

**JOURNAL OF LIMNOLOGY**

**DOI: 10.4081/jlimnol.2022.2077**

**SUPPLEMENTARY MATERIAL**

**Sub-fossil chironomids as indicators of hydrological changes in the shallow and high-altitude lake Shen Co, Tibetan Plateau, over the past two centuries**

Sonja Rigterink<sup>1\*</sup>, Paula Echeverría-Galindo<sup>1</sup>, Rodrigo Martínez-Abarca<sup>1</sup>,  
Julieta Massaferro<sup>2</sup>, Philipp Hoelzmann<sup>3</sup>, Bernd Wünnemann<sup>3</sup>, Andreas Laug<sup>1</sup>,  
Liseth Pérez<sup>1</sup>, Wengang Kang<sup>1</sup>, Nicole Börner<sup>1</sup>, Anja Schwarz<sup>1</sup>, Ping Peng<sup>4</sup>,  
Junbo Wang<sup>4</sup>, Liping Zhu<sup>4</sup>, Antje Schwalb<sup>1</sup>

<sup>1</sup>Institute of Geosystems and Bioindication, Technische Universität Braunschweig,  
38106 Braunschweig, Germany

<sup>2</sup>National Scientific and Technical Research Council of Argentina (CONICET),  
Bariloche, Argentina

<sup>3</sup>Institute of Geographical Sciences, Physical Geography, Freie Universität Berlin,  
12249 Berlin, Germany

<sup>4</sup>Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute  
of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China

**\*Corresponding author:** [s.rigterink@tu-braunschweig.de](mailto:s.rigterink@tu-braunschweig.de)

Suppl. 1: Environmental parameters of Shen Co taken during fieldwork in July 2018 at coring site.

|  |                   |
|--|-------------------|
| <b>Core ID</b>                                   | <b>NC-18-C-40</b> |
| <b>Samling site</b>                              |                   |
| Date   | 06.07.2018        |
| Time   | 16:20             |
| Weather  | sunny             |
| Latitude of sampling site                        | 31.01631          |
| Longitude of sampling site                       | 90.50021          |
| Altitude (m asl) of sampling site                | 4,733             |
| Shore distance (m)                               | 1,500             |
| Max water depth (m) at sampling site             | 4,8               |
| Macrophytes (%)                                  | NO                |
| Anthropogenic influence                          | grazing           |
| <b>Environmental data taken at sampling site</b> |                   |
| Secchi depth (m)                                 | 1.96              |
| Conductivity ( $\mu\text{S cm}^{-1}$ )           | 17,970            |
| Salinity ( $\text{mg L}^{-1}$ )                  | 9                 |
| Water Temperature ( $^{\circ}\text{C}$ )         | 15.0              |
| pH   | 9.51              |
| O <sub>2</sub> ( $\text{mg L}^{-1}$ )            | 5.82              |
| O <sub>2</sub> (%)                               | 103.4             |
| Alkalinity ( $\text{mmol L}^{-1}$ )              | 201.0             |

Suppl. 2a: <sup>210</sup>Pb, <sup>137</sup>Cs and <sup>241</sup>Am activities of sediment core NC-18-C-40b.

| Depth | Dry mass           | <sup>210</sup> Pb   |       |                     |       |                     |       | Cum Unsupported    |       |                     |      |                     |      |
|-------|--------------------|---------------------|-------|---------------------|-------|---------------------|-------|--------------------|-------|---------------------|------|---------------------|------|
|       |                    | Total               |       | Supported           |       | Unsupp              |       | <sup>210</sup> Pb  |       | <sup>137</sup> Cs   |      | <sup>241</sup> Am   |      |
| cm    | g cm <sup>-2</sup> | Bq Kg <sup>-1</sup> | ±     | Bq Kg <sup>-1</sup> | ±     | Bq Kg <sup>-1</sup> | ±     | Bq m <sup>-2</sup> | ±     | Bq Kg <sup>-1</sup> | ±    | Bq Kg <sup>-1</sup> | ±    |
| 0.5   | 0.1632             | 339.2               | 52.15 | 47.08               | 11.91 | 292.12              | 53.49 | 500.7              | 66.6  | 16.22               | 6.51 | 0                   | 0    |
| 3     | 1.0252             | 172.51              | 19.93 | 23.6                | 4.05  | 148.91              | 20.34 | 2332.8             | 307.3 | 18.77               | 2.65 | 2.69                | 1.51 |
| 5     | 1.8116             | 137.35              | 9.54  | 33.22               | 2.15  | 104.13              | 9.78  | 3317.3             | 344.7 | 11.78               | 1.22 | 0                   | 0    |
| 6     | 2.227              | 119.53              | 8.67  | 37.05               | 2.02  | 82.48               | 8.9   | 3703.2             | 348.6 | 11.22               | 1.13 | 0                   | 0    |
| 7     | 2.6662             | 128                 | 10.87 | 30.19               | 2.36  | 97.81               | 11.12 | 4098.2             | 351.5 | 12.99               | 1.45 | 1.46                | 0.9  |
| 8     | 3.1176             | 96.53               | 7.49  | 37.06               | 1.83  | 59.47               | 7.71  | 4446               | 355.1 | 15.99               | 1.14 | 0                   | 0    |
| 9     | 3.5761             | 89.81               | 9.53  | 34.62               | 2.18  | 55.19               | 9.78  | 4708.7             | 357.3 | 15.24               | 1.33 | 0                   | 0    |
| 10    | 4.0038             | 89.12               | 8.19  | 35.67               | 2.09  | 53.45               | 8.45  | 4941               | 359.9 | 12.95               | 1.18 | 0                   | 0    |
| 11    | 4.3971             | 78.61               | 10.82 | 38.91               | 3     | 39.7                | 11.23 | 5122.8             | 361.9 | 15.21               | 1.72 | 0                   | 0    |
| 12    | 4.8095             | 66.33               | 10.09 | 47.67               | 3.07  | 18.66               | 10.55 | 5237.8             | 364.7 | 10.99               | 1.62 | 0                   | 0    |
| 13    | 5.2145             | 78.88               | 7.65  | 36.57               | 1.9   | 42.31               | 7.88  | 5354.8             | 367   | 2.43                | 0.85 | 0                   | 0    |
| 13.5  | 5.4069             | 67.04               | 7.73  | 34.64               | 2.02  | 32.4                | 7.99  | 5426.2             | 367.5 | 2.38                | 0.75 | 0                   | 0    |
| 14    | 5.5892             | 59.22               | 7.14  | 34.92               | 1.86  | 24.3                | 7.38  | 5477.6             | 367.8 | 0.00                | 0.00 | 1.12                | 0.64 |
| 15    | 5.969              | 46.97               | 7.67  | 42.83               | 2.39  | 4.14                | 8.03  | 5520.8             | 368.7 | 0.00                | 0.00 | 0                   | 0    |
| 16    | 6.3942             | 35.98               | 4.25  | 37.03               | 1.18  | -1.05               | 4.41  | 5527.4             | 369.9 | 2.32                | 0.43 | 0                   | 0    |

Suppl. 2b: Sediment accumulation rates (SAR) of sediment core NC-18-C-40b.

| Depth (cm) |      | cm | age diff | yr cm <sup>-1</sup> | cm yr <sup>-1</sup> | Chronology |
|------------|------|----|----------|---------------------|---------------------|------------|
| 0          | 2018 |    |          |                     |                     | 2018.0     |
| 0.5        |      |    |          | 5.1163              | 0.1955              | 2015.4     |
| 2.75       |      |    |          | 5.1163              | 0.1955              | 2003.9     |
| 4.75       |      |    |          | 5.1163              | 0.1955              | 1993.7     |
| 5.75       |      |    |          | 5.1163              | 0.1955              | 1988.6     |
| 6.75       |      |    |          | 5.1163              | 0.1955              | 1983.5     |
| ou7.75     |      |    |          | 5.1163              | 0.1955              | 1978.3     |
| 8.75       |      |    |          | 5.1163              | 0.1955              | 1973.2     |
| 9.75       |      |    |          | 5.1163              | 0.1955              | 1968.1     |
| 10.75      | 1963 | 55 | 10.75    | 5.1163              | 0.1955              | 1963.0     |
| 11.75      |      |    |          | 4.3333              | 0.2308              | 1958.7     |
| 12.75      |      |    |          | 4.3333              | 0.2308              | 1954.3     |
| 13.25      |      |    |          | 4.3333              | 0.2308              | 1952.2     |
| 13.75      | 1950 | 13 | 3        | 4.3333              | 0.2308              | 1950.0     |
| 14.75      |      |    |          | 4.3333              | 0.2308              | 1945.7     |
| 15.75      |      |    |          | 4.3333              | 0.2308              | 1941.3     |

Suppl. 2c: Chronology of Shen Co of sediment core NC-18-C-40b determined using linear regression.

| Depth | corr age cal BP | Sed rate cm yr <sup>-1</sup> | year (AD) |
|-------|-----------------|------------------------------|-----------|
| 0     | -68             | 0.1955                       | 2018      |
| 0.5   |                 | 0.1955                       | 2017      |
| 1     |                 | 0.1955                       | 2014      |
| 1.5   |                 | 0.1955                       | 2012      |
| 2     |                 | 0.1955                       | 2009      |
| 2.5   |                 | 0.1955                       | 2007      |
| 3     | -54             | 0.1955                       | 2004      |
| 3.5   |                 | 0.1955                       | 2002      |
| 4     |                 | 0.1955                       | 1999      |
| 4.5   |                 | 0.1955                       | 1997      |
| 5     |                 | 0.1955                       | 1994      |
| 5.5   |                 | 0.1955                       | 1992      |
| 6     |                 | 0.1955                       | 1989      |
| 6.5   |                 | 0.1955                       | 1987      |
| 7     |                 | 0.1955                       | 1984      |
| 7.5   |                 | 0.1955                       | 1982      |
| 8     |                 | 0.1955                       | 1979      |
| 8.5   |                 | 0.1955                       | 1977      |
| 9     |                 | 0.1955                       | 1974      |
| 9.5   |                 | 0.1955                       | 1972      |
| 10    |                 | 0.1955                       | 1969      |
| 10.5  |                 | 0.1955                       | 1967      |
| 11    | -13             | 0.1955                       | 1963      |
| 11.5  |                 | 0.1955                       | 1962      |
| 12    |                 | 0.2308                       | 1959      |
| 12.5  |                 | 0.2308                       | 1957      |
| 13    |                 | 0.2308                       | 1954      |
| 13.5  |                 | 0.2308                       | 1951      |
| 14    | 0               | 0.2308                       | 1950      |
| 14.5  |                 | 0.2308                       | 1946      |
| 15    |                 | 0.2308                       | 1944      |
| 15.5  |                 | 0.2308                       | 1941      |
| 16    | 9               | 0.2308                       | 1941      |
| 16.5  |                 |                              | 1936      |
| 17    |                 |                              | 1934      |
| 17.5  |                 |                              | 1931      |
| 18    |                 |                              | 1929      |
| 18.5  |                 |                              | 1926      |
| 19    | 25              | 0.1955                       | 1925      |
| 19.5  |                 |                              | 1921      |
| 20    |                 |                              | 1919      |
| 20.5  |                 |                              | 1916      |
| 21    |                 |                              | 1914      |
| 21.5  |                 |                              | 1911      |

|      |     |        |      |
|------|-----|--------|------|
| 22   |     |        | 1909 |
| 22.5 |     |        | 1906 |
| 23   | 46  | 0.1955 | 1904 |
| 23.5 |     |        | 1901 |
| 24   |     |        | 1899 |
| 24.5 |     |        | 1896 |
| 25   |     |        | 1894 |
| 25.5 |     |        | 1891 |
| 26   |     |        | 1889 |
| 26.5 |     |        | 1886 |
| 27   |     |        | 1884 |
| 27.5 |     |        | 1881 |
| 28   |     |        | 1879 |
| 28.5 |     |        | 1876 |
| 29   |     |        | 1873 |
| 29.5 |     |        | 1871 |
| 30   |     |        | 1868 |
| 30.5 |     |        | 1866 |
| 31   |     |        | 1863 |
| 31.5 |     |        | 1861 |
| 32   |     |        | 1858 |
| 32.5 |     |        | 1856 |
| 33   |     |        | 1853 |
| 33.5 |     |        | 1851 |
| 34   |     |        | 1848 |
| 34.5 |     |        | 1846 |
| 35   |     |        | 1843 |
| 35.5 |     |        | 1841 |
| 36   |     |        | 1838 |
| 36.5 | 116 | 0.1955 | 1834 |
| 37   |     |        | 1833 |
| 37.5 |     |        | 1831 |

Suppl. 2d: Radiocarbon C14-dating of sediment core NC-18-C-40b.

| Depth (cm) | Conventional age | Dev | Pb/Cs age | RE   | Corr age cal BP | Sed rate yr cm <sup>-1</sup> | Cal yr BP weighted mean | Dev | Year (AD) |
|------------|------------------|-----|-----------|------|-----------------|------------------------------|-------------------------|-----|-----------|
| 0.5        |                  |     | -68       |      | -68             | 5.11627907                   | -68                     |     | 2018      |
| 3          | 1540             | 30  | -53.9     | 1594 | -54             | 5.11627907                   | -54                     | -   | 2004      |
| 11         |                  |     | -13       |      | -13             | 5.11627907                   | -13                     |     | 1963      |
| 14         |                  |     | 0         |      | 0               | 5.11627907                   | 0                       |     | 1950      |
| 16         |                  |     | 9         |      | 9               | 4.333333329                  | 9                       |     | 1941      |
| 19         | 2650             | 30  | 25        | 2620 | 25              | 5.11627907                   | 25                      | -   | 1925      |
| 20         |                  |     |           |      |                 | 5.11627907                   | 31                      |     | 1919      |
| 21         |                  |     |           |      |                 | 5.11627907                   | 36                      |     | 1914      |
| 22         |                  |     |           |      |                 | 5.11627907                   | 41                      |     | 1909      |
| 23         | 3140             | 30  | 46        | 3094 | 46              | 5.11627907                   | 46                      | -   | 1904      |
| 36.5       | 4010             | 30  | 116       | 3894 | 116             | 5.11627907                   | 125*                    | 58  | 1834      |

Suppl 2e: IntCal20-calibration.

| Calib 8.1.0 (2020) |     |      |     |          |           |          |  |
|--------------------|-----|------|-----|----------|-----------|----------|--|
| from               | to  | mean | dev | factor   | cal yr BP | dev2     |  |
| 10                 | 150 | 80   | 70  | 0.710452 | 56.8361   | 49.7316  |  |
| 187                | 197 | 192  | 5   | 0.01997  | 3.8342    | 0.0998   |  |
| 210                | 270 | 240  | 30  | 0.26957  | 64.696    | 8.0871   |  |
|                    |     |      |     |          | 125.3672  | 57.91859 |  |

Suppl. 3: Stratigraphy and lithology of sediment core NC-18-C-40b.

| Depth          | Units  | Description  | Boundaries                                  | Colour                    | Munsell scale               |
|----------------|--------|--|---|---------------------------|-----------------------------|
| 0 - 2 cm       | Unit 1 | clay, massive, organic rich, aquatic plant remains, pale yellow, no organization                         |   | pale yellow               | Hue 2,5 YR 8/3              |
| 2 - 3 cm       |        |  |   | gray yellow-red           | Hue 7,5 YR 8/2              |
| 3 - 5 cm       |        |  |   | pale yellow               | Hue 2,5 YR 8/3              |
| 5 - 9.5 cm     |        |  |   | light gray yellow         | Hue 10 Y 8/8                |
| 9.5 - 10.5 cm  |        |  |   | yellow                    | Hue 5 Y 6/4                 |
| 10.5 - 12.5 cm |        |  |   | pale yellow               | Hue 2,5 YR 8/3              |
| 12.5 - 13.5 cm |        |  |   | yellow                    | Hue 5 YR 6/4                |
| 13.5 - 15.5 cm |        |  |   | yellow-orange             | Hue 10 YR 8/6               |
| 15.5 - 17.5 cm |        |  |   | yellow                    | Hue 5 YR 7/6                |
| 17.5 - 18 cm   | Unit 2 | clay, laminated with fine sand layers  | gradual inferior boundary                   | light yellow-red          | Hue 7,5 YR 8/3              |
| 18 - 20.5 cm   |        |  |   | yellow                    | Hue 5 YR 7/6                |
| 20.5 - 21.5 cm |        |  | erosive superior boundary                   | yellow                    | Hue 2,5 YR 8 /6             |
| 21.5 - 25.5 cm | Unit 3 | silt, massive with alternation of dark fine sand of 1 cm thickness, well sorted, subrounded-rounded, and |   | yellowish                 | Hue 10 YR 7/6               |
| 25.5 - 26.5 cm |        | Dark, fine sand of 1 cm thickness  | erosive superior boundary, gradual inferior | olive-yellow              | Hue 5 YR 6/3                |
| 26.5 - 27.5 cm | Unit 3 | silt, massive  |   | dull yellow-orange        | Hue 10 YR 7/4               |
| 27.5 - 28.5 cm |        | Dark, fine sand of 1 cm thickness  | erosive superior boundary, gradual inferior | olive                     | Hue 5 YR 5/4                |
| 28.5 - 29.5 cm | Unit 3 | silt, massive  |   | olive                     | Hue 5 YR 5/4                |
| 29.5 - 30.5 cm |        | Dark, fine sand of 1 cm thickness  | erosive superior boundary, gradual inferior | dull yellow-orange, olive | Hue 10 YR 7/4, Hue 5 YR 5/4 |
| 30.5 - 32.5 cm | Unit 3 | silt, massive  |   | yellowish                 | Hue 10 YR 7/6               |
| 32.5 - 34.5 cm | Unit 1 | clay, massive, organic rich, aquatic plant remains, pale yellow, no organization                         |   | yellowish, yellow         | Hue 10 YR 7/6, Hue 5 YR 6/4 |
| 34.5 - 35.5 cm |        | Dark, fine sand of 1 cm thickness  |   | yellow, yellowish         | Hue 10 YR 7/6, Hue 5 YR 6/4 |
| 36 - 37.5 cm   | Unit 3 | silt, massive  |   | dull yellow-orange        | Hue 10 YR 7/4               |

Supp. 4a: Mineralogical composition of sediment core NC-18-C-40b.

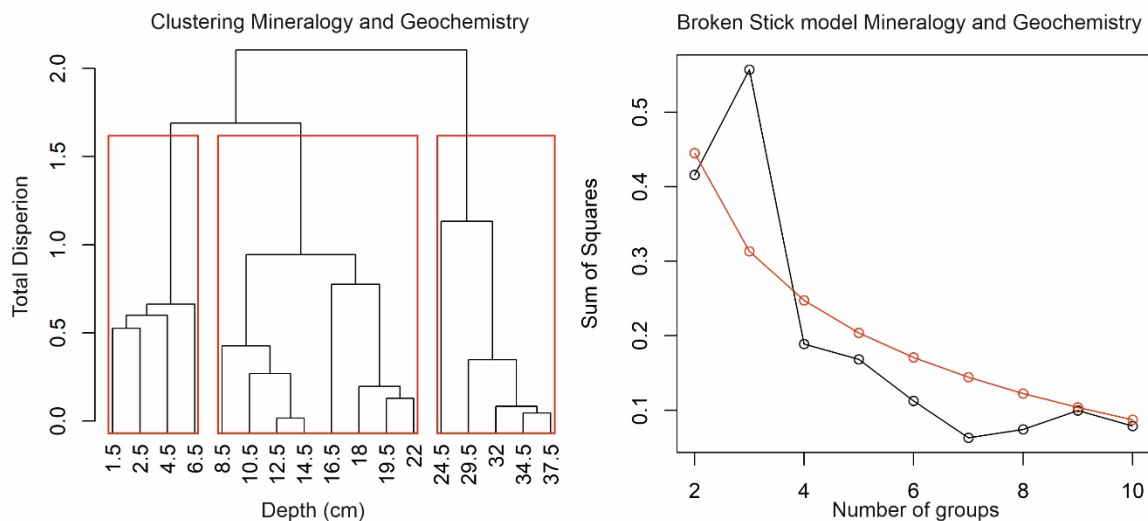
| Depth | Quartz | Biotite | Muscovite | Montmorillonite | Illite | Calcite | Dolomite | Magnetite | Albit | Orthoclase |
|-------|--------|---------|-----------|-----------------|--------|---------|----------|-----------|-------|------------|
| 1.5   | 21.3   | 5.3     | 0         | 0               | 0      | 59.2    | 0        | 4.6       | 9.6   | 0          |
| 2.5   | 7.1    | 2.9     | 0         | 0               | 0      | 84.1    | 0        | 5.9       | 0     | 0          |
| 4.5   | 21.7   | 17.3    | 0         | 0               | 0      | 58.1    | 0        | 2.9       | 0     | 0          |
| 6.5   | 7.5    | 3.3     | 0         | 0               | 0      | 83.7    | 0        | 5.5       | 0     | 0          |
| 8.5   | 36.7   | 4.2     | 0         | 0               | 0      | 41.7    | 0        | 0         | 0     | 17.4       |
| 10.5  | 51.1   | 2.4     | 0         | 0               | 0      | 44.5    | 0        | 2         | 0     | 0          |
| 12.5  | 45.9   | 2.3     | 0         | 0               | 0      | 40.3    | 0        | 1.3       | 0     | 10.2       |
| 14.5  | 45.4   | 2.4     | 0         | 0               | 0      | 40.8    | 0        | 0         | 0     | 11.4       |
| 16.5  | 38.4   | 0       | 21.2      | 0               | 7.6    | 32.8    | 0        | 0         | 0     | 0          |
| 18    | 49.5   | 2       | 0         | 0               | 6.8    | 41.7    | 0        | 0         | 0     | 0          |
| 19.5  | 46.9   | 6.2     | 0         | 0               | 11.6   | 35.3    | 0        | 0         | 0     | 0          |
| 22    | 46     | 2.2     | 0         | 0               | 21.9   | 29.9    | 0        | 0         | 0     | 0          |
| 24.5  | 18     | 7.9     | 0         | 0               | 22.1   | 45.5    | 6.5      | 0         | 0     | 0          |
| 26.5  | 21.8   | 11.7    | 0         | 0               | 0      | 56.4    | 8        | 2.1       | 0     | 0          |
| 29.5  | 23.8   | 4.1     | 0         | 0               | 0      | 62.6    | 9.5      | 0         | 0     | 0          |
| 32    | 20     | 0       | 0         | 3.8             | 0      | 55.7    | 18.2     | 2.3       | 0     | 0          |
| 34.5  | 21.7   | 0       | 0         | 2.1             | 0      | 60.9    | 13.1     | 2.2       | 0     | 0          |
| 37.5  | 21.5   | 0       | 0         | 3               | 0      | 62.4    | 13.1     | 0         | 0     | 0          |

Suppl. 4b: Geochemical analysis of sediment core NC-18-C-40b.

|      | TOC (%) | TIC (%) | TN (%) | C/N  | Al/Si | Ca/Fe  | Sr/Rb |
|------|---------|---------|--------|------|-------|--------|-------|
| 1.5  | 2.04    | 6.64    | 0.39   | 6.2  | 0.521 | 13.425 | 16.29 |
| 2.5  | 1.84    | 6.48    | 0.34   | 6.4  | 0.44  | 14.845 | 17.80 |
| 4.5  | 1.93    | 6.58    | 0.3    | 7.5  | 0.428 | 14.917 | 19.47 |
| 6.5  | 1.9     | 5.92    | 0.26   | 8.7  | 0.359 | 15.106 | 17.26 |
| 8.5  | 1.09    | 6.45    | 0.23   | 5.6  | 0.399 | 14.817 | 16.94 |
| 10.5 | 1.61    | 5.87    | 0.24   | 8    | 0.341 | 16.168 | 18.10 |
| 12.5 | 3.29    | 5.14    | 0.24   | 15.8 | 0.436 | 16.602 | 21.75 |
| 14.5 | 3.17    | 5.56    | 0.28   | 13.1 | 0.387 | 13.299 | 21.47 |
| 16.5 | 2.07    | 5.39    | 0.23   | 10.5 | 0.324 | 12.713 | 13.9  |
| 18   | 3.91    | 4.92    | 0.29   | 15.8 | 0.399 | 12.951 | 17.47 |
| 19.5 | 1.85    | 6.55    | 0.25   | 8.6  | 0.375 | 14.345 | 18.88 |
| 22   | 0.86    | 5.87    | 0.11   | 9.1  | 0.28  | 13.668 | 16.11 |
| 24.5 | 3.24    | 5.64    | 0.18   | 21.2 | 0.425 | 24.178 | 34.29 |
| 26.5 | NA      | 7.09    | 0.09   | NA   | 0.265 | 16.896 | 17.79 |
| 29.5 | 0.15    | 5.76    | 0.09   | NA   | 0.264 | 17.711 | 17.19 |
| 32   | 1.01    | 6.92    | 0.15   | 7.7  | 0.372 | 19.89  | 25.45 |
| 34.5 | 0.59    | 6.77    | 0.11   | NA   | 0.286 | 17.944 | 23.4  |
| 37.5 | 1.13    | 6.44    | 0.1    | 13.9 | 0.334 | 21.36  | 25.16 |



Suppl. 4c: Constrained Clustering Mineralogy and Geochemistry of sediment core NC-18-C-40b.



Suppl. 5a: Chironomidae assemblage of sediment core NC-18-C-40b.

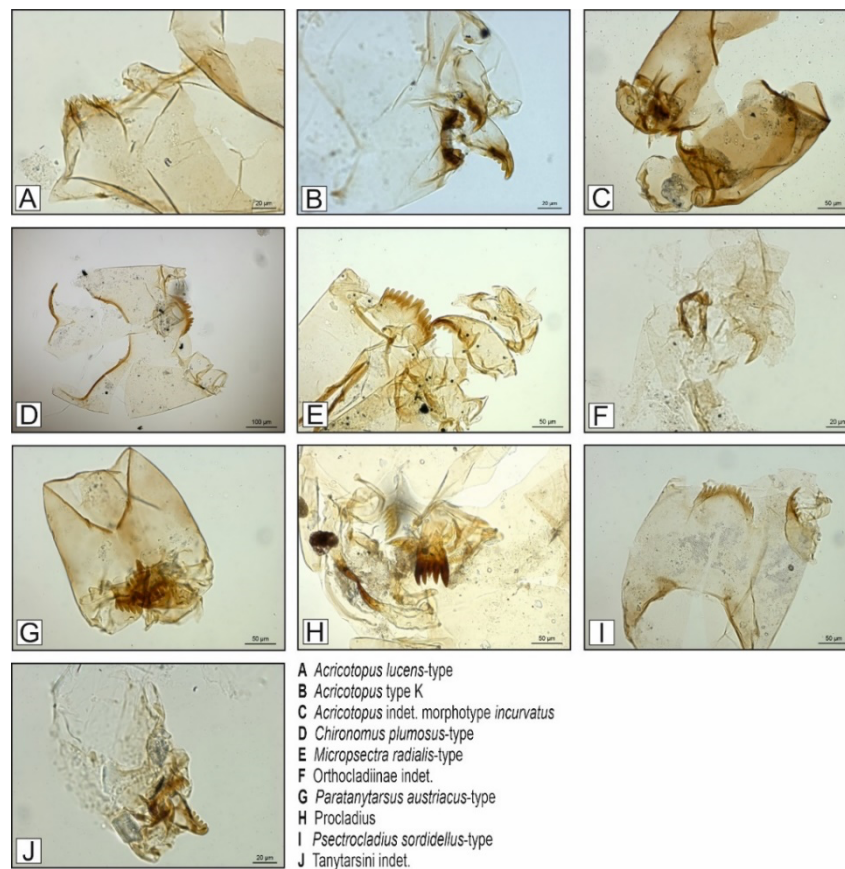
| Depth | Concentration of head capsules | Number of head capsules | Number of non-rare taxa | <i>Procladius</i> | <i>Tanytarsini</i> indet. | <i>Paratanytarsus austriacus</i> -type | <i>Micropectra radialis</i> -type | <i>Orthocladinae</i> indet. | <i>Acricotopus</i> type K | <i>Acricotopus</i> indet. morphotype <i>incurvatus</i> | <i>Acricotopus lucens</i> -type | <i>Psectrocladius sordidellus</i> -type | <i>Chironomus plumosus</i> -type |
|-------|--------------------------------|-------------------------|-------------------------|-------------------|---------------------------|--|-----------------------------------|-----------------------------|---------------------------|--|---------------------------------|---|----------------------------------|
| 0.5   | 202.25                         | 54.0                    | 4.0                     | 77.8              | 0.0                       | 3.7                                    | 1.9                               | 0.0                         | 0.0                       | 0.0  | 0.0                             | 14.8                                    | 1.9                              |
| 1     | 110.04                         | 57.0                    | 2.0                     | 85.2              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 0.0                       | 0.0  | 0.0                             | 14.8                                    | 0                                |
| 1.5   | 175.76                         | 80.5                    | 5.0                     | 68.3              | 0.0                       | 1.2                                    | 0.0                               | 0.0                         | 0.0                       | 0.0  | 0.0                             | 29.2                                    | 1.2                              |
| 2     | 284.59                         | 90.5                    | 5.0                     | 86.2              | 0.0                       | 1.1                                    | 0.0                               | 0.0                         | 1.1                       | 5.5  | 0.0                             | 6.1                                     | 0                                |
| 2.5   | 246.89                         | 79.5                    | 4.0                     | 88.7              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 0.0                       | 11.3   | 0.0                             | 0.0                                     | 0                                |
| 3     | 204.20                         | 107.0                   | 3.0                     | 81.3              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 2.8                       | 15.9   | 0.0                             | 0.0                                     | 0                                |
| 3.5   | 112.07                         | 53.0                    | 3.0                     | 73.1              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 0.0                       | 26.0   | 0.0                             | 1.0                                     | 0                                |
| 4     | 97.70                          | 51.0                    | 4.0                     | 60.8              | 0.0                       | 0.0                                    | 0.0                               | 2.0                         | 0.0                       | 35.3   | 0.0                             | 2.0                                     | 0                                |
| 4.5   | 135.66                         | 54.5                    | 5.0                     | 72.4              | 0.0                       | 0.0                                    | 1.9                               | 0.0                         | 3.8                       | 20.0   | 0.0                             | 1.9                                     | 0                                |
| 5     | 100.98                         | 62.0                    | 2.0                     | 69.4              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 0.0                       | 30.6   | 0.0                             | 0.0                                     | 0                                |
| 5.5   | 86.42                          | 49.0                    | 3.0                     | 67.3              | 0.0                       | 0.0                                    | 0.0                               | 2.0                         | 0.0                       | 30.6   | 0.0                             | 0.0                                     | 0                                |
| 6     | 59.62                          | 46.5                    | 4.0                     | 60.2              | 0.0                       | 2.2                                    | 0.0                               | 0.0                         | 1.1                       | 36.6   | 0.0                             | 0.0                                     | 0                                |
| 6.5   | 129.03                         | 60.0                    | 3.0                     | 66.7              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 0.0                       | 33.3   | 0.0                             | 0.0                                     | 0                                |
| 7     | 166.94                         | 101.0                   | 4.0                     | 74.5              | 0.0                       | 0.0                                    | 0.0                               | 0.0                         | 0.0                       | 24.5   | 0.0                             | 1.0                                     | 0                                |
| 7.5   | 96.87                          | 68.0                    | 3.0                     | 73.5              | 0.0                       | 0.0                                    | 0.0                               | 1.5                         | 0.0                       | 25.0   | 0.0                             | 0.0                                     | 0                                |



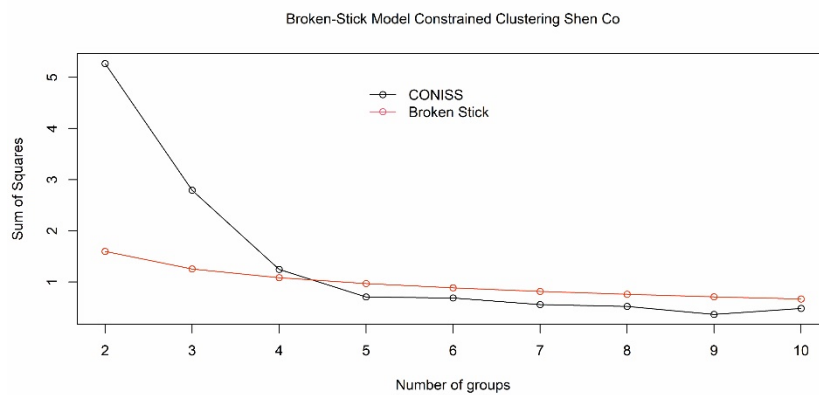
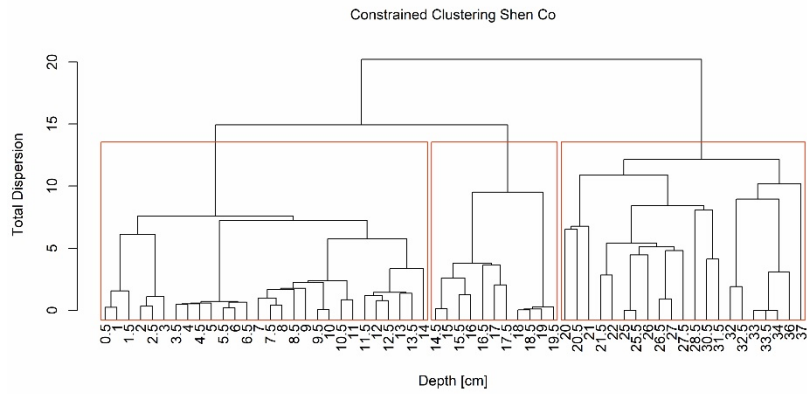
|      |       |     |     |     |   |     |   |   |   |   |   |   |   |
|------|-------|-----|-----|-----|---|-----|---|---|---|---|---|---|---|
| 31.5 | 15.63 | 2.0 | 1.0 | 2   | 0 | 0   | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 32   | 35.21 | 5.0 | 1.0 | 5   | 5 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 32.5 | 14.99 | 7.0 | 3.0 | 7   | 4 | 0   | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 33   | 4.62  | 2.0 | 1.0 | 2   | 2 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33.5 | 4.20  | 2.0 | 1.0 | 2   | 2 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34   | 4.43  | 2.0 | 1.0 | 2   | 2 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34.5 | 0.00  | 0.0 | 0.0 | 0   | 0 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35   | 0.00  | 0.0 | 0.0 | 0   | 0 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35.5 | 0.00  | 0.0 | 0.0 | 0   | 0 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36   | 8.70  | 1.0 | 1.0 | 1   | 1 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36.5 | 0.00  | 0.0 | 0.0 | 0   | 0 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37   | 4.16  | 1.5 | 1.0 | 1.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37.5 | 0.00  | 0.0 | 0.0 | 0   | 0 | 0   | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Grey parts = total abundance of chironomid morphotypes

Suppl. 5b: Images of chironomid morphotypes from Shen Co sediment core NC-18-C-40b.



Suppl. 5c: Constrained clustering of chironomid assemblage of sediment core NC-18-C-40b.



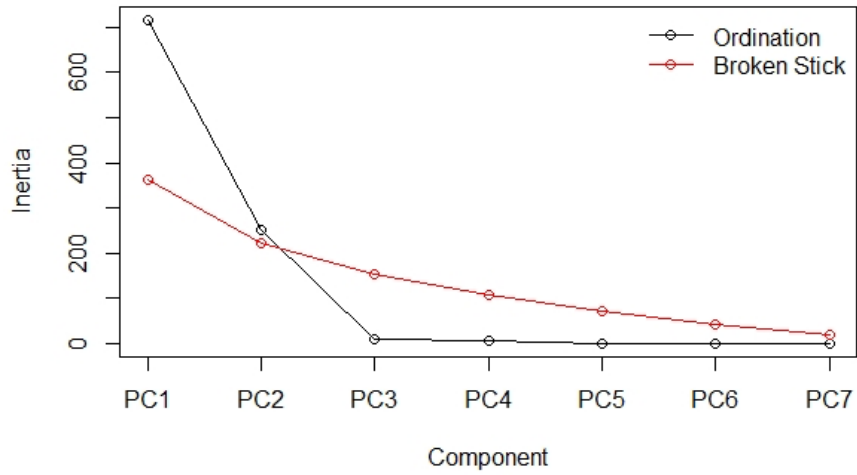
Supp. 6a: Results of PCA and RDA from chironomid and geochemical data of sediment core NC-18-C-40b.

| <b>PCA importance of components:</b>                   |             |             |             |
|--|-------------|-------------|-------------|
|  | <b>PC1</b>  | <b>PC2</b>  | <b>PC3</b>  |
| Eigenvalue   | 715.94      | 250.32      | 9.23        |
| Proportion explained                                   | 0.73        | 0.26        | 0.01        |
| Cumulative proportion                                  | 0.73        | 0.99        | 0.99        |
| <b>RDA importance of components:</b>                   |             |             |             |
|  | <b>RDA1</b> | <b>RDA2</b> | <b>RDA3</b> |
| Eigenvalue   | 8.6153      | 5.9403      | 0.81446     |
| Proportion Explained                                   | 0.4193      | 0.2891      | 0.03964     |
| Cumulative Proportion                                  | 0.4193      | 0.7084      | 0.74809     |
| <b>RDA species scores</b>                              |             |             |             |
|  | <b>RDA1</b> | <b>RDA2</b> | <b>RDA3</b> |
| <i>Procladius</i>                                      | -3.614994   | 1.11119     | 0.29026     |
| <i>Paratanytarsus austriacus</i> -type                 | -0.056566   | -0.06364    | -0.20903    |
| <i>Micropsectra radialis</i> -type                     | 0.005124    | -0.18035    | -0.12168    |
| Orthocladiinae indet.                                  | -0.532358   | -0.01764    | -0.33848    |
| <i>Acricotopus</i> type K                              | -0.103631   | 0.13076     | -0.06536    |
| <i>Acricotopus</i> indet. morphotype <i>incurvatus</i> | -1.700683   | -2.7364     | -0.08552    |
| <i>Psectrocladius sordidellus</i> -type                | -0.872298   | 0.72834     | -0.80899    |

|       | PCA and RDA Site scores |          |          |          | Diversity     |
|-------|-------------------------|----------|----------|----------|---------------|
| Depth | PC1                     | PCA2     | RDA1     | RDA2     | Shannon index |
| 0.5   | 1.37194                 | -1.66103 | -0.92635 | 2.72013  | 0.668331      |
| 1     | 1.86431                 | -1.7603  | -1.19176 | 2.89793  | 0.438413      |
| 1.5   | 2.34697                 | -1.93548 | -1.64583 | 3.30667  | 0.756225      |
| 1.75  | 3.94977                 | -1.57543 | -2.43838 | 1.90658  | 0.557874      |
| 2.25  | 3.41331                 | -1.18844 | -2.11608 | 1.12148  | 0.367658      |
| 2.75  | 4.67365                 | -0.23977 | -2.81425 | 0.4828   | 0.560731      |
| 3.25  | 1.17856                 | 0.05854  | -1.32818 | 0.02116  | 0.623974      |
| 3.75  | 0.72658                 | 0.69745  | -1.27733 | -0.44622 | 0.824369      |
| 4.25  | 1.15932                 | -0.30533 | -1.28509 | 0.34584  | 0.831213      |
| 4.75  | 1.57789                 | 0.6461   | -1.57691 | -0.42984 | 0.616232      |
| 5.25  | 0.83697                 | 0.3161   | -1.16843 | -0.33539 | 0.708035      |
| 5.75  | 0.50238                 | 0.62621  | -0.96435 | -0.59913 | 0.804618      |
| 6.25  | 1.36665                 | 0.69186  | -1.5378  | -0.49371 | 0.702686      |
| 6.75  | 3.94777                 | 0.6371   | -2.83518 | 0.01281  | 0.642327      |
| 7.25  | 2.05486                 | 0.30659  | -1.82814 | -0.15294 | 0.634717      |
| 7.75  | 2.6828                  | 0.88897  | -2.32791 | -0.20994 | 0.769145      |
| 8.25  | 2.2154                  | -1.42644 | -1.4541  | 1.46035  | 0.370741      |
| 8.75  | 2.80709                 | 2.1429   | -2.51744 | -0.84713 | 0.727448      |
| 9.25  | 1.15927                 | 0.7959   | -1.44674 | -0.60653 | 0.79506       |
| 9.75  | 1.32219                 | 1.06346  | -1.50478 | -0.76135 | 0.725814      |
| 10.25 | 3.45118                 | 1.22622  | -2.62006 | -0.39885 | 0.624982      |
| 10.75 | 3.65967                 | -0.65685 | -2.6025  | 1.03086  | 0.749122      |
| 11.25 | 1.53279                 | -0.98822 | -1.29616 | 1.01647  | 0.526427      |
| 11.75 | 2.51645                 | -1.38463 | -1.79191 | 1.62204  | 0.456857      |
| 12.25 | 1.99595                 | -1.26849 | -1.78766 | 1.7078   | 0.779197      |
| 12.75 | 0.98125                 | -1.35613 | -1.13051 | 1.8556   | 0.783756      |
| 13.25 | 1.71548                 | -0.74631 | -1.67651 | 0.98623  | 0.761666      |
| 13.75 | 4.74433                 | -1.33992 | -2.99407 | 1.81483  | 0.937912      |
| 14.25 | -0.71445                | 4.52185  | -0.40036 | -3.07335 | 0.629397      |
| 14.75 | -0.95712                | 4.14844  | -0.06818 | -3.03996 | 0.566046      |
| 15.25 | -0.2468                 | 3.09127  | -0.79845 | -2.16253 | 0.743618      |
| 15.75 | 0.28359                 | 2.00583  | -1.00939 | -1.4283  | 0.770504      |
| 16.25 | -0.77438                | -0.14104 | 0.21373  | -0.34928 | 0.684906      |
| 16.75 | 0.41778                 | 1.43353  | -1.02197 | -1.187   | 0.907741      |
| 17.25 | -0.08239                | 3.78079  | -0.96125 | -2.36731 | 0.782749      |
| 17.75 | -0.75747                | 5.8671   | -0.39793 | -3.60447 | 0.406092      |
| 18.25 | -1.04849                | 5.80742  | 0.16251  | -3.89554 | 0.334571      |
| 18.75 | -1.09784                | 6.11568  | 0.69764  | -4.23471 | 0             |
| 19.25 | -1.0856                 | 5.25792  | 0.23116  | -3.51378 | 0.182738      |
| 19.75 | -1.55135                | -0.95104 | 1.74658  | 0.45225  | 0.636         |
| 20.25 | -0.62631                | -1.08466 | 0.35327  | 1.09001  | 0.379535      |

|       |          |          |         |          |        |
|-------|----------|----------|---------|----------|--------|
| 20.75 | -1.55579 | -1.01081 | 1.89854 | 0.89935  | 0      |
| 21.25 | -1.46744 | -0.78637 | 1.4054  | 0.1115   | 0.693  |
| 21.75 | -1.60864 | -0.75658 | 2.04473 | -0.29579 | 0.9556 |
| 22.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 22.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 23.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 23.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 24.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 24.75 | -1.61751 | -0.87666 | 2.14044 | 0.01029  | 0      |
| 25.25 | -1.61751 | -0.87666 | 2.14044 | 0.01029  | 0      |
| 25.75 | -1.47632 | -0.9059  | 1.49441 | 0.37341  | 0.636  |
| 26.25 | -1.5997  | -0.63731 | 1.98377 | -0.49426 | 0.562  |
| 26.75 | -1.59975 | -0.6376  | 1.98312 | -0.45258 | 0      |
| 27.25 | -1.617   | -0.8766  | 2.14044 | 0.01029  | 0      |
| 27.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 28.25 | -1.55162 | -1.01728 | 1.78831 | 1.06765  | 0.693  |
| 28.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 29.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 29.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 30.25 | -1.54261 | -0.82989 | 1.62104 | 0.09554  | 0.9251 |
| 30.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 31.25 | -1.60863 | -0.75713 | 2.05142 | -0.25161 | 0      |
| 31.75 | -1.2734  | -1.06929 | 1.33389 | 1.21672  | 0      |
| 32.25 | -1.34398 | -1.05398 | 1.43523 | 1.09973  | 0.867  |
| 32.75 | -1.48519 | -1.02543 | 1.70932 | 1.0057   | 0      |
| 33.25 | -1.48519 | -1.02543 | 1.70932 | 1.0057   | 0      |
| 33.75 | -1.48519 | -1.02543 | 1.70932 | 1.0057   | 0      |
| 34.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 34.75 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 35.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 35.75 | -1.55579 | -1.01081 | 1.89854 | 0.89935  | 0      |
| 36.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |
| 36.75 | -1.62642 | -0.99578 | 2.3482  | 0.62788  | 0      |
| 37.25 | -1.62638 | -0.99618 | 2.35535 | 0.64259  | 0      |

PCA Broken Stick Shen Co



Suppl. 6b: Results of ANOVA.

| Variable | Df | Variance | F      | Pr(>F) | Significance | VIF   |
|----------|----|----------|--------|--------|--------------|-------|
| TOC      | 1  | 2.7617   | 4.3233 | 0.014  | *            | 16.67 |
| TN       | 1  | 7.1232   | 11.151 | 0.001  | ***          | 15.91 |
| Ca/Fe    | 1  | 1.901    | 2.9759 | 0.062  | .            | 10.08 |
| Al/Si    | 1  | 1.7104   | 2.6776 | 0.074  | .            | 7.75  |
| Sr/Rb    | 1  | 1.0685   | 1.6727 | 0.189  |              | 9.15  |
| C/N      | 1  | 0.0421   | 0.0658 | 0.985  |              | 12.47 |

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Suppl. 7: Lake surface area from 1973 - 2021 of Shen Co determined by Landsat imagery.

| CE   | Lake surface area [km <sup>2</sup> ] | Island surface area [km <sup>2</sup> ] |
|------|--------------------------------------|--|
| 1973 | 42.121                               | 0.196901                               |
| 1977 | 42.8                                 | 0.172938                               |
| 1989 | 40.9349                              | 0.145135                               |
| 1995 | 43.0773                              | 0.088307                               |
| 2001 | 44.1518                              | 0.051064                               |
| 2005 | 52.8                                 | 0                                      |
| 2008 | 51.7617                              | 0                                      |
| 2015 | 50.6333                              | 0                                      |
| 2021 | 52.0971                              | 0                                      |

Suppl. 8: Paleoclimatic records from the Tibetan Plateau.

| Age  | Dunde                 | Guliya                | Puruogangri           | Kusai Lake | Dulan    | Sugan Lake    | Nir'pa Co     | Ximencuo      |
|------|-----------------------|-----------------------|-----------------------|------------|----------|---------------|---------------|---------------|
|      | Ice core              | Ice core              | Ice core              | Pollen     | Treering | Chironomids   | Lake sediment | Lake sediment |
|      | $\delta^{18}\text{O}$ | $\delta^{18}\text{O}$ | $\delta^{18}\text{O}$ | MAP        | MAP      | Salinity      | Silt          | TOC           |
|      | per mil               | per mil               | per mil               | (mm)       | (mm)     | (sigma units) | (%)           | (%)           |
| 2010 |                       |                       |                       |            | 365.05   |               |               |               |
| 2006 |                       |                       |                       | 311        |          |               |               |               |
| 2004 |                       |                       |                       | 298        |          |               |               | 5.27          |
| 2002 |                       |                       |                       |            |          | 1.729         |               |               |
| 2001 |                       |                       |                       | 304        |          |               |               |               |
| 2000 |                       |                       |                       |            | 290.039  |               |               |               |
| 1999 |                       |                       |                       | 303        |          |               | 76.58         |               |
| 1996 |                       |                       |                       | 298        |          |               |               |               |
| 1994 |                       |                       |                       |            |          | 0.3105        |               | 5.57          |
| 1993 |                       |                       |                       | 289        |          |               |               |               |
| 1990 |                       | -12.35                | -12.2                 |            | 246.35   |               |               |               |
| 1989 |                       |                       |                       | 296        |          |               |               |               |
| 1987 | -10.09                |                       |                       |            |          |               |               |               |
| 1986 |                       |                       |                       | 288        |          |               |               |               |
| 1984 |                       |                       |                       |            |          |               |               | 5.85          |
| 1980 | -10.33                | -13.75                | -12.05                |            | 271.658  |               |               |               |
| 1979 |                       |                       |                       |            |          | -0.4931       |               |               |
| 1978 |                       |                       |                       | 283        |          |               |               |               |
| 1974 |                       |                       |                       |            |          |               |               | 5.55          |
| 1972 |                       |                       |                       | 293        |          |               |               |               |
| 1970 | -10.39                | -12.63                | -13.05                |            | 229.564  |               |               |               |
| 1969 |                       |                       |                       |            |          | 0.881         |               |               |
| 1967 |                       |                       |                       | 280        |          |               |               |               |
| 1964 |                       |                       |                       |            |          |               |               | 5.27          |
| 1963 |                       |                       |                       | 289        |          |               |               |               |
| 1962 |                       |                       |                       |            |          | -0.2835       | 78.38         |               |
| 1960 | -9.74                 | -13.74                | -12.97                | 283        | 221.999  |               |               |               |
| 1955 |                       |                       |                       | 293        |          |               |               |               |
| 1954 |                       |                       |                       |            |          |               |               | 5.27          |
| 1950 | -9.22                 | -12.78                | -13.53                |            | 235.187  |               |               |               |
| 1949 |                       |                       |                       |            |          | 0.2262        |               |               |
| 1947 |                       |                       |                       | 295        |          |               |               |               |
| 1945 |                       |                       |                       | 269        |          |               |               |               |
| 1944 |                       |                       |                       |            |          | -0.076        |               | 5.02          |
| 1940 | -9.43                 | -13.46                | -14.23                |            | 246.46   |               |               |               |
| 1936 |                       |                       |                       | 272        |          | 0.7179        |               |               |
| 1934 |                       |                       |                       |            |          |               |               | 4.73          |
| 1933 |                       |                       |                       |            |          | 0.4019        |               |               |



|      |        |        |        |     |         |        |       |      |
|------|--------|--------|--------|-----|---------|--------|-------|------|
| 1930 | -9.85  | -13.29 | -13.11 | 274 | 200.585 |        |       |      |
| 1926 |        |        |        | 282 |         |        |       |      |
| 1924 |        |        |        |     |         |        | 71.47 | 4.61 |
| 1923 |        |        |        | 273 |         |        |       |      |
| 1922 |        |        |        |     |         | 0.7575 |       |      |
| 1920 | -9.74  | -14.22 | -11.4  |     | 211.999 |        |       |      |
| 1916 |        |        |        | 287 |         |        |       |      |
| 1914 |        |        |        |     |         |        |       | 4.41 |
| 1913 |        |        |        | 289 |         |        |       |      |
| 1911 |        |        |        | 284 |         |        |       |      |
| 1910 | -10.86 | -14.18 | -12.9  |     | 201.094 |        |       |      |
| 1909 |        |        |        | 278 |         |        |       |      |
| 1905 |        |        |        | 278 |         |        |       |      |
| 1904 |        |        |        |     |         |        | 69.18 | 4.37 |
| 1901 |        |        |        |     |         | 0.5726 |       |      |
| 1900 | -10.16 | -14.1  | -15.39 | 268 | 249.633 |        |       |      |
| 1898 |        |        |        | 277 |         |        |       |      |
| 1894 |        |        |        | 271 |         |        |       | 4.24 |
| 1893 |        |        |        |     |         | 0.5513 |       |      |
| 1891 |        |        |        | 274 |         |        |       |      |
| 1890 | -9.89  | -12.28 | -15.3  |     | 244.888 |        |       |      |
| 1887 |        |        |        | 270 |         |        |       |      |
| 1885 |        |        |        |     |         | 0.7184 |       |      |
| 1884 |        |        |        |     |         |        | 71.15 | 4    |
| 1881 |        |        |        | 260 |         |        |       |      |
| 1880 | -11.63 | -15.86 | -13.53 |     | 216.14  |        |       |      |
| 1875 |        |        |        | 263 |         |        |       |      |
| 1874 |        |        |        |     |         |        |       | 3.83 |
| 1872 |        |        |        | 262 |         |        |       |      |
| 1870 | -10    | -14.77 | -13.34 |     | 203.133 | 0.4348 |       |      |
| 1865 |        |        |        | 264 |         |        |       |      |
| 1864 |        |        |        |     |         |        |       | 3.73 |
| 1863 |        |        |        |     |         |        | 72.2  |      |
| 1862 |        |        |        |     |         | 1.156  |       |      |
| 1861 |        |        |        | 262 |         |        |       |      |
| 1860 | -10.08 | -15.29 | -14.33 |     | 217.662 |        |       |      |
| 1858 |        |        |        | 274 |         |        |       |      |
| 1856 |        |        |        | 254 |         |        |       |      |
| 1854 |        |        |        |     |         |        |       | 4.71 |
| 1851 |        |        |        |     |         | 1.371  |       |      |
| 1850 | -10.56 | -14.75 | -15.02 | 260 | 229.722 |        |       |      |
| 1845 |        |        |        | 266 |         |        |       |      |
| 1844 |        |        |        |     |         |        |       | 3.69 |
| 1843 |        |        |        |     |         | 0.3968 |       |      |
| 1841 |        |        |        |     |         |        | 66.78 |      |
| 1840 | -10.24 | -17.14 | -14.74 | 269 | 220.457 |        |       |      |
| 1835 |        |        |        |     |         |        |       | 4.1  |

|      |        |        |        |     |         |  |  |  |
|------|--------|--------|--------|-----|---------|--|--|--|
| 1832 |        |        |        | 276 |         |  |  |  |
| 1830 | -10.77 | -14.38 | -13.87 | 274 | 206.425 |  |  |  |

Note: All plots were fitted using spline smoothing with a spline tension factor of 2 and 200 number of points.