LFY 15 | -39 | 1.94 | -6.38 | 1.46 | 27.7 | 0.053 | 0.28 | 0.19 | 2.22 | 1.35 | 0.61 | 0.30 | 1 |  | 0.67 | 1.07 |
| LFY 14+0.4 | -44 | – | – | 2.44 | 36.1 | 0.068 | 0.30 | 0.22 | 1.49 | 0.69 | 0.47 | 0.17 | 1 |  | 0.63 | 1.15 |
| LFY 14+0.2 | -57 | 1.97 | -6.70 | 3.56 | 29.1 | 0.122 | 0.30 | 0.41 | 0.80 | 0.24 | 0.30 | 0.11 |  |  |  | 1.16 |
| LFY 14+0.1 | -64 | 2.22 | -6.59 | 2.84 | 27.2 | 0.105 | 0.38 | 0.27 | 0.33 | 0.20 | 0.32 | 0.11 |  |  | 0.54 | 1.30 |
| Event definition |  |  |  |  | ≥ 100 |  |  |  |  | ≥ 0.5 | ≥ 0.5 |  |  |  |  |  |
| Background total |  |  |  |  | 557.5 |  |  |  |  | 0.45 | 1.03 |  |  |  |  |  |
| Background average |  |  |  |  | 55.7 |  |  |  |  | 0.04 | 0.09 |  |  |  |  |  |

Red samples are white clay originated from ash. Orange values are events. Olive parts show background. Data of C31 hopane 22S/(22S+22R) and Rc (MPR) show that there are no contamination of modern hydrocarbons. Average (%) and rate of Hg/TOC and Cor/Phe are used in Figure 2. Percentage data of Hg/TOC and Cor/Phe–Total of peaks divided by total > Event definition. Cor–coronene. Phe–phenanthrene. \*data measured by the analyzer before correction according to the weight loss engendered by the acid treatment.

**Table DR 2. Geochemical data in the Bulla section, northern Italy**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  | TOC | Residue |  |  | Cor/ |  |  |  |  |  |
|  | Height | 13Ccarb | 18Ocarb | Hg | Hg/TOC | TOC | before | rate | (e+ghi+cor) | Cor/Phe | (e+ghi+Cor) | (C27n+C29n+C31n)/ | Volcanic | Biotic | C31 Hopane | Rc |
| Sample | (cm) | (‰） | (‰） | (ppb) | (ppb/%) | (%) | collection | by HCl | /Phe |  | Coronene | (C17n+C19n+C21n | event | event | 22S/ | (MPR) |
|  |  |  |  |  |  |  | (%) | in rock |  |  | index | C27n+C29n+C31n) |  |  | (22S+22R) |  |
| BLA 12-8 | 163.5 | 1.27 | -6.51 | 1.98 | 46.1 | 0.043 | 0.44 | 0.097 | 0.478 | 0.084 | 0.18 | 0.13 |  |  | – | – |
| BLA 12-7 | 148 | 1.42 | -6.37 | 1.83 | 41.6 | 0.044 | 0.73 | 0.060 | 0.423 | – | – | 0.05 |  |  | 0.66 | 1.01 |
| BLA 12-6 | 134.5 | 1.72 | -6.38 | 1.28 | 29.8 | 0.043 | 0.81 | 0.053 | 0.588 | 0.093 | 0.16 | 0.08 |  |  | 0.66 | – |
| BLA 12-5 | 123 | 1.74 | -6.37 | 1.71 | 27.1 | 0.063 | 0.51 | 0.123 | 0.458 | – | – | 0.13 |  |  | 0.66 | 0.91 |
| BLA 12-4 | 112.5 | 1.71 | -6.46 | 1.70 | 32.8 | 0.052 | 0.46 | 0.113 | 0.264 | 0.020 | 0.08 | 0.13 |  |  | – | – |
| BLA 12-3 | 104 | 1.55 | -6.55 | 1.51 | 44.5 | 0.034 | 0.54 | 0.063 | 0.684 | – | – | 0.11 |  |  | 0.66 | 0.91 |
| BLA 12-2 | 93.5 | 1.42 | -6.89 | 0.52 | 27.2 | 0.019 | 0.81 | 0.023 | 0.303 | 0.038 | 0.12 | 0.05 |  |  | 0.71 | – |
| BLA 12-1 | 81.5 | 1.37 | -6.94 | 0.48 | 30.1 | 0.016 | 0.69 | 0.023 | 0.956 | – | – | 0.09 |  |  | 0.64 | 0.97 |
| BLA 11 (top 8 cm) | 76 | 1.24 | -6.38 | 2.29 | 120.3 | 0.019 | 0.10 | 0.194 | 0.321 | 0.049 | 0.15 | 0.09 |  |  | 0.65 | 0.92 |
| BLA 10 | 55 | 1.00 | -6.33 | 2.66 | 115.5 | 0.023 | 0.07 | 0.344 | 1.613 | 0.238 | 0.15 | 0.09 |  |  | 0.63 | 0.64 |
| BLA 9 | 44 | 0.90 | -6.84 | 5.08 | 118.1 | 0.043 | 0.07 | 0.641 | 0.536 | 0.061 | 0.23 | 0.24 |  |  | 0.61 | 0.97 |
| BLA 8 (31-37 cm) | 34 | 1.16 | -7.64 | 2.56 | 116.3 | 0.022 | 0.44 | 0.050 | 0.193 | 0.388 | 0.28 | 0.14 | 2 |  | 0.67 | 0.96 |
| BLA 8 (27-31 cm) | 29 | 1.27 | -7.77 | 2.33 | 105.8 | 0.022 | 0.55 | 0.040 | 0.378 | 0.129 | 0.34 | 0.16 | 2 |  | 0.66 | 0.98 |
| BLA 8 (24-27 cm) | 25.5 | 1.33 | -7.87 | 2.54 | 195.0 | 0.013 | 0.31 | 0.041 | 0.316 | 0.142 | 0.45 | 0.19 | 2 |  | 0.65 | 1.02 |
| BLA 8 (21-24 cm) | 22.5 | 1.46 | -8.47 | 1.87 | 77.8 | 0.024 | 0.46 | 0.052 | 0.471 | 0.203 | 0.43 | 0.15 | 2 | EPE | 0.63 | 1.03 |
| BLA 8 (20-21 cm) | 20.5 | 1.38 | -8.24 | 1.99 | 37.6 | 0.053 | 1.24 | 0.043 | 0.336 | 0.121 | 0.36 | 0.21 | 2 |  | 0.67 | 1.02 |
| BLA 8 (19-20 cm) | 19.5 | 1.53 | -8.15 | 4.73 | 50.8 | 0.093 | 1.07 | 0.087 | 0.501 | 0.149 | 0.30 | 0.19 | 2 |  | 0.59 | 1.05 |
| BLA 8 (14-19 cm) | 15.5 | 1.66 | -7.72 | 2.04 | 65.8 | 0.031 | 0.70 | 0.044 | 0.213 | 0.037 | 0.17 | 0.13 |  |  | 0.68 | 0.96 |
| BLA 8 (9-14 cm) | 11.5 | 1.64 | -7.41 | 2.21 | 91.9 | 0.024 | 0.58 | 0.041 | 0.194 | 0.071 | 0.37 | 0.18 | 1 |  | 0.58 | 0.05 |
| BLA 8 (6-9 cm) | 7.5 | 1.64 | -7.27 | 2.30 | 74.1 | 0.031 | 0.89 | 0.035 | 0.123 | 0.031 | 0.25 | 0.24 | 1 |  | 0.58 | 1.05 |
| BLA 8 (3-6 cm) | 4.5 | 2.26 | -6.61 | 3.00 | 93.7 | 0.032 | 1.08 | 0.030 | 0.169 | 0.063 | 0.37 | 0.16 | 1 |  | 0.7 | 1.01 |
| BLA 8 (0-3 cm) | 1.5 | 3.48 | -5.83 | 2.26 | 23.0 | 0.098 | 3.14 | 0.031 | 0.123 | 0.027 | 0.22 | 0.07 | 1 | EPPE | 0.62 | 1.08 |
| BLA 7A | -0.5 | – | – | 18.61 | 15.9 | 1.170 | 5.48 | 0.213 | 2.021 | 0.081 | 0.04 | 0.22 | 1 |  | 0.65 | 1.03 |
| BLA 6 (8-10 cm) | -2 | – | – | 1.18 | 1.1 | 1.040 | 4.98 | 0.209 | 0.033 | 0.0003 | 0.01 | 0.21 |  |  | 0.59 | 1.13 |
| BLA 6 (6-8 cm) | -4 | 3.55 | -6.18 | 1.06 | 4.8 | 0.220 | 10.38 | 0.021 | 0.035 | 0.0021 | 0.01 | 0.28 |  |  | 0.59 | 1.13 |
| BLA 6 (3-6 cm) | -6.5 | 3.65 | -5.96 | 1.50 | 7.5 | 0.200 | 6.34 | 0.032 | 0.045 | 0.0014 | 0.03 | 0.15 |  |  | 0.63 | 1.09 |
| BLA 6 (0-3 cm) | -9.5 | 3.20 | -6.90 | 2.34 | 5.6 | 0.420 | 7.89 | 0.053 | 0.025 | 0.0003 | 0.01 | 0.23 |  |  | 0.61 | 1.13 |
| BLA 5 (25-27 cm) | -15 | – | – | 5.66 | 2.6 | 2.150 | 7.56 | 0.285 | 0.15 | 0.0013 | 0.01 | 0.20 |  |  | 0.59 | 1.19 |
| BLA 5 (15-25 cm) | -21 | 3.14 | -7.23 | 1.53 | 7.3 | 0.210 | 8.62 | 0.024 | 0.001 | 0.0001 | 0.14 | 0.25 |  |  | 0.63 | 1.05 |
| BLA 5 (11-15 cm) | -28 | 3.65 | -5.90 | 0.98 | 10.1 | 0.097 | 6.86 | 0.014 | 0.065 | 0.0022 | 0.03 | 0.21 |  |  | 0.64 | 1.06 |
| Event definition |  |  |  |  | > 70 |  |  |  |  | > 0.02 | > 0.2 |  |  |  |  |  |
| Background total |  |  |  |  | 39.0 |  |  |  |  | 0.008 | 0.252 |  |  |  |  |  |
| Background average |  |  |  |  | 5.6 |  |  |  |  | 0.001 | 0.036 |  |  |  |  |  |

Explanations are the same as Table DR1.

**Table DR 3. Geochemical data in the Meishan section, South China craton**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Hg/ |  |  |  | Cor/ |  |  |  |  |  |
|  | Height | Hg | TOC | TOC | (e+ghi+cor) | Cor/Phe | (e+ghi+Cor) | Volcanic | Biotic | Extinct taxa | C31 Hopane | Rc |
| Sample | (cm) | (ppb) | (ppb/%) | (%) | /Phe |  | Coronene | event | event | (Kaiho et al., 2006) | 22S/ | (MPR) |
|  |  |  |  |  |  |  | index |  |  |  | (22S+22R) |  |
| CHMIA (+80~+90) | 85.0 | 14.17 | 76.0 | 0.19 | 0.21 | 0.05 | 0.23 |  |  |  |  |  |
| CHMIA 09 (+70~+80) | 75.0 | 30.99 | 166.0 | 0.19 | 0.46 | 0.07 | 0.16 |  |  |  | 0.65 | 0.65 |
| CHMI (+61~+70) | 65.5 | 21.55 | 136.0 | 0.16 | 0.97 | 0.22 | 0.23 |  |  |  | 0.60 | 0.60 |
| CHMI (+50~+57) | 54.0 | 36.52 | 183.0 | 0.20 | 1.25 | 0.23 | 0.18 |  |  |  | 0.57 | 0.57 |
| CHMIA (+41~+45) | 43.0 | 24.45 | 140.0 | 0.18 | 1.94 | 1.02 | 0.53 |  |  |  | 0.61 | 0.61 |
| CHMIA 09 (+31~+36) | 33.5 | 7.26 | 113.0 | 0.06 | 2.23 | 1.51 | 0.68 |  |  |  |  |  |
| CHMIA 09 (+29~+31) | 30.0 | 11.92 | 145.0 | 0.08 | 0.85 | 0.39 | 0.46 |  |  |  | 0.67 | 0.67 |
| CHMIA 09 (+26~+29) | 28.0 | 9.71 | 106.0 | 0.09 | 0.37 | 0.12 | 0.33 |  |  |  |  |  |
| CHMIA (+23~+26) | 25.0 | 12.50 | 37.0 | 0.33 | 0.78 | 0.31 | 0.40 |  |  | Foraminifera | 0.55 | 0.55 |
| CHMIA 09 (+20~+23) | 21.5 | 12.37 | 116.0 | 0.11 | 0.92 | 0.46 | 0.50 |  |  |  | 0.58 | 0.58 |
| CHMIA 21 | 21.0 |  |  |  | 1.07 | 0.5 | 0.47 |  |  |  |  |  |
| CHMIA 09 (+18~+20) | 19.0 | 11.61 | 33.0 | 0.36 | 0.92 | 0.53 | 0.58 |  |  |  | 0.58 | 0.58 |
| CHMIA 17.5 | 17.5 |  |  |  | 1.06 | 0.23 | 0.22 |  |  |  |  |  |
| CHMIA 15-18 | 16.5 | 15.70 | 144.0 | 0.11 | 2.29 | 1.62 | 0.71 | 3 |  |  | 0.65 | 0.65 |
| CHMIA 09 (+13~+15) | 14.0 | 12.37 | 171.0 | 0.07 | 2.93 | 2.19 | 0.75 | 3 |  |  | 0.60 | 0.60 |
| CHMIA13 | 13.0 |  |  |  | 0.63 | 0.41 | 0.65 |  |  |  |  |  |
| CHMI (+8~+9) | 8.5 | 15.11 | 37.0 | 0.40 | 4.82 | 0.86 | 0.18 |  |  |  |  |  |
| CHMIA 09 (Bed 26) | 7.0 | 75.93 | 96.0 | 0.79 | 0.63 | 0.09 | 0.14 |  |  |  | 0.62 | 0.62 |
| CHMI +4 +5 | 4.5 |  |  |  | 4.15 | 0.33 | 0.08 |  |  |  |  |  |
| CHMI (+2~+3) | 2.5 | 20.97 | 46.0 | 0.46 | 10.14 | 0.97 | 0.10 |  |  |  | 0.75 | 0.65 |
| CHMI -1 0 | -0.5 |  |  |  | 4.59 | 2.32 | 0.51 | 2 | EPE |  |  |  |
| CHMIA 09(-1~0) | -0.5 | 43.46 | 71.0 | 0.61 | 0.10 | 0.01 | 0.13 | 2 | EPE | Sponge, Crinoids, Ostracods | 0.64 | 0.64 |
| CHMIA 09(-2~-1) | -1.5 |  |  |  | 0.10 | 0.02 | 0.17 | 2 | EPE |  | 0.66 | 0.66 |
| CHMI -2-1 | -1.5 | 11.21 | 24.0 | 0.46 | 0.35 | 0.03 | 0.10 | 2 | EPE |  |  |  |
| CHMI -2.5 | -2.5 | 35.69 | 22.0 | 1.63 | 0.36 | 0.05 | 0.13 | 2 | EPE |  |  |  |
| CHMIA 09(-4~-2) | -3.0 |  |  |  | 0.03 | 0 | 0.09 | 2 | EPE | Coral, Fusulinids | 0.59 | 0.59 |
| CHMIA (-6~-4) | -5.0 | 6.67 | 43.0 | 0.15 | 5.27 | 2.92 | 0.56 | 2 |  |  |  |  |
| CHMIA (-5.5) | -5.5 | 20.64 | 39.0 | 0.53 | 0.24 | 0.04 | 0.16 | 2 |  |  |  |  |
| CHMI -10 -8 | -9.0 |  |  |  | 1.08 | 0.39 | 0.36 | 2 |  |  |  |  |
| CHMI -10 | -10.0 | 25.24 | 20.0 | 1.23 | 0.28 | 0.03 | 0.11 | 2 |  |  |  |  |
| CHMI (-14~-12) | -13.0 | 27.61 | 42.0 | 0.65 | 0.44 | 0.08 | 0.18 | 2 |  |  |  |  |
| CHMI -20 -18 | -19.0 | 9.89 | 32.0 | 0.31 | 0.81 | 0.37 | 0.46 | 2 |  |  |  |  |
| CHMI (-27~-23) | -25.0 | 21.24 | 17.0 | 1.28 | 0.06 | 0 | 0.04 |  |  |  |  |  |
| CHMI (-27~-23) | -25.0 |  |  |  | 0.15 | 0.03 | 0.19 |  |  |  | 0.65 | 0.65 |
| CHMI (-40~-36) | -38.0 | 23.50 | 25.0 | 0.96 | 0.10 | 0.01 | 0.07 |  |  |  | 0.66 | 0.66 |
| CHMI (-40) | -40.0 | 17.84 | 20.0 | 0.89 | 0.14 | 0.02 | 0.11 |  |  |  |  |  |
| CHMIA (-55) | -55.0 | 27.01 | 26.0 | 1.06 | 0.26 | 0.01 | 0.05 |  |  |  |  |  |
| CHMI (-79~-63) | -71.0 | 4.00 | 17.0 | 0.24 | 0.89 | 0.37 | 0.41 | 1 |  |  | 0.65 | 0.65 |
| CHMI (-89~-84) | -86.5 | 14.20 | 19.0 | 0.77 | 0.07 | 0 | 0.07 | 1 |  |  | 0.67 | 0.67 |
| CHMI (-94~-89) | -91.5 | 7.74 | 18.0 | 0.44 |  |  |  |  |  |  | 0.68 | 0.68 |
| CHMIA 09(-104~-94) | -99.0 | 27.86 | 41.0 | 0.67 | 0.19 | 0.08 | 0.42 | 1 |  |  | 0.62 | 0.62 |
| CHMI (-112~-104) | -108.0 | 4.74 | 14.0 | 0.34 | 0.32 | 0.1 | 0.33 | 1 |  |  | 0.63 | 0.63 |
| CHMIA 09(-120~-112) | -116.0 | 3.88 | 32.0 | 0.12 | 0.16 | 0.03 | 0.21 | 1 |  |  | 0.58 | 0.58 |
| CHMI -125 | -125.0 |  |  |  | 1.95 | 0.82 | 0.42 | 1 |  |  |  |  |
| CHMI (-130~-120) | -125.0 | 9.50 | 23.0 | 0.42 | 1.03 | 0.38 | 0.37 | 1 |  |  | 0.65 | 0.65 |
| CHMI (-137~-135) | -136.0 | 33.90 | 43.0 | 0.78 | 0.10 | 0.01 | 0.11 | 1 |  |  | 0.69 | 0.69 |
| CHMI (-140) | -140.0 | 11.95 | 118.0 | 0.10 | 1.36 | 0.72 | 0.53 | 1 |  |  |  |  |
| CHMIA 09 (-145~-140) | -142.5 | 5.67 | 34.0 | 0.17 | 0.08 | 0.01 | 0.18 |  |  |  | 0.69 | 0.69 |
| CHMIA (-155~-150) | -152.5 | 20.66 | 42.0 | 0.49 | 0.16 | 0.02 | 0.15 |  |  |  | 0.62 | 0.62 |
| CHMIA 09 (-160~-155) | -157.5 | 3.76 | 24.0 | 0.16 | 0.24 | 0.05 | 0.21 |  |  |  | 0.62 | 0.62 |
| CHMIA 09 (-170~-160) | -165.0 | 4.85 | 24.0 | 0.20 | 0.43 | 0.21 | 0.49 | 1 |  |  | 0.68 | 0.68 |
| CHMI -170 | -170.0 |  |  |  | 0.88 | 0.17 | 0.19 |  |  |  |  |  |
| CHMIA 09 (-175~-170) | -172.5 | 5.27 | 42.0 | 0.13 | 0.15 | 0.07 | 0.45 | 1 |  |  | 0.61 | 0.61 |
| CHMIA 09 (-180~-175) | -177.5 | 7.61 | 45.0 | 0.17 | 0.13 | 0.04 | 0.34 |  |  |  | 0.62 | 0.62 |
| CHMIA 09 (-190~-180) | -185.0 | 18.79 | 53.0 | 0.35 | 0.20 | 0.08 | 0.41 |  |  |  | 0.59 | 0.59 |
| CHMIA 09 (-195~-190) | -192.5 | 19.85 | 72.0 | 0.28 | 0.18 | 0.05 | 0.30 |  |  |  | 0.61 | 0.61 |
| CHMIA 09 (-200~-195) | -197.5 | 12.10 | 43.0 | 0.28 | 0.07 | 0.01 | 0.16 |  |  |  | 0.63 | 0.63 |
| CHMI (-200) | -200.0 | 12.09 | 37.0 | 0.33 | 2.27 | 1.12 | 0.49 |  |  |  |  |  |
| Event definition |  |  | > 70 |  |  | ≥ 0.4 | ≥ 0.3 |  |  |  |  |  |
| Background total |  |  | 142.0 |  |  | 0.73 | 1.80 |  |  |  |  |  |
| Background average |  |  | 20.3 |  |  | 0.06 | 0.15 |  |  |  |  |  |

Explanations are the same as Table DR1.

The other biomarker data are available from Kaiho et al. (2016a).

**Table DR 4. Ten measurement data of a low TOC sample**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Number of | Sample | Sample name | Ampl | Ampl | Ampl | δ13Corg | Amt% | Residue rate | TOC |
| measurement | weight（mg） |  | 44 | 45 | 46 |  |  | after HCl treatment | (%) |
| 4001 | 8.54 | LFY 17 (14.5-16.5) | 2180 | 2591 | 3123 | -27.022 | 0.229742389 | 0.16 | 0.0368 |
| 4002 | 10.56 | LFY 17 (14.5-16.5) | 2657 | 3158 | 3813 | -27.117 | 0.226448864 | 0.16 | 0.0362 |
| 4003 | 11.03 | LFY 17 (14.5-16.5) | 2736 | 3253 | 3932 | -27.014 | 0.223245694 | 0.16 | 0.0357 |
| 4004 | 9.87 | LFY 17 (14.5-16.5) | 2466 | 2936 | 3553 | -26.933 | 0.224863222 | 0.16 | 0.0360 |
| 4005 | 9.14 | LFY 17 (14.5-16.5) | 2275 | 2708 | 3281 | -26.998 | 0.224015317 | 0.16 | 0.0358 |
| 4006 | 10.46 | LFY 17 (14.5-16.5) | 2607 | 3101 | 3761 | -27.08 | 0.224311663 | 0.16 | 0.0359 |
| 4007 | 9.4 | LFY 17 (14.5-16.5) | 2308 | 2745 | 3333 | -27.111 | 0.220978723 | 0.16 | 0.0354 |
| 4008 | 9.28 | LFY 17 (14.5-16.5) | 2296 | 2731 | 3318 | -27.036 | 0.222672414 | 0.16 | 0.0356 |
| 4009 | 9.81 | LFY 17 (14.5-16.5) | 2370 | 2820 | 3426 | -26.992 | 0.217431193 | 0.16 | 0.0348 |
| 4010 | 9.73 | LFY 17 (14.5-16.5) | 2402 | 2857 | 3474 | -27.024 | 0.222178828 | 0.16 | 0.0355 |

TOC (%) is the product of Amt% and residue rate after HCl treatment. The lowest detection limit is 100 in the Ampl. values of 44, 45, and 46 mass of CO2. Ampl = Amplitude. Amt = Amount.

**Table DR 5. Fundamental data set for TOC to show that all carbon amount values in ampl 44, 45, 46 mass of CO2 are more than five times of the lowest detection limit (100).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | Identifier | Analysis no. | Amount (mg) | Ampl 44 | Ampl 45 | Ampl 46 | Amt% |
| LFY 26+0.2 | 190 | 2728 | 10.086 | 6084 | 7254 | 8881 | 0.564 |
| LFY 25-0.5 | 189 | 2727 | 11.042 | 3056 | 3641 | 4468 | 0.259 |
| LFY 25-0.3 | 121 | 2631 | 34.721 | 1224 | 1464 | 1781 | 0.212 |
| LFY 25-0.1 | 188 | 2726 | 10.307 | 7767 | 9255 | 11329 | 0.704 |
| LFY 24+0.4 | 120 | 2630 | 39.044 | 1733 | 2070 | 2523 | 0.268 |
| LFY 24+0.3 | 200 | 2740 | 1.852 | 3076 | 3654 | 4490 | 1.269 |
| LFY 24+0.2 | 187 | 2725 | 10.054 | 2777 | 3311 | 4051 | 0.258 |
| LFY 24+0.1 | 186 | 2724 | 9.847 | 2328 | 2777 | 3391 | 0.221 |
| LFY 23+0.5 | 119 | 2629 | 33.925 | 1093 | 1305 | 1594 | 0.195 |
| LFY 23+0.3 | 118 | 2628 | 34.975 | 814 | 972 | 1190 | 0.143 |
| LFY 23+0.2 | 117 | 2627 | 32.429 | 959 | 1146 | 1400 | 0.184 |
| LFY 22 | 116 | 2626 | 38.611 | 607 | 726 | 889 | 0.101 |
| LFY 21C (12-15) | 202 | 2743 | 9.484 | 2012 | 2400 | 2930 | 0.162 |
| LFY 21C (9-12) | 199 | 2739 | 9.842 | 2003 | 2393 | 2924 | 0.155 |
| LFY 21C (6-9) | 198 | 2738 | 9.775 | 2266 | 2703 | 3296 | 0.177 |
| LFY 21C (3-6) | 197 | 2735 | 9.562 | 1258 | 1501 | 1836 | 0.123 |
| LFY 21C(0-3) | 115 | 2625 | 39.378 | 489 | 585 | 717 | 0.081 |
| LFY 21b | 114 | 2624 | 30.695 | 901 | 1076 | 1317 | 0.186 |
| LFY 21a (10-13) | 196 | 2734 | 11.223 | 1319 | 1576 | 1926 | 0.110 |
| LFY 21a (7-10) | 179 | 2716 | 11.033 | 2148 | 2563 | 3130 | 0.182 |
| LFY 21a (4-7) | 185 | 2722 | 9.897 | 2584 | 3078 | 3776 | 0.244 |
| LFY 21a (0-4) | 113 | 2623 | 34.703 | 641 | 766 | 934 | 0.123 |
| LFY 20 | 112 | 2621 | 39.582 | 754 | 901 | 1104 | 0.120 |
| LFY 19 (4-6) | 195 | 2733 | 10.013 | 3171 | 3781 | 4619 | 0.296 |
| LFY 19 (2-4) | 194 | 2732 | 10.17 | 2685 | 3202 | 3911 | 0.247 |
| LFY 19(0-2) | 111 | 2620 | 38.642 | 779 | 930 | 1136 | 0.131 |
| LFY 18 | 184 | 2721 | 11.247 | 3488 | 4157 | 5082 | 0.290 |
| LFY 17 (16.5-18.5) | 183 | 2720 | 10.931 | 2545 | 3035 | 3703 | 0.217 |
| LFY 17(12.5-14.5) | 178 | 2715 | 9.694 | 2302 | 2745 | 3354 | 0.222 |
| LFY 17(10.5-12.5) | 177 | 2714 | 10.049 | 2086 | 2485 | 3042 | 0.194 |
| LFY 17(8.5-10.5) | 169 | 2705 | 9.298 | 2002 | 2388 | 2919 | 0.201 |
| LFY 17 (6.5-8.5) | 182 | 2719 | 9.965 | 2113 | 2521 | 3079 | 0.198 |
| LFY 17(4.5-6.5) | 176 | 2713 | 11.31 | 2268 | 2703 | 3309 | 0.187 |
| LFY 17(2.5-4.5) | 170 | 2706 | 10.77 | 2274 | 2712 | 3314 | 0.197 |
| LFY 17(0-2.5) | 110 | 2619 | 35.659 | 785 | 938 | 1144 | 0.145 |
| LFY 16(Clay) | 109 | 2618 | 37.327 | 614 | 733 | 896 | 0.107 |
| LFY 16 (Carbonate) | 193 | 2731 | 10.646 | 3724 | 4464 | 5418 | 0.327 |
| LFY 15 | 192 | 2730 | 9.61 | 2848 | 3398 | 4152 | 0.277 |
| LFY 14+0.4 | 108 | 2617 | 31.944 | 1536 | 1836 | 2231 | 0.302 |
| LFY 14+0.2 | 191 | 2729 | 11.132 | 3581 | 4267 | 5229 | 0.301 |
| LFY 14+0.1 | 181 | 2718 | 9.37 | 3843 | 4579 | 5599 | 0.383 |
|  |  |  |  |  |  |  |  |
| BLA 12-8 | 222 | 2764 | 9.705 | 9039 | 10783 | 13148 | 0.712 |
| BLA 12-8 | 138 | 2650 | 21.818 | 1570 | 1874 | 2275 | 0.418 |
| BLA (12-7) | 174 | 2711 | 10.129 | 7918 | 9446 | 11536 | 0.730 |
| BLA (12-6) | 167 | 2703 | 9.556 | 8334 | 9933 | 12109 | 0.815 |
| BLA (12-5) | 165 | 2701 | 12.507 | 6829 | 8136 | 9929 | 0.510 |
| BLA 12-4 | 224 | 2766 | 9.878 | 5963 | 7108 | 8697 | 0.461 |
| BLA (12-3) | 173 | 2710 | 9.941 | 5664 | 6757 | 8254 | 0.532 |
| BLA (12-2) | 172 | 2709 | 10.284 | 8811 | 10512 | 12822 | 0.800 |
| BLA (12-1) | 171 | 2708 | 11.754 | 8472 | 10104 | 12293 | 0.673 |
| BLA 9(Clay) | 137 | 2649 | 21.445 | 617 | 735 | 887 | 0.175 |
| BLA 9 | 223 | 2765 | 9.345 | 5663 | 6758 | 8259 | 0.463 |
| BLA 9 (Base 1 cm) | 164 | 2700 | 10.021 | 5548 | 6618 | 8089 | 0.517 |
| BLA 7A(Black Clay) | 136 | 2647 | 22.934 | 18926 | 23007 | 27141 | 7.244 |
|  |  |  |  |  |  |  |  |
| CHMIA 09 (+84~+89) | 226 | 2768 | 10.441 | 3433 | 4096 | 5016 | 0.251 |
| CHMIA 09(+80~+90) | 135 | 2646 | 23.121 | 5178 | 6126 | 7316 | 0.781 |
| CHMIA +84 | 228 | 2770 | 12.705 | 7450 | 8881 | 10863 | 0.448 |
| CHMIA 09 (+70~+80) | 236 | 2779 | 9.141 | 3355 | 4002 | 4897 | 0.280 |
| CHMI (+61~+70) | 227 | 2769 | 9.914 | 3729 | 4450 | 5446 | 0.287 |
| CHMI (+50~+57) | 149 | 2684 | 11.987 | 5373 | 6403 | 7815 | 0.419 |
| CHMIA (+42~+44) | 221 | 2763 | 9.195 | 4054 | 4834 | 5878 | 0.337 |
| CHMI (+41~+45) | 225 | 2767 | 9.369 | 3239 | 3862 | 4727 | 0.264 |
| CHMIA 09(+31~+36) | 128 | 2639 | 23.674 | 687 | 821 | 996 | 0.170 |
| CHMIA (+30~33.5) | 207 | 2748 | 10.046 | 2949 | 3515 | 4304 | 0.224 |
| CHMIA 09(+29~+31) | 129 | 2640 | 21.426 | 741 | 885 | 1076 | 0.207 |
| CHMIA 09 (+26~+29) | 231 | 2774 | 10.223 | 4087 | 4868 | 5939 | 0.305 |
| CHMIA 09(+23~+26) | 130 | 2641 | 21.089 | 5280 | 6248 | 7463 | 0.872 |
| CHMIA 09(+20~+23) | 131 | 2642 | 22.643 | 1128 | 1346 | 1636 | 0.297 |
| CHMIA 09 (+18~+20) | 152 | 2687 | 11.188 | 9158 | 10928 | 13291 | 0.765 |
| CHMIA 09 (+15~18) | 232 | 2775 | 11.203 | 4747 | 5660 | 6912 | 0.324 |
| CHMIA 09(+13~+15) | 132 | 2643 | 21.312 | 693 | 826 | 1007 | 0.192 |
| CHMI +8~+9 | 159 | 2695 | 10.342 | 4586 | 5464 | 6645 | 0.414 |
| CHMIA 09 (Bed 26) | 158 | 2694 | 3.476 | 3496 | 4151 | 5051 | 0.940 |
| CHMIA Bed 25 | 144 | 2679 | 11.349 | 3576 | 4261 | 5140 | 0.294 |
| CHMI (+2~+3) | 230 | 2772 | 10.608 | 6713 | 7995 | 9786 | 0.483 |
| CHMIA 09 (-1~-0) | 239 | 2782 | 0.522 | 2208 | 2633 | 3216 | 3.231 |
| CHMIA 09 (-2~-1) | 220 | 2762 | 1.198 | 1174 | 1398 | 1702 | 0.749 |
| CHMIA -2.5 | 217 | 2759 | 1.232 | 929 | 1107 | 1348 | 0.576 |
| CHMIA 09 (-4~-2) | 211 | 2752 | 0.549 | 3255 | 3874 | 4736 | 4.529 |
| CHMI -6~-4 | 143 | 2678 | 1.107 | 4982 | 5930 | 7146 | 4.204 |
| CHMIA -5.5 | 142 | 2677 | 0.352 | 2396 | 2851 | 3435 | 6.359 |
| CHMIA (-10) | 209 | 2750 | 0.663 | 4693 | 5591 | 6848 | 5.408 |
| CHMIA (-12~-8) | 216 | 2758 | 0.704 | 3791 | 4517 | 5500 | 4.114 |
| CHMI (-14~-12) | 214 | 2755 | 0.673 | 1180 | 1406 | 1715 | 1.339 |
| CHMI -19~-20 | 157 | 2693 | 1.258 | 5493 | 6534 | 7932 | 4.079 |
| CHMI (-27~-23) | 233 | 2776 | 0.632 | 5769 | 6863 | 8402 | 6.973 |
| CHMI (-40~-36) | 218 | 2760 | 1.297 | 5951 | 7083 | 8621 | 3.505 |
| CHMI -40 | 147 | 2682 | 0.978 | 5731 | 6820 | 8281 | 5.474 |
| CHMIA -55 | 213 | 2754 | 0.798 | 3319 | 3949 | 4822 | 3.177 |
| CHMI (-79~-63) | 150 | 2685 | 1.278 | 4058 | 4835 | 5901 | 2.966 |
| CHMI (-89~-84) | 210 | 2751 | 0.281 | 2065 | 2457 | 3010 | 5.614 |
| CHMIA 09 (-94~-89) | 141 | 2676 | 1.009 | 6735 | 8010 | 9637 | 6.236 |
| CHMIA 09 (-104~-94) | 238 | 2781 | 1.399 | 5788 | 6893 | 8433 | 3.161 |
| CHMI -112~-104 | 156 | 2692 | 1.225 | 3932 | 4681 | 5682 | 2.999 |
| CHMIA 09(-120~-112) | 127 | 2638 | 22.753 | 8064 | 9709 | 11543 | 2.266 |
| CHMI -130~-120 | 155 | 2690 | 1.085 | 8556 | 10201 | 12389 | 7.367 |
| CHMI (-137~-135) | 219 | 2761 | 0.985 | 4269 | 5083 | 6183 | 3.311 |
| CHMI (-140) | 208 | 2749 | 10.657 | 3780 | 4508 | 5517 | 0.271 |
| CHMIA 09(-145~-140) | 126 | 2637 | 21.937 | 14041 | 16983 | 20103 | 5.068 |
| CHMIA (-156~-155) | 215 | 2756 | 0.78 | 3418 | 4075 | 4964 | 3.348 |
| CHMIA 09(-160~-156) | 212 | 2753 | 1.266 | 1703 | 2031 | 2477 | 1.028 |
| CHMIA 09 (-170~-166) | 145 | 2680 | 0.672 | 5504 | 6560 | 7990 | 7.651 |
| CHMIA -170 | 237 | 2780 | 1.055 | 1624 | 1937 | 2374 | 1.176 |
| CHMIA 09(-175~-170) | 125 | 2636 | 22.088 | 10122 | 12223 | 14488 | 3.133 |
| CHMIA 09(-180~-175) | 124 | 2634 | 22.088 | 13862 | 16804 | 19806 | 4.638 |
| CHMIA 09 (-190~-180) | 146 | 2681 | 0.97 | 3218 | 3839 | 4662 | 3.099 |
| CHMIA 09(-195~-190) | 123 | 2633 | 22.571 | 12777 | 15475 | 18274 | 4.138 |
| CHMIA 09(-200~-195) | 122 | 2632 | 22.195 | 19675 | 23914 | 28201 | 7.727 |
| CHMI -200 | 153 | 2688 | 0.541 | 3812 | 4547 | 5540 | 6.582 |

**Table DR 6. Fundamental data set to show that all carbon amount values are more than eight times of the lowest detection limit (0.01%) for the other Bulla (BLA) TOC data**

|  |  |  |  |
| --- | --- | --- | --- |
| **sample** |  | **C** | **δ13C-PDB** |
|  |  | **(%)** | **(‰)** |
| Standard (BBOT) |  | 70.4 | -26.9 |
| BLA 8 (19.5-20) |  | 1.04 | -28.4 |
| BLA 8 (20-20.5) |  | 0.956 | -28.1 |
| BLA 8 (21-24) |  | 0.683 | -28.3 |
| BLA 8 (24-27) |  | 0.506 | -27.9 |
| BLA 8 (27-31) |  | 0.522 | -28.1 |
| Standard (BBOT) |  | 70.4 | -26.7 |
| BLA 8 (31-37) |  | 0.461 | -28.6 |
| BLA 9 |  | 0.080 | -27.2 |
| BLA 10 |  | 0.121 | -27.4 |
| BLA 11top |  | 0.148 | -27.9 |
| Standard (BBOT) |  | 70.6 | -26.6 |

These data were measured by Shoukou-Tsusho Co. Sugito laboratory (Present name: SI Science Co.), 473–3 Hongo, Sugito, Saitama 345-0023, Japan (Gorjan et al., 2008). The lowest limit of C measurement is 0.01%. Therefore, the measuremet data are from 0.08 to 1.04% are believable. Gorjan, P. Kaiho, K., and Chen, Z.Q., 2008, A carbon-isotopic study of an end-Permian mass-extinction horizon, Bulla, northern Italy: a negative 13C shift prior to the marine extinction: Terra Nova v. 20, p. 253–258.